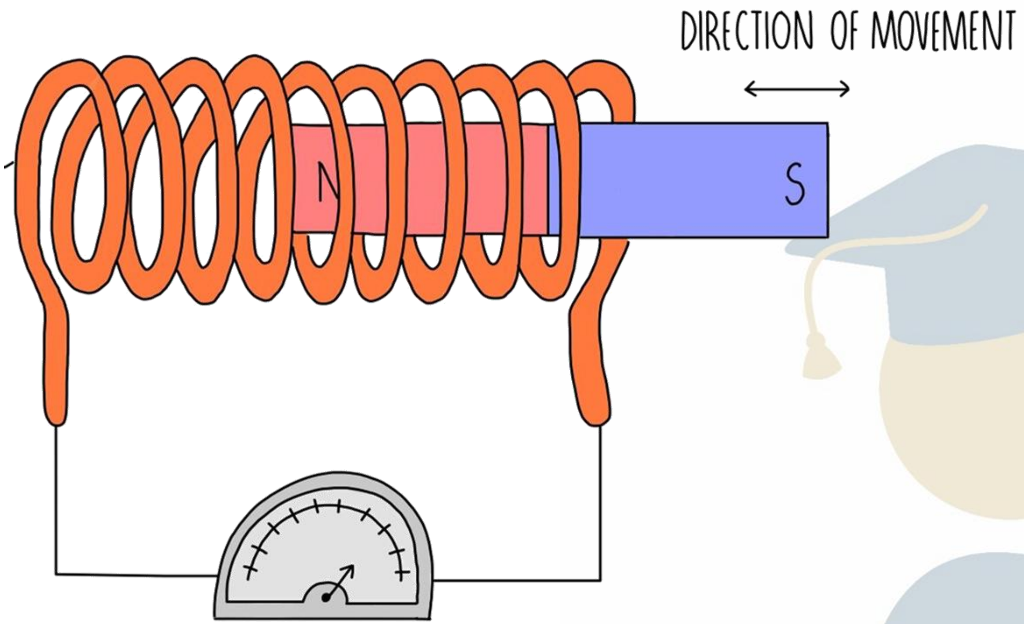
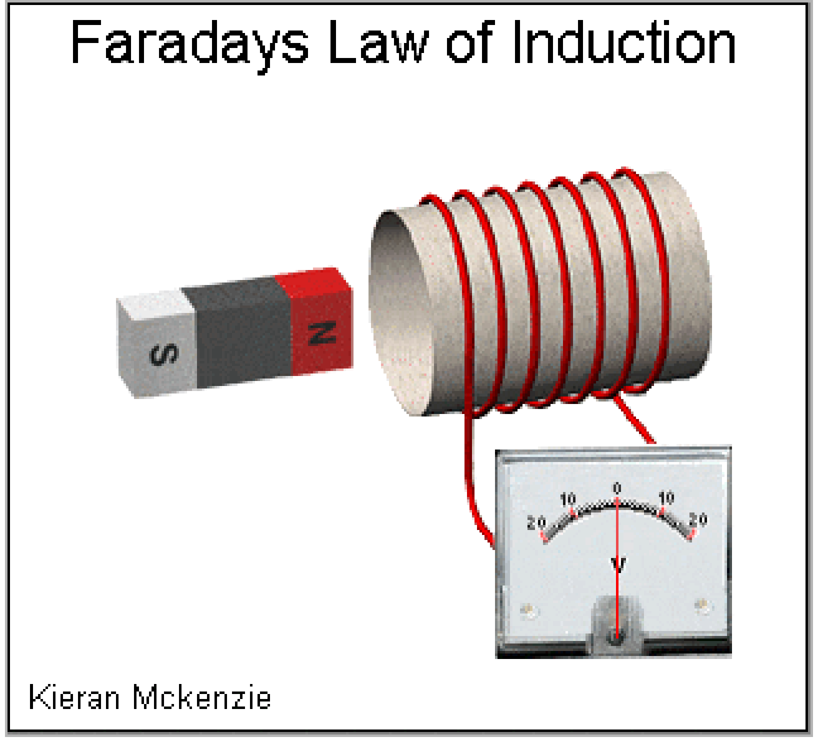




Physics – Grade 12 LS & GS

Unit Two – Electricity

Chapter8 – Electromagnetic Induction

Think then Solve

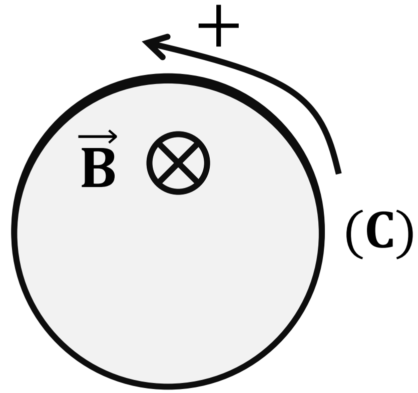
Exercise 1:

The aim of this exercise is to study the electromagnetic magnetic induction phenomenon.

For this aim, we consider a flat coil (C) of area $S = 5 \times 10^{-3} m^2$, resistance $R = 10\Omega$ and of 50 turns.

Part I: Variation of the magnetic field:

(C) is placed in a magnetic field $\vec{B}$ & perpendicular to its plane as shown in document 1.

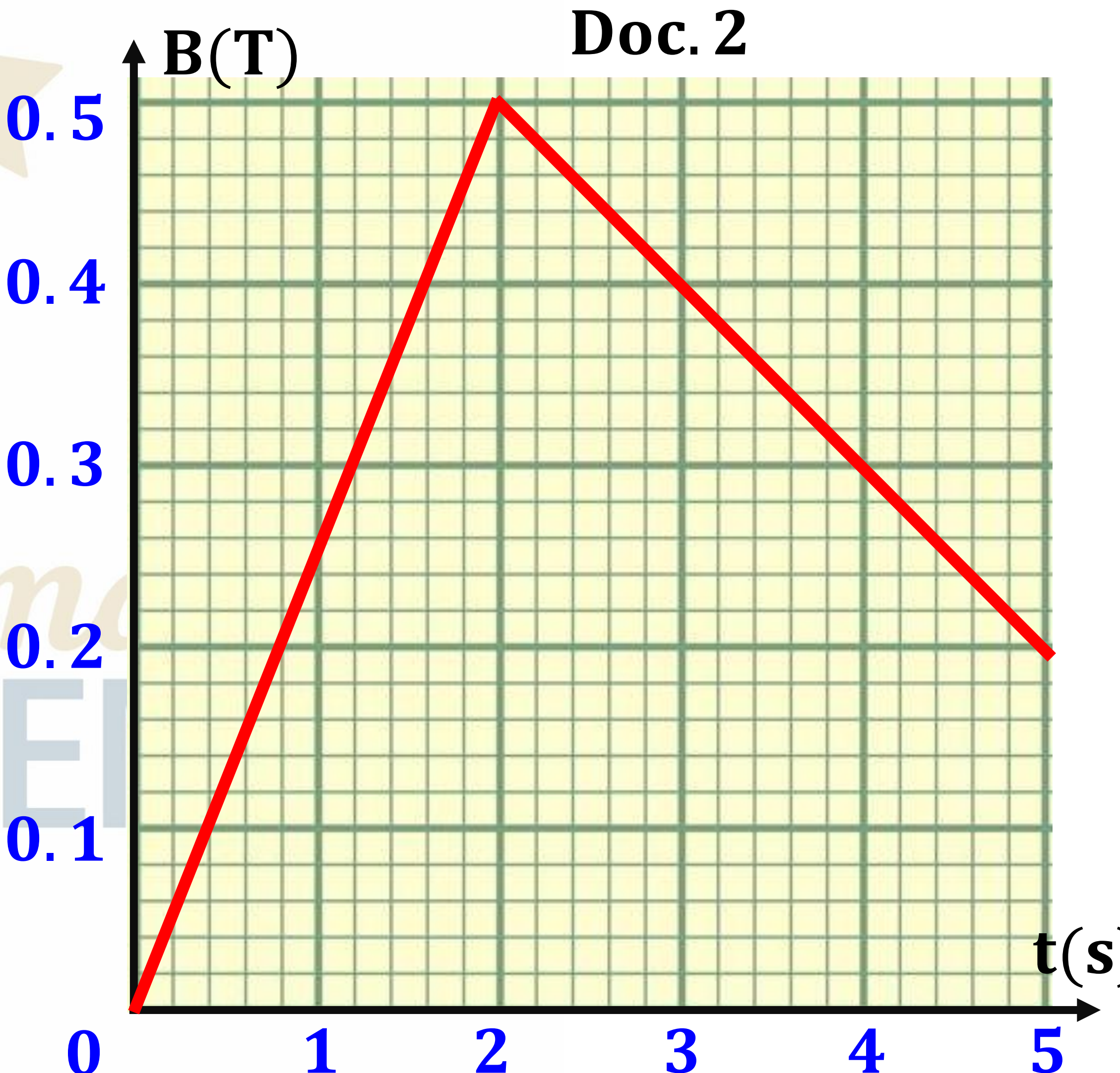


Doc. 1

Exercise 1:

Document 2 represents the variation of the intensity B of $\overrightarrow{B}$ as a function of time.

1. **Explain the existence of an induced current i traversing (C).**
2. **Show that the expression of this induced current is in the form of $i = \frac{NS}{R} \times \frac{dB}{dt}$.**

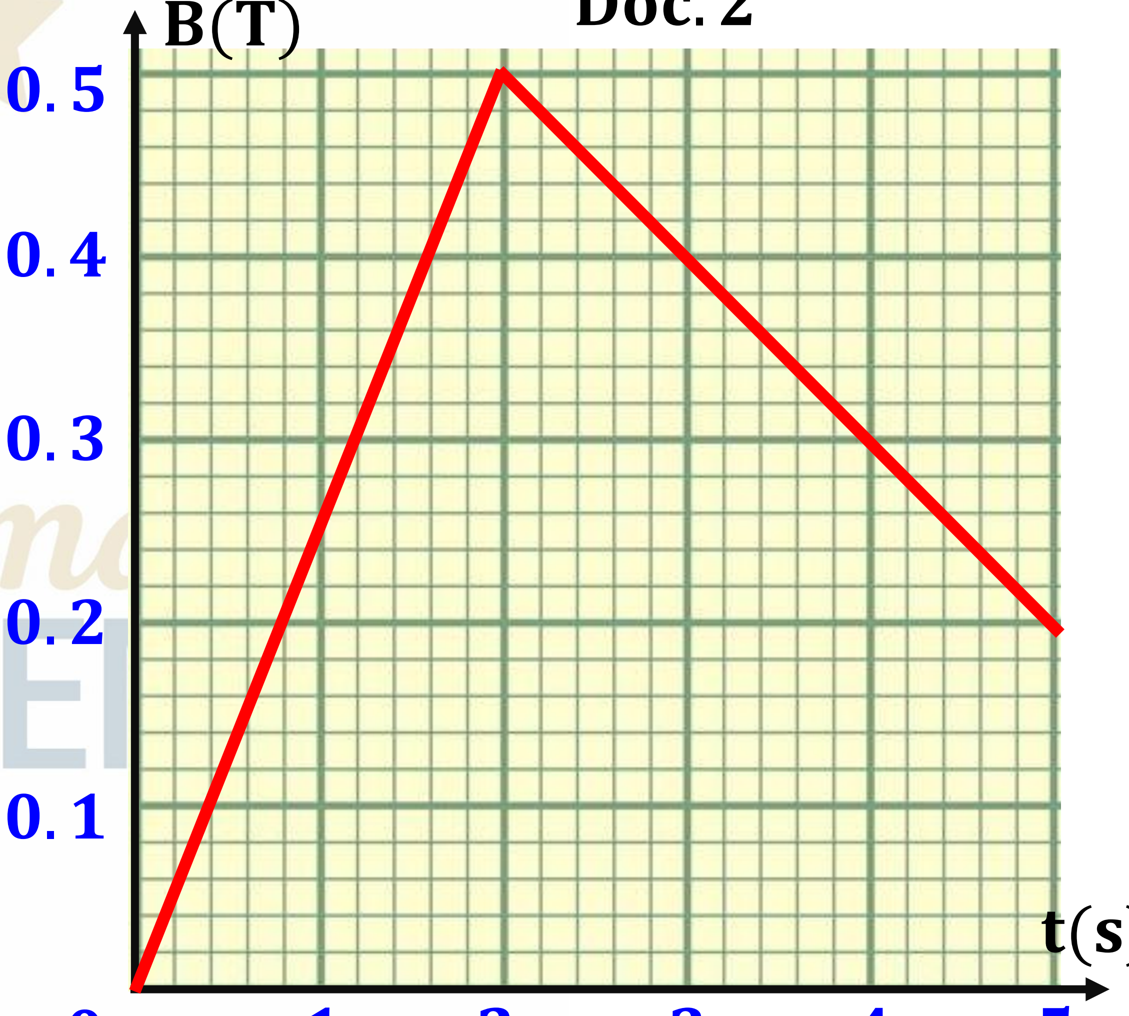


Exercise 1:

3. Calculate the values of i for the following $0 \leq t \leq 2s$ and for $2s \leq t \leq 5s$. Deduce its direction.

4. Apply Lenz's law to verify the results obtained in part 3.

Doc. 2



Exercise 1:

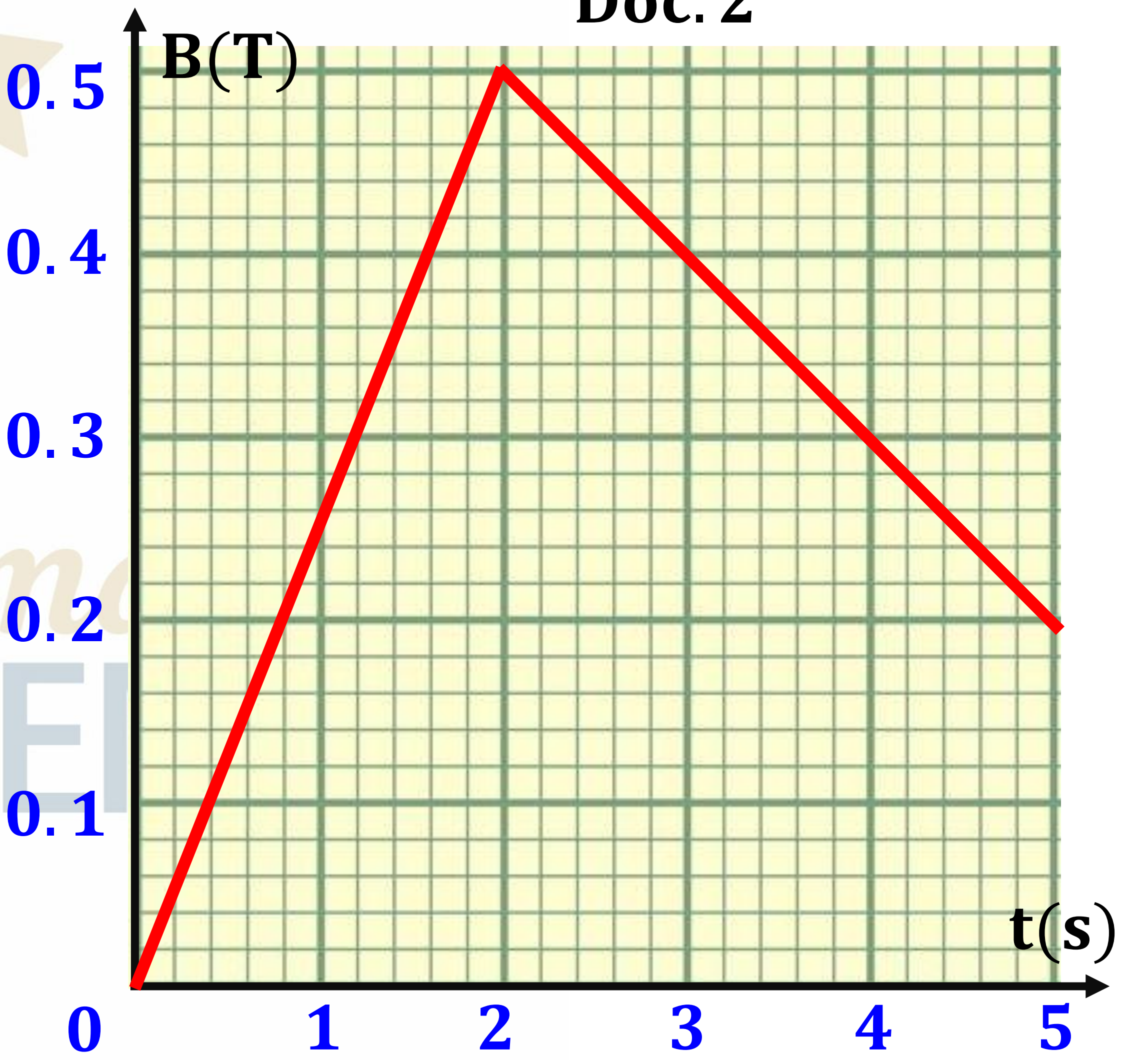
$S = 5 \times 10^{-3} m^2$, R = 10Ω and of 50 turns.

1. Explain the existence of an induced current i traversing (C).

The magnetic flux is variable because the magnetic field ($\vec{B}$) is variable.

The e.m.f "e" exist then the induced current flow in the flat coil (C).

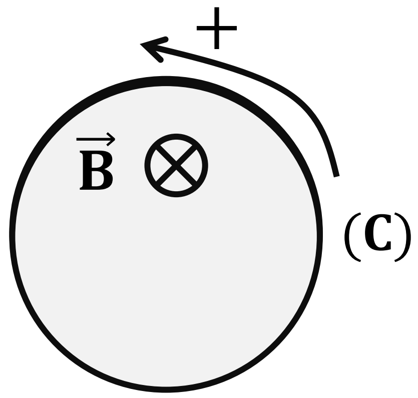
Doc. 2



Exercise 1:

$S = 5 \times 10^{-3} m^2$, $\mathrm{R} = 10\Omega$ and of 50 turns.

2.Show that the expression of this induced current is in the form of $i = \frac{NS}{R} \times \frac{dB}{dt}$.



Doc. 1

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

$$\emptyset = NBS\cos(180)$$

$$\emptyset = -NBS$$

$$e = -\frac{d\emptyset}{dt} \Rightarrow e = +NS\frac{dB}{dt}$$

$$i = \frac{e}{R}$$

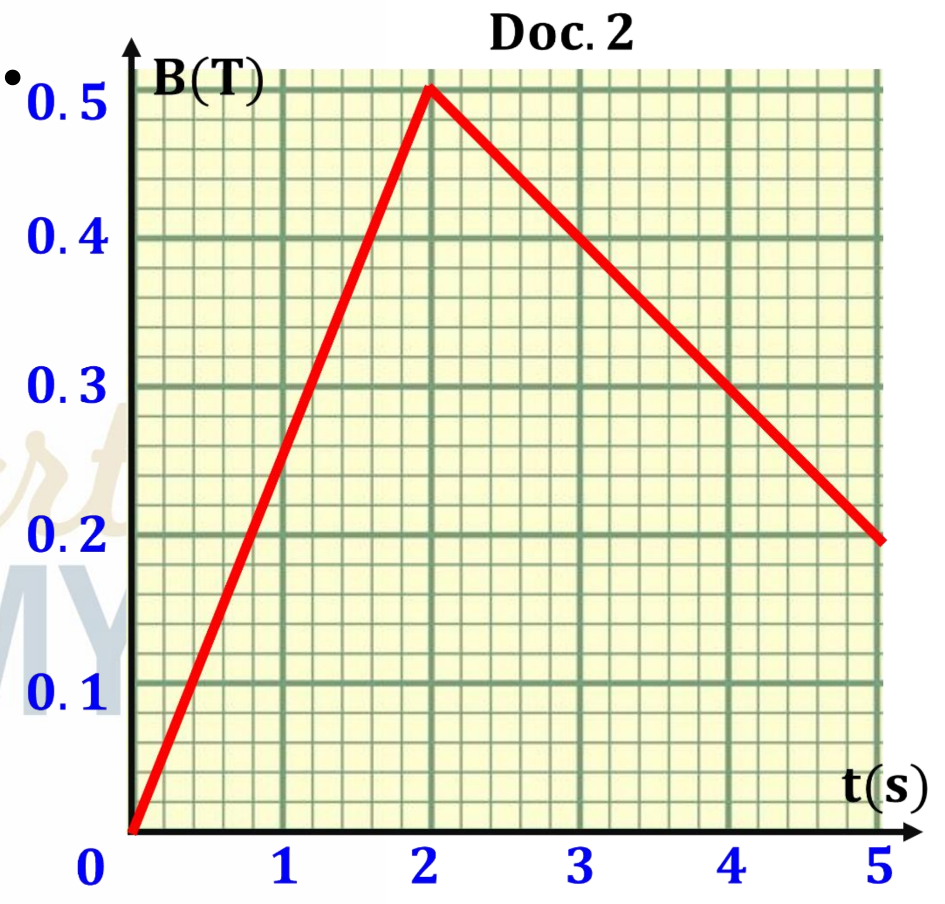
$$i = \frac{NS\frac{dB}{dt}}{R}$$

$$i = \frac{NS}{R} \times \frac{dB}{dt}$$

Exercise 1:

$S = 5 \times 10^{-3} m^2$, r = 10Ω and of 50 turns.

3. Calculate the values of i for the following $0 \leq t \leq 2s$ and for $2s \leq t \leq 5s$. Deduce its direction.



For $0 \leq t \leq 2s$

$$\text{slope} = \frac{dB}{dt} = \frac{B_2 - B_1}{t_2 - t_1} = \frac{0.5 - 0}{2 - 0}$$

$$\frac{dB}{dt} = 0.25\ T/s$$

Exercise 1:

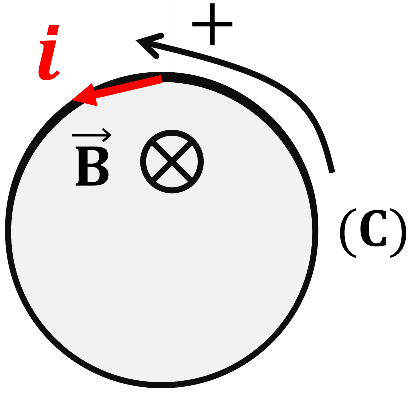
$S = 5 \times 10^{-3} m^2$, r = 10Ω and of 50 turns.

$$i = \frac{NS}{R} \times \frac{dB}{dt}$$

$$i = \frac{50 \times 5 \times 10^{-3}}{10} \times 0.25$$

$$i = 6.25 \times 10^{-3} A$$

Since $i > 0$ the I flow as the positive direction



Doc. 1

Exercise 1:

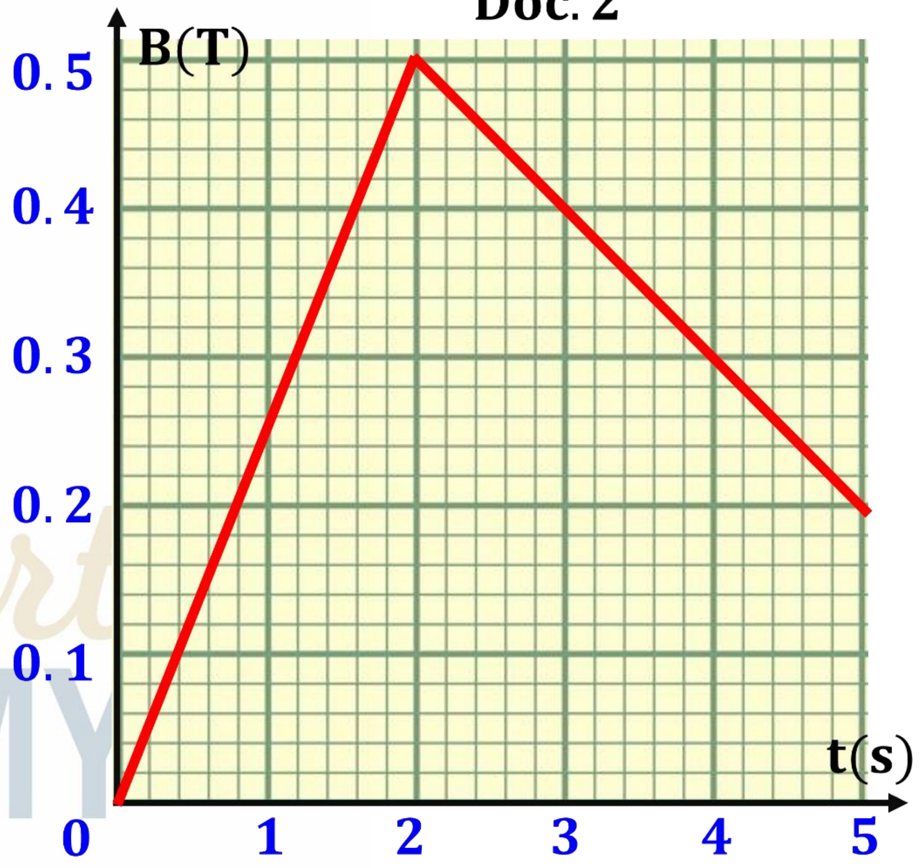
$S = 5 \times 10^{-3} m^2$, r = 10Ω and of 50 turns.

For $2s \leq t \leq 5s$

$$\text{slope} = \frac{dB}{dt} = \frac{B_2 - B_1}{t_2 - t_1} = \frac{0.2 - 0.5}{5 - 2}$$

$$\frac{dB}{dt} = -0.1\ T/s$$

Doc. 2



Exercise 1:

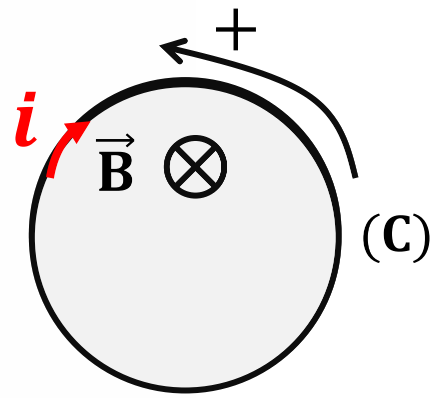
$S = 5 \times 10^{-3} m^2$, r = 10Ω and of 50 turns.

$$i = \frac{NS}{R} \times \frac{dB}{dt}$$

$$i = \frac{50 \times 5 \times 10^{-3}}{10} \times (-0.1)$$

$$i = -2.5 \times 10^{-3} A$$

Since $i < 0$ the I flow in opposite direction to positive direction



Doc. 1

Exercise 1:

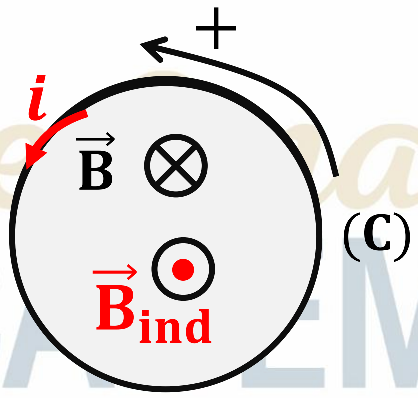
$S = 5 \times 10^{-3} m^2$, r $= 10\Omega$ and of 50 turns.

4. Apply Lenz's law to verify the results obtained in part 3.

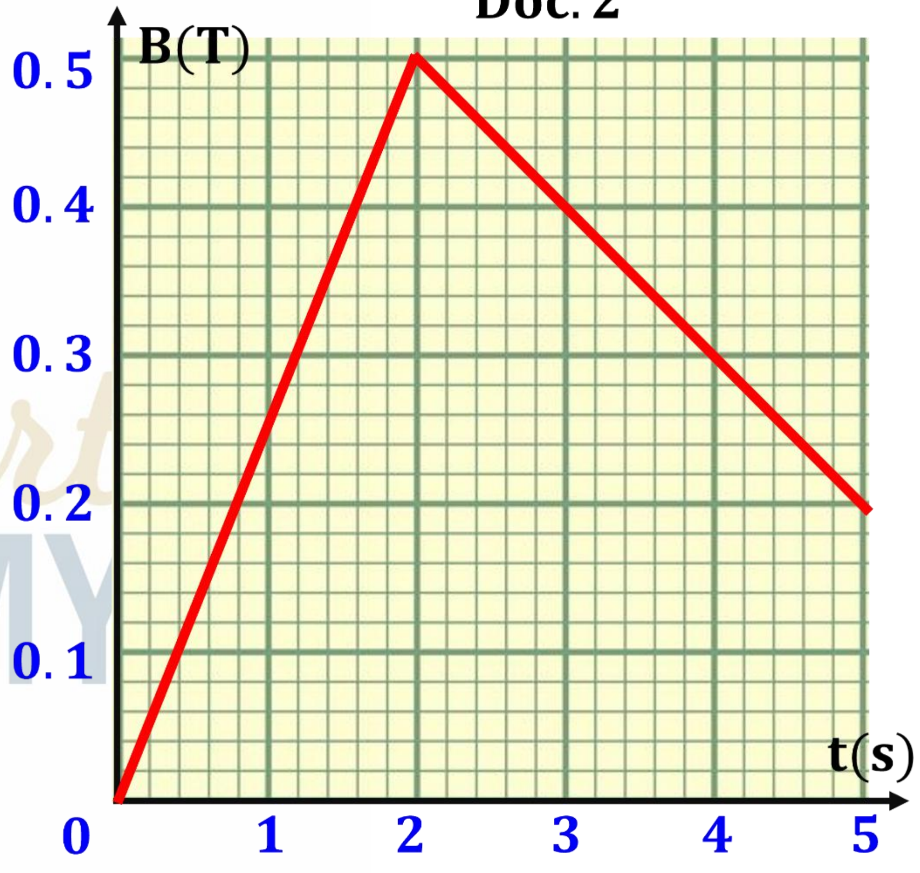
For $0 \leq t \leq 2s$

The magnetic field ($\vec{B}$) increases then $\vec{B}_{ind}$ is in opposite direction.

Using RHR along $\vec{B}_{ind}$:
i flow as positive direction



Doc. 1



Doc. 2

Exercise 1:

$S = 5 \times 10^{-3} m^2$, r = 10Ω and of 50 turns.

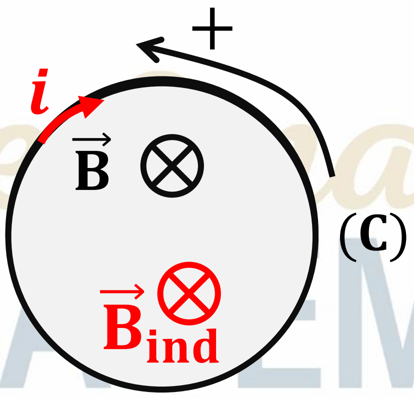
4. Apply Lenz's law to verify the results obtained in part 3.

For $2s \leq t \leq 5s$

The magnetic field ($\vec{B}$) decreases then $\vec{B}_{ind}$ is in same direction.

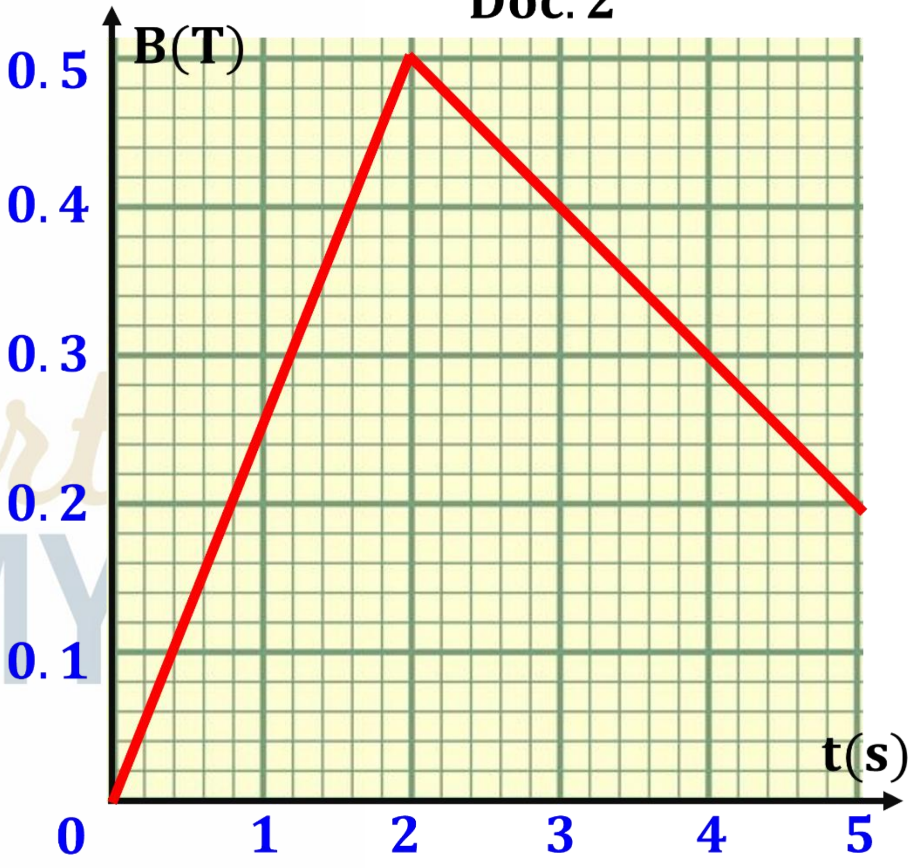
Using RHR along $\vec{B}_{ind}$:

i flow opposite to positive direction



Doc. 1

Doc. 2

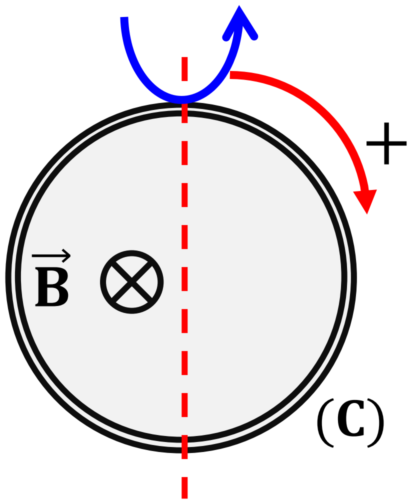


Exercise 1:

Part 2: Rotation of the coil:

The intensity of the magnetic field $\vec{B}$ is adjusted at $B = 0.5T$. (C) rotates at a constant angular velocity ω about its diameter as shown in document 3.

Let θ be the angle between the normal $\vec{n}$ to the plane of (C) and $\vec{B}$ at an instant t.



Doc. 3

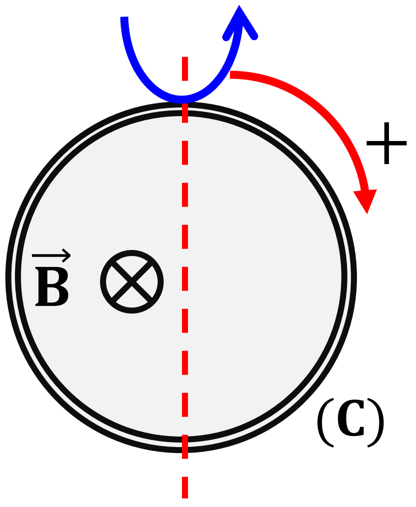
1. **Knowing that $\theta_0 = 0$ at the instant $t_0 = 0$, show that $\theta = wt$.**
2. **Deduce that the expression of the magnetic flux crossing (C) is given by: $\emptyset = NBScos(\omega t)$.**

Exercise 1:

3. **Justify, qualitatively, the existence of an induced e.m.f "e" during the rotation of (C).**
4. **Determine, in terms of N, S, B, ω and t, the expression of the induced e.m.f "e".**
5. **Calculate the value of ω knowing that the maximum induced emf is $0.5V$.**

Exercise 1:

1. Knowing that $\theta_0 = 0$ at the instant $t_0 = 0$, show that $\theta = wt$.



(C) rotates at a constant angular velocity ω:

The motion is uniform circular motion:

$$\theta = \omega t + \theta_0 \quad \Rightarrow \quad \theta = \omega t + 0$$

$$\theta = \omega t$$

2. Deduce that the expression of the magnetic flux crossing (C) is given by: $\emptyset = NBScos(\omega t)$.

$$\emptyset = NBScos(\theta)$$

$$\emptyset = NBScos(\omega t)$$

Exercise 1:

3. **Justify, qualitatively, the existence of an induced e.m.f “e” during the rotation of (C).**

The magnetic flux (∅) is variable, because of the rotation of the coil around the axis then:

The induced e.m.f “e” exist during the rotation of (C).

Exercise 1:

4. Determine, in terms of N, S, B, ω and t, the expression of the induced e.m.f "e".

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

$$e = -\frac{d(NBS\cos(\omega t))}{dt}$$

$$e = -NBS\frac{d(\cos(\omega t))}{dt}$$

$$e = +NBS\omega.\sin(\omega t)$$

Exercise 1:

5. Calculate the value of ω knowing that the maximum induced emf is $0.5V$.

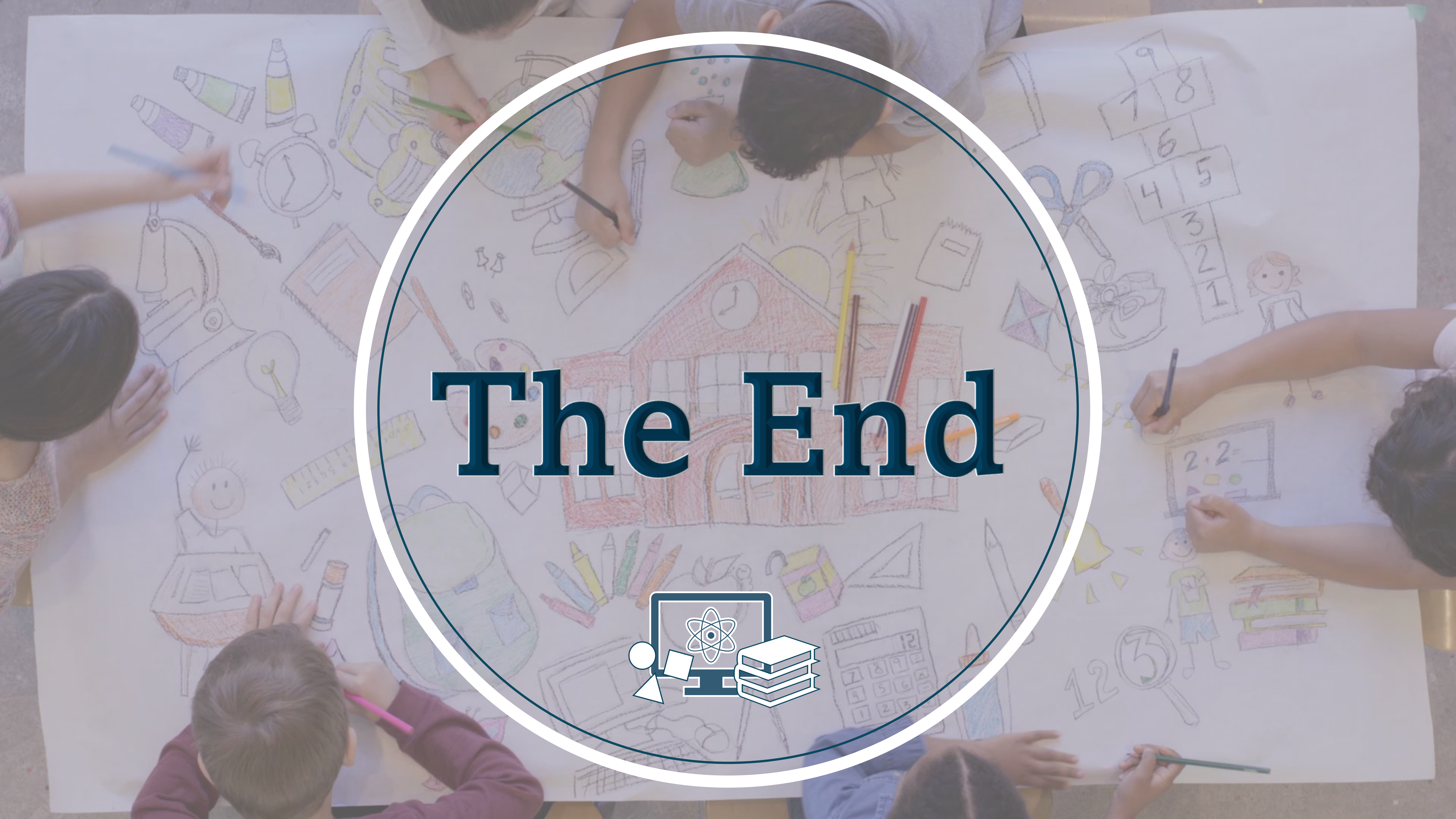
$$e = +NBS\omega . sin(\omega t)$$

e is maximum for $\sin(\omega t) = 1$

$$e = +NBS\omega$$

$$\omega = \frac{e}{NBS} \Rightarrow \omega = \frac{0.5}{50 \times 0.5 \times 5 \times 10^{-3}}$$

$$\omega = 4rad/s$$

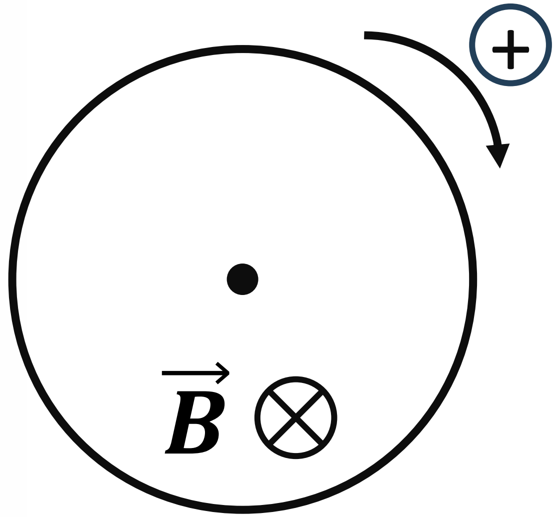

The End

Think then Solve

Exercise 2:

The purpose of this exercise is to determine the direction of the induced current in a circular loop by two different methods. Consider a circular conducting loop of radius r = 10 cm and resistance R = 2 Ω. The loop is placed in a uniform magnetic field $\vec{B}$.

The value B of the magnetic field $\vec{B}$ decreases with time according to the relation: $B = -0.04t + 0.8$ (SI).



Exercise 2:

1) A current is induced in the loop during the time interval. Justify.
2) Apply Lenz’s law to specify the direction of the induced current.
3) Determine the expression of the magnetic flux crossing the loop as a function of time.
4) Deduce the value of the induced electromotive force « e».
5) Deduce the value and the direction of «i».
6) Compare the direction of the induced current obtained in part (2) to that obtained in part (5).

Exercise 2:

1) **A current is induced in the loop during the time interval. Justify.**

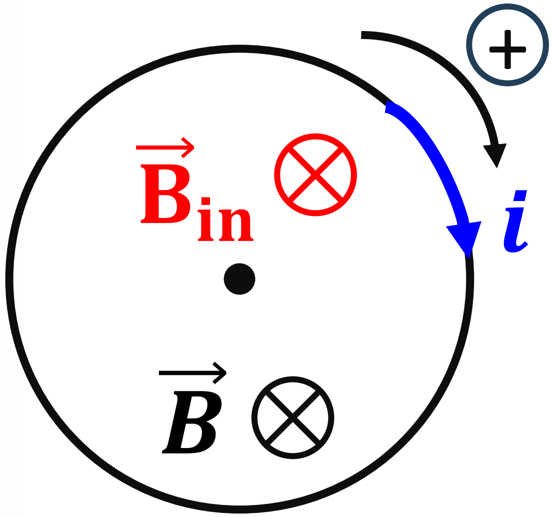
The magnitude of the magnetic field ($\vec{B}$) changes, then:
The loop is crossed by a variable magnetic flux; therefore:
The loop becomes the seat of induced emf.
The loop forms a closed circuit, then it carries electric current.

Exercise 3:

2) **Apply Lenz's law to specify the direction of the induced current.**

The magnitude B of the magnetic field decreases then:

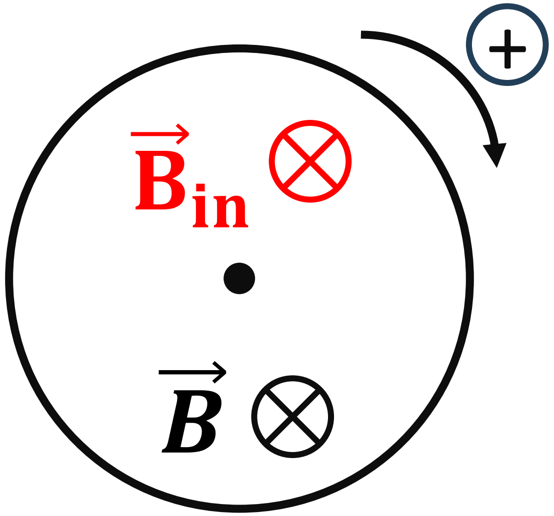
The direction of the induced magnetic field ($\vec{B}_{in}$) is the same as that of $\vec{B}$.



According to the RHR, the induced current passes in the loop in the chosen positive sense

Exercise 1:

r = 10 cm; R = 2 Ω; $B = -0.04t + 0.8$



3) Determine the expression of the magnetic flux crossing the loop as a function of time.

$$\emptyset = BS\cos(\vec{B},\vec{n}) \Rightarrow \emptyset = BS\cos(0)$$

$$\emptyset = B \times \pi r^2 \times (1) \Rightarrow \emptyset = (-0.04t + 0.8) \times \pi(0.1)^2$$

$$\emptyset = (-0.04t + 0.8) \times 0.01\pi$$

$$\emptyset = -4\pi \times 10^{-4}t + 8\pi \times 10^{-4}$$

Exercise 1:

r = 10 cm; R = 2 Ω; B $= -0.04t + 0.8$

4)Deduce the value of the induced electromotive force « e».

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

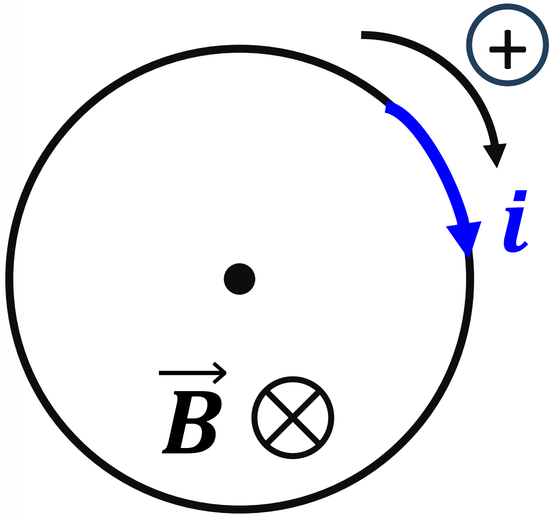
$$e = -\frac{d\left[-4\pi \times 10^{-4}t + 8\pi \times 10^{-4}\right]}{dt}$$

$$e = 4\pi \times 10^{-4} V$$

Exercise 1:

$r = 10\ cm;\ R = 2\ \Omega;\ B = -0.04t + 0.8$

5)Deduce the value and the direction of «*i*».



$$i = \frac{e}{R} \Rightarrow i = \frac{4\pi \times 10^{-4}}{2}$$

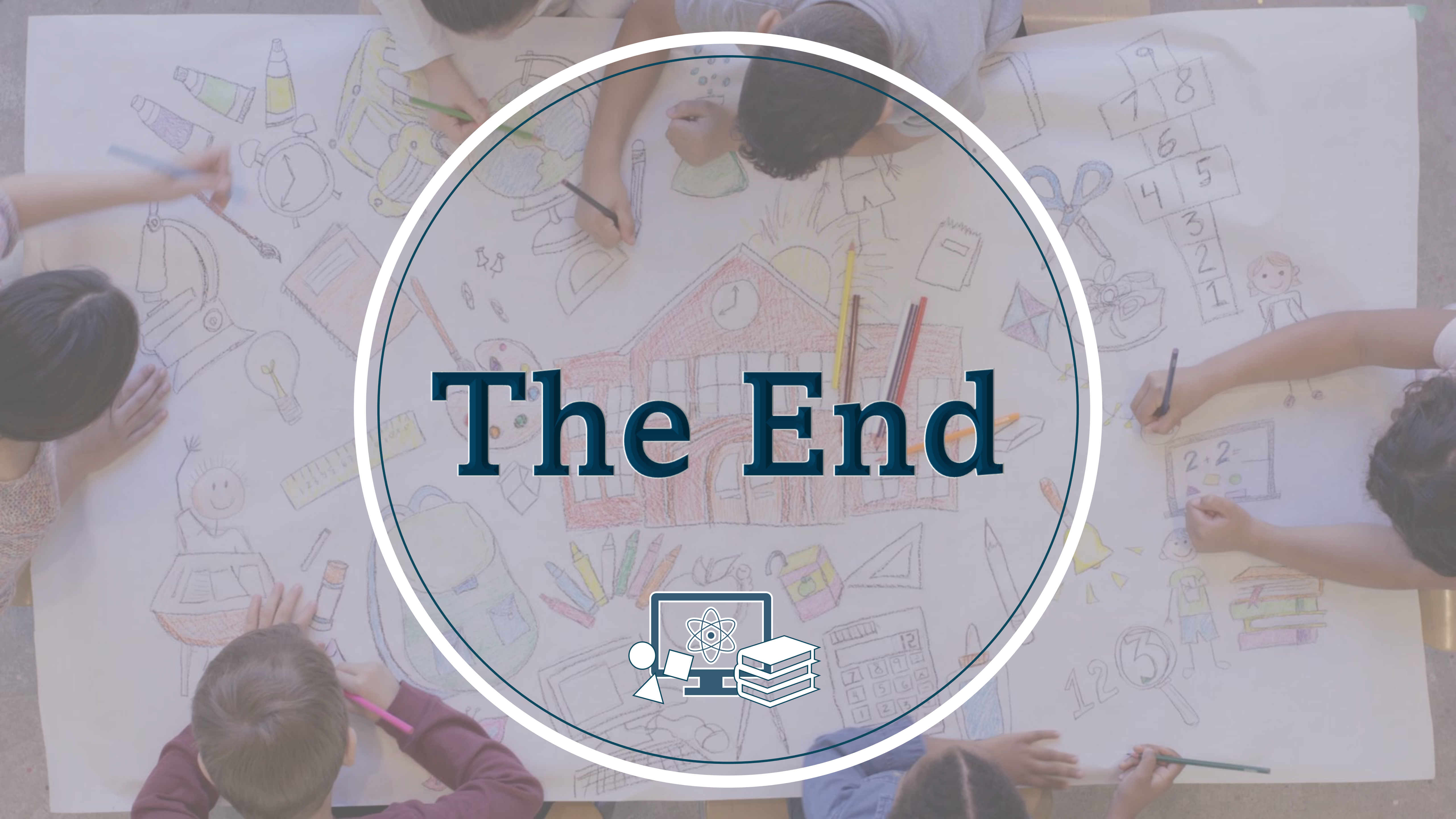
$$i = 6.3 \times 10^{-3} A$$

i>0, then the current is in the chosen positive sense

Exercise 1:

6) **Compare the direction of the induced current obtained in part (2) to that obtained in part (5).**

The direction is the same in the two parts.


The End

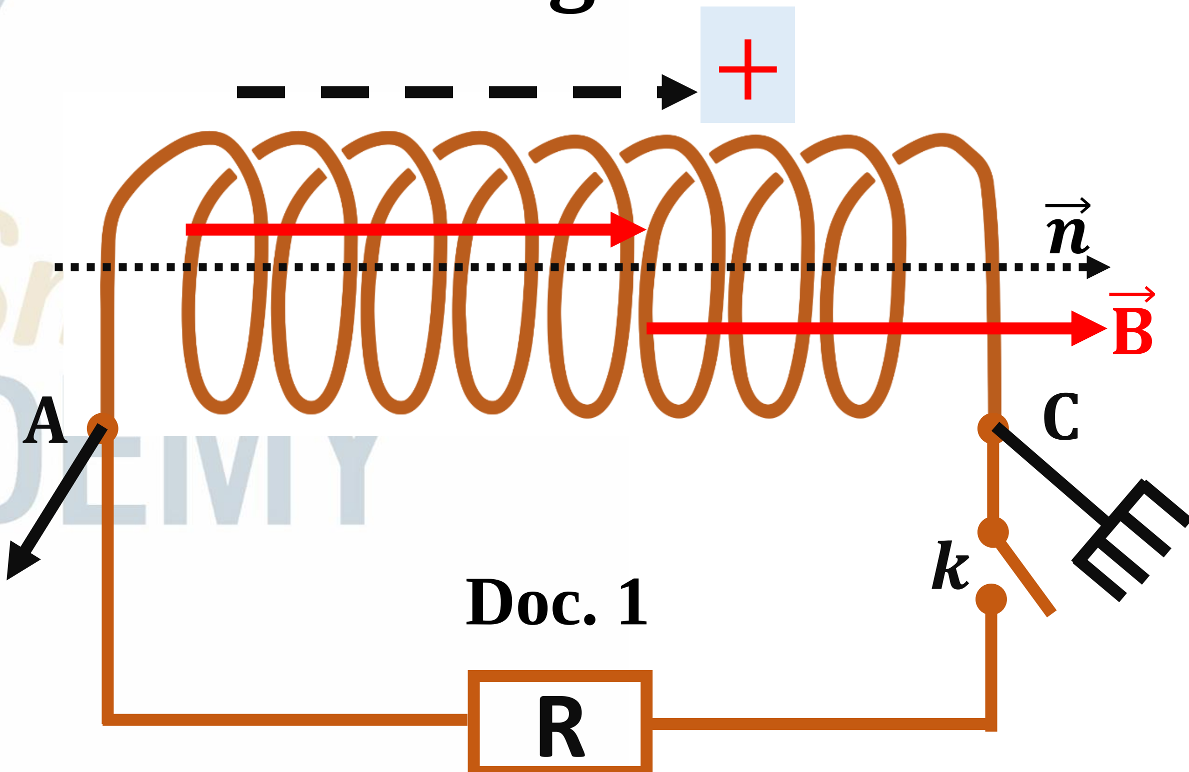
Think then Solve

Exercise 3:

A coil of 1000 turns, and of internal resistance r, is connected to a switch K and a resistor of resistance $R = 8\Omega$.

The area of each loop is S. The coil whose axis is horizontal is placed in a uniform magnetic field $\vec{B}$ of magnitude B that varies with time

An oscilloscope is connected across the terminals A and C of the coil to display the voltage u_{AC}.



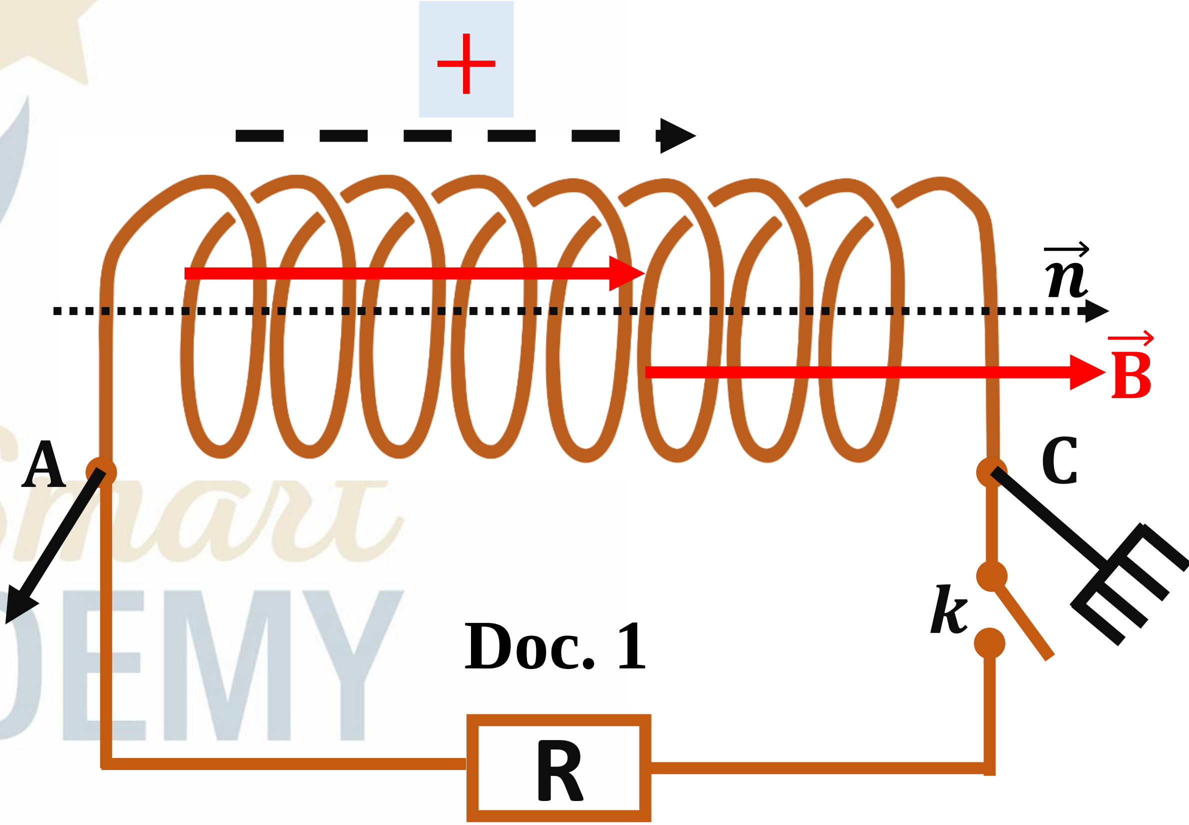
Doc. 1

Exercise 3:

In the absence of any voltage, the horizontal luminous line is displayed through the center of the screen of the oscilloscope.

The coil is oriented positively from A to C, and $\vec{n}$ is the normal unit vector to the plane of the loons (Document 1).

The aim of this exercise is to determine the surface area S of each loop and the resistance r of the coil.



Doc. 1

Exercise 3:

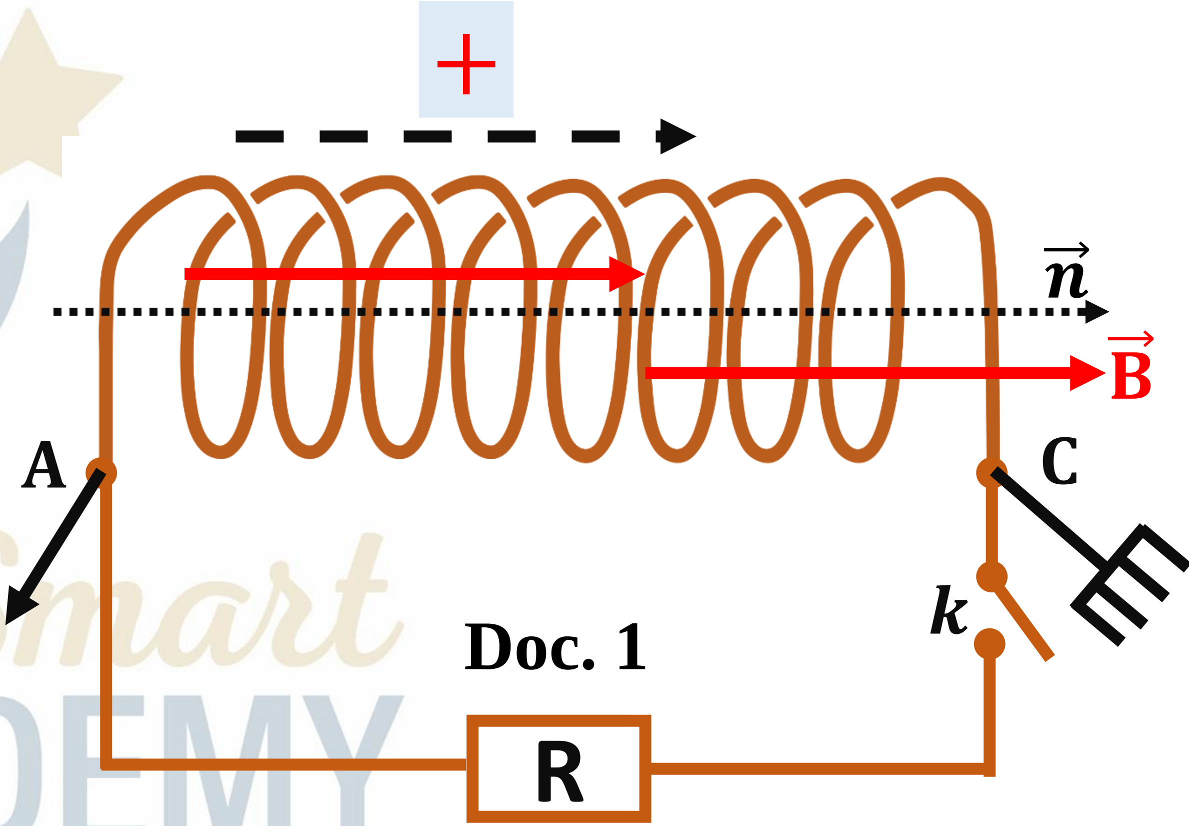
1)Theoretical Study:

1.1. Determine the expression of the magnetic flux crossing the coil in terms of S and B.

1.2. Determine the expression of the induced electromotive force "e" in the coil in terms of S and $\frac{dB}{dt}$.

Exercise 3:

1.1. Determine the expression of the magnetic flux crossing the coil in terms of S and B.



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

$$\emptyset = 1000 \times B \times S \times \cos(0)$$

$$\emptyset = 1000B.S$$

Exercise 3:

1.2. Determine the expression of the induced electromotive force "e" in the coil in terms of S and $\frac{dB}{dt}$.

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

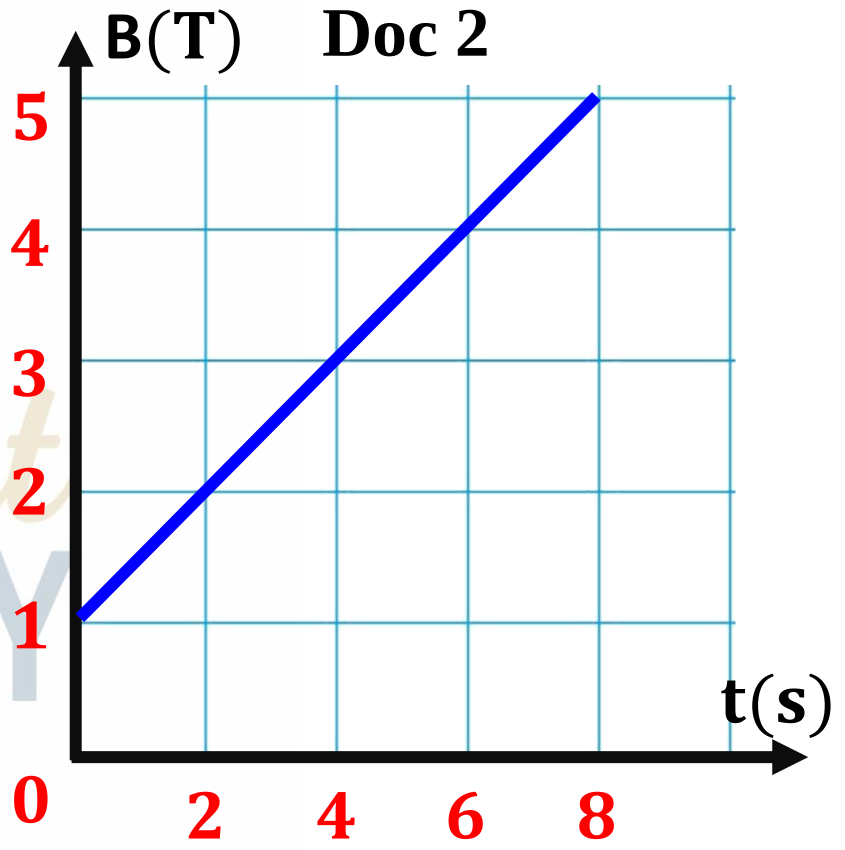
$$e = -\frac{d(1000BS)}{dt}$$

$$e = -1000S\frac{dB}{dt}$$

Exercise 3:

The switch K is opened:

Document 2 represents the magnitude B of the magnetic field $\vec{B}$ as function of time.



2.1. Use document 2, show that the expression of the induced electromotive force "e" in terms of S is $e = -500 \times S$.

Exercise 3:

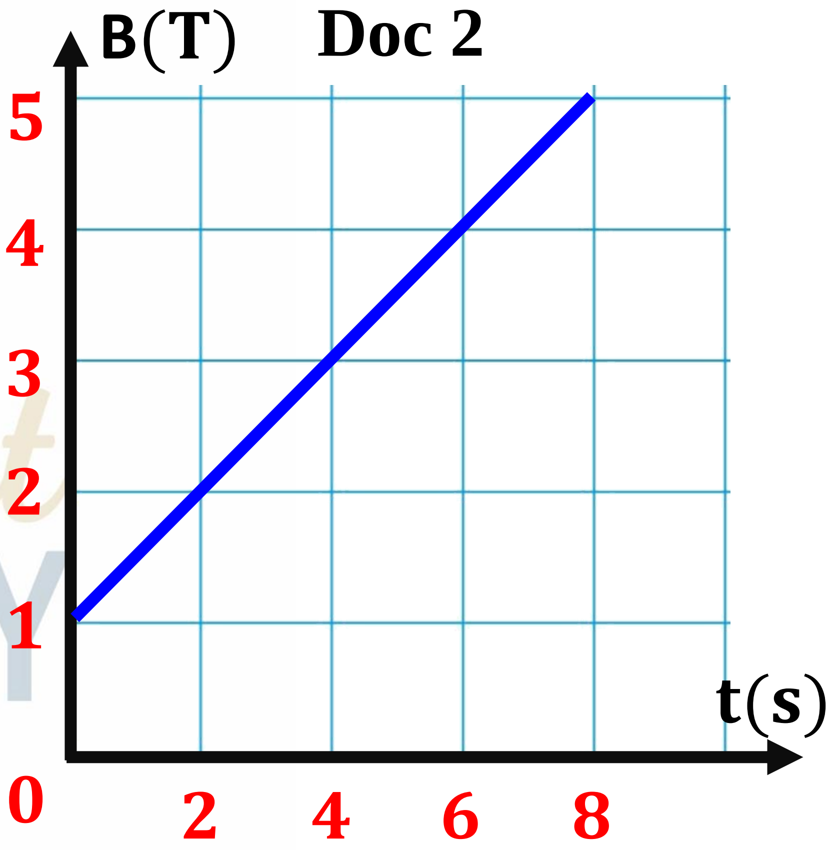
2.1. Use document 1, show that the expression of the induced electromotive force "e" in terms of S is $e = -500 \times S$

The given St. line of equation $B = a.t$, where a is the slope

$$a = \frac{\Delta B}{\Delta t} = \frac{4-2}{6-2} \Rightarrow a = 0.5T/s$$

$$e = -1000S\frac{dB}{dt} \Rightarrow e = -1000S \times 0.5$$

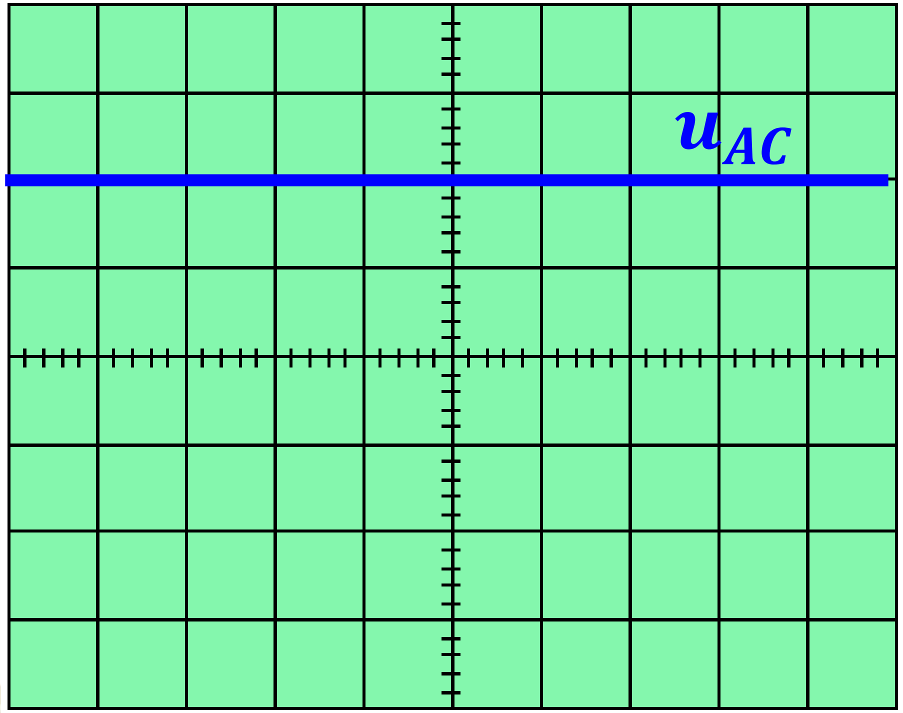
$$e = -500S$$



Exercise 3:

2.2. Use document 3, calculate the value of the voltage u_{AC}.

$$u_{AC} = S_V \times y = 0.5 \times 2 \Rightarrow u_{AC} = 1V$$



$S_V = 0.5V/div$

2.3. Deduce that the area of each loop is $S = 20cm^2$.

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

Opened circuit then $i = 0$

$$u_{AC} = -e$$

$$1 = -(-500S)$$

$$S = \frac{1}{500} = 0.002m^2$$

$$S = 20cm^2$$

Exercise 3:

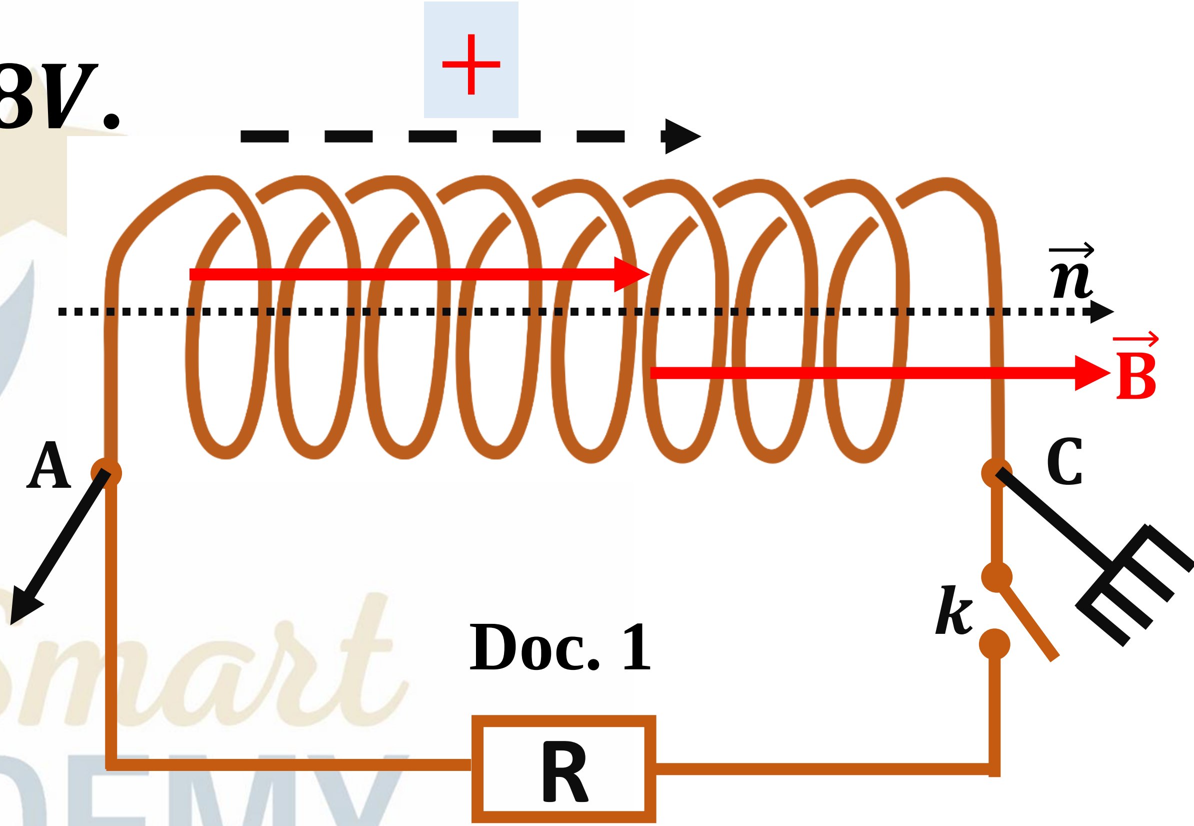
The switch K is closed:

In this case the voltage $u_{AC} = 0.8V$.

3.1. Apply Lenz's law to determine the direction of the induced current.

3.2. Calculate the induced current i.

3.3. Knowing that the induced current is $i = \frac{e}{R+r}$, deduce the value of r.



Doc. 1

Exercise 3:

3.1. Apply Lenz's law to determine the direction of the induced current.

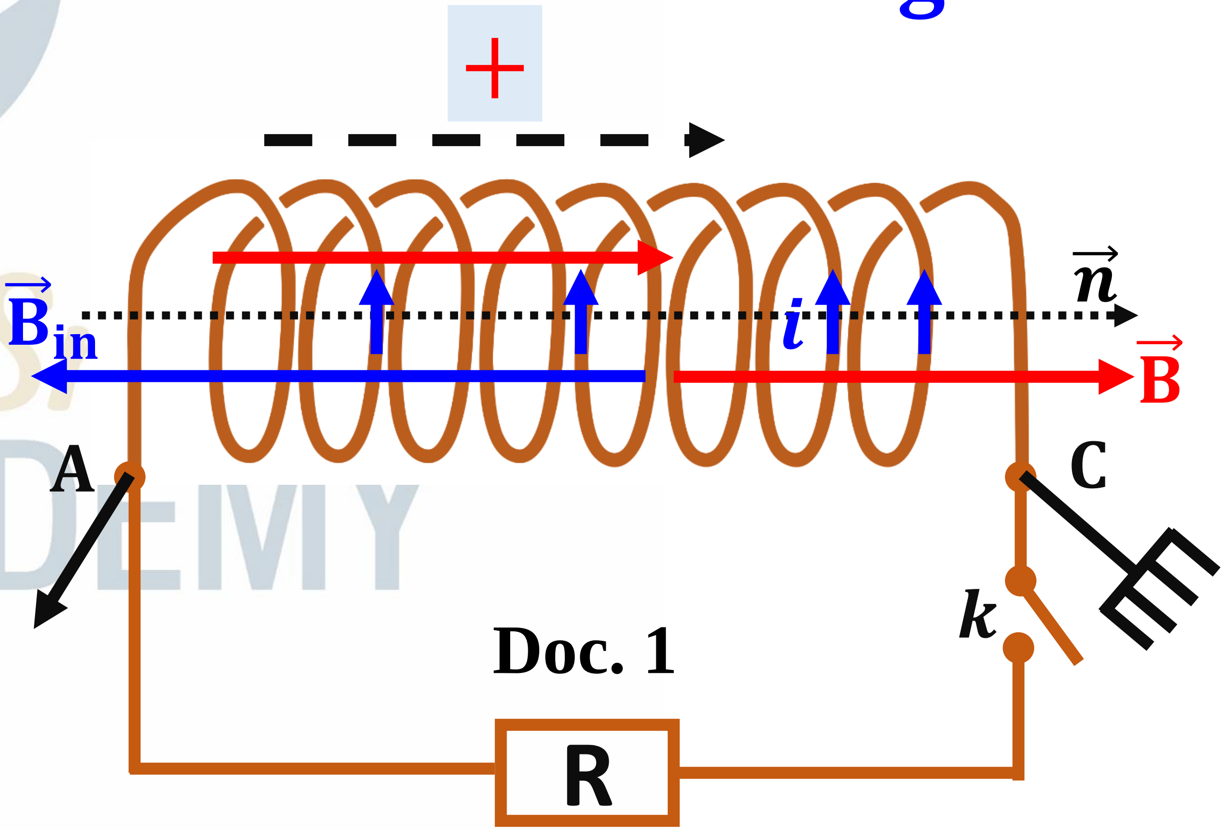
Lenz's law states that:

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

Exercise 3:

The magnetic field $\vec{B}$ increases then $\vec{B}_{in}$ is opposite to $\vec{B}$. Then $\vec{B}_{in}$ directed horizontally due left.

Using RHR the induced current is mentioned on the figure.



Exercise 1:

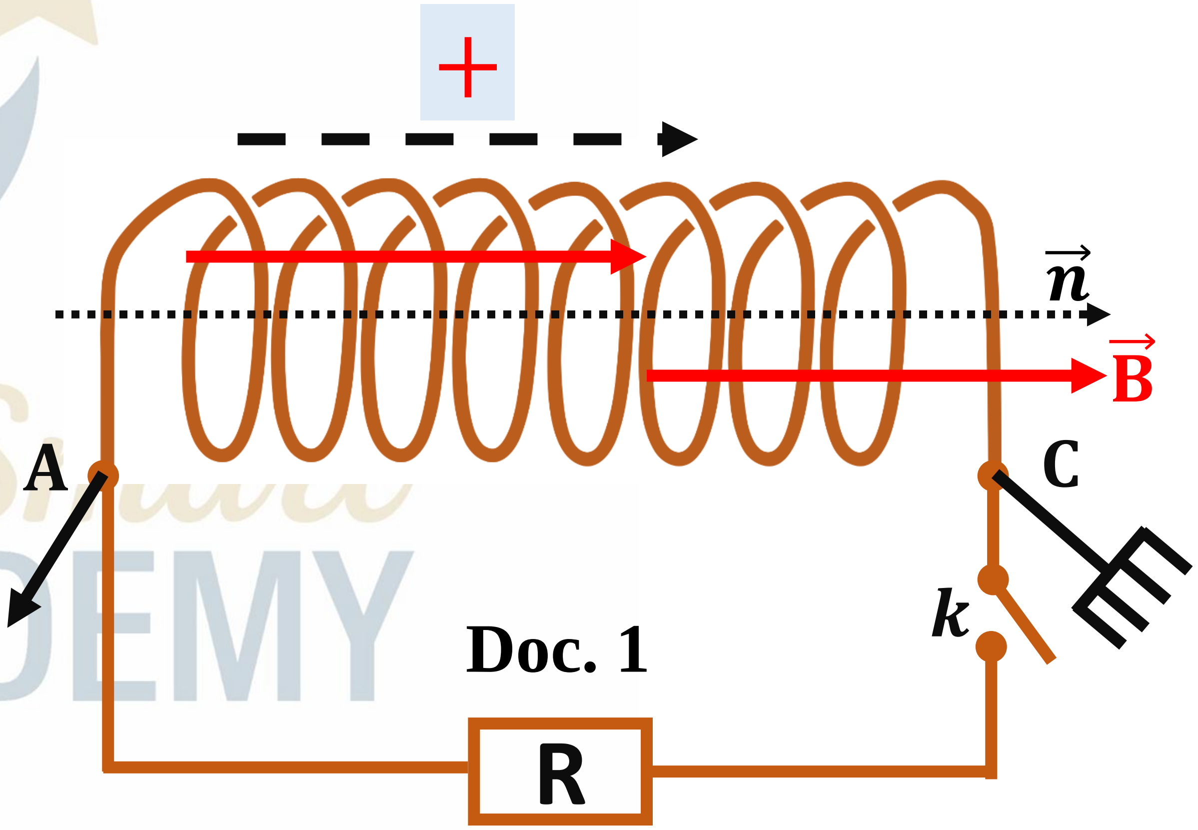
3.2. Calculate the induced current i

Apply Ohm's law of resistor:

$$u_{AC} = Ri$$

$$0.8V = 8i$$

$$i = \frac{0.8}{8} = 0.1A$$



Exercise 1:

3.3. Knowing that the induced current is $i = \frac{e}{R+r}$, deduce the value of r.

$$e = -500S$$

$$e = -500 \times (20 \times 10^{-4})$$

$$e = 1V$$

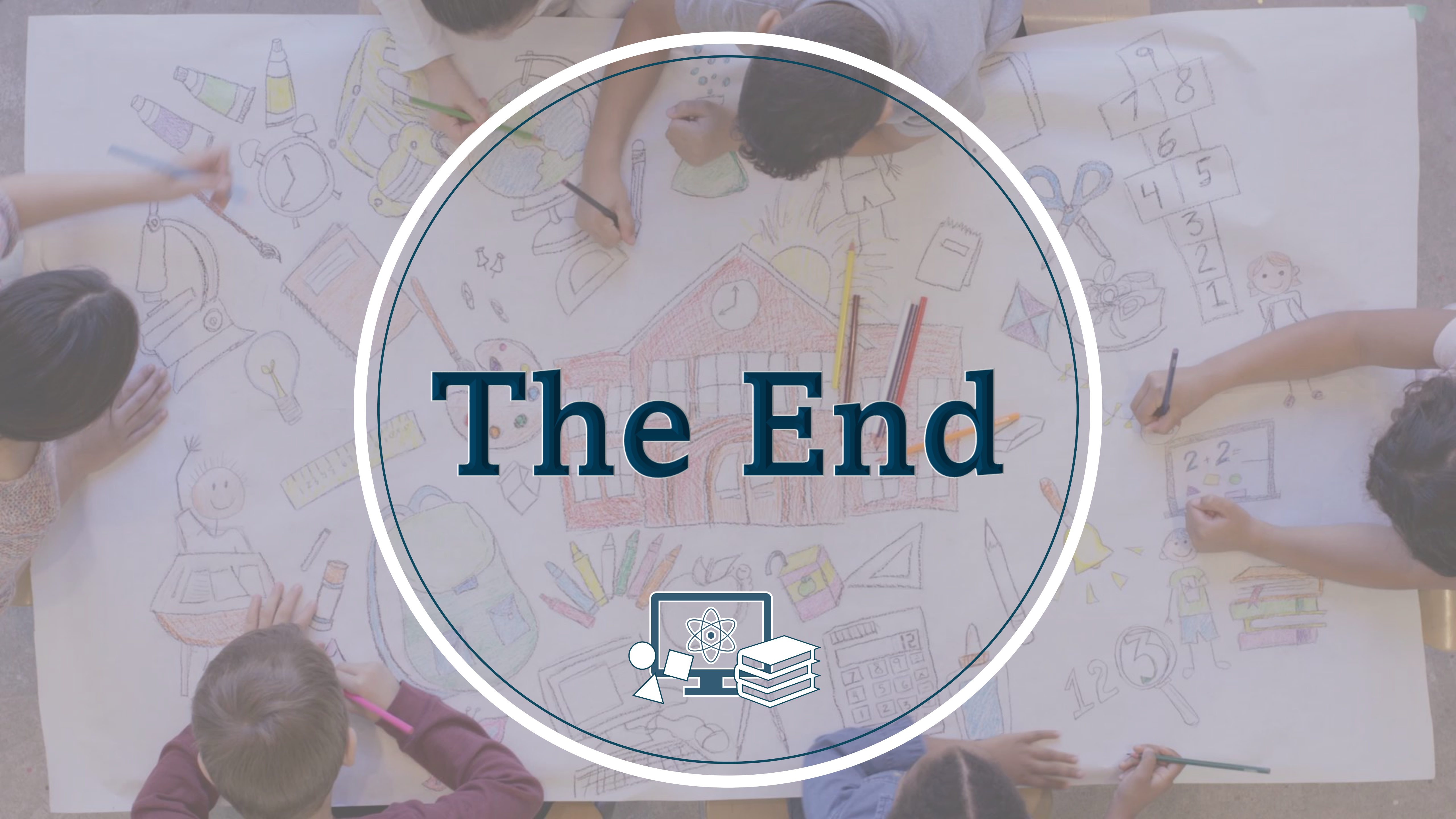
$$i = \frac{e}{R+r}$$

$$0.1 = \frac{1}{8+r}$$

$$8+r = \frac{1}{0.1}$$

$$8+r = 10$$

$$r = \Omega$$



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