CONTENTS

9th Physics

UNIT 01

PHYSICAL QUANTITIES AND MEASUREMENT

Introduction

In this chapter we will learn about the measurement of length, mass, time and volume in daily life activities by using various measuring instruments and brief description about the various branches of physics.

Q1. Define science.

091301001

Ans. *"The knowledge gained through observations and experimentations is called Science."*

The word science is derived from the Latin word "**Scientia**" which means knowledge. "*Various aspects of material objects were studied under a single subject* called **natural philosophy**". But as the knowledge increased, it was divided into two main streams; **Physical sciences** *which deal with the study of non-living things* and **Biological sciences** *which are concerned with the study of living things.*

Q2. Define physics and explain its branches.

091301002

Ans. *"The branch of science which deals with the study of matter, energy and their interaction."* The laws and principles of Physics help us to understand the nature.

BRANCHES OF PHYSICS

i. Mechanics **(F.B. 2016)**

It is the study of motion of objects, its causes and effects, which influence motion.

ii. Heat

It deals with the nature of heat, modes of transfer and effects of heat.

iii. Sound → Sound always produces by vibrating body

It deals with the physical aspects of sound waves, their production, properties and applications.

iv. Light (Optics)

It is the study of physical aspects of light, its properties, working and use of optical instruments.

v. Electricity and Magnetism

It is the study of the charges at rest and in motion, their effects and their relationship with magnetism.

vi. Atomic Physics **(F.B. 2018)**

It is the study of the structure and properties of atoms.

vii. Plasma Physics

It is the study of production, properties of the ionic state of matter – the fourth state of matter.

viii. Geophysics **(F.B. 2016)**

It is the study of the internal structure of the Earth.

ix. Nuclear Physics **(F.B. 2018)**

It deals with the properties and behaviour of nuclei and the particles within the nuclei.

Q3. Write the importance of physics in our daily life.

091301003

(OR) Describe the role of Physics in Science and Technology.

Ans. The rapid progress in science during the recent years has become possible due to the discoveries and inventions in the field of Physics. The technologies are the applications of scientific principles. Most of the technologies of our modern society throughout the world are related to Physics.

Development in the field of Physics has changed the outlook of mankind. Computer network connection made easy to contact with one another. In our daily life, we hardly find a device where physics is not involved.

A Car is made on the principle of mechanics.

A refrigerator is based on the principles of thermodynamics.

The pulleys that make easy to lift heavy loads.

Electricity is used not only to get light and heat but also mechanical energy that drives fans and electric motors etc.

The means of transportation Such as car and aeroplanes all work on the basic principle of physics.

Domestic appliances Such as air-conditioners, refrigerators, vacuum cleaners, washing machines and microwave ovens etc. All these appliances work on the basic principles of Physics.

The means of communication Such as radio, TV, telephone and computer are the result of applications of Physics. These devices have made our lives much easier, faster and more comfortable than the past.
A mobile phone allows us to contact people anywhere in the world and to get latest world wide information. We can take and save pictures, sent and receive messages of our friends. We can also receive radio transmission and can also use it as a calculator as well. All these are the fruits by the hard work of physicists.

Q4. What is the harmful effect of scientific invention on environment? 091301004

Ans. The scientific inventions have also caused harms and destruction of serious nature. One of which is the environmental pollution and the other is the deadly weapons.

Q5. Define physical quantities. Also write its types. (OR) What is difference between base and derived quantities? 091301005

Ans. Physical Quantities;

Those quantities which can be measured are called ***physical quantities.***

For example: length, mass, time and temperature etc.

A physical quantity possesses at least two characteristics.

(i) Its numerical value

(ii) Unit in which it is measured.

For example, if the length of a student is 104 cm then 104 is its numerical value and centimeter is the unit of measurement. Physical quantities are divided into two quantities

i. BASE QUANTITIES

"There are seven physical quantities which form the foundation of other physical quantities. These physical quantities are called the base quantities".

For example: length, mass, time, electric current, temperature, intensity of light and the amount of a substance.

ii. DERIVED QUANTITIES

"Those physical quantities which are expressed in terms of base quantities are called the derived quantities".

For example: area, volume, speed, force, work, energy, power, electric charge, electric potential, etc.

Q6. What is International system of units?

(OR) What role SI Units have played in the development of Science? 091301006

Ans. With the development in the field of science and technology, the need for a commonly acceptable system of units was seriously felt all over the world particularly to exchange scientific and technical information. The eleventh General Conference on Weight and Measures was held in Paris in 1960 adopted a world-wide system of measurements called **International System of Units.** The International System of Units is commonly named as **SI.**

Q7. What are base units and derived units?

(OR) What is the difference between base and derived Units? 091301007

Ans. i. BASE UNITS

The units that describe base quantities are called base units. Each base quantity has its SI unit.

Example:

Unit of length is metre.

Unit of mass is kilogram.

Base quantities, their SI units with symbols

Quantity		Unit	
	Symbol	Name	Symbol
Length	ℓ	Metre	m
Mass	m	Kilogramme	kg
Time	t	Second	s
Electric current	I	Ampere	A
Intensity of light	L	Candela	cd
Temperature	T	Kelvin	K
Amount of a substance	n	Mole	mol

ii. DERIVED UNITS

"The units used to measure derived quantities are called derived units".

These are derived in terms of base units and are obtained by multiplying or dividing one or more base units with each other.

Examples: (1) The unit of area (metre)^2 and the unit of volume (metre)^3 are based on the unit of length, which is metre. Thus the unit of length is the base unit while the unit of area and volume are derived units. (2) Speed is defined as distance covered in unit time; therefore its unit is metre per second. Some derived units and their symbols are given below

Derived quantities, their SI units with symbols

Quantity		Unit	
Name	Symbol	Name	Symbol
Speed	v	metre per sec.	ms^{-1}
Acceleration	a	metre per sec per second.	ms^{-2}
Volume	*V*	cubic metre	m^3
Pressure	*P*	Pascal	Pa or ($N\ m^{-2}$)
Density	ρ	kg per cubic metre	$Kg\ m^{-3}$
Charge	*Q*	Coulomb	C or (As)

Q8. Define prefixes and give example. **(F.B. 2014)** **091301008**

Ans. Prefixes: *"The words or letters added before SI units and stand for multiples and sub multiples of that unit are known as prefixes".* For example kilo, mega, giga etc. The prefixes are useful to express very large or small quantities.

For example: Divide 20,000 g by 1000 to express it into kilogramme, since kilo represents 10^3 or 1000.

Thus $20{,}000\ g = \frac{20{,}000}{1000} kg = 20kg$ Or $20{,}000\ g = 20 \times 10^3 g = 20kg$

Let few more examples are:

(i) 200000 ms^{-1} $= 200\times10^3\ ms^{-1}$ $= 200\ kms^{-1}$

(ii) 4800000 W $= 4800\times10^3$ W $= 4800$ kW
$= 4.8\times10^6$ W $= 4.8$ MW

(iii) 3300000000 Hz $= 3300\times10^6$ Hz $= 3300$ MHz
$= 3.3\times10^3$ MHz $= 3.3$ GHz

(iv) 0.00002 g $= 0.02\times10^{-3}$ g $= 20\times10^{-6}$g
$= 20\mu g$

(v) 0.0000000081m $= 0.0081\times10^{-6}$ m $= 8.1\times10^{-9}$m
$= 8.1nm$

Double prefixes are not used. For example, no prefix is used with kilogramme since it already contains the prefix kilo.

Some Prefixes

Prefix	Symbol	Multiplier
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^9
mega	M	10^6
kilo	k	10^3
hecto	h	10^2
deca	da	10^1
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

Multiples and sub-multiples of length

1 km	10^{3} m
1 cm	10^{-2} m
1 mm	10^{-3} m
1 μm	10^{-6} m
1 nm	10^{-9} m

091301009

Q9. Define Scientific Notation and give examples.

Ans. Scientific Notation: *"In scientific notation a number is expressed as some power of ten multiplied by a number between 1 and 10".*

For example, a number 62750 can be expressed as 6.275×10^{4} preferably be taken as the standard form. In standard form or scientific notation, a number has only one non-zero digit before the decimal. Similarly the standard form of 0.00045 s is 4.5×10^{-4}s.

Q10. What are measuring instruments? Explain metre rule and measuring tape. 091301010

Ans. Measuring instruments are used to measure various physical quantities such as length, mass, time, volume, etc.

THE METRE RULE

"A metre rule is a length measuring instrument as shown in figure. It is commonly used in the daily life to measure length of an object or distance between two points". Least count of metre rule is 0.1 cm (or) 1mm

A Metre Rule

Construction: It is one metre long and have100 centimetres. Each big division (cm) is divided into 10 small divisions called millimetre (mm). One millimetre is the smallest reading that can be taken by using a metre rule and is called its **least count**.

Note: While measuring length, or distance, eye must be kept vertically above the reading point. The reading becomes doubtful if the eye is positioned either left or right to the reading scale.

i. THE MEASURING TAPE

"Measuring tapes are used to measure length in metres and centimetres. A measuring tape is used by blacksmith and carpenters".

Construction: A measuring tape consists of a thin and long strip of cotton, metal or plastic generally 10 m, 20 m, 50 m or 100 m long. Measuring tapes are marked in centimetres as well as in inches. At least count is equal to 0.1cm (or) 1mm.

Q11. What is meant by vernier callipers? Write its construction and working. 091301011

Ans. Vernier Callipers: "An instrument used to measure small lengths such as internal (or) external diameter or length of a cylinder is called Vernier Callipers".

The accuracy obtained in measurements using a metre rule is upto 1 mm. However an accuracy greater than 1 mm can be obtained by using some instrument called vernier callipers.

"It is an instrument which is used to measure the 10^{th} part of mm".

Construction

A Vernier Callipers consists of two jaws. One is a fixed jaw with main scale. It has marks centimetre and millimetre. The other jaw is a moveable jaw. It has vernier scale having 10 divisions over it and each of its division is 0.9 mm.

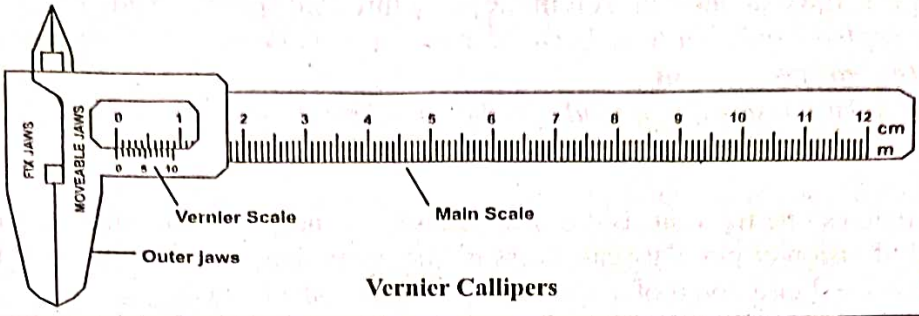
Vernier Constant:

The difference between one small division on main scale division and one vernier scale division is 0.1 mm is vernier constant or ***Least count (LC) of the Vernier Callipers.*** Least count of the Vernier Callipers can also be found as given below:

$$\text{Least count of vernier callipers} = \frac{\text{smallest reading on main scale}}{\text{no. of divisions on vernier scale}}$$

$$= \frac{1\,\text{mm}}{10} = 0.1\,\text{mm}$$

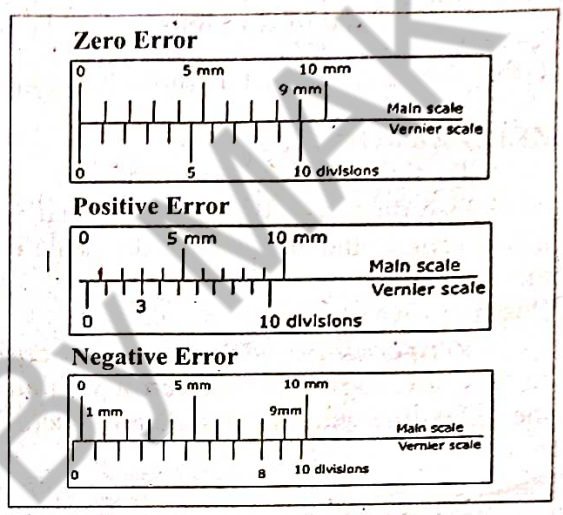
Hence L.C = 0.1 mm = 0.01 cm



Vernier Callipers

Working:

First of all, find the zero error if any in the measuring instrument. Knowing the zero error, necessary correction can be made to find the correct measurement. Such a correction is called zero correction of the instrument. Zero correction is negative of the zero error. Then open the jaws and place solid cylinder between the jaws and note main scale and vernier scale reading. Then apply the necessary zero correction.



Zero Error

To find the zero error, close the jaws of Vernier Callipers. If zero of the vernier scale coincides with the zero of the main scale then there is no zero error in the instrument.)

Definition

Zero error will exist if zero of the vernier scale is not coinciding with the zero of main scale. There are two types of errors.

i. Positive Zero Error

Zero error will be positive if zero of vernier scale is on the right side of the zero of the main scale.

ii. Negative Zero Error

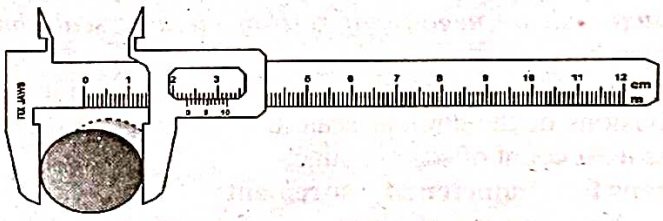
If zero line of vernier scale is on the left side of zero of the main scale then zero error will be negative.

Q12. How can we take reading on Vernier Callipers? 091301012

Ans. Taking reading on Vernier Callipers

To find the diameter of a solid cylinder by using Vernier Callipers place the solid cylinder between jaws of the Vernier Callipers. Close the jaws till they press the opposite sides of the object gently.

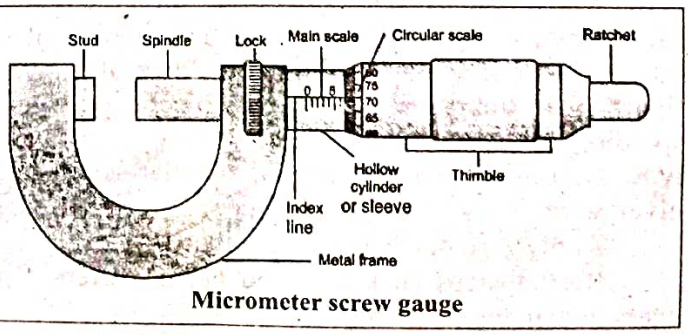
Now, find the complete divisions of main scale before the vernier scale zero and note the vernier scale division that is coinciding with any division on the main scale. Multiply it by least count of Vernier Callipers and add it in the main scale reading. This will be equal to the diameter of the solid cylinder. Apply zero correction, if any (Z.C), to get correct measurement.



A cylinder placed between the outer jaws of vernier callipers.

Q13. Define "SCREW GAUGE" and write its construction and working. 091301013

Ans. Screw Gauge: *"A screw gauge is an instrument that is used to measure small lengths with accuracy greater than a Vernier Callipers."* It is an instrument which is used to measure 100^{th} part of mm. It is also called as ***micrometer screw gauge***.



Micrometer screw gauge

Construction

A simple screw gauge consists of a U-shaped metal frame with a metal stud at its one end. A hollow cylinder (or sleeve) has a millimetre scale over it along a line called index line. The hollow

cylinder acts as a nut. It is fixed at one end. A thimble has a threaded spindle inside it.

Pitch: *The thimble completes one rotation, hundred division, spindle moves 1 mm distance. This distance is called the* ***pitch of screw gauge.*** **or**

The distance between consecutive threads on the spindle is 1mm. This distance is called ***pitch of screw gauge.***

Least Count:

As thimble completes one rotation, 100 divisions pass the index line the thimble moves 1 mm along the main scale. Thus each division of circular scale crossing the index line moves the thimble through 1/100 mm or 0.01 mm on the main scale. Least count of a screw gauge can be calculated as:

$$\text{Least count} = \frac{\text{pitch of the screw gauge}}{\text{no. of divisions on circular scale}}$$

$$= \frac{1\text{mm}}{100} = 0.01 \text{ mm} = 0.001 \text{ cm}$$

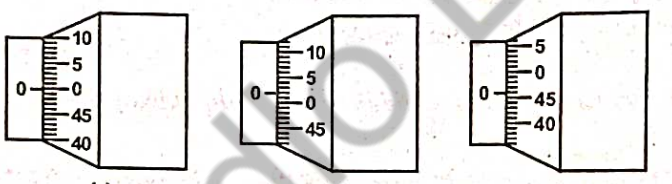
ZERO ERROR

To find the zero error, close the gap between the spindle and the stud by rotating the ratchet in the clockwise direction. If zero of circular scale coincides with the index line, then there is no zero error in the instrument. If the zero of circular scale cross or below the index line then there is zero error. In screw gauge, there are two types of error.

Positive zero error

Zero error of instrument will be positive if zero of circular scale is behind the index line.

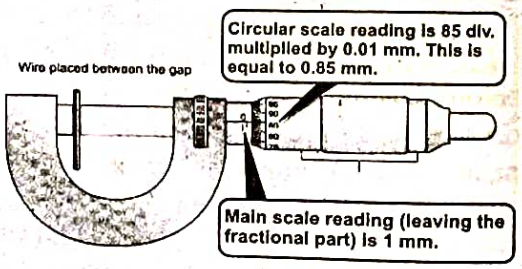
In this case, to find the zero error we multiply the number of divisions of the circular scale that has not crossed the index line with the least count of screw gauge.



Negative zero error

Zero error of screw gauge will be negative if zero of circular scale has crossed the index line.

In this case, to find the zero error we multiply the number of divisions of the circular scale that has crossed the index line with the least count of screw gauge.



Measuring the diameter of a wire using a micrometer

Steps for Diameter Measurement:

The diameter of a given wire can be found as follows:

i. Close the gap between the spindle and the stud of the screw gauge by turning the ratchet in the clockwise direction.

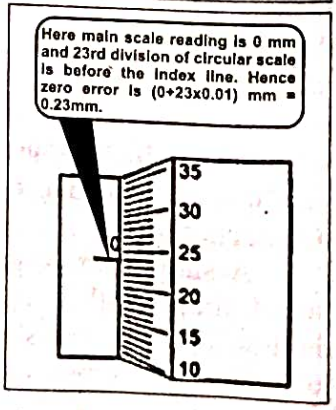
ii. Note main scale as well as circular scale readings to find zero error and hence zero correction of the screw gauge.

iii. Open the gap between stud and spindle of the screw gauge by turning the ratchet in anti-clockwise direction. Place the given wire in the gap as shown in figure. Turn the ratchet so that the object is pressed gently between the studs and the spindle.

iv. Note main scale as well as circular scale readings to find the diameter of the given wire.

v. Apply zero correction to get the correct diameter of the wire.

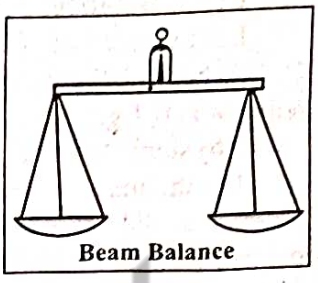
vi. Repeat steps (iii), (iv) and (v) at different places of the wire to obtain its average diameter.



Q14. What are mass measuring instruments? 091301014

Ans. *The instruments that are used to measure the mass of different objects are called mass measuring instruments.*

Pots were used to measure grain in various parts of the world in the ancient times. However, balances were also in use by Greeks and Romans such as **beam balance**. In a beam balance, the unknown mass is placed in one pan and is balanced by putting known masses in the other pan. Today we use many types of mechanical and electronic balances. Such as physical balance, lever balance, Electronic Balance etc.



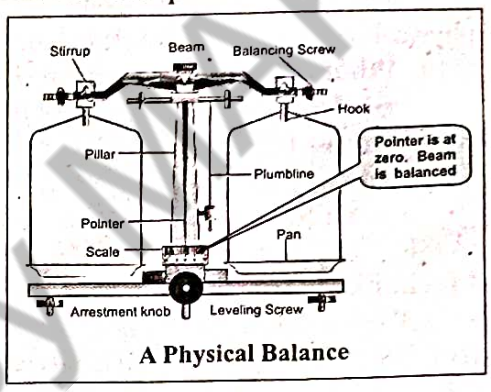
Beam Balance

Q15. What is physical balance? Write its construction and working. 091301015

Ans. Physical Balance: *"A physical balance is used in the laboratory to measure the mass of objects".*

Construction

It consists of a beam resting at the centre on a fulcrum. The beam carries scale pans over the hooks on either side. Unknown mass is placed on the left pan and some standard masses are placed in right pans to bring the pointer at zero position.



A Physical Balance

Working:

Following steps are used to measure the mass of an object.

i. First of all adjust the leveling screws with the help of plumb line to level the platform of physical balance by placing it on horizontal surface.

ii. Raise the beam by turning the arresting knob clockwise. Balance the pans by screw level and bring the pointer at zero.

iii. Bring beam back on its support by knob. Place the given object (stone) on its left pan.

iv. Place standard masses in the right pan. Raise the beam. Lower the beam if its pointer is not at zero.

v. Repeat adding or removing standard masses in the right pan till the pointer rests at zero position.

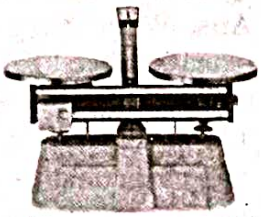
vi. Note the standard masses on the right pan. Their sum is the total mass of the object on the left pan.

Mass of Various Objects

6×10^{27}g	Mass of Earth
5.3×10^{21}g	Earth's atmosphere to 2500 km
1.4×10^{24}g	Ocean
5×10^{6}g	Elephant
7.5×10^{4}g	Average human
10^{3}g	1.0 Litre of water
3.0×10^{-4}g	Grain of Table salt
6.0×10^{-18}g	Typical protein molecule
3.98×10^{-25}g	Uranium atom
2.9×10^{-23}g	Water molecules

Q16. What is the Lever Balance? 091301016

Ans: Lever Balance: A lever balance consists of a system of levers. When lever is lifted placing the object in one pan and standard masses on the other pan, the pointer of the lever system moves. The pointer is brought to zero by varying standard masses.



Q17. What do you know about Electronic Balance? 091301017

Ans: Electronic Balance: Electronic balances come in various ranges, milligram ranges, gram ranges and kilogramme ranges. Before measuring the mass of a body, it is switched ON and its reading is set to zero. Next place the object to be weighed. The reading on the balance gives you the mass of the body placed over it. Electronic balance is the most precise balance.

Q18. Show by an example which one is the most accurate balance?

Ans. Suppose the mass of one rupee coin is done using different balances as given below:

(a) Beam Balance

Let the mass of coin be 3.2 g by using beam balance.

A beam balance is able to detect a change as small as of 0.1 g or 100 mg i.e. the least count of beam balance is 0.1 g.

(b) Physical Balance

Let the mass of coin be 3.24g by physical balance.

Since the least count of the physical balance is 0.01 g or 10 mg. Therefore, its measurement is more precise than a sensitive beam balance.

(c) Electronic Balance

Let the mass of coin be 3.247 g by electronic balance.

Least count of an electronic balance is 0.001 g or 1 mg. Therefore, its measurement is more precise than a physical balance, so electronic balance is the most sensitive balance in the above balances.

Q19. What is meant by Stopwatch? Write its types and their working.

OR How can a mechanical and digital stop watch be used?

Ans. Stopwatch *A stopwatch is used to measure the time interval of an event.*

Types of stop watches

There are two types of stopwatches.

i. Mechanical stopwatch **ii.** Digital stopwatch

Mechanical Stopwatch

A mechanical stopwatch can measure a time interval up to minimum 0.1 second. So its least count is 10^{th} part of a second or 0.1 sec.

A mechanical stopwatch has a knob. It is used as a start-stop and reset button, the watch starts when the knob is pressed once. When pressed second time, it stops the watch while the third press brings the needle back to zero position.

091301019

Mechanical Stopwatch

Digital Stopwatch

Digital stopwatch used in laboratories to measure a time interval as small as 0.01 second. So its least count is 100^{th} part of a second or 0.01s.

The digital stopwatch starts to indicate the time lapsed as the start/stop button is pressed. As soon as start/stop button is pressed again, it stops and shows the time interval recorded by it between start and stop of an event. A reset button brings it to zero setting.

Digital Stop Watch

091301020

Q20. What is a measuring cylinder? Explain.

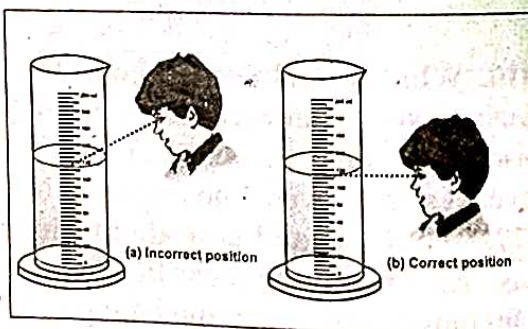
Ans. *A measuring cylinder is made of a glass or transparent plastic material. It has a scale that indicates the volume in millilitre (mL). It has different capacities from 100 mL to 2500 mL. They are used to measure the volume of a liquid or powdered substance.*

It can also be used to find the volume of an irregular shaped solid which is insoluble in a liquid by displacement method. The solid object is lowered into a measuring cylinder containing liquid. The level of liquid rises. The increase in the volume of liquid is the volume of the given solid object.

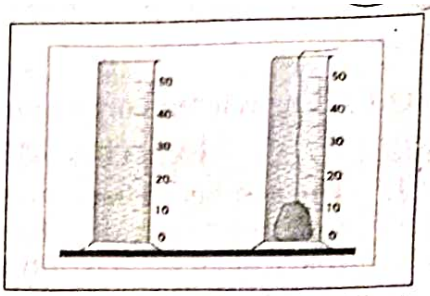
Q21. How can we use a measuring cylinder?

091301021

Ans. While using a measuring cylinder, it must be kept vertical on a plane surface. Take a measuring cylinder place it vertically on the table. Pour some water into it. The meniscus of the most liquids curve downwards while the meniscus of mercury curves upwards. The correct method to note the level of a liquid in the cylinder is to keep the eye at the same level as the meniscus of the liquid. It is incorrect to note the liquid level keeping the eye above the level of liquid level, the meniscus appears higher on the scale. Similarly when the eye is below the liquid level, the meniscus appears lower than actual height of the liquid. correct position of eye to note the liquid level keeping eye at liquid level.



Q22. How can we measure the volume of an irregular shaped solid object? 091301022



Ans. Measuring cylinder can be used to find the volume of a small irregular shaped solid that sinks in water. Suppose we want to find the volume of a small stone. Take some water in a graduated measuring cylinder. Note the volume V_i of water in the cylinder. Tie the solid with a thread and lower the solid into the cylinder till it is fully immersed in water. Note the volume V_f of water. Volume of the solid will be $V_f - V_i$.

Q23. Define Significant Figures and upon what factors does accuracy of physical quantity depend? What are the rules to find the significant figures in a measurement? (F.B. 2015) 091301023

Ans. Significant Figures *All the accurately known digits and the first doubtful digit in a measurement are called significant figures."*

It reflects the precision of a measured value of a physical quantity. The accuracy of measured physical quantity depends upon following factors

- The quality of the measuring instrument
- The experience of the observer
- The number of observations made

For example, a student measures the length of a book as 18cm by using a measuring tape. The numbers of significant figures in the measurement are two. The left digit 1 is the accurately known digit. While the digit 8 is the doubtful digit for which the student may not be sure.

Rules to find the significant digits in a measurement

i. Digits other than zero are always significant.
For Example: 27 has 2 significant digits and 275 has 3 significant digits.
ii. Zeros between significant digits are also significant.
For Example: 2705 has 4 significant digits.
iii. Final zero or zeros after decimal are significant.
For Example: 275.00 has 5 significant digits.
iv. Zeros used for spacing the decimal point are not significant. Here zeros are place holder only.
For Example: 0.03 has 1 significant digit and 0.027 has 2 significant digits.
v. In whole numbers that end in one or more zeros without a decimal point. These zeros may or may not be significant. In such cases, it is not clear which zeros serve to locate the position value and which are actually parts of the measurement. In such a case, express the quantity using scientific notation to find the significant zero. If numbers are recorded in scientific notation then all the digits before the power of 10 are significant.
For example: In 1.50×10^6, the numbers of significant figures are three.

Q24. On closing the stud and spindle of a screw gauge, if the zero of the circular scale is behind the index line and 8^{th} division of the circular scale coincides with the index line. There are 50 divisions on the circular scale and the distance between two consecutive threads on the spindle is 0.5 mm. Find the zero error and zero correction. (F.B. 2018) 091301024

Ans: Pitch of screw gauge = 0.5 mm
Total divisions on circular scale = 50 division

$$\text{Least count of screw gauge} = \frac{\text{Pitch of screw gauge}}{\text{Total division on circular scale}}$$

$$L.C = \frac{0.5\text{ mm}}{50}$$

$$L.C = 0.01\text{ mm}$$

Zero Error:

On closing the stud and spindle of screw gauge if the zero line of circular scale is behind the index line then error will be positive.

The division on circular scale coincide with index line = n = 8^{th} division.

Positive zero error = $n \times L.C$
= $8^{th} \times 0.01$ mm
Positive zero error = 0.08 mm

Zero Correction:

Zero correction is negative of zero error.
Zero correction = –0.08 mm

Multiple Choice Questions

Q.1.1 Encircle the correct answer from the given choices:

Exercise MCQs

1. The number of base units in SI are: 091301025
(a) 3 (b) 6
(c) 7 (d) 9

2. Which one of the following unit is not a derived unit? 091301026
(a) pascal (b) kilogramme
(c) newton (d) watt

3. Amount of a substance in terms of numbers is measured in: (F.B. 2015) 091301027
(a) gram (b) kilogramme
(c) newton (d) mole

4. An interval of 200 μs equivalent to: (F.B. 2015) 091301028
(a) 0.2s (b) 0.02s
(c) 2×10^{-4}s (d) 2×10^{-6}s

5. Which one of the following is the smallest quantity? 091301029
(a) 0.01g (b) 2mg
(c) 100μg (d) 5000ng

6. Which instrument is most suitable to measure the internal diameter of a test tube? (F.B. 2017) 091301030
(a) Metre rule (b) Vernier Callipers
(c) Measuring tape (d) Screw Gauge

7. A student claimed the diameter of a wire as 1.032cm using Vernier callipers. Upto what extent do you agree with it? 091301031
(a) 1 cm (b) 1.0 cm
(c) 1.03 cm (d) 1.032 cm

8. A measuring cylinder is used to measure: (F.B 2107) 091301032
(a) mass (b) area
(c) volume (d) level of liquid

9. A student noted the thickness of glass sheet using screw gauge. On the main scale it reads 3 divisions while 8^{th} division on the circular scale coincides with index line. Its thickness is. (F.B. 2017) 091301033
(a) 3.8 cm (b) 3.08 mm
(c) 3.8 mm (d) 3.08 m

10. Significant figures in an expression are: 091301034
(a) all the digits
(b) all accurately known digits
(c) all the accurately known digits and the first doubtful digit
(d) all the accurately known digits and all the doubtful digits

Additional MCQs

11. 1micro(μ)= 091301035
(a) 10^{-3} (b) 10^{-6}
(c) 10^{-12} (d) 10^{-2}

12. 1nm have meters. 091301036
(a) 10^{-3}m (b) 10^{-6} m
(c) 10^{-9}m (d) 10^{-10}m

13. In measurement 1.032 numbers of significant figure are: 091301037
(a) 1 (b) 2
(c) 3 (d) 4

14. The unit of electric current is: 091301038
(a) candela (b) metre
(c) second (d) ampere

15. Andromeda is one of the billions of galaxies of known. 091301039
(a) star (b) asteroid
(c) pole (d) universe

16. The study of the structure and properties of atom is called: 091301040
(a) Electricity (b) nuclear physics
(c) geo physics (d) atomic physics

17. The eleventh general conference was held in Paris in: 091301041
(a) 1959 (b) 1961
(c) 1660 (d) 1960

18. The unit of electric charge is. 091301042
(a) coulomb (b) ampere
(c) volt (d) joule

19. The least count of vernier callipers is: 091301043
(a) 0.01mm (b) 0.1mm
(c) 0.001mm (d) 0.01m

20. The least count of screw gauge is: 091301044
(a) .01mm (b) 0.1mm
(c) .001mm (d) .01m

21. A thimble of circular scale consists of equal division. 091301045
(a) 100 (b) 10
(c) 1000 (d) 01

22. In screw gauge if zero of circular scale is behind the index line then error is: 091301046
(a) positive (b) zero
(c) negative (d) no error

23. The number 275.00 consists of significant figures: (F.B. 2016) 091301047
(a) 3 (b) 5
(c) 4 (d) 2

24. Science is that word which is derived by Latin word: 091301048
(a) scient (b) scientis
(c) scientia (d) scincet

25. The number 0.00580 in scientific notation is: 091301049
(a) 5.80×10^{5} (b) 5.80×10^{-4}
(c) 5.80×10^{-3} (d) 5.80×10^{-2}

26. The unit of force is: 091301050
(a) newton (b) m^3
(c) ms^{-2} (d) ms^{-1}

27. The study of internal structure of Earth is called: 091301051
(a) Atomic physics (b) Plasma physics
(c) Nuclear physics (d) Geo physics

28. One cubic metre is equal to: 091301052
(a) 100litre (b) 1000 litre
(c) 10000 litre (d) $\frac{1}{1000}$ litre

29. The base quantity is: 091301053
(a) mass (b) volume
(c) torque (d) momentum

30. The smallest division that can be taken by a meter rule is: 091301054
(a) 1cm (b) 1mm
(c) 1 dm (d) 1km

31. Least count of digital vernier callipers is:
(a) 0.01cm (b) 0.01mm 091301055
(c) 0.1mm (d) 0.1cm

32. For balancing the beam balance, pointer must be at : 091301056
(a) zero (b) extreme position
(c) the right side (d) the left side

33. Least count of physical balance is: 091301057
(a) 0.001g (b) 0.01g
(c) 0.1g (d) 0.001g

34. Least count of electronic balance is: 091301058
(a) 0.001g (b) 0.01g
(c) 0.1g (d) 0.0001g

35. Least count of digital stop watch is: 091301059
(a) 0.01 sec (b) 0.1sec
(c) 1 sec (d) 10 sec

36. Mechanical stop watch can measure up to part of a second: 091301060
(a) 1 (b) $1/10^{th}$
(c) $1/100^{th}$ (d) $1/1000^{th}$

37. Meniscus of which liquid curves upward: 091301061
(a) Water (b) Honey
(c) Milk (d) Mercury

38. While rounding the numbers if last digit is 5, then: 091301062
(a) It is simply dropped
(b) The digit on its left is increased by 1
(c) It is rounded to get nearest even number.
(d) It remain same

39. The value we get after rounding 1.47 is: 091301063
(a) 1.4 (b) 1.5
(c) 1.47 (d) 1.46

40. In vernier callipers if zero line of vernier scale is on the left side of zero of the main scale then the error will be: 091301064
(a) positive (b) negative
(c) zero (d) nil error

41. 1mm = : 091301065
(a) 10^{3} m (b) 10^{-2} m
(c) 10^{-3}m (d) 10^{-6} m

42. A car is made on the principles of: 091301066
(a) Mechanics
(b) Electricity
(c) Thermodynamics
(d) Electronics

43. A refrigerator is based on the principles of: 091301067
(a) Mechanics
(b) Electricity
(c) Thermodynamics
(d) Electronics

44. In the nineteenth century, physical sciences were divided into how many distinct discipline? 091301068
(a) 4 (b) 5
(c) 6 (d) 7

45. A physical quantity possesses -characteristics:
(a) 2 (b) 3 091301069
(c) 4 (d) 5

46. The word science means: 091301070
(a) Intelligence (b) Nature
(c) Knowledge (d) Philosphy

47. The skull and crossbones is a classic warning sign,  but can you name the type of danger? 091301071
(a) General danger
(b) Flammable material
(c) Toxic or poisonous material
(d) Dangerous to eat/drink otherwise safe

48.  **Symbol is used for describing hazard. Which type of hazard this symbol shows?** 091301072

(a) Bio hazard
(b) Radiation hazard
(c) Electric hazard
(d) Radioactive biological hazard

49.  **This symbol is often confused with a similar-looking symbol. What does it mean?** 091301073

(a) Flammable, keep away from heat or flame
(b) Oxidizer
(c) Heat-sensitive explosive
(d) Fire goes here / Don't expose to sunlight

50. **The warning sign used for radioactivity is:**

(a)  (b)  091301074

(c)  (d) 

51. **The warning sign used for flammable is:**

(a)  (b)  091301075

(c)  (d) 

52. **The sign used for electric hazard is:**

(a)  (b)  091301075

(c)  (d) 

53. **The sign used for poison is:** 091301077

(a)  (b) 

(c)  (d) 

54. **The warning sign**  **is used for:** 091301078

(a) Radioactivity (b) Poision
(c) Explosive (d) Electric hazards

55. **The warning sign**  **represents:** 091301079

(a) General danger (b) Poision
(c) Explosive (d) Electric hazards

56. **What are the significant in the measurement 0.00450 kg?** (F.B. 2017) 091301080

(a) 2, (b) 3
(c) 5 (d) 6

57. **1 L = _____ :** (F.B. 2017) 091301081

(a) 1000 dm^3 (b) 100 dm^3
(c) 10 dm^3 (d) 1 dm^3

58. **The least count of screw gauge having pitch 0.5mm and 50 divisions on its circular scale is:** (F.B. 2017) 091301082

(a) 0.001 cm (b) 0.01 cm
(c) 0.0 cm (d) 1.0 cm

59. **1mm per day is equal to:** (F.B. 2017) 091301083

(a) $11.57m5^{-1}$ (b) $11:57nms^{-1}$
(c) $1.57pms^{-1}$ (d) $11.57lms^{-1}$

60. **10^{-12} stands for:** (F.B. 2016) 091301084

(a) Micro (b) Pico
(c) Femto (d) Nano

61. **The Least Count of a measuing cylinder is:** (F.B. 2018) 091301084(a)

(a) 1 m^3 (b) 0.01 mL
(c) 0.1 mL (d) 1mL

Answer Key

1.	c	2.	b	3.	d	4.	c	5.	d
6.	b	7.	c	8.	c	9.	b	10.	c
11.	b	12.	c	13.	d	14.	d	15.	d
16.	d	17.	d	18.	a	19	b	20	a
21.	a	22.	a	23.	b	24.	c	25.	c
26.	a	27.	d	28.	b	29.	a	30.	b
31.	b	32.	a	33.	b	34.	a	35.	a
36.	b	37.	d	38.	c	39.	b	40.	b
41.	c	42.	a	43.	c	44.	b	45.	a
46.	c	47.	c	48.	c	49.	a	50.	d
51.	a	52.	b	53.	c	54.	c	55.	a
56.	b	57.	d	58.	a	59.	b	60.	B
61.	d								

Q1.2 What is the difference between base quantities and derived quantities. Give three examples in each case. 091301085

Ans. Base Quantities: There are seven physical quantities which form the foundation for other physical quantities called base quantities.

Examples: Length, mass, time and temperature etc.

Derived Quantities: Those physical quantities which are expressed in terms of base quantities are called derived quantities.

Examples: Work, energy and power.

Q1.3 Pick out the base units in the following. 091301086

Ans. joule, newton, kilogramme, hertz, mole, ampere, metre, kelvin, coulomb and watt.

Base Units	Derived Units
Kilogramme	Joule
Mole	Newton
Ampere	Hertz
Meter	Coulomb
Kelvin	Watt

Q1.4. Find the base quantities involved in each of the following derived quantities: (F.B. 2013) 091301087

(a)speed (b) volume
(c)force (d) work

Ans.

(a) Speed:

It is distance covered per unit time. i.e.

$$v = \frac{\text{Distance}}{\text{Time}}$$

So, in speed, base quantities involved are length (distance) and time

(b) Volume:

Volume = Length × height × width
= Length × length × length

So, the base quantity in volume involved is length.

(c) Force:

We know that

$$F = ma = \text{mass}\ \frac{\Delta v}{\Delta t} = m \times \frac{l}{t} \times \frac{d}{t}$$

In the formula of force the base quantities mass of object, length and time are involved.

(d) Work:

We know that.

Work = F × distance
= ma × distance

$$= m\left(\frac{\Delta v}{\Delta t}\right)S \quad = m \times \frac{d}{t} \times \frac{l}{t} \times S$$

In the formula of work, base quantities mass, length (distance) and time are involved.

Q1.5 Estimate your age in seconds. 091301088

Ans. Suppose the age of Student is 15 years

Age=15 year

Age in days = 15 × 365 = 5475 days
Age in hours = 5475 × 24= 131400 hours
Age in minutes = 131400 × 60
= 7884000 minutes
Age in seconds is = 7884000 × 60
= 473040000 seconds
= 4.73040×10^8 seconds

Q1.6 What role SI units have played in the development of science? 091301089

Ans. With the development in the field of science and technology the need for commonly acceptable system of units was seriously felt all over the world particularly to exchange scientific and technical information. So, in 1960 International Bureau of Weight and Measurements were decided to introduce worldwide system of measurements that is called international system of unit and is commonly written as SI.

Q1.7 What is meant by vernier constant? 091301090

Ans. The least count of vernier callipers is also called vernier constant. It is defined as "the difference between one main scale division and one vernier scale division is called vernier constant or least count." i.e.

1 mm – 0.9 mm = 0.1 mm

Q1.8 What do you understand by the zero error of a measuring instrument? 091301091

Ans. In measuring instruments there may be systematic error, due to which a measurement may be less or greater than actual measurement. Zero error influence all the measurements equally. Zero error is caused by incorrect position of zero point.

Q1.9 Why is the use of zero error necessary in a measuring instrument? 091301092

Ans. Since zero error of instruments affect all the measurements, so it must be necessary that we have to calculate the zero error of an instrument before taking measurements. If we don't calculate the zero error then consistent difference in the reading will be calculated.

Q1.10 What is a stopwatch? What is the least count of a mechanical stopwatch you have used in the laboratories? (F.B. 2015) 091301093

Ans. A stop watch is used to measure time interval of an event. The mechanical stop watch has least count 0.1 second.

Q1.11 Why do we need to measure extremely small interval of time? 091301094

Ans. In most of experiments and in scientific calculations, time is recorded for very short intervals. So, we need to measure small interval of time.

Q1.12 What is meant by significant figures of a measurement? 091301095

Ans. All the accurately known digits and the first doubtful digit in a measurement are called significant figures. It reflects the precision of a measured value of physical quantity.

Q1.13 How is precision related to the significant figures in a measured quantity? 091301096

Ans. In any measurement, greater the number of significant figures, greater is precision. An improvement in the quality of measurement by using better instrument increases the significant figures in the measured result. The significant figures are all the digits that are known accurately and the one estimated digit. More significant figures means greater precision. e.g. measurements taken by screw gauge is more precise than vernier callipers and meter rule.

Additional Answer Questions

Q14. What do you know about Andromeda? 091301097

Ans. Andromeda is one of the billions of galaxies of known universe.

Q15. Change 16 years age into seconds. 091301098

Ans. Suppose the age is 16 year

Age=16 years

Age in days $=16\times 365 = 5840$ days

Age in hours $= 5840 \times 24 = 140160$ hours

Age in minutes $=140160 \times 60$

$= 8409600$ minutes

Age in seconds $= 8409600 \times 60$

$= 504576000$ seconds

$= 5.0457 \times 10^8$ seconds

Q16. Define physics. 091301099

Ans. The branch of science which deals with the study of matter, energy and their interaction. The laws and principles of physics help us to understand nature.

Q17. What is meant by zero error and zero correction of vernier callipers? 091301100

Ans. Zero error

Zero error will exist if zero of the vernier scale is not coinciding with the zero of main scale. There are two types of errors.

i. Positive Zero Error

Zero error will be positive if zero of vernier scale is on the right side of the zero of the main scale.

ii. Negative Zero Error

If zero line of vernier scale is on the left side of zero of the main scale then zero error will be negative.

Zero Correction

(i) To correct the positive zero error subtract the value of error from final answer

(ii) To correct negative zero error add the value of error into the final answer.

Q18. Define metre rule. 091301101

Ans. "A metre rule is a length measuring instrument. It is commonly used in the daily life to measure length of an object or distance between two points".

It is one metre long which is equal to 100 centimetres. Each centimeter (cm) is divided into 10 small divisions called (millimeter (mm). Thus one milimetre is the smallest reading that can be taken using a metre rule and is called its least count.

Q19. Define measuring tape. 091301102

Ans. "Measuring tapes are used to measure length in metres and centimetres. A measuring tape is used by blacksmith and carpenters". A measuring tape consists of a thin and long strip of cotton, metal or plastic generally 10 m, 20 m, 50 m or 100 m long. Measuring tapes are marked in centimeters as well as in inches.

Q20. Define vernier callipers. 091301103

Ans. "It is an instrument which is used to measure the 10^{th} part of mm" Least count of the Vernier Callipers is 0.1 mm or 0.01 cm.

Q21. Define screw gauge. Write its Least Count. 091301104

Ans. "A screw gauge is an instrument that is used to measure small lengths with accuracy greater than a Vernier Callipers". It is used to measure the 100^{th}

part of one millimetre least count of screw gauge 0.01mm or 0.001cm.

Q22. Define physical balance. 091301105

Ans. "A physical balance is used in the laboratory to measure the mass of various objects by comparison. It consists of a beam resting at the centre on a fulcrum. The beam carries scale pans over the hooks on either side. Unknown mass is placed on the left pan. Find some suitable standard masses that cause the pointer to remain at zero on raising the beam.

Q23. Define measuring cylinder. 091301106

Ans. A measuring cylinder is made of a glass or transparent plastic material. It is used to measure volume of a liquid or powdered substance. It has a scale that indicates the volume in millilitre (mL). It has different capacities from 100 mL to 2500 mL.

Q24. What is meant by international system of units (SI)? 091301107

Ans. In 1960 international Bureau of weight and measures decided to introduce worldwide system of measurements that is called international system of unit and is commonly written as SI.

Q25. Name the telescope which orbits around the Earth? 091301108

Ans. Hubble space telescope orbits around the Earth. It provides information about stars.

Q26. What do you know about digital vernier callipers? 091301109

Ans. Digital vernier callipers has greater precision than mechanical vernier callipers. Least count of digital vernier callipers is 0.01mm.

Q27. How precision of a balance varies in measuring mass of an object with different balances? 091301110

Ans. The precision of a balance varies in measuring mass of an object is different for different balances. A sensitive balance cannot measure large masses. Similarly a balance that measures large masses cannot be sensitive.

Some digital balances measure even smaller differences of the order of 0.0001g or 0.1 mg. Such balances are considered the most precise balance.

Q28. Write the laboratory safety rules.

(F.B. 2017) 091301111

Ans. The students should know what to do in case of an accident. The charts or posters are to be displayed in the laboratory to handle situations arising from any mishap or accident. For your won safety and for the safety of others in the laboratory, follow safety rules given below:

- Do not carry out any experiment without the permission of your teacher.
- Do not eat, drink, play or run in the laboratory.
- Read the instructions carefully to familiarize yourself with the possible hazards before handling equipments and materials.
- Handle equipments and materials with care.
- Do not hesitate to consult your teacher in case of any doubt.
- Do not temper with the electrical appliances and other fittings in the laboratory.
- Report any accident or injuries immediately to your teacher.

Q29. How can we round the number? 091301112

Ans. (i) If the last digit is less than 5 then it is simply dropped for example 1.943 is rounded to 1.94.

(ii) If the last digit is greater than 5 then the digit on its left is increased by 1. For example 1.47 is rounded to 1.5

(iii) If the last digit is 5 then it is rounded to get nearest even number. For example 1.35 rounded to 1.4 and 1.45 is also rounded to 1.4.

Q30. Write the names of the necessary laboratory safety equipments.

(F.B. 2015) 091301113

Ans. Laboratory Safety Equipments:

A school laboratory must have safety equipments such as:

- Waste-disposal basket
- Fire extinguisher.
- Fire alarm.
- First Aid Box.
- Sand and water buckets.
- Fire blanket to put off fire.
- Substances and equipments that need extra care must bear proper warning signs.

Q31. Convert of the following:

a) 10km/h into ms^{-1}

b) 100 μm into nm

c) 5 litre into m^3 (F.B. 2017) 091301114

Ans.

a) $10\text{km/h} = \frac{10\times10^3\text{m}}{60\times60\text{s}} = \frac{10\times10^3\text{m}}{3600}\text{ms}^{-1} = 2.77\text{ms}^{-1}$

b) $100\mu\text{m} = 100\times10^{-6}\text{m} = \frac{100\times10^{-3}\times10^{-6}\text{m}}{10^{-3}}\text{ms}^{-1}$

$= \frac{100}{10^{-3}}\times10^{-9}\text{m} = 100,000\times10^{-9}\text{m} = 100000\text{nm}$

c) 5 litre $= 5\times10^{-3}\text{m}^3$ $\therefore$ 1 litre $= 10^{-3}\text{m}^3$

Quick Quiz

Q32. Name five prefixes commonly used. 091301115

Ans. Milli, micro, mega, kilo, nano, pico are commonly uses prefixes.

Q33. Identify the base quantity in the following:
(i) Speed (ii) Area 091301116
(iii) Force (iv) Distance

Ans. Distance (length) is the base quantity.

Q34. Identify the following as base or derived quantity: 091301117

Density, force, mass, speed, time, length, temperature and volume.

Ans. Base quantities:

Base quantities are mass, time, length, temperature.

Derived Quantities

Derived quantities are density, force, speed and volume.

Q35. The Sun is one hundred and fifty million kilometers away from the Earth. Write this (F.B. 2017) 091301118

(a) as an ordinary whole number.

(b) In scientific notation.

Ans. (a) 150,000,000 km

(b) 15×10^7 km

$= 1.5 \times 10^8$ km $\quad \therefore\ 1k = 10^3$

$= 1.5 \times 10^8 \times 10^3$ m

In scientific notation $= 1.5 \times 10^{11}$ m

Q36. Write the number given below in scientific notation. 091301119

(a) 3000000000 ms^{-1} (b) 6400000 m

(c) 0.00000000 16g (d) 0.0000548 s

Ans. (a) $3.0 \times 10^9 ms^{-1}$

(b) 6.4×10^6 m

(c) 1.6×10^{-9} g

(d) 5.48×10^{-5} s

Q37. What is the least count of vernier callipers? 091301120

Ans. The difference between one small division on main scale and one vernier scale division is 0.1mm. It is called least count of vernier callipers.

$$\text{Least count of vernier callipers} = \frac{\text{smallest reading on M.S}}{\text{no. of div. on V.S}}$$

$$= \frac{1\text{mm}}{10\text{divisions}}$$

L.C = 0.1mm or 0.01cm

Q38. Why do we study Physics? 091301121

Ans. Physics is the most fundamental Branch of science. We study Physics to understand the nature, properties of matter, energy and their mutual relationship. Today most of progress in the field of science and technology has become possible due to invention in the field of physics. Physics explains most of Phenomena of the universe.

Q39. What is the range of vernier callipers used in your physics laboratory? 091301122

Ans. The range of vernier callipers in physics laboratory is 120mm or 12cm.

Q40. Name any five branches of Physics. 091301123

Ans. Mechanics, Heat, Sound, Light, Geophysics.

Q41. How many divisions are there on its veriner scale? 091301124

Ans. There are 10 divisions on the vernier scale of the vernier callipers.

Q42. Why do we use zero correction? 091301125

Ans. We use zero correction to get an accurate and error free measurement. By applying zero correction, the readings will not be doubtful.

Mini Exercise

Q43. What is the least count of a screw gauge? 091301126

Ans. When thimble of screw gauge completes one rotation, 100 divisions pass the index line and the thimble moves 1mm along the main scale. Thus each division of circular scale crossing the index line move the thimble through 1/100mm or 0.01mm on the main scale.

$$\text{Least Count} = \frac{\text{pitch of screw gauge}}{\text{no. of div. on circular scale}} = \frac{1\text{mm}}{100}$$

L.C. = 0.01mm or 0.001cm

Q44. What is the pitch of your laboratory screw gauge? 091301127

Ans. The pitch of laboratory screw gauge is 1mm.

Q45. What is the range of your laboratory screw gauge? 091301128

Ans. The range of laboratory screw gauge is 0.25mm.

Q46. What is the function of balancing screws in a physical balance? 091301129

Ans. There are two screws on the physical balance named as balancing screw, their function is to bring

the pointer of the scale at zero position and to balance the pans.

Q47. On what pan we place the object and why? 091301130

Ans. We usually place the object on the left pan and standard masses on the right pan. It is just for the human convenience. Because majority of people are right handed.

Q48. How many seconds are in a year? 091301131

Ans.

1 Year = 365 days

= 365 × 24 hours

= 365 × 24 × 60 min

= 365 × 24 × 60 × 60 seconds

= 31536000 seconds

= 3.1536×10^7 seconds

One year has 3.1536×10^7 seconds.

Q49. Which source gives us pollution free electricity? 091301132

Ans. Wind turbines used to run the electric generator gives us pollution free electricity.

Q50. What is digital vernier calipers? 091301133

Ans. A digital vernier calipers has greater precision then mechanical vernier calipers. Least count of digital vernier calipers is 0.01mm.

Q51. Which one of the two instruments is more precise and why? 091301134

(a) Vernier Callipers

(b) Screw gauge

Ans. Screw gauge is more precise than vernier callipers because it measure 100^{th} part of a millimeter while vernier callipers measures 10^{th} part of a millimeter.

Least counts of Measuring Instruments:

1)	Meter Rule = 1mm or 0.1cm	2)	Measuring tape = 1mm or 0.1 cm
3)	Vernier callipers = 0.1mm or 0.01cm	4)	Screw Gauge = 0.01mm or 0.001cm
5)	Physical Balance = 0.01g or 10mg	6)	Beam Balance = 0.1g or 100mg
7)	Electronic Balance = 0.001g or 1mg	8)	Mechanical stop watch = 0.1 sec
9)	Digital Stop watch = 0.01 sec		

Mini Exercise:

Volume is a derived quantity

1 L = 1000 mL

1 L = 1 dm^3

= $(10\ cm)^3$

= 1000 cm^3

∴ 1 mL = 1 cm^3

Express 1 m^3 in litres = 1000 L.

Solved Examples

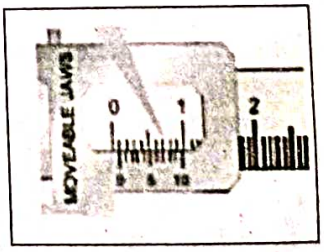
Example 1.1

Find the diameter of a cylinder placed between the outer jaws of Vernier Callipers as shown in figure. 091301135

Solution:

Zero correction

On closing the jaws of Vernier Callipers, the position of vernier scale as shown in figure.



Main scale reading = 0.0 cm

Vernier division coinciding with main scale = 7 div.

Vernier scale reading= 7 × 0.01 cm= 0.07 cm

Zero error = 0.0 cm + 0.07 cm = +0.07 cm

Zero correction (Z.C) = −0.07 cm

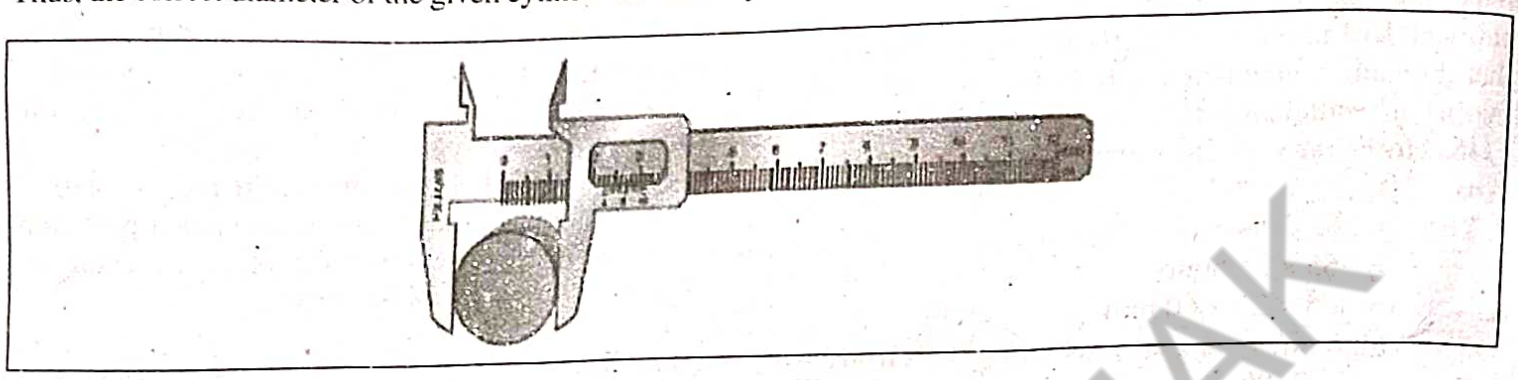
Diameter of the cylinder

Main scale reading = 2.2cm

(When the given cylinder is kept between the jaws of the Vernier Callipers as shown in figure.)

Vernier div. coinciding with main scale div. =6 div.

Vernier scale reading = 6×0.01 cm = 0.06 cm
Observed diameter of the cylinder = 2.2 cm + 0.06 cm = 2.26 cm
Correct diameter of the cylinder = 2.26 cm - 0.07 cm = 2.19cm
Thus, the correct diameter of the given cylinder as found by Vernier Callipers is 2.19 cm.



Example 1.2: Find the diameter of a wire using a screw gauge. 091301136

Solution:

The diameter of a given wire can be found as follows:

(i) Close the gap between the spindle and the stud of the screw gauge by turning the ratchet in the clockwise direction.

(ii) Note main scale as well as circular scale readings to find zero error and hence zero correction of the screw gauge.

(iii) Open the gap between stud and spindle of the screw gauge by turning the ratchet in anti-clockwise direction. Place the given wire in the gap as shown in figure 1.11. Turn the ratchet so that the object is pressed gently between the studs and the spindle.

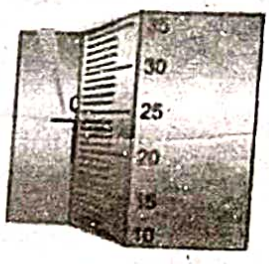
(iv) Note main scale as well as circular scale readings to find the diameter of the given wire.

(v) Apply zero correction to get the correct diameter of the wire.

(vi) Repeat steps iii, iv and v at different places of the wire to obtain its average diameter.

Zero correction:

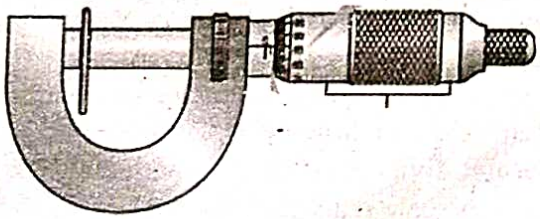
Closing the gap of the screw gauge



Main scale reading = 0 mm
Circular scale reading = 24×0.01 mm
= 0.24 mm
Zero error of the screw gauge = 0 mm + 0.24 mm
= + 0.24 mm
Zero correction Z.C. = – 0.24 mm

Diameter of the wire

Main scale reading = 1 mm
(when the given wire is pressed by the stud and spindle of the screw gauge)



No. of divisions of circular scale = 85 div
Circular scale reading = 85×0.01 mm
= 0.85 mm
Observed diameter of the given wire = 1 mm + 0.85 mm
= 1.85 mm
Correct diameter of the given wire = 1.85 mm – 0.24 mm
= 1.61 mm

Thus diameter of the given wire is 1.61 mm.

Example 1.3: Find the mass of a small stone by a physical balance. 091301137

Solution:

Follow the steps to measure the mass of a given objects.

(i) Adjusting the levelling screws with the help of plumbline to level the platform of physical balance.
(ii) Raise the beam gently by turning the arresting knob clockwise. Using balancing screws at the ends of its beam, bring the pointer at zero position.
(iii) Turn the arresting knob to bring the beam back on its supports. Place the given object (stone) on its left pan.
(iv) Place suitable standard masses from the weight box on the right pan. Raise the beam. Lower the beam if its pointer is not at zero.
(v) Repeat adding or removing suitable standard masses in the right pan till the pointer rests at zero on raising the beam.
(vi) Note the standard masses on the right pan. Their sum is the mass of the object on the left pam.

Example 1.4: Find the number of significant figures in each of the following values. Also express them in scientific notations. 091301138

(a) 100.8 s (b) 0.00580 km (c) 210.0g

Solution:

(a) In 100.8s all the four digits are significant. The zeros between the two significant figures 1 and 8 are significant. To write the quantity in scientific notation, we move the decimal point two places to the left, thus

$100.8\ s = 1.008 \times 10^2\ s$

(b) In 0.00580 km the first two zeros are not significant. They are used to space the decimal point. The digit 5, 8 and the final zero are significant. Thus there are three significant. In scientific notation, it can be written as

5.80×10^{-3} km.

(c) In 210.0g the final zero is significant since it comes after the decimal point. The zero between last zero and 1 is also significant because it comes between the significant figures. Thus the number of significant figures in this case are four. In scientific notation, it can be written as

$210.0\ g = 2.100 \times 10^2\ g$

Numerical Problems

Q1.1. Express the following quantities using prefixes. 091301139

(a) 5000 g (b) 2000 000 W
(c) 52×10^{-10}kg (d) 225×10^{-8} s

Solution

(a) 5000g
$= 5 \times 10^3$g
= 5kg

$\therefore$ 1 kilo = 10^3

(b) 2000, 000 W
$= 2 \times 10^6$W.
= 2 mega watt,
= 2MW.

$\therefore$ 1 Mega = 10^6

10^6W=1MW

(c) 52×10^{-10} kg
$=5.2 \times 10^{+1} \times 10^{-10}$ kg
$=5.2 \times 10^{1-10}$ kg
$=5.2 \times 10^{-9}$ kg
$=5.2 \times 10^{-9} \times 10^3$ g
$=5.2 \times 10^{-9+3}$ g
$=5.2 \times 10^{-6}$ g
$=5.2\ \mu$ g

$\therefore$ 1 Kilo = 10^3

$\therefore$ 1micro = 10^{-6}
1 μ = 10^{-6}

(d) 225×10^{-8} sec
$=2.25 \times 10^2 \times 10^{-8}$ sec
$=2.25 \times 10^{2-8}$ sec
$=2.25 \times 10^{-6}$ sec
$=2.25\ \mu$ sec
$=2.25\ \mu$s

$\therefore$ 10^{-6} = 1μ

Q1.2 How do the prefixes micro, nano and pico relate to each other? 091301140

Solution:

1 micro = 10^{-6}
1 nano = 10^{-9}
1 pico = 10^{-12}

Take1 micro = 10^{-6}
Multiplying on both sides by 10^{-3}
10^{-3} micro = $10^{-6} \times 10^{-3}$
$10^{-3} \times$ micro = 10^{-9}
10^{-3}micro = 1nano

and

One micro = 10^3 nano

Now, 1 nano = 10^{-9}
Multiplying on both sides by 10^{-3}
10^{-3}nano = $10^{-9} \times 10^{-3}$
10^{-3} nano = 10^{-12}
10^{-3} nano = 1 pico

and

1 nano = 10^3 pico

Q1.3 Your hair grow at the rate of 1mm per day. Find their growth rate in nms^{-1}. 091301141

Solution:

Rate of hair growth $= \frac{1mm}{day}$

To Find:

Growth rate in nms^{-1} = ?

Solution:

1 day have seconds $= 24 \times 60 \times 60$ s

$= 86400\,s = 8.64 \times 10^{4}$ s

$\because 1mm = 10^{-3}$ m

$$\text{Hair growth rate} = \frac{1\times10^{-3}}{8.64\times10^{4}}\,ms^{-1}$$

$$= \frac{1}{8.64}\times10^{-3}\times10^{-4}ms^{-1}$$

$$= 0.1157\times10^{-7}ms^{-1}$$

$$= 11.57\times10^{-2}\times10^{-7}ms^{-1}$$

$$= 11.57\times10^{-9}\,ms^{-1}$$

so, hair growth rate in $nms^{-1} = 11.57nms^{-1}$

Q1.4 Rewrite the following in standard form. 091301142

(a) 1168×10^{-27} **(b)** 32×10^{5}

(c) $725\times10^{-5}kg$ **(d)** 0.02×10^{-8}

Solution

(a) 1168×10^{-27}

$= 1.168 \times 10^{3} \times 10^{-27}$

$= 1.168 \times 10^{-24}$

(b) 32×10^{5}

$= 3.2 \times 10^{1} \times 10^{5}$

$= 3.2 \times 10^{6}$

(c) 725×10^{-5} kg

$= 7.25 \times 10^{-5} \times 10^{2}$ kg

$= 7.25 \times 10^{-3}$ kg

$= 7.25 \times 10^{-3} \times 10^{3}$ g

$\therefore$ 1 Kilo $= 10^{3}$

$= 7.25$ g

(d) 0.02×10^{-8}

$= 2 \times 10^{-2} \times 10^{-8}$

$= 2 \times 10^{-10}$

Q1.5 Write the following quantities in standard form. 091301143

(a) 6400 km **(b) 380 000km**

(c) 300, 000, 000ms^{-1} **(d) seconds in a day**

Solution

(a) 6400km

$= 6.4 \times 10^{3}$km

(b) 380000 km

$= 38 \times 10^{4}$ km

$= 3.8 \times 10^{+5}$ km

(c) 300, 000, 000 ms^{-1}.

$= 3 \times 10^{8} ms^{-1}$.

(d) Seconds in a day are $= 24 \times 60 \times 60$ sec

$= 86400$ s

$= 864 \times 10^{2}$ sec

$= 8.64 \times 10^{2} \times 10^{2}$ sec

$= 8.64 \times 10^{4}$ sec

Q1.6 On closing the jaws of a Vernier Callipers, zero of the vernier scale is on the right to its main scale such that 4^{th} division of its vernier scale coincides with one of the main scale division. Find its zero error and zero correction. 091301144

Solution

Since the zero of vernier scale is on the right side of the main scale. So the error is positive and its correction will be negative.

Zero error of vernier $= 4 \times 0.01$cm

$= 0.04$ cm

Correction will be $= -0.04$ cm

Q1.7 A screw gauge has 50 divisions on its circular scale. The pitch of the screw gauge is 0.5mm. What is its least count? 091301145

Solution

Division on circular scale = 50

pitch of screw gauge is 0.5mm

Least count = ?

$$\text{Least Count} = \frac{pitch\ of\ screw\ guage}{division\ on\ circular\ scale}$$

$$= \frac{0.5mm}{50} = \frac{1mm}{100}$$

$= 0.01$mm.

Least Count $= 0.01$mm

Or $= \frac{0.01}{10}cm$

$= 0.001cm$.

$\therefore$ 1cm = 10 mm

$1mm = \frac{1}{10}$cm

Q1.8 Which of the following quantities have three significant figures? 091301146

(a) 3.0066m **(b) 0.00309kg**

(c) 5.05×10^{27}kg **(d) 301.0 s**

Solution

(a) 3.0066m

As zero between the digits are significant, so

Its significant figures are = 5

(b) 0.00309 kg

Zero written on the left side of the decimal point for the purpose of spacing the decimal point are not significant. So,

Its significant figures are = 3

(c) 5.05×10^{-27} kg

In standard form the digits before the power of 10 are considered significant.

Its significant figures are = 3.

(d) 30.10 sec

Zero on the right in the decimal fraction are significant.

Its significant figures are = 4

So (b) and (c) have 3 significant figures.

Q1.9 What are the significant figures in the following measurements? 091301147

(a) 1.009m **(b) 0.00450kg**

(c) 1.66×10^{27}kg **(d) 2001 s**

Solution:

(a) 1.009 m.

Significant figures are = 4

(b) 0.00450 kg

Significant figures are = 3

(c) 1.66×10^{-27} kg

Significant figures are = 3

(d) 2001 sec

Significant figures are = 4

Q1.10 A chocolate wrapper is 6.7 cm long and 5.4 cm wide. Calculate its area upto reasonable number of significant figures.

Given data: 091301148

Length of chocolate wrapper = 6.7cm.

Width of chocolate wrapper = 5.4cm.

To Find:

Area = ?

Solution:

Area = Length × Width

$= 6.7 \times 5.4$

$= 36.18 \text{ cm}^2$

$A = 36 \text{ cm}^2$

Area in the reasonable number of significant figures is 36cm^2.

UNIT 02 KINEMATICS

Introduction:

In this unit, we will study the types of motion, scalar and vector quantities, the relation between displacement, speed, velocity and acceleration; linear motion and equations of motion.

The first thing concerning the motion of an object is kinematics.

"Kinematics mean the study of motion of an object without describing the cause of motion".

Q.1 Differentiate between rest and motion. Also give an example that all motions are relative. 091302001

Ans. Rest: *"A body is said to be at rest, if it does not change its position with respect to its surroundings."*

Motion: *"A body is said to be in motion, if it changes its position with respect to its surroundings."*

Example: The state of rest or motion of a body are relative to each other. For example, a passenger sitting in a moving bus is at rest because he is not changing his position with respect to other passengers in the bus. But to an observer outside the bus, the passengers inside the bus are in motion which shows that motion and rest are relative to each other.

So we can say that "Rest & motion are relative states."

Q.2 What is surrounding? 091302002

Surroundings are the places in the neighbourhood where various objects are present.

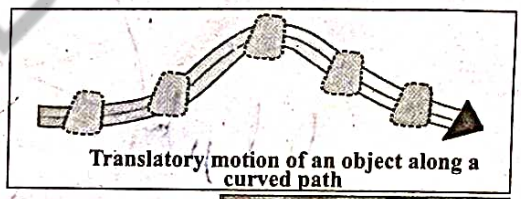
Q.3 Explain different types of motion and give examples. Further explain types of translatory motion. 091302003

Ans. There are three types of motion.

(i) Translatory motion **(ii)** Rotatory motion **(ii)** Vibratory motion

1. Translatory Motion: **(F.B. 2015)**

In translational motion, a body moves along a line without any rotation. The line may be straight or curved.



Translatory motion of an object along a curved path

For example

- A car is moving along a straight line and an aeroplane moving in a straight line.
- A car moves along a curved path without rotation. Riders moving in a Ferris wheel are also in translational motion.
  Their motion is in a circle without rotation.

Translatory motion of riders in Ferris Wheel

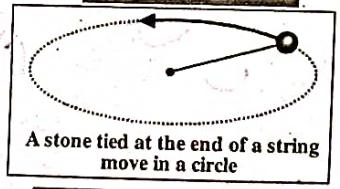
Types of translatory motion

(a) Linear Motion :- *"If a body moves along a straight line then the motion of a body is known as linear motion".*

Example: • Aeroplane flying straight in air.

- Objects falling vertically down are also the example of linear motion.
- A car moving on a straight and level road is in a linear motion.

(b) Circular Motion:- *"The motion of an object in a circular path is known as circular motion".*

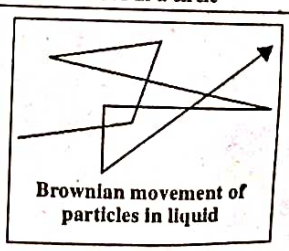


A stone tied at the end of a string move in a circle

For example:-

- Motion of earth around the sun.
- Motion of stone tied to string is a circular motion.
- A bicycle or a car moving along a circular track possess circular motion.
- Motion of moon around the earth is also example of circular motion.

(c) Random Motion:-*"The irregular or disordered motion of an object is called random motion".* **(F.B. 2016)**



Brownian movement of particles in liquid

Examples

- Motion of mosquitoes and insects.
- The motion of dust or smoke particles in the air.
- The Brownian motion of a gas or liquid molecules along a zig-zag path.


Rotatory Motion

(ii) Rotatory Motion:- **(F.B. 2016)**

"The spinning motion of a body about its axis is called rotatory motion".

Examples:

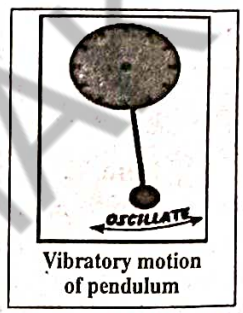
- Motion of wheel about its axis
- Motion of earth around its own axis
- Motion of steering wheel

(iii) Vibratory Motion:- **(Board 2016)**

"To and fro motion of a body about its mean position is known as vibratory motion".

Examples:-

- Motion of pendulum.
- Motion of see-saw.
- A baby in a cradle has to and fro motion about its mean position.
- To and fro motion of the hammer of a ringing electric bell.
- Motion of the strings of a sitar.



Vibratory motion of pendulum

Q.4 Differentiate between Scalar and Vector quantities. **(F.B. 2016)** 091302004

Ans. Scalar Quantities:- *"A physical quantity which can be completely described by its magnitude only is called a scalar quantity".* The magnitude of a quantity means its numerical value with suitable unit.

Examples: mass, length, time, speed, volume, work, energy, pressure and power etc.

Vector quantities:- *"A physical quantity which can be described completely by magnitude and direction is called a vector quantity.*

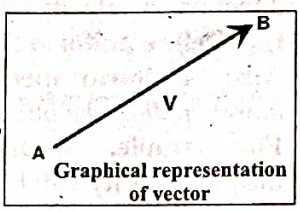
Examples: velocity, displacement, force, momentum, torque, acceleration and weight etc.

Q.5 How is a vector represented? Imp 091302005

Ans. A vector is represented by two methods symbolically and graphically.

i. Symbolically

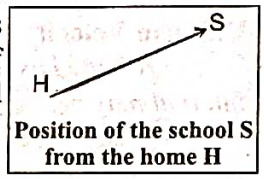
Symbolically, we generally use bold letters to represent vector quantities, such as **F**, **a**, **d** or a bar or arrow over or below their symbols such as $\bar{F}$, $\bar{a}$, $\bar{d}$ or $\vec{F}$, $\vec{a}$ and $\vec{d}$ or $\underline{F}$, $\underline{a}$, $\underline{d}$, $\underline{F}$, $\underline{a}$, $\underline{d}$..



Graphical representation of vector

ii. Graphically

Graphically, a vector can be represented by a straight line with an arrow head at its one end. In figure, the line AB with arrow head of B represents a vector **V**. The length of the line AB gives the magnitude of the vector **V** on a selected scale. While the arrow head of the line from A to B gives the direction of the vector **V**.



Position of the school S from the home H

Q.6 What do you know about position? 091302006

Ans. Position:- *"The distance & direction of a body from a fixed point shows the position of a body".*

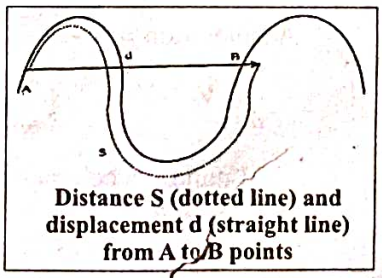
OR *"The term position describes the location of a place or a point with respect to some reference point called origin."*

Example: We want to describe the position of our school from our home. Let the school be represented by S and home by H. The position of your school from your home will be represented by a straight line HS in the direction from H to S.

Q.7 Differentiate between Distance and Displacement. or Describe distance and displacement by diagram and explain. 091302007

Ans. Distance: *"Length of a path between two points is called the distance between those points".*

Distance is scalar quantity and is represented by S.



Distance S (dotted line) and displacement d (straight line) from A to B points

Displacement:-

"Displacement is the shortest distance between two points which has magnitude and direction".

It is a vector quantity and represented by **d**.

Example:

Consider a body that moves from point A to point B along the curved path. The length of curved path between point A and B is the distance between these points. The shortest distance which has magnitude and direction from point A to point B in particular direction is called displacement.

Q.8 Differentiate between Speed and Velocity **(F.B. 2014)** 091302008

Ans. Speed: *"The distance covered by a body in unit time is called its speed".*

Formula: If 'S' is the distance covered by body in time 't', then.

$$\text{Speed} = \frac{\text{Distance covered}}{\text{time taken}}$$

$$\text{i.e } v = \frac{S}{t} \quad \text{or} \quad \text{Distance} = \text{Speed} \times \text{Time} \quad \text{or} \quad S = vt \ldots\ldots\ldots(2.1)$$

Here 'S' is the distance covered by the body, 'v' is its speed and 't' is the time taken by it. Distance is scalar; therefore, speed is also a scalar quantity.

SI unit of speed is metre per second (ms^{-1}). For large distances Kmh^{-1} is used.

Velocity: *"The rate of displacement of a body is called its velocity".*

Formula: If **"d"** is the displacement covered by a body in time 't', then

$$\text{Velocity} = \frac{\text{displacement}}{\text{time}} \quad \text{or} \quad \mathbf{v} = \frac{\mathbf{d}}{t} \quad \mathbf{d} = \mathbf{vt} \ldots\ldots\ldots(2.2)$$

Here **d** is the displacement of the body moving with velocity **v** in time t. Displacement is a vector quality, therefore velocity is also a vector quantity.

SI unit of velocity is the same as speed i.e., metre per second (ms^{-1}). Kmh^{-1} is used for large distances.

Note: Speedometer of a car tells the speed only whereas ships & aeroplanes have meters which tell speed & direction so velocity is observed through meters of ships & aeroplanes.

Q.9 Define uniform Speed and uniform velocity. 091302009

Ans: Uniform Speed: *"A body has uniform speed if it covers equal distances in equal intervals of time however short the interval may be".*

For example, A car covers 30m distance in 20 seconds in next 20 seconds, car again covers 30m distance, then its velocity will be uniform.

If the speed of a body does not vary and has same value. Then the body possesses uniform speed.

Uniform Velocity **(F.B. 2015)**

A body has uniform velocity if it covers equal displacement in equal intervals of time however short the interval may be.

In many cases, the speed and direction of a body does not change. In such case, the body possesses uniform velocity. It means the velocity of a body during any interval of time has same magnitude and direction.

Q.10 Define Acceleration and write its formula. 091302010

Ans: Acceleration: *"Acceleration is defined as the rate of change of velocity of a body".*

Formula: Suppose a body is moving with initial velocity 'v_i' after time 't' its velocity becomes 'v_f' then.

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

$$a = \frac{V_f - V_i}{t} \ldots\ldots\ldots(2.3)$$

SI unit of acceleration is metre per second per second (ms^{-2}).

Q.11 Define Uniform Acceleration, and give its any example. (F.B. 2015) 091302011

Ans: Uniform Acceleration: *A body has uniform acceleration if it has equal change in velocity in equal intervals of time, however short the interval may be.*

Example: The uniform acceleration produced by a freely falling body due to gravitational force.

Q.12 What is meant by positive and negative acceleration? 091302012

Ans: Positive acceleration: *Acceleration of a body is positive if the velocity of body increases with time. The direction of this acceleration is the same in which the body is moving without change in its direction.*

Negative acceleration: *Acceleration of a body is negative if velocity of the body decreases with time. The direction of negative acceleration is opposite to the direction in which the body is moving.* Negative acceleration is also called **deceleration** or **retardation.**

Q.13 What is meant by graph? 091302013

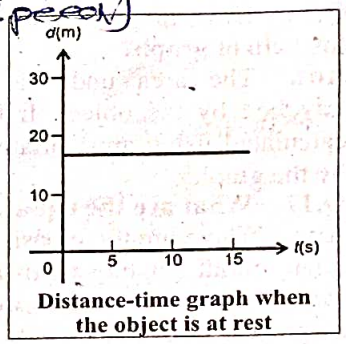
Ans. Graph:

A graph is the pictorial way of presenting information about the relationship between various quantities.

A graph is a relation between two physical quantities which may be straight line or curved line. The quantities between which a graph is plotted are called the **variables**. One of the quantities is called the **independent quantity** and the other quantity, is called **dependent quantity**. Graph is drawn between two mutually perpendicular lines called x–axis and y–axis. The point where these two lines meet is called **origin.** Independent quantities are taken on x–axis and dependent quantities are taken on y–axis.

Q.14 Explain the Distance-Time Graph. 091302014

It is useful to represent the motion of objects by using graphs. In a distance-time graph, time is taken along horizontal axis while vertical axis shows the distance covered by the object.



Distance-time graph when the object is at rest

(i) Object is at rest 091302015

In the graph, the distance moved by the object with time is zero. That is, the object is at rest. Thus, a horizontal line parallel to time axis on a distance-time graph shows that speed of the object is zero.

(ii) Object is moving with constant speed 091302016

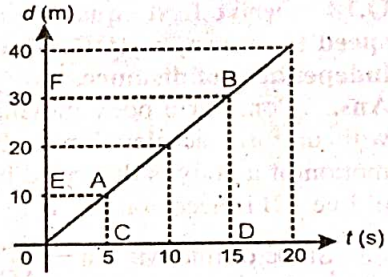
The speed of an object is said to be constant if it covers equal distances in equal intervals of time. The distance-time graph as shown in figure is a straight line. Its slope gives the speed of the object. Consider two points A and B on the graph.

Speed of the object = slope of line AB

$$\text{Speed} = \frac{\text{distance EF}}{\text{time CD}}$$

$$= \frac{20\text{m}}{10\text{s}} = 2\text{ms}^{-1}$$

The speed found from the graph is 2ms^{-1}.

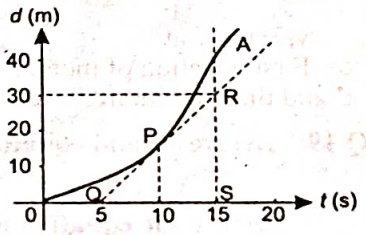


Distance-time graph showing constant speed

(iii) Object is moving with variable speed. (F.B. 2018) 091302017

When an object does not cover equal distances in equal intervals of time then its speed is not constant. In this case the distance-time graph is not a straight line as shown. The slope of the curve at any point can be found from the slope of the tangent at that point. For example,

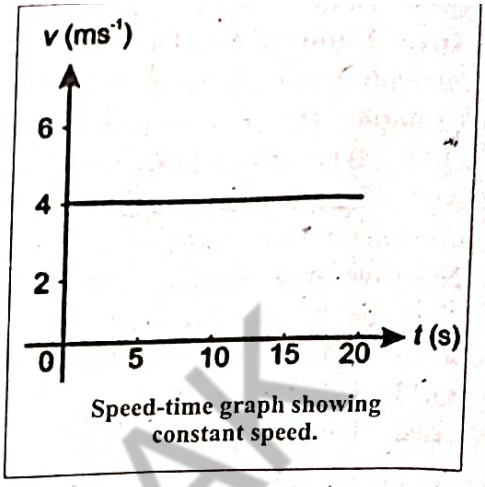
Slope of the tangent at P = $\frac{RS}{QS}$



Distance-time graph showing variable speed

$$= \frac{30m}{10s} = 3ms^{-1}$$

Thus, speed of the object at P is $3ms^{-1}$. "The speed is higher at instants when slope is greater; speed is zero at instants when slope is horizontal". The slope of distance – time graph shows the speed of moving object at that point.



Speed-time graph showing constant speed.

Q.15 Explain Speed-time Graph. 091302018

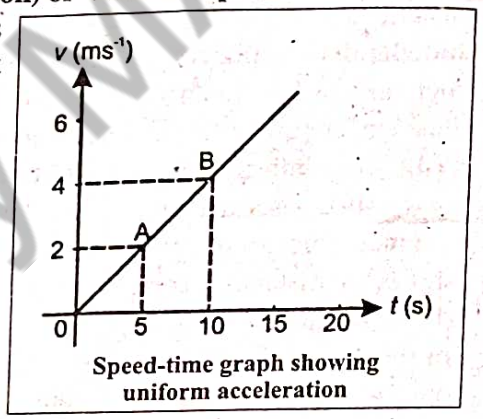
In a speed time graph, time is taken along x-axis and speed is taken along y-axis.

(i) Object moving with constant speed. 091302019

When the speed of an object is constant i.e ($4\ ms^{-1}$) with time, then the speed time graph will be a horizontal line parallel to time axis along x-axis as shown in figure. In other words, a straight line parallel to time axis represents constant speed of the object.

(ii) Object moving with uniformly changing speed (uniform acceleration) or Variable Speed 091302020

Let the speed of an object be changing uniformly. In such a case speed is changing at constant rate. Thus its speed time graph would be a straight line such as shown in figure. A straight line means that the object is moving with uniform acceleration. Slope of the line gives the magnitude of its acceleration.



Speed-time graph showing uniform acceleration

Q.16 How can you calculate distance travelled by a moving object with the help of graph? 091302021

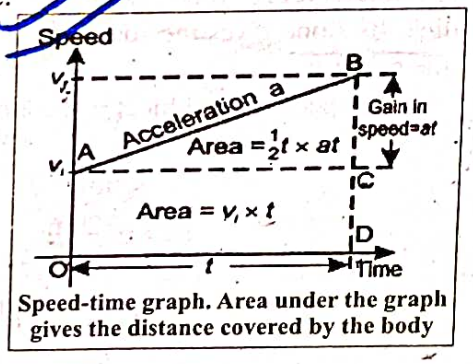
Ans. The area under a speed-time graph represents the distance travelled by the object. If the motion is uniform then the area can be calculated using appropriate formula for geometrical shapes represented by the graph.

Q.17 What are the equations of motion? 091302022

Ans. There are three basic equations of motion of bodies moving with uniform acceleration. These equations relate initial velocity v_i, final velocity v_f, acceleration **a**, time **t** and distance **S** covered by a moving body. In these equations of motion we suppose the motion of a body is along a straight line. Hence, we consider only the magnitude of displacements, velocities, and acceleration along straight line.

Q.18 Derive first equation of motion. $v_f = v_i + at$. with the help of speed-time graph. (OR) Derive the equation of motion which is independent of distance. (F.B. 2010) 091302023

Ans. Consider a body moving with initial velocity v_i in a straight line with uniform acceleration **a**. Its velocity becomes v_f after time t. The motion of a body is described by speed-time graph by line AB. The slope of line AB is acceleration "**a**".



Speed-time graph. Area under the graph gives the distance covered by the body

$$\text{Slope of line AB} = a = \frac{BC}{AC} = \frac{BD - CD}{OD} \qquad \because BC = BD - CD$$

as $BD = v_f$ $CD = v_i$ and $OD = t$ $\qquad \because AC = OD$

Hence $a = \frac{v_f - v_i}{t}$ or $v_f - v_i = at$

$\therefore$ $v_f = v_i + at$

First equation of motion shows the relationship between initial velocity 'v_i', final velocity 'v_f', acceleration 'a' and time duration 't'.

Q.19: Derive second equation of motion. $S = v_i t + \frac{1}{2} a t^2$

OR (F.B. 2017) 091302024

Derive the equation of motion which is independent of final velocity.

Ans. Consider a body moving with initial velocity "v_i" in a straight line with uniform acceleration **a**. Its

velocity becomes "v_f" after time "t". The motion of body is described by speed-time graph by line AB. The slope of line AB is acceleration "**a**" the total distance covered by the body is shown by the shaded area under the line AB.

In speed-time graph shown in figure, the total distance S travelled by the body is equal to the total area OABD under the graph. That is

Total distance S = area of (rectangle OACD + triangle ABC)

Area of rectangle = Length x width

Area of Rectangle *OACD* = OA × OD $\quad \therefore$ OA = v_i

$= v_i \times t \quad \therefore$ OD = t

Area of triangle $= \frac{1}{2}$ base x height

Area of the triangle ABC $= \frac{1}{2}(AC \times BC) \quad \therefore AC = OD = t$

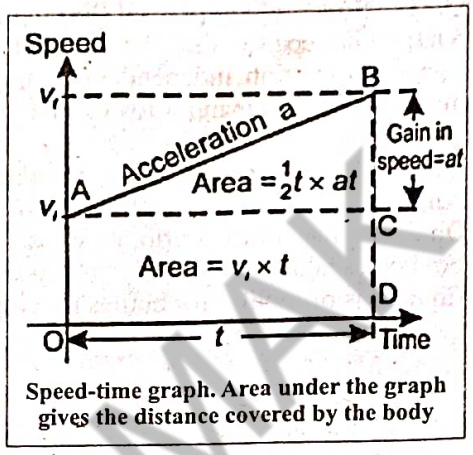
$= \frac{1}{2} t \times at \quad \therefore BC = at$

Since Total area OABD = area of rectangle OACD + area of triangle ABC

Putting values in the above equation, we get

$$S = v_i t + \frac{1}{2} t \times at$$

$$S = v_i t + \frac{1}{2} at^2$$



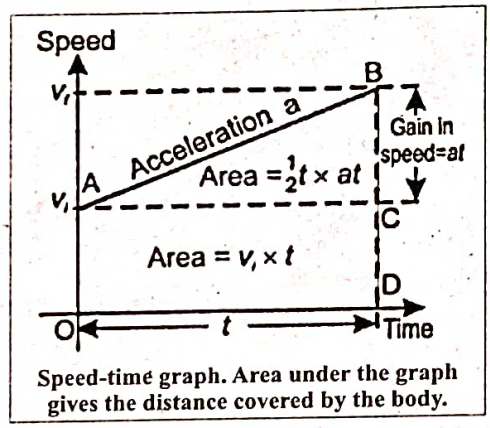
Speed-time graph. Area under the graph gives the distance covered by the body

Second equation of motion shows the relationship between initial velocity 'v_i' acceleration 'a' time duration 't' and distance 's' covered by the moving body.

Q.20: Derive third Equation of motion. $2aS = v_f^2 - v_i^2$ **OR** (F.B. 2017) 091302025

Derive the equation of motion which is independent of time?

Consider a body moving with initial velocity "v_i" in a straight line with uniform acceleration **a**. Its velocity becomes "v_f" after time "t". The motion of a body is described by speed-time graph by line AB. The slope of line AB is acceleration "**a**". The total distance covered by the body is shown by the shaded area under the line AB. The total distance S travelled by the body is given by the total area OABD under the graph.



Speed-time graph. Area under the graph gives the distance covered by the body.

Total area of trapezium OABD = Distance

$S = \frac{1}{2}$[Sum of parallel sides] x perpendicular distance between parallel side

Total area OABD = . $S = \frac{OA + BD}{2} \times OD$

Or $\quad 2S = (OA + BD) \times OD$

Multiplying both sides by $\frac{BC}{OD}$

$$2 \times \frac{BC}{OD} \times S = (OA + BD) \times OD \times \frac{BC}{OD}$$

So $2 \times \frac{BC}{OD} \times S = (OA + BD) \times BC \quad \therefore BC = BD - CD$

$$2 \times \frac{BC}{OD} \times S = (OA + BD) \times (BD - CD)$$

Since $\frac{BC}{OD} = a$

$\therefore BD = v_f ; \quad CD = v_i ; \quad OA = v_i$

Putting the values in the above equation we get

$2a \times S = (v_i + v_f) \times (v_f - v_i)$, $2aS = (v_f + v_i)(v_f - v_i)$, $2aS = v_f^2 - v_i^2$

Third equation of motion shows the relationship between acceleration **'a'** initial velocity 'v_i', final velocity 'v_f' and distance covered by the moving body.

Q.21 How Galileo proved that acceleration of free falling bodies is the same? 091302026

Ans: Galileo was the first scientist to notice that all the freely falling objects have the same acceleration independent of their masses. He dropped various objects of different masses from the leaning tower of Pisa. He found that all of them reach the ground at the same time.

Q.22 What is gravitational acceleration? Also write its value. 091302027

Ans: *The acceleration of freely falling bodies is called gravitational acceleration.* It is denoted by 'g'. On the surface of the Earth, its value is approximately 10 ms^{-2}.

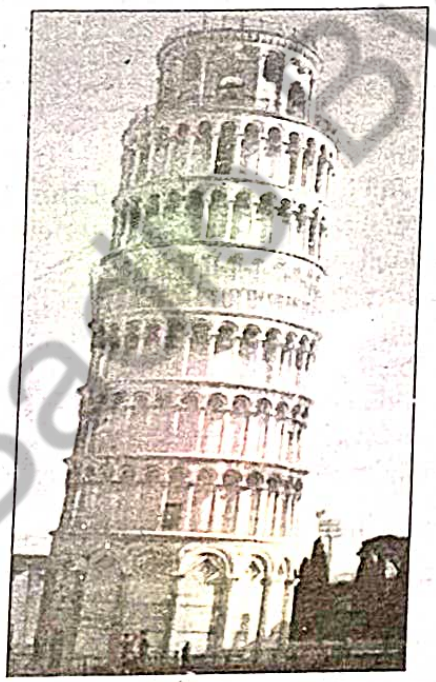
For bodies falling down freely '*g*' is positive and is negative for bodies moving up.

Equations of motion for bodies moving under the force of gravity as:

$$v_f = v_i + gt$$

$$h = v_i t + \frac{1}{2} gt^2$$

$$2gh = v_f^2 - v_i^2$$



Leaning Tower of Pisa

Multiple Choice Questions

2.1 Encircle the correct answer from the given choices:

Exercise MCQs

1. A body has translatory motion if it moves along a: 091302028
(a) Straight line (b) circle
(c) line without rotation (d) curved path

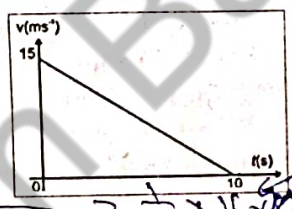
2. The motion of a body about an axis is called: 091302029
(a) Circular motion
(b) rotatory motion
(c) vibratory motion
(d) random motion

3. Which of the following is a vector quantity? 091302030
(a) speed (b) distance
(c) displacement (d) power

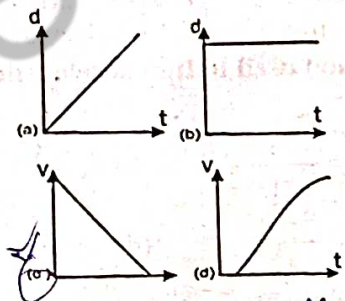
4. If an object is moving with constant speed then its distance time graph will be a straight line: 091302031
(a) along time-axis
(b) along distance –axis
(c) parallel to time–axis
(d) inclined to time–axis

5. A straight line parallel to time-axis on a distance-time graph tells that the object is: 091302032
(a) moving with constant speed
(b) at rest
(c) moving with variable speed
(d) in motion

6. The speed–time graph of a car is shown in the figure, which of the following statement is true? 091302033
(a) car has an acceleration of $1.5 ms^{-2}$
(b) car has constant speed of $7.5 ms^{-1}$
(c) distance travelled by the car is 75m
(d) average speed of the car is $15 ms^{-1}$



7. Which one of the following graphs is representing uniform acceleration? (F.B. 2017) 091302034



8. By dividing displacement of a moving body with time, we obtain: 091302035
(a) speed (b) acceleration
(c) velocity (d) deceleration

9. A ball is thrown vertically upward. Its velocity at the highest point is: 091302036
(a) $-10 ms^{-1}$ (b) zero (F.B. 2015)
(c) $10 ms^{-2}$ (d) none of them

10. A train is moving at a speed of 36 kmh^{-1} Its speed expressed in ms^{-1} is: 091302037
(a) $10 ms^{-1}$ (b) $20 ms^{-1}$
(c) $25 ms^{-1}$ (d) $30 ms^{-1}$

11. A change in position from point A to B is called: (F.B. 2017) 091302038
(a) speed (b) velocity
(c) displacement (d) distance

12. A car starts from rest. It acquires a speed of 25 ms^{-1} after 20 s. The distance moved by the car during this time is: 091302039
(a) 31.25 m (b) 250 m
(c) 500 m (d) 5000 m

Additional MCQs

13. The fastest bird falcon has speed. 091302040
(a) $100 kmh^{-1}$ (b) $200 kmh^{-1}$
(c) $300 kmh^{-1}$ (d) $400 kmh^{-1}$

14. The average speed of cheetah is: 091302041
(a) $60 kmh^{-1}$ (b) $75 kmh^{-1}$
(c) $70 kmh^{-1}$ (d) $80 kmh^{-1}$

15. The unit of acceleration is: 091302042
(a) ms^{-1} (b) ms
(c) ms^{-2} (d) ms^2

16. Displacement is a quantity: 091302043
(a) Scalar (b) Vector
(c) Both a & b (d) None of these

17. When an object is moving with uniformly changing speed then the slope of the speed-time graph determines the magnitude of: (F.B. 2018) 091302044
(a) distance (b) displacement
(c) velocity (d) acceleration

18. The value of gravitational acceleration when a body is moving in downward direction is: 091302045
(a) $10 ms^{-1}$ (b) $10 ms^{-2}$
(c) 10m (d) $-10 ms$

distance time graph does not gives acceleration

19. The slope of distance time graph shows: 091302046
(a) speed (b) Displacement
(c) acceleration (d) Distance

20. The motion of the rider in Ferris wheel is: 091302047
(a) Translatory (b) Vibratory
(c) Rotatory (d) Linear

21. First equation of motion is: 091302048
(a) $v_f = v_i + at$ (b) $S = v_i t + \frac{1}{2} at^2$
(c) $2aS = v_f^2 - v_i^2$ (d) All of these

22. If an object is moving with a uniform changing speed then speed time graph is: 091302049
(a) Straight line
(b) Variable
(c) Parallel to time axis
(d) All of these

23. The unit of velocity and speed is: 091302050
(a) ms (b) ms^{-2}
(c) ms^{-3} (d) ms^{-1}

24. Brownian motion is an example of: 091302051
(a) Random motion
(b) Linear motion
(c) Circular motion
(d) Vibratory motion

25. The to and fro motion of a body about its mean position is called: 091302052
(a) Circular motion
(b) Random motion
(c) Rotatory motion
(d) Vibratory motion

26. The motion of a body in straight line is: 091302053
(a) Random motion
(b) Circular motion
(c) Linear motion
(d) Translatory motion

27. If the velocity of body increases with time, the acceleration will be: 091302054
(a) Negative (b) Uniform
(c) Positive (d) Variable

28. If the velocity of body decreases with time then acceleration will be: 091302055
(a) Negative (b) Positive
(c) Uniform (d) Variable

29. The value of gravitational acceleration for bodies moving upward is: 091302056
(a) $10ms^{-1}$ (b) $10ms^{-2}$
(c) 10m (d) $-10ms^{-2}$

30. Rate of change of velocity is known as: 091302057
(a) Speed (b) Acceleration
(c) Distance (d) Velocity

31. Pressure is a quantity: 091302058
(a) Scalar (b) Vector
(c) Base (d) Derived

32. Motion of butterfly is an example of: 091302059
(a) Random (b) Circular
(c) Linear (d) Vibratory

33. Graph is plotted between ____ variables: 091302060
(a) 2 (b) 3
(c) 4 (d) 1

34. Independent quantities are taken on: 091302061
(a) – x–axis (b) x–axis
(c) –y–axis (d) y–axis

35. Dependent quantities are taken on: 091302062
(a) x–axis (b) –ve x–axis
(c) y–axis (d) –ve –axis

36. A car covers 100m distance in 10s. Its average speed is: 091302063
(a) 1000 ms^{-1} (b) 10 ms^{-1}
(c) 1 ms^{-1} (d) 20 ms^{-1}

37. A train start from rest. Its velocity becomes 40ms^{-1} in 10s. Its acceleration will be: 091302064
(a) 4 ms^{-2} (b) 4 ms^{-1}
(c) 40 ms^{-1} (d) 40 ms^{-2}

38. Paratrooper while coming down attains a velocity called: 091302065
(a) Variable velocity
(b) Terminal velocity
(c) Uniform velocity
(d) Average velocity

39. LIDAR gun is used to calculate the vehicle's: 091302066
(a) Velocity (b) Acceleration
(c) Speed (d) Distance

40. The acceleration of a body moving with uniform velocity is: 091302067
(a) Zero (b) Variable
(c) Uniform (d) Negative

41. Relation used to find acceleration is: 091302068
(a) $a = \frac{v_f - v_i}{t}$ (b) $a = \frac{v_f^2 - v_i^2}{t}$
(c) $a = \frac{S - v_i}{t^2}$ (d) $a = v_f - v_i$

42. **Distance covered by freely falling downward body in first second of motion is:** 091302069
(a) 5m (b) 29.4m
(c) 10m (d) 19.6m

43. **The quantities that are completely described by only magnitude are:** 091302070
(a) Scalar (b) Vector
(c) Base (d) Derived

44. **The quantities that describe completely by magnitude and direction are:** 091302071
(a) Base (b) Derived
(c) Scalar (d) Vector

45. **The scientist who notice that all the freely falling objects have same acceleration:** 091302072
(a) Newton (b) Galileo
(c) Coulomb (d) Einstein

46. **The velocity of bodies falling down:** 091302073
(a) Decreases (b) Increases
(c) Constant (d) Zero

47. **The velocity of freely falling bodies moving upward:** 091302074
(a) Decreases (b) Increases
(c) Constant (d) Zero

48. **Speedometer measures the:** 091302075
(a) Velocity (b) Speed
(c) Acceleration (d) All of these

49. **When two bodies are in motion then the velocity of one body relative to the other is called:** 091302076
(a) Relative velocity
(b) Uniform velocity
(c) Variable velocity
(d) Average velocity

50. **Quantities between which a graph is plotted are called:** 091302077
(a) Scalars (b) Vectors
(c) Variables (d) None

51. **In graph reference point is taken as:** 091302078
(a) Origin (b) Coordinates
(c) x-axis (d) Variable

52. **A stone is dropped from a top of tower. The stone hits the ground 5s, the height of tower is:** 091302079
(a) 100 m (b) 125 m
(c) 150 m (d) 175 m

53. **Which is not a vector quantity?** 091302080 (F.B. 2016)
(a) Momentum (b) Pressure
(c) Weight (d) Torque

54. **The distance time graph for an object moving with variable speed is a:** 091302081
(a) Straight line parallel to vertical axis
(b) Straight line parallel to time axis
(c) Straight line passing through origin
(d) Carved line

55. **A body is moving with uniform velocity. What will be its acceleration?** 091302082
(a) Uniform (b) Zero
(c) $10ms^{-2}$ (d) $-10ms^{-2}$

Answers

1.	c	2.	b	3.	c	4.	d	5.	b
6.	c	7.	c	8.	c	9.	b	10.	a
11.	c	12.	b	13.	b	14.	c	15.	c
16.	b	17.	d	18.	b	19.	a	20.	a
21.	a	22.	a	23.	d	24.	a	25.	d
26.	c	27.	c	28.	a	29.	d	30.	b
31.	a	32.	a	33.	a	34.	b	35.	c
36.	b	37.	a	38.	b	39.	c	40.	a
41.	a	42.	a	43.	a	44.	d	45.	b
46.	b	47.	a	48.	b	49.	a	50.	c
51.	a	52	b	53	b	54	d	55	b

2.2 Explain translatory motion and give examples of various types of translatory motion. 091302083

Ans. See Q.No.3 on page No.

2.3 Differentiate between the following: 091302084

i. Rest and motion.
ii. Circular motion and rotatory motion.
iii. Distance and displacement
iv. Speed and velocity.
v. Linear and random motion.
vi. Scalars and vectors.

Ans.

i. Rest and motion.

Rest: A body is said to be at rest if it does not change its position with respect to its surroundings.

Motion: A body is said to be in motion if it changes its position with respect to its surroundings.

ii. Circular motion and rotatory motion.

Circular motion: The motion of an object in a circular path is known as circular motion.

Rotatory motion: The spinning motion of a body about its axis is called its rotatory motion.

iii. Distance and displacement

Distance: Length of a path between two points is called the distance between those points.

Displacement: The shortest distance between two points which has magnitude and direction is called displacement.

iv. Speed and velocity: (F.B. 2015)

Speed: The distance covered by a body in unit time is called its speed. It is a scalar quantity.

Velocity: Rate of change of displacement is called velocity. It is denoted by **v**. It is a scalar quantity.

v. Linear and random motion:

Linear motion: If a body moves along a straight line then the motion of a body is known as its linear motion.

Random motion: The irregular or disordered motion of an object is called random motion.

vi. Scalars and vectors:

Scalars: A physical quantity which can be completely described by its magnitude only is called a scalar quantity. For example, mass, length, time, speed, volume, pressure, etc.

Vector: A physical quantity which can be completely described by its magnitude and direction is called a vector quantity. For example, force, displacement, momentum, torque, acceleration, etc.

2.4 Define the terms speed, velocity, and acceleration. 091302085

Ans. Speed: The distance covered by a body in unit time is called its speed.

Formula:- $v = \frac{S}{t}$

Unit:- ms^{-1} or kmh^{-1}

Quantity:- Scalar

Velocity: The rate of displacement of a body is called its velocity.

Formula:- $v = \frac{d}{t}$

Unit:- ms^{-1} or kmh^{-1}

Quantity:- Vector

Acceleration: Acceleration is defined as the rate of change of velocity of a body.

Formula:- $a = \frac{v_f - v_i}{t}$

$a = \frac{\Delta V}{t}$

Unit:- ms^{-2} or kmh^{-2}

Quantity:- Vector

2.5 Can a body moving at a constant speed have acceleration? (F.B. 2017) 091302086

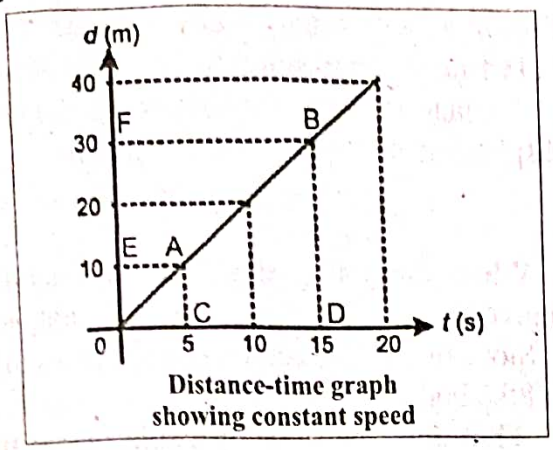
Ans. Yes! A body moving with constant speed have acceleration if the direction of moving body changes, which produce acceleration, e.g a body moving in a circle with uniform speed have acceleration because at any point its direction of motion changes.

2.6 How do riders in a Ferris wheel possess translatory motion but not rotatory motion? 091302087

Ans. Since the rider in Ferris wheel is moving without rotation in circular path so the rider in Ferris wheel possesses translatory motion.

2.7 Sketch a distance-time graph for a body starting from rest. How will you determine the speed of a body from this graph? 091302088

Ans.



Distance-time graph showing constant speed

Speed of the object = slope of line AB

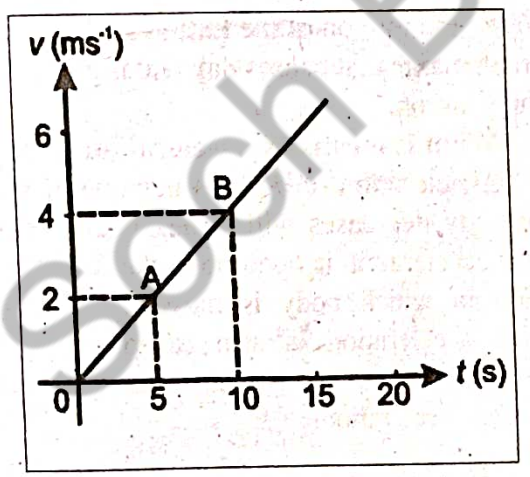
$$\text{Speed} = \frac{\text{distance EF}}{\text{time CD}}$$

$$v = \frac{20\text{m}}{10\text{s}} = 2\text{ms}^{-1}$$

The speed found from the graph is 2ms^{-1}.

2.8 What would be the shape of a speed – time graph of a body moving with variable speed? 091302089

Ans. Let the speed of an object be changing uniformly. In such a case speed is changing at constant rate. Thus its speed time graph would be a straight line such as shown in figure. A straight line means that the object is moving with uniform acceleration. Slope of the line gives the magnitude of its acceleration.



2.9 Which of the following can be obtained from speed – time graph of a body? 091302090

(i) Initial speed.

(ii) Final speed.

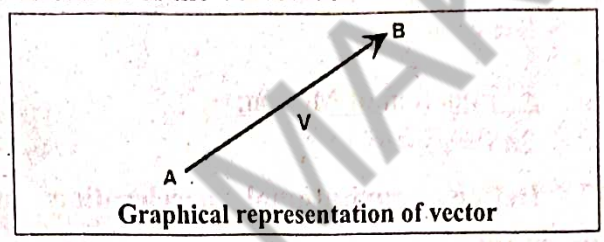
(iii) Distance covered in time *t*.

(iv) Acceleration of motion.

Ans. We can calculate all the above mentioned terms from a speed time graph.

2.10 How can vector quantities be represented graphically? 091302091

Ans. Graphically, a vector can be represented by a straight line with an arrow head at its one end. In figure, the line AB with arrow head of B represents a vector **V**. The length of the line AB gives the magnitude of the vector **V** on a selected scale. While the arrow head of the line from A to B gives the direction of the vector **V**.



Graphical representation of vector

2.11 Why vector quantities cannot be added and subtracted like scalar quantities. 091302092

Ans. Vector and scalar quantities cannot be added and subtracted by same method because vector quantity need magnitude and direction vector quantities are added by **head to tail rule** while scalars are added by **algebraic method**.

2.12 How are vector quantities important to us in our daily life? 091302093

Ans. Vectors are important tools to learn all in Physics and Engineering. Vectors are used whenever we have to calculate both size and direction of a parameter.

With the help of vector quantities we can explain the position of an object with distance and direction. Vectors are used in airplanes and in sail boat.

2.13 Derive equations of motion for uniformly accelerated rectilinear motion. 091302094

Ans. See the question no. 18, 19, 20 on Page no. 26,27

2.14 Sketch a velocity – time graph for the motion of the body. From the graph explaining each step, calculate total distance covered by the body. 091302095

Ans. See Example no. 2.9 on Page no. 37.

Additional Short Answer Questions

Q15. How can we write equations of motion under the action of gravity? 091302096

Ans. Equations of motions for freely falling bodies are:

i) $v_f = v_i + gt$ ii) $h = v_i t + \frac{1}{2} gt^2$

iii) $2gh = v_f^2 - v_i^2$

Q16. Write second and third equation of motion in mathematical form. 091302097

Ans. 2nd Equation of Motion:

$$S = v_i t + \frac{1}{2} at^2$$

3rd Equation of Motion:

$$2aS = v_f^2 - v_i^2$$

Q17. Define gravitational acceleration and write its value. 091302098

Ans. The acceleration of freely falling bodies is called gravitational acceleration. It is denoted by 'g'. It value is $10 ms^{-2}$ on earth.

Q18. Which is the fastest bird on the Earth? 091302099

Ans. Falcon is the fastest bird, it can fly at a speed of $200 kmh^{-1}$.

Q19. Which is the fastest animal on the Earth? 091302100

Ans. Cheetah is the fastest animal, it can run at a speed of $70 kmh^{-1}$.

Q20. What is LIDAR gun and for what purpose is it used? 091302101

Ans. A LIDAR gun is light detection and ranging speed gun. It uses the time taken by laser pulse to make a series of measurements of a vehicle's distance from the gun. The data is then used to calculate the vehicle's speed.

Q21. How does a paratrooper comes to ground? 091302102

Ans. A paratrooper attains a uniform velocity called terminal velocity with which it comes to ground.

Q22. What are the applications of graphs in everyday life? 091302103

Ans. A graph is used in everyday life such as to show year-wise rainfall, a patient's temperature record or runs per over scored by a team and so on.

Q23. How velocity affects the direction of acceleration? 091302104

Ans. Acceleration of a moving object will be in the direction of velocity if its velocity is increasing. Acceleration of the object is opposite to the direction of velocity if its velocity is decreasing.

Q24. Define average velocity. 091302105

Ans. Average velocity of a body is defined as the total displacement divided by the total time.

$$v_{av} = \frac{\text{total displacement}}{\text{total time}}$$

Q25. What does the slope of distance-time graph give? 091302106

Ans. Slope of the distance-time graph gives the speed of the body.

Q26. What does the slope of displacement time graph give? 091302107

Ans. Slope of the displacement time graph gives the velocity of the body.

Q27. What does the slope of velocity time graph give? 091302108

Ans. Slope of the velocity-time graph gives the acceleration of the body.

Q28. Define position. 091302109

Ans. Position means the location of a certain place or object from a reference point.

Q29. Define axis. 091302110

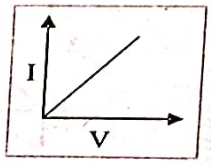
Ans. An axis is a line around which a body can rotates.

Q30. Explain the motion of the Earth about its axis and around the sun. 091302111

Ans. The motion of the Earth around the Sun is circular motion and not the spinning motion. However, the motion of the Earth about its geographic axis that causes day and night is rotatory motion.

Q31. What is meant by deceleration? 091302112

Ans. Acceleration of body is negative if velocity of the body decreases with time. The direction of negative acceleration is opposite to the direction in which body is moving. Negative acceleration is also called deceleration. It is also named as retardation acceleration.



e.g. graph between V and I is a strength line.

Q32. What is graph? 091302113

Ans. Graph is a pictorial way of presenting information about the relation between various quantities.

Q33. Name the first scientist who noticed freely falling objects? 091302114

Ans. Galileo was first scientist who noticed the freely falling object.

Q34. A cyclist completes half round of a circular track of diameter 636m in 1.5 minutes. Find his velocity. (F.B. 2018) 091302115

Ans. Given data:

Diameter = 636m
Displacement = 636m
Time taken = 1.5 minutes
= 60 s + 30 s
= 90 s

To find:

Velocity = V = ?

Solution:

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

$$V = \frac{d}{t}$$

$$V = \frac{636m}{90s}$$

$$V = 7.07\ ms^{-1}$$

$$V = 7.1\ ms^{-1}$$

Result:

The velocity of cyclist while moving in a half circular track is 7.1 ms^{-1}.

Mini Exercise

Q35. When a body is said to be at rest? 091302116

Ans. A body is said to be at rest if it does not change its position with respect to some observer.

Q36. Give an example of a body that is at rest and in motion at the same time. 091302117

Ans. A person driving a car is a good example of this question because when a person is driving his body is in rest but also in motion due to the motion of car.

Q37. Mention the type of motion in each of the following: 091302118

i) A ball moving vertically upward ⇒ Linear motion
ii) A child moving down a slide ⇒ Linear motion
iii) Movement of a player in a football ground ⇒ Random motion
iv) The flight of a butterfly ⇒ Random motion
v) An athlete running in a circular track ⇒ Circular motion
vi) The motion of a wheel ⇒ Rotatory motion
vii) The motion of a cradle ⇒ Vibratory motion

Conversions

Q1. How to convert ms^{-1} to kmh^{-1}? 091302119

$$1ms^{-1} = 0.001km \times 3600h^{-1} = 3.6kmh^{-1}$$

Thus multiply speed in ms^{-1} by 3.6 to get speed in kmh^{-1}.

e.g.

$$20ms^{-1} = 20 \times 3.6kmh^{-1}$$

$$= 72kmh^{-1}$$

Q2. How to convert kmh^{-1} to ms^{-1}? 091302120

$$1kmh^{-1} = \frac{1000m}{60 \times 60s} = \frac{10}{36}ms^{-1}$$

Thus multiply speed in kmh^{-1} by $\frac{10}{36}$ to get speed in ms^{-1} e.g.

$$50kmh^{-1} = 50 \times \frac{10}{36} = 13.88ms^{-1}$$

Q3. How to convert ms^{-2} to kmh^{-2}? 091302121

Multiply acceleration in ms^{-2} by

$$\left[(3600 \times 3600)/1000\right] = 12960$$ to get value in kmh^{-2}

Q4. How convert kmh^{-2} to ms^{-2}? 091302122

Divide acceleration in kmh^{-2} by 12960 to get value in ms^{-2}.

Solved Examples

Example 2.1: Represent a force of 80N acting toward North of East. 091302123

Solution

Step 1

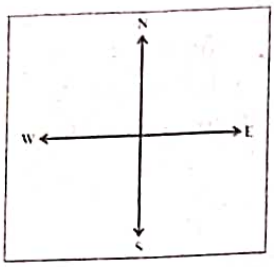
Draw the directions.

Step 2

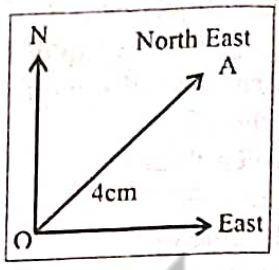
Select a suitable scale to represent the given vector.

i.e 20 N = 1cm

80 N = 4cm



Representing 80 N force acting North – East



Step 3

Draw a line according to the scale in the direction of the vector. In this case, draw a line OA of length 4cm along North-East.

Step 4

Put an arrow head at the end of the line. In this case arrow head is at point A. Thus, the line OA will represent a vector i.e., the force of 80N acting towards North-East.

Example 2.2

A sprinter completes its 100 metre race in 12s. Find its average speed. 091302124

Solution

Total distance = S = 100 m

Total time taken = t = 12 s

$$\text{Average Speed} = \frac{\text{Total distance}}{\text{Total time}}$$

$$\text{Average Speed} = \frac{100}{12} = 8.33 ms^{-1}$$

Thus the speed of the sprinter is $8.33 ms^{-1}$.

Example 2.3

A cyclist completes half round of a circular track of radius 318m in 1.5 minutes. Find its speed and velocity. (F.B. 2017) 09130212

Given data:

Radius = r = 318 m

Time taken = t = 1.5 minutes = 1 min. 30S

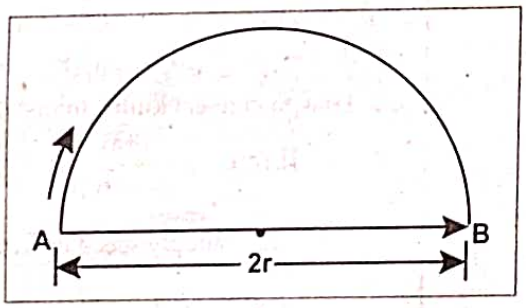
= $1.5 \times 60 = 90$ sec

Distance covered = $\pi \times$ radius

Distance covered = $3.14 \times 318m = 999m$

Displacement = 2 r

Displacement = $2 \times 318m = 636$ m



To Find:

Speed = ?

Velocity = ?

Solution: $\text{speed} = \frac{\text{distance}}{\text{time}}$

$$v = \frac{S}{t}$$

$$\text{speed} = \frac{999}{90} = 11.1 ms^{-1}$$

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

$$v = \frac{d}{t}$$

$$\text{velocity} = \frac{636}{90} = 7.07 ms^{-1}$$

Result:

Thus speed of the cyclist is $11.1 ms^{-1}$ along the track and its velocity is about $7.1 ms^{-1}$ along the diameter AB of the track.

Example 2.4: A car starts from rest. Its velocity becomes $20 ms^{-1}$ in 8s. Find its acceleration.

Given Data: (F.B. 2016) 091302126

Initial velocity = $v_i = 0\ ms^{-1}$

Final velocity = $v_f = 20\ ms^{-1}$

Time taken = $t = 8\ s$

To Find: a = ?

Solution:

As $a = \frac{V_f - V_i}{t}$

Or $a = \frac{20 - 0}{8}$ $\quad a = 2.5\ ms^{-2}$

Result:

The acceleration of car is $2.5 ms^{-2}$.

Example 2.5: Find the retardation produced when a car moving at a velocity of $30 ms^{-1}$ slows down uniformly to $15 ms^{-1}$ in 5s. (F.B. 2017) 091302127

Given Data:

Initial velocity = $v_i = 30 ms^{-1}$

Final velocity = $v_f = 15 ms^{-1}$

Change in velocity = $v_f - v_i$

$= 15 - 30 = -15\ ms^{-1}$

Time taken = $t = 5\ s$

To Find: a = ?

Solution:

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time interval}}$$

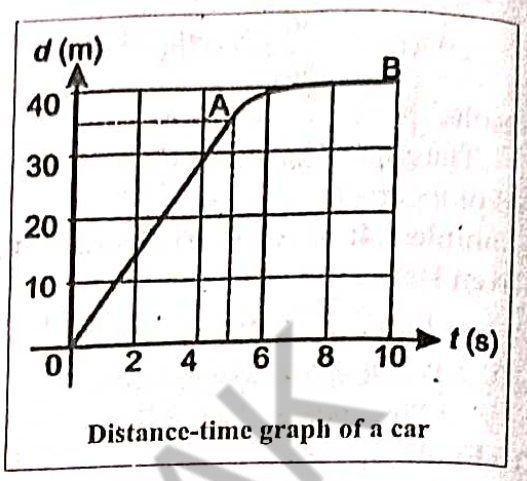
as $$= \frac{v_f - v_i}{t} = \frac{15 - 30}{5}$$

or $$a = \frac{-15}{5} = -3 ms^{-2}$$

So deceleration of the car is $3 ms^{-2}$.

Example 2.6: Figure shows the distance-time graph of a moving car. From the graph, find. 091302128

(a) The distance car has travelled.
(b) The speed during the first five seconds.
(c) Average speed of the car.
(d) Speed during the last 5 seconds.



Distance-time graph of a car

Solution:

a. Total distance travelled = 40 m

b. Distance travelled during first 5 s is 35 m

$$\therefore \quad \text{Speed} = \frac{35\text{m}}{5\text{s}} = 7\ \text{ms}^{-1}$$

c. $$\text{Average speed} = \frac{40\text{m}}{10\text{s}} = 4\ \text{ms}^{-1}$$

d. Distance moved during the last 5 s = 5 m

$$\therefore \quad \text{Speed} = \frac{5\text{m}}{5\text{s}} = 1\ \text{ms}^{-1}$$

Example 2.7: Find the acceleration from speed-time graph shown in figure (F.B. 2017) 091302129

Solution:

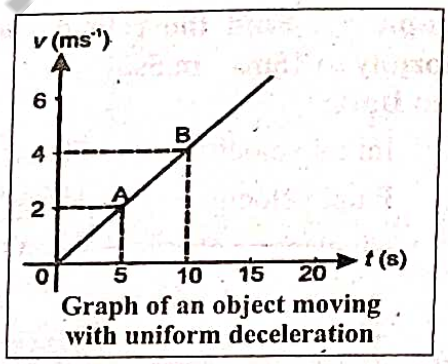
On the graph in figure, point A gives speed of the object as 2 ms^{-1} after 5 s and point B gives speed of the object as 4 ms^{-1} after 10 s.

As acceleration = slope of AB

where slope $= \frac{\text{Change in velocity}}{\text{Time interval}}$

$$\therefore \text{ acceleration} = \frac{V_f - V_i}{t_f - t_i}$$

$$\therefore \text{ acceleration} = \frac{4-2}{10-5} = \frac{2}{5} = 0.4\,\text{ms}^{-2}$$



Graph of an object moving with uniform deceleration

Result:

Speed-time graph in figure gives acceleration of the object as 0.4 ms^{-2}

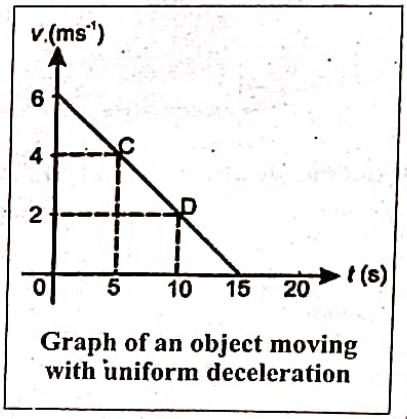
Example 2.8: Find the acceleration from speed-time graph shown in figure 091302130

Solution:

The graph in figure shows that the speed of the object is decreasing with time. The speed after 5 s is 4 ms^{-1} and it becomes 2 ms^{-1} after 10s.

As acceleration = slope of CD

$$\therefore \text{ acceleration} = \frac{v_f - v_i}{t_f - t_i} = \frac{2-4}{10-5} = -\frac{2}{5} = -0.4\,\text{ms}^{-2}$$



Graph of an object moving with uniform deceleration

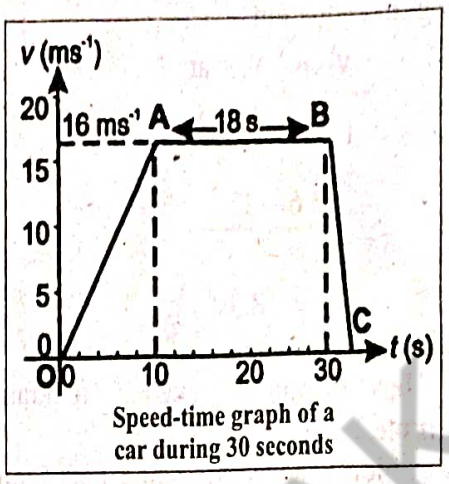
Result:

Speed time graph in figure gives negative slope. Thus, the object has deceleration of 0.4ms^{-2}

Example 2.9

A car moves in a straight line. The speed-time graph of its motion is shown in figure. From the graph, find 091302131

a. Its acceleration during the first 10 seconds.
b. Its deceleration during the last 2 seconds.
c. Total distance travelled.
d. Average speed of the car during its journey.



Speed-time graph of a car during 30 seconds

Solution:

a. Acceleration during the first 10 seconds

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time taken}} = \frac{16-0}{10} = 1.6\ ms^{-2}$$

b. Acceleration during the last 2 seconds

$$\text{Acceleration} = \frac{0-16}{2} = -8\ ms^{-2}$$

c. Total distance travelled = area under the graph (trapezium OABC)

$$= \frac{1}{2}(\text{sum of parallel sides}) \times (\text{Perpendicular distance between parallel sides})$$

$$= \frac{1}{2}(18+30)\times(16) = \frac{1}{2}(48)\times(16) = 384\ m$$

d. Average speed $= V_{av} = \frac{\text{Total distance}}{\text{Total time}} = \frac{384}{30} = 12.8\ ms^{-1}$

Example 2.10:

A car travelling at 10 ms^{-1} accelerates uniformly at 2 ms^{-2}. Calculate its velocity after 5 s. 091302132

Given data:

$v_i = 10\ ms^{-1}$
$a = 2\ ms^{-2}$
$t = 5s$

To Find:

$v_f = ?$

Using the first equation

Solution:

$$v_f = v_i + at$$
$$v_f = 10 + 2\times5$$

or $v_f = 20\ ms^{-1}$

Result:

The velocity of the car after 5 s is 20 ms^{-1}

Examples 2.11: A train slows down from 80 kmh^{-1} with a uniform retardation of 2 ms^{-2}. How long will it take to attain a speed of 20kmh^{-1}? (F.B. 2017) 091302133

Given Data:

$v_i = 80\ kmh^{-1}$

$$= \frac{80\times1000}{60\times60}$$

$$= 22.2\ ms^{-1}$$

$$v_f = \frac{20\times1000}{60\times60}$$

$$= 5.6\ ms^{-1}$$

$a = -2\ ms^{-2}$

LMIPRJSTB

To Find:

$t = ?$

Solution:

Using first equation

$$v_f = v_i + at$$

$$t = \frac{v_f - v_i}{a}$$

$$= \frac{5.6 - 22.2}{-2}$$

$$t = 8.3s \text{ s}$$

Result:

Thus the train will take 8.3 s to attain the required speed.

Example 2.12

A bicycle accelerates at 1 ms^{-2} from an initial velocity of 4 ms^{-1} for 10s. Find the distance moved by it during this interval of time. 091302134

Given Data:

$v_i = 4ms^{-1}$

$a = 1ms^{-2}$

$t = 10s$

To Find:

$S = ?$

Solution:

Using the second equation

$$S = v_i t + \tfrac{1}{2} at^2$$

$$S = 4 \times 10 + \tfrac{1}{2} \times 1 \times (10)^2$$

$$= 40 + \tfrac{1}{2} \times 100$$

$$= 40+50$$

$$= 40 + 50 = 90 \text{ m}$$

Result:

Thus, the bicycle will move 90 metres in 10 seconds.

Example 2.13

A car travels with a velocity of 5 ms^{-1}. It then accelerates uniformly and travels a distance of 50 m. If the velocity reached is 15ms^{-1}. Find the acceleration and the time to travel this distance. 091302135

Given Data:

$v_i = 5 ms^{-1}$

$s = 50 \text{ m}$

$v_f = 15 ms^{-1}$

To Find:

$a = ?$

$t = ?$

Solution:

Putting values in the third equation of motion, we get

$$2aS = v_f^2 - v_i^2$$

$$\therefore 2a \times 50 = (15)^2 - (5)^2$$

$$(100)a = 225 - 25$$

$$100a = 200$$

$$a = \frac{200}{100}$$

or $a = 2ms^{-2}$

Using first equation of motion to find t, we get

$v_f = v_i + at$

$\therefore \quad 15 = 5 + 2 \times t$

$15 - 5 = 2 \times t$

or $2 \times t = 10$

or $t = \frac{10}{2} = 5s$

Result:

Thus, the acceleration of the car is 2 ms^{-2} and it takes 5 seconds to travel 50m distance.

Example 2.14: A stone is dropped from the top of a tower. The stone hits the ground after 5 seconds. Find 091302136

a) The height of the tower.

b) The velocity with which the stone hits the ground.

Given Data:

Initial velocity = $v_i = 0$

Gravitational acceleration = $g = 10\ ms^{-2}$

$t = 5s$

To Find:

$S = h = ?$

$v_f = ?$

Solution:

a) Applying the equation

$h = v_i t + \frac{1}{2} g t^2,$

$h = 0 \times 5 + 1/2 \times 10 \times (5)^2$

or $h = 0 + 125$

$h = 125m$

b) Applying the equation

$v_f^2 - v_i^2 = 2gh$

$v_f^2 - (0)^2 = 2 \times 10 \times 125$

$v_f^2 = 2500$

$\sqrt{v_f^2} = \sqrt{2500}$

$v_f = 50ms^{-1}$

Result:

Thus the height of the tower is 125 metres and it will hit the ground with a velocity of 50 ms^{-1}.

Example 2.15 091302137

A boy throws a ball vertically up. It returns to the ground after 5 seconds. Find

a. The maximum height reached by the ball.

b. The velocity with which the ball is thrown up.

Given Data:

Gravitational acceleration	=	$g = -10\ ms^{-2}$
Time for up and down motion		$t_o = 5\ s$
Velocity at maximum height		$v_f = 0$

To Find:

Maximum height	=	$S = h = ?$
Initial velocity (upward)	=	$v_i = ?$

Solution:

As the acceleration due to gravity is uniform, hence the time t taken by the ball to go up will be equal to the time taken to come down = ½ t_o

or $t = 1/2 \times 5 = 2.5$ s

$v_f = v_i + gt$

$0 = v_i - 10 \times 2.5 = v_i - 25 \Rightarrow v_i = 25\ ms^{-1}$

a) Applying the equation

$h = v_i t + \frac{1}{2} gt^2$

$h = 25 \times 2.5 - \frac{1}{2} \times 10 \times (2.5)^2$ or $h = 62.5 - 31.25 = 31.25$m

Result:

Thus, the ball was thrown up with a speed of 25 ms^{-1} and the maximum height to which the ball rises is 31.25 m.

Numerical Problems

Q. 2.1 A train moves with a uniform velocity of 36 kmh^{-1} for 10s. Find the distance travelled by it. 091302138

Given Data:

$v = 36$ km/h

$= \frac{36 \times 1000}{3600} = 10\ ms^{-1}$

$t = 10$ sec

To Find:

$S = ?$

Solution:

We Know

$S = v \times t$

$S = 10 \times 10 = 100$ m

Result: The distance travelled by the train is 100m.

Q. 2.2 A train starts from rest. It moves through 1 R.S km in 100 s with uniform acceleration. What will be its speed at the end of 100 s. 091302139

Given Data:

$v_i = 0$

$t = 100$ sec

$S = 1$ km $= 1000$ m

To Find:

$v_f = ?$

Solution:

We know

$S = v_{av} \times t$

$S = \left(\frac{v_i + v_f}{2}\right) t$

$1000 = \left(\frac{0 + V_f}{2}\right) 100$

$1000 \times 2 = (v_f)(100)$

$\frac{2000}{100} = v_f$

$v_f = 20\ ms^{-1}$

Result: At the end of the 100s, the velocity of the train will be $20ms^{-1}$.

Q.2.3 A car has a velocity of 10 ms^{-1}. It accelerates at 0.2 ms^{-2} for half minute. Find the distance travelled during this time and the final velocity of the car. (F.B. 2016) 091302140

Given Data:

$a = 0.2\ m/s^2$

$v_i = 10$ m/s

$t = 0.5$ min

$= 0.5 \times 60$ sec

$t = 30$ sec

To Find:

$S = ?$

$v_f = ?$

Solution: We know

$v_f = v_i + at$

$v_f = 10 + (0.2)(30)$

$= 10 + 6$

$v_f = 16$m/s

$S = v_{av} \times t$

$S = \frac{v_f + v_i}{2} t$

$S = \left(\frac{16 + 10}{2}\right) 30$

$S = \left(\frac{26^{13}}{2}\right) 30$ $S = 390$ m

Result: Hence, the final velocity of the car is $16ms^{-1}$ and car has travelled the distance 390m .

Q. 2.4 **A tennis ball is hit vertically upward with a velocity of 30ms^{-1}. It takes 3s to reach the highest point. Calculate the maximum height reached by the ball. How long will it take to return to ground?** 091302141

Given Data:

$v_i = 30\ ms^{-1}$

$t = 3\ sec$

To Find:

Total time = T = ?

S = ?

$v_f = 0$

$g = -10 m/s^2$

Solution: We know

$2gh = v_f^2 - v_i^2$

$2(-10)(h) = (0)^2 - (30)^2$

$-20h = -900$

$h = \frac{-900}{-20} = \boxed{h = 45\ m}$

$$\text{Total time} = \begin{pmatrix}\text{Time to}\\ \text{reach}\\ \text{at Max}\\ \text{height}\end{pmatrix} + \begin{pmatrix}\text{Time to}\\ \text{reach}\\ \text{ground form}\\ \text{height}\end{pmatrix}$$

$= 3 + 3$

$\boxed{\text{Total time} = 6\ sec}$

Result: The tennis ball reaches the maximum height 45m and it will take 6s to return to ground.

Q. 2.5 **A car moves with uniform velocity of 40 ms^{-1} for 5 s. It comes to rest in the next 10 s with uniform deceleration. Find (i) deceleration (ii) Total distance travelled by the car.** 091302142

Given Data:

$v_i = 40\ m/s$

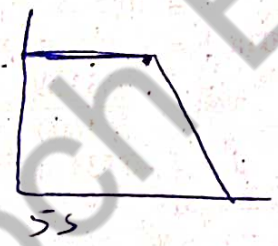
$v_f = 0$

$t = 10\ sec$

To Find:

S = ?

a = ?



Solution: We know

$v_f = v_i + at$

$0 = 40 + a(10)$

$-40 = 10(a)$

$\frac{-40}{10} = a$

$\boxed{a = -4 ms^{-2}}$

Distance travelled in first five second

$S = v_i \times t$

$S = 40 \times 5$

$S = 200m$

Let

$S_1 = S$

$S_1 = 200m$

Distance covered in last 10 second

$2aS_2 = v_f^2 - v_i^2$

$2(-4)\ S_2 = (0)^2 - (40)^2$

$8S_2 = 1600$

$S_2 = \frac{1600}{8}$

$S_2 = 200m$

Total Distance = $S_1 + S_2$

$S = 200 + 200 = 400m$

Result: The car accelerates with 4ms^{-2} covers 400m distance.

Q 2.6 **A train starts from rest with an acceleration of 0.5 ms^{-2}. Find its speed in kmh^{-1}, when it has moved through 100 m.** 091302143

Given Data:

$v_i = 0$

$a = 0.5\ m/s^2$

$S = 100\ m$

To Find:

v_f = ?

Solution: We know

$2a\ S = v_f^2 - v_i^2$

$2(0.5)\ (100) = (v_f)^2 - (0)^2$

$100 = v_f^2 - 0$

$\sqrt{100} = \sqrt{v_f^2}$

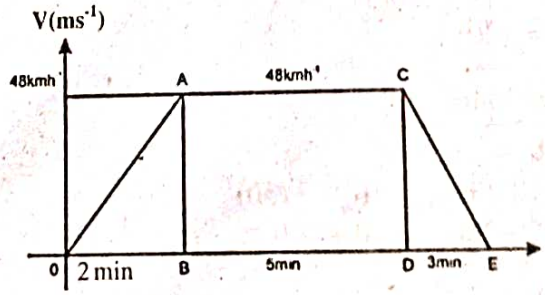
$V_f = 10\ ms^{-1}$

to convert in km / h

$V_f = \frac{10 \times 3600}{1000} = \boxed{V_f = 36\ km\ h^{-1}}$

Result: The final speed of train is 36kmh^{-1}.

Q. 2.7 **A train starting from rest, accelerates uniformly and attains a velocity 48 kmh^{-1} in 2 minutes. It travels at this speed for 5 minutes. Finally, it moves with uniform retardation and is stopped after 3 minutes. Find the total distance travelled by the train.** 091302144



Given Data:

$v_i = 0$

$v_f = 48\ kmh^{-1}$

From the Speed – Time graph:

$AB = V = \frac{48 \times 1000}{3600} = 13.33\ ms^{-1}$

$OE = 10min = 10 \times 60 = 600\ sec$

$AC = 5min = 5 \times 60 = 300\ sec$

To Find:

Total distance = S = ?

Solution:

Total distance covered = Area of trapezium

$S = \frac{1}{2}$ (sum of parallel sides) × Height

distance between parallel sides.

$S = \frac{1}{2}(OE + AC) \times AB$

$S = \frac{1}{2}(600s + 300s) \times 13.33 ms^{-1}$

$S = ½\ (15) \times 60 \times 13.33$

$S = 5998.5\ m$

$S = 6000m$

Result: The total distance travelled by train is 6000m.

Q 2.8 A cricket ball is hit vertically upwards and returns to ground 6 s later. Calculate (i) maximum height reached by the ball. (ii) Initial velocity of the ball. 091302145

Given Data:

$v_f = 0$

$g = -10 m/s^2$

Total time = 6 sec ⇒ Total time = [time to rearch at Max height] + [Time to reach ground]

$= 3 + 3$

$= 6\ sec$

$t = 3sec$ (time to reach maximum height).

To Find:

$S = ?$

$v_i = ?$

Solution: We know

$v_f = v_i + gt$

$0 = v_i + (-10)(3)$

$-v_i = -30$

$\boxed{v_i = 30 ms^{-1}}$

$2gh = v_f^2 - v_i^2$

$-2 \times 10 \times h = (0)^2 - (30)^2$

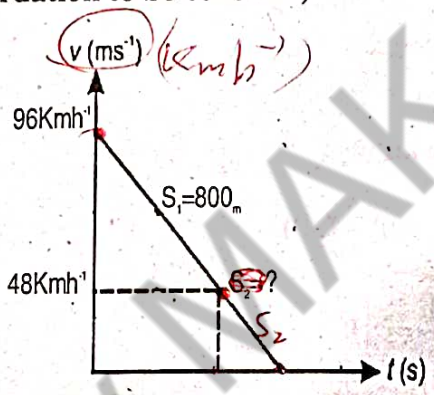
$-20h = 0 - 900$

$h = \frac{-900}{-20}$

$h = 45\ m$

Result: The cricket ball has initial velocity $30 ms^{-1}$ and reach the maximum height of 45m.

Q 2.9 When brakes are applied, the speed of a train decreases from 96 kmh^{-1} to 48 kmh^{-1} in 800 m. How much further will the train move before coming to rest? (Assuming the retardation to be constant). 091302146



Given Data:

$S_1 = 800m$

$v_i = 96\ kmh^{-1} = \frac{96 \times 1000}{3600} = 26.67 ms^{-1}$

$v_f = 48\ kmh^{-1} = \frac{48 \times 1000}{3600} = 13.33 ms^{-1}$

To Find:

S_2 = ? (Before train stops)

Solution: We know

To find S_1

$2a S_1 = v_f^2 - v_i^2$

$2\ (a)\ (800) = (13.33)^2 - (26.67)^2$

$= 177.69 - 711.289$

$1600\ (a) = -533.5989$

$a = \frac{-533.5989}{1600}$

$a = -0.333\ ms^{-2}$

To Find 'S_2'

$2aS_2 = v_f^2 - v_i^2$

$-2\ (0.3335)\ (S_2) = (0)^2 - (13.33)^2$

$-(0.667)\ S_2 = -177.6889$

$S_2 = \frac{-177.6889}{-0.667} = 266.40m$

Result: Before coming to rest of the train has covered the distance 266.40m.

Q. 2.10 **In the above problem, find the time taken by the train to stop after the application of brakes.**

Given Data:

$v_f = 0\ ms^{-1}$

$v_i = 26.67\ ms^{-1}$

$a = -0.333 ms^{-2}$

To Find:

$t = ?$

Solution: We know

$v_f = v_i + at$

$0 = 26.67 + (-0.3335)\ t$

$0 = 26.67 - 0.3335\ t$

$0.3335\ t = 26.67$

$$t = \frac{26.67}{0.333}$$

$t = 80$ sec

Result: The time taken by the train to stop after application of brakes is 80s.

UNIT 03 DYNAMICS

Introduction:

In this unit we will learn about momentum, Newton's law of motion, friction, uniform circular motion.

Q. 1 Differentiate between kinematics & dynamics. 091303001

Ans. Kinematics:- *The branch of mechanics that deals with the study of motion of a body without discussing the cause of motion is called kinematics.*

Dynamics:- *The branch of mechanics that deals with the study of motion of an object and the cause of its motion is called dynamics.*

Q.2 Define the following terms: 091303002

(i) Force (ii) Inertia (iii) Momentum

Ans.(i) Force:- *A Force moves or tends to move, stops or tends to stop the motion of a body. The force can also change the direction of motion of a body. It can also change the shape or size of the object.*

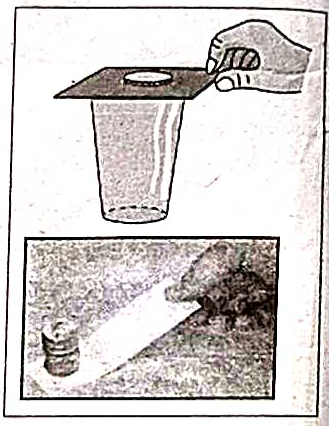
i. It is a vector quantity
ii. It is represented by F.
iii. Its unit is newton represented by N.
iv. Its formula is F = ma

(ii) Inertia:- *Inertia is that characteristic of a body due to which it resists any change in its state of rest or of uniform motion.*

Inertia of a body depends upon mass of body. Greater is mass greater is inertia.

Examples to understand inertia:

Take a glass and cover it with a piece of cardboard. Place a coin on the cardboard as shown in figure. Now kick the card horizontally with a jerk of your finger. The coin does not move with the cardboard due to inertia and fell into the glass because it continues its state of rest.



Consider another example of inertia. Cut a strip of paper. Place it on the table. Stack a few coins at its one end as shown in the figure. Pull out the paper strip under the coins with a jerk. The coin will remain at its position due to inertia.

(iii) Momentum:- *The quantity of motion of a body it possesses due to its mass and velocity is called momentum.* (F. B. 2017)

i. It is a vector quantity.
ii. It is represented by P.
iii. Its SI unit is $Kgms^{-1}$ or (Ns).
iv. Its formula is as P = mv.

Momentum of system depends upon mass and velocity of body.

Q.3 State Newton's first law of motion. Why is it called law of inertia?
OR State and explain the Newton's first law of motion. (F.B. 2018) 091303003

Ans. Newton's first law of motion:- *"Everybody continues its state of rest or of uniform motion in a straight line provided no net force acts on it".*

According to Newton's first law of motion, a body at rest remains at rest provided no net force acts on it. This part of the law is true as we observe that objects do not move by themselves unless someone moves them. For example, a book lying on a table remains at rest as long as no net force acts on it.

Similarly, a moving object does not stop moving by itself. A ball rolled on a rough ground stops earlier than that rolled on a smooth ground. It is because rough surfaces offer greater friction. If there would be no force to oppose the motion of a body then the moving body would never stop.

Newton's first law as law of inertia:

Since Newton's first law of motion deals with the inertial property of matter, therefore, Newton's first law of motion is also known as law of inertia.

Q.4 State and Derive Newton's Second law of motion. 091303004

Ans. Newton's Second law of motion:

"When a net force acts on a body an acceleration is produced in the direction of net force, the magnitude of acceleration is directly proportional to the applied force and is inversely proportional to mass of body".

Explanation: If a force 'F' produces an acceleration **'a'** in a body of mass 'm', then the body will be accelerated in the direction of force. If we double the applied force, the acceleration will be doubled. The

magnitude of acceleration is directly proportional to applied force. i.e.

$$a \propto F \quad \ldots\ldots (1)$$

It is easy to produce acceleration in a lighter body than that of heavier body. It means that acceleration produced by the force is inversely proportional to the mass of body.

$$a \propto \frac{1}{m} \quad \ldots\ldots\ldots (2)$$

By Combining (1) and (2)

$$\Rightarrow \quad a \propto \frac{F}{m}$$

$$a = \text{constant} \frac{F}{m}$$

putting 'k' as proportionality constant, we get

$$a = \frac{kF}{m}$$

Let F = 1N which produce acceleration $1ms^{-2}$ in a body of mass 1kg. In SI units, the value of k comes out to be 1. Thus above Eq. becomes

$$a = \frac{F}{m} \qquad \Rightarrow \qquad \boxed{F = ma}$$

Q.5 Define Newton (unit of force). (OR) Define force and write the name of its unit? 091303005

Ans. Definition:- *"One newton is that force which produces an acceleration of one metre per second square in a body of mass one kilogram".*

i.e. $1N = 1kg \times 1ms^{-2}$

$1N = kgms^{-2}$

Q. 6 What is the difference between Mass & weight? **(F.B. 2017)** 091303006

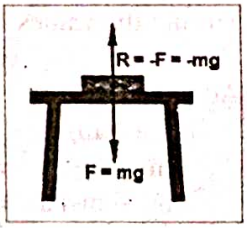
(OR) Give two differences between Mass & Weight.

Sr.#	Mass	Weight
i.	Mass of a body is the quantity of matter possessed by the body.	Weight of a body is equal to the force with which Earth attracts the body towards its centre.
ii.	It is a scalar quantity.	It is a vector quantity.
iii.	It is represented by m.	It is represented by W.
iv.	It does not change with change of place.	It varies from point to point depending upon the value of g.
v.	It is measured by Physical balance.	It is measured by spring balance.
vi.	Its unit is kg .	Its unit is Newton.
vii.	Formula of mass is $m = \frac{F}{a}$	Formula of weight is w = mg
viii.	Mass can never be zero.	Weight can be zero.

Q.7: Explain Newton's Third Law of Motion. 091303007

Ans. Statement:- *"To every action there is always an equal but opposite reaction".*

Explanation:- Newton's third law of motion deals with the reaction of a body when a force acts on it. Let a body A exerts a force on another body B, the body B reacts against this force and exerts a force on body A. The force exerted by body A on B is called **action**. Whereas the force exerted by body B on A is called the **reaction force**.

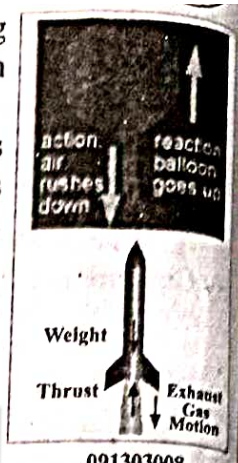


Note:- According to this law, action is always accompanied by a reaction force and the two forces must always be equal and opposite. Action and reaction forces act on two different bodies.

Example 1:- Consider a book on a table as shown in figure. The weight of the book is acting on the table in the downward direction. This is called action. The reaction of the table acts on the book in the upward direction. This is called reaction.

Example 2:- Take an air-filled balloon. When the balloon is set free, the air inside it rushes out and the balloon moves forward. In this example, the action is by the balloon that pushes the air out of it when set free. The reaction of the air which escapes out from the balloon acts on the balloon. It is due to this reaction of the escaping air that moves the balloon forward.

Example 3:- A rocket moves on the same principle. When its fuel burns, hot gases escape out from its tail with a very high speed. The reaction of these gases on the rocket causes it to move opposite to the gases rushing out of its tail.



091303008

Q.8 Define tension. Also write its conditions during the vertical motion of a block.

Ans. Definition:- *"The force exerted along a string when it is subjected to pull."* Tension and weight are in opposite direction. **(OR)**

The force acting along the string is called tension.

i.e. $T = W = mg$.

It is a vector quantity. And its SI unit is Newton.

It is represented by T.

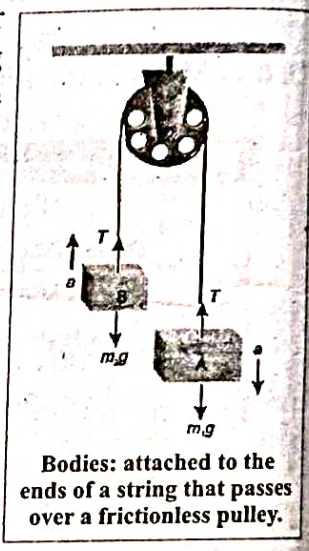
Conditions:-

i. If T > w then body moves upward **iii.** If T < w then body moves downward

ii. If T = w then body does not move.

Q.9: Find the tension and acceleration during vertical motion of two bodies attached to the ends of a string that passes over a frictionless pulley. **(F.B. 2017)** 091303009

Ans. Consider two bodies **"A"** and **"B"** of masses m_1 and m_2 respectively. Let m_1 is greater than m_2. The bodies are attached to the opposite ends of an inextensible string. The string passes over a frictionless pulley as shown in figure. The body **"A"** being heavier must be moving downwards with some acceleration. Let this acceleration be **"a"**. At the same time, the body B attached to the other end of the string moves up with the same acceleration **"a"**. As the pulley is frictionless, hence tension will be the same throughout the string. Let the tension in the string be **"T"**.



Bodies: attached to the ends of a string that passes over a frictionless pulley.

Since the body **"A"** moves downward, hence its weight m_1g is greater than the tension T in the string.

Net force acting on body A = weight –T

$$F_1 = w_1 - T \Rightarrow F_1 = m_1g - T$$

From second law of motion:

$$F_1 = m_1a$$

Putting the values in above equation

$$\Rightarrow \quad m_1a = m_1g - T \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

As body B moves upward, hence its weight is less than the tension T in the string.

Net force acting on body B = T – weight

$$F_2 = T - w_2 \Rightarrow F_2 = T - m_2g$$

And from second law

$$F_2 = m_2a$$

Putting the values in above equation

$$m_2a = T - m_2g \ldots \ldots \ldots (2)$$

Adding Eq. (1) and Eq. (2) we get acceleration a.

$$m_1a + m_2a = m_1g - T + T - m_2g$$

$$(m_1 + m_2)\,a = m_1g - m_2g$$

$$(m_1 + m_2)\,a = (m_1 - m_2)g$$

$$\boxed{a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)g} \quad \text{.....(A)}$$

By using this formula we can find acceleration.

By dividing Eq. (1) and (2), we get the relation to find tension.

$$\frac{m_1 a}{m_2 a} = \frac{m_1 g - T}{T - m_2 g}$$

$$\frac{m_1}{m_2} = \frac{m_1 g - T}{T - m_2 g}$$

$$\Rightarrow \quad m_1(T - m_2 g) = m_2(m_1 g - T)$$

$$m_1 T - m_1 m_2 g = m_1 m_2 g - m_2 T$$

$$m_1 T + m_2 T = m_1 m_2 g + m_1 m_2 g$$

$$T(m_1 + m_2) = 2m_1 m_2 g$$

$$\boxed{T = \left(\frac{2m_1 m_2}{m_1 + m_2}\right)g}$$

The above arrangement is also known as Atwood machine. It can be used to find the acceleration g due to gravity by using relation given below:

$$\boxed{g = \left(\frac{m_1 + m_2}{m_1 - m_2}\right)a}$$

Q10. What is Atwood machine? 091303010

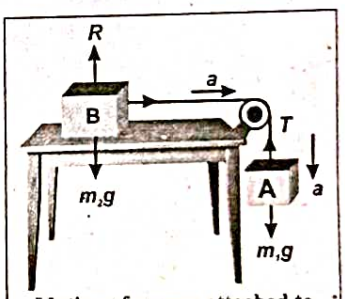
Ans: Definition: *"It is a machine which is used to find the acceleration due to gravity".*

Construction: Atwood machine is an arrangement of two objects of unequal masses. Both the objects are attached to the ends of a string. The string passes over a frictionless pulley.

$$\boxed{g = \frac{(m_1 + m_2)a}{(m_1 - m_2)}}$$

Q.11: Find out a relation for acceleration and tension for motion of two bodies attached to the ends of a string that passes over a frictionless pulley such that one body moves vertically and the other moves on a smooth horizontal surface. 091303011

Ans. Consider two bodies **A** and **B** of masses m_1 and m_2 respectively attached to the ends of an inextensible string as shown in figure. Let the body **"A"** moves downward with an acceleration **"a".** Body **"B"** also moves over the horizontal surface with same acceleration **"a".** As the pulley is frictionless, hence tension T will be the same throughout the string.



Motion of masses attached to a string that passes over a frictionless pulley.

Since body A moves downwards, therefore, its weight $m_1 g$ is greater than the tension **T** in the string.

Net force acting on body A

Net force acting on body A

$F_1 = m_1 g - T$

And from second law $F_1 = m_1 a$

$m_1 a = m_1 g - T$ .....(1)

The forces acting on body B

The forces acting on body B are:

i. Weight $m_2 g$ of the body B acting downwards.

ii. Reaction R of the horizontal surface acting on body B in the upward direction.

iii. Tension *T* in the string pulling the body B horizontally over the smooth surface.

As body B has no vertical motion, hence resultant of vertical forces (m_2 g and R) must be zero. Thus, the net force acting on body B is T.

$F_2 = T$

According to Newton's second law of motion $F_2 = m_2a$

$m_2a = T$ ... ...(2)

Adding Eq. (1) & (2)

$m_1a + m_2a = m_1g - T + T$

$m_1a + m_2a = m_1g$

$a(m_1 + m_2) = m_1g$

$$a = \frac{m_1g}{m_1 + m_2} \quad \text{... ... ... (A)}$$

Putting this value of "a" in Eq. no (2) we get the formula for tension.

$$T = \frac{m_1m_2}{m_1 + m_2}g \quad \text{... ...(B)}$$

Q.12: Show that rate of change of momentum is equal to applied force. **(F.B. 2017)** **091303012**

(OR) How can you relate a force with the change of momentum of a body?

Ans. *"When a force acts on a body, it produces an acceleration in the body and will be equal to the rate of change of momentum of the body".*

Explanation: Consider a body of mass '*m*' moving with initial velocity v_i.

When a force acts upon a body an acceleration is produced in it, this change the velocity v_i of the body to final velocity v_f.

If P_i and P_f be the initial momentum and final momentum of the body related to initial and final velocities respectively then

$P_i = mv_i$

and $P_f = mv_f$

Change in Momentum = final momentum - initial momentum

$P_f - P_i = mv_f - mv_i$

The rate of change in momentum is given by

$$\frac{P_f - P_i}{t} = \frac{mv_f - mv_i}{t}$$

$$\frac{P_f - P_i}{t} = m\frac{v_f - v_i}{t} \quad \text{... ... ...(1)}$$

Since $\frac{v_f - v_i}{t} = a$

$$\therefore \frac{P_f - P_i}{t} = ma \quad \text{... ... ... (2)}$$

According to Newton's second law of motion,

$F = ma$ put in Eq. no. (2)

$$\frac{P_f - P_i}{t} = F$$

OR.

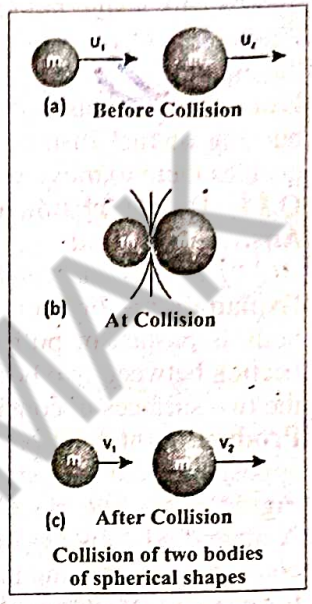
$F = \frac{\Delta P}{t}$ This equation shows that rate of change of momentum is equal to applied force.

Q.13 Explain law of conservation of momentum? Also derive its formula.
(OR) State and explain law of conservation of momentum. **(F.B. 2016)** 091303013

Ans. Law of conservation of Momentum:

Statement:- *"The momentum of an isolated system of two or more than two interacting bodies remain constant".*

Momentum of a system depends on its mass and velocity. *"An **isolated system** is a group of interacting bodies on which no external force is acting."* If no unbalanced or net force acts on a system, its momentum remains constant. Thus the momentum of an isolated system is always conserved. This is the Law of conservation of Momentum.



Collision of two bodies of spherical shapes

Explanation:

Consider an isolated system of two spheres of masses m_1 and m_2 as shown in figure. They are moving in a straight line with initial velocities $\mathbf{u_1}$ and $\mathbf{u_2}$ respectively, such that $\mathbf{u_1}$ is greater than $\mathbf{u_2}$. Sphere of mass m_1 approaches the sphere of mass m_2 as they move.

Initial momentum of mass $m_1 = m_1u_1$

Initial momentum of mass $m_2 = m_2u_2$

Total initial momentum of the system before collision $= m_1u_1 + m_2u_2$.

After sometime mass m_1 hits m_2 with some force. According to Newton's third law of motion, m_2 exerts an equal and opposite reaction force on m_1. Let their velocities become v_1 and v_2 respectively after collision. Then

Final momentum of mass $m_1 = m_1v_1$

Final momentum of mass $m_2 = m_2v_2$

Total final momentum of the system after collision $= m_1v_1 + m_2v_2$

According to the law of conservation of momentum

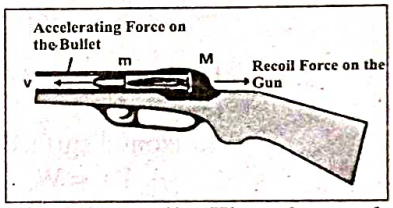
$$\begin{pmatrix}\text{Total initial momentum of}\\ \text{the system before collision}\end{pmatrix} = \begin{pmatrix}\text{Total final momentum of}\\ \text{the system after collision}\end{pmatrix}$$

$$\boxed{m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$$

This equation shows that the momentum of an isolated system before and after collisions remains the same which is the law of conservation of momentum.

Law of conservation of momentum is an important law and has vast applications.

Application of law of conservation of momentum: 091303014



Consider a system of gun and a bullet. Before firing the gun, both the gun and bullet are at rest, so the total momentum of the system is zero. As the gun is fired, bullet shoots out of the gun and acquires momentum. To conserve momentum of the system, the gun recoils. According to the law of conservation of momentum, the total momentum of the gun and the bullet will also be zero after the gun is fired. Let m be the mass of the bullet and **v** be its velocity on firing the gun; M be the mass of the gun and V be the velocity with which it recoils. Thus the total momentum of the gun and the bullet after the gun is fired will be;

$$\begin{pmatrix}\text{Total momentum of the}\\ \text{gun and the bullet after}\\ \text{the gun is fired}\end{pmatrix} = M\,V + m\,v$$

According to the law of conservation of momentum

$$\begin{pmatrix}\text{Total momentum of the}\\ \text{gun and the bullet after}\\ \text{the gun is fired}\end{pmatrix} = \begin{pmatrix}\text{Total momentum of the}\\ \text{gun and the bullet before}\\ \text{the gun is fired}\end{pmatrix}$$

$$\therefore \quad MV + m\,v = 0$$

or $M V = - m v$

Hence $V = -\frac{m}{M} v$

Equation gives the velocity V of the gun.

Negative sign indicates that velocity of the gun is opposite to the velocity of the bullet i.e., the gun recoils. Since mass of the gun is much larger than the bullet, therefore, the recoil is much smaller than the velocity of the bullet.

Example: Rockets and jet engines also work on the same principle. In these machines, hot gases produced by burning of fuel rush out with large momentum. The machines gain an equal and opposite momentum. This enables them to move with very high velocities.

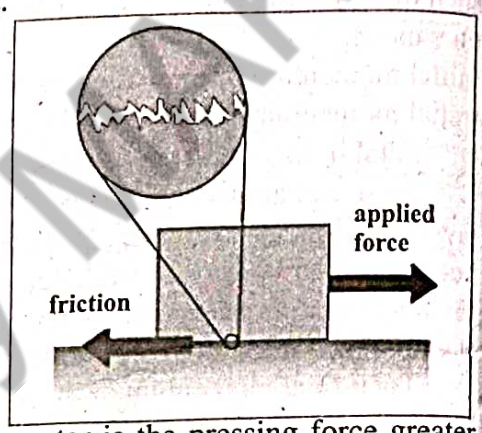
091303015

Q.14 Define friction and how does it produce?

Ans. Definition:

"The force that opposes the motion of moving objects is called friction."

Explanation:- Friction is a force that comes into action as soon as a body is pushed or pulled over a surface. In case of solids, the force of friction between two bodies depends upon many factors such as nature of the two surfaces in contact and the pressing force between them.



Production of friction:- No surface is perfectly smooth. A surface that appears smooth has pits and bumps that can be seen under a microscope. Figure shows two wooden blocks with their polished surfaces in contact. A magnified view of two smooth surfaces in contact shows the gaps and contacts between them. The contact points between the two surfaces form a sort of cold welds. These cold welds resist the surfaces sliding over each other. Adding weight over the upper block increases the force pressing the surfaces together and hence, increases the resistance. Thus, greater is the pressing force greater will be the friction between the sliding surfaces.

091303016

Q.15 Define Limiting friction.

Ans. Limiting friction:- *"The maximum value of friction is known as the force of limiting friction (F_s)".* It depends on the normal reaction (pressing force) between the two surfaces in contact.

091303017

Q.16 What is meant by coefficient of friction? Write its mathematical form.

Ans. Co-efficient of friction:- *"The ratio between the force of limiting friction F_s and the normal reaction R is constant. This constant is called the coefficient of friction and is represented by μ."*

Thus $\mu = \frac{F_s}{R}$

$F_s = \mu R$

If *m* be the mass of the block, then for horizontal surface:

$R = W \quad \therefore \quad W = mg$

$R = mg$

Hence $F_s = \mu mg$

Unit: Co-efficient of friction has no unit.

Co-efficient of friction between some common materials	
Materials	μ_s
Glass and Glass	0.9
Glass and Metal	0.5 – 0.7
Ice and Wood	0.05
Iron and Iron	1.0
Rubber and Concrete	0.6
Steel and Steel	0.8
Tyre and dry road	1
Tyre and wet road	0.2
Wood and Wood	0.25 – 0.6
Wood and Metal	0.2 – 0.6
Wood and Concrete	0.62

091303018

Q.17 Why is rolling friction less than sliding friction?

Ans. When the axle of a wheel is pushed, the force of friction between the wheel and the ground at the point of contact provides the reaction force. The reaction force acts at the contact points of the wheel in a direction opposite to the applied force. The wheel rolls without rupturing the cold welds. That is why the rolling friction is extremely smaller than sliding friction.

Q.18 Write a few applications of rolling friction. **(F.B. 2017)** **091303019**

Ans. Application of rolling friction:

i. The fact that rolling friction is less than sliding friction is applied in ball bearings or roller bearings to reduce losses due to friction.

ii. The wheel would not roll on pushing it if there would be no friction between the wheel and the ground. Thus, friction between the wheel and the ground is desirable for wheels to roll over a surface. It is dangerous to drive on a wet road because the friction between the road and the tyres is very small. This increases the chance of slipping the tyres from the road. The threading on tyres is designed to increase friction. Thus, threading improves road grip and make it safer to drive even on wet road.

iii. A cyclist applies brakes to stop bicycle. As soon as brakes are applied, the wheels stop rolling and begin to slide over the road. Since sliding friction is much greater than rolling friction. Therefore, the cycle stops very quickly.

Q.19: How does Braking and Skidding happen? **091303020**

Ans. Braking and Skidding

The wheels of a moving vehicle have two velocity components:

i. Motion of wheels along the road. **ii.** Rotation of wheels about their axis.

Braking:- *"The force of friction (gripping force) between the tyres and the road must be enough that prevents them from slipping".*

To move a vehicle on the road as well as to stop a moving vehicle requires friction between its tyres and the road. For example, if the road is slippery or the tyres are worn out then the tyres instead of rolling, slip over the road. The vehicle will not move if the wheels start slipping at the same point on the slippery road. Thus for the wheels to roll, the force of friction between the tyres and the road must be enough that prevent from slipping.

Skidding:- *"In order to reduce the chance of skidding, it is advisable not to apply brakes too hard that lock up their rolling motion especially at high speeds. Moreover, it is unsafe to drive a vehicle with worn out tyres".*

To stop a car quickly, a large force of friction between the tyres and the road is needed. But there is a limit to this force of friction that tyres can provide. If the brakes are applied too strongly, the wheels of the car will lock up (stop turning) and the car will skid due to its large momentum. It will lose its directional control that may result in an accident.

Q.20 Write advantages and disadvantages of friction. **091303021**

Ans. Disadvantages of friction:

i. Friction is undesirable when moving at high speeds because it opposes the motion and thus limits the speed of moving object.
ii. Most of energy is lost as heat and sound due to the friction between various moving parts of machines.
iii. In machines, friction also causes wear and tear of their moving parts.
iv. Shoes and clothes also wear out due to friction.
v. Nails remain fixed in the walls due to friction.
vi. Most of living bodies climb on trees only due to friction.

Advantages of friction:

(i) Friction is needed to walk on the ground.
(ii) We cannot write with pencil if there is no friction between pencil and paper.
(iii) Athletes use special shoes that have extraordinary ground grip. Such shoes prevent them from slipping while running fast.
(iv) We can stop the fast moving vehicles when we apply brakes.
(v) Birds cannot fly, if there is not air resistance. The reaction of pushed air enables the birds to fly.

Q.21 Write down few methods of reducing friction. **091303022**

Ans. The friction can be reduced by following proper methods:

i. Making the sliding surfaces smooth by polish.
ii. Making the fast moving objects a streamline shape (fish shape) such as cars, aeroplanes, etc. This causes the smooth flow of air and thus minimize air resistance at high speeds.
iii. Lubricating the sliding surfaces e.g (oil or grease is used for this purpose).
iv. Using ball bearings or roller bearings, necause the rolling friction is lesser than the sliding friction.

Q.22 Define circular motion. Also write its example.

091303023

Circular motion of a stone attached with a string.

Ans. Definition: *The motion of an object in a circular path is known as circular motion".*

Example 1:- Take a small stone. Tie it at one end of a string and keep the other end of the string in your hand as shown in fig. Now rotate the stone holding the string. The stone will move in a circular path. The motion of stone will be called as circular motion.

Example 2:- Motion of the moon around the Earth is circular motion.

Q.23 Define and explain centripetal force and write down its mathematical form. **(F.B. 2017)** 091303024

Ans. Centripetal Force:

Definition:- *"Centripetal force is a force that keeps a body to move in a circle".*

Example 1:- The moon revolves around the Earth. The gravitational force of the Earth provides the necessary centripetal force.

Example 2:- Electrons revolve around the Nucleus. The electrostatic force between electrons and nucleus provides the necessary centripetal force.

Example 3:- A stone tied to one end of a string rotating in a circle. The tension in the string provides the necessary centripetal force. It keeps the stone to remain in a circle.

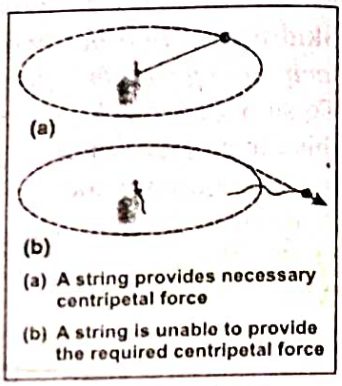
Factors:- Centripetal force depends on the following factors:-

(i) Mass of body (m)

(ii) Square of velocity of body (v^2)

(iii) Radius of circle (r)

Explanation:



(a)

(b)

(a) A string provides necessary centripetal force

(b) A string is unable to provide the required centripetal force

Let a body of mass m move with uniform speed **v** in a circle of radius r. The acceleration a_c produced by the centripetal force F_c is given by

Centripetal acceleration $a_c = \frac{v^2}{r}$

The acceleration produced by the centripetal force is always directed towards the centre of circle is called ***centripetal acceleration.***

According to Newton's second law of motion, the centripetal force F_c is given by

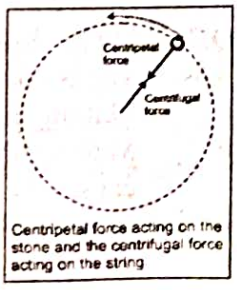
$$F_c = m a_c$$

$$F_c = \frac{mv^2}{r}$$

Above Equation shows that the centripetal force needed by a body moving in a circle depends on the mass m of the body, square of its velocity v and reciprocal to the radius r of the circle. Centripetal force always acts perpendicular to the motion of the body.

- If the mass of body is doubled then centripetal force will also become doubled.
- If velocity of body is doubled then centripetal force becomes four-time.
- If radius of circle is doubled then centripetal force is reduced to half.
- Centripetal force is always perpendicular to the motion of the body.
- Centripetal force and centripetal acceleration is directed towards the centre of circle.

Q.24 Define centrifugal force. 091303025



Centripetal force acting on the stone and the centrifugal force acting on the string

Ans. Definition:- *"A force which pulls the body outwards during the circular motion is called centrifugal force".*

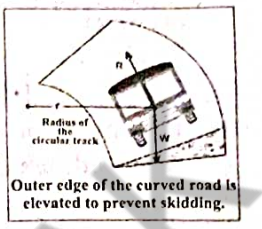
Explanation:- Consider a stone, shown in figure, tied to a string moving in a circle. The necessary centripetal force acts on the stone through the string that keeps it to move in a circle. According to Newton's third law of motion, there exists a reaction to this centripetal force. Centripetal reaction that pulls the string outwards is sometimes called the centrifugal force.

Q.25 From where does centripetal force F_c come during motion on circular (curved) track? 091303026

Ans. When a car takes a turn, centripetal force is needed to keep it in its curved track. The friction between the tyres and the road provides the necessary centripetal force.

Q.26 Why is the outer edge of road kept higher than inner edge? 091303027
OR What is meant by banking of road?

Ans. When a car takes a turn, centripetal force is needed to keep it in its curved track. The friction between the tyres and the road provides the necessary centripetal force. The car would skid off, if the force of friction between the tyres and the road is not sufficient enough particularly when the roads are wet. This problem is solved by banking of curved roads. Banking of a road means that the outer edge of a road is raised. Imagine a vehicle on a curved road such as shown in figure.



Outer edge of the curved road is elevated to prevent skidding.

Q.27 Explain the working of washing machine. (OR) How does washing machine dryer work? 091303028

Ans. The dryer of a washing machine is basket spinners. They have a perforated wall having large numbers of fine holes in the cylindrical rotor as shown in figure.

The lid of the cylindrical container is closed after putting wet clothes in it. When it spins at high speed, the water from wet clothes is forced out through these holes due to lack of centripetal force.

Dryer of washing machines has perforated wall.

Q.28 Explain cream separator. 091303029

Ans. Most modern plants use a separator to control the fat contents of various products. A separator is a high-speed spinner. It acts on the same principle of centrifuge machines.

The bowl spins at very high speed causing the heavier contents of milk to move outward in the bowl pushing the lighter contents inward towards the spinning axis. Cream or butterfat is lighter than other components in milk. Therefore, skimmed milk, which is denser than cream is collected at the outer wall of the bowl. The lighter part (cream) is pushed towards the centre from where it is collected through a pipe.

MULTIPLE CHOICE QUESTIONS

3.1 Encircle the correct answer from the given choices

Exercise MCQs

1. Newton's first law of motion is valid only in the absence of: 091303030
(a) force (b) net force
(c) friction (d) momentum

2. Inertia depends upon: (F.B. 2017) 91303031
(a) force (b) net force
(c) mass (d) velocity

3. A boy jumps out of a moving bus. There is a danger for him to fall: 091303032
(a) towards the moving bus
(b) away from the bus
(c) in the direction of motion
(d) opposite to the direction of motion

4. A string is stretched by two equal and opposite force 10 N each. The tension in the string is: 091303033
(a) zero (b) 5N
(c) 10 N (d) 20 N

5. The mass of a body: 091303034
(a) decreases when accelerated
(b) increases when accelerated
(c) decreases when moving with high velocity
(d) none of the above.

6. Two bodies of masses m_1 and m_2 attached to the ends of an inextensible string passing over a frictionless pulley such that both move vertically. The acceleration of the bodies is: 091303035
(a) $\frac{m_1 \times m_2}{m_1 + m_2}$ (b) $\frac{m_1 - m_2}{m_1 + m_2} g$
(c) $\frac{m_1 + m_2}{m_1 - m_2} g$ (d) $\frac{2m_1 m_2}{m_1 + m_2} g$

7. Which of the following is the unit of momentum? (F.B. 2017) 091303036
(a) Nm (b) $kgms^{-2}$
(c) Ns (d) Ns^{-1}

8. When horse pulls a cart, the action is on the:
(a) cart (b) Earth 091303037
(c) horse (d) Earth and cart

9. Which of the following material lowers friction when pushed between metal plates? 091303038
(a) water (b) fine marble powder
(c) air (d) oil

Additional MCQs

10. The study of motion without reference to mass and force: 091303039
(a) Mechanics (b) Dynamics
(c) Kinematics (d) Electronics

11. Which is unitless quantity: 091303040
(a) mass (b) force
(c) Inertia (d) momentum

12. The direction of momentum is: 091303041
(a) opposite to motion
(b) along the velocity
(c) perpendicular to motion
(d) None

13. Which law of motion is called law of inertia:
(a) first law of motion 091303042
(b) second law of motion
(c) third law of motion
(d) law of conservation of momentum

14. The unit of momentum is: (F.B. 2017) 091303043
(a) $kgms^{-2}$ (b) $kgms^{-1}$
(c) Ns^{-1} (d) kgms

15. Action and reaction are always on: 091303044
(a) same body
(b) different bodies
(c) any body
(d) small body

16. Mass is measured by: 091303045
(a) spring balance
(b) measuring cylinder
(c) physical balance
(d) stop watch

17. Weight is measured by: 091303046
(a) spring balance
(b) measuring cylinder
(c) physical balance
(d) stop watch

18. Formula of weight is derived from which law? 091303047
(a) First law
(b) Second law
(c) Third law
(d) Law of conservation of momentum

19. Walking on earth is the example of which law? 091303048
(a) First law of motion
(b) Second law of motion
(c) Third law of motion
(d) Law of momentum

20. Motion of a rocket is the example of which law? 091303049
(a) first law of motion
(b) second law of motion
(c) third law of motion
(d) law of inertia

21. If the weight of body is greater than tension then body will. 091303050
(a) move upward
(b) move downward
(c) not move
(d) None

22. If a force of 25 N is acting along the string to balance the weight then tension in string is. 091303051
(a) 25 N (b) 50 N
(c) zero (d) 100N

23. The rate of change of momentum is equal. 091303052
(a) mass (b) force
(c) weight (d) None

24. If no external force acting on a body then such system is called. 091303053
(a) ideal system
(b) controlled system
(c) isolated system
(d) None

25. The force which opposes the motion is called. 091303054
(a) momentum (b) friction
(c) inertia (d) tension

26. Which type of friction is minimum? 091303055
(a) Sliding (b) Limiting
(c) Rolling (d) Static friction

27. Which type of friction is maximum? 091303056
(a) Sliding (b) Rolling
(c) Both a, b (d) None

28. Friction is due to: 091303057
(a) Roughness (b) Shape
(c) Smoothness (d) None

29. When a block is placed on the surface its weight produce: 091303058
(a) Tension (b) Momentum
(c) Inertia (d) Normal reaction

30. **What is the effect of lubrication?** 091303059
(a) Increase friction
(b) No effect
(c) Reduce friction
(d) None

31. **In circular motion, the motion of every particle of body is:** 091303060
(a) Different (b) Opposite
(c) Same (d) None of these

32. **The force which compels a body to move in circle is:** 091303061
(a) Centripetal force
(b) Centrifugal force
(c) Perpendicular force
(d) Tension

33. **If the velocity of a moving body in a circle is doubled, then its centripetal force is:** 091303062
(a) double (b) half
(c) four times (d) remain

34. **The centripetal acceleration is always along:** 091303063
(a) Normal forces
(b) Centripetal forces
(c) Mass
(d) Horizontal force

35. **The unit of coefficient of friction:** 091303064
(a) Newton (b) ms^{-1}
(c) ms^{-2} (d) No unit

36. **Coefficient of friction between tyre and dry road is.** 091303065
(a)0.6 (b) 1
(c)0.05 (d) 0.2

37. **1 Newton = _____** 091303066
(a)1kg ms^{-2} (b) 1 kg ms
(c)1kg $m^{-1}s^{-2}$ (d) $kg^{-1}m^{-1}s^{-1}$

38. **The weight of boy is 147N. Its mass will be _____ when g = 10ms^{-2}** 091303067
(a) 1.47 kg (b) 14.7 kg
(c) 47 kg (d) 1.51 kg

39. **Product of mass and velocity of a body is called:** 091303068
(a)Torque (b) Force
(c)Work (d) Momentum

40. **In an isolated system the momentum after collision of two bodies.** 091303069
(a) increase (b) constant
(c) decrease (d) zero

41. **If radius of circle is doubled then centripetal acceleration becomes:** 091303070
(a) Doubled (b) Three times
(c) Four times (d) Half time

42. **Rolling friction is _____ then sliding friction:** 091303071
(a) Greater (b) Less
(c) Some (d) Half

43. **If the mass of moving body in a circle is doubled then centripetal force will be:** 091303072
(a) Doubled (b) Half
(c) 4-Times (d) Same

44. **Momentum is a quantity.** 091303073
(a) Scalar (b) Vector
(c) Base (d) All

45. **Which machine is used to find acceleration due to gravity?** 091303074
(a) Centrifuge
(b) Atwood machine
(c) Hydrolic machine
(d) Washing machine

46. **Co-efficient of friction between glass and glass.** 091303075
(a) 1.0 (b) 0.9
(c) 0.6 (d) 0.8

47. **Co-efficient of friction between wood and concrete.** 091303076
(a) 0.62 (b) 0.8
(c) 1 (d) 0.9

48. **Laws of motion was presented by the Scientist.** 091303077
(a) Einstein (b) Newton
(c) Galileo (d) Archimedes

49. **If the mass of body is doubled while keeping the force constant, then acceleration will be:** 091303078
(a) Doubled (b) One Half
(c) 4 times (d) One fourth

50. **When a force of 4 Newton is applied on a body of mass 2kg, the acceleration produced in it will be:** 091303079
(a) $2ms^{-2}$ (b) $4ms^{-2}$
(c) $8ms^{-2}$ (d) $6ms^{-2}$

51. **The weight of body on earth with mass 8kg is:** 091303080
(a) 10 N (b) 100 N
(c) 80 N (d) 8 N

52. **Which parameter remain same everywhere?** 091303081
(a) Force (b) Mass
(c) Weight (d) Velocity

53. If a 20 N weight of block hang with the string vertically then tension in string is: 091303082
(a) 0 N (b) 20 N
(c) 2 N (d) 10 N

54. The maximum value of friction is: 091303083
(a) Kinetic friction
(b) Rolling friction
(c) Limiting friction
(d) Dynamic friction

55. Sliding friction can be changed into rolling friction by using: 091303084
(a) Ball bearing (b) Roller bearing
(c) Both a, b (d) None of these

56. The velocity and acceleration of body moving with uniform speed in a circular path will be: (F.B 2016) 091303085
(a) In same direction
(b) In opposite direction
(c) Mutually perpendicular
(d) Equal

57. F = _____ 091303086
(a) $P_f - P_i$ (b) $P_i - P_f$
(c) $\frac{P_f - P_i}{t}$ (d) $\frac{t}{P_f - P_i}$

58. $Kgms^{-2}$ is equal to: 091303087
(a) Joule (b) Mole
(c) Newton (d) Watt

59. Time required to change 22 Ns momentum by a force of 44 N is: 091303088
(a) 0.5s (b) 1s
(c) 2 s (d) 3 s

60. Limiting friction can be calculated by the formula: 091303089
(a) Fs = R (b) Fs = mg
(c) Fs = μmg (d) $\mu = \frac{Fs}{mg}$

61. A body of mass 'm' is hanging vertically downward with the help of a mass-less string. If the body is at rest then the tension in the string will be. 091303090
(a) T = 0 (b) T < W
(c) T > W (d) T = W

62. A string is stretched by two equal and opposite forces F Newton each. The tension in the string is: (F.B. 2018) 091303090 (a)
(a) Zero (b) 2F Newton
(c) F Newton (d) $\frac{1}{2}$F Newton

Answer

1.	b	2.	c	3.	c	4.	c	5.	d
6.	b	7.	c	8.	d	9.	d	10.	c
11.	c	12.	b	13.	a	14.	b	15.	b
16.	c	17.	a	18.	b	19.	c	20.	c
21.	b	22.	a	23.	b	24.	c	25.	b
26.	c	27.	a	28.	a	29.	d	30.	c
31.	c	32.	a	33.	c	34.	b	35.	d
36.	b	37.	a	38.	b	39.	d	40.	b
41.	d	42.	b	43.	a	44.	b	45.	b
46.	b	47.	a	48.	b	49.	b	50.	a
51.	c	52.	b	53.	b	54.	c	55.	c
56.	c	57.	c	58.	c	59.	a	60.	C
61.	d	62.	c						

Exercise Answer Questions

Q.3.2 Define the following terms. 091303091
(i) Inertia (ii) Momentum (iii) Force
(iv) Force of friction (v) Centripetal force

(i) Inertia: Inertia is that characteristic of a body due to which it resists any change in its state of rest or of uniform motion in a straight line. It depends on mass of the body..

(ii) Momentum: The quantity of motion of a body it possesses due to its mass and velocity is called momentum.

(iii) Force: Force is the agency which moves or tends to move, stops or tends to stop the motion of an object. It can also change the direction of motion of an object..

(iv) **Force of friction:**
The force that opposes the motion of an object is called force of friction.

(v) **Centripetal force:** The force that keeps a body to move in a circle is called centripetal force.

Its formula is $F_c = \frac{mv^2}{r}$.

Q.3.3 What is the difference between? 091303092

(i) Mass and weight

(ii) Action and reaction

(iii) Sliding friction and rolling friction

Ans: (i) Mass and Weight:

Mass: Mass of a body is the quantity of matter possessed by the body. It is a scalar quantity. It is represented by m. It does not change with change of place. Its unit is kg .

Weight: Weight of a body is equal to the force with which Earth attracts the body towards its centre. It is a vector quantity. It is represented by W. It varies from point to point depending upon the value of g. Its unit is newton.

(ii) Action and reaction

Action: The force exerted by first body on the second body is called action.

Reaction: The force exerted by the second body in response to the first body is called reaction.

(iii) Sliding friction and rolling friction

Sliding Friction: The force between the sliding object which opposes the relative motion between them is called sliding friction.

Rolling friction: The force of friction between rolling body and the surface over which it rolls is called rolling friction.

Q.3.4 What is the law of inertia? 091303093

Ans. Newton's first law:

Everybody continues its state of rest or of uniform motion in a straight line provided no net force acts upon it. Newton's first law of motion deals with inertial property of matter so, it is also known as law of inertia.

Q.3.5 Why is it dangerous to travel on the roof of a bus? (F.B. 2017) 091303094

Ans. It is dangerous to travel on the roof of a bus because when the driver applies the brakes, the passengers on the roof may fall due to inertia. Due to inertial property, the passengers on roof of bus want to continue their motion with the bus. They can fall due to inertia.

Q.3.6 Why does a passenger move outwards when a bus takes a turn? 091303095

Ans. When a bus takes a sharp turn, passengers fall in the outward direction. It is due to inertia that they want to continue their motion in a straight line and thus fall outwards.

Q.3.7 How can you relate a force with the change of momentum of a body? 091303096

Ans. See Q. No. 12 on page No. 50

Q.3.8 What will be the tension in a rope that is pulled from its ends by two opposite forces 100 N each? 091303097

Ans. A rope that is pulled from its ends by two opposite forces 100N each then the tension in the string will be 100N.

Q.3.9 Action and reaction are always equal and opposite. Then how does a body move? 091303098

Ans. Action and reaction are always equal and opposite but body moves because action and reaction are applied on two different bodies. The two forces can only cancel if they act on same object.

Q.3.10 A horse pushes the cart. If the action and reaction are equal and opposite then how does the cart move? 091303099

Ans. A horse pushes the Earth in the backward direction, this is action and in reaction Earth pushes the horse in the forward direction . In this way cart moves. The action and reaction are applied on the different bodies.

Q.3.11 What is the law of conservation of momentum? 091303100

Ans. "The momentum of an isolated system of two or more than two interacting bodies remains constant".

Q.3.12 Why is the law of conservation of momentum important? 091303101

Ans. Law of conservation of momentum is an important law and has vast applications.

It is applicable universally not only for smaller bodies like electrons & protons but also for large bodies like planets and stars.

Q.3.13 When a gun is fired, it recoils, why? (F.B. 2017) 091303102

Ans. Consider a system of gun and a bullet. Before firing the gun, both the gun and bullet are at rest, so the total momentum of the system is zero. As the gun is fired, bullet shoots out of the gun and acquires momentum. To conserve momentum of the system, the gun recoils. But its recoil is smaller than the velocity of bullet because mass of gun is greater than the bullet.

Q.3.14 Describe two situations in which force of friction is needed. 091303103

Ans.

(i) Friction is needed to walk on the ground.

(ii) It is risky to run on wet floor with shoes that have smooth soles.

(iii) Friction is required by birds to fly in the sky.

(iv) Athletes use special shoes that have extraordinary ground grip. Such shoes prevent them from slipping while running fast.

Q.3.15 How does oiling the moving parts of a machine lower friction? 091303104

Ans. Because liquid friction is less than solids. No surface is completely smooth. By oiling the surface, the pits and bumps are filled with oil and so friction is reduced. Also surfaces become slippery due to oiling.

Q.3.16 Describe ways to reduce friction. 091303105

Ans. The friction can be reduced by following methods:

i. Making the sliding surfaces smooth.

ii. Making the fast moving objects a streamline shape (fish shape) such as cars, aeroplanes, etc. This causes the smooth flow of air and thus minimizes air resistance at high speeds.

ii. Lubricating the sliding surfaces e.g (oil or grease is used for this purpose).

iv. Using ball bearings or roller bearings. Because the rolling friction is lesser than the sliding friction.

Q.3.17 Why rolling friction is less than sliding friction? 091303106

Ans. The rolling friction is less than sliding because

(i) The contact between wheel and surface is only at one point

(ii) There is no relative motion between wheel and surface.

Q.3.18 What you know about the following. 091303107

Ans.

i. Tension in a string

The force exerted by a string when it is subjected to pull." Tension and weight are in opposite direction.

It is a vector quantity. Its SI unit is newton. It is represented by T.

Formula: T = w = mg

ii. Limiting force of friction

The maximum value of friction is known as the force of limiting friction (F_s).

It depends on the normal reaction (pressing force) between the two surfaces in contact.

iii. Braking force

The maximum force of friction between tyres of vehicles and surface of road which is necessary to stop the vehicle is called "Braking force".

iv. Skidding of vehicles

If force of friction between tyres of vehicles and roads is not sufficient and brakes are put on too strongly, the wheels of car will lockup and its directional control will be lost. This is called skidding of vehicles.

v. Seatbelts

Seatbelts are the belts connected with the seats of vehicles. It stops the upper part of passengers to move forward due to inertia, and save the passengers from serious injuries.

vi. Banking of road

Banking of road means that the outer edge of a road track is kept higher than the inner edge.

vii. Cream separator:

Most modern plants use a separator to control the fat contents of various products. A separator is a high-speed spinner. It acts on the same principle of centrifuge machines. It is used to separate cream from milk

Q.3.19 What would happen if all friction suddenly disappears? 091303108

Ans. If all the friction suddenly disappears then bodies can't be moved and can't be turned and even can't change their state. We cannot walk without friction. We would keep sliding. Noting would be steady on the ground. We cannot hold anything. We cannot turn a page and cannot write with pen. Everything will collapse if there will be no friction.

Q.3.20 Why the spinner of a washing machine is made to spin at a very high speed? 091303109

Ans. The spinner of a washing machine moves with a very high speed to provide required centrifugal force, due to which undesired particles can be easily removed from the clothes.

Additional Short Questions

Q.21. Define inertia. Describe the factor on which it depends. (F.B. 2018) 091303110

Ans: Inertia of a body is its property due to which it resists any change in its state of rest or motion. Inertia of a body depends upon mass of a body. Greater is mass of a body, greater will be its inertia.

Q.22 What is perforated wall? 091303111

Ans. Such wall having number of holes in it, used in dryer of washing machine is called perforated wall.

Q.23 Why don't the riders of coaster cars fall out of it? 091303112

Ans. While the coaster cars move around the loop, the track provides centripetal force preventing them to move away from the circle.

Q.24 Which force is highly desirable when climbing up a hill? 091303113

Ans. Friction is highly desirable when climbing up a hill.

Q.25 Write two real life application of friction. 091303114

Ans. 1. A cyclist keeps on pedaling to over come friction.

2. Friction helps in pushing the ground backwards while walking or running.

Q.26 Why the shape of fast moving vehicles must be streamlined? 091303115

Ans. Fast moving vehicles, such as bullet train, must be stream lined because it reduces air resistance at high speed.

Q.27 What is the direction of centripetal force and its components? 091303116

Ans. Centripetal force is always directed towards the centre and has no component in the direction of motion.

Q.28 Define momentum. 091303117

Ans. Momentum of a body is the quantity of motion it possess due to its motion and velocity.

Formula:- $P = mv$

Unit:- $kgms^{-1}$ or Ns

Quantity:- vector

Q.29 For a body of mass "m" moving in a circle of radius "r". If its velocity is doubled, what will be the effect on value of centripetal force. 091303118

Ans. Centripetal force for a body of mass 'm' is given by,

$$F_c = \frac{mv^2}{r} \quad ....(i)$$

If velocity is double

$$v' = 2v$$

put the value of v' in equation (i)

$$F_c' = \frac{m(2v)^2}{r}$$

$$F_c' = \frac{m4v^2}{r}$$

$$F_c' = 4\left(\frac{mv^2}{r}\right)$$

$$F_c' = 4(F)$$

So, when we double the velocity, the force becomes four times of the original force.

Q.30 What is cold welds? 091303119

Ans. The contact points between the two surfaces form cold welds. These cold welds resist the surface from sliding over each other.

Q.31 How a person enable himself to move up in between the opposite walls with the help of his hands and feet? 091303120

Ans. Pushing the opposite walls by palms and feet increases friction. This enables the person to move up on the walls.

Q.32 If we tie a stone at the end of a string and start moving it in circular motion, name the forces acting on the stone and the string. 091303121

Ans. Stone tied to the end of the string moving in circular path has the forces:

1. Centripetal force
2. Centrifugal force

Centripetal force acts towards the centre of circle and the centrifugal force acts away from the centre of circle.

Q.33 What is an isolated system? 091303122

Ans. An isolated system is a group of interacting bodies on which no external force is acting. E.g. the molecules of gas enclosed in a glass vessel have a constant temperature.

Q.34 On which principle rockets and jet engines works? And How? 091303123

Ans. Rockets and jet engine also work on the principle of law of conservation of momentum. In these machines, hot gases produced by burning of fuel rush out with large momentum. The machines gain an equal and opposite momentum. This enables them to move with a very high speed.

Q.35 Why fragile objects are packed with styrofoam rings or polythene sheets? 091303124

Ans. Fragile object such as glass wares etc. are packed with suitable materials such as Styrofoam rings, balls, polythene sheets with air sacks etc. Air enclosed in the cavities of these materials makes them flexible and soft. An increase in impact time lowers the rate of change of momentum and hence lessens the impact of force. This lowers the possible damage due to an accident.

Q.36 What happened when a person is not wearing seat belts had an accident? 091303125

Ans. In case of an accident, a person not wearing seatbelt will continue moving until stopped suddenly by something before him. This something may be a windscreen, another passenger or back of the seat in front of him/her.

Q.37 Why is fastening of a seat belt necessary while driving? 091303126

Ans. Seatbelts are useful in two ways:

1. They provide an external force to a person wearing seatbelt.
2. The additional time is required for stretching seat belts. This prolongs the stopping time for momentum to change and reduces the effect of collision.

Q.38 What happened when a vehicle had an accident at high speed? What safety precautions offered by the car? 091303127

Ans. In an accident at high speed, the impact force is very large due to the extremely short stopping time. For safety purposes, vehicles have rigid cages for passengers with crumple zones at their front and rear ends.

During an accident, crumple zones collapse. This increases the impact time by providing extra time for crumpling. The impact of force is highly reduced and saves the passengers from severe injuries.

Q.39 What is Centrifuge? What is its function? 091303128

Ans. It is a machine designed to separate heavy material from lighter material. (OR) It is a device that is used for the separation of fluids based on density of fluids.

Q.40 Why it is hard to stop a fast moving and heavy vehicles? 091303129

Ans. Fast moving objects have large momentum than slow moving objects. Momentum of a body depends on mass and velocity by relation P = mV so, vehicles that are heavy and moving fast posses large momentum than slow moving objects. So it is hard to stop a heavy and fast moving vehicles.

Q.41 Define centripetal force. Write its equation. 091303130

Ans. "Centripetal force is a force that keeps a body to more in a circle".

Equation

$F_c = ma_c$ ..... (i)

F_c = Centripetal force

m = mass of the body

a_c = centripetal acceleration

where

$$a_c = \frac{v^2}{r}$$

Now *eq* (1) comes as:

$$F_c = \frac{mv^2}{r}$$

Q.42. On what factors the centripetal force depends? 091303131

Ans: As we know that

$$F_c = \frac{mv^2}{r}$$

According to this relation centripetal force depends on the following factors.

(i) mass of a body.

(ii) square of velocity of a body.

(iii) radius of circle.

Q.43. When we push the card with sudden stroke of finger, the card will move ahead while the coin falls in the glass why? 091303132

Ans. When card is push with sudden stroke of finger, the card move ahead while the coin falls into the glass due to inertia because coin resist to change its state. That is why fall into the glass.

Q.44. A body is moving with uniform speed. Will its velocity be uniform? 091303133

Ans. Yes, when the body move in a straight line.

No, when the body move in circular path, because body change its direction point to point.

Q.45. A moving train has greater momentum as compared to moving ball having same velocity. Why? 091303134

Ans. Momentum in the quantity of motion in a body. Momentum depends upon mass and velocity. The mass of train is greater as compared to ball. Therefore moving train has greater momentum as compared to ball.

Q.46. To work on sand or muddy ground is difficult. Why? 091303135

Ans. For walking, the friction between the feet and ground is essential. On sandy or muddy ground, the friction is less and it is difficult to push the ground in backward direction with greater force. That is why walking on sand or muddy ground is difficult.

Q.47. Calculate the acceleration of the mini lorry in the figure below given that friction between its tyres and the floor is 60N. 091303136

Ans.

F = 100 N

m = 20 kg
a = ?
f = 60 N
F – f = ma
100 – 60 = 20a
40 = 20a

$\frac{40}{20} = a$

$a = 2ms^{-2}$

Quick Quiz

Q1. Stretch out your palm and hold a book on:

i. How much force you need to prevent the book from falling? 091303137

Ans. Force equal to the weight of the book is required to prevent the book from falling.

ii. What is action? 091303138

Ans. Weight of book is action.

iii. Is there any reaction? If yes, then what is its direction? 091303139

Ans. The force required to prevent the book from falling is the reaction. Its direction is opposite to the action.

Q2. Which shoes offer less friction? 091303140

Ans. Shoe with smooth sole will offer less friction.

i. Which shoe is better for walking on dry track? 091303141

Ans. Shoe with rigid sole is better for walking on dry track.

ii. Which shoe is better for jogging? 091303142

Ans. Shoe with irregular sole is better for jogging.

iii. Which sole will wear out early? 091303143

Ans. Shoe with smooth sole will wear out early.

iv. Why is it easy to role cylindrical eraser on a paper sheet than to slide it? 091303144

Ans. As rolling friction is less than sliding friction that's why it is easy to roll cylindrical eraser or a paper sheet than to slide it.

Q4. Do we roll or slide the eraser to remove the pencil work from our note book? 091303145

Ans. We slide the eraser to remove the pencil work because sliding friction is much greater than rolling friction. So it will remove the work more quickly.

Mini Exercise

Q.1 (1) In which case do you need smaller force and why? (F.B. 2017) 091303146

(i) rolling (ii) sliding

Ans. In rolling case we need smaller force because rolling friction is less than sliding friction.

2. In which case it is easy for the tyre to roll over? 091303147

(i) rough ground (ii) Smooth ground

Ans. On rough ground it is easy for the tyre to roll over because friction is required for the tyre to roll over.

SOLVED EXAMPLES

Example 3.1

Find the acceleration that is produced by a 20 N force in a mass of 8 kg. 091303148

Solution:

Here m = 8 kg
F = 20N
a = ?

Using the formula F = ma

$20 = 8 \times a$

Or $a = \frac{20}{8}$

$a = 2.5$

$= 2.5\ ms^{-2}$

Thus acceleration produced by the force is $2.5\ ms^{-2}$.

Example 3.2: A force acting on a body of mass 5 kg produces an acceleration of $10ms^{-2}$. What acceleration the same force will produce in a body of mass 8 kg. (F.B. 2017) 091303149

Solution:

Here $m_1 = 5kg$

$m_2 = 8kg$

$a_1 = 10ms^{-2}$

$a_2 = ?$

Applying Newton's second law of motion, we get

$F = m_1a_1$

$F = m_2a_2$

Comparing the equations, we get

$m_1a_1 = m_2a_2$

$5 \times 10 = 8a_2$

or $a_2 = 6.25\ ms^{-2}$

Hence, the acceleration produced is $6.25\ ms^{-2}$.

Example 3.3

A cyclist of mass 40 kg exerts a force of 200 N to move his bicycle with an acceleration of $3ms^{-2}$. How much is the force of friction between the road and the tyres. (F.B. 2017) 091303150

Solution:

Here $m = 40kg$

$a = 3ms^{-2}$

$F_o = 200\ N$

Net Force $F = ?$

Force of friction $f = ?$

As net Force $F = ma$

$= 40 \times 3 = 120\ N$

$\therefore$ Net force = Applied Force – Force of friction

$120\ N = 200\ N - f$

Hence $f = 80\ N$

Thus, the force of friction between the road and the tyres is 80 N.

Example 3.4: Two masses 5.2 kg and 4.8 kg are attached to the ends of an inextensible string which passes over a frictionless pulley. Find the acceleration in the system and the tension in the string when both the masses are moving vertically. 091303151

Solution

$m_1 = 5.2\ kg$

$m_2 = 4.8\ kg$

as $a = \frac{m_1 - m_2}{m_1 + m_2} g$

$= \frac{5.2 - 4.8}{5.2 + 4.8} \times 10$

$\therefore a = 0.4\ ms^{-2}$

As $T = \frac{2m_1m_2}{m_1+m_2} g$

$= \frac{2 \times 5.2 \times 4.8}{5.2 + 4.8} \times 10$

$\therefore T = 50N$

Thus the acceleration in the system is $0.4\ ms^{-2}$ and tension in the string is 50N.

Example 3.5: Two masses 4 kg and 6 kg are attached to the ends of an inextensible string which passes over a frictionless pulley such that mass 6 kg is moving over a frictionless horizontal surface and the mass 4 kg is moving vertically downwards. Find the acceleration in the system and the tension in the string. 091303152

Solution

$m_1 = 4$ kg

$m_2 = 6$ kg

as $a = \frac{m_1}{m_1 + m_2} g$

$= \frac{4}{4+6} \times 10$

$= \frac{40}{10}$

$\therefore \quad a = 4\ ms^{-2}$

as $T = \frac{m_1 m_2}{m_1 + m_2} g$

$= \frac{4 \times 6}{4+6} \times 10$

$= \frac{240}{10}$

$\therefore \quad T = 24$ N

Thus the acceleration in the system is 4 ms^{-2} and tension in the string is 24N.

EXAMPLE 3.6: A body of mass 5 kg is moving with velocity of 10ms^{-1}. Find the force required to stop it in 2 seconds. 091303153

Solution

$m = 5$ kg

$v_i = 10\ ms^{-1}$

$v_f = 0\ ms^{-1}$

$t = 2$ s

$F = ?$

$P_i = 5 \times 10 = 50$ N.S

$P_f = 5 \times 0 = 0$ N.S

Since $F = \frac{P_f - P_i}{t} = \frac{0-50}{2}$

$= \frac{50-0}{2} = -\frac{50}{2}$

$= -25$ N

-ive sign indicate that opposite force is required to stop the body.

Thus 25 N force is required to stop the body.

EXAMPLE 3.7: A bullet of mass 20 g is fired from a gun with a muzzle velocity 100 ms^{-1}. Find the recoil of the gun if its mass is 5 kg. 091303154

Solution

$m = 20$ g $= 0.02$ kg

$v = 100\ ms^{-1}$

$M = 5$ kg

$V = ?$

According to the law of conservation of momentum:

$MV + mv = 0$

Putting the values, we get

$\therefore \quad 5 \times V + (0.02) \times (100) = 0$

Or $\quad 5 \times V = -(0.02) \times (100)$

Or $\quad V = -\frac{0.02 \times 100}{5} = -0.4 \text{ ms}^{-1}$

The negative sign indicates that the gun recoils i.e. moves in the backward direction opposite to the motion of the bullet with a velocity of 0.4 ms^{-1}.

Example 3.8

A stone of mass 100 g is attached to a string 1 m long. The stone is rotating in a circle with a speed of 5ms^{-1}. Find the tension in the string. 091303155

Solution

m = 100g = 0.1kg

v = 5ms^{-1}

r = 1m

T = F_c = ?

Tension T in the string provides the necessary centripetal force given by

$$F_c = \frac{mv^2}{r}$$

$$T = \frac{0.1 \times (5)^2}{1}$$

T = 2.5 N

Thus, tension in the string will be equal to 2.5 N.

NUMERICAL PROBLEMS

3.1 A force of 20 N moves a body with an acceleration of 2ms^{-2}. What is its mass? 091303156

Given data:

Force = F = 20N

Acceleration = a = 2ms^{-2}

To find:

Mass = m = ?

Solution

According to 2nd law of motion

F = ma

20 = m(2)

$\frac{20}{2}$ = m

10 = m

m = 10kg

The mass of body is 10 kg.

3.2 The weight of a body is 147 N. What is its mass? (Take the value of g as 10ms^{-2}) 091303157

Given data:

Weight= w = 147N

g = 10 ms^{-2}

To find:

Mass = m = ?

Solution:

As we have

w = mg

147 = m(10)

$\frac{147}{10}$ = m

14.7 = m

m = 14.7 kg

The mass of body is 14.7 kg.

3.3 How much force is needed to prevent a body of mass 10 kg from falling? 091303158

Given data:

Mass = m = 10kg

g = 10ms^{-2}

To find:

Force = F = ?

Solution:

To prevent its falling we require a force equal to its weight so

F = w

As w = mg

Where g = 10ms^{-2}

So F = (10)(10)

F = 100N

This force acts in upward direction.

3.4 Find the acceleration produced by a force of 100 N in a mass of 50 kg. 091303159

Given data

Force = F = 100N

mass = m = 50kg

To find:

Acceleration = a = ?

Solution:

from second law of motion

$F = ma$

$100 = (50)(a)$

$\frac{100}{50} = a$

$\boxed{a = 2ms^{-2}}$

The acceleration produced in a body of mass 50 kg is $2ms^{-2}$.

3.5 A body has weight 20 N. How much force is required to move it vertically upwards with an acceleration of $2ms^{-2}$? (F.B. 2017) 091303160

Given data:

Weight = $W = F_1 = 20N$

Acceleration $a = 2ms^{-2}$

$g = 10\ ms^{-2}$

To find:

Force = F = ?

Solution:

From second law of motion

$F = ma$

But $F = W$

So, $w = mg$

$20 = m(10)$

$\frac{20}{10} = m$

$m = 2\ kg$

So

$F_2 = ma$

$F_2 = (2)(2)$

$F_2 = 4N$

As 20N force is required to support it in rest position and 4N is required to produce acceleration.

So

$F_T = F_1 + F_2$

$= 20 + 4$

$\boxed{F_T = 24N}$

24N to force is required to produce acceleration $2ms^{-2}$.

3.6 Two masses 52 kg and 48 kg are attached to the ends of string that passes over a frictionless pulley. Find the tension in the string and acceleration in the bodies. When both the masses are moving vertically. 091303161

Given data:

$m_1 = 52\ kg$

$m_2 = 48\ kg$

$g = 10\ ms^{-2}$

To find:

T = ?

a = ?

Solution:

As we have

$a = \frac{m_1 - m_2}{m_1 + m_2} g$ Putting values

$= \frac{52-48}{52+48}(10)$ $= \frac{4}{100} \times 10$ $= \frac{4}{10}$

$\boxed{a = 0.4ms^{-2}}$

The acceleration is produced in the body is $0.4ms^{-2}$.

And

$T = \frac{2m_1 m_2 g}{m_1 + m_2}$

$= \frac{2(52)(48)(10)}{52+48} = \frac{104 \times 480}{100}$

$\boxed{T = 500\ N}$

The tension in the string is 500N.

3.7 Two masses 26 kg and 24 kg are attached to the ends of a string which passes over a frictionless pulley. 26 kg is lying over a smooth horizontal table. 24 kg mass is moving vertically downward. Find the tension in the string and the acceleration in the bodies. 091303162

Given data:

$m_1 = 24\ kg$

$m_2 = 26\ kg$

$g = 10\ ms^{-2}$

To find:

T = ?

a = ?

Solution

As we have

$a = \frac{m_1 g}{m_1 + m_2}$

$= \frac{24 \times 10}{24+26} = \frac{240}{50}$

$a = 4.8\ ms^{-2}$

The acceleration produced in the body $4.8ms^{-2}$.

And

$$T = \frac{m_1 m_2 g}{m_1 + m_2}$$

$$T = \frac{24 \times 26 \times 10}{24 + 26}$$

$$T = \frac{6240}{50}$$

$$\boxed{T = 124.5\ N}$$

The tension in the string is 124.5N.

3.8 How much time is required to change 22 Ns momentum by a force of 20 N? Given data: (F.B. 2018) 091303163

ΔP = 22Ns

F = 20N

To find:

t = ?

Solution:

As we have

Rate of change of momentum = applied force

$$\frac{\Delta P}{t} = F$$

$$20 = \frac{22}{t} \Rightarrow t = \frac{22}{20}$$

$$\boxed{t = 1.1 sec}$$

The time required to change momentum by the force is 1.1sec.

3.9 How much is the force of friction between a wood block of mass 5 kg and the horizontal marble floor? The coefficient of friction between wood and marble is 0.6? 091303164

Given data:

Mass = m = 5 kg

Coefficient of friction $\mu = 0.6$

To find:

Friction = F_s = ?

Solution

As we have $F = \mu R$ $\therefore R = w = mg$

$F_s = \mu mg$

So

$F_s = (0.6)(5)(10)$

$\boxed{F_s = 30N}$

The force of friction between a wooden block and the marble floor is 30N.

3.10 How much centripetal force is needed to make a body of mass 0.5 kg to move in a circle of radius 50 cm with a speed 3 ms^{-1}? 091303165

Given data

Mass = m = 0.5 kg

Radius r = 50cm

$$= \frac{50}{100} m = 0.5m$$

velocity = v = 3 ms^{-1}

To find:

Centripetal force = F_c = ?

Solution:

As we have

$$F_c = \frac{mv^2}{r}$$

$$= \frac{0.5 \times (3)^2}{0.5}$$

$$\boxed{F_c = 9\ N}$$

9N centripetal force is required to move body in a circle.

How much vector required for zero vector?

Ans = 3

UNIT 04

TURNING EFFECT OF FORCES

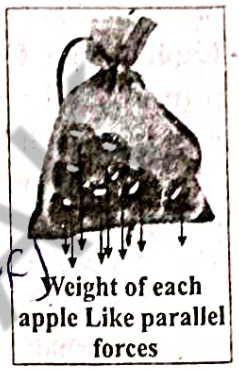
Introduction

In this unit, we will learn many interesting concepts such as forces on bodies, addition of forces, resolution of forces, moment of a force, principle of moments, centre of mass, couple, equilibrium and stability.

Q1. Define parallel forces. Also explain its types. or what is the difference between like and unlike parallel forces? 091304001

Ans. Parallel Forces:

"Such forces which are parallel to each other are called parallel forces". **(OR)** *"If a number of forces are acting on a body in such a way that their point of action are different but lines of action are parallel to each other. These are called parallel forces."*



Weight of each apple Like parallel forces

Types of Parallel Forces:

Like parallel forces:

"Like parallel forces are the forces that are parallel to each other and have the same direction."

Example

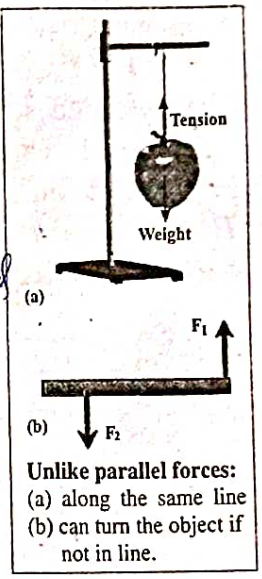
Figure shows a bag with apples in it. The weight of the bag is due to the weight of all the apples in it. Since the weight of every apple in the bag is the force of gravity acting on it vertically downwards. Since all these forces are acting in the same direction. Such forces are called like parallel forces.

Unlike parallel forces:

"Unlike parallel forces are the forces that are parallel but have directions opposite to each other".

Example

An apple is suspended by a string. The string is stretched due to weight of the apple. The forces acting on it are weight of the apple acting vertically downwards and tension in the string pulling it vertically upward. The two forces are parallel but opposite to each other. These forces are called unlike parallel forces.



Unlike parallel forces:
(a) along the same line
(b) can turn the object if not in line.

Example

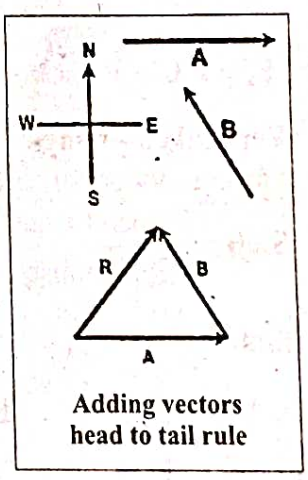
In figure (b) forces $\mathbf{F_1}$ and $\mathbf{F_2}$ are also unlike parallel force, because they are parallel and opposite to each other. But $\mathbf{F_1}$ and $\mathbf{F_2}$ are not acting along the same line and hence they are capable to rotate the body.

Q2. What is meant by addition of forces? (OR) Define resultant force. Also describe head to tail rule to find addition of forces. 091304002

Ans. *"A resultant force is a single force that has the same effect as the combined effect of all the forces to be added."*

One of the method for the addition of forces is a graphical method called head to tail rule method.

"A graphical method used for the addition and subtraction of two or more than two vectors is called head to tail rule."



Adding vectors head to tail rule

Head to tail rule:

We will consider the following rules to add forces.

(1) Select a suitable scale in order to add the forces.

(2) Draw the vectors of all the forces according to the suitable scale; named as vectors **A** and **B**.

(3) Draw the vector **A** and then place the vector **B** such that tail of vector **B** coincides with the head of the first vector **A**.

(4) Now draw a resultant vector **R** such that its tail is at the tail of Vector **A**, the first vector, while its head is at the head of vector **B**, the last vector as shown is figure.

(5) Vector **R** represents the resultant force with magnitude and direction.

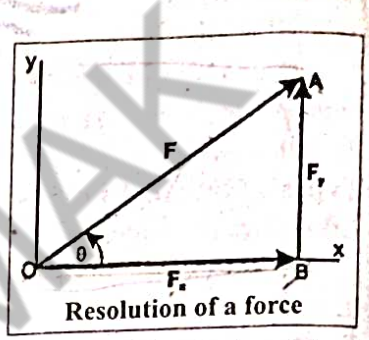
Q3. What is meant by resolution of forces? Explain. (OR) Define rectangular components? How can a force be resolved into its rectangles component? (F.B. 2017) 091304003

Ans. *"The process of splitting up of a force into two mutually perpendicular components is called the resolution of force".*

Perpendicular components (Rectangular components)

If a force is formed from two mutually perpendicular components then such components are called its perpendicular components or rectangular components.

Explanation: Consider a force **F** is making an angle "θ" along "x"-axis. Draw its perpendicular components represent by "OB" and "AB" drawn in two perpendicular lines x–axis and y–axis.



Resolution of a force

According to head to tail rule, **OA** is the resultant of vector represented by **OB** and **BA**.

Thus $OA = OB + BA$ ... ...(1)

The components **OB** and **BA** are perpendicular to each other. They are called perpendicular components of **OA** represents force **F**. Hence **OB** represents its x–component "F_x" called horizontal component and **BA** represents its y-component F_y called its vertical component. Therefore, equation (1) can be expressed as

$$\mathbf{F = F_x + F_y} \quad \ldots \ldots \ldots (2)$$

The magnitudes F_x and F_y can be found by using the trigonometric ratios in right angled triangle OBA

Horizontal component "F_x"

The component of force which is along x-axis is called x-component (or) horizontal component of force.

$$\text{Cos}\theta = \frac{\text{Base}}{\text{Hypotenuse}}$$

$$\text{Cos}\theta = \frac{OB}{OA}$$

$$\therefore OB = F_x$$

$$\therefore OA = F$$

$$\text{Cos}\theta = \frac{F_x}{F}$$

$$\mathbf{F_x = F\,Cos\theta} \quad \ldots \ldots \ldots \ldots (3)$$

Ratio/θ	0°	30°	45°	60°	90°
Sin θ	0	0.5	0.707	0.866	1
Cos θ	1	0.866	0.707	0.5	0
Tan θ	0	0.577	1	1.732	∞

Vertical component "F_y"

The component of force which is along y-axis is called y-component (or) vertical component of force.

$$\text{Sin}\theta = \frac{\text{Perpendicular}}{\text{Hypotenuse}}$$

$$\text{Sin}\theta = \frac{AB}{OA}$$

$$\therefore AB = F_y, \quad OA = F$$

$$\therefore \text{Sin}\theta = \frac{F_y}{F}$$

$$\mathbf{F_y = F\,Sin\theta} \quad \ldots \ldots \ldots \ldots (4)$$

Equations (3) and (4) give the perpendicular components (rectangular components) F_x and F_y respectively.

Q4. How can we determine a force from its perpendicular components? Also find its direction. 091304004

Ans. Consider F_x and F_y as the perpendicular components of a force **F.** These perpendicular components F_x and F_y are represented by lines **OP** and **PR** respectively. According to head to tail rule:

$$\mathbf{OR = OP + PR}$$

Thus **OR** will completely represent the force **F** whose x and y-components are $\mathbf{F_x}$ and $\mathbf{F_y}$ respectively.

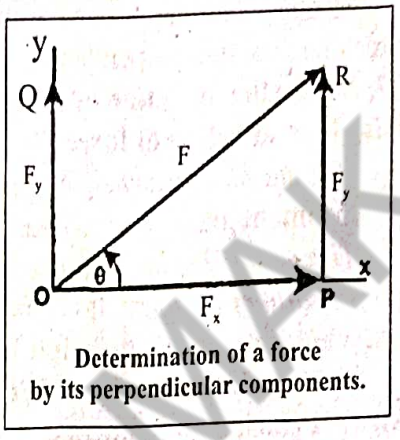
That is $\mathbf{F = F_x + F_y}$

The magnitude of the force **F** can be determined using the right angled triangle OPR. By using Pythagoras theorem.

$$(OR)^2 = (OP)^2 + (PR)^2$$

$$\therefore \quad F^2 = F_x^2 + F_y^2$$

$$\text{Hence} \quad F = \sqrt{F_x^2 + F_y^2}$$



Determination of a force by its perpendicular components.

Direction of Force F

The direction of force F can be found by using the following relation:

$$\text{Tan}\,\theta = \frac{PR}{OP} = \frac{F_y}{F_x}$$

$$\therefore \quad \theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

This gives the direction of force "**F**".

Q5. What is meant by rigid body and axis of rotation? (OR) What is the difference between rigid body and axis of rotation? 091304005

Ans. Rigid body:

"A body is composed of large number of small particles. If the distances between all pairs of particles of the body do not change by applying a force then it is called a rigid body." Remember, a rigid body is the one that has no deformation by applying force.

Axis of rotation:

Axis of rotation is the imaginary line about which a body rotates. **(OR)**

A rigid body rotating about a line, the particles of the body move in circles with their centers all lying on the line. This line is called the axis of rotation of the body.

Q6. What is meant by torque or moment of a force? Explain the factors on which it depends. 091304006

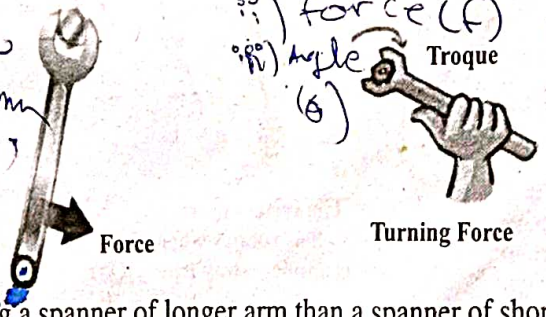
Ans. *"The turning effect of a force is called torque or moment of the force".*

Examples

Forces that produce turning effect are very common.

i. Turning pencil in a sharpener
ii. Turning stopcock of a water tap
iii. Turning doorknob are some of the examples where a force produces turning effect.

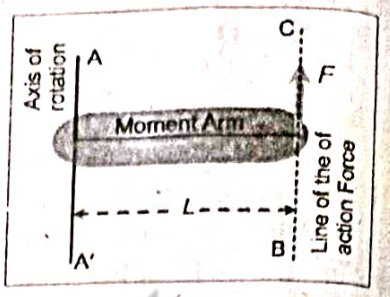
Let us study the factors on which torque or moment of a force depends. You might have seen that a mechanic uses a spanner to loosen or tighten a nut or a bolt. A spanner having long arm help him to do it with greater ease than the one having short arm. It is because the turning effect of the force is different in the two cases. The moment produced by a force using a spanner of longer arm is greater than the torque produced by the same force but using a spanner of shorter arm.



It is easy to tighten a nut using a spanner of longer arm than a spanner of shorter arm.

Factors: Torque depends on the following factors.

(i) Force **(ii)** Moment arm of the force. Greater is a force, greater is the moment of the force. Similarly, longer is the moment arm greater is the moment of the force.



Mathematical form:

The moment of the force or torque τ is determined by the product of force F and its moment arm L. Mathematically,

Torque = $\tau = F \times L$

Unit of torque:

SI unit of torque is newton-metre (Nm). A torque of 1 N m is caused by a force of 1 N acting perpendicular to the moment arm 1 m long.

091304007

Q7. Define line of action of force and moment arm.

Ans. Line of action of force

The line along which a force acts is called the line of action of the force.

Moment arm (F.B. 2017)

The perpendicular distance between the axis of rotation and the line of action of the force is called the moment arm of the force. It is represented by the distance *L*.

Q8. What is meant by principle of moments? Explain clockwise moment and anticlockwise moment.

091304008

(OR) What is moment? Write its principle.

Ans. Principle of moments:

Definition: *"A body is balanced if the sum of clockwise moments acting on the body is equal to the sum of anticlockwise moments acting on it."*

Clockwise moment:

A force that turns a spanner in the clockwise direction generally used to tighten a nut. The torque or moment of the force so produced is called clockwise moment.

Anticlockwise moment:

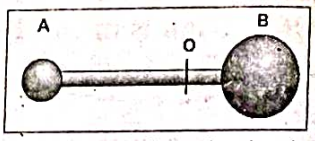
To loosen a nut, the force is applied such that it turns the nut in the anticlockwise direction. The torque or moment of the force so produced is called anticlockwise moment.

Note:- Remember clockwise torque is negative and anticlockwise torque is positive.

Q9. What is meant by centre of mass?

091304009

Ans. Centre of Mass:



"Centre of mass of a system is such a point where an applied force causes the system to move without rotation".

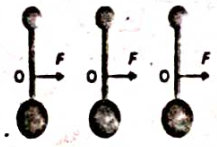
It is observed that the centre of mass of a system moves as if its entire mass is confined at that point. A force applied at such a point in the body does not produce any torque in it i.e. the body moves in the direction of net force F without rotation.

Explanation:

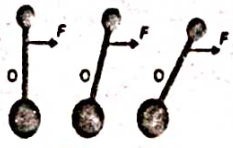
Consider a system of two particles A and B connected by a light rigid rod as shown in figure.

Let O is a point anywhere between A and B such that the force F is applied at point O as shown in figure. If the system moves in the direction of force F without rotation, then point O is the centre of mass of the system.

Figure (ii) and (iii) show that when we apply force away from the common point the system moves as well as rotate.



A force applied at COM moves the system without rotation



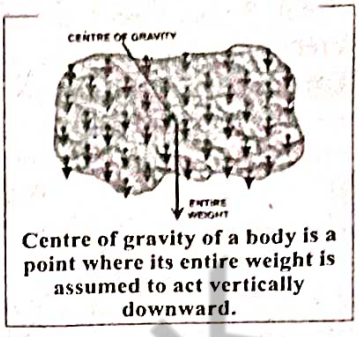
The system moves as well as rotates when a force is applied away from COM.

The system moves as well as rotates when a force is applied away from COM.

Q10. What is meant by Centre of Gravity? (OR) Define centre of gravity.

Ans. Centre of gravity

"A point where the whole weight of the body appears to act vertically downwards is called centre of gravity of a body".



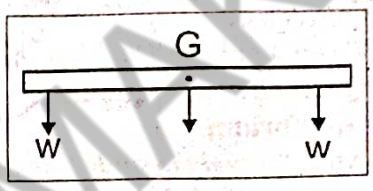
Centre of gravity of a body is a point where its entire weight is assumed to act vertically downward.

Explanation:

A body is made up of a large number of particles. Earth attracts each of these particles vertically downward towards its centre. The pull of the Earth acting on a particle is equal to its weight. These forces acting on the particles of a body are almost parallel. The resultant of all these parallel forces is a single force equal to the weight of the body. A point where this resultant force acts vertically towards the centre of the Earth is called the centre of gravity G of the body.

CENTRE OF GRAVITY OF SOME SYMMETRICAL OBJECTS

The centre of gravity of objects which have symmetrical shapes can be found from their geometry. For example,



(i) The centre of gravity of a uniform rod lies at a point where it is balanced. This balance point is its middle point G as shown in figure

(ii) The centre of a gravity of a uniform square or a rectangular sheet is the point of intersection of its diagonals as shown in figure.(a) and (c)

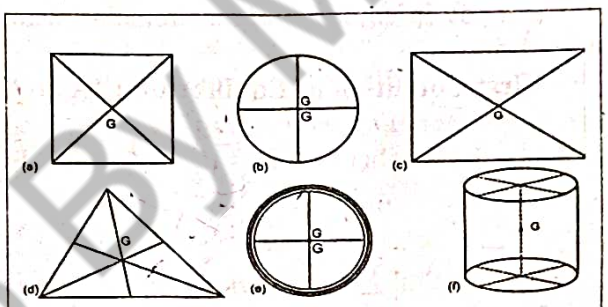
(iii) The centre of gravity of a uniform circular disc is its centre as shown in figure (b)

(iv) The centre of gravity of a solid sphere or hollow sphere is the centre of the spheres as shown in figure (b)

(v) The centre of gravity of a uniform triangular sheet is the point of intersection of its medians as shown in fig (d)

(vi) The centre of gravity of a uniform solid or hollow cylinder is the middle point on its axis as shown in fig (f).

(vii) The centre of gravity of a uniform circular ring is the centre of ring as shown in fig (e)



Centre of gravity of some symmetrical objects.

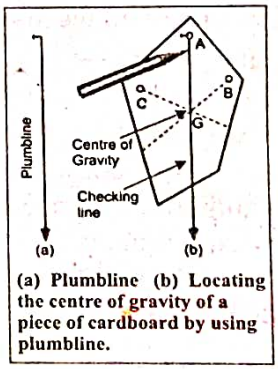
Q11. Define plumb line. **091304011**

Ans. A plumb line consists of a small metal bob (lead or brass) supported by a string. When the bob is suspended freely by the string, it rests along the vertical direction due to its weight acting vertically downward is called plumb line. The builders use a plumb line to keep the walls vertically straight.

Q12. Describe an experiment which explains the centre of gravity of an irregular shaped thin lamina. (OR) How can you find centre of gravity of irregular shaped body? Explain it with experiment. **091304012**

Ans. Experiment

Take an irregular piece of cardboard. Make holes A, B and C as shown in figure near its edge. Fix a nail on a wall. Support the cardboard on the nail through one of the holes (let it be A), so that the cardboard can swing freely about A. The cardboard will come to rest with its centre of gravity just vertically below the nail. Vertical line from A can be located using a plumb line hung from the nail. Mark the line on the cardboard behind the plumb line. Repeat it by supporting the cardboard from hole B. The line from B will intersect at a point G. Similarly, draw another line from the hole C. Note that this line also passes through G. It will be found that all the vertical lines from holes A, B and C have a common point G. This common point G is the centre of gravity of the cardboard.



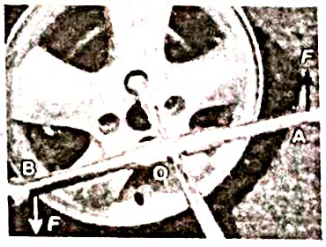
(a) Plumbline (b) Locating the centre of gravity of a piece of cardboard by using plumbline.

Q13. Define couple and couple arm. Explain the process of couple. **(F.B. 2015)** **091304013**

(OR) Define Couple. How torque produced in right body due to couple?

Ans. Couple:

"A couple is formed by two unlike parallel forces of the same magnitude but not acting along the same line."



Example:

When a driver turns a vehicle, he applies forces that produce a torque. This torque turns the steering wheel. These forces act on opposite sides of the steering wheel and are equal in magnitude but opposite in direction. So, these two forces form a couple.

Torque due to couple

Consider a double arm spanner is used to open a nut equal forces each of magnitude F are applied on end A and B of a spanner in opposite direction. These forces form a couple that turns the spanner about point O.

The torques produced by the forces of a couple have the same direction. The total torque produced by the couple will be total torque of the couple = $F \times OA + F \times OB = F(OA + OB)$

$\therefore$ Torque of the couple = $F \times AB$ ... ...

The torque of a couple is given by the product of one of the two forces and the perpendicular distance between them.

Couple arm: *"The perpendicular distance between two forces of couple is called couple arm."*

Q14. Define equilibrium also explain the first condition of equilibrium and second condition of equilibrium. **(F.B. 2016)** **091304014**

Ans. *"A body is said to be in equilibrium if no net force is acting on the body".*

A body in equilibrium thus remains at rest or moves with uniform velocity. There are two conditions of equilibrium

First Condition of Equilibrium: *"A body is said to satisfy first condition of equilibrium if the resultant of all the forces acting on it is zero".*

Let n be the number of forces $F_1, F_2, F_3, \ldots\ldots, F_n$ are acting on a body such that

$F_1 + F_2 + F_3 + \ldots\ldots F_n = 0$

Or $\sum F = 0$ .... (1)

The symbol $\sum$ is a Greek letter called *sigma* used for summation.

Explanation with x and y components of force:

The first condition of equilibrium can also be defined in terms of x and y-components of the force acting on the body.

Sum of x–components of force

$F_{1x} + F_{2x} + F_{3x} + \ldots\ldots + F_{nx} = 0$

Sum of y_components of force

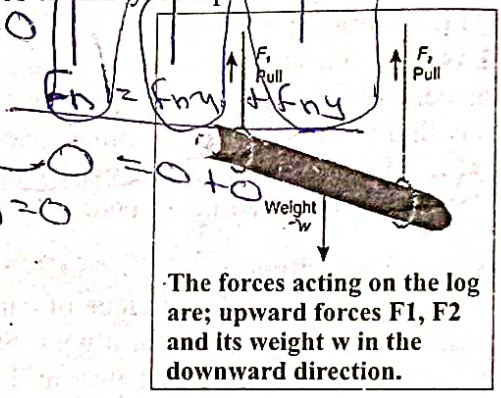
and $F_{1y} + F_{2y} + F_{3y} + \ldots\ldots + F_{ny} = 0$

or $\sum F_x = 0$

i.e sum of all the x–components of forces is equal to zero.

and $\sum F_y = 0$

i.e sum of all the y–components of forces is equal to zero.



The forces acting on the log are; upward forces F1, F2 and its weight w in the downward direction.

Examples

A book lying on a table or a picture hanging on a wall are at rest and thus satisfy first condition of equilibrium. A paratrooper coming down with terminal velocity (uniform velocity) also satisfies first condition of equilibrium.

Second Condition of Equilibrium: **(F.B. 2016)**

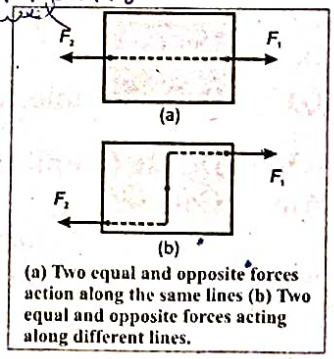
Definition

"If the sum of all the torque acting on the body is equal to zero then the body satisfies second condition of equilibrium." $\Sigma\tau = 0$

Explanation:

Consider a body pulled by the forces F_1 and F_2 as shown in figure **(a)** both forces are equal in magnitude but opposite in direction. Hence their resultant will be zero. According to the first condition, the body will be in equilibrium.

Now shift the location of the forces as shown in figure **(b)** the body is not in equilibrium although the first condition of equilibrium is still satisfied. It is because the



(a) Two equal and opposite forces action along the same lines (b) Two equal and opposite forces acting along different lines.

body has tendency to rotate. This situation demands another condition for equilibrium in addition to the first condition for equilibrium. This is called **second condition for equilibrium.** According to this,

"A body satisfies second condition for equilibrium when the resultant torque acting on it is zero." Mathematically, it can be written as

$$\sum \tau = 0$$

Q15. Explain states of equilibrium. (OR) Define three states of equilibrium. Explain these states with reference to the centre of gravity? (F.B. 2014, 18) 091304015

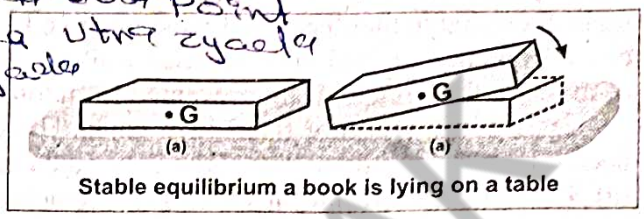
Ans. There are three states of equilibrium

(1) Stable equilibrium

(2) Unstable equilibrium

(3) Neutral equilibrium.

A body may be in one of these three states of equilibrium.



Stable equilibrium a book is lying on a table

Stable Equilibrium

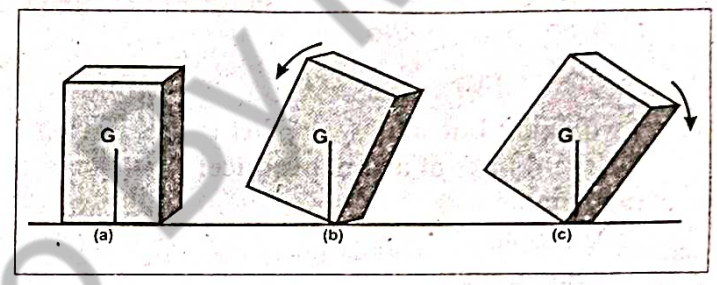
"A body is said to be in stable equilibrium if after a slight tilt it returns to its previous position."

Example:

Consider a book lying on the table. Tilt the book slightly about its one edge by lifting it from the opposite side. It returns to its previous position when sets free. Such a state of the body is called stable equilibrium.

Explanation

When a body is in stable equilibrium, its centre of gravity is at the lowest position. When it is tilted, its centre of gravity rises. It returns to its stable state by lowering its centre of gravity. A body remains in stable equilibrium as long as the centre of gravity acts through the base of the body.



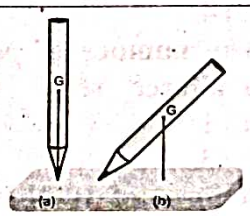
Consider a block as shown in fig (a). When the block is tilted, its centre of gravity G rises. If the vertical line through G passes through its base in the tilted position as shown in fig (b), the block returns to its initial position. If the vertical line through G gets out of its base as shown in figure (c), the block does not return to its previous position. It topples over its base and moves to new stable equilibrium position.

2. Unstable Equilibrium

"If a body does not return to its previous position when sets free after a slightest tilt is said to be in unstable equilibrium".

Example

Take a pencil and try to keep it in the vertical position on its tip as shown in figure. Whenever you leave it, the pencil topples over about its tip and falls down. This is called the unstable equilibrium. In unstable equilibrium, the centre of gravity of the body is at its highest position in the state of unstable equilibrium. As the body topples over about its base (tip), its centre of gravity moves towards its lower position and does not return to its previous position.



unstable equilibrium

(a) pencil just balanced at its tip with centre of gravity G at the highest position. (b) pencil topples over caused by the torque of its weight acting at G

3. Neutral Equilibrium:

Definition:

"If a body remains in its new position when disturbed from its previous position, it is said to be in the state of neutral equilibrium. In this state centre of gravity remains at the same position."

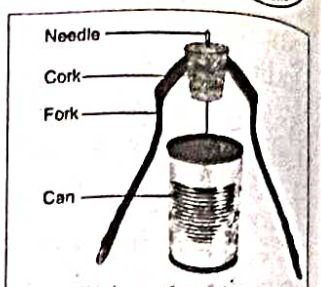
Explanation

Take a ball and place it on a horizontal surface as shown in figure. Roll the ball over the surface and leave it after displacing from its initial position. It remains in its new position and does not return to its initial position. This is called neutral equilibrium.

Neutral equilibrium

(a) a ball is placed on a horizontal surface.
(b) the ball remains in its new displaced position.

There are various objects which have neutral equilibrium such as a ball, a sphere, a roller, a pencil lying horizontally, an egg lying horizontally on a flat surface etc.



A needle is made to balance at its tip

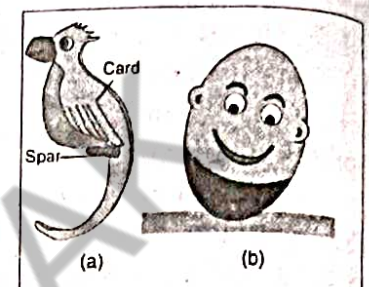
Q16. Explain with example the stability and position of centre of mass. 091304016

Ans. To make bodies stable, their centre of mass must be kept as low as possible. Here are few examples in which lowering of centre of mass make the objects stable. These objects return to their stable states when disturbed. In each case centre of mass is vertically below their point of support. This makes their equilibrium stable.

Racing cars are made heavy at the bottom and their height is kept to be minimum to make them stable their centre of mass must be low.

e.g. **Circus artists** such as tight rope walkers use long poles to lower their centre of mass. In this way they are prevented from topple over.

A sewing needle fixed in a cork. The cork is balanced on the tip of the needle by hanging forks. The forks lower the centre of mass of the system. Figure (a) shows **a perched parrot** which is made heavy at its tail. Figure (b) shows **a toy** that keeps itself upright when titled. It has a heavy semi-spherical base. When it is tilted, its centre of mass rises. It returns to its upright position at which its centre of mass is at the lowest.



(a) A perched parrot
(b) A self righting toy

MULTIPLE CHOICE QUESTIONS

Exercise MCQs

1. Two equal but unlike parallel forces having different lines of action produce: 091304017
(a) a torque
(b) a couple
(c) equilibrium
(d) neutral equilibrium

2. The number of forces that can be added by head to tail rule are: 091304018
(a) 2 (b) 3
(c) 4 (d) any number

3. The number of perpendicular components of a force are: (F.B. 2017) 091304019
(a) 1 (b) 2
(c) 3 (d) 4

4. A force of 10 N is making an angle of 30° with the horizontal. Its horizontal component will be: (F.B. 2013, 17) 091304020
(a) 4 N (b) 5 N
(c) 7 N (d) 8.7 N

5. A couple is formed by: (F.B. 2013) 091304021
(a) two forces perpendicular to each other
(b) two like parallel forces
(c) two equal and opposite forces in the same line
(d) two equal and opposite forces not in the same line

6. A body is in equilibrium when its: 091304022
(a) acceleration is uniform
(b) speed is uniform
(c) speed and acceleration are uniform
(d) acceleration is zero.

7. A body is in neutral equilibrium when its centre of gravity: 091304023
(a) is at its highest position
(b) is at the lowest position
(c) Keeps its height if displaced
(d) is situated at its bottom

8. Racing cars are made stable by: 091304024
(a) increasing their speed
(b) decreasing their mass
(c) lowering their centre of gravity
(d) decreasing their width

Additional MCQs

9. The parallel forces which have same direction are called: 091304025
(a) resultant force
(b) like parallel forces
(c) unlike parallel
(d) Null forces

10. The vector which has the same effect as the combined effect of vectors: 091304026
(a) negative vector
(b) the vector
(c) Resultant vector
(d) Zero vector

11. $\frac{\text{Base}}{\text{Hypotenuse}}$ is called: 091304027
(a) $\sin\theta$ (b) $\cos\theta$
(c) $\tan\theta$ (d) $\cot\theta$

12. Tan θ is equal to: 091304028
(a) $\frac{\text{Perpendicular}}{\text{Hypotenuse}}$ (b) $\frac{\text{Base}}{\text{Perpendicular}}$
(c) $\frac{\text{Base}}{\text{Hyp}}$ (d) $\frac{\text{Perpendicular}}{\text{Base}}$

13. $\frac{\text{Perpendicular}}{\text{Hypotenuse}}$ is called: 091304029
(a) cos θ (b) sin θ
(c) tan θ (d) $\tan^{-1}\theta$

14. Sin 45° is 091304030
(a) 0.707 (b) 0.5
(c) 0.86 (d) 0.2

15. Cos 0^0 is 091304031
(a) 0 (b) 2
(c) 1 (d) 0.5

16. To find x component of force 'F' we use formula: 091304032
(a) F cos θ (b) F sin θ
(c) F Tan θ (d) $\frac{F}{F_y}$

17. The formula of y component of force 'F' is: 091304033
(a) F cos θ (b) F sin θ
(c) F tan θ (d) $\tan^{-1}\theta$

18. If F_x and F_y are the rectangular components of a vector 'F' then magnitude of vector 'F' is: (F.B. 2016) 091304034
(a) $\sqrt{F_x^2 + F_y^2}$ (b) $\sqrt{F^2 + F_1^2}$
(c) $\sqrt{F_x^2 + F_y}$ (d) $\sqrt{F_x + F_y}$

19. The unit of torque is: 091304035
(a) Nm^{-2} (b) Ncm
(c) Nm^{-1} (d) Nm

20. The conditions of equilibrium are: 091304036
(a) 2 (b) 3
(c) 5 (d) 4

21. The centre of gravity of uniform triangle is: (F.B. 2014) 091304037
(a) Point of intersection of its medians
(b) on its vertex
(c) on middle point of its axis
(d) point of intersection of diagonal

22. The centre of gravity of hollow cylinder is the middle point on its: 091304038
(a) curved side (b) axis
(c) bottom (d) on upper side

23. Forces on double arm spanner are called: 091304039
(a) Torque
(b) Couple
(c) Moment of force
(d) Moment arm

24. After tilting if body comes back to its original position then the body is in: 091304040
(a) stable equilibrium
(b) unstable equilibrium
(c) neutral equilibrium
(d) equilibrium

25. Turning effect of a force is called: 091304041
(a) torque (b) moment
(c) couple (d) torque and momentum

26. First condition of equilibrium is: 091304042
(a) $\sum F = 0$
(b) $\sum \tau = 0$
(c) $\sum F = 0, \sum \tau = 0$
(d) All of these

27. Complete equation $\frac{F_y}{F_x} =$ 091304043
(a) sin θ (b) cos θ
(c) tan θ (d) cosec θ

28. It is easy to turn a steering wheel by applying a : 091304044
(a) torque (b) force
(c) momentum (d) couple

29. The value of tan 45° is: 091304045
(a) 0.5 (b) 1.732
(c) 0.5777 (d) 1

30. If $F_y = 4N$ and $F_x = 3N$, what is the magnitude of resolution of force: 091304046
(a) 7N (b) 5N
(c) 12N (d) 10N

31. The net torque acting on a rotating body with uniform speed is: 091304047
(a) 1 (b) 2
(c) 5 (d) 0

32. In right angle triangle, length of base is 4cm and its hypotenuse is 5cm, then length of perpendicular is: 091304048
(a) 1 cm (b) 20 cm
(c) 3 cm (d) 9 cm

33. The centre of gravity of irregular shaped body can be found with the help of: 091304049
(a) wedge (b) meter rod
(c) plumb line (d) screw gauge

34. At what angle sinθ and cosθ has same values: 091304050
(a) 30° (b) 45°
(c) 60° (d) 90°

35. **If we increase the length of spanner, the torque produced will be:** 091304051
(a) increased (b) decreased
(c) constant (d) zero

36. **Unit of Resultant force is:** 091304052
(a) Nm^{-2} (b) N.m
(c) Nm^{-1} (d) N

37. **Center of gravity of a uniform square is:** 091304053
(a) Intersection of diagonals
(b) Point of intersection of medians
(c) At center
(d) None of these

38. **Centre of gravity of sphere is at:** 091304054
(a) centre of sphere
(b) outside of sphere
(c) radius of sphere
(d) none of these

39. **Torque depends on:** (F.B. 2016) 091304055
(a) Force (b) Moment arm
(c) Acceleration (d) Both a and b

40. **Cos θ is equal to :** (F.B. 2016) 091304056
(a) $\frac{\text{Hypotenuse}}{\text{Base}}$ (b) $\frac{\text{Base}}{\text{Hypotenuse}}$
(c) $\frac{\text{Perpendicular}}{\text{Base}}$ (d) $\frac{\text{Base}}{\text{Perpendicular}}$

41. **A spanner is used to loosen a nut. The turning effect depends on the force applied and the perpendicular distance from the force to the nut. Which name is given to the turning effects?** (F.B. 2016) 091304057
(a) Torque (b) Pivot
(c) Pressure (d) Resultant

ANSWERS

1.	b	2.	d	3.	b	4.	d	5.	d
6.	d	7.	c	8.	c	9.	b	10.	c
11.	b	12.	d	13.	b	14.	a	15.	c
16.	a	17.	b	18.	a	19.	d	20.	a
21.	a	22.	b	23.	b	24.	a	25.	a
26.	a	27.	c	28.	d	29.	d	30.	b
31.	d	32.	c	33.	c	34.	b	35.	a
36.	d	37.	a	38.	a	39	d	40	b
41	a								

Exercise Question Answer

Q 4.2. Define the following: (F.B.2017) 091304058
(i) Resultant vector
(ii) Torque
(iii) Centre of mass
(iv) Centre of gravity

Ans. (i) Resultant Vector: Resultant vector is a single vector that has same effect as the combined effect of all the vectors to be added. This gives the magnitude and direction of the resultant force.

(ii) Torque: The turning effect of a force is called torque.

$$\text{Torque} = \tau = F \times L$$

(iii) Centre of Mass: (F.B. 2016)
Centre of mass of a system is such a point where an applied force causes the system to move without rotation.

(iv) Centre of Gravity:
A point where the whole weight of the body appears to act vertically downwards is called centre of gravity of body.

Q 4.3. Differentiate between the following: 091304059
(i) Like and unlike forces
(ii) Torque and couple
(iii) Stable and neutral equilibrium

Ans: (i) Like and Unlike forces

Ans. Like forces: Like forces are the forces that are parallel to each other and have the same direction.

Unlike forces: Unlike forces are the forces that are parallel but have directions opposite to each other.

(ii) Torque and Couple (F.B. 2017)

Torque: The turning effect of a force is called torque or moment of the force.

$$\text{Torque} = \tau = F \times L$$

Couple:
A couple is formed by two unlike parallel forces of the same magnitude but not acting along the same line.

(iii) Stable and neutral equilibrium:

Ans. Stable equilibrium: A body is said to be in stable equilibrium if after a slight tilt it returns to its previous position.

Neutral equilibrium: If a body remains in its new position when disturbed from its previous position, it is said to be in the state of neutral equilibrium. In this state centre of gravity remains at the same position.

Q 4.4. How head to tail rule helps to find the resultant of forces? 091304060

Ans: See Q. No. 2 on page No.69

Q 4.5. How can a force be resolved into its rectangular components? 091304061

Ans: See Q. No. 3 on page No.70

Q 4.6. When a body is said to be in equilibrium? 091304062

Ans. Equilibrium: "A body is said to be in equilibrium if no net force is acting on the body". A body in equilibrium thus remains at rest or moves with uniform velocity.

Q 4.7. Explain the first condition for equilibrium. **(F.B. 2016)** 091304063

Ans: See Q. No. 14 on page No.74

Q 4.8. Why there is a need of second condition for equilibrium if a body satisfies first condition for equilibrium? 091304064

Ans: See Q. No. 14 on page No.74

Q 4.9. What is second condition for equilibrium. Write its formula. **(F.B. 2016)** 091304065

Ans. "If the sum of all the torque acting on the body is equal to zero then the body satisfies the second condition of equilibrium."

i.e. $\Sigma\tau = 0$

Q 4.10. Give an example of a moving body which is in equilibrium. 091304066

Ans. (i) A paratrooper coming down with terminal velocity is in equilibrium because his weight in downward direction is equal to the force of friction of air in upward direction. Paratrooper is moving with uniform velocity, so the paratrooper is in equilibrium.

(ii) An object is moving with uniform velocity having zero acceleration is an example of equilibrium.

(iii) A car moving with uniform velocity on leveled road is the example of equilibrium.

Q 4.11. Think of a body which is at rest but not in equilibrium. 091304067

Ans.

(i) In simple pendulum when the pendulum is at extreme position it is at rest for a while but at that time gravitational force remains acting on it. So the pendulum is at rest but not in equilibrium.

(ii) When a ball is thrown vertically upward it comes to rest at the top position before falling towards ground. At that position ball is at rest but not in equilibrium.

Q 4.12. Why a body cannot be in equilibrium due to single force acting on it? 091304068

Ans. When a single force acts on a body, body moves in the direction of force and produce acceleration. This force is not balanced by any other force. Hence body is not in equilibrium when a single force acts on a body. It produces motion as well as rotation in a body.

Q 4.13. Why the height of vehicles is kept as low as possible? **(F.B. 2017)** 091304069

Ans. We know that position of centre of mass of an object plays an important role in their stability. To get stability their centre of mass must be kept as low as possible so it is the reason that height of vehicle is kept as low as possible.

Q 4.14. Explain what is meant by stable, unstable and neutral equilibrium. Give one examples in each case. **(F.B. 2018)** 091304070

Ans. See Q. No. 15 on page No.75

Additional Short Questions

Q.15 How many forces can be added by head to tail rule? 091304071

Ans. Any number of forces can be added by head to tail rule method.

Q.16 Why is it easy to open or close a door by pushing or pulling at handle? 091304072

Ans. As handle force produce more turning effect due to greater moment arm. So door is easy to open or close at handle.

Q.17 How is wheel of bicycle rotated? 091304073

Ans. A cyclist pushes the pedals of a bicycle. This forms a couple that acts on a pedals. The pedals cause the toothed wheel to turn making the rear wheel of the bicycle to rotate.

Q.18 Why there is a need of second condition for equilibrium if a body satisfies first condition for equilibrium? 091304074

Ans. When two equal and opposite forces acting on a body, the body is in equilibrium under the first condition of equilibrium but if we shift the location of forces then the body will not be in equilibrium

although the first condition of equilibrium is satisfying. This situation demands another condition for equilibrium in addition to the first condition which is the second condition of equilibrium.

Q.19 Why is a vehicle made heavy at its bottom to keep its centre of gravity as low as possible? 091304075

Ans. Vehicles are made heavy at the bottom. This lowers their centre of gravity and helps to increase their stability. A lower centre of gravity keeps it more stable. Moreover, the base of a vehicle is made wide so that the vertical line passing through its centre of gravity should not get out of its base during a turn.

Q.20 Define perpendicular components. 091304076

Ans. The components of a force which are mutually perpendicular to each other are called perpendicular components.

Q.21 Define resolution of force. Write the names of its components. 091304077

Ans. Resolution of force:-

Splitting up of a force into two mutually perpendicular components is called the resolution of the force.

It has two components:

i) Horizontal Component

ii) Vertical Component

Q.22 On doubling the moment arm, find its effect on the value of torque. 091304078

Ans. The torque will be double if we double the moment arm,

as $\tau = F \times L$ .....(i)

put $L' = 2L$

by putting the value of L' in equation (i)

$$\tau' = F \times (2L)$$

$$= 2(F \times L)$$

Hence $\tau' = 2\tau$

On doubling the moment arm the value of torque will be doubled.

Q.23 Define Trigonometry. 091304079

Ans. The branch of Mathematics which deals with the measurements of sides and angles of a right-angled triangle and the ratios regarding these sides.

Q.24 Define Trigonometric Ratios. 091304080

Ans. The ratios of the sides of a right-angled triangle is called Trigonometric ratios.

$$\text{Sin}\theta = \frac{\text{Perpendicular}}{\text{Hypotenuse}}, \qquad \text{Cos}\theta = \frac{\text{Base}}{\text{Hypotenuse}}$$

$$\text{Tan}\theta = \frac{\text{Perpendicular}}{\text{Base}}$$

Q.25 A force "F" is acting on a body at an angle θ with x-axis. Write the magnitude of horizontal and vertical component. 091304081

Ans. Magnitudes of the components of forces are:

Horizontal component:

$$F_x = F\cos\theta$$

Vertical component:

$$F_y = F\sin\theta$$

Q.26 Define component of forces. 091304082

Ans. If a force is formed from two mutually perpendicular components then such components are called its perpendicular components or components of force.

Q.27 Define rigid body. 091304083

Ans. "A body is composed of large number of small particles. If the distances between all pairs of particles of the body do not change by applying a force then it is called a rigid body. Remember, a rigid body is the one that has no deformation by applying force."

Q.28 Define axis of rotation. 091304084

Ans. The particles of the body move in circles with their centers all lying on the line. This line is called the axis of rotation of the body.

Q.29 Define moment arm. (F.B.2016) 091304085

Ans. The perpendicular distance between the axis of rotation and the line of action of the force is called the moment arm of the force. It is represented by the distance L.

Q.30 Define clockwise and anti clockwise moments. 091304086

Ans. Clockwise moment: A force that turns a spanner in the clockwise direction generally used to tighten a nut. The torque or moment of the force so produced is called clockwise moment.

Anticlockwise moment: To loosen a nut, the force is applied such that it turns the nut in the anticlockwise direction. The torque or moment of the force so produced is called anticlockwise moment.

Q.31 State the principle of moment. 091304087

Ans. "A body is balanced if the sum of clockwise moments acting on the body is equal to the sum of anticlockwise moments acting on it."

Q.32 Define plumb line. 091304088

Ans. A plumb line consists of a small metal bob (lead or brass) supported by a string. When the bob

is suspended freely by the string, it rests along the vertical direction due to its weight acting vertically downward called plumb line.

Q.33 How direction of torque can be found? 091304089

Ans. The direction of torque can be found by right hand rule. According to right hand rule, if rotation is along the curl of the fingers of right hand then thumb points the direction of torque.

Q.34 Why the handle of a door is fixed near the outer edge of a door? 091304090

Ans. We can open or close a door more easily by applying a force at the outer edge of a door rather than near the hinge. Location of applied force to turn a body is very important. The torque produced by a force with longer moment arm is greater as compared to the torque produced by the same force with shorter moment arm.

Q.35 Is the paratrooper coming down in the state of equilibrium. 091304091

Ans. Yes, the paratrooper coming down with uniform velocity called terminal velocity is in equilibrium. As velocity is uniform so, acceleration is zero. The weight of paratroop is balanced by the air resistance which is in upward direction. If net force is zero body is in the state of equilibrium.

Q.36 Why we use a spanner instead of hand to loosen a bike axle nut? 091304092

Ans. Normally, the use of spanner is best to tighten or loosen a nut instead of hand. The turning effect of force produced by the spanner is greater than the torque produced by the hand. So, use of spanner is recommended.

Q.37 How women and children in the villages carry water pitchers on their heads? 091304093

Ans. Women and children in the villages often carry pitchers with water on heads and walk with these pitchers. The reason is that water pitchers are semi-spherical in shape and its centre of mass is raised when tilted and return back to its initial position by lowering its centre of mass and thus attain the stability.

Q.38 Which type of forces are required to start a bus? 091304094

Ans. Like parallel forces are required to start a bus because these forces are in same direction and increases the resultant force.

Q.39 Give an example of a body when the resultant force is zero but resultant torque is not zero. 091304095

Ans. In case of couple two equal and opposite force are acting on the body and body rotates. In this case first condition of equilibrium is satisfied i.e. resultant forces acting on it is zero but resultant torque is not zero. These equal and opposite forces produce rotation in the body.

Q.40 It is easy to open the nut with long spanner. Why? 091304096

Ans. It is easy to open the nut with long spanner because of large moment arm.

Q.41 Will a vector be zero if one of its components is zero? (F.B. 2018) 091304097

Ans. No, a vector will not be zero if we know that

$$F = \sqrt{(F_x)^2 + (F_y)^2}$$

If $F_x = 0$

Then $F = \sqrt{0 + (F_y)^2}$

$$F = \sqrt{(F_y)^x} = F_y$$

$$F = F_y$$

Q.42 Find the angle made by a vector F with the x-axis, if the magnitude of its horizontal and vertical components are equal. 091304098

Ans.

$$\text{Tan}\,\theta = \frac{F_y}{F_x} \quad \text{If } F_x = F_y$$

Then $\text{Tan}\,\theta = \frac{F_x}{F_x}$

$$\text{Tan}\,\theta = 1$$

$$\theta = \text{Tan}^{-1}(1)$$

$$\theta = 45°$$

Quick Quiz

Q43. Can a small child play with a fat child on the see-saw? Explain how? (F.B. 2018) 091304099

Ans. Yes, they can play on a see-saw by adjusting the moment arm to compensate the difference of forces which they exert.

Q44. Two children are sitting on the see-saw, such that they cannot swing. What is the net torque in this situation? 091304100

Ans. In this condition, their net torque is zero as clock wise moments is cancelling the anti-clock wise moments.

Q45. A ladder leaning at a wall as shown in figure is in equilibrium. How? 091304101

Ans. The ladder is in equilibrium because it is satisfying second condition of equilibrium.

A ladder leaning at a wall

Q46. The weight of the ladder in fig. produces an anti-clock wise torque. The wall pushes the ladder at its top end thus produces a clock wise torque. Does the ladder satisfy second condition of equilibrium? 091304102

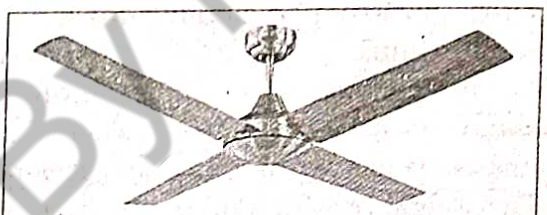
Ans. Yes, ladder satisfies the second condition of equilibrium because anti-clock wise torque is equal to the clock-wise torque and they are opposite in direction so net torque is zero.

Q47. Does the speed of a ceiling fan go on increasing all the time? 091304103

Ans. No, after attaining maximum speed its speed does not increase.

Q48. Does the fan satisfy second condition of equilibrium when rotating with uniform speed? 091304104

Ans. Yes, a fan satisfies the second condition of equilibrium as resultant torque acting on it is zero. A rotating body is in equilibrium because the rate of rotation is unchanged by the forces acting on it.



A ceiling fan rotating at constant speed is in equilibrium as net torque acting on it is zero.

Mini Exercise 1

In a right angled triangle length of base is 4 cm and its perpendicular is 3 cm. Find: 091304105

(i) Length of hypotenuse

(ii) Sin θ (iii) Cos θ (iv) Tan θ (F.B. 2017)

Ans.

We know that

(i) $(Hyp)^2 = (base)^2 + (perpendicular)^2$

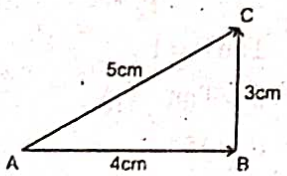
$(Hyp)^2 = (4)^2 + (3)^2$

$(Hyp)^2 = 16 + 9 = 25$

$\sqrt{(Hyp)^2} = \sqrt{25}$

$Hyp = 5cm$

(ii) $\sin\theta = \frac{3}{5}$



(iii) $\cos\theta = \frac{4}{5}$

(iv) $\tan\theta = \frac{3}{4}$

Mini Exercise 2

A force of 150 N can loosen a nut when applied at the end of a spanner 10 cm long. 091304106

(i) What should be the length of the spanner to loosen the same nut with a 60 N Force

(ii) How much force would be sufficient to loosen it with a 6 cm long spanner?

(i) $F = 150N$

$L = 10cm = \frac{10}{100}m = 0.1\ m$

$\tau = ?$

$\tau = F \times L$

$= 150 \times 0.1$

$= 15$ Nm

If force F= 60 N then

$L = ?$

$\tau = F \times L$

$15 = 60 \times L$

$\frac{15}{60} = L$

$L = \frac{15}{60}$

$L = 0.25$ m

((ii) If $L = 6$cm

$= 0.06$ m

$\tau = F \times L$

$15 = F \times 0.06$

$F = \frac{15}{0.06}$

$F =$ **250 N**

SOLVED EXAMPLES

EXAMPLE 4.1: Find the resultant of three forces 12 N along x-axis, 8 N making an angle of 45° with x-axis and 8 N along y-axis. 091304107

Solution

Here $F_1 = 12$ N along x-axis

$F_2 = 8$ N at 45° with x-axis

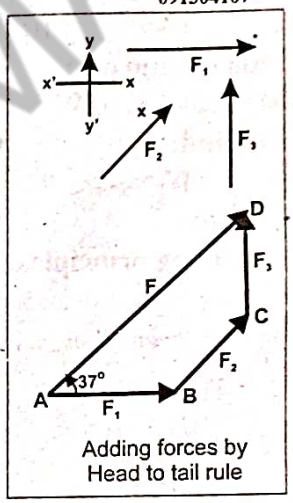
$F_3 = 8$ N along y-axis

Scale: 1 cm= 2N

(i) Represent the forces by vectors F_1, $F_2$and F_3 According to the scale and direction.

(ii) Arrange these forces $\mathbf{F_1}$, $\mathbf{F_2}$ and $\mathbf{F_3}$. The tail of force $\mathbf{F_2}$ coincides with the head of force $\mathbf{F_1}$ at point B. Similarly the tail of force $\mathbf{F_3}$ coincides with the head of force $\mathbf{F_2}$ at point C.

(iii) Join point A the tail of the force $\mathbf{F_1}$ and point D the head of force $\mathbf{F_3}$. Let AD represent force **F**. According to head to tail rule, force **F** represents the resultant force.



Adding forces by Head to tail rule

(iv) Measure AD and multiply it by 2N to find the magnitude of the resultant force **F**.

(v) Measure the angle ∠DAB using the protractor which the force F makes with x-axis. This gives the direction of the resultant force.

EXAMPLE 4.2

A man is pulling a trolley on a horizontal road with force of 200 N making 30° with the road. Find the horizontal and vertical components of its force. (F.B. 2015) 091304108

Given Data:

$F = 200$ N

$\theta = 30°$ with the horizontal

To Find:

$F_x = ?$

$F_y = ?$

Solution:

Since $F_x = F \cos \theta$

Or $F_x = 200 \times \cos 30°$

$= 200 \times 0.866 = 173.2$ N

Similarly $F_y = F \sin \theta$

Or $F_y = 200 \times \sin 30°$

$= 200 \times 0.5 = 100$N

Result:

Thus, horizontal and vertical components of the pulling force are 173.2 N and 100 N respectively.

EXAMPLE 4.3: A mechanic tightens the nut of a bicycle using a 15 cm long spanner by exerting a force of 200 N. Find the torque that has tightened it. (F.B. 2016) 091304109

Given Data:

To Find:

F = 200 N

L = 15 cm = 0.15 m

mks → meter, kg, second

cgs → cm, g, second

Solution:

$\tau = F \times L = 200 \times 0.15 = 30 \text{ N m}$

Result:

Thus, a torque of 30 N m is used to tighten the nut.

Examples 4.4: A metre rod is supported at its middle point O as shown in figure. The block of weight 10 N is suspended at point B, 40 cm from O. Find the weight of the block that balances it at point A, 25 cm from O. 091304110

Given Data:

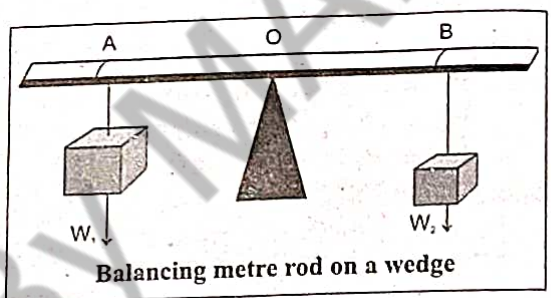
$W_2 = 10N$

Moment arm of W_1 = OA = 25cm = 0.25m

Moment arm of W_2 = OB = 40cm = 0.40m

To Find:

$W_1 = ?$



Balancing metre rod on a wedge

Solution:

Applying principle of moments:

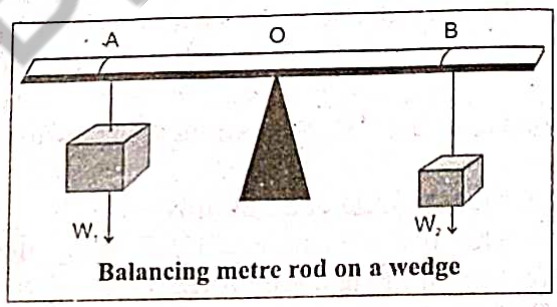
Clockwise moments = Anticlockwise moments

$W_2 \times$ *moment arm of* W_2 $= W_1 \times$ *moment arm of* W_1

Thus $W_2 \times OB = W_1 \times OA$

$W_1 = \frac{W_2 \times OB}{OA}$ $\therefore$ $W_1 = \frac{10 \times 0.40}{0.25}$

$W_1 = 16 N$



Balancing metre rod on a wedge

Result:

Thus, weight of the block suspended at point A is 16 N.

Example 4.5: A block of weight 10 N is hanging through cord as shown in figure. Find the tension in the cord. 091304111

Given Data:

Weight of the block w = 10N

To Find:

Tension in the cord T = ?

Solution:

Applying first condition for equilibrium. $\Sigma F_x = 0$

Since There is no force acting along x-axis.

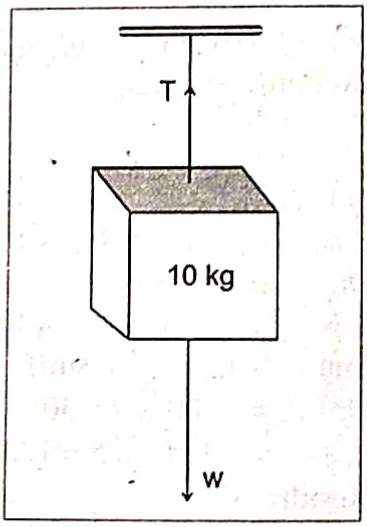
$\therefore \quad \Sigma F_y = 0$

Or T - w = 0

Or T = w

Or T = 10 N

Result: Thus, the tension in the cord is 10 N



Example 4.6

A uniform rod of length 1.5 m is placed over a wedge at 0.5 m from its one end. A force of 100 N is applied at one of its ends near the wedge to keep it horizontal. Find the weight of the rod and the reaction of the wedge.

091304112

Given Data:

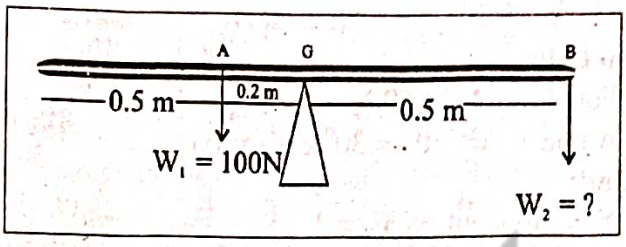
$F = 100\ N$

$OA = 0.5\ m$

$AG = BG = 0.75\ m$

$OG = AG - AO = 0.75\ m - 0.5\ m$

$= 0.25\ m$



To Find:

$w = ?$

$R = ?$

Solution:

Applying second condition for equilibrium, taking torques about O.

$$\sum \tau = 0$$

$$F \times AO + R \times 0 - w \times OG = 0$$

$$100N \times 0.5m - w \times 0.25m = 0$$

$$\text{or } w \times 0.25m = 100 \times 0.5$$

$$w = \frac{100N \times 0.5m}{0.25m}$$

$$w = 200\ N$$

Applying first condition for equilibrium.

$$\Sigma F_y = O$$

$$R - w - F = O$$

$$R = w + F$$

$$R = 200N + 100N$$

$$R = 300N$$

Result: Thus, weight of the rod is 200 N and reaction of the wedge is 300 N.

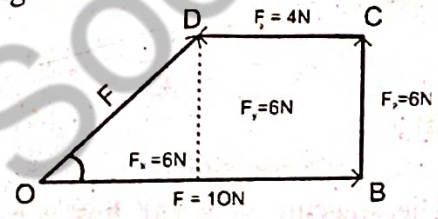
NUMERICAL PROBLEMS

4.1. Find the resultant of the following forces.

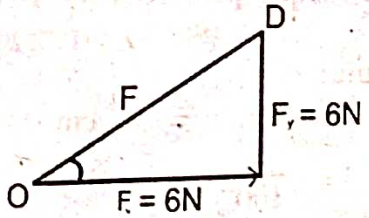
091304113

Given data

1) 10 N along x – axis
2) 6 N along y axis
3) 4 N along x-aixs



From Triangle OAD



Net force

Along x – axis = $F_x = 10 - 4 = 6\ N$

$F_x = 6N$

Net force acting

Along y – axis

$F_y = 6N$

To find:

$F = ?$

Solution

$$F = \sqrt{F_x^2 + F_y^2}$$

$$F = \sqrt{36+36}$$

$$F = \sqrt{72}$$

$F = 8.5N$ Ans

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

$$\theta = \tan^{-1}\left(\frac{6}{6}\right) = 45^0 \text{ with x – axis}$$

Result:

The magnitude of force is 8.5N that makes an angle of 45° with x – axis.

4.2 Find the perpendicular components of a force of 50 N making an angle of 30° with x-axis.

(F.B. 2017) 091304114

Given data

Force = F = 50 N

Angle = θ = 30° with x axis

To find:

Y component = F_y = ?

X component = F_x = ?

Solution

$F_y = F \sin \theta$

$= 50 \times \sin 30°$

$= 50 \times 0.5$

$= 25$ N

$F_x = F \cos \theta$

$= 50 \times \cos 30°$

$= 50 \times 0.866$

$= 43.3$N

Result:

The perpendicular components of a force are 43.3N and 25N.

4.3 Find the magnitude and direction of a force, if its x–component is 12N and y–component is 5N. **(F.B. 2013)** 091304115

Given data:

X component = F_x = 12 N

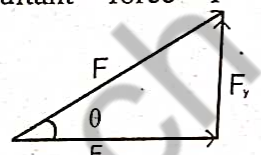
Y component = F_y = 5N

To find:

Resultant force = F = ?

Direction = θ =?

Direction of resultant = force = F = ?



Solution

$$F = \sqrt{F_x^2 + F_y^2}$$

$$= \sqrt{12^2 + 5^2}$$

$$\sqrt{144 + 25} = \sqrt{169}$$

$$F = 13 \text{ N}$$

Direction of force = F

$$\theta = \text{Tan}^{-1} \frac{F_y}{F_x}$$

$$= \text{Tan}^{-1} \frac{5}{12}$$

$$= 22.6° \text{ along x–axis}$$

Result:

The magnitude of force is 13N that is acting 22.6° along x – axis.

4.4. A force of 100 N is applied perpendicularly on a spanner at a distance of 10 cm from a nut. Find the torque produced by the force. 091304116

Given data:

Force = F = 100N

Moment arm = L = 10cm

$$= \frac{10}{100} \text{ m} = 0.1\text{m}$$

To find:

Torque = τ = ?

Solution:

$\tau = F \times L$

$= 100 \times 0.1$

$= 10$ Nm

Result:

The torque produce by the force is 10N.m

4.5 A force is acting on a body making an angle of 30° with the horizontal. The horizontal component of the force is 20 N. Find the force.

091304117

Given data

Horizontal component of force = F_x = 20N

Angle = θ = 30°

To find:

Force = F = ?

Solution:

$F_x = F \cos \theta$

$20 = F \cos 30°$

$20 = F \times 0.866$

$$F = \frac{20}{0.866} = 23.1 \text{ N}$$

Result:

The force 23.1N is acting on the body.

4.6. The steering of a car has a radius 16 cm. Find the torque produced by a couple of 50 N.

(F.B. 2017) 091304118

Given data:

Radius = r = 16 cm

$$= \frac{16}{100} = 0.16 \text{ m}$$

Force = F = 50 N

To find:

Torque due to couple = τ = ?

Solution:

By using the formula:

Torque of couple = Force × Couple arm

= Force × Perpendicular distance between them

In case of steering of a car, the perpendicular distance is equal to the diameter of steering.

Diameter = 2 × radius = 2r

Torque of couple = Force × Diameter

= F × 2r

= 50 × 2 × 0.16

τ = 16 N.m

Result:

The torque produced by the couple is 16N.m.

4.7 A picture frame is hanging by two vertical strings. The tensions in the strings are 3.8 N and 4.4 N. Find the weight of the picture frame.

091304119

Given Data:

Tension in 1st string = $T_1 = 3.8$ N

Tension in 2nd string = $T_2 = 4.4$N

To find:

Weight of picture frame = w = ?

Solution:

According to 1st condition of equilibrium

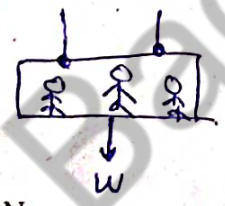
Upward forces = Downward forces

So

$T_1 + T_2 = w$

$w = 3.8 + 4.4$

$w = 8.2$ N



Result:

The weight of picture frame is 8.2N.

4.8 Two blocks of masses 5 kg and 3 kg are suspended by the two strings as shown. Find the tension in each string. 091304120

Given data:

Mass of 1st block = m_1 = 5 kg

Weight of 1st block

= $w_1 = m_1 g$ = 5 × 10

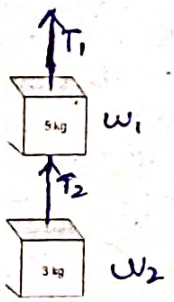
= 50N

Mass of 2nd block = m_2 = 3 kg

Weight of 2nd block = $w_2 = m_2 g$

= 3 × 10

= 30 N



To find:

Tension in 1st string = T_1 = ?

Tension in 2nd string = T_2 = ?

Solution:

From 1st condition of equilibrium

$T_1 = W_1 + W_2$

T_1 = 50 + 30

= 80N

$T_2 = W_2$

T_2 = 30 N

Result:

The tension in the 1st string is 80N and in 2nd string is 30N.

4.9 A nut has been tightened by a force of 200N using 10cm long spanner. What length of a spanner is required to loosen the same nut with 150N force? 091304121

Given data:

Force = F = 200N

Moment arm = L_1 = 10 cm

$L_1 = \frac{10}{100}$ = 0.1m

To find:

Torque = τ = ?

Length of spanner = Moment arm = L_2 = ?

If F = 150N

Solution:

Torque = Force × moment arm

τ = 200 × 0.1

= 20Nm

Length of spanner = ?

Torque = Force × moment arm

20 = 150 × L_2

$L_2 = \frac{20}{150}$

= 0.133 m

= 0.133 × 100 = 13.3cm

Result:

13.3cm long spanner is required to loosen the nut with 150N force.

4.10 A block of mass 10 kg is suspended at a distance of 20cm from the centre of a uniform bar 1 m long. What force is required to balance it at its centre of gravity by applying the force at the other end of the bar? 091304122

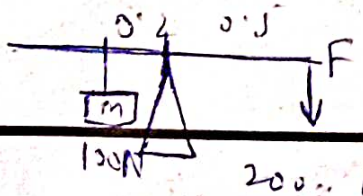
Given data:

Mass of block = m = 10 kg

Weight of block = w = 10 × 10

W = 100 N

Distance of weight from C.G. = AG = 20 cm



$$AG = \frac{20}{100} = 0.2 \text{ m}$$

Distance of force from C.G. BG = 50 cm

$$= \frac{50}{100} = 0.5 \text{ m}$$

To find:

Force on the other end to balance the rod =

W_2 = ?

Solution:

According to 2nd condition of equilibrium

Clock wise torque = Anti clock wise torque

$W_2 \times BG = AG \times W_1$

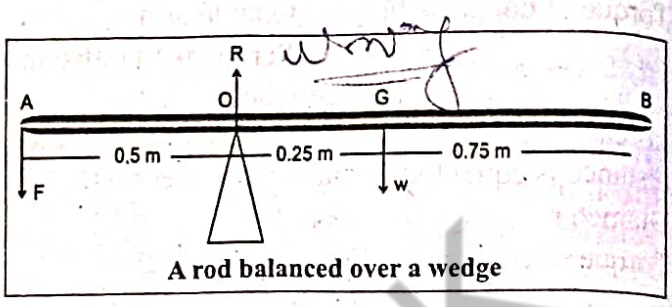
$W_2 \times 0.5 = 0.2 \times W_1$

$$W_2 = \frac{0.2 \times 100}{0.5}$$

$$= \frac{20}{0.5}$$

$$= \frac{20 \times 10}{5}$$

$$= 40 \text{ N}$$



A rod balanced over a wedge

Result:

40N force is required to balance the 1m long bar.

UNIT 05

GRAVITATION

Introduction

In this unit we would learn about law of gravitation, mass of Earth, variation of g, motion of artificial satellite.

Q1. Who is the first man that gave the idea of gravity? 091305001

Ans. The first man who gave the idea of gravity was **"Isaac Newton".** It was an evening of 1665 when he was trying to solve the mystery why planets revolve around the Sun. Suddenly an apple fell from the tree under which he was sitting. The idea of gravity flashed in his mind. He discovered not only the cause of falling apple, but also the cause that makes the planets to revolve around the Sun and moon around the Earth.

Q2. State and explain Newton's law of gravitation. (Or) What is meant by the force of gravitation? Also explain the law of gravitation. (F.B. 2015, 18) 091305002

Ans. The Force of Gravitation (F.B. 2016)

Newton gave the idea that there exists a force due to which everybody of the universe attracts every other body. He named this force the force of gravitation.

Law of Gravitation:-

According to Newton's law of gravitation, *"Everybody in the universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers."*

Mathematical Form

Consider two bodies of masses "m_1" and "m_2". The distance between the centers of masses is "d" as shown in figure. According to the law of gravitation, the gravitational force of attraction "F" with which the two masses "m_1" and "m_2" separated by a distance d attract each other is given by:

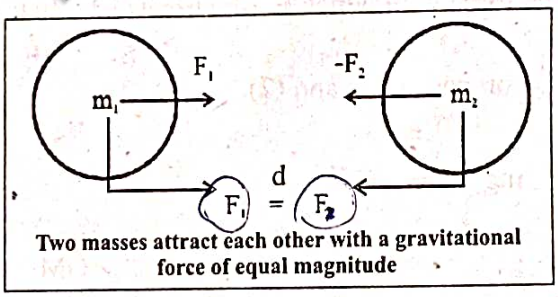
$$F \propto m_1 m_2 \quad \text{.....(i)}$$

$$F \propto \frac{1}{d^2} \quad \text{.....(ii)}$$

By (i) and (ii)

$$F \propto \frac{m_1 m_2}{d^2}$$

$$F = G\frac{m_1 m_2}{d^2}$$



Two masses attract each other with a gravitational force of equal magnitude

Here 'G' is constant of proportionality is called universal constant of gravitation. In SI unit its value is $6.673 \times 10^{-11}\ Nm^2kg^{-2}$ and is remain same everywhere.

Q3. Why can we not feel the force of attraction between the objects around us? 091305003

Ans. Due to small value of G, the gravitational force of attraction between objects around us is very small and we do not feel it. Since the mass of Earth is very large, it attracts nearby objects with a significant force. The weight of an object on the Earth is the result of gravitational force of attraction between the Earth and the object.

Q4. How does Law of Gravitation relate with third Law of Motion? How does Newton's third law of motion related to Newton law of Gravitation 091305004

Ans. Law of gravitation and Newton's third law of motion

By Newton's 3rd Law of Motion

Action & reaction are:

i. Equal in magnitude

ii. Opposite in direction

According to Law of Gravitation mass "m_1" applies a force on mass "m_2" due to force of attraction. If the force F_1 acting on m_1 is considered as action then force acting on m_2 will be reaction.

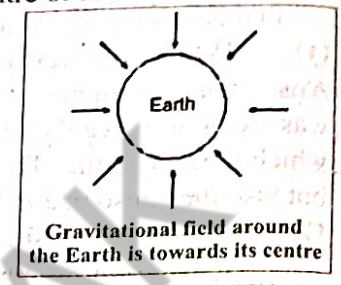
The action and reaction due to gravitation are equal in magnitude but opposite in direction as shown in figure. Hence law of gravitation and Newton's third law is consistent with each other.

Q5. How can you say that gravitational force is a field force? 091305005

Ans. Gravitational Field:-

According to the Newton's law of gravitation. The gravitational force between a body of mass m and the Earth is given by: $F = G\frac{mMe}{r^2}$

Where "M_e" is the mass of the Earth and r is the distance of the body from the centre of the Earth. The weight of a body is due to the gravitational force with which the Earth attracts a body. Gravitational force is a non-contact force. For example, the velocity of a body, thrown up, goes on decreasing while on return its velocity goes on increasing. This is due to the gravitational pull of the Earth acting on the body which Earth attracts the bodies towards its centre. Such, a force is called the field force. It is assumed that a gravitational field exists all around the Earth. This field is directed towards the centre of the Earth as shown by arrows in figure. The gravitational field force becomes weaker and weaker as we go higher and higher away from the Earth.



Gravitational field around the Earth is towards its centre

Q6. What is gravitational field strength near the surface of the Earth? (F.B. 2016) 091305006

Ans. *"In the gravitational field of the Earth, the gravitational force per unit mass is called the gravitational field strength of the Earth."* At any place, its value is equal to the value of "g" at that point. Near the surface of Earth, the gravitational field strength is 10 Nkg^{-1}

Q7. Find the mass of Earth by using the law of gravitation. (F.B. 2016) 091305007

Ans. Mass of the Earth

Consider a body of mass "m" is placed on the surface of the Earth. Let the mass of the Earth be "M_e" and radius of the Earth be "R". The distance of the body from the centre of the Earth will also be equal to the radius "R" of the Earth.

According to the law of gravitation, the gravitational force "F" of the Earth acting on a body is given by

$$F = G\frac{mM_e}{R^2} \longrightarrow (1)$$

The force with which Earth attracts a body towards its centre is equal to its weight w.

$$F = w = mg \longrightarrow (2)$$

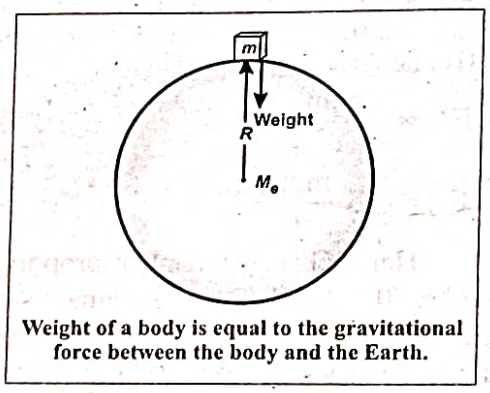
By comparing (1) and (2)

$$mg = G\frac{mM_e}{R^2}$$

$$\therefore g = G\frac{M_e}{R^2} \ldots\ldots \Rightarrow gR^2 = GM_e$$

and $$\frac{gR^2}{G} = M_e$$

$$M_e = \frac{gR^2}{G}$$



Weight of a body is equal to the gravitational force between the body and the Earth.

Here $R = 6.4 \times 10^6 m$

$g = 10 ms^{-2}$

$G = 6.673 \times 10^{-11} Nm^2 kg^{-2}$

So

$$M_e = \frac{(6.4\times10^6 m)^2 \times 10 ms^{-2}}{6.673\times10^{-11} Nm^2 kg^{-2}} = \frac{6.4 \times 6.4 \times 10^{12} \times 10}{6.673 \times 10^{-11}}$$

$$= \frac{6.4 \times 6.4 \times 10^{13+11}}{6.673} = 6 \times 10^{24} kg$$

Thus, mass of the earth is 6×10^{24} kg.

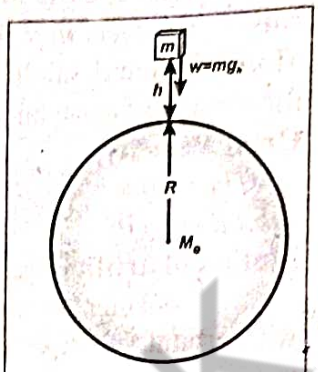
Q8. How the value of 'g' varies with altitude? 091305008

Ans. Variation of g with altitude:

The value of "g" depends on the radius of the Earth at its surface. Its value decreases as an object moves away from the surface of Earth.

Consider a body of mass "m" is placed at an altitude "h" as shown in figure. The distance of the body from the center of the Earth becomes "R + h".

At height h from surface of Earth value of 'g' is equal to = $g_h = \frac{GM_e}{(R+h)^2}$



Weight of a body decreases as its height increases from the surface of the Earth

According to the above equation, we can calculate the value of "g" at any height "h" from the surface of Earth.

The value of *g* is inversely proportional to the square of the distance from the centre of the Earth. But it does not remain constant. It decreases with altitude. Altitude is the height of an object or place above sea level. The value of *g* is greater at sea level than at the hills.

At a height equal to one Earth's radius above the surface of Earth, 'g' becomes one fourth of its value on the Earth. Similarly, at a distance of two Earth's radius above the Earth's surface, the value of 'g' becomes one ninth of its value on the Earth.

$g = \frac{GM_e}{(R+h)^2}$

$g = \frac{\text{constant}}{(R+h)^2}$

$g \propto \frac{1}{(R+h)^2}$

DO YOU KNOW

Value of g on the surface of a celestial object depends on its mass and its radius. The value of g on some of the objects is given below:

Object	g (ms^{-2})
Sun	274.2
Mercury	3.7
Venus	8.87
Moon	1.62
Mars	3.73
Jupiter	25.94

Q9. Explain the artificial satellites? (F.B. 2016) 091305009

Ans. Satellite: *An object that revolves around a planet is called a satellite.*

The moon revolves around the Earth so moon is a natural satellite of the Earth.

Artificial Satellite: Scientists have sent many objects into space. Some of these objects revolve around the Earth. These are called artificial satellites.

Uses of Satellite: Most of the artificial satellites, orbiting around the Earth are used for communication purposes. Artificial satellites carry instruments or passenger to perform experiments in space.

Satellite revolving around earth

Large number of artificial satellites have been launched in different orbits around the Earth. They take different time to complete their one revolution around the Earth depending upon their distance *h* from the Earth.

Communication Satellites: Communication satellites take 24 hours to complete their one revolution around the Earth. As Earth also completes its one rotation about its axis in 24 hours, hence, these communication satellites appear to be stationary with respect to Earth. It is due to the reason that the orbit of such a satellite is called geostationary orbit. Dish antennas sending and receiving the signals from them have fixed direction depending upon their location on the Earth.

Q10. Define satellites. Find the orbital velocity of an artificial satellites. (OR) Describe the method to find orbital speed of artificial satellites? (F.B. 2017) 091305010

Ans. *An object that revolves around a planet is called* ***satellite.***

Moon is natural satellite of our Earth. Some artificial satellites are revolving around the Earth which are used for communication and space research.

Orbit Velocity:

The critical velocity of a satellite in order to keep on moving around the earth at a specific height is called orbital velocity.

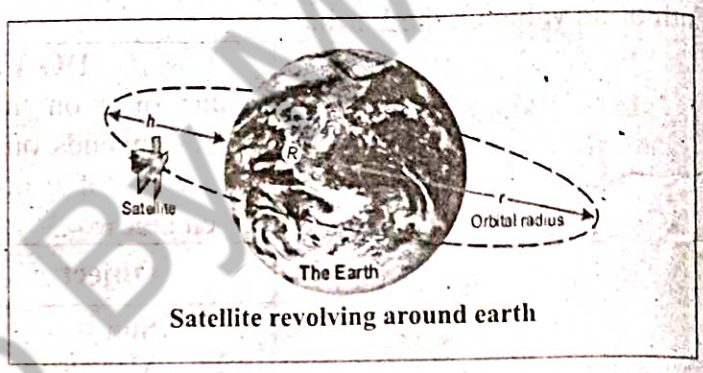
Motion of artificial satellites

Consider a satellite of mass "m" revolving around the Earth at an altitude "h" in an orbit of radius "r_o" with orbital velocity "v_o". The necessary centripetal force which help the satellite to move around Earth, which is provided by force of attraction between the satellite and Earth is given by:

$$F_c = \frac{mv_o^2}{r_o} \quad \text{.....(1)}$$

This force is provided by the gravitational force of attraction between the Earth and satellite which is equal to the weight of satellite w′; Thus

$$F_c = w' = mg_h \quad \text{..... (2)}$$



Satellite revolving around earth

By comparing eq. 1 and 2

$$\text{or} \quad mg_h = \frac{mv_o^2}{r_o}$$

$$\text{or} \quad v_o^2 = g_h r_o$$

$$\text{or} \quad v_o = \sqrt{g_h\ r_o}$$

$$\text{as} \quad r_o = R + h$$

$$\therefore \quad v_o = \sqrt{g_h\ (R+h)} \quad \text{.....(3)}$$

This is the velocity, which a satellite must possess when launched in an orbit of radius $r_o = (R + h)$ around the Earth. An approximation can be made for a satellite revolving close to the Earth such that R >> h. So *h* is negligible i.e $h \approx 0$.

Hence

$$R + h \approx R$$

and $g_h \approx g$

By putting the value in. eq (3) we will get,

$$\therefore \quad v_o = \sqrt{g\,R} \quad \text{..... (4)}$$

As $g = 10 ms^{-2}$

$R = 6.4 \times 10^6 m$

$$v_o = \sqrt{10 ms^{-2} \times 6.4 \times 10^6 m}$$

$$= \sqrt{64000000}$$

$V_o = 8000 ms^{-1}$ (or) $8 kms^{-1}$

A satellite revolving around very close to the Earth, has speed "v_o" nearly 8 kms^{-1} or 29000 kmh^{-1}.

MULTIPLE CHOICE QUESTIONS

Exercise MCQs

1. Earth's gravitational force of attraction vanishes at: 091305011
(a) 6400km (b) infinity
(c) 42300 km (d) 1000 km

2. Value of g increases with the: 091305012
(a) increase in mass of the body
(b) increase in altitude
(c) decrease in altitude
(d) none of the above

3. The value of g at a height one Earth's radius above the surface of the Earth is: (F.B. 2015) 091305013
(a) 2 g (b) ½ g
(c) ⅓ g (d) ¼ g

4. The value of g on moon's surface is 1.6 ms^{-2}. What will be the weight of a 100 kg body on the surface of the moon? (F.B. 2017) 091305014
(a) 100 N (b) 160 N
(c) 1000N (d) 1600N

5. The altitude of geostationary orbits in which communication satellites are launched above the surface of the Earth is: 091305015
(a) 850 km (b) 1000 km
(c) 6400 km (d) 42, 300 km

6. The orbital speed of a low orbit satellite is: (F.B. 2015, 16) 091305016
(a) zero (b) 8 ms^{-1}
(c) 800 ms^{-1} (d) 8000 ms^{-1}

Additional MCQs

7. The first man who gave the idea of gravity: 091305017
(a) Hero (b) Einstein
(c) Newton (d) Faraday

8. Earth revolves around the: 091305018
(a) Moon (b) Sun
(c) Galaxy (d) None

9. Law of Gravitation is consistence with: 091305019
(a) 1st Law of motion
(b) 2nd Law of motion
(c) 3rd Law of motion
(d) Law of momentum

10. Gravitational force is a: 091305020
(a) Electric force
(b) Magnetic force
(c) reactional force
(d) electromotive force

11. Near the Earth's surface, the gravitational field strength is: 091305021
(a) 1N kg^{-1} (b) 100 Nkg^{-1}
(c) 10 Nkg^{-1} (d) 101Nkg^{-1}

12. Mass of Earth is equal to: (F.B. 2016) 091305022
(a) 7.1×10^{24}kg (b) 6.0×10^{24}kg
(c) 6.5×10^{24} kg (d) 9.1×10^{24} kg

13. The value of 'g' on the surface of moon is: 091305023
(a) 1.62 ms^{-2} (b) 10ms^{-2}
(c) 20ms^{-2} (d) zero

14. The value of 'g' on the surface of Mars: 091305024
(a) 3.73 ms^{-2} (b) 1.62 ms^{-2}
(c) Zero (d) constant

15. The value of 'g' is greater at: 091305025
(a) moon (b) Hills
(c) sea level (d) desert

16. The velocity of geostationary satellites with respect to the Earth is 091305026
(a) maximum (b) Zero
(c) minimum (d) 100ms^{-1}

17. Moon is our satellite: 091305027
(a) artificial (b) permanent
(c) natural (d) communication

18. GPS system consist of earth satellites: 091305028
(a) 4 (b) 24
(c) 20 (d) 30

19. Orbital velocity v_o =: 091305029
(a) $\sqrt{gR}$ (b) $\sqrt{RG}$
(c) gR (d) gR^2

20. Moon is nearly away from the Earth: 091305030
(a) 3,80,000km (b) 3800 km
(c) 3,80 km (d) 38 km

21. A satellite revolving around very close to Earth has speed nearly: 091305031
(a) 5 kms^{-1} (b) 8 kms^{-1}
(c) 10kms^{-1} (d) 100kms^{-1}

22. The Earth attracts a body with a force equal to its: 091305032
(a) velocity (b) gravity
(c) weight (d) mass

23. The value of gravitational constant "G" is: (F.B. 2016) 091305033
(a) $6.67 \times 10^{-21}\ Nm^2kg^{-2}$
(b) $6.67 \times 10^{-11}\ Nm^2kg^{-2}$
(c) $6.67 \times 10^{-23}\ Nm^2kg^{-2}$
(d) $6.67 \times 10^{11}\ Nm^2kg^{-2}$

24. The unit of gravitational constant is: 091305034
(a) Nm^2kg (b) Nm^2kg^{-2}
(c) Nm^2kg^{-1} (d) $N-m^2$

25. Moon completes its one revolution around earth: (F.B. 2017) 091305035
(a) 400 hours (b) 300 hours
(c) 27.3 days (d) 26 days

26. The relationship between gravitational acceleration and the attitude from the earth is: 091305036
(a) $g \propto R$ (b) $g \propto R^2$
(c) $g \propto \frac{1}{R}$ (d) $g_h \propto \frac{1}{(R+h)^2}$

27. Earth completes one rotation about its axis in: 091305037
(a) 27 days
(b) 364 days
(c) 24 hours
(d) 24 days

28. Weight of the body is due to the: 091305038
(a) gravitational force
(b) centripetal force
(c) centrifugal force
(d) all of the above

29. Velocity of the body moving in upward direction from the surface of the earth. 091305039
(a) increases
(b) decreases
(c) remain constant
(d) none

30. Weight of the body is _____ to the force of gravity between body and earth: 091305040
(a) Less than (b) greater than
(c) equal (d) constant

31. Weight of the body when we increase its height from earth's surface: 091305041
(a) Increases (b) Decreases
(c) remain constant (d) None

32. Speed of the satellites of GPS around earth is: 091305042
(a) $3.87\ ms^{-1}$ (b) $387\ Kms^{-1}$
(c) $3.87\ Kms^{-1}$ (d) $38.7\ Kms^{-1}$

33. The radius R of the earth is: 091305043
(a) $6\times10^{18}\ m$ (b) $6.4\times10^{6}\ m$
(c) $6.4\times10^{8}\ m$ (d) $6.4\times10^{12}\ m$

34. At the surface of the earth value of 'g' is measured by using formula: 091305044
(a) $g = \frac{GMe}{R}$ (b) $g = \frac{GMe}{R^2}$
(c) $g = \frac{2GMe}{R^2}$ (d) $g = \frac{GMe}{2R}$

35. The value of g is maximum at: 091305045
(a) Mountains (b) Maximum height
(c) Surface of earth (d) At 2R

36. Formula used to calculate the mass of Earth is: 091305046
(a) $M_e = \frac{G}{gr^2}$ (b) $M_e = \frac{gR^2}{G}$
(c) $M_e = \frac{G}{R^2}$ (d) $M_e = \frac{gr}{G}$

37. The value of 'g' on the surface of sun is: 091305047
(a) $8.81ms^{-2}$ (b) $274.2ms^{-2}$
(c) $10ms^{-2}$ (d) $400ms^{-2}$

38. The value of 'g' on the surface of Jupiter: 091305048
(a) $1.62ms^{-2}$ (b) $3.37ms^{-2}$
(c) $25.94ms^{-2}$ (d) $10ms^{-2}$

39. The value of 'g' on the surface of venus is: 091305049
(a) $8.87ms^{-2}$ (b) $9.9ms^{-2}$
(c) $1.66ms^{-2}$ (d) $8.87ms^{-2}$

40. The value of 'g' at a height two Earth's radius above the surface of the Earth. 091305050
(a) $\frac{1}{3}g$ (b) $\frac{1}{9}g$
(c) 9g (d) 4g

41. The value of the 'gravitational field strength" of the Earth at a distance R (where R is the radius of the Earth) from the surface of the Earth will be: (F.B. 2018) 091305050 (a)
(a) $5Nkg^{-1}$ (b) $10\,Nkg^{-1}$
(c) $2.5\,Nkg^{-1}$ (d) $1.1\,Nkg^{-1}$

ANSWERS

1.	b	2.	C	3.	d	4.	b	5.	d
6.	d	7.	c	8.	b	9.	c	10.	c
11.	c	12.	b	13.	a	14.	a	15.	c
16.	b	17.	c	18.	b	19.	a	20.	a
21.	b	22.	c	23.	b	24.	b	25.	c
26.	d	27.	c	28.	a	29.	b	30.	c
31.	b	32.	c	33.	b	34.	b	35.	c
36.	b	37.	b	38.	c	39.	a	40.	b
41.	c								

Exercise Question Answers

Q.5.2 What is meant by force of gravitation? (F.B. 2017) 091305051

Ans. The force due to which every object in the universe attracts every other object is called force of gravitation.

Q.5.3 Do you attract the Earth or Earth attracts you? Which one is attracting with a larger force? You or the Earth. 091305052

Ans. We attract earth and earth also attract us. The magnitude of attractive force of Earth is equal to the weight of the body. Both bodies attract each other with equal force.

Q.5.4 What is a field force? 091305053

Ans. The gravitational pull of Earth acting on a body whether the body is in contact with Earth or not is called field force.

Q.5.5 Why could earlier scientists not guess about the gravitational force? 091305054

Ans. The earliest Greek scientist believed that Earth remain stationary at the center while planets including Sun and Moon revolves around it. In 16^{th} century another theory was explained. In which Sun is stationary at the center, Earth and planets revolve around it in different orbits. To resolve the conflict between these theories Newton explained the theory of gravity and law of Gravitation.

Q.5.6 How can you say that gravitational force is a field force? 091305055

Ans. We can say that gravitational force is field force. To understand it consider a body moving in upward direction its velocity continuously decreases and a body moving in downward direction, its velocity continuously increases. This is due to gravitational pull of the Earth. This shows that gravitational force is field force.

Q.5.7 Explain, what is meant by gravitational field strength? 091305056

Ans. In the gravitational field of the Earth, the gravitational force per unit mass is called the gravitational field strength of the Earth. Gravitational field strength is greater on the surface of Earth but as we go higher from surface of Earth, its value decreases.

Q.5.8 Why is law of Gravitation important to us? 091305057

Ans. Newton's Law of gravitation explains the motion of objects in space, motion of planets around the sun and motion of moon around the earth. By using this law, we are able to send satellites into space, rocket mission is also possible after the explanation of this law. Rain and snow fall is also possible due to the gravitational pull of the earth.

It also explains the motion of the planets in the solar system. By using the law of gravitation we can find the mass of Earth. It also helps to understand the motion of satellites.

Q.5.9 Explain the law of gravitation. 091305058

Ans. See Q. No. 2 Page no. 89.

Q.5.10 How the mass of Earth can be determined? 091305059

Ans. See Q. No. 7 Page no. 90.

Q.5.11 Can you determine the mass of our moon? If yes, then what do you need to know? 091305060

Ans. Yes, mass of Moon can be determine by the following formula.

$$M_m = \frac{g_m R_m^2}{G}$$

In this equation 'g_m' is the gravitational acceleration on the surface of Moon and 'G' is gravitational constant. If we know the radius of

Moon, then we can find the mass of Moon by using this relation.

Q.5.12 Why does the value of "g" vary from place to place? 091305061

Ans. As we know $g_h = \frac{GM}{(R+h)^2}$

According to this equation value of 'g' depends upon the height. That is why value of 'g' varies from place to place.

Q.5.13 Explain how the value of "g" varies with altitude? (F.B. 2017) 091305062

Ans. By the equation $g_h = \frac{GM}{(R+h)^2}$

We can see that the value of 'g' is inversely proportional to the square of height from the surface of Earth So as we go higher, the value of "g" becomes less and as we move towards Earth its value increases.

Q.5.14 What are artificial satellites? 091305063

Ans. Scientists have sent many objects into space. Some of these objects revolves around the Earth these are called artificial satellites

Q.5.15 How Newton's law of gravitation helps in understanding the motion of satellites? 091305064

Ans. To keep the satellite move in circular orbit centripetal force is necessary which is supplied by the gravitational force of attraction between earth and satellite.

Q.5.16 On what factor the orbital speed of a satellite depends? (F.B. 2015, 16, 17) 091305065

Ans. The orbital speed of satellite depends upon the altitude.

Since $V_{orb} = \sqrt{\frac{GM}{(R+h)}}$

Where h is altitude so, orbital velocity depends on the altitude from earth surface.

Q.5.17 Why communication satellites stationed at geostationary orbits? 091305066

Ans. Since Earth completes its one rotation in 24 hours and communication satellites also take 24 hours to complete its one round. So communication satellites are stationary with respect to Earth. So they are called geostationary satellite. Velocity of geostationary satellite relative to earth is zero.

Additional Short Questions

Q.18 What is GPS? or What is navigation system? (Board 2014) 091305067

Ans. Global Positioning System (GPS) is satellites navigation system. It helps us to find the exact position of an object anywhere on the land, on the sea or in the air. GPS consists of 24 Earth satellites. These satellites revolve around the Earth twice a day with a speed of 3.87 kms^{-1}.

Q.19 Does the weight of an apple increase, decrease or remain constant when taken to the top of a mountains? 091305068

Ans. The weight of an apple decreases when taken to the top of a mountain because the value of g decreases as the altitude increases.

Q20. What is satellite? What are their kinds? 091305069

Ans. An object that revolves around a planet is called a satellite. Its of two types.

(i) Artificial satellite

(ii) Natural satellite

Q.21 What is the height and speed of geostationary satellites from the surface of the Earth? 091305070

Ans. The height of a geostationary satellite is about 42,300 km from the surface of the Earth. Its velocity with respect to Earth is zero.

Q.22 Why communication satellites are called geostationary satellite? 091305071

Ans. Communication satellites take 24 hours to complete their one revolution around the Earth. As Earth also completes its one rotation about its axis in 24 hours, hence, these communication satellites appear to be stationary with respect to Earth. It is due to this reason that the orbit of such a satellite is called geostationary orbit. Dish antennas sending and receiving the signals from them have fixed direction depending upon their location on the Earth.

Q.23 How far Moon is from Earth and in how much time it completes its rotation? 091305072

Ans. Moon is nearly 3,80,000 km away from the Earth. It completes its one revolution around the Earth in 27.3 days.

Q.24 How the gravitational force of attraction would be affected if the distance between 2 bodies is doubled? 091305073

Ans.

$F = G\frac{m_1 m_2}{d^2}$ ..... (i)

Distance is doubled, d = 2d, so new force

$$F' = G\frac{m_1 m_2}{(2d)^2}$$

$$F' = G\frac{m_1 m_2}{4d^2}$$

Putting value of F from (i)

$$F' = \frac{1}{4} \times \frac{Gm_1 m_2}{d^2}$$

$$F' = \frac{1}{4}F$$

Thus, if the distance between 2 objects is doubled, the force will reduced to one-fourth as compared to the value of 'g' on Earth's surface.

Q.25 At what height value of 'g' would become one-ninth than on the surface of the earth? 09130507

Ans.

$$g_h = \frac{g}{9}$$

$$\Rightarrow 9g_h = g \quad \text{..... (A)}$$

We know that

$$g = \frac{GM_e}{R^2} \quad \text{..... (i)}$$

$$g_h = \frac{GM_e}{(R+h)^2} \quad \text{.....(ii)}$$

Put the value of g and g_h from Eq (i) & (ii) in Eq. A

$$9\left(\frac{\cancel{GMe}}{(R+h)^2}\right) = \frac{\cancel{GMe}}{R^2}$$

$$\frac{9}{(R+h)^2} = \frac{1}{R^2}$$

$$\Rightarrow \sqrt{(R+h)^2} = \sqrt{9R^2}$$

$$\Rightarrow R + h = 3R$$

$$h = 3R - R$$

$$h = 2R$$

Altitude = 2 (Earth radius)

At the height of 2R from the surface of the earth, value of g would be 1/9 as compared to value of 'g' on Earth's surface.

Q.26 Why all the planets and the earth move around/revolve around the sun? 091305075

Ans. According to law of Gravitation, a force of attraction exists between all the objects of the universe. This force is the main cause of the motion of the earth and planets around the sun.

Q.27 Define gravitational field? 091305076

Ans. Gravitational field is a space or region around the earth where other object experience the gravitational force. Gravitational field varies from the surface of earth.

Q.28 What is the effect of mass on gravitational acceleration? 091305077

Ans. Since $g = \frac{GM_e}{R^2}$

This equation shows that gravitational acceleration does not depend upon mass of the body. Galileo notice that all the bodies falling freely have same uniform acceleration independent of their masses. Lighter and heavier bodies should fall down towards the centre of Earth with same acceleration.

Q.29 What is the effect of distance of freely falling bodies from the centre of the earth? 091305078

Ans. Value of 'g' is inversely proportional to the square of distance from the surface of earth. It means if the distance from the centre of earth is increased then the value of 'g' will be decreased. Due to this reason value of 'g' is greater at sea level and less at hills.

Q.30 Is there any difference between the values of 'g' at the equator and at the poles? 091305079

Ans. The value of 'g' is greater at the poles than at the equator due to non spherical shape of the earth. It is because the radius of earth is slightly greater at the equator that at the poles.

Q.31 When a man is standing on the ground, how much upward force is exerted on him by the earth? Why does not this force lift him from the earth upward? 091305080

Ans. When a man is standing on the ground he exert a force equal to the weight on the earth. Since these forces are equal in magnitude and opposite in direction so, a person remains stationary on the earth.

Q.32 What is orbital speed of a low orbit satellite? 091305081

Ans. A satellite revolving around very close to the earth, is known as low orbit satellite, and its value is:

$$v_o = \sqrt{Rg}$$

$$g = 10ms^{-2}$$

$$R = 6.4\times10^6 m$$

$$v_o = 8000ms^{-1}$$

or

$$v_o = 8kms^{-1}$$

Q.33 Differentiate between 'g' and 'G'. 091305082

Ans

(Acceleration due to gravity) "g"	(Universal gravitational constant) "G"
• The acceleration which is produced on a Freely Falling body due to gravitational force is known as acceleration due to gravity.	• The force of attraction between any object, separated by a unit distance is known as universal gravitational constant.
• It changes from place to place.	• It's value remains constant everywhere.
• It is a vector quantity.	• It a scalar quantity.
• It's unit is m/sec^2.	• It's unit is are Nm^2/kg^2.
• It's value on the Earth surface is $10ms^{-2}$.	• It's value is $6.673 \times 10^{-11} Nm^2kg^{-2}$.

Q.34 On the surface of the Earth, the weight of a boy is 400N but on a mountain peak his weight is 360N. Calculate the value of 'g' on the mountain peak. (F.B. 2018) 091305083

Ans: Given data:

Weight of boy on Earth surface = W = 400N Value of 'g' on Earth surface = g = $10ms^{-2}$

$$\text{Mass of boy} = m = \frac{w}{g} = \frac{400}{10} = 40 \text{ kg}$$

Weight of boy on mountain = w' = 360N

To Find:

Value of 'g' on mountain peak = g' =?

Solution:

As mass of a body remain same everywhere.

Thus:

$$W' = mg'$$
$$360 = 40\, g'$$
$$\frac{36\cancel{0}}{4\cancel{0}} = g'$$
$$g' = \frac{\cancel{36}^{9}}{\cancel{4}}$$
$$g' = 9 \text{ ms}^{-2}$$

Result:

Value of g' on mountain peak is 9 ms^{-2}.

MINI EXERCISE

Q.35 Does an apple attract the Earth towards it? 091305084

Ans. Yes an apple also attract the Earth with the same force with which Earth attract an apple. As apple has very small mass as compared to the Earth. So, when an apple set free from a height it always move towards the Earth.

Q.36 With what force an apple weighing 1N attracts the Earth? 091305085

Ans. The weight of apple is 1N.

The force of attraction is equal to the weight of object. So, the force of apple is also 1N.

Q.37 Does the weight of an apple increase, decrease or remain constant when taken to the top of a mountain? 091305086

Ans. As

$$g_h \propto \frac{1}{(R+h)^2}$$

As the value of 'g' is inversely proportional to the square of altitude. Therefore the weight of an apple decreases when taken to the top of a mountain.

SOLVE EXAMPLES

Example 5.1;

Two lead spheres each of mass 1000 kg are kept with their centers 1 m apart. Find the gravitational force with which they attract each other. 091305087

Given data

Here $m_1 = 1000$ kg

$m_2 = 1000$ kg

$d = 1$m

$G = 6.673 \times 10^{-11} Nm^2 kg^{-2}$

To Find: F = ?

Solution:

Since $F = G\frac{m_1 m_2}{d^2}$

Putting the values, we get

$$F = 6.673 \times 10^{-11} \times \frac{1000 \times 1000}{(1)^2}$$

$$= 6.673 \times 10^{-11} \times 10^3 \times 10^3$$

$$= 6.673 \times 10^{-11+3+3}$$

$$F = 6.673 \times 10^{-5} \text{ N}$$

Result: Thus, gravitational force of attraction between the lead spheres is 6.673×10^{-5} N.

Example 5.2

Calculate the value of g, the acceleration due to gravity at an altitude 1000km. The mass of the Earth is 6.0×10^{24} kg. The radius of the Earth is 6400km. 091305088

Given data:

Here $R = 6400$ km

$h = 1000$ km

$M_e = 6.0 \times 10^{24}$ kg

To find:

$g_h = ?$

$R + h = 6400 \text{ km} + 1000 \text{ km}$

$= 7400 \text{ km} = 7400 \times 10^3 \text{m}$

$= 7.4 \times 10^6 \text{ m}$

Solution:

As $g_h = G\frac{M_e}{(R+h)^2}$

$$g_h = \frac{6.673 \times 10^{-11} \times 6.0 \times 10^{24}}{(7.4 \times 10^6)^2}$$

$$= \frac{6.673 \times 6 \times 10^{24-11}}{7.4 \times 7.4 \times 10^{12}}$$

$$= \frac{40.038 \times 10^{13-12}}{54.76}$$

$$= 0.73 \times 10 \qquad \because 1 \text{Nkg}^{-1} = 1 \text{ms}^{-2}$$

$$= 7.3 \text{ N kg}^{-1}$$

$$g_h = 7.3 \text{ ms}^{-2}$$

Result: The value of g, the acceleration due to gravity at an altitude of 1000km will be 7.3ms^{-2}.

NUMERICAL PROBLEMS

5.1. Find the gravitational force of attraction between two spheres each of mass 1000 kg. The distance between the centers of the spheres is 0.5 m. 091305089

Given Data

Mass of first sphere $= m_1 =$ 1000 kg

Mass of second sphere $= m_2 =$ 1000 kg

The distance between their centers $= d = 0.5$m

Gravitational constant $= G = 6.673 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$

To find:

Gravitational force $= F = ?$

Solution

$$F = G\frac{m_1 m_2}{d^2}$$

$$= \frac{6.673 \times 10^{-11} \times 1000 \times 1000}{(0.5)^2}$$

$$F = \frac{6.673 \times 10^{-5}}{0.25}$$

$$F = 26.69 \times 10^{-5}$$

$$F = 2.67 \times 10^{-4} \text{N}$$ **Ans.**

Result:

The required force of attraction between two spheres is 2.67×10^{-4}N.

5.2. The gravitational force between two identical lead spheres kept at 1 m apart is 0.006673 N. Find their masses. 091305090

Given data

Gravitational force $= F = 0.006673$ N

Distance between two identical spheres $d = 1$m

Gravitational Constant $= G = 6.673 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$

To find:

Masses of identical sphere $m_1 = m_2 = m = ?$

Solution

$$F = G\frac{m_1 m_2}{d^2}$$

$\because m_1 = m_2 = m$

$$F = G\frac{m \times m}{d^2}$$

$$Gm^2 = Fd^2$$

$$\sqrt{m^2} = \sqrt{\frac{Fd^2}{G}}$$

$$m = \sqrt{\frac{0.006673 \times 1}{6.673 \times 10^{-11}}}$$

$$= \sqrt{\frac{0.006673 \times 10^{11}}{6.673}}$$

$$= \sqrt{\frac{6673 \times 10^{11} \times 10^3}{6673 \times 10^6}}$$

$$= \sqrt{\frac{10^{11+3}}{10^6}}$$

$$= \sqrt{10^{14-6}}$$

$$= \sqrt{10^8}$$

$$= \sqrt{(10^4)^2}$$

$$m = 10,000 \text{ kg}$$

Since $m_1 = m_2$

$m_1 = 10{,}000$kg

$m_2 = 10{,}000$kg

Result:

Each sphere has mass 10,000 kg.

5.3. Find the acceleration due to gravity on the surface of the Mars. The mass of Mars is 6.42×10^{23} kg and its radius is 3370 km. 091305091

Given data

Mass of Mars $= M = 6.4 \times 10^{23}$ kg

Radius of Mars $= R = 3370$ km

$R = 3370 \times 10^3$m

Gravitational constant $= G = 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}

To find:

Gravitational acceleration $= g = ?$

Solution

$$g = \frac{GM}{R^2}$$

$$= \frac{6.673 \times 10^{-11} \times 6.42 \times 10^{23}}{(3370 \times 10^3)^2}$$

$$= \frac{42.84066 \times 10^{23-11}}{11356900 \times 10^6}$$

$$= \frac{42.84066 \times 10^{12-6}}{11356900}$$

$$= 0.000003772 \times 10^6$$

$$= 3.77 \text{ ms}^{-2}$$

$g = 3.77$ms^{-2}

Result:

The acceleration due to gravity on the surface of Mars is 3.77ms^{-2}.

5.4. The acceleration due to gravity on the surface of moon is 1.62 ms^{-2}. The radius of Moon is 1740 km. Find the mass of moon. 091305092

Given Data

Acceleration due to gravity on the surface of moon $= g_m = 1.62$ ms^{-2}

The radius of Moon

$R_m = 1740$ km $= 1740 \times 10^3$ m

Gravitational constant

$G = 6.673 \times 10^{-11}$ Nm^{2}kg^{-2}

To find:

Mass of Moon $= M_m = ?$

Solution

We know that

$$M_m = \frac{gR^2}{G}$$

$$M_m = \frac{1.62 \times (1740 \times 10^3)^2}{6.673 \times 10^{-11}}$$

$$= \frac{1.62 \times 3027600 \times 10^6}{6.673 \times 10^{-11}}$$

$$= \frac{4904712 \times 10^6}{6.673 \times 10^{-11}}$$

$$735008.5 \times 10^{17}$$

$M_m = 7.35 \times 10^{22}$ kg

Mass of moon $= 7.35 \times 10^{22}$ kg

Result:

The required mass of Moon is 7.35×10^{22} kg.

5.5. Calculate the value of g at a height of 3600 km above the surface of the Earth. 091305093

Given data:

Height $= h = 3600$ km

$h = 3600 \times 10^3$m $\Rightarrow 3600000$m

$R = 6.4 \times 10^6$m

$G = 6.673 \times 10^{-11}$ Nm^{2}kg^{-2}

$M = 6 \times 10^{24}$kg

To find:

$g_h = ?$

Solution:

$$g_h = \frac{GM}{(R+h)^2}$$

$$= \frac{6.673\times10^{-11}\times6\times10^{24}}{(3600000+6.4\times10^6)^2}$$

$$= \frac{40.038\times10^{24-11}}{(3.6\times10^6+6.4\times10^6)^2}$$

$$= \frac{40.038\times10^{13}}{(10^7)^2}$$

$$= \frac{40.038\times10^{13}}{10^{14}}$$

$$= \frac{40.038}{10^{14-13}} = \frac{40.038}{10}$$

$$g_h = 4.0\ ms^{-2}$$

Result:

The value of 'g' at a height 3600 km above the Earth's surface is $4.0 ms^{-2}$.

5.6. Find the value of g due to the Earth at geostationary satellite. The radius of the geostationary orbit is 48700 km. 091305094

Given Data:

Radius of the geostationary orbit: $= r = R+h$

$= 48700$ km

$= 48700\times10^3$ m

$G = 6.673\times10^{-11}\ Nm^2kg^{-2}$

Mass of Earth = $M = 6\times10^{24}$ kg

To find:

$g = ?$

Solution

$$g_h = \frac{GM_e}{(R+h)^2} = \frac{GM_e}{r^2}$$

$$g = \frac{6.673\times10^{-11}\times6\times10^{24}}{(48700000)^2}$$

$$= \frac{40.038\times10^{24-11}}{(487)^2\times(10^5)^2}$$

$$= \frac{40.038\times10^{13}}{237169\times10^{10}}$$

$$= 0.00016\times10^{13-10}$$

$$= 0.00016\times10^3$$

$$g = 0.1688\ ms^{-2}$$

$$g = 0.17\ ms^{-2}$$

Result:

The value of 'g' is $0.17 ms^{-2}$.

5.7. The value of g is $4.0\ ms^{-2}$ at a distance of 10000 km from the centre of the Earth. Find the mass of the Earth. 091305095

Given Data:

$g = 4ms^{-2}$

Height= $h = 10000km$

$h = 10000\times10^3 m$

$h = 10^7 m$

$G = 6.673\times10^{-11} Nm^2\ kg^{-2}$

To find:

Mass of Earth = $M_e = ?$

Solution:

$$g = \frac{GM_e}{R^2}$$

$$M_e = \frac{gR^2}{G}$$

$$= \frac{4\times(10000000)^2}{(6.673\times10^{-11})}$$

$$= \frac{4\times(10^7)^2}{6.673\times10^{-11}}$$

$$= \frac{4\times10^{14}}{6.673\times10^{-11}}$$

$$= 0.599\times10^{14+11}$$

$$= 0.5999\times10^{25}$$

$$= 5.99\times10^{-1}\times10^{25}$$

$$M_e = 5.99\times10^{24}\ kg$$

Result:

The value of mass of the Earth is 5.99×10^{24} kg.

5.8. At what altitude the value of g would become one fourth than on the surface of the earth? (F.B. 2017) 091305096

Given Data

$$g_h = \frac{g}{4}$$

To Find altitude $h = ?$

Solution

As we know that

$$g = \frac{GMe}{R^2} \text{.....(i)}$$

and

$$g_h = \frac{GMe}{(R+h)^2} \text{.....(ii)}$$

From given data

$$g_h = \frac{g}{4}$$

$$\Rightarrow 4g_h = g$$

Put the value of g and 'g_h' from equation (i) and (ii)

$$4\frac{GMe}{(R+h)^2}=\frac{GMe}{R^2}$$

$$\frac{4}{(R+h)^2}=\frac{1}{R^2}$$

$$(R+h)^2=4R^2$$

Taking square root on both sides

$$\sqrt{(R+h)^2}=\sqrt{4R^2}$$

$R + h = 2R$

$h = 2R - R = R = 6.4 \times 10^6$ m

Since altitude $h = R = 6.4 \times 10^6$ m

Result:

Value of 'g' become $\frac{1}{4}$ at an altitude equal to one earth radius.

5.9. A polar satellite is launched at 850 km above Earth. Find its orbital speed. 091305097

Given Data:

$R = 6.4 \times 10^6$m

Height = $h = 850$ km

$h = 850 \times 10^3$m

$G = 6.673 \times 10^{-11}$ Nm^{2}kg^{-2}

$Me = 6 \times 10^{24}$ kg

To find:

$V_{orb} = ?$

Solution

$$g_h = \frac{GM_e}{(R+h)^2}$$

$$= \frac{6.673\times10^{-11}\times6\times10^{24}}{(6.4\times10^6+850000)^2}$$

$$= \frac{40.038\times10^{24-11}}{(6400000+850000)^2}$$

$$= \frac{40.038\times10^{13}}{(7250000)^2}$$

$$= \frac{40.038\times10^{13}}{525625\times10^8}$$

$$= \frac{40.038\times10^{13-8}}{525625}$$

$$= 0.000076172\times10^5$$

$$g_h = 7.6172\,ms^{-2}$$

Now $V_0 = \sqrt{g_h(R+h)}$

$$= \sqrt{7.6172\times(6.4\times10^6+850000)}$$

$$= \sqrt{7.6172\times(6400000+850000)}$$

$$= \sqrt{7.6172\times7250000}$$

$$= \sqrt{55224700}$$

$V_0 = 7431 ms^{-1}$

Result:

The orbital velocity of a polar satellites is $7431 ms^{-1}$.

5.10. A communication satellite is launched at 42000 km above Earth. Find its orbital speed. 091305098

Given data

$h = 42000$km

$h = 42000 \times 10^3$m

Mass of earth = $M_e = 6 \times 10^{24}$kg

$G = 6.673 \times 10^{-11}$ Nm^2 kg^{-2}

To find:

$V_{orb} = ?$

Solution:

$$g_h = \frac{GM}{(R+h)^2}$$

$$= \frac{6.673\times10^{-11}\times6\times10^{24}}{(6.4\times10^6+42000000)^2}$$

$$= \frac{40.038\times10^{24-11}}{(6400000+42000000)^2}$$

$$= \frac{40.02\times10^{13}}{(48400000)^2}$$

$$= \frac{40.038\times10^{13}}{234256\times10^{10}}$$

$$= 0.000171\times10^{13-10}$$

$g_h = 0.000171\times10^3$

$g_h = 0.171\,ms^{-2}$

Now

$v_o = \sqrt{g_h(R+h)}$

$v_o = \sqrt{0.171(6.4\times10^6+42000000)}$

$v_o = \sqrt{0.171(48400000)}$

$= \sqrt{8276400}$

$v_o = 2876 ms^{-1}$

Result:

The orbital velocity of the communication satellite is $2876 ms^{-1}$.

UNIT 06 WORK AND ENERGY

Introduction

In this unit, we will study about work, energy, kinetic energy, potential energy, forms of energy, inter conversion of energy, major source of energy, efficiency and power.

Q.1 Define work. Write its condition, formula and unit. (F.B. 2017) 091306001

Ans. Definition:-

"Work is done when force acting on a body displaces it in the direction of a force".

Work is a scalar quantity. It depends on the force acting on a body, displacement of the body and the angle between them.

Mathematical form

Work is a product of force F and displacement S in the direction of force. Thus

work done = Force × displacement

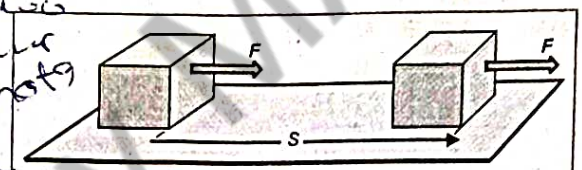
$W = F S$

The unit of work is Joule (J).

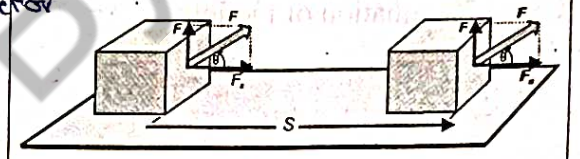
Conditions:- Work only done if:

(i) Force should act on the body.

(ii) Body should cover distance in the direction of force.



Work done in displacing a body in the direction of force.



Work done by a force-inclined with the displacement.

Work along the angle "θ"

Sometimes force and displacement do not have the same direction. Here the force F is acting on the body making an angle θ with the surface on which the body is moved. Resolving F into its perpendicular components F_x and F_y as:

$F_x = F \cos\theta$

$F_y = F \sin\theta$

In the case when force and displacement are not parallel then only the x-component F_x parallel to the surface causes the body to move on the surface and not the y-component F_y.

Hence $W = F_x S$

$= (F \cos\theta) S$

$= F S \cos\theta$

Q.2 What is the unit of work, define it? 091306002

Ans. The SI unit of work is joule (J). It is defined as

"The amount of work is one joule when a force of one newton displaces a body through one metre in the direction of force".

Thus $1\ J = 1\ N \times 1\ m$

Joule is a small unit of work. Its bigger units are:

1 kilo joule (kJ) = $1000\ J = 10^3 J$

1 mega joule (MJ) = $1000,000\ J = 10^6 J$

Q3. Define Energy. Write the names of its forms. 091306003

Ans. Definition:- *"The ability of a body to do work is called energy".*

The energy is an important and fundamental concept in science. It links almost all the natural phenomena. A body has energy if it has the ability to do work.

Mechanical energy possessed by a body is of two types: **kinetic energy** and **potential energy.** Energy is a scalar quantity.

Forms of energy:

Energy exists in many forms such as mechanical energy, heat energy, light energy, sound energy, electrical energy, chemical energy and nuclear energy. It can be transformed from one form to another form. Its unit is also joule.

Q4. Define kinetic energy. Derive its formula K.E = $\frac{1}{2}mv^2$. Write its examples. 091306004

or Define kinetic energy and also write its equation. (F.B. 2017)

Ans. Definition:- *"The energy possessed by a body due to its motion is called its kinetic energy".*

Example:

For example running water, moving wind are the examples of kinetic energy. Wind energy drives windmills and push sailing boats. Moving water in a river can carry wooden logs through large distances and can can be used to drive turbines for generating electricity. Thus a moving body has kinetic energy because it can do work due to its motion.

Derivation:- Consider a body of mass 'm' moving with velocity 'v'. The body stops after moving through some distance 'S' due to some opposing force such as force of friction acting on it. The body possesses kinetic energy and is capable to do work against opposing force 'F' until all of its kinetic energy is used up.

∴ K.E. of the body = work done by it due to motion

K.E. = F S ... ... (1)

v_i = v

As v_f = 0

F = ma

∴ $a = -\frac{F}{m}$

Since motion of object is opposed, hence, 'a' is negative.

Using 3rd equation of motion:

$2aS = v_f^2 - v_i^2$

$2\left(-\frac{F}{m}\right)S = (0)^2 - (v)^2$

$FS = \frac{1}{2}mv^2$ ... ... (2)

From Eq. 1 and 2 we get

$K.E. = \frac{1}{2}mv^2$ ... ... (3)

Equation 3 gives the K.E. possessed by a body of mass m moving with velocity ' v '.

Q5. Define potential energy. Give its examples and derive its equation P.E =m g h. 091306005

or Define potential energy and write its formula.

Ans. Definition:- *"The energy possessed by a body due to its position is known as its potential energy".*

Examples:- Stored water in dam possesses potential energy due to its height. A hammer raised up to some height has the ability to do work because it possesses potential energy. A stretched bow has potential energy due to its stretched position. When released, the stored energy of the bow pushes the arrow out of it. *The energy present in the stretched bow is called* ***elastic potential energy.***

Gravitational potential energy

"The energy present in a body due to its height is called gravitational potential energy"

Derivation

Let a body of mass m be raised up through height h from the ground. The body will acquire potential energy equal to the work done in lifting it to height h.

Thus Potential energy P.E. = F × h

= w × h ∴ F = w

(Here weight of the body = w = mg)

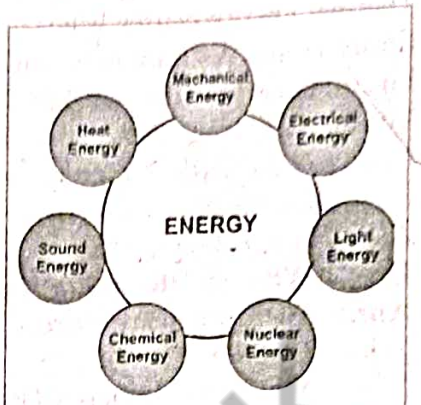
So, P.E = mgh

Thus, the potential energy possessed by the body with respect to the ground is mgh and is equal to the work in lifting it to height h.

Q6. Explain the different forms of energy.

Ans. Energy exists in various forms.

Forms of Energy:



Some of the main forms of energy.

MECHANICAL ENERGY

Ans. Definition:- *"The energy possessed by a body both due to its motion or position is called mechanical energy".*

Example:- Water running down a stream, wind, a moving car, a lifted hammer, a stretched bow, a catapult or a compressed spring etc possess mechanical energy.

i. HEAT ENERGY

Definition:- *" Heat is a form of energy given out by hot bodies".*

Large amount of heat is obtained by burning fuel. Sun is also main source of heat energy. Heat is also produced when motion is opposed by frictional forces. The foods we take provide us heat energy.

ii. ELECTRICAL ENERGY.

Definition:- *"The energy produced by the electricity is called electrical energy"*

Example:- Electrical energy can be supplied easily to any desired place through wires. We get electrical energy from batteries and electric generators. These electric generators are run by hydro power, thermal or nuclear power.

iii. SOUND ENERGY

Definition:- *"It is form of energy which is produced due to vibrating a body".*

Examples:- A vibrating diaphragm of a drum, vibrating strings of a sitar and vibrating air column of wind instruments such as flute pipe produce sound energy.

iv. LIGHT ENERGY:-

Definition: *"The energy obtained from light source is called light energy".* Light is an important form of energy.

Example:- Plants produce food in the presence of light. We also need light to see things. We get light from candles, electric bulbs, fluorescent tubes and also by burning fuel. However, most of the light comes from the Sun.

v. CHEMICAL ENERGY:-

Definition: *"The energy obtained by various chemical reactions is called chemical energy".*

Example:-

Chemical energy is present in food, fuels and in other substances. Electrical energy is obtained from electric cells and batteries as a result of chemical reaction between various substances present in them. Animals get heat and muscular energy from the food they eat.

vi. NUCLEAR ENERGY:-

Definition: *"Nuclear energy is the energy released in the form of nuclear radiations in addition to heat and light during nuclear reactions".*

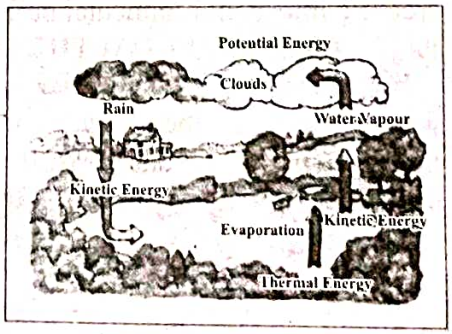
Examples

In fission and fusion reactions heat energy released in nuclear reactors is converted into electrical energy. The energy coming from the sun for the last billions of years is the result of nuclear reactions taking place on the sun.

Q7. Explain interconversion of energy. OR How is energy converted from one form to another? Explain.

091306007

Ans. *"Energy cannot be destroyed, but it can be converted into some other forms of energy".*



i. During the rubbing of our hands we use muscular energy in rubbing hands as a result heat is produced. In the process of rubbing hands, mechanical energy is converted into heat energy.

ii. *Processes in nature are the result of energy changes.*

Example:- Heat energy from the Sun is taken up by water in the oceans. This increases the thermal energy. Thermal energy causes water to evaporate from the surface to form water vapours. These vapours rise up and form clouds. As they cool down, they form water drops and fall down as rain. Potential energy changes to kinetic energy as the rain falls. This rain water may reach a lake or a dam. As the rain water flows down, its kinetic energy changes into thermal energy while parts of the kinetic energy of flowing water is used to wash away soil particles of rocks known as **soil erosion**.

During the interconversion of energy, energy from one form changes to an other form but the total energy at any time remains constant.

Q8. What are the major sources of energy? Explain. 091306008

Ans. There are many sources of energy. Some of them are given below

i. FOSSIL FUELS

We use fossil fuels such as coal, oil and gas to get heat in our houses and run industry and transport. They are usually hydrocarbons (compounds of carbon and hydrogen). When these compounds of carbon burnt, they combine with oxygen from the air. The carbon becomes carbon dioxide; hydrogen becomes hydrogen oxide called **water**; while energy is released in the form of heat.

In case of coal:

Carbon + Oxygen → carbon dioxide + heat energy

Hydrocarbon + Oxygen → carbon dioxide + water + heat energy

The fossil fuels took millions of years for their formation. They are known as **non-renewable resources**. We are using fossil fuels at a very fast rate. Their use is increasing day by day to meet our energy needs. If we continue to use them at present rate, they will soon be exhausted. Once their supply is exhausted, the world would face serious energy crisis.

Thus, fossil fuels would not be able to meet our future energy needs. This would cause serious social and economical problems for countries like us. Therefore, we must use them wisely and at the same time develop new energy sources for our future survival.

Main problems by the burning of fossil fuel:

Fossil fuels release waste products which include carbon mono-oxide, and other harmful gases which pollute the environment. This causes serious health problems such as headache, tension, nausea, allergic reactions, irritation of eyes, nose and throat. Long exposure of these harmful gases may cause asthma, lungs cancer, heart diseases and even damage to brain, nerves and other organs of our body.

ii. NUCLEAR FUELS

In nuclear power plants, we get energy as a result of **fission reaction**. During fission reaction, heavy atoms, such as uranium atoms, spilt up into smaller parts releasing a large amount of energy. Nuclear power plants give out a lot of nuclear radiations and vast amount of heat. A part of this heat is used to run power plants while lot of heat goes waste into the environment.

iii. RENEWABLE ENERGY SOURCES

Sunlight and water power are the renewable sources of energy. They will not run out like coal, oil and gas.

iv. ENERGY FROM WATER

Energy from water power is very cheap. Dams are being constructed which serve for many purposes. They help to control floods by storing water. The water stored in dams is used for irrigation and also to generate electrical energy without creating much environmental problems.

v. ENERGY FROM THE SUN

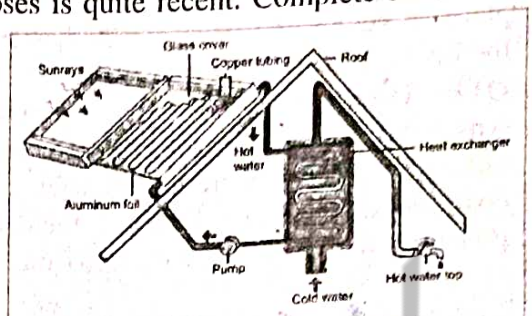
Solar energy is the energy which does not pollute the environment in any way. The rays are the ultimate source of life on the Earth. We are dependent on the Sun for all our food and fuels. If we find a suitable method to use a fraction of the solar energy reaching the Earth, then it would be enough to fulfil our energy requirement.

Q9. Write a note on Solar House Heating System. 091306009

i. SOLAR HOUSE HEATING

The use of solar energy for commercial and industrial purposes is quite recent. Complete solar house heating systems are successfully used in areas with a minimum amount of sunshine in winter. A heating system consists of:

- A collector
- A storage device
- A distribution system



A Solar house heating system.

Solar collector made of glass panels over blank metal plates. The plates absorb the Sun's energy which heats a liquid flowing in the pipes at the back of the collector. The hot water can be used for cooking, washing and heating the buildings.

Solar energy is used in solar cookers, solar distillation plants and solar power plants, etc.

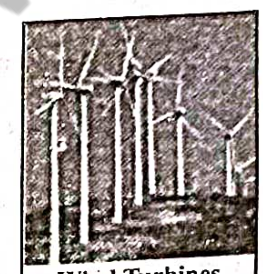
ii. SOLAR CELLS

Solar energy can also be converted directly into electricity by solar cells. A solar cell also called photo cell is made from silicon wafer. When sunlight falls on a solar cell, it converts the light directly into electrical energy. Solar cells are used in calculators, watches and toys. Large numbers of solar cells are wired together to form solar panels. Solar panels can provide power to telephone booths, light houses and scientific research centers. Solar panels are also used to power satellites.

Q10. Write the uses of Wind Energy. 091306010

Ans: WIND ENERGY

Wind has been used as a source of energy for centuries. It has powered sailing ships across the oceans. It has been used by windmills to grind grains and pump water. More recently, wind power is used to turn wind turbines. When many wind machines are grouped together on wind farms, they can generate enough power to operate a power plant. In the United States, some wind farms generate more than 1300 MW of electricity a day.

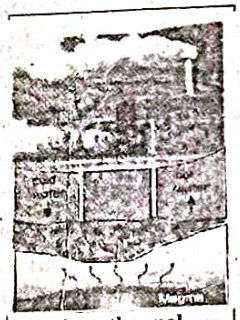

Wind Turbines

Q11. What is the geothermal energy? 091306011

Ans: GEOTHERMAL ENERGY

In some parts of the world, the Earth provides us hot water from geysers and hot springs. There is hot molten part, deep in the Earth called magma. Water reaching close to the magma changes to steam due to the high temperature of magma. This energy is called geothermal energy.

Geothermal well can be built by drilling deep near hot rocks at places, where magma is not very deep. Water is then pushed down into the well. The rocks quickly heat the water and change it into steam. It expands and moves up to the surface. The steam can be piped directly into houses and offices for heating purposes or it can be used to generate electricity.


A geothermal power station

Q12. How energy is obtained from biomass? 091306012

Ans: ENERGY FROM BIOMASS

Biomass is plant or animal wastes that can be burnt as fuel. Other forms of biomass are garbage, farm wastes, sugarcane and other plants. These wastes are used to run power plants. Many industries that use forest products get half of their electricity by burning bark and other wood wastes. Biomass can serve as another energy source, but problems are there in its use.

When animal dung, dead plants and dead animals decompose, they give off a mixture of methane and carbon dioxide. Electricity can be generated by burning methane.


Bio mass plant using animal dung

Q13. What is mass-energy equation? Explain. (F.B. 2016) 091306013

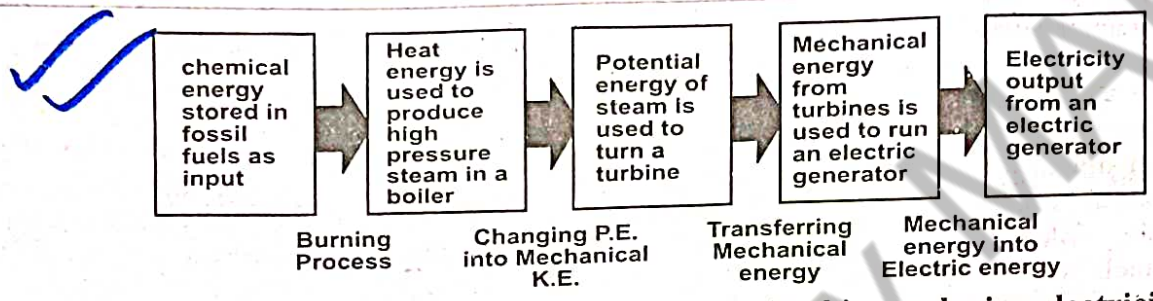
Ans. Einstein gave an idea of inter conversion of matter and energy. According to this theory, *a loss in the mass of a body provides a lot of energy. This happens in nuclear reactions. The relation between mass m and energy E is given by Einstein's mass-energy equation.*

$$E = mc^2$$

Here c is the speed of light (3×10^8 ms^{-1}). This equation shows that large amount of energy can be obtained from small quantity of matter. It appears that matter is a highly concentrated form of energy. The process of getting energy from our nuclear power plants is based on the above equation. The process is taking place on the Sun and stars for the last millions of years. Only a very small fraction of the Sun's energy reaches the Earth. This is very small fraction of the Sun's energy is responsible for life on the Earth.

Q14. How does electricity produce from fossil fuels? 091306014

Ans. We are using electricity in houses, offices, schools, business centers, factories and in farms. We have different ways of generating electricity. Most of the electricity is obtained using fossil fuels such as oil, gas and coal. Fossil fuels are burnt in thermal power stations to produce electricity. Various energy conversion processes in producing electricity from coal are described in a block diagram as shown.



Several energy conversion processes are involved in producing electricity.

Q15. How does the use of energy in different ways pollute our environment? (OR) What are the environmental issues associated with energy? 091306015

Ans. Environmental problem:

Energy has many advantages as well as has following environmental problems.

Pollution

Noise pollution, air pollution and water pollution may arise by using different sources of energy such as fossil fuels and nuclear energy. Pollution is the change in the quality of environment that can be harmful and unpleasant for living things.

Thermal pollution

A temperature rise in the environment that disturbs life is called thermal pollution. Thermal pollution upsets the balance of life and endangers the survival of many species.

Natural processes

Natural processes such as volcanic eruptions, forest fires and dust storms add pollutant to the air. These pollutant, rarely build up to harmful levels.

Burning of fuel

On the other hand, the burning of fuel and solid wastes in homes, automobiles and factories releases harmful amount of air pollutants.

Radioactive wastes

All power plants produce waste heat, but fission plants produce the heat released into a lake, a river or an ocean upsets the balance of life in them. Unlike other power plants, nuclear power plants do not produce carbon dioxide. But they do produce dangerous radioactive wastes.

Q16. What methods should be adopted to control the pollution? 091306016

Ans. In many countries governments have passed laws to control air pollution. Some of these laws limit the amount of pollution that, power plants, factories and automobiles are allowed to give off. To meet these conditions for automobiles, new cars have catalytic converters. These devices convert some polluting gases. The use of lead free petrol has greatly reduced the amount of lead in the air. Engineers are working to improve new kinds of car engines that use electricity or energy sources other than diesel and petrol.

Many individual communities have laws which protect their areas from pollution. Individuals can help to control air pollution simply by reducing the use of cars and other machines that burn fuel. Sharing rides and using public transportation are the ways to reduce the number of automobiles in use.

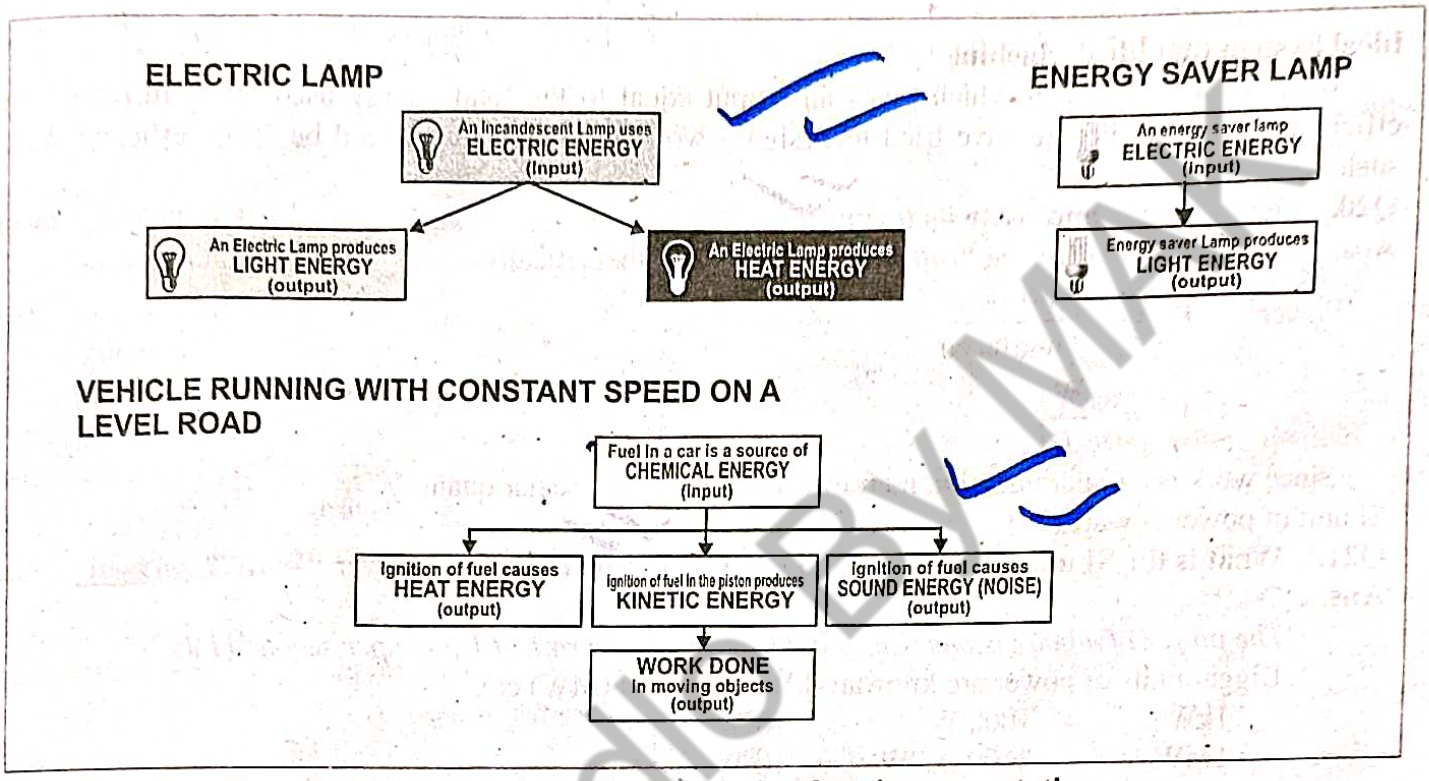
Q17. Explain flow diagram of an energy converter. 091306017

Ans. In an energy converter, a part of the energy taken (used up) by the system is converted into useful work. Remaining part of the energy is dissipated as heat energy, sound energy (noise) into the environment. Energy flow diagrams given below show the energy taken up by an energy converter to transform it into other forms of energy.

ELECTRIC LAMP

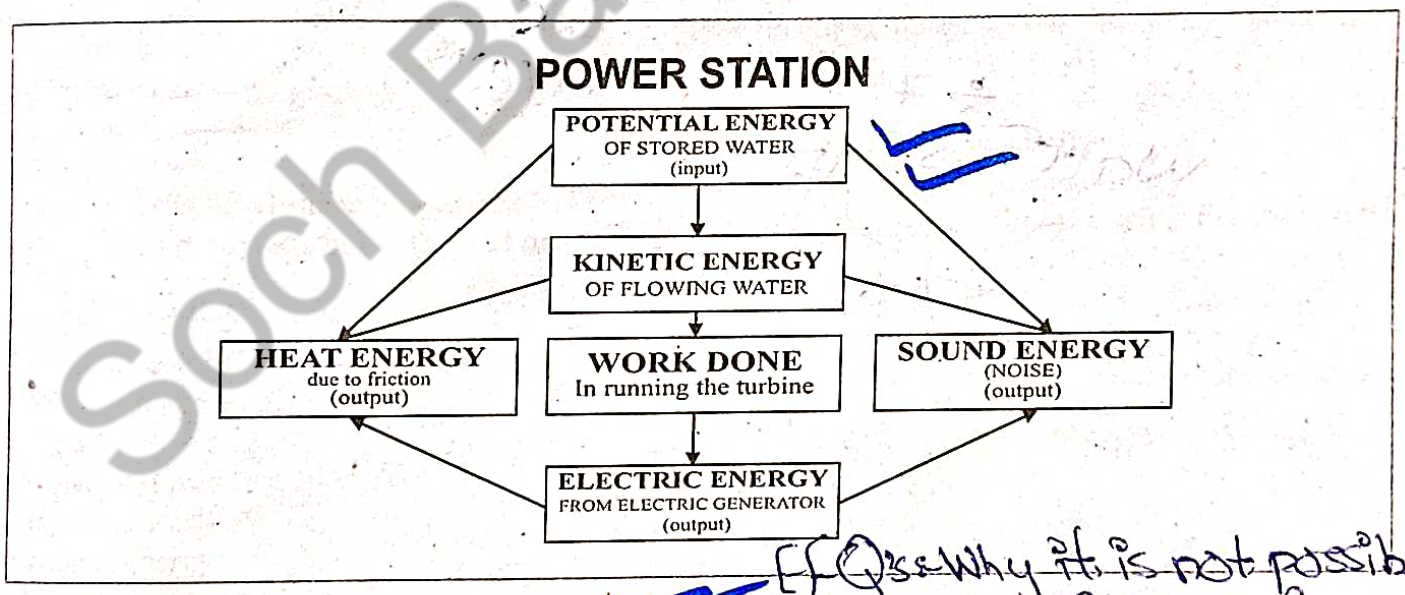
(i) An incandescent Lamp uses electrical energy that is converted in to light energy and heat energy

(ii) Energy saver lamp uses electrical energy that is converted into light energy.



Q18. Make a flow diagram of energy conversion for a hydroelectric power station.

(F.B. 2018) 091306018



Q19. Define efficiency. Write its formula. OR What is meant by the efficiency of a system? 091306019

Ans. *"Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input."*

Formula:

$$\text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}}$$

$$\% \text{ Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \times 100$$

ADDITIONAL INFORMATION

Efficiencies of some typical devices / machines

Energy Input	Device or Machine	Useful work done	% Efficiency
100 J	Electric Lamp	5 J	5 %
100 J	Petrol Engine	25 J	25 %
100 J	Electric Motor	80 J	80 %
100 J	Electric Fan	55 J	55 %
100 J	Solar Cell	3 J	3 %

Ideal System (or) Ideal Machine

An ideal system is that which gives an output equal to the total energy used by it. In other words, its efficiency is 100%. People have tried to design a working system that would be 100% efficient. Practically such system does not exist.

Q20. Define power and write its formula. **(F.B. 2017)** 091306020 **(F.B. 2016)**

Ans. *Power is defined as the "rate of doing work"* Mathematically,

$$\text{Power} \quad P = \frac{\text{Work done}}{\text{Time taken}}$$

$$P = \frac{W}{t}$$

Since work is a scalar quantity, therefore, power is also a scalar quantity.

Sl unit of power is **watt (W)**.

Q21. What is the SI unit of power? Define it. OR Define the unit of power "Watt"? 091306021

Ans. Watt

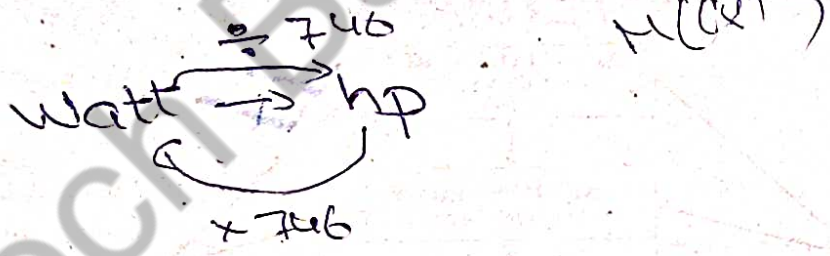
"The power of a body is one watt if it does work at the rate of 1 joule per second (1 Js^{-1})"

Bigger units of power are kilowatt (kW) megawatt (MW) etc.

1kW = 1000 W = 10^3W

1MW = 1000 000W = 10^6W

1 horse power = 1 hp = 746W



MULTIPLE CHOICE QUESTIONS

6.1 Encircle the correct answer from the given choices:

Exercise MCQs

1. The work done will be zero when the angle between the force and the distance is: (F.B. 2017) 091306022
(a) 45° (b) 60°
(c) 90° (d) 180°

2. If the direction of motion of the force is perpendicular to the direction of motion of the body, then work done will be: 091306023
(a) Maximum (b) Minimum
(c) Zero (d) None of the above

3. If the velocity of a body becomes double, then its kinetic energy will: 091306024
(a) Remain the same
(b) Become double
(c) Become four times
(d) Become half

4. The work done in lifting a brick of mass 2 kg through a height of 5m above ground will be: 091306025
(a) 2.5 J (b) 10 J
(c) 50 J (d) 100 J

5. The kinetic energy of a body of mass 2 kg is 25 J. Its speed is: (F.B. 2017) 091306026
(a) $5 ms^{-1}$ (b) $12.5 ms^{-1}$
(c) $25 ms^{-1}$ (d) $50 ms^{-1}$

6. Which one of the following converts light energy into electrical energy? 091306027
(a) Electric bulb
(b) Electric generator
(c) Photocell
(d) Electric cell

7. When a body is lifted through a height h, the work done on it appears in the form of its: 091306028
(a) Kinetic energy
(b) Potential energy
(c) Elastic potential energy
(d) Geothermal energy

8. The energy stored in coal is 091306029
(a) Heat energy
(b) Kinetic energy
(c) Chemical energy
(d) nuclear energy

9. The energy stored in a dam is: 091306030
(a) Electric energy (b) Potential energy
(c) Kinetic energy (d) Thermal energy

10. In Einstein's mass-energy equation, c is the: 091306031
(a) Speed of sound (b) Speed of light
(c) Speed of electron (d) Speed of Earth

Additional MCQs

11. Rate of doing work is called: 091306032
(a) Energy (b) Torque
(c) Power (d) Momentum

12. In Einstein's mass-energy equation, c means speed of light. Its value is: 091306033
(a) $3\times10^{-8} ms^{-1}$ (b) $3\times10^{8} ms^{-1}$
(c) $3\times10^{9} ms^{-1}$ (d) $3\times10^{18} ms^{-1}$

13. Which is possessed by a body if it is capable to do work? 091306034
(a) Energy (b) Power
(c) Force (d) Speed

14. If a person is not moving when he lifts a load on his head work is. 091306035
(a) FS (b) FS cosθ
(c) FS Sinθ (d) Zero

15. Formula of work is: 091306036
(a) FS (b) Fv
(c) $\frac{F}{S}$ (d) $\frac{S}{F}$

16. 1MJ = 091306037
(a) 10^3 J (b) 10^6 J
(c) 10^7 J (d) 10^{-3} J

17. Running water possess energy: 091306037
(a) Kinetic
(b) potential
(c) Elastic Potential energy
(d) Gravitational potential Energy

18. The energy of a body during the motion is called: 091306038
(a) Potential Energy (b) Kinetic Energy
(c) Elastic P.E (d) Heat Energy

19. Formula of Gravitational potential Energy is:
(a) mgh (b) $\frac{mg}{n}$ 091306039
(c) $\frac{1}{2}mv^2$ (d) mg

20. Stretched bow has type of energy:
(a) Kinetic energy (F.B. 2015, 16) 091306040
(b) mgh
(c) Potential energy
(d) Elastic potential energy

21. One horse power is equal to: (F.B. 2016) 091306041
(a) 746 W (b) 749 W
(c) 764 W (d) 794 W

22. Which quantity is scalar? 091306042
(a) Force (b) Power
(c) Velocity (d) Torque

23. Solar cells are also known as: 091306043
(a) Electric cell (b) Photo cells
(c) Sun cells (d) Nuclear Cells

24. A solar cell is made up of wafers of: 091306044
(a) Silicon (b) Aluminium
(c) Nickel (d) Brass

25. How many components are there of a solar heating system? 091306045
(a) 2 (b) 3
(c) 4 (d) 5

26. Kinetic and potential energy are the kinds of energy: 091306046
(a) Chemical (b) Nuclear
(c) Light (d) Mechanical

27. From following, which one is a renewable source of energy? 091306047
(a) Coal (b) Gas
(c) Sunlight (d) Petroleum

28. Mass-energy equation was given by: 091306048
(a) Newton (b) Einstein
(c) Joule (d) Pascal

29. A temperature rise in the environment disturbs life is called: 091306049
(a) Air pollution (b) Land pollution
(c) Noise pollution (d) Thermal pollution

30. What kind of waste is produced by nuclear power plant? 091306050
(a) Carbon dioxide (b) Radioactive
(c) Fuels (d) Toxic material

31. An ideal system gives output: 091306051
(a) 50% (b) 70%
(c) 80% (d) 100%

32. Fossil fuels are usually: 091306052
(a) Carbon dioxide
(b) Hydrogen
(c) Hydrocarbons
(d) Carbon monoxide

33. Einstein's mass-energy equation relation is: 091306053
(a) $E = \frac{1}{2}mc^2$ (b) $E = mc^2$
(c) $E = m^2c$ (d) $E = 2mc^2$

34. The energy present in our food is: 091306054
(a) Mechanical energy
(b) Gravitational potential energy
(c) Chemical energy
(d) Nuclear energy

35. Which of following units is equal to Kgm^2s^{-2}. 091306055
(a) Newton (b) Joule
(c) Watt (d) Coloumb

36. Hammer raised up and stretched bow both have: (F.B. 2017) 091306056
(a) Kinetic energy (b) Potential energy
(c) Heat energy (d) Light energy

37. According to the Einstein mass – energy equation, if mass is one gram then energy is: 091306057
(a) 3×10^{13}J (b) 3×10^{16}J
(c) 9×10^{16}J (d) 9×10^{13}J

38. 1J = _____ 091306058
(a) $N.m^2$ (b) 1N ×1m
(c) $\frac{N}{m}$ (d) $\frac{m}{d}$

39. Which type of energy is possessed by the stored water at height? 091306059
(a) Sound energy
(b) Gravitational potential energy
(c) Light energy
(d) Kinetic energy

40. A body of mass 50 kg is raised to a height of 3m. What is its potential energy? 091306060
(a) 150J (b) 15J
(c) 1500J (d) 15000J

41. The amount of work done in carrying a bag of mass 10 kg to a height of 3.6 m is: (F.B. 2014) 091306061
(a) 360J (b) 36J
(c) 3.6J (d) 3600J

42. Which of the following is a form of biomass? 091306062
(a) Farm wastes (b) Garbage
(c) Sugarcane (d) All of these

43. Formula used to find the K.E of a body is: 091306063
(a) mr^2 (b) $\frac{1}{2}mv$
(c) $\frac{1}{2}mv^2$ (d) $2mv^2$

44. Which type of energy is produced due to vibrating bodies? 091306064
(a) Heat energy (b) Chemical energy
(c) Sound energy (d) Nuclear energy

45. Efficiency of electric motor is: 091306065
(a) 5% (b) 3%
(c) 80% (d) 10%

46. Efficiency of solar cell is: 091306066
(a) 25% (b) 3%
(c) 100% (d) 9%

47. If the mass of a body is halved and the velocity is doubled, then its kinetic energy will be: (F.B. 2018) 091306066 (a)
(a) $\frac{1}{2}mv^2$ (b) mv^2
(c) $2mv^2$ (d) $\frac{1}{4}mv^2$

48. If 100N force moves a body of mass 3kg through a distance of 3m then work done will be: (F.B. 2018) 091306066 (b)
(a) 900J (b) 600J
(c) 300J (d) 100J

ANSWERS

1.	c	2.	c	3.	c	4.	d	5.	a
6.	c	7.	b	8.	c	9.	b	10.	b
11.	c	12.	b	13.	a	14.	d	15.	a
16.	b	17.	a	18.	b	19.	a	20.	d
21.	a	22.	b	23.	b	24.	a	25.	b
26.	d	27.	c	28.	b	29.	d	30.	b
31.	d	32.	c	33.	b	34.	c	35.	b
36.	b	37.	d	38.	b	39.	b	40.	c
41.	a	42.	d	43.	c	44.	c	45.	c
46.	b	47.	b	48.	c				

Exercise Question Answers

Q.6.2 Define work. What is its SI unit? 091306067

Ans: Work:

"Work is done when a force acting on a body displaces it in the direction of a force".

Work is a scalar quantity. It depends on the force acting on a body, displacement of the body and the angle between them.

SI unit:

In SI unit of work is joule (J). It is defined as

"The amount of work is one joule when a force of one newton displaces a body through one metre in the direction of force".

Thus $1\ J = 1\ N \times 1\ m$

Joule is a small unit of work. Its bigger units are:

1 kilo joule (kJ) $= 1000\ J = 10^3 J$

1 mega joule (MJ) $= 1000,000\ J = 10^6 J$

Q.6.3 When does a force do work? Explain. 091306068

Ans. In Physics, work is said to be done when a force acts on a body and moves it in the direction of the force. Greater is the force acting on the body longer is the distance moved by it, larger would be the work done.

Work is the product of force F and displacement S.

Work done = Force × displacement

$W = FS$

Q.6.4 Why do we need energy? 091306069

Ans: We always need energy to do any type of work. The energy has an important and fundamental concept in science. It links almost all the natural phenomena. We say that a body has energy when it has the ability to do work. e.g. water running down the stream has the ability to do work, so it possesses energy. The energy of running water can be used to run water mills or water turbines. Our body gets energy stored in the food we take to perform various activities.

Q.6.5 Define energy, give two types of mechanical energy. 091306070

Ans.

Energy:- "The ability of a body to do work is called energy".

Mechanical energy possessed by a body is of two types: **kinetic energy** and **potential energy.** Energy is a scalar quantity.

Q.6.6 Define K.E. and derive its relation. 091306071

Ans.

Kinetic Energy:- "The energy possessed by a body due to its motion is called its kinetic energy".

Derivation:- Consider a body of mass 'm' moving with velocity 'v'. The body stops after moving through some distance 'S' due to some opposing force such as force of friction acting on it. The body possesses kinetic energy and is capable to do work against opposing force F until all of its kinetic energy is used up.

K.E. $= F.S$ _____ (1)

$v_i = v$

As $v_f = 0$

$F = ma$

$$\therefore \quad a = -\frac{F}{m}$$

Since motion of object is opposed, hence, 'a' is negative.

Using 3rd equation of motion:

$$2aS = v_f^2 - v_i^2$$

$$2\left(-\frac{F}{m}\right)S = (0)^2 - (v)^2$$

$$\frac{2FS}{m} = v^2$$

$$FS = \frac{1}{2}mv^2 \quad \ldots \quad \ldots \quad \ldots \qquad (2)$$

From Eq. 1 and 2 we get

$$K.E. = \frac{1}{2}mv^2 \quad \ldots \quad \ldots \quad \ldots \qquad (3)$$

Q.6.7 Define potential energy and derive its relation. 091306072

Ans.

Potential Energy:- "The energy possessed by a body due to its position is known as its potential energy".

Gravitational potential energy

"The energy present in a body due to its height is called gravitational potential energy"

Derivation

Let a body of mass m be raised up through height h from the ground. The body will acquire potential energy equal to the work done in lifting it to height h.

Thus Potential energy P.E. $= F \times h$

$= w \times h \quad \therefore F = w$

(Here weight of the body = w = mg)

So, P.E = mgh

Thus, the potential energy possessed by the body with respect to the ground is mgh and is equal to the work done in lifting it to height h.

Q.6.8 Why fossil fuels are called non-renewable sources of energy? 091306073

Ans. Fossil fuels took million of years for their formation and they cannot be generated artificially in the short time so they are known as non-renewable resources. We are using fossil fuels at a very fast rate. Their use is increasing day by day to meet our energy needs. If we continue to use them at present rate, they will soon be exhausted. Once their supply is exhausted, the world would face serious energy crisis. Thus, fossil fuels would not be able to meet our future energy needs. This would cause serious social and economical problems for countries like us. Therefore, we must use them wisely and at the same time develop new energy sources for our future survival.

Q.6.9 Which form of energy is most preferred and why? (F.B. 2017) 091306074

Ans. Solar energy is more preferable because it can directly obtain from Sun and it does not have any type of pollution in it. It is also cheaper and renewable source of energy.

Q.6.10 How is energy converted from one form to another? Explain. 091306075

Ans.

"Energy cannot be destroyed, but it can be converted into some other forms of energy".

i. During the rubbing of our hands we use muscular energy in rubbing hands as a result heat is produced. In the process of rubbing hands, mechanical energy is converted into heat energy.

ii. Processes in nature are the result of energy changes.

Example:- Heat energy from the Sun is taken up by water in the oceans. This increases the thermal energy. Thermal energy causes water to evaporate from the surface to form water vapours. These vapours rise up and form clouds. As they cool down, they form water drops and fall down as rain. Potential energy changes to kinetic energy as the rain falls. This rain water may reach a lake or a dam. As the rain water flows down, its kinetic energy changes into thermal energy while parts of the kinetic energy of flowing water is used to wash away soil particles of rocks known as **soil erosion.**

During the interconversion of energy, energy from one form changes to another form but the total energy at any time remains constant.

Q.6.11 Name the five devices that convert electrical energy into mechanical energy.

Ans. (F.B. 2015) 091306076

(1) Electric motor:

Converts electrical energy to mechanical energy

(2) Washing Machine:

In washing machine electrical energy is converted into mechanical energy.

(3) Electric vibrator:

In electric vibrator electrical energy is converted into mechanical energy.

(4) Electric fan:

In electric fan electrical energy is converted into mechanical energy.

(5) Lifts in the buildings:

In lifts electrical energy is converted into mechanical energy.

Q.6.12 Name a device that converts mechanical energy into electrical energy. 091306077

Ans. A.C generator converts the mechanical energy into electrical energy.

Q.6.13 What is meant by the efficiency of a system? 091306078

Ans.

$$E = \frac{\text{required form of output}}{\text{total input energy}}$$

$$\%E = \frac{\text{required form of output}}{\text{total input energy}} \times 100$$

"Efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input."

Q.6.14 How can you find the efficiency of a system? 091306079

Ans.

Efficiency of the system can be found by using the formula:

$$\%\ \text{Efficiency} = \frac{\text{required form of output}}{\text{total input energy}} \times 100$$

Q.6.15 What is meant by the term power? (F.B. 2017) 091306080

Ans.

Power is defined as the "rate of doing work" Mathematically,

$$\text{Power} = P = \frac{\text{Work done}}{\text{Time taken}}$$

$$P = \frac{W}{t}$$

Since work is a scalar quantity, therefore, power is also a scalar quantity

Q.6.16 Define watt. 091306081

Ans.

"The power of a body is one watt if it does work at the rate of 1 joule per second ($1\ Js^{-1}$)"

Bigger units of power are kilowatt (kW) megawatt (MW) etc.

1kW = 1000 W = 10^3W

1MW = 1000 000W = 10^6W

1 horse power = 1 hp = 746W

Additional Short Question Answers

Q.17 How a pole vaulter acquired changes of energy? (OR) Why does a pole vaulter run as fast as possible before jumping over the hurdle/bar? 091306082

Ans: A pole vaulter uses a flexible vaulting pole made of special material. It is capable to store all the vaulter's kinetic energy while bending in the form of potential energy. The vaulter runs as fast as possible to gain speed. The kinetic energy gained by the vaulter due to speed helps him/her to rise up as the vaulter straightens. Thus, he attains height as the pole returns the potential energy stored by the vaulter in the pole.

Q.18 How mechanical energy changes into heat energy? 091306083

Ans. During the rubbing of our hands we use muscular energy as a result heat is produced. In this process mechanical energy is converted into heat energy.

Q19. Differentiate between sound energy and mechanical energy? 091306084

Sound Energy	Mechanical Energy
It is a form of energy which is produced due to vibration of a body	The energy possessed by a body both due to its motion or position is called mechanical energy.

Q20 How can every citizen be helpful in controlling air pollution? 091306085

Ans. Individuals can help control air pollution simply by reducing the use of cars and other machines that burn fuel. Sharing rides and using public transportation are the ways to reduce the number of auto mobiles in use.

Q21. Write two disadvantages of thermal pollution. 091306086

Ans.

1) Thermal pollution upsets the balance of life.

2) It endangers the survival of many species.

Q22. Why geothermal wells are made? 091306087

Ans. Geothermal well can be built by drilling deep near hot rocks at places, where magma is not very deep. Water is then pushed down into the well. The

rocks quickly heat the water and change it into steam. It expands and move up to the surface. The steam can be piped directly in to houses and offices for heating purposes or it can be used to generate electricity.

Q23. How does our body gets energy? 091306088

Ans. Our body gets energy stored in the food we take to perform various activities.

Q24. How does a nuclear power plant get energy? 091306089

Ans. A nuclear power plant uses the energy released in nuclear reactor such as fission to generate electric power.

Q25. Why is it not possible to make a 100% efficient system? (OR) The efficiency of machine is always less than 100%. Why? 091306090

Ans. Every system meets energy losses due to friction that causes heat, noise etc. These are not the useful form of energy and go waste. That's why it is not possible to make 100% efficient system.

Q26. Write down the equation of Einstein and value of c. 091306091

Ans. The relation between mass and energy is given by Einstein and known as Einstein's mass energy equation.

i.e. $E = mc^2$

where $c = 3\times10^8 ms^{-1}$

Q27. What is an ideal system? 091306092

Ans. An ideal system is that which gives an output equal to the total energy used by it. In other words, its efficiency is 100%.

Q.28. What are the bigger units of power? 091306093

Ans. Bigger units of power are kilo watt (kW) and megawatt (MW)

$1\ kW = 1000 = 10^3 W$

$1MW = 1000000\ W = 10^6 W$

Q29. How much Sun's energy reaches the Earth? 091306094

Ans. Only a very small fraction of the sun's energy reaches the Earth. This very small fraction of the sun's energy is responsible for life on Earth.

Q30. Name some uses of solar cells? 091306095

Ans. 1. Solar cells are used in calculators, watches and toys.

2. Large numbers of solar cells are wired together to form panel.

Q31. What are the uses of solar panel? 091306096

Ans. Solar panels can provide power to telephone booths, light houses and scientific research centres.

Solar panels are also used to power satellites.

Q32. What are the components of solar heating system? Name them. 091306097

Ans. A solar heating system consists of three parts:

i. A collector
ii. A storage device
iii. A distribution system

Q33. What are the types of mechanical energy? 091306098

Ans. Mechanical energy possessed by a body is of two types:

i. Kinetic Energy
ii. Potential Energy

Q34. Which kind of energy possessed by stored water and a raised hammer? 091306099

Ans. Stored water and a raised hammer possess potential energy due to its height, which is known as gravitational potential energy.

Q35. What kind of energy possess by running water? 091306100

Ans. Kinetic energy is possessed by running water.

Q36. What will be the kinetic energy of the body if its velocity is double? 091306101

Ans. As

$$K.E = \frac{1}{2}mv^2 \text{ --------- (i)}$$

According to condition if velocity is doubled then.

$$v' = 2v$$

Putting the value of v in eqt.(i)

$$K.E' = \frac{1}{2}mv'^2$$

$$= \frac{1}{2}m(2v)^2$$

$$= \frac{1}{2}m\,4v^2$$

$$K.E' = 4\left(\frac{1}{2}mv^2\right)$$

$$K.E' = 4\,K.E$$

So K.E will become four times if velocity is double.

Q.37. Which energy is possessed by a stretched bow? 091306102

Ans. A stretched bow has potential energy due to its stretched position. When released the stored energy of the bow pushes the arrow out of it. This energy is called elastic potential energy.

Q38. How clouds are formed 091306103

Ans. Heat energy from the sun is taken by water in the oceans. This increases the thermal energy. Thermal energy causes water to evaporate from the surface to form water vapours. These vapours rise up and form clouds.

Q.39 Which energy changes are the reason of soil erosion? 091306104

Ans. As the rain water flows down, its kinetic energy changes into thermal energy while parts of the kinetic energy of flowing water is used to wash away soil particles of rocks known as soil erosion.

Q40. What is the other name of solar cells? 091306105

Ans. Solar cells are also called photo cells.

Q41. In $E = mc^2$, what does 'c' represent? 091306106

Ans. In Einstein's, mass – energy equation, 'c' is the speed of light and its value is 3×10^8 ms^{-1}.

Q42. What is meant by inter conversion of energy? 091306107

Ans. "Energy cannot be destroyed, but it can be converted into some other forms of energy".

Q.43. What is biomass? 091306108

Ans. Biomass is plant or animal wastes that can be burnt as fuel. Other forms of biomass are garbage, farm wastes, sugarcane and other plants.

Q.44. Which power plants produce the most heat? 091306109

Ans. Fission (Nuclear) plant produce the most heat among all power plants.

Q.45. What is meant by nuclear fission reaction? 091306110

Ans. The process during which a heavy atom, such as uranium atoms, split up into smaller parts releasing a large amount of energy is called as nuclear fission reaction.

Q.46. Differentiate between renewable and non-renewable energy sources. 091306111

Ans.

Renewable sources of energy	Non-renewable sources of energy
All those sources of energy which can be reused are called renewable energy sources. These sources are friendly for environment and do not cause any type of pollution. e.g. wind energy, solar energy and energy from water. The sources which will not run out with time are known as renewable sources.	All those sources of energy which cannot be reused are called non-renewable energy sources. These sources of energy cause pollution and are harmful for the environment. e.g. fossile fuels oil, gas and petroleum and nuclear fuels. The sources which will run out with the passage of time are known as non renewable sources.

Q.47. Differentiate between solar cells and solar panels. 091306112

Ans.

Solar Cell	Solar Panels
Solar energy can also be converted directly into electricity by solar cells. A solar cell also called photo cell is made from silicon wafer. When sunlight falls on a solar cell, it converts the light directly into electrical energy. **Uses:** Solar cells are used in calculators, watches and toys.	Large number of solar cells are wired together to form solar panels. **Uses:** Solar panels provide power to telephone booths, light houses and scientific research centers. It is also used to power the satellites in space.

Q.48. Which harmful waste is produced by burning fossil fuels? 091306113

Ans. Fossil fuels release harmful waste products by burning these fuels. These wastes include carbon mono-oxide and other harmful gases. These gases pollute the environment and also causes serious health problems.

Q.49. What health problems created due to burning of fossil fuels? 091306114

Ans. Serious health problems such as headache, tension, nausea, allergic reactions, irritation of eyes, nose and throat is caused due to binding of fossil fuels. Long exposure of these harmful gases may cause asthma, lungs cancer, heart diseases and even damage to brain, nerves and other organs of our body.

Q.50. Differentiate between chemical and mechanical energy? 091306115

Chemical Energy	Mechanical Energy
(i) The energy obtained by various chemical reactions. (ii) Example: chemical energy is present in foods, fuels and in other substances.	(i) The energy possessed by a body due to its motion or position. (ii) Example: Wind, a moving car, a compressed spring etc.

Mini Exercise

Q.1: A crate is moved by pulling the rope attached to it. It moves 10 m on a straight horizontal road by a force of 100 N. How much work will be done if

i. The rope is parallel to the road.

ii. The rope is making an angle of 30° with the road. 091306116

Given Data:

Distance = S = 10m

Force = F = 100N

To Find:

Work = W = ?

Solution:

i. $W = FS\cos\theta$

When rope is parallel to the road then $\theta = 0$

$W = F S \cos(0)$

$W = F S \times 1$

$W = 100 \times 10$

$W = 1000\ J$

ii. For angle $\theta = 30^\circ$

$W = FS \cos 30$

$W = 100 \times 10 \times 0.8666 = 866\ J$

Q.2: The Kinetic energy of a body of mass 2kg is 25 J. Find its speed. 091306117

Given Data:

$m = 2kg$

$K.E = 25J$

To Find:

$v = ?$

Solution:

Formula:

$$K.E = \frac{1}{2}mv^2$$

$$\frac{2K.E}{m} = v^2$$

$$\frac{2\times 25}{2} = v^2$$

Taking square root on both side

$$\sqrt{25} = \sqrt{v^2}$$

$$\sqrt{v^2} = \sqrt{25}$$

$$v = 5ms^{-1}$$

Its speed will be $5ms^{-1}$.

Q.3: A machine does 4 joule of work in 2 sec, calculate its power. 091306118

Given data

Work = W = 4 joule

time = t = 2 sec

To Find:

Power = ?

Solution:

$$P = \frac{W}{t}$$

$$= \frac{4}{2}$$

$$\boxed{P = 2Watt}$$

SOLVED EXAMPLES

Example 6.1

A girl carries a 10 kg bag upstairs to a height of 18 steps, each 20 cm high. Calculate the amount of work she has done to carry the bag. (Take $g = 10ms^{-2}$) 091306119

Given Data:

Mass of the bag m = 10kg

Weight of the bag w = mg

$= 10\ kg \times 10\ ms^{-2}$

$= 100\ N$

To Find: Work = W = ?

Solution:

To carry the bag upstairs, the girl exerts an upward force F equal to W, the weight of the bag. Thus

F = W = 100 N

Height h = 18 x 0.2 m = 3.6 m

W = F.h

= 100 x 3.6 = 360 J

Result:

The girl has done 360 J of work.

Example 6.2

A stone of mass 500g strikes the ground with a velocity of $20ms^{-1}$. How much is the kinetic energy of the stone at the time it strikes the ground? 091306120

Given Data:

m = 500g = 0.5kg

v = $20ms^{-1}$

To Find: K.E = ?

Solution:

Since $K.E = \frac{1}{2} mv^2$

$K.E = \frac{1}{2} \times 0.5 \times (20)^2$

$= \frac{1}{2} \times 0.5 \times 400$

$= 100\ J$

Result:

Thus, the kinetic energy of the stone is 100 J as it strikes the ground.

Example 6.3:-

A body of mass 50kg is raised to a height of 3m. What is its potential energy? 091306121

($g = 10ms^{-2}$)

Given Data:

Mass = m = 50 kg

Height = h = 3 m

g = $10\ ms^{-2}$

To Find:

P.E. = ?

Solution:

as P.E. = m g h

$\therefore$ P.E. = $50 \times 10 \times 3$

= $50 \times 10 \times 3$

= 1500 J

Result:

The potential energy of the body is 1500 J.

Example 6.4

A force of 200 N acts on a body of mass 20 kg. The force accelerates the body from rest until it attains a velocity of 50 ms^{-1}. Through what distance the force acts? (F.B. 2014) 091306122

Given Data:

Force = F = 200N

Mass = m = 20 kg

Velocity = v = $50\ ms^{-1}$

To Find:

Distance = S = ?

Solution:

Since Work done on the body = K. E. Gained by it

$$\therefore \quad FS = \frac{1}{2}mv^2$$

$$S = \frac{(20)\times(50)^2}{2\times 200} = 125 \text{ m}$$

Result:

Thus, the distance moved by the body is 125 m.

Example 6.5

A cyclist does 12 joules of useful work while pedaling his bike from every 100 joules of food energy which he takes. What is his efficiency? 091306123

Solution

Useful work done by the cyclist = 12 J

Energy used by the cyclist = 100 J

$$\text{Efficiency} = \frac{12}{100}$$

$$= 0.12$$

% efficiency = $0.12 \times 100 = 12\%$

Result:

The efficiency of the cyclist is 12%

Example 6.6

A man M_1 takes 80 s in lifting a load of 200 N through a height of 10 m. While another man M_2 takes 10 s in doing the same job. Find the power of each. 091306124

Given data:

F = 200 N

S = 10 m

Time taken by man M_1 = t_1 = 80s

Time taken by man M_2 = t_2 = 10s

To Find:

Power = ?

Solution:

As work done = $F \times S$

$= 200 \text{ N} \times 10 \text{ m}$

$= 2000 \text{ J}$

$$\text{Power of man } M_1 = \frac{\text{Work}}{t_1}$$

$$= \frac{2000}{80} = 25 \text{ Js}^{-1}$$

$= 25$ watts

$$\text{And Power of man } M_2 = \frac{\text{Work}}{t_2}$$

$$= \frac{2000}{10} = 200 \text{ Js}^{-1}$$

$= 200$ watts

Result:

Thus the power of man M_1 is 25 watts and that of man M_2 is 200 watts.

Example 6.7

Calculate the power of a pump which can lift 70 kg of water through a vertical height of 16 meter in 10 seconds. Also find the power in horse power. 091306125

Given Data:

Mass of water = m = 70 kg
Height = S = 16 m
Time taken = t = 10 s

To Find:

Power = ?

Solution:

Force required = F = w = mg
= 70 × 10
= 700 N

Work done W = F × S
W = 700 × 16
= 11200 J

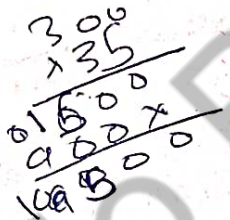
Power $P = \frac{W}{t} = \frac{11200}{10} = 1120\ Js^{-1}$
= 1120 watts

As 1hp = 746 watts

$P = \frac{1120}{746}$ hp
= 1.5 hp

Result:

Thus, power of the pump is 1.5 hp.



NUMERICAL PROBLEMS

6.1 A Man has pulled a cart through 35m applying a force of 300N. Find the work done by the man. (F.B. 2016) 091306126

Given data

Force = F = 300 N
Distance = S = 35 m
Work = W = ?

Solution

W = F × S
W = 300 × 35
W = 10500 J

Result:

The work done by the man is 10500J.

6.2 A block weighing 20N is lifted 6 m vertically upward. Calculate the potential energy stored in it. 091306127

Given data:

Force = F = W = mg = 20 N
Height = h = 6m

To find:

Potential Energy = E = ?

Solution

Potential Energy = mgh
= 20×6
P.E = 120 J

Result:

The potential energy 120J is stored.

6.3 A car weighing 12 kN has speed of 20 ms^{-1}. Find its kinetic energy. 091306128

Given data:

Weight = W = mg = 12 kN
mg = 12× 10^3N
m×10 = 12×10^3

$m = \frac{12\times10^3}{10}$ kg

m = 12×10^2 kg.
v = 20 ms^{-1}.

To find: K.E = ?

Solution

$K.E = \frac{1}{2} mv^2$

$K.E = \frac{1}{2}\times 12^6 \times 10^2 \times (20)^2$

K.E = 6×10^2 × 400

K.E = 2400×10^2 J OR

K.E = 240×10^3 J

K.E = 240 kJ

Result:

The kinetic energy of the car is 240 KJ.

6.4 A 500 g stone is thrown up with a velocity of 15ms^{-1}. Find its, (F.B. 2014) 091306129

(i) P.E at maximum height

(ii) K.E when it hits the ground

Given data:

mass = 500g = $\frac{500}{1000}$ = 0. 5 kg.

Initial velocity = V_i = 15 ms^{-1}

Final velocity = V_f = 0

To Find:

P.E = ?

K.E = ?

Solution

P.E = mgh .....(1)

First we find the height "h"

$2gh = v_f^2 - v_i^2$

$2(-10) \times (h) = 0 - (15)^2$

$-20h = -225$

$h = \frac{-225}{-20}$

h = 11.25m

Put in (1)

P. E = m g h

P. E = (0.5) × (10) × 11.25

P.E = 56.25 J

(ii) $K.E = \frac{1}{2}mv^2$

$= \frac{1}{2} \times 0.5 \times (15)^2$

$= \frac{1}{2} \times 0.5 \times 225$

= 56.25J

Result:

P.E at maximum height will be 56.25J. The K.E when it hits the ground is 56.25J.

6.5 On reaching the top of a slope 6m high from its bottom, a cyclist has a speed of 1.5 ms^{-1}. Find the kinetic energy and the potential energy of the cyclist. The mass of the cyclist and his bicycle is 40kg. 091306130

Given Data:

Height of Inclined Plane = h = 6m

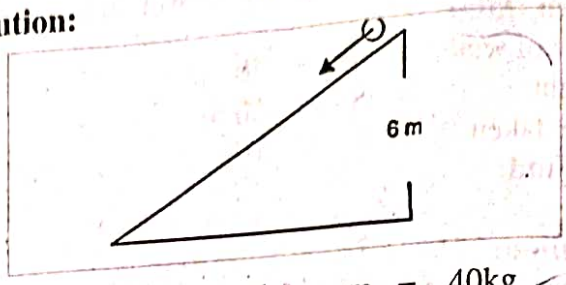
Initial speed = v_i = 1.5 ms^{-1}.

To Find:

K.E = ?

P.E. = ?

Solution:



Mass of cyclist and cycle = m = 40kg.

i) $K.E = \frac{1}{2}mv^2$

$K.E = \frac{1}{2} \times 40 \times (1.5)^2$

K.E = 45 J. Ans.

ii) P.E = mgh

P.E = 40 ×10 × 6

P.E = 2400J

Result:

(i) K.E is equal to 45J.

(ii) P.E of cyclist is 2400J.

6.6 A motor boat moves at a steady speed of 4ms^{-1}. Water resistance acting on it is 4000 N. Calculate the power of its engine. (F.B. 2018) 091306131

Given Data:

Speed of Motor Boat = v = 4ms^{-1}

force = F = 4000 N

To Find:

Power = P = ?

Solution:

$P = \frac{W}{t}$

$P = F.\frac{S}{t}$

$P = F.v \quad \therefore \quad \frac{S}{t} = v$

P = F. v

P = (4000)(4)

P = 16000 W

or **P = 16kW**

Result:

The power of the engine is 16 KW.

6.7 A man pulls a block with a force of 300 N through 50 m in 60 s. Find the power used by him to pull the block. 091306132

Given Data:

Force = F = 300 N

Time = t = 60 s

Height = h = 50 m

To Find:

Power = P = ?

Solution:

$$P = \frac{W}{t} \qquad \therefore W = F.S$$

$$P = \frac{F.S}{t}$$

$$P = \frac{F.h}{t} \qquad (S = h)$$

$$P = \frac{300 \times 50}{60}$$

$$\boxed{P = 250 \text{ watt}}$$

Result:

Power 250W is used by the man to pull the block.

6.8. A 50kg man moved 25 steps up in 20 seconds. Find his power, if each step is 16 cm high. 091306133

Given data

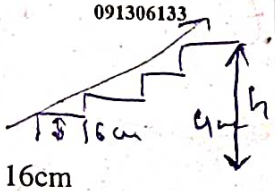
Mass = m = 50 kg

Time = t = 20 sec.

No of steps = 25

Height of each step = h = 16cm

$$= \frac{16}{100} = 0.16\text{m}$$



To Find:

Power = ?

Solution:

First we find the height " h "

Number of steps × height of each step

Total height of 25 steps = h = 25 × 0.16

= h = 4 m

Power = P = ?

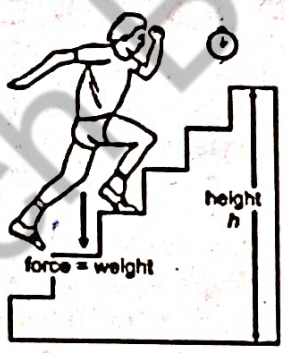
$$P = \frac{W}{t}$$

$$P = \frac{F.S}{t}$$

$$F = W = mg$$

$$P = \frac{mgh}{t}$$

$$P = \frac{50 \times 10 \times 4}{20}$$



$$\boxed{P = 100 \text{ watt}}$$

Result:

The power of the man is 100W.

6.9 Calculate the power of a pump which can lift 200 kg of water through a height of 6 m in 10 seconds. 091306134

Given Data:

mass = m = 200 kg

time = t = 10 sec

height = h = 6m

To Find:

Power = P = ?

Solution:

$$P = \frac{W}{t} \qquad \therefore F = W = mg$$

$$= \frac{F.S}{t} = \frac{mgh}{t} \qquad \therefore S = h$$

$$P = \frac{200 \times 10 \times 6}{10}$$

$$P = 1200 \text{ watt}$$

Result:

1200W power is required to lift the water at height 6m.

6.10 An electric motor of 1 hp is used to run water pump. The water pump takes 10 minutes to fill an overhead tank. The tank has a capacity of 800 liters and height of 15 m. Find the actual work done by the electric motor to fill the tank. Also find the efficiency of the system. 091306135

Given Data:

(Density of water = 1000 kgm^{-3})

(Mass of 1 liter of water = 1kg)

Power of motor = 1 hp.

= 746 watt.

Time = t = 10 min

= 10 × 60 sec

= 600 sec.

Height = h = 15m

Capacity of tank = v = 800 liter.

To Find:

Work = W = ?

Efficiency = ?

Solution:

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

$$P = \frac{W}{t}$$

$$P \times t = W$$

$$746 \times 600 = W$$

Input = $\boxed{W = 447600 \text{ J}}$

Now $\rho = \frac{m}{V}$

$m = \rho \times v$

v = 800 liters

$\therefore$ 1 litre $= 10^{-3} m^3$

$V = 800 \times 10^{-3} m^3$

$m = \rho \times V$

$m = 1000 \times 800 \times 10^{-3}$

$m = 800$ kg

Output $= W = mgh$

$= 800 \times 10 \times 15$

$= 120000$ J

Input $= 447600$J

$\%$ efficiency $= \frac{\text{Output}}{\text{Input}} \times 100$

$= \frac{120000}{447600} \times 100$

$= 26.8\%$

Result:

(a) To fill the tank, the work done by the electric motor is 447600J.

(b) The efficiency of the system is 26.8%.

Actual work = Input

$\therefore$ 800 L = 800 kg

$W = mgh$

$W = mgh$ Output

Input

UNIT 07

PROPERTIES OF MATTER

Introduction

In this chapter we will study about kinetic molecular model of matter, density, pressure, atmospheric pressure, pressure in liquids, upthrust, principle of floatation, elasticity, stress, strain, and young modulus.

Q1. Describe briefly about the matter? 091307001

Ans. Matter exists in three states, solid, liquid and gas. There are many properties associated with matter. For example, matter has weight and occupies space. There are some other properties which are associated with one state of matter but not with other. For example, solids have shape of their own while liquids and gases do not. Liquids on the other hand have definite volume while gases do not have. Various materials differ in their hardness, density, solubility, flow, elasticity, conductivity and many other qualities.

Q2. What are the features of kinetic molecular model of matter? (F.B. 2017) 091307002

Ans. Kinetic molecular model of matter:

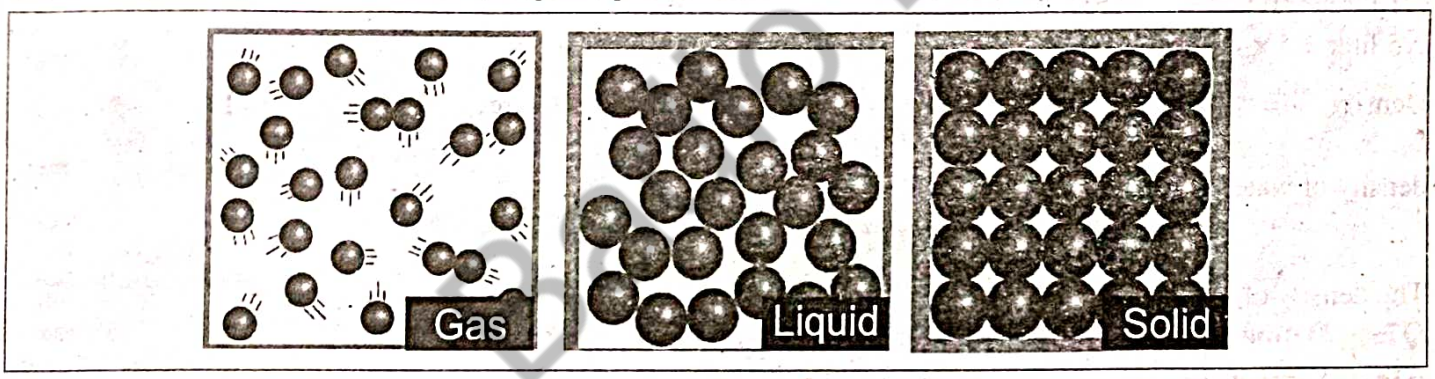
The kinetic molecular model of matter has some important features:

- Matter is made up of many small particles called molecules.
- The molecules remain in continuous motion. Their motion may be translatory, rotatory or vibratory.
- Molecules of matter attract each other. It helps to explain three states of matter.

Q3. Explain states of matter. 091307003

Properties of Solids:

(i) Solid substance having specific shape and volume.
(ii) Their molecules are held closer together by strong forces of attraction.
(iii) They vibrate about their mean positions, but do not move from one place to another place.
(iv) Example of Solids are stone, metal spoon, pencil, etc.



Properties of liquids:

(i) The distances between the molecules of a liquid are more than in solids.
(ii) Attractive forces between them are weaker.
(iii) Like solids, molecules of a liquid also vibrate about their mean position but are not rigidly held with each other.
(iv) Due to the weaker attractive forces, they slide over one another. That's why liquids can flow
(v) The volume of a certain amount of liquid remains the same but due to its property of flow, it attains the shape of a container to which it is put.

Properties of gases:

(i) Gases such as air have no fixed shape or volume.
(ii) Their molecules have random motion and move with very high velocities.
(iii) In gases, molecules are much farther apart than solids or liquids
(iv) Gases are much lighter than solids and liquids.
(v) Gases can be squeezed into smaller volumes.
(vi) The molecules of a gas are constantly striking the walls of a container. Thus, a gas exerts pressure on the walls of the container.

Q.4. Define Plasma. Discuss it as fourth state of matter. 091307004

Ans. Plasma – the fourth state of matter:

The kinetic energy of gas molecules goes on increasing on heating which causes the gas molecules to move faster and faster. The collision between atoms and molecules of the gas become so strong that they tear off the atoms. Atoms lose their electrons and become positive ions. *This ionic state of matter is called plasma.*

(i) *Plasma is also formed in gas discharge tube when electric current passes through these tubes.*

(ii) Plasma is called the fourth state of matter in which a gas occurs in its ionic state.

(iii) Positive ions and electrons get separated in the presence of electric or magnetic fields.

(iv) Plasma also exists in neon and fluorescent tubes when they glow.

(v) Most of the matter that fills the universe is in plasma state. In stars such as our sun, gases exist in their ionic state.

(vi) Plasma is highly conducting state of matter. It allows electric current to pass through it.

Q.5. Define density and write down its mathematical form and unit. 091307005

Ans. Density:

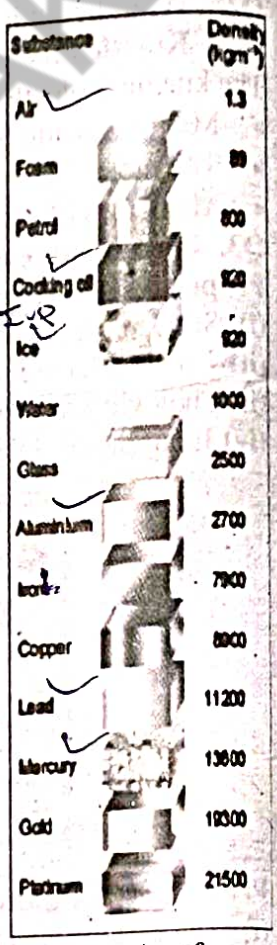
"Density of a substance is defined as its mass per unit volume".

$$\text{Density} = \frac{\text{mass of a substance}}{\text{volume of that substance}}$$

$$\text{Density} = \frac{m}{V}$$

SI unit of density is **kilogram per cubic metre (kgm^{-3}).**

Density can be calculated if mass and volume are known.



Density of various substances

Q.6. Calculate the density of 5 litre of water having mass 5 Kg. 091307006

Ans. Suppose the mass of 5 litre of water is 5 kg its density will be

$\therefore 1 \text{ litre} = 10^{-3} m^3$

$\therefore 5 \text{ liter} = 5 \times 10^{-3} m^3.$

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{density of water} = \frac{5kg}{5 \times 10^{-3} m^3}$$

$$= 1000 \text{ kgm}^{-3}.$$

The density of water is $1000 kgm^{-3}$.

Useful Information

1 metre cube (1 m^3)	= 1000 litre
1 litre	= 10^{-3} m^3
1 cm^3	= 10^{-6} m^3
1000 kgm^{-3}	= 1 gcm^{-3}

Q7. Define pressure and write its formula. 091307007

Ans. Pressure:

The force acting normally per unit area on the surface of a body is called pressure.

Thus Pressure $P = \frac{\text{Force}}{\text{Area}}$

Or $P = \frac{F}{A}$

Quantity: Pressure is a scalar quantity.

Unit: Unit of pressure is Nm^{-2} also called pascal (Pa). Thus

$1 \text{ N m}^{-2} = 1 \text{ Pa}$

Q8. What is atmospheric pressure? Explain it with the help of experiment. (OR) Show by experiment that atmospheric pressure exert in all direction. 091307008

Ans. Atmospheric Pressure:

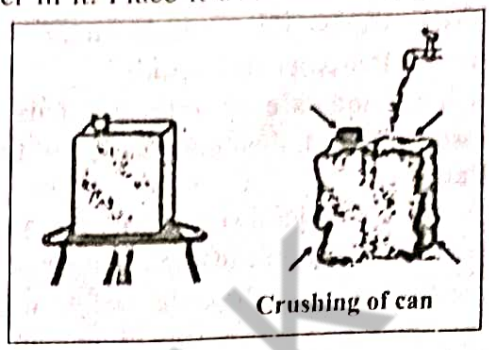
The atmospheric pressure is the weight of gases above a certain point on the earth. The Earth is surrounded by a cover of air called atmosphere. It extends to few hundred kilometers above sea level. Just as certain sea creatures live at the bottom of

Air pressure inside the balloon is equal to the atmospheric pressure.

ocean, we live at the bottom of a huge ocean of air. Air is a mixture of gases. The density of air in the atmosphere is not uniform. It decreases continuously as we go up. The fact that atmosphere exerts pressure can be explained by experiment.

EXPERIMENT:

Take an empty tin can with a lid. Open its cap and put some water in it. Place it over flame. Wait till water begins to boil and the steam expels the air out of the can. Remove it from the flame. Close the can firmly by its cap. Now place the can under tap water.


Crushing of can

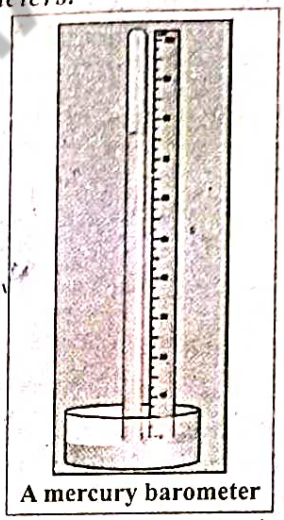
When the can is cooled by tap water, the steam in it condenses. As the steam changes into water, it leaves an empty space behind it. This lowers the pressure inside the can as compared to the atmospheric pressure outside the can. This will cause the can to collapse from all directions. This experiment shows that atmosphere exerts pressure in all directions.

Q. 9 How can we measure the atmospheric pressure? or Explain the method to measure the atmospheric pressure. 091307009

Ans. *"The instruments that are used to measure atmospheric pressure are called barometers.*

Construction:

One of the simple barometers is a mercury barometer. It consists of a glass tube 1m long closed at one end.


A mercury barometer

Working: After filling it with mercury, it is inverted in a mercury trough. Mercury in the tube descends and stops at a certain height. The column of mercury held in the tube exerts pressure at its base. At sea level the height of mercury column above the mercury in the trough is found to be about 76 cm. Pressure exerted by 76 cm of mercury column is nearly 101, 300 Nm^{-2} equal to atmospheric pressure. It is common to express atmospheric pressure in terms of the height of mercury column. As the atmospheric pressure at a place does not remain constant, hence, the height of mercury column also varies with atmospheric pressure. Mercury is 13.6 times denser than water. Atmospheric pressure can hold vertical column of water about 13.6 times the height of mercury column at a place. Thus, at sea level, vertical height of water column would be 0.76 m ×13.6 = 10.34 m. Thus, a glass tube more than 10 m long is required to make a water barometer. At sea level, the atmospheric pressure is about 101,300 Pa or 101, 300 Nm^{-2}.

Q10. Explain the variation in atmospheric pressure. (OR) How atmospheric pressure vary with height. (OR) Write a detailed note on variation in atmospheric pressure. (F.B. 2017) 091307010

Ans. The atmospheric pressure decreases as we go up. The atmospheric pressure on mountains is lower than at sea level. At a height of about 30 km, the atmospheric pressure becomes only 7 mm of mercury which is approximately 1000 Pa. It would become zero at an altitude where there is no air. Thus, we can determine the altitude of a place by knowing the atmospheric pressure at that place.

i. Variation of atmospheric pressure in cold and hot regions:

On a hot day, air above the Earth becomes hot and expands, this causes a fall of pressure in that region. On the other hand, during cold chilly nights, air above the earth cools down. This causes an increase in atmospheric pressure.

ii. Variation of weather due to change of atmospheric pressure:

The changes in atmospheric pressure at a certain place indicate the expected changes in the weather conditions of that place. **For example**, a gradual and average drop in atmospheric pressure means a low pressure in a neighbouring locality. Minor but rapid fall in atmospheric pressure indicates a windy and showery condition in the nearby region. A **decrease in atmospheric pressure** is accompanied by breeze and rain. Whereas a sudden fall in atmospheric pressure often followed by a storm, rain and typhoon to occur in few hours time.

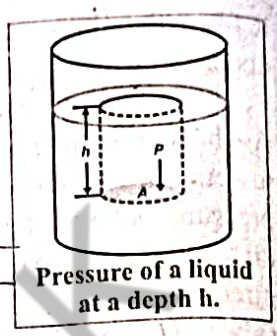
An increasing atmospheric pressure with a decline later on predicts an intense weather conditions. A gradual large increase in the atmospheric pressure indicates a long spell of pleasant weather. A rapid increase in atmospheric pressure means that it will soon be followed by a decrease in the atmospheric pressure indicating poor weather ahead.

Q.11 What do you mean by pressure of liquids? Also prove that P= ρgh. **(F.B. 2017)** 091307011

(OR) Derive the formula for pressure in any liquid.

Ans. Pressure in Liquids

Liquids exert pressure. This acts in all directions. If we take a pressure sensor inside a liquid, then the pressure of the liquid varies with the depth of sensor.



Pressure of a liquid at a depth h.

Proof

Consider a surface of area A in a liquid at a depth h as shown by shaded region in figure. The length of the cylinder of liquid over this surface will be h. The force acting on this surface will be the weight w of the liquid above this surface. If ρ is the density of the liquid and m is mass of liquid above the surface, then

Mass of the liquid cylinder m = volume × density

$$m = (A \times h) \times \rho \quad \ldots\ldots\ldots\ldots (i)$$

Force acting on area A = F = w = mg ……(ii)

Put (m) in eq.(ii)

$$F = A h \rho g$$

By the definition of pressure.

$$P = \frac{F}{A}$$

$$= \frac{A h \rho g}{A}$$

$$\boxed{P = \rho g h}$$

∴ Liquid pressure at depth h = P = ρ g h … (7.3)

Result gives the pressure at a depth h in a liquid of density ρ. It shows that pressure in a liquid increases with the increase in depth.

Characteristics of Liquid Pressure:

The pressure at any point in a liquid has following characteristics.

(i) Liquid exert pressure in all directions.

(ii) Liquid pressure depends on the density and depth of liquid.

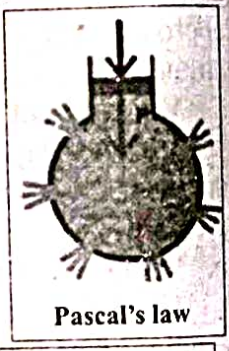
(iii) The formula for liquid pressure is P = ρ gh.

It means that with the increase in depth of liquid, liquid pressure increases.

Q12. State the Pascal's law. What are its applications in our daily life? **(F.B. 2017-18)** 091307012

Ans. Pascal's Law:

"Pressure applied at any point of a liquid enclosed in a container, is transmitted without loss to all other parts of the liquid".


Pascal's law

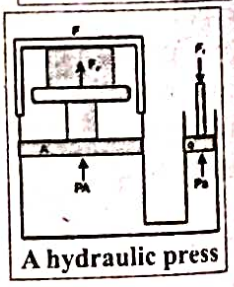
Explanation:

It can be demonstrated with the help of a glass vessel having holes all over its surface as shown in figure. Fill it with water. Push the piston. The water rushes out of the holes in the vessel with the same pressure. The force applied on the piston exerts pressure on water. This pressure is transmitted equally throughout the liquid in all directions.

In general, this law holds good for fluids both for liquids, as well as gases.

Applications of Pascal's Law:

Pascal's law is applicable in many ways in our daily life such as automobiles, hydraulic brake system, hydraulic jack, hydraulic press and other hydraulic machine.


A hydraulic press

Q13. Explain the working of Hydraulic press. (OR) Find force applied on large piston using Pascal's law in hydraulic press. 091307013

Ans. Hydraulic press is a machine which works on Pascal's law.

Construction:

It consists of two cylinders of different cross- sectional areas. They are fitted with pistons of cross-sectional areas **a** and **A**.

Working:

The object to be compressed is placed over the piston of large cross-sectional area **A**. The force F_1 is applied on the piston of small cross- sectional area **a**. The pressure **P** produced by small piston is transmitted equally to the large piston and a force F_2 acts on **A** which is much larger than F_1

Pressure on piston of small area **"a"** is given by

$$P = \frac{F_1}{a} \quad \ldots\ldots\ldots\ldots (1)$$

Apply Pascal's law, the pressure on large piston of area A will be the same as on small piston.

$$\therefore \quad P = \frac{F_2}{A} \quad \ldots\ldots\ldots\ldots (2)$$

Comparing the equations (1) and (2) we get

$$\frac{F_2}{A} = \frac{F_1}{a}$$

$$\therefore \quad F_2 = A \times \frac{F_1}{a}$$

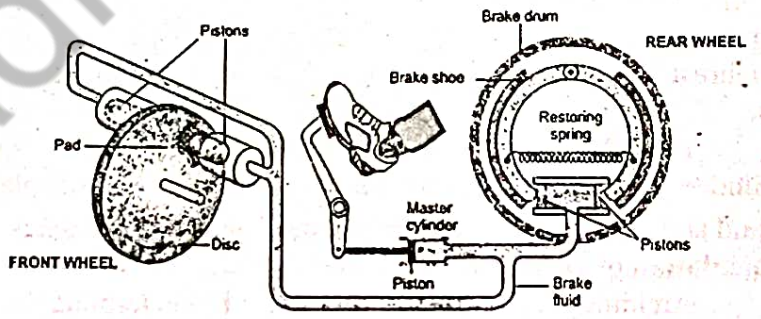
$$\text{or} \quad F_2 = F_1 \times \frac{A}{a} \quad \ldots$$

Conclusion:

Since the ratio $\frac{A}{a}$ is greater than 1, hence the force F_2 that acts on the larger piston is greater than the force F_1 acting on the smaller piston. Hydraulic systems working in this way are known as **force multipliers.**

Q14. Explain braking system in vehicles which work on the principle of Pascal's law. 091307014

Ans. The braking system of cars, buses, etc. also work on Pascal's law. The hydraulic brakes allow equal pressure to be transmitted throughout the liquid. When brake pedal is pushed, it exerts a force on the master cylinder, which increases the liquid pressure in it. The liquid pressure is transmitted equally through the liquid in the metal pipes to all the pistons of other cylinders. Due to the increase in liquid pressure, the pistons in the cylinders move outwards pressing the brake pads with the brake drums. The force of friction between the brake pads and the brake drum stops the wheels.



A hydraulic brake of a car

Q15. State and explain Archimedes principle. How can we determine the density of solid using it? (F.B. 2014,17) 091307015

Ans. Statement:

"When an object is totally or partially immersed in a liquid, an upthrust acts on it equal to the weight of the liquid it displaces".

Explanation:

Consider a solid cylinder of cross-sectional area 'A' and height "h" immersed in a liquid. Let 'h_1' and 'h_2' be the depths of the top and bottom faces of the cylinder respectively from the surface of the liquid.

Then $h_2 - h_1 = h$

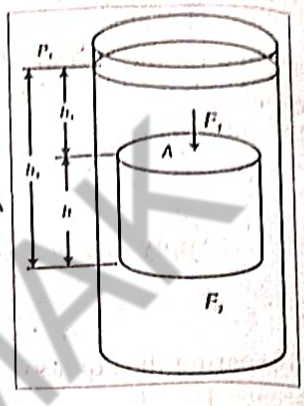
If P_1 and P_2 are the liquid pressures at depths h_1 and h_2 respectively and ρ is its density, then according to equation

$P_1 = \rho g h_1$ ..... (1)

$P_2 = \rho g h_2$ ..... (2)

Let the force F_1 is exerted at the cylinder top by the liquid due to pressure P_1 and the force F_2 is exerted at the bottom of the cylinder by the liquid due to P_2

By the definition of pressure



Force at top:

$P_1 = \frac{F_1}{A}$

$F_1 = P_1 A$

$F_1 = \rho g h_1 A$

Force at bottom:

$P_2 = \frac{F_2}{A}$

$F_2 = P_2 A$

$F_2 = \rho g h_2 A$

F_1 and F_2 are acting on the opposite faces of the cylinder. Therefore, the net force F will be $F_2 - F_1$ in the direction of F_2. This net force F on the cylinder is called the **upthrust of the liquid.**

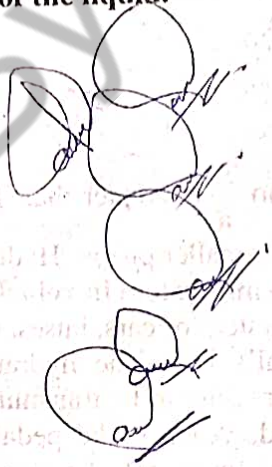
$\therefore \quad F_2 - F_1 = \rho g h_2 A - \rho g h_1 A$

$F_2 - F_1 = \rho g A (h_2 - h_1)$ $\quad \therefore h_2 - h_1 = h$

Or Upthrust force of liquid $= \rho g Ah$.

Or $= \rho g V$ $\quad \therefore V = Ah$

$\therefore m = \rho \times v$



$F_2 - F_1 = m \times g$

$F_2 - F_1 = mg$

Up thrust $= mg$

Up thrust $= F = w$

So,

Here Ah is the volume V of the cylinder and is equal to the volume of the liquid displaced by the cylinder. Therefore, $\rho g V$ is the weight of the liquid displaced. An upthurst acts on the body immersed in a liquid and is equal to the weight of liquid displaced, which is Archimedes principle.

Calculation of Density of an Object:

Archimedes principle is also helpful to determine the density of an object. The ratio in the weights of a body with an equal volume of liquid is the same as in their densities.

Let Density of the object $= D$

Density of the liquid $= \rho$

Weight of the object $= w_1$

Weight of equal volume of liquid. $= w = w_1 - w_2$. Here w_2 is the weight of the solid in liquid According to Archimedes principle, w_2 is less than its actual weight w_1 by an amount w.

Since $\frac{D}{\rho} = \frac{w_1}{w}$

$\therefore \quad D = \frac{w_1}{w} \times \rho$ Or $\boxed{D = \frac{w_1}{w_1 - w_2} \times \rho}$

Hence this formula is used to measure the density of any object.

Q16. Under what conditions an object sinks and floats on the surface of water? 091307016

Ans: An object sinks if its weight is greater than the upthrust force acting on it. An object floats if its weight is equal or less than the upthrust force. An object floats in a liquid if the upthrust acting on it is equal to the weight of the object.

Q17. What is the principle of floatation? 091307017

Ans. Principle of Floatation:

"A floating object displaces a fluid having weight equal to the weight of the object".

Explanation:

In case of floating object, the object may be partially immersed. The upthrust is always equal to the weight of the fluid displaced by the object. This is the principle of the fluid displaced by the object.

Q18. Write the Applications of Archimedes principle. 091307018

Ans. SHIPS AND SUBMARINES

Ships:

Wooden Block: A wooden block floats on water. It is because the weight of an equal volume of water is greater than the weight of the block. According to the principle of floatation, a body floats if it displaces water equal to the weight of the body when it is partially or completely immersed in water.

Ships and boats: Ships and boats are designed on the same principle of floatation. They carry passengers and goods over water. It would sink in water if its weight including the weight of the passengers and goods becomes greater than the upthrust of water.

Submarine: A Submarine can travel over as well as under water. It also works on the principle of floatation. It floats over water when the weight of water equal to its volume is greater than its weight. Under this condition, it is similar to a ship and remains partially above water level. It has a system of tanks which can be filled with and emptied from sea water. When these tanks are filled with seawater, the weight of the submarine increases. As soon as its weight becomes greater than the upthrust, it dives into water and remains under water. To come up on the surface, the tanks are emptied from sea water.

Q19. Define elasticity. **(Board 2016)** 091307019

Ans. *"The property of a body to restore its original size and shape as the deforming force ceases to act is called elasticity."*

Q20. Define stress and write its formula and unit. 091307020

Ans. *"The deforming force acting on unit area at the surface of a body."*

$$\text{Thus} \quad \text{Stress} = \frac{\text{Force}}{\text{Area}}$$

In SI, the unit of stress is Newton per square metre (Nm^{-2}).

Q21. Define and Explain Strain. 091307021

Ans. Definition:

"The ratio of change in size to the original size is called strain"

Explanation: When stress acts on a body, it may change its length, volume, or shape. A comparison of such a change caused by the stress with the original length, volume or shape is called as strain. If stress produces a change in the length of an object then the strain is called tensile strain.

$$\text{Tensile strain} = \frac{\text{change in length}}{\text{original length}} = \frac{\Delta L}{L_o}$$

Strain has no unit as it is a ratio between two similar quantities.

Q22. State and explain Hooke's Law. or Define Hooke's law and elastic limit.

(F.B. 2018) 091307022

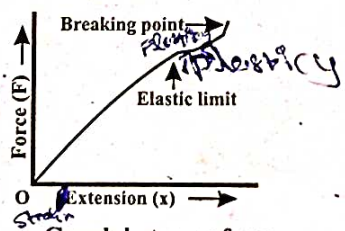
Ans. HOOKE'S LAW:

"The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body".

Thus stress $\propto$ strain

Or stress = constant $\times$ strain

Or $\frac{\text{stress}}{\text{strain}} = \text{constant} \quad \ldots$



Graph between force and extension

Elastic limit:

Hooke's law is applicable to all kinds of deformation and all types of matter i.e. solids, liquids or gases within certain limit. This limit tells the maximum stress that can be safely applied on a body without causing permanent deformation in its length, volume or shape. In other words, it is a limit within which a body recovers its original length, volume or shape after the deforming force is removed. When a stress crosses this limit, called the **elastic limit**, a body is permanently deformed and is unable to restore its original state after the stress is removed.

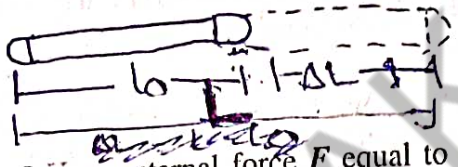
Q23. What do you mean by Young's modulus? Derive formula to calculate young's modulus. 091307023

Ans. Young's Modulus:

"The ratio of stress to tensile strain is called young's modulus".

Mathematically,

$$\text{Young's modulus } Y = \frac{\text{stress}}{\text{Tensile strain}}$$



Explanation:

Consider a long bar of length L_o and cross-sectional area A. Let an external force F equal to the weight W stretches it such that the stretched length becomes L. According to Hooke's law, the ratio of this stress to tensile strain is constant within the elastic limit of the body.

Let ΔL be the change in length of the rod, then

$$\Delta L = L - L_o$$

$$\text{Since Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

$$\text{And Tensile strain} = \frac{L - L_o}{L_o} = \frac{\Delta L}{L_o}$$

$$\text{As } Y = \frac{\text{stress}}{\text{Tensile strain}}$$

$$= \frac{F}{A} \times \frac{L_o}{\Delta L}$$

$$\therefore \boxed{Y = \frac{FL_o}{A\Delta L}}$$

SI unit of young's modulus is **Newton per square metre (Nm^{-2}).**

Young's Modulus of some common materials

Material	Young's modulus $\times 10^9$ Nm^{-2}
Aluminium	70
Bone	0.02
Brass	91
Coppper	110
Diamond	1120
Glass	60
Iron	190
Lead	16
Nickel	200
Rubber	0.0007
Steel	200
Tungsten	400
Wood (Parallel gain)	10
Wood (Perpendicular gain)	1

MULTIPLE CHOICE QUESTIONS

7.1 Encircle the correct answer form the given choices:

Exercise MCQs

1. In which of the following state molecules do not leave their position? 091307024
(a) Solid (b) liquid
(c) gas (d) plasma

2. Which of the substance is the lightest one? (F.B. 2017) 091307025
(a) copper (b) mercury
(c) aluminum (d) lead

3. SI unit of pressure is pascal, which is equal to: 091307026
(a) 10^4 Nm^{-2} (b) 1 Nm^{-2}
(c) 10^2 Nm^{-2} (d) 10^3 Nm^{-2}

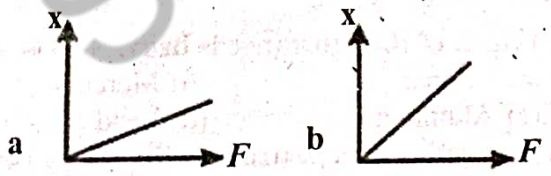
4. What should be the approximate length of a glass tube to construct a water barometer? (F.B. 2015) 091307027
(a) 0.5 m (b) 1 m
(c) 2.5 m (d) 11m

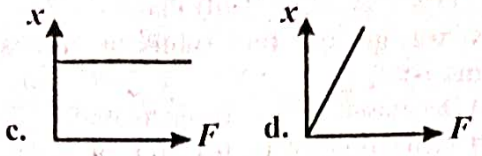
5. According to Archimedes, upthrust is equal to: 091307028
(a) weight of displaced liquid
(b) volume of displaced liquid
(c) mass of displaced liquid
(d) none of these

6. The density of a substance can be found with the help of : 091307029
(a) Pascal's law
(b) Hooke's law
(c) Archimedes principle
(d) Principle of floatation

7. According to Hooke's law: 091307030
(a) Stress × strain = constant
(b) Stress / strain = constant
(c) S train / stress = constant
(d) Stress = strain

The following force-extension graphs of a spring are drawn on the same scale. Answer the questions given below from (viii) to (x). 091307031





8. Which graph does not obey Hooke's law as shown in above _____ 091307032
(a) (b)
(c) (d)

9. Which graph gives the smallest value of spring constant? 091307033
(a) (b)
(c) (d)

10. Which graph gives the largest value of spring constant? 091307034
(a) (b)
(c) (d)

Additional MCQs

11. Substances having specific shape and volume are called: 091307035
(a) solids (b) liquids
(c) gases (d) plasma

12. Such state of matter which has no specific shape is called: 091307036
(a) solid (b) liquid, gas
(c) gas (d) solid & plasma

13. Most of the matter that fills the universe is in state: 091307037
(a) solid (b) plasma
(c) liquid (d) gas

14. 1litre is equal to: 091307038
(a) 10^2 m^3 (b) 10^{-3}m^3
(c) 10^3 m^3 (d) 10^6 m^3

15. The formula of Density is: 091307039
(a) $\frac{m}{v}$ (b) $\frac{v}{m}$
(c) m x v (d) None of these

16. Pressure is quantity: 091307040
(a) Scalar (b) Vector
(c) Constant (d) Dependent

17. The formula of pressure is: 091307041
(a) F × a (b) $\frac{A}{F}$
(c) $\frac{F}{A}$ (d) F . a

18. The density of water is: 091307042
(a) 5500 kgm^{-3} (b) 10000 kgm^{-3}
(c) 1000 kgm^{-3} (d) 330 kgm^{-3}

19. The Fourth state of matter is: 091307043
(a) Solid (b) Liquid
(c) Gas (d) Plasma

20. As we go up the value of atmospheric pressure is: 091307044
(a) Decreased (b) Increased
(c) Remains constant (d) None of these

21. At sea level, the atmospheric pressure is about: 091307045
(a) 101320 Pa (b) 101300 Pa
(c) 10110 Pa (d) 10112 Pa

22. Atmospheric pressure is measured by an instrument called: 091307046
(a) Barometer (b) Altimeter
(c) Meter rod (d) Hydrometer

23. How many times Mercury is denser than water? 091307047
(a) 12.5 (b) 13.6
(c) 76 (d) 76.5

24. During the hot summer day the value of atmospheric pressure is: 091307048
(a) Increases (b) Decreases
(c) Constant (d) Four times

25. Which of the following works on Pascal's law? 091307049
(a) Screw gauge (b) Vernier callipers
(c) Hydraulic press (d) Wedge

26. In SI system, unit of density is: 091307050
(a) kgm^{-1} (b) kgm^{-3}
(c) kgm^{-2} (d) kgm

27. Hydraulic press is a machine which works on: 091307051
(a) Hook's law
(b) Pascal's law
(c) Boyle's law
(d) Archimedes principle

28. Density is quantity: 091307052
(a) Scalar (b) Vector
(c) Constant (d) Base

29. Highly conducting state of matter is: 091307053
(a) Solid (b) Liquid
(c) Gas (d) Plasma

30. As we go up the density of air in the atmosphere: 091307054
(a) decreases (b) increases
(c) remain constant (d) none of these

31. At a height of 30km, atmospheric pressure is: 091307055
(a) 101300Pa (b) 1000 Pa
(c) 10000 Pa (d) 101325 Pa

32. Where there is no air the atmospheric pressure is: 091307056
(a) Zero (b) $101300P_a$
(c) 7 nm Hg (d) $1000Nm^{-2}$

33. Minor but rapid change in atmospheric pressure causes: 091307057
(a) Poor condition
(b) Intense condition
(c) Windy condition
(d) Pleasant condition

34. Decrease in atmospheric pressure predicts: 091307058
(a) Breeze + Rainy condition
(b) Intense condition
(c) Windy condition
(d) Pleasant condition

35. An increasing atmospheric pressure with decline rate cause: 091307059
(a) Rainy condition
(b) Pleasant condition
(c) Windy condition
(d) Intense condition

36. A gradual large increase in atmospheric pressure shows: 091307060
(a) Pleasant condition
(b) Rainy condition
(c) Intense condition
(d) Windy condition

37. Which property can be determine by Archimedes principle: 091307061
(a) Vapour pressure (b) Density
(c) Compressibility (d) Elasticity

38. The type of hydrometer which is used to measure the concentration of acid in a battery is called: 091307062
(a) Chemical meter (b) Acid meter
(c) Barometer (d) pH meter

39. Formula for finding the density of an object is: 091307063
(a) $D = \frac{w_2}{w_2 + w_1}\rho$ (b) $\rho = \frac{w_1}{w_1 - w_2}D$
(c) $D = \frac{w_1}{w_1 - w_2}\rho$ (d) $\rho = \frac{w_2}{w_2 + w_2}D$

40. Which of the substance is heaviest? 091307064
(a) Copper (b) Mercury
(c) Aluminum (d) Lead

41. Atmospheric pressure acts in: 091307065
(a) Upward direction
(b) Downward direction
(c) Opposite to force
(d) All direction

42. Liquid pressure at depth h is: 091307066

(a) ρ/gh (b) $h/\rho g$

(c) ρgh (d) $1/\rho gh$

43. Archimedes is a scientist: 091307067

(a) Greek (b) Italian

(c) French (d) English

44. Unit of strain is: 091307068

(a) Nm^{-2} (b) Nm

(c) N (d) No unit

45. Tensile strain produces the change in the object: 091307069

(a) length (b) Volume

(c) Area (d) Density

46. Young's Modulus = 091307070

(a) $A\Delta/FL_o$ (b) $FL_o/A\Delta L$

(c) $AF/L_o\Delta L$ (d) $F\Delta L/AL_o$

47. Hooke's law is applicable to _____ (F.B 2014) 091307071

(a) Solids (b) Liquids

(c) Gases (d) All of these

48. Unit of Young's Modulus is: 091307072

(a) Nm (b) Nm^{-2}

(c) Nm^{-1} (d) Nm^2

49. Upthrust is equal to: 091307073

(a) $\frac{\rho}{V}$ (b) ρm

(c) ρgV (d) $\rho \times m$

50. Young's Modulus of aluminium is: 091307074

(a) $70 \times 10^9\ Nm^{-2}$ (b) $110 \times 10^9\ Nm^{-2}$

(c) $10\ Nm^{-2}$ (d) $400 \times 10^9\ Nm^{-2}$

51. Density of air is: 091307075

(a) $1.3\ Kgm^{-3}$ (b) $1000\ Kgm^{-3}$

(c) $2500\ Kgm^{-3}$ (d) $3000\ Kgm^{-3}$

52. $1m^3$ = _____: 091307076

(a) 1000 litre (b) 10 litre

(c) 1 litre (d) 100 litre

53. $1cm^3$ = _____: 091307077

(a) $10^{-9}m^3$ (b) $10^{-6}m^3$

(c) $10^{-12}m^3$ (d) $10^{-15}m^3$

54. In which direction, liquid exert pressure? 091307078

(a) One direction (b) Two direction

(c) Three direction (d) All direction

55. Pressure of a liquid depends on: (F.B. 2018) 091307078 (a)

(a) Depth in the liquid

(b) Depth and density of the liquid

(c) Depth and mass of the liquid

(d) Density and weight of the liquid

ANSWERS

1.	a	2.	c	3.	b	4.	d	5.	a
6.	c	7.	b	8.	c	9.	d	10.	a
11.	a	12.	b	13.	b	14.	b	15.	a
16.	a	17.	c	18.	c	19.	d	20.	a
21.	b	22.	a	23.	b	24.	b	25.	c
26.	b	27	b	28	a	29	d	30	a
31.	b	32.	a	33.	c	34.	a	35.	d
36.	a	37.	b	38.	b	39.	c	40.	b
41.	d	42.	c	43.	a	44.	d	45.	a
46.	b	47.	d	48.	b	49.	c	50.	a
51.	a	52.	a	53.	b	54.	d	55.	b

Q.7.2 How kinetic molecular model of matter is helpful in differentiating various states of matter? 091307079

Ans. By finding density, solubility, motion of molecules we can differentiate between solids liquids and gases. Kinetic molecular theory deals with the motion of particles of matter. Kinetic molecular theory is useful in describing the properties of solids, liquids and gases. It is also helpful for explaining, why substances change their phase under certain conditions.

Q.7.3 Does there exist a fourth state of matter? What is that? 091307080

Ans. Yes! there is fourth state of matter which is called plasma. Plasma consists of ions which exists on Sun and in fluorescent tubes. Plasma is the highly conducting state of matter. It allows electric current to pass through it.

Q.7.4. What is meant by density? What is its SI unit? 091307081

Ans. Density of a substance is defined as its mass per unit volume.

$$\text{Density} = \frac{\text{mass of a substance}}{\text{Volume of that substance}}$$

$$\text{Density} = \frac{m}{v}$$

$$\text{SI unit} = \frac{kg}{m^3} = \text{kgm}^{-3}$$

Q.7.5 Can we use a hydrometer to measure the density of milk? 091307082

Ans. Yes! we can find the density of milk by hydrometer. But for this we use a special hydrometer called lactometer.

Q.7.6. Define the term pressure. 091307083

Ans. The force acting normally per unit area on the surface of a body is called pressure.

$$P = \frac{Force}{Area}$$

$$P = F / A$$

Q.7.7. Show that atmosphere exerts pressure. 091307084

Ans. See Q. No. 8 on page #

Q.7.8 It is easy to fill air in a balloon but it is very difficult to remove air from a glass bottle. Why? 091307085

Ans. A balloon has elasticity and elastic body always tends to restore its original shape and size. So, it is easy to fill or remove air inside a balloon. An air filled balloon has greater air pressure than surrounding air pressure. The glass bottle is rigid. So it is easy to fill air in a balloon but it is difficult to remove air from glass bottle because air pressure inside the glass bottle is less than atmospheric pressure.

Q.7.9 What is a barometer? 091307086

Ans. It is an instrument which is used to measure atmospheric pressure.

Q.7.10 Why water is not suitable to be used in a barometer? (F.B. 2017) 091307087

Ans. Since the density of water is much less than mercury so we cannot use water in barometer. If we use water in barometer a longer glass tube is required more than 10 meter.

Q.7.11 What makes a sucker pressed on a smooth wall sticks to it? 091307088

Ans. When the sucker is pressed on a smooth wall, the air pressure below it becomes very small as compared to air pressure above it. Therefore it sticks the wall.

Q.7.12 Why does the atmospheric pressure vary with height? (F.B. 2017) 091307089

Ans. With the increase of height, quantity of air began to decrease due to which atmospheric pressure also becomes low. Density of air and value of 'g' decreases with height so atmospheric pressure varies with height.

Q.7.13 What does it mean when the atmospheric pressure at a place fall suddenly? 091307090

Ans. When the atmospheric pressure fall suddenly at a place, it may follow the storm or rain and the typhoon occur at that place.

Q.7.14 What changes are expected in weather if the barometer reading shows a sudden increase? 091307091

Ans. When the atmospheric pressure increases suddenly this means that there is poor weather ahead.

Q.7.15 State the Pascal's law. 091307092

Ans. Pressure applied at any point of a liquid enclosed in a container is transmitted without loss to all other parts of the liquid.

Q.7.16 Explain the working of hydraulic press. 091307093

Ans. Hydraulic press is a machine which works on Pascal's law. It consists of two cylinders of

different cross sectional areas. They are filled with pistons of cross – sectional areas a and A.

Q.7.17 What is meant by elasticity? 091307094

Ans. The property of a body to restore its original size and shape as the deforming force ceases to act is called elasticity.

Q.7.18 State Archimedes principle. 091307095

Ans. When an object is totally or partially immersed in a liquid, an upthrust acts on it equal to the weight of the liquid it displaces.

Q.19 What is upthrust? Explain the principle of floatation. 091307096

Ans. **Upthrust:** Upthrust is the force of liquid which acts on the floating object in the upward direction, which are immersed in liquid and is equal to the weight of displaced water.

Principle of Floatation: A floating object displace a fluid having weight equal to the weight of object.

Q.7.20 Explain how a submarine moves up the water surface and down into water.

(F.B. 2017) 091307097

Ans. A Submarine can travel over as well as under water. It also works on the principle of floatation. It floats over water when the weight of water equal to its volume is greater than its weight. Under this condition, it is similar to a ship and remains partially above water level. It has a system of tanks which can be filled with and emptied from sea water. When these tanks are filled with seawater, the weight of the submarine increases. As soon as its weight becomes greater than the upthrust, it dives into water and remains under water. To come up on the surface, the tanks are emptied from sea water.

Q.7.21 Why does a piece of stone sink in water but a ship with a huge weight floats?

(F.B. 2018) 091307098

Ans. According to principle of floatation "A floating object displaces a fluid having weight equal to the weight of object."

A stone sink in water because upthrust force is less than the displaced liquid weight but a huge ship floats because it displaces water equal to the weight of body when it is partially or completely immersed in water. In this case upthrust of liquid is equal or greater than the weight of displaced liquid. So a piece of stone sink and a ship with huge weight floats.

Q.7.22 What is Hooke's Law? What is meant by elastic limit? 091307099

Ans. See Q. No. 22. Page no. 131

Q.7.23 Take a rubber band. Construct a balance of your own using a rubber band. Check its accuracy by weighing various objects. 091307100

Ans. Rubber band is the elastic body and it changes its length if the deforming force is acting. If we hang an object with Rubber band with scale marked at one end of box. The length of rubber band increases on stretching it. The pointer of balance is lowered when body is suspended from it. It can measure the weight of an object.

ADDITIONAL ANSWER QUESTIONS

Q.1 What is effect on atmospheric pressure as we go higher? 091307101

Ans. Earth's atmosphere extends upward about a few hundred kilometers with continuously decreasing density. Nearly half of its mass is between sea level and 10 km. Up to 30 km from sea level contains about 99% of the mass of the atmosphere. The air becomes thinner and thinner as we go up.

Q.2 How does vacuum cleaner work?

(F.B. 2014) 091307102

Ans. The fan in a vacuum cleaner lowers air pressure in its bucket. The atmospheric air rushes into it carrying dust and dirt with it through its intake port. The dust and dirt particles are blocked by the filter while air escapes out.

Q.3 How liquid push up in straw? 091307103

Ans. When air is sucked through straw with its other end dipped in a liquid, the air pressure in the straw decreases. This causes the atmospheric pressure to push the liquid up the straw.

Q.4 How liquid enter in the syringe? 091307104

Ans. The piston of the syringe is pulled out. This lowers the pressure in the cylinder. The liquid from the bottle enters into the piston through the needle.

Q.5 How does hydrometer work?

(F.B. 2015) 091307105

Ans. Hydrometer is a glass tube with a scale marked on its stem and heavy weight in the bottom. It is partially immersed in a fluid, the density of which is to be measured. One type of hydrometer is used to measure the concentration of acid in a battery. It is called acid meter.

Q.6 What is deforming force? 091307106

Ans. The applied force that changes shape length or volume of a substance is called deforming force.

Q.7 What changes have to be done for making a water barometer? 091307107

Ans. Atmospheric pressure can hold vertical column of water about 13.6 times the height of mercury column at a place. Thus, at sea level, vertical height of water column would be 0.76 m $\times 13.6 = 10.34$ m. Thus, a glass tube more than 10 m long is required to make a water barometer. At sea level, the atmospheric pressure is about 101,300 Pa or 101, 300 Nm^{-2}.

Q.8 Is atmospheric pressure at mounta-ins higher or lower than at sea level? 091307108

Ans. Atmospheric pressure on the mountain is lower than at sea level.

Q.9 What is the atmospheric pressure at a height about 30km? 091307109

Ans. At a height of about 30km, the atmospheric pressure becomes only 7mm of mercury which is approximately 1000 Pa.

Q.10 What will be atmospheric pressure at altitude where there is no air? 091307110

Ans. The atmospheric pressure at height where there is no air is zero.

Q.11 What changes in a weather expected if there is a minor but rapid fall in atmospheric pressure? 091307111

Ans. Minor but rapid fall in atmospheric pressure indicates a windy and showery conditions in the nearby region.

Q.12 What does decrease in atmospheric pressure predict? 091307112

Ans. Decrease in atmospheric pressure predicts blowing breeze and rain.

Q.13 What does an increase in atmospheric pressure predict? 091307113

Ans. An increasing atmospheric pressure with a decline, later on predicts an intense weather conditions.

Q.14 What does a gradual large increase in the atmospheric pressure indicates? 091307114

Ans. A gradual large increase in the atmospheric pressure indicates a long spell of pleasant weather.

Q.15 Which physical property can be determined by Archimedes principle? 091307115

Ans. Archimedes principle is helpful to determine the density of an object.

Q.16 What is the atmospheric pressure at sea level? 091307116

Ans. 101300 Pa is the atmospheric pressure at sea level.

Q.17 On what factors pressure of a liquid depends? 091307117

Ans. Pressure of a liquid depends on depth and density of the liquid. $\therefore P = \rho gh$

Q.18 What is the fourth state of matter? 091307118

Ans. Plasma is the fourth state of matter, that exist in universe.

At very high temperature, the collision between atoms and molecules tears off their electrons. Atoms become positive ions. This ionic state of matter is called plasma-the fourth state of matter.

Q.19 State Pascal' law. 091307119

Ans. "Pressure applied at any point of a liquid enclosed in a container, is transmitted without loss to all other parts of the liquid".

Q.20 State the Archimedes principle. 091307120

Ans. "When an object is totally or partially immersed in a liquid, an upthrust acts on it equal to the weight of the liquid it displaces".

Q.21 State the principle of floatation. 091307121

Ans. "A floating object displaces a fluid having weight equal to the weight of the object".

Q.22 Define elasticity and elastic body. 091307122

Ans. Elasticity: "The property of a body to restore its original size and shape as the deforming force ceases to act is called elasticity."

Elastic Body: A body which has the property of elasticity is called elastic body. Due to this property we can determine the strength of material and the deformation produced under the action of forces.

Q.23 Define stress and strain. 091307123

Ans. "The deforming force acting on unit area at the surface of a body is called stress."

$$\text{Thus} \quad \text{Stress} = \frac{\text{Force}}{\text{Area}}$$

In SI, the unit of stress is Newton per square metre (Nm^{-2})

Strain: "The ratio of change in size to the original size is called strain"

$$\text{strain} = \frac{\text{change in size (length, volume or shape)}}{\text{orginal size (lengh, volume or shape)}}$$

Q.24 Define elastic limit, Hooke's Law and Young's modulus. 091307124

Ans. Elastic Limit: It is a limit with in which a body recovers its original length, volume or shape after the deforming force is removed. When a stress

crosses this limit, a body is permanently deformed and is unable to restore its original state after the stress is removed.

Hooke's Law: "The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body".

Young's modulus: The ratio of stress to tensile strain is called young's modulus"

$$Y = \frac{\text{Stress}}{\text{Tensile Strain}}$$

Q.25 Why is iron heavier than wood? 091307125

Ans. If we take an equal piece of wood and iron having equal volume. We say that iron is heavier than that of wood because mass of iron is greater than that of wood. It means that iron is more denser than wood. To know which substance is denser or which is lighter we generally compare the densities of various substances.

$$\text{Density} = \frac{\text{mass of substance}}{\text{volume of that substance}}$$

Q.26 Why is the shape of soap bubbles spherical? 091307126

Ans. Atmospheric pressure exert in all directions. Soap bubbles expand till the pressure of air in them is equal to the atmospheric pressure. The soap bubbles so formed have spherical shape.

Q.27 Steel is more elastic than rubber. Why? 091307127

Ans. In steel more effort is required to change the shape as compared to rubber because the steel molecules retain their shape quickly as the deforming force ceases to act. That is why steel is more elastic than rubber.

Q.28 Why a large log of wood floats on water but a steel needle sinks? 091307128

Ans. A large log of wood floats on the surface of water because upthrust acting on large log of wood is greater when it is immersed in water as compared to a steel needle. So steel needle sinks and wooden log floats on water.

Q.29 Explain the conditions when objects float or sink in water? 091307129

Ans. Two forces act on the object when it is immersed in water, one is its weight 'w' that acts in the downward direction and the other is the (buoyant force) upthrust of liquid that acts in the upward direction. It is the resultant of these forces that decide whether the object will sink or float.

(i) If the weight of the immersed object is greater than the upthrust of liquid, then the resultant force acts in downward direction and object will sink.

(ii) If the upthrust force is greater or equal than the weight of the immersed object, then the resultant force will act in the upward direction and object will float.

Q.30 Describe the factors on which up thrust of a liquid depends? (F.B 2018) 091307130

Ans. As we know that up thrust = ρgV

In this relation, up thrust depend on the following factors:

'ρ' is the density of liquid that depend on both pressure and temperature of liquid.

'g' is the acceleration due to gravity that has constant value on Earth's surface.

'v' is the volume of displaced liquid or volume of body.

There are two factors on which upthrust of liquid depend. Volume of body and density of liquid.

Q.31 What is meant by upthrust or Buoyancy? 091307131

Ans. When a body is partially or totally immersed in a liquid, an upward force acts on it is known as upthrust as buoyant force.

The property of liquid to exert an upward force on a body immersed in it is called buoyancy.

Q.32 Convert $1gcm^{-3}$ into kgm^{-3} (F.B 2018) 091307132

Ans. $\frac{\text{one gram}}{\text{cubic centimeter}} = \frac{1g}{1cm^3}$ -------- (A)

As we know that

$1000g = 1kg$

or $1g = \frac{1\,kg}{1000}$ -------- (i)

And $100cm = 1m$

$1cm = \frac{1m}{100}$

$(1cm)^3 = \left(\frac{1m}{100}\right)^3$

$1cm^3 = \frac{1m^3}{1000000} = \frac{1m^3}{10^6}$

$1cm^3 = 10^{-6}m^3$ -------- (ii)

Put the value of 1g and $1cm^3$ in Eq. (A)

$$\frac{1g}{1cm^3} = \frac{1kg/1000}{10^{-6}m^3} = \frac{1}{1000} \times \frac{10^6}{1} kgm^{-3}$$

$$\boxed{1gcm^{-3} = 1000kgm^{-3}}$$

EXAMPLE 7.1 091307133

The mass of 200 cm^3 of stone is 500 g. Find its density.

Given data:

m = 500g

v = 200 cm^3

To Find:

Density = ?

Solution:

$$\text{Density} = \frac{\text{mass}}{\text{Volume}}$$

$$= \frac{500g}{200cm^3} = 2.5gcm^{-3}$$

Density Equations:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Mass} = \text{Density} \times \text{Volume}$$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

Result:

The density of stone is $2.5gcm^{-3}$.

EXAMPLE 7.2

In a hydraulic press, a force of 100 N is applied on the piston of a pump of cross-sectional area 0.01m^2. Find the force that compresses a cotton bale placed on larger piston of cross- sectional area 1 m^2 091307134

Given Data:

Here $F_1 = 100N$

$a = 0.01\ m^2$

$A = 1\ m^2$

To Find:

F_2 = ?

Pressure P on smaller piston $= \frac{F_1}{a}$

$$= \frac{100}{0.01}$$

$$= 10000\ Nm^{-2}$$

Applying Pascal's law, we get

Force F_2 acting on the bale $= PA$

$= 10000 \times 1$

$= 10000\ N$

Result:

Thus, hydraulic press will compress the cotton bale with a force of 10000 N.

EXAMPLE 7.3

A wooden cube of sides 10 cm each has been dipped completely in water. Calculate the upthrust of water acting on it 091307135

Given Data:

Length of side $L = 10\ cm = 0.1m$

Volume $V = L^3 = (0.1m)^3 = 1 \times 10^{-3}\ m^3$

Density of water $\rho = 1000\ kgm^{-3}$

To Find:

Upthrust = ?

Solution:

Upthrust of water $= \rho\ g\ V$

$= 1000 \times 10 \times 1 \times 10^{-3}$

$= 10\ N$

Result:

Thus, upthrust of water acting on the wooden cube is 10 N.

EXAMPLE 7.4

The weight of a metal spoon in air is 0.48 N. Its weight in water is 0.42 N. Find its density.

091307136

Given Data:

Weight of the spoon $w_1 = 0.48\ N$

Weight of spoon in water $w_2 = 0.42\ N$

To Find:

Density = ?

Solution:

Density of water $\rho = 1000\ kg\ m^{-3}$

Density of spoon $D = ?$

We Know that

$$D = \frac{w_1}{w_1 - w_2} \times \rho$$

$$= \frac{0.48}{0.48 - 0.42} \times 1000$$

$$D = 8000\ kg\ m^{-3}\ Ans.$$

Result:

Thus, the density of metal spoon is 8000 kgm^{-3}.

EXAMPLE 7.5

An empty meteorological balloon weighs 80 N. It is filled with 10 cubic metres of hydrogen. How much maximum contents the balloon can lift besides its own weight? The density of hydrogen is 0.09kgm $^{-3}$ and the density of air is 1.3kgm^{-3}.

091307137

Given Data:

Weight of the balloon $w = 80\ N$

Volume of hydrogen $V = 10\ m^3$

Density of hydrogen $\rho_1 = 0.09\ kg\ m^{-3}$

Density of air $\rho_2 = 1.3\ kg\ m^{-3}$

To Find:

Weight of hydrogen $w_1 = ?$

Weight of the contents $w_2 = ?$

Solution:

Up thrust F = Weight of air displaced.

$= \rho_2 V g$

$= 1.3 \times 10 \times 10$

$= 130\ N$

Weight of hydrogen $w_1 = \rho_1 V g$

$= 0.09 \times 10 \times 10$

$= 9\ N$

Total weight lifted = $w + w_1 + w_2$

To lift the contents, the total weight of the balloon should not exceed F.

Thus $w + w_1 + w_2 = F$

Or $80N + 9N + w_2 = 130\ N$

Or $w_2 = 130\ N - 89\ N$

$= 41\ N$

Result:

Thus, the maximum weight of 41 N can be lifted by the balloon in addition to its own weight.

EXAMPLE 7.6 MTP Sep 2023 For Board

A barge, 40 metre long and 8 metre broad, whose sides are vertical, floats partially, loaded in water. If 125000 N of cargo is added, how many meters will it sink? (F.B. 2017) 091307138

Given Data:

Area of the barge $A = 40 \times 8$

$= 320\ m^2$

Additional load w to carry $W = 125000\ N$

To find:

Depth = h = ?

Solution:

Increased up thrust F of water must be equal to the additional load. Hence

$F = \rho Vg$ ..... (1)

Since $F = w$ .....(2)

Comparing (1) & (2)

$w = \rho Vg$

$125000 = 1000 \times V \times 10$

$\boxed{V = 12.5 m^3}$

We know

$V = Ah$

$h = \frac{V}{A}$

$\therefore \quad h = \frac{12.5}{320}$

Depth "h" to which barge sinks

$= 0.04\ m = \boxed{4\ cm}$

Result: Thus, the barge will sink 4 cm in water on adding 125000 N cargo.

EXAMPLE 7.7

A steel wire 1 m long and cross- sectional area $5 \times 10^{-5}\ m^2$ is stretched through 1 mm by a force of 10,000 N. Find the Young's modulus of the wire. 091307139

Given Data:

Force $F = 10{,}000\ N$

Length $L_o = 1m$

Extension $\Delta L = 1mm = 0.001m$

Cross sectional Area $A = 5 \times 10^{-5}\ m^2$

To Find:

Y = ?

Solution:

Since $Y = \frac{FL_o}{A\Delta L}$

$Y = \frac{10000 \times 1}{5 \times 10^{-5} \times 0.001}$

$Y = 2 \times 10^{11}\ N\ m^{-2}$

Result: Thus, young's modulus of steel is $2 \times 10^{11}\ Nm^{-2}$

NUMERICAL PROBLEMS

7.1 A wooden block measuring 40 cm × 10cm × 5cm has a mass 850 g. Find the density of wood? 091307140

Given data

Volume = 40 cm × 10 cm × 5cm
= 2000 cm^3
= 2000 × $(10^{-2})^3$
= 2000 × 10^{-6} m^3
= 2×10^{-3} m^3

Mass = m = 850 g = $\frac{850}{1000}$ kg
= 0.85 kg

To Find:

Density = d = ?

Solution

We know

$d = \frac{m}{v}$

$= \frac{0.85}{2\times10^{-3}}$

$= 0.425\times10^{+3}$

d = 425 kgm^{-3}

Result:

Thus the density of wooden block is 425kgm^{-3}

7.2 How much would be the volume of ice formed by freezing 1 litre of water? (F.B. 2017) 091307141

Given Data:

Volume of water = V_w = 1 Litre = 1 ×$10^{-3}$$m^3$ Since 1 litre = $10^{-3}$$m^3$

Density of water = ρ_w = 1000 kg m^{-3}

Density of ice = d_{ice} = 920 kgm^{-3}

To Find:

Volume of ice = V_{ice} = ?

Solution:

We know that

$\rho_w = \frac{m_w}{V_w}$ $\Rightarrow m_w = m_{ice}$

$m_w = \rho_w \times V_w$ $(\rho_w \times V_w) = (\rho_{ice} \times V_{ice})$

Also

Since $d_{ice} = \frac{m_{ice}}{V_{ice}}$

As mass remains constant so

$m_w = m_{(ice)}$

$\rho_w V_w = d_{ice} V_{ice}$

$V_{(ice)} = \rho_w \frac{V_w}{d_{ice}}$

$= \frac{1000\times10^{-3}}{920}$

$= 1.09 \times 10^{-3}$ m^3

$= 1.09\ (10^{-3}m^3)$ $\therefore 10^{-3}m^3$=litre

$V_{(ice)}$ = 1.09 litre

Result:

Thus, the volume of ice is 1.09 litre.

7.3Calculate the volume of the following objects: 091307142

(i) An iron sphere of mass 5 kg, the density of iron is 8200 kgm^{-3}

(ii) 200 g of lead shot having density 113000 kgm^{-3}

(iii)A gold bar of mass 0.2 kg the density of gold is 19300 kgm^{-3}

Given Data:

(i) Mass = m = 5 kg

Density = d = 8200 kgm^{-3}

To Find:

Volume = V = ?

Solution:

$d = \frac{m}{v}$

$V = \frac{m}{d}$

$V = \frac{5}{8200}$

$V = \frac{5}{8.2\times10^3}$

$V = \frac{5}{8.2}\times10^{-3}$

$V = 0.609 \times 10^{-3}$

$V = 6.09 \times 10^{-4}$ m^3

$V = 6.1 \times 10^{-4}$ m^3

$V = 6.1\times10^{-4}$ m^3

Result:

Volume of iron sphere is 6.1 × $10^{-4}$$m^3$.

(ii)

Given data:

mass = m = 200g = $\frac{200}{1000}$ kg = 0.2 kg

Density = d = 11300 kg m^{-3}

To find:

Volume = V = ?

Solution :

$$d = \frac{m}{V}$$

$$V = \frac{m}{d}$$

$$= \frac{0.2}{11300}$$

$$= \frac{0.2}{1.13\times10^{4}}$$

$$= \frac{2\times10^{-1}\times10^{-4}}{1.13}$$

$$= 1.769 \times 10^{-5} \ m^3$$

$$= 1.77 \times 10^{-5} m^3$$

Result:

Thus, the volume of lead sphere is $1.77\times10^{-5}m^3$.

(iii)

Given data

mass = m = 0.2 kg

Density = d = 193000 kgm^{-3}

To find:

Volume = V = ?

Solution:

$$d = \frac{m}{V}$$

$$V = \frac{m}{d}$$

$$= \frac{0.2}{19300}$$

$$= \frac{2\times10^{-1}}{1.93\times10^{4}}$$

$$= \frac{2}{1.93} \times10^{-1} \times10^{-4}$$

$$= 1.036\times10^{-5} m^3$$

$$V = \boxed{1.04 \times10^{-5} m^3} \text{ Ans.}$$

Result:

Thus, the volume of gold bar is $1.04 \times 10^{-5}m^3$.

7.4 The density of air is 1.3 kgm^{-3} Find the mass of air in a room measuring 8m × 5m × 4 m. **(F.B 2015)** **091307143**

Given Data

Density. = ρ = 1.3 kgm^{-3}

Volume = 8m × 5m × 4m

= 160 m^3

To find:

Mass = m = ?

Solution:

We know

$$\rho = \frac{m}{v}$$

$$m = \rho V$$

$$= 1.3 \times 160$$

$$m = 208 \text{ kg.}$$

Result:

Thus, the mass of air in the room is 208kg.

7.5 A student presses her palm by her thumb with a force of 75 N. How much would be the pressure under her thumb having contact area 1.5 cm^2 ? **091307144**

Given Data:

Force = F = 75 N

Area = 1.5 cm^2

= $1.5 \times (10^{-2}m)^2$

= $1.5 \times 10^{-4} m^2$

1 cm = 10^{-2}m

To find:

Pressure = P = ?

Solution:

We know

$$P = \frac{F}{A}$$

$$= \frac{75}{1.5\times10^{-4}}$$

$$= \frac{75}{1.5} \times10^{4}$$

$$= 50\times10^{4} \ Nm^{-2}$$

$$= 5\times10\times10^{4} \ Nm^{-2}$$

$$P = \boxed{5\times10^{5} \ Nm^{-2}}$$

Result:

The pressure under her thumb is $5 \times 10^5 Nm^{-2}$.

7.6 The head of a pin is a square of side 10 mm. Find the pressure on it due to a force of 20 N. **091307145**

Given Data:

Force = F = 20 N

length = L = 10 mm = 10×10^{-3} m

Area = A = L×L = $10 \times10^{-3} \times10\times10^{-3}$

$A=1\times10^{-4} m^2$

To find:

Pressure = P = ?

Solution:

We know

$$P = \frac{F}{A}$$

$$= \frac{20}{1\times10^{-4}}$$

$$= 20\times10^{4}\ Nm^{-2}$$

$$P = 2\times10^{5}\ Nm^{-2}$$

Result:

The pressure on the head of pin by applying a force is $2\times10^{5} Nm^{-2}$.

7.7 A uniform rectangular block of wood 20 cm × 7.5 cm × 7.5 cm and of mass 1000 g stands on a horizontal surface with its longest edge vertically.

Find

(i) the pressure exerted by the block on the surface 091307146

(ii) density of the wood.

Given Data:

Mass = m = 1000g = 1 kg

Weight = W = F = mg = 1×10 = 10N

Area = 7.5 cm × 7.5 cm

$A = 7.5\times7.5\times(10^{-2}\ m)^2$

$A = 56.25\times10^{-4} m^2$

$A = 5.625\times10^{-3} m^2$

Volume = V = 7.5 cm × 7.5 cm × 20cm

$= 1125\times(10^{-2}\ m)^3$

$= 1125\times10^{-6} m^3$

$= 1.125\times10^{-3} m^3$

To Find:

Pressure = P = ?

Density = d = ?

Solution

We know

$$P = \frac{F}{A}$$

$$= \frac{10}{5.625\times10^{-3}}$$

$$= \frac{10\times1000}{5.625}$$

$$= \frac{10000}{5.625}$$

$$P = \boxed{1778\ Nm^{-2}}$$

$$d = \frac{m}{v}$$

$$= \frac{1}{1.125\times10^{-3}}$$

$$= \frac{1000}{1.125}$$

$$= 888.9\ kgm^{-3}$$

$$d = \boxed{889\ kgm^{-3}}$$

Result:

(i) Thus, the pressure exerted by the wooden block is $177 Nm^{-2}$.

(ii) The density of wooden block is $889\ Kgm^{-3}$.

7.8 A cube of glass of 5 cm side and mass 306 g, has a cavity inside it. If the density of glass is 2.55 gcm^{-3}. Find the volume of the cavity. 091307147

Given Data

Length = L = 5 cm

Volume of glass cube without Cavity = V'

Volume = V' = $5\times5\times5 = 125\ cm^3$

Mass = m = 306 g

$d = 2.55\ g\,cm^{-3}$

To Find:

Volume of Cavity = ?

Solution:

As we know that

$$\therefore d = \frac{m}{v}$$

Volume of glass cube with cavity = $V = \frac{m}{d}$

$$V = \frac{306}{2.55}$$

$$V = 120\ cm^3$$

Volume of cavity = V' − V

= 125 − 120

Volume of cavity = $\boxed{5cm^3}$

Result:

Thus, the volume of cavity inside the glass cube is $5cm^3$.

7.9 An object has weight 18 N in air. Its weight is found to be 11.4 N when immersed in water. Calculate its density. Can you guess the material of the object? 091307148

Given Data:

Weight of object in air = w_1 = 18N

Weight of object in water = w_2 = 11.6N

Loss in weight = W = $W_1 - W_2$

= 18 − 11.6 = 6.6 N

Density of water = ρ_w = 1000 kgm^{-3}

To find: Density of object D = ?

Solution:

We know

$$D = \frac{w_1}{w_1 - w_2}\times\rho_w$$

$$D = \frac{w_1}{w_1 - w_2} \times 1000$$

$$= \frac{18}{6.6} \times 1000$$

$$D = 2727 \text{ kgm}^{-3}$$

Result:

The density of material is 2727 kgm^{-3}.

Material is Aluminum, because the answer is very close to the density of aluminum.

7.10 A solid block of wood of density 0.6 gcm^{-3} weighs 3.06 N in air. Determine (a) volume of the block (b) the volume of the block immersed when placed freely in a liquid of density 0.9gcm^{-3}?

091307149

Given Data:

$W = 3.06\,N$

$W = mg$

$3.06 = m \times 10$

$\frac{3.06}{10} = m$

$0.306\,kg = m$

$0.306 \times 1000\,g = m$

$306g = m \Rightarrow m = 306\,g$

Density of liquid = $\rho = 0.9\ gcm^{-3}$

Density of the block = $d = 0.6g\ cm^{-3}$

To Find:

Volume of block in air = V = ?

Volume of the Block in liquid = V = ?

(a) Solution: Volume of block in air

$$V = \frac{m}{d} = \frac{306}{0.6}$$

$$= 510\,cm^3$$

Result:

Thus, the volume of the wooden block in air is $510cm^3$.

(b) Volume of block in liquid.

$$V = \frac{m}{\rho} = \frac{306}{0.9}$$

$$= 340\,cm^3$$

Result:

Thus, the volume of the block in water is $340cm^3$.

7.11 The diameter of the piston of a hydraulic press is 30 cm. How much force is required to lift a car weighing 20000 N on its piston if the diameter of the piston of the pump is 3 cm?

091307150

Given data:

Diameter of piston of Hydraulic press

$D = 30\,cm = 0.3m$

Radius of piston of Hydraulic press

$$R = \frac{D}{2} = \frac{0.3}{2} m = 0.15m$$

Area of piston of Hydraulic press

$A = \pi R^2 = (0.15)^2 \pi$

Diameter of Piston of pump

$d = 3cm = 0.03\ m$

Radius of Piston of pump

$$r = \frac{d}{2}$$

$$r = \frac{0.03}{2} = .015m$$

Area of Piston of Pump = $a = \pi r^2$

$= (0.015)^2 \pi$

Weight on larger Piston $= F_2 = 20000\ N$

To Find:

Force to lift the car = F_1 = ?

Solution:

We know

$$\frac{F_2}{A} = \frac{F_1}{a}$$

$$\frac{F_2}{F_1} = \frac{A}{a}$$

$$F_1 = \frac{F_2 \times a}{A}$$

$$= \frac{20000 \times (0.015)^2 \pi}{(0.15)^2 \pi}$$

$$F_1 = \frac{20000 \times .000225}{.0225} = \frac{4.5}{0.0225} = 200N$$

Result:

200 N force is required to lift a car.

7.12 A steel wire of cross-sectional area 2×10^{-5} m^2 is stretched through 2 mm by a force of 4000 N. Find the Young's modulus of the wire. The length of the wire is 2 m.

091307151

Given Data:

Area = $A = 2 \times 10^{-5}\ m^2$

Increase in length = $\Delta L = 2mm = 2 \times 10^{-3}\ m$

Force = 4000 N

Length = L_o = 2m

To Find:

Young Modulus = Y = ?

Solution:

$$Y = \frac{F/A}{\Delta L/L_o}$$

$$= \frac{F \times L_o}{A \times \Delta L}$$

$$= \frac{4000 \times 2}{2 \times 10^{-5} \times 2 \times 10^{-3}}$$

$$= \frac{4 \times 10^{3} \times 2 \times 10^{5} \times 10^{3}}{2 \times 2}$$

$$Y = 2 \times 10^{11} \ Nm^{-2}$$

Result:

Thus, the Young's Modulus of wire is $2 \times 10^{11} Nm^{-2}$.

$$\text{i.e.} \quad \frac{3.06N}{g} = \frac{mg}{g}$$

$$= \frac{3.06}{10} kg = 0.306 kg$$

$$= 0.306 \times 10^{3} g$$

$$\Rightarrow \boxed{m = 306 g.}$$

UNIT 08

THERMAL PROPERTIES OF MATTER

Introduction

In this chapter we will study about temperature, heat, thermometer, specific heat, latent heat of fusion, latent heat of vaporization, evaporation and thermal expansion.

Q.1 Define Temperature and Heat. 091308001

Ans. When we touch a body, we feel it hot or cold. The temperature of a body tells us how hot or cold a body is.

Definition : *"Temperature of a body is the degree of hotness or coldness of the body."*

Example: A candle flame is hot and is said to be at high temperature. Ice on the other hand is cold and is said to be at low temperature. our sense of touch is a simple way to know how much hot or cold a body is.

Heat: *"Heat is the energy that is transferred from one body to the other in thermal contact with each other as a result of the difference of temperature between them."*

Heat is therefore, called as the **energy in transit.**

Q.2 Define Internal energy OR what is internal energy of a body? (F.B. 2017) 091308002

Ans. *"The sum of kinetic energy and potential energy associated with the atoms, molecules and particles of a body is called its internal energy."* Internal energy = K.E + P.E

Factors:

Internal energy of a body depends on many factors such as the mass of the body, kinetic and potential energies of molecules etc. Kinetic energy of an atom or molecule is due to its motion which depends upon the temperature. Potential energy of atoms or molecules is the stored energy due to intermolecular forces.

Q.3 Define thermal equilibrium. 091308003

Ans. *"Thermal equilibrium is the property of substance when all parts of system have same temperature along with its surrounding."*

Example: When two objects A and B at different temperatures are in thermal contact with each other. The heat flow from higher to lower temperature till both the bodies attain same temperature along with surrounding. At this temperature, bodies are said to be in thermal equilibrium. At thermal equilibrium, no heat exchange will occur.

Q.4 Define thermometer. What are the properties of thermometric materials? Also define thermometric substance. (F.B. 2014) 091308004

Ans. Thermometer

Thermometric Materials: *"A device that is used to measure the temperature of a body is called thermometer."*

Thermometric Material:

Substances that show a change with temperature can be used as a thermometric material. **Example:** Some substances expand on heating, some change their colours, some change their electric resistance, etc. Liquids also expand on heating and are suitable as **thermometric materials.** Common thermometers are generally made using some suitable liquid as thermometric material.

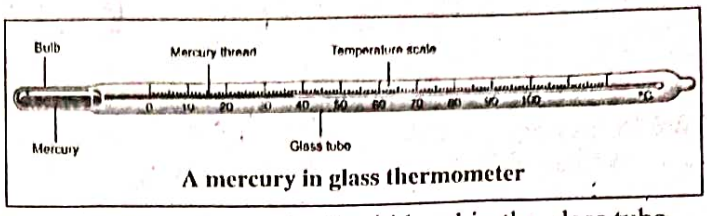
Properties of thermometric liquid:

A thermometric liquid should have the following properties:

- It should be visible.
- It should have uniform thermal expansion.
- It should have a low freezing point.
- It should have a high boiling point.
- It should not wet glass.
- It should be a good conductor of heat.
- It should have a small specific heat capacity.

Q.5 Explain liquid in glass thermometer. 091308005

Ans. A liquid-in-glass thermometer has a bulb with a long capillary tube of uniform and fine bore such as shown in figure. A suitable liquid i.e. mercury is filled in the bulb. When the bulb of thermometer is placed in a hot object, the liquid in it expands and rises in the tube. The glass stem of a thermometer is thick and acts as a cylindrical lens. This makes it easy to see the liquid level in the glass tube.



A mercury in glass thermometer

Mercury freezes at −39°C and boils at 357°C. So the mercury is one of the most suitable thermometric material.

Uses: Mercury-in-glass thermometers are widely used in laboratories, clinics and houses to measure temperatures in the range from – 10C° to 150C°.

Q. 6 What do you mean by lower and upper fixed points? 091308006

Ans. A thermometer has a scale on its stem. This scale has two fixed points. The lower fixed point is marked to show the position of liquid in the thermometer when it is placed in ice. Similarly, upper fixed point is marked to show the position of liquid in the thermometer when it is placed in steam at standard pressure above boiling water.

Q.7 In which scales, is temperature measured? Explain. (OR) Explain the different scales of temperatue. (F.B. 2016) 091308007

Ans Three scales of temperature which are in common use are:

- Celsius scale or centigrade scale
- Fahrenheit scale.
- Kelvin scale.

i. Celsius Scale or Centigrade Scale:

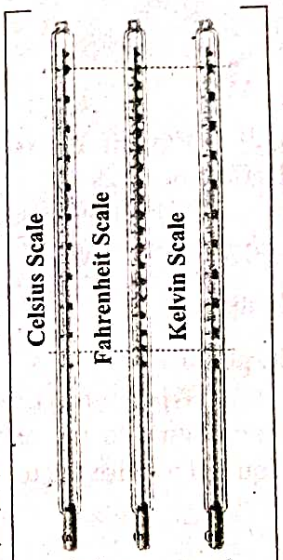
On Celsius scale, the interval between lower and upper fixed points is divided into 100 equal parts. The lower fixed point is marked as 0°C and the upper fixed point is marked as 100°C.

ii. Fahrenheit scale:

On Fahrenheit scale, the interval between lower and upper fixed points is divided into 180 equal parts. Its lower fixed point is marked as 32°F and upper fixed point is marked as 212°F.

iii. Kelvin scale:

In SI units, the unit of temperature is Kelvin (K) and its scale is called Kelvin scale of temperature. The interval between the lower and upper fixed points is divided into 100 equal parts. Thus, a change in 1°C is equal to a change of 1K. The lower fixed point on this scale is 273K and the upper fixed point is 373 K. The zero on this scale is called the absolute zero and is equal to – 273°C.



Various scales of temperature.

Q.8 How can we convert temperature from one scale to other? (OR) Give formulas for the conversion of temperature from one scale to other. 091308008

Ans. From Celsius to Kelvin scale:

The temperature *T* on Kelvin scale can be obtained by adding 273 in the temperature °C on Celsius scale.

Thus

$$T_K = 273 + C$$

From Kelvin to Celsius scale:

The temperature on Celsius scale can be found by subtracting 273 from the temperature in Kelvin Scale.

Thus

$$C = T_K - 273$$

From celsius to Fahrenheit scale:

Since 100 divisions on Celsius scale are equal to 180 divisions on Fahrenheit scale. Therefore, each division on Celsius scale is equal to 1.8 divisions on Fahrenheit scale. Moreover, 0°C corresponds to 32°F.

$$F = \frac{9}{5} C + 32$$

$$\therefore \quad \boxed{F = 1.8C + 32}$$

Here F is the temperature on Fahrenheit scale and C is the temperature on Celsius scale.

From Fahrenheit to scale:

We can find the temperature on Celsius scale from Fahrenheit Scale.

$$F = 1.8C + 32$$

$$1.8C = F - 32$$

$$\boxed{C = \frac{F-32}{1.8}}$$

Do You Know?	
Sun's core	15 000 000 °C
Sun's Surface	6000 °C
Electric Lamp	2500 °C
Gas Lamp	1580 °C
Boiling Water	100 °C
Human Body	37 °C
Freezing Water	0 °C
Ice in Freezer	– 18 °C
Liquid Oxygen	– 180 °C

Q.9 Explain the specific heat capacity. or Define specific heat. **(F.B. 2017)** 091308009

Definition

"Specific heat of a substance is the amount of heat required to raise the temperature of 1kg mass of that substance through 1K."

Mathematically, $c = \frac{\Delta Q}{m\Delta T}$

Explanation:

When a body is heated, its temperature increases. Increase in the temperature of a body is found to be proportional to the amount of heat absorbed by it. It has also been observed that the quantity of heat ΔQ required to raise the temperature ΔT of a body is proportional to the mass m of the body. Thus

$$\Delta Q \propto m \longrightarrow \text{(i)}$$

$$\Delta Q \propto \Delta T \longrightarrow \text{(ii)}$$

Combining (i) and (ii)

$$\Delta Q \propto m\Delta T \qquad \Delta Q = \text{constant } m\Delta T$$

Or $\Delta Q = cm\Delta T$

Here ΔQ is the amount of heat absorbed by the body and c is the constant of proportionality called the specific heat capacity or simply specific heat .

In Sl units, mass m is measured in kilogramme (kg), heat ΔQ is measured in joule (J) and temperature increase ΔT is taken in Kelvin (K).

Unit: Sl unit of specific heat is $Jkg^{-1}K^{-1}$.

Specific heat of some common substances	
Substance	**Specific heat $Jkg^{-1}k^{-1}$**
Alcohol	2500.0
Aluminium	903.0
Bricks	900.0

Carbon	121.0
Clay	920.0
Copper	387.0
Ether	2010.0
Glass	840.0
Gold	128.0
Granite	790.0
Ice	2100.0
Iron	470.0
Lead	128.0
Mercury	138.6
Sand	835.0
Silver	235.0
Soil (dry)	810.0
Steam	2016.0
Tungsten	134.8
Turpentine	1760.3
Water	4200.0
Zinc	385.0

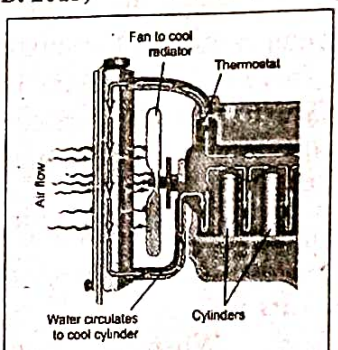
Q.10 Write the importance of large specific heat capacity of water. **(F.B. 2015)** **091308010**

Ans. Specific heat of water is 4200 $Jkg^{-1}K^{-1}$ and that of dry soil is about 810 $Jkg^{-1}K^{-1}$. So we can say that temperature of soil would increase five times more than the same mass of water by the same amount of heat.

Thus, the temperature of land rises and falls more rapidly than that of the sea. Hence, the temperature variations from summer to winter are much smaller at places near the sea than land far away from the sea.

Water has a large specific heat capacity. For this reason, it is very useful in storing and carrying thermal energy due to its high specific heat capacity.

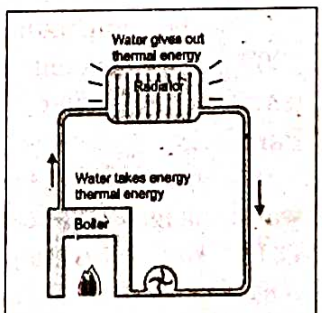
Following are applications of high specific heat capacity of water.



A cooling system in automobile

Cooling system in auto mobile:

The cooling system of automobiles uses water to carry away unwanted thermal energy. In an automobile, large amount of heat is produced by its engine due to which its temperature goes on increasing. The engine would cease unless it is not cooled down.



Central heating system

Central Heating System;

In central heating systems hot water is used to carry thermal energy through pipes from boiler to radiators. These radiators are fixed inside the house at suitable places.

Q.11 What is meant by heat capacity? Explain. **091308011**

Ans. HEAT CAPACITY:

Definition: *"Heat capacity of a body is the quantity of thermal energy absorbed by it for one Kelvin (1K) increase in its temperature".*

Explanation : If the temperature of a body increases through ΔT on adding ΔQ amount of heat, then its heat capacity will be $\frac{\Delta Q}{\Delta T}$.

By the definition of specific heat

$$\Delta Q = mc\Delta T$$

Dividing both sides by ΔT.

$$\frac{\Delta Q}{\Delta T} = mc\frac{\Delta T}{\Delta T}$$

$$\frac{\Delta Q}{\Delta T} = mc$$

$\therefore$ Heat capacity = mc

Equation shows that heat capacity of a body is equal to the product of its mass of the body and its specific heat capacity.

Example

Heat capacity of 5 kg of water is (5 kg × 4200 $Jkg^{-1}K^{-1}$) 21000 JK^{-1}. That is; 5 kg of water needs 21000 joules of heat for every 1 Kelvin rise in its temperature. Thus, larger is the quantity of a substance, larger will be its heat capacity.

Do You Know?

The presence of large water reservoirs such as lakes and seas keep the climates of nearby land moderate due to the large heat capacity of these reservoirs.

Q.12 Explain change of state in matter with example. (OR) **(F.B. 2016)** 091308012

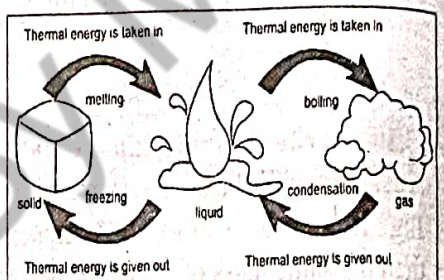
Draw a temperature-time graph showing the change of state of ice into water and steam.

Ans. Matter can be changed from one state to another. For such a change to occur, thermal energy is added to or removed from a substance.

Activity:

Take a beaker and place it over a stand. Put small pieces of ice in the beaker and suspend a thermometer in the beaker to measure the temperature of ice.

Now heat the beaker, the ice will start melting. The temperature of the mixture containing ice and water will not increase above 0°C until all the ice melts and we get water at 0°C. If this water at 0°C is further heated, its temperature will begin to increase above 0°C as shown by the graph in figure.



Heat energy brings about change of state in matter.

Part AB:

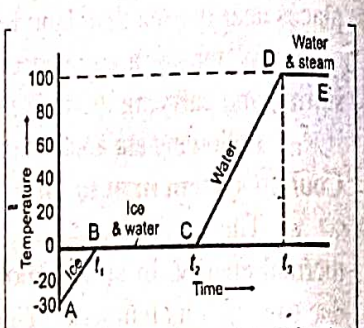
On this portion of the curve, the temperature of ice increases from –30°C to 0°C.

Part BC:

When the temperature of ice reaches 0°C, the ice water mixture remains at this temperature until all the ice melts.

Part CD:

The temperature of the substance gradually increases from 0°C to 100°C. The amount of energy so added is used up in increasing the temperature of water.



A graph of temperature and time showing change of state of ice into water and steam.

Part DE:

At 100°C water begins to boil and changes into steam. The temperature remains 100°C until all the water changes into steam.

Q.13 Define fusion point and freezing point. 091308013

Ans *"When a substance is changed from solid to liquid state by heating, the process is called melting or fusion."* The temperature at which a solid starts melting is called its **fusion point or melting point.**

When the process is reversed i.e. when a liquid is cooled, it changes into solid state. *"The temperature at which a substance changes from liquid to solid state is called its freezing point."* Different substances have different melting points. However, the freezing point of a substance is the same as its melting point.

Q.14 What is meant by latent heat of fusion? Explain it with experiment. (F.B. 2014) 091308014

Latent heat of fusion:

"Heat energy required to change unit mass of a substance from solid to liquid state at its melting point without change in its temperature is called its latent heat of fusion."

It is denoted by H_f.

$$H_f = \frac{\Delta Q_f}{m}$$

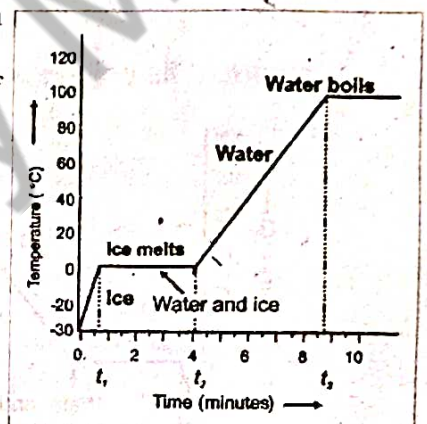
or $$\Delta Q_f = mH_f$$

Ice changes at 0°C into water. Latent heat of fusion of ice is 3.36×10^5 Jkg^{-1}. That is 3.36×10^5 joule heat is required to melt 1 kg of ice into water at 0°C.

Experiment:

Take a beaker and put small pieces of ice in it and suspend a thermometer in the beaker to measure the temperature. Place a burner under the beaker. The ice will start melting. The temperature of the mixture containing ice and water will not increase above 0°C until whole of the ice melts. Note the time which the ice takes to melt completely into water at 0°C.

Continue heating the water at 0 °C in the beaker. Its temperature will begin to increase. Note the time which the water in the beaker takes to reach its boiling point at 100°C from 0°C.



Temperature - time graph as ice changes into water that boils as heating continues.

Draw a temperature time graph. Calculate the latent heat of fusion of ice from the data as follows:

Let mass of ice = m

Time taken by ice to melt completely at 0°C $= t_f = t_2 - t_1 = 3.6$ min.

Time taken by water to heat from 0 °C to 100 °C $= t_0 = t_3 - t_2 = 4.6$ min

Specific heat of water $c = 4200\ Jkg^{-1}\ K^{-1}$.

Increase in the temperature of water: $= \Delta T = 100\ °C = 100\ K$

Heat required by water from 0 °C to 100 °C.

$$\Delta Q = m\, c\Delta T$$

$$= m \times 4200\ Jkg^{-1}\ K^{-1} \times 100\ K$$

$$= m \times 420\,000\ Jkg^{-1}$$

$$= m \times 4.2 \times 10^5\ Jkg^{-1}.$$

Heat ΔQ is supplied to water in time t_0 to raise its temperature from 0 °C to 100 °C. Hence, the rate of absorbing heat by water in the beaker is given by

$$\text{Rate of absorbing heat} = \frac{\Delta Q}{t_o}$$

$$\therefore \text{Heat absorbed in time } t_f = \Delta Q_f = \frac{\Delta Q \times t_f}{t_o}$$

$$= \frac{\Delta Q \times t_f}{t_o}$$

Since $\Delta Q_f = m \times H_f$

Putting the values, we get

$$\cancel{m} \times H_f = \cancel{m} \times 4.2 \times 10^5\ Jkg^{-1} \times \frac{t_f}{t_o}$$

or

$$H_f = 4.2 \times 10^5\ Jkg^{-1} \times \frac{t_f}{t_o}$$

The values of t_f and t_o can be found from the graph. Put the values in the above equation to get.

$$H_f = 4.2 \times 10^5 \text{ Jkg}^{-1} \times \frac{3.6 \text{ min.}}{4.6 \text{ min.}}$$

$$= 3.29 \times 10^5 \text{ Jkg}^{-1}$$

The latent heat of fusion of ice found by the above experiment is 3.29×10^5 Jkg^{-1} while its actual value is 3.36×10^5 Jkg^{-1}.

Q.15 Define and explain the latent heat of vaporization. Also explain it with experiment. 091308015

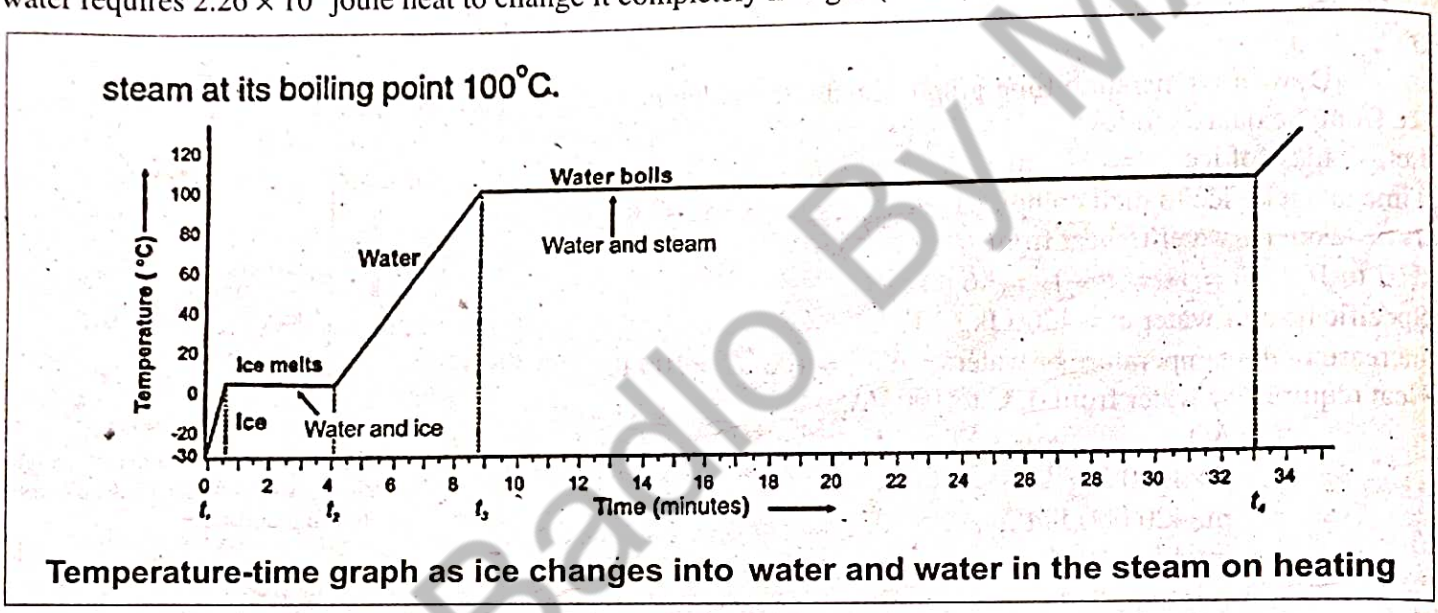
or Define latent heat of vaporization.

Ans. *"The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point without any change in its temperature is called its latent heat of vaporization."*

It is denoted by H_v :

$$H_v = \frac{\Delta Q_v}{m}, \qquad \Delta Q_v = mH_v$$

When water is heated, it boils at 100 °C under standard pressure. Its temperature remains 100°C until it is changed completely into steam. Its latent heat of vaporization is 2.26×10^6 Jkg^{-1}. That is; one kilogramme of water requires 2.26×10^6 joule heat to change it completely into gas (steam) at its boiling point.



Temperature-time graph as ice changes into water and water in the steam on heating

Experiment:

Take the beaker and boil it. Continue heating water till all the water changes into steam. Note the time which the water in the beaker takes to change completely into steam at its boiling point 100°C.

Extend the temperature –time graph as shown in figure. Calculate the latent heat of fusion of ice from the data as follows:

Let

Mass of ice = m

Time t_o taken to heat water from 0 °C to 100 °C (melt) = t_o = $t_3 - t_2 = 4.6$ min

Time taken by water at 100 °C to change it into steam = t_v = $t_4 - t_3 = 24.4$ min

Specific heat of water c increase in the temperature of water = 4200 Jkg^{-1}K^{-1}

Increase in temperature of water = $\Delta T = 100$ °C = 100K

Heat required to heat water from 0 °C to100 °C = $\Delta Q = mc\ \Delta T$

$= m \times 4200 \times 100$

$= m \times 420\ 000$

$= m \times 4.2 \times 10^5$ Jkg^{-1}

As burner supplies heat ΔQ to water in time t_o to raise its temperature from 0 °C to 100 °C. Hence, the rate at which heat is absorbed by the beaker is given by

Rate of absorbing heat $= \frac{\Delta Q}{t_o}$

Heat absorbed in time $t_v = \Delta Q_v = \frac{\Delta Q \times t_v}{t_o} = \Delta Q \times \frac{t_v}{t_o}$

Since

By the definition of formula of heat of vaporization

$\Delta Q_v = m \times H_v$

Putting the values, we get

$m \times H_v = m \times 4.2 \times 10^5 \times \frac{t_v}{t_o}$

$H_v = 4.2 \times 10^5 \times \frac{t_v}{t_o}$

Putting the values of t_v and t_o from the graph, we get

$H_v = 4.2 \times 10^5 \times \frac{24.4}{4.6}$

$= 2.23 \times 10^6 \text{ Jkg}^{-1}$

The latent heat of vaporization of water found by the above experiment is 2.23×10^6 Jkg^{-1} while its actual value is 2.26×10^6 Jkg^{-1}

Melting point, boiling point, latent heat of fusion and latent heat of vaporization of some common substances.

Substance	Melting point (°C)	Boiling point(°C)	Heat of fusion (kJkg^{-1})	Heat of vaporization (kJkg^{-1})
Aluminium	660	2450	39.7	10500
Copper	1083	2595	205.0	4810
Gold	1063	2660	64.0	1580
Helium	–270	–269	5.2	21
Lead	327	1750	23.0	858
Mercury	–39	357	11.7	270
Nitrogen	–210	–196	25.5	200
Oxygen	–219	–183	13.8	210
Water	0	100	336.0	2260

Q.16 Define and explain evaporation. What are the factors on which it depends? 091308016

Ans. Evaporation is the changing of a liquid into vapours (gaseous state) from the surface of the liquid without heating it.

Cooling effect of Evaporation:

Evaporation plays an important role in our daily life. Wet clothes dry up rapidly when spread. Evaporation causes cooling. During evaporation fast moving molecules escape out from the surface of the liquid. Molecules that have lower kinetic energies are left behind. This lowers the average kinetic energy of the liquid molecules and the temperature of the liquid. Since temperature of a substance depends on the average kinetic energy of the molecules. Evaporation of perspiration helps to cool our bodies.

Factors

Evaporation takes place at all temperature from the surface of liquid. The rate of evaporation is affected by various factors.

i) Temperature

At higher temperature, more molecules of liquid are moving with high velocities. Thus, more molecules escape from its surface. Thus, evaporation is faster at high temperature than at low temperature.

ii) Surface Area

Larger is the surface area of a liquid, greater number of molecules has the chance to escape from its surface.

iii) Wind

Wind blowing over the surface of a liquid sweeps away the liquid molecules that have just escaped out. This increases the chance for more liquid molecules to escape out.

iv) Nature of the Liquid

Liquids differ in the rate at which they evaporate i.e. evaporation depends upon the nature of liquid.

Q.17 What is meant by thermal expansion? Or Write any two applications of thermal expansion.

091308017

Ans Most of the substances solids, liquids and gases expand on heating and contract on cooling. Their thermal expansions and contractions are usually small and are not noticeable. However, these expansions and contractions are important in our daily life.

Explanation on the basis of kinetic molecular theory:

The kinetic energy of the molecules of an object depends on its temperature. The molecules of a solid vibrate with larger amplitude at high temperature than at low temperature. Thus, on heating, the amplitude of vibration of the atoms or molecules of an object increases. They push one another farther away as the amplitude of vibration increases. Thermal expansion results in increase in length breadth and thickness of a substance.

Q.18 Define and explain Linear Thermal Expansion.

091308018

Ans *"The expansion of substance along length on heating it, is called linear thermal expansion."*

Dependence of Linear expansion:

If we heat a metal rod whose length is much larger than its thickness then, the increase in length depend on three factors:

(i) Original length of rod (L_o)
(ii) Change in temperature ($T - T_o$)
(iii) Nature of material.

Explanation:

Consider a metal rod of length L_o at certain temperature T_o. Let its length on heating to a temperature T becomes L. Thus

Increase in length of the rod $= \Delta L = L - L_o$

Increase in temperature $= \Delta T = T - T_o$

It is found that change in length ΔL of a solid is directly proportional to its original length L_o, and the change in temperature ΔT.

That is;

$$\Delta L \propto L_o \Delta T$$

$$\Delta L = \alpha L_o \Delta T \quad \ldots\ldots\ldots\ldots (1)$$

Or $$L - L_o = \alpha L_o \Delta T$$

Or $$L = L_o(1 + \alpha \Delta T)$$

Where α is called the **coefficient of linear thermal expansion of the substance.**

From equation (1), we get

$$\alpha = \frac{\Delta L}{L_o \Delta T}$$

Co-efficient of linear expansion:

"The fractional increase in its length per Kelvin rise in temperature is called coefficient of linear expansion."

Its unit is K^{-1}

Coefficient of linear thermal expansion (α) of some common solids.	
Substance	**α (K^{-1})**
Aluminum	2.4×10^{-5}
Brass	1.9×10^{-5}
Copper	1.7×10^{-5}
Steel	1.2×10^{-5}
Silver	1.93×10^{-5}
Gold	1.3×10^{-5}
Platinum	8.6×10^{-5}
Tungsten	0.4×10^{-5}
Glass (pyrex)	0.4×10^{-5}
Glass (ordinary)	0.9×10^{-5}
Concrete	1.2×10^{-5}

Q.19 Define and explain Volume Thermal Expansion. 091308019

Ans Definition

"The volume of a solid also changes with the change in temperature and is called volume thermal expansion or cubical thermal expansion."

Dependence of Volume Expansion:

Volume thermal expansion depends upon the following factors:

(i) Original Volume (V_o)

(ii) Change in temperature ($T - T_o$)

(iii) Nature of material.

Explanation

Consider a solid of initial volume V_o at certain temperature T_o. On heating the solid to a temperature T, let its volume becomes V, then

Change in the volume of a solid $\Delta V = V - V_o$

and Change in temperature is $\Delta T = T - T_o$

Like linear expansion, the change in volume ΔV is found to be proportional to its original volume V_o and change in temperature ΔT.

Thus

$$\Delta V \propto V_o \Delta T$$

or $$\Delta V = \beta V_o \Delta T$$

or $$V - V_o = \beta V_o \Delta T$$

or $$V = V_o(1 + \beta \Delta T)$$

Where β is the temperature coefficient of volume expansion.

Coefficient of Volume Expansion

The fractional change in its volume per Kelvin change in temperature is called coefficient of volume of expansion."

$$\boxed{\beta = \frac{\Delta V}{V_o \Delta T}}$$

Relation between α & β

The coefficients of linear expansion and volume expansion are related by the equation: $\beta = 3\alpha$
Coefficient of volume expansion is three times the coefficient of linear thermal expansion.

Coefficient of volume expansion of various substances.	
Substance	**β (K^{-1})**
Aluminum	7.2×10^{-5}
Brass	6.0×10^{-5}
Copper	5.1×10^{-5}
Steel	3.6×10^{-5}
Platinum	27.0×10^{-5}
Glass (ordinary)	2.7×10^{-5}
Glass (pyrex)	1.2×10^{-5}
Glycerine	53×10^{-5}
Mercury	18×10^{-5}
Water	21×10^{-5}
Air	3.67×10^{-3}
Carbon dioxide	3.72×10^{-3}
Hydrogen	3.66×10^{-3}

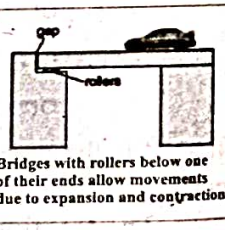
Q.20 Why are gaps left in railway tracks? **(F.B. 2013, 17)** 091308020

Ans. The expansion of solids may damage the bridges, railway tracks and roads as they are constantly subjected to temperature changes. So, gaps are made during construction for expansion and contraction with temperature. For example, railway tracks buckled on a hot summer day due to expansion if gaps are not left between sections.

Gaps are left in railway tracks to compensate thermal expansion during hot season

Q.21 Why is one end of bridges placed on roller? 091308021

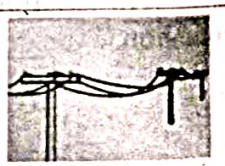
Ans. Bridges made of steel girders also expand during the day and contract during night. They will bend if their ends are fixed. To allow thermal expansion, one end is fixed while the other end of the girder rests on rollers in the gap left for expansion.



Bridges with rollers below one of their ends allow movements due to expansion and contraction

Q.22 Why overhead transmission lines are given a certain amount of Sag? 091308022

Ans. Overhead transmission lines are also given a certain amount of sag so that they can contract in winter without snapping.



Wires on electric poles are given some sag to prevent breaking in winter

Q.23 What are the applications of thermal expansion in our daily life? 091308023

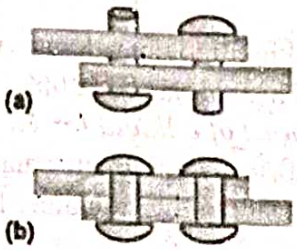
Ans Application of Thermal Expansion

(i) In thermometers, thermal expansion is used in temperature measurements.

(ii) To open the cap of a bottle that is tight enough, immerse it in hot water for a minute or so. Metal cap expands and becomes loose. It would now be easy to turn it to open.

(iii) To join steel plates tightly together, red hot rivets are forced through holes in the plates. The end of hot rivet is then hammered. On cooling, the rivets contract and bring the plates tightly gripped.

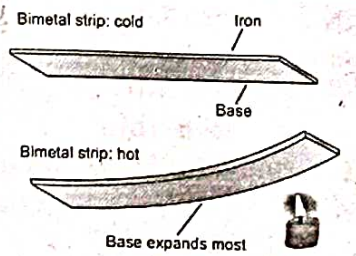
(iv) Iron rims are fixed on wooden wheels of carts iron rim is heated and allow it to slip over the wooden wheel. Then water is poured on it to cool. The rim contract and becomes tight over the wheel.



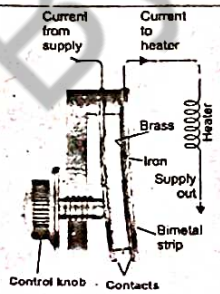
(a) Hot rivets inserted (b) after hammering, rivets are cold down.

Q.24 What is meant by Bimetal Strip? Write its uses. (F.B. 2018) 091308024

Ans *A bimetal strip consists of two thin strips of different metals such as brass and iron joined together. On heating the strip, brass expands more than iron. This unequal expansion causes bending of the strip.*



Bimetallic strip



Binetal thermostat breaks electrical circuit at preset temperature.

Uses of Bimetallic Strip

Bimetal strips are used for various purposes.

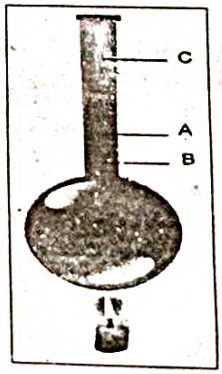
(i) Bimetal thermometers are used to measure temperatures especially in furnaces and ovens.

(ii) Bimetal strips are also used in thermostats. Bimetal thermostat switch is used to control the temperature of heater coil in an electric iron.

Q.25 Explain the thermal expansion of liquid. 091308025

Ans: Thermal Expansion of Liquids

The molecules of liquids are free to move in all directions in the liquid. On heating a liquid, the average amplitude of vibration of its molecules increases. The molecules push each other and need more space to occupy. This accounts for the expansion in liquids is greater than solids due to the weak intermolecular forces. Therefore, the coefficient of volume expansion of liquids is greater than solids.



Properties of Liquids

Liquids have no definite shape of their own.

A liquid always attains shape of the container in which it is poured.

When a liquid is heated, both liquid and the container undergo a change in their volume. Thus, there are two types of thermal volume expansion for liquid.

- Apparent volume expansion
- Real volume expansion.

Activity

Take a long-necked flask. Fill it with some coloured liquid up to the mark A on its neck. Now start heating the flask from bottom. The liquid level first falls to B and then rises to C.

The heat first reaches the flask which expands and its volume increases. As a result liquid descends in the flask and its level falls to B. After sometime, the liquid begins to rise above B on getting hot. At certain temperature it reaches at C. The rise in level from A to C is due to the apparent expansion in the volume of the liquid. Actual expansion of the liquid is greater than the apparent expansion of liquid and expansion of flask. Thus real expansion of the liquid is equal to the volume difference between A and C in addition to the volume expansion of the flask. Hence addition to the volume expansion of the flask. Hence

Real expansion of the liquid = apparent expansion of the liquid + expansion of the flask

Or $BC = AC + AB$

The expansion of the volume of a liquid taking into consideration the expansion of the container also, is called the **real volume expansion of the liquid**. The real rate of volume expansion β_r of a liquid is defined as

"The actual change in the unit volume of a liquid for 1K (or 1°C) rise in its temperature."

The real rate of volume expansion β_r is always greater than the apparent rate of volume expansion β_a by an amount equal to the rate of volume expansion of the container β_g Thus

$\beta_r = \beta_a + \beta_g$

It should be noted that different liquids have different coefficients of volume expansion.

MULTIPLE CHOICE QUESTIONS

8.1 Encircle the correct answer from the given choices:

Exercise MCQs

1. Water freezes at (F.B. 2014) 091308026
   (a) 0°F (b) 32°F
   (c) −273 K (d) 0 K

2. Normal human body temperature is: (F.B. 2013) 091308027
   (a) 15 °C (b) 37 °C
   (c) 37 °F (d) 98.6 °C

3. Mercury is used as thermometric material because it has: 091308028
   (a) uniform thermal expansion
   (b) low freezing point
   (c) small heat capacity
   (d) all the above properties

4. Which of the following material has large specific heat? (F.B. 2014, 17) 091308029
   (a) copper (b) ice
   (c) water (d) mercury

5. Which of the following material has large value of temperature coefficient of linear expansion? 091308030
   (a) aluminum (b) gold
   (c) brass (d) steel

6. What will be the value of β for a solid for which α has a value of $2 \times 10^{-5}\ K^{-1}$? 091308031
   (a) $2 \times 10^{-5}\ K^{-1}$ (b) $6 \times 10^{-5}\ K^{-1}$
   (c) $8 \times 10^{-15}\ K^{-1}$ (d) $8 \times 10^{-5}\ K^{-1}$

7. A large water reservoir keeps the temperature of nearby land moderate due to: 091308032
   (a) low temperature of water
   (b) low specific heat of water
   (c) less absorption of heat
   (d) large specific heat of water

8. Which of the following affects evaporation? 091308033
   (a) temperature
   (b) surface area of the liquid
   (c) wind
   (d) all of the above

Additional MCQs

9. Unit of Specific heat is: 091308034
   (a) J (b) Jkg^{-1}
   (c) $Jkg^{-1}K^{-1}$ (d) Jkg K

10. The unit of heat is: 091308035
    (a) kelvin (b) joule (J)
    (c) $Jkg^{-1}K^{-1}$ (d) kg

11. Density of water is: 091308036
    (a) $1000\ kgm^{-3}$ (b) $4200\ kgm^{-3}$
    (c) $4300\ kgm^{-3}$ (d) $4500\ kgm^{-3}$

12. The unit of co-efficient of linear expansion 091308037
    (a) K (b) K^{-1}
    (c) $Jkg^{-1}K^{-1}$ (d) $J\ K^{-1}$

13. The relation between co-efficient of linear expansion and volume expansion is: 091308038
    (a) $\alpha = 3\beta$ (b) $\beta = 3\alpha$
    (c) $\alpha = \frac{3}{\beta}$ (d) $\beta = \frac{3}{\alpha}$

14. The formula for conversion of Celsius into Kelvin is 091308039
    (a) $T_k = 273 - C^o$ (b) $T_k = 273 + C^o$
    (c) $F = 1.8C + 32$ (d) $C = \frac{1.8 - 32}{F}$

15. Degree of hotness or coldness of a body is called: 091308040
    (a) Heat
    (b) Internal energy
    (c) Temperature
    (d) Potential energy

16. The sum of kinetic energy and potential energy of molecules or atoms is called: 091308041
    (a) Temperature
    (b) Internal energy
    (c) Kinetic energy
    (d) Potential energy

17. The energy store in an atom or molecule due to intermolecular force is: 091308042
    (a) Kinetic energy (b) Potential energy
    (c) Internal energy (d) G.P.E

18. The freezing point of Mercury is: 091308043
    (a) 49°C (b) −49°C
    (c) 39°C (d) −39°C

19. The boiling point of mercury is: 091308044
    (a) −10°C (b) 150°C
    (c) 357°C (d) 457°C

Q.8.3 Define the terms heat and temperature. 091308087

Ans. Heat "Heat is the energy that is transferred from one body to the other in thermal contact with each other as a result of the difference of temperature between them."

Define temperature

"Temperature of a body is the degree of hotness or coldness of the body."

Q.8.4 What is meant by internal energy of a body? 091308088

Ans. The total sum of potential energy and kinetic energy associated with atoms, molecules and particles of a body is called internal energy of a body.

Q.8.5 How does heating affect the motion of molecules of a gas? 091308089

Ans. When heat is added to gas molecules, the molecules of gas move with higher velocities, that increases the average kinetic energy of gas molecules. When gas molecules are heated, the gas particles expand and their volume increases. If volume is increases then with the increase in temperature, average kinetic energy of gas molecules increases which exert more pressure on the walls of container.

$$T \propto K.E$$

Q.8.6 What is a thermometer? Why mercury is preferred as a thermometric substance? 091308090

Ans. A device which is used to measure temperature is called thermometer. Mercury is preferred as thermometric substance because it has high boiling point, less specific heat, low freezing point and has uniform thermal expansion. It is a good conductor of heat and it is visible.

Q.8.7 Explain the volumetric thermal expansion. 091308091

Ans. See Q. No. 19. Page no 157.

Q.8.8 Define specific heat. How would you find the specific heat of a solid? 091308092

Ans. See Q. No. 9. Page no 150.

Q.8.9 Define and explain latent heat of fusion. 091308093

Ans. See Q. No. 14. Page no 153.

Q.8.10 Define latent heat of vaporization. (F.B. 2017) 091308094

Ans. See Q. No.,15. Page no 154.

Q.8.11 What is meant by evaporation? On what factors the evaporation of a liquid depends? Explain how cooling is produced by evaporation. (F.B. 2015) 091308095

Ans. The changing of liquid into vapours state without heating is called evaporation. Evaporation takes place at all the temperature at the surface of liquid. When fast moving molecules escape out from the surface of liquid the molecule that have low kinetic energy are left behind this lowers down the average kinetic energy of liquid molecules and temperature of liquids. Hence cooling is produce due to evaporation.

Factors of evaporation: (1) Temperature (2) Surface area (3) Wind (4) Nature of liquid

Additional Question Answers

Q.12 How does cooling effect produce in Refrigerator? 091308096

Ans. Cooling is produced in refrigerators by evaporation of a liquified gas. This produces cooling effect. Freon, a CFC, was used as a refrigerant gas. But Freon gas is now replaced by Ammonia and other substances which are not harmful to the environment.

Q.13 What is clinical thermometer? What is the use of clinical thermometer ? Write its range. 091308097

Ans. A clinical thermometer is used to measure the temperature of human body. It has a narrow range from 35°C to 42°C. It has a construction that prevents the mercury to return. Thus, its reading does not change until reset.

Q.14 What is meant by anomalous expansion of water? 091308098

Ans. Water on cooling below 4°C begins to expand until it reaches to 0°C. On further cooling its volume increases suddenly as it changes into ice at 0°C. When ice is cooled below 0°C, it contracts i.e. its volume decreases like solids. This unusual expansion of water is called the anomalous expansion of water.

Q.15 What is the effect of large water reservoirs on climate? 091308099

Ans. The presence of large water reservoirs such as lakes and seas keep the climate of near by land moderate due to the large heat capacity of these water reservoirs.

Q.16 Write three scales of temperature. 091308100

Ans. Two scales of temperature are:

1) Celsius scale
2) Fahrenheit scale
3) Kelvin scale

Q.17 Which flower is known as natural thermometer and why? 091308101

Ans. The crocus flower is a natural thermometer. It opens when the temperature is precisely 23°C and closes when the temperature drops.

Q.18 What is meant by thermal equilibrium? 091308102

Ans. The property of a system when all parts of the system have same temperature along with its surrounding. In other words, the condition under which two substances are in physical contact with each other exchange no heat energy.

Q.19 Define co-efficient of linear expression. 091308103

Ans. The thermal co-efficient of linear expansion α of a substance is defined as the fractional increases in its length per Kelvin rise in temperature.

$$\alpha = \frac{\Delta L}{L_o \Delta T}$$

Q.20 Write the formula to convert scales of temperature from one another. 091308104

Ans. 1. $T(K) = 273 + C$

2. $F = 1.8C + 32$

3. $C = \frac{F-32}{1.8}$

Q.21 Define latent heat of vaporization. 091308105

Ans. "The quantity of heat that changes unit mass of a liquid completely into gas at its boiling point without any change in its temperature is called its latent heat of vaporization."

It is denoted by H_v $\quad H_v = \frac{\Delta Q_v}{m}$

Q.22 Define thermal expansion. 091308106

Ans. The expansion of substance with the change in temperature is called thermal expansion. Most of the substances solids, liquids and gases expand on heating and contract on cooling. The expansion and contraction of solids are usually small and are not noticeable.

Q.23 Define coefficient of volume expansion. 091308107

Ans. The fractional change in its volume per Kelvin change in temperature is called coefficient of volume thermal expansion." $\beta = \frac{\Delta V}{V_0 \Delta T}$

Q.24 Define bimetallic strip. 091308108

Ans. A bimetal strip consists of two thin strips of different metals such as brass and iron joined together. On heating the strip, brass expands more than iron. This unequal expansion causes bending of the strip.

Q.25 What is the freezing and boiling point of mercury? 091308109

Ans. Mercury freezes at –39°C and boils at 357°C.

Q.26 What is upper and lower fixed point? 091308110

Ans. A thermometer has a scale on its stem. This scale has two fixed points. The lower fixed point is marked to show the position of liquid in the thermometer when it is placed in ice. Similarly, upper fixed point is marked to show the position of liquid in the thermometer when it is placed in steam at standard pressure above boiling water.

Q.27 What is the benefit of large specific heat of water? 091308111

Ans. Water has a large specific heat capacity. For this reason, it is very useful in storing and carrying thermal energy.

Q.28 Define fusion point / melting point. 091308112

Ans. "When a substance is changed from solid to liquid state by heating, the process is called melting or fusion." The temperature at which a solid starts melting is called its **fusion point or melting point.**

Q.29 Define freezing point. 091308113

Ans. When a liquid is cooled, it changes into solid state. The temperature at which a substance changes from liquid to solid state is called its **freezing point**.

Q.30 Define evaporation. 091308114

Ans. Evaporation is the changing of a liquid into vapours (gaseous state) from the surface of the liquid without heating it.

Q.31 On what factor kinetic energy of an object depends? 091308115

Ans. The kinetic energy of the molecules of an object depends on its temperature.

Q.32 What is the relation between coefficient of linear and volume expansion. 091308116

Ans. The coefficients of linear expansion and volume expansion are related by the equation: $\beta = 3\alpha$

Q.33 What is thermostat? 091308117

Ans. Thermostat switch is used to control the temperature of heater coil in an electric iron.

Q.34 How many types of thermal expansion of liquids? 091308118

Ans. A. There are two types of thermal volume expansion for liquid .

(a) Apparent volume expansion

(b) Real volume expansion

Q.35 What happens when we touch a hot body? 091308119

Ans. When we touch a hot body, heat energy will transfer from hot to cold body. The temperature of hot body falls. It loses energy. This energy enters the body at lower temperature. Cold body gains energy and its temperature rises. The transfer of heat continues till both the bodies have same temperature.

Q.36 Why in summer, ice is wrap with cloth or stored in thermos flask? 091308120

Ans. To store ice, in summer, people wrap the ice with cloth or keep it in wooden box or in thermos flask. In this way they avoid the thermal contact of ice with its hot surroundings otherwise ice will soon melt away. Wooden boxes, air and clothes are bad conductor of heat.

Q.37 Why are desert nights colder whereas day very hot? 091308121

Ans. It is due to low specific heat of sand. Sand get hot in day time earlier and in night becomes cold. The substance which have low specific heat capacity it gain and loss heat quickly with the increase and decrease in temperature. so, due to this reason desert nights are colder whereas days are very hot.

Q.38 Why does the temperature of a solid substance not increase during its fusion process? (F.B. 2018) 091308122

Ans. Below the 0°C, when the solid is given to heat its temperature increases upto 0°C. After this substance under goes a change from solid to liquid. At this time, temperature remains constant till all the solid completely change into liquid. During this time all the heat given to system is utilize to break the inter molecular forces between them. That is why temperature not increasing during fusion process.

Q.39 Differentiate between boiling and condensation. (F.B. 2018) 091308123

Ans.

Boiling	Condensation
Boiling refers to the change of phase from liquid to gas. This change occurs at a specific temperature called boiling point.	Condensation refers to the change of phase from gas to liquid. It is the opposite to boiling.

Q.40 Calculate the coefficient of linear thermal expansion of aluminium if the value of its coefficient of volume expansion is $7.2 \times 10^{-5} k^{-1}$. (F.B. 2016) 091308124

Ans. Coefficient of volume expansion

$= \beta = 7.2 \times 10^{-5} k^{-1}$

Coefficient of linear thermal expansion $= \alpha = ?$

Relation between α and β are

$\beta = 3\alpha$

$7.2 \times 10^{-5} = 3\alpha$

$\frac{7.2 \times 10^{-5}}{3} = \alpha$

$\alpha = 2.4 \times 10^{-5} k^{-1}$

Result:

Thus the coefficient of linear thermal expansion α is $2.4 \times 10^{-5} k^{-1}$.

Q.41 Why do wet clothes dry up more quickly in summer than in winter? (F.B. 2013) 091308125

Ans. In summer, temperature is higher. At higher temperature, more molecules of liquid escape from its surface. Rate of evaporation is higher at higher temperature than that at lower temperature. This is the reason that we clothes dry up more quickly in summer than in winter.

Q.42 Calculate the value of latent heat of fusion of 4kg of ice at 0°C. 091308126

Ans. Latent heat of fusion to melt 1kg of ice into water at $0°C = 3.36 \times 10^5 J$

Latent heat of fusion to melt 4kg of ice in to water at $0°C = 3.36 \times 10^5 \times 4$

$= 13.44 \times 10^5 J$

MINI EXERCISE

Q.43 Which of the following substances have greater average kinetic energy of its molecules of 10°C. 091308127

(a) steel (b) copper
(c) water (d) mercury

Ans. Water has greater average kinetic energy of its molecule at 10°C.

Q.44 Every thermometer makes use of some property of material that varies with temperature, name the property used in: 091308128

(a) strip thermometers
(b) mercury thermometers

Ans. (a) Strip thermometer: In strip thermometer, thin film of liquid crystals are used, that changes its colour with the change in temperature. liquid crystal mixture is enclosed in separate portions in strip thermometer. These portions indicate temperature both in Celsius and Fahrenheit according to amount of heat present. Liquid crystals respond to change in temperature by changing colours from red to orange, yellow, green, blue and purple.

(b) Mercury thermometer: In mercury thermometer, liquid mercury is used. Mercury expand on heating. Mercury has uniform thermal expansion, easily visible, low freezing point, high boiling point, small specific heat capacity and good conductor of heat. Due to these properties mercury is used in mercury thermometer.

Q.45 How specific heat differs from heat capacity? 091308129

Ans.

Heat Capacity	Specific Heat
(i) Heat capacity of a body is the quantity of thermal energy absorbed by it for one Kelvin increase in temperature.	(i) Specific Heat of a substance is the amount of heat required to raise the temperature of 1kg mass of that substance through 1K.
(ii) Heat capacity can be calculated by the relation: Heat capacity = mc	(ii) Specific heat can be calculated by the relation: $C = \frac{\Delta Q}{m\Delta T}$
(iii) Unit of heat capacity is Jk^{-1}.	(iii) Unit of specific heat is $Jkg^{-1}K^{-1}$.

Q.46 Give two uses of cooling effects by evaporation. 091308130

Ans.

(i) Evaporation causes cooling. Human body makes use of evaporative cooling by perspiration. It helps to cool our bodies.

(ii) Water evaporation from the leaves of trees also cool our environment.

(iii) In villages, water is cooled in the pot. Pot contain large pores, the high energy water molecules evaporates via these pores and the remaining water inside the pot to be cooled.

Q.47 How evaporation differs from vaporization? (F.B. 2018) 091308131

Ans.

Evaporation	Vaporization
Evaporation is the changing of a liquid into vapours (gaseous state) from the surface of the liquid without heating it.	Vaporization is the changing of a liquid into gaseous state from the surface of liquid with heating it.
Evaporization takes place at all temperatures.	The process of boiling take place at a certain fixed temperature.
	Vaporization take place not only from the surface of liquid but also within the liquid.

Q.48 The temperature of soil increases more than the same mass of water. Why? (F.B. 2017) 091308132

Ans. Specific heat of soil is much smaller than the water. Specific heat of water is $4200Jkg^{-1}k^{-1}$ of and that of dry soil is about $810\ Jkg^{-1}k^{-1}$. So we can say that temperature of soil would increase five times more than the same mass of water by providing the same amount of heat.

SOLVED EXAMPLES

Example 8.1

What will be the temperature on Kelvin scale of temperature when it is 20°C on Celsius scale? 091308133

Solution

C = 20°C

as T = 273 + C

T = 273+20 = 293K

Example 8.2 091308134

Change 300K on Kelvin scale into Celsius scale of temperature.

Solution

T = 300 K

Since C = T(K) – 273

∴ C = (300 – 273) °C Or C = 27°C

Example 8.3 091308135

Convert 50°C on Celsius scale into Fahrenheit temperature scale.

Solution

C = 50°C

Since F = (1.8 × C + 32)

F = (1.8 × 50 + 32) Or F = 122°F

Result:

Thus, 50°C on Celsius scale is 122°F on Fahrenheit scale.

Example 8.4 (F.B. 2017) 091308136

Convert 100 °F into the temperature on Celsius scale.

Solution

F = 100 °F

Since 1.8C = F – 32

∴ = 100 – 32

Or 1.8 C = 68 Or C = 68/1.8 Or C = 37.8°C

Result:

Thus, 100°F is equal to 37.8°C

Examples 8.5

A container has 2.5 litres of water at 20°C. How much heat is required to boil the water? (F.B. 2017) 091308137

Solution

Volume of water = V = 2.5 litres

Mass of water = m = 2.5 kg

(since density of water is 1000kgm^{-3} or 1kgL^{-1})

Specific heat of water = c = 4200 Jkg^{-1} K^{-1}

Initial temperature = T_1 = 20°C

Final temperature = T_2 = 100°C

Temperature Increase ΔT = $T_2 - T_1$

= 100°C – 20°C

= 80°C or 80K

Since Δ Q = cmΔT

∴ Δ Q = 4200 × 2.5 × 80

Or Δ Q = 840 000J

Result:

Thus, required amount of heat is 840 000 J or 840 kJ.

Example 8.6

A brass rod is 1m long at 0°C. Find its length at 30°C 091308138
(Co-efficient of linear expansion of brass = $1.9 \times 10^{-5}\ K^{-1}$)

Solution

$L_o = 1m$

$T_o = 0+273 = 273\ K$

$T = 30+273 = 303\ K$

$\Delta T = T - T_o$

$= 303\ K - 273\ K$

$= 30\ K$

$\alpha = 1.9 \times 10^{-5}\ K^{-1}$

Since $L = L_o(1+\alpha\Delta T)$

$L = 1(1 + 1.9 \times 10^{-5} \times 30)$

$L = 1.00057\ m$

Result:

Hence, the length of the brass bar at 30 °C will be 1.00057 m.

Example 8.7

Find the volume of a brass cube at 100°C whose side is 10cm at 0°C (Coefficient of linear thermal expansion of brass = $1.9 \times 10^{-5} K^{-1}$) **(F.B. 2013)** 091308139

Solution

$L_o = 10cm = 0.1m$

$T_o = 0\ °C = (0+273)\ K = 273K$

$T = 100\ °C = (100+273)\ K = 373K$

$\Delta T = T - T_o$

$= 373K - 273\ K = 100\ K$

$\alpha = 1.9 \times 10^{-5}\ K^{-1}$

As $\boxed{\beta = 3\alpha}$

$\beta = 3 \times 1.9 \times 10^{-5}$

$= 5.7 \times 10^{-5}\ K^{-1}$

Initial volume $v_o = (L_o)^3 = (0.1\ m)^3$

$= 0.001\ m^3 = 10^{-3}\ m^3$

Since $\boxed{V = V_o(1+\beta\Delta T)}$

$V = 10^{-3} \times (1 + 5.7 \times 10^{-5} \times 100)$

$V = 10^{-3} \times (1 + 5.7 \times 10^{-3})$

$V = 10^{-3} \times (1 + 0.0057)$

$V = 1.0057 \times 10^{-3}\ m^3$

Result:

Hence, the volume of brass cube at 100 °C will be $1.0057 \times 10^{-3}\ m^3$

NUMERICAL PROBLEMS

8.1 Temperature of water in a beaker is 50°C. What is its value in Fahrenheit scale? 091308140

Given data:

Temperature in centigrade = $T_c = 50C^o$

To Find:

Temperature in Fahrenheit = T_F = ?

Solution:

$$T_F = \frac{9}{5}T_c + 32$$
$$= \frac{9}{5}50 + 32$$
$$= 9\times10 + 32$$
$$= 90 + 32$$
$$T_F = 122°F$$

Result:

Temperature of 50°C of water is equal to 122°F.

8.2 Normal human body temperature is 98.6°F. Convert it into Celsius scale and Kelvin scale. (F.B. 2014) 091308141

Given data:

Temperature in Fahrenheit = $T_F = 98.6\ F^o$

To Find:

Temperature in Celsius Scale = T_c = ?

Temperature in Kelvin Scale = T_k = ?

Solution:

$$T_c = \frac{5}{9}(T_F-32)$$
$$= \frac{5}{9}(98.6-32)$$
$$= \frac{5}{9}\times 66.6$$
$$= \frac{333}{9}$$
$$T_c = 37C^o$$
$$T_k = T_c + 273$$
$$= 37 + 273$$
$$T_k = 310\ K$$

Result:

Temperature in Kelvin is 310K.

8.3 Calculate the increase in the length of an aluminum bar 2 m long when heated from 0 °C to 20 °C. If the thermal coefficient of linear expansion of aluminum is $2.5 \times 10^{-5}\ K^{-1}$. 091308142

Given data:

Original length = L = 2m

Initial temperature = T_1 = 0°C
= 0+273
= 273 K

Final Temperature = T_2 = 20^0C
= 20+273
= 293 K

Co-efficient of linear expansion = α
$\alpha = 2.5 \times 10^{-5}K^{-1}$

To Find:

Increase in length = $\Delta L = L\text{-}L_o$=?

Solution:

$$L-L_o = \alpha L_o \Delta T$$
$$= 2.5 \times 10^{-5} \times 2 \times (293\text{-}273)$$
$$= 2.5 \times 10^{-5} \times 2 \times 20$$
$$L-L_o = 40\times2.5\times10^{-5}$$
$$= 100 \times 10^{-5}\ m = 10^2\times10^{-5}m$$
$$= 10^{-3}\ m$$
$$= 0.1 \times 10^{-2}\ m$$
$$L-L_o = 0.1\ cm$$

Result:

The increasing length of an aluminium bar is 0.1cm.

8.4 A balloon contains $1.2m^3$ air at 15 °C. Find its volume at 40 °C. Thermal coefficient of volume expansion of air is $3.67 \times 10^{-3}\ K^{-1}$. 091308143

Given data:

Initial volume = $V_o = 1.2\ m^3$

Initial Temperature = T_1 = 15°C
= 15+273
= 288 K

Final Temperature = T_2 = 40°C
= 40+273
= 313 K

Temperature difference ΔT =
$T_2 - T_1 = 313 - 218 = 25K$

Coefficient of volume expansion = β
$= 3.67 \times 10^{-3}K^{-1}$

To find:

Volume = V = ?

Solution:

$$V = V_o(1 + \beta\Delta T)$$
$$= 1.2(1+3.67 \times 10^{-3}\times 25)$$
$$= 1.2\ (1 + 0.09175)$$
$$= 1.2\ (1.09175)$$
$$V = 1.3m^3$$

Result:

A balloon's volume at 40°C is equal to $1.3m^3$.

8.5 How much heat is required to increase the temperature of 0.5 kg of water from 10 °C to 65 °C? 091308144

Given data:

Mass = m = 0.5 Kg

Initial temperature = T_1 = 10°C.
= 10+273
= 283 K

Final temperature = T_2 = 65°C
= 65+273
= 338K

Specific heat of water = c = 4200Jkg^{-1} K^{-1}.

To Find

Heat = Q = ?

Solution:

$\Delta Q = mc\Delta T$
$= 0.5 \times 4200\ (338-283)$
$= 2100 \times 55$
$\Delta Q = 115500$ J

Result:

115500J of heat is required to increase the temperature of water.

8.6 An electric heater supplies heat at the rate of 1000 joule per second. How much time is required to raise the temperature of 200 g of water from 20 °C to 90 °C? 091308145

Given data:

Rate of heat supplied = $\frac{Q}{t}$ = 1000Js^{-1}.

Mass of water = m = 200 g = 0.2 Kg

Specific heat of water = c = 4200J kg^{-1} K^{-1}.

Initial temperature = T_o = 20 °C.
= 20+273
= 293 K

Final temperature = T = 90° = 90+273=363 K

Temperature difference = $\Delta T = T - T_o$
= 363 − 293 = 70K

To Find:

Time = t = ?

Solution

Rate of Heat = $\frac{Q}{t}$ = 1000 Js^{-1}

$Q = 1000 \times t$

As we know that

$Q = mc\Delta t$

$1000 \times t = mc\Delta T$

$t = \frac{mc\Delta T}{1000}$

$t = \frac{mc\Delta T}{1000}$

$= \frac{0.2 \times 4200 \times 70}{1000}$

$= \frac{58800}{1000}$

t = 58.8s

Result:

58.8s is required to raise the temperature of 200g of water from 20°C to 90°C.

8.7 How much ice will melt by 50000 J of heat? Latent heat of fusion of ice = 336000 Jkg^{-1}. 091308146

Given data:

Heat = Q = 50000 J

Latent heat of fusion = H_f = 336000JKg^{-1}.

To Find:

Mass = m = ?

Solution:

$\Delta Q_f = mH_f$

$m = \frac{\Delta Q_f}{H_f}$

$= \frac{50000}{336000}$

$= \frac{50}{336}$

= 0.15kg = 0.15 × 1000 g

m = 150g

Result:

150g ice will melt by 50000J of heat.

8.8 Find the quantity of heat needed to melt 100g of ice at −10°C into water at 10°C. 091308147

Given data:

Mass of ice = m = 100g = 0.1Kg

Initial temperature = T_1 = −10°C = −10+273
= 263 K

Temperature of melted ice = T_2 = 0°C
= 0+273
= 273 K

Final temperature of water = T_3 = 10°C
= 10+273
= 283 K

Specific heat of water = C = 4200 J kg^{-1} K^{-1}.

Specific heat of ice = C_{ice} = 2100 Jkg^{-1} K^{-1}.

Latent heat of fusion of ice = H_f
= 336000 Jkg^{-1}.

To Find:

Heat absorbed by ice = Q = ?

Solution:

Heat absorbed by ice to change temperature (-10°C to 0°C) from 263 K to 273 K = Q_1 = ?

$Q_1 = mC_{ice}\,\Delta T$

$= mC_{ice}(T_2 - T_1)$

$= 0.1 \times 2100(273 - 263)$

$= 210 \times 10$

$Q_1 = 2100J$

Heat absorbed by ice to melt = Q_2

$Q_2 = mH_f$

$= 0.1 \times 336000$

$= 33600J$

Heat absorbed by water from 0°C to 10°C

$= Q_3 = mc\Delta T$

$= mc(T_3 - T_2)$

$= 0.1 \times 4200 \times (283 - 273)$

$= 0.1 \times 4200 \times 10$

$Q_3 = 4200J$

Total heat absorbed = $Q = Q_1 + Q_2 + Q_3$.

$= 2100 + 33600 + 4200$

$Q = 39900\ J$

Result:

39900J heat is required to melt ice at -10°C to water at 10°C.

8.9 How much heat is required to change 100 g of water at 100 °C into steam? (Latent heat of vaporization of water is 2.26 x 10^6 Jkg^{-1}.

(Board 2013-15)091308148

Given data:

Mass of water = m = 100 g = 0.1 kg

Temperature = T = 100 °C

= 273+100 = 373 K

Latent heat of vaporization of water = H_v

$H_v = 2.26 \times 10^6\ Jkg^{-1}$.

To Find: Heat = Q ?

Solution:

$Q = mH_V$

$Q = 0.1 \times 2.26 \times 10^6 = 2.26 \times 10^5 J$

Result:

2.26×10^5J amount of heat is required to change water into steam.

8.10 Find the temperature of water after passing 5 g of steam at 100 °C through 500 g of water at 10°C.

(Note: Specific heat of water is 4200 Jkg^{-1} K^{-1}, latent heat of vaporization of water is 2.26 x 10^6 Jkg^{-1}).

091308149

Given data:

Mass of steam = m_1 = 5g = $\frac{5kg}{1000}$ = 0.005kg

Temperature of steam = T_1 = 100°C = 100+273 = 373K

Initial temperature of water = T_2 = 10°C

T_2 = 10+273

= 283 K

Mass of water = m_2 = 500g

= 0.5 Kg

Latent heat of vaporization of water = H_V

= 226000J kg^{-1}

Specific heat of water = c = 4200 Jkg^{-1} K^{-1}.

To Find:

Temperature of mixture = T = ?

Solution:

According to law of heat exchange

Heat lost = Heat gained

Heat lost by the steam to become water at 100°C + Heat lost by the steam to reach final temperature = heat gained by water to reach at final temperature.

$m_1 H_v + m_1 c\Delta T = m_2 c\Delta T$

$m_1 H_v + mc(T_1 - T) = m_2 c(T - T_2)$

$0.005 \times 2260000 + 0.005 \times 4200(373 - T)$

$= 0.5 \times 4200(T - 283)$

$11300 + 21(373 - T) = 2100(T - 283)$

$11300 + 7833 - 21T = 2100T - 594300$

$11300 + 7833 + 594300 = 21T + 2100T$

$613433 = 2121T$

$T = \frac{613433}{2121}$

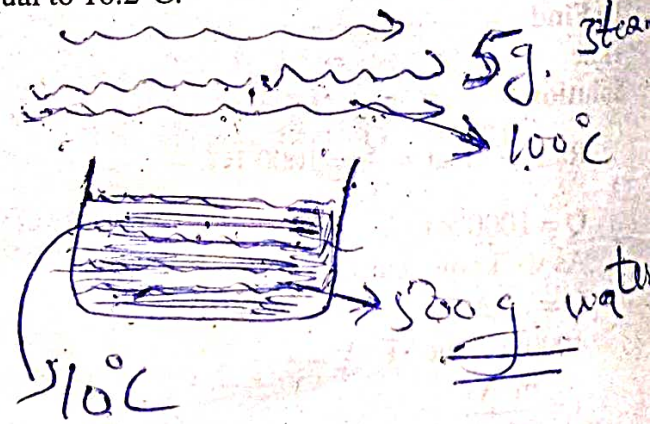
$T_k = 289.2\ K$

$T_c = T_k - 273$

$T_c = 289.2 - 273 = 16.2\ °C$

Result:

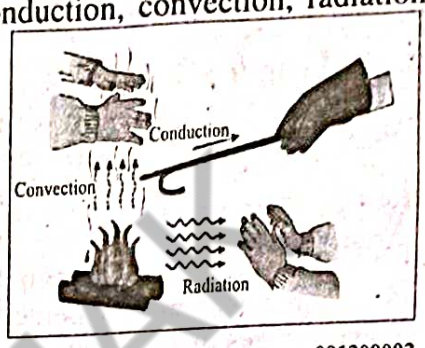
The temperature of water after passing steam is equal to 16.2°C.



UNIT 09 TRANSFER OF HEAT

Introduction:

In this unit we will learn about the three process of heat transfer, conduction, convection, radiation, consequences and everyday applications of heat transfer.



091309002

Q1. Define heat. Also write its uses. 091309001

Ans *"Heat is an important form of energy, which flows from one body to another body due to the difference of temperature".*

(i) It is necessary for our survival.

(ii) We need heat to cook our food and to maintain our body temperature.

(iii) Heat is also needed in various industrial processes.

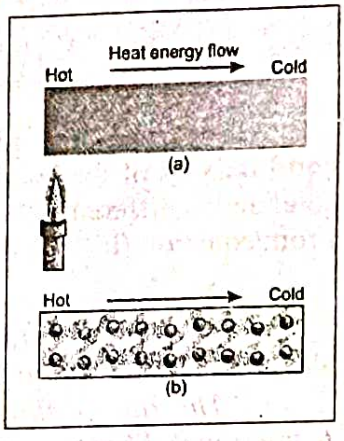
Q.2 How is heat transferred? Name the process (method) of heat transferring.

Ans. When bodies are in thermal contact with each other. Thermal energy from hot body flows to cold body, which is called **heat transfer**. Transfer of heat is a natural process. It continues all the time as long as the bodies in thermal contact are at different temperature. There are three ways of heat transfer:

(i) Conduction (ii) Convection (iii) Radiation

Q.3 Explain conduction process. (OR) How heat is transfer in solids explain? 091309003

Ans. *"The mode of transfer of heat by vibrating atoms and free electrons in solids from hot to cold parts of a body is called conduction of heat".*



Metals are generally better conductors than non-metals.

In solids, atoms and molecules are tightly packed. They continue to vibrate about their mean position.

When a solid body is heated atoms or molecules present at the end begin to vibrate more rapidly. They also collide with their neighbouring atoms or molecules. In doing so, they pass some of their energy to neighbouring atoms or molecules during collisions with them with the increase in their vibrations. These atoms or molecules in turn pass on a part of the energy to their neighbouring particles. In this way some heat reaches the other parts of the solids. This is a slow process and very small transfer of heat takes place from hot to cold parts in solids.

Metals have free electrons. These free electrons move with very high velocities within the metal objects. They carry energy at a very fast rate from hot to cold parts of the metal objects.

Conductors:

The substances through which heat conduct easily are called conductors. They contain free electrons for conduction. All metals are good conductors of heat.

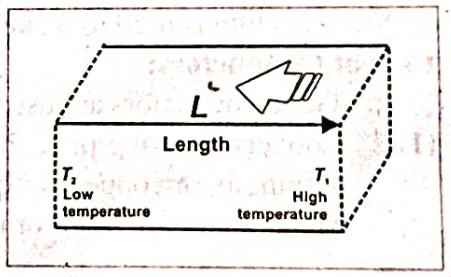
Insulator:

The substances through which heat does not conduct easily are called bad conductors or insulators. No, free electrons are available for conduction.

For Example: Wood, cork, cotton, wool, glass, rubber, etc, are bad conductors or insulators.

Q.4 Define Thermal Conductivity. What are the factors on which it depends? Explain. 091309004

Ans. *"The rate of flow of heat across the opposite faces of a metre cube of a substance maintained at a temperature difference of one kelvin is called the thermal conductivity of the substance".*



Consider a solid block as shown in figure.

One of its two opposite faces each of cross-sectional area "A" is heated to a temperature "T_1". Heat "Q" flows along its length **"L"** to opposite face at temperature "T_2" in "t" seconds.

Rate of the heat flow: *"The amount of heat that flows in unit time is called the rate of flow of heat".*

Thus rate of flow of heat = $\frac{Q}{t}$

It is observed that the rate at which heat flows through a solid object depends upon various factors.

1. Cross-sectional area of the solid:

Larger cross-sectional area A of a solid contains larger number of molecules and free electrons on each layer parallel to its cross-sectional area and hence greater will be the rate of flow of heat through the solid. Thus

Rate of flow of heat $\frac{Q}{t} \propto A$ .....(i)

2. Length of Solid:

Larger is the length between the hot and cold ends of solid more time it will take to conduct heat to the colder end and smaller will be the rate of flow of heat.

Rate of flow of heat = $\frac{Q}{t} \propto \frac{1}{L}$ .....(ii)

3. Temperature difference between ends:

Greater is the temperature difference $(T_1 - T_2)$ between hot and cold faces of the solid, greater will be the rate of flow of heat. Thus

Rate of flow of heat = $\frac{Q}{t} \propto (T_1 - T_2)$ .....(iii)

By combining (i), (ii) and (iii)

$$\frac{Q}{t} \propto \frac{A(T_1 - T_2)}{L}$$

$$\frac{Q}{t} = \frac{kA(T_1 - T_2)}{L} \quad \text{..... (iii)}$$

Here k is the proportionality constant called **thermal conductivity** of the solid. Its value depends on the nature of the solid and is different for different materials.

From equation (iii), we find k as:

$$k = \frac{Q}{t} \times \frac{L}{A(T_1 - T_2)} \quad \text{... ...}$$

Thermal conductivities of some common substances	
Substances	**$Wm^{-1} K^{-1}$**
Air (dry)	0.026
Aluminum	245
Brase	105
Brick	0.6
Copper	400
Glass	0.8
Ice	1.7
Iron	85
Lead	35
Plastic foam	0.03
Rubber	0.2
Silver	430
Water	0.59
Wood	0.08

Thermal conductivity: **(F.B. 2014)**

"The rate of flow of heat across the opposite faces of a metre cube of a substance maintained at a temperature difference of one Kelvin is called the thermal conductivity of the substance".

Unit of thermal conductivity is $Wm^{-1} K^{-1}$

091309005

Q.5 What are the uses of conductors and Non conductors?

Ans. Uses of non-conductors/insulators:

1. They are used in home utensils such as handles of sauce-pans, hot plates, spoons, etc. They are made up of wood or plastic.
2. Air is one of the bad conductors or best insulator. That is why cavity walls i.e. two walls separated by an air space and double glazed windows keep the houses warm in winter and cool in summer.
3. Materials which trap air i.e. wool, felt, fur, feathers, polystyrenes, fibre glass are also bad conductors. Some of these materials are used for laggings to insulate water pipes, hot water cylinders, ovens, refrigerators, walls and roofs of houses.
4. Woollen cloth is used to make warm winter clothes.


Feathers give good thermal insulation especially when fluffed up.

Uses of Conductors:

Good conductors are used when quick transfer of heat is required through a body.

(1) Cookers, cooking plate, boiler radiators and condensers of refrigerators, etc. are made of metals such as aluminum or copper, for quick transfer of heat.

(2) Metal boxes are used for making ice, ice cream, etc.

Q.6 What measures should be taken to save energy in our houses? 091309006

Ans. In houses, good thermal insulation means lower consumption of fuel. For this, following measures may be taken to save energy.

1. Hot water tanks are insulated by plastic or foam lagging.
2. Wall cavities are filled with plastic foam or wool.
3. Ceiling of rooms is covered by insulating materials (false ceiling).
4. Double glazed window panes are used. These window panes have air between glass sheets that provides good insulation.

Q.7 Explain convection process. 091309007

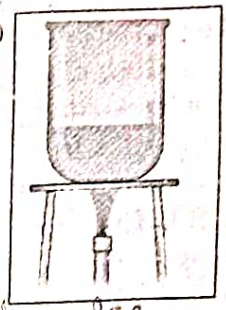
Ans. *"Transfer of heat by actual movement of molecules from hot place to a cold place is known as convection".*

Explanation:

Liquids and gases are poor conductor of heat. However, heat is transferred through fluids (liquids or gases) easily by another method called convection.

A liquid or a gas becomes lighter (less dense) as it expands on heating. Hot liquid or gas rises up above the heated area. The cooler liquid or gas from the surroundings fills the places which in turns is heated up. In this way, all the fluid is heated up. Therefore, transfer of heat through fluids takes place by the actual movement of heated molecules from hot to cold parts of the fluid.

Experiment:



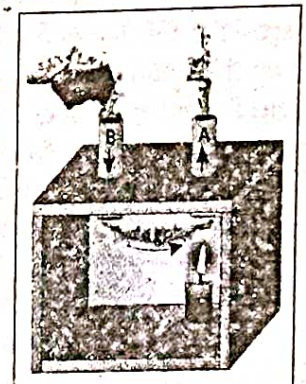
Take a beaker and fill two-third of it with water. Heat the beaker by keeping a burner below it. Drop two or three crystals of potassium permanganate in the water. It will be seen that coloured streaks of water formed by the crystals move upwards above the flame and then move downwards from side ways as shown in the figure.

These coloured streaks show the path of currents in the liquid. When the water at the bottom of the beaker gets hot, it expands, becomes lighter and rises up. While the cold but denser water moves downward to take its place.

Q.8 What is convection currents and uses of Convection currents? 091309008

Ans. Convection Currents in Air:

Gases also expand on heating, thus convection currents are easily set up due to the differences in the densities of air at various parts in the atmosphere.



Smoke showing the path of the convection

Use of Convection Currents:

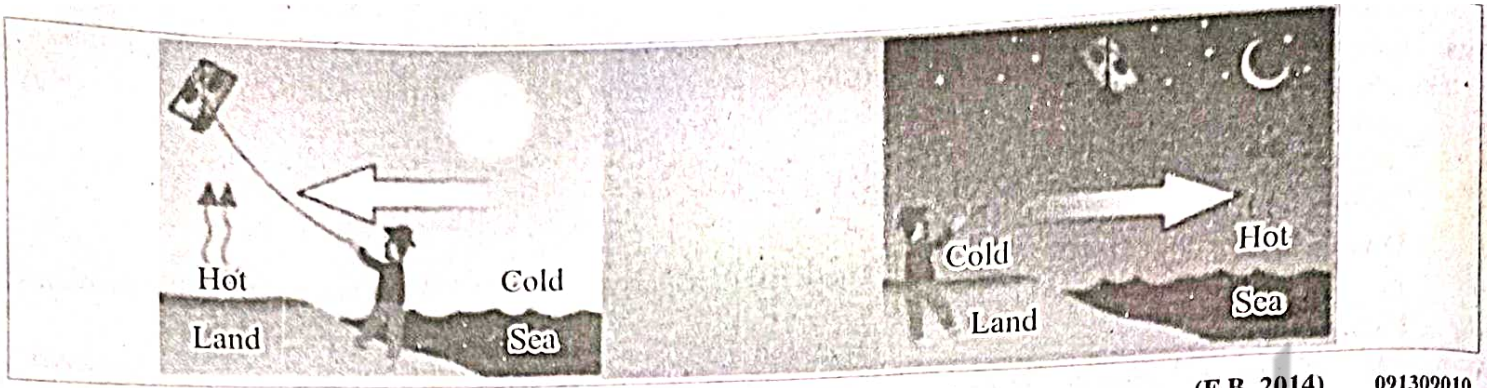
(i) Convection currents set up by electric, gas or coal heaters help to warm our homes and offices.
(ii) Central heating systems in buildings work on the same principle by convection.
(iii) Convection currents occur on a large scale in nature.
(iv) The day-to-day temperature changes in the atmosphere result from the circulation of warm or cold air that travels across the region.
(v) Land and sea breezes are also the examples of convection currents.

Q.9 Why does sea breeze blow during the day? (F.B. 2017) 091309009

OR

Explain land and sea breezes are examples of convection. (Board 2013-15)

Ans. Land and sea breezes are the result of convection. On a hot day, the temperature of the land increases more quickly than the sea. It is because the specific heat of land is much smaller as compared to that of water. The air above land gets hot and rises up. Cold air from the sea begins to move towards the land. It is called sea breeze.



Q.10 Why does land breeze blows from land to sea during night? **(F.B. 2014)** 091309010

Ans. At night, the land cools faster than the sea. Therefore, air above the sea is warmer, rises up and the cold air from the land begins to move towards the sea. It is called land breeze.

Q.11 What causes the glider to remain in air? 091309011

Ans. A glider looks like a small aeroplane without engine. Glider pilots use upward movement of hot air currents due to convection of heat. These rising currents of hot air are called **thermals**. Gliders ride over these thermals. The upward movement of air currents in thermals help them to stay in air for a long period.

Q.12 How do thermals help birds to fly for hours without flapping their wings? 091309012

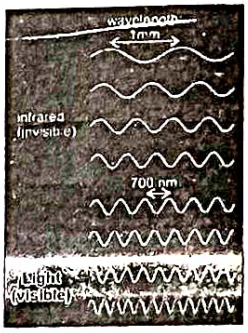
Ans. The birds stretch out their wings and circle in these thermals. The upward movement of air helps birds to climb up with it. Eagles, hawks and vultures are expert **thermal climbers.** After getting a free lift, birds are able to fly for hours without flapping their wings. They glide from one thermal to another and thus travel through large distances and hardly need to flap their wings.

Q.13 Explain radiation process. 091309013

Ans. *"Radiation is the mode of transfer of heat from one place to another in the form of waves called electromagnetic waves".*

Heat from sun

Our Sun is the major source of heat energy. Since there is space between Sun and Earth so there is a third mode called radiation. Through radiation heat reaches us from the Sun through radiation.



Thermal radiation and visible light spectrum

Heat from fire place

A fireplace is used for room heating. Heat does not reach us by conduction through air from a fire place because air is a poor conductor of heat. Heat does not reach us directly by convection because the air getting heat from the fire place does not move in all directions. Hot air moves upward from the fireplace. Heat from the fireplace reaches us directly by different processes in the form of waves called radiation. A sheet of paper or cardboard kept in the path of radiations stop these waves to reach us.

Factors affecting radiation

Radiations are emitted by all bodies. The rate at which radiations are emitted depends upon various factors such as

1. Colour and texture of the surface.
2. Surface temperature.
3. Surface area.

1. Colour and texture of the surface

The rate at which various surfaces absorb heat also depends upon the nature of those surfaces. For example, take two surfaces, one is dull black and the other is a silver polished surface, as shown in figure, with a candle at the middle of the surface. It is found that a dull black surface is a good absorber of heat as its temperature rises rapidly.

A polished surface poor absorber of heat as its temperature rises very slowly. The observations made from the set, are shown in the table given below:

Surfaces	Emitter	Absorber	Reflector
Dull black surface	Best	Best	Worst
Coloured surface	Good	Good	Bad
White surface	Bad	Bad	Good
Shining silvered surface	Worst	Worst	Best

2. Surface temperature **(F.B. 2017, F.B. 2016)**

When temperature of an object is higher than its surroundings then it is radiating more heat than it is absorbing. As a result, its temperature goes on decreasing till it becomes equal to the temperature of its surroundings. At this stage, the body is giving out the amount of heat equal to the amount of heat it is absorbing. So in this way hot cup of tea becomes cold after sometime.

3. Surface Area

It is also found that the transfer of heat by radiation is also affected by the surface area of the body emitting or absorbing heat. Larger is the area, greater will be the transfer of heat. It is due to this reason that large number of slots are made in radiators to increase their surface area.

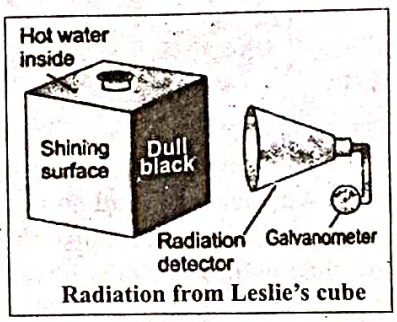
When temperature of an object is lower than its surroundings, then it is radiating less heat than it is absorbing. As a result, its temperature goes on increasing till it becomes equal to its surroundings. The rate at which various surfaces emit heat depends upon the nature of the surface. So a glass of chilled water becomes hot after sometime.

Q.14 Explain Emission and Absorption of Radiation. (OR) How various surfaces can be compared by Leslie's cube? **091309014**

Ans. A Leslie's cube is a metal box having faces of different nature as shown in figure. The four faces of Leslie's cube may be as follows:

- A shining silvered surface
- A dull black surface
- A white surface
- A coloured surface

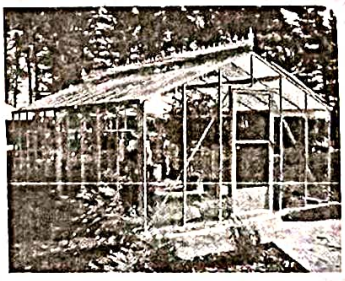
Hot water is filled in the Leslie's cube and is placed with one of its face towards a radiation detector. It is found that black dull surface is good emitter of heat.



Radiation from Leslie's cube

Q.15 What is greenhouse effect? **091309015**

Ans. Greenhouse effect:



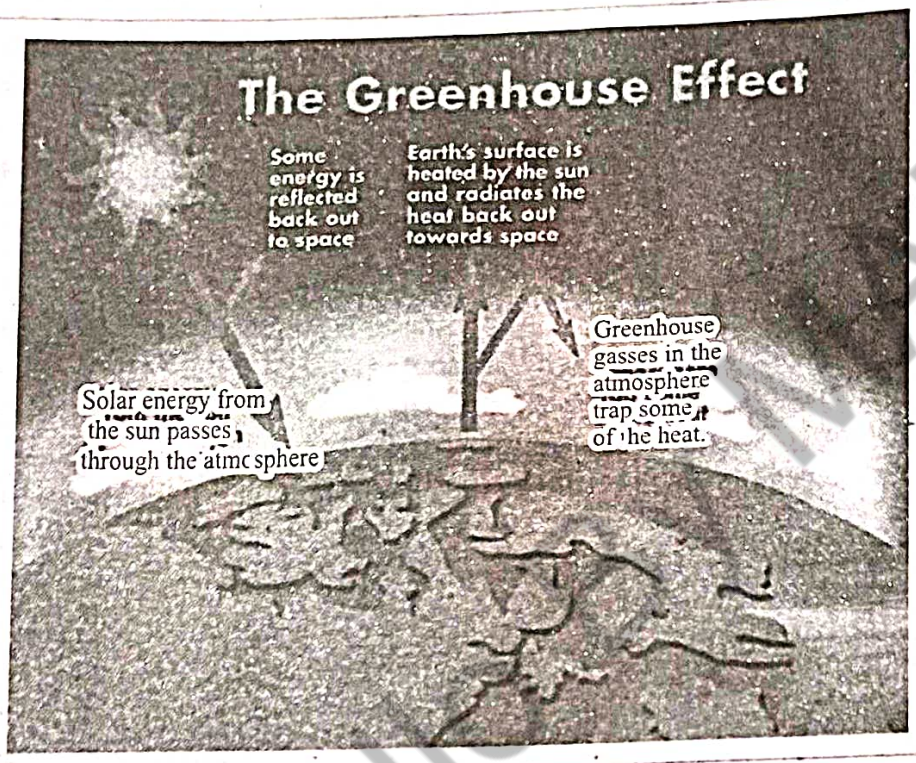
Light from the Sun contains thermal radiations (infrared) of long wavelengths as well as light and ultraviolet radiations of short wavelengths. Glass and transparent polythene sheets allow radiations of short wavelength to pass through easily but not long wavelengths of thermal radiations. Thus, a greenhouse becomes a heat trap. Radiations from the Sun pass easily through glass and warms up the objects in a greenhouse. These objects and plants, such as shown in figure, give out radiation of much longer wavelengths. Glass and transparent polythene sheets do not allow them to escape out easily and are reflected back in the greenhouse. This maintains the inside temperature of the greenhouse. Greenhouse effect promises better growth of some plants.

Q.16Explain the impact of greenhouse effect in global warming.

Ans. Carbon dioxide and water also behave in a similar way to radiations as glass or polythene. Earth's atmosphere contains carbon dioxide and water vapours. It causes greenhouse effect as shown in figure and thus maintains the temperature of the Earth.

Greenhouse effect and global warming on Earth:

During the recent years, *the percentage of carbon dioxide has been increased considerably. This has caused an increase in the average temperature of the Earth by trapping more heat due to greenhouse effect. This phenomenon is known as* ***global warming.*** This has serious implications for the global climate.



Q.17 What are the applications and consequences of Radiation? 091309017

Ans. Applications and consequences of radiation:

Different objects absorb different amounts of heat radiation falling upon them reflecting the remaining part. The amount of heat absorbed by a body depends upon the colour and nature of its surface. A black and rough surface absorbs more heat than a white or polished surface. Since good absorbers are also good radiators of heat. Thus, a black coloured body gets hot quickly by absorbing heat reaching it during a sunny day and also cools down quickly by giving out its heat to its surroundings. The bottoms of cooking pots are made black to increase the absorption of heat from fire.

Like light rays, heat radiations also obey laws of reflection. The amount of heat reflected from an object depends upon its colour and nature of the surface. White surface reflect more than coloured or black surfaces. Similarly, polished surfaces are good reflectors than rough surfaces and reflection of heat radiations is greater from polished surfaces. Hence, we wear white or light coloured clothes in summer which reflect most of the heat radiation reaching us during the hot day. We polish the interior of the cooking and hotpots for reflecting back most of the heat radiation within them.

MULTIPLE CHOICE QUESTIONS

9.1 Encircle the correct answer from the given choices:

Exercise MCQs

1. In solids, heat is transferred by: 091309018
   (a) radiation (b) conduction
   (c) convection (d) absorption

2. What happens to the thermal conductivity of a wall if its thickness is doubled? (F.B.2017) 091309019
   (a) becomes double
   (b) remains the same
   (c) becomes half
   (d) becomes one fourth

3. Metals are good conductor of heat due to the: (F.B.2016) 091309020
   (a) free electrons
   (b) big size of their molecules
   (c) small size of their molecules
   (d) rapid vibrations of their atoms

4. In gases, heat is mainly transferred by: 091309021
   (a) molecular collision
   (b) conduction
   (c) convection
   (d) radiation

5. Convection of heat is the process of heat transfer due to the: 091309022
   (a) random motion of molecules
   (b) downward movement of molecules
   (c) upward movement of molecules
   (d) free movement of molecules

6. False ceiling is done to: 091309023
   (a) lower the height of ceiling
   (b) keep the roof clean
   (c) cool the room
   (d) insulate the ceiling

7. Rooms are heated using gas heaters by: (F.B. 2014) 091309024
   (a) Conduction only
   (b) Convection and radiation
   (c) Radiation only
   (d) Convection only

8. Land breeze blows from: 091309025
   (a) sea to land during night
   (b) sea to land during the day
   (c) land to sea during night
   (d) land to sea during the day

9. Which of the following is a good radiator of heat? 091309026
   (a) a shinning silvered surface
   (b) a dull black surface
   (c) a white black surface
   (d) a shinning colored surface

Additional MCQs

10. There are ways to transfer the heat from one place to another 091309027
   (a) 1 (b) 2
   (c) 3 (d) 4

11. Which one box is used to keep food hot and ice cream cold for long period? 091309028
   (a) Iron box (b) Aluminium box
   (c) Styrofoam box (b) Plastic box

12. Unit of thermal conductivity is: 091309029
   (a) WmK (b) $W\ m^{-1}K^{-1}$
   (c) Wm^{-1} (d) Wm

13. Thermal conductivity of iron is: 091309030
   (a) 85 $Wm^{-1}K^{-1}$ (b) 36 $Wm^{-1}K^{-1}$
   (c) 89 $Wm^{-1}K^{-1}$ (d) 86 $Wm^{-1}K^{-1}$

14. Air & water is conductor: 091309031
   (a) Poor (b) Good
   (c) Excellent (d) All of these

15. Sea breeze blows from sea to land during: 091309032
   (a) day (b) Night
   (c) afternoon (d) morning

16. Land breeze from land to sea during: 091309033
   (a) Day (b) night
   (c) Afternoon (d) morning

17. The process in which heat is transfer due to actual movement of molecule is called: 091309034
   (a) Conduction (b) Radiation
   (c) Convection (d) All of these

18. The example of bad conductor is: 091309035
   (a) Wool (b) Copper
   (c) Gold (d) Iron

19. Flow of thermal energy from hot body cold body is called: 091309036
   (a) specific heat (b) Latent heat
   (c) Transfer of heat (d) Heat capacity

20. Wood, cork, cotton, wool, rubber are the examples of : 091309037
   (a) conductor (b) Thermal conductor
   (c) Insulator (d) both a & b

21. In buildings central heating system works on the process of: 091309038
   (a) Convection (b) Radiation
   (c) Conduction (d) both a and b

22. The main source of energy in the universe is: 091309039
   (a) Moon (b) Stars
   (c) Sun (d) Planets

23. **The bad conductor of heat is:** 091309040
(a) Iron (b) Copper
(c) Air (d) Aluminium

24. **Leslie cube have faces:** 091309041
(a) 2 (b) 3
(c) 4 (d) 5

25. **More radiation is reflected by the surface:** 091309042
(a) White (b) Coloured
(c) Black (d) Rough

26. **The quantity of heat absorbed by the body depends upon:** 091309043
(a) Colour of surface (b) Nature of surface
(c) Shape of surface (d) Both a & b

27. **Dull black surface is a best:** 091309044
(a) Emitter (b) Absorber
(c) Reflector (d) Both (a) and (b)

28. **Shining silvered surface is a best:** 091309045
(a) Emitter (b) Absorber
(c) Reflector (d) None of these

29. **Leslie's cube is a box of:** 091309046
(a) Metal (b) None-metals
(c) Wood (d) Metalloids

30. **Leslie's cube is filled with:** 091309047
(a) Cold water (b) Hot water
(c) Mercury (d) Air

31. **Glass and transparent polythene sheets allow radiations of which wavelength to pass through them:** 091309048
(a) Long (b) Medium
(c) Short (d) All

32. **Which gas behaves as glass or polythene to radiation?** 091309049
(a) Nitrogen (b) Hydrogen
(c) Carbon dioxide (d) Methane

33. **Thermos flask, is used to maintain:** 091309050
(a) Heat (b) Temperature
(c) Density (d) Pressure

34. **Land and sea breezes are the results of:** 091309051
(a) Conduction
(b) Convection
(c) Radiation
(d) Conduction and radiation

35. **Feathers of bird give good thermal:** 091309052
(a) Conduction (b) Insulation
(c) Convection (d) None of these

36. **On heating air becomes:** 091309053
(a) Heavier (b) Lighter
(c) Remain same (d) None

37. **SI unit of thermal conductivity constant 'K' is:** 091309054
(a) $kgms^{-3}k^{-1}$ (b) $kgm^{-2}s^{-2}k^{-2}$
(c) $kgm^{2}k^{-2}$ (d) $kg^{-1}m^{-2}s^{-2}k^{-1}$

ANSWERS

1.	b	2.	c	3.	a	4.	d	5.	d
6.	d	7.	b	8.	c	9.	b	10.	c
11.	c	12.	b	13.	a	14.	a	15.	a
16.	b	17.	c	18.	a	19	c	20	c
21.	a	22.	c	23.	c	24.	c	25.	a
26.	d	27.	d	28.	c	29.	a	30.	b
31.	c	32.	c	33.	b	34.	b	35.	b
36.	b	37.	a						

Exercise Answer Questions

Q.9.2 Why metals are good conductors of heat? 091309055

Ans. Metals are good conductors of heat because they contain free electrons which transfer heat, from one end of solid to other end.

Q.9.3 Explain why: 091309056

(a) A metal feels colder to touch than wood kept in a cold place?

Ans. Since metal is a good conductor of heat while wood is an insulator so metal feel colder to touch than wood because when we touch the cold conductor there is transfer of heat from our hand to cold conductor and it feels cold.

(b) Land breeze blows from land towards sea? 091309057

Ans. Since specific heat of land is less than that of sea so at night it becomes colder faster than the sea so warmer air above the sea rises up and colder air from the land flows towards sea.

(c) Double walled glass vessel is used in thermos flask? 091309058

Ans. A double walled glass vessel is used in thermos flask because vacuum between double wall glass vessels stop the flow of heat due to conduction and convection.

(d) Deserts soon get hot during the day and soon get cold after sunset? 091309059

Ans. Since the specific heat of sand is less so absorb the heat more quickly and gets hot in day. In night, it releases heat more quickly and becomes cold quickly after sun set.

Q.9.4 Why conduction of heat does not take place in gases? 091309060

Ans. Since the gas molecules are at greater distance so conduction of heat does not take place in gases. In gas molecules, space between molecules is more than liquid and solids. So by conduction it makes the transfer of energy low. That's why conduction of heat does not take place in gases.

Q.9.5 What measures do you suggest to conserve energy in houses? 091309061

Ans. To save energy in houses following measures may be suggested:

(1) Water tank are covered by plastic or any insulating material.

(2) Wool, cloth or plastic should use to cover wall cavities.

(3) By using insulating materials false ceiling should be done.

(4) Double glaze windows panes are used, these windows pans have air between glass sheets that provides good insulations.

Q.9.6 Why transfer of heat in fluids take place by convection? 091309062

Ans. Since the distance between liquid/gas molecules is greater as compared to solids, so transfer of heat cannot be done by conduction process. In fluid heat is flow due to convection process only because movement of molecules is easy in fluids.

Q.9.7 What is meant by convection current? 091309063

Ans. The convection current is set up due to the difference in densities of air at various parts in the atmosphere.

Q.9.8 Suggest a simple activity to show convection of heat in gases not given in the book. 091309064

Ans. (i) Geysers in our houses work on convection. Water in the boiler is heated by convection and reaches to upper part of tank. **(ii)** When we perfume our body the particle of the fragrance of perfume mix with molecules of air and travels in all direction due to convection.

Q.9.9 How does heat from sun reaches on the earth? (or) How does heat reach us from the sun? 091309065

Ans. Sun is the major source of energy. Heat energy from the sun reaches to the earth by the third mode of transfer of heat called radiation. The space between the sun and the earth's atmosphere is empty. So, a method of transfer of heat in which there is no contact between the source and the body is called radiation. Solar radiation including visible light, ultraviolet and infrared radiation are the packets of energy emitted from the sun's surface and travel through vaccum with the speed of light by the process of radiation.

Q.9.10 How can various surfaces be compared by a Leslie cube? 091309066

Ans. The rate at which various surfaces emit heat depends upon the nature of the surface. Various surface can be compared with Leslie's cube. A Leslie's cube is a metal box having faces of different nature.

(a) A shining silvered surface
(b) A dull black surface
(c) A white surface
(d) A coloured surface

Hot water is filled in the Leslie's cube and is placed with one of its face towards a radiator detector. It is found that black dull surface is good emitter of heat.

Q.9.11 What is greenhouse effect? 091309067

Ans. See Q. No. 15 Page no. 177.

Q.9.12 Explain the impact of greenhouse effect in global warming. 091309068

Ans. See Q. No. 16 Page no. 178.

Q.12Why are Styrofoam boxes used to keep food hot or ice cream cold for a long time? 091309069

Ans. Styrofoam is a bad conductor of heat. It does not allow heat to leave or enter the box easily. It keep food hot or ice cream cold for long time.

Q.13Why do we use thermos flask? 091309070

Ans. In a thermos flask, most of the heat is prevented to enter or leave the flask. This is done by suitable measures to reduce the conduction, convection and radiation. Thus, anything kept in it, maintains its temperature for a long time.

Q.14 Why it is not advisible to wear dark colours in summer? 091309071

Ans. As dark colours are good absorbers of heat, that's why it is not advisible to wear dark colours in summers.

Q.15 Explain why is double glass vessel used in thermos flask? (F.B. 2017) 091309072

Ans. Thermos flask is a doubled walled glassed vessel, which is used to keep the temperature constant of a material for a long time. In thermos flof the heat is prevented to enter or leave the flask. This is done by suitable measures to reduce the transfer of heat.

Q.16 Why sauce pans are made of metal? 091309073

Ans. Sauce pans are made of metal for quick heat transfer. Because metals are good conductor of heat and contain free electrons. These free electrons transfer heat to other parts of solid quickly.

Q.17 Describe the effect of length of the solid on thermal conductivity? 091309074

Ans. Length of Solid:

Larger the length more time it will take to conduct heat to the colder end .i.e.

$$\text{Rate of flow of heat } \frac{Q}{t} \propto \frac{I}{L}.$$

Q18. Define Conduction, convection and radiation. 091309075

Ans. Conduction: "The mode of transfer of heat by vibrating atoms and free electrons in solids from hot to cold parts of a body is called conduction of heat".

Convection: "Transfer of heat by actual movement of molecules from hot place to a cold place is known as convection".

Radiation: "Radiation is the mode of transfer of heat from one place to another in the form of waves called electromagnetic waves".

Q19. Define convection. 091309076

Ans. "Transfer of heat by actual movement of molecules from hot place to a cold place is known as connection".

Q20. Define thermal conductivity. 091309077

Ans. "The rate of flow of heat across the opposite faces of a metre cube of a substance maintained at a temperature difference of one Kelvin is called the thermal conductivity of the substance".

Q21. Why we wear light colours clothes in summer? 091309078

Ans. we wear white or light coloured clothes in summer which reflect most of the heat radiation reaching us during the hot day, so that our body remain cool.

Q22. What is Global warming. 091309079

Ans. During the recent years, the percentage of carbon dioxide has been increased considerably. This has caused an increase in the average temperature of the Earth by trapping more heat due to 'green house effect. This phenomenon is known as **global warming.**

Q23. How does heat flow from hot to cold parts in metals so rapidly than non-metals? 091309080

Ans. Metals have free electrons. These free electrons move with very high velocities within the metal objects. They carry energy at a very fast rate from hot to cold parts of metal objects quickly than non metals.

Q24. Why a balloon inflated with hot air rises up? 091309081

Ans. A gas becomes lighter (less dense) as it expands on heating. Hot gases rises up above the heated area. The cooler air from the surroundings fills the place which in turn is heated up. In this way balloons inflated with hot air rise up air become lighter on heating.

Q25. Why transfer of heat in fluids takes place by convections? 091309082

Ans. Convection is the mode of transfer of heat by the actual movement of molecules from hot place to cold place. Convection take place in fluids (liquid or gases). As a fluid is heated, it becomes lighter and expand this gives the decrease in density of molecules. This hot fluid rises and move towards the cold region of fluid. Cold denser molecules moves downward and get heat energy and again expand and rises, by this process the whole fluid gets hotter after some time.

Q26. How do the land and sea breeze help to keep the temperature moderate in coastal areas? 091309083

Ans. The sea water has large heat capacity than the land. As the temperature of land rises, the land heat the air above it. The warm air is less denser and rises. This rising air lower the air pressure so cool air from the sea begin to move towards land. This is the sea breeze. The strength of the sea breeze is directly proportional to the temperature difference between land and sea.

At night, the temperature of land cools quickly due to less heat capacity of sand. The water along the shore will be warmer than the land creating the movement of cold air from land towards sea at night. So that's why the land and sea breeze keep the temperature moderate in coastal areas.

Q27. What is meant by thermal climbers? (F.B. 2015) 091309084

Ans. Such birds that fly for hours without flapping their wings are called thermal climbers. Birds stretched out their wings and circle in those thermals. The upward movement of air helps birds to climb up with it. eagles, hawks and vultures are expert thermal climbers.

Q28. What are the factors on which rate of flow of heat in solids depends? 091309085

Ans. The rate of flow of heat depends upon the following factors:

(1) Cross-sectional area of solid
(2) Length of solid
(3) Temperature differences
(4) Nature of solid

Q29. How does the heat reach us directly from a fireplace? 091309086

Ans. A fireplace is used for room heating. Heat does not reach us by conduction through air from a fire place because air is a poor conductor of heat. Heat does not reach us directly by convection because the air getting heat from the fire place does not move in all directions. Hot air moves upward from the fireplace. Heat from the fireplace reaches us directly by different processes in the form of waves called radiation. A sheet of paper or cardboard kept in the path of radiations stop these waves to reach us.

Q30. Why does a cup of hot tea become cold after sometime? (F.B. 2016,17) 091309087

Ans. When temperature of an object is higher than its surroundings then it is radiating more heat than it is absorbing. As a result, its temperature goes on decreasing till it becomes equal to the temperature of its surroundings. At this stage, the body is giving out the amount of heat equal to the amount of heat it is absorbing. So in this way hot cup of tea becomes cold after sometime.

Q31. Why does a glass of chilled water become hot after sometime? 091309088

Ans. When temperature of an object is lower than its surroundings, then it is radiating less heat than it is absorbing. As a result, its temperature goes on increasing till it becomes equal to its surroundings. The rate at which various surfaces emit heat depends upon the nature of the surface. So a glass of chilled water becomes hot after sometime.

SOLVED EXAMPLES

EXAMPLE 9.1

The exterior brick wall of a house of thickness 25cm an area $20m^2$. The temperature inside the house is 15°C and outside is 35° C. Find the rate at which thermal energy will be conducted through the wall, the value of k for bricks is 0.6 $W\,m^{-1}\,K^{-1}$. 091309089

Solution:

Here $A = 20\ m^2$

$L = 25\ cm = 0.25\ m$

$T_1 = 35 + 273 = 308\ K$

$T_2 = 15 + 273 = 288\ K$

$\Delta T = T_1 - T_2$

$= 308 - 288 = 20\ K$

$K = 0.6\ Wm^{-1}\,K^{-1}$

We know the formula of rate of flow of conduction

$$\frac{Q}{t} = \frac{kA(T_1 - T_2)}{L}$$

$$= \frac{0.6 \times 20 \times 20}{0.25}$$

$= 960$ watt or $960\ Js^{-1}$

Result: Thus, the rate of flow of thermal energy across the wall will be 960 joules per second.

NUMERICAL PROBLEMS

9.1 **The concrete roof of a house of thickness 20 cm has an area 200 m^2. The temperature inside the house is 15°C and outside is 35°C. Find the rate at which thermal energy will be conducted through the roof. The value of k for concrete is 0.65 $Wm^{-1}K^{-1}$.** 091309090

Given data:

Length=L = 20cm = $\frac{20}{100}$ = 0.2m

Area=A = $200m^2$

Outside temperature = T_1 = 35°C

= 35 + 273 = 308K

Inside temperature = T_2 = 15°C

= 15 + 273 = 288K

$\Delta T = T_2 - T_1$

= 308 − 288 = 20 K

ΔT = 20 K

Thermal conductivity k = $0.65 Wm^{-1}K^{-1}$

To Find: Rate of flow $\frac{Q}{t}$ = ?

Solution:

$$\frac{Q}{t} = \frac{kA(T_1 - T_2)}{L}$$

$$= \frac{0.65 \times 200 \times 20}{0.2}$$

Rate of heat flow = $\frac{Q}{t} = \frac{65 \times 200 \times 20 \times 10}{2 \times 100}$

$$\frac{Q}{t} = 13000\ Js^{-1}$$

Result:

Thus, 13000 Js^{-1} is the rate of flow of heat. This amount of thermal energy will be conducted through the roof.

9.2 **How much heat is lost in an hour through a glass window measuring 2.0 m by 2.5 m when inside temperature is 25°C and that of outside is 5°C, the thickness of glass is 0.8 cm and the value of k for glass is 0.8 $Wm^{-1}K^{-1}$?**

(F.B. 2018) 091309091

Given Data: (F.B. 2015)

Time = t = 1 hour = 3600 sec

Area A = $2 \times 2.5 = 5m^2$

Length L = 0.8 cm = $\frac{0.8}{100}$ = 0.008m

T_1 = 25°C = 25 + 273 = 298K

T_2 = $5C^0$ = 5 + 273 = 278K

$\Delta T = T_1 - T_2$

= 298 − 278

ΔT = 20 K

Thermal conductivity = $0.8 wn^{-1}k^{-1}$

To Find: heat loss = Q = ?

Solution:

$$\frac{Q}{t} = \frac{KA(T_1 - T_2)}{L}$$

$$Q = t \times \frac{KA(T_1 - T_2)}{L}$$

$$Q = \frac{3600 \times 0.8 \times 5 \times 20}{0.008}$$

$$= \frac{36 \times 5 \times 2 \times 10^3 \times 8 \times 1000}{10 \times 8}$$

$$= \frac{36 \times 10 \times 10^3 \times 8 \times 1000}{10 \times 8}$$

$$= 36 \times 10^6 J$$

$$Q = 3.6 \times 10^7 J$$

Result:

Thus, 3.6×10^7J heat is lost in an hour through a glass window.