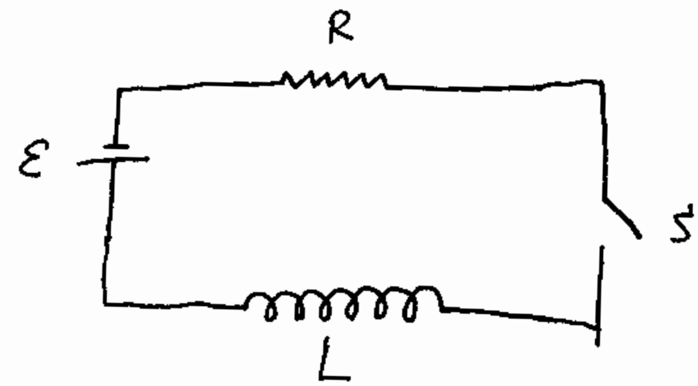
Physics 102.

Lecture 20.

Wed. Oct. 27, 2004

- RL circuits.



Induced emf:

$$\mathcal{E}_L = -N\frac{d\Phi}{dt}$$

$$|\mathcal{E}_L| = L\cdot\left|\frac{dI}{dt}\right|$$

Lenz's law. induced current will oppose the change.

$\therefore$ No abrupt change in I of L

e.g. when you switch on the circuit at time $t=0$.

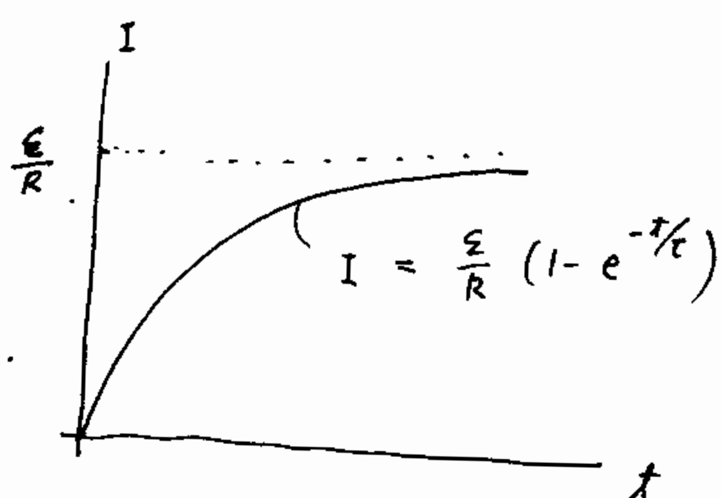
Then, the current will go up gradually.

After a long time ($t\to\infty$).

the system is stable.

i.e. $\frac{dI}{dt}=0$.

No more induced current.



$\therefore$ L has no effect.

just behave like a wire. (ideally $R_L=0$).

Then. $I=\frac{\mathcal{E}}{R}$. ($t\to\infty$).

- time dependence of the current in L:

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

where time constant τ is:

$$\tau = \frac{L}{R}.$$

The larger the L, the stronger the inductance effect.

The longer it takes to reach a stable state.

- Energy stored in an inductor

$$U = \frac{1}{2} L I^2 .$$

In fact, the energy is stored in the $\vec{B}$-field inside the inductor.

magnetic energy density:

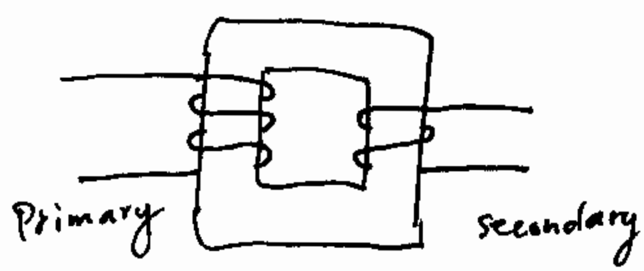
$$u_B = \frac{B^2}{2\mu_0} .$$

Note: electric energy density: (e.g: inside a capacitor)

$$u_E = \varepsilon_0 E^2/2 .$$

- Transformer:

$$\frac{\mathcal{E}_p}{\mathcal{E}_s} = \frac{N_p}{N_s} .$$



OR:

$$\boxed{\frac{V_p}{V_s} = \frac{N_p}{V_s} .}$$

Why? you work it out!

Problem. *44. of ch.23.

A solenoid. N, A, ℓ.

when $\frac{dI}{dt} = 2.0\,A/s$, $\varepsilon = 75\,mV$

(a). $L = ?$

$$|\varepsilon| = L \cdot \left|\frac{dI}{dt}\right|.$$

$$L = |\varepsilon| \Big/ \frac{dI}{dt} = \frac{75\,mV}{2\,A/s} = 3.75 \times 10^{-2}\,H.$$

$$\simeq 38\,mH.$$

(b). $\left.\begin{matrix} N, A \\ \frac{dI}{dt} \end{matrix}\right\}$ unchanged, but ℓ is doubled. $(\ell' = 2\ell)$.

What would happen to $|\varepsilon|$?

For a solenoid, $L = \mu_0 n^2 A \ell = \mu_0 \frac{N^2 A}{\ell}$.

When ℓ is doubled.

L will be ~~[illegible]~~ halved.

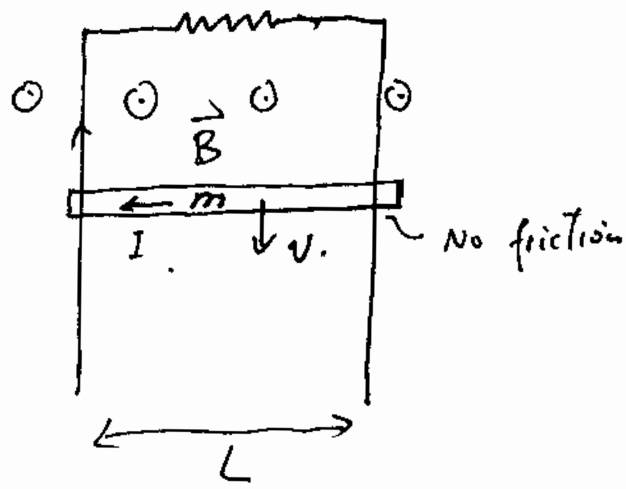
$\therefore$ $|\varepsilon| = L\left|\frac{dI}{dt}\right|$ will be halved.

$\therefore$ $|\varepsilon| < 75\,mV$.

(c). $|\varepsilon| = \frac{1}{2} \cdot 75\,mV \simeq 38\,mV$.

Problem #77 of Ch. 23.

① Motion of rod.



(a) just released. $v = 0$.

No magnetic force.

$a = g$.

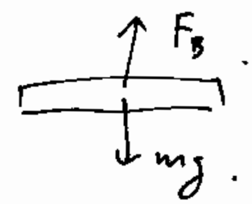
Then, $v \neq 0$.

$I \neq 0$, $I = BLv/R$

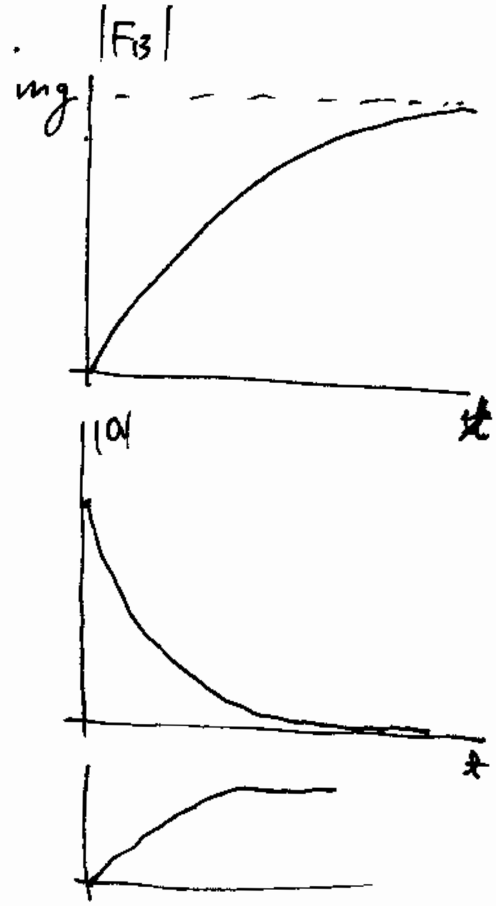
Magnetic force: $F_B = BIL$

$$= \frac{B^2 L^2 v}{R}.$$

against the motion: $F_B = -\frac{B^2 L^2 v}{R}$



just like drag force on an falling object in air.



The speed of falling will keep increasing until.

$$\frac{B^2 L^2 v}{R} = mg.$$

Then, $F_{net} = 0$.

$a = 0$.

$v = v_{Terminal}$.

The rod will eventually ~~fall~~ reach a constant speed of falling.

← terminal velocity.

(b). Direction of current.

RHR. $\leftarrow$

OR Lenz's law. $\leftarrow$

(c). at terminal speed:

$$F_{net} = 0.$$

$$F_B - mg = 0.$$

$$\frac{B^2 L^2 v}{R} = mg.$$

$$v = \frac{mgR}{B^2 L^2}.$$

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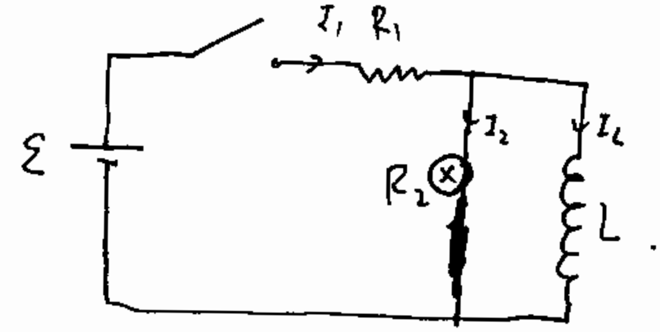
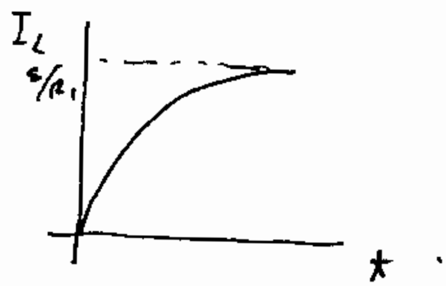
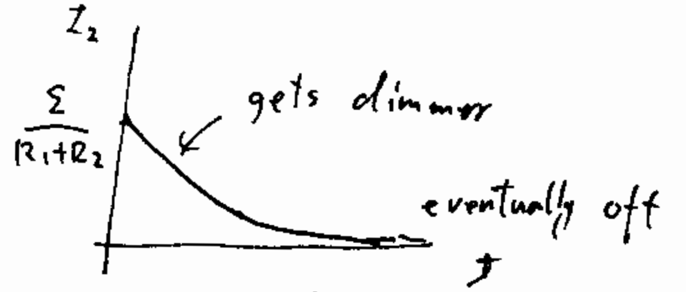
79. a). $t \to \infty$ L is like a resistor $R_L = 0$.

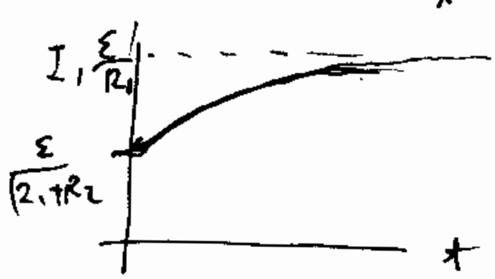


$\cancel{I = \left(\frac{\mathcal{E}}{R_1+R_2}\right.}$ $\quad I = \frac{\mathcal{E}}{R_1}$

b).







c). induced emf.

d). $V_{before} = 0$

$V_{after} = IR_2 = \left(\frac{\mathcal{E}}{R_1}\right) R_2$