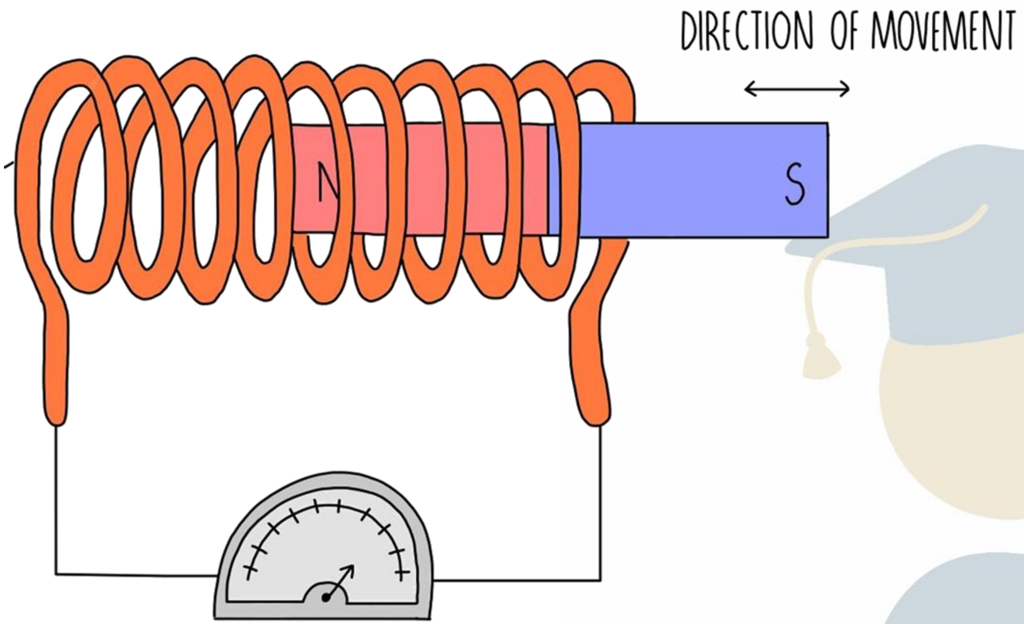
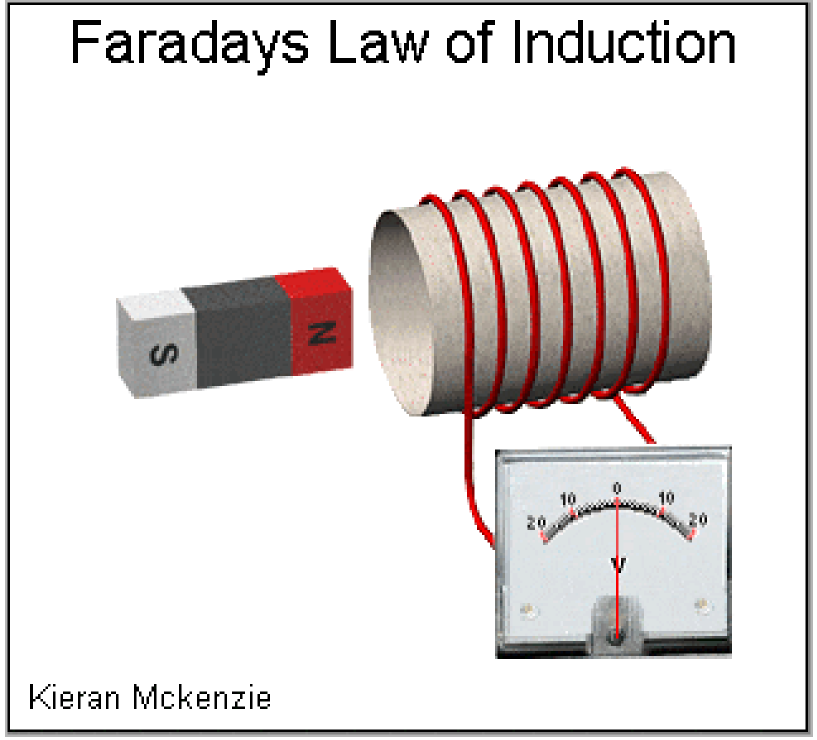




Physics – Grade 12 LS & GS

Unit Two – Electricity

Chapter8 – Electromagnetic Induction

OBJECTIVES

1 **Definition and properties of magnet**

2 **Types of Magnets**

3 **Magnetic field created by electric current**

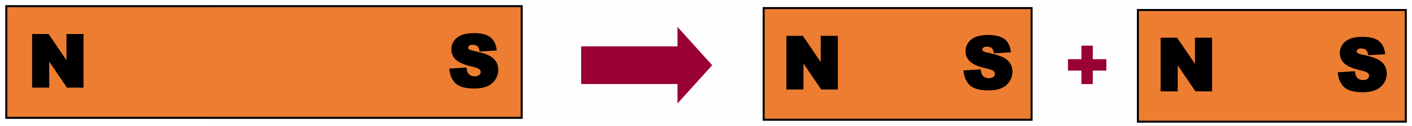
Definition of a magnet

Magnet: a magnet is a metal that creates around themselves an invisible field called **magnetic field ($\vec{B}$).**

The SI unit of the magnetic field ($\vec{B}$) is the Tesla (T).

A magnet has two poles south (S) and North (N).

When a magnet is cut into smaller pieces, each smaller piece is a new magnet having both a north and south pole.



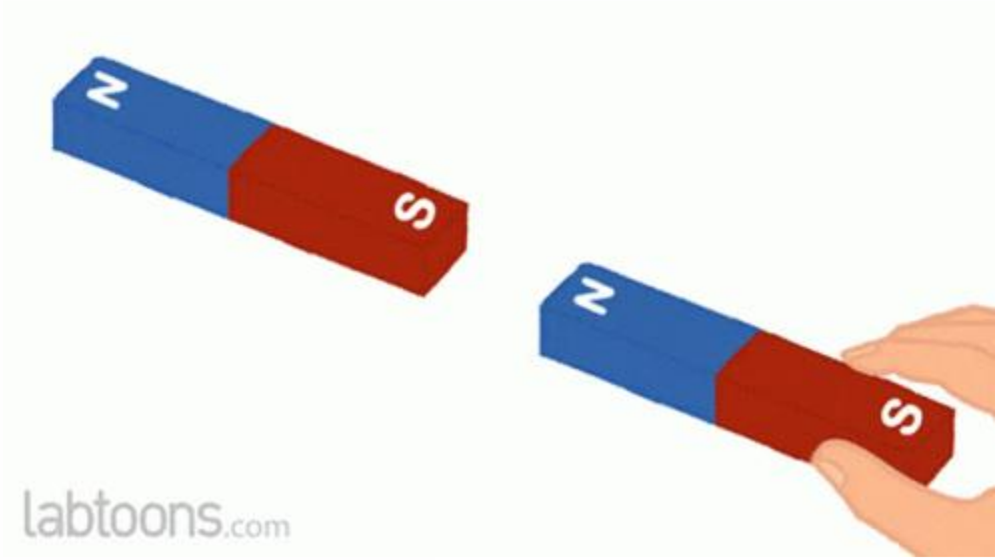
Definition of a magnet

The magnitude of the magnetic field decreases as we move away from the magnet.

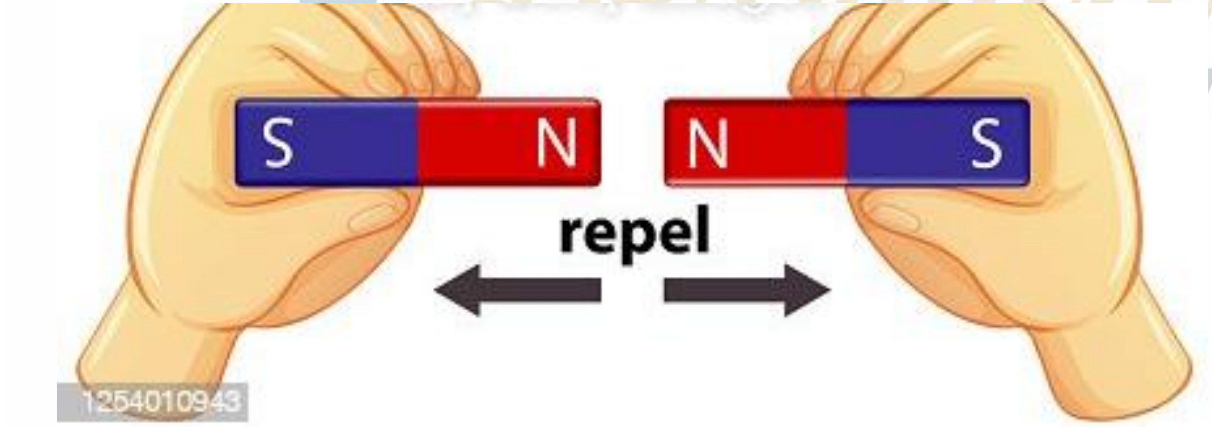
The magnetic field lines enters from (S) pole and leaves from (N) pole.

Definition of a magnet

The north pole of one magnet attracts the south pole of another, and the south pole attracts the north pole of another magnet.



Two north poles or two south poles repel each other.

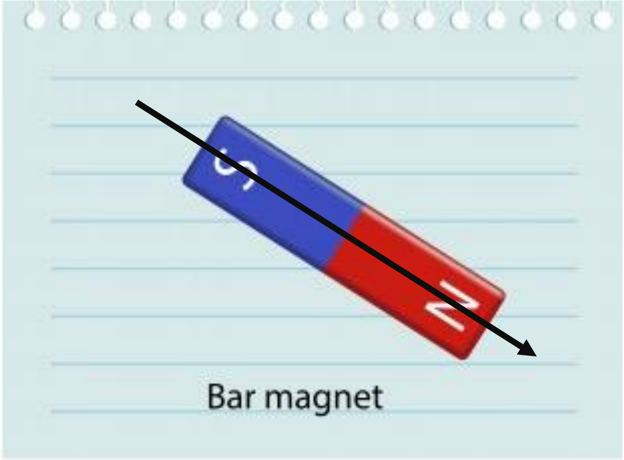


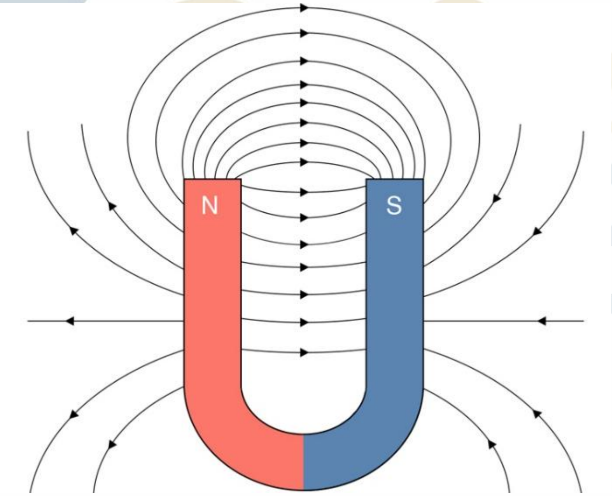
Types of magnet

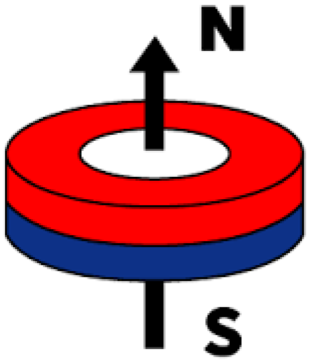
Bar Magnetic: The magnetic field $\vec{B}$ always directed from S pole to N pole of the magnet bar.

U-shape magnet: The magnetic field lines in the U-shape magnet are parallel, same magnitude and direction.

Circular magnet: The magnetic field lines are parallel to each other and perpendicular to surface.

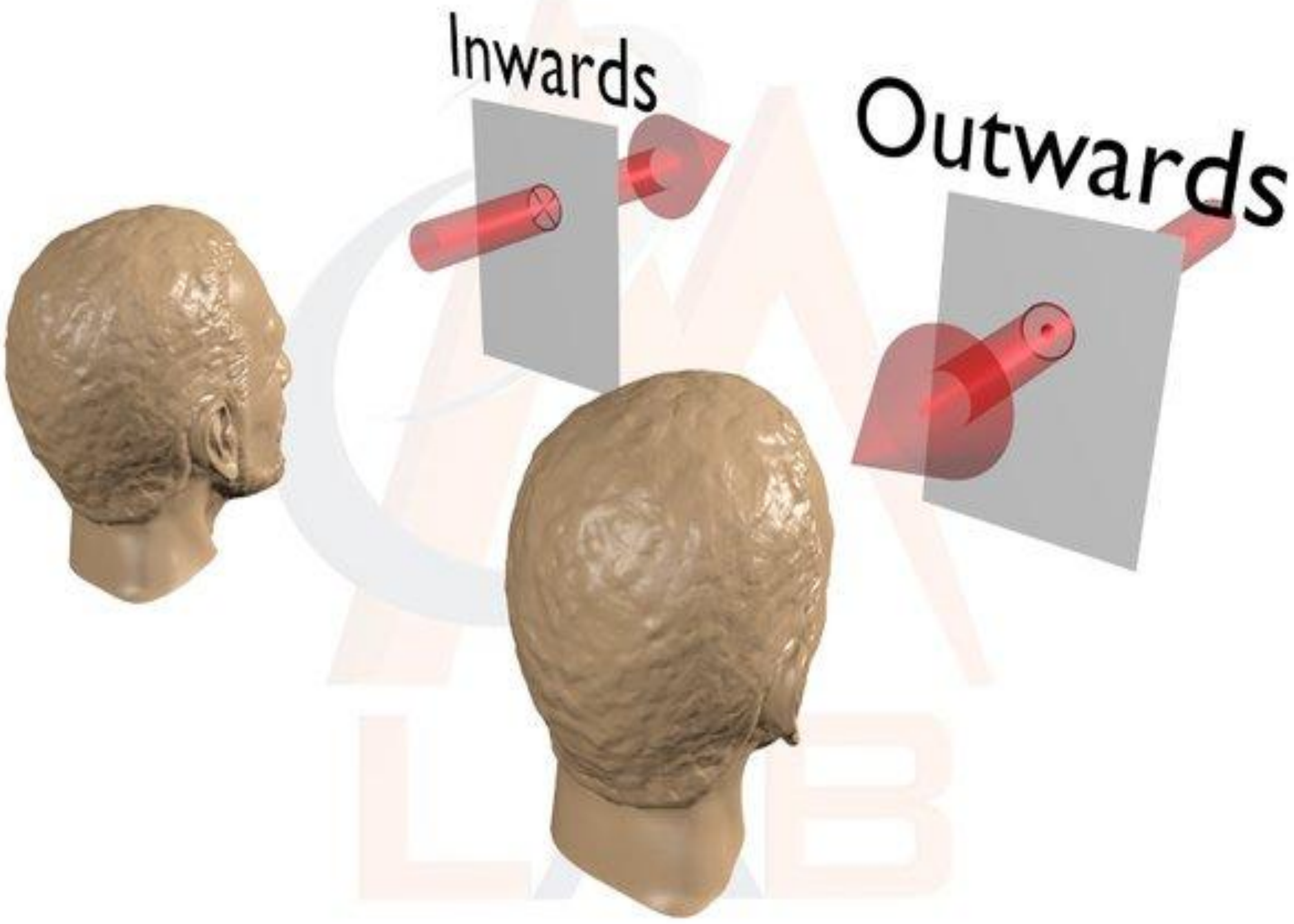






Magnetic field created by electric current

- $\otimes$: $\vec{B}$ is ⊥ to the plane of paper and directed away from the reader (inward).
- $\odot$: $\vec{B}$ is ⊥ to the plane of paper and directed towards the reader (outward).



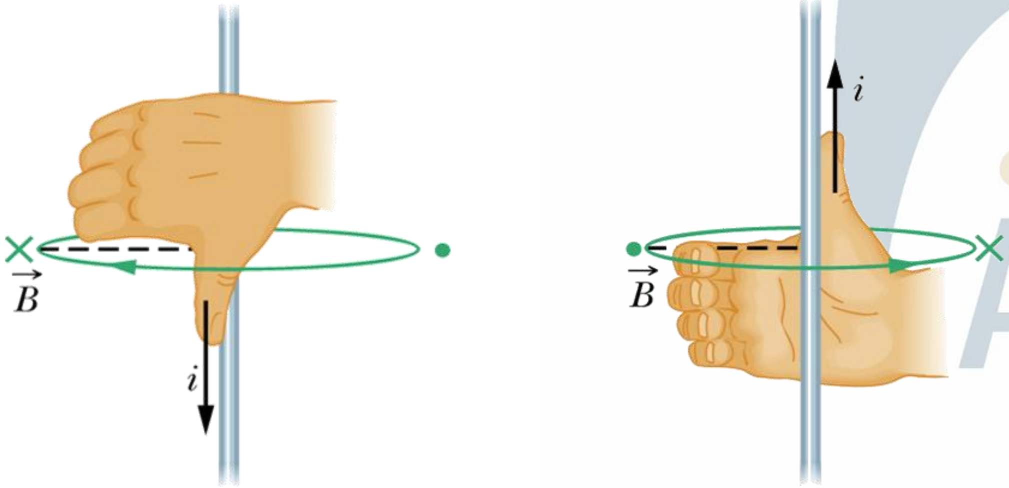
Magnetic field created by electric current/ Long straight wire

The magnitude of the magnetic field created by a current I flowing in a wire at point M at a distance d from the wire is:

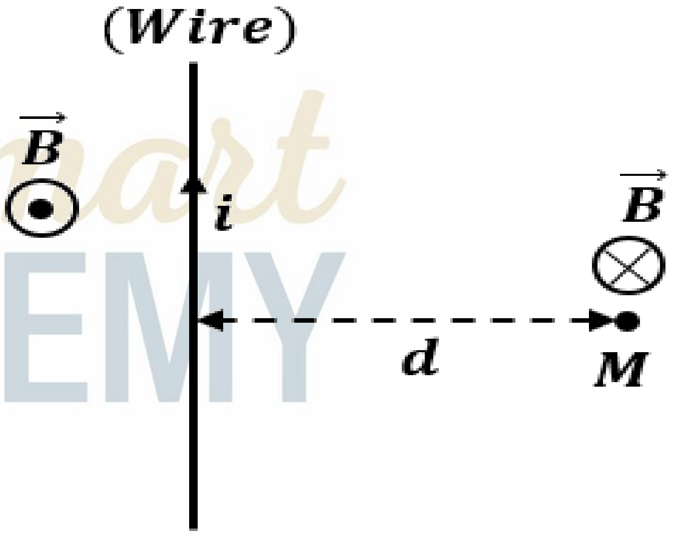
$$B = \frac{2 \times 10^{-7}}{d} i$$

i: current traverses the wire, in Amperes (A).

d: distance between the point and the wire, in (m).



(a) (b)



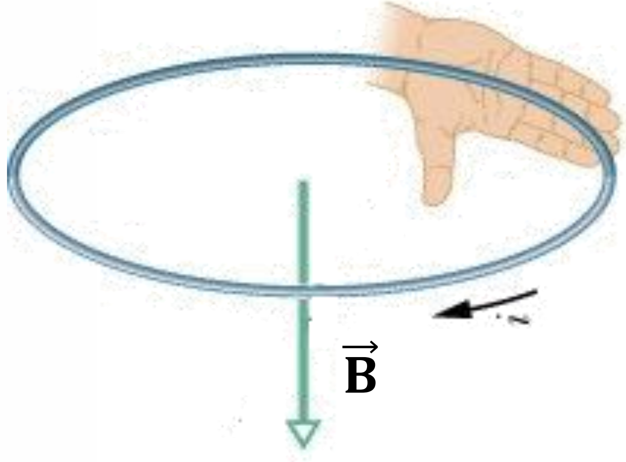
Magnetic field created by electric current/flat coil

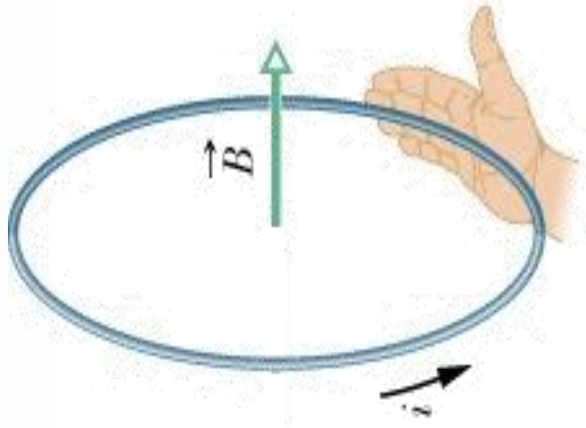
If a current i flows in a coil, a magnetic field $\overrightarrow{B}$ is created at the center of the coil such that:

Direction of ($\overrightarrow{B}$):

By RHR (curl your four fingers of your right hand along the direction of the current:

The thumb indicates the direction of $\overrightarrow{B}$.

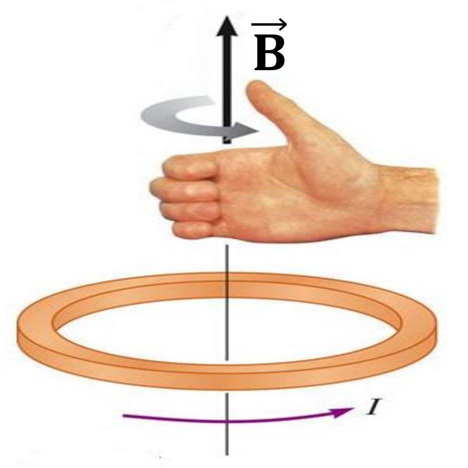




Magnetic field created by electric current/flat coil

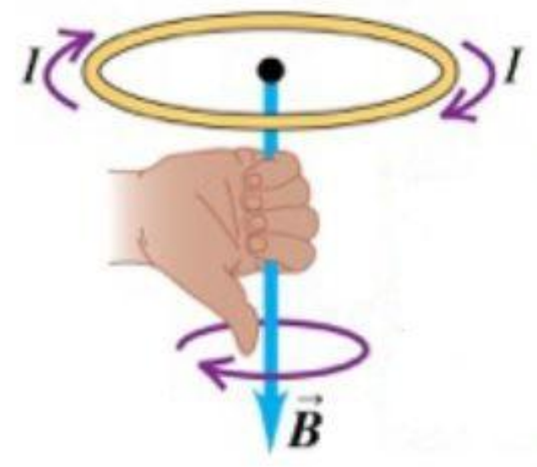
Magnitude: the magnitude of the magnetic field is given by:

$$B = \frac{(2\pi \times 10^{-7})N}{R} i$$



- i: current traverses the wire, in Amperes (A).
- **N:** the number of turns.
- **R:** radius of one loop.

Note: A coil acts as a magnet having North Pole (N) at the face where $\vec{B}$ goes out and south pole (S).



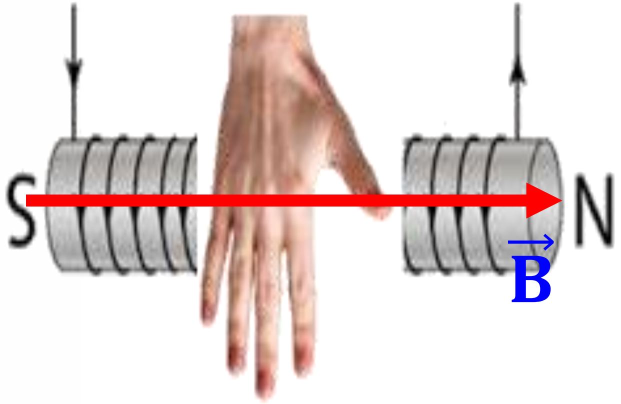
Magnetic field created by electric current/ Solenoid

If a currents traverses a solenoid, then a magnetic field $\vec{B}$ is created at any point inside the solenoid such that:

Direction of ($\vec{B}$):

By RHR: (curl your four fingers of your right hand along the direction of the current:

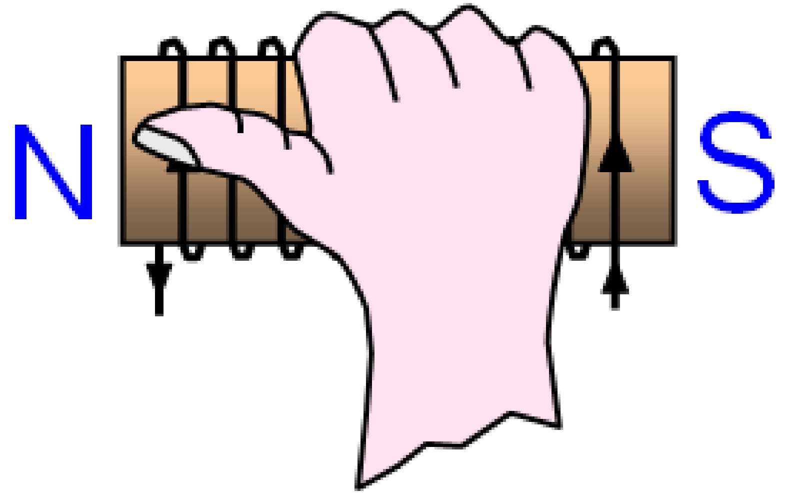
The thumb indicates the direction of $\vec{B}$.



Magnetic field created by electric current/ Solenoid

Magnitude: the magnitude of the magnetic field is given by:

$$B = \frac{(4\pi \times 10^{-7})N}{L} i$$



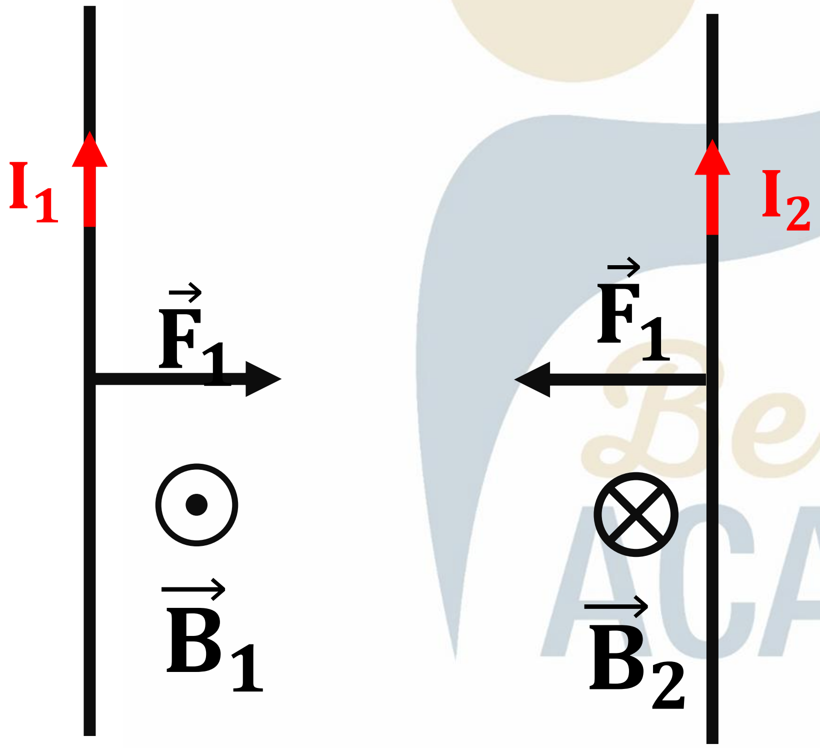
- **i: current traverses the wire, in (A).**
- **N: the number of loops.**
- **L: length of the solenoid.**

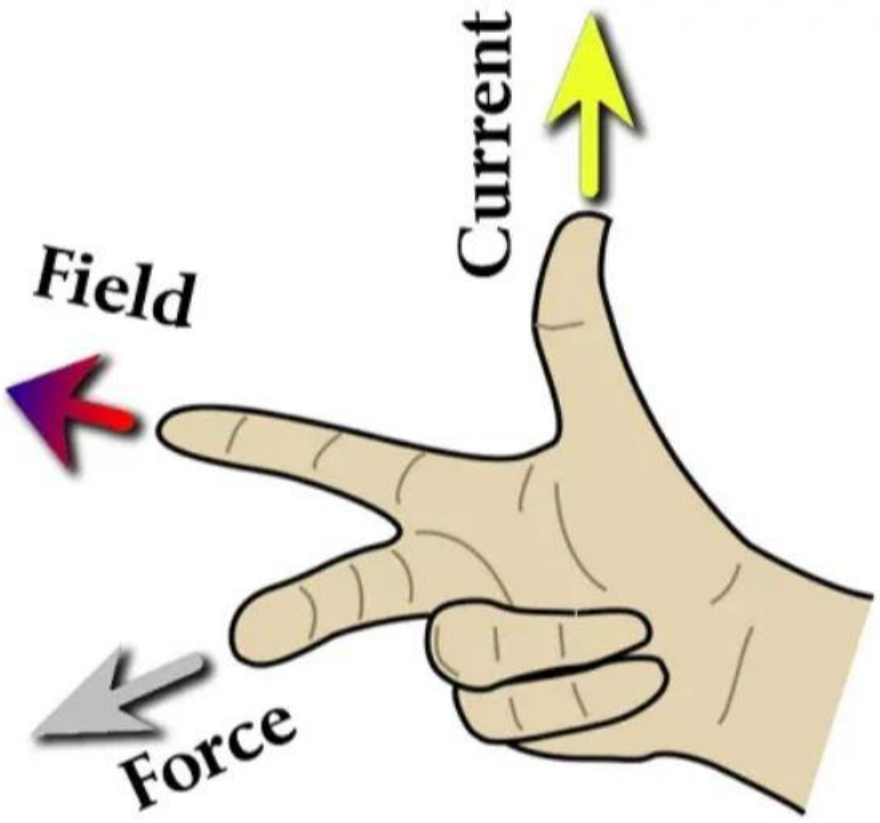
Note:

A solenoid acts as a magnet having North Pole (N) at the face where $\vec{B}$ goes out and south pole (S).

Electromagnetic force (Laplace Force)

A wire traversed by a current, in presence of a magnetic field $\overrightarrow{B}$, is is subjected to a force $\vec{F}$ called Laplace force:





Electromagnetic force (Laplace Force)

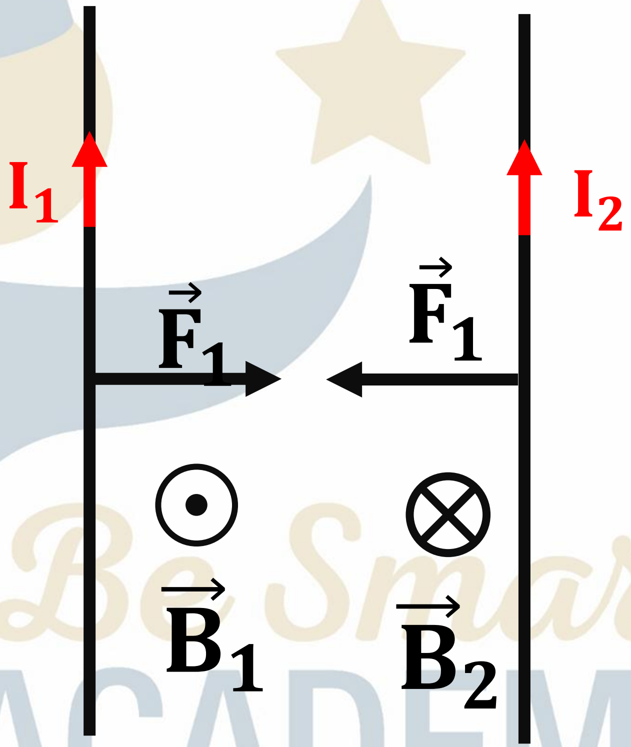
Characteristics of Laplace force:

Point of application:

The midpoint of the straight conductor.

Direction:

Indicated by RHR: Right, Left, up or down



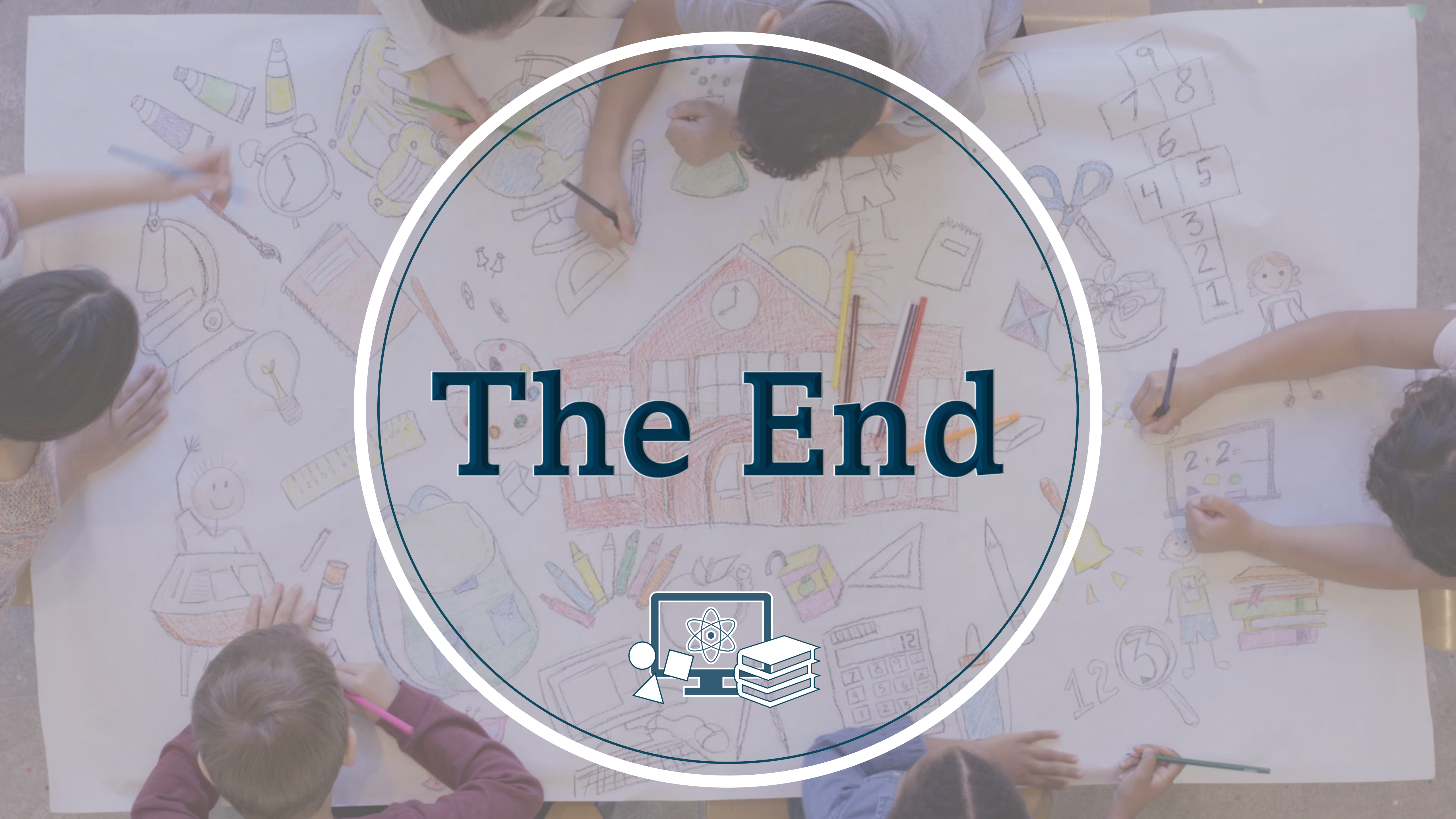
Line of action:

The direction of the force $\vec{F}$ is $\perp$ to $\vec{i}$ and $\vec{B}$.

Magnitude:

$F = IBLsin\alpha$

Where α is between $\vec{\imath}$ and $\vec{B}$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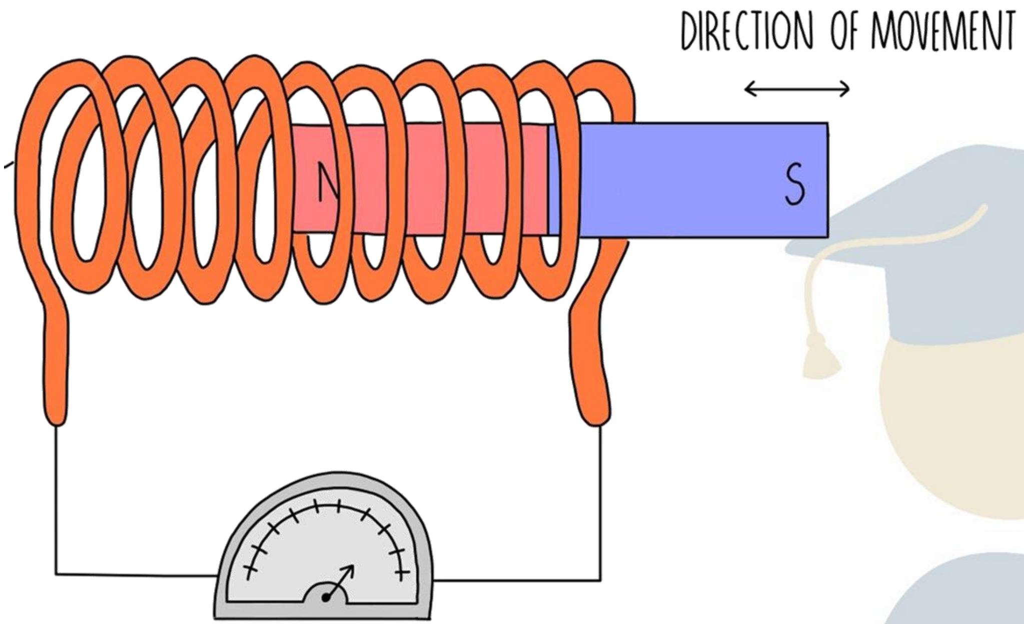
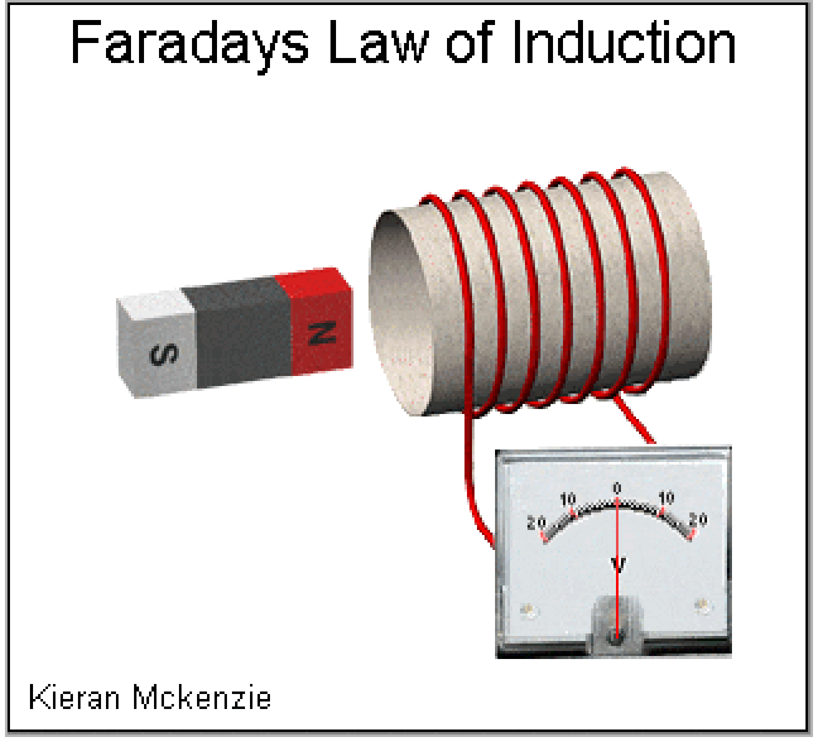




Physics – Grade 12 LS & GS

Unit Two – Electricity

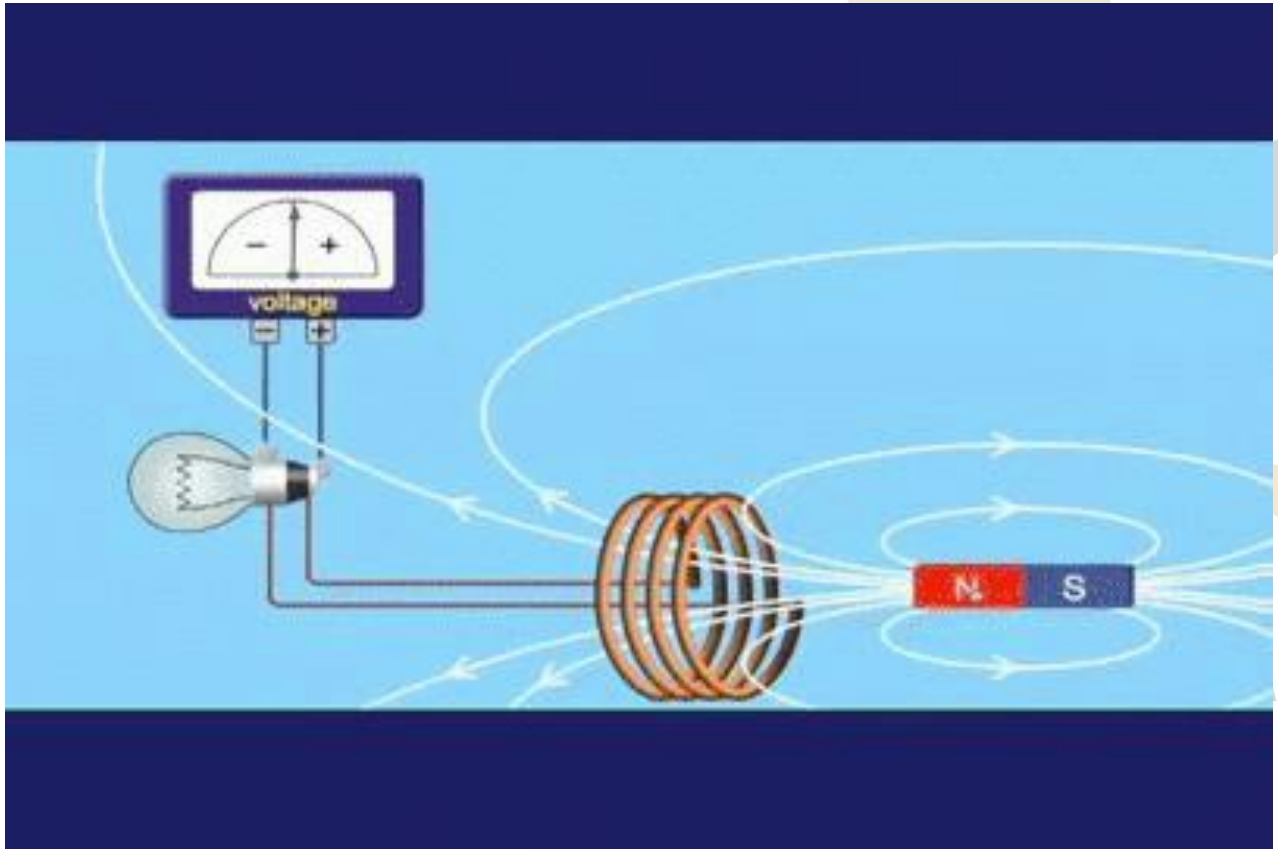
Chapter8 – Electromagnetic Induction

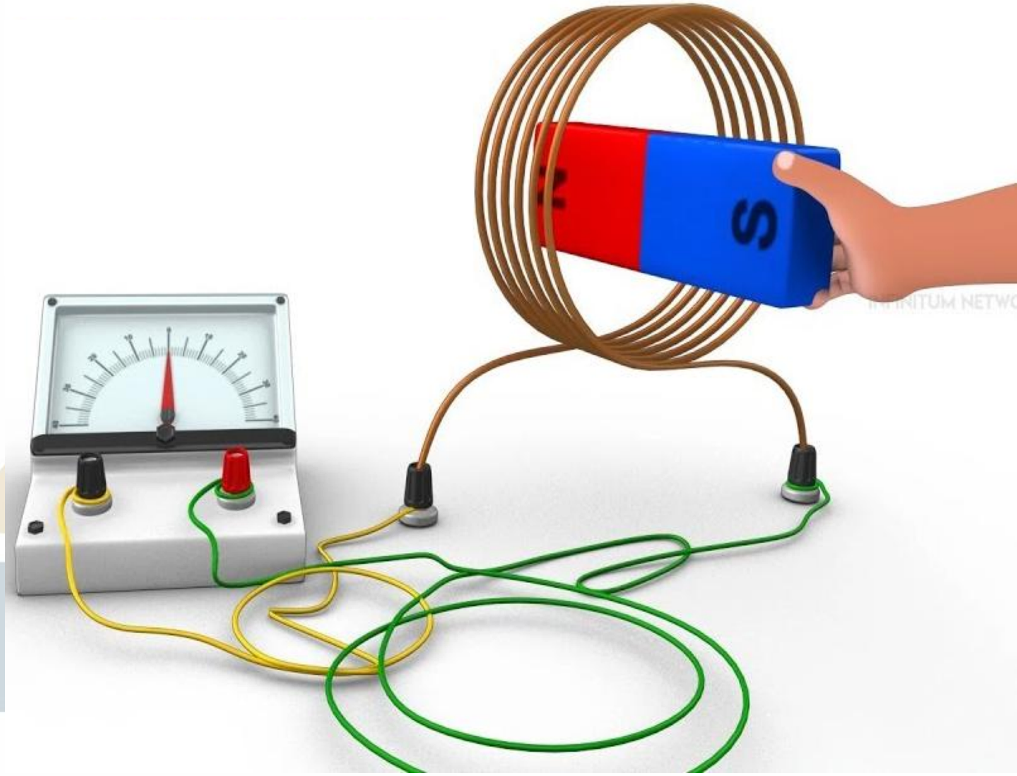
OBJECTIVES

1. To define electromagnetic Induction.
2. To show electromagnetic induction experimentally
3. To define magnetic flux ($\emptyset$).

Electromagnetic induction.

It’s a physical phenomenon of producing of electric current across a coil by the effect of a magnet.





Electromagnetic induction.

We move the magnet towards the coil.

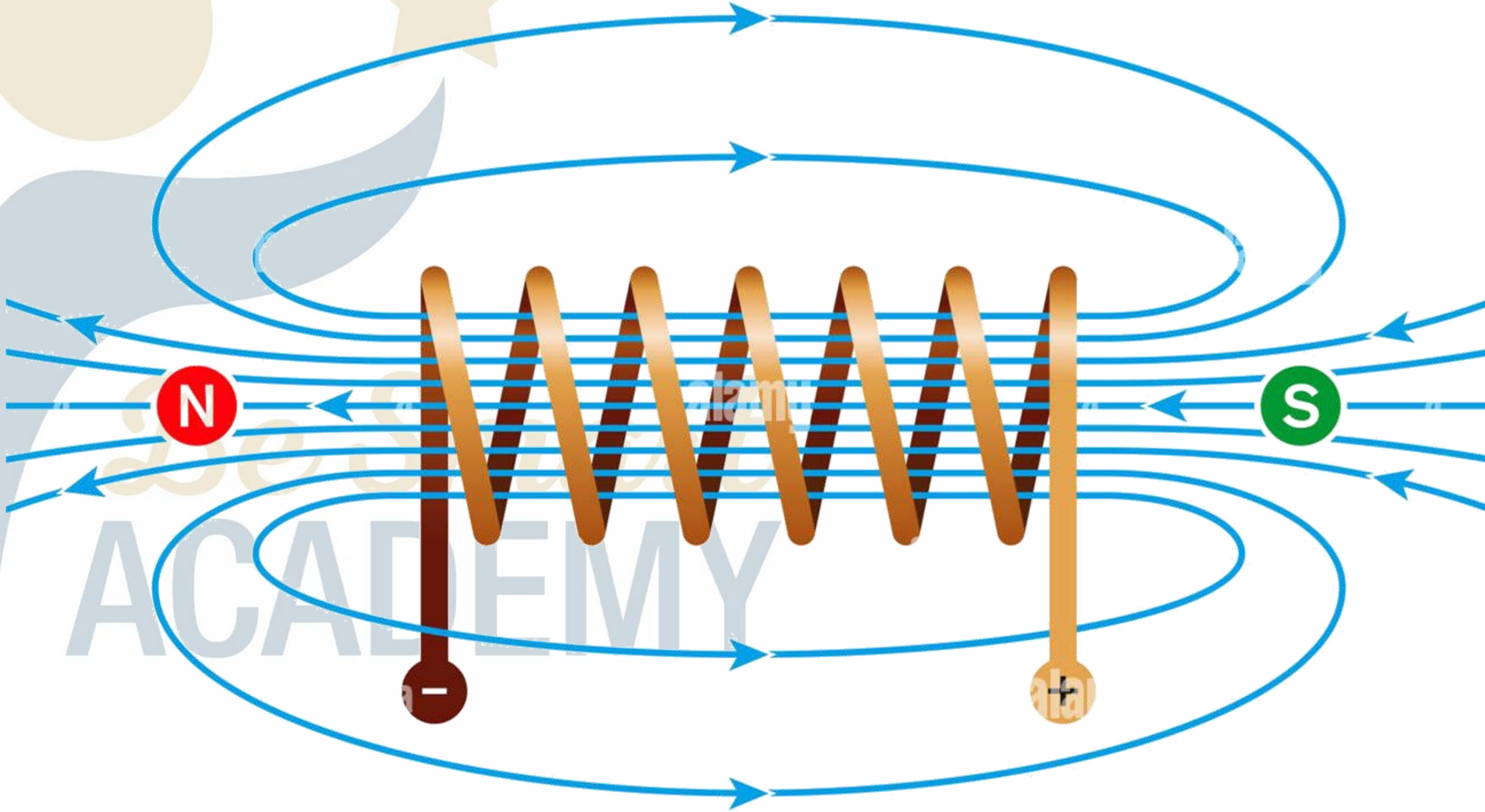
- **We observe that the needle defects in a certain direction which indicates the passage of electric current in the coil called induced current i_{ind}.**
- **When the magnet stops, this current disappears when the ($i_{ind} = 0$).**
- **When we move the magnet away from the coil, we observe the needle defects in opposite direction.**


eLearnIn

Electromagnetic induction.

- Because i_{ind} passes through the coil, it acts as a magnet of (S) and (N) poles with an induced magnetic field $\overrightarrow{B}_{ind}$.

- The direction of $\overrightarrow{B}_{ind}$ and i_{ind} are related to each other by R.H.R.

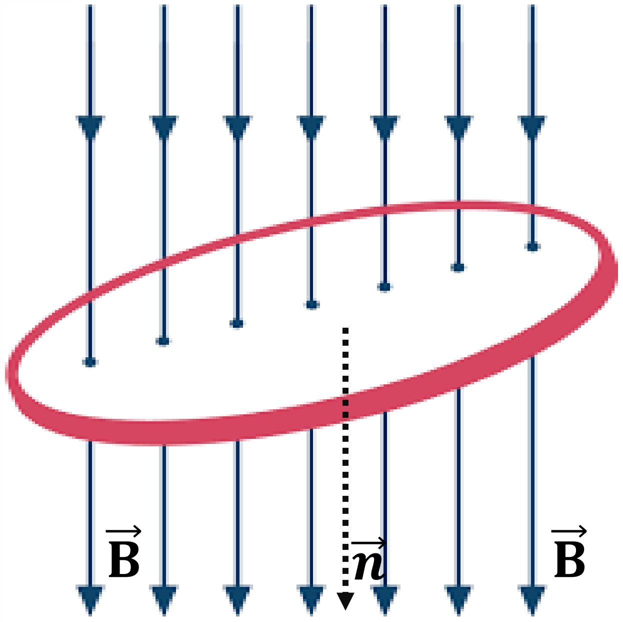


Magnetic flux (∅)

The magnetic flux ∅: is a measurement of the total magnetic field which passes through a given surface area (S).

The magnetic flux expressed (SI unit) in weber ($Wb = T.m^2$)

$$\emptyset = NBS\cos(\vec{B},\vec{n})$$

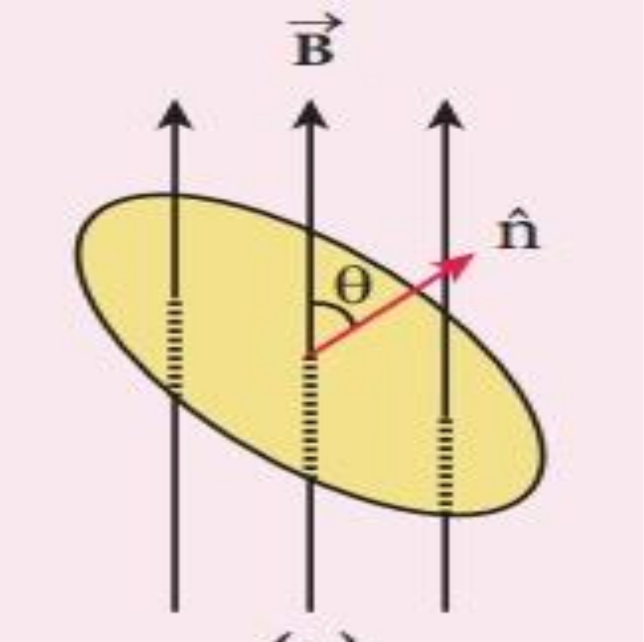


- **N:** number of turns
- **B:** magnetic field, in Tesla (T)
- **S:** surface area, in m^2
- **Angle (θ):** angle between $\vec{B}$ and $\vec{n}$
- **$\vec{n}$:** normal vector, it is ⊥ to surface.

Magnetic flux (∅)

$$\emptyset = NBS\cos(\vec{B}, \vec{n})$$

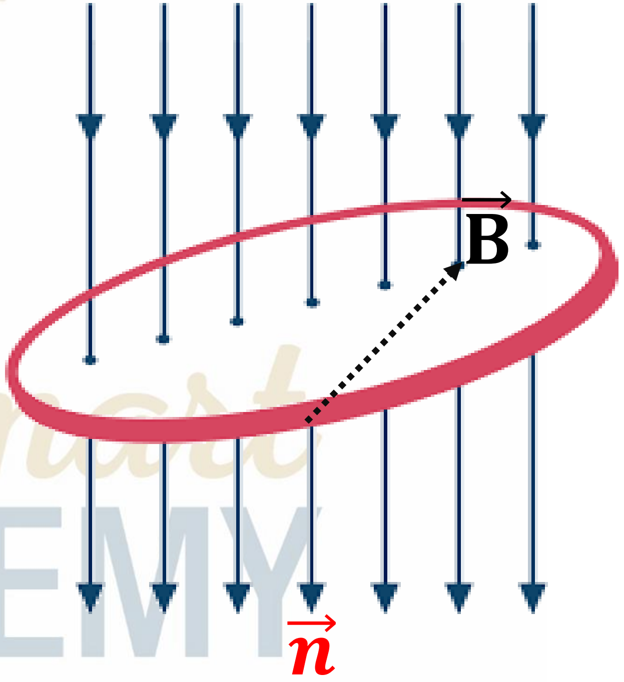
If $0 \le \theta < 90$:



(a)

$\cos\theta > 0$, then $\emptyset > 0$

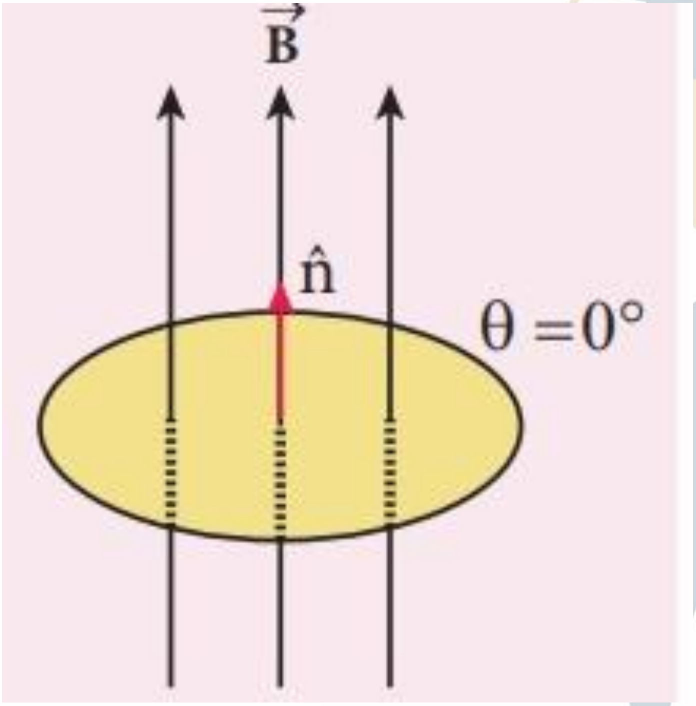
If $90 < \theta \le 180$:



$\cos\theta < 0$ then $\emptyset < 0$

Magnetic flux (∅)

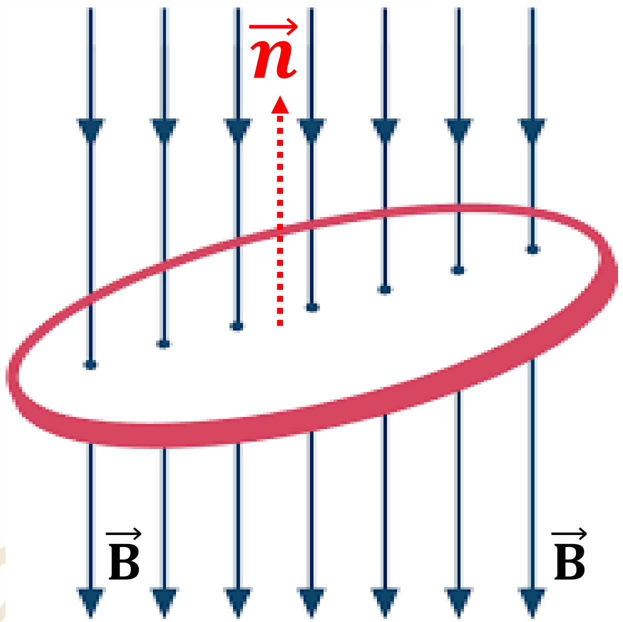
If $\theta = 0$:



$cos 0 = 1$

Flux is maximum

If θ = 180:



$\cos 180 = -1$

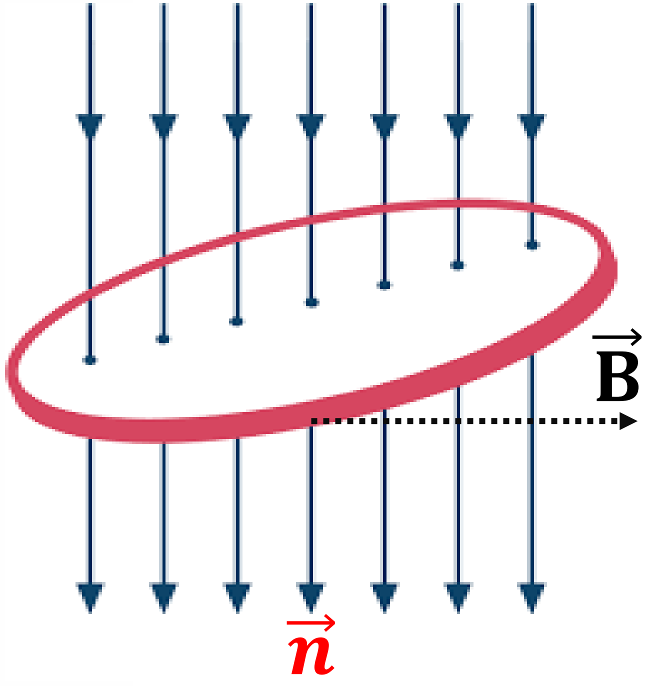
Flux minimum

Magnetic flux ($\emptyset$)

If $\theta = 90$:

$$cos90 = 0$$

$$\emptyset = 0$$



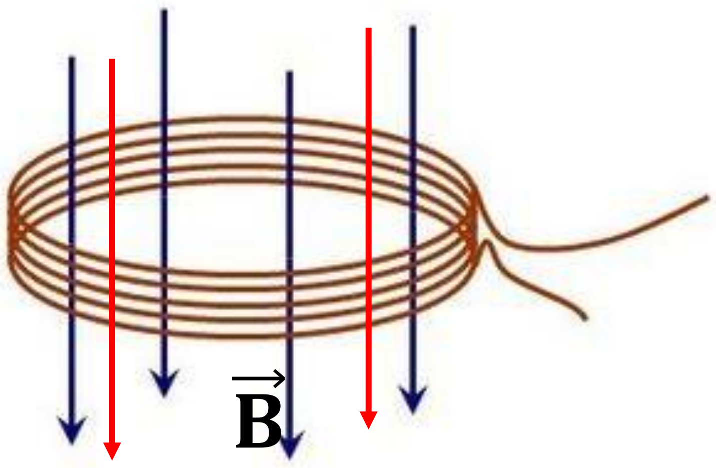
Magnetic flux (∅)

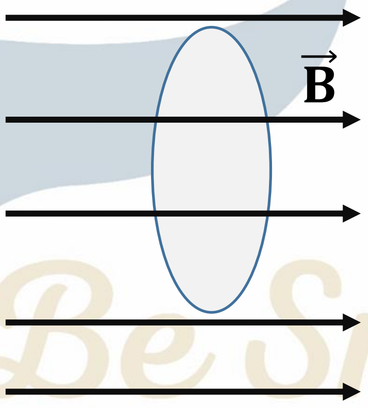
Direction of normal vector ($\vec{n}$):

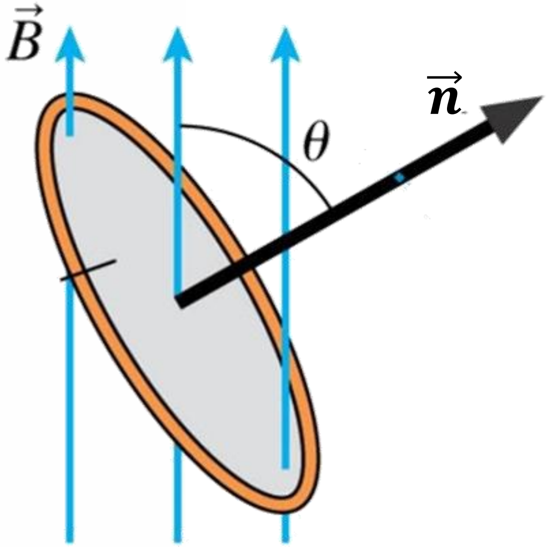
The direction of normal vector is by RHR according to given positive direction.

Magnetic flux (∅)

The magnetic flux $\emptyset = NBScos(\theta)$ depends on the three factors may be variable: $\vec{B}$, S, and the angle θ.



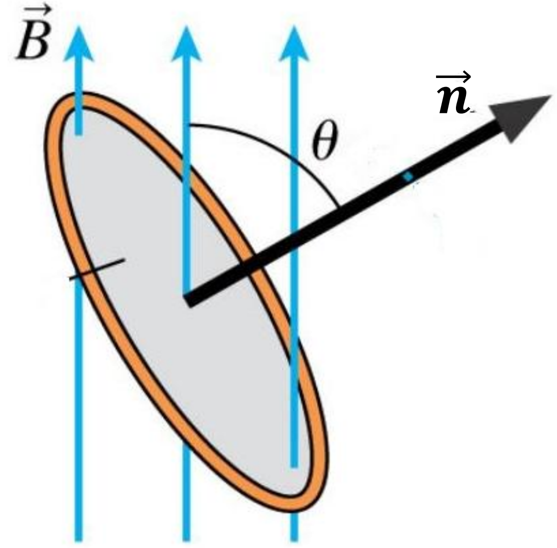




Magnetic flux (∅)

Application 1:

A conducting loop of area $S = 8000cm^2$ is placed in a region with constant magnetic field B=80mT.



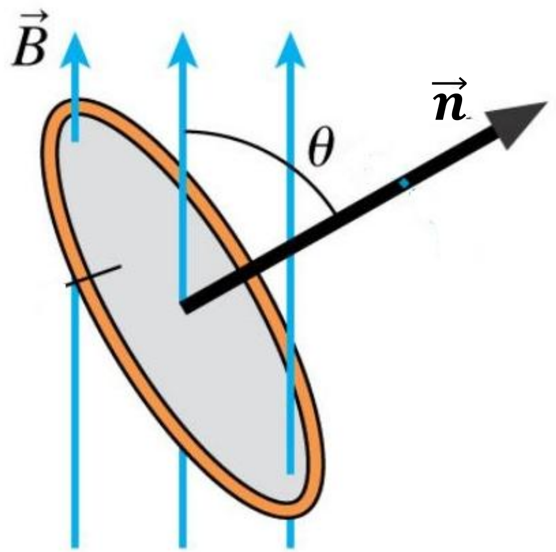
The magnetic field lines making an angle $\theta = 30^{\circ}$ with the normal vector of the loop.

1. Calculate the magnetic flux crossing the loop.
2. We rotate the loop to make the magnetic flux variable. Calculate the angle between normal and B to reach maximum flux.

Magnetic flux (∅)

$S = 8000cm^2$; B=80mT; $\theta = 30^{\circ}$

1.Calculate the magnetic flux crossing the loop.



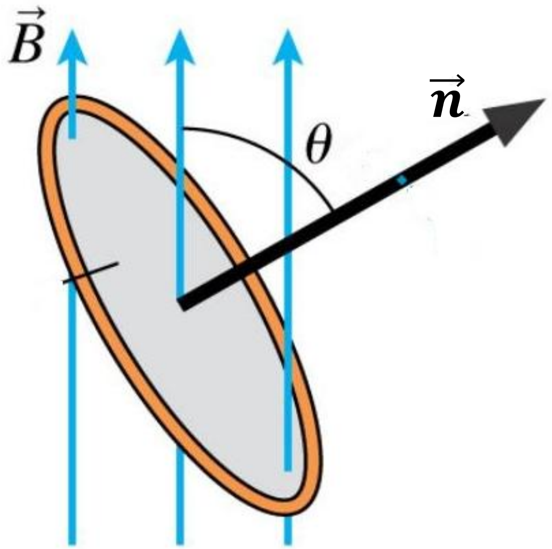
$$\emptyset = NBScos\theta$$

$$\emptyset = 1 \times (80 \times 10^{-3}) \times (8000 \times 10^{-4}) \times cos30$$

$$\emptyset = 0.055Wb$$

Magnetic flux (∅)

2. We rotate the loop to make the magnetic flux variable. Calculate the angle between normal and B to reach maximum flux.



$$\emptyset = NBScos\theta$$

The flux is maximum for $\cos\theta = 1$

$\cos\theta = 1$ ⇨ $\theta = 0$

Magnetic flux (∅)

Application 2:

A coil of surface area $S = 100cm^2$ is placed in a region with variable magnetic field $B = 2t + 1$.

The magnetic field lines making an angle $\theta = 60^\circ$ with the normal vector of the loop.

1.Define electromagnetic induction.

Electromagnetic induction is the induction of a potential difference or electromotive force e.m.f "e" in a conductor when it is placed in a varying magnetic flux.

Magnetic flux (∅)

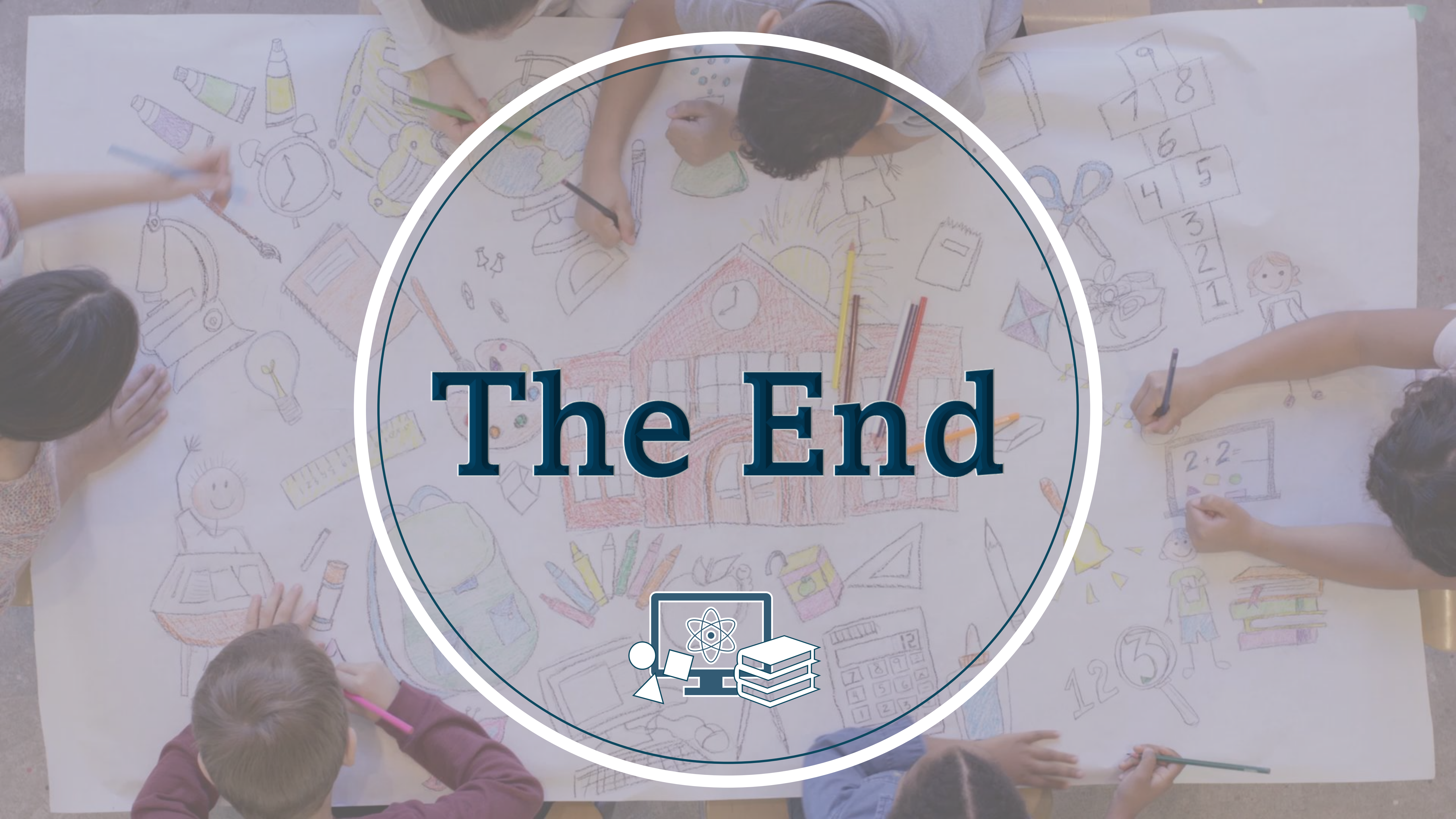
2. Calculate the magnetic flux crossing the loop.

$$\emptyset = NBScos\theta$$

$$\emptyset = 1 \times (100 \times 10^{-4}) \times (2t + 1) \times cos(60)$$

$$\emptyset = 0.05 \times (2t + 1)$$

$$\emptyset = 0.1t + 0.05$$



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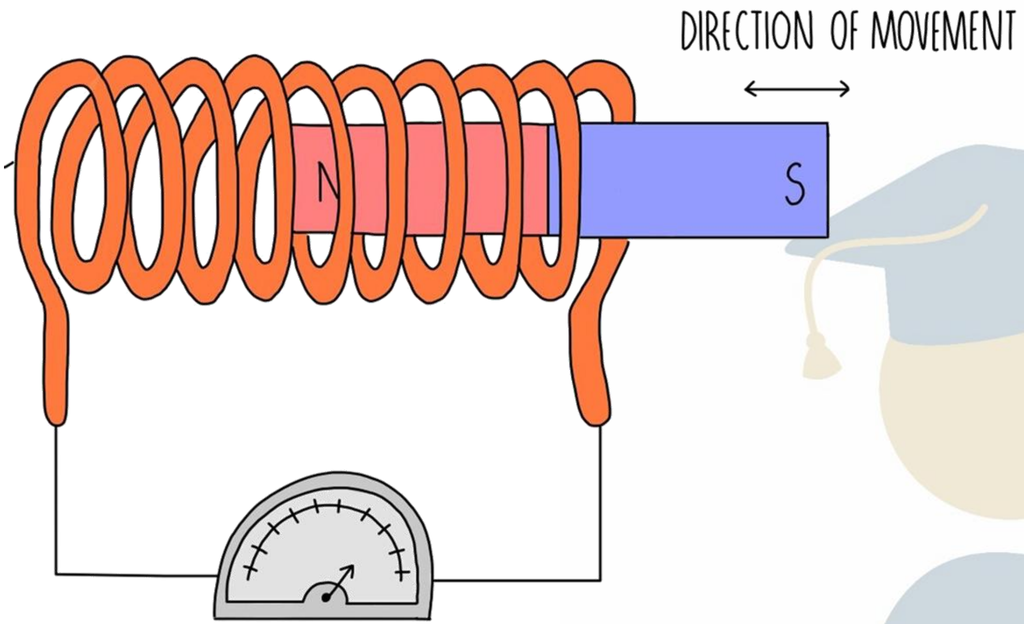
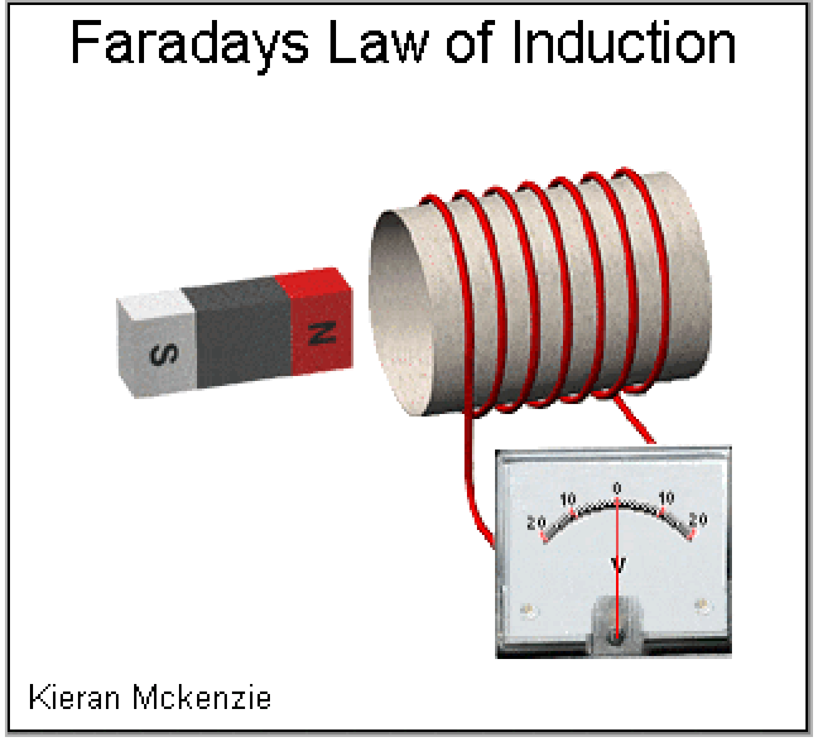




Physics – Grade 12 LS & GS

Unit Two – Electricity

Chapter8 – Electromagnetic Induction

OBJECTIVES

1 To state and apply Faraday’s Law of induction.

Faraday’s Law of induction

Michael Faraday: is English scientist who contributed to the study of electromagnetism.

His main discoveries includes the principle of electromagnetic induction.

His discovery related to electromagnetic induction known as Faraday’s Law of induction.

Faraday’s Law of induction

Any change in the magnetic flux of a coil will cause an electromotive force (emf) “e” to be "induced" in the coil.

Faraday’s notice that:

- **For constant flux (ϕ), the electromotive force (emf) is zero:** $e = 0$.
- **For a variable flux (ϕ), the electromotive force (emf) exist:** $e \neq 0$

$$e = -\frac{d\emptyset}{dt}$$

Faraday's Law of induction

Discussion about Faraday's Law

Case 1: If flux (ϕ) is constant:

$$\frac{d\phi}{dt} = 0$$

$$e = -\frac{d\phi}{dt} = 0$$

The induced current is zero $i = 0$

Electromagnetic induction does not take place

Faraday's Law of induction

Case 2: Variable flux and increasing:

$$\frac{d\emptyset}{dt} > 0 \Rightarrow e = -\frac{d\emptyset}{dt} < 0$$

The induced current is $i = \frac{e}{R+r} < 0$

⇓

The induced current i flows in opposite direction to positive direction in the coil.

Faraday's Law of induction

Case 3: Variable flux and decreasing:

$$\frac{d\emptyset}{dt} < 0 \quad \Rightarrow \quad e = -\frac{d\emptyset}{dt} > 0$$

The induced current is $i = \frac{e}{R+r} > 0$

⇓

The induced current i flows in same direction as the positive direction in the coil.

Faraday's Law of induction

Application 3:

Consider a coil of internal resistance $r = 2\Omega$ and of 20 turns placed within a magnetic field of magnitude $B = 300mT$. The surface area of the coil is $500cm^2$ and the magnetic field lines making an angle $\theta = 60^\circ$ with the normal vector.

1. Calculate the magnetic flux.

$$\emptyset = NBScos\theta$$

$$\emptyset = 20 \times (300 \times 10^{-3}) \times (500 \times 10^{-4}) \times cos60$$

$$\emptyset = 0.15Wb$$

Faraday's Law of induction

2.Calculate the value of the electromotive force (emf).

$$e = -\frac{d\emptyset}{dt} \Rightarrow e = -\frac{d(0.15)}{dt}$$

$$e = 0$$

3.Deduce the value of the electric current.

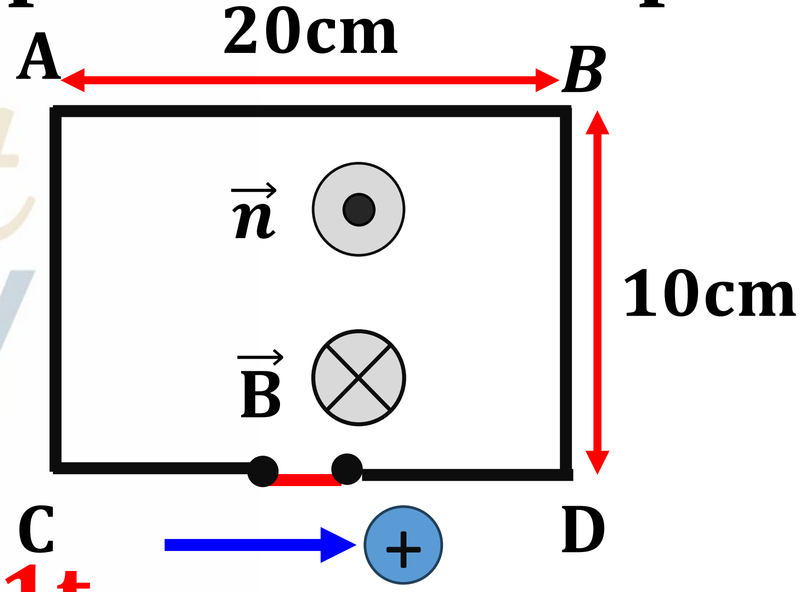
$$i = \frac{e}{R_{eq}} \Rightarrow i = \frac{e}{R_{eq}} = 0$$

$$i = 0$$

Application 4:

Consider a rectangular loop ABCD of resistance $r = 2\Omega$, is placed in a uniform magnetic field $\vec{B}$, whose magnitude varies with time and given by $B = 5t\ T$.

The direction of B is perpendicular to the plane of the loop as shown in the figure.



1.Calculate the magnetic flux.

$$\phi = NBScos\theta$$

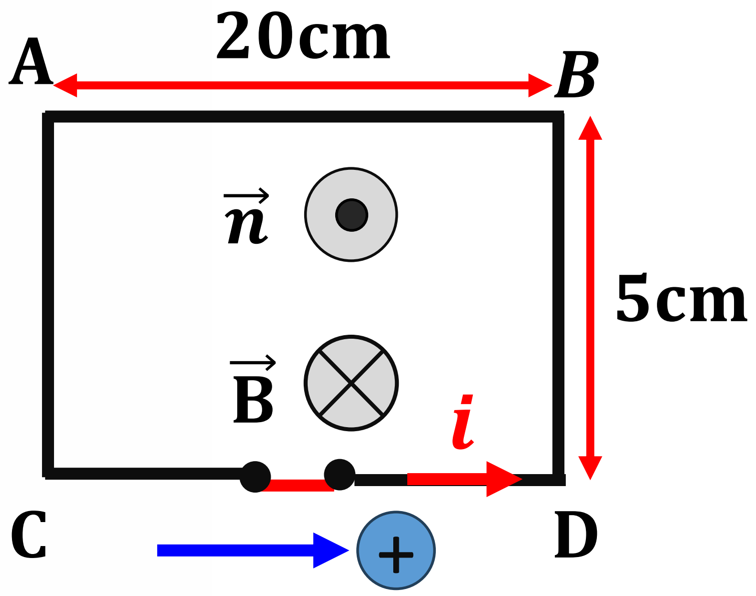
$$\phi = 1 \times (5t) \times (L \times W) \times cos(180)$$

$$\phi = (5t) \times (0.2 \times 0.1) \quad \Rightarrow \quad \phi = -0.1t$$

Faraday's Law of induction

2. Calculate the value of the electromotive force (emf).

$$e = -\frac{d\emptyset}{dt} \Rightarrow e = -\frac{d(-0.1t)}{dt}$$



$$e = +0.1V$$

3. Determine the value and the direction of the electric current.

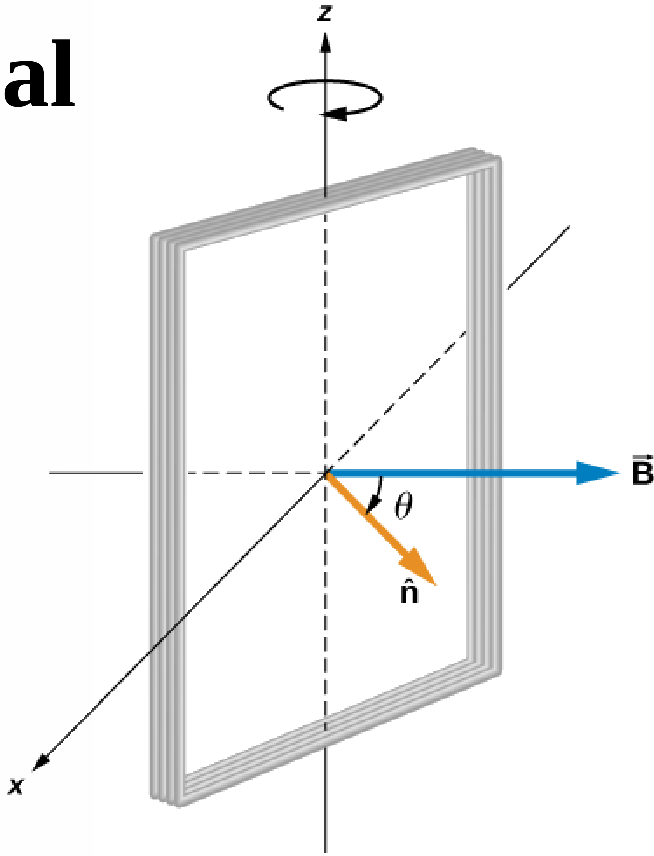
$$i = \frac{e}{r} \Rightarrow i = \frac{0.1}{2} \Rightarrow i = +0.05A$$

Since $i > 0$ then i flow in same direction as positive direction

Faraday’s Law of induction

Application 5: **Consider a rotating coil of resistance $r = 2\Omega$ and of 100 turns, each of cross-sectional area $S = 100cm^2$ has a constant magnetic field of magnitude $B = 8T$.**

The angle of rotation between the normal vector and the magnetic field lines is $\theta = \frac{\pi}{4}t$.



1. Calculate the magnetic flux of the coil.

$$\emptyset = NBS\cos\theta$$

$$\emptyset = 100 \times 8 \times (100 \times 10^{-4}) \times \cos(\frac{\pi}{4}t)$$

$$\emptyset = 8\cos\left(\frac{\pi}{4}t\right)$$

Faraday's Law of induction

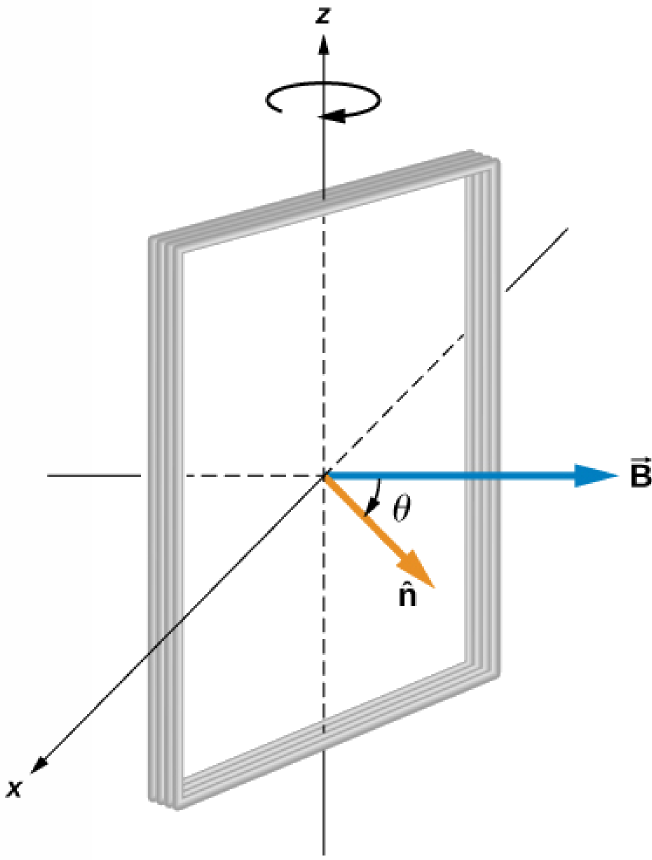
2. Calculate electromotive force e of the coil.

$$e = -\frac{d\emptyset}{dt}$$

$$e = -\frac{d\left(8\cos\left(\frac{\pi}{4}t\right)\right)}{dt}$$

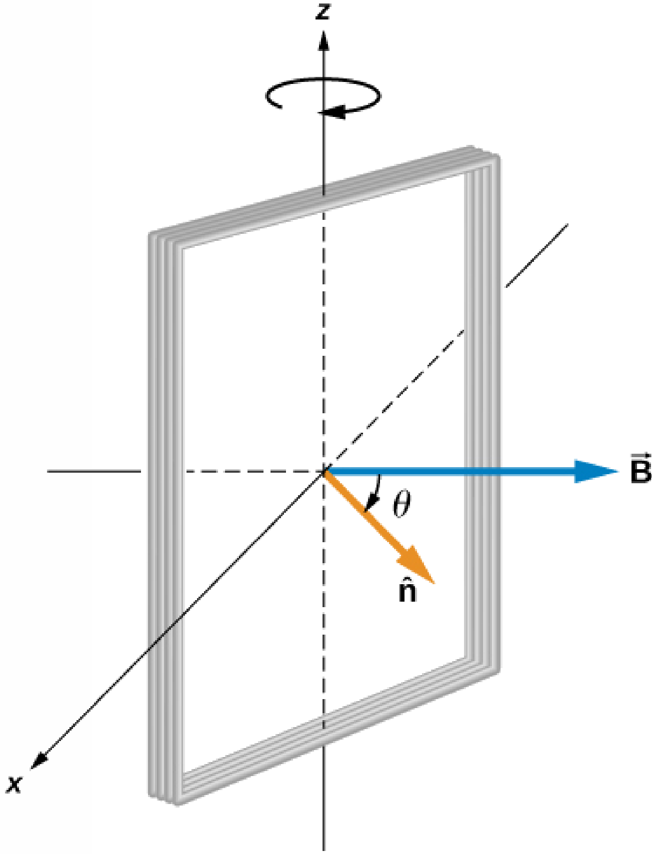
$$e = +8 \times \frac{\pi}{4} \sin\left(\frac{\pi}{4}t\right)$$

$$e = 2\pi . \sin\left(\frac{\pi}{4}t\right)$$



Faraday's Law of induction

3. **Knowing that the coil is in closed circuit, deduce the value of the induced current at $t = 1s$.**



$$i = \frac{e}{r} \Rightarrow i = \frac{2\pi . sin\left(\frac{\pi}{4}t\right)}{2}$$

$$i = \pi . sin\left(\frac{\pi}{4} \times 1\right) \Rightarrow i = 3.14 \times 0.707$$

$$i = 2.22A$$

Faraday's Law of induction

Variable flux ($NBScos\theta$)

Variable area

Variable magnetic field

Variable angle

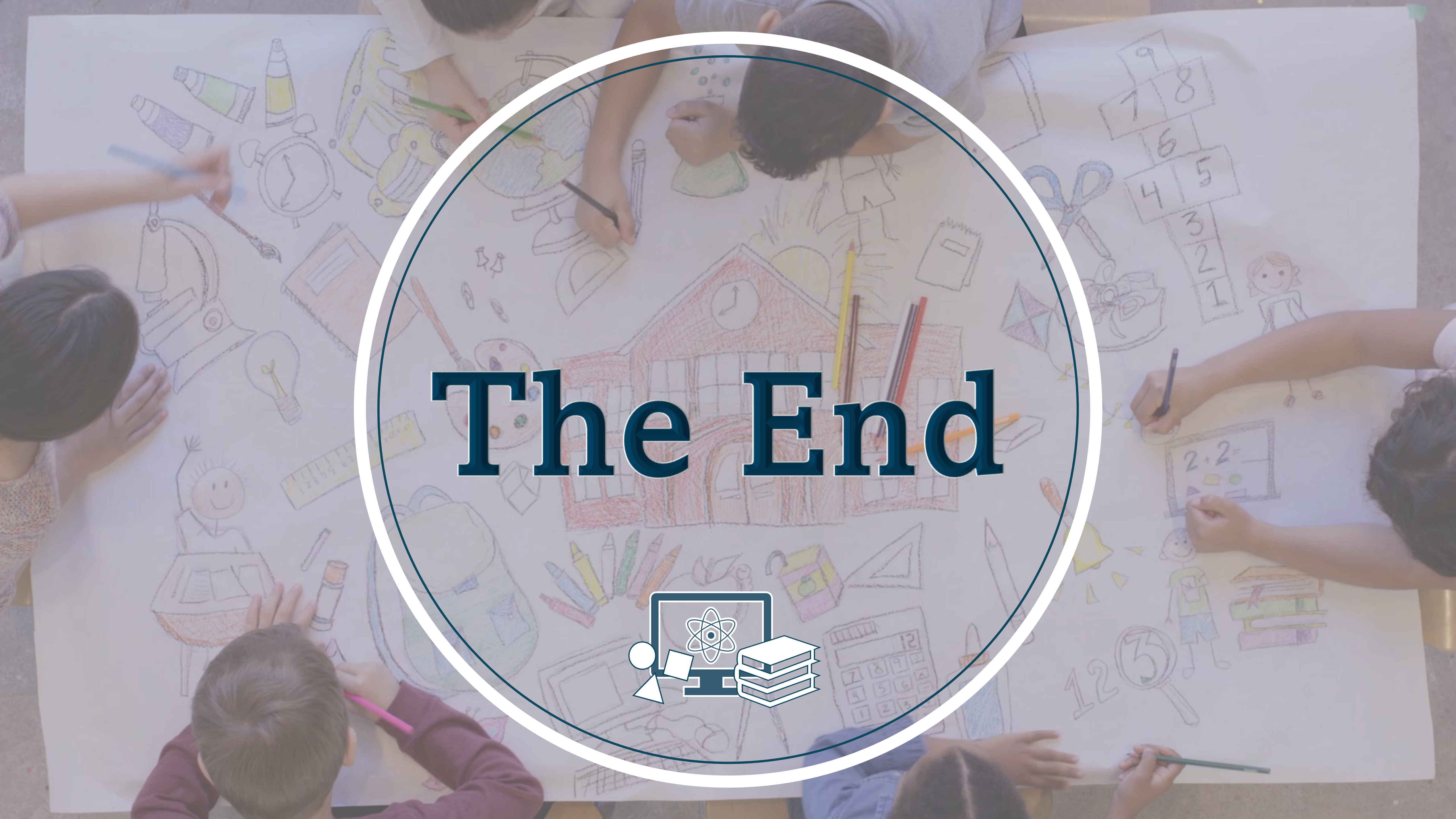
Electromotive force (emf) exist:

$$e = -\frac{d\emptyset}{dt}$$

Induced magnetic field in the coil ($\overrightarrow{B_i}$)

Induced current (closed circuit): $i = \frac{e}{R}$,

Direction by RHR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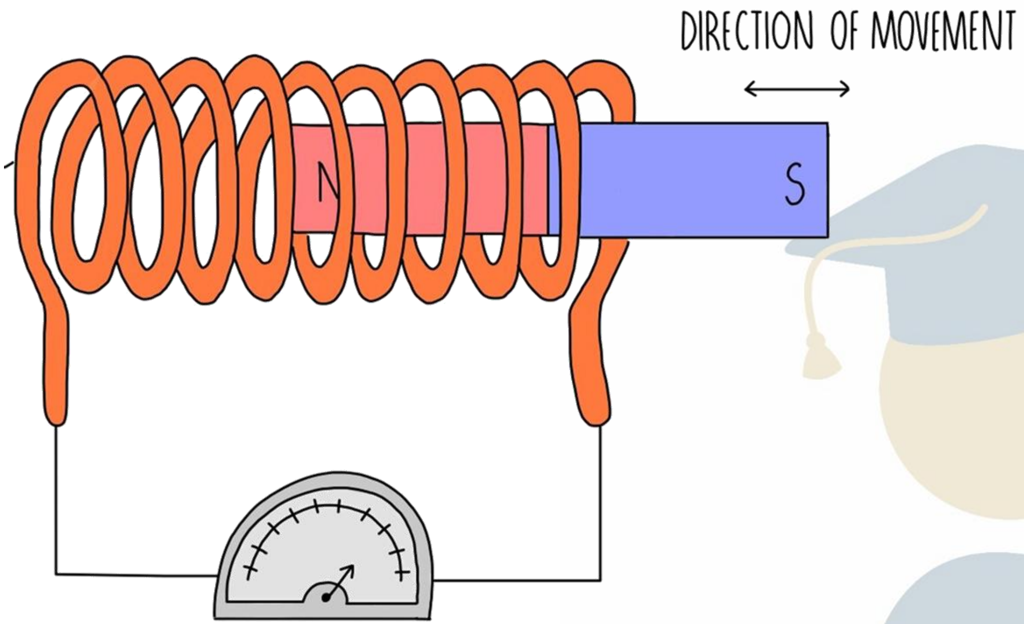
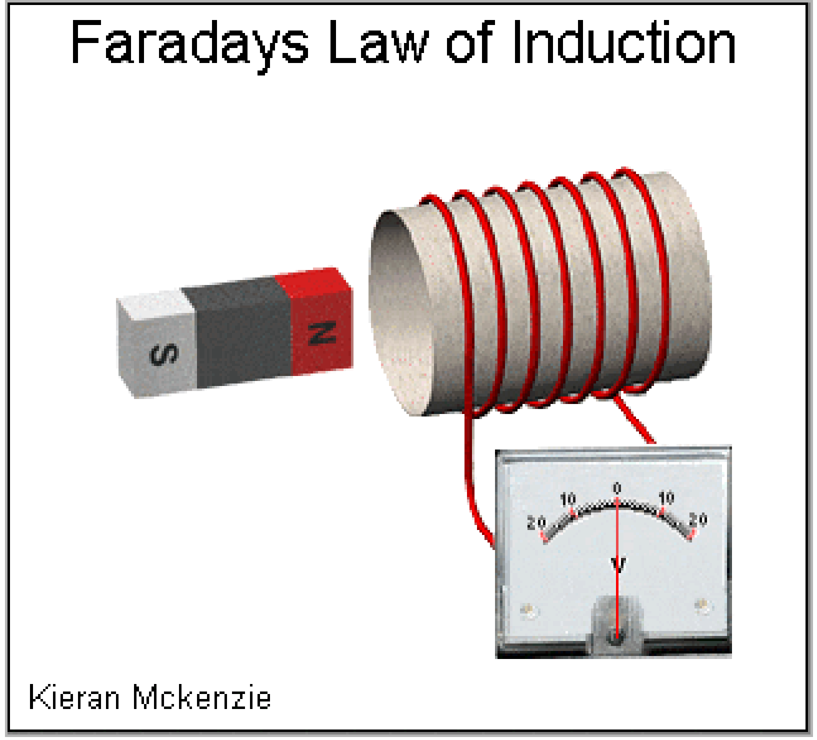




Physics – Grade 12 LS & GS

Unit Two – Electricity

Chapter8 – Electromagnetic Induction

OBJECTIVES

1 To state and apply Lenz's Law of induction.

Lenz’s Law of induction

Statement of Lenz’s law:

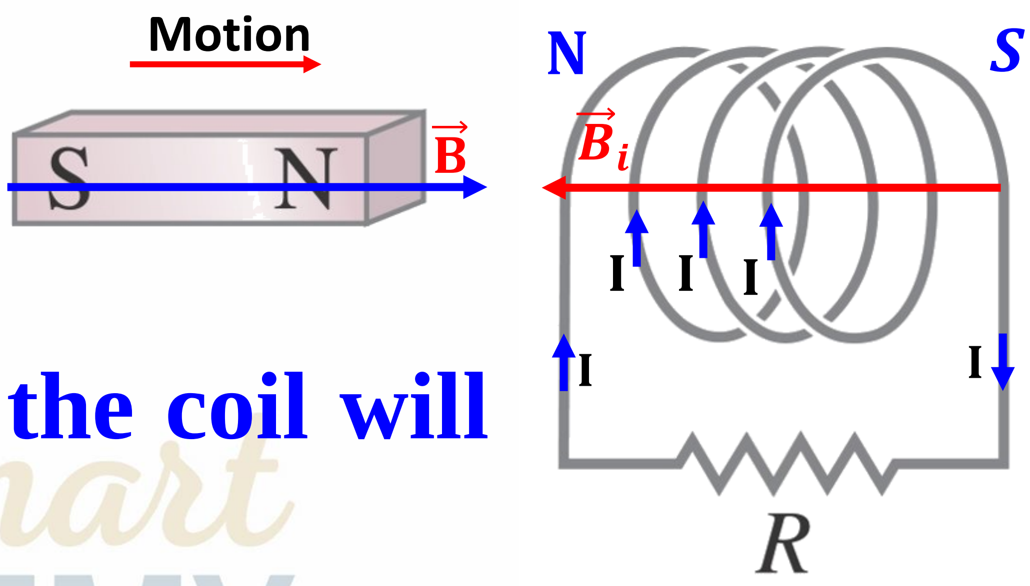
When an e.m.f is induced due to a variation in the magnetic flux, the <u>direction of the induced current</u> is such that its electromagnetic effects <u>oppose the cause</u> that is producing it.

Direction of induced magnetic field
- **May be of same direction**
- **May be of opposite direction**

Lenz's Law of induction

Application 6: **Determine the direction of the current induced in the circuit below.**

The magnet moves towards the coil, then the magnetic filed ($\vec{B}$) increase:



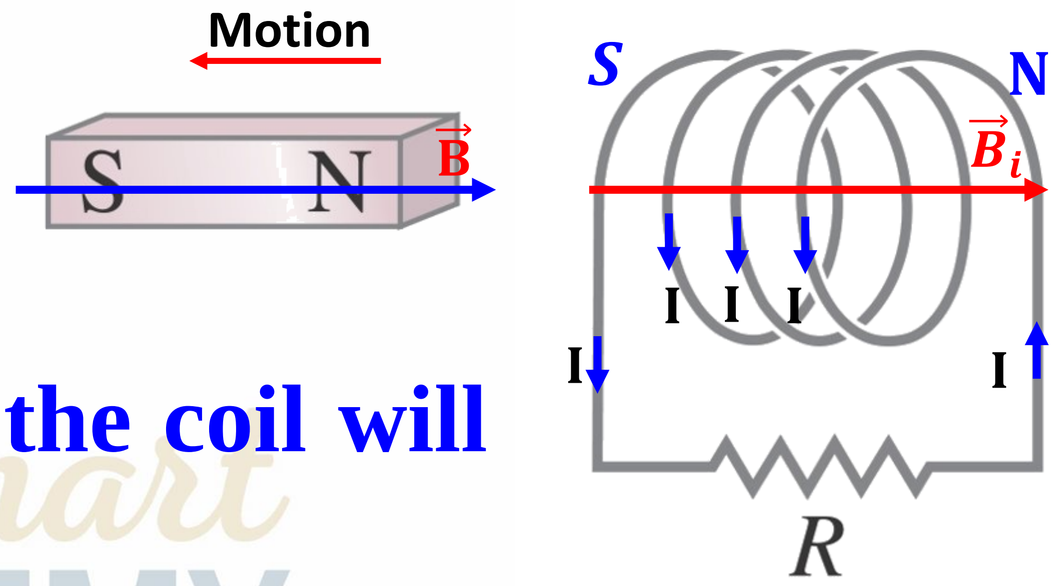
The induced magnetic filed ($\vec{B}_i$) in the coil will be opposite to its cause ($\vec{B}$).

- **The induced current determined by RHR.**
- **The coil acts as a magnet of two faces N and S indicated on the figure.**

Lenz's Law of induction

Application 6: **The magnet moves away from the coil. Determine the direction of induced current.**

The magnet moves away from the coil, then the magnetic filed ($\vec{B}$) decrease:

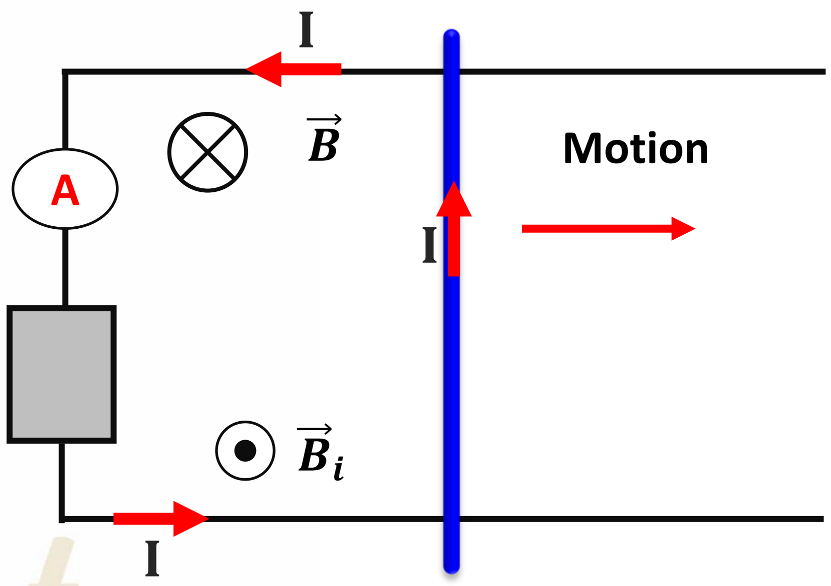


The induced magnetic filed ($\vec{B}_i$) in the coil will be in same direction to its cause.

- The induced current determined by RHR.
- The coil acts as a magnet of two faces N and S indicated on the figure.

Lenz's Law of induction

Application 7: using Len's law, determine the direction of induced current in the circuit below.



The area increase, the magnetic flux increase.

The induced magnetic field ($\vec{B}_i$) become opposite to its cause ($\vec{B}$).

The induced current represented on the figure using RHR

Lenz's Law of induction (Summary)

Magnetic filed increase → magnetic flux increase → $\vec{B}_i$ is opposite to $\vec{B}$ → i_{ind} indicated by RHR

Magnetic filed decrease → magnetic flux decrease → $\vec{B}_i$ is same as $\vec{B}$ → i_{ind} indicated by RHR

Lenz's Law of induction (Summary)

Area increase → magnetic flux increase → $\vec{B}_i$ is opposite to $\vec{B}$ → i_{ind} indicated by RHR

Area decrease → magnetic flux decrease → $\vec{B}_i$ is same as $\vec{B}$ → i_{ind} indicated by RHR

Lenz's Law of induction (Summary)

Angle increase → magnetic flux increase → $\vec{B}_i$ is opposite to $\vec{B}$ → i_{ind} indicated by RHR

Angle decrease → magnetic flux decrease → $\vec{B}_i$ is same as $\vec{B}$ → i_{ind} indicated by RHR

Application 7:

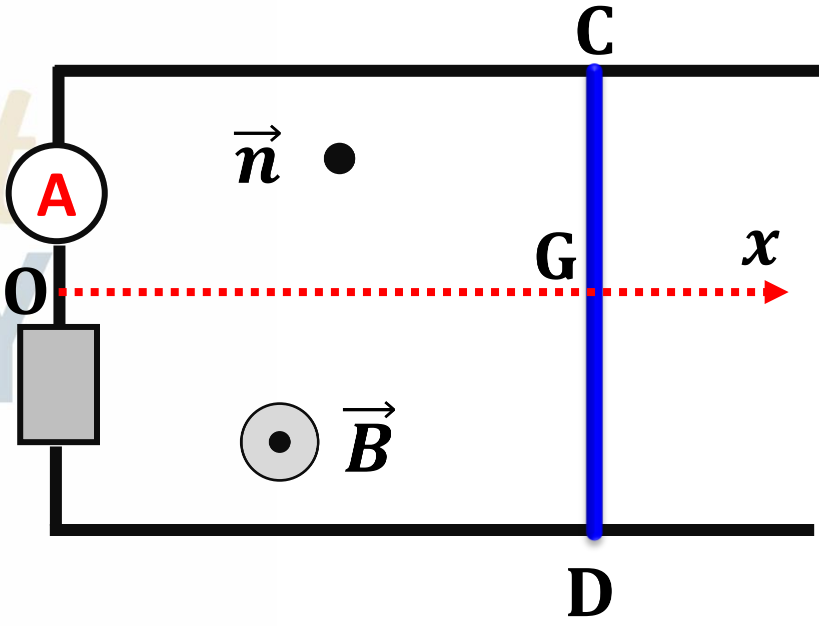
A metal rod CD of length $l = 50cm$ and of negligible resistance, can moves on two parallel and conducting rails.

A resistor of resistance $R = 10\Omega$ is connected as shown.

The set is placed in a uniform and vertical magnetic field $\vec{B}$ of intensity $B = 0.4T$.

At $t = 0$ the center of gravity G of the rod is at O then the rod moves to right with a speed $v = 2m/s$.

At instant t, the abscissa of G is $x = \overline{OG}$



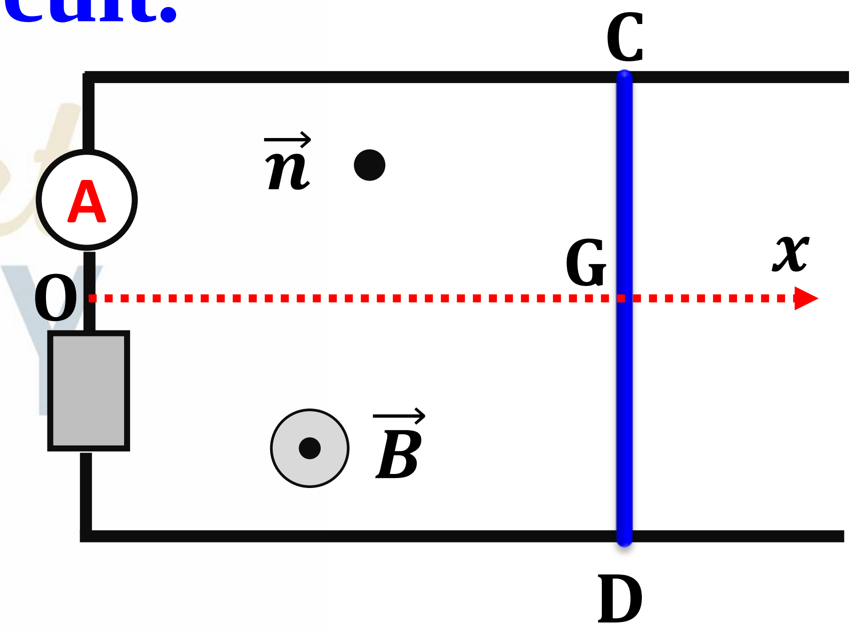
Lenz’s Law of induction (Summary)

1. Name the phenomenon that appears in the circuit.
2. Determine the expression of the magnetic flux as a function of B, *l*, v, and t.
3. Calculate the induced emf “e” in the circuit.
4. Using Lenz’s law determine the direction of induced current.
5. Calculate the intensity of the induced current

Lenz's Law of induction (Summary)

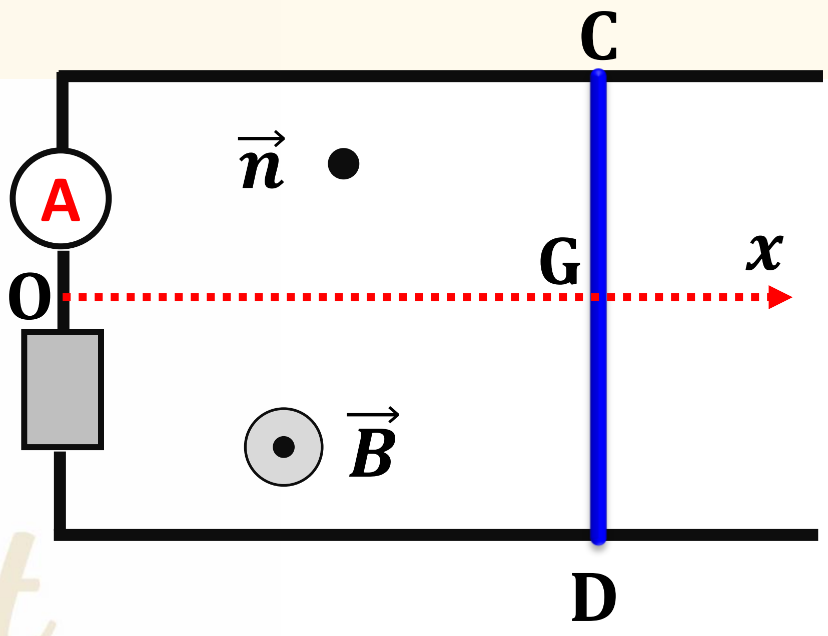
1.Name the phenomenon that appears in the circuit.

Electromagnetic induction takes place in the circuit, because the variable magnetic flux creates an emf "e": then an induced current in the closed circuit.



Lenz's Law of induction (Summary)

2.Determine the expression of the magnetic flux as a function of B, *l*, v, and t



$$\emptyset = NBScos(\vec{n}, \vec{B})$$

$$\emptyset = 1 \times B(L \times x)cos(0)$$

$$\emptyset = B[L \times (vt + x_0)] \times 1$$

$$\emptyset = B[L \times (vt + 0)]$$

$$\emptyset = BLvt$$

Lenz's Law of induction (Summary)

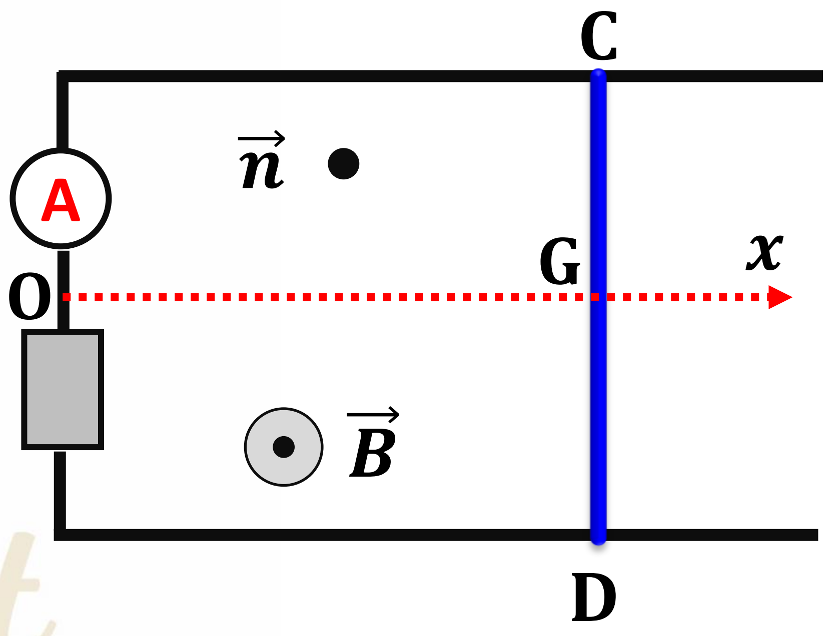
3.Calculate the induced emf "e" in the circuit

$$e = -\frac{d\emptyset}{dt} \Rightarrow e = -\frac{d(BLvt)}{dt}$$

$$e = -BLv$$

$$e = -0.4 \times 0.5 \times 2$$

$$e = -0.4V$$



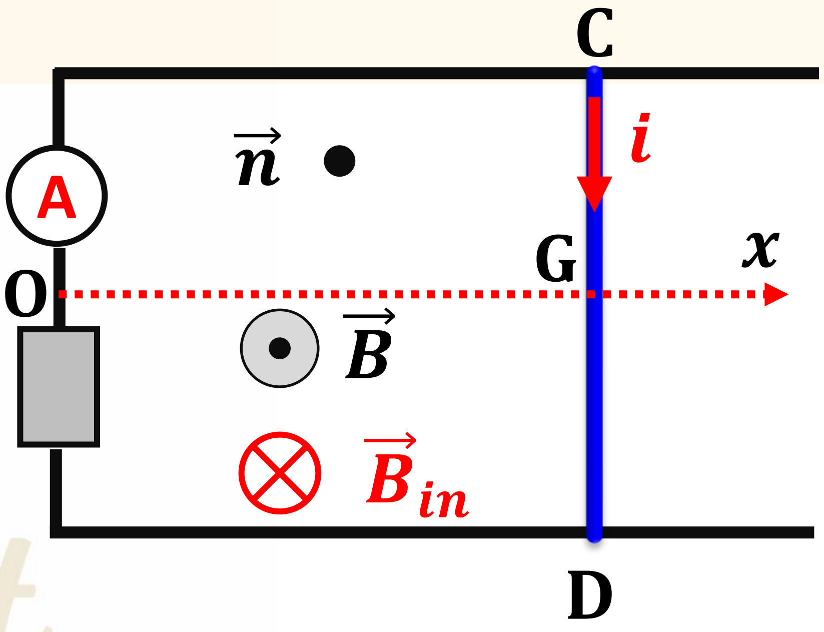
Lenz's Law of induction (Summary)

4.Using Lenz's law determine the direction of induced current

The area of the circuit increases with time then:

B_{in} is in opposite direction to its cause ($\vec{B}$).

Using RHR, the induced current is directed from C to D



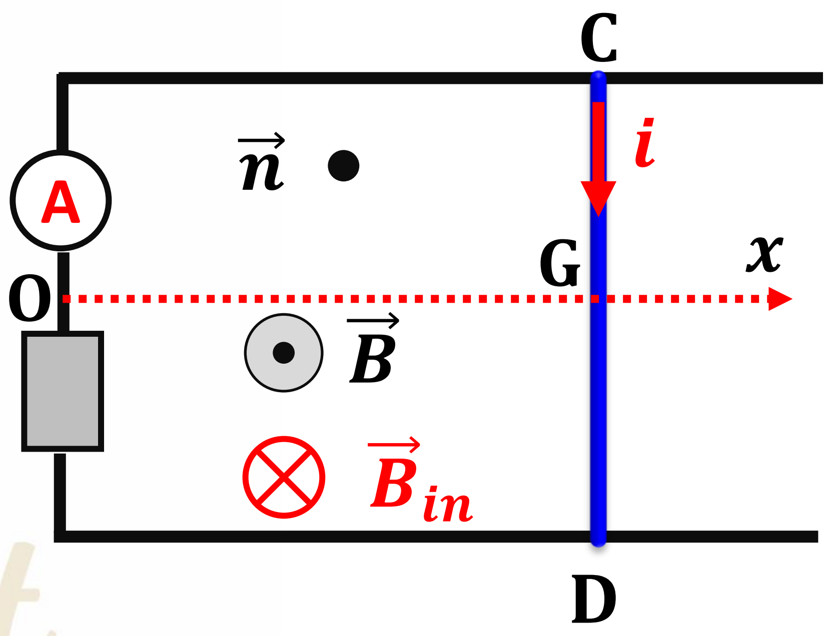
Lenz's Law of induction (Summary)

5.Calculate the intensity of the induced current.

$$i = \frac{e}{R_{eq}}$$

$$i = \frac{-0.4}{10}$$

$$i = -0.04A$$



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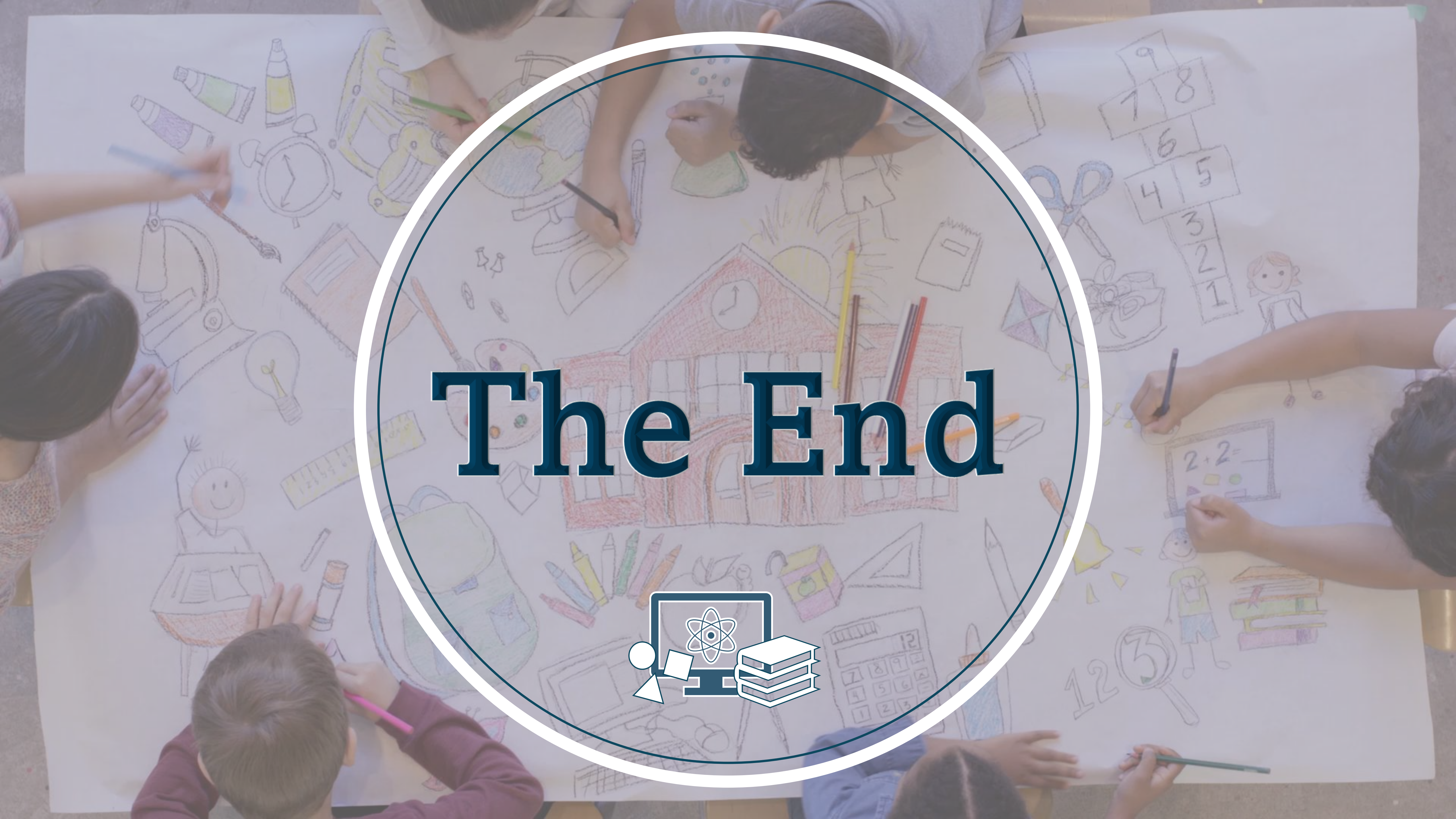
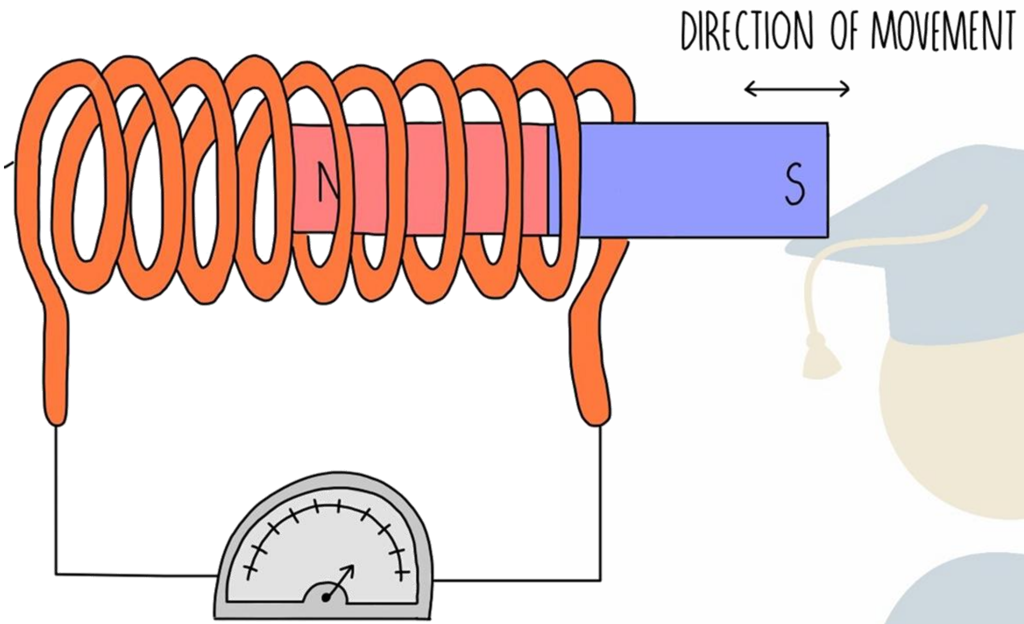
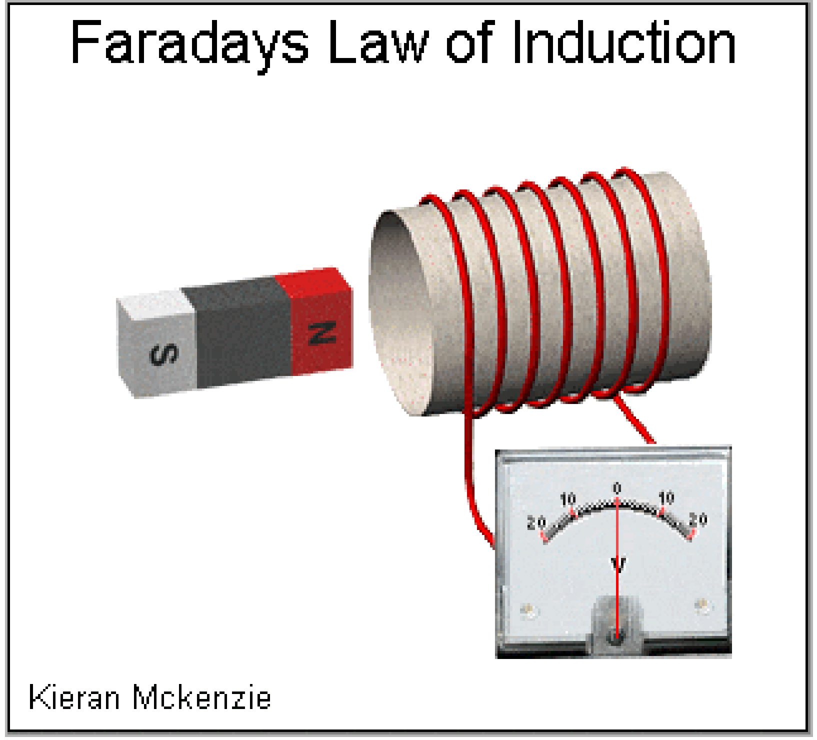






Physics – Grade 12 LS & GS

Unit Two – Electricity

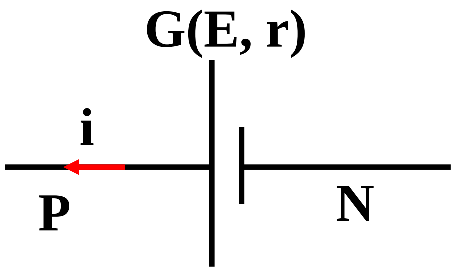
Chapter8 – Electromagnetic Induction

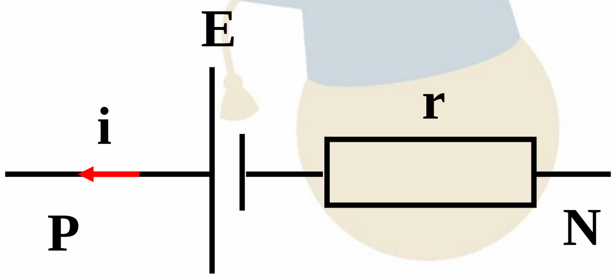
OBJECTIVES

1. To draw the equivalent generator of the coil
2. To study power distribution in the induced circuit.

The equivalent generator of the coil

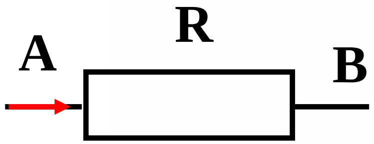
Ohm's law case of a generator G(E, r):





$$U_{PN} = e - ri$$

Ohm's law case of a resistor R:



$$U_{AB} = Ri$$

Ohm's law case of a receiver M(e, r')

$$U_M = e + r'i$$

Electric power and energy:

The electric power:

$$P = U \times i$$

The electric energy:

$$E = P \times t$$

The heat (lost) power:

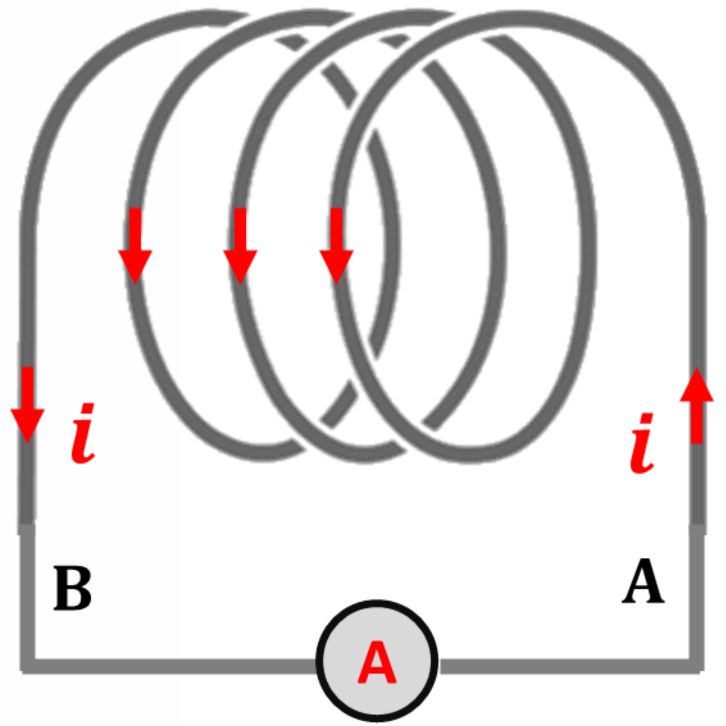
$$P = r \times i^2$$

The heat (lost) energy:

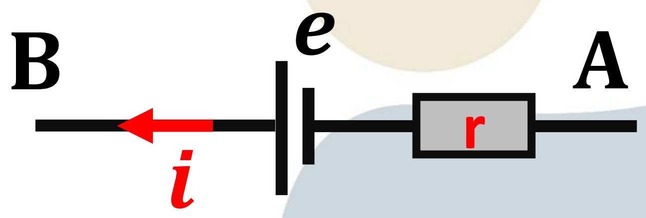
$$E = r \times i^2 \times t$$

Drawing the equivalent generator

Electrically, the coil is equivalent to a series combination of an ideal generator of e.m.f “e” and a resistor of resistance r.



The current i must flow out from the positive pole of the generator.



Potential difference across the coil. $u_{BA} = e - ri$

Voltage across the coil in the direction of the current is:

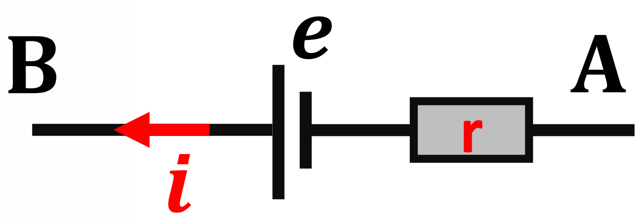
$$u_{AB} = ri - e$$

In case of open circuit, the voltage across the coil in the direction of the current is:

Opened circuit then $i = 0$ $u_{AB} = -e$

Power distribution in the induced circuit

$$u_{BA} = e - ri$$



$$u_{BA} = e - ri \ldots\ldots\ldots(\times i)$$

$$i \times u_{BA} = e \times i - ri^2$$

$$i.e = ri^2 + i.u_{BA}$$

$$i.e = ri^2 + i.u_{BA}$$

Power distribution in the induced circuit

$$i.e = ri^2 + i.u_{BA}$$

$P_{total} = ie$: is the total electrical power due to the variation of the magnetic flux caused by the relative motion of the magnet and the coil

$P_{lost} = ri^2$: represents the power dissipated due to Joule's effect in the coil

$P_{useful} = iu_{BA}$: represents the electrical power transferred to the external circuit across the terminals A and B of the coil.

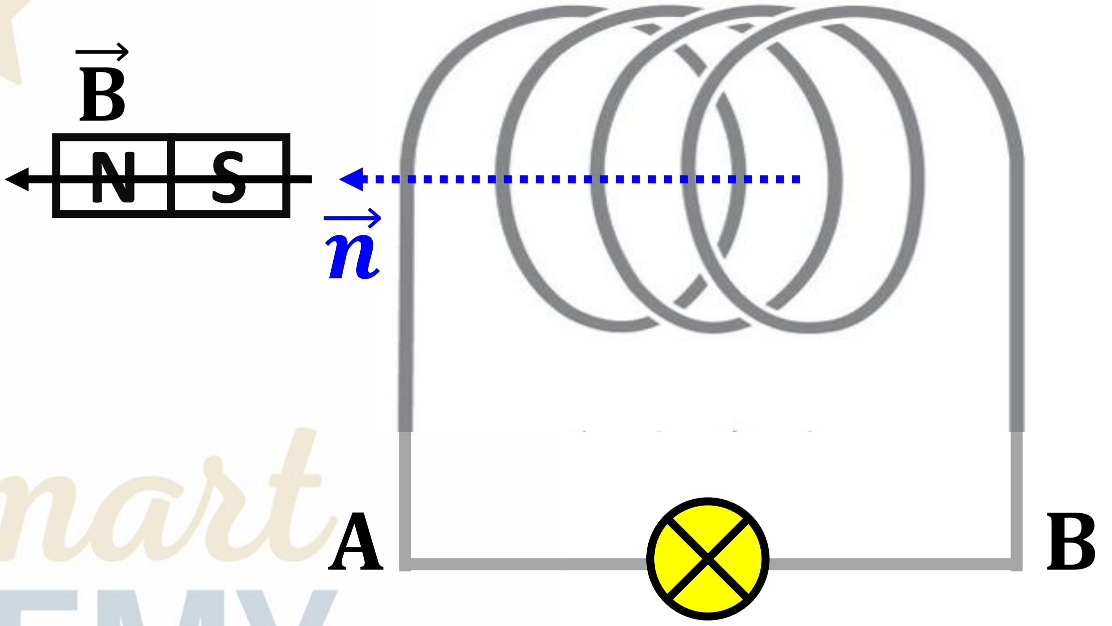
$$P_{total} = P_{lost} + P_{useful}$$

Power distribution in the induced circuit

Application 8:

Consider a coil of 200 turns, each of area $S = 100cm^2$ and of internal resistance $r = 3\Omega$.

The lamp L acts as a resistor of resistance $R = 7\Omega$ is connected across the coil as shown in the figure.

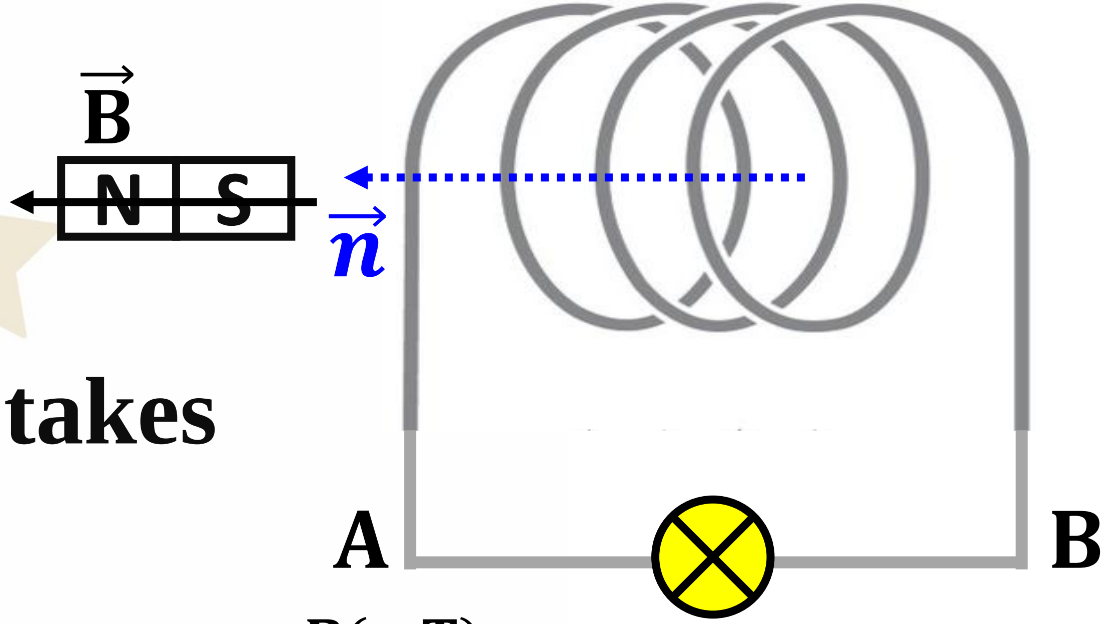


A magnet is displaced as shown in the figure.

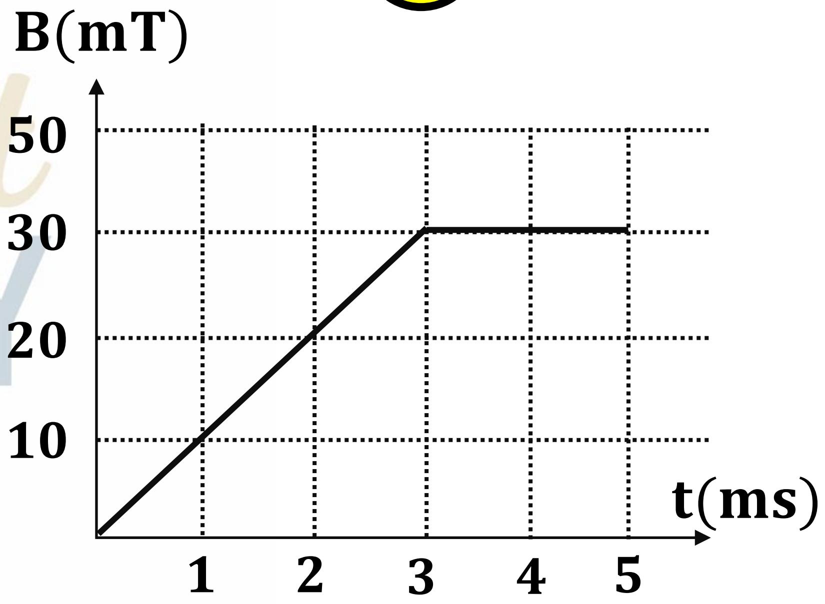
Power distribution in the induced circuit

The magnitude B of magnetic filed ($\vec{B}$) varies as a function of time as shown in the figure.

1. Name the phenomenon that takes place in this experiment.

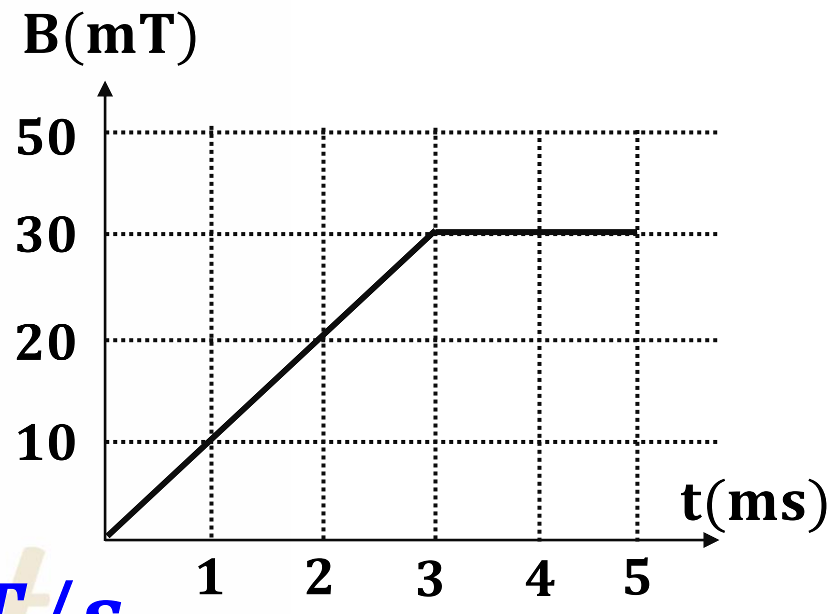


Electromagnetic induction, because of variable magnetic flux creates induced current in the circuit.



Power distribution in the induced circuit

2. Determine the expression of the magnetic field in each interval $0 \le t \le 3$ and for $3 \le t \le 5$.



For $0 \le t \le 3$:

B is St. line passing through origin of equation: $B = at$

$$a = \frac{B_2 - B_1}{t_2 - t_1} = \frac{(20 - 10) \times 10^{-3}}{(2 - 1) \times 10^{-3}} = 10T/s$$

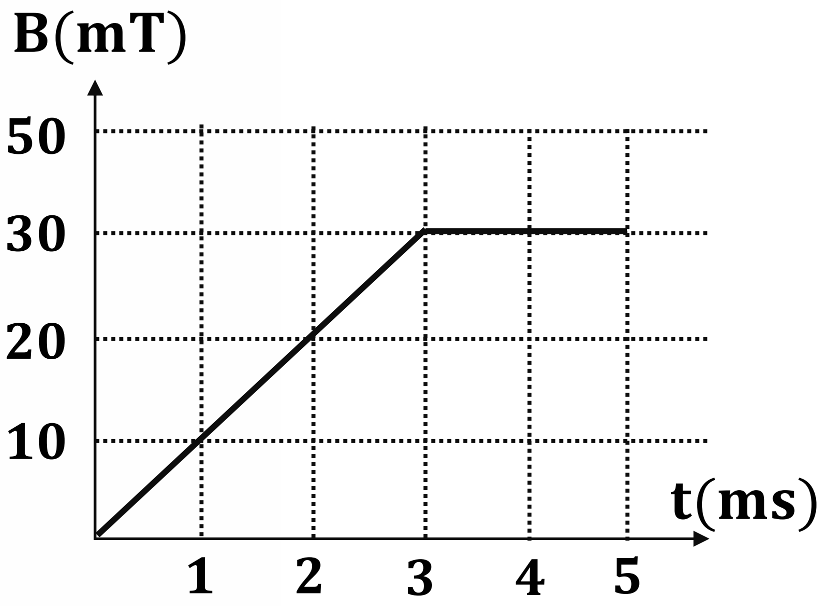
$$B = 10t$$

Power distribution in the induced circuit

For $3 \leq t \leq 5$:

The magnetic field is constant

$$B = 30 \times 10^{-3}\text{T}$$

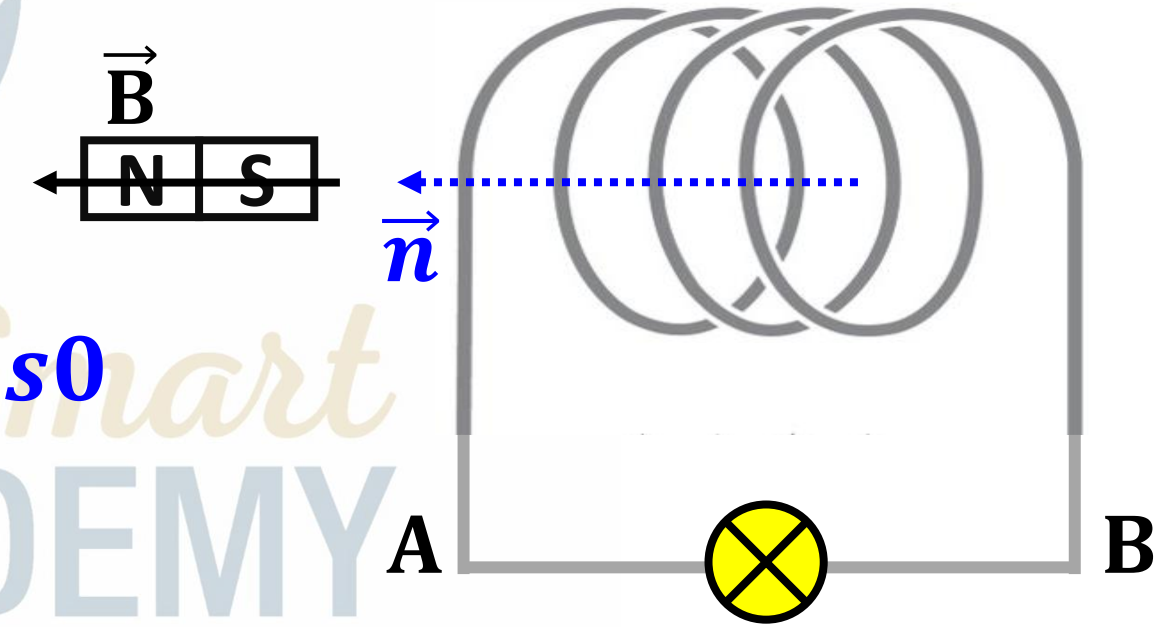


Power distribution in the induced circuit

3. Determine the expression of the magnetic flux in each interval $0 \le t \le 3$ and for $3 \le t \le 5$.

For $0 \le t \le 3$: $B = 10t$

$$\emptyset = NBScos\theta$$



$$\emptyset = 200 \times 10t \times 100 \times 10^{-4} cos0$$

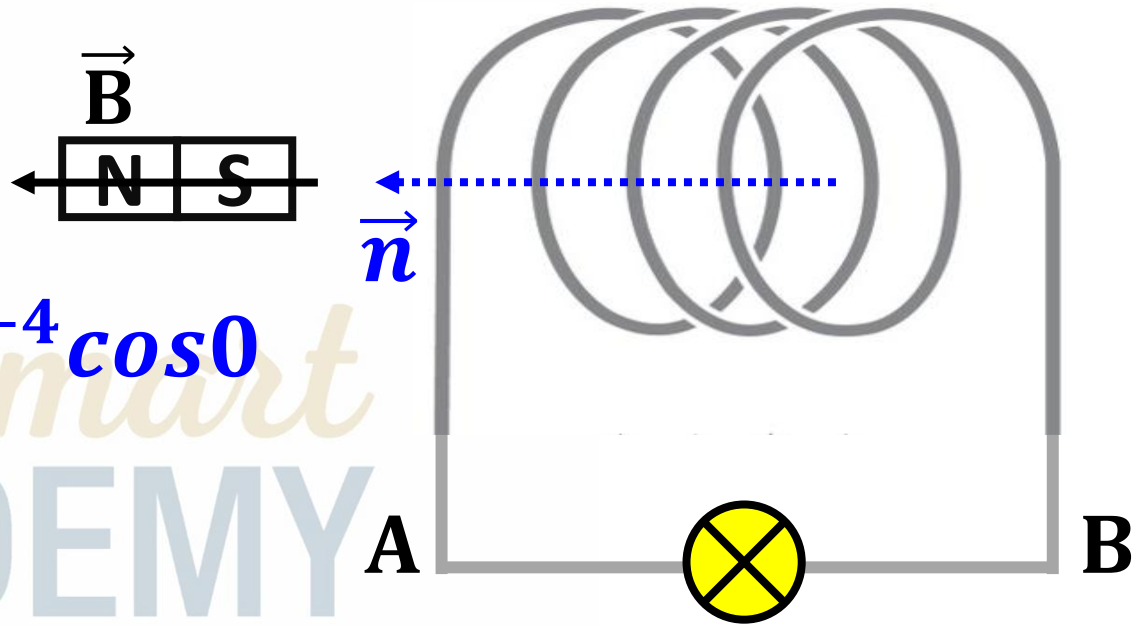
$$\emptyset = 20t$$

Power distribution in the induced circuit

3. Determine the expression of the magnetic flux in each interval $0 \le t \le 3$ and for $3 \le t \le 5$.

For $3s \le t \le 5s$: $B = 30 \times 10^{-3}\ T$

$$\emptyset = NBS\cos\theta$$



$$\emptyset = 200 \times 30 \times 10^{-4} \times 100 \times 10^{-4} \cos 0$$

$$\emptyset = 0.006\text{wb}$$

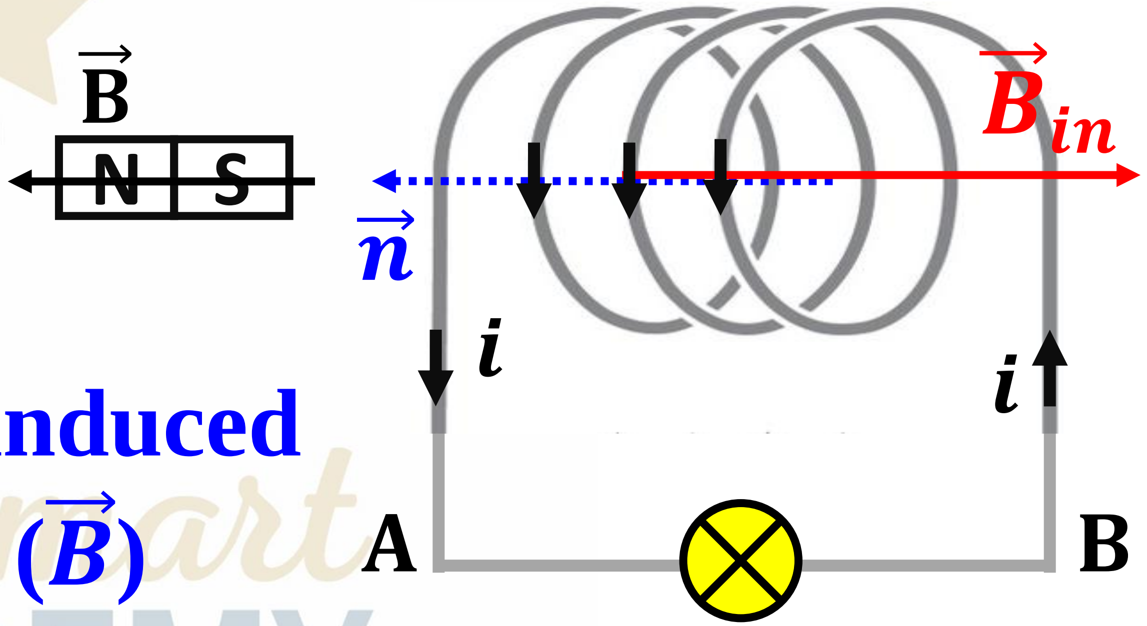
Power distribution in the induced circuit

4. Using Lenz's law, determine the direction of induced current in the coil for the given intervals of time.

For $0 \leq t \leq 3s$:

The magnetic field is increasing with time:

According to Lenz's law, the induced magnetic field ($\vec{B}_{in}$) is opposite to ($\vec{B}$)



using RHR along $\vec{B}_{in}$ the current indicated on the figure.

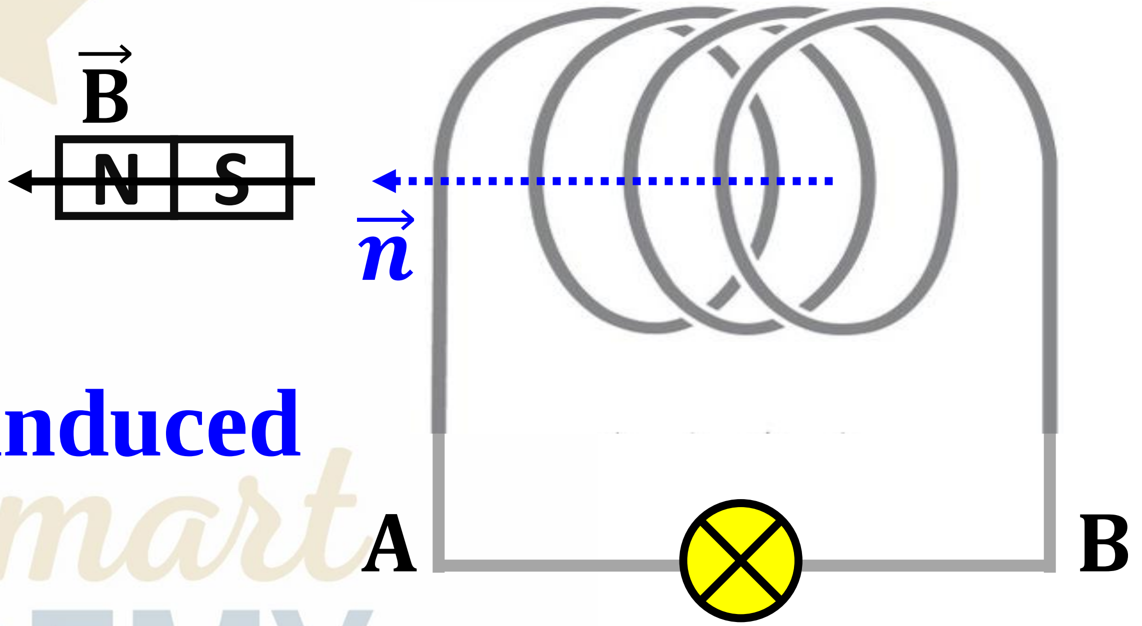
Power distribution in the induced circuit

4. **Using Lenz's law, determine the direction of induced current in the coil for the given intervals of time.**

For $3s \le t \le 5s$:

The magnetic field is constant then:

No induced magnetic field, so no induced current passes through the coil.



Power distribution in the induced circuit

5. Calculate the value of the emf "e" of the coil in the given intervals of time.

For $0 \le t \le 3$: $\emptyset = 20t$

$$e = -\frac{d\emptyset}{dt}$$

$$e = -\frac{d20t}{dt}$$

$$e = -20V$$

For $3 \le t \le 5$: $\emptyset = 0.006\text{wb}$

$$e = -\frac{d\emptyset}{dt}$$

$$e = -\frac{d0.06}{dt}$$

$$e = 0V$$

Power distribution in the induced circuit

6. Calculate the induced current in the given intervals of time.

For $0 \le t \le 3$: $e = -20V$

$$i = \frac{e}{R_{eq}} = \frac{e}{r + R}$$

$$i = \frac{-20}{(3 + 7)}$$

$$i = -2A$$

For $3 \le t \le 5$: $e = 0V$

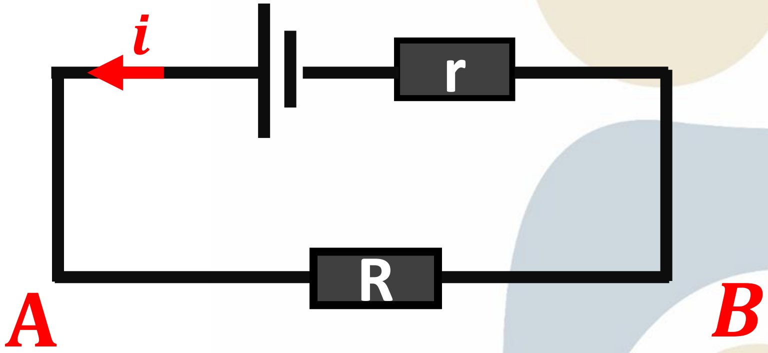
$$i = \frac{e}{R_{eq}} = \frac{e}{r + R}$$

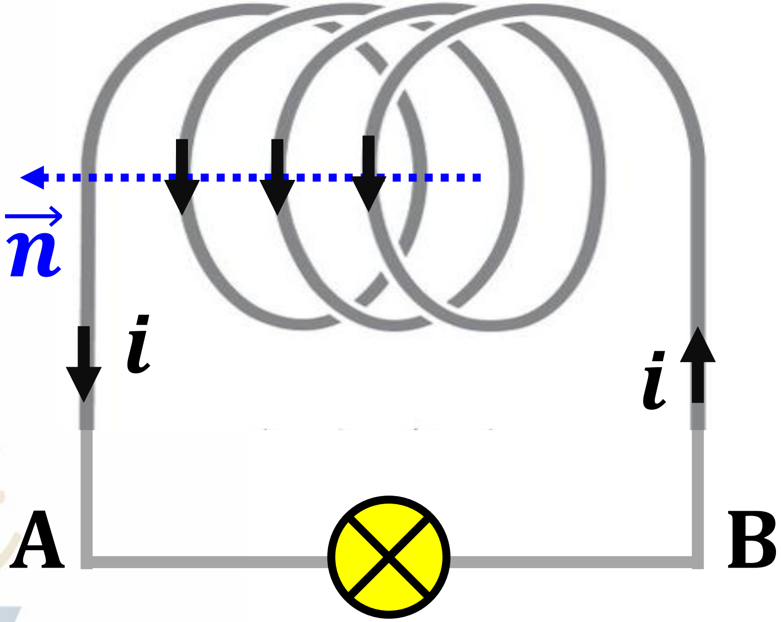
$$i = \frac{0}{(3 + 7)}$$

$$i = 0A$$

Power distribution in the induced circuit

7. **Draw a diagram represent the generator equivalent of the coil in the interval [0, 3s], then Calculate the voltage of the coil.**





$$u_{AB} = e - ri$$

$$u_{AB} = -20 - 3(-2) = -14V$$

$$u_{BA} = 14V$$

Power distribution in the induced circuit

8. Calculate the power lost by the coil and that used by the circuit. Deduce the total power.

$$P_{lost} = ri^2$$

$$P_{lost} = 3 \times (-2)^2$$

$$P_{lost} = 12\,Watt$$

$$P_{used} = iu_{AB}$$

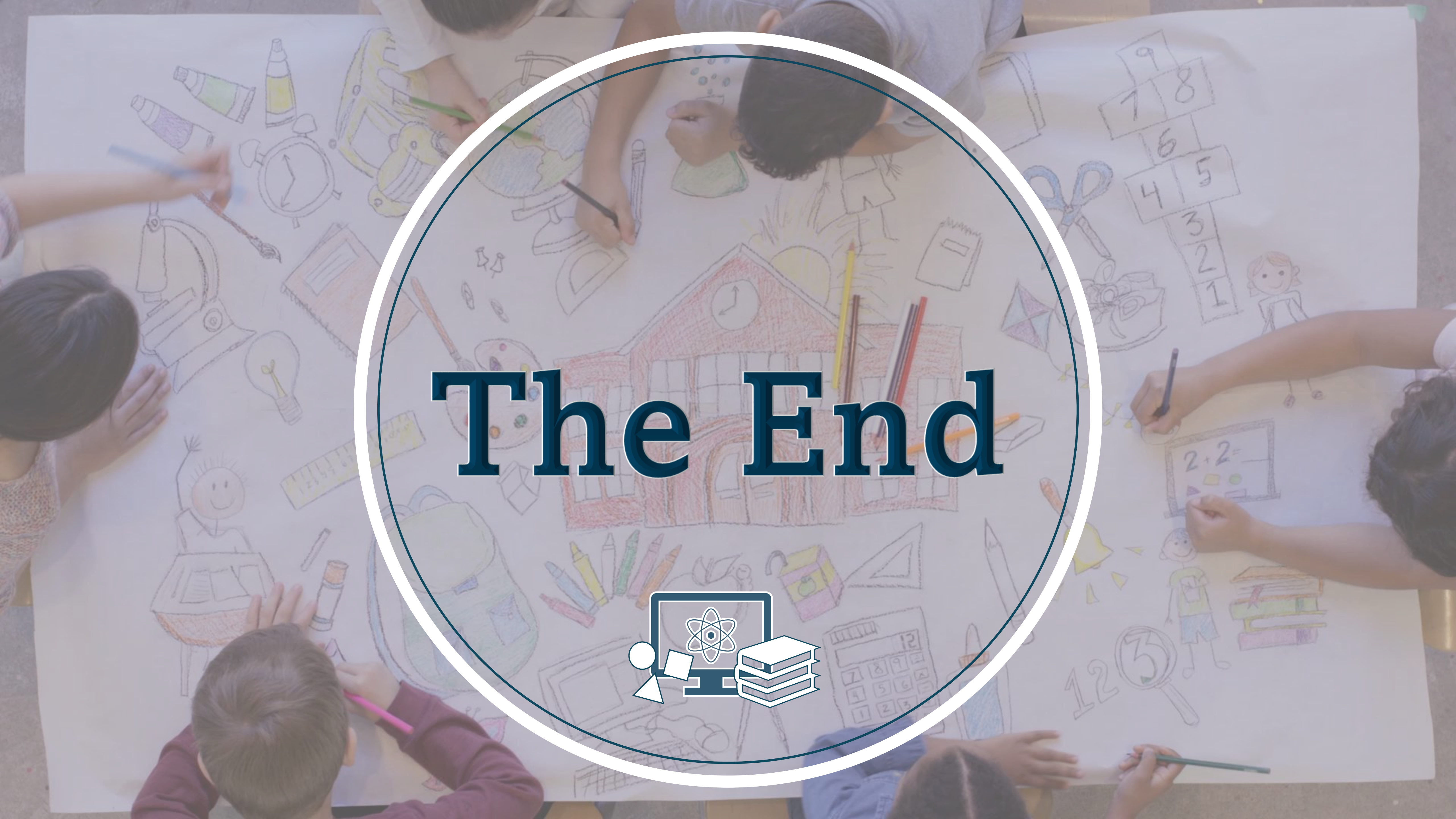
$$P_{used} = -2 \times (-14)$$

$$P_{used} = 28Watt$$

$$P_{total} = P_{lost} + P_{used}$$

$$P_{total} = 12 + 28$$

$$P_{total} = 40\,Watt$$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