Chapter 4: Rotational and Circular Motion

Exercise: Short Questions with Answers

Q.1 What is the value of angular acceleration of the minute hand of your wrist watch?

Answer:

Angular Velocity of the Minute Hand:

The minute hand completes one full revolution in 60 minutes (3600 seconds).

Calculation:

Angular displacement, $\theta = 2\pi$ rad

Time, $t = 3600$ s

Angular velocity, $\omega = \theta / t = 2 \times 3.142 / 3600 = 0.00174556$ rad/s $\approx 1.746 \times 10^{-3}$ rad/s

Angular Acceleration:

Since angular velocity is constant,

Angular acceleration, $\alpha = 0$

Q.2 Define the following angular quantities: Displacement, velocity, acceleration.

Answer:

1. Angular Displacement (θ):

It is the angle through which a point or line has been rotated in a specified sense about a specified axis.

SI Unit: Radian (rad)

2. Angular Velocity (ω):

It is the rate of change of angular displacement with respect to time.

Formula: $\omega = \theta / t$

SI Unit: rad/s

3. Angular Acceleration (α):

It is the rate of change of angular velocity with respect to time.

Formula: $\alpha = \Delta\omega / t$

SI Unit: rad/s²

Q.3: Define the following terms: Radian, Angular velocity, Angular acceleration.

Answer

1. Radian:

A radian is the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle.

1 radian = 57.3°

2. Angular Velocity (ω):
It is the angular displacement covered per unit time.
Formula: $\omega = \theta / t$
Unit: rad/s

3. Angular Acceleration (α):
It is the change in angular velocity per unit time.
Formula: $\alpha = \Delta\omega / t$
Unit: rad/s²

Q.4 Is centripetal force a fundamental force? Can any combination of the fundamental forces provide it?
Answer:
Nature of Centripetal Force:
Centripetal force is not a fundamental force. It is a resultant force acting on an object moving in a circular path, directed toward the center.

Sources of Centripetal Force:
It can be provided by:

- Gravitational force (e.g., planets in orbit)
- Electromagnetic force (e.g., electrons in atoms)
- Tension (e.g., in a string)
- Magnetic force (e.g., in charged particles)

Q.5 Why do heavy vehicles have double tyres on one side of an axle? Will their moment of inertia differ from that of a single tyre?
Answer:
Moment of Inertia Explanation:
Yes, the moment of inertia will be different.
Moment of inertia, $I = mr^2$
For two tyres, total $I = I_1 + I_2 = 2 \times mr^2$

Conclusion:
The double tyre configuration has approximately double the moment of inertia compared to a single tyre.

Q.6 Why is it best to have helicopter blades rotate in opposite directions when there are two sets?
Answer:
Reason for Opposite Rotation:

- Main rotor provides lift and propulsion

- Second rotor counteracts torque produced by the first rotor
- Some helicopters use tandem or coaxial rotors spinning in opposite directions
- This eliminates the need for a tail rotor, offering stability and control

Q.7 What happens to Earth's rotational speed if its diameter becomes half, assuming mass remains constant?

Answer

Given:

Original time period, $T_1 = 24$ h

Original radius, R

New radius, R/2

Use conservation of angular momentum:

$I_1\omega_1 = I_2\omega_2$

$(2/5)MR^2 \times \omega_1 = (2/5)M(R^2/4) \times \omega_2$

$\Rightarrow \omega_2 = 4\omega_1$

New Time Period:

$\omega_2 = 2\pi/T_2 = 4(2\pi/T_1)$

$T_2 = T_1 / 4 = 24 / 4 = 6$ hours

Q.8 Why does tangential acceleration change magnitude but not direction of velocity in circular motion?

Answer:

Explanation:

- Tangential acceleration affects the speed (magnitude of velocity)
- It does not affect direction because that is controlled by centripetal acceleration
- Tangential acceleration is along the direction of motion
- Centripetal acceleration is perpendicular, responsible for changing direction

Q.9 Why is artificial gravity usually less than 9.8 m/s²?

Answer;

Reason:

- Higher artificial gravity requires high rotation speed or large structure, which is difficult
- Can cause discomfort or health issues
- Lower levels are practical and sufficient
- Saves energy and resources, especially important for space missions

Q.10 Why is gyroscope used in airplanes?

Answer:

Function of Gyroscope:

- Helps in navigation and flight stability

- Used in attitude indicators, autopilot systems, and inertial navigation systems
- Provides feedback on aircraft orientation
- Ensures accurate control, safety, and efficiency

Q.11 How does a flywheel help in power delivery of an engine?

Answer:

Role of Flywheel:

- During power strokes, stores excess energy by rotating faster
- During non-power strokes, releases stored energy to maintain power output
- Flywheel's mass and inertia smooth out fluctuations, providing steady rotation
- Ensures consistent engine operation

Additional Questions

Q.1 Why is the acceleration of a body moving uniformly in a circle directed towards the centre?

Answer:

Centripetal Acceleration:

In circular motion, the direction of velocity continuously changes, even though the speed is constant. This change in direction means there is acceleration.

Direction of Force and Acceleration:

According to Newton's second law, force and acceleration are in the same direction. Since the required centripetal force is towards the centre, the acceleration is also directed towards the centre.

Q.2 Is there any work done by centripetal force?

Answer:

Work Formula:

Work done = Force × Displacement × cos(θ)

In circular motion, the angle between centripetal force and displacement is 90°.

Result:

cos(90°) = 0 → Work done = 0

Hence, no work is done by the centripetal force.

Q.3 A motorcyclist moves in a death well but does not fall. Why?

Answer:

Tilt Creates Centripetal Force:

The rider tilts towards the centre while moving in a circular path, creating the necessary centripetal force.

Reaction Force:

A centrifugal reaction force acts outward. It balances the rider's weight and friction, allowing the rider to move in a circle without falling.

Q.4 On what factors does the centripetal force depend?

Answer:

Factors Affecting Centripetal Force:

Centripetal force depends on:

- Mass (m) of the object
- Speed (v) of the object
- Radius (r) of the circular path

Formula:

$F = mv^2/r$

So, if mass or speed increases, the force increases; if radius increases, force decreases.

Q.5 What provides the centripetal force to the moon to revolve around the Earth?

Answer:

Source of Centripetal Force:

The gravitational force of the Earth provides the necessary centripetal force to the moon, keeping it in circular orbit around Earth.

Q.6 Can a body move in a circle without centripetal force?

Answer:

No, It Cannot:

Centripetal force is essential for circular motion. Without it, the object would move in a straight line due to inertia (Newton's 1st law).

Q.7 What is centrifugal reaction?

Answer:

Definition:

It is the reaction force to centripetal force, acting outward from the centre of the circular path.

Explanation:

According to Newton's 3rd law, every action has an equal and opposite reaction. So, centrifugal reaction acts opposite to centripetal force.

Q.8 Why does a body move away from the centre when whirled in a circle and the string breaks?

Answer:

Reason:

When the string breaks, centripetal force vanishes.

Due to inertia, the body moves tangentially to the circular path — not outward but in a straight line along the direction it was moving.

Q.9 On what principle is a centrifuge machine based?

Answer:

Working Principle:

A centrifuge uses the concept of centrifugal reaction force to separate particles from a liquid.

Application:

Heavier particles are pushed outward more strongly and settle at the bottom due to the centrifugal effect.

Q.10 What is the need for banking of roads?

Answer:

Purpose of Banking:

Banking provides the required centripetal force during turns.

How It Helps:

Tilting the road surface reduces reliance on friction and prevents skidding, especially at higher speeds.

Q.11 Why does a cyclist lean while taking a turn?

Answer:

Leaning Produces Centripetal Force:

Leaning inward helps the cyclist create a component of the normal reaction force that acts as centripetal force, allowing safe turning.

Q.12 On what factors does the angle of banking depend?

Answer:

Factors:

The angle of banking depends on:

- Speed of the vehicle
- Radius of the curve
- Gravitational acceleration

Relation:

Greater the speed and tighter the curve, larger the banking angle required.

Q.13 Why are curved roads banked?

Answer:

To Provide Centripetal Force:

Banked roads help vehicles turn safely by providing necessary centripetal force through the normal component, reducing the chance of slipping.

Q.14 What is meant by centripetal force? Write its expression.

Answer:

Definition:

Centripetal force is the force directed towards the centre of the circular path, keeping the body in circular motion.

Expression:

$$F = mv^2/r$$

Where:
m = mass
v = velocity
r = radius

Q.15 What provides centripetal force to a car moving on a leveled road?
Answer:
Source of Force:
On a flat (leveled) road, the friction between tyres and road provides the required centripetal force for turning.

Chapter 9: Waves

Exercise Short Questions

Q1. Two identical waves undergo pure constructive interference. Is the resultant intensity twice that of the individual waves?
Ans:
No, the resultant intensity becomes four times while the amplitude is doubled.

Explanation:
Constructive interference causes amplitudes to add up:
Resultant amplitude = 2A
Intensity $\propto$ (Amplitude)^2
So, Intensity = $(2A)^2 = 4A^2$

Hence, the intensity becomes 4 times.

Q2. Why do circular water waves decrease in amplitude as they move away from the point where a rock is dropped?
Ans:
Due to viscosity between fluid molecules.
Explanation:
As waves propagate, energy is lost due to friction (viscosity) among water molecules, decreasing wave amplitude gradually.

Q3. Differentiate between constructive and destructive interference.

Constructive Interference	Destructive Interference:
1. Occurs when two waves meet in the same phase and reinforce each other.	1. Occurs when two waves meet out of phase and cancel each other.
2. The phase difference between the waves is an even multiple of π (2mπ).	2. The phase difference between the waves is an odd multiple of π ((2m+1)π).
3. The amplitude of the resultant wave increases ($A = A_1 + A_2$).	3. The amplitude of the resultant wave decreases ($A = A_1 - A_2$).
4. The path difference between waves is an integral multiple of wavelength ($\Delta x = m\lambda$, where m = 0,1,2…).	4. The path difference between waves is a half-integral multiple of wavelength ($\Delta x = (m + ½)\lambda$).
5. The intensity of the resultant wave increases.	5. The intensity of the resultant wave decreases.
6. The wave amplitudes add up, leading to maximum displacement.	6. The wave amplitudes cancel, possibly leading to zero displacement at some points.

Q4. Other than length, which two factors affect the frequency of a stretched string?

Ans:

1. Tension in the string
2. Mass per unit length of the string

Formula:

$f = (1/2L)\sqrt{(T/\mu)}$

Q5. What are stationary waves and how are they produced?

Ans:

Stationary waves appear to oscillate in place without travelling through the medium.

Formation:

Produced when two identical waves of same frequency travel in opposite directions and superpose.

Important Points:

- Distance between adjacent nodes = λ/2
- Distance between node and antinode = λ/4
- No energy transfer; energy oscillates between kinetic and potential forms.

Q6. What is Doppler's Effect? Will a fire engine crew observe this effect? State one application.

Ans:

(i) Doppler's Effect is the apparent change in frequency or pitch due to relative motion between source and observer.
(ii) No, the fire engine crew won't notice the change as there is no relative motion between them and the siren.
(iii) Applications:

- SONAR (Sound Navigation and Ranging)
- Medical ultrasound
- Aerospace navigation

Q7. How should a sound source move so that the observer hears no change in frequency?
Ans:
There should be no relative motion between source and observer.

Examples:

- Both moving in same direction with same speed.
- Source moving in a circle around stationary observer (or vice versa).

Q8. Can sound waves be polarized? Explain.
Ans:
No, sound waves cannot be polarized.

Reason:
They are longitudinal waves, oscillating in the direction of motion. Only transverse waves can be polarized.

Q9. Light passes through two Polaroid filters with parallel axes. What is the result?
Ans:
Result: Polarized light passes through.
Reason: First filter polarizes unpolarized light. Second filter, being aligned, allows fully polarized light to pass.

Q10. Give three examples of gravitational waves.
Ans:
1. When a star explodes asymmetrically
2. When two big stars orbit each other
3. When two black holes orbit and merge

Definition:
Gravitational waves are ripples in space-time caused by massive accelerating objects.

Q11. What is an Interferometer?
Ans:

A device that splits light into two paths and then recombines them to produce interference.

Examples:

- Michelson Interferometer: Measures wavelength/length
- Gravitational Wave Interferometer: Detects gravitational waves (e.g., LIGO)

Q12. Which sunglasses reduce glare from water surface? (Based on filter axis)

Ans:

Pair A (with vertical polarization axis) is most effective.

Explanation:

Reflected light from water is horizontally polarized. Vertical filters block this glare.

Additional Questions

Q1. A boy moves away with half the speed of sound emitted by a speaker of a mosque. What frequency of sound is heard by him?

Answer:

When an observer moves away from the source of sound with velocity , the frequency observed by him is given by the **formula:**

$$f' = (v - v_0) / v \times f$$

where

v is the speed of sound

v_0 is the speed of the observer

f is the actual frequency of the source

Here, the observer (boy) moves with half the speed of sound, so:

$v_0 = v / 2$

Substituting in the formula:

$f' = (v - v/2) / v \times f = (v/2) / v \times f = f / 2$

Conclusion:

The boy hears the sound at half the original frequency.

Q2. What is the difference between progressive and stationary waves?

Answer:

Progressive Wave	Stationary Wave
1. The wave profile moves forward.	1. The wave profile does not move.
2. All particles vibrate with the same amplitude.	2. Particles between two adjacent nodes vibrate with different amplitudes.

3. Neighboring particles vibrate with different phases.	3. Particles between two adjacent nodes vibrate in phase.
4. All particles vibrate.	4. Particles at nodes do not vibrate at all.
5. Produced by a disturbance in a medium.	5. Produced by the superposition of two waves moving in opposite directions.
6. It transmits energy.	6. It does not transmit energy.

Q3. Clearly explain the difference between longitudinal and transverse waves.

Answer:

Transverse Waves	Longitudinal Waves:
1. Particles of the medium vibrate at right angles to the direction of wave propagation.	1. Particles of the medium vibrate parallel to the direction of wave propagation.
2. Consist of crests and troughs.	2. Consist of compressions and rarefactions.
3. No pressure variation occurs.	3. Pressure variation occurs throughout the medium.
4. There is no change in the density of the medium.	4. There is a change in density throughout the medium.
5. Light waves and waves on strings are examples.	5. Sound waves are examples.
6. Transverse waves can be polarized.	6. Longitudinal waves cannot be polarized.

Q4. How are beats useful in tuning musical instruments?

Answer:

To tune a musical instrument:

1. Play the instrument alongside a note of known frequency.
2. If the two frequencies differ slightly, beats are produced.
3. Adjust the instrument's frequency until the beats disappear.
4. The disappearance of beats indicates that both frequencies are now equal.
5. This method helps in fine-tuning the instrument accurately.

Chapter 13:Relativity

Exercise Short Questions

Q.1: What is the difference between inertial and non-inertial frames of reference?

Answer:

Inertial Frame	Non-Inertial Frame
1. It is a frame of reference that is either at rest or moving with constant velocity.	1. It is a frame of reference that is accelerating or moving with variable velocity.
2. The law of inertia is valid in it.	2. The law of inertia is not valid in it.
3. The net external force acting on the body is zero, so acceleration is zero.	3. A fictitious force appears to act, and acceleration is not zero.
4. Example: A train moving with constant speed in a straight line.	4. Example: A freely falling elevator.

Q.2: What are the postulates of special relativity?

Answer:

1. Principle of Relativity:

The laws of physics are the same in all inertial frames of reference.

2. Constancy of Speed of Light:

The speed of light in vacuum is always constant for all observers, regardless of the motion of the source or observer.

Q.3: Why is it impossible for a particle with mass to move faster than light?

Answer:

As the speed of an object approaches the speed of light, its mass increases dramatically.

If the speed becomes equal to the speed of light, the mass becomes infinite.

To move an object with infinite mass, infinite force and energy would be required, which is not possible.

Therefore, no material object can reach or exceed the speed of light.

Q.4: Will a person see their reflection in a mirror on a train moving at the speed of light?

Answer:

Newtonian Concept: No reflection. Since the light and train are moving at the same speed, light can't reach the mirror.

Relativistic Concept: Yes, reflection is visible. According to the principle of constancy of the speed of light, light travels at the same speed in all inertial frames. It will reach the mirror and reflect back to the person's eyes.

Q.5: What happens to the density of an object as its speed increases?

Answer:

- Relativistic mass increases as speed increases.
- Length contraction occurs along the direction of motion, reducing volume.
- Since mass increases and volume decreases, density increases at relativistic speeds.

Q.6: What is meant by relativity of simultaneity?

Answer:

Two events that appear simultaneous in one frame may not appear simultaneous in another frame moving relative to the first.

Example: A person on a platform sees two lightning bolts strike two trees at the same time. A person on a fast-moving train sees the bolt in front first and the one behind later.
This shows simultaneity depends on the observer's frame of reference.

Additional Questions

Q1: The length of the spaceship is measured to be exactly half its proper length. Find the velocity of the spaceship.

Answer:

Using the concept of relativistic length contraction, we can use the equation:

$$L = L_0 \sqrt{(1 - (v^2/c^2))}$$

Where:
L is the contracted length (half of the proper length),
L_0 is the proper length,
v is the velocity of the spaceship, and
c is the speed of light.

Since $L = L_0/2$, we substitute this into the equation:

$$L_0/2 = L_0 \sqrt{(1 - (v^2/c^2))}$$

Dividing both sides by L_0:

$1/2 = \sqrt{(1 - (v^2/c^2))}$

Squaring both sides:

$1/4 = 1 - (v^2/c^2)$

Rearranging the equation:

$v^2/c^2 = 3/4$

Thus, solving for v:

$v = \sqrt{(3/4)} \times c = 0.866c$

So, the velocity of the spaceship is v = 0.866c.

Q2: An electron has 5/3 times its rest mass. Find the kinetic energy (K.E.) of the electron.

Answer:
The total energy of the electron is given by:

$$E = \gamma m_0 c^2$$

Where:
E is the total energy,
m_0 is the rest mass,
c is the speed of light,
γ is the Lorentz factor, which is $1 / \sqrt{(1 - (v^2/c^2))}$.

Since the electron has 5/3 times its rest mass, we substitute $m = 5/3\ m_0$:

$$E = (5/3\ m_0)\ c^2 - m_0\ c^2$$

Simplifying:
$E = (5/3)\ m_0\ c^2 - m_0\ c^2 = (2/3)\ m_0\ c^2$
Thus, the kinetic energy of the electron is:

$$K.E. = (2/3)\ m_0\ c^2$$

Q3: Why must the rest mass of a photon be zero?
Answer:
In special relativity, when a material object with actual mass moves at high speed, its apparent mass is given by the equation:

$$m = m_0 / \sqrt{(1 - (v^2/c^2))}$$

Now, a photon travels at the speed of light (v = c), so substituting into the equation:

$$m = m_0 / \sqrt{(1 - (c^2/c^2))}$$

This simplifies to:

$$m = m_0 / \sqrt{(0)} = 0$$

Therefore, the rest mass of a photon must be zero.

Q4: Predict the motion of an object relative to a different frame of reference, e.g., dropping a ball in a moving vehicle observed from the vehicle and by a person standing on the sidewalk.
Answer:
Imagine a person throws and catches a ball while on a train moving at a constant velocity past a station.

To the person on the train, the ball simply travels vertically up and then down under the influence of gravity.

However, to an observer standing on the station platform, the ball appears to travel in a parabola, with a constant horizontal component of velocity equal to the velocity of the train. This is illustrated below.

This difference in observations occurs because the two observers are in different frames of reference, which are in relative motion to each other.

A frame of reference is a set of coordinates used to determine the positions and velocities of objects within that frame. Different frames of reference move relative to one another.

Chapter 14:Particle Physics

Q1. Why does beta-minus (β^-) decay lead to an increase in the atomic number of the nucleus, while beta-plus (β^+) decay results in a decrease in the atomic number?

Answer:

Effect on Atomic Number by Beta-negative Decay:

In beta negative decay, a neutron within the nucleus is transformed into a proton, an electron (beta-minus particle), and an antineutrino. The emitted beta-minus particle is an electron. The newly formed proton stays in the nucleus, which increases the atomic number by 1.

Effect on Atomic Number by Beta-positive Decay:

In beta positive decay, a proton within the nucleus is transformed into a neutron, a positron (beta-plus particle), and a neutrino. The emitted beta-plus particle is a positron, which is the antiparticle of an electron. The transformation of a proton into a neutron decreases the atomic number by 1.

Q2. Explain how the mass-energy equivalence principle, as expressed by Einstein's famous equation "$E = mc^2$", is relevant to understanding the energy release in nuclear processes such as alpha decay.

Answer:

In alpha decay, unstable heavy nuclei reduce their mass number by 4 and their atomic number by 2 with the emission of a helium nucleus (alpha particle). The mass of the parent atom is greater than the sum of the masses of its daughter atom and the helium atom. This difference in mass, known as mass defect, is converted into energy according to Einstein's equation "$E = mc^2$", which explains the energy released in the process.

Q3. Do principles of nucleon conservation and charge conservation in nuclear reactions reflect deeper symmetries and conservation laws present in the fundamental interactions of subatomic particles?

Answer:

Yes, these principles provide deep insight into the underlying symmetries and interactions within the subatomic world.

Principle of Conservation of Charge:

In nuclear processes, the charges of the particles involved (protons, electrons, positrons) are carefully balanced to maintain overall charge neutrality. Charge is a conserved quantity, meaning it cannot be created or destroyed.

Principle of Conservation of Nucleons:
Nucleons (protons and neutrons) are bound together in the nucleus by the strong nuclear force. The total number of nucleons remains constant before and after a nuclear reaction or decay, due to the strong force that governs these interactions.

Q4. Can anti-matter burn? Explain.
Answer:
Antimatter does not "burn" in the conventional sense like chemical fuels. However, when antimatter comes into contact with normal matter, they annihilate each other, releasing energy in the form of gamma-rays. Combustion involves chemical reactions with oxygen, but antimatter would hypothetically "burn" with anti-oxygen, releasing energy through annihilation.

Q5. List at least three applications of antimatter.
Answer:
1. Medical Diagnostic Techniques:
Positrons are used in Positron Emission Tomography (PET) scans for imaging internal parts of the body, especially for heart and brain evaluations, and cancer detection.

2. Antimatter Rockets:
Antimatter rockets are proposed as a future power source for space travel, offering high energy density and specific impulse due to the energy released from matter-antimatter annihilation.

3. Industrial Applications:
Positrons are being used in material science to detect abnormalities in metals and semiconductors.

Q6. Why are gluons short-range exchange particles? Explain.
Answer:
Gluons are the exchange particles for the strong nuclear force, which itself is short-ranged. Gluons are massless particles that mediate the interaction between quarks within protons and neutrons. The strong nuclear force, responsible for binding quarks, only acts over very short distances, which makes gluons short-range exchange particles.

Q7. Why do gluons interact only with particles in the first two rows of the standard model?
Answer:
Gluons interact with quarks and not leptons because the strong nuclear force, which gluons mediate, acts only on quarks. Leptons (like electrons and neutrinos) do not have color charge, so they do not interact with gluons.

Q8. What are Feynman diagrams? What information about particles do these diagrams give?

Answer:

Feynman diagrams are visual representations of particle interactions in quantum field theory. They help in calculating the probability of particle reactions and decays by representing the exchange of particles and the forces acting between them.

Q9. What are the differences between quarks and leptons?

Answer:

Feature	Quarks	Leptons
Existence	Quarks cannot exist as individual particles.	Leptons can exist as individual particles.
Color Charge	Quarks have color charge.	Leptons do not have color charge.
Charge	Quarks have fractional charge (e.g., +2/3, -1/3).	Leptons have integral charge (e.g., -1, +1).
Types/Flavors	Quarks have six flavors: up, down, charm, strange, top, bottom.	Leptons have six flavors: electron, electron neutrino, muon, muon neutrino, tau, tau neutrino.
Interaction	Quarks interact via all four fundamental forces: gravitational, electromagnetic, weak nuclear, and strong nuclear.	Leptons interact via weak nuclear force, electromagnetic force, and gravity.
Mass	Quarks are generally more massive than leptons.	Leptons are generally less massive compared to quarks.

Q10. What advantages do circular particle accelerators have over linear particle accelerators?

Answer:

Circular particle accelerators have the following advantages over linear accelerators:

1. They provide very high-energy particles.
2. They occupy less space.
3. They are more cost-effective because particles gain energy with each revolution around the circular path.

Q11. What is the difference between quantum field theory and string theory? In general, how do we determine if a particle reaction or decay occurs?

Answer:

Quantum Field Theory:

- Combines quantum mechanics with relativity to explain particle interactions.
- Describes particles and forces in the familiar four dimensions (three spatial dimensions and one time dimension).

String Theory:

- Proposes that all particles are made of tiny vibrating strings.
- Includes extra dimensions beyond the familiar four, which are compact at very small scales.

To determine if a particle reaction or decay occurs, physicists use these theories to calculate the probabilities of interactions and check if the resulting energy and particles match expected patterns.