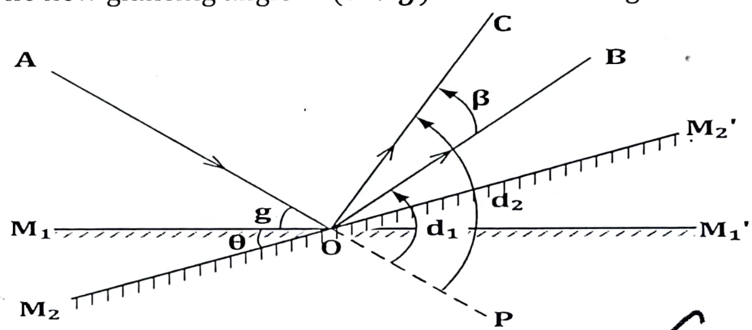
JJEB MOCK EXAMINATIONS 2023

P510/2 PHYSICS MARKING GUIDE

✓	Full mark
✓	Half mark

SECTION A

1. (a) (i) Consider a fixed incident ray **AO** incident on mirror M_1M_1' at **O**
Let initial glancing angle = **g**, before rotation of the mirror M_1M_1'
After rotated anti-clockwise through an angle **θ**
The new glancing angle $= (\theta + g)$ as shown in figure below.



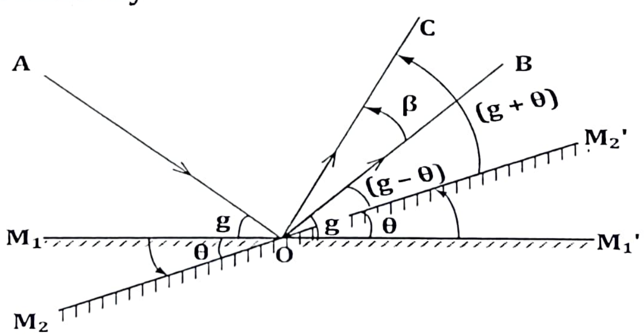
$\therefore$ *Angle BOC*, $\beta =$ *angle POC* − *angle POB*

$= d_2 - d_1$

$= 2(g + \theta) - 2g$

$\therefore\ \beta = 2\theta$ *anti-clockwise.* **[03]**

Alternatively:



Angle M_1OM_2 = *angle* $M_1'OM_2'$ = θ (*angle of rotation of the mirror*)

Angle AOM_1 = *angle* BOM_1' = g (*initial glancing angle*)

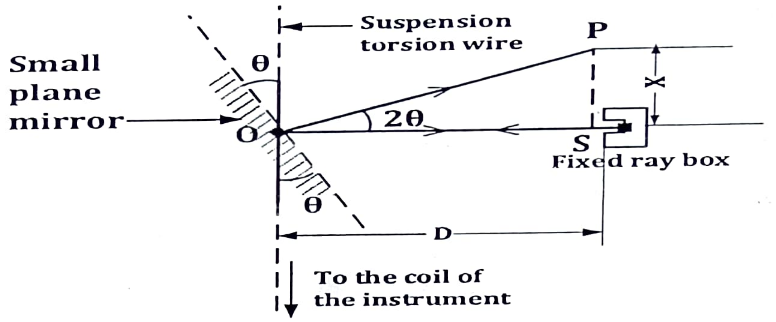
Angle AOM_2 = *angle* COM_2' = $(g + \theta)$(*final glancing angle*)

Angle BOM_2' = (*angle* $BOM_1' - M_2'OM_1'$) = $(g - \theta)$

$\therefore$ *Angle BOC* $= M_2'OC - M_2'OB = (g + \theta) - (g - \theta)$

$\therefore$ *Angle BOC* $= 2\theta$ (*Twice the angle of rotation of the mirror*) [03]

(ii)

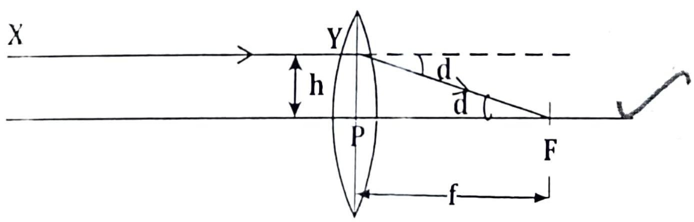


- When ***no current*** is passed through the coil of the instrument, a ray of light **SO** from a fixed ray box, strikes the mirror normally and bounces back along the same path **OS.**
- When a current, **I**, passes through the coil it experiences a deflection torque that turns it about a vertical axis, together with ***a small plane mirror*** mounted on the suspension torsion wire through an angle **θ**.
- The mirror then rotates about point O through an angle θ. This then causes the reflected ray to turn through **2θ**
  This sweeps out a distance x on the scale that is noted.
- Since the deflection **θ** is proportional to the current, I flowing through the coil, it implies that, $\theta \propto I \Rightarrow \theta = k\,I$ …………………. (i)
- For small angles, θ and 2θ all expressed in radians,
  $\tan\theta \cong \theta$ *and* $\tan 2\theta \cong 2\theta = \frac{x}{D} \Rightarrow \theta = \frac{x}{2D}$ ……………. (ii)
- From (i) above, $\theta = k\,I \Rightarrow I = \frac{x}{2\,D\,k}$

  Thus, having known values of x, D and k, the current **I** flowing through the instrument can then be calculated. **[04]**

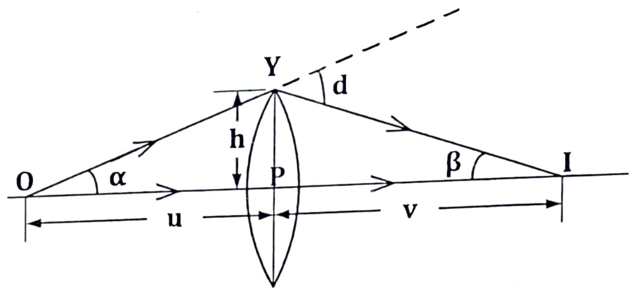
(b) (i) This is a point on the principal axis where incident rays that are parallel and close to the principal axis pass through after refraction by the lens. **[01]**

(ii) Consider a ray XY incident onto the lens and parallel to the principal axis at a height h.



For small angle, d, in radians, $\tan d \cong d = \frac{h}{f}$ …………………… (i)

Consider ray OY from a point object, O, incident onto the lens surface at a height, h, above the principal axis



The ray suffers the same deviation, d, at the same height, h.

Thus, from ΔOYI: $\alpha + \beta = d$ …………………………… (ii)

For small angle, α and β, in radians, $\tan\alpha \cong \alpha = \frac{h}{u}$ and $\tan\beta \cong \beta = \frac{h}{v}$ ..(iii)

Substituting, (i) and (iii) into (ii) $\Rightarrow \frac{h}{u} + \frac{h}{v} = \frac{h}{f}$

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ *Hence the lens formula* **[04]**

(c) Consider action of the concave mirror first. $u_1 = 15.0$ cm, $f_m = 10.0$ cm, $v_1 = ?$

(i) Using $\frac{1}{u_1} + \frac{1}{v_1} = \frac{1}{f} \Rightarrow \frac{1}{v_1} = \frac{1}{f} - \frac{1}{u_1}$

$\frac{1}{v_1} = \frac{1}{10.0} - \frac{1}{15.0}$ $\Rightarrow v_1 = \mathbf{30.0\ cm}$

Action of the lens L: Using $\frac{1}{u_2} + \frac{1}{v_2} = \frac{1}{f} \Rightarrow \frac{1}{v_2} = \frac{1}{f} - \frac{1}{u_2}$

$where, u_2 = (20 - 30) = -10.0\ cm$, $f_2 = 8.0\ cm\ and\ v_2 = ?$

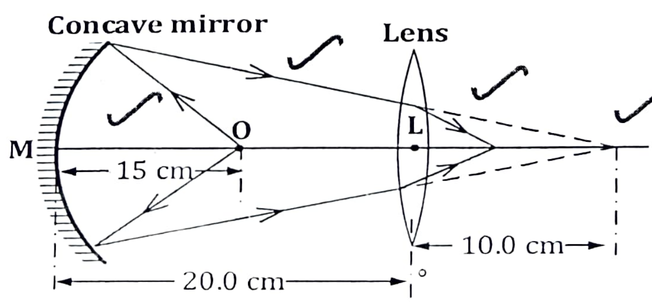
$i.e.\ \frac{1}{v_2} = \frac{1}{8.0} - \left(\frac{1}{-10.0}\right)$

$\Rightarrow \frac{1}{v_2} = \frac{1}{8.0} + \frac{1}{10.0} \Rightarrow v_2 = \mathbf{4.44\ cm}$ **[04]**

∴Image is real and is ***4.44 cm behind the convex lens.***

(ii) $m = m_1 \times m_2 = \frac{30.0}{15.0} \times \frac{4.44}{10.0} = \mathbf{0.888}$ **[02]**

(iii) **Ray diagram**



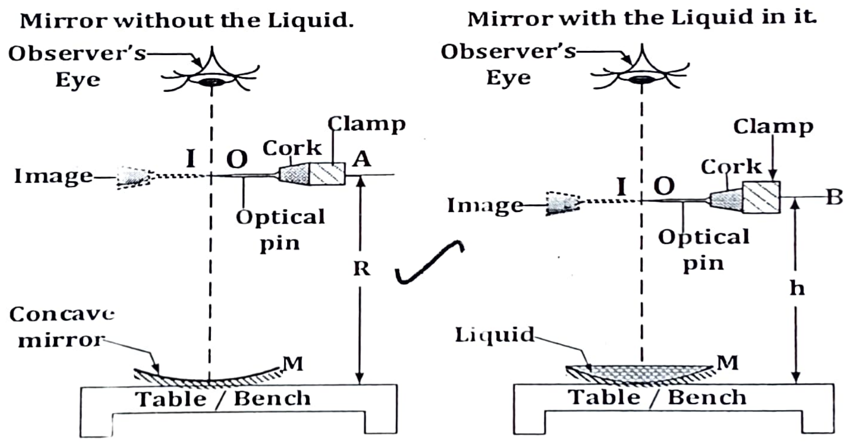
[02]

2.(a) (i) This is radius of the sphere for which the concave mirror forms part. [01]

Or The distance from the centre of curvature to the pole of the mirror.

(ii) A concave mirror **M** is placed on a flat horizontal surface with its reflecting surface facing up.

- An optical pin **O** is then clamped horizontally directly above the mirror with its tip lying along the principal axis of the mirror.
- Pin O is moved slowly up and down until it coincides with its own image, **I** by no parallax at position **A** of the pin.
- Distance, **R** from point **O** of no parallax up to the mirror surface is measured using a metre rule and recorded down.
- A small quantity of the liquid under test is then poured into the mirror.
- The optical pin, **O** is again moved up and down until it coincides with its image **I** by no parallax at a new position, **B** of the pin.



- A new distance, **h**, from point **O** up to the top surface of the table is noted.
- The refractive index of the small quantity of the liquid, n, is then calculated from the expression, $n = \frac{R}{h}$ [05]

(b) (i) Using, $n = \frac{R-d}{h-d}$ where $d = 0.2cm$, $h = (15.0 + 0.2) = 15.2\ cm$

$$n_1 = \left(\frac{R-d}{h-d}\right) \quad where, d = 0.20\ cm\ and\ (h-d) = 15.0\ cm$$

$$\therefore 1.35 = \left(\frac{R-0.20}{15.0}\right) \Rightarrow (1.35 \times 15.0) = (R - 0.20)$$

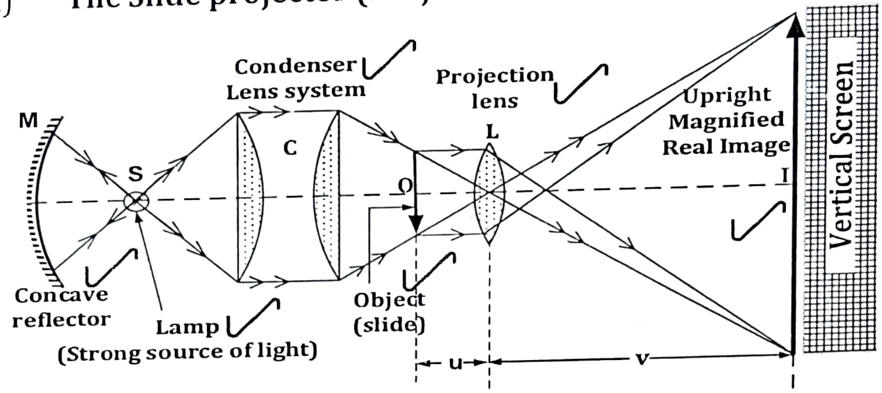
$$\therefore Radius\ of\ curvature, R = 20.45\ cm$$ [03]

(ii) $n_2 = \left(\frac{R-d}{h-d}\right)$ where, $d = 0.20\ cm$ and $(h-d) = 18.0\ cm$

$n_2 = \left(\frac{20.45 - 0.20}{18.0}\right)$

$\Rightarrow \boldsymbol{n_2 = 1.125}$ **[02]**

(c) (i) **The Slide projector (Projection Lantern)**



[03]

(ii) $L_0 = 5.08\ cm \Rightarrow A_0 = L_0^{\ 2} = 25.8064\ cm^2$

$L_i = 200\ cm \Rightarrow A_i = L_i^{\ 2} = 40{,}000\ cm^2$

$Area\ magnification, (ASF) = \frac{Area\ of\ the\ Image}{Area\ of\ the\ Object} = \frac{40{,}000}{25.8064} = 1550$

$Linear\ magnification, (LSF) = \frac{Image\ distance}{Object\ distance} = \left(\frac{v}{f} - 1\right)$

$LSF = \frac{350}{u} = \left(\frac{350}{f} - 1\right)$ But using the relationship

$(LSF) = \sqrt{(ASF)} \quad \Rightarrow \left(\frac{350}{f} - 1\right) = \sqrt{(1500)} = 38.73\ cm$

$\therefore Focal\ length\ of\ the\ lens, f = \frac{350}{39.73} = 8.81\ cm\ or\ f = \mathbf{0.0881\ m}$

[04]

(d) Chromatic aberration – is minimized by using an ***achromatic lens*** combination ***(doublet).***
The convex lens produces ***dispersion of white light in one sense*** while the second lens (concave lens) ***reverses the dispersion*** produced by the first lens, and ***completely cancels it out in the opposite sense.***
Thus, the final image that results is relatively ***free*** from the defect of having colored edges hence ***a white image is formed.*** [02]

SECTION B

3. (a)(i)

Transverse waves	Longitudinal wave
Undergo polarization	Do not undergo polarization
Particles perpendicular to the direction of travel of the wave.	Particles vibrate back and forth parallel to the direction of travel of the wave.
Particle density is uniform throughout the wave profile provided the source of disturbance is maintained.	There is variation in particle density along the wave profile forming regions of rarefaction and compressions.
The distance between two successive crests or successive troughs is the wavelength λ.	The distance between two consecutive rare-factions or compressions is the wavelength λ.
The reflected waves have a phase change of π radians after rebounding from the reflecting surface or barrier.	The reflected waves have no phase change if the reflection takes place at a fixed reflecting surface, boundary or barrier.

Accept any three correct corresponding pairs of responses. **[03]**

(ii) **Examples of transverse waves**

- Light waves
- Water waves

Examples of longitudinal waves

- Sound waves
- Slinky spring waves

[04]

(b) (i) **Overtones** – are ***sound notes of higher frequencies*** than the fundamental note that are ***multiples of the fundamental frequency***, that can be produced by a particular musical instrument in its allowed modes. **[01]**

(ii) Un-stopped pipes ***produce both odd and even harmonics*** (all the harmonics) while stopped pipes produce only the odd harmonics.

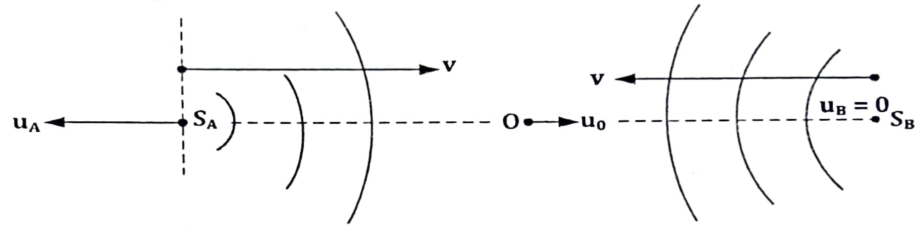
Hence for the same intensity of sound, ***unstopped pipes*** produce ***more overtones*** than stopped pipes.

Since the ***quality*** of sound ***depends*** on intensity and relative ***number of overtones***.

Unstopped piped instruments produce ***more overtones*** than the stopped piped instrument, hence they produce ***higher quality sound*** than the stopped piped ones. [03]

(c) (i) **Doppler effect** – is the apparent change of frequency of the waves received by the observer due to relative motion between the source of the waves and the observer. **[01]**

(ii) Let f_A *and* f_B *represent apparent frequencies of waves* Received by the observer from sources A and B respectively.



$$f_A = \frac{v'}{\lambda'} \text{ where } v' = (v - u_0) \text{ and } \lambda' = \frac{(v + u_A)}{f}$$

Thus, $f_A = \left(\frac{v - u_0}{v + u_A}\right) f$

Similarly, for source B

$$f_B = \frac{v''}{\lambda''} \text{ where } v'' = (v + u_0) \text{ and } \lambda'' = \frac{(v \pm u_B)}{f} \text{ but } u_B = 0$$

Thus, $f_B = \left(\frac{v + u_0}{v}\right) f$

$$f_A = \left(\frac{340 - 5}{340 + 10}\right) 500 = 478.57\ Hz$$

$$f_B = \left(\frac{340 + 5}{340}\right) 500 = 507.35\ Hz$$

$\therefore$ *Beat frequency,* $f_b = (f_B - f_A) = (507.35 - 478.57) = \mathbf{28.78\ Hz}$

[01]

(d) Two sound notes of ***slightly different frequencies*** and of *similar amplitudes* are sounded together, the sound notes superpose and interfere.

When the two *wave trains* ***meet in phase*** *they reinforce* and produce ***a loud sound 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 process repeats itself periodically leading to the formation of beats. **[03]**

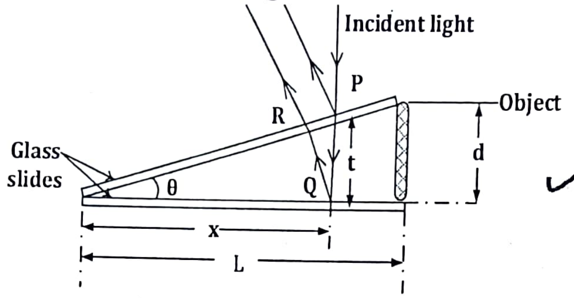
4. (a) (i) **Diffraction** – is the spreading of the waves beyond their geometrical barriers or shadows. **[01]**

(ii) Factors affecting diffraction are:

- Size of the geometrical barrier or size of the slit.
- Wavelength of the radiation incident on the slit. [02]

(b) (i) **Path difference** – is the difference in the optical path lengths of two wave trains from the plane of two coherent sources up to the point where they overlap each other and interfere. **[01]**

(ii) Consider a ray of monochromatic light incident almost normally on the top slide of the air wedge.



The waves reflected at the bottom surface of the top slide at P and those reflected from the top surface of the bottom slide at Q and emerging at R overlap each other above the top slide and interfere. Dark linear bands are observed between the two glass slides when, the

Path difference $2t = m\lambda$

But for very small angle θ in radians

$tan\,\theta \approx \theta = \frac{t}{x} \Rightarrow t = x\theta, thus\ the\ mth\ dark\ band\ is\ formed$

$when, 2t = 2x_m\theta = m\lambda \ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)\ where\ m = 0,1,2,3 \ldots$

$\therefore mth\ dark\ fringe\ position from\ point\ O, x_m = \frac{m\lambda}{2\tan\theta} \approx \frac{m\lambda}{2\theta}$

$\therefore (m+1)th\ fringe position, x_{m+1} = \frac{(m+1)\lambda}{2\tan\theta} \approx \frac{(m+1)\lambda}{2\theta}$

$\therefore The\ fringe\ separation, y = (x_{m+1} - x_m) = \frac{\lambda}{2\tan\theta}\ or\ y = \frac{\lambda}{2\theta}$

[04]

(iii) ***Applications of interference of light include:***

- Testing surface quality e.g. Flatness, roundness, roughness e.t.c.
- Lens blooming i.e. Anti – reflecting surfaces on lenses of cameras, spectacles and projectors.
- Hologram technology.
- Radio astronomy e.g. measuring light intensity in retrieving images from telescopes.
- The Blue morpho butterfly colour on its wings.
- The coloured appearance of soap bubbles.
- Formation of coloured patches on wet oily roads. **[04]**

Accept the first two correct responses @ 1 mark.

(c) (i) The following formula may be used to calculate the ***fringe separation*** is given by, $y = \frac{D\lambda}{a}$ where,

D as distance of the screen from the common plane of the slits.

λ is the wavelength light used to illuminate the slits.

a is the slit separation. [02]

(ii) Given that, the m^th^ bright fringe is $x_m = \frac{m\lambda D}{a}$

The fourth bright fringe, $x_4 = \frac{4\lambda D}{a}$

The second bright fringe, $x_2 = \frac{2\lambda D}{a}$

Then, $(x_4 - x_2) = \left[\frac{4\lambda D}{a} - \frac{2\lambda D}{a}\right] = \frac{2\lambda D}{a} = 2y$

But the fifth dark band is half fringe separation after the fourth bright band, $\Rightarrow \left(2y + \frac{y}{2}\right) = 2.0\ cm$

$\left(\frac{5y}{2}\right) = 2.0\ cm \Rightarrow y = \frac{4}{5} cm \Rightarrow \mathbf{y = 8.0 \times 10^{-3} m}$

Thus, using $a = 1.5\ mm = 1.5 \times 10^{-3}\ m, D = 3.0\ m$ and

$y = 8.0 \times 10^{-3} m\ then\ using\ \lambda = \frac{ay}{D}$

$\lambda = \frac{1.5 \times 10^{-3} \times 8.0 \times 10^{-3}}{3.0}$

$\therefore Wavelength, \lambda = \mathbf{4.0 \times 10^{-6}\ m}$ [04]

(d) (i) From the expression, $y = \frac{D\lambda}{a} \Rightarrow y \propto \frac{1}{a}$

Reducing the value of a leads to increase in the value of y

Hence, ***a reduction in distance between the slits*** leads to ***increase in the fringe separation.*** [01]

(ii) Conditions for observation fringes on a screen in the Young's double slit experiment include:

- A small distance of separation between the slits.
- The sources of light must be coherent sources.
- The distance of separation between the slits and the screen should be reasonably large.
- The slits should be narrow. [03]

Accept the first three correct responses @ 1 mark.

SECTION C

5.(a) (i) ***Angle of dip*** – is the angle between the Earth's resultant magnetic field and the horizontal component of the earth's magnetic field.
Or the angle between the horizontal and the axis through the poles of a freely suspended bar magnet when it sets. **[01]**

(ii) ***Magnetic Meridian*** – is a vertical plane passing through the Earth's magnetic North and South poles. **[01]**

(b) (i) A search coil of known geometry is connected in series with a calibrated ballistic galvanometer.

- The plane of the search coil is placed vertically perpendicular to the magnetic meridian.
- The coil is rotated about its horizontal diameter through 180° and the maximum deflection $\boldsymbol{\theta_H}$ on the BG scale is noted.
- The horizontal component of the earth's magnetic field, $B_H = \frac{R\,k\,\theta_H}{2\,N\,A} = k\,\theta_H$
- The plane of the search coil is now made horizontal so that its threaded normally by the vertical component of the earth's magnetic field $\boldsymbol{B_V}$.
- The coil is again rotated about its horizontal diameter through 180° and the maximum deflection $\boldsymbol{\theta_V}$ on the BG scale is noted.
- The vertical component of the earth's magnetic field, $B_V = \frac{R\,k\,\theta_V}{2\,N\,A} = k\,\theta_V$
- The angle of dip of the earth's magnetic flux density, α is then calculated from the expression, $\tan\alpha = \frac{B_V}{B_H} = \frac{\theta_V}{\theta_H} \implies \alpha = \tan^{-1}\left(\frac{\theta_V}{\theta_H}\right)$ **[06]**

(ii) $B_H = 2.50 \times 10^{-3}T$ *while* $B_V = 4.33 \times 10^{-3}T$ and $B = \sqrt{{B_H}^2 + {B_V}^2}$

$$\implies B = \sqrt{(2.50 \times 10^{-3})^2 + (4.33 \times 10^{-3})^2}$$

$$\therefore \boldsymbol{B = 5.00 \times 10^{-3}\,T}$$

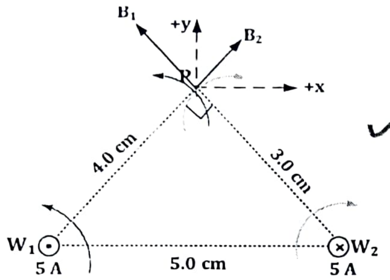
$$\tan\alpha = \frac{B_V}{B_H} = \frac{4.33 \times 10^{-3}}{2.50 \times 10^{-3}} \implies \alpha = \tan^{-1}\left(\frac{4.33}{2.50}\right)$$

$$\therefore Angle\ of\ dip, \boldsymbol{\alpha = 60°}$$ **[04]**

(c) Using $B = \frac{\mu_0 N I}{2R}$. But, $B = \frac{\pi}{2} \implies \frac{\pi}{2} = \frac{\mu_0 N I}{2R}$

Hence, $\boldsymbol{I} = \frac{\pi R}{\mu_0 N}$ [0:]

(d) Magnetic flux density, B, at a point P, a perpendicular distance d, from a given straight wire in air is given by, $B = \frac{\mu_0 I}{2\pi d}$



$B_1 = \frac{\mu_0 I_1}{2\pi d_1} = \frac{4\pi \times 10^{-7} \times 4.0}{2\pi \times (0.04)} = 2.0 \times 10^{-5} T, away\ from\ P\ along\ QP$

$B_2 = \frac{\mu_0 I_2}{2\pi d_2} = \frac{4\pi \times 10^{-7} \times 3.0}{2\pi \times (0.03)} = 2.0 \times 10^{-5} T, away\ from\ P\ along\ RP$

Since B_1 and B_2 are perpendicular to each other at point P, the magnitude of the resultant, $B = \sqrt{{B_1}^2 + {B_2}^2}$

$\therefore$ The resultant, $B_P = \sqrt{(2.0 \times 10^{-5})^2 + (2.0 \times 10^{-5})^2}$

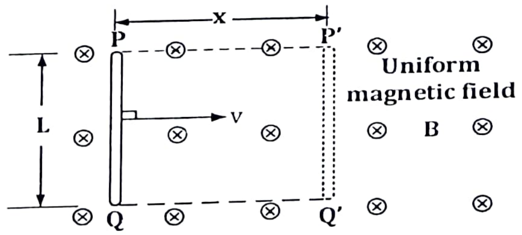
$\therefore$ $\mathbf{B_P = 2.83 \times 10^{-5}\ T}$ **[05]**

6. (a) (i) ***Electromagnetic induction*** – is the production or generation of an induced e.m.f in a coil, or conductor whenever there is relative change of magnetic flux linked with it. **[01]**

(ii) The ***magnitude*** of the e.m.f. induced in a coil or across the ends of a conductor is directly proportional the rate of change magnetic flux linkage or to the rate of cutting of the magnetic flux.

The *e.m.f. induced* in a coil or closed circuit acts in such ***a direction*** as to ***oppose the change*** of the magnetic flux that ***causing it.*** **[02]**

(b) (i) The proof or derivation comes from the diagram below.



Suppose the metal conductor moves from PQ to P'Q', a displacement x, the area swept out by the rod $A = L \times x$

Magnetic flux cut, $\Phi = BA = BLx$

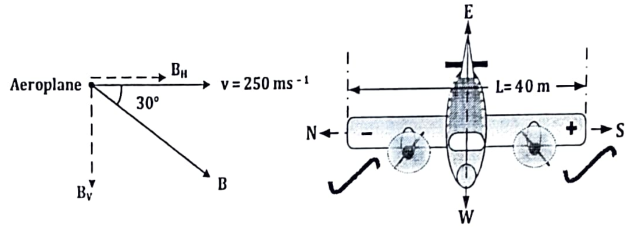
The magnitude of induced e.m.f, $|E| = \frac{d\Phi}{dt} = \frac{d\,(BLx)}{dt} = BL\left(\frac{dx}{dt}\right) = BLv$

Where $\frac{dx}{dt} = v\ (rate\ of\ change\ of\ displacement\ with\ time)$

Thus induced e.m.f., $E = BLv$ [04]

Accept other workable alternative methods @ 4 marks.

(ii) (i) $\Rightarrow v = 250\ ms^{-1}$, e.m.f. E = 50 mV = 50×10^{-3} V



$B_V = B \sin 30°$, velocity v = 250 ms^{-1}

Using $E = B_V\,L\,v$ *where* $B_V = B \sin 60°$

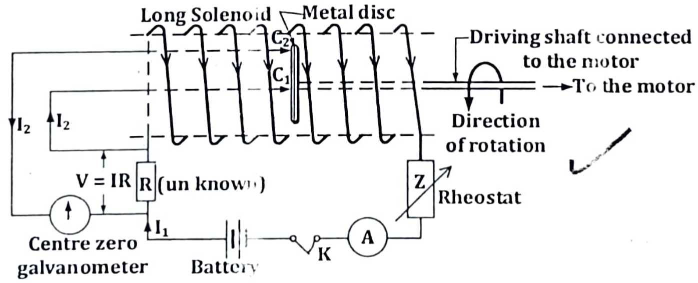
$\Rightarrow\ 10 \times 10^{-3} = B\sin 30° \times 40 \times 250$

$$B = \frac{10 \times 10^{-3}}{40 \times 250 \times \sin 30°}$$

$\therefore\ \boldsymbol{B = 2.0 \times 10^{-6}\ T}$ [04]

Use Fleming's Right-Hand Rule to check signs at wing tips @ ½ mark

(c) ***Absolute measurement of resistance.***



- The experiment is set up as shown on the diagram in the figure above.
- The metal (copper) disc of a known measured radius, r, is placed at the centre of a solenoid of, n, turns per metre, with the plane of the disc perpendicular to the axis of the solenoid.
- Switch, K is closed and the rheostat, Z, is adjusted to a suitable value, then the copper disc is rotated via the shaft connected to an electric motor, in an appropriate direction to reduce the value of current flowing through, G, to zero.

- The speed of rotation of the motor, is adjusted until the centre – zero galvanometer, G, shows no deflection.
- The number of revolutions per second, f, made by the metal disc is noted from the revolution meter attached to the motor.
- Using p.d. across, R, equals the induced e.m.f. $IR = B\,\pi\, r^2 f \ \ where$ $B = \mu_0 nI \Rightarrow IR = \mu_0 nI\pi\, r^2 f$
  Hence, the resistance, R, is calculated from, $\boldsymbol{R = \mu_o n\pi r^2 f}$. **[06]**

(d) (i) Given that, $N_p = 500\ turns, V_s = 6.8\ V, V_p = 1.70\ V?, and\ V_{rms} \propto V_0$

From $\frac{N_S}{N_P} = \frac{V_S}{V_P}$, $N_s = \frac{6.8}{1.70} \times 500$

$\therefore \boldsymbol{N_s = 2000\ turns}$ **[02]**

(ii) From $\frac{N_S}{N_P} = \frac{I_P}{I_S}$ or $\frac{I_P}{I_S} = \frac{V_S}{V_P}$

$I_p = \frac{V_S \times I_S}{V_P}$

$I_s = \frac{6.8}{1.70} \times 1.50$

$\therefore \boldsymbol{I_s = 6.00\ A}$ **[02]**

7. (a) (i) This is the steady or direct current that converts electrical energy to other forms of energy in a given resistance at the same rate as the alternating current.

Or The value of steady current that dissipates heat energy in a resistor at the same rate as the alternating current. **[01]**

(ii) Suppose $I = I_0 \sin 2\pi f t$ is the instantaneous a.c flowing through a resistor of resistance **R** at any time for a time, **t.**
Instantaneous, alternating power expended, in the resistance, **R**

$P = I^2R = (I_0 \sin 2\pi f t)^2 R$

$P = {I_0}^2 R \sin^2 2\pi f t$

The average power expended or dissipated in the resistor over one complete cycle, $\langle P\rangle_T = \langle {I_0}^2 R \sin^2 2\pi f t\rangle = {I_0}^2 R\langle \sin^2 2\pi f t\rangle$

But, $\langle \sin^2 2\pi f t\rangle_T = \frac{1}{2}$

$\therefore \boldsymbol{\langle P\rangle_T = \frac{1}{2}\left({I_0}^2 R\right) = \frac{{I_0}^2 R}{2}}$ **[03]**

(b) (i) The instantaneous charge Q, at any time, t, stored in the capacitor plates is given by, $Q = CV, Q = CV_0 \cos 2\pi f t$

The instantaneous current $I = rate\ of\ change\ of\ charge\ with\ time$

$$i.e \quad I = \frac{dQ}{dt} \Rightarrow I = \frac{d}{dt}(CV_0 \cos 2\pi ft) = -2\pi fCVo \sin 2\pi ft$$

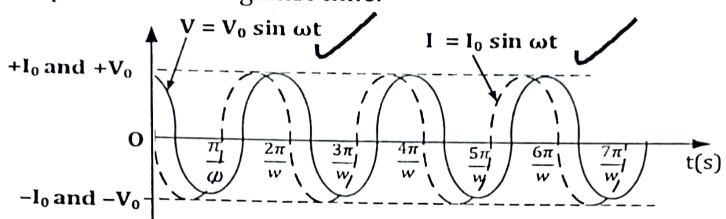
$$I = -2\pi fCVo \sin 2\pi ft \Rightarrow I = -I_0 \sin 2\pi ft$$

$$Where, I_0 = 2\pi fCV_0$$

$$Reactance\ of\ the\ capacitor, X_C = \frac{V_0}{I_0} = \frac{V_0}{2\pi f\, Vo} = \frac{1}{2\pi fC}$$

[04]

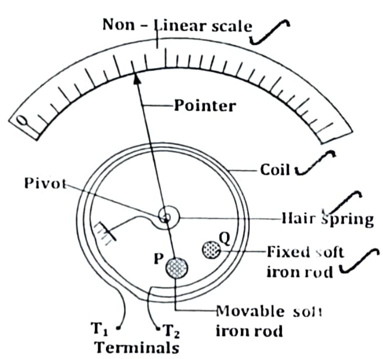
(ii) Graphs of V and I against time.



Current, I, leads voltage, V by 90° or π/2 radians

[02]

(c) (i) ***The repulsion type of moving iron ammeter.***



- Current, **I** is fed into the coil via terminals 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* irrespective of the direction of flow of current in the coil.
- The rods P and Q begin to *repel each other with an average force* which is proportional to the square of the current flowing through the coil.
- The fixed soft iron rod **Q** repels rod **P**, causing it to rotate about the pivot and moves over the scale through an angle **θ**, until it is stopped by the restoring torque due to the couple provided by 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 the instrument has* ***a non linear scale.***

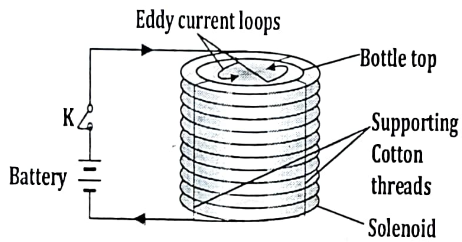
[05]

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

- They can be used for measuring both alternating currents (A.C) and direct currents (d.c) unlike the moving coil meters that measure only d.c.
- The A.C. meters are also more durable than the moving coil meters, because they do not have delicate coils that can easily be blown off when overloaded.
- They are also robust and cheaper to construct or manufacture and purchase.
- The A.C. meters can be adapted to measure large currents and voltages even at ***high frequencies***. **[03]**

Accept the first three correct responses @ 1 mark.

(d) Effect of eddy currents



- When switch, K, is just closed, a ***rapidly increasing current*** flows through the solenoid in a specified direction (clockwise direction).
- A rapidly ***changing magnetic flux*** is created inside and at around the solenoid, which in turn threads the bottle top.
- This induced e.m.f. in the bottle top induces eddy currents in the bottle top in such a way that the lower surface of the bottle top has the same polarity as the top part of the coil (i.e. South pole).
- The two like poles (south poles) then repel each other. This causes the bottle top to be repelled and it jumps off.
- When the current becomes steady in the coil no e.m.f is induced and Eddy currents are induced in the bottle top, so it falls back down to the threads on top of the coil due to the influence only its own weight.

[02]

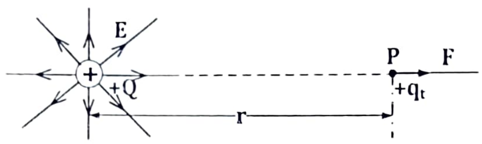
SECTION D

8. (a) (i) **Electric field intensity** – is the force exerted on a +1C charge placed in an electric field.

SI unit is **newton per coulomb ($N\ C^{-1}$)** and a **volt per metre ($V\ m^{-1}$).**

[02]

(ii) Consider a test charge, +q, located at a point P, a distance, r, from an isolated point charge, +Q in free space.



The electrostatic force, F, between 2point charges is given by; $F = \frac{Q\,q_t}{4\pi\varepsilon_0 r^2}$

The electric field intensity at point, P is given by, $\vec{E} = \frac{F}{q_t} = \frac{Q\,q_t}{4\pi\varepsilon_0 r^2} \times \frac{1}{q_t}$

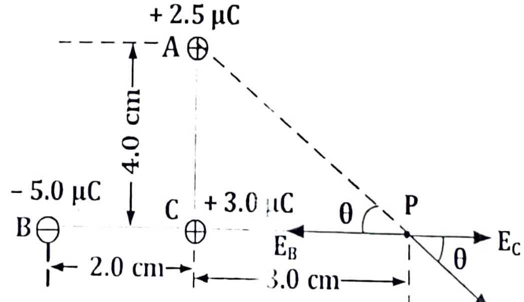
Thus, electric field intensity at a point, P, is $\vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2}$ **[03]**

(b) (i) *An equipotential surface is an envelope or enclosure or surface where electric potential is constant through out every point on it.*
No work is done to move a charge from one point on the surface to another point within the same surface.
Electric field lines are normal to the equipotential surface. **[03]**

(ii) ***Electric field lines are normal to the surface of a conductor b'se,***

- Every conductor of whatever shape is *an equipotential surface.*
- No work is done to move a charge from one point on the surface to any 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.
- This therefore implies that, the only field lines (lines of force) that exist on a charged conductor are only those that are normal to the surface
- Hence, all electric field lines are perpendicular to the conductor irrespective of the shape or curvature of the conductor. **[04]**

(c) Let E_A represent electric field intensity at point A, E



Using $\vec{E} = \frac{Q}{4\pi\varepsilon_0 r^2} = k\frac{Q}{r^2}$ from the figure AP = 5.0 cm, $\tan\theta = \frac{4}{3} \Rightarrow \theta = 53.1°$

$$\therefore E_A = \frac{(2.5 \times 10^{-6}) \times (9.0 \times 10^{9})}{(5.0 \times 10^{-2})^2} = 9.0 \times 10^6\ NC^{-1}$$

$$\therefore E_B = \frac{(5.0 \times 10^{-6}) \times (9.0 \times 10^{9})}{(5.0 \times 10^{-2})^2} = 1.8 \times 10^7\ NC^{-1}$$

$$\therefore E_C = \frac{(3.0 \times 10^{-6}) \times (9.0 \times 10^{9})}{(3.0 \times 10^{-2})^2} = 3.0 \times 10^7\ NC^{-1}$$

$$\sum E_x = (E_C + E_A \cos\theta) - E_B$$

$$E_x = (3.0 + 0.90 \cos 53.1°) \times 10^7 - 1.8 \times 10^7$$

$$\therefore E_x = 1.74 \times 10^7\ NC^{-1}$$

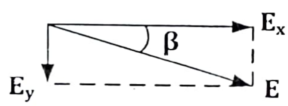
$$\sum E_y = -E_A \sin\theta = (-9.0 \times 10^6 \sin 53.1°)$$

$$\therefore E_y = -7.20 \times 10^6\ NC^{-1}$$

Thus, the resultant electric field at point P, $E_P = \sqrt{E_x^{\ 2} + E_y^{\ 2}}$

$$E_P = \sqrt{(1.74 \times 10^7)^2 + (7.20 \times 10^6)^2}$$

$\therefore E_D = 1.88 \times 10^7\ NC^{-1}$ *at an angle β to the $+x-$ direction.*



$$\tan\beta = \frac{E_y}{E_x} = \frac{7.20 \times 10^6}{1.74 \times 10^7} \Rightarrow \beta = 22.5°$$ [05]

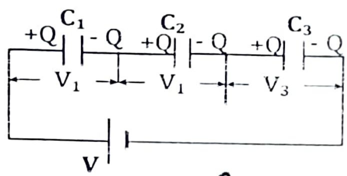
(d) - Negative charge from the clouds drain down towards the earth's
- surface along a low resistance path called the jagged path of stepped leader.
- A very strong electric field created along the stepped leader ionizes the air in the neighborhood.
- The stepped leader also induces positive charge on tall objects on the earth's surface that in turn create an electric field that ionizes the air.
- The two strong opposite electric field create stream of fast moving ionized air charges in opposite directions.
- These ionized charges recombine and give off excess energy in form of sparks that join the stepped leader creating lightning flashes. **[03]**

9. (a) (i) *A capacitor* – is a device used for storing electric charge. [01]

(ii) *Industrial uses of capacitors*

Tuning circuits in radio receivers and T.V sets.
Preventing or eliminating sparking in switches.
Used in rechargeable torches and lamps. [03]

(b) The same magnitude of *charge*, Q is induced on each of the plates of all the capacitors.



Net p.d, $V = V_1 + V_2 + V_3$

But, $V_1 = \frac{Q}{C_1}$, $V_2 = \frac{Q}{C_2}$ and $V_3 = \frac{Q}{C_3}$

$\Rightarrow V = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$

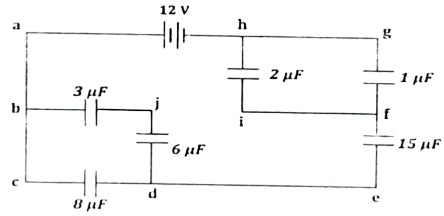
$V = Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right) \Rightarrow \frac{V}{Q} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$

$But\ \frac{V}{Q} = \frac{1}{C}$

$\frac{1}{C} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$ *where, C is the effective capacitance*

[04]

(c) Using the circuit below.



(i) 1.0μF and 2.0μF capacitors are in parallel, and their effective capacitance, $C' = 1.0 + 2.0 = 3.0\ \mu F$

$C' = 3.0\ \mu F$ and 15.0μF along **e f**, are now in series, and their effective capacitance.

$C'' = \frac{3.0 \times 15.0}{3.0 + 15.0} = 2.5\ \mu F$

Now the 3.0 μF along **bj** and the 6.0 μF along **jd** are in series
Their effective capacitance

$C''' = \frac{3.0 \times 6.0}{3.0 + 6.0} = 2.0\ \mu F$

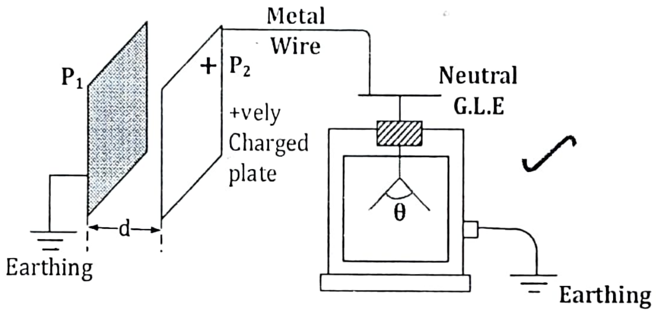
while $C''' = 2.0\mu F$ *and* $8.0\mu F$ are in parallel.
Their effective capacitance, $C'''' = (2.0 + 8.0) = 10.0\ \mu F$
The overall effective capacitance of the whole circuit network,

$C = \frac{2.5 \times 10.0}{2.5 + 10.0} = 2.0\ \mu F$ *Accept the alternative method.* [04]

(ii) The **charge stored** in the network, $Q = CV \Rightarrow (2.0 \times 10^{-6} \times 12.0)$
$Q = 2.4 \times 10^{-5}$ C or 24μC. [02]

(d) A capacitor is initially connected to a d.c. source to charge the capacitor fully.

- The capacitor is then disconnected from the source and isolated.
- The positive plate of the capacitor is then connected to the cap of a neutral G.L.E. while the other plate is earthed.
- While keeping all the ***other factors constant***, the plates are placed parallel to each other with maximum area of overlap of the plates.
- The initial deflection θ_1 of the gold leaves is noted on the scale of the G.L.E.
- Plate P_2 is pulled sideways relative to P_1 to increase the distance, **d**, of separation between the plates.

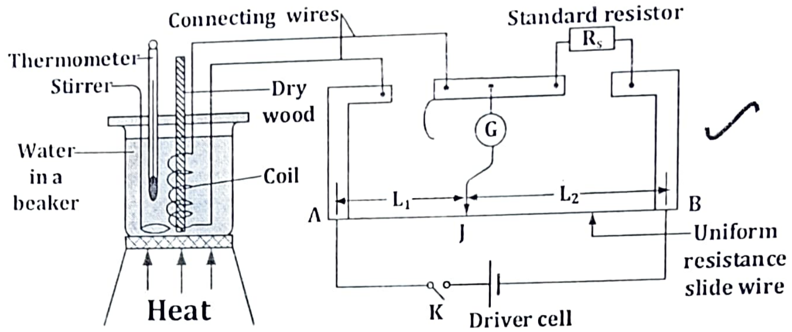


- The final deflection θ_2 of the gold leaves against the scale is noted on the G.L.E.
- Its observed that **θ_2 is greater** than θ_1 i.e. $\theta_2 > \theta_1$ *showing* ***a reduction in the p.d.*** *between the plates.*
- Thus, ***increasing the distance of separation between the plates*** of a charged capacitor leads to a ***reduction in the capacitance*** of the capacitor and vice versa. **[05]**

10. (a) (i) ***T.C.R.*** – is the fractional change in the resistance of a material at 0°C per degree Celsius or per kelvin rise in temperature.

Or It's the change in resistance of a material per kelvin or degree rise in temperature divided by resistance of the material at zero degree Celsius. **[01]**

(ii) *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 below.*



- At room temperature, switch K is closed and the sliding contact J is tapped along the uniform resistance slide wire, AB 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 gently and gradually while stirring, at a given temperature, θ, switch 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 a metal wire is then calculated from the expression, $\alpha = \frac{R_0}{S}$ **[06]**

(b) (i) $Efficiency,\ \eta = \frac{(Power\ output)}{(Power\ input)} \times 100$

$Power\ output = P = I^2R$

$Power\ input = EI$

$\eta = \frac{I^2R}{EI} \times 100\%$ But for a complete circuit

$E = I(R + r)$

$\eta = \frac{I^2R}{I^2(R+r)} \times 100\%$

$\eta = \frac{R}{R+r} \times 100\%$ [03]

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

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

For max. power, $\frac{dP}{dr} = 0$, let $u = E^2R$, $V = (R+r)^2$

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

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

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

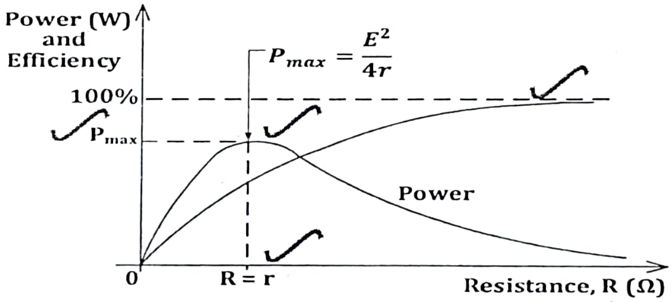
$\Rightarrow r - R = 0$

$R = r$ *is the condition for maximum power output.*

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

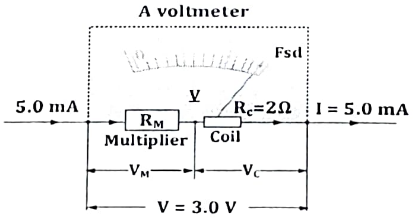
$P_{max} = \frac{E^2}{4r}$ **[04]**

(iii) **Graphs of power and efficiency against load resistance**



[02]

(c) $R_c = 2\,\Omega$, $I_c = 5.0 \times 10^{-3}\,A$



The p.d. across the instrument. i.e. $V = V_c + V_M$

i.e. $V = I_c(R_c + R_M)$ *from which,* R_M *is calculated.*

$\therefore$ $R_M = \left[\left(\frac{V}{I_c}\right) - R_c\right]$ *is the value of the Multiplier to be used.*

$\therefore$ $R_M = \left[\left(\frac{3.00}{5.0 \times 10^{-3}}\right) - 2\right] = 598\,\Omega$

$\therefore$ $R_M = 598\,\Omega$ is the multiplier connected in series with the meter.

[04]

=END=