HIGHER SECONDARY SECOND YEAR EXAMINATION – MARCH 2024

PHYSICS ANSWER KEY

Note:

1. Answers written with **Blue** or **Black ink** only to be evaluated.
2. Choose the most suitable answer in Part A, from the given alternatives and write the **option code** and the **corresponding answer.**
3. For answers in Part-II, Part-III and Part-IV like reasoning, explanation, narration, description and listing of points, students may write in their own words but without changing the concepts and without skipping any point.
4. In numerical problems, if formula is not written, marks should be given for the remaining correct steps.
5. In graphical representation, physical variables for X-axis and Y-axis should be marked.

PART – I

Answer all the questions. **15x1=15**

Q. No.	OPTION	TYPE – A	Q. No.	OPTION	TYPE – B
1	(a)	Photovoltaic action	1	(c)	1.1eV
2	(c)	900 Vm^{-1}	2	(c)	480 W
3	(c)	480 W	3	(a)	$\frac{Q}{\sqrt{2}}$
4	(a)	3	4	(d)	3750 Å
5	(c)	polarisation	5	(d)	6 μF
6	(a)	$\frac{Q}{\sqrt{2}}$	6	(a)	Photovoltaic action
7	(d)	$\frac{3}{\pi} p_m$	7	(d)	its wavelength
8	(d)	its wavelength	8	(c)	900 Vm^{-1}
9	(b)	$\frac{\pi}{4}$	9	(d)	$\frac{3}{\pi} p_m$
10	(a)	more than before	10	(b)	$\frac{\pi}{4}$
11	(d)	6 μF	11	(a)	more than before
12	(d)	3750 Å	12	(a)	3
13	(a)	plane polarised	13	(c)	polarisation
14	(a)	Albert Einstein	14	(a)	plane polarised
15	(c)	1.1eV	15	(a)	Albert Einstein

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PART – II

Answer **any six** questions. Question number **24 is compulsory.** 6x2=12

16	**Hysteresis:** Hysteresis means ‘**lagging behind’**. The phenomenon of **lagging of magnetic induction (B) behind the magnetizing field** (H) is called hysteresis.	**2**	**2**
17	**Malus’ Law:** When a beam of plane polarized light of intensity I_0 is incident on an analyzer, the light transmitted of intensity I from the analyzer varies **directly as the square of the cosine of the angle** θ **between the transmission axis of polarizer and analyzer.** This is known as **Malus’ law.** $I = I_0 \text{Cos}^2\theta$ **(Equation only -----------1 Mark)**	**2**	**2**
18	**Electrostatic potential:** The electric potential at a point is equal to **the work done by an external force to bring a unit positive charge with constant velocity from infinity** to the point in the region of the external electric field. **Its unit is volt (V).**	**2**	**2**
19	Magnetic flux (ϕ) =4 mWb = 4 x 10^{-3} Wb ; time (t) = 0.4 Sec. The magnitude of induced emf (e) = $\frac{d\phi}{dt} = \frac{4 \text{ x } 10^{-3}}{0.4} = 10^{-2}$; **e = 10 mV**	**2**	**2**
20	**Applications of Seebeck Effect:** Seebeck effect is used in **thermoelectric generators** (Seebeck generators). This effect is utilized in **automobiles as automotive thermoelectric generators.** Seebeck effect is used in **thermocouples and thermopiles.** (Any Two Applications 2 x1=2)	**2 x 1 =2**	**2**
21	$\lambda = \frac{0.6931}{T_{1/2}}$; $= \frac{0.6931}{5.01 \text{ Day}}$ $\lambda = 0.1383 \text{ d}^{-1}$ (or) $\lambda = \frac{0.6931}{T_{1/2}}$; $= \frac{0.6931}{5.01 \text{ x } 24 \text{ x } 60 \text{x } 60}$; $\lambda = 1.6 \text{ x } 10^{-6} \text{ s}^{-1}$	**1** **1**	**2**
22	**Electromagnetic waves:** Electromagnetic waves are **non-mechanical waves** which move with speed equals to the speed of light (in vacuum)	**2**	**2**

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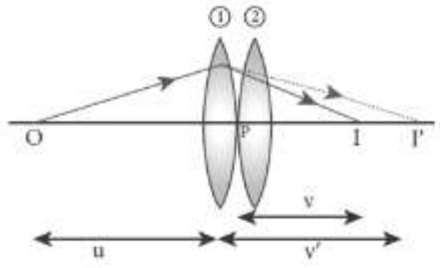
23	**Biasing and its types:** Biasing is **the process of giving external energy to charge carriers to overcome the barrier potential and make them move in a particular direction.** The external voltage applied to the p-n junction is called bias voltage. Depending on the polarity of the external source to the P-N junction we have **two types of biasing (1) Forward bias (2) Reverse bias**	**1 ½** **½**	**2**
24	Focal length, f = 150 cm (or) f = 1.5 m Equation for **power of lens** is, P = $\frac{1}{f}$ Substituting the values, P = $\frac{1}{1.5}$ = 0.67 diopter As the power is positive, it is a converging lens.	**1** **1**	**2**

PART – III

Answer **any six** questions. Question number **33 is compulsory.** 6x3=18

25	**β+ - decay:** In β+ - decay, the **atomic number of the nucleus decreases by one** but **mass number remains the same.** $^{A}_{Z}X \rightarrow {}_{Z-1}^{A}Y + {}^{0}_{1}e + v$. (e.g.) $^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + {}^{0}_{1}e + v$	**2** **1**	**3**
26	The relation between drift velocity of electrons and current in a wire of cross- sectional area A is $V_d = \frac{I}{neA}$; $= \frac{0.2}{8.4x\, 10^{28}\, x\, 1.6\, x\, 10^{-19}\, x\, 0.5\, x\, 10^{-6}}$; = $\frac{2\, x\, 10^{-3}}{6.72}$ **V_d = 0.03 x 10^{-3} ms^{-1}**	**1** **1** **1**	**3**
27	**Focal length of lenses in contact:** Let us consider two lenses ① and ② of focal lengths f_1 and f_2 placed co-axially in contact with each other. Let the object is placed at 'O' beyond the principal focus of ① on the principal axis.  It forms an image at I′ . This image I′ acts as an object for lens ② and hence the final image is formed at 'I' Writing the lens equation for lens ① $\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1}$ ....(1) Writing the lens equation for lens ② $\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2}$ ....(2)	**1** **½**	**3**

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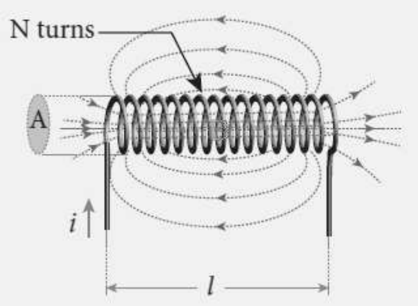
	Adding equation (1) and (2), we get, $\frac{1}{v'} - \frac{1}{u} + \frac{1}{v} - \frac{1}{v'} = \frac{1}{f_1} + \frac{1}{f_2}$ $\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2}$ .... (3) If this combination acts as a single lens of focal length "F", then, $\frac{1}{v} - \frac{1}{u} = \frac{1}{F}$ .... (4) Compare equation (3) and (4) $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ .... (5) For any number of lenses, $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \frac{1}{f_4} + ...$ Let P_1, P_2, P_3, P_4 .... be the power of each lens then the net power of the lens combination, $P = P_1 + P_2 + P_3 + P_4 + ...$ Let m_1, m_2, m_3, m_4 .... be the magnification of each lens then the net magnification of the lens combination, $m = m_1 \times m_2 \times m_3 \times m_4 \times ....$	½ 1	
28	**Current sensitivity of a galvanometer:** It is defined as the deflection produced per unit current flowing through it. $I_s = \frac{\theta}{I}$; $= \frac{NBA}{K}$; $= \frac{1}{G}$ **Methods to increase current sensitivity of galvanometer:** By increasing the **number of turns (N)** By increasing the **magnetic induction (B)** By increasing the **area of the coil (A)** By decreasing the **couple per unit twist** of the suspension wire.	1 2	3
29	**Number of photons emanate per second:** $n_P = \frac{P}{E} = \frac{P\lambda}{hc}$; $= \frac{50 \times 10^3 \times 640 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^8}$; $= \frac{32000 \times 10^{-6}}{19.8 \times 10^{-26}}$; $= 1616.16 \times 10^{20}$ $\mathbf{n_P = 1.6 \times 10^{17}\ s^{-1}}$	1 1 1	3
30	**Self-inductance of a long solenoid (L):** Consider a long solenoid of length 'l', area of cross section 'A' having 'N' number of turns. Let 'n' be number of turns per unit length (i.e.) turn density. When an electric current 'i' is passed through the coil, a magnetic field at any point inside the solenoid is, $B = \mu_0\, n\, i$  Due to this field, the magnetic flux linked with the solenoid is, $\phi_B = \oint \vec{B}.\vec{dA} = \oint B\,A \cos 90^0 = B\,A$	1	3

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$\phi_B = [\mu_0 n\, i]\, A$

Hence the total magnetic flux linked (i.e.) flux linkage 1

$N\phi_B = N\, \mu_0\, n\, i\, A = (n\, l)\, \mu_0\, n\, i\, A$

$N\phi_B = \mu_0\, n^2\, \boldsymbol{i\, A\, l}$

Let 'L' be the self-inductance of the solenoid, then

$L = \frac{N\,\phi_B}{i} = \frac{\mu_0 n^2 i A\, l}{i}$; $L = \mu_0\, n^2\, \boldsymbol{A\, l}$ 1

If the solenoid is filled with a dielectric medium of relative permeability 'μ_r', then $L = \mu_0\, \mu_r\, n^2\, \boldsymbol{A\, l} = \mu\, n^2\, \boldsymbol{A\, l}$

Thus, the inductance depends on

(i) Geometry of the solenoid

(ii) Medium present inside the solenoid

31

Interference	Diffraction
Superposition of two waves	Bending of waves around edges
Superposition of waves from two Coherent sources.	Superposition wave fronts emitted from various points of the same wave front.
Equally spaced fringes.	**Unequally spaced fringes**
Intensity of all the bright fringes is almost same	**Intensity falls rapidly** for higher orders
Large number of fringes are obtained	**Less number** of fringes are obtained

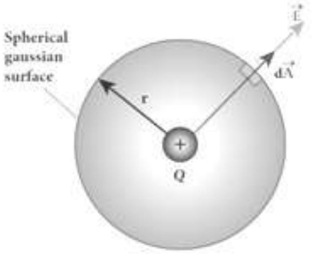
3 3

32

Gauss law from Coulomb's law:

Consider a charged particle of charge '+q'

Draw a Gaussian spherical surface of radius 'r' around this charge. 1



Due to symmetry, the electric field $\vec{E}$ at all the points on the spherical surface have same magnitude and radically outward in direction.

If a test charge 'q_0' is placed on the Gaussian surface, by Coulomb law the force acting it is, $|\vec{F}| = \frac{1}{4\pi\varepsilon_0}\frac{Qq_0}{r^2}$

By definition, the electric field, $|\vec{F}| = \frac{|\vec{F}|}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ .... (1) 1

Since the area element is along the electric field, we have $\theta = 0^0$.

Hence the electric flux through the Gaussian surface is,

$$\Phi_E = \oint \vec{E}.\vec{dA}\ ; = \oint E\, dA \cos 0^0\ ; = E \oint dA$$

Here $\oint dA = 4\pi r^2 \longrightarrow$ area of Gaussian sphere. put in equation (1) 1

$\Phi_E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \times 4\pi r^2$; $\therefore\ \Phi_E = \frac{Q}{\varepsilon_0}$ .This is known as Gauss law

3

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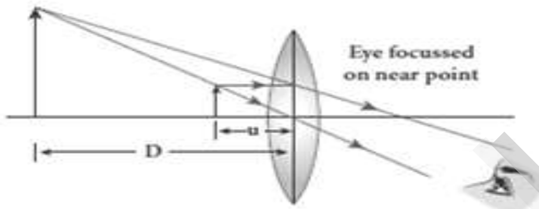
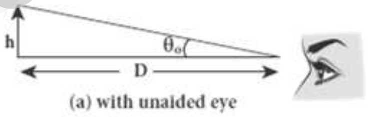
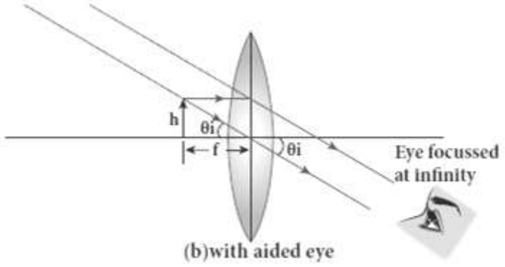
33	$E_g = \frac{hc}{\lambda}$; Therefore, $\lambda = \frac{hc}{E_g}$; = $\frac{6.6 \text{ x } 10^{-34} \text{ x } 3 \text{ x } 10^{8}}{1.875 \text{ x } 1.6 \text{ x } 10^{-19}}$; = 660 nm The wavelength 660 nm corresponds to **red colour** light.	1 1 ½ ½	3

PART – IV

Answer **all** the questions. 5x5=25

34 (a) (i)	**Simple microscope - Near point focusing:** A simple microscope is a **single magnifying lens of small focal length.** In near point focusing, object distance ‘u’ is less than ‘f’ The image is formed at near point or least distance ‘D’ of distinct vision.	1	5
(ii)	The magnification ‘m’ is given by, $m = \frac{v}{u}$ Using lens equation, $m = 1 - \frac{v}{f}$; substitute, $v = -D$ $\mathbf{m = 1 + \frac{D}{f}}$ 	1	
	Simple microscope - Normal focusing: Here the image is formed at infinity. So we will not get direct practical relation for magnification. Hence we can practically use the angular magnification.  (a) with unaided eye	1	
	The angular magnification is defined as the ratio of angle (θ_i) subtended by the image with aided eye to the angle (θ_O) subtended by the object with unaided eye.  (b)with aided eye That is, $m = \frac{\theta_0}{\theta_i}$ .... (1)	1	
	For unaided eye, $\tan\theta_0 \approx \theta_0 = \frac{h}{D}$ For aided eye, $\tan\theta_i \approx \theta_i = \frac{h}{f}$ Thus equation (1) becomes, $m = \frac{\theta_0}{\theta_i} = \frac{\left(\frac{h}{D}\right)}{\left(\frac{h}{f}\right)}$; $m = \frac{D}{f}$	1	

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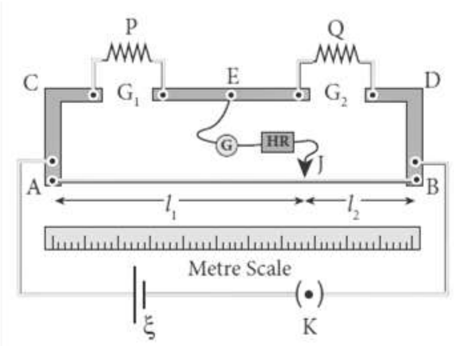
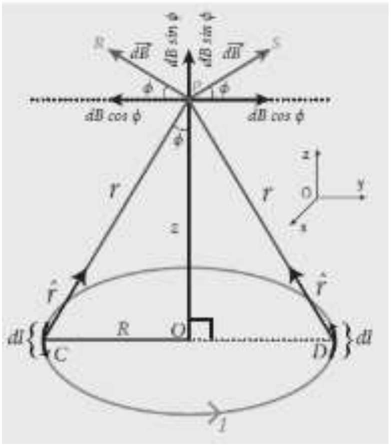
34 (b)	**Meter bridge:**  **Metre Bridge** is another form of **Wheatstone's bridge.** It consists of uniform manganin wire AB of 1m length. This wire is stretched along a metre scale between two copper strips C and D. E is another copper strip mounted with two gaps G_1 and G_2. An unknown resistance P is connected in G_1 and standard resistance connected in G_2 A jockey J is connected from E through a galvanometer G and high resistance HR. A Lechlanche cell ξ and key K is connected across the bridge wire. The position of jockey is adjusted so that the **galvanometer shows zero deflection**. Let the point be 'J' The lengths AJ and JB now replace the resistance R and S of the Wheatstone's bridge. Then $\frac{P}{Q} = \frac{R}{S}$; = $\frac{R'AJ}{R'JB}$. Where R' ⟶ resistance per unit length, $\frac{P}{Q} = \frac{AJ}{JB} = \frac{l_1}{l_2}$ ....(1) ; (or) P = Q $\frac{l_1}{l_2}$ ....(2) **Due to imperfect contact of wire at its ends, some resistance might be introduced at the contact. These are called end resistances.** By interchange P and Q, this error can be eliminated, and the average value of P is found. Let l be the length and r be the radius of wire, its specific resistance (resistivity) is given be. $\rho = \frac{\rho A}{l}$; = $\frac{\rho \pi r^2}{l}$ ....(3)	1 1 1 1 1	5
35 (a)	**<u>Magnetic field due to current carrying circular coil:</u>** Consider a circular coil of radius 'R' carrying a current 'I' in anti-clock wise direction. Let 'P' be the point on the axis at a distance 'z' from centre 'O'  Consider two diametrically opposite line elements of the coil of each of length $\vec{dl}$ at C and D. Let $\vec{r}$ be the vector joining the current element $I\,\vec{dl}$ at C to the point P. **According to Biot - Savart law**, The magnitude of $d\vec{B}$ is $d\vec{B} = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}\,\hat{n}$ The magnetic field at 'P' due to the current element $I\vec{dl}$ is, $d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,dl}{r^2}\,\hat{n} \because \theta = 90^0]$ Here, $d\vec{B}$can be resolved in to two components. $d\vec{B}\sin\theta$ – horizontal component (Y - axis) $d\vec{B}\cos\theta$ – vertical component (Z - axis)	1 1	5

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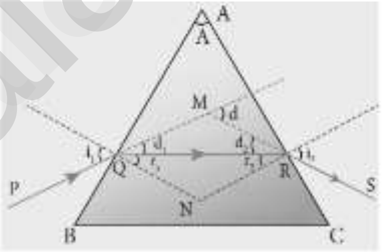
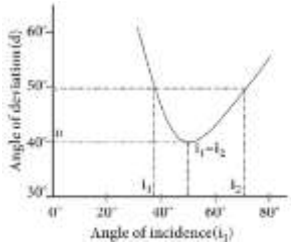
	Here horizontal components of each element cancel each other. But vertical components alone contribute to total magnetic field at the point 'P' $\vec{B}= \int d\vec{B} = \int dB \sin\phi\,\hat{k}$; $\vec{B} = \frac{\mu_0 I}{4\pi}\int \frac{dl}{r^2}\sin\phi\,\hat{k}$ .... (1) Also from ΔOCP, $\sin\phi = \frac{R}{(R^2+Z^2)^{\frac{1}{2}}}$ and $r^2 = R^2 + z^2$ But from equation (1) $\vec{B}= \frac{\mu_0 I}{4\pi}\int \frac{dl}{(R^2+Z^2)}\frac{R}{(R^2+Z^2)^{\frac{1}{2}}}\hat{k}$ $\vec{B}= \frac{\mu_0 I R}{4\pi(R^2+Z^2)^{\frac{3}{2}}}\int dl\,\hat{k}$, Where, $\int dl = 2\pi R$ →total length of the coil. $\vec{B}= \frac{\mu_0 I R}{4\pi(R^2+Z^2)^{\frac{3}{2}}}[2\pi R]\,\hat{k}$; $\boldsymbol{\vec{B} = \frac{\mu_0 I R^2}{2(R^2+Z^2)^{\frac{3}{2}}}\hat{k}}$ If the circular coil contains N turns , then the magnetic field $\vec{B} = \frac{\mu_0 N I R^2}{2(R^2+Z^2)^{\frac{3}{2}}}\hat{k}$ The magnetic field at the centre of the coil z=0 $\vec{B} = \frac{\mu_0 N I}{2R}\hat{k}$	1 1 1	
35 (b)	**Angle of deviation (d) :** Let 'ABC' be the section of triangular prism. Here face 'BC' is grounded and it is called base of the prism. The other two faces **'AB' and 'AC' are polished which are called refracting faces.** The angle between two refraction faces is called angle of the prism 'A'  Here, 'PQ' be incident ray, 'QR' be refracted ray and 'RS' be emergent ray. The angle between incident ray and emergent ray is called angle of deviation (d). Let QN and RN be the normal drawn at the points Q and R The incident and emergent ray meet at a point M From figure, $\angle MQR = d_1 = i_1 - r_1$ and $\angle MRQ = d_2 = i_2 - r_2$ Then total angle of deviation, $d = d_1 + d_2$ $d = (i_1 - r_1) + (i_2 - r_2)$; $d = (i_1 + i_2) + (r_1 + r_2)$ ....(1) In the quadrilateral AQNR, $\angle Q = \angle R = 90^0$ Hence $A + \angle QNR = 180^0$ (or) $A = 180^0 - \angle QNR$ .... (2) In ΔQNR, $r_1 + r_2 + \angle QNR = 180^0$; $r_1 + r_2 = 180^0 - \angle QNR$---------(3) From equation (2) and (3) $A = r_1 + r_2$ .... (4) 	1 1 1	5

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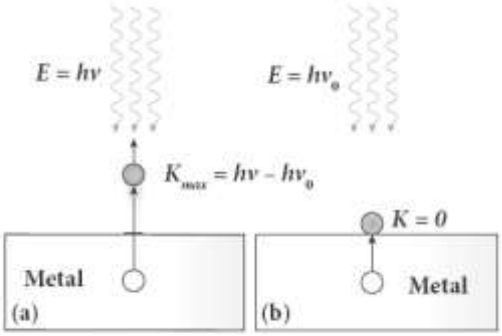
	Put equation (4) in equation (1), $d = (i_1 + i_2) - A$ ....(5) Thus **the angle of deviation depends** on, (1) The angle of incidence (i_1) (2) The angle of the prism (A) (3) The material of the prism (n) (4) The wavelength of the light (λ) **Angle of minimum deviation (D):** A graph is plotted between the angle of incidence along x-axis and angle of deviation along y-axis. From the graph, as angle of incidence increases, the angle of deviation decreases, reaches a minimum value and then continues to increase. The **minimum value of angled of deviation** is called angle of minimum deviation (D). At minimum deviation, (1) $i_1 + i_2$ (2) $r_1 + r_2$ (3) Refracted ray 'QR' is parallel to the base 'BC' of the prism. **Refractive index of the material of the prism (n):** At angle of minimum deviation, $i_1 = i_2 = i$; $r_1 = r_2 = r$ i_1 and r_1 values substitute in equation (4) and (5) $A = r + r = 2r$ (or) $r = \frac{A}{2}$ .... (6) and $D = (i + i) - A = 2i - A$ (or) $2i = A + D$ $i = \frac{A+D}{2}$ .... (7); Then by Snell's law, $n = \frac{\sin i}{\sin r}$; $n = \frac{\sin\left[\frac{A+D}{2}\right]}{\sin\left[\frac{A}{2}\right]}$	1 1	
36 (a)	**Einstein's explanation of photoelectric equation:** When a photon of energy 'hv' is incident on a metal surface, it is completely absorbed by a single electron and the electron is ejected. In this process, the energy of incident photon is utilized in two ways.  (1) Part of the photon energy is used for the ejection of the electrons from the metal surface and it is called work function (ϕ_0) (2) Remaining energy as the kinetic energy (K) of the ejected electron. From the **law of conservation of energy**, $hv = \phi_0 + K$ (or) $hv = \phi_0 + \frac{1}{2}mv^2$ .... (1) Where m → mass of the electron and v → velocity	1 1	5

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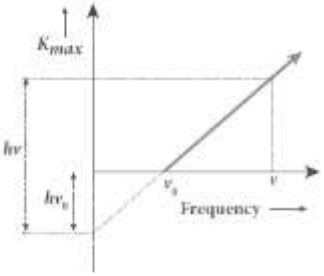
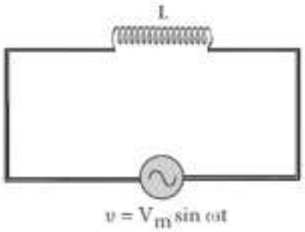
	At threshold frequency, the kinetic energy of ejected electrons will be zero. (i.e.) when $v = v_0$ then K = 0 Thus equation (1) becomes $hv_0 = \phi_0$ ....(2) Put equation (2) in (1) $hv = hv_0 + \frac{1}{2}mv^2$........... (3) The equation (3) is known as **Einstein's photoelectric equation.**  If the electron does not lose energy by internal collisions, then it is emitted with maximum kinetic energy K_{max}. Then $hv = hv_0 + \left[\frac{1}{2}mv^2\right]_{max}$ (or) $\frac{1}{2}mv_{max}^2 = hv - hv_0$ (or) $K_{max} = hv - \phi_0$.................... (4) A graph between maximum kinetic energy K_{max} of the photoelectron and frequency v of the incident light is a straight line.	1 1 1	
36 (b)	**AC circuit containing pure Inductor:**  Let a pure inductor of inductance 'L' connected across an alternating voltage source 'v. . The instantaneous value of the alternating voltage is given by, $v = V_m \sin \omega t$ ---- (1) Let 'i' be the alternating current flowing in the circuit due to this voltage, which induces a self-inducted emf (back emf) across "L" and it is given by $\in = -L\frac{di}{dt}$ ---- (2) From Kirchhoff's loop rule, $v - (-\in) = 0$ (or) $v = -\in$ $V_m \sin \omega t = --(-L\frac{di}{dt})$; $V_m \sin \omega t = L\frac{di}{dt}$ $\therefore di = \frac{V_m}{L} \sin \omega t\, dt$ Integrate on both sides, $i = \frac{V_m}{L}\int \sin \omega t\, dt$; $i = \frac{V_m}{L}\left(\frac{-\cos \omega t}{\omega}\right)$; $i = \frac{V_m}{\omega L}\left[-\sin\left(\frac{\pi}{2} - \omega t\right)\right]$; $i = \frac{V_m}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$ $i = I_m \sin\left(\omega t - \frac{\pi}{2}\right)$ ---- (3) Where, $\frac{V_m}{\omega L} = I_m$ → Peak value of AC From equation (1) and (3), it is clear that, current lags behind the applied voltage by $\frac{\pi}{2}$. this is indicated in the phasor and wave diagram.	1 1 1 1	5

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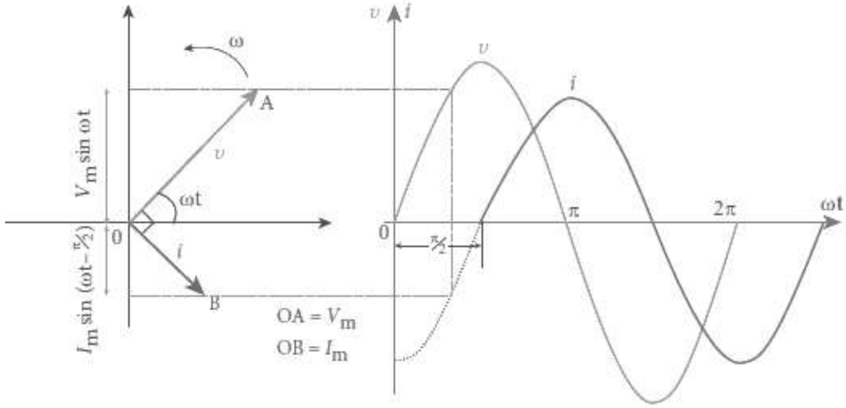
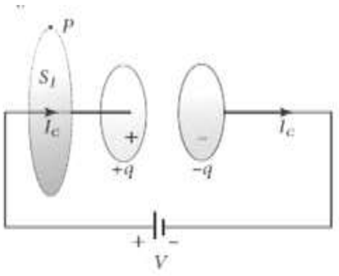
	 **Inductive reactance (X_L) :** In pure inductive circuit, 'ωL' is the resistance offered by the inductor and it is called inductive reactance (X_L). Its unit is ohm (Ω) $X_L = \omega L = 2\pi fL$	1	
37(a)	**Frequency modulation (FM)** If the frequency of the carrier signal is modified according to the instantaneous amplitude of the baseband signal, then it is called frequency modulation (FM) **Advantages of FM:** 1. Large decrease in noise. This leads to an increase in signal-noise ratio. 2. The operating range is quite large. 3. The transmission efficiency is very high as all the transmitted power is useful. 4. FM bandwidth covers the entire frequency range which humans can hear. Due to this, FM radio has better quality compared to AM radio. **Limitations of FM:** 1. FM requires a much wider channel. 2. FM transmitters and receivers are more complex and costly. 3. In FM reception, less area is covered compared to AM.	3 2	5
37 (b)	**Maxwell's corrections to Ampere's circuital law:** According to Faraday's law of electromagnetic induction, the change in magnetic field produces an electric field. Mathematically  $\oint \vec{E}.\vec{dl} = -\frac{\partial}{\partial t}\Phi_B = -\frac{\partial}{\partial t}\oint \vec{B}.\vec{dA}$ It implies that the electric field $\vec{E}$ is induced along a closed loop by the changing magnetic flux ϕ_B in the region encircled by the loop. The converse of this statement that is change in electric flux produces magnetic field is explained by Maxwell. $\oint \vec{B}.\vec{dl} = -\frac{\partial}{\partial t}\Phi_E = -\frac{\partial}{\partial t}\oint \vec{E}.\vec{dA}$ This is known as Maxwell's law of induction.	1 1	5

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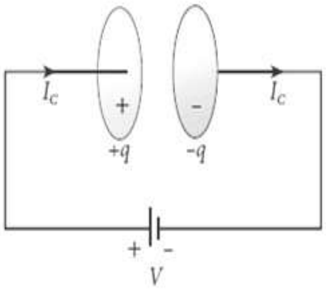
To understand how the changing electric field produces magnetic field, let us consider the situation of charging a parallel plate capacitor.

The electric current passing through the wire is the conduction current ‘I_C’.

This current generates magnetic field around the wire connected across the capacitor. To calculate the magnetic field at a point ‘P’ near the wire, let us consider an amperian loop which encloses the surface S_1 . **1**



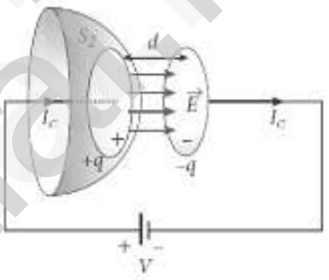
Thus from **Ampere circuital law,** $\oint \vec{\mathbf{B}}.\vec{\mathbf{d}l} = \mu_0 I_C$ ....(1)

Suppose the same loop is enclosed by balloon shaped surface S_2, then the boundaries of two surfaces are same but shape of the enclosing surfaces are different. Ampere’s law does not depend on shape of the enclosing surface and hence the integrals will give the same answer.

But there is **no current in between the plates of the capacitor, the magnetic field on the surface is zero.** So the magnetic field at ‘P’ is zero. Hence, $\oint \vec{B}.\vec{dl} = 0$ ....(2) **1**

Here there is an inconsistency between equation (1) and (2). Maxwell resolved this inconsistency as follows.

Due to external source, the capacitor gets charged up because of current flowing through the capacitor. This produces an increasing electric field between the capacitor plates. This time varying electric field (or flux) existing between the plates of the capacitor also produces a current known as displacement current. **1**



From Gauss’s law, $\phi_E = \oint \vec{E}.\vec{dA} = EA = \frac{q}{\varepsilon_0}$

The change in electric flux is, $\frac{d\phi_E}{dt} = \frac{1}{\varepsilon_0}\frac{dq}{dt} = \frac{1}{\varepsilon_0} I_d$

$\therefore I_d = \varepsilon_0 \frac{d\phi_E}{dt}$. Where, $\frac{dq}{dt} = I_d$ → Displacement Current

The displacement current can be defined **as the current which comes in to play in the region in which the electric field and the electric flux are changing with time.**

So Maxwell modified Ampere’s law as

$$\oint \vec{B}.\vec{dl} = \mu_0 I = (I_c + I_d) \quad ....(3)$$

Where, $I = I_c + I_d$ → Total Current

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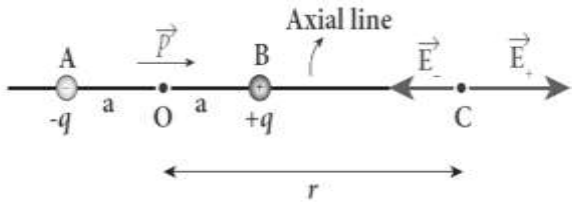
38 (a)

Electric field due to dipole on its axial line:

Consider a dipole AB along X - axis. Its dipole moment be p = **2**qa and its direction be along − q to + q.

Let 'C' be the point at a distance 'r' from the midpoint 'O' on its axial line.

1



Electric field at C due to +q

1

$$\vec{E}_+ = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}$$

Electric field at C due to −q

$$\vec{E}_- = -\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$$

Since +q is located closer to point 'C' than −q , $\vec{E}_+ > \vec{E}_-$.

1

By superposition principle, the total electric field at 'C' due to dipole is,

$$\vec{E}_{tot} = \vec{E}_+ + \vec{E}_-$$

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$$

5

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p} \;;$$

1

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{(r+a)^2-(r-a)^2}{(r-a)^2\,(r+a)^2}\right]\hat{p}$$

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{r^2+a^2+2ra-r^2-a^2+2ra}{((r-a)\;\;(r+a))^2}\right]\hat{p}$$

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{4ra}{(r^2-a^2)^2}\right]\hat{p}$$

Here the direction of total electric field is the dipole moment $\hat{p}$

1

If r >>a, then neglecting a^2. We get $\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0} q\left[\frac{4ra}{r^4}\right]\hat{p}$;

$$= \frac{1}{4\pi\varepsilon_0} q\left[\frac{4a}{r^3}\right]\hat{p}$$

$$\vec{E}_{tot} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3} \qquad [q\,2a\hat{p} = \vec{p}]$$

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38 (b)	**Nuclear reactor:** Nuclear reactor is a system in which **the nuclear fission takes place in a self-sustained controlled manner**. The energy produced is used either for **research purpose or for power generation**. The first nuclear reactor was built in the year 1942 at Chicago, USA.	1	5
	Moderators: The probability of initiating fission by fast neutron in another nucleus is very low. Therefore, slow neutrons are preferred for sustained nuclear reactions. The **moderator is a material used to convert fast neutrons into slow neutrons.** Usually the **moderators having mass comparable to that of neutrons.** Hence, these light nuclei undergo collision with fast neutrons and the speed of the neutron is reduced. **Most of the reactors use water, heavy water (D_2O) and graphite as moderators.**	2	
	Control rods: The control rods are used **to adjust the reaction rate**. During each fission, on an **average 2.5 neutrons are emitted**. In order to have the controlled chain reactions, **only one neutron is allowed to cause fission and the remaining neutrons are absorbed by the control rods.** Usually **cadmium or boron acts as control rod** material.	1	
	Coolants: The cooling system removes the heat generated in the reactor core. **Ordinary water, heavy water and liquid sodium** are used as **coolant** since they have very high specific heat capacity and have large boiling point under high pressure. **This coolant passes through the fuel block and carries away the heat to the steam generator through heat exchanger**. The steam runs the turbines which produces electricity in power reactors.	1	

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