SOLUTIONS TO PHYSICS PAPER 2 SEMINAR QUESTIONS – HELD AT ST. JOSEPH'S S.S.S. NAGGALAMA

1. (a) (i)

Real objects	Virtual objects
- Real rays emerge or originate from them. i.e. (source of the rays)Are formed by actual intersection of real rays.	- Are apparent positions of origin of virtual or imaginary rays i.e. virtual rays appear to emerge from them.
- They have actual size or height and shape. i.e ⟹they can be touched.	- They appear to have actual size or height and shape i.e. the do not have physical existence.
- Incident light from it is a divergent beam.	- Incident light from it is a convergent beam.

(ii)

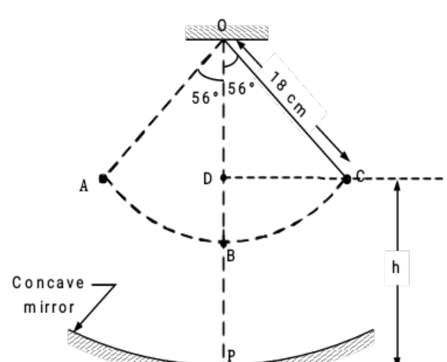
(b) (i) Linear magnification – is the ratio of the size (height) of the image to the size (height) of the object.

(ii) $1 + \frac{1}{m} = \frac{u_1}{f}$ ……………….(i) $1 - \frac{1}{m} = \frac{u_2}{f}$ ……………….(i)

Equation (i) - (ii) $\Rightarrow \frac{1}{m} - \left(-\frac{1}{m}\right) = \frac{u_1}{f} - \frac{u_2}{f} = \frac{u_1 - u_2}{f} = \frac{d}{f}$

$\Rightarrow \frac{1}{m} + \frac{1}{m} = \frac{u_1 - u_2}{f} \Rightarrow \frac{2}{m} = \frac{d}{f}$

$\therefore f = \frac{1}{2} md$



(c) Using, $\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \Rightarrow \frac{1}{u}=\frac{1}{10}-\frac{1}{30}$ $\therefore$ u = 15 cm

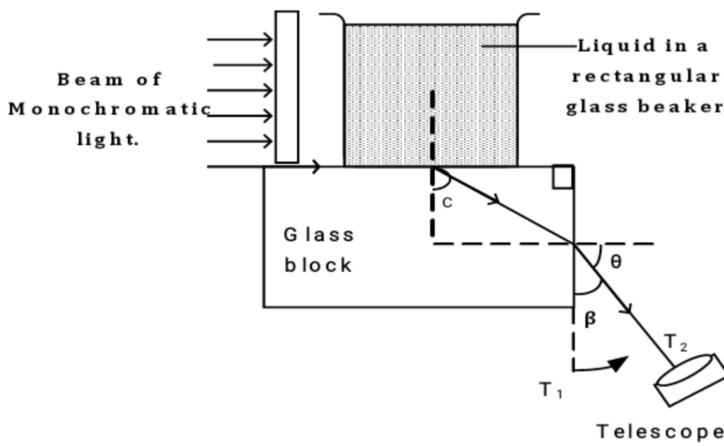
$\therefore$ BP = u = 15 cm, while OD = 18cos 56°

$\therefore$ OD = 18cos 56°=10.07 cm

$\Rightarrow$BD = 18 - 10.07 = 7.93 cm

$\therefore$ h = BD + BP = (7.93+15.0) = 22.93 cm

(d) (i) A thin walled rectangular glass tank is filled with an optical liquid and placed on top of a rectangular glass prism of known refractive index, n_g as shown in the figure below.



A fine beam of monochromatic light is then made incident on one side of the liquid tank and observed at the extreme end on a telescope.

Starting with the telescope, T at the edge of the prism, the initial position T_1 on the scale of the instrument is noted.

The telescope is then turned away from the prism until the image of the illuminated source is received at the centre of the telescope.

The new position T_2 of the telescope on its scale is noted.

The angle β between the two positions T_1 and T_2 of the telescope, is the measured and recorded down.

The refractive index, n_L of the liquid is calculated from the expression,

$$n_L = \sqrt{n_g^2 - \sin^2(90° - \beta)} \quad \text{or} \quad n_L = \sqrt{n_g^2 - \sin^2\theta}$$

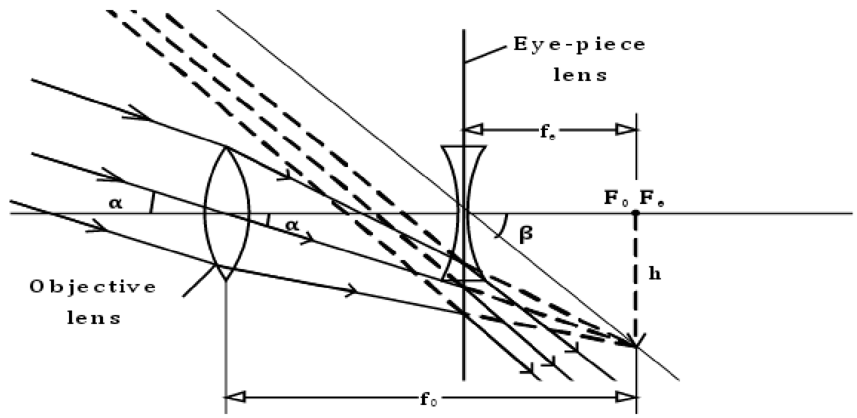
(ii) Using, $n_L = \sqrt{n_g^2 - \sin^2\theta}$

$$n_L = \sqrt{1.50^2 - \sin^2 43°}$$

$\therefore n_L = 1.34$

2. (a) (i) Angular magnification is the ratio of the angle subtended at the aided eye by the final image to the angle subtended at the naked eye by the object.

(ii)



Angular magnification, $M = \frac{\beta}{\alpha}$

For α and β being small angles expressed in radians,

$\tan\alpha \cong \alpha = \frac{h}{f_0}$, $\tan\beta \cong \beta = \frac{h}{f_e}$,

$\Rightarrow M = \frac{\beta}{\alpha} = \frac{h}{f_e} \div \frac{h}{f_0} = \frac{h}{f_e} \times \frac{f_0}{h}$

$\therefore M = \frac{f_0}{f_e}$

(iii) A Galilean telescope is ***compact and more portable*** *than an Astronomical telescope owing to the length of the telescope of* $(f_0 - f_e)$ *as opposed to* $(f_0 + f_e)$ *for an Astronomical telescope when both are in normal adjustment or use.*

A *Galilean telescope also forms* ***final upright images*** *making it more suitable for observing objects on land and on water surfaces unlike Astronomical telescopes that form final inverted images.*

Disadvantage(s).

A Galilean telescope however has ***a virtual eye ring*** *making measurements involving it* ***less accurate*** *since the observer's eye cannot be placed at exactly the eye ring position but just near the eye piece lens.*

It also has ***a narrow field of view*** *due the virtual eye ring unlike Astronomical telescopes that has a real eye ring and thus having a wider field of view.*

(b) $L_oL_e = 96$ cm M = 15 u = 14.4 m =1440 cm

$f_o + f_e = 96$

$\frac{f_o}{f_e} = 15 \quad \Rightarrow \quad f_o = 15 f_e$

$\therefore 15f_e + f_e = 96 \qquad 16f_e = 96$

$f_e = 6$ cm and $\therefore f_o = 90$ cm

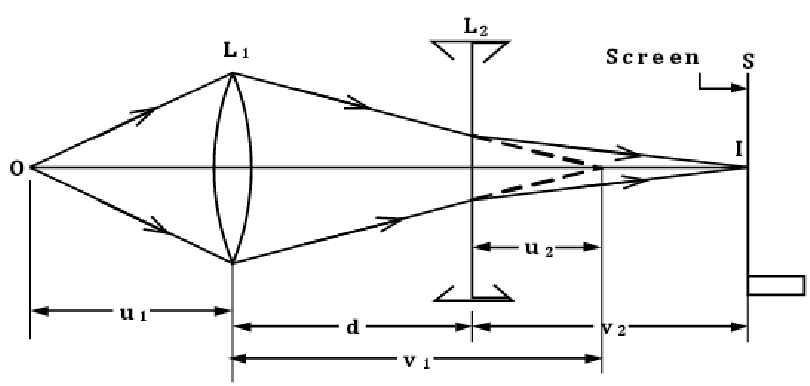
From $\frac{1}{u_0} + \frac{1}{v_0} = \frac{1}{f_0}$

$$\frac{1}{v_0} = \frac{1}{90} - \frac{1}{1440}$$

$$\Rightarrow \quad v_0 = 96 \text{ cm}$$

Thus, the eyepiece ***is moved away from the original position*** by a distance of 6 cm i.e. away from the objective in order to bring about the required change.

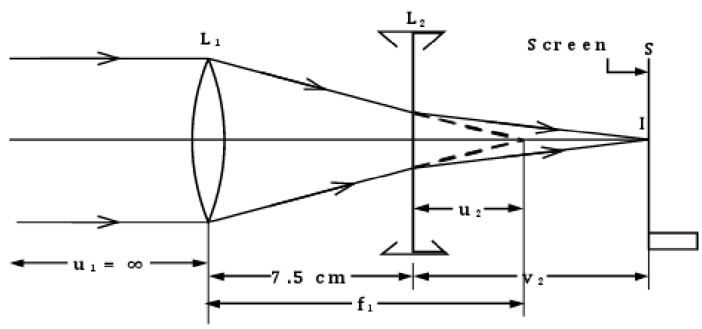
(c) (i) A convex lens L_1 is mounted vertically on a lens holder and an illuminated object O is mounted infront of lens L_1 at a distance $u_1 > f_1$
A vertical screen is then set up behind L_1 first in the absence of lens L_2



Starting with initial distance, $u_1 > f_1$, the screen **S** is moved to and fro lens L_1 until a sharp real image I_1 is formed on it.
Distance v_1 is measured using a metre rule and recorded and the position of **S** is noted.
A concave lens L_2 is now introduced and placed co-axially with L_1 somewhere between L_1 and the screen S.
The position of screen S is adjusted by moving it backwards until another sharp real image I_2 is formed on the screen S.
Distance v_2 is noted.
Distance **d** between the lenses is also noted.
Distance $u_2 = -(v_1 - d)$ is obtained, from which the focal length **f** of the concave

lens is calculated from $\frac{1}{f} = \frac{1}{-(v_1-d)} + \frac{1}{v_2}$.

(c) (ii) f_1 = 17.5 cm, f_2 = -15.0 cm d = 7.5cm



Action of L_2

$$\frac{1}{u_2} + \frac{1}{v_2} = \frac{1}{f_2} \quad \Rightarrow \quad \frac{1}{10} + \frac{1}{v_2} = \frac{1}{15}$$

$$\therefore \quad \frac{1}{v_2} = \frac{1}{10} - \frac{1}{15}$$

$$v_2 = 30.0\text{cm}$$

Thus image formed is real, upright, inverted and magnified

$$m = \frac{v}{u} = \frac{30}{10} = 3$$

3. (a) ***Free oscillations*** are oscillations that are not subjected to dissipative damping forces hence the energy and the amplitude are constant.

Damped oscillations are oscillations subjected to dissipative damping forces where the energy and amplitude decrease with time.

(b) (i) ***End correction*** is the length of the vibrating air column to be added to the length of the pipe in order for a given mode of vibration to be complete.

(ii) An open ended pipe is inserted inside a water trough with its top just seen above the water surface.
A tuning fork is set into vibration and held just above the pipe.
The vibrating fork and the pipe are gently raised until the first loud sound is heard.
The length l of part of the pipe above the water surface.

From $l + e = \frac{\lambda}{4}$

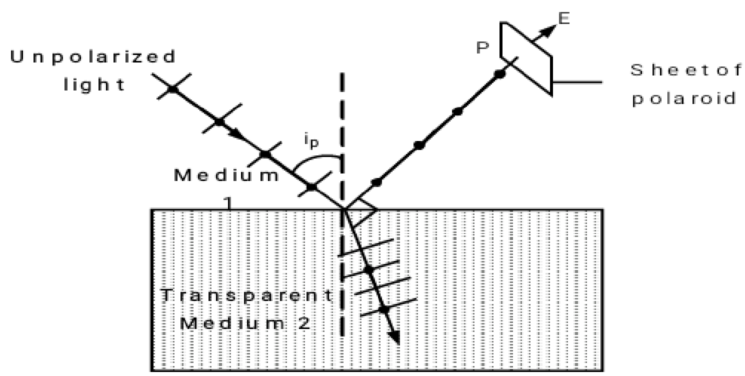
$$l + e = \frac{v}{4f}$$

$$e = \frac{v}{4f} - l$$

The end correction ***e*** is then calculated where **v** is known speed of sound in air and **f** is the frequency of the tuning fork.

(c) (i) ***Un- polarized light*** is one whose vibrating electric vector is not restricted to any particular plane of vibration ***while***
Plane polarized light – is one where ***vibrations*** of its ***electric vector*** take place in ***only one plane*** perpendicular to the direction of propagation of the wave.

(ii) ***Polarization by reflection***



Un-polarized light is directed onto a piece glass at a very small angle to the normal as shown on the diagram.

A sheet of polaroid P held in the direction of the reflected light with its plane perpendicular to that of propagation of the reflected light, is slowly rotated while observing intensity of the emergent light at E, beyond P.

The angle of incidence i is gradually increased and each time P is slowly rotated while observing intensity of the emergent light at E, beyond P.

At one particular value of $i = i_p$ called the polarizing angle, light emerging beyond P is cut off except at only two positions of the polaroid, implying the reflected light is now completely plane – polarized.

(d) (i) ***Doppler effect*** is the apparent change in the frequency of waves received by the observer due to relative motion between the source of the waves and the observer.

(ii) when the child moves toward the source (whistle)

$$f' = \left(\frac{v+u_0}{v}\right)f$$

Pitch $\frac{f'}{f} = \frac{v+u_0}{v}$ ………………………….(i)

When the moves away from the whistle

$$f'' = \left(\frac{v-u_0}{v}\right)f$$

Pitch $\frac{f''}{f} = \frac{v-u_0}{v}$ ……………………….....(ii)

But $\frac{f'}{f} = \frac{105}{100}\frac{f''}{f} \Rightarrow \frac{v+u_0}{v} = \frac{105}{100}\left(\frac{v-u_0}{v}\right)$

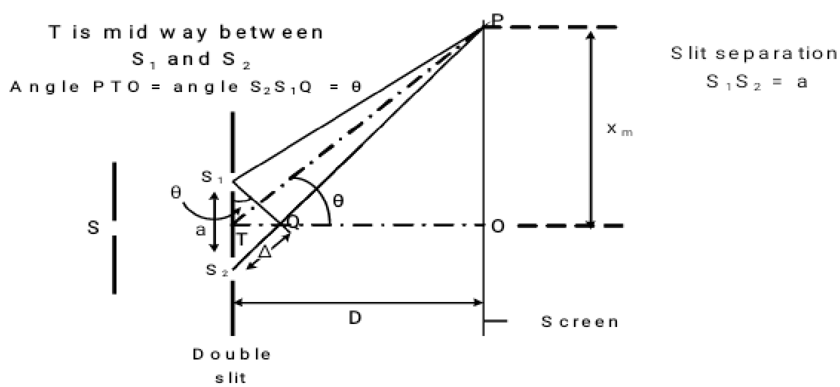
$\therefore \quad 100v + 100u_0 = 105v - 105u_0$

$205u_0 = 5v \Rightarrow u_0 = \frac{5}{205}\times 340 = 8.3ms^{-1}$

4. (a) (i) ***Diffraction*** is the spreading of waves beyond their geometrical barriers.

Interference is the super position between two wave trains originating from coherent sources leading to formation of alternate regions of bright and dark boards.

(ii) ***Derivation of fringe separation, y***



Triangle S_1S_2Q is similar to triangle PTO
Suppose P is the position of the m[th] bright fringe, then the path difference,
$S_2P - S_1P = m\lambda$ ……………………………………………….(i)
The path difference between the waves arriving at P from S_1 and S_2 is
$S_2Q = (S_2P - S_1P)$ ……………………………………………....(ii)

For small values of angle θ, in radians, $\sin\theta \approx \tan\theta \approx \theta = \frac{x_m}{D}$

But, $S_2Q \approx a\sin\theta = a\tan\theta = \frac{a\,x_m}{D}$

Hence , $S_2Q = \frac{a\,x_m}{D}$ ………………………………………….......(iii)

From (i) and (iii) , the m^{th} bright fringe is obtained from, $m\lambda = \frac{a\,x_m}{D}$

implying , $x_m = \frac{mD\lambda}{a}$ ………………………………………….(iv)

The (m – 1)th bright fringe, $x_{m-1} = \frac{(m-1)\lambda D}{a}$ ....(v)

Fringe separation, $y = (x_m - x_{m-1}) = \frac{\lambda D}{a}$ from (iv) and (v)

Thus, ***Fringe width(separation),*** $y = \frac{D\lambda}{a}$

(b) (i) ***Coherent sources*** are sources having the *same frequency*, similar or *comparable amplitudes* and having a *constant phase* or phase relationship.

Path difference is the difference in the geometrical path travelled by two waves from a common plane of origin up to a point where they overlap or superpose each other.

(ii) $AD = \sqrt{30^2+3.5^2}$
$= 30.20cm$
$BD = \sqrt{30^2+10.5^2}$
$= 31.78cm$
∴ path difference
DP = BD – AD = 31.78 – 30.20
= 1.58 cm

For the 1st minimum,

Path difference $= \frac{\lambda}{2}$

$1.58 = \frac{\lambda}{2}$

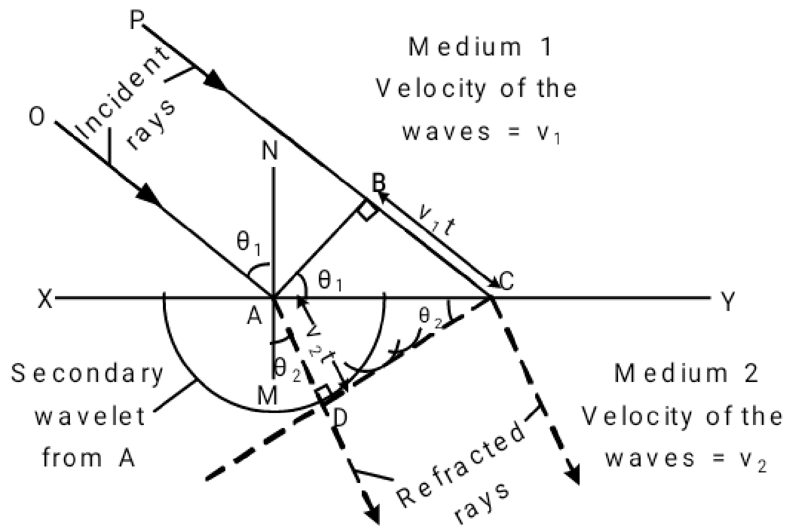
∴ $\lambda = 3.16cm$

(c) (i) ***Huygens's principle states that***:

Every point on a wave front can be regarded as a source of a new spherical wavelet that advances with the wave velocity and the line joining the tangents to the wavelets becomes the new secondary wave front.

(ii) Incident wave front AB reaches the plane-refracting surface at A first then Later reaches B.

If t is the time lapse before B reaches C, it implies distance BC = v_1t, the refracted ray at A begins to bend and in the same time t, it covers distance AD = v_2t.



From the geometry of the diagram above, ΔABC has angle CAB = angle OAN = θ_1, while from ΔACD, angle ACD = angle MAD = θ_2

From Snell's law of refraction n sin i = a constant, using ΔABC and ΔACD

$$BC = v_1 t \qquad AD = v_2 t$$

$$1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{BC}{AC}\times\frac{AC}{AD} = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2}$$

But $v_1 = \frac{c}{n_1}$, $\quad v_2 = \frac{C}{n_2}$

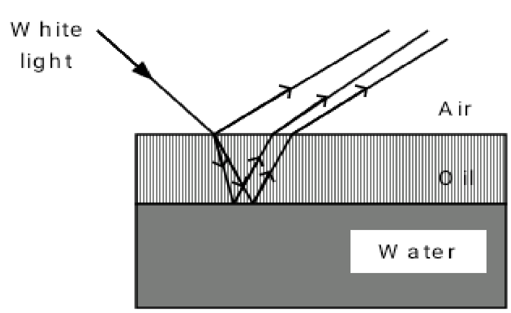
$$\Rightarrow \frac{v_1}{v_2} = \frac{c}{n_1}\times\frac{n_2}{C} = \frac{n_2}{n_1}$$

Also $v = f\lambda$

$$\Rightarrow \frac{f\lambda_1}{f\lambda_2} = \frac{n_2}{n_1}$$

$$n_1\lambda_1 = n_2\lambda_2$$

(d) When white light is incident on to the oil film, it is partly **reflected** and partly **refracted**.



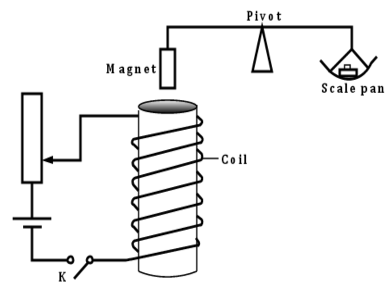
Due to refraction, **dispersion** takes place. The dispersed light is reflected at the

interface between oil and water.
The light reflected from both surfaces meet again in air and superpose.

The colour for which **constructive superposition** takes place at a given position is the one being viewed there, hence coloured fringes are observed.

5. (a) (i) An ***ampere*** is the steady current which when flowing in each of the two straight, parallel and infinitely long wires of negligible cross – sectional area placed 1m apart in vacuum exert a force of $2\times10^{-7}Nm^{-1}$ on each other.

(ii) $F = BIL\sin\theta$



Current flowing $I = \frac{Ne}{t}$

$\therefore F = BNe\frac{l}{t}\sin\theta$

$\therefore F = B\,Nev\sin\theta$ but $\frac{l}{t} = v$

Force on one electron $F_1 = \frac{F}{N}$

$F_1 = Bev\sin\theta$

(b) (i) When switch K is closed, a current flows through the solenoid, clockwise. This makes the top end of the coil a south pole, but since there is an increase in the size of the force required to establish horizontal equilibrium, it makes the lower end of the magnet a **north pole** being attracted by the south pole of the top side of the solenoid.

(ii) When K is open, weight of the magnet = weight in the pan = 0.20 N

When K is closed, a current flows through the coil and a magnetic force created is proportional to square of current flowing i.e. $F \propto I^2$

$\Rightarrow F = kI^2 \;\therefore\; 0.20 + kI_1^{\,2} = 0.22$..............(i) when $I_1 = 0.50$ A

$\Rightarrow k = 0.08\ NA^{-2}$ thus when the current becomes $I_2 = 2.0$ A

$\Rightarrow 0.20 + kI_2^{\,2} = F'$...................................(ii)

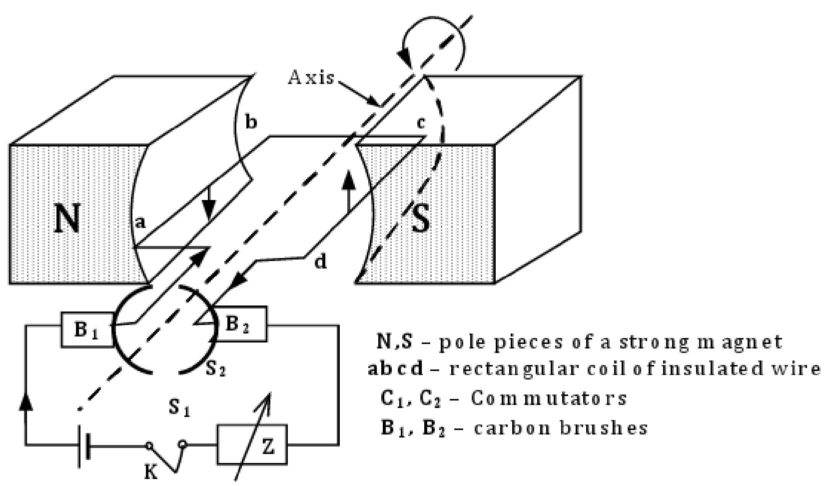
$\therefore\; F' = 0.20 + 0.08\times 2.0^{\,2} = 0.20 + 0.32 = 0.52$ N

(c) Using induced charge $Q = \frac{\Delta\emptyset}{R} = \frac{2NAB}{R}$ where $B = \mu_0 n I$

$\Rightarrow Q = \frac{2\,\mu_0 n\,I\,NA}{R}$ but $Q = k\theta = \frac{1}{k'}\theta$ where $k' = 2$ div per μC

$$\therefore I = \frac{RQ}{2\mu_0 n NA} = \frac{20 \times \frac{1}{2} \times 8.0 \times 10^{-6}}{2 \times 4\pi \times 10^{-7} \times 1000 \times 10 \times \pi (2.5)^2 \times 10^{-4}} = 1.62 \text{ A}$$

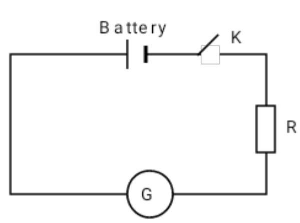
(d) ***The working principle of a d.c. motor.***



When switch K is closed, a current I flows through the coil in a clockwise direction. Side ab of the coil placed between the pole pieces of the U-shaped magnet experiences a downward force while side cd experiences an upward force
(By Fleming's left hand rule)
The coil rotates I a clockwise direction.

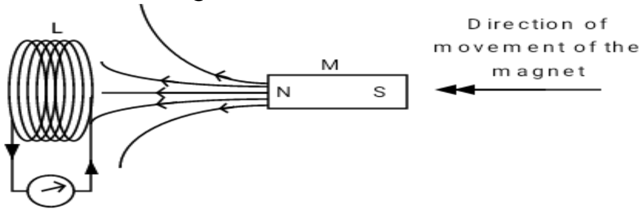
After 90° turn (quarter revolution), the carbon brushes B_1 and B_2 lose contact with the commutators and current is cut off. However due to momentum of the coil, C_1 and C_2 interchange contacts with B_1 andB_2.
After half revolution (180° turn) contacts are interchanged and current reverses direction of flow in the coil, however the direction of rotation of the coil is maintained.

6. (a) A centre zero galvanometer G, a switch K, resistor R and source of e.m.f. are connected in series to ascertain the direction of deflection of the galvanometer for a given direction of flow of current as shown in the figure below.



Switch K is closed and the direction of deflection of the centre zero galvanometer is noted.

The source of e.m.f., a switch K and a resistor R are replaced by a coil of known sense of winding as shown.



A bar magnet with its north pole closer to the coil is moved **towards** the coil, and G is seen to deflect to the right.
When the magnet is withdrawn and pulled away from the coil, the galvanometer G deflects in the opposite direction (to the left).
When the bar magnet is moved towards the coil, the increasing magnetic flux threading and linking the coil causes an e.m.f. to be induced in the coil.
An induced current I flows in such a direction to make the end of the coil nearer the approaching magnet a north pole also opposing the approaching north pole of the bar magnet.
When the magnet recedes (is withdrawing), the reducing magnetic flux threading the coil induces an induced e.m.f. which acts in such a direction as to cause an induced current I to flow in such a way as to make the end of the coil a south pole attracting the receding north pole.
Thus in every action of the magnet the coil responds in a way as crate activity that opposes the action that caused it, hence Lenz's law.

(b) At the axle the radius of axle is negligible. $V = 0\ m\ s^{-1}$
At the rim the velocity is $V\ ms^{-1}$
Thus the average velocity of the rim = ½ (0 + V) but $V = r\omega$
Average velocity $v = \frac{1}{2} r\omega$.
Induced e.m.f $E = BLv \sin\theta$ where L, is the length of each spoke cutting the magnetic field.
Thus $L = r$. Therefore $E = Brv$

$E = \frac{1}{2} Br^2\omega$ where $\omega = 2\pi f$

$E = B\pi r^2 f$

(c) (i) since transformers, work on the principle of mutual induction a change of current in the primary induces e.m.f in the secondary given by

$$E_s = \frac{d}{dt} N_s \Phi$$

$$= N_s A \frac{dB}{dt} \quad \text{where } B = \mu_o nI$$

$$\Longrightarrow B = KI_o \sin 2\pi ft$$

$$= N_s AK \times 2\pi f \sin 2\pi ft$$

$$E_s = E_o \sin 2\pi ft$$

Where $E_o = 2\pi fNAKI_o$

Since $E_s \propto f$

A fall in the supply frequency causes a fall in the secondary output voltage.

(ii) from $\frac{V_s}{V_p} = \frac{N_s}{N_p}$

$$\Rightarrow \quad V_s = V_p\frac{N_s}{N_p}$$

$$V_s \propto \frac{1}{N_p}$$

Thus reduction in the number of turns in the primary causes the output voltage V_s to increase.

(d) N_s = 60 turns $\qquad V_s$ = 240V

N_p = 1200 turns $\qquad \eta$ = 80%

R_s = 3Ω $\qquad I_s$ = ?

Using $I_sV_s = \frac{80}{100}I_pV_p$ but $I_s = \frac{V_s}{R} \Rightarrow \frac{V_s^{\,2}}{R} = \frac{80}{100}I_pV_p \Rightarrow I_p = \frac{100\,V_s^{\,2}}{80\,R\,V_p}$

$$\Rightarrow I_p = \frac{100 \times V_s^{\,2}}{80\,R\,V_p} \text{ but } V_s = V_p\frac{N_s}{N_p} \Rightarrow I_p = \frac{100\left(V_p\frac{N_s}{N_p}\right)^2}{80\,R\,V_p}$$

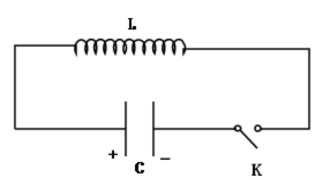
$$\Rightarrow I_p = \frac{10\ V_p}{8\,R}\times\left(\frac{N_s}{N_p}\right)^2 = \frac{10 \times 240}{8 \times 3}\times\left(\frac{60}{1200}\right)^2 = 0.25\text{ A}$$

7. (a) (i) Peak value of a.c. is the *__maximum__* value of the alternating current.

__While__

R ms is the *__steady current__* that dissipates electrical energy in a given resistor at the *__same rate as the__* alternating current.

(b) The capacitor is already charged and when switch K Is closed, the capacitor begins to discharge and as a Current flows, magnetic field begins to build up in L,



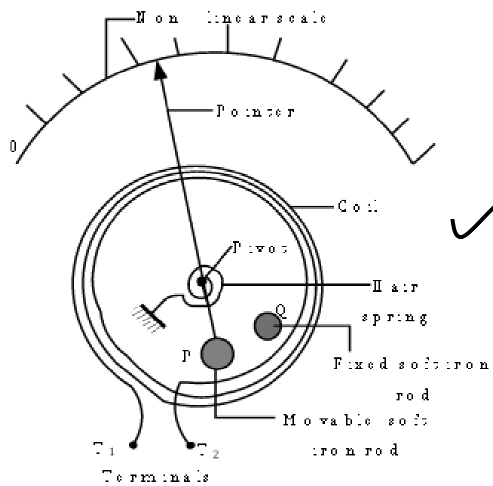
known as a back e.m.f. and acts in such a direction as to oppose the flow of current through L. When the capacitor is fully discharged, the energy it originally had is now transferred to the magnetic field of the inductor.

At this time the magnetic field in the inductor begins to collapse. Current therefore begins to flow in the same direction as before and the capacitor gets charged now in the reverse sense. When the capacitor is fully charged again but in the opposite sense the p.d across L would have dropped to zero. The capacitor now discharges again but in the opposite direction to that in the first case and the process repeats itself causing a.c. flow in the circuit.

(c) (i) Current I is fed into the coil via terminal T_1 and T_2 , creating a magnetic field at the centre of the coil.

The two soft iron rods P and Q get magnetized in the same sense and begin to repel each other with an average force which is proportional to the square of the current flowing through the coil.

The fixed rod Q repels rod P, causing it to rotate about the pivot and moves over the scale through an angle θ, until its stopped by the restoring couple due to a pair of hair springs.



- The deflection θ produced is proportional to the average of the square current. i.e. $\theta \propto \langle I^2 \rangle$ Hence a non - linear scale.

(ii) **Advantages of a moving iron meter over a moving coil meter:**

- It can be used for measuring both alternating current and direct current unlike the moving coil meter that can be used for measuring only direct current.

- The meter is also more durable than the moving coil meter, because it does not have a delicate coil that can easily be blown off like that of a moving coil meter when a large current is passed through it.
- It's also cheaper to make and purchase, since a strong and permanent U – shaped magnet used in moving coil meter is quite expensive to make.

(d) (i) When K is closed bulb B_1 lights instantly while B_2 will be dim initially, but gradually attains maximum brightness.

When K is just closed current begins to grow in the circuit, a back e.m.f. is then induced inductor in series with the bulb B_2 and suppresses the growth of current making B_2 dim since the net current through it is small.

When the current becomes steady, the back e.m.f. becomes zero and so maximum current flows through B_2.

(ii) When K is opened, B_1 goes off instantly, while B_2 goes off gradually.
When K is just switched off, the decaying current in the circuit induces an e.m.f. again in the inductor L, and gives back energy it had stored, back to the system and thus maintains some current flowing through B_2 for some time before completely going off.

(iii) Replacing a d.c source with an a.c. source causes bulb B_2 to remain dim throughout as long as the switch is closed, while B_1 remains maximally bright. This is because B_2 is in series with an inductor L where a back e.m.f. is always induced whenever a current changes and causes a current to flow in a direction as to oppose the applied value.

8. (a) (i) *This is the resistance across opposite faces of a cube of the material of side 1 m.*

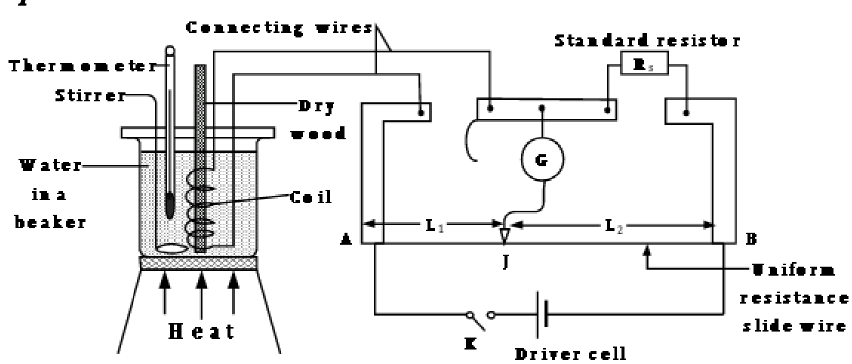
(ii) Cross sectional area, $A = (1.00 \times 0.05)\ mm^2 = 0.05 \times 10^{-6}\ m^2$

$$\text{Using Power, } P = \frac{V^2}{R} \quad \text{but , } R = \frac{\rho L}{A} \Rightarrow L = \frac{R A}{\rho} = \frac{V^2 A}{P\rho}$$

$$\Rightarrow L = \frac{V^2 A}{P\rho} = \frac{(240)^2 \times 5.0 \times 10^{-5}}{\rho \times 800} = \frac{3.6 \times 10^{-3}}{1.2 \times 10^{-6}}$$

$\therefore L = 3.0 \times 10^3\ m$

(b) ***Measurement of temperature coefficient of resistance of a wire.***



- A sample of a material of copper is made into a coil of wire is wrapped around a dry piece of wood and immersed inside a beaker of water with its ends connected to the left hand gap of a metre bridge as shown.

- At room temperature, switch K is closed and the sliding contact J is tapped along the slide wire until the centre zero galvanometer G shows no deflection.

- Balance lengths L_1 and L¬$_2$ or $(100 – L_1)$ are measured using a metre rule and recorded.

- The liquid containing the coil is then heated gradually while stirring, at a given temperature, θ, K is closed at the balance point and balance lengths are noted.

- The experiment is repeated for several increasing values of θ, and at any given temperature, a corresponding balance point and balance lengths are noted.

- The results are tabulated in a suitable table including values of θ, L_1, L_2 and $R_\theta = R_S\left(\frac{L_1}{L_2}\right)$ where R_S is the resistance of a standard resistor connected on the right hand gap of the metre bridge.

- A graph of R_θ against θ is plotted with the temperature axis starting at zero as the origin.

- The ***slope* S** of the graph is then determined together with the ***intercept R₀*** on the resistance axis when θ = 0°C.

The ***temperature coefficient of resistance α*** of copper is then calculated from the expression, **α =** $\frac{R_0}{S}$.

(c)

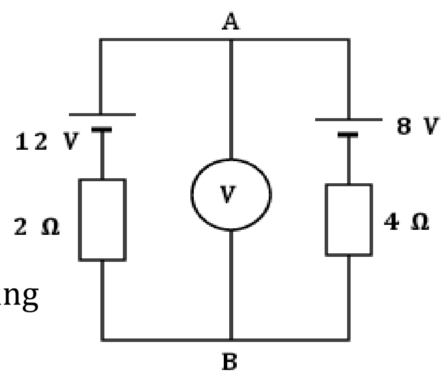
(c) (i) The net e.m.f. E = (12 – 8) = 4 V
Total resistance of the circuit,
R = (2 + 4) = 6 Ω
Using, ∑E.m.f = ∑I R

$\Rightarrow I = \frac{E}{R} = \frac{4}{6} = 0.667$ A

∴ P.d. cross AB, = voltmeter reading

$V_{AB} = 12 - 2I$ or $V_{AB} = 8 + 4I$

$\Rightarrow V_{AB} = 12 - 2 \times 0.667 = 10.67$ V



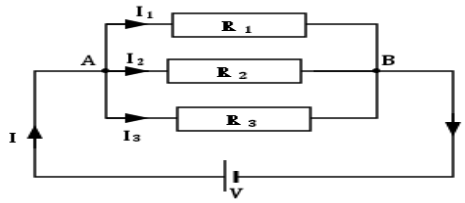
(ii) Power dissipated in the 4Ω resistor $P = I^2R = (0.667)^2 \times 4$
∴ Power, P = 1.78 W

9. (a) (i) ***volt*** is the *potential difference* across opposite faces of a resistor or (conductor) of one ohm when the current flowing through it is *one ampere*.

Or ***volt*** is the *work done* to move a charge of 1C across opposite faces of a conductor having a resistance of 1Ω.

Electromotive force is the energy required to drive **1C** of charge around a complete closed circuit to which the battery itself is connected.
Or
E.m.f - is the terminal p.d across a battery on an open circuit.

(ii) Let R_1, R_2 and R_3 be the resistnces of three resistor in parallel.



All the resistors have the ***same p.d*** across but different currents.

$$I = I_1 + I_2 + I_3$$

$$= \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

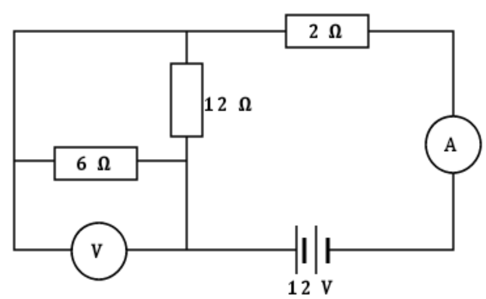
$$I = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\therefore \quad \frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{I}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

But $\frac{I}{V} = \frac{I}{R}$ where ***R is the effective resistance*** of the circuit.

(b) When the positions of the voltmeter and 6Ω are interchanged, 12Ω and 6Ω are in parallel.



Their effective resistance $R' = \frac{6 \times 12}{6 + 12} = 4\ \Omega$

∴ Effective resistance of the circuit = R
where, R = (4+2) = 6 Ω
Thus the current supplied by the battery,

$I = \frac{E}{R} = \frac{12}{6} = 2.0$ A

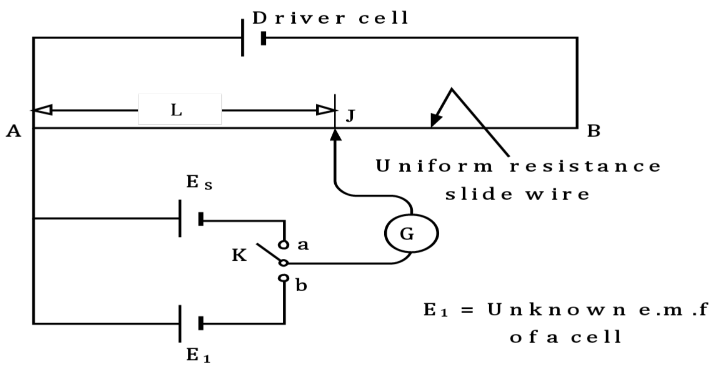
Hence ammeter reading = 2.0 A

The p.d across 2Ω = 2×2.0 = 4.0 V

∴ The p.d across, R' = **Voltmeter** reading = (12-4.0) **= 8.0** V

(c) ***Standardizing a potentiometer*** involves determining value of it's ***p.d per cm.***

A standard cell (source of e.m.f), **Es** is connected across a uniform resistance slide connected in series with the driver cell (an accumulator) as shown in the figure below.



Switch **K** is thrown to position **a**, and the sliding contact **J** is tapped on the uniform resistance slide wire **AB** until the centre zero galvanometer **G**, shows no deflection. The balance length L_S is measured using a metre rule and recorded.

At balance E_S = p.d per cm × L_S From which the calibration value, of

Pd per cm = $\frac{E_S}{L_S}$ **is the calibration value of the potentiometer.**

*Any unknown e.m.f. **E1** to be measured is connected by throwing switch K to position b and the balance point located and balance length, say L is obtained.*

Implying at balance, E_1 **=** pd per cm ×L **=** $\left(\frac{E_S}{L_S}\right)\times L$

(d) $R_{AB} = 4\Omega$ AB = 100cm

∴ resistance per cm $= \frac{4}{100} = 0.04\Omega cm^{-1}$

Total resistance of driver circuit

$R = (1+4) = 5\Omega$

Current through slide win $I_P = \frac{3.0}{5.0} = 0.6A$

$\therefore$ Pd/cm = $0.04\times0.6 = 0.024\ Vcm^{-1}$

(i) When K_1 is closed and K_2 open

$E_s = pd/cm\times l$

$= 0.024\times60.0$

$= 1.44V$

(ii) Observed voltmeter reading

$V_o = 1.14V$

With K_1 open K_2 closed, $l' = 80.0cm$

$\therefore$ pd across R, $V_m = iR$

$= \left(\frac{E_y}{r+R}\right)R$

$V_m = \left(\frac{1.2\times10}{0.5+10}\right)$

$= 1.143V$

Error in voltmeter reading

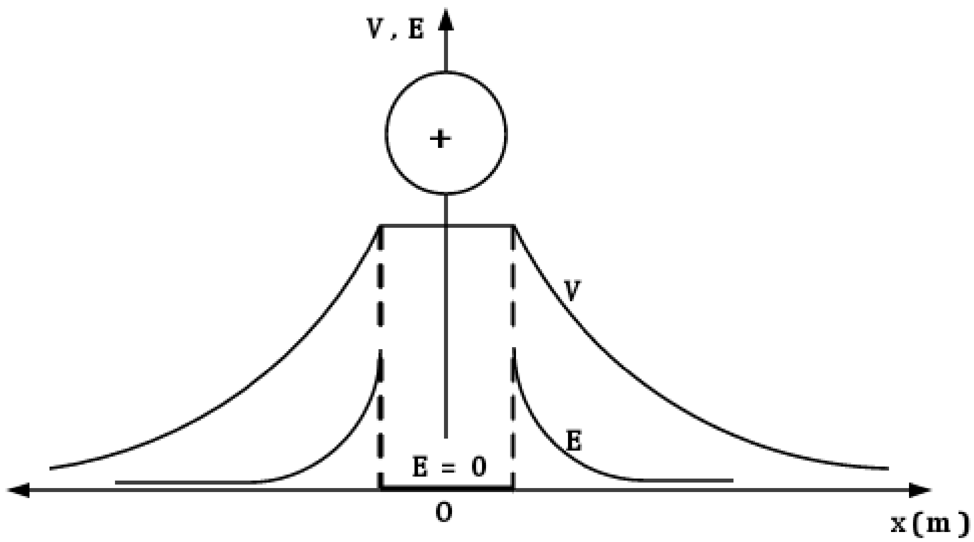
$\Delta V = V_m - V_o = 1.143 - 1.14$

$= 0.003V$

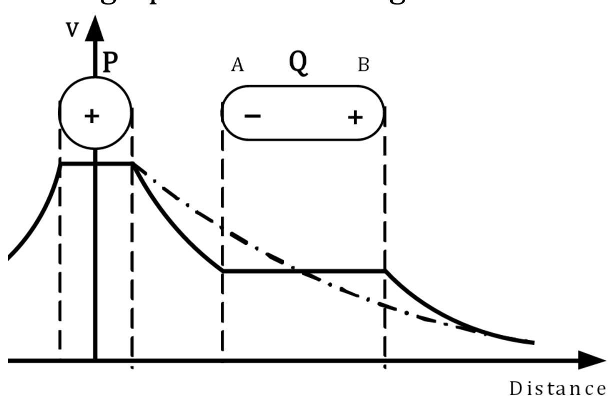
$\%Error = \frac{0.003}{1.143} \times 100$

$= 0.265\%$

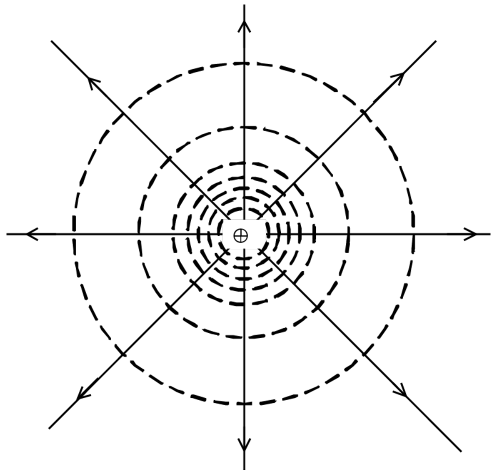
10. (a) (i) ***Graphs of Electric potential and Electric field intensity with distance From the centre of a positively charged conductor***.



(ii) A sketch graph of Potential against distance.



(b) (i)



(ii) *Between one* ***equipotential line/surface*** *and the next* ***is a constant value of potential difference.***

- *As you move away from the charged object e.g. conductor, the lines or surfaces get further apart* because *the electric field decreases inversely with distance* $\left(\text{from } E=\frac{V}{d} \text{ for a constant potential, } E \propto \frac{1}{d}\right)$ *in such a way that the further you are from the object the smaller the value of E, becomes.*

- *The potential near a point charge decreases inversely with distance.*

  i.e. $V \propto \frac{1}{d}$ *hence as the distance from the charge increases, the potential decreases tremendously. So the potential near the charge is large while the one far from the charge is small.*

- *Since the potential is large near the charge, the surfaces are closer and crowded near it. The distance between two equipotential surfaces increases as one moves away from the charge.*

(c) (i) Electric potential – is the work done to move *a +1C* charge from infinity to a point in an electric field against electrostatic repulsive force.

Electric field intensity is *force exerted on a +1C* charge placed in an electric field.

(ii) Small work done in moving a test charge δq towards a charge Q, by a small distance δx is given by;

$\delta W = -F\,\delta x$ but $F = EQ$

$\therefore\ \delta W = -EQ\,\delta x$ but also $\delta W = Q\delta V$

thus, $Q\delta V = -EQ\,\delta x \implies \delta V = -E\,\delta x \implies E = -\frac{\delta V}{\delta x}$

In the limit as $\delta x \to 0$ then $\frac{\delta V}{\delta x} = \frac{dV}{dx}$

$\therefore E = -\frac{dV}{dx}$

(d) (i) Electric potential energy is the work done to move a charge q from a point of lower electric potential to a point of higher electric potential in an electric field. Or it is the product of the electric potential at a point in an electric field and the charge placed at the point.
ie E.P.E = Vq

(ii) let V_A = electric potential at P due to the charge at A

$\therefore \quad V_A = \frac{Q_A}{4\pi\varepsilon_0 r}$

$= \frac{9.0\times10^{-6}\times9.0\times10^{9}}{0.03}$

$= 2.7\times10^{-6}V$

$V_B = \frac{16.0\times10^{-6}\times9.0\times10^{9}}{0.04}$

$3.6\times10^{6}V$

$\therefore \quad V_p = V_A + V_B = (2.7-3.6)\times10^{6} = -9.0\times10^{5}$

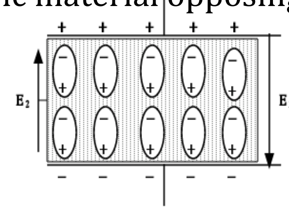
$\Longrightarrow \quad E.P.E = qV_p = (-2.0\times10^{-6})\times(-9.0\times10^{5}) = 1.80J$

11. (a) (i) **Capacitance** – is the ratio of the magnitude of charge on any one plate of the capacitor to the p.d across the plates.

(ii) **Dielectric constant** – is the ratio of the capacitance of a capacitor having a dielectric material filling the space between the plates to the capacitance of the same capacitor with a vacuum between the plates.

(b) ***Effect of inserting a dielectric between the plates of a charged capacitor.***

When a dielectric is inserted between the plates of a charge capacitor, the molecules of the dielectric get *polarized*.
An *opposite electric field* E_2 is set up across the dielectric material opposing due to charge on the plates.
The net Electric field $E = E_1 - E_2$ reduces.



Since $E = \frac{V}{d}$ the p.d across the plates reduces.

From $C = \frac{Q}{V}$ a reduction in the p.d causes the capacitance to increase. Hence, inserting a dielectric causes the capacitance of the capacitor to increase.

(c) (i) A dielectric is an insulator placed between the plates of the capacitor in order to :-
Separate the charged plates
Increase the capacitance of the capacitor.

Increase the dielectric field strength of the capacitor.

(ii) using $C = \frac{I}{fV}$ $\Rightarrow C = KI$

Before inserting dielectric

$$C_o = \frac{\varepsilon_{o\varepsilon_r} A}{d} = KI \ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

$$C' = \frac{\varepsilon_o A}{2d}(\varepsilon_r + 1) = KI' \ldots\text{(ii)}$$

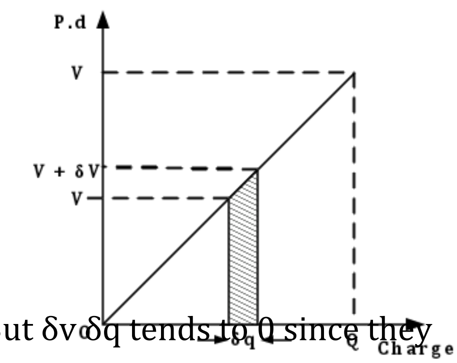
Eqn. (i) ÷ (ii)

$$\frac{\varepsilon_o \varepsilon_r A}{d} \times \frac{2d}{\varepsilon_o A(1+\varepsilon_r)} = \frac{I}{I'}$$

$$\therefore \in_r = \frac{I}{2I' - I}$$

(d) (i) Small work done in increasing charge on the plates by δq

δW = element of area (shaded part)



$$\delta W = \frac{1}{2}\delta q[V + (V + \delta v)]$$

$$\delta W = \frac{1}{2}\delta q(2V + \Delta v)$$

$$\delta W = \frac{1}{2} \times 2V\delta q + \frac{1}{2} \times \delta v \delta q$$

But $\delta v \delta q$ tends to 0 since they are very small

$\therefore$ E.O.A = $V\delta q$

Total area = total work done increasing the charge from 0 to Q

$$W = \frac{1}{2}bh = \frac{1}{2}QV, \text{But } Q = CV, \therefore \text{ Energy stored} = \frac{1}{2}CV \times V = \frac{1}{2}CV^2$$

Alternatively:

In charging a capacitor work is done by the source in transferring

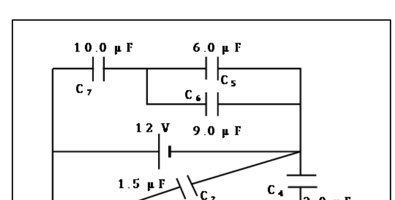
charge q $\delta W = V\delta q$ but $V = \frac{q}{C}$

total work done $W = \int_0^Q \frac{q}{C}\, dq = \frac{Q^2}{2C}$

$$W = \frac{CV^2}{2}$$

(ii) For the

C_1 and C_3 are in parallel



$\therefore C' = C_1 + C_3 = 1.0 + 2.0 = 3.0\mu F$

Now C' and C_4 are in series

$$\therefore C'' = \frac{C'C_4}{C'+C_4} = \frac{3.0\times3.0}{3.0+3.0} = 1.5\mu F$$

Now C'' and C_2 are in parallel

$\therefore C''' = (1.5+1.5) = 3.0\mu F$

On the other side

C_5 and C_6 are in parallel.

$\therefore C_0 = (6.0+9.0) = 15.0\mu F$

Now C_0 and C_7 are in series

$$\therefore C'_0 = \frac{15.0\times10.0}{15.0+10.0} = \frac{150}{25} = 6.0\mu F$$

Finally, C'_0 and C''' are in parallel

$\therefore$ Effective capacitance, $C = C'_0 + C'''$

$\implies C = (6.0+3.0) = 9.0\mu F$

Using charge, $Q = CV \implies Q = 12\times9.0\times10^{-6}$

$= 1.08\times10^{-4}C$

$$\text{Energy} = \frac{1}{2}CV^2 = \frac{1}{2}\times9.0\times10^{-6}\times12^2$$

$$= 6.48\times10^{-4}J$$

(e) Case I

$$C_1 = \frac{Q}{V_1} = \frac{\varepsilon_o A}{d_1} \qquad \implies E_1 = \frac{1}{2}QV_1$$

$$= \frac{Q^2}{2C}$$

$$E_1 = \frac{Q^2 d_1}{2\varepsilon_o A}$$

Case II

$$C_2 = \frac{Q}{V_2} = \frac{\varepsilon_o A}{2d_1}$$

$$E_2 = \frac{Q^2}{2C_2} = \frac{Q^2}{2\varepsilon_o A}\times2d_1$$

$$E_2 = 2\left(\frac{Q^2 d}{2\varepsilon_o A}\right)$$

$\therefore E_2 = 2E_1$

Thus, when the separation of the plates is ***doubled***, energy is also ***doubled.***

The increase in energy is a result of work done in pulling the charged plates a part against electrostatic attraction between oppositely charged plates.

= END =