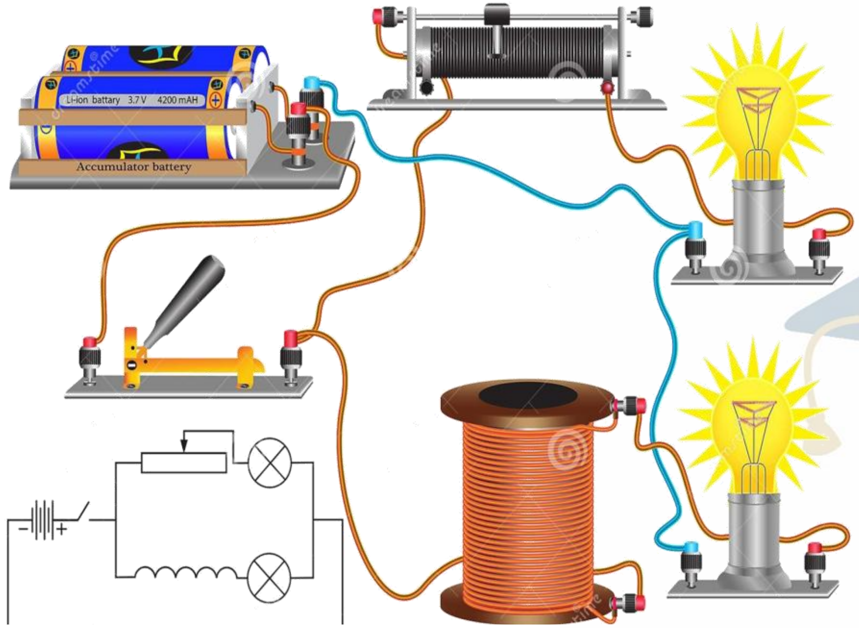
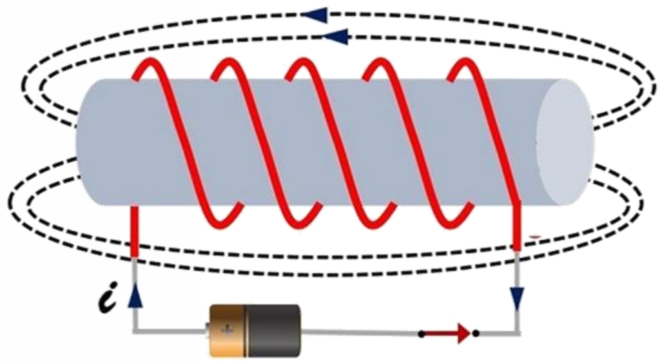


What is Self Induction?



Physics – Grade 12

Unit Two – Electricity

Chapter 9 – Self Induction

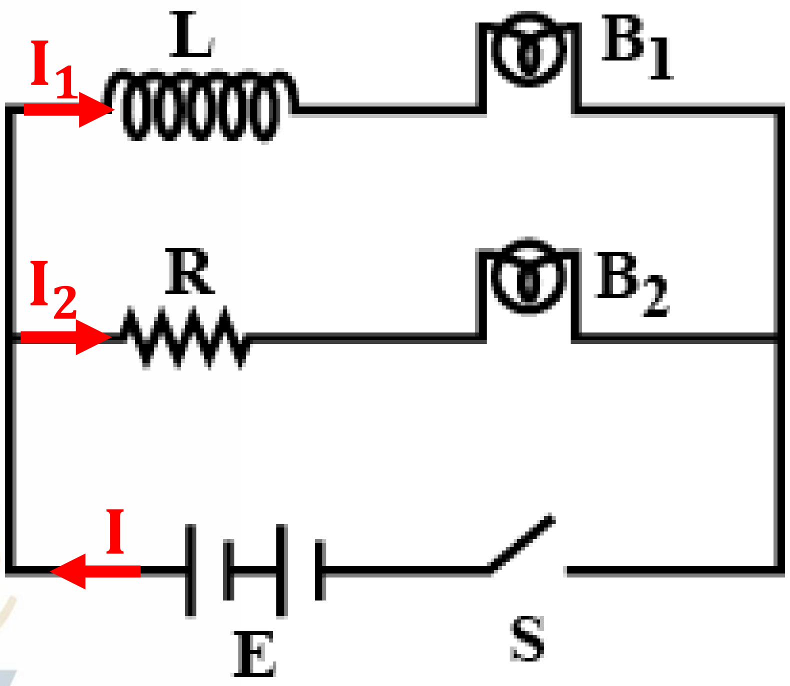
Prepared & Presented by: Mr. Mohamad Seif

OBJECTIVES

1. Evidence of Self induction
2. Inductance of the coil
3. Derive the expression of the electromotive force e.m.f

Experimental Evidence of Self induction

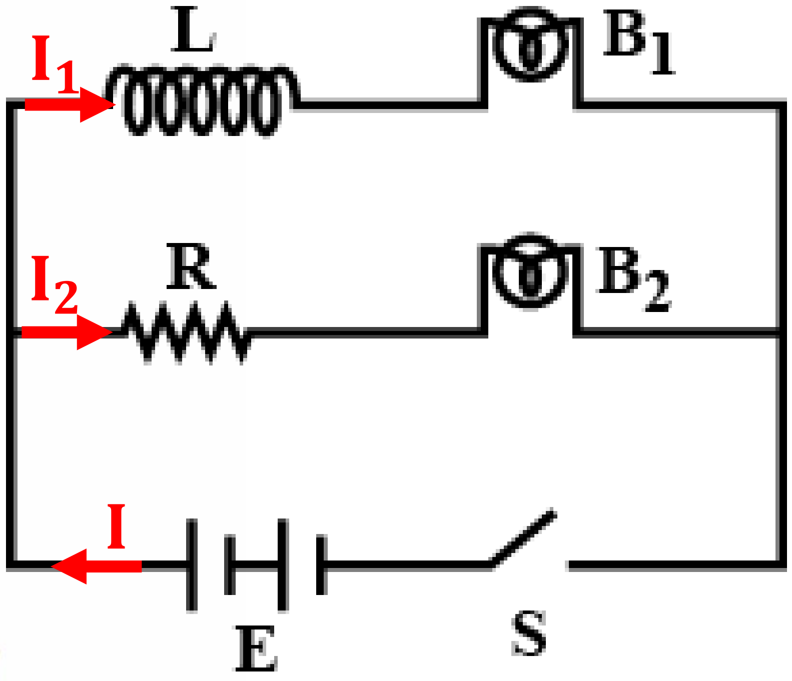
The two parallel branches shown contain two identical lamps B_1 and B_2.



The resistor has the same resistance of the coil.

The two currents in the two branches are expected to be equal and the two lamps are expected to glow in the same manner.

Experimental Evidence of Self induction



First case: Close the switch K:

We notice that Lamp B_2 glows instantly, while B_1 glows gradually with a noticeable delay in B_1 with respect to B_2. Then B_1 glows as bright as B_2.

Second case: Open the switch K:

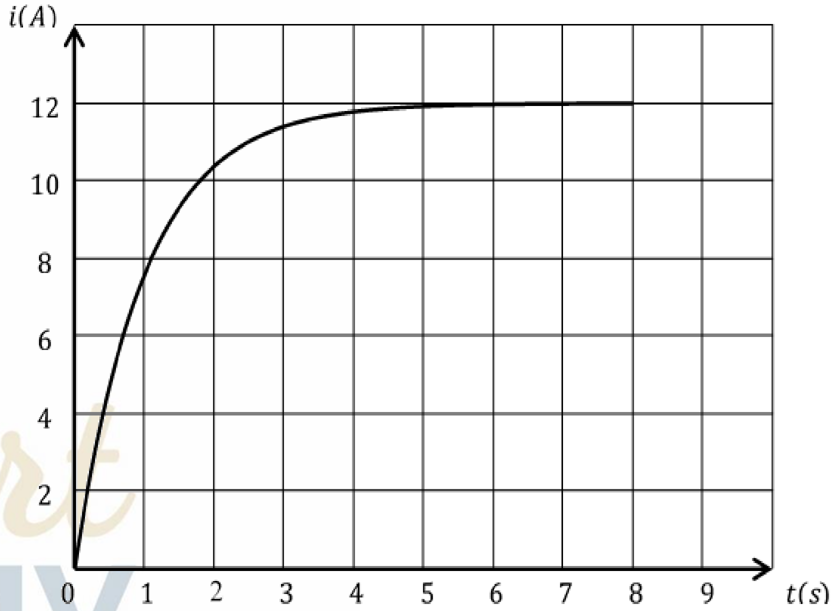
We notice that Lamp B_2 turns off instantly, while the brightness of B_1 decrease gradually with a noticeable delay of time. Then B_1 turns off.

Experimental Evidence of Self induction

First case: Close the switch K

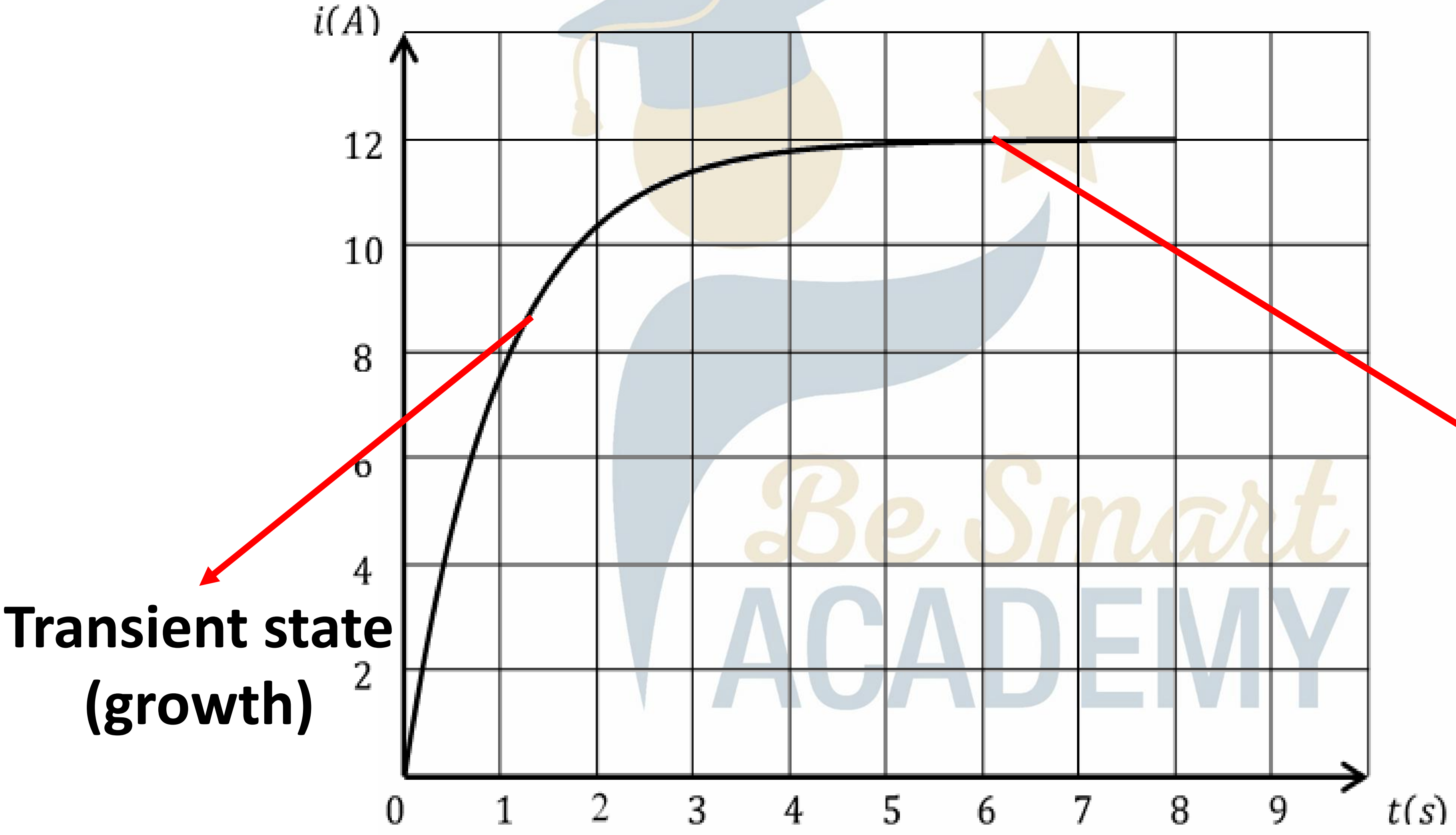
In a resistor the current increases suddenly from zero to a value I.

In the coil the current grows progressively from zero to reach the same value I in the steady state.



In fact, a variable current traverses the coil, then a variable magnetic field is created inside the coil.

Experimental Evidence of Self induction



Experimental Evidence of Self induction

Due to this current, the coil is crossed by a variable flux. The variable magnetic flux leads to an induced electromotive force, then an induced current traverses the coil.

According to Lenz's law, the induced current opposes the increase of the main current. As a result, the main current takes a period of time to reach its maximum value I.

This phenomenon is called self induction.

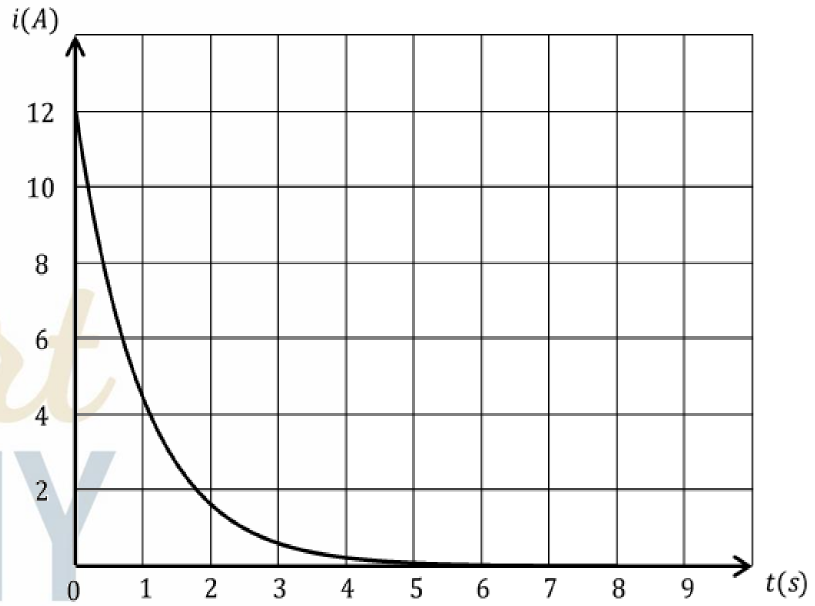
The Flux is called self or proper flux

Electromotive force is called self indued electromotive force

Experimental Evidence of Self induction

Second case: open the switch K

In the resistor the current decreases suddenly from I to zero, while in coil the current decreases progressively from I to zero.



In fact, a variable current traverses the coil, and then a variable magnetic field is created inside the coil.

Due to this current, the coil is crossed by a variable magnetic flux.

Experimental Evidence of Self induction

The variable magnetic flux leads to an induced electromotive force, then an induced current traverses the coil.

According to Lenz's law the induced current opposes the decrease of the main current, for this reason the main current takes an elapse of time to reach zero.

This phenomenon is called self induction.

Inductance of the coil

The self –flux (∅) crossing a coil depends on the current flowing in it.

The The self –flux is given by the following expression:

$$\emptyset = L.i$$

***L*: characteristic property of the coil, called inductance, in Henry (H).**

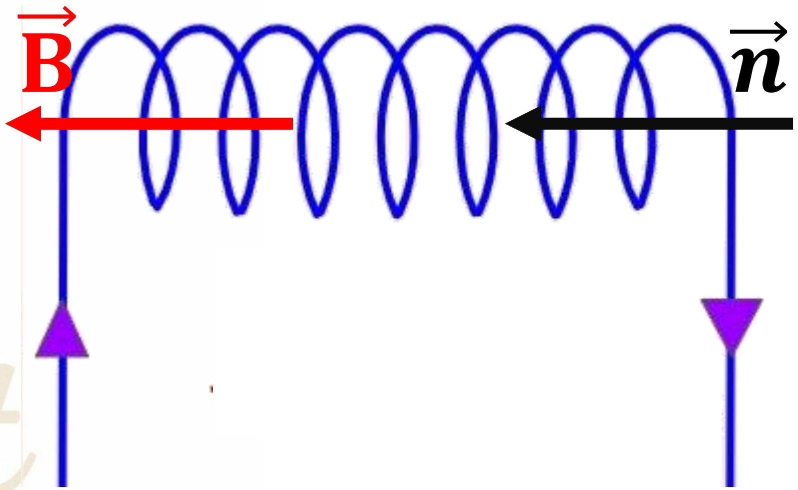
∅: self flux in Wb.

***i*: the electric current traversing the coil in ampere (A).**

Inductance of the coil

The value of the inductance of long solenoid:

The magnetic flux of the coil is $\emptyset = \text{NBScos}(\theta)$, where the angle θ is the angle between $\vec{n}$ and $\vec{B}$



In this chapter, it is preferable to make the positive sense in the direction of the current, thus the angle $\theta = 0$

$$\emptyset = \text{NBScos}(0)$$

$$\emptyset = \text{NBS}$$

Inductance of the coil

$$\emptyset = Li$$

$$L = \frac{\emptyset}{i}$$

$$L = \frac{NBS}{i}$$

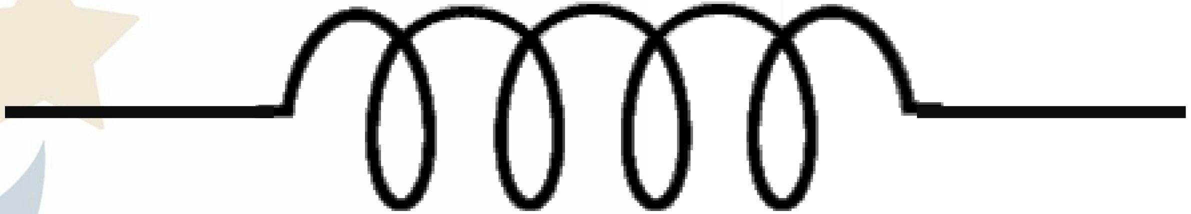
$$L = \frac{NS\left[4\pi \times 10^{-7}\frac{Ni}{l}\right]}{i}$$

$$L = \frac{4\pi \times 10^{-7} N^2 S}{l}$$

(must be derived before use)

Expression of the self-induced electromotive force e.m.f

The electromotive force "e" is the negative of the derivative of the self flux:

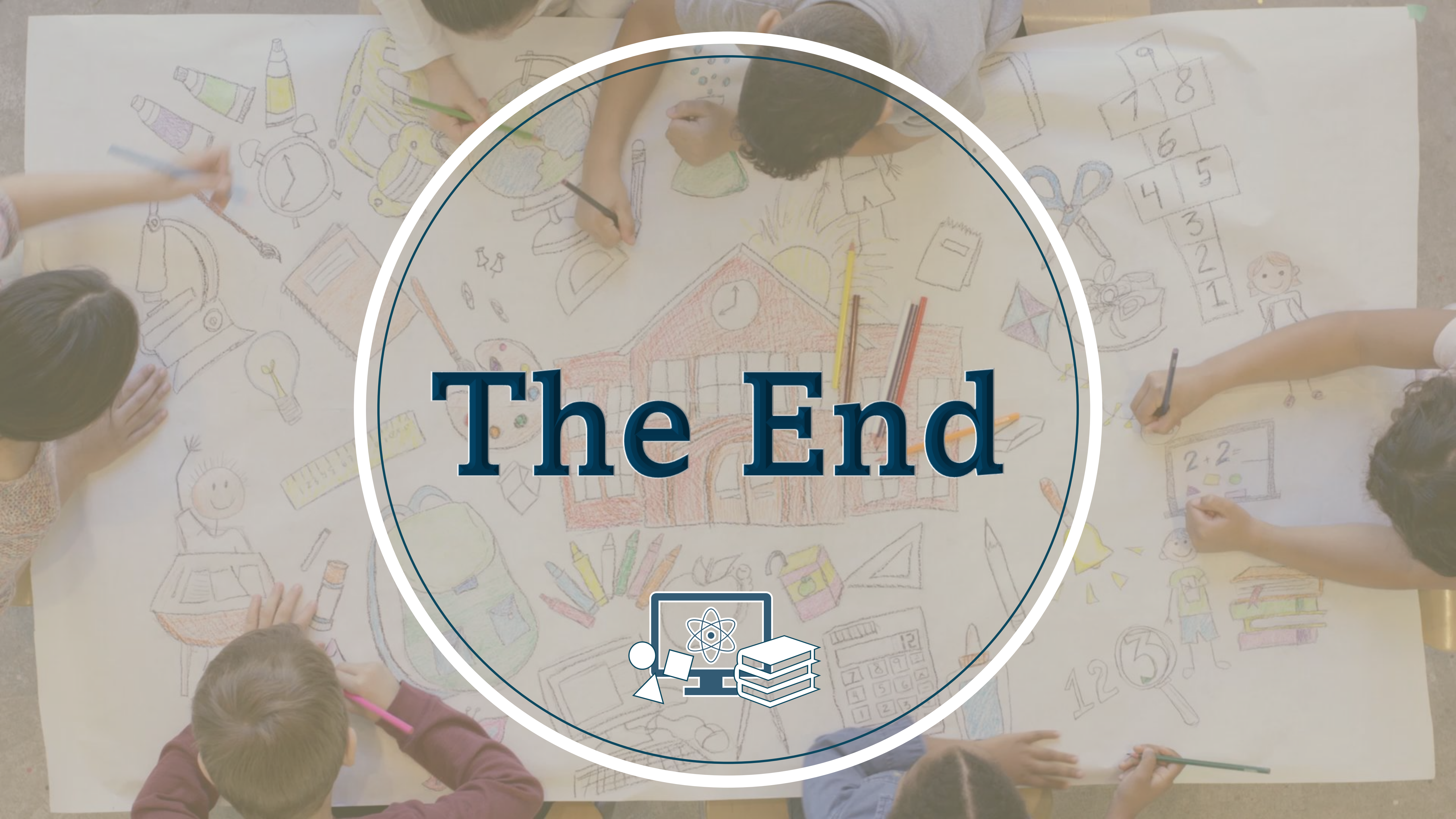


$$e = -\frac{d\emptyset}{dt}$$

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

$$e = -L\frac{di}{dt}$$

Since L >0 then e and $\frac{di}{dt}$ are of opposite signs



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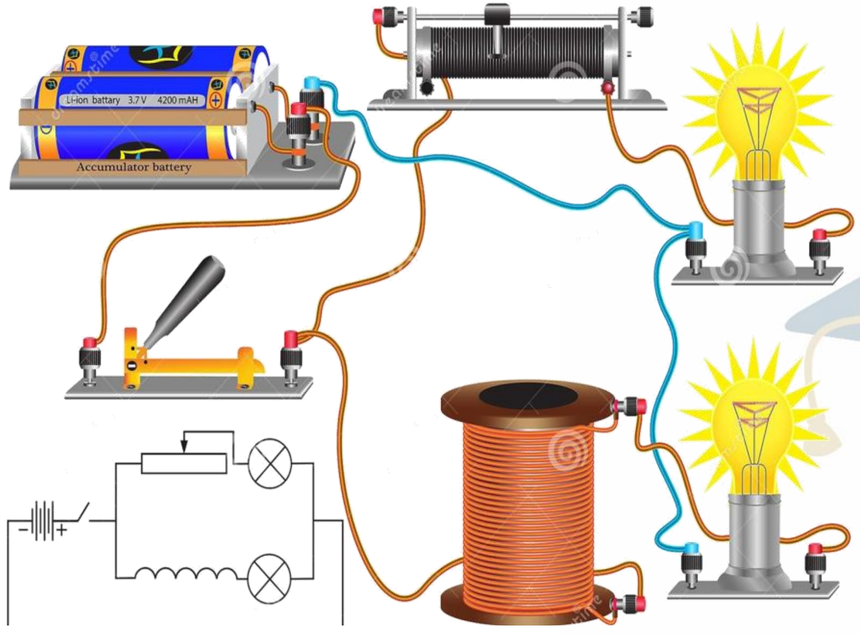
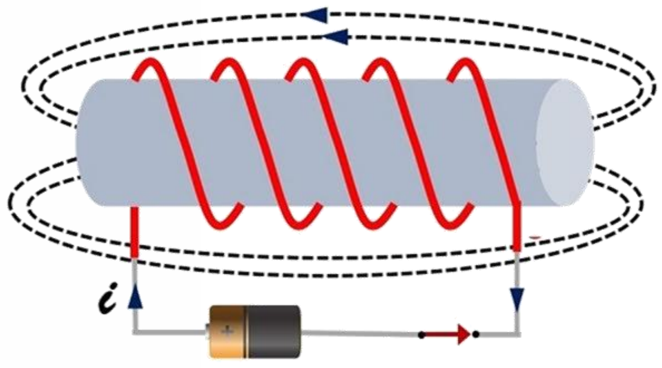


What is Self Induction?



Physics – Grade 12

Unit Two – Electricity

Chapter 9 – Self Induction

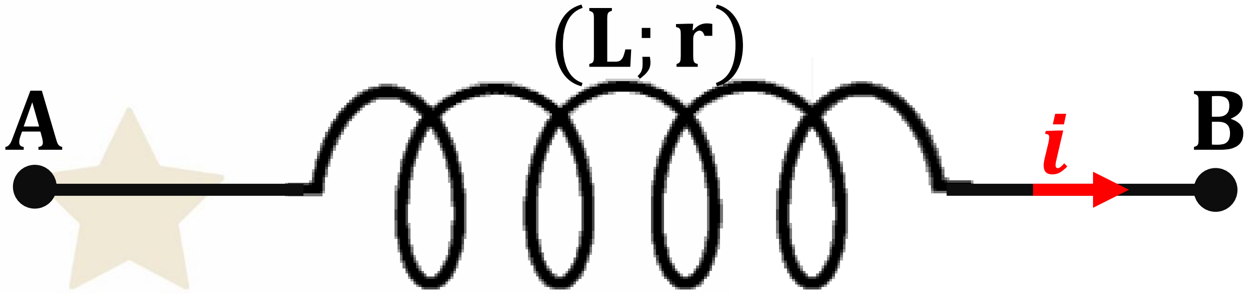
Prepared & Presented by: Mr. Mohamad Seif

OBJECTIVES

1. Derive the voltage of the coil
2. Specify the Role of the coil
3. Derive the distribution of the power in the circuit

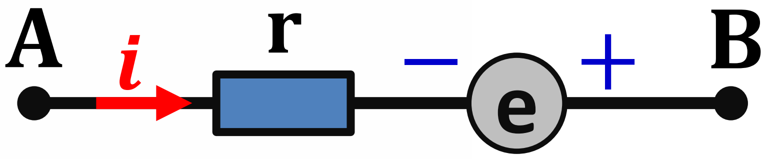
Voltage of the coil

Ohm's law case of a coil:



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

But $e = -L\frac{di}{dt}$



$$u_{AB} = ri - \left[-L\frac{di}{dt}\right]$$

$$u_{AB} = ri + L\frac{di}{dt}$$

Voltage of the coil

$$u_{AB} = ri + L\frac{di}{dt}$$

Special cases:

Case 1: Coil of negligible resistance ($r = 0$):

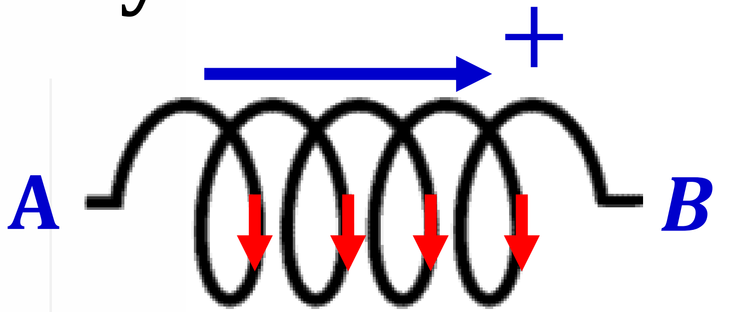
$$u_{AB} = L\frac{di}{dt}$$

Case 2: at steady state: The current is constant

$$\frac{di}{dt} = 0 \Rightarrow u_{AB} = ri$$

Role of the coil

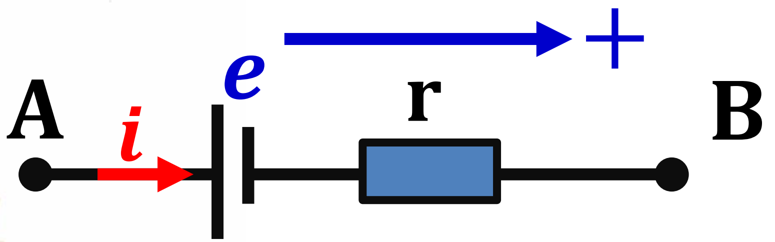
A coil carrying a current i is oriented positively from A to B:



Case 1: the coil acts as a receiver

The electric current increases with time:

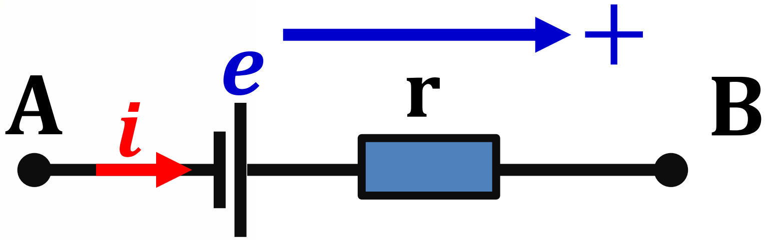
$$e = -L\frac{di}{dt} < 0 \quad \Rightarrow \quad e.i < 0$$



Case 2: the coil acts as a generator

The electric current decreases with time:

$$e = -L\frac{di}{dt} > 0 \quad \Rightarrow \quad e.i > 0$$

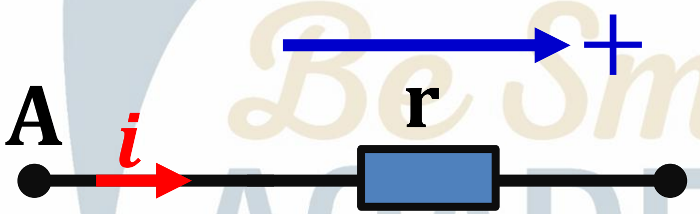


Role of the coil

Case 3: the coil acts as a resitor

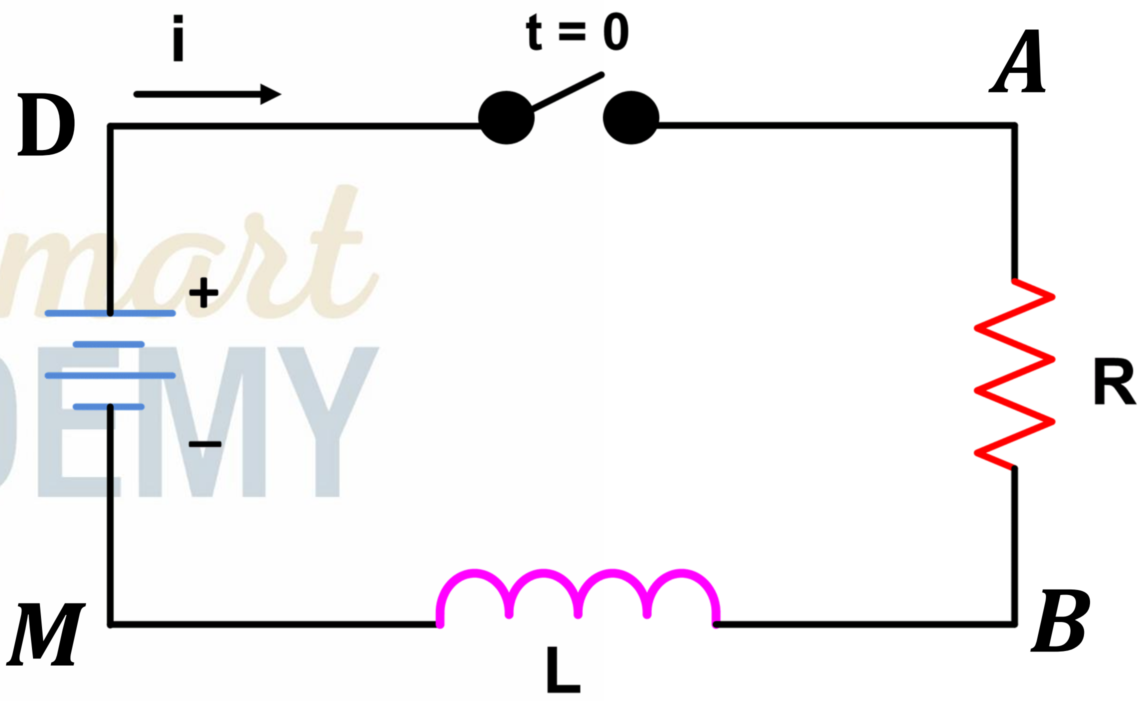
The electric current is constant:

$$e = -L\frac{di}{dt} = 0 \Rightarrow u_{AB} = ri \Rightarrow \text{Steady state}$$



Role of the coil

Application 1: A coil of inductance $L = 10mH$ and of internal resistance $r = 5\Omega$ is connected in series with a resistor of resistance $R = 15\Omega$, a switch K, and an ideal battery of electromotive force $E = 12V$ as shown in the adjacent figure.



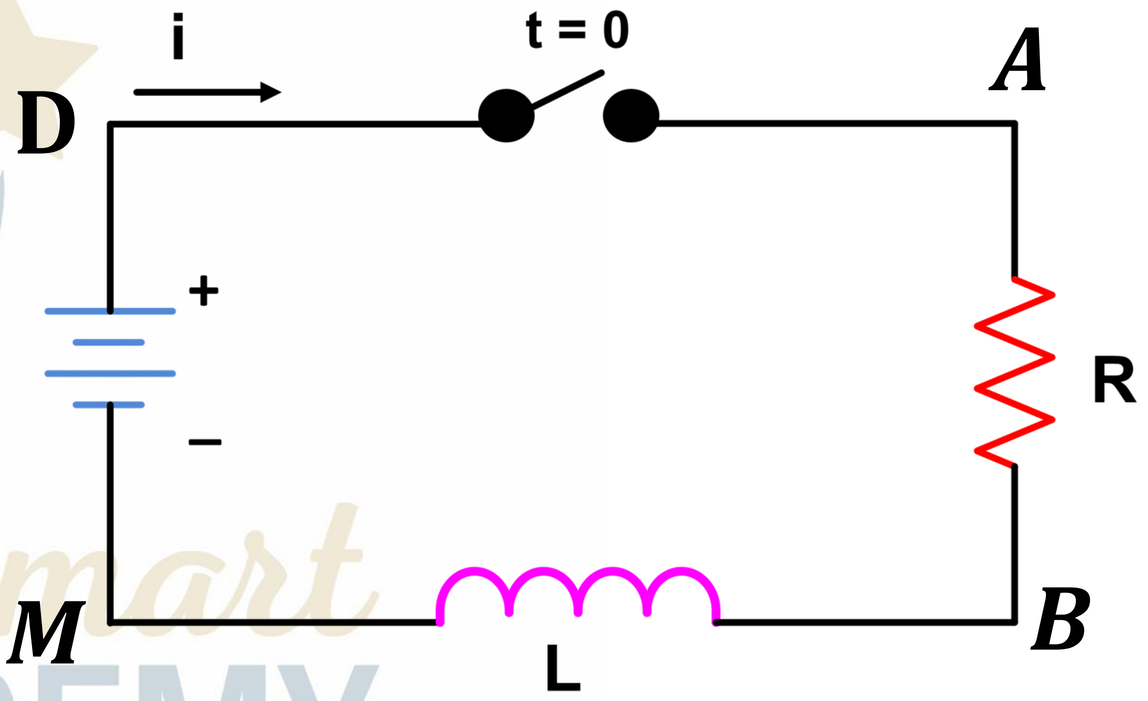
1) At the instant $t_0 = 0$:

a. Indicate the value of the current i in the circuit.

At $t_0 = 0$, $i_0 = 0$

Role of the coil

b. Apply the law of addition of voltage to determine the voltage u_{BM} across the coil.



$$u_{DM} = u_{DA} + u_{AB} + u_{BM}$$

$$E = 0 + Ri + u_{BM}$$

$$E = 0 + R(0) + u_{BM}$$

$$u_{BM} = E = 12V$$

c. Calculate the value of the self-induced e.m.f "e".

$$u_{BM} = ri - e \Rightarrow 12V = r(0) - e \Rightarrow e = -12V$$

Role of the coil

d. Deduce the value of $\frac{di}{dt}$

$$e = -L\frac{di}{dt}$$

$$-12 = -(10 \times 10^{-3})\frac{di}{dt}$$

$$\frac{di}{dt} = \frac{-12}{-10 \times 10^{-3}}$$

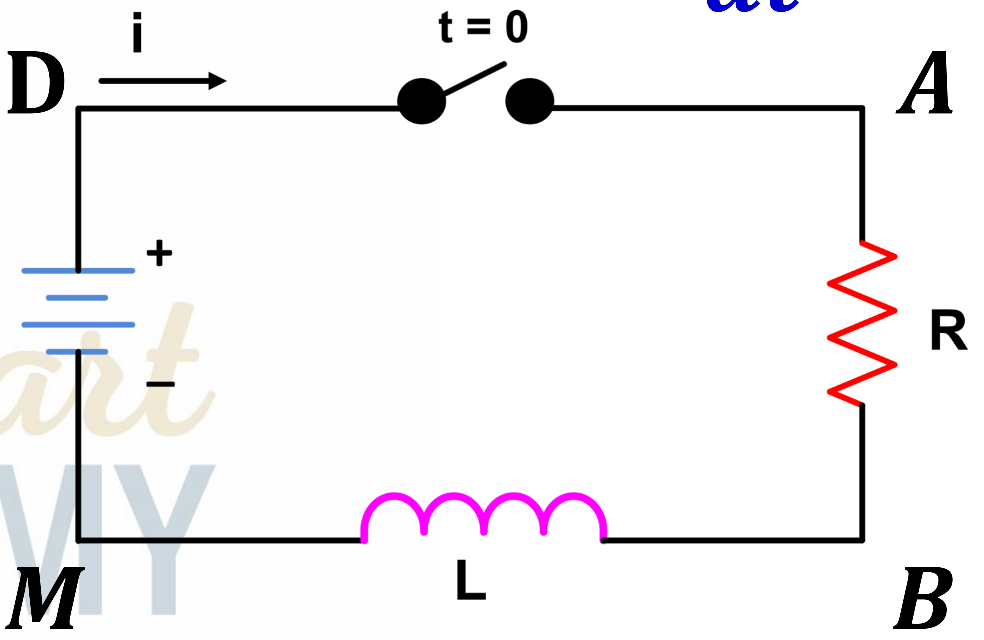
$$\frac{di}{dt} = 1200 A/s$$

Role of the coil

2)At instant t_1, $\frac{di}{dt} = 441.455A/s$, determine the current i.

$$u_{DM} = u_{DA} + u_{AB} + u_{BM} \Rightarrow E = 0 + Ri + ri + L\frac{di}{dt}$$

$$E = (R + r)i + L\frac{di}{dt}$$



$$12 = (15 + 5)i + 10 \times 10^{-3} \times 441.455$$

$$12 = 20i + 4.41455$$

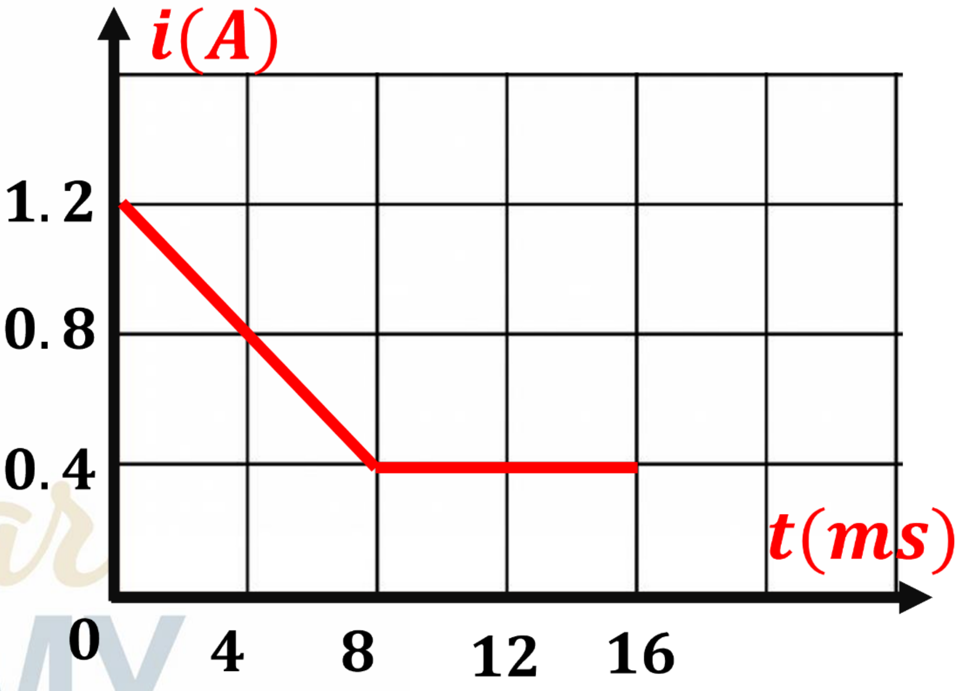
$$12 - 4.41455 = 20i$$

$$7.58545 = 20i \Rightarrow i = 0.379A$$

Application 2:

A coil of inductance $L = 20mH$ carries an electric current whose value varies with time according to the graph below:

1) Specify the name of the phenomenon taking place in the coil during the time interval [0, 8s]

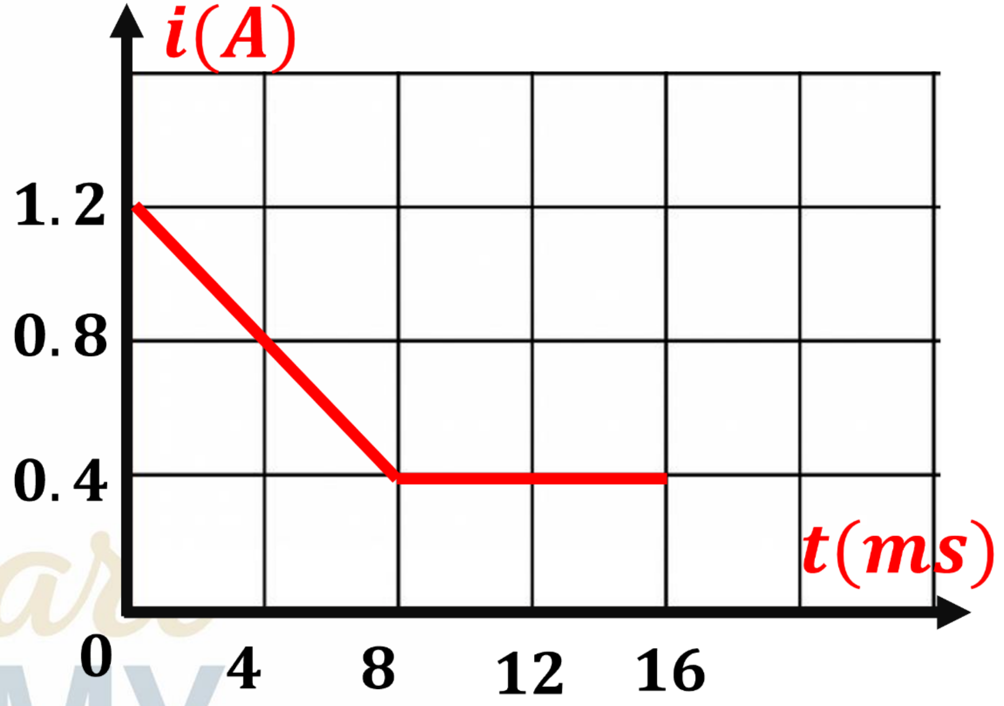


During this interval of time, the current is variable.

Then, the coil is crossed by a varying self flux. Therefore, self induction is taking place

Role of the coil

2)Specify the role of the coil in each interval of time.



For the time interval [0, 8s]

The current decreases with time:

$$\frac{di}{dt} < 0 \quad \Rightarrow \quad e = -L\frac{di}{dt} > 0$$

$$e.i > 0$$

The coil acts as a generator

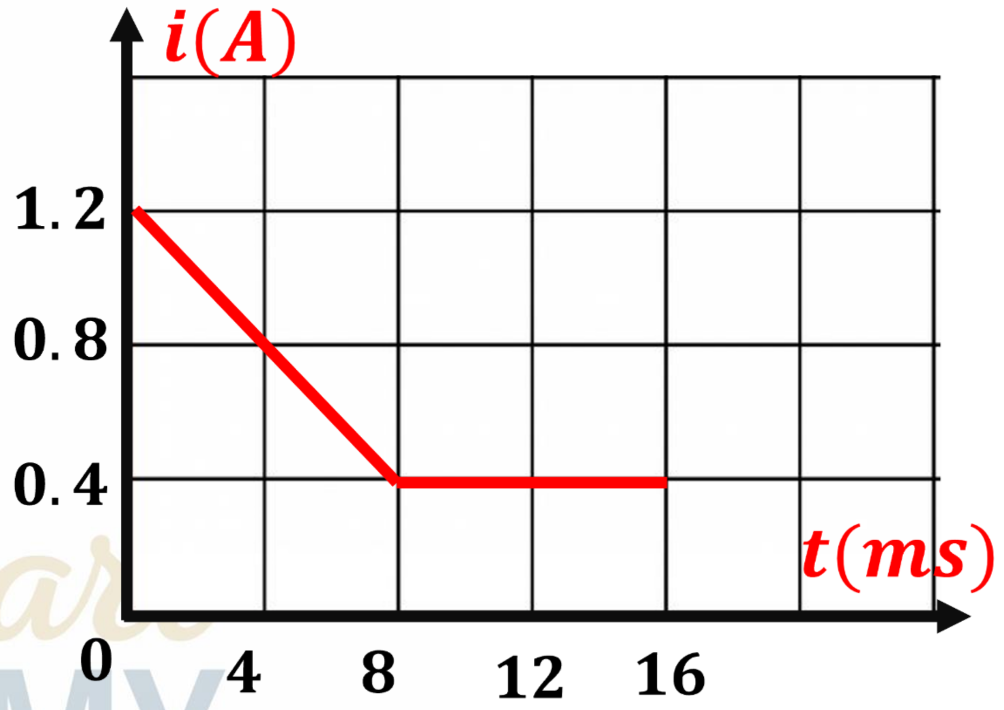
Role of the coil

2)Specify the role of the coil in each interval of time.

For the time interval [8s, 16s]

The current is constant:

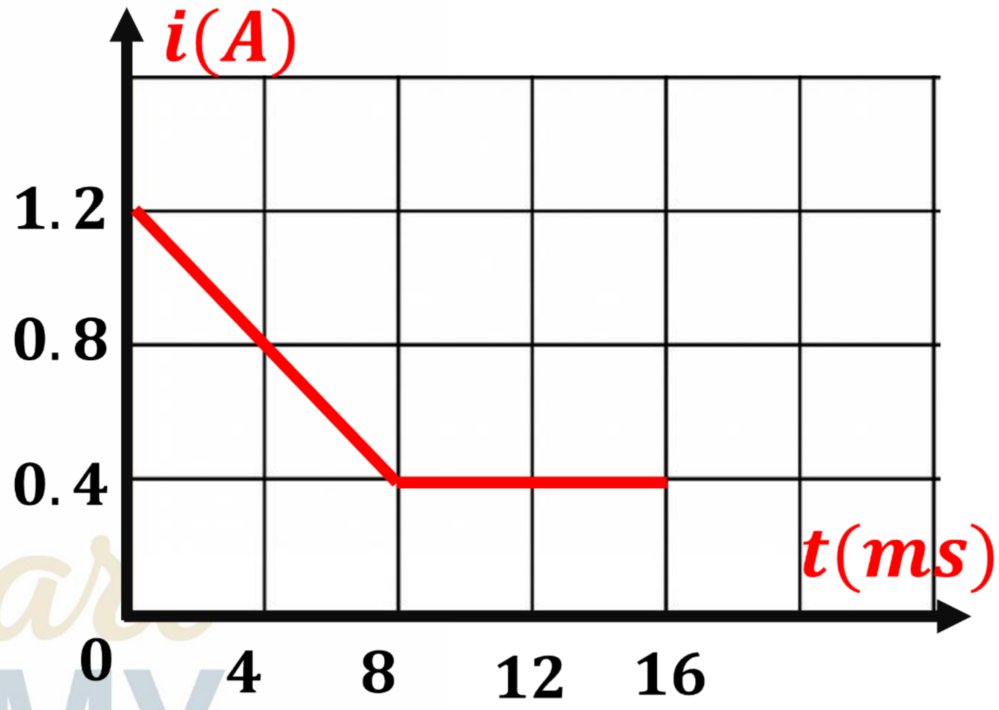
$$\frac{di}{dt} = 0 \Rightarrow e = -L\frac{di}{dt} = 0$$



The coil acts as a resistor

Role of the coil

3) Determine the value of the electromotive force "e" during each interval of time.



For the time interval [0, 8s]

$\frac{di}{dt}$ is the slope of the St. line

$$\frac{di}{dt} = \frac{0.4 - 1.2}{(8 - 0) \times 10^{-3}} = -100A/s$$

$$e = -L\frac{di}{dt} = -20 \times 10^{-3} \times (-100)$$ ⇒ $$e = 2V$$

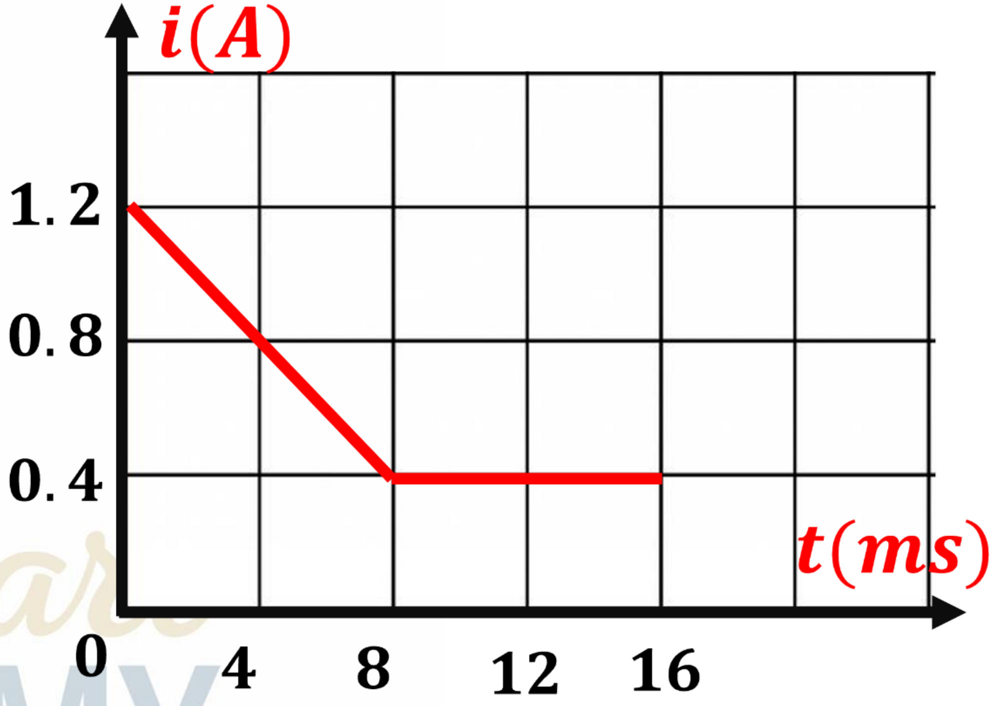
Role of the coil

For the time interval [8s, 16s]

The current is constant then $\frac{di}{dt} = 0$

$$e = -L\frac{di}{dt} = -20 \times 10^{-3} \times (0)$$

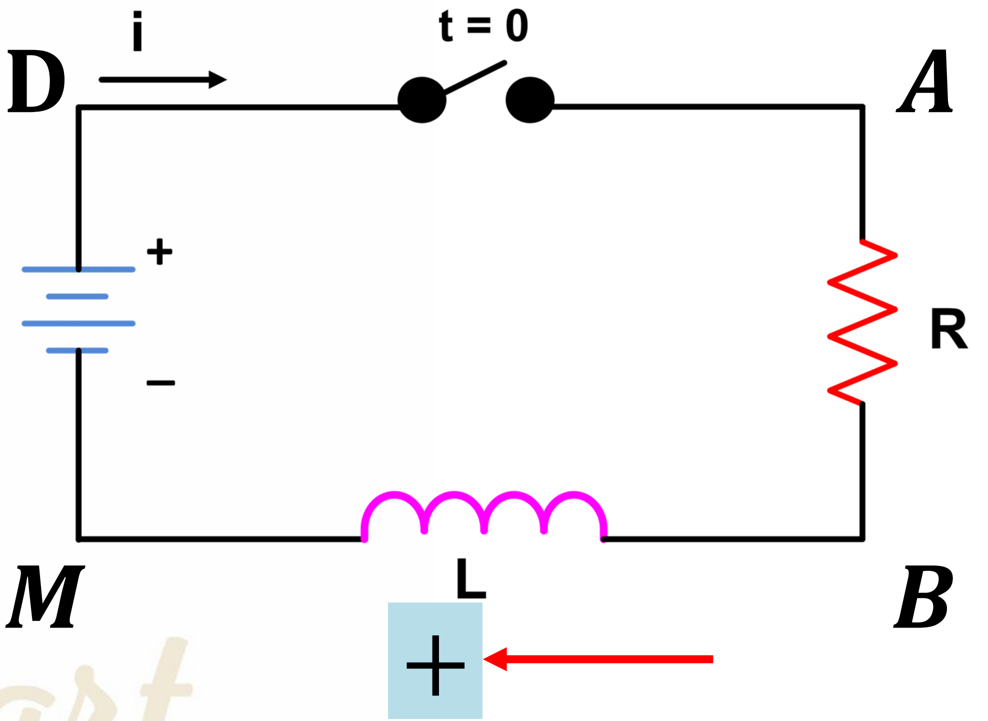
$$e = 0V$$



Power distribution in the circuit

A coil is oriented positively as shown:

$$u_{BM} = ri + L\frac{di}{dt}$$



Multiply the equation by (i)

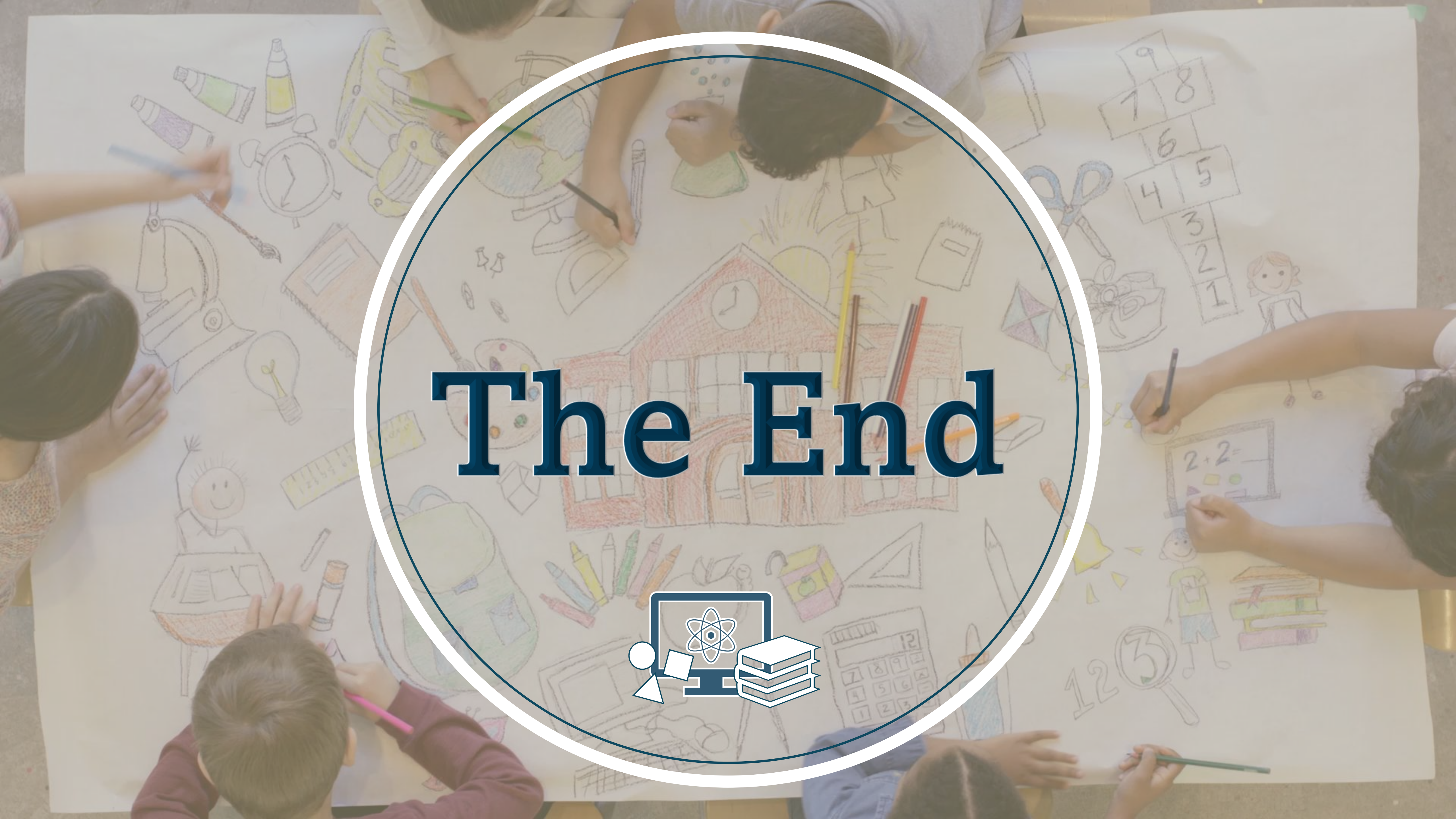
$$i.u_{BM} = ri^2 + Li\frac{di}{dt}$$

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

Power distribution in the circuit

$$i.u_{BM} = ri^2 + Li\frac{di}{dt}$$

- $P_{total} = i.u_{BM}$: is the total electric power received by the coil during the growth process.
- $P_{lost} = ri^2$: lost power due to Joule's effect in the coil
- $P_{magnetic} = Li\frac{di}{dt}$: magnetic power (rate of storing magnetic energy)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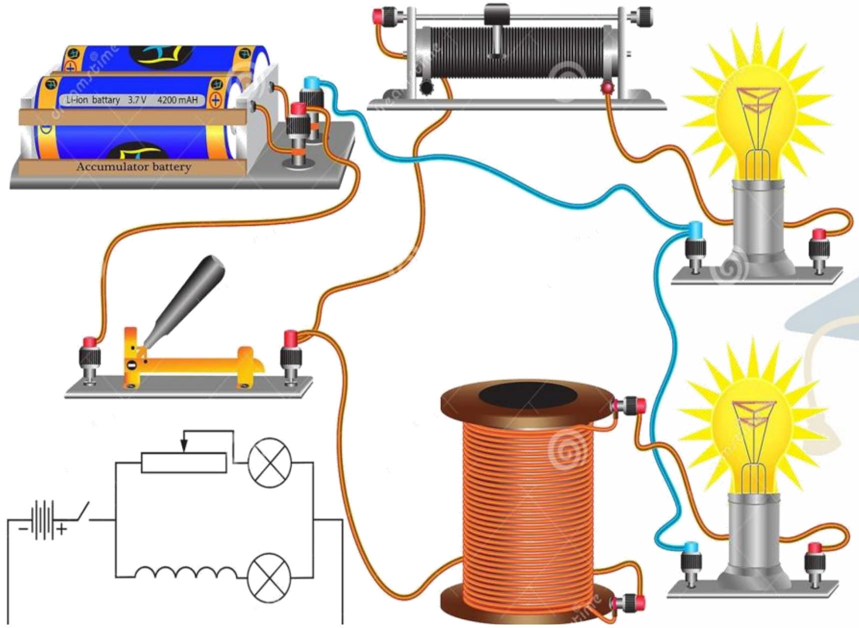
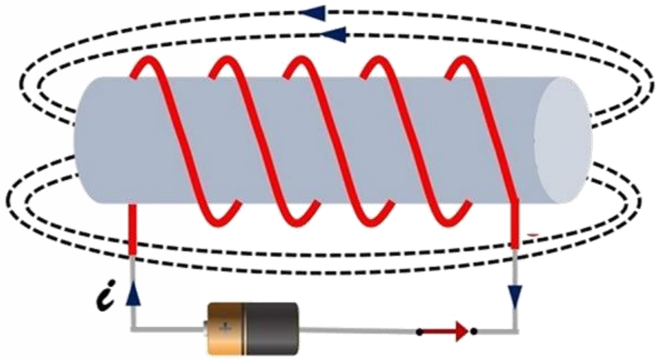


What is Self Induction?



Physics – Grade 12

Unit Two – Electricity

Chapter 9 – Self Induction

Prepared & Presented by: Mr. Mohamad Seif

OBJECTIVES

1 **Derive the expression of the magnetic energy**

Magnetic energy stored in the coil.

The expression of the instantaneous power of an energy conversion is:

$$P = \frac{dW}{dt} \quad \Rightarrow \quad dW = Pdt$$

$$\int dW = \int Pdt$$

$$W = \int Li\frac{di}{dt}dt$$

Magnetic energy stored in the coil.

$$W = \int Li\frac{di}{dt}dt$$

$$W = \int Lidi$$

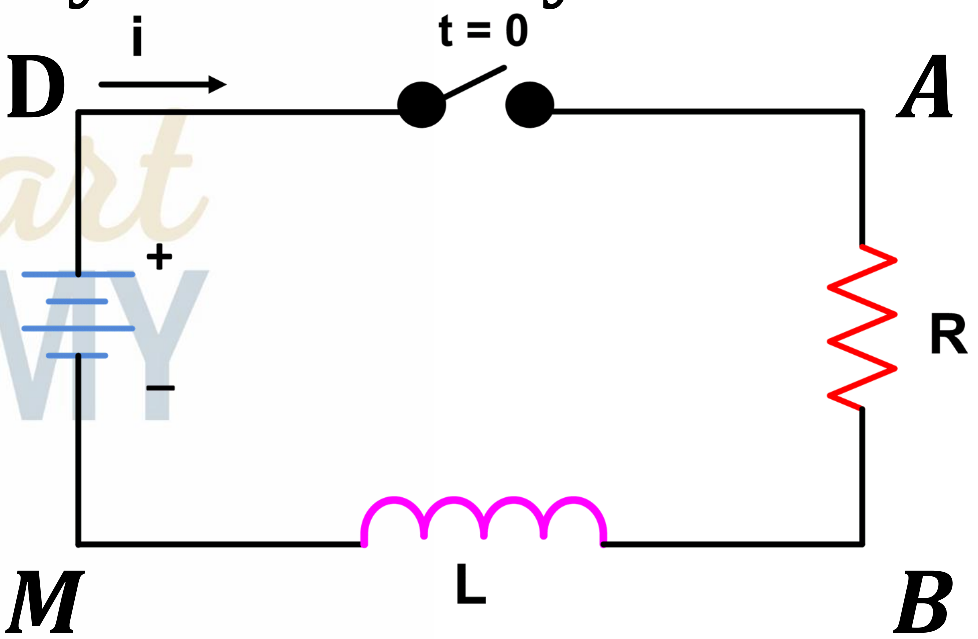
$$W = \frac{1}{2}Li^2$$

Magnetic energy stored in the coil.

Application 3: The circuit below includes a coil of inductance $L = 1mH$ and internal resistance $r = 2\Omega$, a resistor of resistance $R = 8\Omega$, an ideal battery of electromotive force $E = 10V$, and a switch K.

1.Show that at $t_0 = 0$ the current sent by the battery is zero.

$$W = \frac{1}{2}Li^2$$



At $t_0 = 0$, the magnetic energy stored in the coil is zero then:

$$0 = \frac{1}{2}L{i_0}^2 \Rightarrow i_0 = 0$$

Magnetic energy stored in the coil.

2. Calculate the value of the maximum current I_m at steady state.

At steady state: $I_m = \frac{E}{r+R}$ ➡ $I_m = \frac{10}{2+8}$

$$I_m = 1A$$

3. Deduce the maximum magnetic energy stored in the coil.

$W_{max} = \frac{1}{2}Li^2$ ➡ $W_{max} = \frac{1}{2}(1\times10^{-3})(1)^2$

$$W_{max} = 5\times10^{-4}J$$

Magnetic energy stored in the coil.

4. The electric energy delivered by the battery between t_0 and t_1 is $8W_{max}$. Determine the dissipated energy in the circuit due to Joule's effect.

$$W_g = W_{max} + W_{heat} \Rightarrow 8W_{max} = W_{max} + W_{heat}$$

$$W_{heat} = 7W_{max}$$

$$W_{heat} = 7 \times 5 \times 10^{-4}$$

$$W_{heat} = 35 \times 10^{-4} J$$

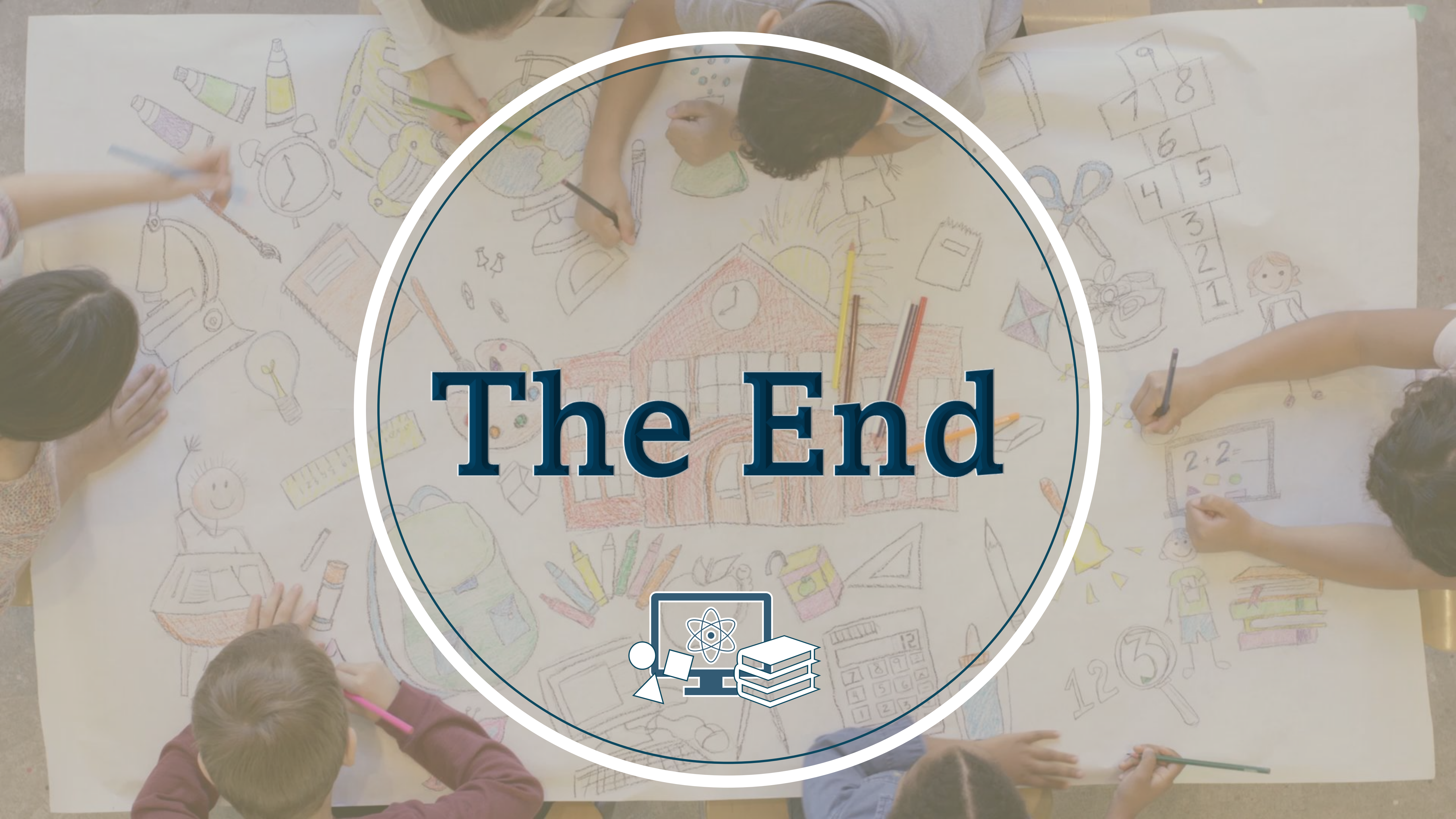
Magnetic energy stored in the coil.

5. Specify the role of the coil between $t_0 = 0$ and t_1.

The current flowing in the coil increases from zero to its maximum value at the steady state:

Then the coil is storing magnetic energy:

Then the coil acts as a receiver.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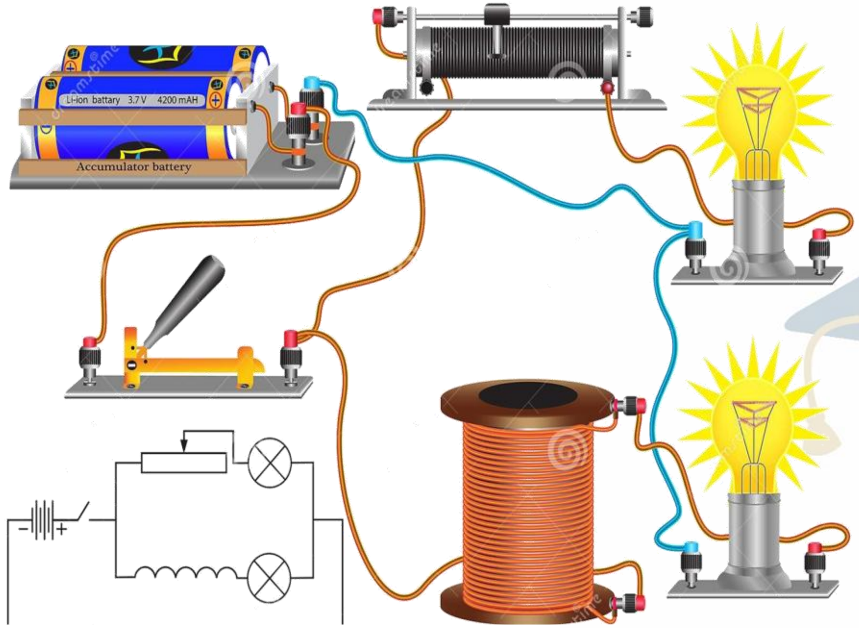

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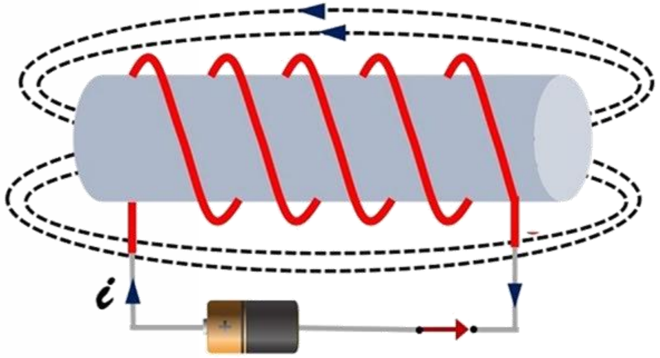


Physics – Grade 12

Unit Two – Electricity

Chapter 9 – Self Induction

Prepared & Presented by: Mr. Mohamad Seif

OBJECTIVES

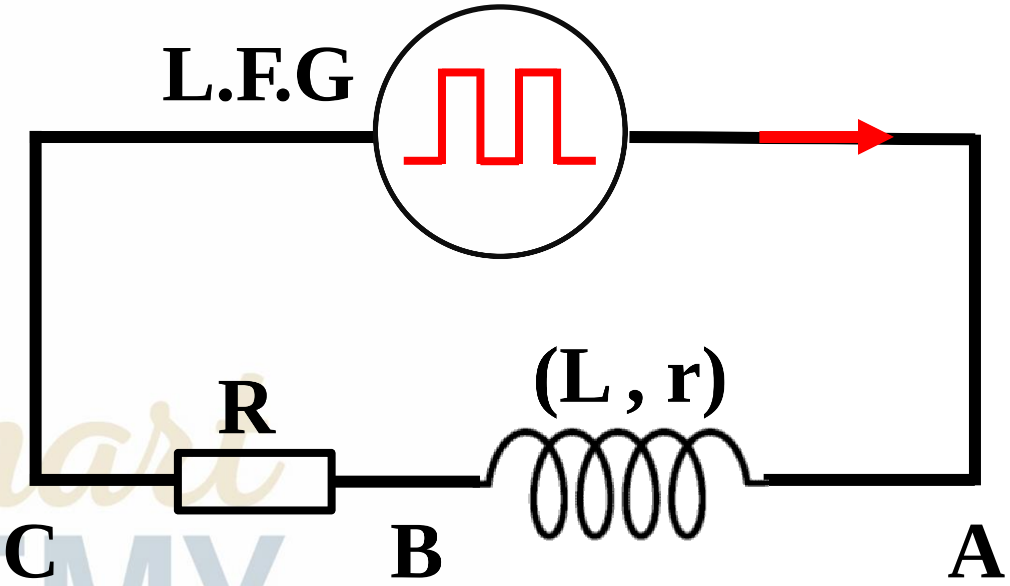
1 **study the growth of the current in RL circuit**

Theoretical study of the growth of the current in RL circuit.

Consider the following circuit:

The Voltage u_{AC} of the generator is square voltage:

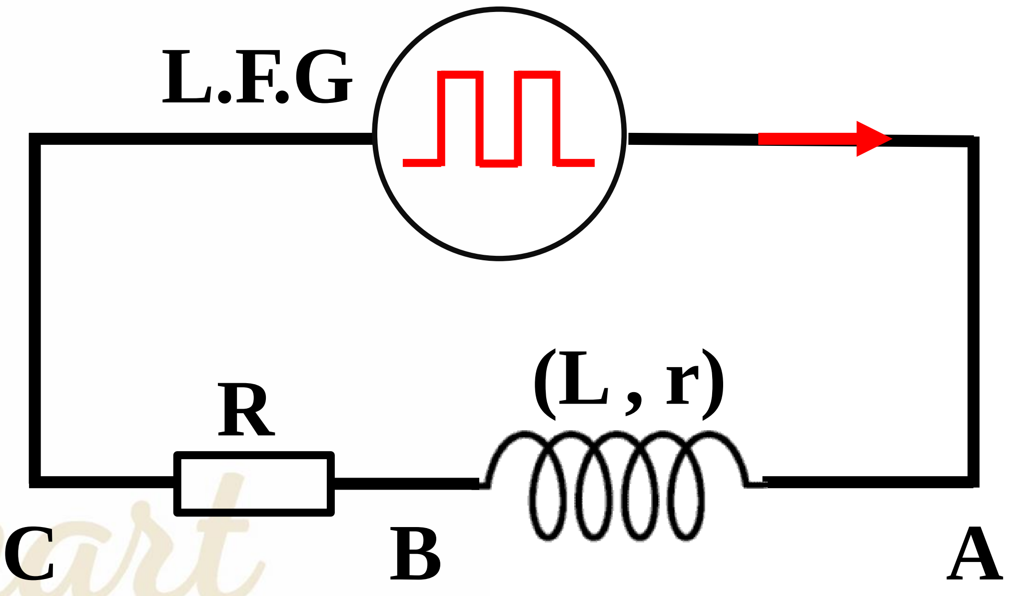
$$u_{AC} = \begin{cases} u_{AC} = E \ldots\ldots 0 < t < \frac{T}{2} \\ u_{AC} = 0 \ldots\ldots \frac{T}{2} < t < T \end{cases}$$



Theoretical study of the growth of the current in RL circuit.

Growth of the current : $u_{AC} = E \dots \dots 0 < t < \frac{T}{2}$

Apply law of addition of voltages:



$$u_{AC} = u_{AB} + u_{BC}$$

$$E = ri + L\frac{di}{dt} + Ri$$

$$E = (R + r)i + L\frac{di}{dt}$$

Differential equation in terms of current *i*

Theoretical study of the growth of the current in RL circuit.

The solution of the differential equation is: $i = I(1 - e^{-\frac{t}{\tau}})$

Where $\tau = \frac{L}{(r+R)}$ And $I = \frac{E}{(r+R)}$

At $t = 0$:

$$i = I\left(1 - e^{-\frac{0}{\tau}}\right)$$

$$i = I(1 - 1)$$

$$i = 0$$

Theoretical study of the growth of the current in RL circuit.

At $t = \tau$

$$i = I\left(1 - e^{-\frac{\tau}{\tau}}\right)$$

$$i = I\left(1 - e^{-1}\right) \quad \Rightarrow \quad i = I(1 - 0.37)$$

$$i = 0.63I = 63\%I$$

$t = \tau$: Time constant is the interval of time after which the current reaches 63% of its max value during growth process.

Theoretical study of the growth of the current in RL circuit.

At $t = 5\tau$

$$i = I\left[1 - e^{-\frac{5\tau}{\tau}}\right]$$

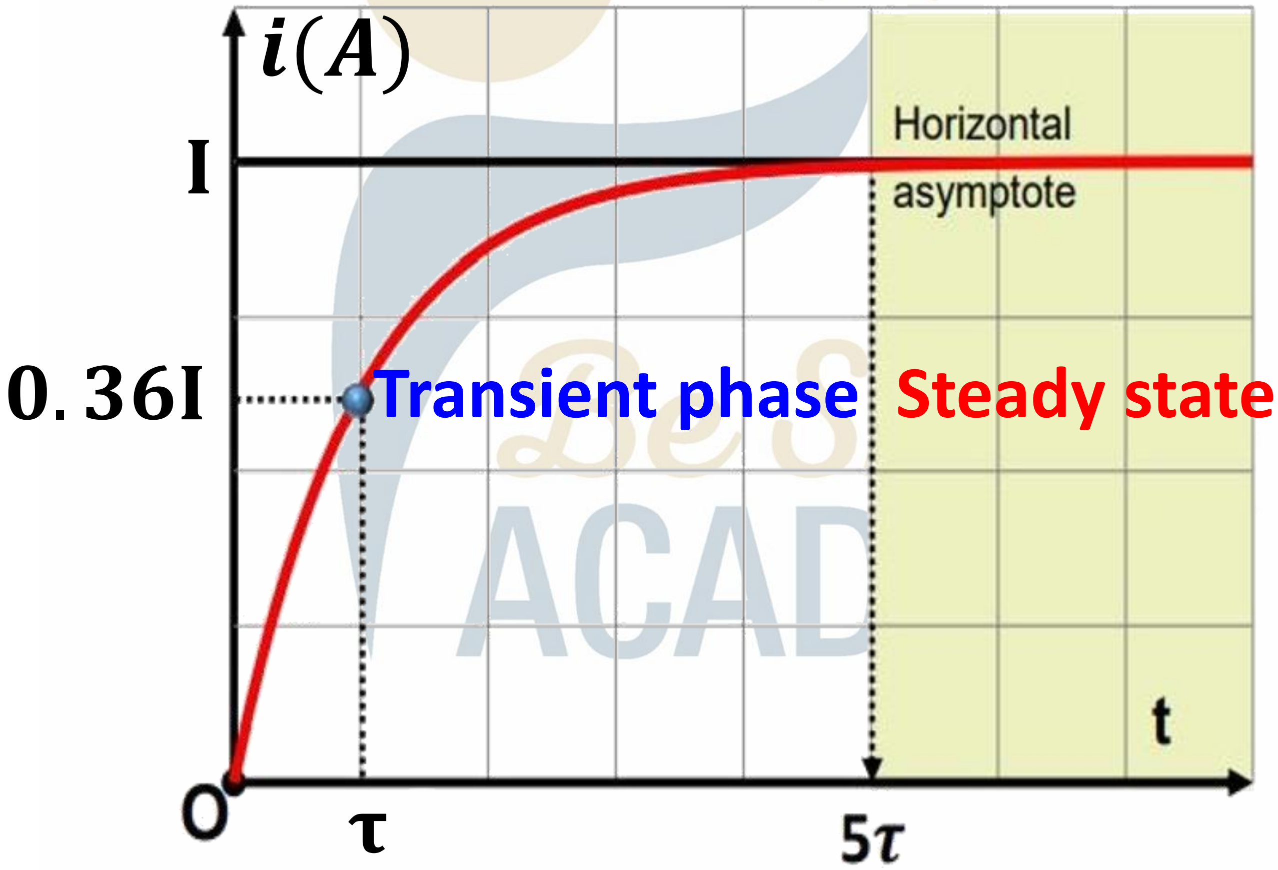
$$u_C = I\left(1 - e^{-5}\right) \Rightarrow i = I(1 - 0.0067)$$

$$i = 0.99I \approx I$$

At $t = 5\tau$, the steady state is attained and the coil acts as a resistor of resistance r.

Theoretical study of the growth of the current in RL circuit.

$t = 0$	$t = \tau$	$t = 5\tau$
$i = 0$	$i = 0.63I$	$i = I$



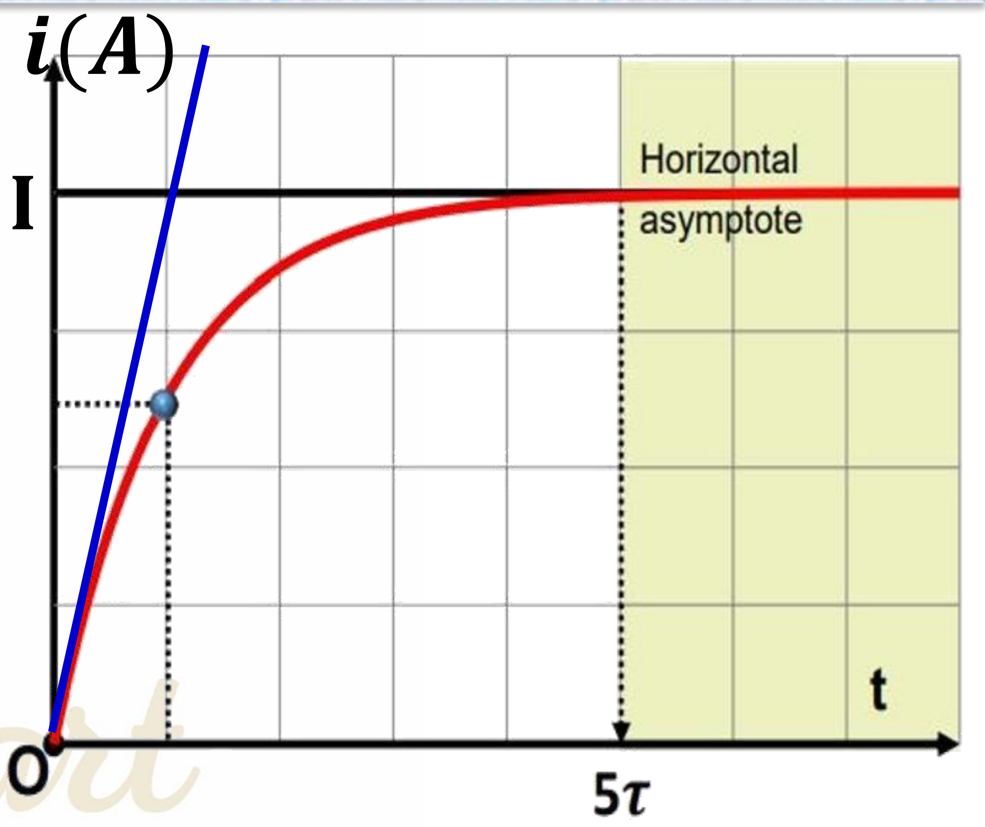
Theoretical study of the growth of the current in RL circuit.

Time constant using Tangent method:

First method:

Tangent to $i = f(t)$ at $t = 0$ is drawn

The slope of the tangent at $t = 0$ is $\frac{di}{dt}$



$$i = I(1 - e^{-\frac{t}{\tau}}) \Rightarrow \frac{di}{dt} = I\left[\frac{1}{\tau}\right]e^{-\frac{t}{\tau}}$$

At $t = 0$:

$$\frac{di}{dt} = I\left[\frac{1}{\tau}\right]e^{-\frac{0}{\tau}} \Rightarrow \text{slope} = \frac{di}{dt} = \frac{I}{\tau}$$

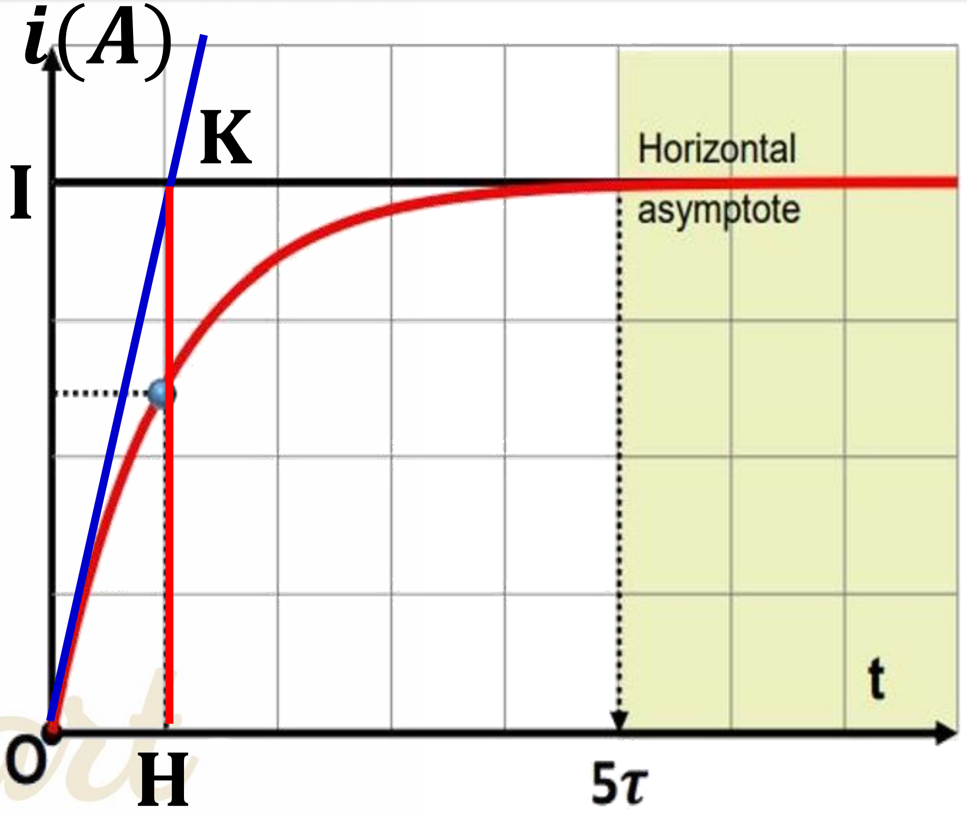
Theoretical study of the growth of the current in RL circuit.

In Δ OHK: $tan(\alpha) = \frac{HK}{OH} = \frac{I}{OH}$

$slope\ of\ tangent$

$\frac{I}{\tau} = \frac{I}{OH}$

$\tau = OH$



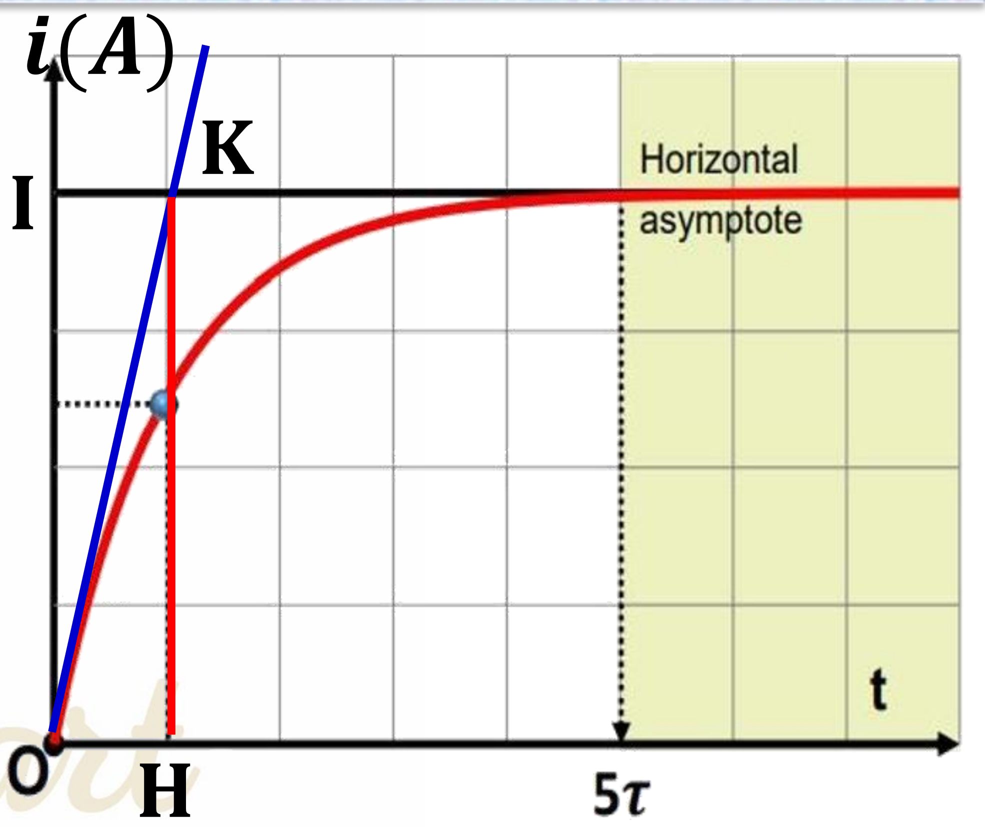
Therefore, the tangent to i at $t = 0$ meets the asymptote in a point of abscissa τ

Theoretical study of the growth of the current in RL circuit.

Second method:

The equation of tangent to i at $t = 0$ is: $i = at$

Where a is the slope of the tangent at $t = 0$



$$i = I(1 - e^{-\frac{t}{\tau}}) \Rightarrow \frac{di}{dt} = I\left[\frac{1}{\tau}\right]e^{-\frac{t}{\tau}}$$

At $t = 0$: $$\frac{di}{dt} = I\left[\frac{1}{\tau}\right]e^{-\frac{0}{\tau}} \Rightarrow \text{slope} = \frac{di}{dt} = \frac{I}{\tau}$$

Theoretical study of the growth of the current in RL circuit.

The equation of tangent is: $i = at$

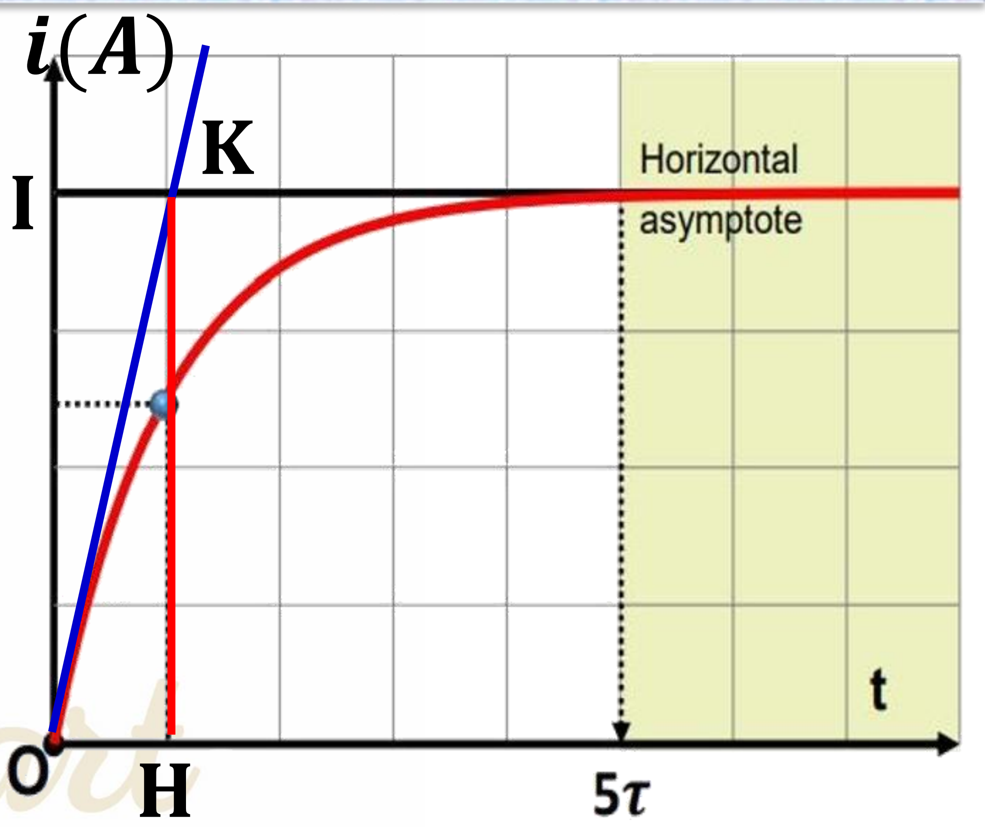
$$i = \frac{I}{\tau} . t$$

The equation of asymptote to i is: $i = I$.

The tangent and asymptote intersect at point K. Then:

$$i_{tangent} = i_{asymptote}$$

$$\frac{I}{\tau} . t = I \quad \Rightarrow \quad t = \tau$$



Therefore, the tangent to i=f(t) at t=0 meets the asymptote in a point of abscissa τ.

Theoretical study of the growth of the current in RL circuit.

Determination of I and τ:

$$E = R_{eq}i + L\frac{di}{dt}$$

$$i = I\left(1 - e^{-\frac{t}{\tau}}\right)$$

$$\frac{di}{dt} = \frac{I}{\tau}.e^{-\frac{t}{\tau}}$$

Substitute i and $\frac{di}{dt}$ in differential equation.

$$E = R_{eq}I\left(1 - e^{-\frac{t}{\tau}}\right) + L.\frac{I}{\tau}.e^{-\frac{t}{\tau}}$$

$$E = R_{eq}I - R_{eq}Ie^{-\frac{t}{\tau}} + \frac{LI}{\tau}.e^{-\frac{t}{\tau}}$$

Theoretical study of the growth of the current in RL circuit.

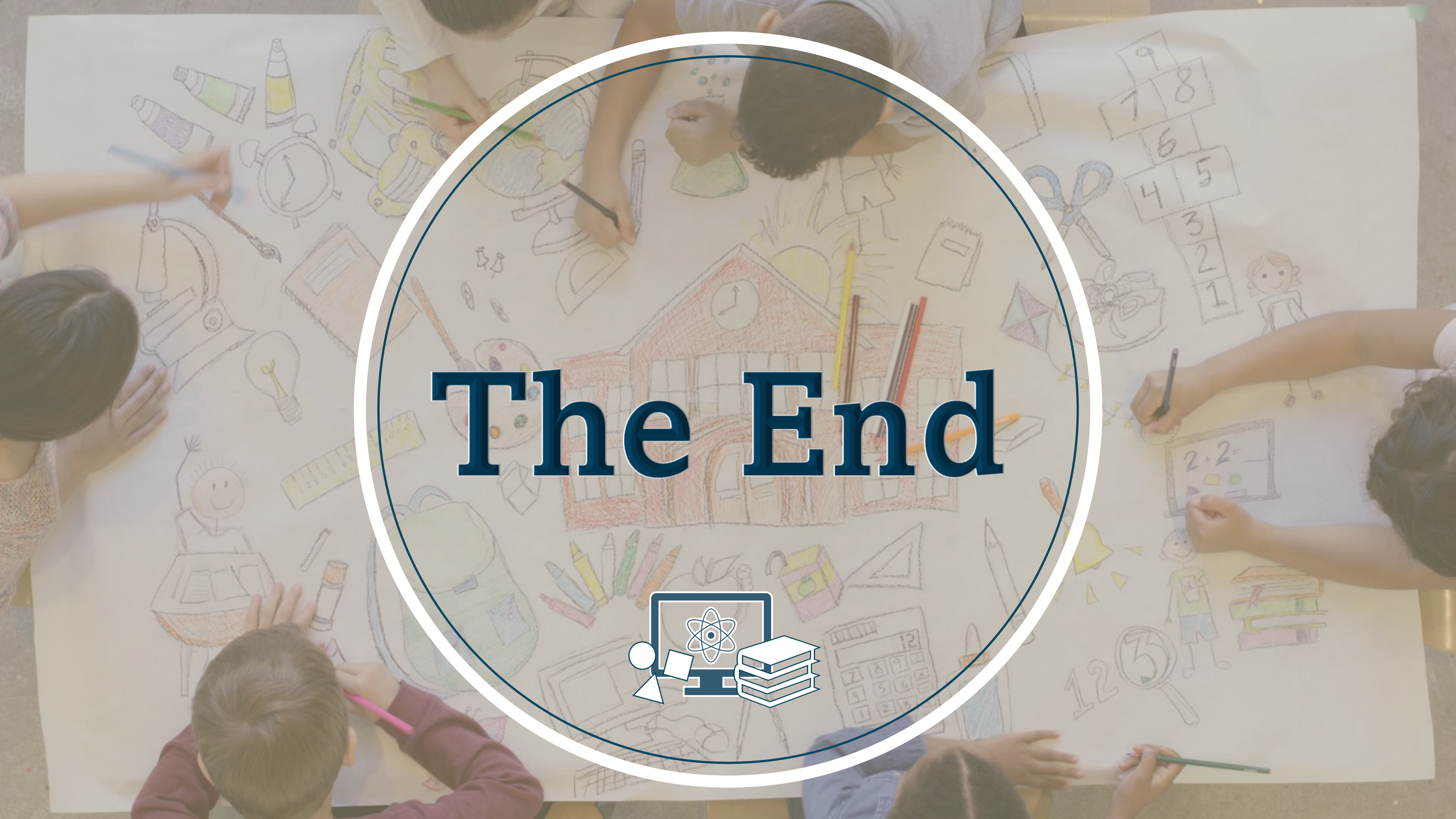
$$E = R_{eq}I - R_{eq}Ie^{-\frac{t}{\tau}} + \frac{LI}{\tau}.e^{-\frac{t}{\tau}}$$

$$E + R_{eq}Ie^{-\frac{t}{\tau}} = R_{eq}I + \frac{LI}{\tau}.e^{-\frac{t}{\tau}}$$

By identification we get:

$$E = R_{eq}I \Rightarrow I = \frac{E}{R_{eq}}$$

$$R_{eq}I = \frac{LI}{\tau} \Rightarrow \tau = \frac{L}{R_{eq}}$$



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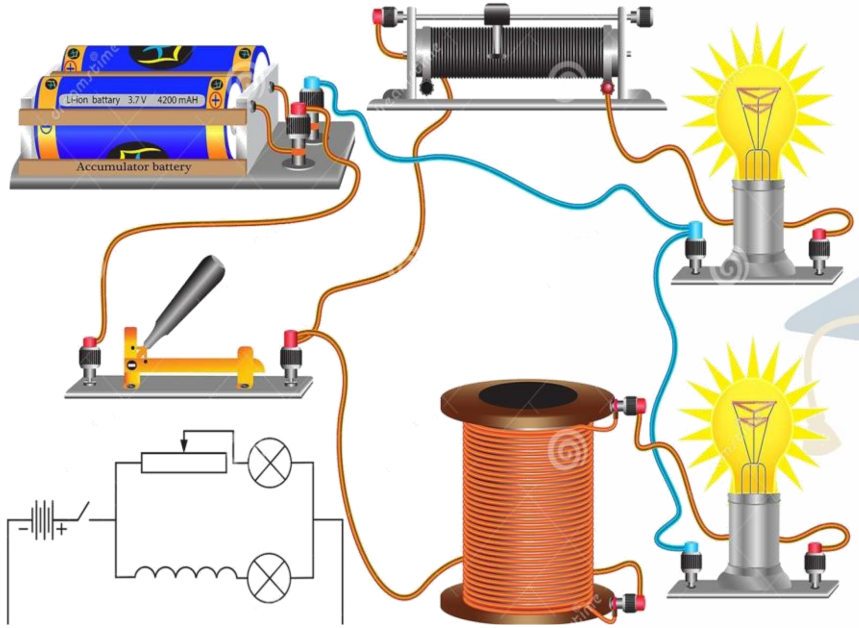
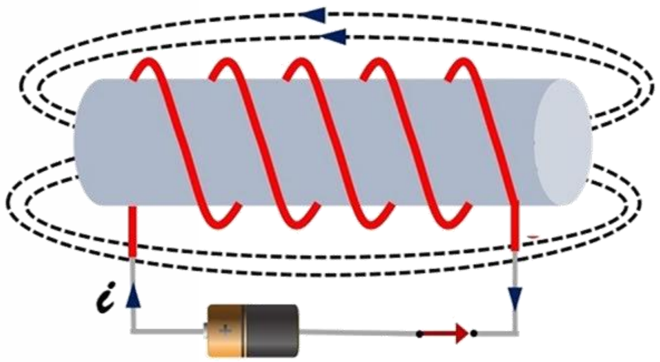


What is Self Induction?



Physics – Grade 12

Unit Two – Electricity

Chapter 9 – Self Induction

Prepared & Presented by: Mr. Mohamad Seif

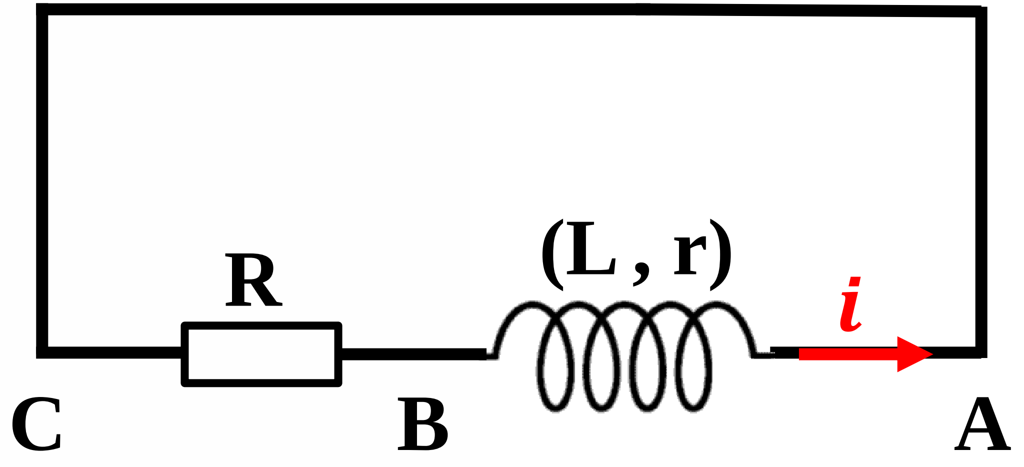
OBJECTIVES

1. Study the decay of the current in RL circuit

Theoretical study of the decay of the current.

Decay of the current: $\left[u_g = 0\right]\ldots\ldots \frac{T}{2} < t < T$

Apply law of addition of voltages:



$$u_{AC} = u_{AB} + u_{BC}$$

$$0 = u_{AB} + u_{BC}$$

$$0 = ri + L\frac{di}{dt} + Ri$$

$$0 = (R + r)i + L\frac{di}{dt}$$

$$R_{eq} = (R + r)$$

Differential equation in terms of current i

Theoretical study of the decay of the current.

The solution of the differential equation is:

$$i = Ie^{-\frac{t}{\tau}}$$

Where $\tau = \frac{L}{(r+R)}$ And $I = \frac{E}{(r+R)}$

At $t = 0$:

$$i = I.e^{-\frac{0}{\tau}}$$

$$i = I(e^{0})$$

$$i = I$$

Theoretical study of the decay of the current.

At $t = \tau$

$$i = I.e^{-\frac{\tau}{\tau}}$$

$$i = I.e^{-1} \Rightarrow i = 0.37I$$

$$i = 0.37I = 37\%I$$

$t = \tau$: **Time constant is the interval of time after which the current reaches 37% of its max value during decay process.**

Theoretical study of the decay of the current.

At $t = 5\tau$

$$i = I.e^{-\frac{5\tau}{\tau}}$$

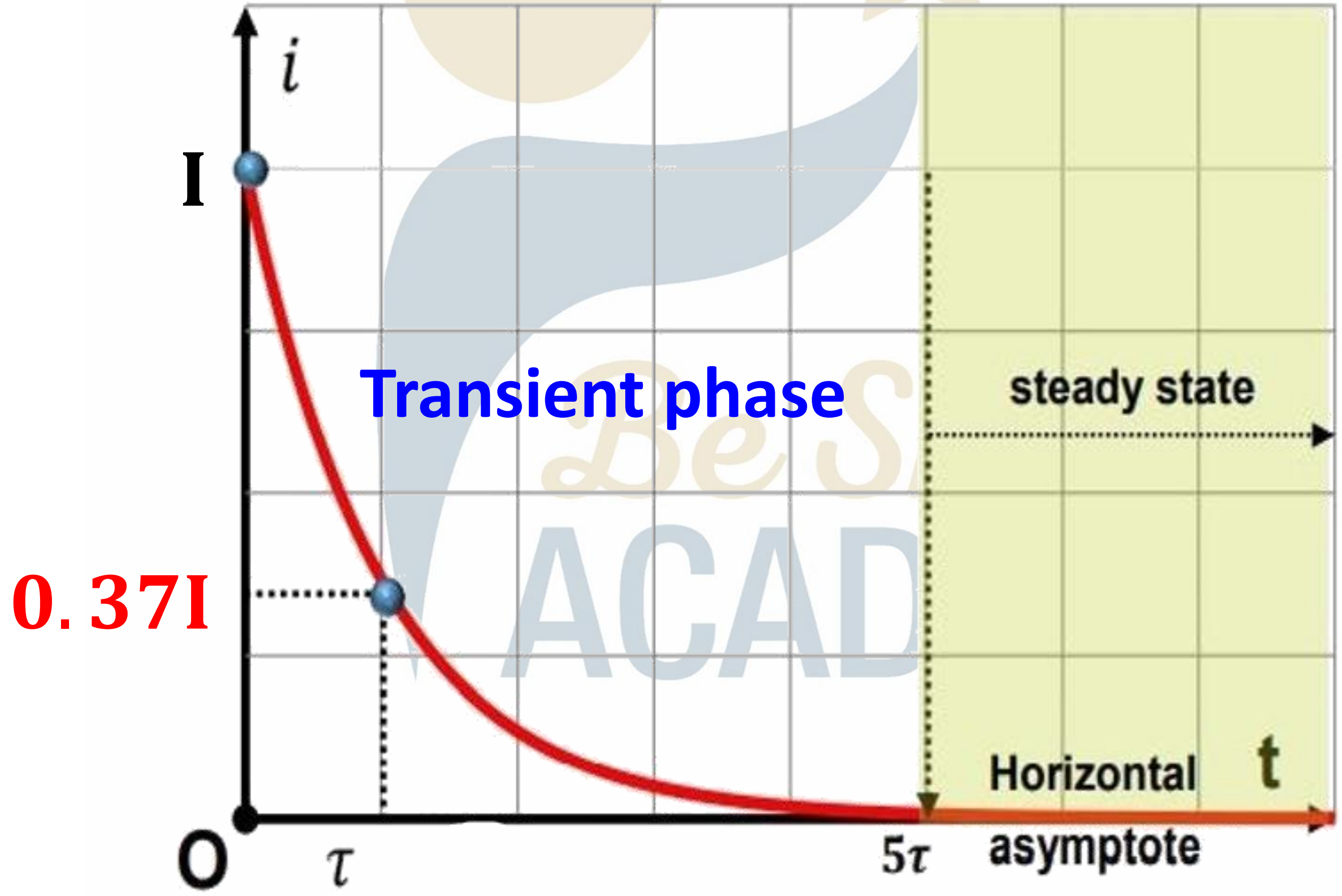
$$u_C = I.e^{-5}$$ ➡ $$i = 0.001I$$

$$i \approx 0$$

At $t = 5\tau$, the steady state is attained and the coil acts as a resistor of resistance r.

Theoretical study of the decay of the current.

$t = 0$	$t = \tau$	$t = 5\tau$
$i = I$	$i = 0.37I$	$i = 0$



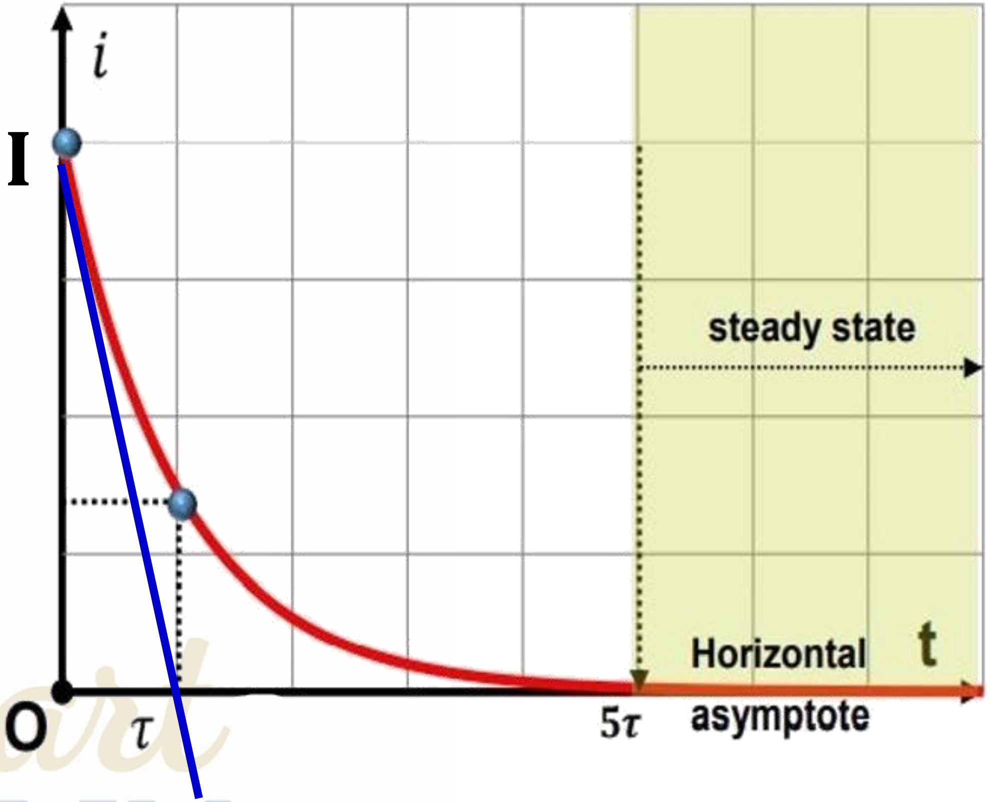
Theoretical study of the decay of the current.

Time constant using tangent method:

First method:

Draw tangent to $i = f(t)$ at $t = 0$

The slope of the tangent at $\mathrm{t = 0}$ is $\frac{\mathrm{di}}{\mathrm{dt}}$



$$i = I.e^{-\frac{t}{\tau}} \Rightarrow \frac{di}{dt} = I\left[\frac{-1}{\tau}\right]e^{-\frac{t}{\tau}}$$

At $t = 0$: $$\frac{di}{dt} = I\left[\frac{-1}{\tau}\right]e^{-\frac{0}{\tau}} \Rightarrow \text{slope} = \frac{di}{dt} = \frac{-I}{\tau}$$

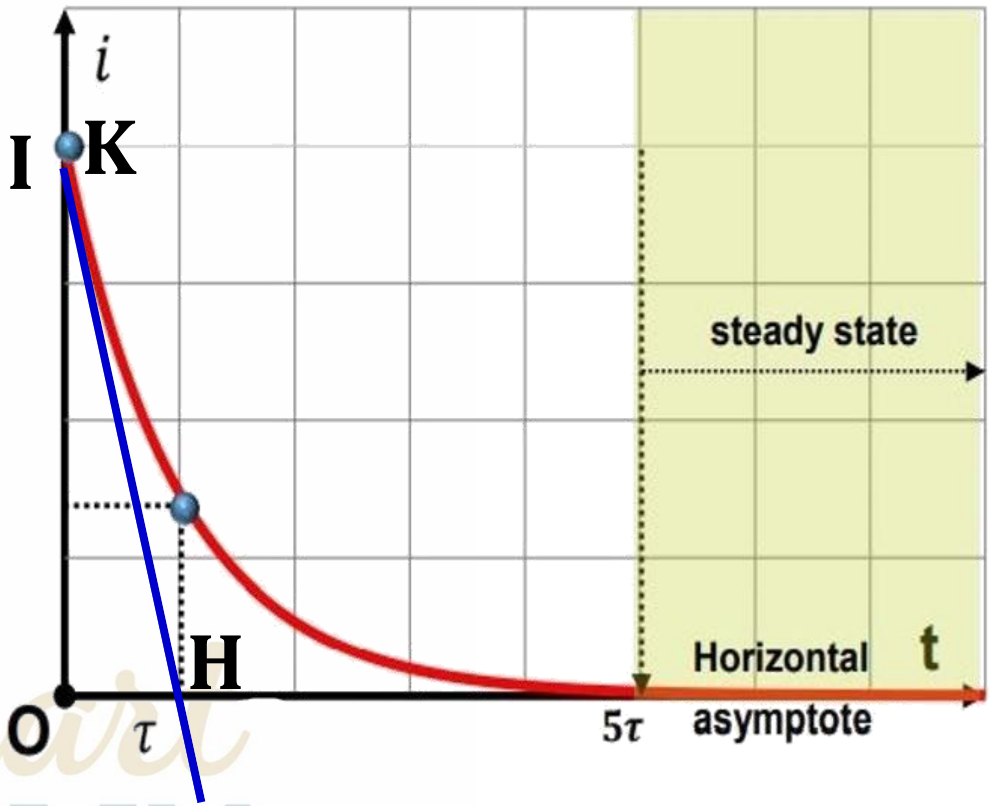
Theoretical study of the decay of the current.

In Δ OHK: $$tan\alpha = \frac{OK}{OH} = \frac{I}{OH}$$

$$slope = -tan\alpha$$

$$\frac{-I}{\tau} = -\frac{I}{OH}$$

$$\tau = OH$$



Therefore, the tangent to i at $t = 0$ meets the horizontal asymptote of equation $i_1 = 0$ at a point of abscissa is τ

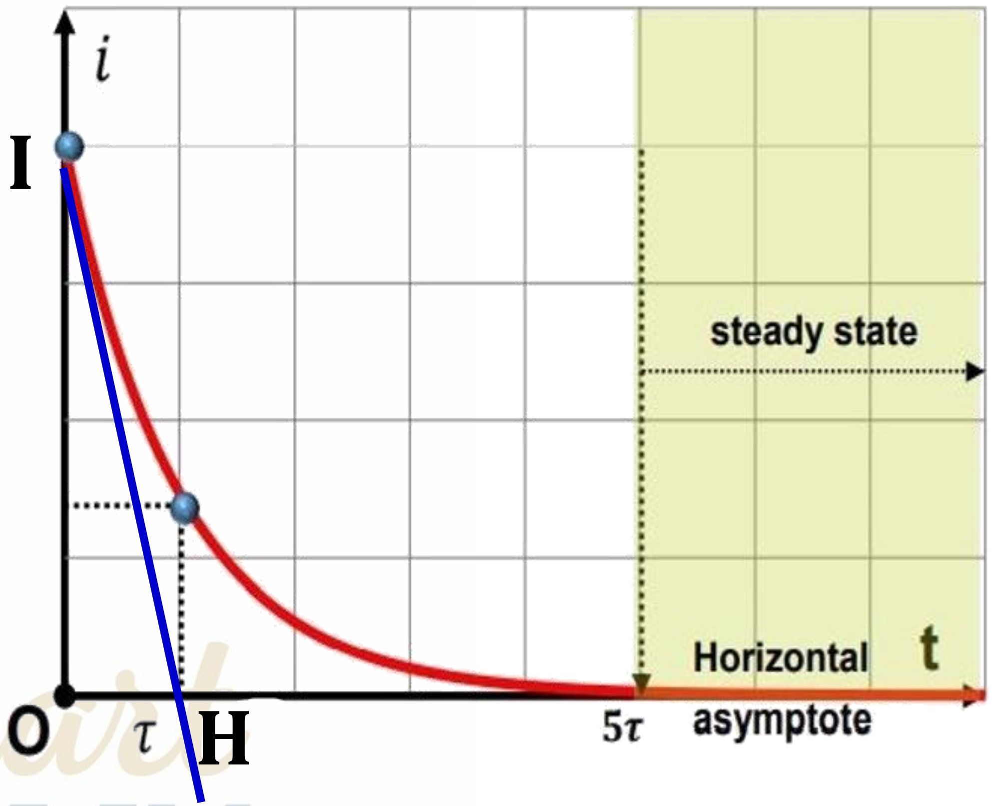
Theoretical study of the decay of the current.

Second method:

The equation of tangent to i at $t = 0$ is: $i = at$

Where a is the slope of the tangent at $t = 0$

$$i = I.e^{-\frac{t}{\tau}} \Rightarrow \frac{di}{dt} = I\left[\frac{-1}{\tau}\right]e^{-\frac{t}{\tau}}$$



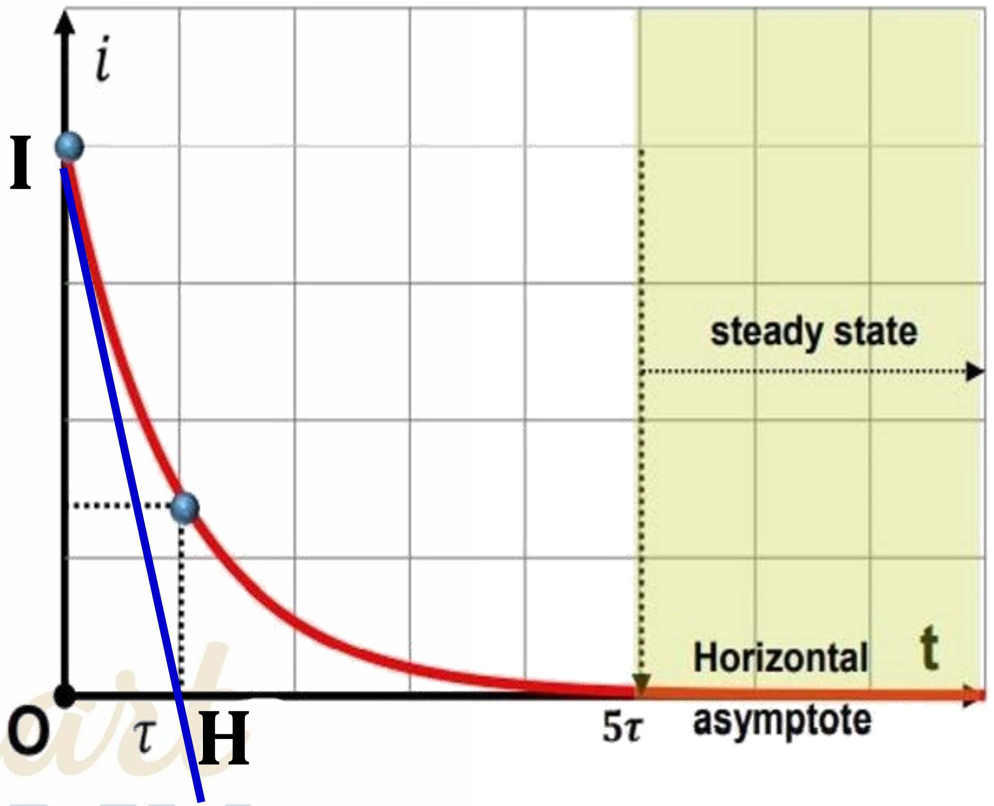
At $t = 0$: $\frac{di}{dt} = I\left[\frac{-1}{\tau}\right]e^{-\frac{0}{\tau}} \Rightarrow$ slope $= \frac{di}{dt} = \frac{-I}{\tau}$

Theoretical study of the decay of the current.

The equation of tangent is: $i = at$

$$\mathrm{i} = -\frac{I}{\tau}.t$$

The tangent meets to $i = f(t)$ meets the horizontal asymptote $i_1 = 0$ at point of of abscissa τ



Theoretical study of the decay of the current.

Determination of I and τ in terms of r, R, and L

$$R_{eq}i + L\frac{di}{dt} = 0$$

$$i = Ie^{-\frac{t}{\tau}}$$

$$\frac{di}{dt} = -\frac{I}{\tau}.e^{-\frac{t}{\tau}}$$

Substitute i *and* $\frac{di}{dt}$ *in differential equation.*

$$R_{eq}I.e^{-\frac{t}{\tau}} - L.\frac{I}{\tau}.e^{-\frac{t}{\tau}} = 0$$

$$R_{eq}Ie^{-\frac{t}{\tau}} = \frac{LI}{\tau}.e^{-\frac{t}{\tau}}$$

Theoretical study of the decay of the current.

$$R_{eq} I e^{-\frac{t}{\tau}} = \frac{LI}{\tau} . e^{-\frac{t}{\tau}}$$

By identification we get:

$$R_{eq} I = \frac{LI}{\tau}$$

$$R_{eq} = \frac{L}{\tau}$$

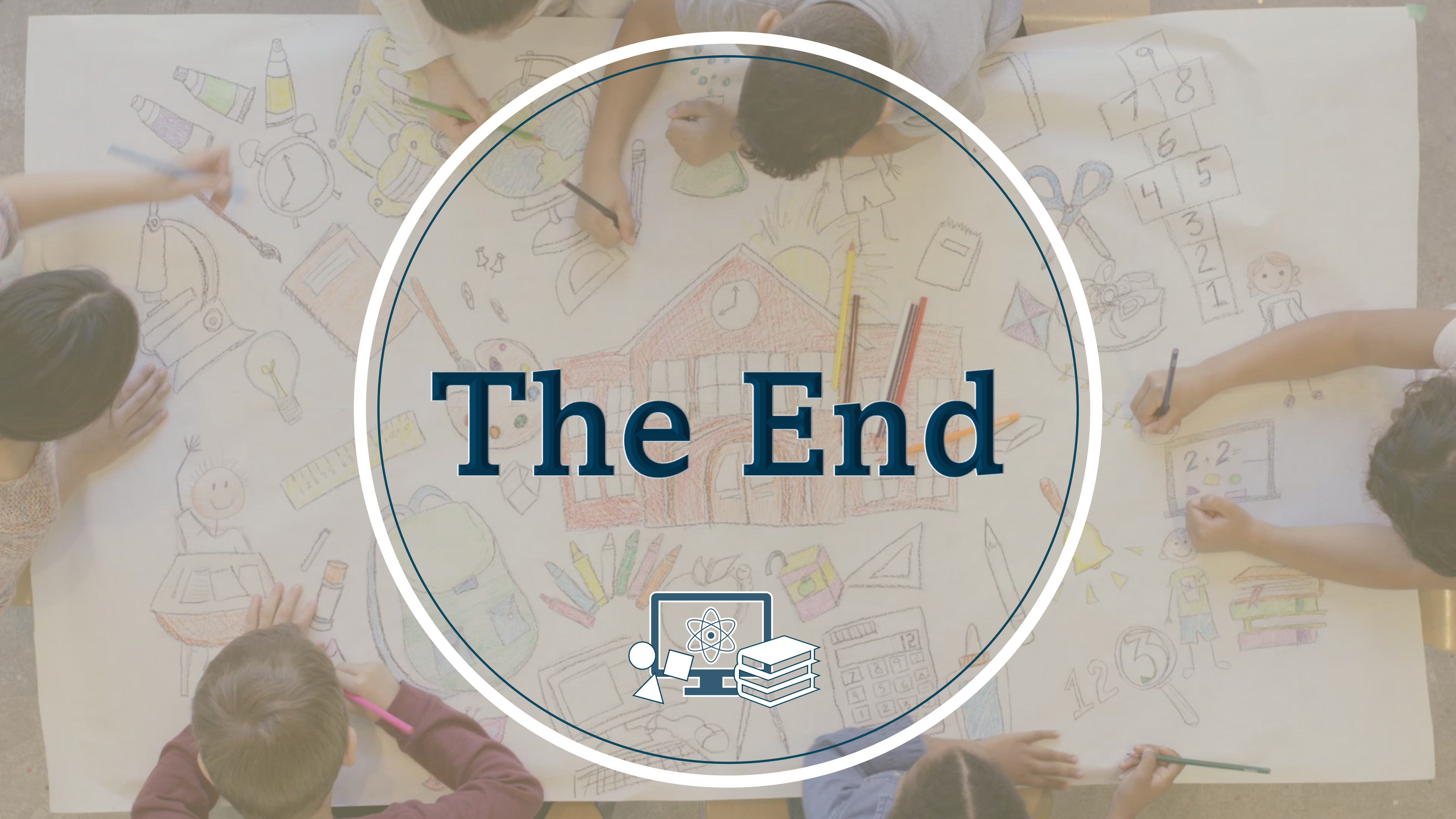
$$\tau = \frac{L}{R_{eq}}$$

Theoretical study of the decay of the current.

$$i = Ie^{-\frac{t}{\tau}}$$

At t = 0: $\mathrm{i} = \dfrac{E}{R_{eq}}$

$$\frac{E}{R_{eq}} = Ie^{0} \Rightarrow \frac{E}{R_{eq}} = I$$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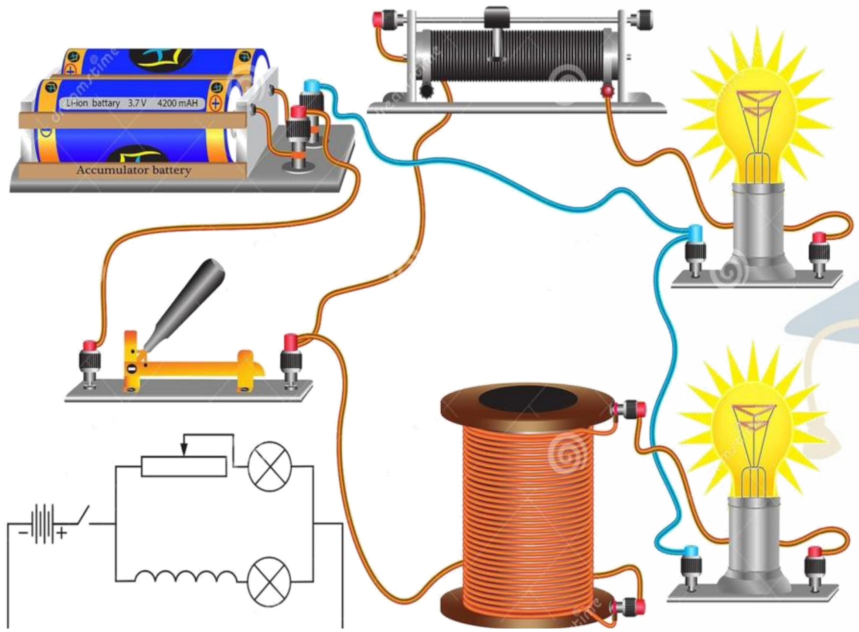
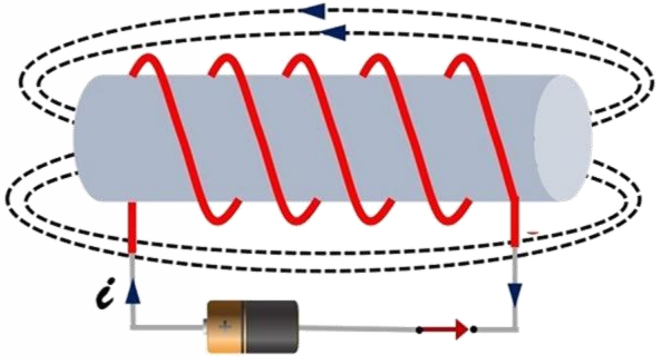


What is Self Induction?



Physics – Grade 12

Unit Two – Electricity

Chapter 9 – Self Induction

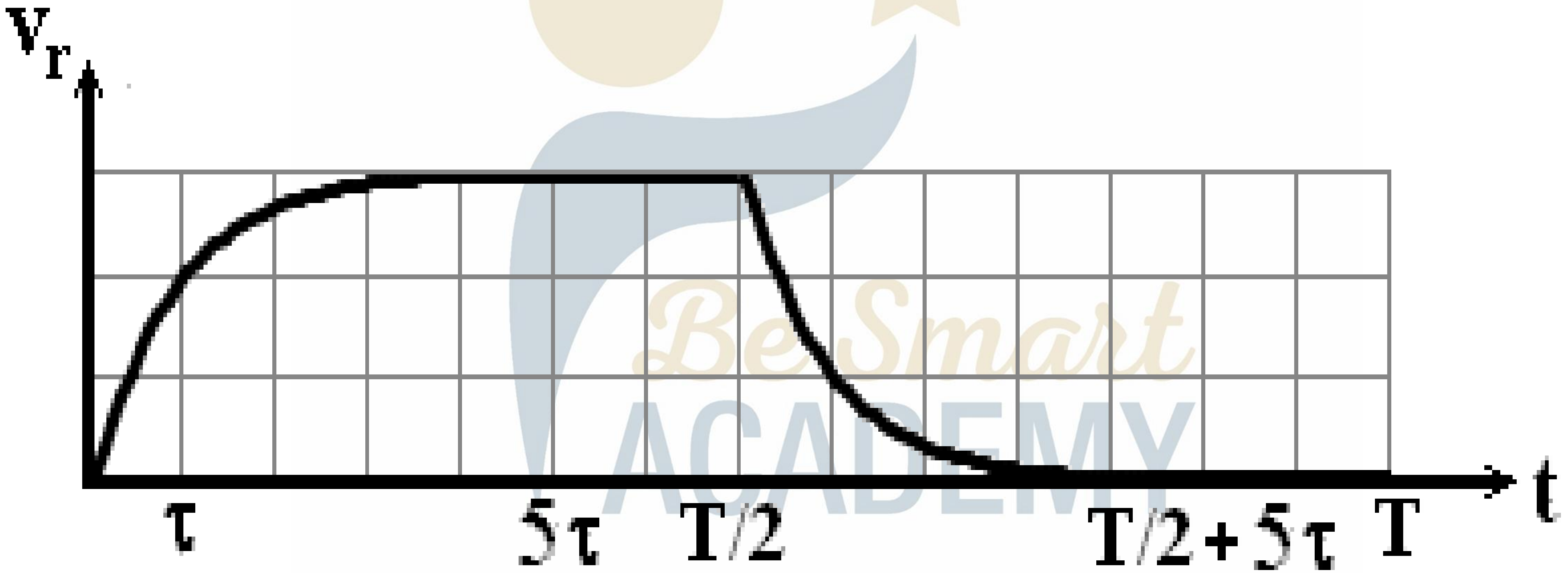
Prepared & Presented by: Mr. Mohamad Seif

OBJECTIVES

1. Study the graphs of the two intervals
2. Study the sparks due to switching off a circuit

Graph of the two intervals

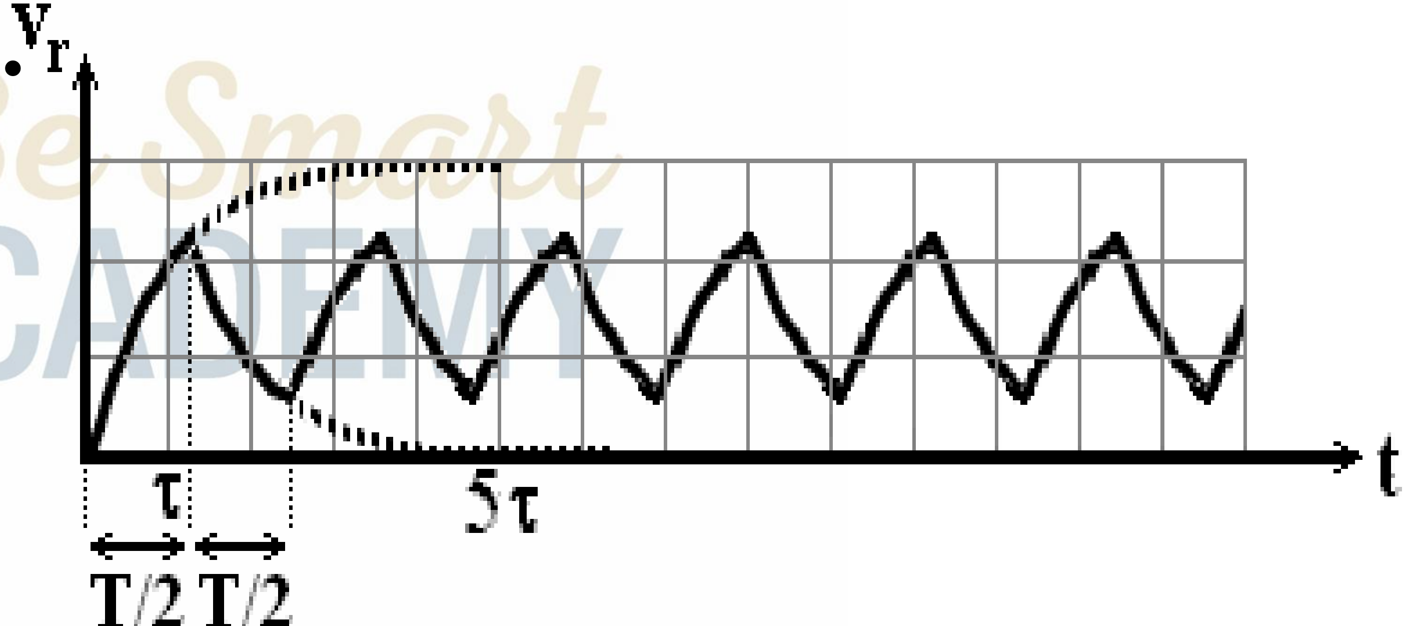
In the case if T/2 (of the L.F.G) > 5 τ, the graph is similar to that obtained by the oscilloscope



Graph of the two intervals

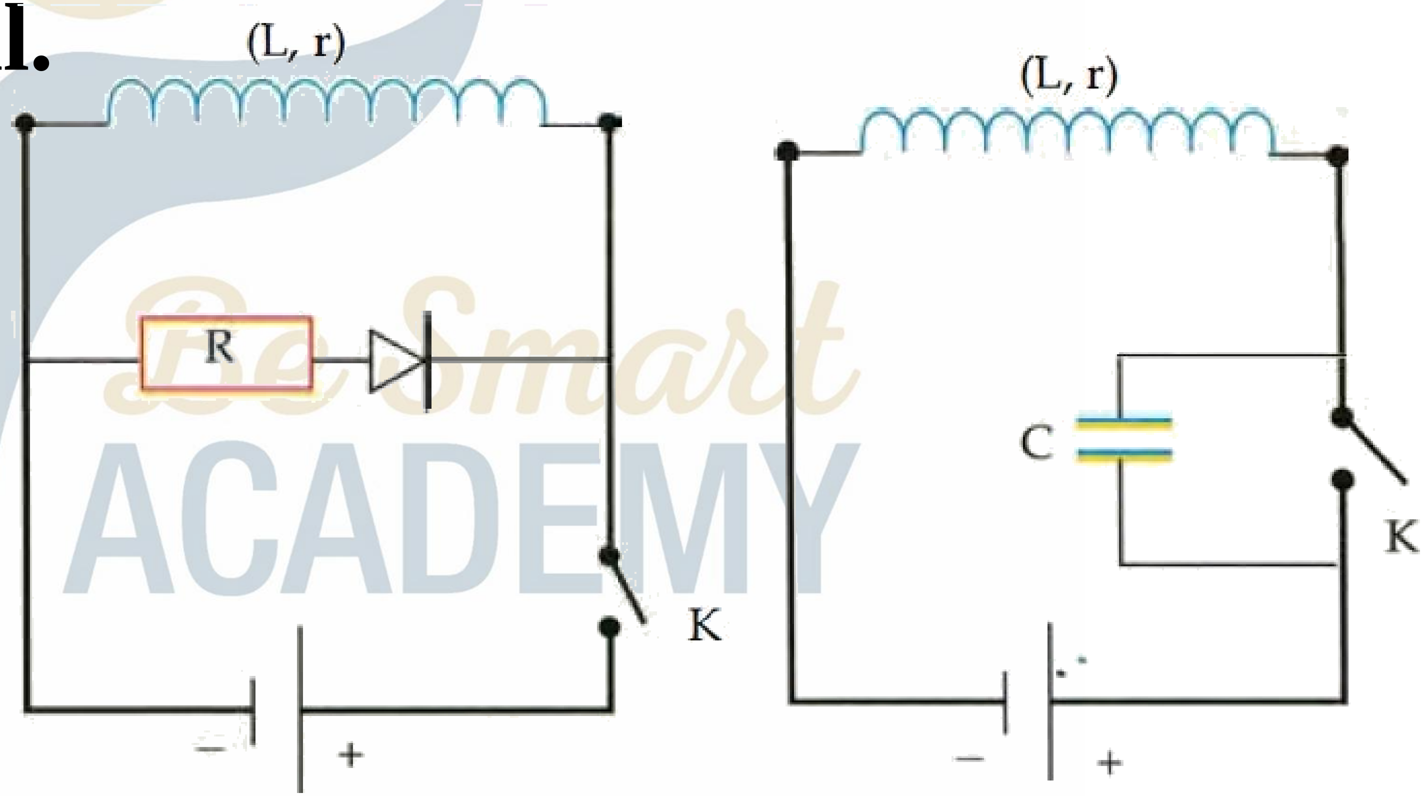
If T/2 (of the L.F.G) < 5 τ, the voltage will not have sufficient time to reach the value V_r, because at $t = T/2$ the e.m.f of the L.F.G becomes zero and V_r begins to decrease.

Also, V_r will not have sufficient time to reach the value 0, because at t = T the e.m.f of the L.F.G increases suddenly to E and V_r begins to increase.



Sparks due to switching off a circuit

When a circuit of large inductance is opened abruptly, a spark appears at the switch contacts due to a very high voltage across its terminals originating from the high e.m.f. "e" induced in the coil.



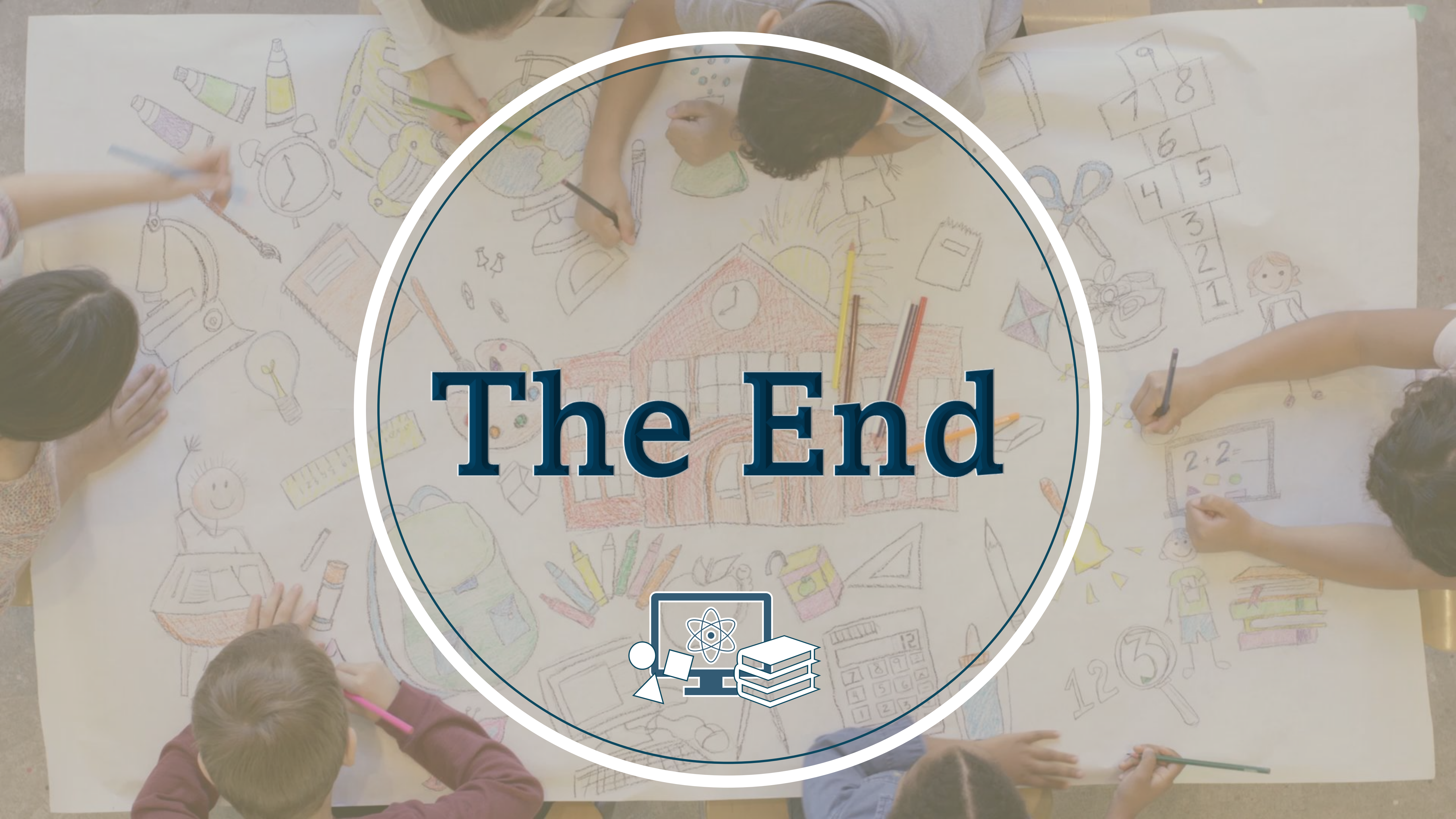
Sparks due to switching off a circuit

Similarly, strong sparks are produced when we suddenly disconnect domestic appliances, including electric motors and transformers (those including coils) from the mains.

This phenomenon is interpreted by the presence of an excess voltage across the terminals of the switch at the instant when the circuit is opening.

The sparks produced may in the long turn destroy the contacts of the switches and can even destroy the brushes in generators and motors or break the insulator of the coil.

To avoid such damage, we must protect the switch.



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