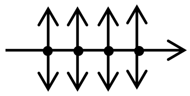
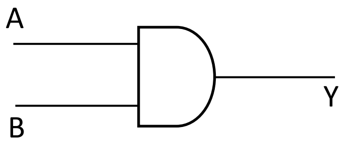
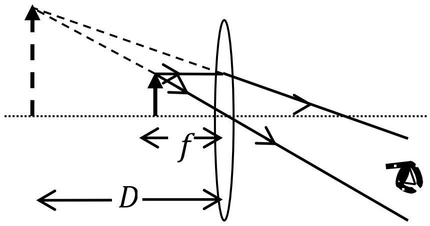
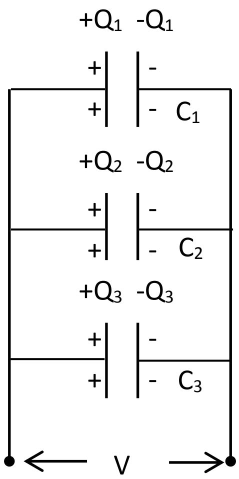
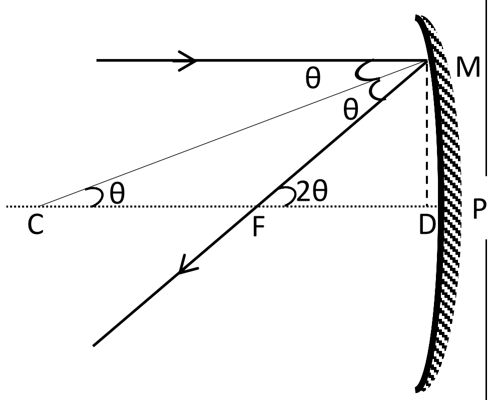
Key answers – Preparatory I 2021 – 22

Q. No.	Answers	Marks
I. 1	**What are matter waves?** The waves associated with moving material particle are matter waves.	1
2	**What do you mean by diffraction of light?** The bending of light around the edges of small obstacles and enter the region where we would expect a shadow is called diffraction of light.	1
3	**Mention the unit of electric dipole moment.** coulomb metre (Cm).	1
4	**The susceptibility of a magnetic material is 89. What is its relative permeability?** 90 ($\mu_r = 1 + \chi = 1 + 89 = 90$)	1
5	**What is the wavelength range of visible light?** 700 nm to 400 nm	1
6	**Represent unpolarized light with a ray diagram.** 	1
7	**Write the logic symbol of AND gate.** 	1
8	**What is an intrinsic semiconductor?** A pure form of semiconductor is called intrinsic semiconductor.	1
9	**What is the source of stellar energy?** Thermonuclear fusion is the source of energy output in the interior of stars.	1
10	**Which magnetic material will exhibit hysteresis property?** Ferromagnetic materials	1
II. 11	**What is a polaroid? Write one use.** A polaroid is a thin plastic like sheet consists of long chain molecules aligned in a particular direction. **Use: i.** To control intensity in sunglasses, **ii.** Control intensity in window panes, **ii.** Used in photographic camera, **iv.** Used in 3D movie cameras. **(ANY ONE)**	1 1
12	**Write Einstein's equation for photoelectric effect and explain the terms involved.** Maximum kinetic energy, $K_{max} = h\nu - \Phi_o$ h – Plank's constant, ν – frequency of radiation, Φ_o – work function.	1 1
13	**Write the expression for radius of a circle when a charged particle moves perpendicular to magnetic field. Explain the terms.** Radius of the circular path, $r = \frac{mv}{qB}$, m – mass of the charged particle and v – velocity of the charged particle, q – charge of the particle, B – magnetic field.	1 1
14	**Define a) Magnetic declination, b) Magnetic inclination.** Magnetic declination (D) at the place is the angle between true geographic north direction and the north shown by the magnetic compass needle. Magnetic inclination (I) at a place is the angle between the earth's total magnetic field at a place and horizontal drawn in magnetic meridian.	1 1

15	**Draw the ray diagram of image formation in the case of simple microscope.** 	1 1
16.	**Name two electron emission processes.** i. Thermionic emission, ii. Field emission, iii. Photo – electric emission **(Any TWO)**	1 each
17	**State and explain Faraday's law of electromagnetic induction.** The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit. Let $d\emptyset_B$ be the changes in magnetic flux in a time interval dt, then magnitude of induced emf, $\lvert\varepsilon\rvert = \left\lvert\frac{d\emptyset_B}{dt}\right\rvert$ If a coil has N turns then, $\lvert\varepsilon\rvert = N\left\lvert\frac{d\emptyset_B}{dt}\right\rvert$.	1 1
18	**Write the expression for limit of resolution of telescope and explain the terms.** Limit of resolution of telescope, $\Delta\theta \simeq \frac{0.61\lambda}{a}$, λ – wavelength of light, a – radius of aperture of the objective of telescope.	1 1
III. 19	**State and explain Coulomb's inverse square law in electrostatics.** The mutual electrostatic force between two point charges is directly proportional to the product of magnitude of charges and inversely proportional to the square of the distance between the charges and acted along the line joining the two charges. If q_1 and q_2 are two point charges separated by a distance r in free space, then the magnitude of force between them is given by, $F \propto \frac{\lvert q_1 q_2\rvert}{r^2}$ OR $F = \frac{1}{4\pi\varepsilon_0}\frac{\lvert q_1 q_2\rvert}{r^2}$ in free space, where $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ Nm^2C^{-2} is the constant of proportionality and $\varepsilon_0 = 8.854 \times 10^{-12}$ $C^2N^{-1}m^{-2}$ is the permittivity of free space.	1 2
20	**Derive the expression for equivalent capacitance when capacitors are connected in parallel.**  Let capacitors of capacitances C_1, C_2 and C_3 are connected in parallel as in the diagram. A battery of potential difference V is connected across the capacitors. The capacitors have charges $+Q_1, -Q_1$, $Q_2, -Q_2, Q_3$ and $-Q_3$ respectively such that $Q_1 = C_1V$, $Q_2 = C_2V$ and $Q_3 = C_3V$. Let this combination of capacitors be replaced by a single capacitor called effective capacitor of effective capacitance C_P. The equivalent capacitor is one with charge, $Q = Q_1 + Q_2 + Q_3$ and potential difference V. $Q = C_PV = C_1V + C_2V + C_3V$ The effective capacitance of combination, $C_P = C_1 + C_2 + C_3$.	1 (diagram & explanation) 1 1

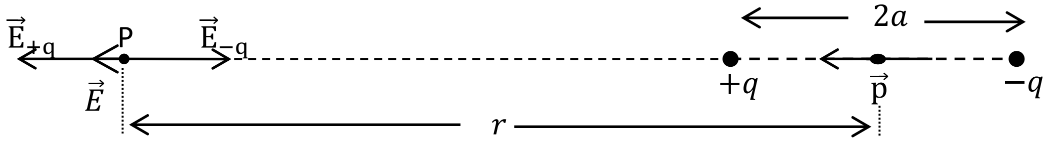
21	**Derive the relation, $\vec{J} = \sigma\vec{E}$ by Ohm's law.** Consider a conductor of length l with area of cross section A carrying a current I. Let V be the applied potential difference. According to Ohm's law, $V = IR$, where R – resistance of conductor. If ρ – is the resistivity of material of conductor then $R = \frac{\rho l}{A}$. Hence $V = I\frac{\rho l}{A}$ or $\frac{I}{A} = \frac{V}{\rho l}$ But $\frac{I}{A} = J$, Current density. Therefore, $J = \frac{V}{\rho l}$ or $\vec{J} = \sigma\vec{E}$. Since $\frac{V}{l} = E$, electric field and $\frac{1}{\rho} = \sigma$, conductivity.	1 1 1
22	**Obtain the expression for mechanical force on a current carrying conductor placed in a magnetic field.** Consider a conductor of length l area of cross section A carrying current I placed in a uniform magnetic field, $\vec{B}$. Let $\vec{v_d}$ be the average drift velocity of the mobile charge carriers. These moving charges in the magnetic field will experience a force is given by, $\vec{F} = q\left(\vec{v_d} \times \vec{B}\right) = (neAl)\left(\vec{v_d} \times \vec{B}\right) = (neA\vec{v_d})\left(l \times \vec{B}\right)$ OR $\vec{F} = I(\vec{l} \times \vec{B})$ Magnitude of force, $F = IlB\sin\theta$, where θ is angle between length of the conductor and magnetic field.	1 1 1
23	**What is the principle of transformer? Mention two sources of power loss in transformer.** Mutual induction. i. Resistance of the windings, ii. Flux leakage, iii. Eddy currents, iv. Hysteresis **(Any TWO)**	1 1 each
24	**Derive the expression for energy stored in a coil.** A back emf ε is established due to the current I in a solenoid of self inductance L. Power, $P = \frac{dW}{dt} = \lvert\varepsilon\rvert I = LI\frac{dI}{dt}$. Since $\lvert\varepsilon\rvert = L\frac{dI}{dt}$. Work done, $W = \int dW = \int_0^I LIdI = L\int_0^I IdI = L\left[\frac{I^2}{2}\right]_0^I = \frac{1}{2}LI^2$. This work done is stored as magnetic potential energy. ∴ Magnetic energy stored, $U_B = \frac{1}{2}LI^2$.	1 1 1
25	**Show that, f = $\frac{R}{2}$ for a spherical mirror.** Consider a concave mirror with pole P and centre of curvature C. Consider a parallel ray parallel to the principal axis striking the mirror at M. Let θ be the angle of incidence and MD be the perpendicular from M on the principal axis.  $\angle MCD = \theta$ & $\angle MFD = 2\theta$; $\tan\theta = \frac{MD}{CD}$ and $\tan 2\theta = \frac{MD}{FD}$ Since θ is small, $\tan\theta \simeq \theta$ and $\tan 2\theta \simeq 2\theta$. $\frac{MD}{FD} = 2\frac{MD}{CD}$ OR $FD = \frac{CD}{2}$ Since D is very close to P, $FD \simeq FP = f$ and $CD \simeq CP = R$ Therefore, $f = \frac{R}{2}$.	1 (diagram & explanation) 1 1

26. **Distinguish between intrinsic and extrinsic semiconductors.**

Intrinsic semiconductor	Extrinsic semiconductor
Pure semiconductor.	Impure semiconductor.
Tetravalent covalent banded atoms.	Pure semiconductors are doped with impurity atoms.
Number of holes are equal to number of free electrons.	Number of holes are not equal to number of free electrons.
Conductivity is less.	Conductivity is more.
$n_e = n_h = n_i$ where n_e – number of free electrons, n_h – number of holes, n_i – intrinsic charge carrier concentration.	$n_e n_h = {n_i}^2$
Conductivity depends on temperature alone.	Conductivity depends on temperature and the amount of doping.

1 each **(Any THREE)**

IV. 27. **Derive the expression for electric field at a distance along the axis of an electric dipole.**



1 (diagram & explanation)

Consider a point P at a distance r from the midpoint of dipole.

The electric field at P due to charge $-q$ and $+q$ are $\vec{E}_{-q} = -\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$ and $\vec{E}_{+q} = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}$ where $\hat{p}$ is the unit vector along the dipole axis from $-q$ to $+q$. — 1

Total field at P, $\vec{E} = \vec{E}_{+q} + \vec{E}_{-q}$. — 1

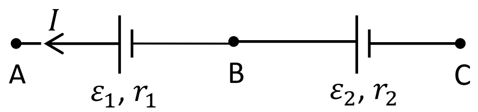
$\vec{E} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\hat{p}$ — 1

$= \frac{q4ar}{4\pi\varepsilon_0(r^2-a^2)^2}\hat{p}$ OR $\vec{E} = \frac{2r\vec{p}}{4\pi\varepsilon_0(r^2-a^2)^2}$. Since $\vec{p} = q2a\hat{p}$. — 1

28. **Define emf of a cell. Derive the expression for equivalent emf and internal resistance when number of cells are connected in series.**

Emf of a cell is the potential difference between the positive and negative electrodes of a cell when no current is flowing through it. — 1

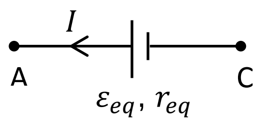
Let the two cells of emf's ε_1 and ε_2 are connected in series. Let r_1 and r_2 be their internal resistances.



1 (diagram & explanation)

Potential difference between A and B, $V_{AB} = \varepsilon_1 - Ir_1$.

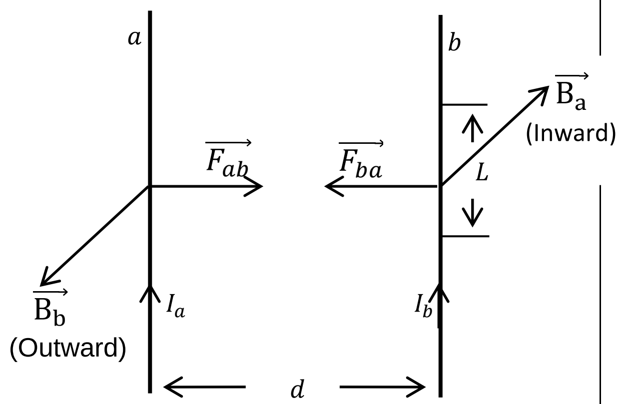
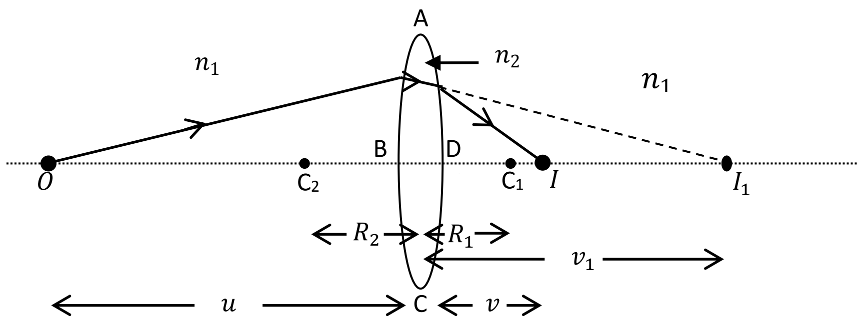
Potential difference between B and C, $V_{BC} = \varepsilon_2 - Ir_2$.

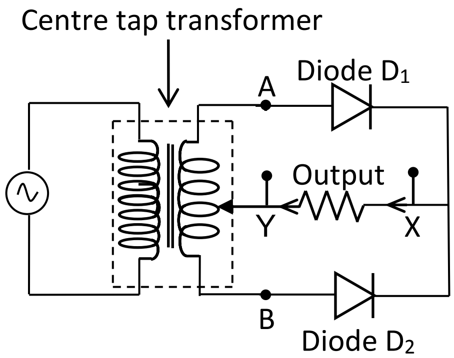
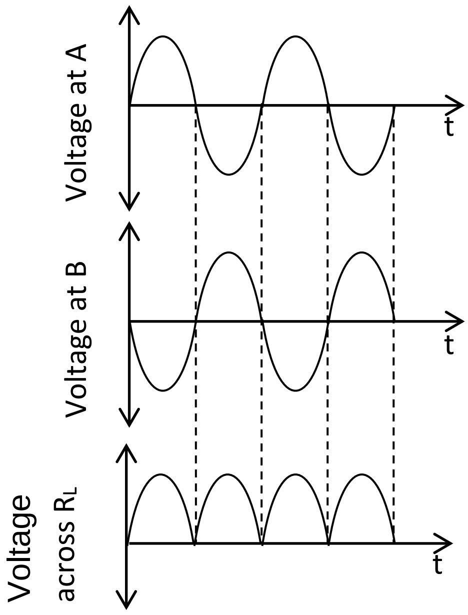


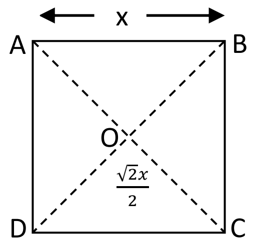
Potential difference between A and C, $V_{AC} = \varepsilon_1 + \varepsilon_2 - I(r_1 + r_2)$ -------- (1) — 1

If we replace this combination of cells by a single cell of emf ε_{eq} and internal resistance r_{eq} between A and C, then $V_{AC} = \varepsilon_{eq} - Ir_{eq}$ -------- (2) — 1

Equating (1) and (2), $\varepsilon_{eq} - Ir_{eq} = \varepsilon_1 + \varepsilon_2 - I(r_1 + r_2)$.

	Comparing, we get $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ and $r_{eq} = r_1 + r_2$. In general for n number of cells, $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2 + \cdots + \varepsilon_n$ and $r_{eq} = r_1 + r_2 + \cdots + r_n$.	1
29	**Obtain the expression for the force between two parallel conductors carrying current and hence define 'ampere'.** Let a and b are two long parallel straight conductors carrying currents I_a and I_b respectively in the same direction. Let the conductors are placed at a distance d apart in air.  The conductor a carrying current I_a produces a magnetic field $\overrightarrow{B_a}$ at all the points along the conductor b and it is given by, $B_a = \frac{\mu_0 I_a}{2\pi d}$. By the right hand rule the direction of B_a is inward. Force on the conductor b carrying current I_b on a length L is given by, $F_{ba} = I_b L B_a = \frac{\mu_0 I_a I_b}{2\pi d} L$. ($\because$ $\theta = 90°$). The force is towards the conductor a. We can find that force on a by b similarly. The force is equal in magnitude and opposite in direction. Therefore, $\overrightarrow{F_{ba}} = -\overrightarrow{F_{ab}}$. Let f_{ba} represent the magnitude of force F_{ba} per unit length. Then $f_{ba} = \frac{\mu_0 I_a I_b}{2\pi d}$. The conductors attract each other. Ampere is that current which when flowing in each of two infinitely long straight parallel conductors of negligible cross section placed 1 metre apart in vacuum produces a force of 2 x 10^{-7} newton per metre length between the conductors.	1 (diagram & explanation) 1 1 1 1
V. 30	**Assuming the formula for refraction at a spherical surface derive lens maker's formula.**  Consider a thin convex lens of focal length f, refractive index of the medium of lens n_2 placed in a medium of refractive index n_1. Let C_1 and C_2 be the centres of curvature and R_1 and R_2 be the radii of the curvatures. For refraction at the first face ABC, (in the absence of second face ADC) O is the object at a distance u from the pole and I_1 is the image at a distance v_1.	1 (diagram & explanation) Deduct one mark for the diagram without arrow mark

	Applying refraction formula we have, $\frac{n_1}{-u}+\frac{n_2}{v_1}=\frac{n_2-n_1}{R_1}$ ------- (1) For refraction at the second face ADC, I_1 acts as a virtual object at a distance v_1 and I is the image at a distance v from the pole. Applying refraction formula we have, $\frac{n_2}{-v_1}+\frac{n_1}{v}=\frac{n_1-n_2}{R_2}=\frac{n_2-n_1}{-R_2}$ ------- (2) Adding (1) and (2), $\frac{n_1}{-u}+\frac{n_1}{v}=(n_2-n_1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ ---------- (3) Suppose object is at infinity $u=\infty$ and $v=f$ Therefore equation (3) becomes, $\frac{n_1}{f}=(n_2-n_1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ ----------- (4) $\frac{1}{f}=\left(\frac{n_2}{n_1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ OR $\frac{1}{f}=(n_{21}-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ ⇒ Lens maker's formula.	1 1 1 1
31	**Derive the expression for radius of orbit of electron in the n^{th} state of hydrogen atom.** Let an electron of mass m, charge $-e$, revolves in a circular stationary n^{th} orbit of radius r_n. Let v_n be the linear velocity and charge at the center of the atom is $+e$. $Centripetal\ force = Electrostatic\ force\ of\ attraction$ $\frac{mv_n^2}{r_n}=\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_n^2}$ $mv_n^2r_n=\frac{e^2}{4\pi\varepsilon_0}$ -------------- (1) For stationary orbit, angular momentum $L=\frac{nh}{2\pi}$ $mv_nr_n=\frac{nh}{2\pi}$ --------------- (2) where n – quantum number. Squaring (2) $m^2v_n^2r_n^2=\frac{n^2h^2}{4\pi^2}$ --------------- (3) (3) / (1) ⇒ $r_n=\frac{n^2h^2\varepsilon_0}{\pi me^2}$.	1 1 1 1 1
32	**Describe with circuit diagram, the working of full wave rectifier. Show the input and output waveforms.**   During positive half transformer output, A is positive and B is negative, diode D_1 is forward biased and D_2 is reverse biased. Therefore D_1 conducts and D_2 does not. Output current is along XY. During negative half cycle A becomes negative and B is positive. Hence D_2 conducts and D_1 does not. Output voltage is in the same direction along XY. So current flows through R_L over complete cycle of AC input and the current is unidirectional. Thus output voltage is unidirectional as shown in the graph.	1 (diagram) 1 (waveform) 1 1 1

VI. 33	**Charges 2 μC, 4 μC and 6 μC are placed at the three corners A, B and C respectively of a square ABCD of side x metre. Find what charge must be placed at the fourth corner so that the total potential at the centre of the square is zero.**  Given $Q_A = 2\,\mu C, Q_B = 4\,\mu C, Q_C = 6\,\mu C, Q_D = ?$ $AB = BC = CD = CA = x$ From the figure, distance between the center and the corner, $OA = OB = OC = OD = \frac{\sqrt{2}x}{2} = \frac{x}{\sqrt{2}}$. We have electric potential, $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ Potential at centre, $V = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q_A}{\frac{x}{\sqrt{2}}} + \frac{Q_B}{\frac{x}{\sqrt{2}}} + \frac{Q_C}{\frac{x}{\sqrt{2}}} + \frac{Q_D}{\frac{x}{\sqrt{2}}}\right) = 0$ OR $\frac{\sqrt{2}\text{x}9\text{x}10^9}{x}(2\text{x}10^{-6} + 4\text{x}10^{-6} + 6\text{x}10^{-6} + Q_D) = 0$ $\Rightarrow 12\text{x}10^{-6} + Q_D = 0$ OR $Q_D = -12\text{x}10^{-6} = -12\ \mu\text{C}$	1 1 1 1 1
34	**A current of 0.5 A is passed through a wire of length 15 m and uniform cross section of radius 2 x 10^{-3} m. If potential difference of 10 V is applied across the ends of the wire, what is the resistivity of the material?** Given $I = 0.5\,A, l = 15\,m, r = 2\text{x}10^{-3}\,m, V = 10\,V, \rho = ?$ We have resistance, $R = \frac{V}{I}$ $= \frac{10}{0.5} = 20\ \Omega$ Resistivity, $\rho = \frac{RA}{l} = \frac{R(\pi r^2)}{l}$ $= \frac{20\text{x}3.14\text{x}(2\text{x}10^{-3})^2}{15}$ $= \frac{251.2\text{x}10^{-6}}{15} = 16.75\text{x}10^{-6}\ \Omega\text{m}$	1 1 1 1 1
35	**A resistor of 200 Ω and a capacitor of 15 μF are connected in series to a 220 V, 50 Hz ac source.** **Calculate the rms current in the circuit.** **Calculate the rms voltage across the resistor and the capacitor.** Given $R = 200\ \Omega, C = 15\ \mu F, v_{rms} = 200\ \text{V}, \nu = 50\ Hz, I_{rms} = ?,\ v_R = ?, v_C = ?$ We have, rms current I the circuit, $I_{rms} = \frac{v_{rms}}{\sqrt{R^2 + \left(\frac{1}{2\pi\nu C}\right)^2}}$ $= \frac{220}{\sqrt{200^2 + \left(\frac{1}{2\text{x}3.14\text{x}50\text{x}15\text{x}10^{-6}}\right)^2}}$ $= \frac{220}{\sqrt{200^2 + 212.13^2}} = \frac{220}{291.55} = 0.7546\ \text{A}$ rms voltage across resistor, $v_R = I_{rms}R = 0.7546\text{x}200 = 150.92\ \text{V}$ rms voltage across capacitor, $v_C = I_{rms}X_C = 0.7546\text{x}212.13 = 160.07\ \text{V}$	1 1 1 1 1

36	**In Young's double slit experiment the slits are separated by 0.28 mm and the screen is placed at a distance of 1.4 m away from the slits. The distance between the central bright fringe and the fifth dark fringe is measured to be 1.35 cm. Calculate the wavelength of the light used. Also find the fringe width if the screen is moved towards the slits by 0.4 m, for the same experimental set up.** Given $d = 0.28\ mm, D = 1.4\ m, n = 4, x_4 = 1.35\ cm, \lambda = ?,\ D' = 1\ m, \beta = ?$ We have for dark fringe distance, $x_n = \frac{\left(n+\frac{1}{2}\right)\lambda D}{d}$ $\Rightarrow 1.35\text{x}10^{-2} = \frac{\left(4+\frac{1}{2}\right)\lambda\text{x}1.4}{0.28\text{x}10^{-3}}$ OR $\lambda = \frac{1.35\text{x}10^{-2}\text{x}0.28\text{x}10^{-3}\text{x}2}{1.4\text{x}9} = 0.06\text{x}10^{-5}\ m$ OR $600\ nm$ Fringe width, $\beta = \frac{\lambda D'}{d}$ $= \frac{0.06\text{x}10^{-5}\text{x}1}{0.28\text{x}10^{-3}} = 2.143\text{x}10^{-3}$ m	1 1 1 1 1
37	**Half life of U – 238 undergoing α – decay, is 4.5 x 10^9 years. What is the activity of one gram of U – 238 sample?** Given $T_{1/2} = 4.5\text{x}10^9\ years, R = ?$ Number of atoms (nuclei) present in 1 g of U – 238, $N = \frac{mN_A}{M} = \frac{1\text{x}6.023\text{x}10^{23}}{238} =$ $2.53\text{x}10^{21}$ nuclei or atoms. Half life, $T_{\frac{1}{2}} = \frac{0.693}{\lambda}$ OR Decay constant, $\lambda = \frac{0.693}{T_{\frac{1}{2}}}$ $= \frac{0.693}{4.5\text{x}10^9\text{x}3.154\text{x}10^7} = \frac{0.693}{14.193\text{x}10^{16}}$ $= 0.0488\text{x}10^{-16}\ s^{-1}$ We have activity, $R = \lambda N$ $= 0.0488\text{x}10^{-16}\text{x}2.53\text{x}10^{21} = 1.235\text{x}10^4\ s^{-1}$	1 1 1 1 1

Note: i) Alternate method should be considered.

ii) Deduct one mark for answers without proper unit in Part D