Mechanics

Rectilinear Motion

- Uniform Rectilinear motion

U.R.M : $x = vt + x_0$ or $\boxed{d = vt}$

v: Constant m/s

d: $x - x_0$ distance (m)

- Uniform Acc. or Decc. Motion
  (a>0) (a<0)

U. A(D). R. M. :

$$d = x - x_0 = \frac{1}{2}at^2 + V_0 t$$

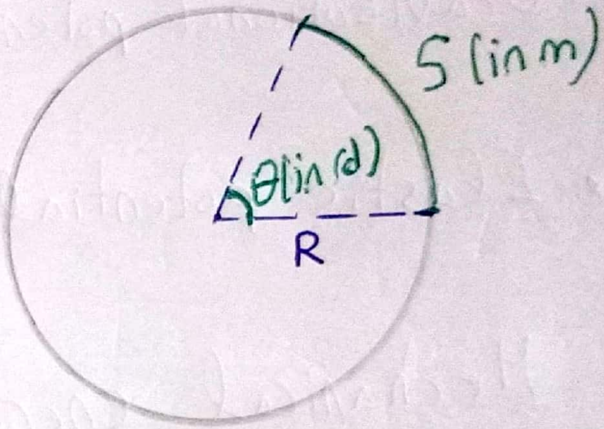
a: acceleration (m/s^2)

V_0: initial speed If from rest $V_0 = 0$

$$V = at + V_0$$

$$V^2 - V_0^2 = 2ad$$

Circular Motion



$$S = R\theta$$

$$V_{av} = \frac{\Delta S}{\Delta t}, \quad \Delta S = n \times P$$

n: nb of turns or times

P: Perimeter or Length of circle (m)

U.C.M. : $\Delta\theta = \theta - \theta_0 = \theta' t$

$\Delta\theta$: Angle in rad

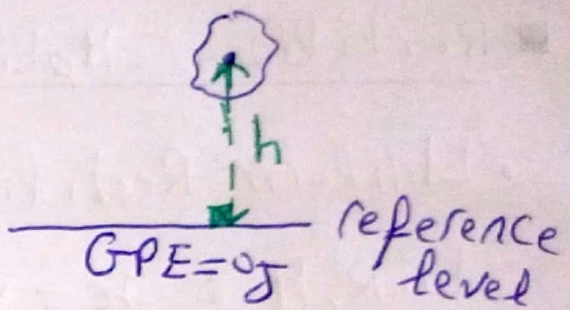
θ': angular speed (rad/s)

rd/s $\leftarrow \theta' = 2\pi N \rightarrow$ turns/s

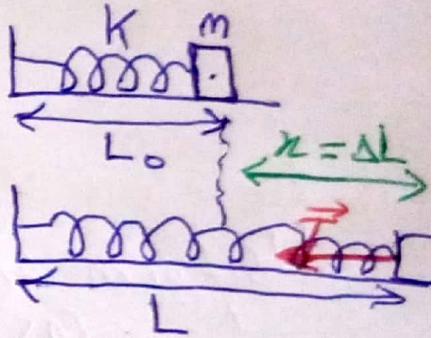
Mechanical Energy

- Kinetic energy : $\underset{(J)}{KE} = \frac{1}{2} m v^2$

- Gravitational potential energy : $\underset{(J)}{GPE} = + mgh$



- Elastic potential energy : $\underset{(J)}{EPE} = \frac{1}{2} K x^2$
  - K → Stiffness (N/m)
  - x → Elongation (m)



Restoring force : $\vec{T} = -Kx\vec{i}$

- Mechanical energy : $ME = KE + PE$

Conservation of ME
$f = 0$
$ME_i = ME_f$

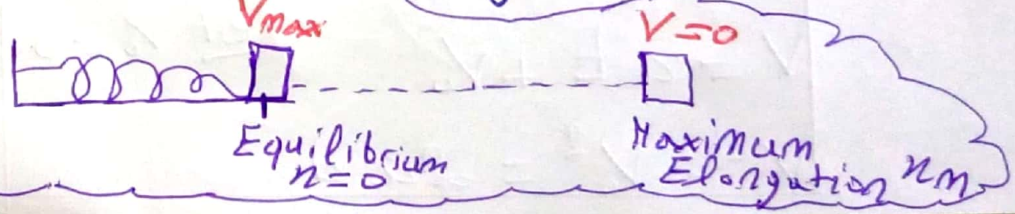
Non-conservation of ME
$f \neq 0$
$\Delta ME = ME_f - ME_i = W_{\vec{f}} = -f \times d$
losing in ME → Heat

Note :

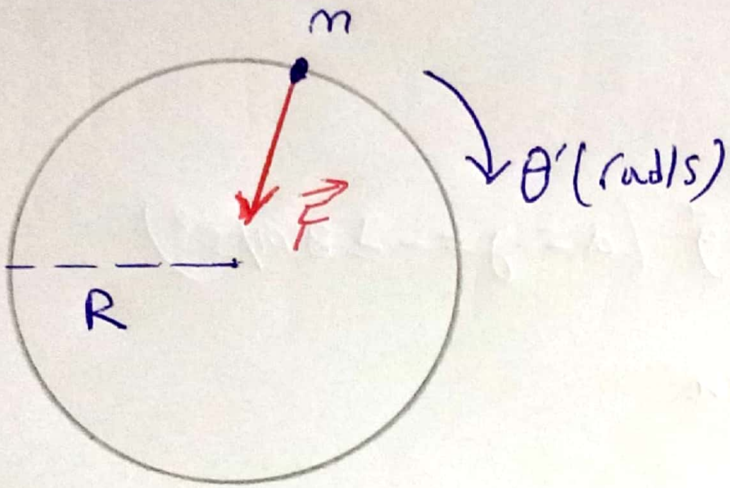
Maximum Height h_{max}
↕
$GPE_{max} = ME$
$KE = 0$
$V = 0$

Maximum Elongation x_{max}
↕
$EPE_{max} = ME$
$KE = 0, V = 0$

Example : Simple Harmonic



Centripetal Force (in circular motion)



$$F = m a_n = m \frac{V^2}{R}$$

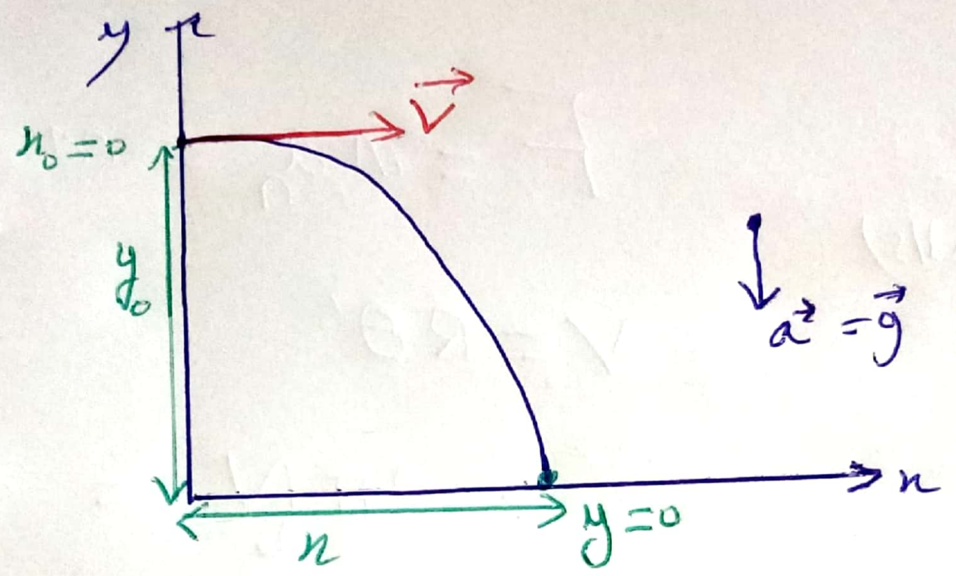
$$V = R\theta'$$

$$\underbrace{\theta'}_{(rad/s)} = 2\pi \underbrace{N}_{\substack{\text{frequency} \\ \text{(turns/s)}}} = \frac{2\pi}{\underbrace{T}_{\text{period in time for revolution}}}$$

Newton's second law:

* $V = cst \rightarrow a = 0$ (U.R.M.) $\rightarrow$ Newton's 1st law: $\sum \vec{F}_{ext} = \vec{0}$
* V varying $\rightarrow$ $a > 0$ (U.A.R.M.) $\rightarrow$ Newton's 2nd law: $\sum \vec{F}_{ext} = m$
  $a < 0$ (U.D.R.M.)

Free fall :



Equation of motion :

$$x = vt + x_0$$

$$y = -\frac{1}{2}gt^2 + y_0$$

Electricity

Electrostatic:

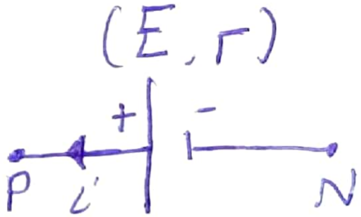
Attraction : opposite charges ⊕ ⊖

Repulsion : Same signs of charges ⊕ ⊕ or ⊖ ⊖

Charge : $Q = N . e$; N = Number of e's , $e = 1.6 \times 10^{-19}$ C
Charge of one electron

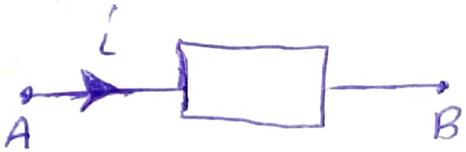
ohm's law:

• Generator:



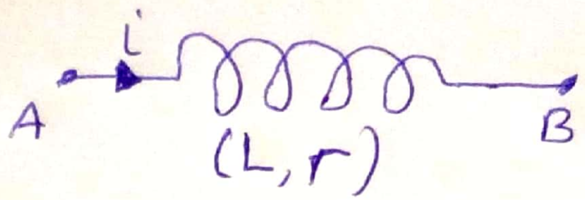
$V_{PN} = V_G = -ri + E$, r : internal resistance in ohm (Ω)
E : electromotive force in Volt

• Resistor:



$V_{AB} = V_R = Ri$

- Coil :



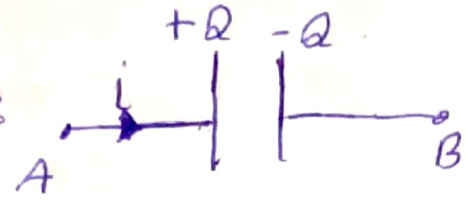
$$V_{AB} = V_L = ri + L\frac{di}{dt}$$

L : inductance in Henry (H)

r : internal resistance in ohm (Ω)

purely inductive coil : $r = 0\,\Omega$

- Capacitor :

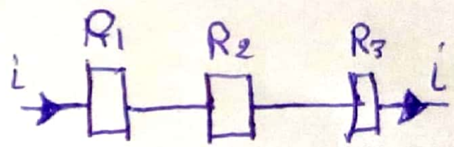


$$V_{AB} = V_C = \frac{Q}{C}$$, C : Capacitance in Farad (F)

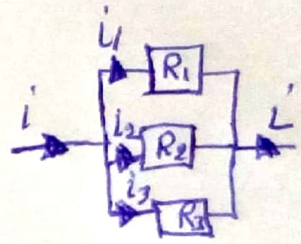
Q : Charge in Coulomb (C)

Resistors :

- In Series : $R_{eq} = R_1 + R_2 + \cdots$



In the n equivalent Resistance : $\boxed{R_{eq} = nR}$

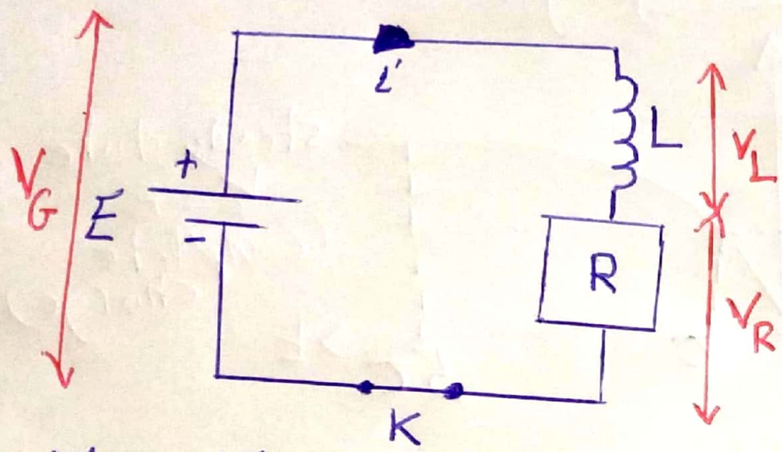


- In parallel : $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$

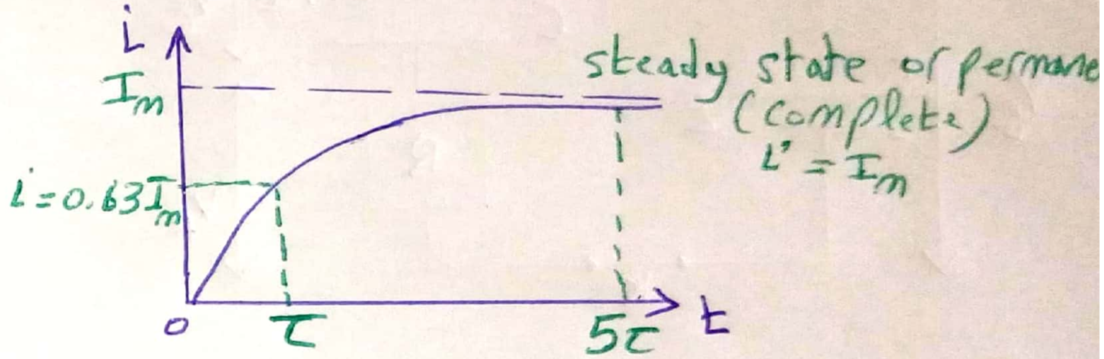
In the case of n equivalent Resistors : $\boxed{R_{eq} = \frac{R}{n}}$

Direct current DC :

R-L circuit



Growth :

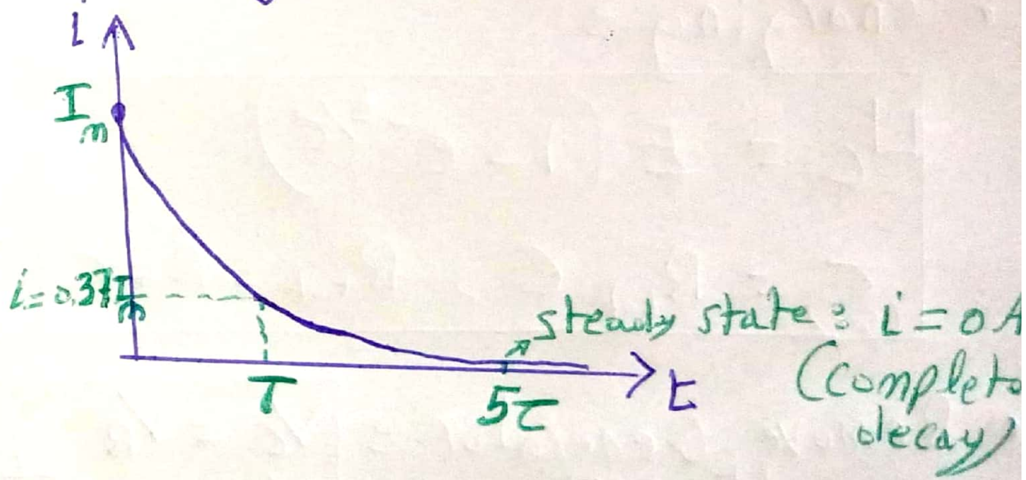


- $V_G = V_L + V_R$
- K closed $\rightarrow i \nearrow \rightarrow$ growth process :

$$\boxed{i = I_m \left(1 - e^{-t/\tau}\right)}$$

$$I_m = \frac{E}{R_{tot}} \;,\; \underset{(ses)}{\tau} = \frac{L}{R_{tot}} \;,\; R_{tot} = R + r$$

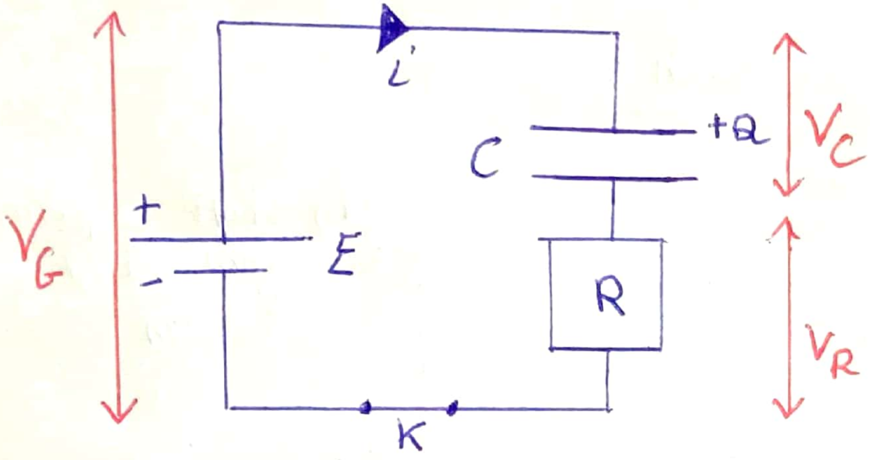
Decay :



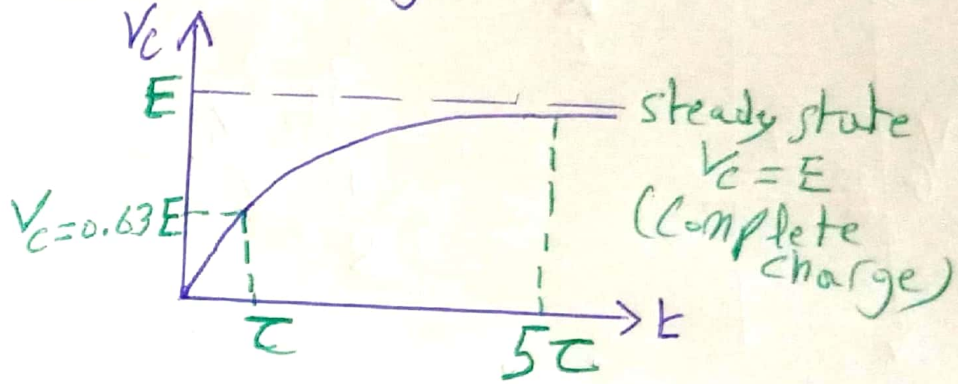
- K open $\rightarrow i \searrow \rightarrow$ decay process :

$$\boxed{i = I_m \, e^{-t/\tau}}$$

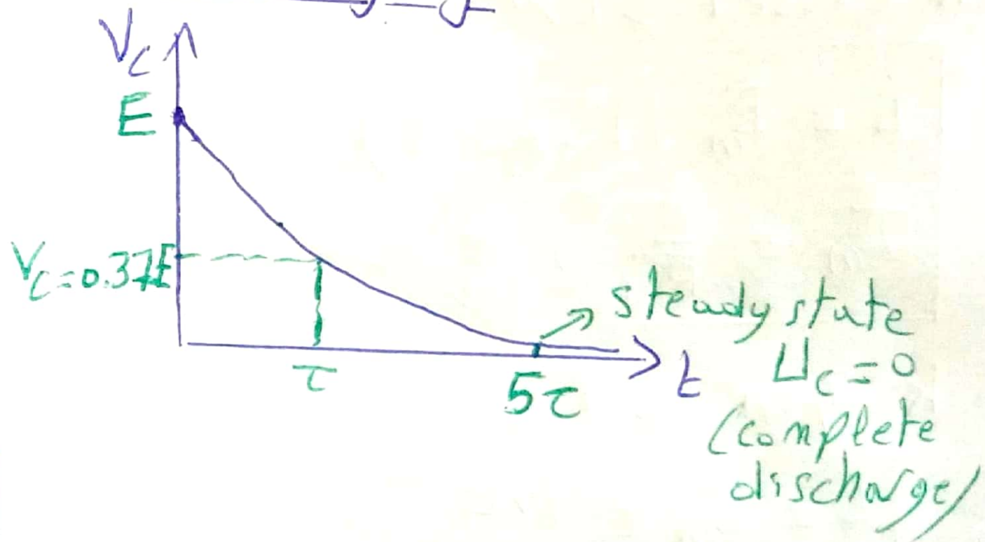
R-C circuit



Charging :



Discharging :



- $V_G = V_C + V_R$
- charging :

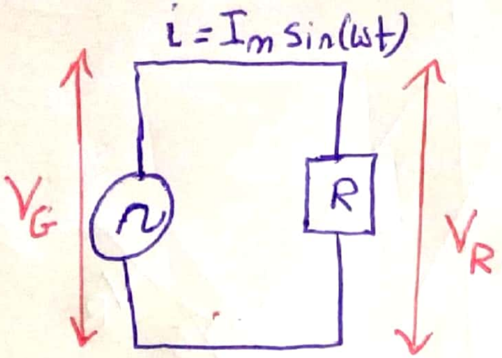
$$\boxed{\begin{array}{l} U_C = E\left(1 - e^{-t/\tau}\right) \\ \underset{(sec)}{\tau} = R_{tot}\, C, \quad R_{tot} = R + r \end{array}}$$

- Remove Generator : $(E = 0V)$

$$\boxed{\begin{array}{l} V_C = V_R \\ V_C = E\, e^{-t/\tau} \end{array}}$$

Alternating Current AC :

* R circuit :

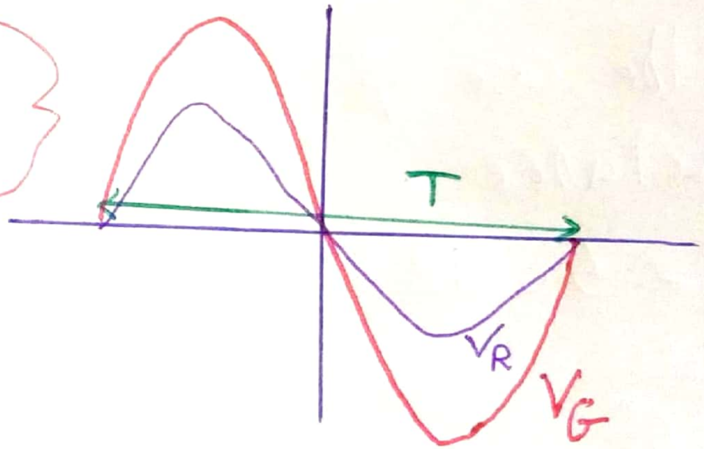


• $V_R = R\,i$, V_R and i are proportional
→ V_R and i are in phase
$\phi = 0$ rd

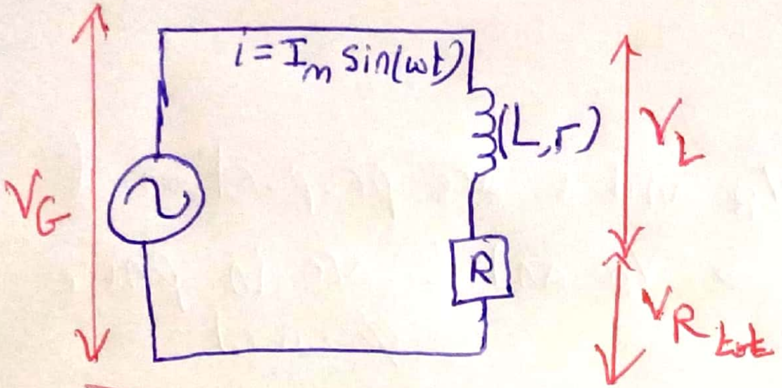
• $V_G = V_R$, V_G and V_R are in phase

pulsation or angular frequency :

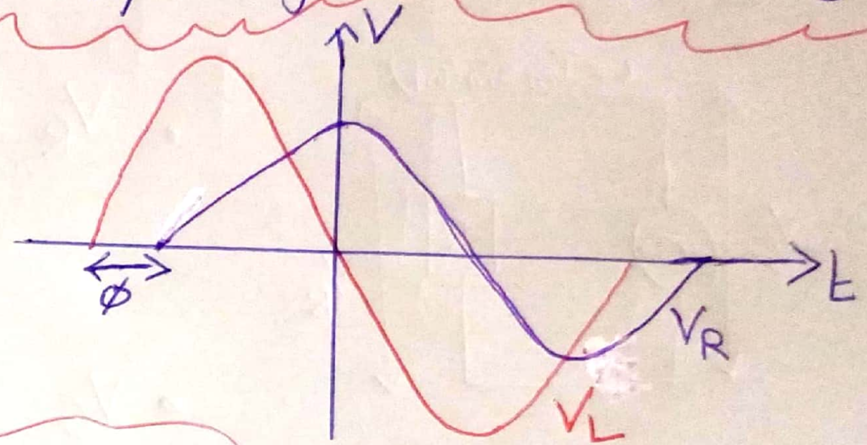
$$\underset{(rad/s)}{\omega} = 2\pi \underset{(Hz)}{f} = \frac{2\pi}{T\,(sec)}$$



* R_L series circuit:



• $i\ (V_R)$ lags behind V_L and V_G



• In the case of $r = 0\,\Omega$
→ i lags behind V_L by $\frac{\pi}{2}$ rd

<u>Note</u>: In the case of reactance

take $f = 50$ Hz

• ohm's law:

$V_R = R I$

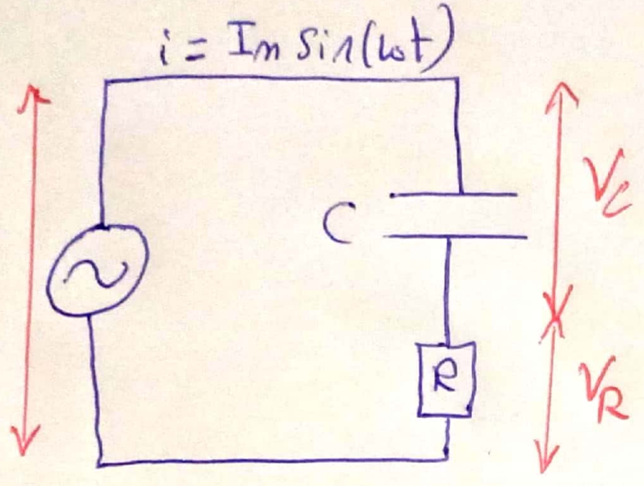
$V_L = X_L I$, $\underset{(\Omega)}{X_L} = 2\pi f L$ is the inductance reactance

$V_G = Z I$, $\underset{(\Omega)}{Z} = \sqrt{R^2 + X_L^2}$ is the impedance

• phase angle: $Z^2 = R^2 + X_L^2$

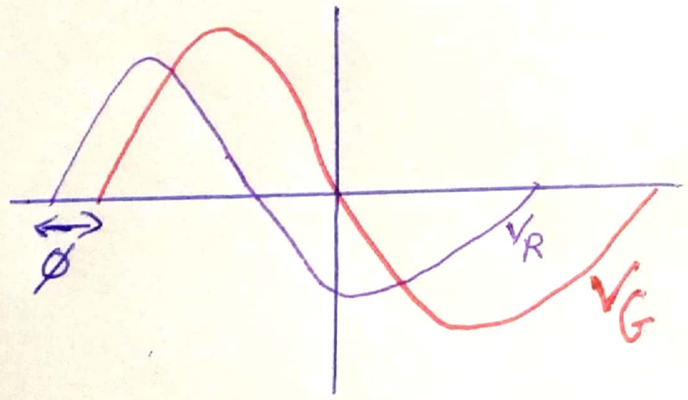
$\cos\phi = \frac{R}{Z}$, $\sin\phi = \frac{X_L}{Z}$, $\tan\phi = \frac{X_L}{R}$

* R – C series circuit :



- $i\,(V_R)$ leads V_C by $\frac{\pi}{2}$ rad

$i\,(V_R)$ leads V_G



- ohm's law :

$$V_R = R\,I$$

$$V_C = X_C\,I, \quad \underset{(\Omega)}{X_C} = \frac{1}{2\pi f C} = \frac{1}{wC}$$

is the capacitance reactance

$$V_G = Z\,I, \quad \underset{(\Omega)}{Z} = \sqrt{R^2 + X_C^2}$$

is the impedance

- phase angle :

$$Z^2 = R^2 + X_c^2$$

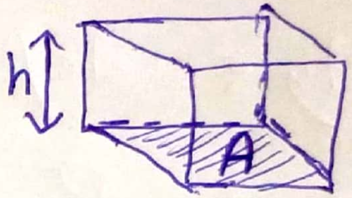
$$\cos\phi = \frac{R}{Z}, \quad \sin\phi = \frac{X_c}{Z}, \quad \tan\phi = \frac{X_c}{R}$$

Fluids and thermodynamics :

Solids (Metals)

* property : definite volume and definite shape

* Density : $\underset{(Kg/m^3)}{\rho} = \dfrac{m\ (Kg)}{V\ (m^3)}$



$\underset{(m^3)}{V} = \underset{\substack{\text{Area} \\ (m^2)}}{A} \times \underset{\substack{\text{Height} \\ (m)}}{h}$

$A = L \times W$ (Rectangle)

$A = S \times S$ (Square)

* Units :

$Kg \xrightarrow{\times 10^3} g$, $g \xrightarrow{\times 10^{-3}} Kg$ $\quad \underline{\underline{m}}$

$m^3 \xrightarrow{\times 10^6} cm^3$, $cm^3 \xrightarrow{\times 10^{-6}} m^3$ $\quad \underline{\underline{V}}$

$Kg/m^3 \xrightarrow{\times 10^{-3}} g/cm^3$, $g/cm^3 \xrightarrow{\times 10^3} Kg/m^3$ $\quad \underline{\underline{\rho}}$

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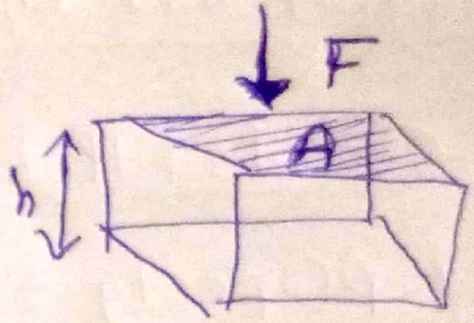
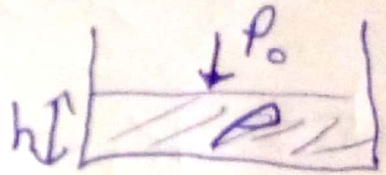
* Pressure: $\underset{\text{(Pascal Pa)}}{P} = \frac{F}{A} = \frac{\text{Force (N)}}{\text{Area (m}^3)}$



$V = A \times h$

Liquids:

* property: definite shape only
* Pressure: $P = \rho g h + P_0$



Gas:

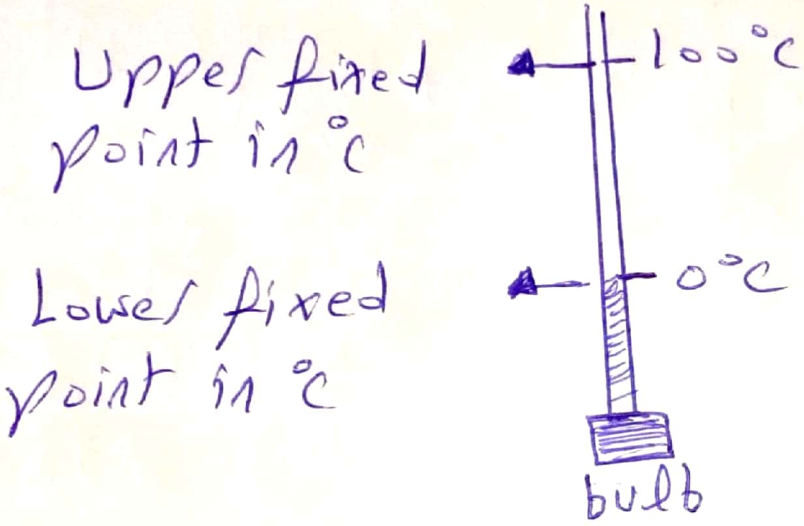
* ideal-gas equation:

$$PV = nRT$$

P → Pressure
V → Volume
n → number of molecules
R → $R = 8.314 \frac{J}{mol.K}$
T → Temperature (Kelvin K)

* The Average Kinetic energy of gas molecules: $KE = \frac{3}{2} RT$

Thermometer:



0°C can be marked on the stem:
we need to put the bulb in pure melting ice (0°C) to mark scale

Sound

* Sound wave is a mechanical wave (need material to propagate) → it doesn't propagate in vacuum

* Sound wave is a longitudinal wave (direction of propagation of the wave // to the displacement of the particles

* $V_{sound} = \lambda f$; $V_{sound\ in\ air} = 343\ m/s$

V_{sound} → Speed depends on the medium of propagation

λ → wavelength in m

f → frequence depends on the source (Hz)

$V_{sound\ in\ solids} > V_{in\ liq.} > V_{in\ gas}$

* Echoes : Reflection of sound causes echoes

Light

* Light is a transversal wave (direction of propagation of wave ⊥ to the displacement of particles)

* Light is an electromagnetic wave (can propagate in both medium and vacuum)

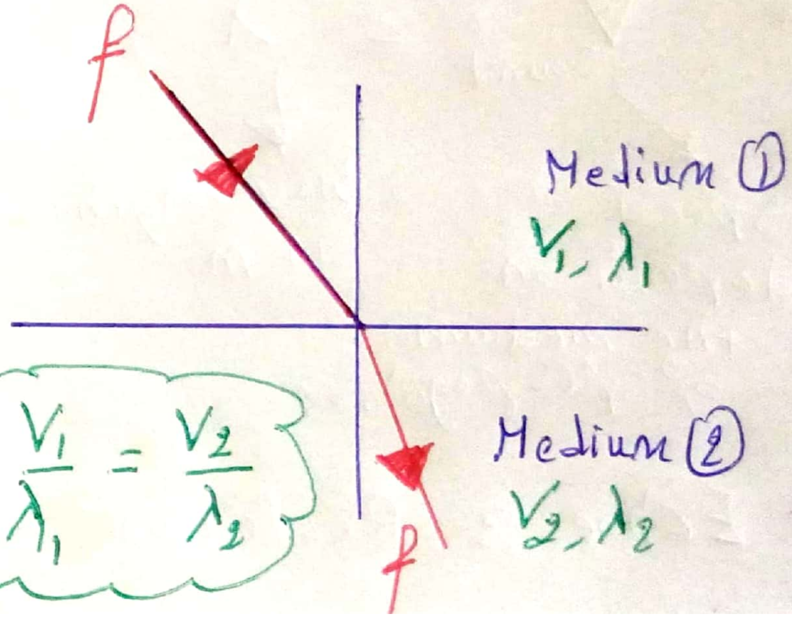
* speed of light in vacuum : $C = 3 \times 10^8 \, m/s$
speed of light in medium of index of refraction n :

$$\boxed{V = \frac{c}{n}}$$

* $V_{light} = \lambda f$

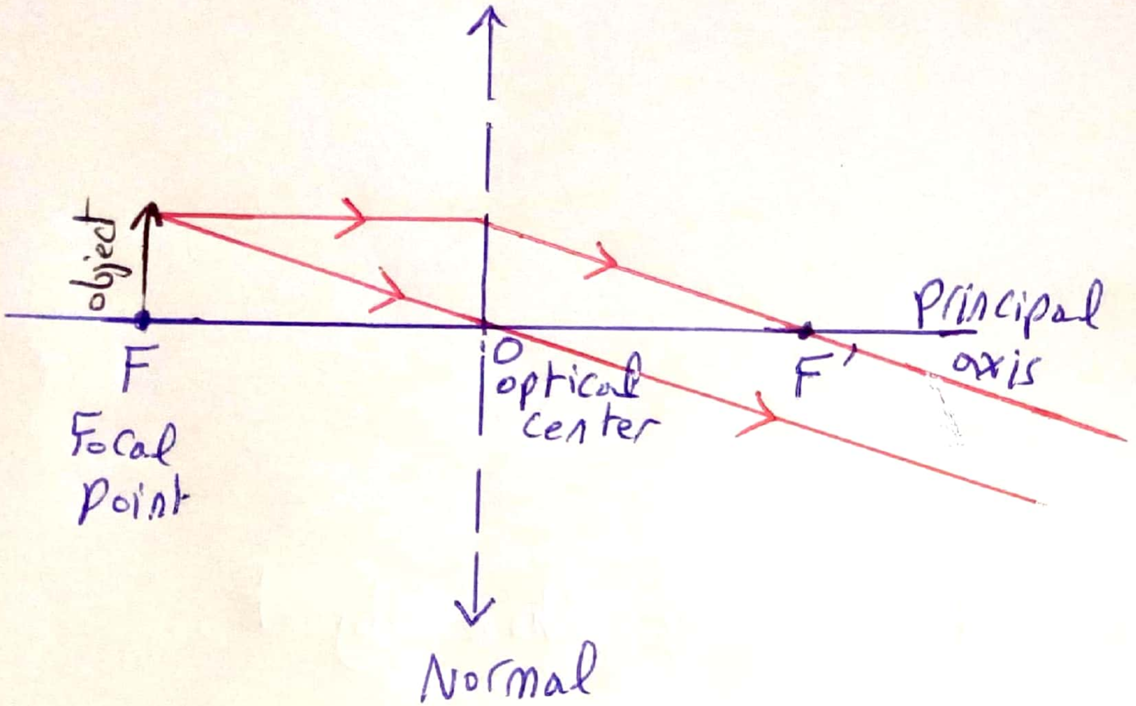
V_{light} → depends of medium

f → depends on source

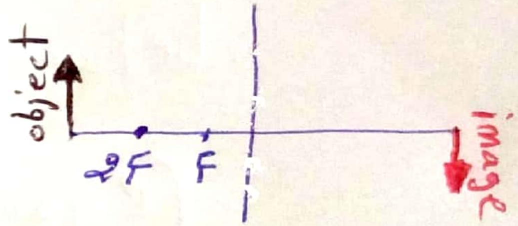


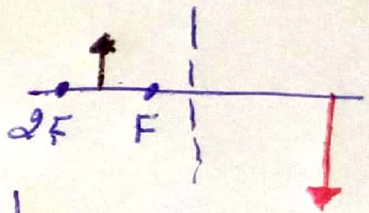
$$\frac{V_1}{\lambda_1} = \frac{V_2}{\lambda_2}$$

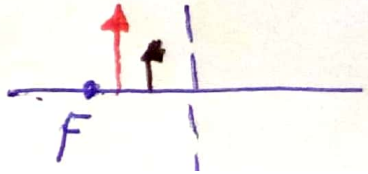
Convergent Lenses (convex lenses)



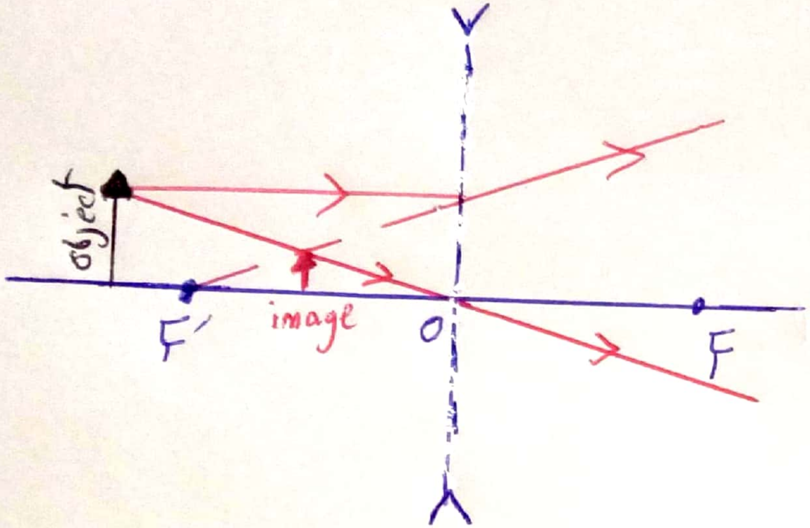
- Object past 2F : Inverted, reduced, real
- object betweem F and 2F : Inverted, Enlarged, Real
- object inside F : upright, Enlarged, virtual







Divergent lenses (Concave lenses)

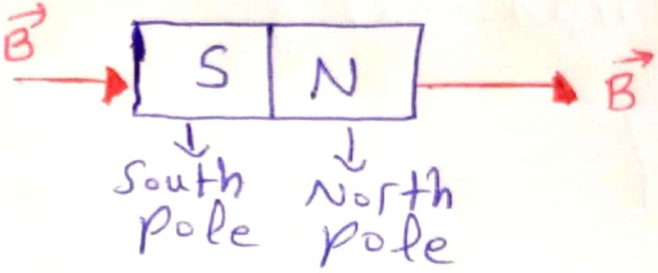


Usually: virtual, upright, smaller than object, between the object and lenses regardless the object position

Magnetism

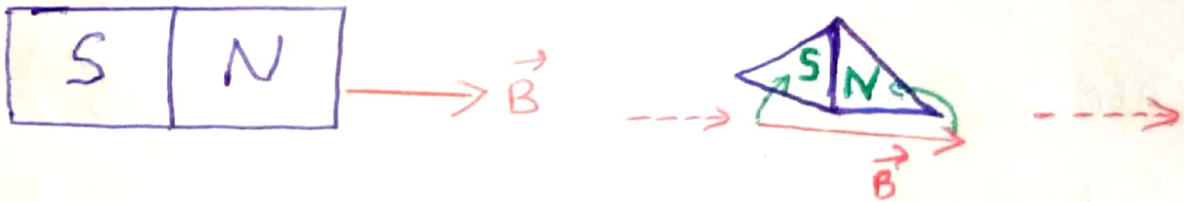
■ Magnetic field $\vec{B}$:

* Bar Magnet :

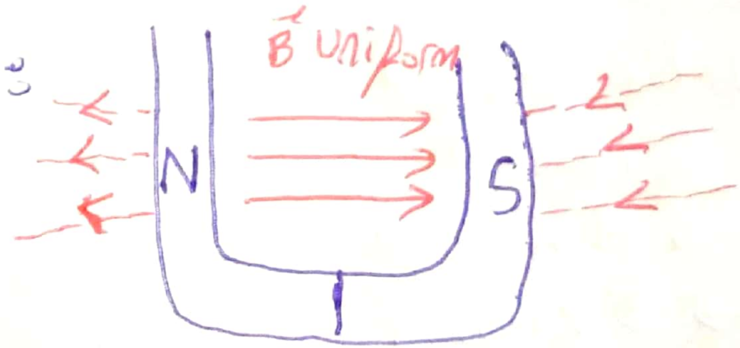


$\vec{B}$ exists from N-pole and enter from S-pole

To identify the poles of magnet: Use a compass needle



* ⊔- shape magnet :

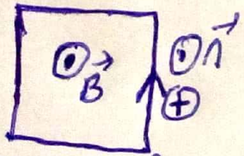


* $\vec{B}$ measured by Teslameter
* Unit of $\vec{B}$ is Tesla (T)
* Attraction : N – S ; Repulsion : N – N, S – S
* Magnetisation of iron bar :

Electromagnetic induction :

Coil in magnetic field $\longrightarrow$ Magnetic flux $\phi = NBS\cos\theta$ (Weber, wb)

where N: number of loops



Square loop

S: surface of the coil (Rectangle: $L \times w$, Square: $s \times s$)

B: Magnetic field

θ: angle between the orientation of $\oplus$ direction and $\vec{B}$

$\rightarrow$ ϕ varying if $\rightarrow$ B varying $\longrightarrow$ e.m.f: $|e| = NS\dfrac{\Delta B}{\Delta t}$ (volt) $\rightarrow i_{induced} = \dfrac{|e|}{R_{tot}}$

$\rightarrow$ S varying $\longrightarrow$ e.m.f: $|e| = NB\dfrac{\Delta S}{\Delta t}$

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Radioactivity :

Types of radioactive or desintegration :

$$\text{Radioactive simple } {}^{A}_{Z}X \xrightarrow{\text{desintegrate}} \text{Daughter } {}^{A'}_{Z'}Y + \text{radiated particles}$$

α : ${}^{4}_{2}He$, Helium

or β^- : ${}^{0}_{-1}e$, electron

or β^+ : ${}^{0}_{+1}e$, positron

Particles	Charge	Speed
α	+	$V = 20000$ km/s
β^-	−	$V = 270\,000$ Km/s
β^+	+	$V = 270\,000$ Km/s

Penetration : $\gamma > \beta > \alpha$

Note :
To determine A', Z' using

ex : $A = A' + 4$ (α-decay)
$Z = Z' + 2$

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Half-life or period:

A time needed by a radioactive sample to decay to its Half mass.

initial mass $\qquad\qquad$ remaining mass

$$m_0 \xrightarrow[\text{One period}]{T} \frac{m_0}{2} \xrightarrow[\text{two periods}]{2T} \frac{m_0}{4} \xrightarrow[\text{Three periods}]{3T} \frac{m_0}{8}$$