Answers to RPH–DS2/Set-1

1. (*b*)

2. (*d*)

3. (*d*)

4. (*d*)

5. (*d*) Magnetic field at the centre of the coil,

$$B_0 = \frac{\mu_0 I}{2r}$$

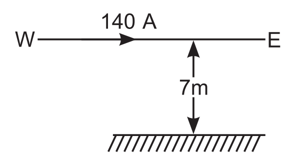
Magnetic field at the axis of the coil, $B' = \frac{\mu_0}{4\pi} \frac{(2\pi r^2) I}{(r^2 + a^2)^{3/2}}$

$$= \frac{\mu_0}{2} \frac{I r^2}{(r^2 + a^2)^{3/2}}$$

At $a = 2r$, $B' = \frac{\mu_0}{2} \frac{I r^2}{5^{3/2} r^3} = \left(\frac{\mu_0}{2} \frac{I}{r}\right) \frac{1}{5^{3/2}}$

$$B' = \frac{B_0}{5^{3/2}}$$

6. (*d*) Here, $I = 140$ A, $r = 7$ m

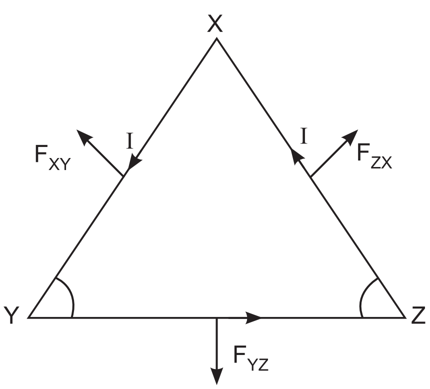


Using, $B = \frac{\mu_0 I}{2\pi r}$

$$= \frac{4\pi \times 10^{-7} \times 140}{2\pi \times 7}$$

$$= 40 \times 10^{-7} = 4 \times 10^{-6} \text{ T}$$

7. (*c*)



Here resultant of F_{XY}, F_{ZX}, F_{YZ} is zero, therefore net force on the entire triangular loop XYZ is zero.

8. (*a*)

9. (*a*) Phase difference,

$$\phi = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

$$= \tan^{-1}\left(\frac{100 \times 10 \times 10^{-3}}{1}\right)$$

$$= \tan^{-1}(1) = 45°$$

10. (*c*)

11. (*b*)

12. (*a*)

13. (*d*) If both Assertion and Reason are false.

14. (*b*) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

15. (*a*) If both Assertion and Reason are true and Reason is correct explanation of Assertion.

16. (*a*) If both Assertion and Reason are true and Reason is correct explanation of Assertion.

17. A p-n junction, in forward bias, allows a large amount of current to flow through it but in reverse bias, it offers a high resistance. Due to this unidirectional property, it is also known as junction diode.

In a depletion region, accumulation of negative charges in p-region whereas accumulation of positive charges in n-region set up a potential difference across the junction which is known as potential barrier.

18. (*i*) **Stopping potential:** It is the minimum negative potential given to an anode plate so that the photoelectric current becomes zero.

(*ii*) **Threshold frequency:** The minimum frequency of an incident radiation below which no photoelectric emission takes place is known as threshold frequency.

19. For first violet fringe,

$$y_1 = \frac{\lambda_1 D}{d}$$

or $$\lambda_1 = \frac{y_1 d}{D}$$

For second red fringe,

$$y_2 = \frac{\lambda_2 D}{d}$$

or $$\lambda_2 = \frac{y_2 d}{D}$$

or $$\lambda_2 - \lambda_1 = (y_2 - y_1)\ \frac{d}{D}$$

Here $$\lambda_2 - \lambda_1 = 300 \text{ nm} = 3 \times 10^{-7} \text{ m}$$

$$y_1 = 2 \text{ mm} = 2 \times 10^{-3} \text{ m}$$

$$d = 0.3 \text{ mm} = 3 \times 10^{-4} \text{ m}$$

$$D = 1.5 \text{ m}$$

∴ $$3 \times 10^{-7} = (y_2 - 2 \times 10^{-3}) \times \frac{3 \times 10^{-4}}{1.5}$$

or $$\frac{3 \times 10^{-7}}{2 \times 10^{-4}} = y_2 - 2 \times 10^{-3}$$

or $$1.5 \times 10^{-3} = y_2 - 2 \times 10^{-3}$$

or $$y_2 = 3.5 \times 10^{-3} = 3.5 \text{ mm}$$

20. (*a*) According to graph, temperature coefficient is given as,

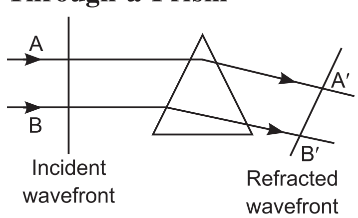
$$\alpha = \frac{R - R_0}{R_0 \times t}$$

(*b*) When the temperature of a conductor is increased, the collision frequency of electrons with positive ions of metal is also increased and hence resistance increases.

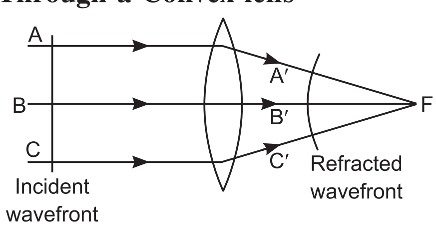
21. Wavefront: It is a continuous locus of all the particles, vibrating in the same phase at any instant.

Shape of a plane wavefront after refraction:

(*a*) **Through a Prism**



(*b*) **Through a Convex lens**



Or

Given: $R_1 = +30$ cm and $R_2 = -30$ cm

$$u = -60 \text{ cm}$$

Using, $$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$= (1.5 - 1)\left(\frac{1}{30} - \frac{1}{-30}\right)$$

$$= 0.5 \times \frac{2}{30} = \frac{1}{30}$$

or $$f = 30 \text{ cm}$$

Using $$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{30} = \frac{1}{v} - \frac{1}{-60}$$

$$\frac{1}{30} = \frac{1}{v} + \frac{1}{60}$$

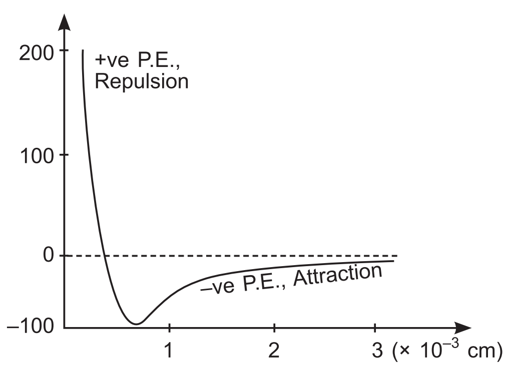
or $$\frac{1}{v} = \frac{1}{30} - \frac{1}{60}$$

$$= \frac{2-1}{60}$$

$$= \frac{1}{60}$$

or $$v = 60 \text{ cm}$$

22. (*a*)



(*b*) **Two features of nuclear force make it different from Coulomb force:**

(*i*) Nuclear forces are charge independent whereas coulomb force is charge dependent.

(*ii*) Nuclear forces are non-conservative whereas coulomb force is conservative in nature.

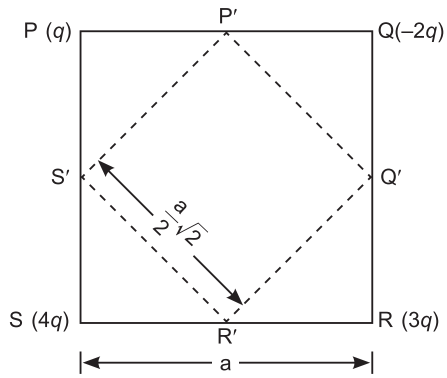
23. Initial potential energy of the system,

$$U_i = \frac{1}{4\pi\varepsilon_0}\left[\frac{q(-2q)}{a} + \frac{(-2q)(3q)}{a} + \frac{(3q)(4q)}{a} + \frac{(4q)(q)}{a} + \frac{(q)(3q)}{a\sqrt{2}} + \frac{(4q)(-2q)}{a\sqrt{2}}\right]$$

$$= \frac{q^2}{4\pi\varepsilon_0 a}\left[-2-6+12+4+\frac{3}{\sqrt{2}}-\frac{8}{\sqrt{2}}\right] = \frac{q^2}{4\pi\varepsilon_0 a}\left[8-\frac{5}{\sqrt{2}}\right]$$

When charges are shifted to new positions P′, Q′, R′ and S′ then

$$P'Q' = Q'R' = R'S' = S'P' = \frac{a}{2}\sqrt{2}$$



∴ Final potential energy of the system is

$$U_f = \frac{1}{4\pi\varepsilon_0}\left[\frac{q(-2q)}{a\sqrt{2}/2}+\frac{(-2q)(3q)}{a\sqrt{2}/2}+\frac{(3q)(4q)}{a\sqrt{2}/2}+\frac{(4q)(q)}{a\sqrt{2}/2} + \frac{(q)(3q)}{a}+\frac{(4q)(-2q)}{a}\right]$$

$$= \frac{q^2}{4\pi\varepsilon_0 a}\left[\frac{16}{\sqrt{2}}-5\right]$$

Work done in shifting the charges to their new locations,

Work done = change in potential energy,

or $$W = -(U_f - U_i) = U_i - U_f$$

$$= \frac{q^2}{4\pi\varepsilon_0 a}\left[8-\frac{5}{\sqrt{2}}\right] - \frac{q^2}{4\pi\varepsilon_0 a}\left[\frac{16}{\sqrt{2}}-5\right]$$

$$= \frac{q^2}{4\pi\varepsilon_0 a}\left[8-\frac{5}{\sqrt{2}}-\frac{16}{\sqrt{2}}+5\right]$$

$$= \frac{q^2}{4\pi\varepsilon_0 a}\left[13-\frac{21}{\sqrt{2}}\right]$$

24. We know that the energy of an electron in n^{th} orbit is

$$E_n = \frac{-13.6}{n^2}$$

When the energy of 12.3 eV is absorbed by the hydrogen atom, let the electron excites from $n = 1$ to $n = n$ level

$$\therefore \quad E = E_n - E_1$$

$$\text{or} \quad 12.3 = \frac{-13.6}{n^2} - \left(-\frac{13.6}{1^2}\right)$$

$$\text{or} \quad 12.3 = \frac{-13.6}{n^2} + 13.6$$

$$\text{or} \quad \frac{-13.6}{n^2} = -1.3$$

$$\text{or} \quad n^2 = \frac{13.6}{1.3} \approx 10$$

$$\text{or} \quad n \approx 3$$

Therefore, the hydrogen atom would be excited upto second excited state.

As orbital period, $T_n \propto n^3$

$$\therefore \quad \frac{T_3}{T_1} = \frac{(3)^3}{(1)^2}$$

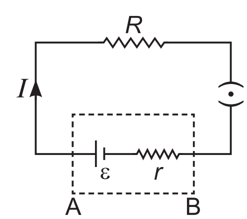
$$\text{or} \quad T_3 = 27\ T_1$$

25. When the circuit is closed, an electric current flows in the wire from positive terminal of the cell towards the negative terminal. But inside the electrolyte of the cell, the positive ions flow from the lower to the higher potential against the background of other ions and neutral atoms of the electrolyte. So, the electrolyte offers some resistance to the flow of current inside the cell. Therefore ε is different from 'V' (terminal potential difference)

This resistance is known as internal resistance and is defined as the resistance offered by the electrolyte of a cell to the flow of current between its electrodes.

Here,

ε = Work done in carrying a unit charge from A to B against external resistance R + Work done in carrying a unit charge from B to A against internal resistance r.



$$\text{or} \quad \varepsilon = V + V'$$

$$\because \quad V = IR \text{ and } V' = Ir$$

$$\therefore \quad \varepsilon = IR + Ir$$

$$\therefore \quad I = \frac{\varepsilon}{R + r}$$

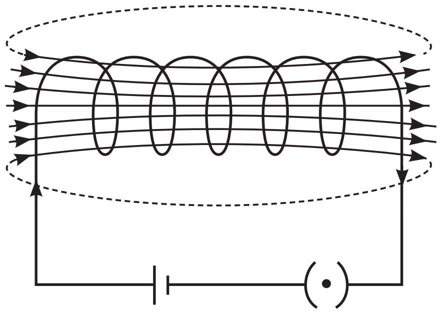
Also, $V = IR$

$$\therefore \quad V = \frac{\varepsilon R}{R + r} \quad \left(\text{putting } I = \frac{\varepsilon}{R + r}\right)$$

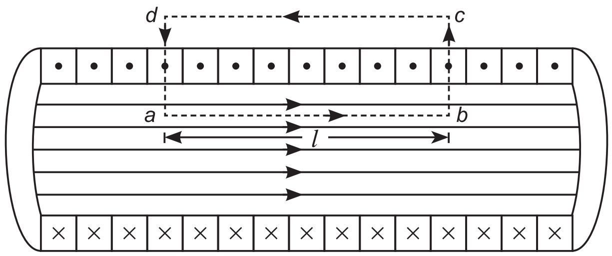
$$\text{or} \quad r = \left(\frac{\varepsilon}{V} - 1\right)R$$

This is the required expression.

26. The given diagram is of solenoid.



Following figure shows the cross-sectional view of the solenoid.



According to Ampere's circuital law,

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \times \text{total current through the loop } abcd.$$

Now $$\oint \vec{B} \cdot d\vec{l} = \int_a^b \vec{B} . d\vec{l} + \int_b^c \vec{B} . d\vec{l} + \int_c^d \vec{B} \cdot d\vec{l} + \int_d^a \vec{B} \cdot d\vec{l}$$

Here, $$\int_b^c \vec{B} \cdot d\vec{l} = \int_d^a \vec{B} \cdot d\vec{l} = 0 \quad [\because \theta = 90°]$$

Also $$\int_c^d \vec{B} \cdot d\vec{l} = 0$$ [As magnetic field outside the solenoid is zero]

$\therefore$ $$\int_a^b Bdl = \mu_0 \, nlI$$ [Where, n = no. of turns per unit length]

or $$Bl = \mu_0 nlI$$

or $$\boxed{B = \mu_0 nI}$$

27.
- Radio waves are of lowest frequency in the segment of electromagnetic waves.
- These waves are produced by rapid acceleration and deceleration of electrons in aerials/antennas.
- Uses: (*i*) In radioastronomy
  (*ii*) In radio and television communication
- Frequency range: 500 KHz to 1000 MHz.

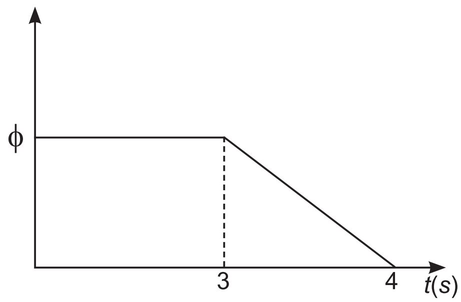
28. (*a*) The induced current in the loop persists for the duration,

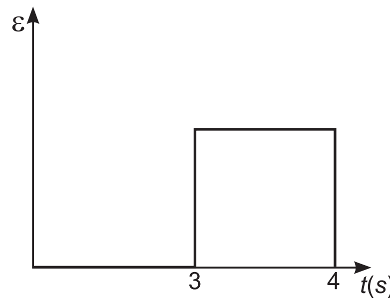
$$t = t_2 - t_1$$

$$t = \frac{d_2}{v_2} - \frac{d_1}{v_1} = \frac{200}{50} - \frac{150}{50} = 4 - 3 = 1 \text{ s}$$

Direction of induced current is clockwise.

(*b*)



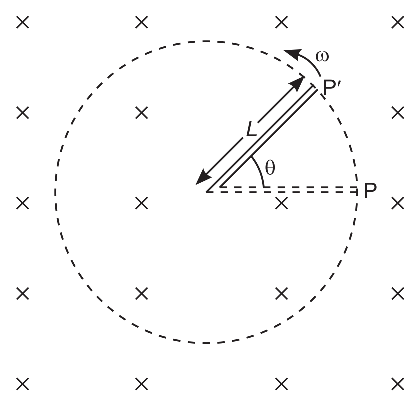


Or

(*a*) Let '*L*' is the length of the rod.

Let in time '*t*' its angular displacement is 'θ'

Then
$$|\varepsilon| = \frac{d\phi_B}{dt}$$
$$= \frac{d(BA)}{dt}$$
$$= B\frac{d}{dt}\left[\frac{1}{2}(L)(PP')\right]$$
$$= \frac{1}{2}BL\frac{d}{dt}(PP')$$
$$= \frac{1}{2}BL\frac{d}{dt}(\theta L)$$
$$= \frac{1}{2}BL^2\frac{d\theta}{dt}$$
$$|\varepsilon| = \frac{1}{2}BL^2\omega \quad \left(\because \frac{d\theta}{dt} = \omega\right)$$



(*b*) Induced current, $I = \frac{\varepsilon}{R} = \frac{1}{2R}BL^2\omega$

(*c*) Heat dissipated in time '*t*', is given as,

$$\text{H} = \frac{\varepsilon^2}{R}t$$

$$\text{H} = \frac{1}{4}\frac{B^2L^4\omega^2}{R}t$$

29. (*i*) (*b*)

(*ii*) (*c*)

(*iii*) (*d*)

(*iv*) (*b*)

Or

(*iv*) (*c*)

30. (*i*) (*d*)

(*ii*) (*d*)

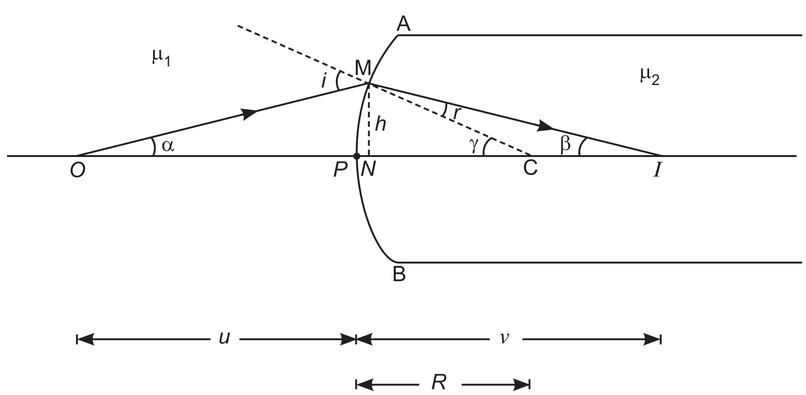
(*iii*) (*c*)

(*iv*) (*a*)

Or

(*iv*) (*a*)

31. (*a*)



In right ΔMNO,

$$\alpha \approx \tan\alpha = \frac{MN}{NO}$$

$\because$ NO ≈ PO

$$\therefore \quad \alpha = \frac{MN}{PO} = \frac{h}{-u} \qquad \ldots(i)$$

In right ΔMNI,

$$\beta \approx \tan\beta = \frac{MN}{NI}$$

$\because$ $NI \approx PI$

$$\therefore \quad \beta \approx \frac{MN}{PI} = \frac{h}{\nu} \qquad \ldots(ii)$$

In right ΔMNC,

$$\gamma \approx \tan\gamma = \frac{MN}{NC}$$

$\because$ $NC \approx PC$

$$\therefore \quad \gamma \approx \frac{MN}{PC} = \frac{h}{R} \qquad \ldots(iii)$$

In ΔMOC, $i = \alpha + \gamma$ ...(*iv*)

In ΔMCI, $\gamma = \beta + r$

or $r = \gamma - \beta$ ... (*v*)

By Snell's law,

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

For Small angles,

$$\frac{i}{r} = \frac{\mu_2}{\mu_1}$$

or $\mu_1 i = \mu_2 r$

Using equations (*iv*) and (*v*), we get

$$\mu_1 (\alpha + \gamma) = \mu_2 (\gamma - \beta)$$

Using equations (*i*), (*ii*) and (*iii*), we get

$$\mu_1\left[\frac{h}{-u} + \frac{h}{R}\right] = \mu_2\left[\frac{h}{R} - \frac{h}{v}\right]$$

or $$\frac{\mu_1}{-u} + \frac{\mu_1}{R} = \frac{\mu_2}{R} - \frac{\mu_2}{v}$$

or $$\boxed{\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}}$$ Hence Proved.

(*b*) Given: $\mu_2 = 1.5$, $\mu_1 = 1$ (for air)

$R = 20$ cm, $v = -180$ cm

Using formula, $\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

Putting values, $\frac{1.5}{-180} - \frac{1}{u} = \frac{1.5 - 1}{20}$

or $$\frac{1}{-120} - \frac{1}{u} = -\frac{1}{40}$$

or $$\frac{1}{u} = -\frac{1}{120} - \frac{1}{40}$$

$$\frac{1}{u} = \frac{-1-3}{120}$$

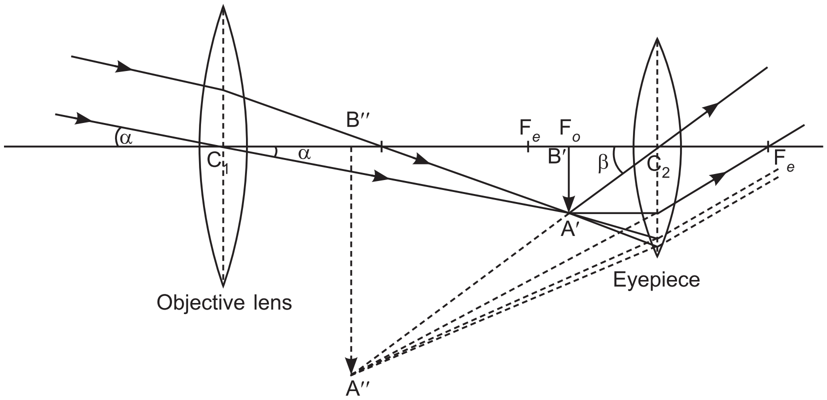
$$= \frac{-4}{120}$$

$$= -\frac{1}{30}$$

or $u = -30$ cm

Or

(*a*)



(*b*) Limitations of refracting type telescope:

(1) It suffers chromatic aberration.

(2) Its magnifying power is small.

(3) It suffers spherical aberration.

To overcome these limitations, reflecting type telescope is used, as

(*a*) there is no chromatic aberration because mirror is used.

(*b*) image formed is bright because there is no loss of energy due to reflection.

(*c*) spherical aberration is removed by using a parabolic mirror.

(*c*) **Magnifying power:** For a relaxed eye, the final image is formed at infinity.

It is defined as the ratio of focal length of objective to that of eye piece

i.e., $$M = -\frac{f_o}{f_e}$$

Its magnifying power can be increased by

(*a*) increasing the focal length of objective.

(*b*) decreasing the focal length of eyepiece.

32. (*a*) When the capacitor is charged then charge on it, $Q = CV$

and energy stored, $U = \frac{1}{2} CV^2$

When this capacitor is connected to another uncharged capacitor, then the flow of charge takes place and it continues until both the capacitors attains a common potential.

By conservation of charge,

$$Q = Q_1 + Q_2$$

or $$CV = CV_1 + CV_2$$

or $$V = V_1 + V_2$$

As both capacitors attain common potential after connecting, therefore $V_1 = V_2$

or $$V_1 = \frac{V}{2}$$

$\therefore$ Total energy stored, $U' = \frac{1}{2}C\left(\frac{V}{2}\right)^2 + \frac{1}{2}C\left(\frac{V}{2}\right)^2$

$$= \frac{1}{4}CV^2$$

As $U' < U$, therefore, loss of energy takes place after combinations.

$\therefore$ Change in energy $= U' - U$

$$= \frac{1}{4}CV^2 - \frac{1}{2}CV^2$$

$$= \frac{1-2}{4}CV^2$$

$$= -\frac{1}{4}CV^2$$

Negative sign shows loss of energy.

(*b*) Given: $C_1 = 1\mu F$, $C_2 = 2\mu F$, $C_3 = 3\mu F$

For series combinations,

Formula used, $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$$= \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$$

$$= \frac{6+3+2}{6}$$

$$= \frac{11}{6}$$

$$C_s = \frac{6}{11}\ \mu F$$

For parallel combination,

Formula used, $C_P = C_1 + C_2 + C_3$

$$= 1 + 2 + 3$$

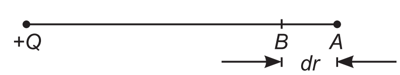
$$= 6\ \mu F$$

$\therefore$ Ratio, $\frac{C_S}{C_P} = \frac{6/11}{11} = \frac{6}{121}$

$C_S : C_P = 6 : 121$

Or

(*a*) Consider a test charge $+q_0$ is displaced from A to B against electric field of +Q then work done



$$dW = q_0 (V_B - V_A) \quad \ldots(i)$$

Also, $dW = -Fdr$

$$dW = q_0 Edr \quad \ldots(ii)$$

From equations (i) and (ii),

$$-q_0\, Edr = q_0\,(V_B - V_A)$$

or
$$E = \frac{(V_B - V_A)}{dr}$$

$$\boxed{E = -\frac{dV}{dr}}$$

This is the required relation between electric field and electric potential gradient.

(b) We know that,

$$E = \frac{-dV}{dr} = \text{negative slope of V-r graph}$$

(i) For $0 < r < 1$,

$$\frac{dV}{dr} = 0, \text{ so electric field} = 0.$$

(ii) For $1 < r < 2$,

$$\frac{dV}{dr} = (-)\text{ ve, so electric field is } (+)\text{ve.}$$

(iii) For $2 < r < 3$,

$$\frac{dV}{dr} = 0, \text{ so electric field} = 0.$$

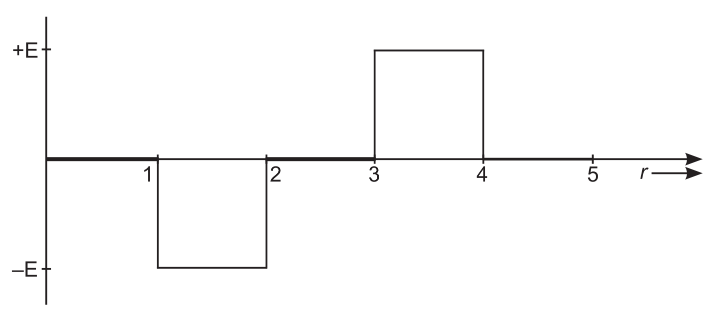
(iv) For $3 < r < 4$,

$$\frac{dV}{dr} = (+)\text{ve, so electric field is } (-)\text{ve.}$$

(v) For $4 < r < 5$,

$$\frac{dV}{dr} = 0, \text{ so electric field} = 0.$$

We get the E-r graph as shown below:



(c) Given: $V = x^2 - 7x + 3$

$\because$ Electric field, $E = \dfrac{-dV}{dx}$

$\therefore$ $E = \dfrac{-d}{dx}(x^2 - 7x + 3)$

$= -[2x - 7]$

At $x = 2$m,

$$E = [2(2) - 7]$$
$$= -[4 - 7]$$
$$= 3 \text{ V/m}$$

33. (*a*) Current in RC circuit is given by,

$$I = \frac{V_{\text{rms}}}{\sqrt{R^2 + (X_C)^2}}$$
$$= \frac{V_{\text{rms}}}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$$
$$= \frac{V_{rms}\,\omega C}{\sqrt{R^2\omega^2C^2 + 1}} \quad \ldots(i)$$

Given that when frequency of the source is $\frac{\omega}{3}$, the current becomes $\frac{I}{2}$. Then

$$\frac{I}{2} = \frac{V_{\text{rms}}\frac{\omega C}{3}}{\sqrt{R^2\left(\frac{\omega}{3}\right)^2 C^2 + 1}}$$
$$= \frac{V_{rms}\,\omega C}{\sqrt{R^2\omega^2C^2 + 9}} \quad \ldots(ii)$$

Dividing equation (*i*) by (*ii*), we get

$$\frac{I}{I/2} = \frac{\frac{V_{\text{rms}}\,\omega C}{\sqrt{R^2\omega^2C^2 + 1}}}{\frac{V_{\text{rms}}\,\omega C}{\sqrt{R^2\omega^2C^2 + 9}}}$$
$$2 = \frac{V_{\text{rms}}\,\omega C}{\sqrt{R^2\omega^2C^2 + 1}} \times \frac{\sqrt{R^2\omega^2C^2 + 1}}{V_{\text{rms}}\,\omega C}$$
$$2 = \sqrt{\frac{R^2\omega^2C^2 + 9}{R^2\omega^2C^2 + 1}}$$

Squaring both sides,

$$4 = \frac{R^2\omega^2C^2 + 9}{R^2\omega^2C^2 + 1}$$

or $\quad 4R^2\omega^2C^2 + 4 = R^2\omega^2C^2 + 9$

or $\quad 3R^2\omega^2C^2 = 5$

or $\quad \frac{R^2}{1/\omega^2C^2} = \frac{5}{3}$

or $\dfrac{R^2}{X_C^2} = \dfrac{5}{3}$

or $\dfrac{R}{X_C} = \sqrt{\dfrac{5}{3}}$

or $\dfrac{X_C}{R} = \sqrt{\dfrac{3}{5}}$

$\therefore$ $X_C : R = \sqrt{3} : \sqrt{5}$

(*b*) The momentary deflection is due to the transient current which flows through the circuit when the capacitor is getting charged. There will be no deflection when the capacitor is fully charged.

Or

(*a*) $X_L = \omega L = 2\pi \nu L$

or $L = \dfrac{X_L}{2\pi\nu} = \dfrac{1}{2\pi} \times$ slope of $X_L - \nu$ graph

$= \dfrac{1}{2\pi} \times \dfrac{80-0}{400-0} = \dfrac{1}{10\,\pi} = 3.18 \times 10^{-2}$ H

(*b*) $\nu = \dfrac{1}{2\pi\sqrt{LC}} = \dfrac{1}{2\pi\sqrt{\dfrac{1}{10\,\pi} \times 4\,\pi \times 10^{-7}}}$

$= \dfrac{1}{4\pi \times 10^{-4}} = 0.0796 \times 10^{4} = 7.96 \times 10^{2}$ Hz

(*c*) $Z = \sqrt{R^2 + X_L^2}$

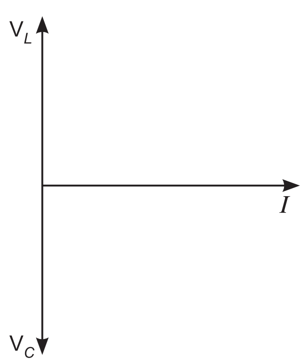
$= \sqrt{(80)^2 + (60)^2}$

$= \sqrt{6400 + 3600}$

$= \sqrt{10000}$

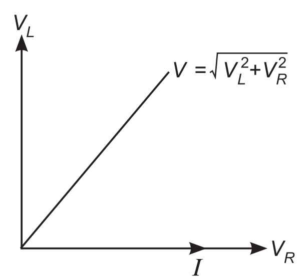
$= 100\ \Omega$

(*d*) (*i*)



Phasor diagram for (b)

(*ii*)



Phasor diagram for (*c*)