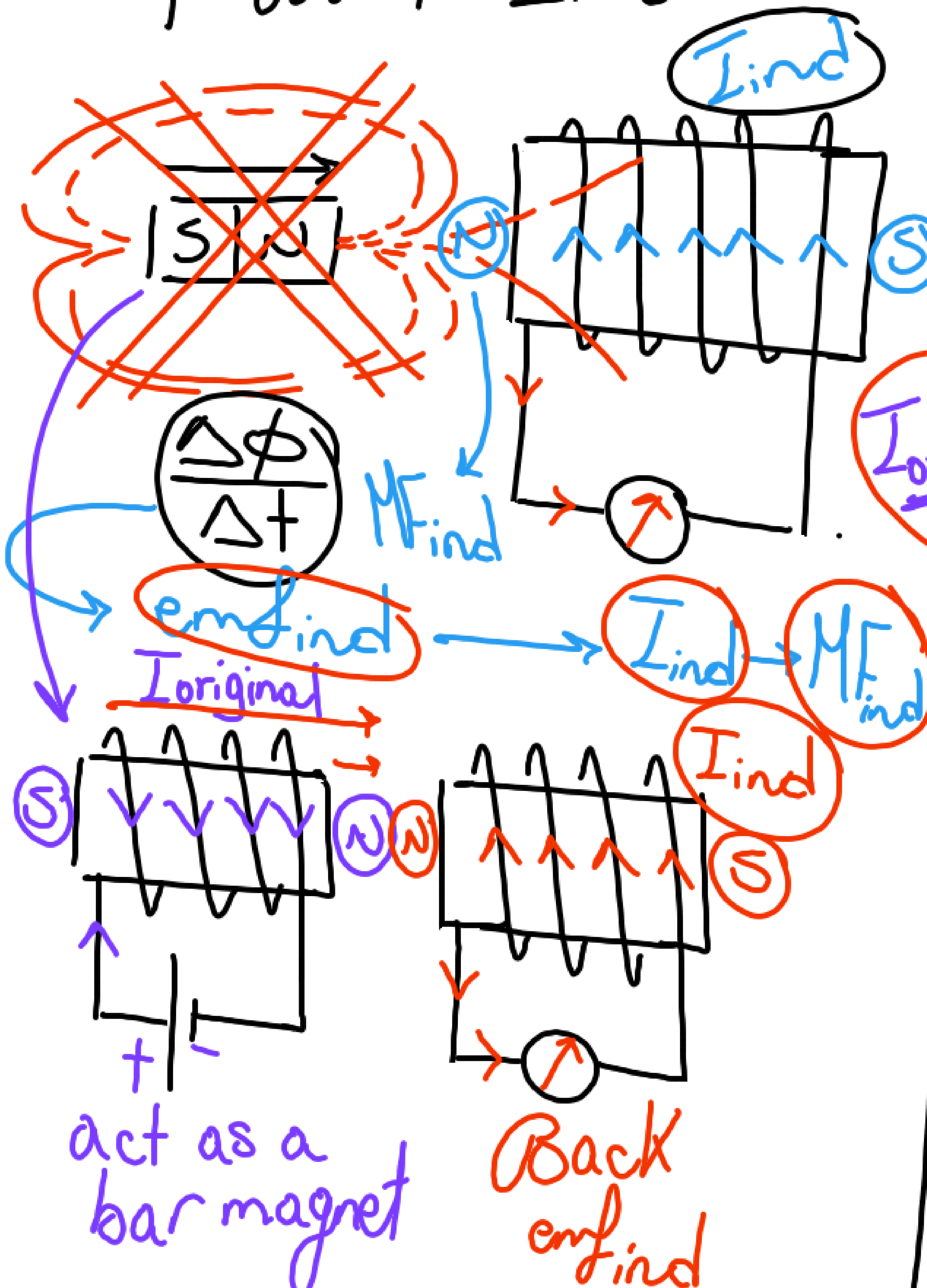
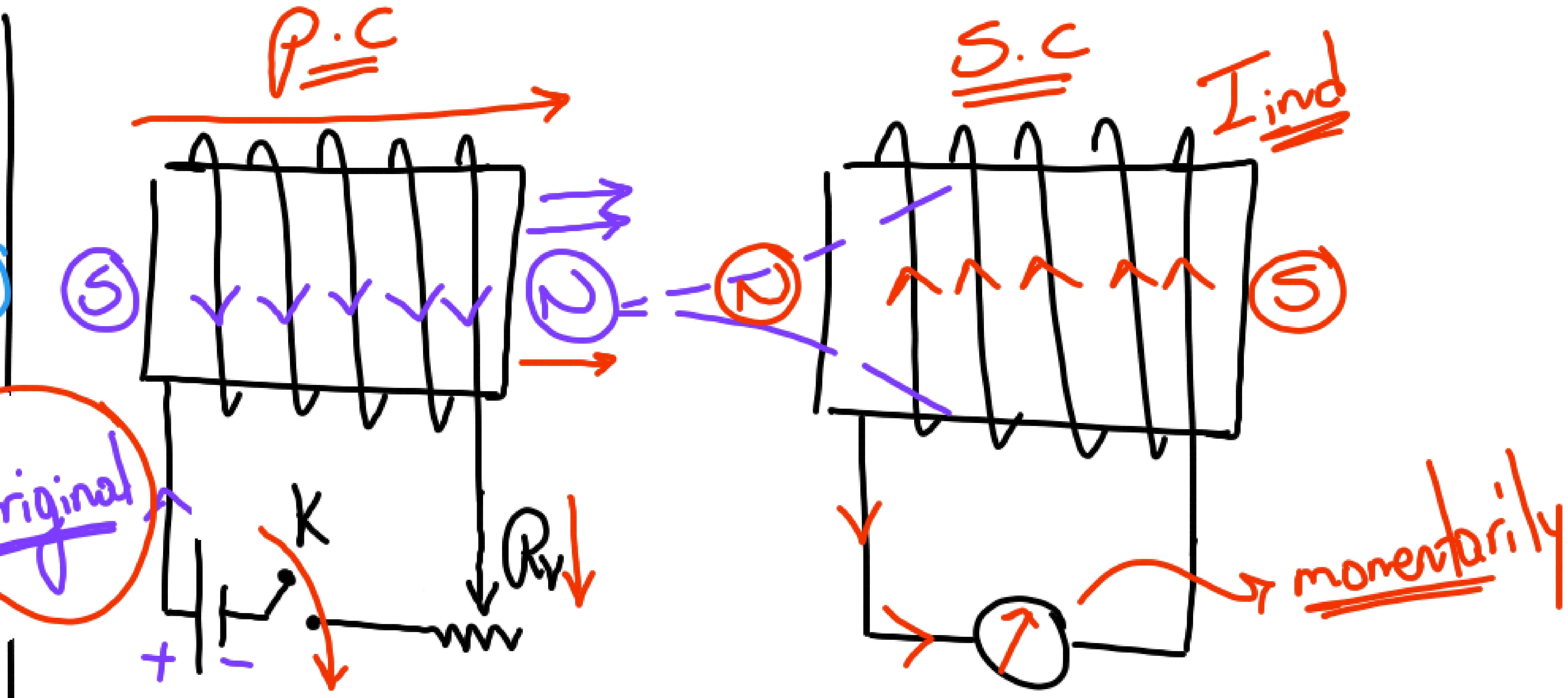
Mutual Induction ⇒ Backward EMF:





1- At the moment of closing "K"

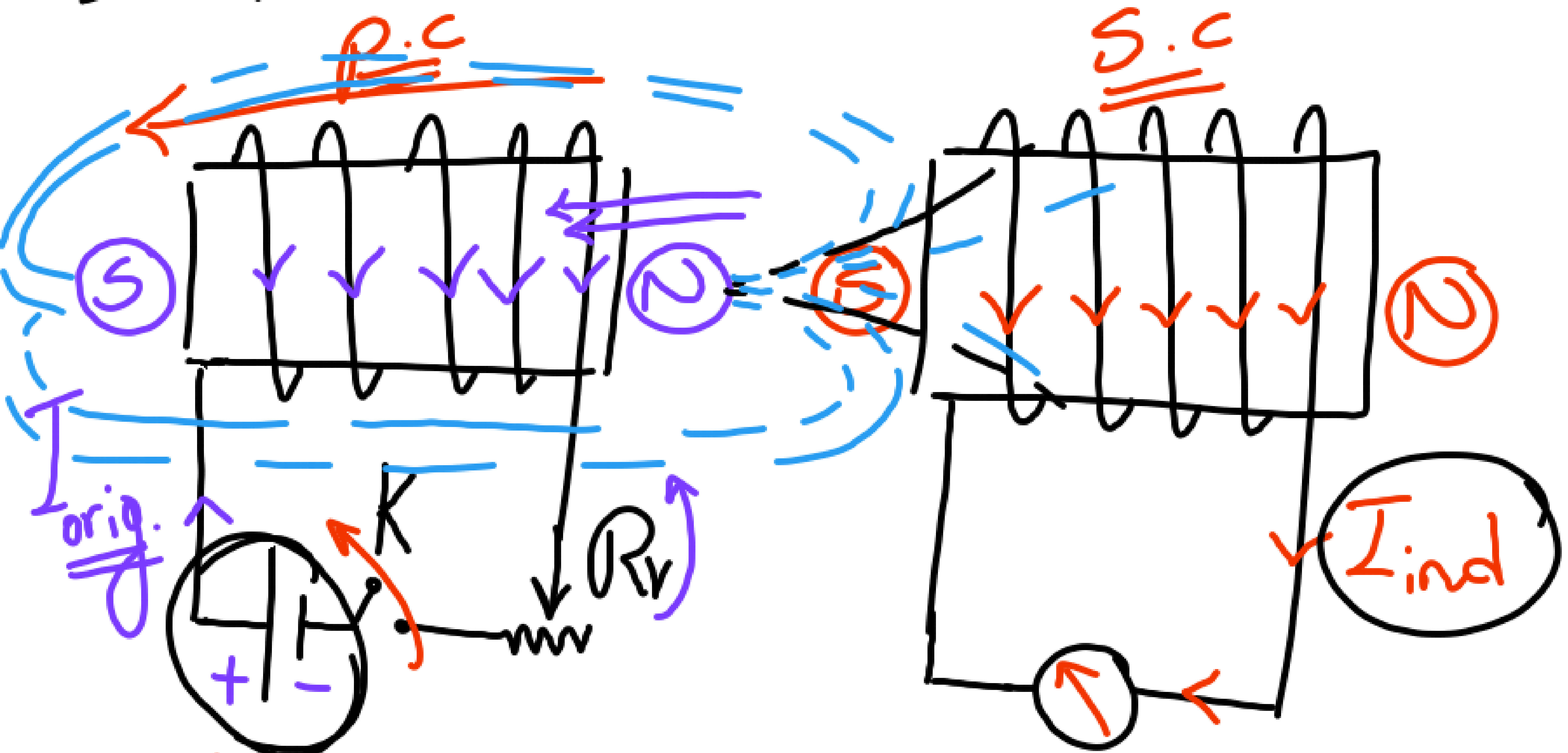
$I\uparrow B\uparrow \phi\uparrow$ "Ka2enny b2rb" → ∴ Backward emf ind

2- At the moment of decreasing "R_v"

$R_v\downarrow I\uparrow B\uparrow \phi\uparrow$

3- Approaching p.c towards s.c

⇒ Forward EMF:



1- At the moment of opening "K"
$I\downarrow B\downarrow \phi\downarrow$ ∴ forward emf ind

2- At the moment of increasing "R_V"
$R_V\uparrow\ I\downarrow B\downarrow \phi\downarrow$

3- Withdrawing P.C away from S.C

Proof:

$$emf_2 \propto \frac{\Delta\phi_2}{\Delta t}$$

$\Delta\phi_2$ → portion of flux from P.C cutting S.C

$$\frac{\Delta\phi_2}{\Delta t} \propto \frac{\Delta I_1}{\Delta t}$$

$$\therefore emf_2 \propto \frac{\Delta I_1}{\Delta t}$$

$$\boxed{emf_2 = -M\frac{\Delta I_1}{\Delta t}}$$

M → Mutual inductance
Coefficient of Mutual induction

$$M = -\frac{emf_2}{\Delta I_1/\Delta t}$$

* $Henry = \frac{Volt.sec}{Ampere} = \Omega.sec = \frac{weber}{Ampere}$

* It is the emf_{ind} in s.c when the rate of change of current in p.c is 1 A/sec

→ Factors affecting on "M":

1- Presence of iron core "μ"
2- Number of turns of both coils
3- Distance between coils
4- Volume of coils

① $emf_2 = -M\frac{\Delta I_1}{\Delta t} = -N_2\frac{\Delta \phi_2}{\Delta t}$

** ② $M\,\Delta I_1 = N_2\,\Delta\phi_2$

$M\,\Delta I_1 = N_2\,\Delta B_1\,A_2$

$M\,\Delta I_1 = N_2 A_2\,\Delta B_1$

$M\,\cancel{\Delta} I_1 = N_2 A_2 \cancel{\Delta}\frac{\mu N_1 \cancel{I_1}}{L_{s1}}$

App: Electric Transformers

* Solenoid "Cylindrical coil" L_{s1}

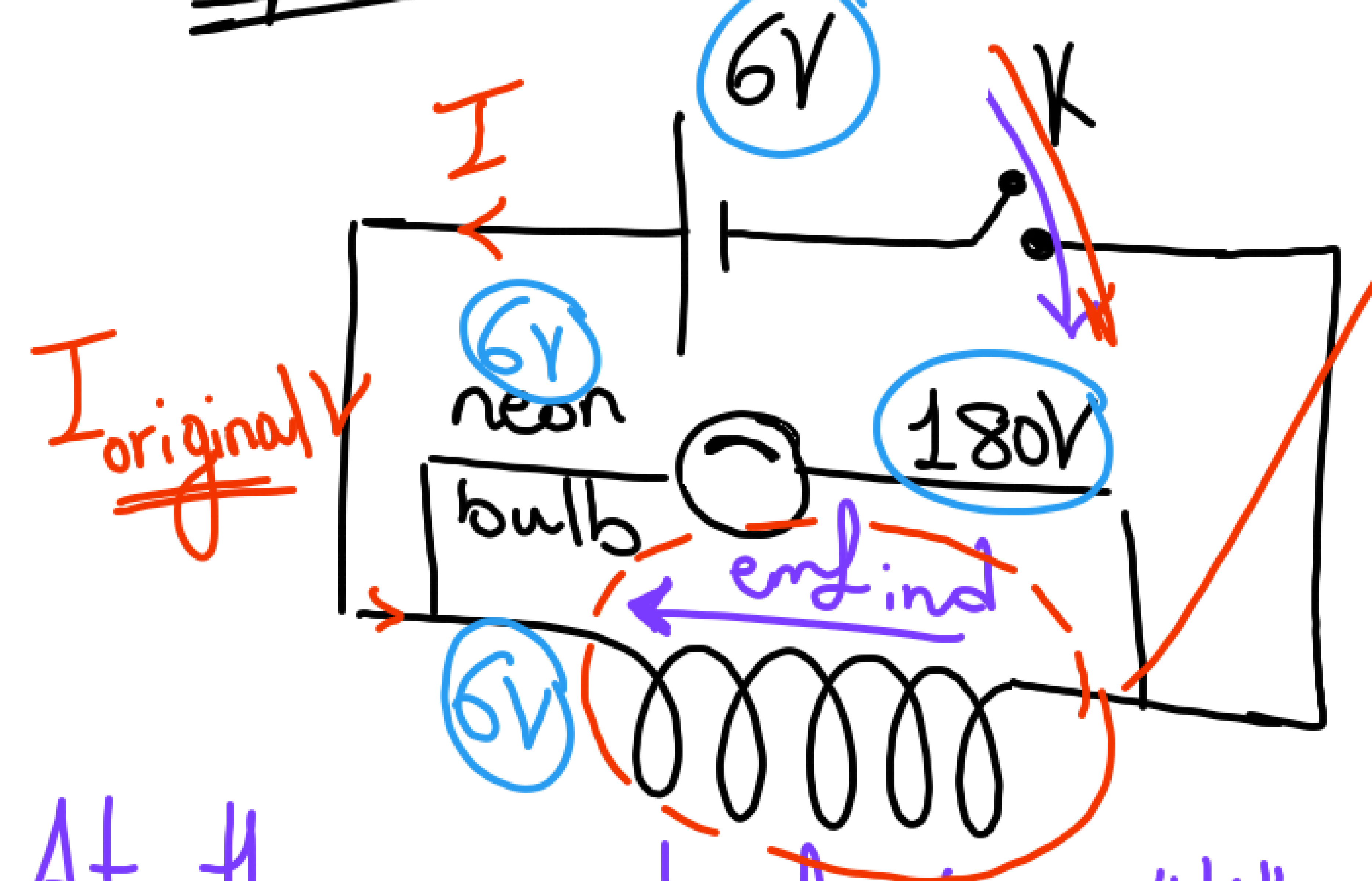
③ $$M = \frac{\mu A_2 N_1 N_2}{L_{s1}} = \mu A_2 n_1 N_2$$

* Circular Coil

$$M = \frac{\mu A_2 N_1 N_2}{2r_1}$$

Self-Induction

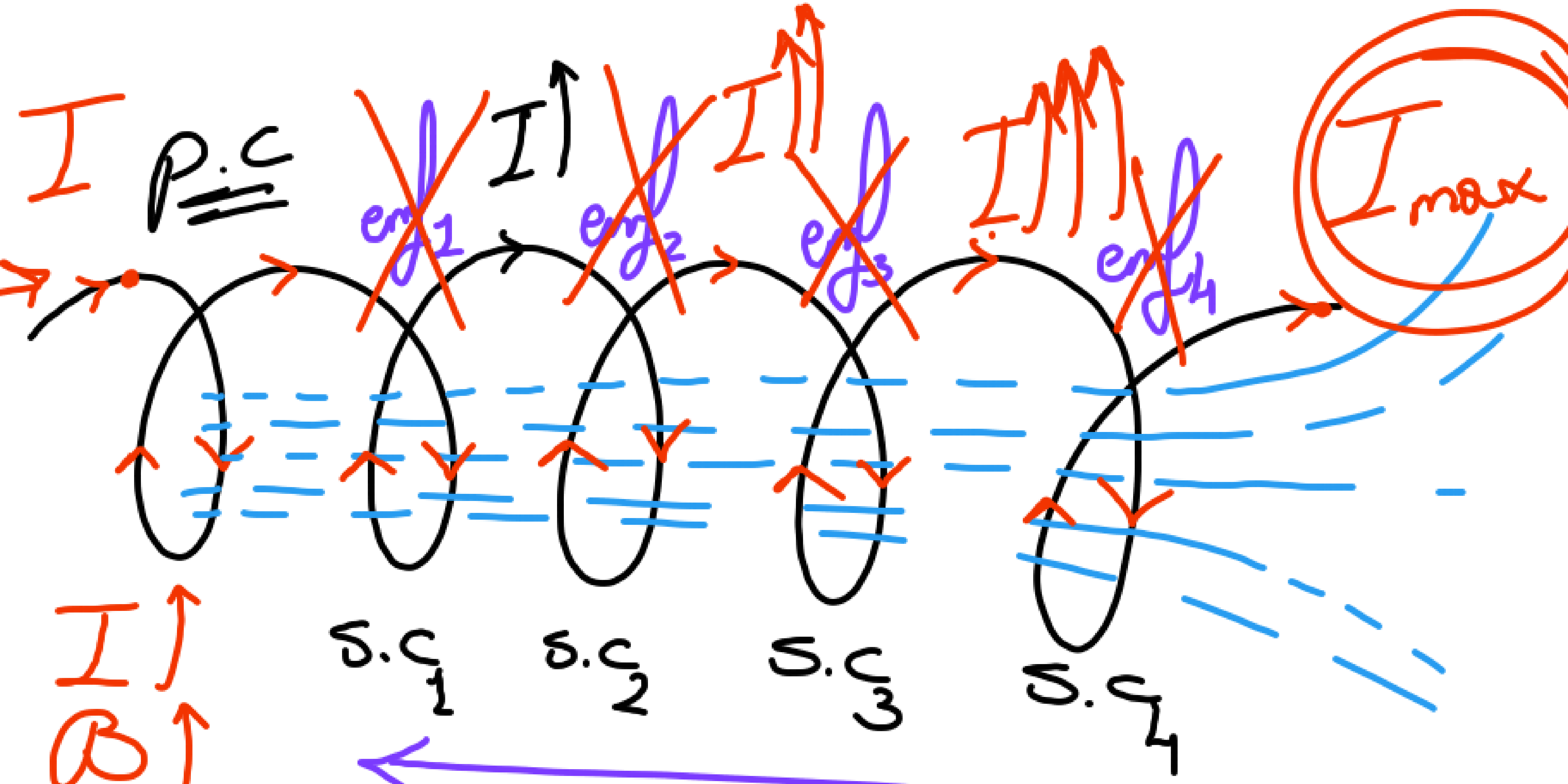
→ Experiment:



At the moment of closing "K":

$I\uparrow\ B\uparrow\ \phi\uparrow$ ∴ Backward "emf ind"

$$\uparrow\downarrow I = \frac{V_B - \downarrow emf_{ind}}{R_T}$$



$I\uparrow$

$B\uparrow$

$\phi\uparrow$

∴ Backward emf ind

Delay in the growth of current.

+

Neon bulb did not glow

($V_B < 180V$)

proof:

$$emf_{ind} \propto \frac{\Delta \phi}{\Delta t}$$

$$\frac{\Delta \phi}{\Delta t} \propto \frac{\Delta I}{\Delta t}$$

$$emf_{ind} \propto \frac{\Delta I}{\Delta t}$$

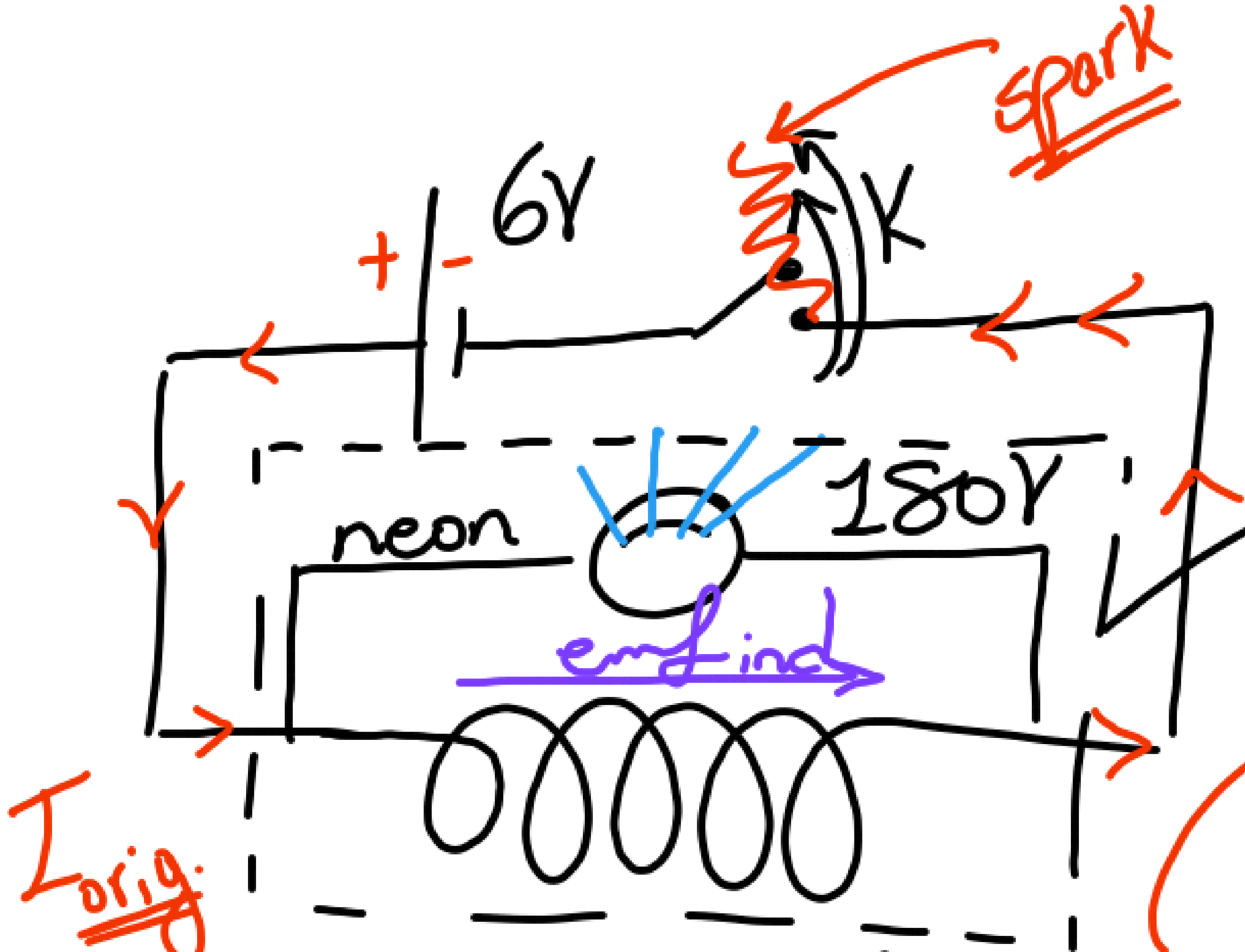
$$\boxed{emf_{ind} = - L \frac{\Delta I}{\Delta t}}$$

Self-inductance

$$\boxed{L = - \frac{emf}{\Delta I / \Delta t}}$$

$$\boxed{Henry = \frac{volt \cdot sec}{Ampere} = \Omega \cdot sec = \frac{weber}{Ampere}}$$

It is the emf induced in a coil when the rate of change of current is 1 A/sec in the coil itself.

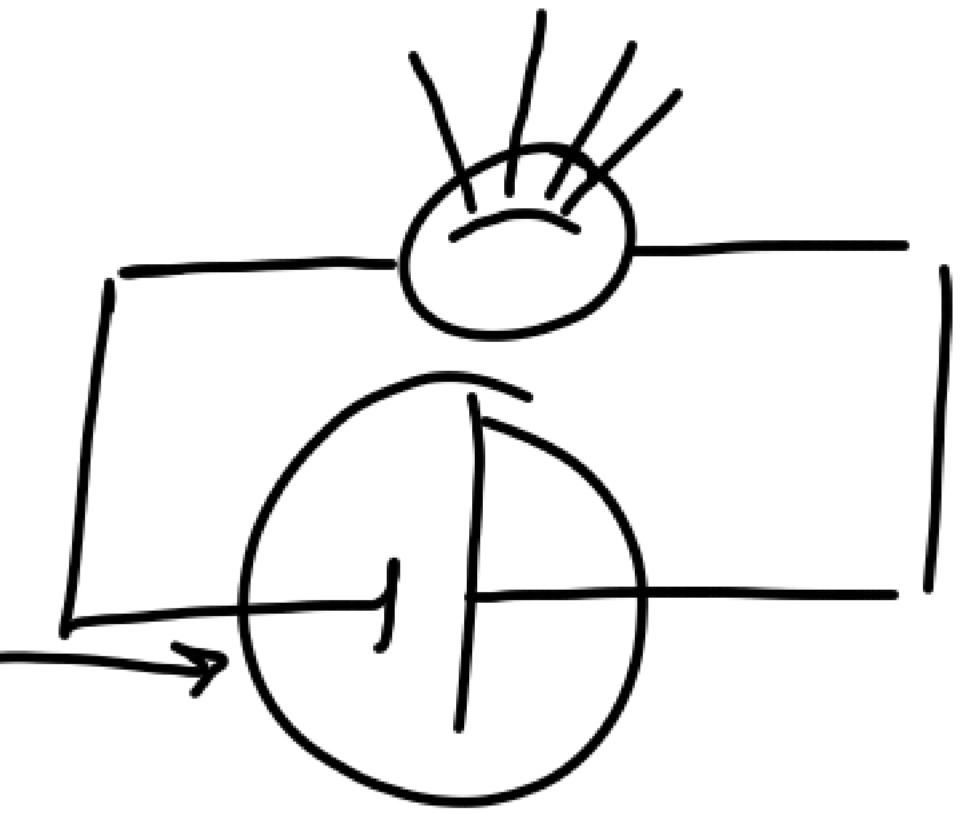


At the moment of opening "K":

$I\downarrow \; B\downarrow \; \phi\downarrow$ ∴ Forward EMF

$$\uparrow I = \frac{V_B + emf_{ind}}{R_T} \uparrow\uparrow$$

Bulb glows momentarily + spark is formed.



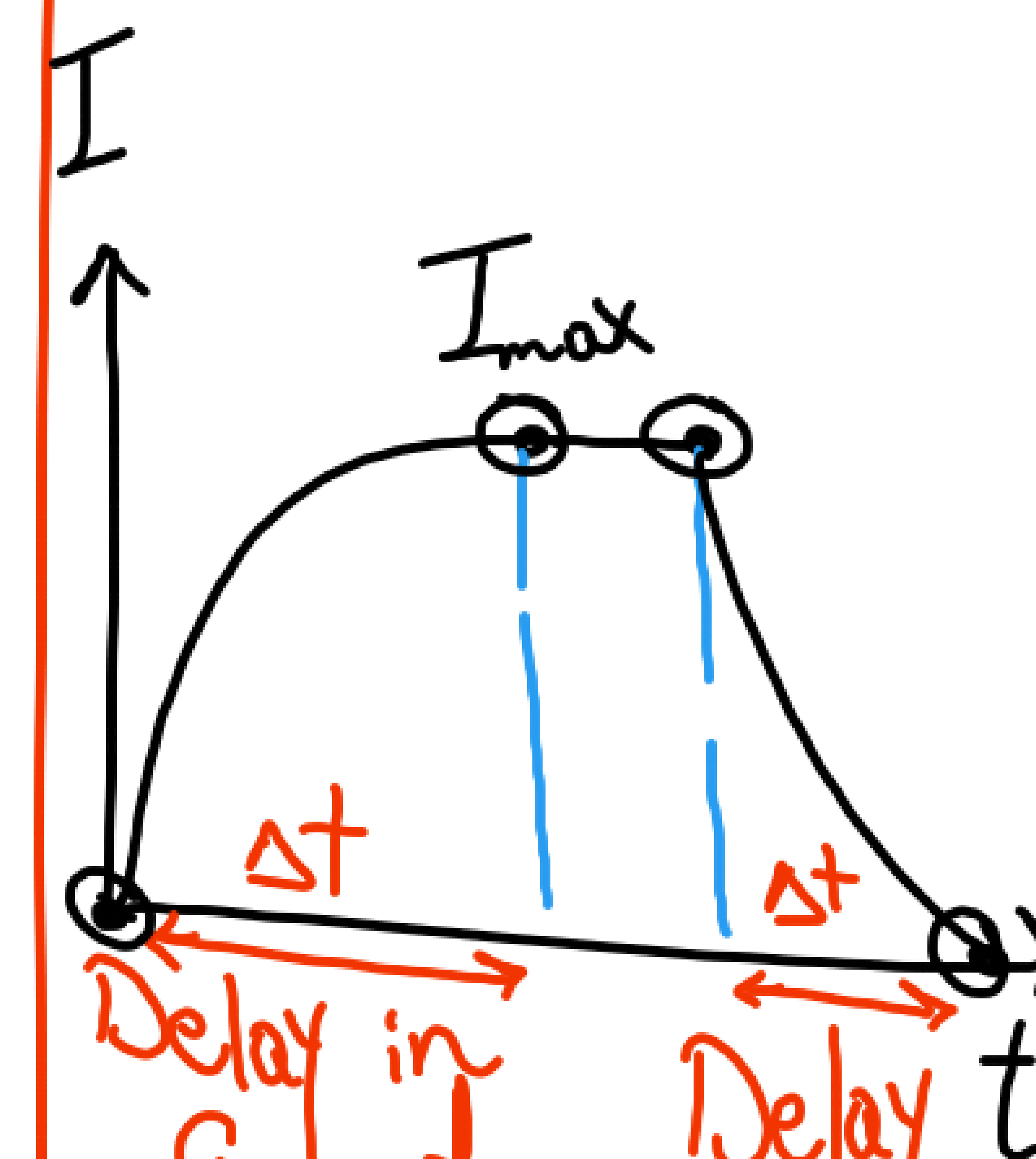
ΔI: $I_{max} \rightarrow 0$

Δt: very short

$$emf = -L \frac{\Delta I}{\Delta t}$$

forward

Delay in the decay of current.



Delay in Growth → Back EMF

Delay in the Decay → Forward EMF

$$emf = \cancel{-}L\frac{\Delta I}{\cancel{\Delta t}} = \cancel{-}N\frac{\Delta \phi}{\cancel{\Delta t}}$$

$$\boxed{L\,\Delta I = N\,\Delta\phi}$$

$$L\,\Delta I = N\,\Delta BA$$

$$L\,\Delta I = N A\,\Delta B$$

$$* \quad L\,\cancel{\Delta I} = N A\,\cancel{\Delta}\frac{\mu N \cancel{I}}{L_s}$$

(1) $$\boxed{L = \frac{\mu A N^2}{Length}}$$

x Length

x Length

(2) $$\boxed{L = \mu A n^2 \, Length}$$

(3) $$\boxed{L = \mu V_o n^2}$$

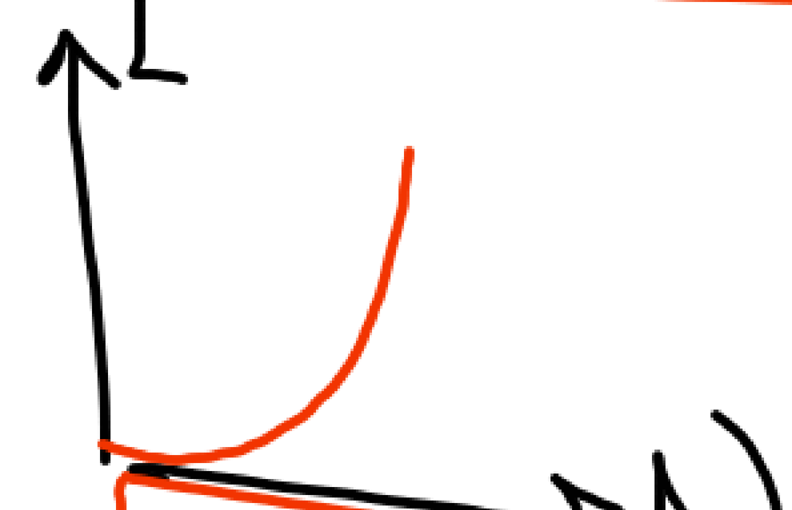
→ Factors affecting on "L":

1- Presence of iron core (μ)

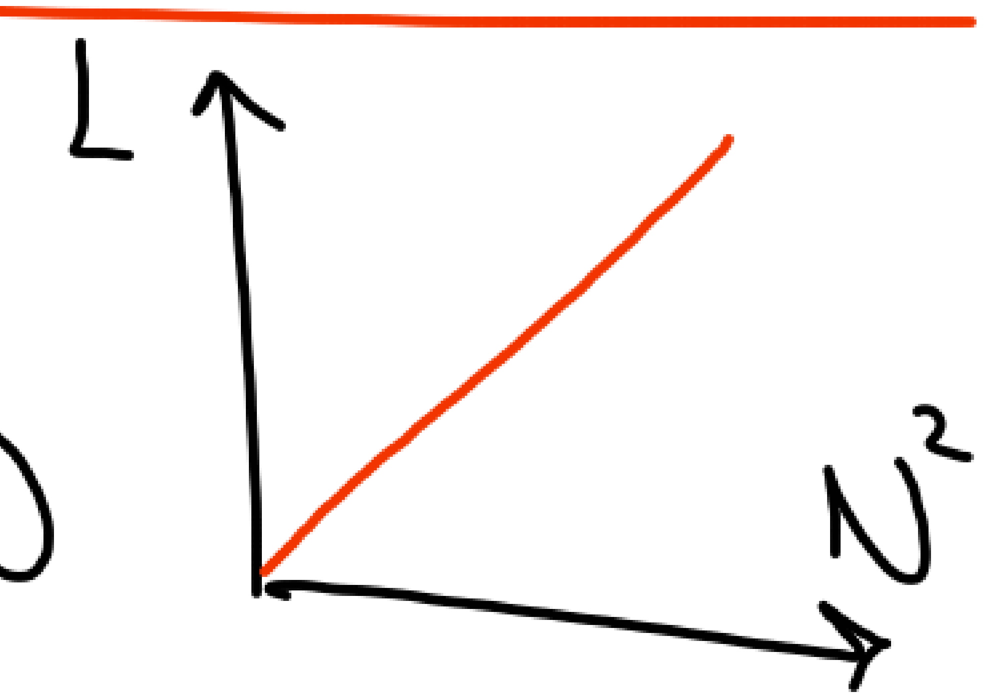
2- Number of turns (N)

3- Distance between turns (L_s)

4- Geometric shape



$\boxed{L \propto N^2}$



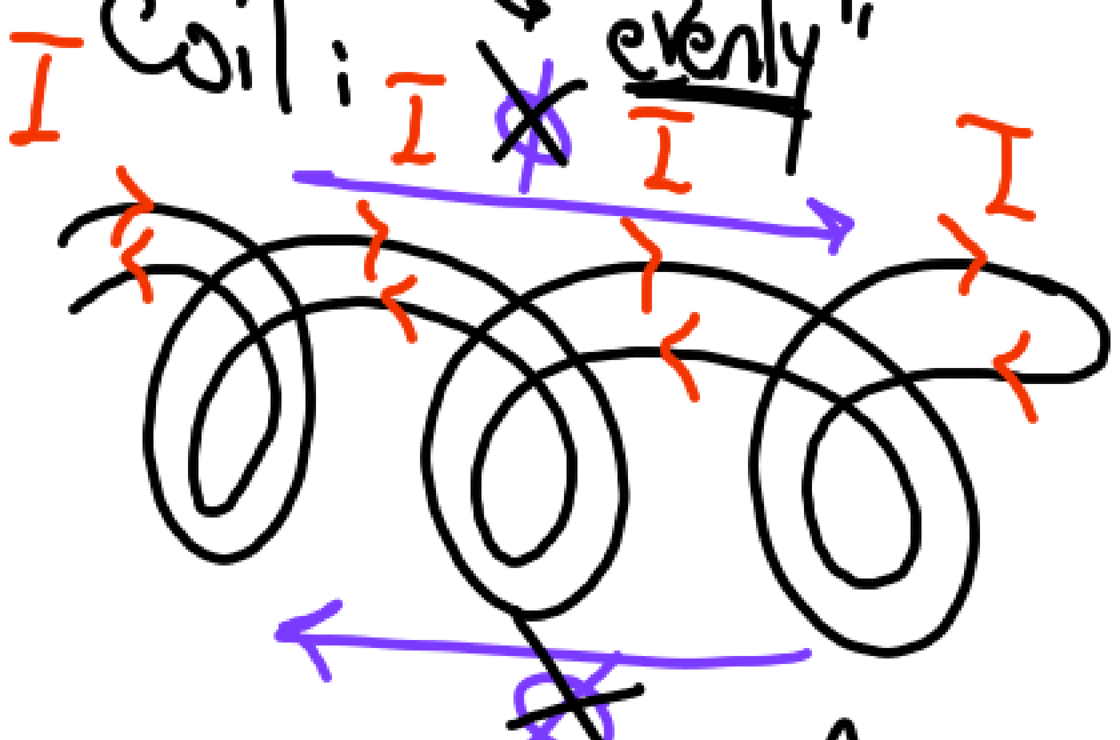
$$\frac{L_1}{L_2} = \frac{A_1 N_1^2 L_{s2}}{A_2 N_2^2 L_{s1}}$$

St. wire vs. Air Cored Coil vs Iron Cored Coil

I ↳ or Double wounded coil

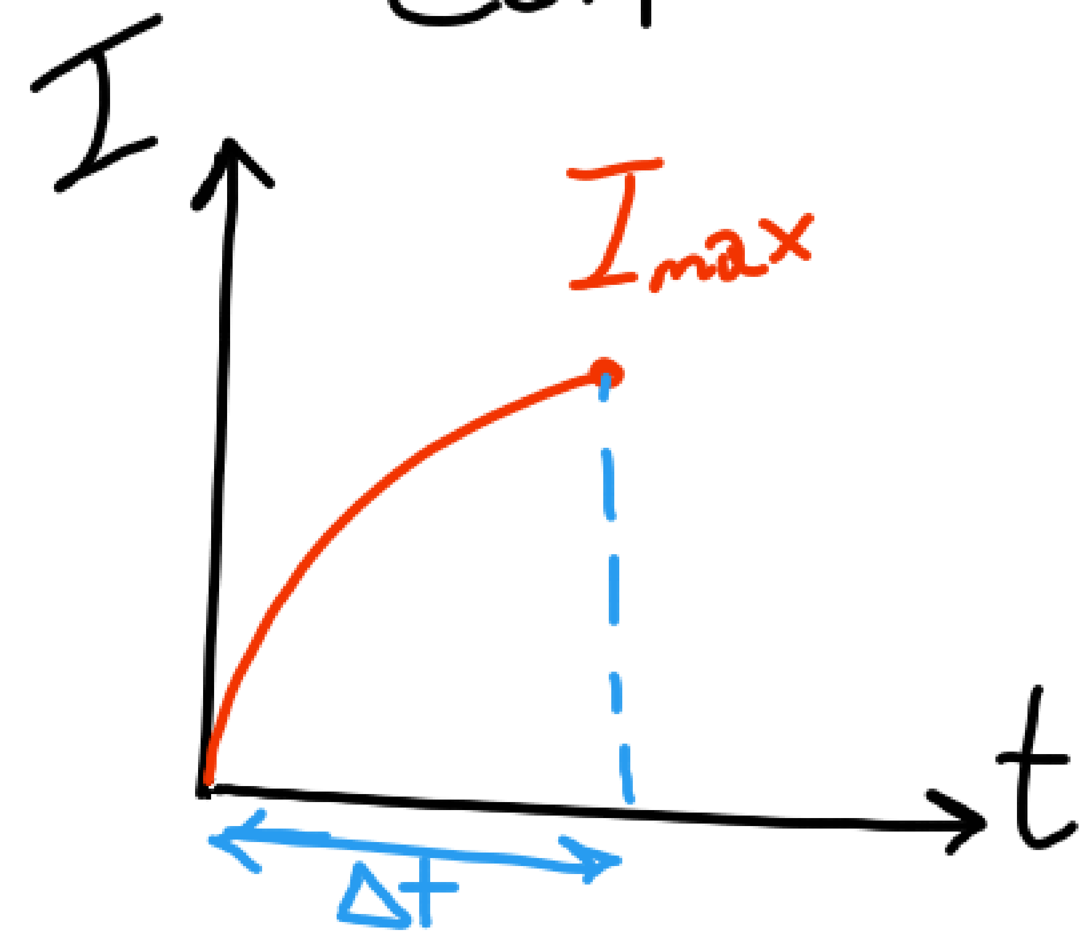
"Pure resistance"

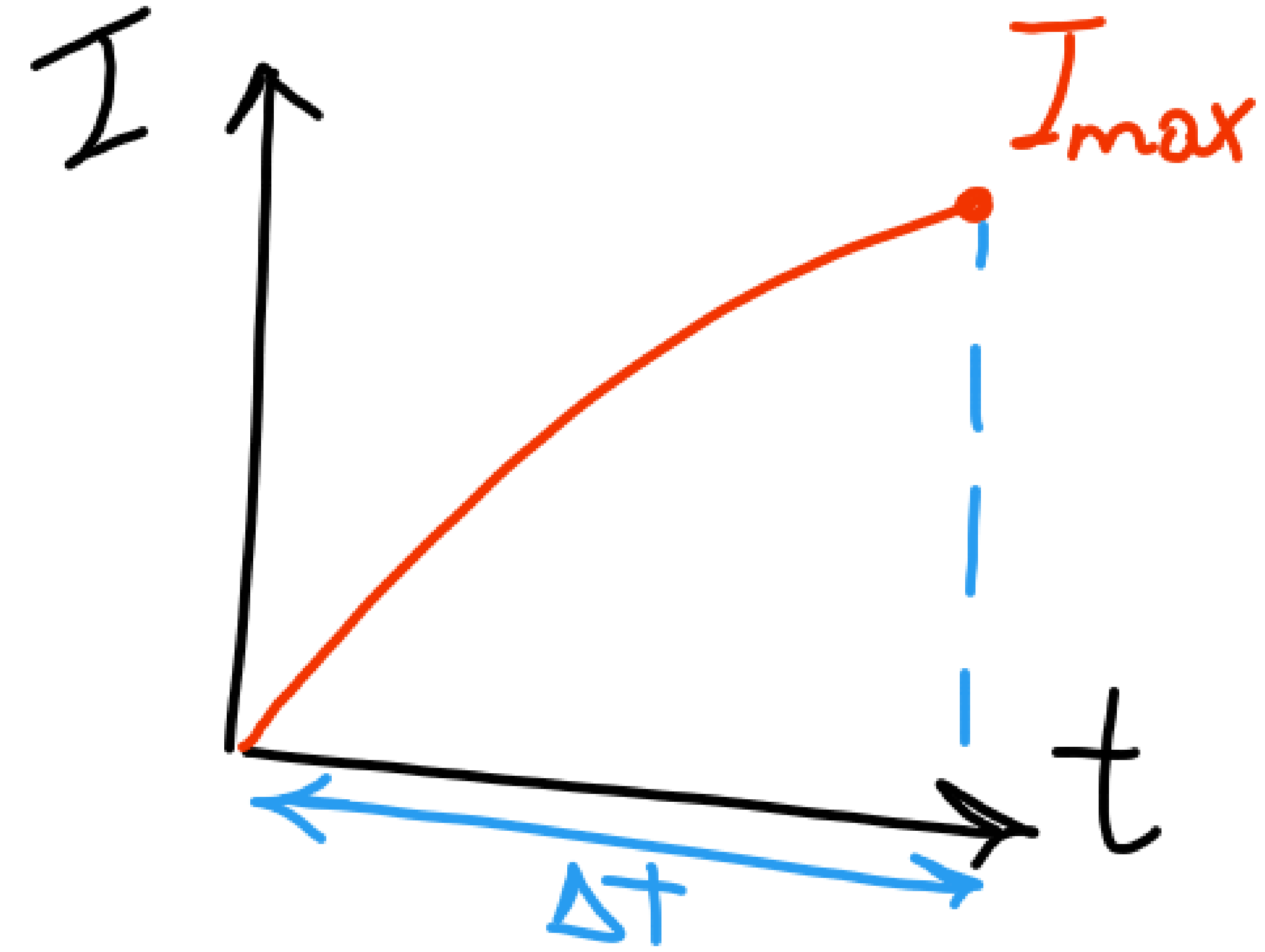
⟹ Double wounded coil: "evenly"



$\Delta\phi = 0$ $\quad emf_{ind} = 0$

$\boxed{L = zero}$





$\mu_{air} < \mu_{iron}$

$L_{air} < L_{iron}$

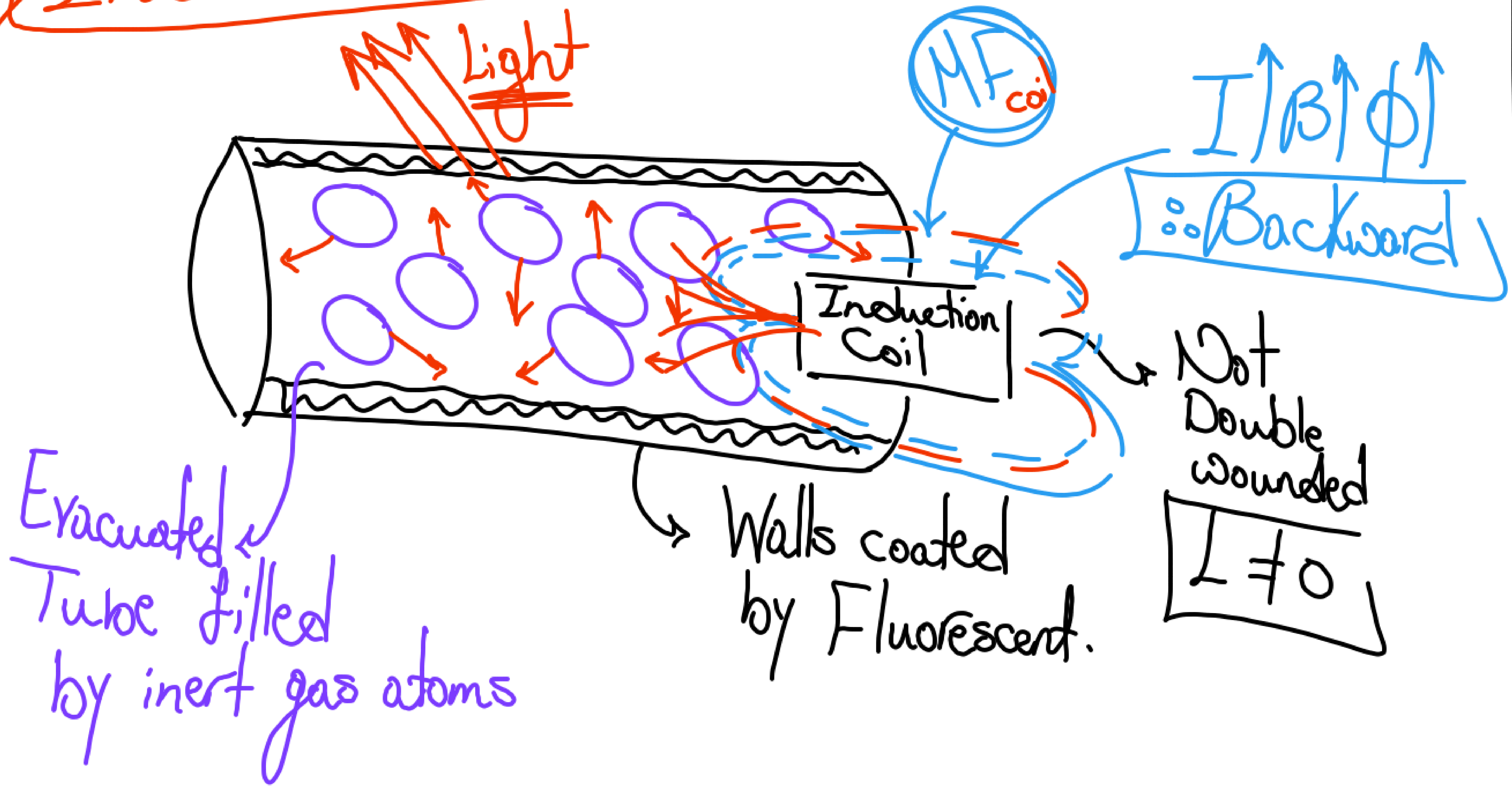
$emf_{ind} < emf_{ind}$

$\uparrow L = \dfrac{\uparrow \mu A N^2}{l_s}$

$\uparrow emf = -\uparrow L \dfrac{\Delta I}{\Delta t}$

App: Self-induction

Induction Coil in Fluorescent Lamp



⇒ Conversions:

Electrical
↓
Magnetic
↓
Mechanical
↓
Light

1. The primary coil of an induction coil is of 200 turns , is wounded around iron core whose length is 10 cm and diameter 3.5 cm and its permeability coefficient equals 0.002 Wb/A.m
If the current flowing through the primary coil is 4A and this is cut off in 0.01 sec.

Calculate :

(a) The induced EMF in the secondary coil whose number of turns 10^5 turns wounded around primary coil .

(b) The mutual induction coefficient

$N_1 = 200 \quad L_s = 0.1m \quad r = 0.0175m \quad \mu = 0.002$

$I_1 = 4A \longrightarrow 0 \quad \Delta t = 0.01s \quad N_2 = 10^5$

$$emf_2 = -M\frac{\Delta I_1}{\Delta t} = -385 \times \frac{0-4}{0.01} = \boxed{1.54 \times 10^5 \, V}$$

$$M = \frac{\mu A_2 N_1 N_2}{L_s} = \frac{0.002 \times \pi (0.0175)^2 \times 200 \times 10^5}{0.1} = \boxed{385 \, H}$$

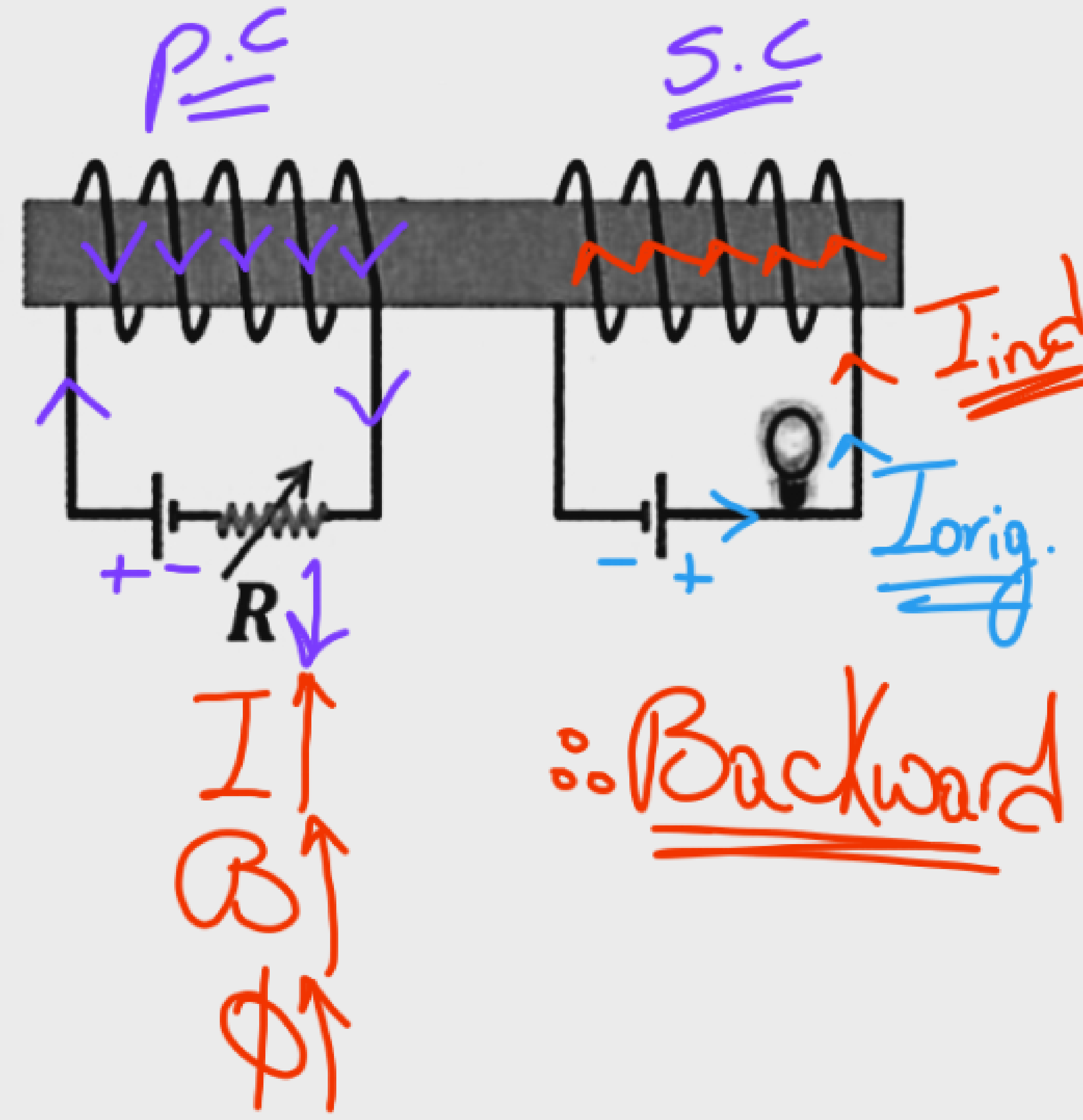
2. In the figure , when the resistance (R) is reduced , the lighting of the lamp ....

(a) decreases momentarily

(b) increases momentarily

(c) remains constant

(d) blow out



3. An electric current of intensity 10 A passes through one of two adjacent coils , when the current vanishes to zero , an induced emf of 60 V is generated in the other coil, if the mutual induction coefficient between the two coils is 0.3 H then the decay time of the current in the first coil equals to ....

(a) 0.005 s

(b) 0.05 s

(c) 0.04 s

(d) 0.4 s

$I_1 = 10A \longrightarrow 0$

$emf_2 = 60V$

$M = 0.3H$

$$emf_2 = -M \frac{\Delta I_1}{\Delta t}$$

$$60 = -0.3 \frac{0-10}{\Delta t}$$

$$\boxed{\Delta t = 0.05 \sec}$$

4. A small coil of resistance 50 Ω that consists of 10 turns , each of area 5 cm^2 is placed at the center of a big circular coil consists of 7 turns each of radius 11 cm and carries an electric current of intensity I . When the coil is inverted , electric charge of 20nC has passed in the small coil . Then the current intensity I passing in the big coil equals..................

(a) 2.5 A

(b) 5 A

(c) 7.5 A

(d) 10 A

$$emf = \frac{2NAB}{\Delta t}$$

Small

$R_2 = 50\Omega$ $N_2 = 10$

$A_2 = 5\times10^{-4}\, m^2$ $Q_2 = 20\times10^{-9}\, C$

Big

$N_1 = 7$ $r_1 = 0.11 m$

$I_1 = I$

$$emf_2 = \frac{2N_2A_2B_1}{\cancel{\Delta t}} = \frac{Q_2}{\cancel{t}} \times R_2$$

$$2N_2A_2B_1 = Q_2 \times R_2$$

$$2\times10\times5\times10^{-4}\times B_1 = 20\times10^{-9}\times50$$

$$\boxed{B_1 = 10^{-4} T}$$

$$B_1 = \frac{\mu N_1 I_1}{2r_1}$$

$$\boxed{I_1 = 2.5 A}$$

5. A solenoid coil whose core is air, its permeability coefficient is $4\pi \times 10^{-7}$ Wb/A.m, its length is 10 cm contains 700 turns, its cross sectional area is 10 cm^2 and a current of intensity 2A passes through it, (π =22/7). Find:

(a) Flux density at a point inside it along its axis.

(b) Induced EMF when current vanishes in 0.01 sec.

(c) Self-inductance of the coil.

$$L = \frac{\mu A N^2}{L_s} = \frac{4\pi \times 10^{-7} \times 10 \times 10^{-4} \times 700^2}{0.1} = \boxed{6.16 \times 10^{-3}\ H}$$

$L_s = 0.1m \quad N = 700 \quad A = 10 \times 10^{-4} m^2 \quad I = 2A$

a) $$B_s = \frac{\mu N I}{L_s} = \frac{4\pi \times 10^{-7} \times 700 \times 2}{0.1} = \boxed{0.0176T}$$

b) $$emf = -L\frac{\Delta I}{\Delta t} = -N\frac{\Delta\phi}{\Delta t} \rightarrow -700 \times \frac{(0 - 0.0176 \times 10 \times 10^{-4})}{0.01}$$

$$= 6.16 \times 10^{-3} \times \frac{0-2}{0.01}$$

6. ***The opposite graph shows the relation between the electric current intensity (I) and the time (t) in an inductor. Which of the following graphs represents the relation between the induced emf in the inductor and time (t) ?***

1st: $\Delta I = 0$ $\quad \Delta\phi = 0$ $\quad emf = 0$

2nd: $\Delta I = -ve$ $\quad \Delta\phi = -ve$ $\quad emf = +ve$

3rd: $\Delta I = +ve$ $\quad \Delta\phi = +ve$ $\quad emf = -ve$

4th: $emf = 0$

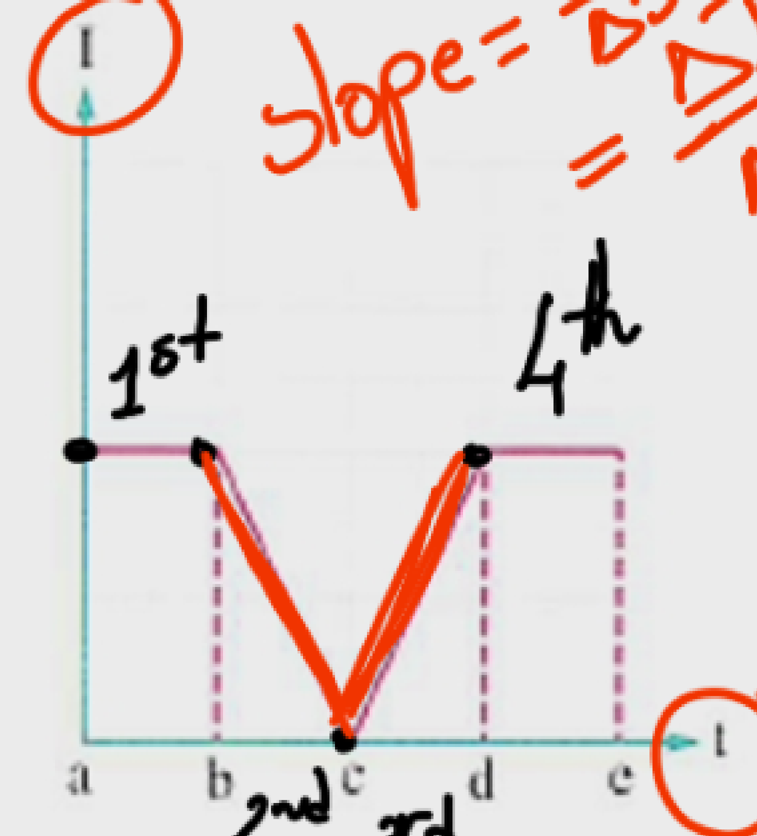
$emf = -L \dfrac{\Delta I}{\Delta t}$

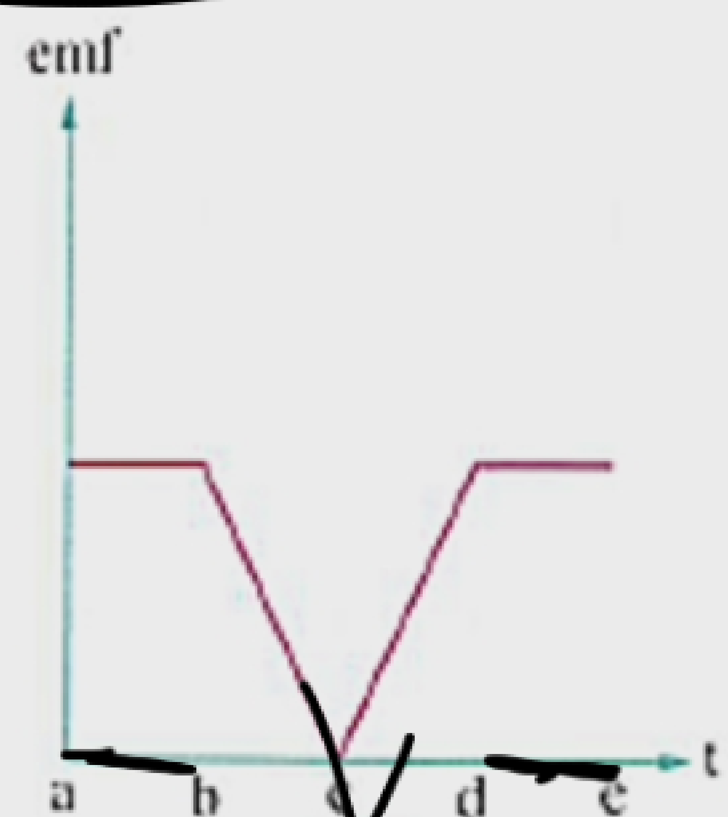
const

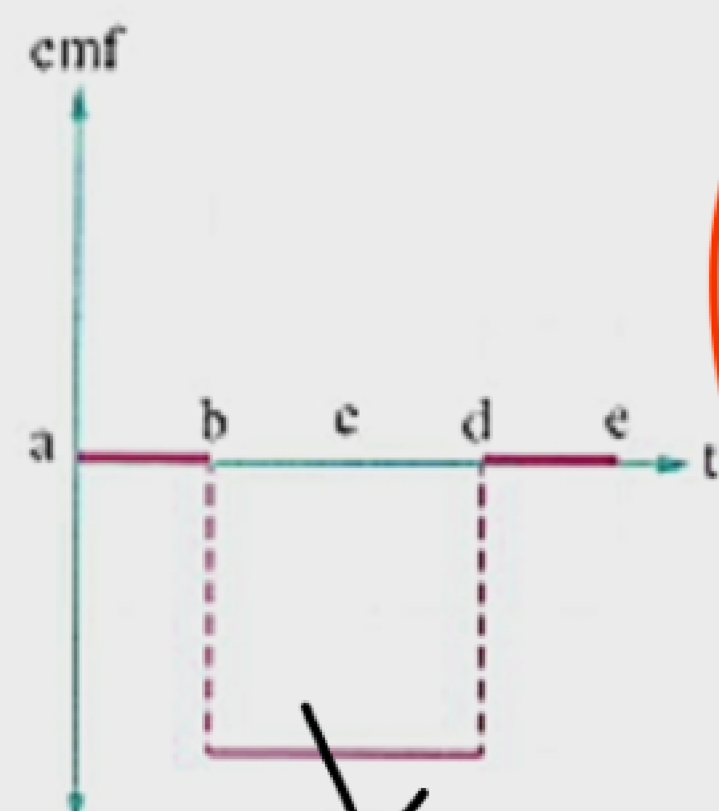
const

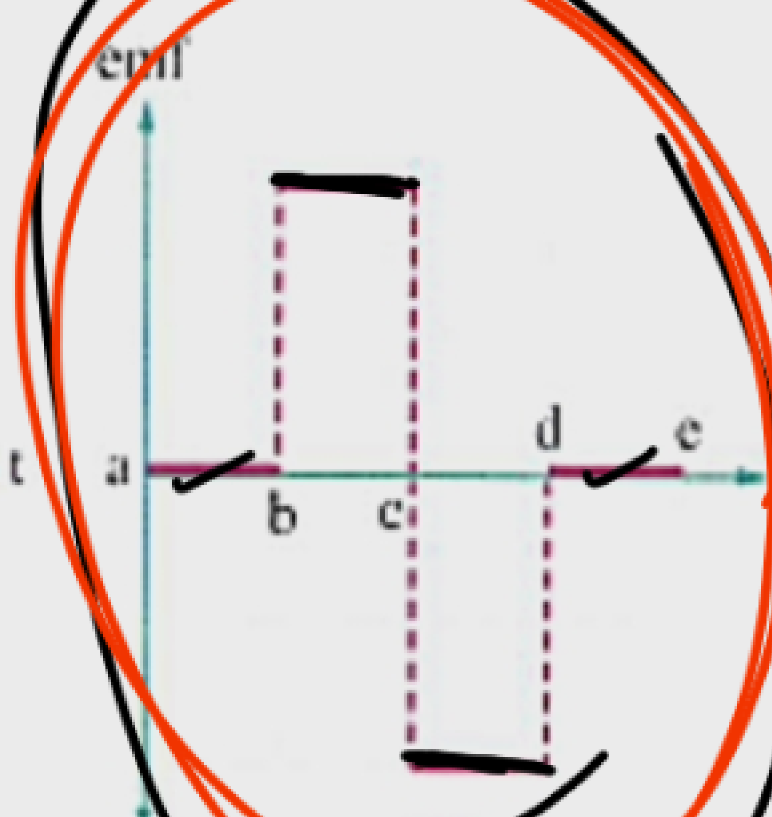
const

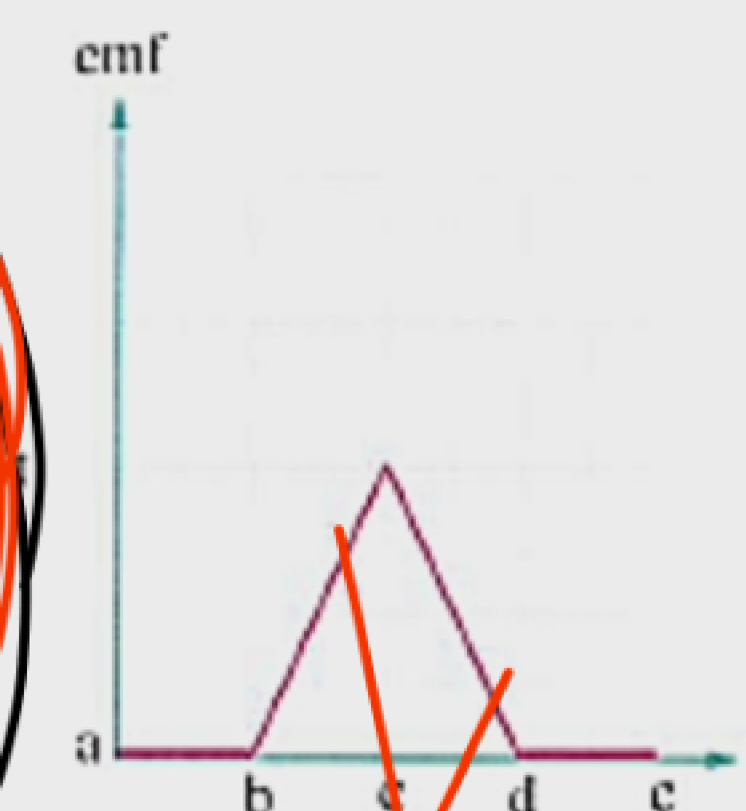
slope $= \dfrac{\Delta y}{\Delta x} = \dfrac{\Delta I}{\Delta t} =$ const.











7. When doubling the length and number of turns of a coil of self inductance L , its self inductance becomes ....

(a) L/2

(b) L

(c) 2 L

(d) 4 L

$N_1 = 1$

$L_{s1} = 1$

$N_2 = 2$

$L_{s2} = 2$

$\frac{L_1}{L_2} = \frac{1}{2}$

$\boxed{L_2 = 2L_1}$

$L = \frac{\mu A N^2}{Length}$

$$\frac{L_1}{L_2} = \frac{\cancel{A_1} N_1^2 L_{s2}}{\cancel{A_2} N_2^2 L_{s1}} = \frac{1^2 \times 2}{2^2 \times 1} = \frac{2}{4} = \frac{1}{2}$$

8. ***Two adjacent coils (x,y) of number of turns 500 and 2000 turns respectively are coiled around an iron core. When the current in coil x is changed by 10 A , the magnetic flux in the coil x gets changed by $2 \times 10^{-3}\ Wb$ and in the coil y by $10^{-4}\ Wb$, then ....***

	Self inductance of the coil X	Mutual Inductance between the two coils
(a)	0.1 H	0.02 H
~~(b)~~	0.1 H	0.04 H
~~(c)~~	0.2 H	0.02 H
~~(d)~~	0.2 H	0.04 H

$N_x = 500$

$\Delta I_x = 10A$

$\Delta\phi_x = 2\times10^{-3}\ wb$

$N_y = 2000$

$\Delta\phi_y = 10^{-4}\ wb$

$emf_x = \cancel{-} L_x \frac{\Delta I_x}{\cancel{\Delta t}} = \cancel{-} N_x \frac{\Delta\phi_x}{\cancel{\Delta t}}$

$L_x \times 10 = 500 \times 2\times10^{-3}$

$\boxed{L_x = 0.1H}$

$emf_y = \cancel{-} M \frac{\Delta I_x}{\cancel{\Delta t}} = \cancel{-} N_y \frac{\Delta\phi_y}{\cancel{\Delta t}}$

$M \times 10 = 2000 \times 10^{-4}$

$\boxed{M = 0.02H}$