BLOOM | BSO Bloom School Olympiad

CLASS 12

Bloom Physics Olympiad
Sample Paper

Maximum Time : 60 Minutes **Maximum Marks : 60**

INSTRUCTIONS

1. There are 50 Multiple Choice Questions in this paper divided into two sections :

   Section A 40 MCQs; 1 Mark each

   Section B 10 MCQs; 2 Marks each

2. Each question has Four Options, out of which **ONLY ONE** is correct.

3. All questions are compulsory.

4. There is no negative marking.

5. No electric device capables of storing and displaying visual information such as calculator and mobile is allowed during the course of the exam.

Roll No.

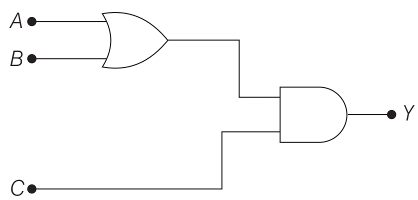
Student's Name

Section-A (1 Mark each)

1. A ball having charge q and mass m is suspended from a string of length L between two parallel plates where a vertical electric field E is established. What will be the time period of simple pendulum if electric field is directed downward.

(a) $2\pi\sqrt{\dfrac{L}{g+\dfrac{qE}{m}}}$ (b) $2\pi\sqrt{\dfrac{L}{g+\dfrac{qE}{2m}}}$ (c) $2\pi\sqrt{\dfrac{L}{g-\dfrac{qE}{m}}}$ (d) $2\pi\sqrt{\dfrac{L}{g-\dfrac{qE}{2m}}}$

2. To get an output 1 from the circuit shown in the figure, the input must be



(a) $A=0, B=1, C=0$
(b) $A=1, B=0, C=0$
(c) $A=1, B=0, C=1$
(d) $A=1, B=1, C=0$

3. The length of a potentiometer wires is l. A cell of emf E is balanced at a length $\left(\dfrac{l}{3}\right)$ from positive end of the wire. If the length of the wire is increased by $\left(\dfrac{l}{2}\right)$, the distance at which the same cell gives the balancing point is

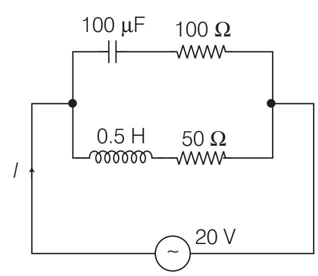
(Cell in the primary is ideal and no series resistance is present in the primary circuit.)

(a) $\dfrac{2l}{3}$ (b) $\dfrac{l}{2}$ (c) $\dfrac{l}{6}$ (d) $\dfrac{4l}{3}$

4. When 1 cm thick surface is illuminated with light of wavelength λ, the stopping potential is V. When the same surface is illuminated by light of wavelength 2λ, the stopping potential is $V/3$. Threshold wavelength for metallic surface is

(a) $4\lambda/3$ (b) 4λ (c) 6λ (d) $8\lambda/3$

5. In the given circuit, the AC source has $\theta = 100$ rad s^{-1}. Considering the inductor and capacitor to be ideal, the value if I is

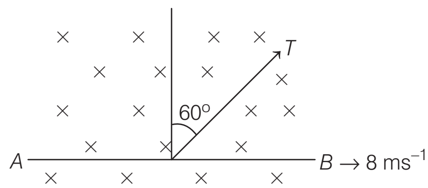


(a) 0.32 A (b) 0.25 A (c) 0.75 A (d) 0.67 A

6. Three point charges of 1C, 2C and 3C are placed at the corners of an equilateral triangle of side 100 cm. The work done to move these charges to the corners of a similar equilateral triangle of side 50 cm, will be

(a) 9.9×10^{10} J (b) 9.9×10^{9} J
(c) 5.2×10^{10} J (d) 5.9×10^{9} J

7. A metal rod *AB* of length 50 cm is moving at a velocity 8 ms^{-1} in a magnetic field of 2T. If the field is at 60° with the plane of motion as shown in the figure, then the potentials V_A and V_B are related by



(a) $V_A - V_B = 8$ V (b) $V_A - V_B = 4$ V
(c) $V_B - V_A = 8$ V (d) $V_B - V_A = 4$ V

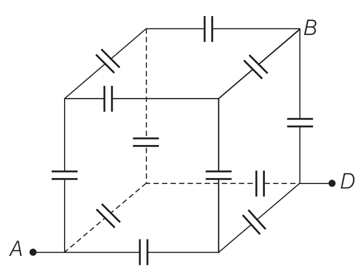
8. Two wires of same length are shaped into a square and a circle. If they carry same current, then ratio of the magnetic moment is

(a) $2 : \pi$ (b) $\pi : 2$
(c) $\pi : 4$ (d) $4 : \pi$

9. A disc of radius *R* rotates with constant angular velocity ω about its own axis. Surface charge density of this disc varies as $\sigma = \alpha r^2$, where *r* is the distance from the centre of disc. Determine the magnetic field intensity at the centre of disc.

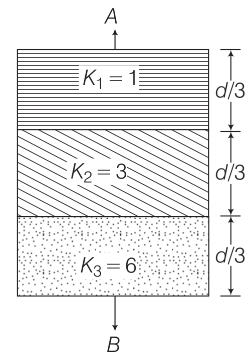
(a) $\mu_0 \alpha \omega R^3$ (b) $\frac{\mu_0 \alpha \omega R^3}{6}$
(c) $\frac{\mu_0 \alpha \omega R^3}{8}$ (d) $\frac{\mu_0 \alpha \omega R^3}{3}$

10. Figure shows a combination of twelve capacitors, each of capacitance *C*, forming a cube. What is the equivalent capacitance of the combination between the diagonally opposite corners *A* and *B* of the cube



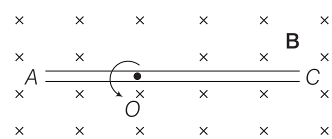
(a) $\frac{5}{6}C$ (b) $\frac{6}{5}C$ (c) $\frac{7}{5}C$ (d) $\frac{5}{7}C$

11. Find the equivalent capacitance between A and B. A = area of each plate, d = separation between plates



(a) $\frac{2A\varepsilon_0}{d}$ (b) $\frac{3A\varepsilon_0}{d}$ (c) $\frac{4A\varepsilon_0}{3d}$ (d) $\frac{5A\varepsilon_0}{4d}$

12. A conducting rod AC of length $4l$ is rotated about a point O in a uniform magnetic field $\mathbf{B}$ directed into the paper. $AO = l$ and $OC = 3l$. Then,



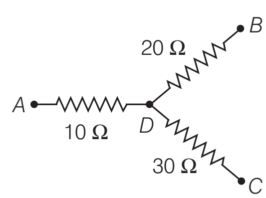
(a) $V_A - V_O = \frac{B\omega l^2}{2}$ (b) $V_O - V_C = \frac{7}{2}B\omega l^2$

(c) $V_A - V_C = 4B\omega l^2$ (d) $V_C - V_O = \frac{9}{2}B\omega l^2$

13. An electron and a photon possess the same de-Broglie wavelength. If E_e and E_p respectively are the energies of electron and photon and v and c are their respective velocities, then $\frac{E_e}{E_p}$ is equal to

(a) $\frac{v}{c}$ (b) $\frac{v}{2c}$ (c) $\frac{v}{3c}$ (d) $\frac{v}{4c}$

14. In the circuit given here, the points A, B and C are 70 V, 0 and 10 V, respectively. Then,



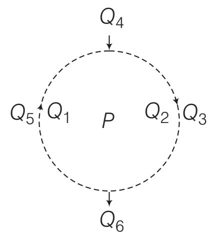
(a) the point D will be at a potential of 60 V

(b) the point D will be at a potential of 20 V

(c) currents in the paths AD, DB and DC are in the ratio of $1:2:3$

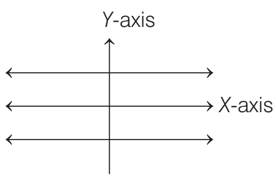
(d) currents in the paths AB, DB and DC are in the ratio of $3:2:1$

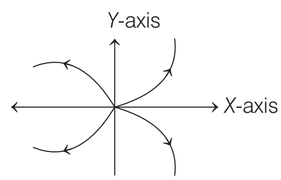
15. The figure shows the various positions (labelled by subscripts) of small magnetised needles P and Q. The arrows show the direction of their magnetic moment. Which configuration corresponds to the lowest potential energy of all the configurations shown?

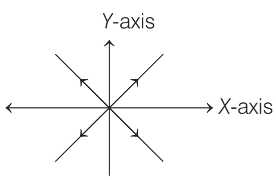


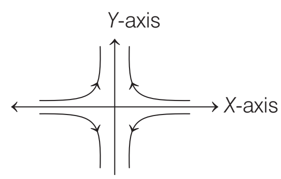
(a) PQ_3 (b) PQ_4 (c) PQ_5 (d) PQ_6

16. The potential in an electric field varies as $V = (x^2 - y^2)$. The electric lines of the force in X-Y plane are

(a) 

(b) 

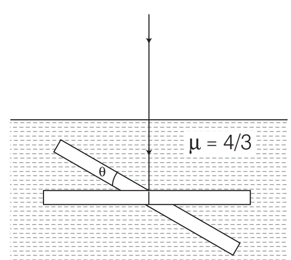
(c) 

(d) 

17. A moving coil galvanometer has 150 equal divisions. Its current sensitivity is 10 divisions per milliampere and voltage sensitivity is 2 divisions per millivolt. In order that each division reads 1 V the resistance (in Ω) needed to be connected in series with the coil will be

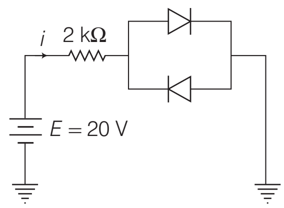
(a) 99995 (b) 9995 (c) 10^3 (d) 10^5

18. A plane mirror is placed horizontally inside water $(\mu = 4/3)$. A ray falls normally on it. Then, mirror is rotated through an angle θ. The minimum value of θ for which ray does not come out of the water surface is



(a) $\pi/4$ (b) $\sin^{-1}\left(\frac{3}{4}\right)$ (c) $\frac{1}{2}\sin^{-1}\left(\frac{3}{4}\right)$ (d) $2\sin^{-1}\left(\frac{3}{4}\right)$

19. Assuming the diodes to be ideal with forward resistance zero, the current i in the following circuit is



(a) 0 (b) 9.65 mA (c) 10 mA (d) 10.36 mA

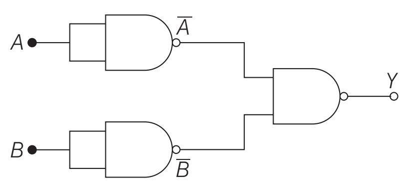
20. The earth's magnetic field at a certain place has a horizontal component 0.3 G and the total strength 0.5 G. The angle of dip is

(a) $\tan^{-1}\left(\frac{3}{4}\right)$ (b) $\sin^{-1}\left(\frac{3}{4}\right)$ (c) $\tan^{-1}\left(\frac{4}{3}\right)$ (d) $\sin^{-1}\left(\frac{3}{5}\right)$

21. A light ray incidents normally on one surface of an equilateral prism. The angle of deviation of the light ray is (refractive index of the material of the prism = $\sqrt{2}$)

(a) 60° (b) 30° (c) 0° (d) 120°

22. The combination of the gates shown in the figure below produces



(a) NOR gate (b) OR gate
(c) AND gate (d) XOR gate

23. An iron rod of 0.2 cm^2 cross-sectional area is subjected to a magnetisting field of 1200 Am^{-1}. The susceptibility of iron is 599. The magnetic flux produced is

(a) 0.904 Wb (b) 1.81×10^{-5} Wb
(c) 0.904×10^{-5} Wb (d) 5.43×10^{-5} Wb

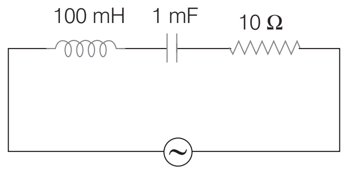
24. A convex lens of focal length 30 cm forms a real image three times larger than the object on a screen. Object and screen are moved until the image becomes twice the size of the object. If the shift of the object is 6 cm. The shift of screen is

(a) 28 cm (b) 14 cm (c) 18 cm (d) 16 cm

25. Two particles of equal mass m and charge q are placed at a distance of 16 cm. They do not experience any force. The value of $\frac{q}{m}$ is

(a) l (b) $\sqrt{\frac{\pi\varepsilon_0}{G}}$ (c) $\sqrt{\frac{G}{4\pi\varepsilon_0}}$ (d) $\sqrt{4\pi\varepsilon_0 G}$

26. The following series *L-C-R* circuit, when driven by an emf source of angular frequency 70 krad/s, the circuit effectively behaves like



(a) purely resistive circuit
(b) series *R-L* circuit
(c) series *R-C* circuit
(d) series *L-C* circuit with $R = 0$

27. Identify the wrong statement.

(a) The electrical potential energy of a system of two protons shall increase if the separation between the two is decreased

(b) The electrical potential energy of a proton-electron system will increase if the separation between the two is decreased

(c) The electrical potential energy of a proton-electron system will increase if the separation between the two is increased

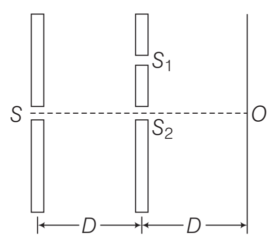
(d) The electrical potential energy of system of two electrons shall increase if the separation between the two is decreased.

28. Coefficient of coupling between two coils of self-inductances L_1 and L_2 is unity. It means

(a) 50% flux of L_1 is linked with L_2
(b) 100% flux of L_1 is linked with L_2
(c) $\sqrt{L_1}$ time of flux of L_1 is linked with L_2
(d) None of the above

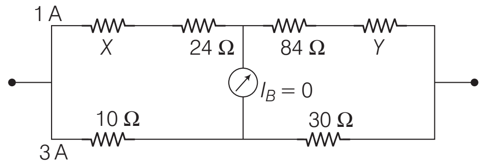
29. Two ideal slits S_1 and S_2 are at a distance d apart and illuminated by light of wavelength λ passing through an ideal source slit S placed on the line through S_2 as shown. The distance between the planes of slits and the source slit is D.

A screen is held at a distance D from the plane of the slits. The minimum value of d for which there is darkness at O is



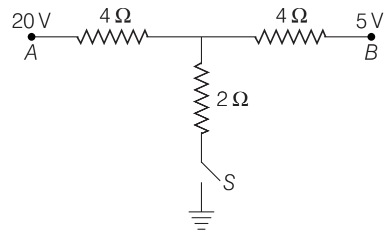
(a) $\sqrt{\frac{3\lambda D}{2}}$
(b) $\sqrt{\lambda D}$
(c) $\sqrt{\frac{\lambda D}{2}}$
(d) $\sqrt{3\lambda D}$

30. In the given circuit, the resistances are given in ohm. The current through the 10 Ω resistance is 3 A while that through the resistance X is 1 A. No current passes through the galvanometer. The values of the unknown resistances X and Y are respectively (in ohm)



(a) 14 and 54 (b) 12 and 6 (c) 6 and 12 (d) 6 and 6

31. As the switch S is closed in the circuit shown in figure, current passing through it is



(a) 4.5 A (b) 6.0 A (c) 3.0 A (d) zero

32. When a DC voltage of 200V is applied to a coil of self inductance $(2\sqrt{3}/\pi)$ H, a current of 1 A flows through it. But by replacing DC source with AC source of 200 V, the current in the coil is reduced to 0.5 A. Then, the frequency of AC supply is

(a) 30 Hz (b) 60 Hz (c) 75 Hz (d) 50 Hz

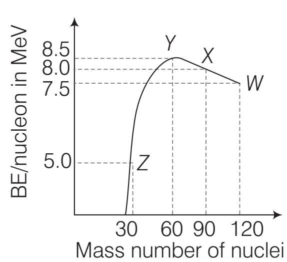
33. Let n_r and n_b be respectively the number of photons emitted by red bulb and blue bulb of equal power in given time, then

(a) $n_r = n_b$ (b) $n_r < n_b$ (c) $n_r > n_b$ (d) None of these

34. If ν_1 is the frequency of the series limit of Lyman series, ν_2 is the frequency of the first line of Lyman series and ν_3 is the frequency of the series limit of the Balmer series. Then,

(a) $\nu_1 - \nu_2 = \nu_3$ (b) $\nu_1 = \nu_2 - \nu_3$ (c) $\frac{1}{\nu_2} = \frac{1}{\nu_1} + \frac{1}{\nu_3}$ (d) $\frac{1}{\nu_1} = \frac{1}{\nu_2} + \frac{1}{\nu_3}$

35. Binding energy per nucleon *versus* mass number curve for nuclei is shown in the figure W, X, Y and Z are four nuclei indicated on the curved. The process that would release energy is



(a) $Y \rightarrow 2Z$ (b) $W \rightarrow X + Y$ (c) $W \rightarrow 2Y$ (d) $X \rightarrow Y + Z$

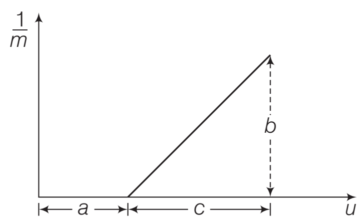
36. A ray of light is incident on surface of glass slab at an angle 45°. If the lateral shift produced per unit thickness is $\frac{1}{\sqrt{3}}$ m, the angle of refraction produced is

(a) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$ (b) $\tan^{-1}\left(1-\sqrt{\frac{2}{3}}\right)$ (c) $\sin^{-1}\left(1-\sqrt{\frac{2}{3}}\right)$ (d) $\tan^{-1}\left(\sqrt{\frac{2}{\sqrt{3}-1}}\right)$

37. The wavelength of K_α line for an element of atomic number 43 is λ, then the wavelength of K_α line for an element of atomic number 29 is

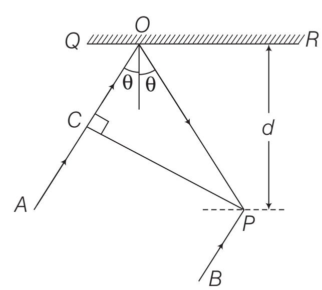
(a) $\frac{43}{29}\lambda$ (b) $\frac{42}{28}\lambda$ (c) $\frac{9}{4}\lambda$ (d) $\frac{4}{9}\lambda$

38. The graph shows, how the inverse of magnification $\frac{1}{m}$ produced by a convex thin lens, with variation in object distance u. What was the focal length of the lens used?



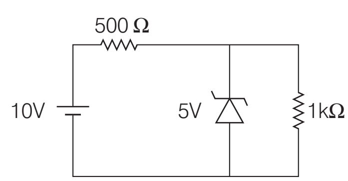
(a) $\frac{b}{c}$ (b) $\frac{b}{ca}$ (c) $\frac{bc}{a}$ (d) $\frac{c}{b}$

39. In the below diagram, CP represents a wavefront and AO and BP, the corresponding two rays. Find the condition of θ for constructive interference at P between the rays BP and reflected ray AOP



(a) $\cos\theta = 3\lambda/2d$ (b) $\cos\theta = \lambda/4d$
(c) $\sec\theta - \cos\theta = \lambda/d$ (d) $\sec\theta - \cos\theta = 4\lambda/d$

40. In the following circuit, the current flowing through $1\,\text{k}\Omega$ resistor is



(a) 0 (b) 5 mA (c) 10 mA (d) 15 mA

Section-B (2 Marks each)

Directions *(Q. Nos. 41-44) These questions consist of two statements each linked as Assertion and Reason. While answering of these questions you are required to choose any one of the following four responses :*

(a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion.
(b) If both Assertion and Reason are true but Reason is not correct explanation of Assertion.
(c) If Assertion is true but Reason is false.
(d) If Assertion is false but Reason is true.

41. **Assertion** Like light radiation, thermal radiation are also electromagnetic radiation.
Reason The thermal radiations require no medium for propagation.

42. **Assertion** To observe diffraction of light the size of obstacle aperture should be of the order of 10^{-7}m.
Reason 10^{-7}m is the order of wavelength of visible light.

43. **Assertion** Positive value of packing fraction implies a large value of binding energy.
Reason The ratio of the difference between the atomic mass of nucleus and the mass number of the nucleus to that of atomic mass is called packing fraction.

44. **Assertion** Wavelength of characteristic X-rays is given by $\frac{1}{\lambda} \propto \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ in transition from n_2 to n_1. In the above relation proportionality constant is series dependent. For different series (K-series, L-series, etc.) value of this constant will be different.
Reason For L-series value of this constant is less than the value for K-series.

Directions *(Q.Nos. 45-47) These questions are based on the following situation. Choose the correct options from those given below.*

An electron with a speed $v_0 << c$ moves in a circle of radius r_0 in a uniform magnetic field. The time required for one revolution of the electron is T_0. The speed of the electron is now doubled to $2v_0$.

45. The radius of the circle will change to
(a) $4r_0$
(b) $2r_0$
(c) r_0
(d) $r_0 / 2$

46. The time required for one revolution of the electron will change to
(a) $4T_0$
(b) $2T_0$
(c) T_0
(d) $T_0 / 2$

47. A charged particle is projected in a magnetic field $\mathbf{B} = (2\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) \times 10^2$ T. The acceleration of the particle is found to be $\mathbf{a} = (x\hat{\mathbf{i}} + 2\hat{\mathbf{j}})\text{ms}^{-2}$. Find the value of x.
(a) 4 ms^{-2}
(b) –4 ms^{-2}
(c) –2 ms^{-2}
(d) 2 ms^{-2}

Directions *(Q. Nos. 48-49) In the following questions, a statement I is followed by a corresponding statement II. Of the following statements, choose the correct one.*

(a) Both Statement I and Statement II are correct and Statement II is the correct explanation of Statement I.
(b) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I.
(c) Statement I is correct but Statement II is incorrect.
(d) Statement I is incorrect but Statement II is correct.

48. **Statement I** Focal length of the eyepiece of telescope is smaller as compared to the objective which has a larger focal length and aperture.
Statement II For larger focal length of objective than eyepiece, magnification is more in astronomical telescopes.

49. **Statement I** It would be extremely difficult to calculate the flux linkage with the outer solenoid when current flows in inner solenoid.
Statement II As the magnetic field due to the inner solenoid would vary across the length as well as cross-section of the outer solenoid (when inner solenoid is smaller in length and radius).

50. Light rays of intensity 3.3×10^{-3} W / m^2 and wavelength 6000 Å falls normally on a photosensitive surface of area 2 cm^2 and work function 2.0 eV. Assuming that there is no light loss due to reflection. Match the results given in Column II for the physical quantities given in Column I.

	Column I		Column II
A.	Energy (in J) of incident photon	p.	2×10^{12}
B.	Work function (in J) of surface	q.	3.3×10^{-19}
C.	Emission of photoelectrons is	r.	3.2×10^{-19}
D.	Number of photoelectrons emitted per second is	s.	Possible

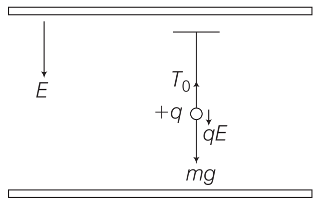
Codes

	A	B	C	D
(a)	q	r	s	p
(b)	r	s	p	q
(c)	q	s	q	p
(d)	r	q	s	p

Solutions with Hints

1. (a) When electric field is downward

For simple pendulum,



Time period, $T = 2\pi\sqrt{\frac{L}{a}}$

where, a is effective acceleration.

$$a = \frac{\text{net external force on the ball}}{\text{mass of the ball}}$$

$$\Rightarrow \qquad a = \frac{mg + qE}{m} = g + \frac{qE}{m}$$

$\therefore$ Time period, $T = 2\pi\sqrt{\frac{L}{g + \frac{qE}{m}}}$

2. (c) The Boolean expression for the output of given combination is

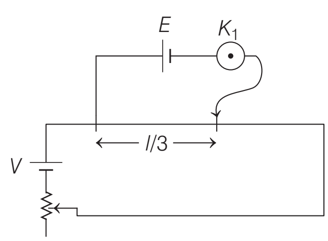
$$Y = (A + B) \cdot C$$

The truth table is

A	B	C	$Y = (A + B) \cdot C$
0	0	0	0
1	0	0	0
0	1	0	0
0	0	1	0
1	1	0	0
0	1	1	1
1	0	1	1
1	1	1	1

Hence, $A = 1, B = 0$ and $C = 1$

3. (b) According to question, the figure is as



If K be the potential gradient of the potentiometer wire, then emf of the cell which gives balancing length $\frac{l}{3}$ is given by

$$E = K.\frac{l}{3} \quad \text{...(i)}$$

where, $$E = \frac{V}{l}.\frac{l}{3} = \frac{V}{3} \quad \text{...(ii)} \left[\because K = \frac{V}{l}\right]$$

When, length of potentiometer wire is increased by $\frac{l}{2}$, then new length,

$$l_1 = l + \frac{l}{2} = \frac{3l}{2}$$

$\therefore$ New potential gradient, $K' = \frac{V}{\frac{3l}{2}} \Rightarrow K' = \frac{2V}{3l}$

If l' be the new balancing length,

then, $$E = K'l' \quad \text{...(iii)}$$

or $$E = \frac{2V}{3l}l'$$

$$\frac{2V}{3l}.l' = \frac{V}{3} \Rightarrow l' = \frac{l}{2} \quad \left[\text{from Eq. (iii)}, E = \frac{V}{3}\right]$$

4. (b) According to the question,

$$eV = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) \quad \text{...(i)}$$

and $$\frac{eV}{3} = hc\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right) \quad \text{...(ii)}$$

Dividing Eq. (i) by Eq. (ii), we get

$$3 = \frac{\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)}{\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right)}$$

or $$3\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right) = \frac{1}{\lambda} - \frac{1}{\lambda_0}$$

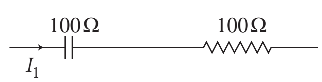
or $$\frac{3}{2\lambda} - \frac{1}{\lambda} = \frac{3}{\lambda_0} - \frac{1}{\lambda_0}$$

or $$\frac{1}{2\lambda} = \frac{2}{\lambda_0}$$

Threshold wavelength for metallic surface, $\lambda_0 = 4\lambda$

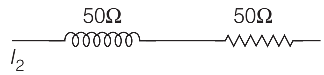
5. (a) $X_L = \omega L = 10 \times 0.5 = 50\,\Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{100 \times 100 \times 10^{-6}} = 100\,\Omega$$

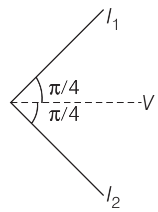


$$Z_1 = 100\sqrt{2}$$
$$I_1 = \frac{V}{Z_1} = \frac{20}{100\sqrt{2}} = \frac{1}{5\sqrt{2}}\text{ A}$$

V across $100\,\Omega = I_1 \cdot R_1 = \dfrac{1}{5\sqrt{2}} \times 100 = \dfrac{20}{\sqrt{2}} \times \dfrac{\sqrt{2}}{\sqrt{2}} = 10\sqrt{2}$ V



Phase difference between I_1 and V,



$$\cos\phi_1 = \frac{R_1}{Z_1} = \frac{100}{100\sqrt{2}} = \frac{1}{\sqrt{2}}$$

$\Rightarrow$ $\phi_1 = \pi/4$

Therefore, I_1 lead V

$$Z_2 = 50\sqrt{2}$$

$$I_2 = \frac{V}{Z_2} = \frac{20}{50\sqrt{2}} = \frac{2}{5\sqrt{2}} \text{ A}$$

V across $50\,\Omega = I_2 R_2 = \dfrac{2}{5\sqrt{2}} \times 50 = \dfrac{20}{\sqrt{2}} = 10\sqrt{2}$ V

$\Rightarrow$ $\cos\phi_2 = \dfrac{R_2}{Z_2} = \dfrac{50}{50\sqrt{2}} = \dfrac{1}{\sqrt{2}}$

$\Rightarrow$ $\phi_2 = \pi/4$

I_2 lag V by $\pi/4$

$\Rightarrow$ $I_{net} = \sqrt{I_1^2 + I_2^2}$

$$I = \sqrt{\frac{1}{25 \times 2} + \frac{4}{25 \times 2}} = \sqrt{\frac{5}{50}} = \frac{1}{\sqrt{10}}$$

$\Rightarrow$ $I = 0.316 \text{ A} \simeq 0.32 \text{ A}$

6. (a) Given, $q_1 = 1\text{C}, q_2 = 2\text{C}, q_3 = 3\text{C}$

and $r_1 = 100 \text{ cm} = 1 \text{m}$

Initial PE of system, $U_1 = \dfrac{1}{4\pi\varepsilon_0 r_1}(q_1q_2 + q_2q_3 + q_3q_1)$

$$= \frac{9 \times 10^9}{1}(1 \times 2 + 2 \times 3 + 3 \times 1)$$

$$= 99 \times 10^9 \text{ J}$$

When $r_2 = 50 \text{ cm} = 0.5 \text{ m}$

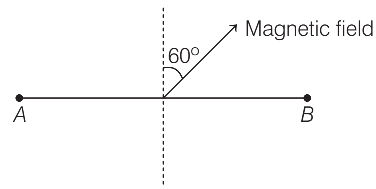
Final PE of system, $U_2 = \dfrac{1}{4\pi\varepsilon_0 r_2}(q_1q_2 + q_2q_3 + q_3q_1)$

$$= \frac{9 \times 10^9}{0.5}(1 \times 2 + 2 \times 3 + 3 \times 1) = 2 \times 99 \times 10^9 \text{ J}$$

Work done, $W = U_2 - U_1 = 2 \times 99 \times 10^9 - 99 \times 10^9$

$$W = 99 \times 10^9 \text{ J}$$
$$= 9.9 \times 10^{10} \text{ J}$$

7. (b) Metal rod AB shown in the figure moves with speed 8 ms^{-1}.



As the emf induced in the metal rod, $e_{AB} = V_A - V_B = l \cdot (\mathbf{v} \times \mathbf{B})$

But, $V_A - V_B = lvB \sin(90^\circ - 60^\circ)$

$$V_A - V_B = 50 \times 10^{-2} \times 8 \times 2 \times \sin 30^\circ$$
$$= 8 \times \frac{1}{2} = 4 \text{ V}$$

8. (c) Let length of each wire is L.

For square length of each side is $L/4$

Area of square $= \left(\frac{L}{4}\right)^2 = \frac{L^2}{16}$

For circle, $L = 2\pi r \Rightarrow r = \frac{L}{2\pi}$

Area of circle $= \pi r^2 = \pi \left(\frac{L}{2\pi}\right)^2 = \frac{L^2}{4\pi}$

As, magnetic moment, $M = iA$

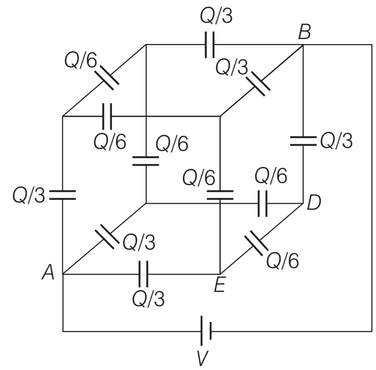
$$\therefore \quad \frac{M_{\text{square}}}{M_{\text{circle}}} = \frac{A_{\text{square}}}{A_{\text{circle}}} = \frac{L^2/16}{L^2/4\pi} = \frac{\pi}{4}$$

9. (b) As, $dA = (2\pi r)\, dr$

$$dq = \sigma \cdot dA = (2\pi\alpha r^3) \cdot dr \qquad [\because \sigma = \alpha r^2]$$
$$i = (dq)\, f = (dq)\frac{\omega}{2\pi} = (\alpha\omega r^3)\, dr$$
$$dB = \frac{\mu_0 i}{2r} = \frac{\alpha\mu_0\omega r^2 dr}{2}$$
$$\therefore \quad B = \int_0^R dB = \frac{\mu_0 \alpha\omega R^3}{6}$$

10. (b) Suppose the charge supplied by the battery is Q. This will be equally divided on the three capacitors connected to A because on looking from A to B three sides of the cube have identical properties. Hence, each capacitor connected to A has charge $\frac{Q}{3}$. Similarly, each capacitor connected to B also has charge $\frac{Q}{3}$.

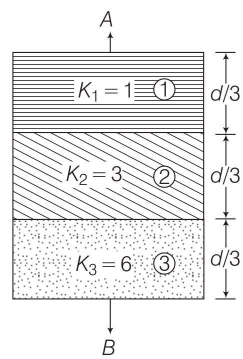
In the figure given below, the charges shown are the charged on the capacitors (i.e., charges on their positive plates)



Now, $V = (V_A - V_E) + (V_E - V_D) + (V_D - V_B) = \dfrac{Q/3}{C} + \dfrac{Q/6}{C} + \dfrac{Q/3}{C} = \dfrac{5Q}{6C}$

$\therefore$ Equivalent capacitance, $C_{\text{eq}} = \dfrac{Q}{V} = \dfrac{6}{5}C$

11. (a) Capacitance, $C_1 = \dfrac{K_1 A\varepsilon_0}{d/3} = \dfrac{3A\varepsilon_0}{d}$



Capacitance, $C_2 = \dfrac{K_2 A\varepsilon_0}{d/3} = \dfrac{9A\varepsilon_0}{d}$

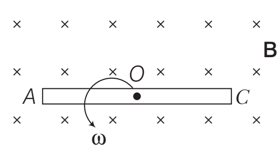
Capacitance, $C_3 = \dfrac{K_3 A\varepsilon_0}{d/3} = \dfrac{18A\varepsilon_0}{d}$

C_1, C_2 and C_3 are in series, $\dfrac{1}{C_{\text{eq}}} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$

$$= \frac{d}{3A\varepsilon_0} + \frac{d}{9A\varepsilon_0} + \frac{d}{18A\varepsilon_0} = \frac{9d}{18A\varepsilon_0} = \frac{d}{2A\varepsilon_0}$$

$\Rightarrow$ $C_{\text{eq}} = \dfrac{2A\varepsilon_0}{d}$

12. (c) For rotating rod, induced emf, $V = \dfrac{1}{2}Bl^2\omega$



For part AO, $V_{OA} = V_O - V_A = \frac{1}{2} Bl^2 \omega$

For part OC, $V_{OC} = V_O - V_C = \frac{1}{2} B(3l)^2 \omega$

$\therefore$ $V_A - V_C = 4Bl^2 \omega$

13. (b) de-Broglie wavelength, $\lambda = \frac{h}{\sqrt{2mE_e}} = \frac{hc}{E_p}$

or $$2mE_e = \frac{E_p^2}{c^2} \quad \text{...(i)}$$

But $E_e = \frac{1}{2} mv^2$ or $m = \frac{2E_e}{v^2}$

From Eq. (i), we get

$$2\left(\frac{2E_e}{v^2}\right) E_e = \frac{E_p^2}{c^2} \quad \text{or} \quad \frac{4E_e^2}{v^2} = \frac{E_p^2}{c^2}$$

or $$\frac{E_e^2}{E_p^2} = \frac{v^2}{4c^2} \quad \text{or} \quad \frac{E_e}{E_p} = \frac{v}{2c}$$

14. (c) Applying Kirchhoff's law at point D, we get

$$i_1 = i_2 + i_3$$

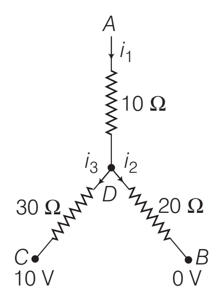
$$\frac{V_A - V_D}{10} = \frac{V_D - V_B}{20} + \frac{V_D - V_C}{30}$$

or $$70 - V_D = \frac{V_D}{2} + \frac{V_D - 10}{3} \quad (\because V_B = 0)$$

$\Rightarrow$ $$V_D = 40 \text{ V}$$

Thus, $$i_1 = \frac{V_A - V_D}{10} = \frac{70 - 40}{10} = 3 \text{ A}$$

$\Rightarrow$ $$i_2 = \frac{40 - 0}{20} = 2 \text{ A}$$



and $$i_3 = \frac{40 - 10}{30} = 1 \text{ A}$$

15. (d) As potential energy is given as $U = -MB(1 - \cos\theta)$

$\Rightarrow$ $U = -MB$ (when $\theta = 0°$, $U =$ minimum)

Hence, **M** and **B** parallel to each other for minimum potential energy.

PQ_6 configuration provides $\theta = 0°$, $U_{\min} = -MB$

16. (c) The potential in an electric field varies as,

$$V = (x^2 - y^2)$$

$\therefore$ Electric field,

$$E = -\left[\frac{dv}{dx}\hat{\mathbf{i}} + \frac{dv}{dy}\hat{\mathbf{j}}\right] \qquad [\because E = \Delta V]$$

$$= -\left[\frac{d}{dx}(x^2 - y^2)\hat{\mathbf{i}} + \frac{d}{dy}(x^2 - y^2)\hat{\mathbf{j}}\right]$$

$$E = -[2x\hat{\mathbf{i}} - 2y\hat{\mathbf{j}}] \Rightarrow E = -2x\hat{\mathbf{i}} + 2y\hat{\mathbf{j}}$$

Expression of the electric field is linear equation in two variables, i.e. straight lines in *XY*-plane and slope having 45°, 35° etc.

17. (b) Voltage sensitivity $= \dfrac{\text{Current sensitivity}\,(S_i)}{\text{Resistance of galvanometer}\,(G)}$

$$G = \frac{S_i}{S_v}$$

$$\Rightarrow \qquad G = \frac{10}{2} = 5\,\Omega$$

Full scale deflection current, $i_g = \dfrac{150}{10} = 15$ mA

Voltage to be measured, $V = iR = 150 \times 1 = 150$ V

Hence, $R = \dfrac{V}{i_g} - G = \dfrac{150}{15 \times 10^{-3}} - 5 = 9995\,\Omega$

18. (c) The reflected ray will rotate by angle 2θ. For TIR to take place at water-air boundary,

$$\sin 2\theta > \sin\theta_C$$

or

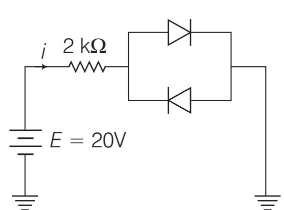
$$\sin 2\theta > \frac{1}{\mu}$$

$\therefore$

$$\theta > \frac{1}{2}\sin^{-1}\left(\frac{3}{4}\right) \qquad \left[\because \mu = \frac{4}{3}\right]$$

19. (c) Given, total resistance in the circuit = 2 kΩ

and $E = 20$ V



$\therefore$ Current $= \dfrac{E}{R} = \dfrac{20}{2000} = 10$ mA

20. (c) Total strength of magnetic field, $B^2 = H^2 + V^2$

$\therefore$

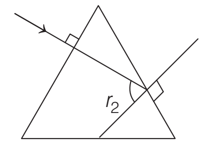
$$V = \sqrt{B^2 - H^2} = \sqrt{(0.5)^2 - (0.3)^2} = 0.4$$

$$\tan\phi = \frac{V}{H} = \frac{0.4}{0.3} = \frac{4}{3}$$

$\therefore$

$$\phi = \tan^{-1}\left(\frac{4}{3}\right)$$

21. (a) Given, $i = 0°$



So, $\frac{\sin i}{\sin r_1} = \sqrt{2}$

$\frac{\sin 0°}{\sin r_1} = \sqrt{2}$

$\sin r_1 = 0$ or $r_1 = 0$

Now, $\frac{\sin r_2}{\sin e} = \frac{1}{\mu}$

$\Rightarrow \quad \sin e = \sqrt{2} \sin r_2$

But, $r_1 + r_2 = 60°$

So, $\sin e = \sqrt{2} \sin 60° = \sqrt{2} \times \sqrt{3} / 2 > 1$

So, light is incidenting at more than critical angle and totally internally reflected.

$\therefore$ Deviation angle $= (i + e) - (r_1 + r_2)$

$= 0 - 60° = 60°$ (in magnitude)

22. (b) The Boolean expression of given combination of gates is written as

$$Y = \overline{\overline{A} \cdot \overline{B}} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$$

So, it produces OR gate.

23. (b) As, $\mu = \mu_0 (1 + \chi)$ or $\mu = 4\pi \times 10^{-7} (1 + 599)$

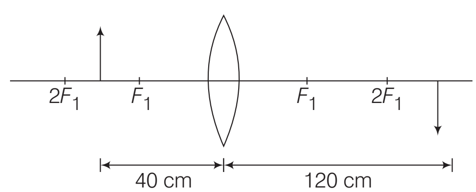
or $\quad \mu = 7.536 \times 10^{-4}$ TmA^{-1}

$B = \mu H = 7.536 \times 10^{-4} \times 1200$

$\therefore$ Hence, $\phi = BA = 7.536 \times 10^{-4} \times 1200 \times 0.2 \times 10^{-4} = 1.81 \times 10^{-5}$ Wb

24. (a) We have, $\frac{1}{3x} - \frac{1}{(-x)} = \frac{1}{+30}$

$\therefore \quad x = 40$ cm and $3x = 120$ cm



To decrease the magnification object should be moved towards $2F_1$.
Hence, image will move towards $2F_2$. Let displacement is y. Then,

$$2(40 + 6) = (120 - y) \qquad \left(\because m = \frac{v}{u}\right)$$

$$\therefore \qquad y = 28 \text{ cm}$$

25. (d) They will not experience any force, if $|\mathbf{F}_G| = |\mathbf{F}_e|$

$$\Rightarrow \qquad \frac{Gm^2}{r^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q^2}{r^2}$$

$$\Rightarrow \qquad \frac{q^2}{m^2} = 4\pi\varepsilon_0 G$$

$$\Rightarrow \qquad q/m = \sqrt{4\pi\varepsilon_0 G}$$

26. (b) Resonance frequency, $\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{100 \times 10^{-6} \times 1 \times 10^{-6}}} = 10^5 \text{ rads}^{-1}$

Now, given $\omega = 70$ k-rads^{-1}

$= 70000 \text{ rads}^{-1}$

$\Rightarrow \qquad \omega_0 > \omega$

As $X_L \propto \omega$ and $X_C \propto \frac{1}{\omega}$

$\therefore \qquad X_L > X_C$

The circuit will be *R-L* circuit.

27. (c) Potential energy as well as force are positive, if there is repulsion between the particles and negative, if there is attraction.

We take of only the magnitude of values when discussing decrease or increase of energy.

As $\qquad U = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$,

Plus or minus i.e., whether both are of the same sign or different, if *r* decreases, the value increase. Therefore, (c) is wrong.

28. (b) Two coils are said to be magnetically coupled, if full or a part of the flux produced by one link with the other. Let L_1 and L_2 be the self-inductances of the coils and M be their mutual inductances, then

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

When 100% flux produced by one coil links with the other, then mutual inductance between the two is maximum and is given by $M = \sqrt{L_1 L_2}$

29. (c) Path difference between the waves reaching at *P*,

$$\Delta = \Delta_1 + \Delta_2$$

where, Δ_1 = initial path difference

and $\qquad \Delta_2$ = path difference between the waves after emerging from slits.

Now, $\qquad \Delta_1 = SS_1 - SS_2 = \sqrt{(D^2 + d^2)} - D$

and $\qquad \Delta_2 = S_1O - S_2O = \sqrt{(D^2 + d^2)} - D$

$$\therefore \qquad \Delta = 2[\sqrt{(D^2 + d^2)} - D] = 2[(D^2 + d^2)^{1/2} - D]$$

$$= 2\left[\left(D + \frac{d^2}{2D}\right) - D\right] \text{ from binomial expansion}$$

$$= \frac{d^2}{D}$$

For obtaining dark at *O*, Δ must be equals to $(2n - 1)\frac{\lambda}{2}$

i.e., $\qquad \frac{d^2}{D} = (2n - 1)\frac{\lambda}{2}$

$$\therefore \qquad d^2 = \frac{(2n - 1)\lambda D}{2}$$

or $\qquad d = \sqrt{\frac{(2n - 1)\lambda D}{2}}$

For minimum distance $n = 1$,

So, $$d = \sqrt{\left(\frac{\lambda D}{2}\right)}$$

30. (d) Using the concept of balanced Wheatstone bridge,

$$\frac{24 + X}{84 + Y} = \frac{10}{30} = \frac{1}{3} \quad \text{...(i)}$$

Now, applying KVL,

$$1(X + 24 + 84 + Y) = 3(10 + 30)$$

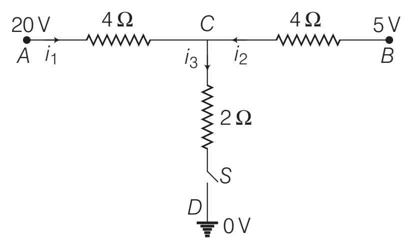
$$\Rightarrow \quad \frac{3}{1} = \frac{24 + 84 + X + Y}{10 + 30} = \frac{108 + X + Y}{40} \quad \text{...(ii)}$$

From Eqs. (i) and (ii), we get

$$X = Y = 6\,\Omega$$

31. (a) Let the potential at junction C, is V.

Applying Kirchhoff's junction law at C



or $$\frac{V_A - V_C}{2} + \frac{V_B - V_C}{4} = \frac{V_C - V_D}{2}$$

or $$\frac{20 - V}{2} + \frac{5 - V}{4} = \frac{V - 0}{2} \text{ or } 5V = 45$$

$\therefore$ $$V = 9\text{ V}$$

$\therefore$ Current through switch S, $i_3 = \frac{9}{2} = 4.5$ A

32. (d) Resistance of coil, $R = \frac{200}{1} = 200\ \Omega$

With AC source, $I = \frac{200}{\sqrt{R^2 + X_L^2}}$

or $$0.5 = \frac{200}{\sqrt{R^2 + X_L^2}}$$

$$\Rightarrow \quad R^2 + (2\pi f L)^2 = (400)^2$$

$$\Rightarrow \quad \left(2\pi f \times \frac{2\sqrt{3}}{\pi}\right)^2 = (400)^2 - (200)^2 = 200 \times 600$$

$$\Rightarrow \quad 4f\sqrt{3} = 2\sqrt{3} \times 100 \Rightarrow f = 50\text{ Hz}$$

33. (c) $p = \frac{nhc}{\lambda}$

$$\Rightarrow \quad n \propto \lambda \Rightarrow \lambda_r > \lambda_b$$

$$\therefore \quad n_r > n_b$$

34. (a) We know that frequency, $\nu = Rc\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

This gives, $\nu_1 = Rc\left(1 - \frac{1}{\infty}\right) = Rc$

$$\Rightarrow \qquad \nu_2 = Rc\left(1 - \frac{1}{4}\right) = \frac{3}{4}Rc$$

$$\nu_3 = Rc\left(\frac{1}{4} - \frac{1}{\infty}\right) = \frac{Rc}{4}$$

$$\Rightarrow \qquad \nu_1 - \nu_2 = \nu_3$$

35. (c) Energy is released in a process when total binding energy (BE) of the nucleus is increased or we can say when total BE of products is more than the reactants. By calculation we can see that only in case of option (c), this happens.

Given, $W \rightarrow 2Y$

BE of reactants $= 120 \times 7.5 = 900$ MeV

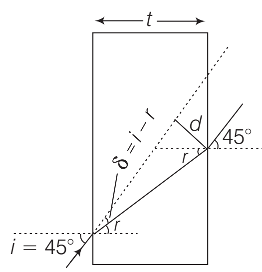
and BE of products

$$= 90 \times 8 + 60 \times 8.5 = 1230 \text{ MeV}$$

i.e., BE of products $>$ BE of reactants.

36. (b) Here, angle of incidence, $i = 45°$

$$\frac{\text{Lateral shift } (d)}{\text{Thickness of glass slab} (t)} = \frac{1}{\sqrt{3}}$$



Lateral shift, $d = \frac{t \sin \delta}{\cos r} = \frac{t \sin (i - r)}{\cos r}$

$$\Rightarrow \qquad \frac{d}{t} = \frac{\sin (i - r)}{\cos r}$$

or $$\frac{d}{t} = \frac{\sin i \cos r - \cos i \sin r}{\cos r}$$

or $$\frac{d}{t} = \frac{\sin 45° \cos r - \cos 45° \sin r}{\cos r} = \frac{\cos r - \sin r}{\sqrt{2} \cos r}$$

$$\Rightarrow \qquad \frac{d}{t} = \frac{1}{\sqrt{2}}(1 - \tan r)$$

$$\Rightarrow \qquad \frac{1}{\sqrt{3}} = \frac{1}{\sqrt{2}}(1 - \tan r)$$

$$\Rightarrow \qquad r = \tan^{-1}\left(1 - \frac{\sqrt{2}}{\sqrt{3}}\right)$$

37. (c) For K_α line, $\lambda_{K_\alpha} \propto \frac{1}{(Z-1)^2}$

So, $$\frac{\lambda_2}{\lambda_1} = \left(\frac{Z_1 - 1}{Z_2 - 1}\right)^2$$

$\Rightarrow$ $$\frac{\lambda_2}{\lambda_1} = \left(\frac{43-1}{29-1}\right)^2 = \left(\frac{42}{28}\right)^2 \Rightarrow \lambda_2 = \frac{9}{4}\lambda_1$$

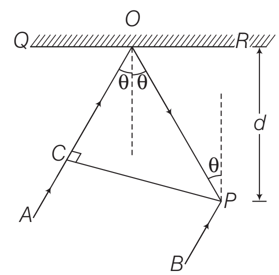
38. (a) From, $\frac{1}{v} - \frac{1}{-u} = \frac{1}{+f}$

$$v = \frac{uf}{u-f} \quad \text{or} \quad \frac{v}{u} = m = \frac{f}{u-f}$$

$\Rightarrow$ $$\frac{1}{m} = \left(\frac{1}{f}\right)u - 1$$

Comparing this with equation of straight line, $1/f$ is the slope of line, which is b/c.

39. (b) Path difference between the two rays is given by



$$\Delta = CO + PO$$

$\because$ $PR = d,$

So, $PO = d \sec\theta$

and $CO = PO\cos 2\theta = d\sec\theta\cos 2\theta$

So, $\Delta = (d\sec\theta + d\sec\theta\cos 2\theta)$

Phase difference between two rays is $\phi = \pi$ (as one ray is reflected one and another is direct).

Now, for constructive interference, path difference should be even multiple of half wavelength.

i.e., $\Delta = \lambda/2, \quad 3\lambda/2, \ldots$

So, $$d\sec\theta + d\sec\theta\cos 2\theta = \frac{\lambda}{2}$$

or $$d\sec\theta\,(1 + \cos 2\theta) = \frac{\lambda}{2}$$

or $$d\sec\theta\,(2\cos^2\theta) = \frac{\lambda}{2}$$

$\therefore$ $\cos\theta = \lambda/4d$

40. (b) In the given circuit, the Zener diode is used as a voltage regulating device.

Hence, the voltage across 1 kΩ is 5 V.

Current flowing through 1 kΩ resistor is

$$i = \frac{5}{1 \times 10^3} = 5 \times 10^{-3}\,\text{A} = 5\text{ mA}$$

41. (b) Light radiations and thermal radiations both belong to electromagnetic spectrum. Light radiation belongs to visible region while thermal radiation belongs to infrared region of EM spectrum.

Also, EM radiations require no medium for propagation.

42. (a) For diffraction to occur, the size of an obstacle/aperture is comparable to the wavelength of light wave. The order of wavelength of light wave is 10^{-7}, so diffraction occurs.

43. (d) Mass defect per nucleon is called the packing fraction,

i.e., $$P = \frac{\Delta m}{A} = \frac{m \sim A}{A}$$

Positive value of P does not mean that Δm is large. Since, binding energy $E = (\Delta m)\,c^2$

44. (c) This proportionality constant $\propto (Z - b)^2$.

For K-series : $b = 1$

For L-series : $b = 7.4$

45. (b) $r_0 = \dfrac{mv}{qB} \Rightarrow r' = \dfrac{m\,(2v_0)}{qB} = 2\,r_0$

46. (c) $T_0 = \dfrac{2\pi m}{qB} \rightarrow$ independent of velocity.

47. (b) As $F \perp B$

Hence, $a \perp B$

$\therefore$ $\mathbf{a} \cdot \mathbf{B} = 0 \Rightarrow (x\hat{\mathbf{i}} + 2\hat{\mathbf{j}}) \cdot (2\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) = 0$

$2x + 8 = 0 \quad \Rightarrow \quad x = -4\,\text{ms}^{-2}$

48. (a) For astronomical telescope, $|m| = \left|\dfrac{f_o}{f_e}\right|$.

So, magnification is inversely proportional to focal length of the eyepiece and directly proportional to focal length of objective. The larger f_o and smaller f_e will given better magnification.

49. (b) It would be extremely difficult to calculate the flux linkage with the outer solenoid as the magnetic field due to the inner solenoid would vary across the length as well as cross-section of the outer solenoid.

50. (a) (A $\rightarrow$ 2; B $\rightarrow$ 3; C $\rightarrow$ 4; D $\rightarrow$ 1)

Energy of incident photon $= \dfrac{hc}{\lambda} = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{6000 \times 10^{-10}} = 3.3 \times 10^{-19}$ J

Work function of surface $= 2$ eV $= 2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{19}$ J

Energy of incident photon is more than the work function of the surface. Therefore, emission of photoelectrons is possible.

Number of photoelectrons emitted = Number of incident photons per second on 2 cm^2 (= 2×10^{-4} m^2) area

$$n = \frac{\text{Intensity of incident radiations} \times \text{Surface area}}{\text{Energy of one photon}}$$

$$n = \frac{2 \times 3.3 \times 10^{-3} \times 10^{-4}}{3.3 \times 10^{-19}} = 2 \times 10^{12}\ \text{s}^{-1}$$