CHAPTER 15

ELECTROMAGNETISM

MAGNETIC EFFECTS OF A STEADY (CONSTANT) CURRENT

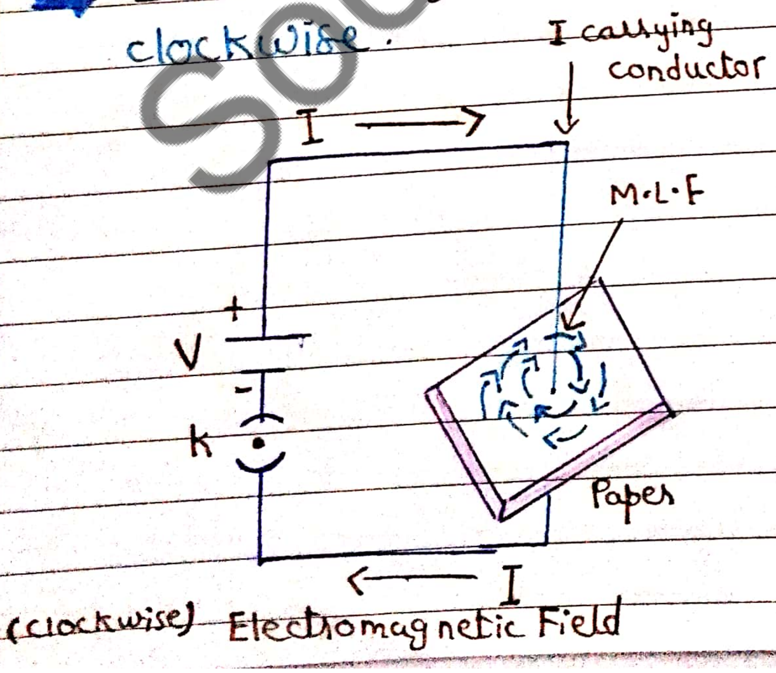
Ampere discovered "When a current passes through a conductor, it produces magnetic field around it."

EXPERIMENT

Take a straight conductor wire. Pass it through the cardboard. Connect the conductor wire with a battery with a connecting wire.

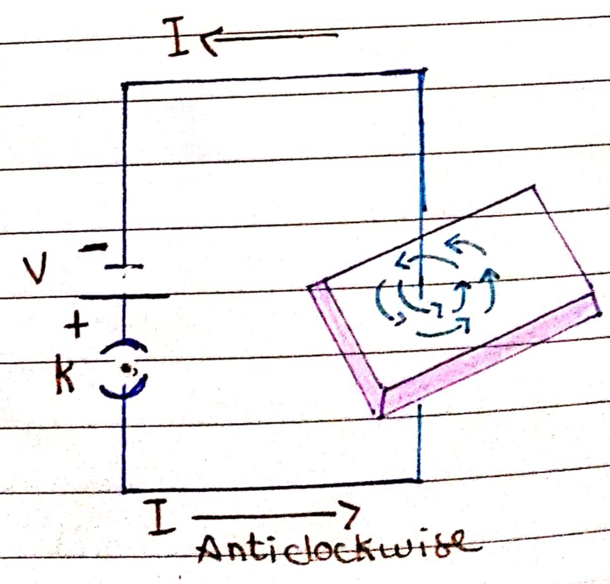
CASE I

- When current is flowing from top to bottom.
- Magnetic lines of force are produced around it in the form of concentric circle.
- Direction of M.L.F is clockwise.



CASE II

- When current is flowing from bottom to top.
- Magnetic lines of force are produced around it in the form of concentric circles.
- Direction of M.L.F is Anticlockwise.



Force On A Current-Carrying Conductor Placed In A Magnetic Field

Take a conductor of length 'L' which is connected with the battery. Now place the conductor in U-shaped permanent magnet.

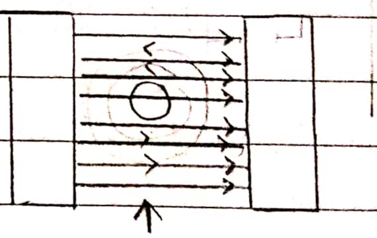
- When current passes through conductor, Magnetic Field will produce around the conductor.
- It is Magnetic Field due to electromagnet.
- The Magnetic Field of the permanent magnet will interact with electromagnetic field.

  $B_{\text{due to } I} + B_{\text{permanent magnet}}$

- Due to interactions of Magnetic Field, conductor will experience a Force.

Magnitude Of The Force

The Force experienced by the conductor depends on:



1. Current (I)
2. Magnetic Field (B)
3. length of conductor (L)

When current carrying conductor is placed perpendicularly to Magnetic Field, then 'F' can be written as:

$$F = ILB \sin\theta$$

B = Tesla

F_{max}

When $\theta = 90°$

$F_{max} = ILB \sin 90°$

$F_{max} = ILB$

$\vec{F} = I(\vec{L} \times \vec{B})$

$B = \frac{F}{IL}$

$1T = \frac{N}{A \times m}$

F_{min}

When $\theta = 0$

$F_{min} = ILB \sin\theta$

$F_{min} = ILB \sin 0$

$\vec{F}_{min} = 0$

DIRECTION OF FORCE

Direction of Force on the conductor can be determined by L.H.R

" Stretch First Finger, Middle Finger and thumb of your left hand in such a way that they are mutually perpendicular. 1st Finger will indicate M.F, Middle Finger will indicate I and thumb will indicate F. "

Turning Effect On A Current-Carrying Coil In A Magnetic Field

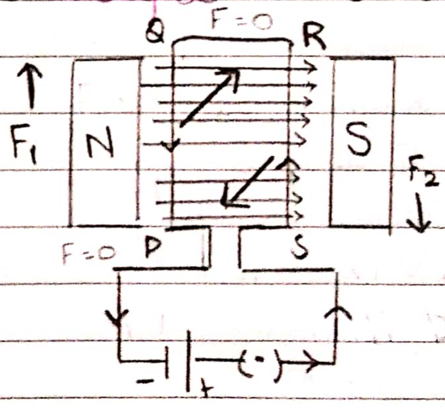
Consider a rectangular coil (PQRS) of wire placed perpendicularly to the Magnetic Field. Ends of coil are connected with the battery.

When 'I' will flow through the loop, its PQ and RS sides will experience a Force.

F_{max} = when conductor ⊥ B

F_{min} : when conductor is ∥ B

* $F_1 = IL_{PQ}B$
  Force experienced by PQ side in upward direction (↑)
* $F_2 = IL_{RS}B$
  Force acting on RS side in downward direction (↓)
* Both Forces are equal in magnitude and opposite in direction. They will produce couple and coil will rotate.



Resulting Torque

Torque = $\tau = NIAB$

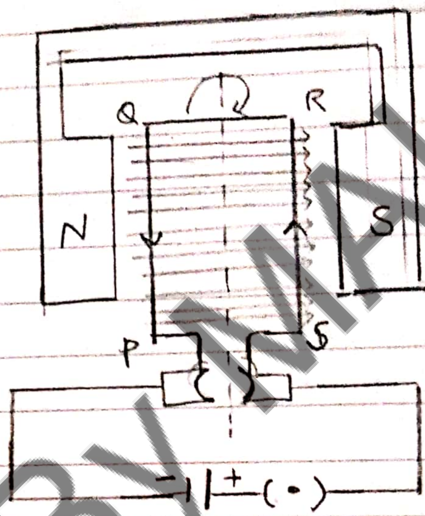
Resulting τ will depend on:

1. Current $\tau \propto I$
2. No. of turns in coil $\tau \propto N$
3. Applied M.F $\tau \propto B$
4. Area of coil $\tau \propto A$

Principle Of Electric Motors

When a current carrying loop is placed inside M.F, it will rotate due to torque.

D.C Motor [Converts Electrical Energy to Mechanical Energy]



Construction

1. Coil
2. Split Rings
3. Carbon brushes
4. Permanent Magnetic Field
5. External voltage source

Direction of current flowing through the coil is reversed due to split rings.

Requirements

When simple coil is placed in magnetic field, it cannot rotate more than 90° so to rotate the coil at 360° we provide a special arrangements. C-brush is an electrical contact which conducts current b/w stationary wires and moving part most Rotating shaft.

Explanation

Split rings are used for the working of D.C motors which are two halves of ring. They are known as Commutators.

Commutators are connected from inner side with coil where carbon brushes are attached at the outer ends. These are graphite pieces and allow current to flow into the loop. deliver current from Rotating part

Split Rings change their position as the coil change its position. Changing brushes reverse the current in the loop.

Conclusion

Direction of Force on PQ and RS is reversed that's why it continues to rotate.

ARMATURE

Armature is a coil which contains many turns. Magnetic Field provided to armature can be permanent magnet or electromagnet.

TORQUE OF ARMATURE

$\tau = NIAB$

$F \times r = NIAB$

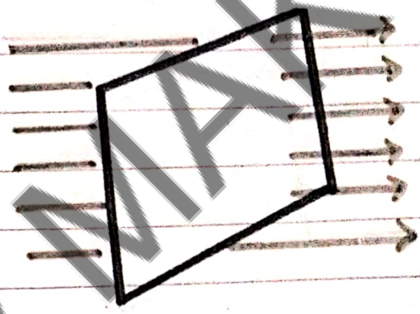
The speed of motor is controlled by changing current.

The Force acting on armature can be increased by following factors:

1. No. of turns of coil (N)
2. Current (I)
3. Area of coil (A)
4. Provided Magnetic Field. (B)

ELECTROMAGNETIC INDUCTION

➡ The process of generating an induced current in a circuit by changing the number of M.L.F passing through it is called electromagnetic induction.



The no. of M.L.F is maximum when surface is held perpendicularly to M.L.F

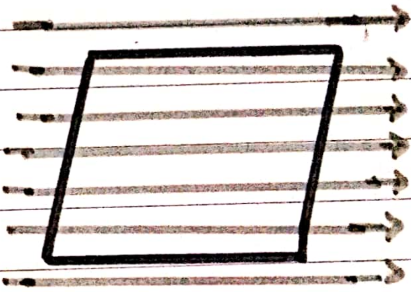
$B \perp$ Area

ϕ = flux = max

$\phi = B \cdot A = BA\cos\theta$

$= BA\cos(0)$

$= BA(1)$



The no. of M.L.F is minimum when surface is held parallel to M.L.F

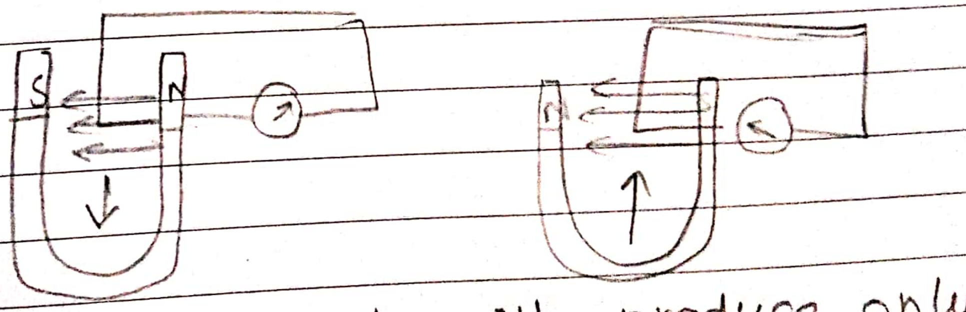
$B \parallel$ Area

ϕ = flux = min

$\phi = B \cdot A = BA\cos\theta$

$= BA\cos 90 = BA(0) \Rightarrow B \cdot A$.

FLUX The number field lines passing through unit area is known as flux.

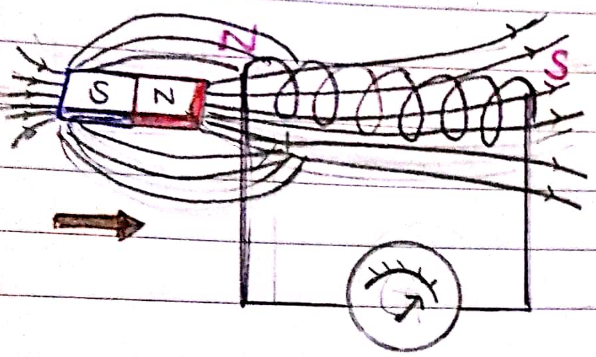


current will produce only when wires cuts M.F

EXAMPLE

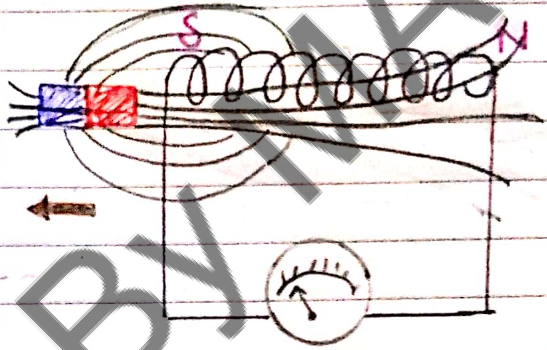
Take a solenoid(coil). Connect it with galvanometer. Bar magnet is moved in different directions. Observations and results are mentioned in such a way:

CASE 1 When bar magnet is moved toward solenoid



1. When we move bar magnet toward solenoid, M.L.F will pass through the solenoid.
2. More M.L.F will pass and induce a current in solenoid.
3. Galvanometer shows deflection toward right.

CASE 2 When bar magnet is moved away from solenoid



1. When we move bar magnet away from solenoid, M.L.F will pass through the solenoid.
2. Less M.L.F will pass and induce a current in solenoid.
3. Galvanometer shows deflection toward left.

CONCLUSION

1. If the bar magnet is stationary in the coil, no current will induce in the coil.

2. If bar magnet is kept stationary and coil is moved away or toward from bar magnet, current will induce.

3. We conclude that e.m.f is produced in the coil when there is a relative motion between coil and magnet.

4. $I_{induced} \propto$ Rate of change of flux.

$$I_{induced} \propto \frac{\Delta \phi}{\Delta t}$$

$$\varepsilon_{induced} \propto \frac{\Delta \phi}{\Delta t}$$

FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION

➡ The value of induced e.m.f in a circuit is directly proportional to the rate of change of number of magnetic lines of force through it.

$\varepsilon_{induced} \propto \frac{\Delta \phi}{\Delta t}$

$$\varepsilon = N \frac{\Delta \phi}{\Delta t}$$

FACTORS AFFECTING INDUCED e.m.f ($\varepsilon_{induced}$)

The magnitude of e.m.f depends on the following factors:

1. Speed of Relative motion of the coil and magnet.
2. No. of turns of coil (N)

LENZ'S LAW [Direction of $\varepsilon_{induced}$]

Lenz deviced a rule to find out the direction of induced current.

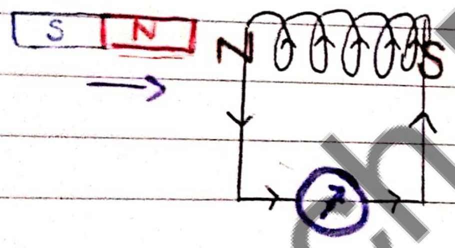
STATEMENT

Direction of induced current in a circuit opposes the cause that produces it.

EXPLANATION

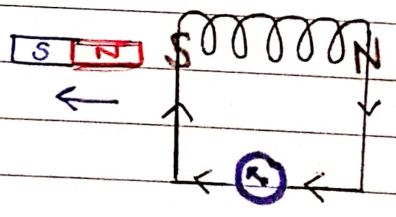
With the help of Lenz's law, we can determine direction of induced current.
Consider solenoid (coil) connected with galvanometer and take a bar magnet.

CASE-1 When a bar magnet is brought near solenoid



1. e.m.f (ε) will be induced in solenoid. (due to electro-magnetic induction)
2. Direction of induced current will oppose the cause (push of bar magnet)

CASE-2 When bar magnet is brought away from solenoid



1. e.m.f (ε) will be induced in solenoid (due to electro-magnetic induction)
2. Direction of induced current will oppose the cause (pull of bar magnet).

3. Front phase of solenoid will develop North pole	3. Front phase of solenoid will develop South pole.
4. As the poles are same, solenoid will repel bar magnet.	4. As the poles are different, solenoid will attract bar magnet.
5. With the help of L.H.R, direction of induced current will be 'Anticlockwise'	5. With the help of L.H.R, direction of induced current will be 'clockwise'.
6. Galvanometer shows deflection in one direction.	6. Galvanometer shows deflection in other direction.

LENZ'S LAW MANIFISTATION OF "LAW OF CONSERVATION OF ENERGY"

Electrical Energy induced in a conductor comes from K.E of moving magnet.
We do work on the magnet to bring it close to solenoid. Resultantly, this work appear as electrical energy.
Hence Lenz's law is a manifistation of low of conservation of energy.

From the Def of Lenz's Law we come to know that induced current is always opposed by the cause that produces it.

- There is extra work done against opposing force.
- The work done Against the opposing force results in change in magnetic flux and hence current is induced.
- The extra work done is known as E.E which is low of...

AC GENERATOR

➡ It is a device which converts Mechanical Energy into Electrical Energy.

Mechanical Energy → Electrical Energy

PRINCIPLE OF A.C. GENERATOR

A.C. Generator works on principle of Faraday's law of electromagnetic induction.
When a coil rotates in M.F, the induced 'I' changes continously from maximum to minimum.

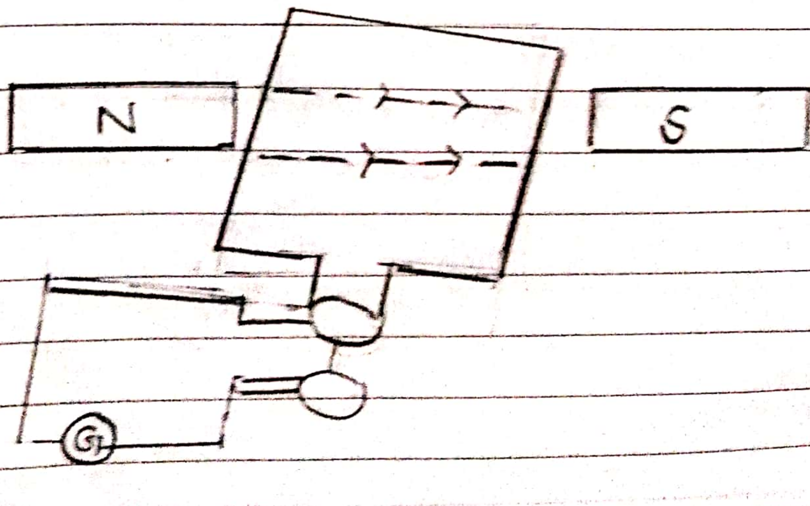
CONSTRUCTION

It consists of

(i) slip rings
(ii) carbon brushes
(iii) coil (armature)
(iv) permanent magnet.

WORKING

When coil is rotated in M.F, M.L.F are cut by the coil, current will induce which is the output.
The value of induced current depends upon No. of M.L.F passing through the coil.
Flux will be max when coil is perpendicular to M.F(B).
Flux will be zero when coil is parallel to M.F



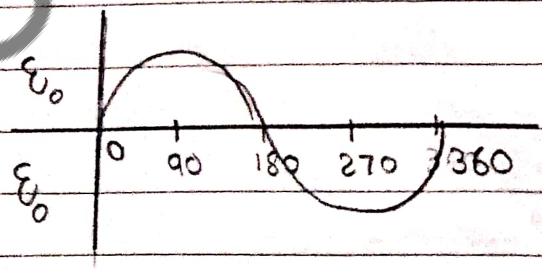
CURRENT FROM GENERATOR

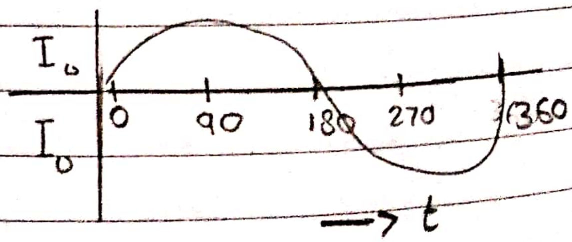
A.C is generated and its value can be determined as:

No. of obs.	Position of plane	Plane of loop and B	$\frac{\Delta\phi}{\Delta t}$	θ	$\mathcal{E} = \mathcal{E}_o \sin\theta$
1	perpendicular	Plane ⊥ B	0	0	$\mathcal{E} = \mathcal{E}_o \sin(0) = 0$
2	Horizontal	Plane ∥ B	max	90	$\mathcal{E} = \mathcal{E}_o \sin(90) = max$
3	perpendicular	Plane ⊥ B	0	180	$\mathcal{E} = \mathcal{E}_o \sin(180) = 0$
4	Horizontal	Plane ∥ B	max	270	$\mathcal{E} = \mathcal{E}_o \sin(270) = -max$
5	perpendicular	Plane ⊥ B	0	360	$\mathcal{E} = \mathcal{E}_o \sin(360) =$

1. When plane of coil is perpendicular to B, there is no change in flux so induced e.m.f will be zero.

2. When plane of coil is horizontal to B, there is max change in flux so induced e.m.f will be maximum.





$\theta = \omega t$.

MUTUAL INDUCTION

STATEMENT

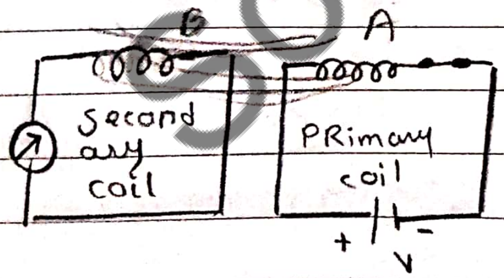
The phenomenon of production of induced current in one coil due to change of current in a neighbouring coil is called mutual induction.

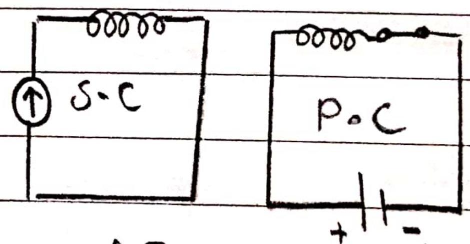
EXPLANATION

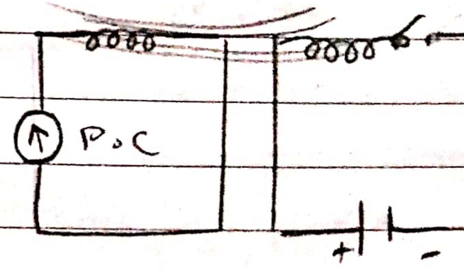
In mutual induction we consider two coils:

1- Primary coil
2- Secondary coil

CASE-1	CASE-2	CASE-3
1- Switch is closed	1- Switch is closed	1- Switch is opemed
2- value of 'I' increases from 0-max.	2- 'I' is constant	2- value of 'I' decreses from max-0
3- M.L.F are induced in coil b so 'I' flow in coil b.	3- M.L.F are not changing so no 'I' is induced in coil b.	3- current induce in coil b.
4- Galvanometer shows deflection.	4- Galvanometer shows no deflection.	4- Galvanometer shows deflection.







$\Delta I = 0$ = steady.

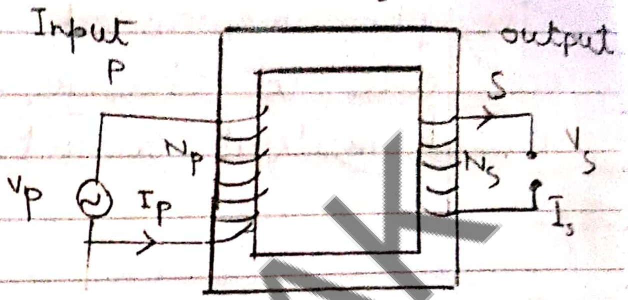
I (0 - max)

TRANSFORMER

"It is an electrical device used to increase or decrease the value of alternating voltages."

CONSTRUCTION

- Iron core
- Primary coil
- secondary coil



$$V_s \propto N_s$$

If Rate of change of flux is constant

$$V_s = \text{constant } N_s \quad \text{— (i)}$$

$$V_p \propto V_s$$

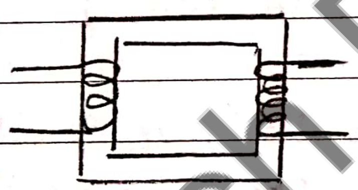
$$V_p = \text{constant } N_p \quad \text{— (ii)}$$

Dividing (i) and (ii)

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

TYPES

Step-Up Transformer



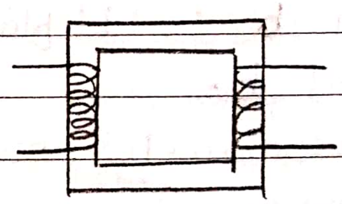
$V_p < V_s$

$I_p < I_s$

$N_p < N_s$

- voltage increases

Step-down Transformer



$V_p > V_s$

$I_p > V_s$

$N_p > N_s$

- voltage decreases

IDEAL TRNSFORMER

$$P_p = P_s$$

$$I_p V_p = I_s V_s$$

$$\frac{V_p}{V_s} = \frac{I_s}{I_p}$$

USES

- Printer
- Game system