JJEB MOCK EXAMINATIONS 2022

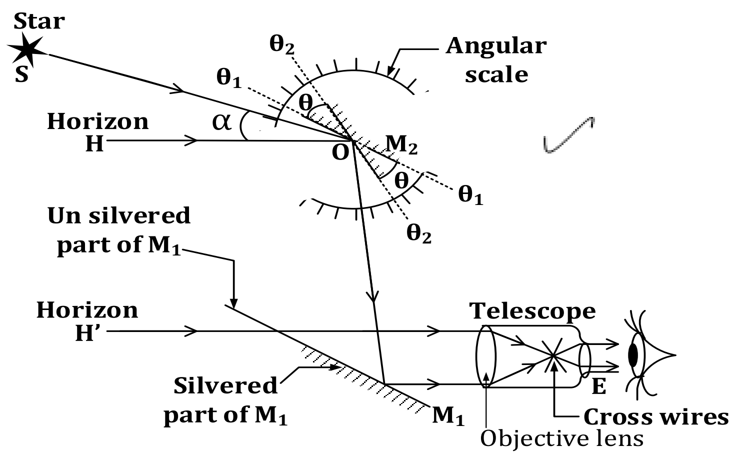
P510/2 PHYSICS MARKING GUIDE

✓	Full mark
✓	Half mark

SECTION A

1. (a) (i) This is the bouncing off light rays from a reflecting surface into the same optical medium. **[01]**

(ii) The structure of the Sextant.

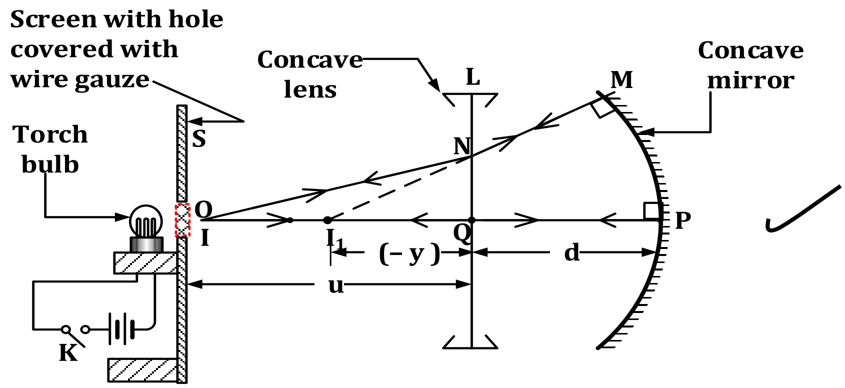


- Light from the Horizon **H'** is viewed directly through the un-silvered part of the fixed mirror $\mathbf{M_1}$, until the image of **H'** of the horizon**,** is in sharp focus or in clear view, at the centre of the **cross wires** of eyepiece, **E** of the telescope.
- Mirror $\mathbf{M_2}$, is then rotated, so as to focus the image of the horizon **H** after two successive reflections of ray **HO** by $\mathbf{M_2}$ and $\mathbf{M_1}$ respectively, until the image of **H** coincides with that of **H' at** the centre of **the cross wires** in the telescope as observed at **E**. This occurs when $\mathbf{M_1}$ and $\mathbf{M_2}$ are parallel to each other.
- The angular position $\boldsymbol{\theta_1}$ of $\mathbf{M_2}$ on the circular angular scale of the sextant is then read and recorded i.e. (noted).
- The mirror $\mathbf{M_2}$ is again turned or rotated slowly until the image of the star **S**, coincides with that of the horizon, **H'** at the centre of the cross wires as observed at the eye – piece **E,** of the telescope.
- The new position $\boldsymbol{\theta_2}$ of $\mathbf{M_2}$ on the angular scale is then noted.
- The angle of rotation of the mirror $\mathbf{M_2}$ i.e. $\boldsymbol{\theta = (\theta_2 - \theta_1)}$ is determined and the angle of rotation of reflected ray (Inclination of the star above the horizon) by M_2, is given by; $\alpha = \boldsymbol{2\theta}$

  $\therefore \boldsymbol{\alpha = 2|(\theta_2 - \theta_1)|}$

  Thus, the angle of elevation of the star is 2θ (***twice the angle of rotation of the mirror*** $\boldsymbol{M_2}$). **[03]**

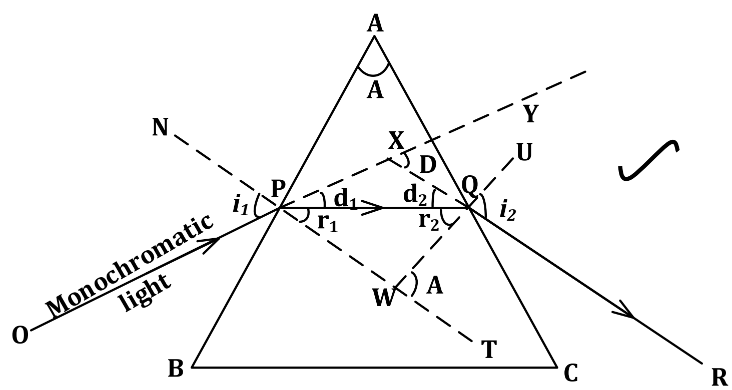
(b) An illuminated object O, a concave lens L and a concave mirror LM of known radius of curvature r, are arranged co-axially as shown on the diagram, with L set at a distance d, less than the radius of curvature r, of mirror M.



- Switch **K** is closed and lens **L** is moved to and fro object O until, the image I of the object O is formed just besides the object O.
- Distances u and d are measured using a meter rule and recorded down.
- The forced length f, of the lens L is their calculated from $\frac{1}{u} + \left[\frac{1}{-(r-d)}\right] = \frac{1}{f}$

[05]

(c) (i) Consider a ray of monochromatic light incident from air into a glass prism at an angle of incidence $\boldsymbol{i_1}$, on plane **AB** and is refracted through $\mathbf{r_1}$ and later emerged out of plane **AC** at an angle, $\boldsymbol{i_2}$, the ray suffers a total deviation **D** as shown in figure below.



A small – angle prism has its refracting angle, **A** being very small.
Thus angles i_1, r_1, r_2 *and* i_2 are all small angles, expressed in radians.

$\therefore\ \sin i_1 = n \sin r_1$

While, $i_1 = (d_1 + r_1) \implies d_1 = (i_1 - r_1)$

At, Q, Using, $n \sin i = a\ constant \implies n \sin r_2 = \sin i_2$

While, $i_2 = (d_2 + r_2) \implies d_2 = (i_2 - r_2)$

The total deviation, $\boldsymbol{D = (d_1 + d_2)}$

$\therefore D = (i_1 - r_1) + (i_2 - r_2) = (i_1 + i_2) - (r_1 + r_2) \ldots\ldots\ldots(i)$

For small angles i_1, i_2, r_1 *and* r_2 *all expressed in radians*,

$\sin i_1 \cong i_1, \sin i_2 \cong i_2, \sin r_1 \cong r_1 \; and \; \sin r_2 \cong r_2$

$\Longrightarrow i_1 \cong n\, r_1 \; and \; i_2 \cong n\, r_2 \; \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (ii)$

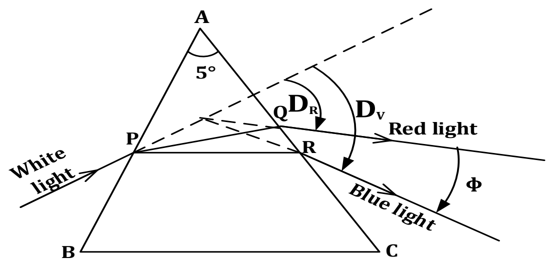
$\therefore substituting\ (ii) into\ (i)$

$\Longrightarrow D = (n\, r_1 + n\, r_2) - (r_1 + r_2) = n(r_1 + r_2) - 1(r_1 + r_2)$

$\Longrightarrow D = (n-1)(r_1 + r_2) \; and\ from\ the\ diagram, (r_1 + r_2) = A$

$Hence, \boldsymbol{D = (n-1)A}$ **[04]**

(ii)



Angular dispersion, $\Phi = D_B - D_R$

$where, D_B = (n_B - 1)A \; and \; D_R = (n_R - 1)A$

$\therefore \Phi = (n_B - n_R)A = (1.54 - 1.52) \times 5$

$\therefore \Phi = (0.02 \times 5) = 0.10°$ **[03]**

(d) (i) The power of a lens – is the ***reciprocal of the focal length, f,*** of the lens when it is ***expressed in metres***. $i.e. P = \frac{1}{f}$ $(when\ f\ is\ in\ metres)$ **[01]**

(ii) $r_1 = +20.0\ cm = 0.200\ m \; while \; r_2 = -25.0\ cm = -0.250\ m$

$Using, \frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

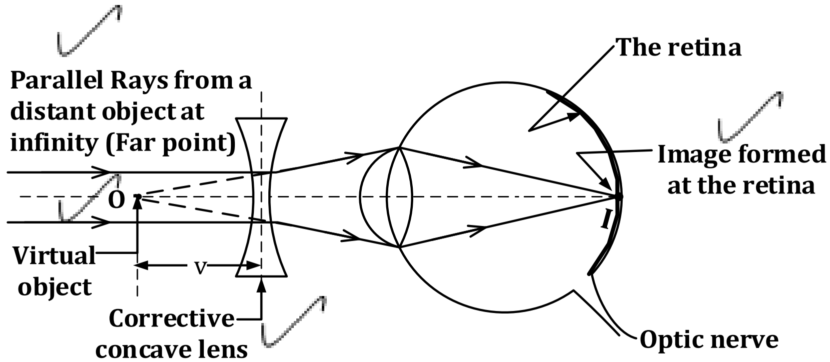
$$\Longrightarrow \frac{1}{f} = (1.50 - 1)\left(\frac{1}{0.200} - \frac{1}{0.250}\right) = +0.50\ D$$

$\therefore \boldsymbol{The\ Power, P = \frac{1}{f} = +0.5\ D}$ **[03]**

2.(a) (i) Myopia (short sightedness) – is a defect in a human eye where the eye is only able to see *nearby objects clearly* while the *distant objects at infinity are blurred (not clear).* **[01]**

(ii) The defect arises when the eye lens loses its flexibility of the accommodation, hence ***remaining squashed with a shorter focal length***.

A concave lens is then placed just outside the eye lens so as to diverge the lens from a distant object so that ***they appear*** to be originating from the original near point that the eye lens can focus on the retina as shown on the diagram Below.

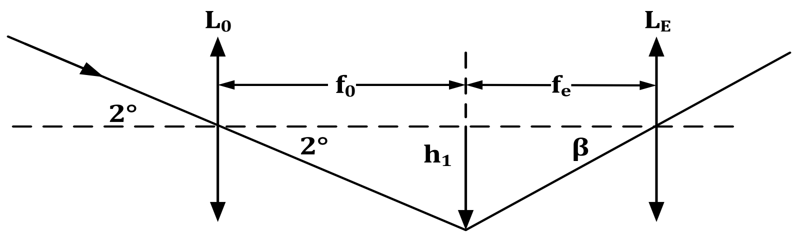


[04]

(b) (i) α = 2⁰, f_o = 300 cm, f_e = 5.0 cm, v_e = 25 cm

Any clear magnification, $M = \frac{fo}{fe}$ $= \frac{300}{5}$ $= 60$

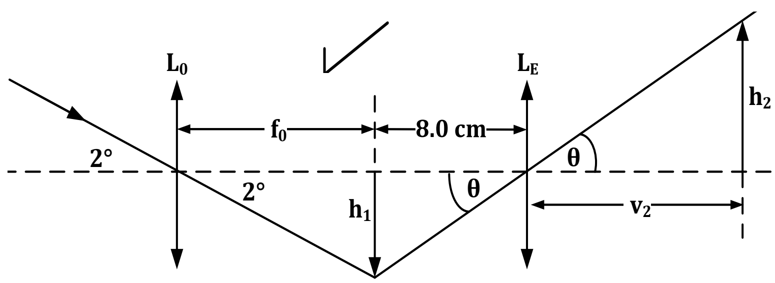
Diagram showing formation of the intermediate image



$\tan 2° = \frac{h_1}{f_0}$ $\Rightarrow h_1 = 300 \times \tan 2°$

$\therefore \boldsymbol{h_1 = 10.48\ cm}$ **[05]**

(ii) When the eyepiece is pulled backwards by 3cm, $u_e = (5 + 3) = 8.0cm$



$u_e = (5.0 + 3.0) = 8.0\ cm$ f_e = 5.0cm V_2 = ?

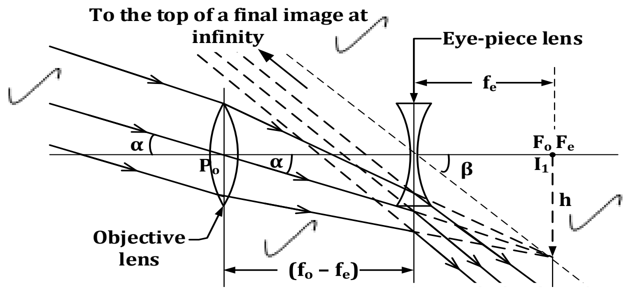
$h_2 = 2h_1 = 20.96\ cm$

Using ratio and proportion, $\frac{h_2}{v_2} = \frac{h_1}{8.0}$ $but, h_2 = 2h_1 \Rightarrow \frac{2h_1}{v_2} = \frac{h_1}{8.0}$

$\therefore \boldsymbol{v_2 = 16.0\ cm}$

Hence the screen is located 16.0 cm behind the eyepiece lens. **[04]**

(c) The Galilean Telescope in normal adjustment.



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

For α and β being small angles in radians,

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

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

$\therefore$ *Angular magnification*, $\boldsymbol{M} = \boldsymbol{\frac{f_0}{f_e}}$ **[05]**

(d) Advantages of a Galilean telescope over a Terrestrial telescope.

The Galilean telescope is compact and much shorter than the terrestrial telescope, since its length is numerically ($f_0 - f_e$) when in normal adjustment, compared to ($f_0 + f_e + 4f$) of the terrestrial telescope.

Its less costly to manufacture compared to the terrestrial telescope because of only two lenses involved unlike the terrestrial type with three lenses involved in the construction. **[03]**

SECTION B

3. (a) (i)

Free oscillations	Damped oscillations
➢ Do not have dissipative forces affecting their oscillations ➢ Energy of the oscillating system is conserved (ie remains constant) ➢ Amplitude of the oscillation of the system remains constant.	➢ Oscillations are affected by the dissipative forces ➢ Energy of the oscillating system diminishes with time. ➢ Amplitude of the oscillating system reduces with time.

[03]

(ii) **Examples of free oscillations**

- Oscillations of a simple pendulum in a vacuum.
- Oscillations of an object connected to a horizontal spring in free space or vacuum.
- Vibrations of the prongs of the tuning fork in a vacuum.
- Notes of musical instruments in short distances e.g organ pipe .etc

Examples of damped oscillations

- Vibrations of a weight attached to a free end of a spring in air
- A swinging pendulum in air or in a fluid.
- An LRC series oscillating circuit. **[02]**

(b) (i) **Resonance** – is the vibration or oscillation of a body or system at its natural frequency due to impulses it receives from a nearby body oscillating at the same frequency. **[01]**

(ii) A glass trough is filled with water (liquid)

- A tube open on both sides is gently lowered vertically into the water trough so that only its tip is visible above the water surface.
- A tuning fork of known frequency, **f** , is set into vibration and held just above the exposed end of the tube.
- The tube together with the tuning fork are simultaneously raised above the water surface until the first loud sound is heard.
- The length of the air column l_1 just above the liquid surface is measured using a meter rule and recorded down.
- The tube is raised further together with the turning fork until the second loud sound is heard.
- The new length l_2 of the air column above the water surface is noted.
  i.e. $(l_1 + l_2) + 2e = \lambda$

$$2e = \lambda - (l_1 + l_2) \; but \; \lambda = \frac{v}{f}$$

$$2e = \frac{v}{f} - (l_1 + l_2)$$

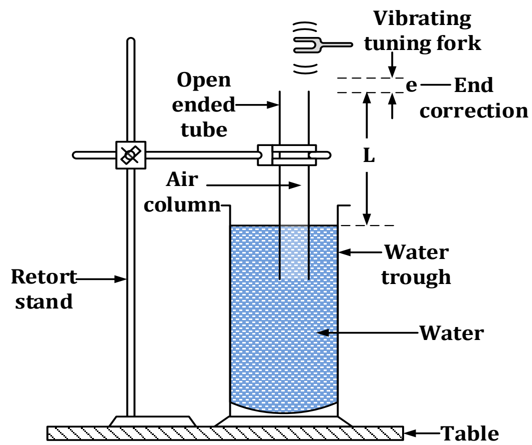
Thus, ***the End correction***, $e = \frac{1}{2}\left[\frac{v}{f} - (l_1 + l_2)\right]$

Where, v = speed of sound in air (330 ms^{-1}) and f = frequency of the tuning fork. **[06]**

Alternative method

- A resonance tube is clamped vertically and made to stand inside a tall jar or trough full of water, so that the tube is almost fully immersed in water.

- Starting with a *very short exposed length of air column*, in the tube, a tuning fork is set into vibration and the vibrating tuning fork is held just over the open mouth of the resonance tube.



- The tube is then gradually raised slowly until a position is attained where the first *loud sound is heard*.
- The *length L* of the air column in the tube is measured using a metre rule and recorded down.
- The *frequency f* of the vibrating tuning fork used in noted & recorded.
- The experiment is then *repeated* with several other tuning forks of different known frequencies, and the results recorded in a suitable table of results including values of, $\frac{1}{f}$ and L.
- A graph of L against $\frac{1}{f}$ is plotted and the intercept, **e**, on the L – axis of the graph determined, and this the end correction of the open ended pipe or tube. **[06]**

(c) (i) **Beats** are the *periodic rise and fall in the intensity of sound waves* produced when two sound notes of *same amplitude* and of *nearly equal frequencies* are sounded together. **[02]**

(ii) Two sound notes of *nearly the same frequency* and of *similar amplitudes* are sounded together, the sound notes superpose and interfere when the *wave trains meet in phase they reinforce* and produce *a loud note* and when they *meet when completely out of phase, they cancel out* each other and *a soft sound and no sound at all is obtained.* This repeats itself periodically leading to the formation of beats. **[03]**

(d) $Let\ f_t = 520\ Hz\ and\ f_p = actual\ frequency\ of\ the\ piano\ string$

$f_t - f_p = \pm f_b \Rightarrow Either\ f_t - f_p = f_b \ldots\ldots..(i)\ Or\ f_p - f_t = f_b \ldots\ldots..(ii)$

$Since, f_b = 3 \Rightarrow f_p = (520 \pm 3)Hz \Rightarrow Either, f_p = 523\ Hz\ or f_p = 517\ Hz$

$From\ eqns.(i) and\ (ii)\ when\ tension\ in\ the\ wire\ is\ \textbf{increased}, f_b\ reduces$

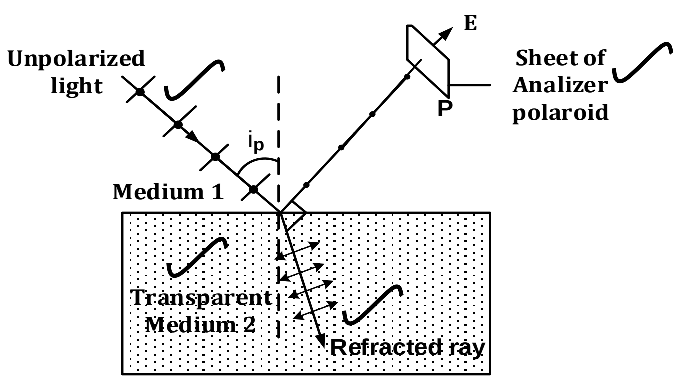
$\Rightarrow f_t - f_p = f_b\ holds \Rightarrow f_t > f_p\ for, f_b\ to\ reduce\ to\ 2\ Hz$

$Hence, the\ actual\ \boldsymbol{Piano\ frequency},\ \boldsymbol{f_p = 517\ Hz}$ **[03]**

4. (a) (i) **Polarized light** – is light in which the <u>vibrations</u> of its electric vector occur in only <u>one plane</u> perpendicular to the direction of propagation of the wave, <u>while</u>

Un polarized light – is light in which the <u>vibrations</u> of its electric vector occur in <u>all planes</u> perpendicular to the direction of propagation of the wave. **[02]**

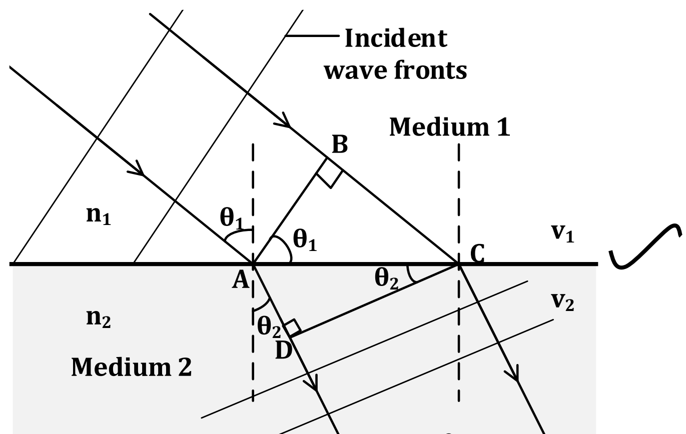
(ii) Polarization of light by reflection.



- A narrow beam of un-polarized light is made incident onto the transparent optical medium e.g. rectangular glass slab placed in a less dense medium.
- The reflected light is observed through a Polaroid P, placed perpendicular to the direction of propagation of the reflected light.
- The angle of incidence, i , is gradually increased progressively.
- At each angle of incidence, the analyzer Polaroid P is rotated about the axis along which the light is incident on it through 360°.
- At one angle of incidence called the Polarizing angle i_p , the light gets cut off from the observer as the Polaroid is being rotated except at only two positions of the Polaroid P.
- Implying the **reflected ray** is now is said to be completely **plane polarized**. **[05]**

(b) (i) **Huygens's principle** states that – *every point on a wave front can be regarded as a source of spherical wavelets that spread outwards at the wave speed and that the tangents or envelope to all the wavelets forms a new secondary wave front.* **[01]**

(ii) Consider incident plane wave fronts travelling from medium 1 of refractive index n_1 to medium 2 of refractive index n_2 with $n_2 > n_1$. Suppose θ_1 and θ_2 are the respective angles that the ray makes with the normal in the two media.
In a time t, seconds later, $BC = v_1 t$, $AD = v_2 t$



$$ {}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{BC}{AC} \div \frac{AD}{AC} = \frac{BC}{AC} \times \frac{AC}{AD} = \frac{BC}{AD} = \frac{v_1\, t}{v_2\, t} = \frac{v_1}{v_2} \ldots\ldots (i) $$

But $v_1 = \frac{C}{n_1}$ *and* $v_2 = \frac{C}{n_2}$ *substituting into (i)above*

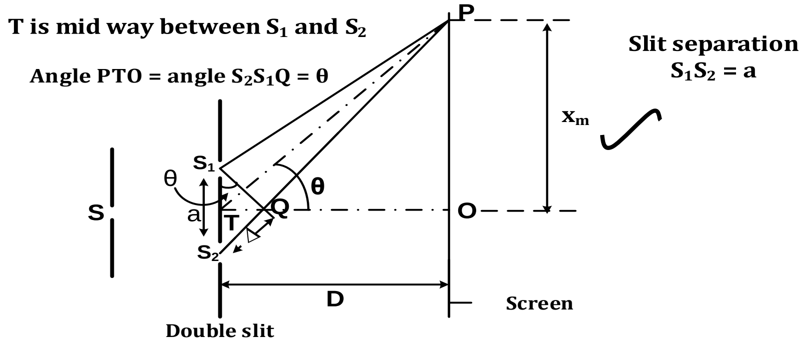
$$ \Longrightarrow {}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{C}{n_1} \times \frac{n_2}{C} = \frac{n_2}{n_1} $$

$$ \therefore\ n_1 \sin\theta_1 = n_2 \sin\theta_2 \text{ Hence Snell's law.} $$ **[04]**

(c) (i) Coherent sources – are sources having the ***same frequency*** and a ***consistent phase relationship*** or ***constant phase difference***. **[01]**

(ii) **The derivation of fringe separation, y, in Young's double slit experiment.**

Suppose P is the position of the m^{th} bright fringe, from the central position, O, of the bright fringe, then the path difference, ΔP is given by
$S_2P - S_1P = m\lambda$ ……………………………………….(i)
The path difference between the waves arriving at P from S_1 and S_2 is $\Delta P = S_2Q = (S_2P - S_1P)$ ……………………..(ii)
For small value of angle θ in radians, $\sin\theta \approx \tan\theta = \frac{x_m}{D}$
$S_2Q \approx a\sin\theta = a\tan\theta = \frac{a\, x_m}{D}$ hence , $S_2Q = \frac{a\, x_m}{D}$



From (i) , (ii) and (iii) , the m^{th} bright fringe is obtained from,

$m\lambda = \frac{a\,x_m}{D}$ implying $x_m = \frac{m\lambda D}{a}$

For the (m – 1)th **bright fringe,** $x_{m-1} = \frac{(m-1)\lambda D}{a}$

$\therefore$ Fringe width(separation), y = $(x_m - x_{m-1}) = \frac{\lambda D}{a}$

Thus Fringe width(separation), $y = \frac{\lambda D}{a}$ **[04]**

(ii) $S_1S_2 = a = 3\ mm = 3.0 \times 10^{-3} m, D = 1.5\ m\ \ y = 1.0 \times 10^{-4} m$

Using, $\lambda = \frac{a\,y}{D}$

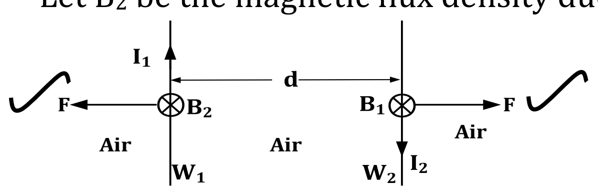
$$\lambda = \frac{3 \times 10^{-3} \times 1.0 \times 10^{-4}}{1.5}$$

$\therefore\ \lambda = \boldsymbol{2.0 \times 10^{-7}\ m}$ **[03]**

SECTION C

5.(a) (i) An ***ampere*** is the steady or direct current which when flowing through each of the two straight, parallel and infinitely long wires of negligible cross-sectional area separated by a distance of 1m apart in a vacuum exert a force of $2 \times 10^{-7} Nm^{-1}$ on each other. **[01]**

(ii) Let B_1 be the magnetic flux density due wire 1 carrying current, I_1.
Let B_2 be the magnetic flux density due wire 2 carrying current, I_2.



Magnetic flux density at a perpendicular distance, **d**, at the position of wire W_2 due to wire $\mathbf{W_1}$ is given by $\boldsymbol{B_1} = \frac{\mu_0 I_1}{2\pi d}$ ……………………………………… $(\boldsymbol{i})$

Similarly, magnetic flux density at a perpendicular distance, d, at the position of wire 1 due to wire W_2 is given by $\boldsymbol{B_2} = \frac{\mu_0 I_2}{2\pi d}$ ………………………………… $(\boldsymbol{ii})$

Thus, by Fleming's left hand rule, a magnetic force,

$F_1 = B_2 I_1 L$ ***acting to the left of*** W_1 & ***sub. for*** B_2 ***from*** (ii), ***we get;***

$$F_1 = B_2 I_1 L = \frac{\mu_0 I_2}{2\pi d} I_1 L$$ ***where L is the length of each wire.***

$$\therefore F_1 = \left(\frac{\mu_0 I_2 I_1 L}{2\pi d}\right)$$ ***acting away from*** W_2 ***i.e. to the left of*** W_1

Likewise, by Fleming's left hand rule, a magnetic force, on wire W_2,

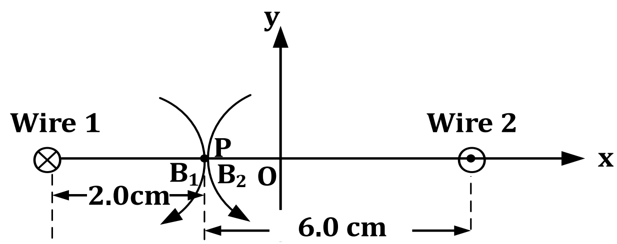
$F_2 = B_1 I_2 L$ ***and substituting for*** B_1 ***from equation*** (i), ***we obtain;***

$$F_2 = B_1 I_2 L = \frac{\mu_0 I_1}{2\pi d} I_2 L$$ ***where L is the length of each wire.***

$$\therefore F_2 = \left(\frac{\mu_0 I_1 I_2 L}{2\pi d}\right)$$ ***acting to the Right of*** W_2 ***i.e away from*** W_2

[05]

(b)



$$B_1 = \frac{\mu_0 I_1}{2\pi x}$$ *is the magnetic flux density at P due to wire 1 while*

$$B_2 = \frac{\mu_0 I_2}{2\pi(0.08 - x)}$$ *is due to wire 2*

$$B_1 = \frac{\mu_0 \boldsymbol{I}}{2\pi \times 0.02}$$, ***while*** $$B_2 = \frac{\mu_0 \boldsymbol{I}}{2\pi \times 0.06}$$ ***Thus the resultant flux density at P***

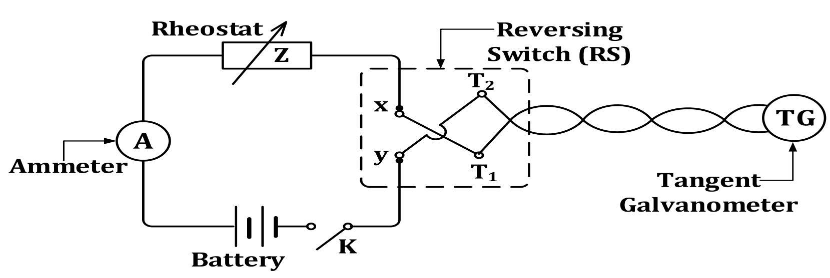
$$B = (B_1 + B_2) = \frac{\mu_0 \boldsymbol{I}}{2\pi}\left(\frac{1}{0.02} + \frac{1}{0.06}\right) = \frac{4.0\pi \times 10^{-7} \boldsymbol{I}}{2\pi}\left(\frac{1}{0.02} + \frac{1}{0.06}\right) = \frac{0.08\boldsymbol{I}}{0.0012}$$

$\therefore \boldsymbol{B} = (\mathbf{1.33} \times 10^{-7})\boldsymbol{I}$ *but given that* $B = 1.0 \times 10^{-2}\,T$

Thus, $(\mathbf{1.33} \times 10^{-7})\boldsymbol{I} = 1.0 \times 10^{-2}$

$\therefore I = \mathbf{7.52 \times 10^{-2}} \boldsymbol{A}$ **[04]**

(c) (i) A coil of known geometry (*i.e. number of turns, N and known radius, r*), containing a deflection magnetometer is placed with its plane in a magnetic meridian i.e. facing the Earth's magnetic North – South poles.



- When switch K is open, the reversing switch contacts, **T₁** and **T₂** are connected to contacts **x** and **y** respectively of the circuit and the pointers of the magnetometer are then set at the 0° – 0° scale positions.
- Using a suitable setting of the rheostat, Z, the switch K is closed, and the deflections, **θ₁** and **θ₂** of the pointers on the tangent galvanometer (T.G) are noted.

- The steady current reading, **I** of the ammeter is also noted.
- Keeping the switch K, closed, and using the same setting of the rheostat, Z as in the first case, the reversing switch contacts are interchanged, so as to reverse the direction of flow of current in the coil i.e. $\mathbf{T_1}$ and $\mathbf{T_2}$ are now connected to contacts **y** and **x** respectively of the circuit and the new deflections, $\boldsymbol{\theta_3}$ and $\boldsymbol{\theta_4}$ of the pointers on the tangent galvanometer (T.G) are noted.
- The average deflection, $\theta = \left(\frac{\theta_1 + \theta_2 + \theta_3 + \theta_4}{4}\right)$ is then determined.

From, $tan\,\theta = \frac{B_C}{B_H} \quad \Rightarrow B_H = \frac{B_C}{tan\,\theta}$

$\therefore \boldsymbol{B_H} = \frac{\boldsymbol{\mu_0 N I}}{\mathbf{2}\,\boldsymbol{r}\,\mathbf{tan}\,\boldsymbol{\theta}}$ *is then calculated using known values of*

N = Number of turns of the coil.
r = Radius of each of the turns of the coil
$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1} (Permeability of free space) and
I = the current flowing through the coil, and measured by ammeter. **[06]**

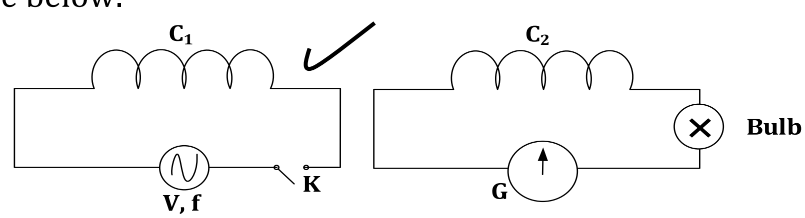
(ii) $I = 5.0\,A, N = 3000\,turns, r = 4.0\,cm = 0.04\,m, \theta = \left(\frac{20° + 22°}{2}\right) = 21°$

Using $\boldsymbol{B_H} = \frac{\boldsymbol{\mu_0 N I}}{\mathbf{2}\,\boldsymbol{r}\,\mathbf{tan}\,\boldsymbol{\theta}} = \frac{4.0\,\pi \times 10^{-7} \times 3000 \times 5.0}{\mathbf{2} \times 0.04 \times \mathbf{tan}\,21°} = \mathbf{0.6138}\,\boldsymbol{T}$

$\boldsymbol{B_H} = \mathbf{6.138} \times 10^{-1}\,T$ **[04]**

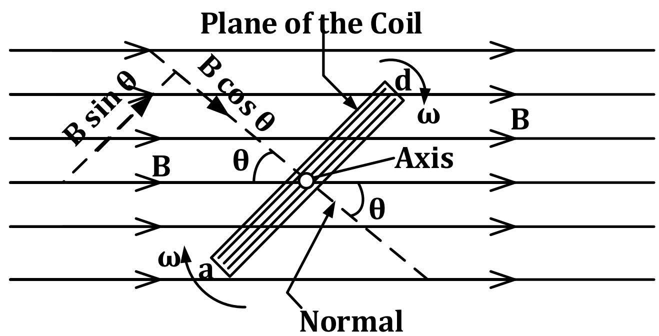
6. (a) (i) **Self-induction** is the production of an induced e.m.f. in a coil when a *changing current flows through the same coil* <u>while</u> **mutual induction** is the production of an induced e.m.f. in the neighbouring secondary coil when *a current flowing in the primary coil changes.* **[02]**

(ii) Two coils C_1 and C_2 known as the primary coil and secondary coils are arranged coaxially a small distance apart either through air or through a magnetic core.
Coil C_1 carries an a.c. source and a switch while coil C_2 is connected to either a centre zero galvanometer or a bulb or both as shown in the figure below.



Switch K is then closed and its observed that the centre zero galvanometer G pointer deflects to and fro about the zero position at the frequency of the a.c. source connected to coil, 1.
The bulb connected in series with coil 2 also lights up fairly dimly and is seen to light continuously so as the switch K is closed.
If the a.c. source is replaced with a d.c. source and switch K is closed and left on for some time, no deflections are observed in G, and no light is seen in the bulb. **[04]**

(b) (i) Suppose a rectangular coil ad is initially vertical at a time t = 0 s



Initially at t = 0 s the plane of the coil is Normal to the magnetic field.

Magnetic flux linking the plane of the coil nornmally after a time t ,

$\Phi = BAN\cos\theta \;\; where\; \theta = \omega t$

E.m.f. induced in the coil because of its rotation,

$$E = -\frac{d(BAN\cos\theta)}{dt} = -NAB\frac{d\,(\cos\omega t)}{dt}$$

$\therefore E = \boldsymbol{NAB\omega\sin\omega t}$

$\therefore\; \boldsymbol{E} = \boldsymbol{E_0\sin\omega t}\;\; where\; \boldsymbol{E_0} = \boldsymbol{NAB\omega}\; is\; the\; \boldsymbol{Maximum\; value}$

of the e.m.f. induced in the rotating coil. **[04]**

(ii) V = 240 V, B = 1.0 T, r = 2 Ω, A= 40 cm^2 I_1 = 5.0A, N = 20 turns

Using, $V - E_b = I\,r, \;\; \Rightarrow \;\; E_b = (V - I\,r)$

$\Rightarrow E_b = (240 - 5.0 \times 2) = 230\text{ V}$

But, $E_b = k\omega = NAB\omega \qquad \Rightarrow \omega = \frac{230}{NAB} = \frac{230}{20 \times 40 \times 10^{-4} \times 1.0} = 0.08$

$\Rightarrow \omega = 8.0 \times 10^{-2}\; rad.\, s^{-1}$ **[03]**

(c) (i) Eddy currents are currents that are induced in a thick metallic conductor when it is "cutting across" magnetic flux lines or when the conductor is placed in *a changing magnetic flux linked with* it, i.e.

Whenever a changing magnetic flux is linked with such a conductor. Eddy currents get induced in it and always flow along low resistance paths, in such a direction as to *oppose the changes* causing them to be produced. **[02]**

(ii) When a current flows through a coil placed in a magnetic field, the deflection torque on the coil causes it to rotate.
The Aluminium metal frame on which the coil is wound on, rotates with the coil causing eddy currents to be induced in it.
These eddy currents act in such a direction as to exert a retarding force to the motion of the coil hence critically damping the motion of the pointer.

(d) $E = -\frac{d\,N\phi}{dt} = -\frac{d}{dt}(BAN) = -\mu_0 nAN\frac{d}{dt}(I)$

$E = -\mu_0 nAN\dfrac{d}{dt}(I_0 \sin 100\pi t\ ) = -\mu_0 nAN \times I_0 \times 100\pi \cos 100\pi t$

$\therefore |E| = \mathbf{100\ \pi\ \mu_0 I_0 nAN \cos 100\pi t}$ ***is the e.m.f. induced in the coil***

The amplitude, $E = E_0$, $where, E_0 = \mathbf{100\ \pi\ \mu_0 I_0 nAN}$

$\therefore\ |E_0| = 4\pi \times 10^{-7} \times 100\pi \times \boldsymbol{I_0} \times 750 \times [\pi \times (0.08)^2] \times 100$

$|E_0| = 4\pi^3 \times 10^{-7} \times 10^4 \times (0.08)^2 \times 750 \times \boldsymbol{I_0}$

$\therefore\ \boldsymbol{E_0} = (\mathbf{59.53}\ \boldsymbol{I_0})\ \boldsymbol{V}$ **[02]**

7. (a) Reactance – is the non – dissipative opposition to the passage of changing or alternating current through it.
SI unit is ohm **(Ω)** **[02]**

(b) (i) $Using, E_b = -V,\ where, V = V_0 \cos 2\pi f t$

$\Longrightarrow E_b = -L\frac{d\,I}{dt} = -V_0 \cos 2\pi f t$

$dI = \frac{V_0}{L}\cos 2\pi f t\ \ dt$

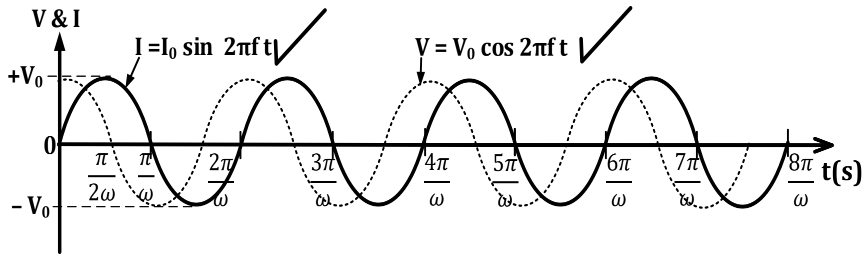
$\int dI = \int \frac{V_0}{L}\cos 2\pi f t\ \ dt$

$\therefore I = \frac{V_0}{2\pi f L}\sin 2\pi f t \implies I = I_0 \sin 2\pi f t$

Where, $I_0 = \dfrac{V_0}{2\pi f L}$

$\therefore Reactance, \boldsymbol{X_L} = \frac{V_0}{I_0} = \boldsymbol{2\pi f L}$ **[04]**

(ii) Graphs of Current I and Voltage V against time.



[02]

(c) Given $N_P = 1200\ turns, V_s = 12\ V\ while\ , I_P = 5A\ and\ \ V_{rms} = 240\ V$
From V = IR

(i) If the transformer is 95 % efficient it means,

only 95% *of the Power input is delivered to the secondary circuit.*

$95\%\ of\ V_pI_p = V_sI_s \implies \frac{95}{100} \times V_pI_p = V_sI_s$

$\therefore\ \boldsymbol{I_S} = \frac{95}{100} \times \frac{V_pI_p}{V_S} = \frac{95}{100} \times \frac{240 \times 5}{12} = \mathbf{95.0}\ \boldsymbol{A}$

$\therefore\ Peak\ value\ of\ current\ in\ the\ secondary, \frac{I_S}{\sqrt{2}} = \frac{95}{\sqrt{2}} = \mathbf{67.18}\ \boldsymbol{A}$ **[03]**

(ii) Using, $\frac{N_S}{N_p} = \frac{V_S}{V_p}$

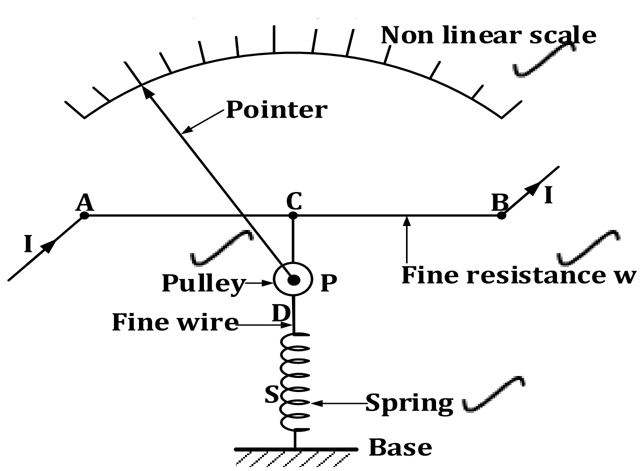
$$N_S = \frac{V_S \times N_p}{V_p}$$

$$= \frac{12 \times 1200}{240}$$

$$\therefore\ \boldsymbol{N_S} = \mathbf{60}\ \boldsymbol{turns}$$

[03]

(d) The structure of the Hot wire ammeter.



- Current, **I** to be measured is passed through the fine resistance wire **AB**.
- The wire gets heated up, it expands and sags.

- The sag is then picked up by the second fine wire **CD** that passes round a grooved pulley **P** and attached to the pointer.
- The pulley rotates and causes the pointer to rotate as it moves over the scale, until it is stopped by the controlling torque provided by a pair of hair springs wen the pointer is deflected through angle θ.
- The deflection, **θ** is proportional to the sag, and is therefore proportional to the square of the average or mean current. i.e. $\boldsymbol{\theta} \propto \langle \mathbf{I^2} \rangle$
- Hence, the instrument has a non-linear or square scale. **[06]**

SECTION D

8. (a) (i) **Electric flux** – is the product of the magnitude of the electric field intensity and the projection of the surface area normal to the field.
SI unit is **newton meters squared per coulomb (Nm^2C^{-1})** and a **volt metre (Vm).** **[02]**

(ii) Electric flux, ϕ due to surface, **S**, enclosing a charge Q, in free space is given by

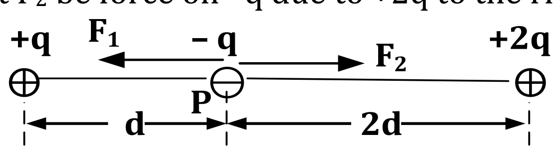
$$\phi = E \times A, \ \textit{where A is the surface area enclosing the charge.}$$

$$\phi = \frac{Q}{4\pi\varepsilon_0 r^2} \times 4\pi r^2 \ \textit{ is applied to a sphere surrouding the charge, Q}$$

$$\therefore \boldsymbol{\phi} = \frac{\boldsymbol{Q}}{\boldsymbol{\varepsilon_0}}$$ **[03]**

(b) (i) The force that exists between two point charges in space is directly proportional to the ***product of the magnitudes of the charges*** and inversely proportional to the square of their mean distance of separation. **[01]**

(ii) Let F_1 be force on –q due to +q to the left of point P
Let F_2 be force on –q due to +2q to the right of point P



$$\textit{Using } F = k\frac{|Q_1| \times |Q_2|}{r^2} \implies F_1 = k\frac{q^2}{d^2} \textit{ and } F_2 = k\frac{2q^2}{4d^2} = k\frac{q^2}{2d^2}$$

Since, $F_1 > F_2$, *the resultant force at P*, $F = (F_1 - F_2)$ *to the left of P*

$$F = (F_1 - F_2) = k\frac{q^2}{d^2} - k\frac{q^2}{2d^2} = k\frac{q^2}{d^2}\left(1 - \frac{1}{2}\right)$$

$$\therefore F = \boldsymbol{k}\frac{\boldsymbol{q^2}}{\boldsymbol{2d^2}} \ \textbf{\textit{or}} \ \boldsymbol{F} = \frac{\boldsymbol{q^2}}{\boldsymbol{8\pi\varepsilon_0 d^2}}$$ **[04]**

(c) (i) The screen of a TV in operation has **excess negative** charges on it and when the hand is passed near it, the **hairs get polarized** with **negative charges repelled to the remote part of the hair**, while the positive charges are left near the screen. The nearby **positive charge gets attracted to the negative charge on the TV screen**, and the hairs get stretched towards the screen (hence they stand out). **[02]**

(ii) **Every conductor** of whatever shape is ***an equipotential surface***.
Thus ***no work is done to move a charge from one point to the other point*** *within the same surface.*
Thus, there is ***no net electric force*** acting on the charged particle ***along the surface*** of the conductor.
Since, ***electric force always acts along the field of force*** (i.e. along electric field lines), this implies there are ***no electric field lines along the surface*** of a conductor.
Hence, ***all electric field lines are perpendicular to the conductor*** *irrespective of the shape or curvature of the conductor.* **[03]**

(d) Let, Electric field intensity at point, D due to a charge, Q_A be $\boldsymbol{E_A} = \frac{\boldsymbol{Q_A}}{\boldsymbol{4\pi\varepsilon_0 r^2}}$

$$\therefore\ |\boldsymbol{E_A}| = \frac{(3.2\times10^{-6})\times(9.0\times10^{9})}{(4.0\times10^{-2})^2} = \boldsymbol{1.80\times10^{7}\ NC^{-1}}\ \textit{to the left of}\ \boldsymbol{D}$$

$$\therefore\ \boldsymbol{E_B} = \frac{(+2.5\times10^{-6})\times(9.0\times10^{9})}{(5.0\times10^{-2})^2} = \boldsymbol{9.00\times10^{6}\ NC^{-1}}\ \textit{from}\ \boldsymbol{D}\ \textit{towards}\ \boldsymbol{B}$$

$$\therefore\ |\boldsymbol{E_C}| = \frac{(2.7\times10^{-6})\times(9.0\times10^{9})}{(3.0\times10^{-2})^2} = \boldsymbol{2.70\times10^{7}\ NC^{-1}}\ \textit{vertically upwards}$$

$$\sum E_x = E_A - E_B\cos\theta = (18.0 - 9.00\cos 36.9°)\times10^{6}$$

$$\therefore\ \boldsymbol{E_x} = \boldsymbol{1.08\times10^{7}\ NC^{-1}}$$

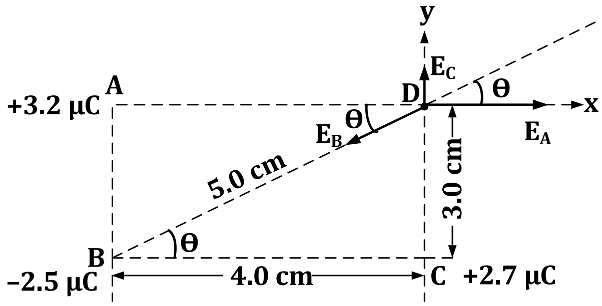
$$\sum E_y = E_C - E_B\sin\theta = (27.0 - 9.00\sin 36.9°)\times10^{6}$$

$$\therefore\ \boldsymbol{E_y} = \boldsymbol{2.16\times10^{7} NC^{-1}}$$

Thus, the resultant electric field at point D, $\boldsymbol{E_D} = \sqrt{\boldsymbol{E_x}^2 + \boldsymbol{E_y}^2}$

$$\boldsymbol{E_D} = \sqrt{(1.08\times10^{7})^2 + (2.16\times10^{7})^2} = \boldsymbol{2.41\times10^{7}\ NC^{-1}}$$

$$\therefore\ \boldsymbol{E_D} = \boldsymbol{2.41\times10^{7}\ NC^{-1}}\ \textit{at an angle}\ \beta\ \textit{to the positive}\ x-\textit{direction.}$$



From Pythagoras theorem,

$BD^2 = BC^2 + CD^2$

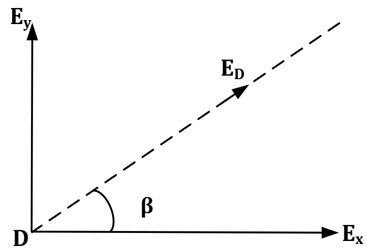
$= 4^2 + 3^2$

$= 25$

Thus, BD = 5.0 cm

From ΔBCD, $\tan \theta = \frac{3}{4}$

Thus, $\theta = 36.9°$



Hence, the resultant electric field intensity at point, D, **[05]**

$\boldsymbol{E_D = 2.41 \times 10^7\ NC^{-1}}$ ***at an angle of*** $\boldsymbol{63.4°}$ ***to the*** $\boldsymbol{+x -}$ ***direction.***

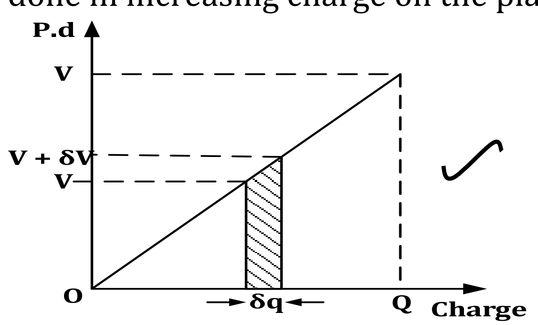
9. (a) Energy conversions that occur when charging a capacitor

When charging a capacitor, ***chemical energy*** in the battery is converted into ***electrical energy*** **+** ***heat energy*** in the connecting wires and finally ***electrostatic potential energy*** in a charged capacitor. **[02]**

(b) (i) **The graphical method**

Suppose the charge on any one of the plates of the capacitor at any time t, is q while the p.d. is V.

Small work done in increasing charge on the plates by δq



$\delta W = element\ of\ area\ (shaded\ part)$

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

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

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

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

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

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

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

$\therefore Energy\ stored, \boldsymbol{E} = \boldsymbol{\frac{1}{2}\ C\,V^2}$

Alternatively

In charging a capacitor the work done by the source in transferring charge q $\quad \delta W = V\delta q$ $\quad but\ V = \frac{q}{C}$

Total work done, $W = \int_0^Q \frac{q}{C}\ dq \ = \left[\frac{q^2}{2C}\right]_0^Q = \boldsymbol{\frac{Q^2}{2C}}$

$Using, Q = CV\ and\ substituting\ above, W = \frac{C^2V^2}{2\,C}$

$Thus, the\ total\ energy, \boldsymbol{E} = \boldsymbol{\frac{1}{2}\ C\,V^2}$ **[04]**

(ii) When the dial is at 120° the capacitance, C_1 = 400 pF and V = 12 V

Charge stored on the capacitor, $Q \ = \ CV$ $= 400 \times 10^{-12} \times 12$

$\therefore \boldsymbol{Q = 4.8 \times 10^{-9}\ C}$ and is maintained if no leakage in the system.

Initial Energy stored in capacitor, $E_1 = \frac{1}{2}CV^2 = \frac{1}{2} \times 400 \times 10^{-12} \times 12^2$

$\therefore \boldsymbol{E_1 = 2.88 \times 10^{-8}\ \mathrm{J}}$

When the dial is changed to 0° the corresponding capacitance C_2 =10 pF

$E_2 = \frac{1}{2}\left(\frac{Q^2}{C}\right)$ $= \frac{1}{2} \times \frac{(4.8 \times 10^{-9})^2}{10 \times 10^{-12}} = \ \boldsymbol{1.152 \times 10^{-6}\ \mathrm{J}}$

$\therefore \boldsymbol{E_2 = 1.152 \times 10^{-6}\ \mathrm{J}}$

Thus the change in energy,

$\Delta \boldsymbol{E} = E_2 - E_1 = (1.152 \times 10^{-6} - 2.88 \times 10^{-8}) = \boldsymbol{1.1232 \times 10^{-6}\ \mathrm{J}}$

The increase in energy of $\Delta E = 1.1232 \times 10^{-6}$ J is due to the external ***work done against electrostatic attraction*** in moving one set of plates against the ***oppositely charged*** set of the ***metal plates***.

It is also due to the work done against ***friction*** at the moving parts of the system. **[06]**

(c) (i) ***Dielectric constant*** – is the ratio of capacitance of a capacitor with a dielectric material filling all the space between the plates, to the capacitance of the same capacitor when placed in a vacuum or with air between its plates. **[01]**

(ii) Measurement of a dielectric constant, $\boldsymbol{\varepsilon_r}$ of a capacitor using a Calibrated Ballistic Galvanometer (B.G)

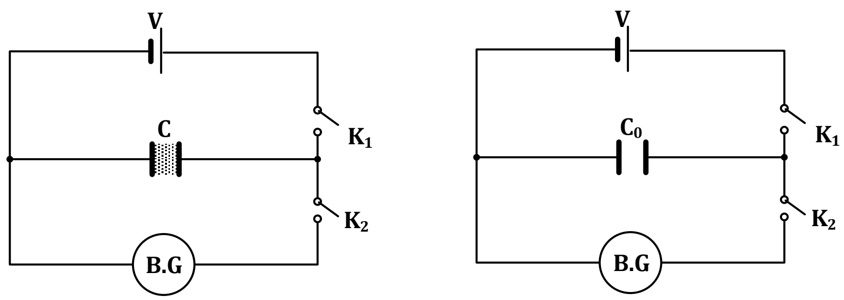
- A standard capacitor has all the space between its plates, filled with a dielectric material and connected to the circuit shown in fig.(i) below.
- Switch K_1 is then closed while switch K_2 is left open for the capacitor to

Accept other methods like vibrating reed & GLE

charge fully, to a maximum value, Q,

- The switch, K_1 is now opened, then K_2 is closed shortly, to discharge the capacitor completely through a calibrated ballistic galvanometer (B.G).
- The maximum deflection, θ of the pointer on the scale of the B.G. is noted,

(i) The Capacitor with a dielectric **(ii) The Capacitor without a dielectric**



- The dielectric originally placed to fill the space between the plates of the capacitor is now ***completely removed*** leaving only air between the plates as shown in figure (ii) and the procedures above are repeated.
- The maximum deflection corresponding to the new setup, θ_0 is noted.
- The dielectric constant, ε_r is obtained from the equation,

$\boldsymbol{\varepsilon_r = \frac{\theta}{\theta_0}}$ *Hence*, the dielectric constant ε_r is then calculated. **[05]**

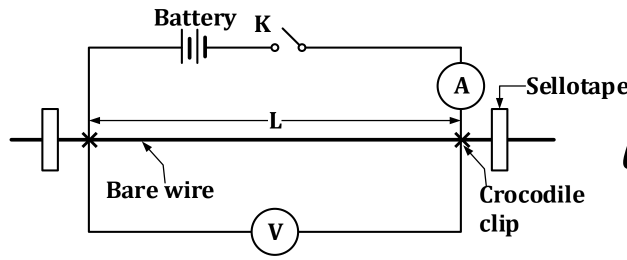
(d) Devices that involve capacitors in their operations include some of the following:

- Tuning circuits in radios and T.Vs receivers.
- Preventing or eliminating sparking in switches.
- Used in rechargeable torches and lamps.
- Used in the operation of condenser microphones.
- Used to store charge in laptops, iPad and phones.
- Providing flashes in cameras and Telephone handsets.
- For smoothing rectified currents and voltages from power supplies during the rectification process.
- Used in filter circuits in the rectification process.
- Used in ignition or timing circuits of vehicles and automobiles.
- Used in mosquito traps (rechargeable mosquito traps).

Any two @ 1 mark **[02]**

10.(a) (i) **Resistance** – is also defined as the ratio of the potential difference across the opposite ends or faces of the conductor or material to the current flowing through the it. i.e. $R = \frac{V}{I}$ **[01]**

(ii) A sample of the test material in form of a wire, has a measured length, L connected to the circuit shown below.



- The experiment is then set up as shown in figure above.
- Starting with a shorter length, L of a measured bare wire, the switch K is closed.
- The ammeter reading, I, and the voltmeter reading, V, are simultaneously read and recorded down.
- The experiment is then ***repeated*** for several increasing values of length, L of the bare wire.
- The results are tabulated in a suitable table of results including values of, L, V, and I.
- A graph of V *against I is plotted and gives a straight line through the origin.*
- The Slope, S, of the graph is determined and this gives the resistance, of the conductor or material
- Hence, resistance, R of a conductor is equal to the slope, S. $i.e. R = S$

[05]

(b) (i) **Using,** $E = I(r+R)$ **when the resistors,** $R_1 = 3\ \Omega\ \&\ R_2 = 9\ \Omega$ are in series, $R = (3+9) = 12\ \Omega$

$when\ R = 12\ \Omega, \mathrm{I} = 1.0\ \mathrm{A} \Rightarrow E = 1.0\,(r+12)\ \ldots\ldots\ldots\ldots\ldots..(i)$

when $R_1 = 3\ \Omega\ \&\ R_2 = 9\ \Omega$ are in parallel, $R = \frac{(3\times 9)}{(3+9)} = 2.25\ \Omega$

$and\ when\ R = 2.25\ \Omega, \mathrm{I} = 2.4\ \mathrm{A}, \Rightarrow E = 2.4\,(r+2.25)\ \ldots\ldots.(ii)$

From (i) and (ii) $1.0\,(r+12) = 2.4\,(r+2.25)$

$\Rightarrow 1.0\,r + 12.0 = 2.4\,r + 5.4$

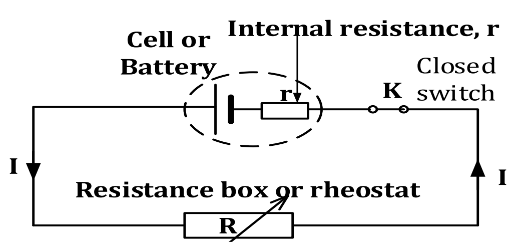
$\Rightarrow 1.4\,r = 6.6$

$\therefore Internal\ Resistance, \boldsymbol{r} = \mathbf{4.71}\ \Omega$ **[03]**

(ii) $Using\ equation\ (i)\ above,\ E = 1.0\,(4.71+12)$

$Thus, the\ e.m.f.of\ the\ battery, \boldsymbol{E} = \mathbf{16.71}\ \boldsymbol{V}$ **[02]**

(c)



$Power\ output = P = I^2R\ where\ I = \frac{E}{R+r}$

$P = \left(\frac{E}{R+r}\right)^2 R \qquad \Rightarrow P = \frac{E^2 R}{(R+r)^2}$

Condition For maximum power output in a closed circuit.

From equation, (iv) above, $\frac{dP}{d\,R} = 0$, let u = E^2R, V = $(R + r)^2$

$\frac{dP}{dR} = \frac{\frac{VdU}{dR} - \frac{UdV}{dR}}{V^2} = 0\,,\ \frac{du}{dR} = E^2,\quad \frac{dv}{dR} = 2(R + r)$

$\frac{(R+r)^2E^2 - E^2R[2(R+r)]}{(R+r)^2} = 0$

$E^2(R + r)[R + r - 2R] = 0$

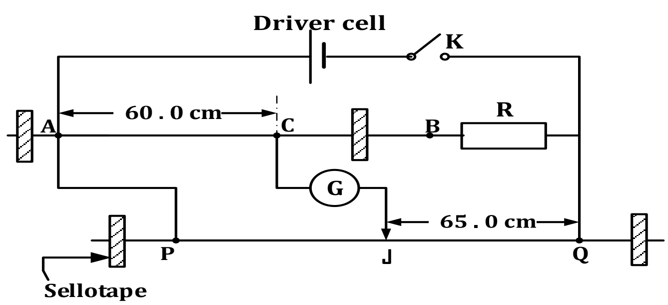
$\Rightarrow \boldsymbol{r - R = 0}$

$\boldsymbol{R\ =\ r\ \ is\ the\ condition\ for\ maximum\ power\ output}.$

$Hence, Maximum\ Power,\ P_{max} = \frac{E^2r}{(r+r)^2}$

$\boldsymbol{P_{max} = \frac{E^2}{4r}}$ **[05]**

(d)



Solution

$Resistance\ per\ cm\ = \frac{R_{AB}}{AB} = 0.40\ \Omega\ cm^{-1}$

$R_{AC} = 60.0\ \times 0.40 = 24\ \Omega$

$R_{CB} = 40.0\ \times 0.40 = 16\ \Omega$

At balance, $\frac{R_{AC}}{(R_{CB}+R)} = \frac{35.0}{(100-35.0)}$

$\frac{24}{(16+R)} = \frac{35.0}{65.0} \Rightarrow \frac{24}{(16+R)} = \frac{7.0}{13.0}$

$7.0(16 + R) = 24 \times 13.0$

$112 + 7R = 312 \ \Rightarrow 7R = 200$

$\therefore \boldsymbol{R = 28.57\ \Omega}$ **[04]**

=END=