Competency Focused Practice Questions

Physics (Volume 1) | Grade 12

Co-created by
CBSE Centre for Excellence in Assessment
and
Educational Initiatives

PREFACE

Assessments are an important tool that help gauge learning. They provide valuable feedback about the effectiveness of instructional methods; about what students have actually understood and also provide actionable insights. The National Education Policy, 2020 has outlined the importance of competency-based assessments in classrooms as a means to reform curriculum and pedagogical methodologies. The policy emphasizes on the development of higher order skills such as analysis, critical thinking and problem solving through classroom instructions and aligned assessments.

Central Board of Secondary Education (CBSE) has been collaborating with Educational Initiatives (Ei) in the area of assessment. Through resources like the Essential Concepts document and A-Question-A-Day (AQAD), high quality questions and concepts critical to learning have been shared with schools and teachers.

Continuing with the vision to ensure that every student is learning with understanding, Question Booklets have been created for subjects for Grade 10th and 12th. These booklets contain competency-based items, designed specifically to test conceptual understanding and application of concepts.

Process of creating competency-based items

All items in these booklets are aligned to the NCERT curriculum and have been created keeping in mind the learning outcomes that are important for students to understand and master. Items are a mix of Free Response Questions (FRQs) and Multiple-Choice Questions (MCQs). In case of MCQs, the options (correct answer and distractors) are specifically created to test for understanding and capturing specific errors/misconceptions that students may harbour. Each incorrect option can thereby inform teachers on specific gaps that may exist in student learning. In case of subjective questions, each question also has a detailed scoring rubric to guide evaluation of students' responses.

Each item has been reviewed by experts, to check for appropriateness of the item, validity of the item, conceptual correctness, language accuracy and other nuances.

How can these item booklets be used?

There are 226 questions in this booklet.

The purpose of these item booklets is to provide samples of high-quality competency-based items to teachers. The items can be used to–

- get an understanding of what good competency-based questions could look like
- give exposure to students to competency-based items
- assist in classroom teaching and learning
- get inspiration to create more such competency-based items

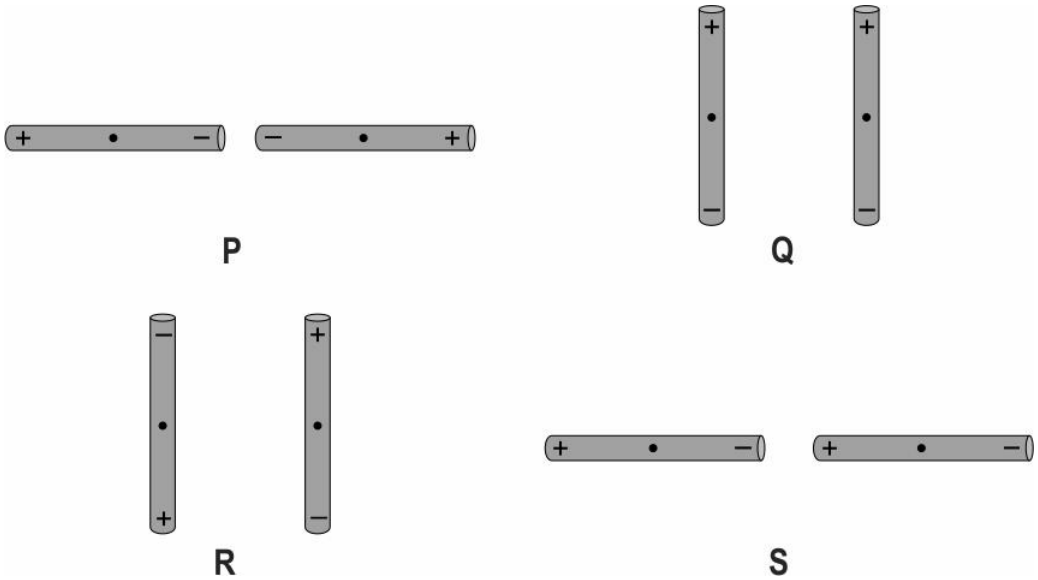
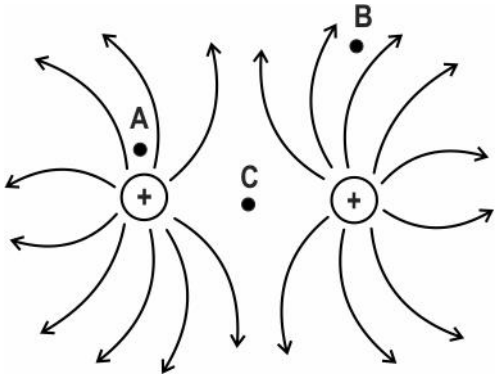
Students can also use this document to understand different kinds of questions and practice specific concepts and competencies. There will be further additions in the future to provide competency focused questions on all chapters.

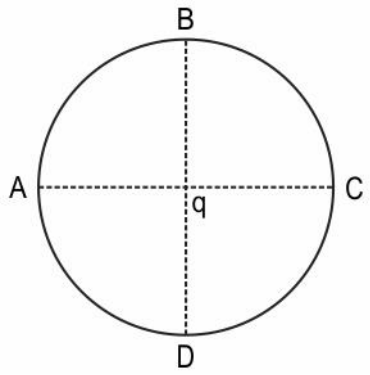
Please write back to us to give your feedback.

Team CBSE

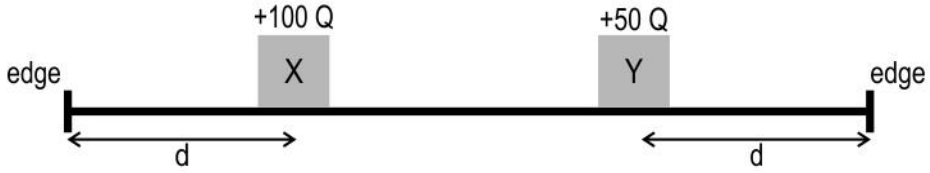
CONTENTS

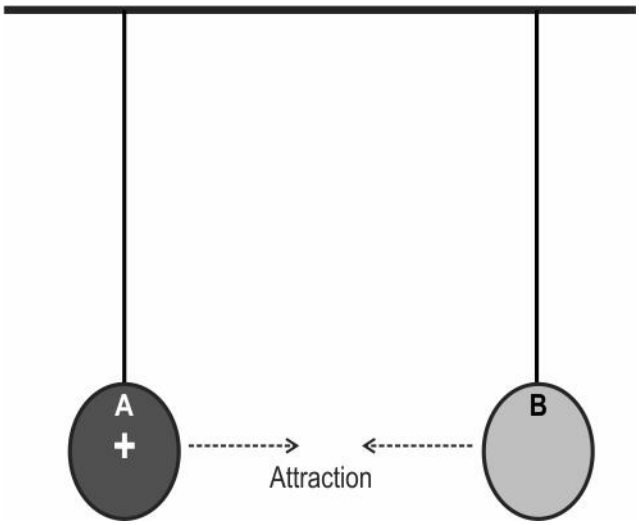
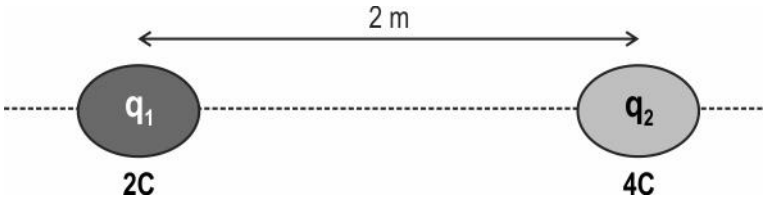
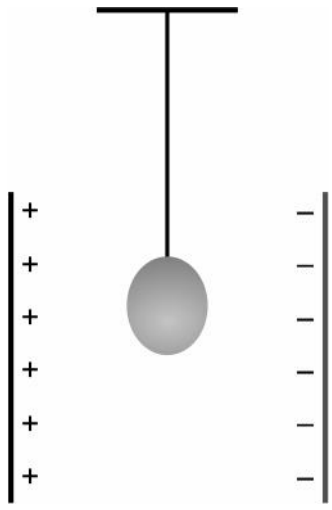
1. Chapter: Electric Charges and Fields & Electrostatic Potential and Capacitance

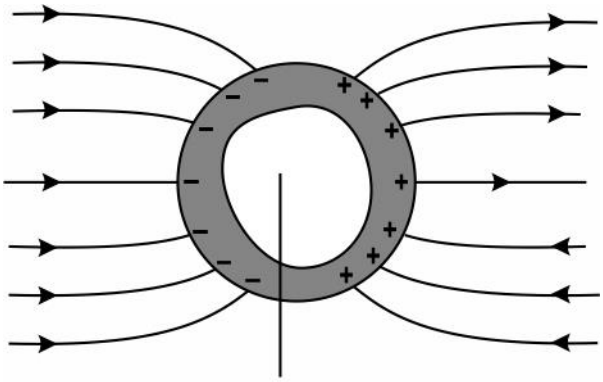
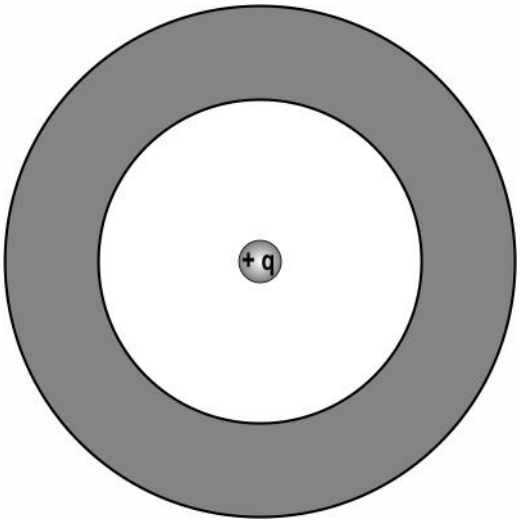
Q.No	Question	Marks
	Multiple Choice Question	
Q.1	Two insulated rods have opposite static charges at their ends. The charged rods are mounted at their centres so that they are free to rotate in the plane of the screen. The two rods can be held in the following 4 orientations as shown below.  Identify which of these orientations are stable such that they return to their original orientation if slightly displaced. A. Orientations P and Q are stable. Orientations R and S are unstable. B. Orientations Q and R are stable. Orientations P and S are unstable. C. Orientations Q and S are stable. Orientations P and R are unstable. D. Orientations P and R are stable. Orientations Q and S are unstable.	1
Q.2	Electric field lines are pictorial representations of electric fields due to static charges on the plane of a paper.  	1

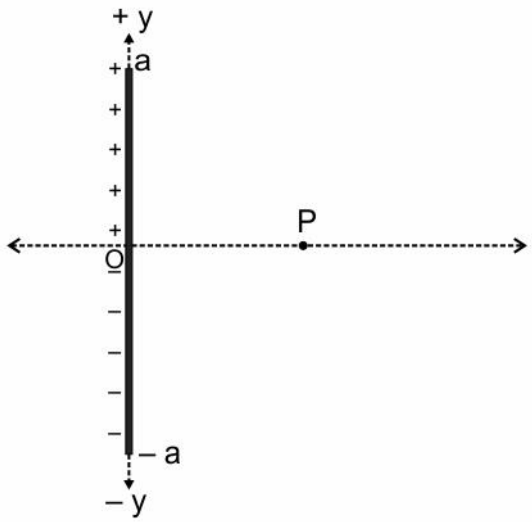
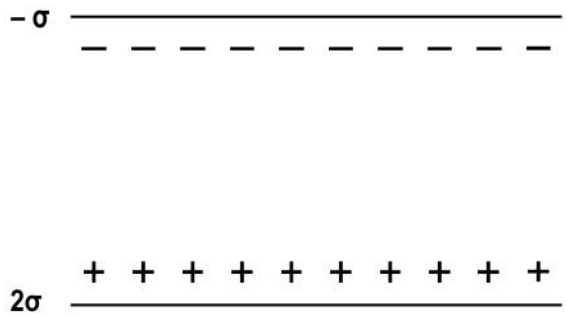
	Study the given electric field representation and identify one INCORRECT qualitative impression given by this representation. A. The electric field at point A is stronger than at point B. B. The electric field distribution is two-dimensional. C. The electric field at point C is zero. D. The electric field always points away from a positive charge.	
Q.3	For a Gaussian surface through which the net flux is zero, the following statements COULD be true. P) No charges are inside the Gaussian surface. Q) The net charge inside the surface is zero. R) The electric field is zero everywhere on the surface. S) The number of field lines entering is equal to the number of lines exiting the surface. Which of the statements is/are DEFINITELY true? A. Only statement Q B. Both statements P and S C. Both statements Q and R D. Both statements Q and S	1
Q.4	A charge q = +2 C is located at the center of a circle of radius 2 m. A unit positive test charge is moved along the circle.  Identify the correct statement. A. Work done in moving a test charge from A to C is maximum. B. Work done in moving a test charge from A to B or from A to D is minimum. C. Work done in moving a test charge from A to B to C to D is more than from A to D. D. Work done in moving a test charge between any two points along the circle is zero.	1
Q.5	A lightning conductor is made of a conducting material with one of its ends earthed while the other end has several sharp metal spikes. It protects the	1

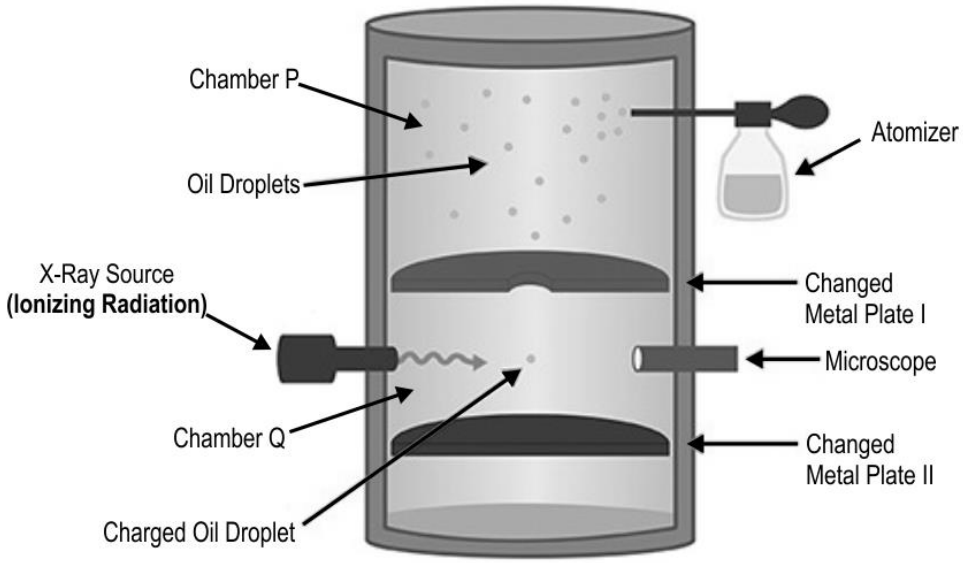
	building from lightning by either neutralizing or conducting the charge of the cloud in the sky to the ground.  Identify ONE statement from below given that DOES NOT contribute to the correct explanation of the working principle of a lightning conductor. A. Charge density on the surface of metal spikes is inversely proportional to the radius of curvature. B. Charges are distributed uniformly on the surface of conductors irrespective of their shapes. C. The surface of a charged conductor behaves as an equipotential surface. D. Charges reside only on the outside of a charged conductor.	
Q.6	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): An electric dipole is in stable equilibrium when placed in a uniform electric field with its dipole moment opposite to the field. Reason (R): No torque acts on an electric dipole when its dipole moment is in a direction opposite to the field. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation of assertion. C. Assertion is true but reason is false. D. Assertion is false but reason is true.	1
Q.7	15 charged particles with the same charge (q) are placed on the x-axis. They are symmetrically distributed on both sides of the y-axis. The distance between any two consecutive particles is R/3 and one of the charges is at the origin. What is the electric flux through a sphere centred at the origin having a radius of 1.5R? A. $15q/\in 0$ B. $8q/\in 0$ C. $9q/\in 0$ D. $5q/\in 0$	1

	Two small metal blocks (X and Y) of the same mass m are placed on an insulated frictionless surface such that both of them are at the same distance from the edge of the surface as shown in the image below. The charge on block X is +100Q and that on Y is +50Q. The two blocks are held in position by an external force.  	
Q.8	If the external force holding the blocks in their respective positions is removed, then which of the following will happen? A. Block X will reach the edge first. B. Block Y will reach the edge first. C. Both the blocks will reach the edge at the same time. D. The blocks will NOT move from their positions.	1
Q.9	If block Y is replaced with another block Z with the same charge but mass 2m, which of the following will happen when the external force holding the blocks in their respective positions is removed? A. Block X will reach the edge first. B. Block Z will reach the edge first. C. Both blocks will reach the edge at the same time. D. The blocks will NOT move from their positions.	1
Q.10	The two blocks X and Y are momentarily brought in contact and placed again in the same initial position as shown in the image. Which block will reach the edge first, once the external force holding them in their positions is removed? A. Block X will reach the edge first. B. Block Y will reach the edge first. C. Both blocks will reach the edge at the same time. D. The blocks will NOT move from their positions.	1
Free Response Questions/Subjective Questions		
Q.11	A positively charged ball A hangs from a string. A non-conducting ball B is brought near ball A. Ball A is seen to be attracted to ball B.	3

	 (a) Give reason why it is NOT possible to determine whether ball B is negatively charged or neutral for sure from the above experiment alone. (b) Suggest any ONE additional experiment with ball B required to determine whether ball B is negatively charged or neutral for sure.	
Q.12	Two positive charges q1 and q2 lie along a straight line separated by a distance of 2 m as shown.  (a) Find a location along the straight line joining the two charges, where if a positive charge q3 is placed, it experiences a zero-resultant force. (b) Will the resultant force on q3 placed at the location of part (a) still be zero, if it is negatively charged? Explain.	4
Q.13	A very small uncharged metal-coated Styrofoam ball is suspended in the region between two parallel oppositely charged metallic plates. A uniform electric field exists between the two plates. 	3

	Describe the motion of the ball when it is brought into contact with one of the plates.	
Q.14	A spherical Gaussian surface encloses a positive charge q. Explain with a reason what happens to the net electric flux through the Gaussian surface if: (a) the charge is tripled (b) the volume of the sphere is tripled (c) the shape of the Gaussian surface is changed into a cuboid (d) the charge is moved into another location inside the Gaussian surface	4
Q.15	The electric field inside a hollow conductor placed in an external electric field is always zero as shown in the figure. This property of a conductor finds a very useful application in shielding sensitive electric equipment. Electric circuits are enclosed within metal boxes that provide shielding from external fields, thereby protecting them from external interferences.  E = O N/C inside cavity Given here is a hollow, electrically neutral spherical conductor. A positive charge q is suspended at its center.  Explain with an appropriate reason if this hollow conductor shields the OUTSIDE from the field produced by the point charge inside. Represent the electric field lines diagrammatically.	3

Q.16	Given is a line of charge of uniform linear density. A charge +q is distributed uniformly between y = 0 and y = a and charge –q is distributed uniformly between y = 0 and y = -a.  Explain how the direction of the resultant electric field at point P can be obtained. Represent using a vector diagram.	3
Q.17	A charge of 10 C each is given to two spherical conductors A and B. The volumes of A and B are in ratio of 1:3. When A and B are connected by a conducting wire, show that it is impossible for the charge to flow from B to A.	3
Q.18	Two charged sheets having charge density 2σ and -σ are placed parallel and close to each other in a vertical plane as shown in the figure. A particle having positive charge q and mass m is placed between these sheets and released from rest under gravity. What is the acceleration of this particle?  	3
Q.19	The figure below represents the set-up of Millikan's oil drop experiment which was used by Millikan to determine the charge on an electron. Tiny droplets of oil in the form of mist are sprayed into the chamber P. Some of these droplets pass through the small hole in the metal plate I and are ionized by X-rays in chamber Q.	3



If it is observed that an ionized oil droplet having a mass of 3.2 x 10 -14 kg and carrying a charge of - 6.4 x 10-19 C, remains stationary between the metal plates I and II when a potential difference 'V' is applied between the plates, then

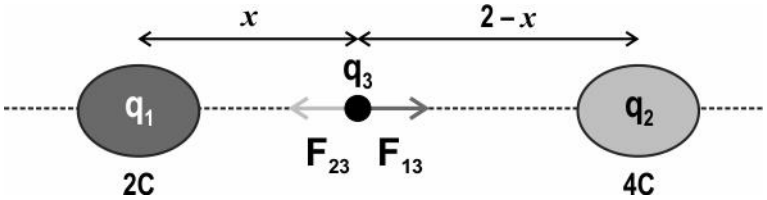
(a) What is the direction of the applied electric field in chamber Q? Give reason.

(b) What is the potential difference 'V' applied between the metal plates, if the plates are separated by a distance of 1 cm?

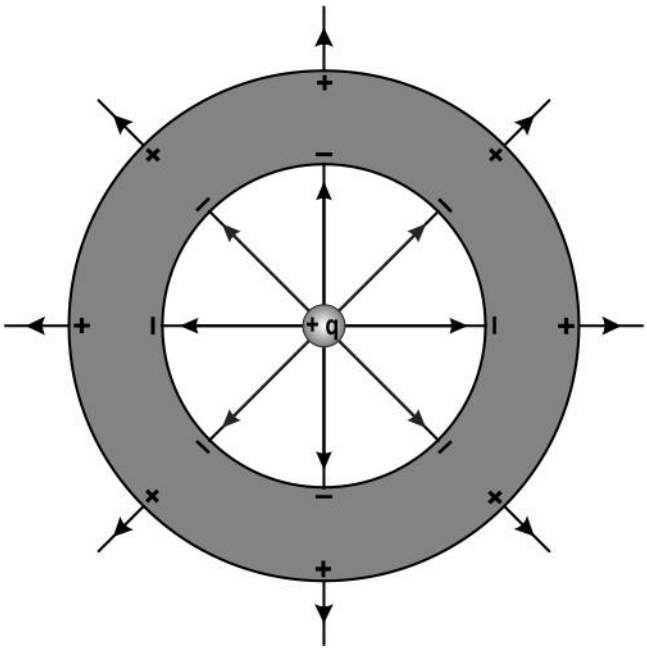
(Assume there is negligible drag force experienced by the oil droplet and take g = 10m/s2)

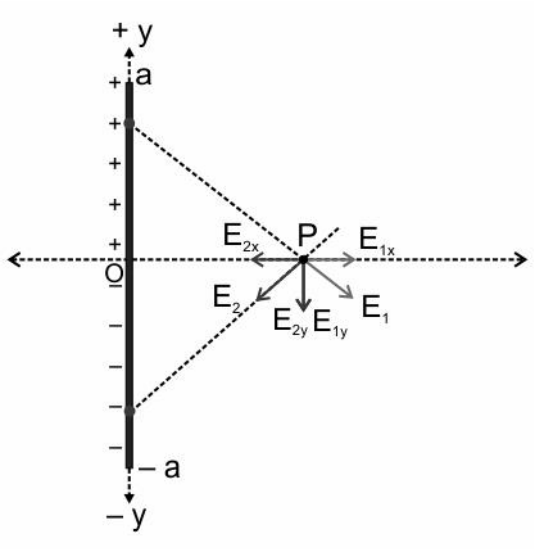
Answer key and Marking Scheme

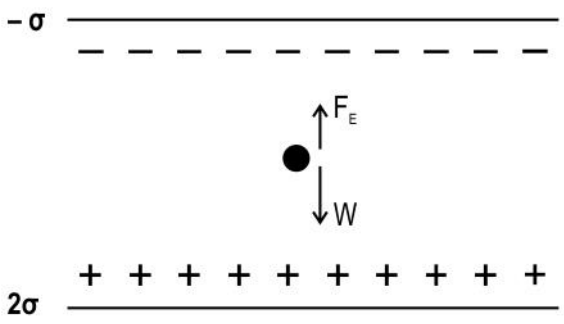
Q.No	Answers	Marks
Q.1	C. Orientations Q and S are stable. Orientations P and R are unstable.	1
Q.2	B. The electric field distribution is two-dimensional.	1
Q.3	D. both statements Q and S	1
Q.4	D. Work done in moving a test charge between any two points along the circle is zero.	1
Q.5	B. Charges are distributed uniformly on the surface of conductors irrespective of their shapes.	1
Q.6	D. Assertion is false but reason is true.	1
Q.7	C. $9q/\in_0$	1
Q.8	C. Both the blocks will reach the edge at the same time.	1
Q.9	A. Block X will reach the edge first.	1
Q.10	C. Both blocks will reach the edge at the same time.	1
Q.11	(a) The attraction between A and B could be due to the following reasons: - B is negatively charged and hence A and B attract each other. [0.5 mark] - B is neutral. The two balls attract each other due to the polarization of molecules in neutral ball B. [0.5 mark] It is not possible to determine for sure that ball B is negative or neutral from this experiment alone. (b) Possible additional experiments: - A known neutral ball can be brought near ball B (without ball A nearby). [1 mark] If the neutral ball is attracted to ball B, then ball B is negatively charged for sure. If there is no interaction between the two balls, then ball B is neutral for sure. [1 mark] OR	3

	- A known negatively charged ball is brought near ball B (without ball A nearby). [1 mark] If ball B repels the negatively charged ball, ball B is negatively charged for sure. On the other hand, if ball B is attracted to the negatively charged ball, then ball B is neutral for sure.[1 mark]	
Q.12	(a) For a resultant force at the location of q_3 to be zero, the net electrostatic force on q_3 due to q_1 and q_2 has to be zero. Since q_3 is positive, it will be under the effect of repulsive force by both q_1 and q_2 as represented by F_{13} and F_{23}.  That is, $F_{13} = F_{23}$ $\frac{kq_1q_3}{x^2} = \frac{kq_2q_3}{(2-x)^2}$ Substitute for values of $q_1 = 2C$, $q_2 = 4C$ and solve to get, $(2-x)^2 = 2x^2$ Solve for x, $x = \frac{2}{\sqrt{2}+1} = 0.83m$ So q_3 placed at 0.83 m away from q1 along the straight line joining q_1 and q_2 experiences a zero resultant force. - 1 mark for drawing the correct diagram and explanation of forces acting on charge q_3 - 1 mark for writing a correct equation for forces on q_3 using Coulombs law - 1 mark for substituting and solving for the value of x (b) Yes, the negative charge at the location of q_3 will experience zero resultant force.	4

	The forces on the negative charge due to q_1 and q_2 will get reversed. [1/2 mark for the first point] [1/2 mark for correct explanation]	
Q.13	- Once the ball is brought in contact with one of the charged plates, say the negatively charged plate, some negative charge gets transferred to the ball. Soon after it gets repelled by the negatively charged plate and attracted to the positive plate at the other end. [1 mark for explaining how the ball interacts with a charged plate] - The ball swings to strike the positive plate. When in contact, the ball loses its negative charge, neutralizes some of the positive charges on the plate, and gains some positive charge on its surface. The ball is repelled by the plate in contact and attracted to the opposite plate. So the ball now swings towards the negative plate. [1 mark for explaining how it gets repelled and strikes the opposite face and neutralizes the charge on the second plate and getting charged again] - Subsequently, the ball keeps swinging back and forth between the two plates. The charge keeps getting transferred from one plate to another till both the plates get completely neutralized. The ball stops swinging thereafter. [1 mark for concluding that the motion of the ball is to and fro and the motion finally stops]	3
Q.14	(a) The net flux is also tripled because as per Gauss law the net flux is proportional to the net charge enclosed. [1 mark for correct explanation] (b) Regardless of the volume of the enclosed surface, if the net charge enclosed is the same, the net flux remains the same as per Gauss law. [1 mark for correct explanation] (c) No change in the net flux as it doesn't depend upon the shape of the closed surface. [1 mark for correct explanation] (d) As long as the new location of the charge remains inside the Gaussian surface, there is no change in net flux. [1 mark for correct explanation]	4

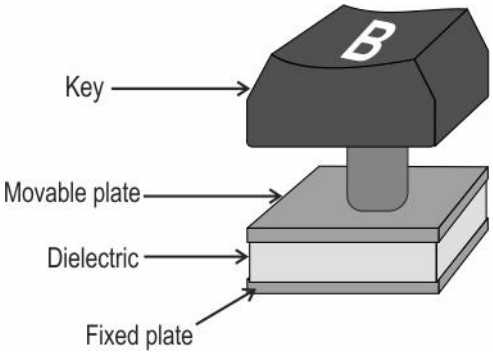
Q.15	The charge +q inside the hollow conductor induces an equal and opposite charge, that is, -q on the interior surface. Electric field lines inside the hollow conductor are produced that are radially directed outwards. [1 mark for explaining the electric field inside the hollow conductor] Equal charge +q is induced on the outer surface of the conductor, which generates radial electric field lines directed outwards.  As the electric field outside the hollow conductor is not zero, it fails to shield its OUTSIDE from the electric field produced by the point charge on the inside. [1 mark for explaining the electric field formed outside the hollow sphere] [1 mark for the correct representation of the field lines in the hollow conductor]	3
Q.16	The x-components of E_1 and E_2, due to two equidistant points on either side of O, cancel each other. The resultant electric field is due to the superposition of the y-components of E_1 and E_2. The direction of the net electric field is along the negative y-axis. This is true for all pairs of equidistant points on either side of O. [0.5 marks for each of the points explained]	3

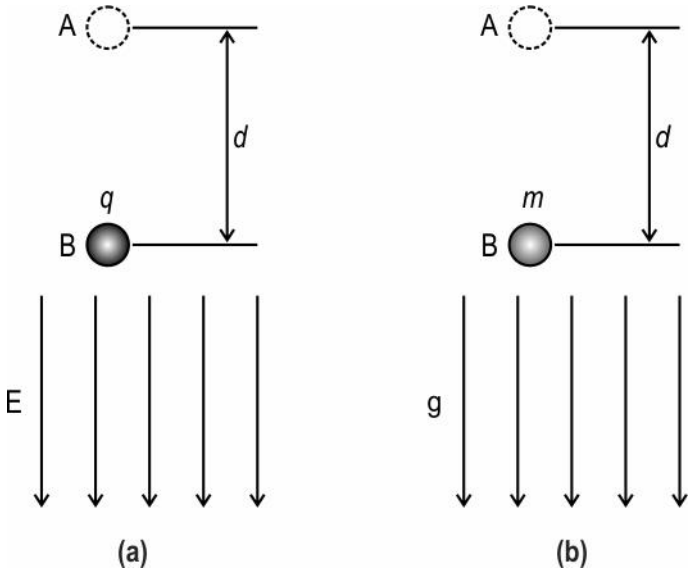
	(Note: Award full marks even if E_1 and E_2 is shown and it is mentioned that E_1 and E_2 are equal and direction of resultant is along the angle bisector of the two vectors.)  [1 marks for the correct representation of E_1, E_2 and the resultant.]	
Q.17	Potential on the surface of spherical conductor = $V = \frac{Q}{C} = \frac{Q}{4\pi\epsilon_0 R}$ [1 mark for the correct formula of potential in terms of the radius of conductor] The greater volume of sphere B corresponds to a greater radius R_B. $R_A < R_B$. So for the same charge given to the two spherical conductors, the conductor with a smaller radius, that is, B is at the lower potential. $V_A > V_B$ The charge always flows from a body at a higher potential to a body at a lower potential. Hence, it is impossible for the charge to flow from B to A as $V_B < V_A$. [1 mark for correct conclusion of $V_A > V_B$] [1 mark for the correct final result]	3
Q.18	Acceleration of the particle (a) =F_{net}/m F_{net} = Electric force (F_E) + Gravitational force (W)	3

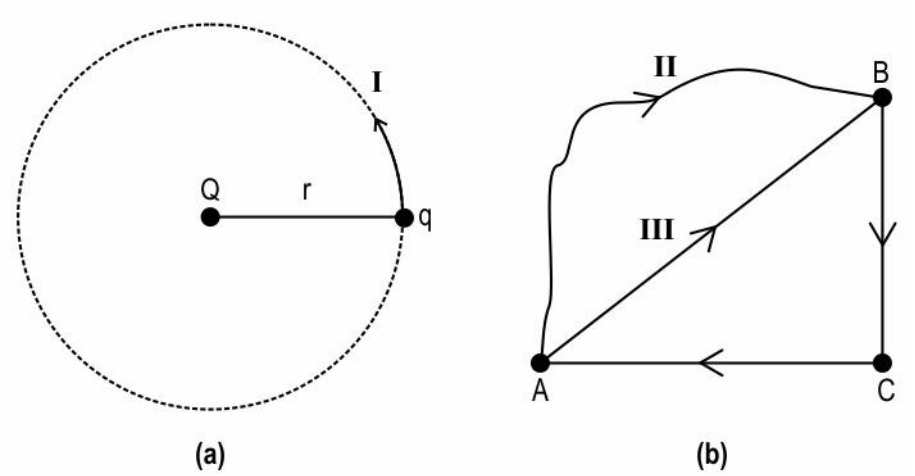
	 Here, F_E=qE Where, E = Electric field Magnitude of electric field due to a charged sheet is given by $\sigma/2\epsilon_0$, where σ is its surface charge density. Thus, E = Electric field between the sheets = $2\sigma/2\epsilon_0 + \sigma/2\epsilon_0 = 3\sigma/2\epsilon_0$ (As fields due to both the sheets are in the same direction so they add up) [1 mark for finding net electric field] [1 mark for writing an expression of force and identifying directions of force] Thus, $F_E = qE = 3\sigma q/2\epsilon_0$ and W = mg Now, as both the forces are in opposite direction, thus $F_{net} = 3q\sigma/2\epsilon_0 - mg$ and acceleration $a = F_{net}/m = 3q\sigma/2m\epsilon_0 - g$ [1 mark for finding correct acceleration]	
Q.19	(a) The applied electric field in the chamber Q is in the downward direction, from metal plate I to metal plate II. (1 mark) The charged oil droplet will experience a downward pull due to gravity. For the droplet to be stationary an equivalent upward force should act on the oil droplet.	3

	This is possible only when the metal plate I acquires a positive charge and the metal plate II acquires a negative charge. (1 mark) (b) When the charged oil droplet is stationary qE = mg (0.5 marks) E = V/d $6.4 \times 10^{-19} \times V/10^{-2} = 3.2 \times 10^{-14} \times 10$ $V = 0.5 \times 10^{4}\ V$ V = 5000 V (0.5 marks)	

2. Chapter: Electrostatic Potential And Capacitance

Q.No	Question	Marks
	Multiple Choice Question	
Q.20	In one kind of computer keyboard, each key is mounted on one end of a plunger. The other end of the plunger is attached to a movable metal plate. Refer to the figure given.  The dielectric material between the two plates is made of a soft material and is compressible. The combination of the two plates and the dielectric between them constitutes a capacitor. Each key on the keyboard when pressed is recognized due to which one of the following factors? A. The pressing of the key increases the capacitance of the capacitor below the key due to a decrease in separation between the plates. B. The decrease in the thickness of the soft dielectric layer decreases the capacitance of the capacitor below the key. C. The momentary decrease in the space between the plates of the capacitor is detected as a mechanical sound signal of a specific frequency. D. all of the above	1
Q.21	Given below are the representations of uniform electric and gravitational fields.	1

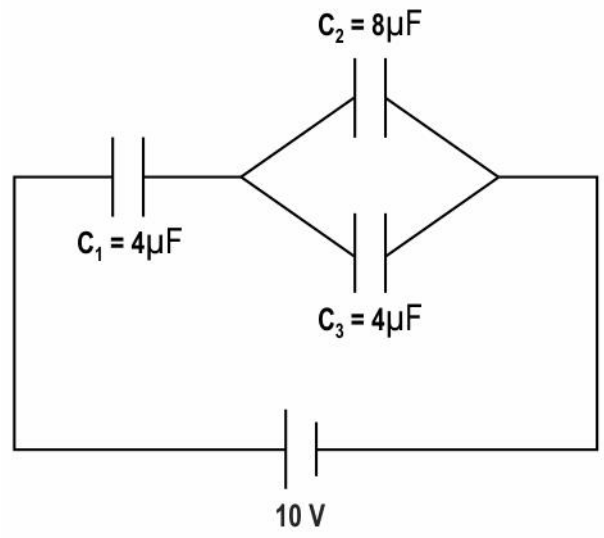
	 In fig (a), a positive charge q moves from A to B in the direction parallel to electric field **E**. The charge-field system undergoes a change in its electrical potential energy. In fig (b), a mass particle m moves from A to B in the direction parallel to gravitational field **g**. The mass-field system undergoes a change in gravitational potential energy. Identify the statement that correctly states the changes in the energies of the above two systems. A. The charge-field system loses electrical potential energy whereas the mass-field system gains gravitational potential energy. B. The charge-field system gains electrical potential energy whereas the mass-field system loses gravitational potential energy. C. Both the charge-field system and the mass-field system lose their respective potential energies. D. Both the charge-field system and the mass-field system gain their respective potential energies.	
Q.22	In Fig (a), a positive charge Q is located at a point. A unit test charge q moves along path I in one complete circle around Q. In Fig (b), II and III represent the paths along which a unit test charge is moved from point A to B in the presence of an electrostatic field.	1



Which of the following statements INCORRECTLY describes the work done in moving the unit test charge in the presence of an electric field in the above context?

A. Work done along path I is zero.
B. Total work done along path II and then along B – C – A is zero.
C. Work done along path II is more than the work done along path III.
D. Total work done along path III and then along B – C – A is EQUAL to the total work done along path II and then along B – C – A.

Q.23 Three capacitors C_1, C_2 and C_3 are connected in a combination as shown below. 1



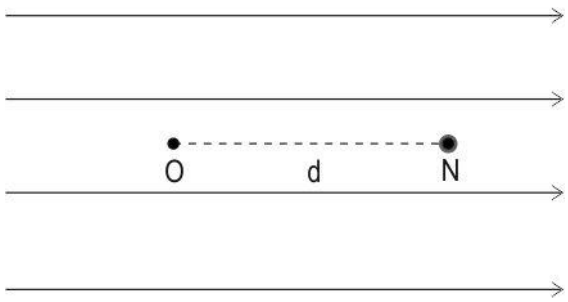
Identify the correct statement(s).

(i) The charge on capacitor C_1 is greater than that on capacitor C_2.

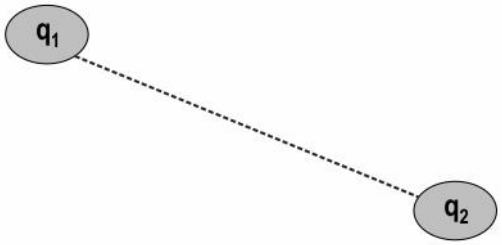
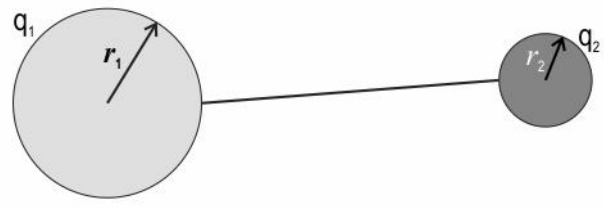
(ii) The charge on capacitor C_1 is the same as that on capacitor C_3.

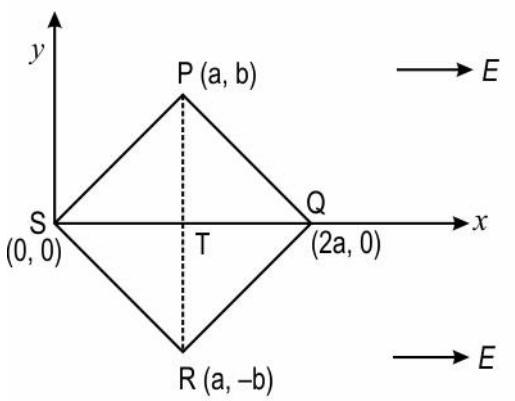
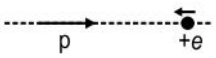
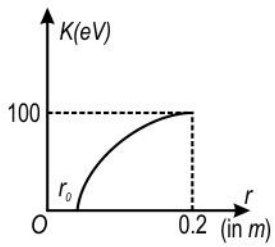
(iii) The charge on capacitor C_1 is 30 μC.

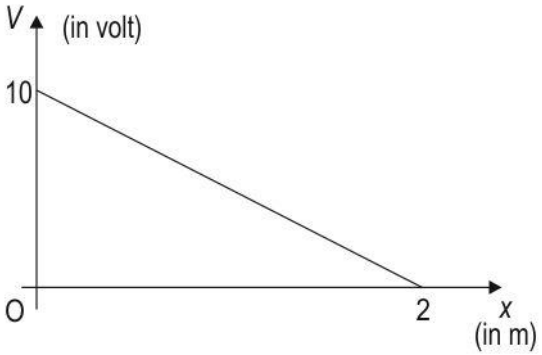
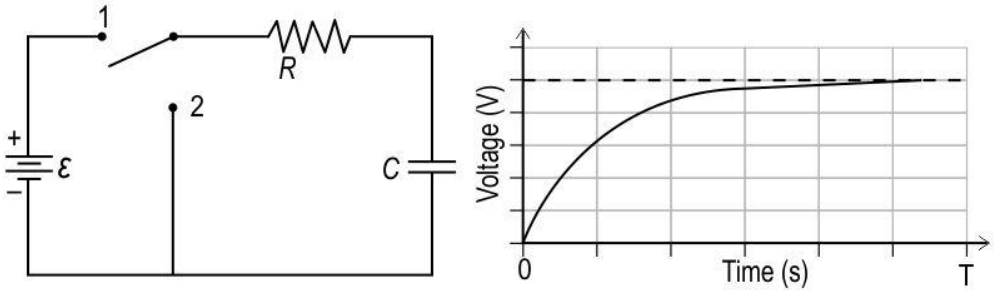
A. Only (i) is correct.

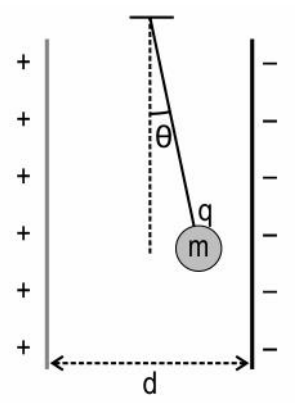
	B. Only (iii) is correct. C. Both (i) and (iii) are correct. D. Both (i) and (ii) are correct.	
Q.24	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The charge-to-voltage ratio increases on insertion of a dielectric material between the capacitor plates, when either the voltage or charge is kept constant. Reason (R): The capacitance of a capacitor increases when it is filled with a dielectric material with a dielectric constant greater than 1. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true and reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but reason is true.	1
Q.25	The electric potential at point N in a uniform electric field is V_0. Now, an electric dipole of dipole moment 'p', charge 'q', and dipole length '2a' is placed in this field with its centre (O) at a distance 'd' (d>>a) from point N as shown in the figure. If the orientation of the dipole is such that its potential energy is maximum, what will be the new electric potential at point N?  A. $V_0-(q/4\pi\in_0 d)$ B. $V_0+(q/4\pi\in_0 d)$ C. $V_0+(p/4\pi\in_0 d^2)$ D. $V_0-(p/4\pi\in_0 d^2)$	1
Q.26	An electron is introduced in a region of an electric field. The charge starts accelerating in the direction opposite to that of the field. Which of the following statements is true?	1

	A. The field does positive work on the electron and its potential energy increases. B. The field does positive work on the electron and its potential energy decreases. C. The field does negative work on the electron and its potential energy increases. D. The field does negative work on the electron and its potential energy decreases.	
Q.27	Assertion: The potential at a point is characteristic of the electric field at a point only whereas electric potential energy at a point is characteristic of the charge–field system. Reason: The potential is independent of a charged test charge placed in the field and the electric potential energy is due to an interaction between the electric field at the point and the charged particle placed in the field at that point. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Q.28	Assertion: The electric potential is constant everywhere inside a charged conductor and is equal to its value at the surface. Reason: A constant work has to be done to move a test charge from the interior of a charged conductor to its surface. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Q.29	Assertion: A thin uncharged metallic plate placed in between the two charged plates of a capacitor results in an arrangement equivalent to two capacitors in a series combination. The equivalent capacitance of this combination stays the same irrespective of the position of the metallic plate in between the plates of the capacitor. Reason: The change in the position of the central metallic plate, results in the decrease in plate separation of one capacitor that is compensated by the increase in plate separation for the other. Select the correct option. A. Both A and R are true and R is the correct explanation of A	1

	B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	
Free Response Questions/Subjective Questions		
Q.30	Two-point charges are placed along the x-axis as shown.  Along the line joining the two charges, how many points are possible at which the total potential due to the charges is zero? Predict the probable locations.	3
Q.31	Given are two charges, q_1, a negative source charge, and q_2, a test charge. The test charge q_2 is initially positive and then changed into a negative charge of the same magnitude.  (a) Will the potential at the position of charge q_2 due to the source charge q_1 (i) remain the same, (ii) increase or (iii) decrease? (b) Will the potential energy of the q_1 & q_2 charge system (i) remain the same, (ii) increase or (iii) decrease? Give an explanation in each case.	3
Q.32	A conducting wire connects two charged conducting spheres such that they attain equilibrium with respect to each other. The distance of separation between the two spheres is very large as compared to either of their radii.  Find the ratio of the magnitudes of the electric fields at the surfaces of the two spheres.	2
Q.33	A parallel plate capacitor of capacitance C is charged to a potential V by a battery. Q is the charge stored in the capacitor. The battery is then disconnected, and the distance between the plates of the capacitor is increased by a small amount.	6

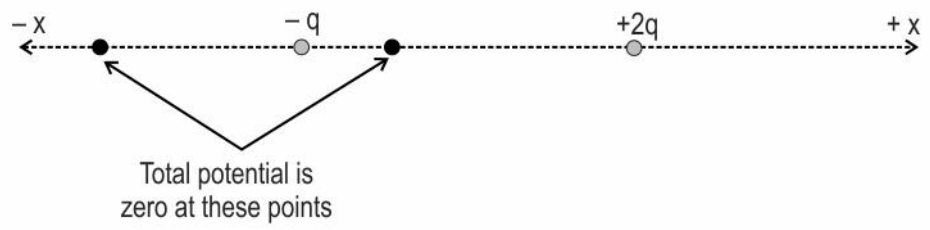
	What changes will occur in each of the following quantities? Will they increase, decrease or remain the same? Give an explanation in each case. (a) Capacitance (b) Charge (c) Potential difference (d) Electric field (e) Energy stored in the capacitor	
Q.34	Test charge q moves along a path P -> Q -> R -> S in a uniform electric field region directed along +x-axis. The coordinates of the points are as follows: P (a, b, 0), Q (2a, 0, 0), R (a, -b, 0) and S (0, 0, 0).  (a) Identify the plane of motion of the test charge. (b) Determine the work done by the electric field as the test charge moves from P to S. Use diagram, if necessary.	3
Q.35	A proton (e) approaches a short fixed electric dipole (p) moving along the dipole axis as shown in the figure. At a large distance from the dipole, the kinetic energy of the proton was K_0 = 400 eV.  The graph below shows the variation of kinetic energy (K) of the proton at points close to the dipole. Find the value of r_0 (r_0>> length of the dipole). In the graph r is the distance from the centre of the dipole.  	3

Q.36	The variation of electric potential in a region is shown in the graph below. Find the magnitude and direction of the force on a particle having a charge of +2 μC just after it is released at a point x = 1 m in this region.  	3
Q.37	The circuit below shows a resistor and an air-filled capacitor connected to a battery. The graph below shows the variation of voltage across the capacitor with time when the switch is moved to position 1.  (a) Draw a graph to show the variation of the voltage across the resistor. (b) At time T, what is the current in the circuit? Give a reason for your answer. (c) When the switch is moved to position 2, how does the voltage across the resistor and the capacitor change? (d) The capacitor in the circuit above is replaced by another capacitor with the same area of plates and distance between the plates but with a dielectric material between the plates. What happens to the following quantities when the switch is in position 1? (i) capacitance (ii) charge (iii) potential difference between plates (iv) energy stored by capacitor	5
Q.38	A parallel plate capacitor is given as in the diagram. A small ball is suspended by an insulated thread in the space between the plates of the capacitor. The thread makes an angle θ with the vertical at equilibrium.	2



What is the potential difference between the capacitor plates?

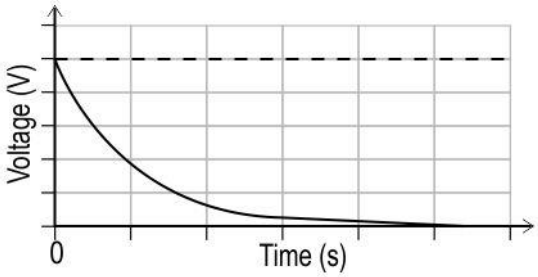
Answer key and Marking Scheme

Q.No	Answers	Marks
Q.20	A. The pressing of the key increases the capacitance of the capacitor below the key due to a decrease in separation between the plates.	1
Q.21	C. Both the charge-field system and the mass-field system lose their respective potential energies.	1
Q.22	C. Work done along path II is more than the work done along path III.	1
Q.23	C. Both (i) and (iii) are correct.	1
Q.24	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.25	D. V0-(p/4π∈0d2)	1
Q.26	B. The field does positive work on the electron and its potential energy decreases.	1
Q.27	A. Both A and R are true and R is the correct explanation of A	1
Q.28	C. A is true but R is false	1
Q.29	A. Both A and R are true and R is the correct explanation of A	1
Q.30	Two places. [1 mark for stating the number of probable locations of zero potential] Location 1: As the two charges are opposite, in between the two charges, there is a location, where the individual electric potentials balance. As the charges are not of equal magnitude, this point of zero potential occurs a little closer to the smaller charge, that is, -q. [1 mark for identification of the first location] Location 2: To the left of the smaller charge, -q, there is another location at which the individual potentials due to –q and +2q will exactly balance each other.  [1 mark for identification of the second location]	3
Q.31	(a) Remains the same.	3

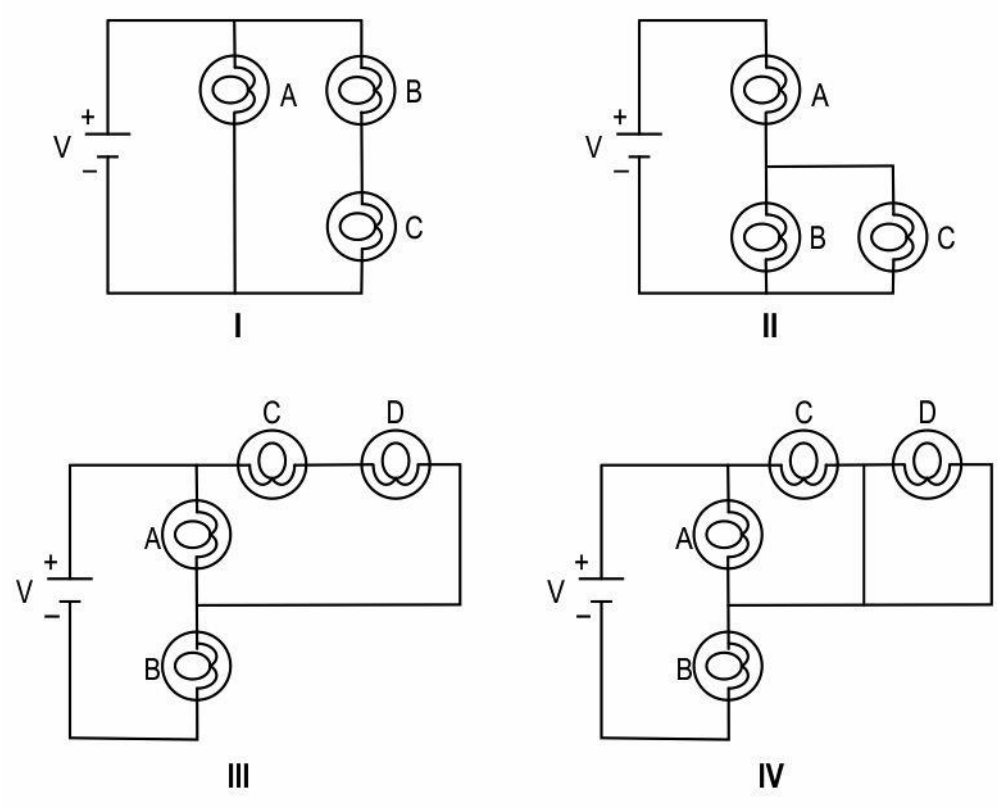
	The potential at a location depends on the source charge. It is independent of the test charge at the location. [0.5 mark for the correct change] [1 mark for the correct explanation] (b) Increases. The initial potential energy of q1 & q2 charge system was negative. When the test charge is changed from positive to negative, the potential energy becomes positive. So it increases. [0.5 mark for the correct change] [1 mark for the correct explanation]	
Q.32	At equilibrium, the potential on the surface of a larger sphere = potential on the surface of a smaller sphere. $V = \frac{kq_1}{r_1} = \frac{kq_2}{r_2}$ So, $\frac{q_1}{q_2} = \frac{r_1}{r_2}$ [1 mark for the correct ratio of q1 to q2] Since the two charges are very far from each other, the electric fields on the surfaces of the two spheres will be: $E_1 = \frac{kq_1}{r_1^2}$ and $E_2 = \frac{kq_2}{r_2^2}$ The ratio of the electric fields is, $\frac{E_1}{E_2} = \frac{r_2}{r_1}$ [1 mark for the correct ratio of E1 to E2]	2
Q.33	(a) Capacitance decreases. Capacitance is inversely proportional to the distance of separation. [0.5 mark for the correct change] [0.5 mark for the correct explanation] (b) Charge remains the same. The battery is disconnected. So charge cannot move into or out of the plates of the capacitor. [0.5 mark for the correct change] [0.5 mark for the correct explanation]	6

	(c) Potential difference increases. As Q =CV Charge Q is constant, C decreases, so V increases. [0.5 mark for the correct change] [0.5 mark for the correct explanation] (d) Electric field remains the same. E due to a plane sheet of charge = σ/∈o is independent of the distance from the sheet. Charge density σ on the plate remains the same because the charge on capacitor plates remains the same. So, E also remains the same. OR As E = V/d = Q/Cd = Q/∈oA Since Q and A remain unchanged, E remains the same. [0.5 mark for the correct change] [0.5 mark for the correct explanation] (e) Energy stored in the capacitor increases. Energy stored is proportional to both charge and potential difference. Charge is constant but the potential difference has increased. [0.5 mark for the correct change] [0.5 mark for the correct explanation]	
Q.34	(a) As the z-coordinate of each of the points is zero, the plane of motion from P to Q to R to S is in x-y plane. [1 mark for the identification of the correct plane] (b) Since E is conservative, the work done is path independent, so replace the path P -> Q -> R -> S with a simpler path as P -> T -> S. [1 mark for suggesting a simpler path] Work done along P -> T = 0, as the path is perpendicular to the direction of E. Work done along T -> S = -qEa So total work done = 0 - qEa = -qEa [1 mark for correct calculation and result] OR Since E is conservative, the work done is path independent, so replace the path P -> Q -> R -> S with a simpler path P -> S. [1 mark for suggesting a simpler path] W = qE. PS. cos (90 + θ) Here, (90 + θ) is the angle between the electric field E and displacement vector PS. θ is the ∠SPT.	3

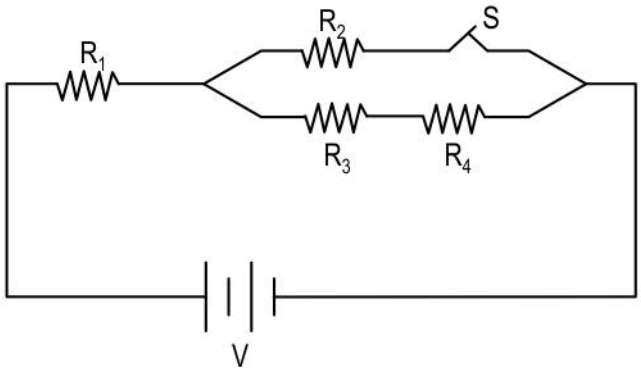
	$W = -qE\sqrt{a^2+b^2}\sin\theta$ $= -qE\sqrt{a^2+b^2}\frac{a}{\sqrt{a^2+b^2}}$ $= -qEa$ [1 mark for correct calculation and result] (Note: Award full marks even if students calculate the work done along P -> Q -> R -> S without suggesting a simpler path.)	
Q.35	Given: Initial kinetic energy of proton = K0 = 400 eV As the proton approaches the dipole its kinetic energy reduces and the potential energy increases, however, the total energy is conserved. Electric potential due to the dipole at axial point = p/4π∈0r2 Let P and K be the potential and kinetic energy of the proton at any instant, respectively. From the graph, at r = 0.2 m, K = 100 eV Applying conservation of energy: K + P = K0 100 + ep/(4π∈0 x 0.22) = 400 This implies ep/4π∈0 = 300 × 0.22 = 12 At r = r0 the kinetic energy is zero and thus we have, ep/4π∈0r02 = 400 12/r02 = 400 r20 = 12/400 r0 = √3/10 m ≈ 0.17 m	3
Q.36	Electric field in this region is given by: E = -dV/dx Here, dV/dx is the slope of the given graph. dV/dx = -10/2 = -5 volt/m Thus, E = -dV/dx = 5 volt/m (0.5 marks for formula and 0.5 marks for correct value of E) Charge on the particle is 2 μC, thus the force on the charge is F = qE = 2 × 10-6 × 5 = 10-5 N (0.5 marks for formula and 0.5 marks for correct value of F)	3

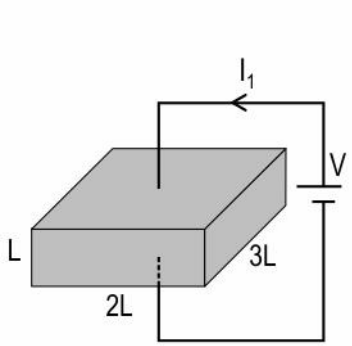
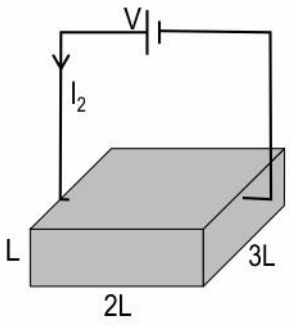
	As the electric field is in the direction in which the electric potential decreases, we can say that the direction of the electric field is along +x direction as V is decreasing as we move towards +x direction. Now, as the particle has a positive charge, it will experience a force in the direction of the electric field i.e., +x direction. (1 mark for correct direction of force)	
Q.37	(a) (1 mark)  (b) Current is zero as the capacitor is fully charged and does not allow the flow of any more charge. (1 mark) (c) The voltage across both the capacitor and the resistor decreases with time till the capacitor is completely discharged and the voltage across both the capacitor and resistor becomes zero. (1 mark) (d) (i) capacitance - increases (ii) charge - increases (iii) potential difference between plates - remain the same (iv) energy stored - increases (0.5 marks each)	5
Q.38	At equilibrium, the forces on the ball are balanced along x-axis and y-axis. Let T be the tension in the thread. $\Sigma F_y = 0$, so $T\cos\theta = mg$ $\Sigma F_x = 0$, so $T\sin\theta = qE$ [0.5 mark for each equation] Dividing, $\tan\theta = qE/mg$ $E = mg\tan\theta/q$ [0.5 mark for finding E or writing the expression for tanθ] Potential difference $V = Ed = mgd\tan\theta/q$ [0.5 mark for writing correct expression of V]	2

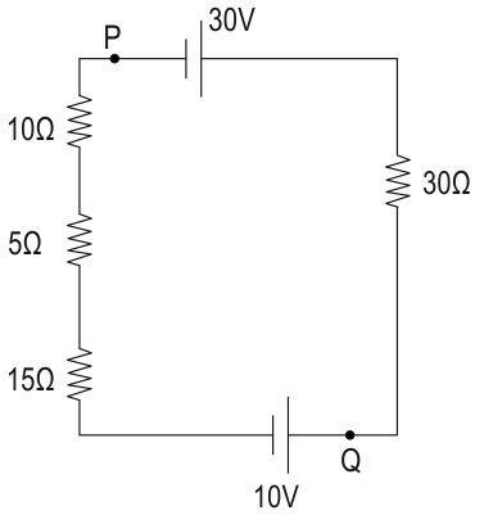
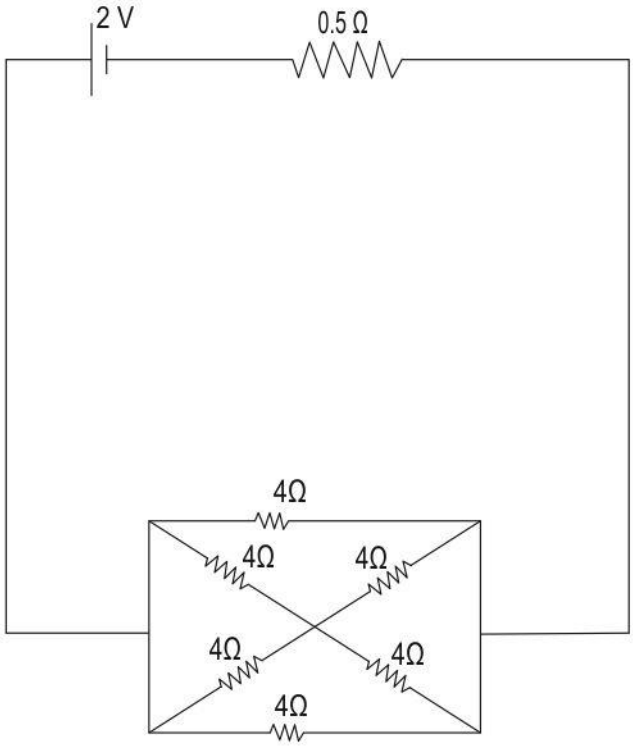
3. Chapter: Current Electricity

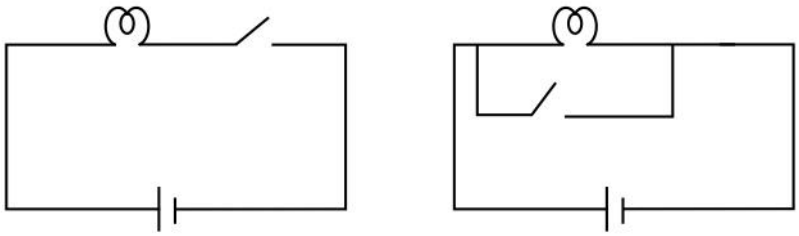
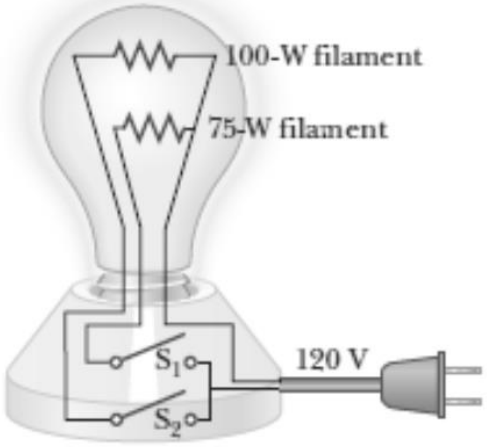
Q.No	Question	Marks
	Multiple Choice Question	
Q.39	A light bulb is rated at 44 W, 220 V, and a table fan is rated at 60 W, 110 V. Which statement is correct if each of the two devices is connected to a power supply of 220 V separately? A. The light bulb has a greater resistance and draws a greater current than the table fan. B. The light bulb has a greater resistance and draws a smaller current than the table fan. C. The light bulb has a smaller resistance and draws a greater current than the table fan. D. The light bulb has a smaller resistance and draws a smaller current than the table fan.	1
Q.40	Given below are four different electrical circuits with identical voltage sources. All the bulbs in each circuit are of the same voltage and power ratings.  Identify the brightest bulb in each circuit.	1

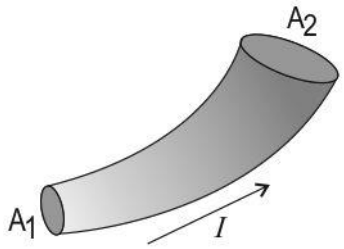
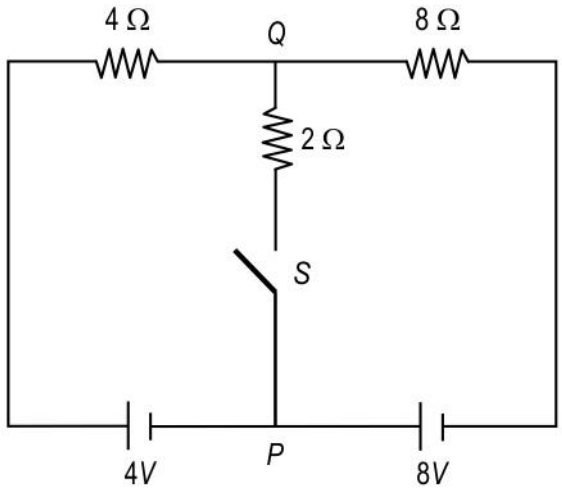
	A. Bulb A in all circuits B. Bulb B in all circuits C. Bulb A in circuits I & II and bulb B in circuits III & IV D. Bulb A in circuits I & II and bulb D in circuits III & IV	
Q.41	There are n identical resistors, all of which can be connected either in a series or in a parallel network. The power dissipated in the series and parallel networks will be different for a given applied voltage V. By what factor must the power dissipated through the series combination be multiplied in order to get the power dissipated through the parallel combination? A. n B. n^2 C. 1/n D. $1/n^2$	1
Q.42	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The net current in an isolated conductor placed in a uniform electric field is zero. Reason (R): There is no motion of electrons inside an isolated conductor placed in a uniform electric field as all charges reside on the surface of the conductor. A. Both Assertion and Reason are true and Reason is the correct explanation of Assertion. B. Both Assertion and Reason are true but Reason is not the correct explanation of Assertion. C. Assertion is true but Reason is false. D. Both Assertion and Reason are false.	1
Q.43	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The resistivity of conductors increases with an increase in temperature. Reason (R): The drift speed of electrons decreases with an increase in temperature. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true and reason is not the correct explanation for assertion.	1

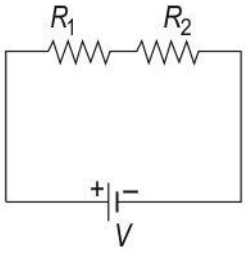
	C. Assertion is true but the reason is false. D. Assertion is false but reason is true.	
Q.44	What happens to the terminal voltage of a cell with an internal resistor as the current drawn from the cell increases? A. The terminal voltage remains constant. B. The terminal voltage decreases linearly. C. The terminal voltage increases linearly. D. The terminal voltage initially remains constant and then increases.	1
Q.45	Shown below is a closed electric circuit. Initially, the switch S is closed. If the switch S is now opened, what happens to the heat dissipated across R_1?  A. Increases B. Decreases C. There is no change D. Cannot be determined without actual values	1
Q.46	Assertion: In a current-carrying ohmic metal wire of decreasing diameter, both the electric current and the drift speed of the charge carriers is more at the thicker end and less at the thinner end of the wire. Reason: A variable drift speed of the charge carriers would result in accumulation of the charge carriers through a wire of decreasing thickness. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Q.47	Assertion: Electrical power given as P = I ΔV, when transported over long distances is the same either at high currents and low potential differences or at low currents and high potential differences but it is preferred to be transported at lower currents and higher potential differences.	1

	Reason: It is cheaper to use high-resistance wires and the current I is kept as low as possible in order to reduce power losses I^2R through the transmission wires. Select the correct option: A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	
Q.48	Assertion: If the charges are placed on an isolated conductor, it results in a zero electric field inside the conductor. On the other hand, a conductor connected to a source of emf, results in a steady current due to a constant electric field inside the conductor. Reason: A conductor is always in an electrostatic equilibrium whether or not it is connected to a source of emf. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true and but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Free Response Questions/Subjective Questions		
Q.49	In the two electric circuits shown below, identical conducting rectangular blocks made of the same material are connected to identical voltage sources. Establish a relationship between the currents I_1 and I_2 in the two circuits.  **Figure A**  **Figure B**	3
Q.50	Two batteries B_1 and B_2 of the same emfs are used to light up a 10 ohm bulb independently. The bulb glows brighter when connected to battery B_2 than when connected to battery B_1. Internal resistances of B_1 and B_2 are 2 ohm and 1 ohm respectively. Determine the ratio of the power delivered to the bulb by B_1 to the power delivered by B_2.	2

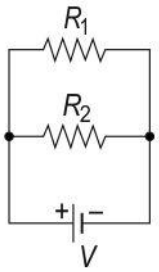
Q.51	In the circuit containing two cells of emfs 30 V and 10 V, determine which of the two points, P or Q is at higher potential.  	2
Q.52	A standard electric heater connected to 220 V power supply in a house uses 8 A of current in its normal heating mode of operation but only 2 A in the standby constant temperature maintain mode. For an hour of operation, how much more electrical energy is used in normal heating mode compared to standby mode? Express your answer in joules.	2
Q.53	In an electric circuit shown, a network of resistors is connected across a cell of emf 2V and internal resistance 0.5 ohm  (a) What is the total current drawn from the battery by the circuit? (b) What is the power consumed by the circuit from the battery?	3

Q.54	The image below shows two circuits (I and II) consisting of a battery, a bulb, and a switch.  circuit I circuit II (a) What is the difference in the working of the bulb in the two circuits when the switch is opened and closed? (b) Which circuit is preferred and why?	2
Q.55	Annie wants to check if a bulb rated 3 V, 6 W is working or not. But she only has a 12 V DC power source. She also has a few resistors with her. (a) How can she use the resistors with the light bulb to ensure that the bulb operates at its correct rating when connected to the 12 V supply? Give a reason for your answer. (b) What should be the resistance of the resistor that she uses with the bulb?	3
Q.56	The image below shows a three-way bulb that can glow at three different brightness. The bulb is rated to operate at 120 V power supply.  Determine how the bulb can have three different brightnesses. Determine the total current through the circuit which causes the bulb to glow in each of the three cases.	3
Q.57	For a current-carrying conductor of changing diameter as shown below, how does each of the following quantities vary along the two ends of conductors with area of cross sections A_1 and A_2 ? Give an explanation for each.	4

	 i. Current ii. Current density iii. Resistance iv. Potential drop	
Q.58	Find the change in power dissipated in the 4 Ω resistor after the switch S is closed. 	3
Q.59	a. Temperature coefficient of resistivity of a material can be positive, negative or zero. An electric heating device consists of a wire of material with an unknown temperature coefficient of resistivity and is connected to a constant voltage supply. Will the power delivered to the electrical device increase, decrease or remain constant with time as the temperature of the wire increases with usage? Give answers with explanations for all the three possible values of temperature coefficient of resistivity of the wire inside the device. b. The operating voltage of a water heater is 220V and that of a coffee whipper is 120V. With this information, can you say or not say, which of the two devices will draw lesser power? Give reason for your answer.	4
Q.60	Given two resistors R_1 and R_2 connected in series in circuit 1 and in parallel in circuit 2 across identical batteries of terminal voltage V with some internal resistance.	2



Circuit 1



Circuit 2

A third unknown resistor R_3 is added in series in circuit 1 and in parallel in circuit 2.

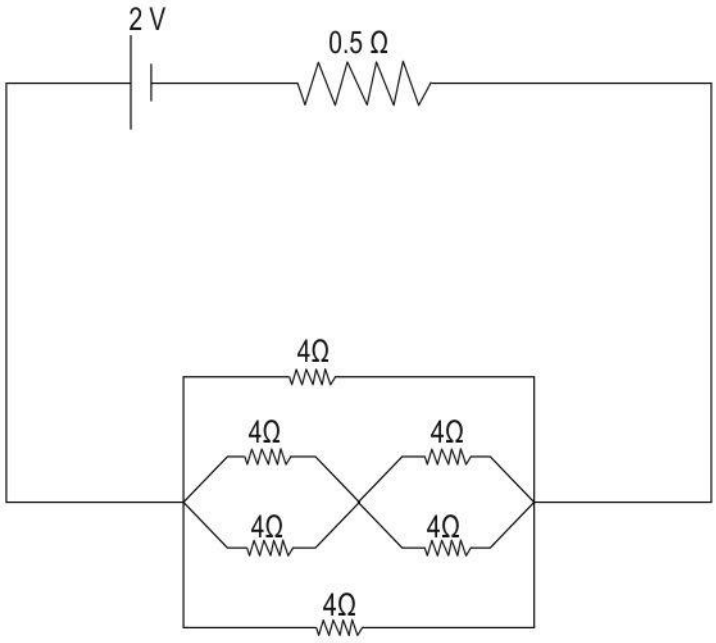
a. Does the current in the battery increase, decrease, or remain the same in each of the two circuits? Give a reason for your answer.

b. Does the terminal voltage of the battery increase, decrease, or remain the same in each of the two circuits? Give a reason for your answer.

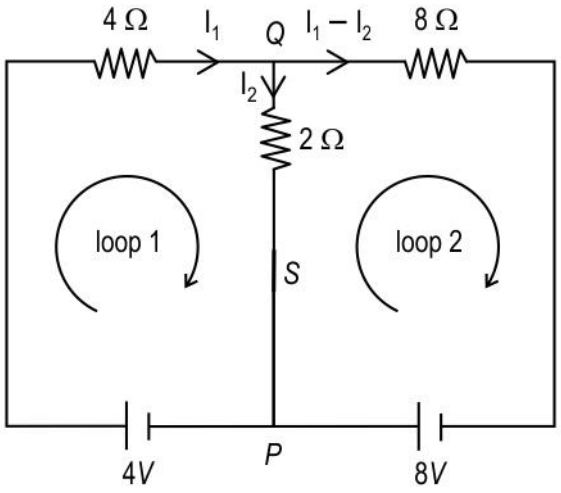
Answer key and Marking Scheme

Q.No	Answers	Marks
Q.39	B. The light bulb has a greater resistance and draws a smaller current than the table fan.	1
Q.40	C. Bulb A in circuits I & II and bulb B in circuits III & IV	1
Q.41	B. n^2	1
Q.42	C. Assertion is true but Reason is false.	1
Q.43	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.44	B. The terminal voltage decreases linearly.	1
Q.45	B. decreases	1
Q.46	D. A is false and R is also false	1
Q.47	A. Both A and R are true and R is the correct explanation of A	1
Q.48	C. A is true but R is false	1
Q.49	Fig A: $\text{Resistance } R_1 = \frac{\rho L}{2L \times 3L} = \frac{\rho}{6L}$ $\text{Current } I_1 = V/R_1 = V \cdot \frac{6L}{\rho}$ [1 mark for the correct expression derived for current I_1] Fig B: $\text{Resistance } R_2 = \frac{\rho(2L)}{L \times 3L} = \frac{2\rho}{3L}$ $\text{Current } I_2 = V/R_2 = V \cdot \frac{3L}{2\rho}$ [1 mark for the correct expression derived for current I_2] So $I_1/I_2 = 4$ $I_1 = 4\ I_2$ [1 mark for the correct relationship between I_1 and I_2]	3
Q.50	The ratio :	2

	$\frac{P_1}{P_2} = \frac{I_1^2 R}{I_2^2 R}$ Here, R is the resistance of the bulb, I_1 and I_2 are the currents flowing through the bulb when connected to battery B_1 and B_2 respectively. (0.5 mark for the correct formula of the power) $I_1 = \frac{V}{R_1} = \frac{V}{R+r_1} = \frac{V}{10+2} = \frac{V}{12}$ $I_2 = \frac{V}{R_2} = \frac{V}{R+r_2} = \frac{V}{10+1} = \frac{V}{11}$ $\frac{P_1}{P_2} = \frac{I_1^2 R}{I_2^2 R} = \frac{11^2}{12^2} = \frac{121}{144}$ (0.5 mark for correct calculation of each current) (0.5 mark for the correct ratio of the powers)	
Q.51	Applying Kirchhoff's rule (in clockwise direction): 30 – 30I – 10 - 15I – 5I – 10I = 0, where I is the current through the loop. Calculating I, I = 1/3 A [*1 mark for the correct value of current through the circuit*] Across points P and Q: $V_P – V_Q$ = -30 +30 x 1/3 = -20 volt $V_Q = V_P + 20$ $V_Q > V_P$ [*1 mark for correct final relation between V_P and V_Q*]	2
Q.52	Energy consumed = P x t = VIt (0.5 mark) Energy consumed in the normal mode E_1 = 220 x 8 x 3600 Energy consumed in the normal mode E_2= 220 x 2 x 3600 (0.5 marks) Additional electrical energy drawn by the heater in normal mode in comparison to that in standby mode $E = E_1 - E_2$= 3600 x 220 (8 - 2)= 4.752 x 10^6 J (1 mark)	2

Q.53	(a) Equivalent network:  Applying the principle of resistors in parallel and series: R_{eq} = 4/3 ohm Current is drawn from the cell due to total Resistance = 4/3 ohm + 0.5 ohm in series = 11/6 ohm (1 mark) V = R I So current drawn from the cell I = 2 x 6/11 = 12/11 A ≈ 1.1 (1 mark) (b) Power consumed by the circuit = $I^2R = (12/11)^2 . (11/6) = 24/11 = 2.2$ W (1 mark)	3
Q.54	(a) Circuit I - the bulb glows when the switch is closed and does not glow when the switch is open. Circuit II - the bulb glows when the switch is open and does not glow when the switch is closed. (0.5 marks for each correct answer.)	2

	(b) Circuit I is preferred because current flows in circuit I only when the switch is closed. In circuit II, current flows both when the switch is opened and closed. This causes a wastage of energy. (OR) In circuit II, when the switch is closed, the battery might get damaged due to short-circuiting. (1 mark for writing the complete answer.)	
Q.55	(a) She can connect the resistors in series with the bulb. When the resistor is connected in series with the bulb, the supply voltage divides between the resistor and the light bulb. Hence, the voltage drop across the bulb can be reduced. (1 mark) (b) Resistance of bulb $R_{bulb} = V^2/P = 3 \times 3/6 = 1.5\ \Omega$ (0.5 marks) For the voltage drop to be 3 V across the bulb, the voltage drop across the resistor should be 9 V. (0.5 marks) Since the same current flows through the resistor and bulb, $V_{bulb}/R_{bulb} = V_{resistor}/R_{resistor}$ $3/1.5 = 9/R_{resistor}$ $R_{resistor} = 4.5\ \Omega$ (1 mark)	3
Q.56	Case (i) - when switch S_1 is closed, only the 75 W filament glows. (0.5 mark) Current through the circuit = P/V = 75/120 = 0.625 A (0.5 mark) Case (ii) - when switch S_2 is closed, only 100 W filament glows (0.5 mark) Current through the circuit = P/V = 100/120 = 0.833 A (0.5 mark) Case (iii) - when both switches are closed, both 75 W and 100 W filament glows. (0.5 mark) Current through the circuit = 0.625 + 0.833 = = 1.458 A (0.5 mark)	3
Q.57	i. Current : It remains the same along the length of the conductor. This is as per Kirchhoff's junction rule. Charge cannot collect at any point along the length of the conductor. [0.5 mark for the correct statement of variation] [0.5 mark for the correct explanation of the same]	4

	ii. Current density J varies inversely with area cross section of the conductor. As J = I/A , more the area cross section, less is the current density, for a constant current through the conductor. [0.5 mark for the correct statement of variation] [0.5 mark for the correct explanation of the same] iii. Resistance varies inversely with area cross section of the wire. R of the wire at broader parts will be lesser than along narrower part. [0.5 mark for the correct statement of variation] [0.5 mark for the correct explanation of the same] iv. Potential drop across two ends of the entire length of the conductor is as provided by the power source. The potential drop across different equal parts along the length of the wire varies in direct proportion to the resistance. Potential drop at narrower end will be more than at broader end (Resistance at narrower end is more than at broader end) [0.5 mark for the correct statement of variation] [0.5 mark for the correct explanation of the same]	
Q.58	When the switch is off, the current through the 4 Ω resistor is I = 12 V/12 Ω = 1 A (0.5 marks) Power dissipated = I^2R = 4 W (0.5 marks) Now, when the switch is closed, let the current in various branches of the circuit be as shown in the image.  Applying KVL in loop 1	3

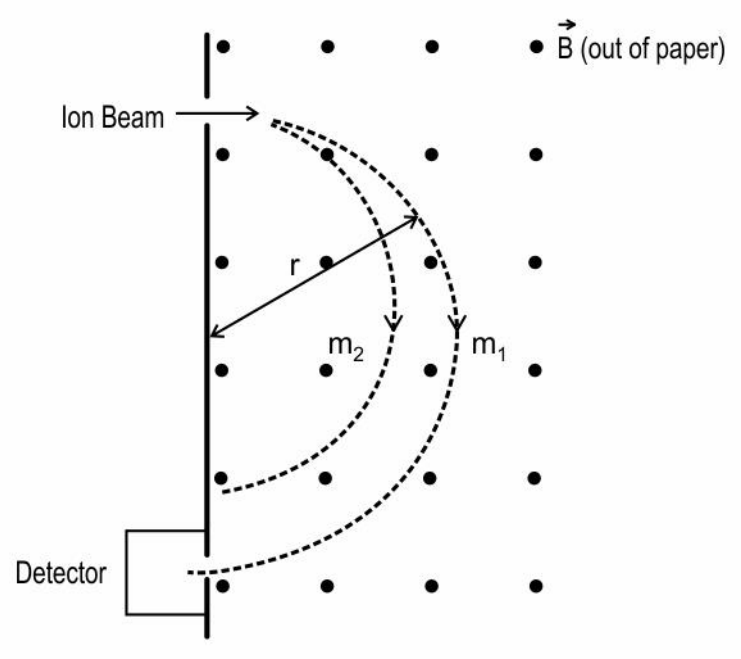
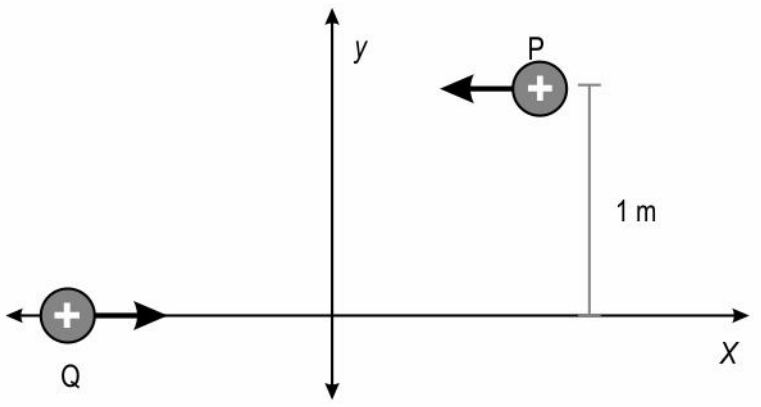
	$4I_1+2I_2 = 4$ $I_2 = 2 - 2I_1$ ...(i) Applying KVL In loop 2 $-2I_2+8I_1-8I_2 = 8$ $-5I_2+4I_1 = 4$ .... (ii) (1 mark for getting two correct equations using Kirchhoff's laws.) from (i) and (ii) $10 - 10I_1 + 4I_1 = 4$ This gives, $I_1 = 1$ A (0.5 mark) The current through the 4 Ω resistor is the same even after the switch is closed, so there will be no change in power dissipated in the 4 Ω resistor. (0.5 mark)	
Q.59	a. Power delivered to a device, $P = V^2/R$ For positive temperature coefficient of resistivity of the material, with time, R will increase. So power delivered will decrease, for a constant voltage supply. For negative temperature coefficient of resistivity of the material, with time, R will decrease. So power delivered will increase, for a constant voltage supply. For a zero-temperature coefficient of resistivity of the material, with time, R will remain constant. So, power delivered will also stay constant, for a constant voltage supply. [1 mark for each case with correct explanation] b. Cannot say. For determining the power drawn by an electric device, the current flowing through the device or the resistance of device is a required. [0.5 mark for correct answer] [0.5 mark for correct explanation]	4
Q.60	a. In circuit 1 - adding another series resistor R_3 increases the total resistance of the circuit 1 and thus reduces the current in the battery. [0.5 mark for the correct explanation]	2

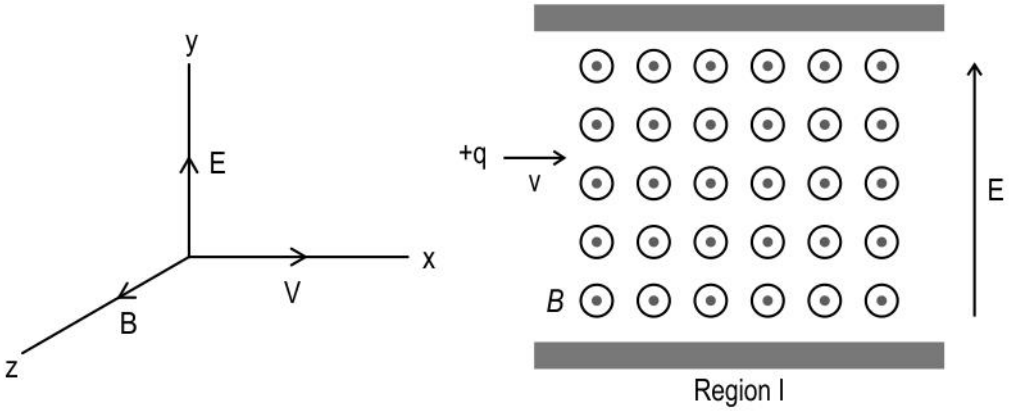
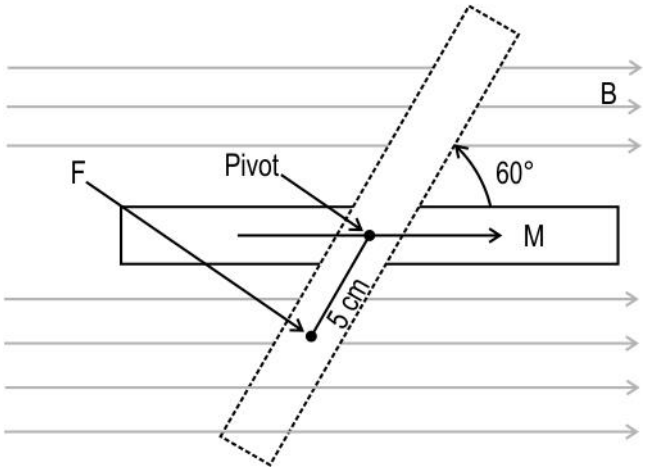
	In circuit 2 - If another resistor R_3 were connected in parallel, the total resistance of the circuit 2 would decrease, and the current in the battery would increase. [0.5 mark for the correct explanation] b. In circuit 1 - The terminal potential difference (V = E -Ir) across the battery terminals increases because the reduced current results in a smaller voltage drop across the internal resistance of the battery. [0.5 mark for the correct explanation] In circuit 2 - The terminal potential difference across the terminals would decrease because the increased current results in a greater voltage drop across the internal resistance of the battery. [0.5 mark for the correct explanation]	

4. Chapter: Moving Charges and Magnetism

Q.No	Question	Marks
	Multiple Choice Question	
Q.61	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The work done by the magnetic field on a proton moving in a circular path in a uniform magnetic field is zero. Reason (R): The force on a charged particle moving in a uniform magnetic field is perpendicular to the direction of motion. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true and reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Both assertion and reason are false.	1
Q.62	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The kinetic energy of a charged particle describing a circular path in a uniform magnetic field does **NOT** remain constant with time. Reason (R): The velocity of a charged particle moving in a circular path in a uniform magnetic field changes with time. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true and reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true.	1
Q.63	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): All atoms have a net magnetic moment. Reason (R): Every electron in an atom possesses an intrinsic magnetic moment.	1

	A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true and reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but reason is true.	
Q.64	A wire of length L is bent to make a triangular coil. All the sides of the triangle are of the same length. If the triangular coil carries a current I, what is its magnetic dipole moment? A. Zero B. IL^2 C. $(\sqrt{3} \times IL^2)/4$ D. $(\sqrt{3} \times IL^2)/36$	1
Q.65	Assertion: In a velocity selector arrangement, with E ⊥ B, all charged particles that move perpendicular to both E and B fields, with speeds v = E/B, go undeflected. The magnetic force on the particles moving at speeds greater than v, is stronger than the electric force, and those moving at speeds less than v will experience a magnetic force that is less than the electric force. Reason: Electric force on the charged particles is independent of velocities, and the magnetic force is directly proportional to the speed of the charged particle. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Free Response Questions/Subjective Questions		
Q.66	A straight wire of length 4 m carrying a current of 0.5 A can be turned into either a square or a circular loop of 2 turns, before placing it in a magnetic field of intensity 0.1 T. Which loop do you think will require less counter torque in order to hold it in a position such that the axis of the loop is perpendicular to the magnetic field? Find the value of this counter-torque.	2
Q.67	A stream of singly charged particles of mass $m_1 = 0.8 \times 10^{-26}$ kg accelerated through a potential difference V are projected into a uniform magnetic field $B_1 =$ 0.2 T. The stream deflects along a curved path under the effect of the magnetic field and strikes the detector.	3

	 Another stream of singly charged particles of mass $m_2 = 0.2 \times 10^{-26}$ kg, projected through the same accelerating potential and into the same magnetic field B_1, fail to reach the detector. To what value should the magnetic field be changed so that this stream of particles strikes the detector?	
Q.68	P and Q are two identical charged particles of mass 4×10^{-26} kg and charge 4.8×10^{-19} C, each moving with the same speed of 2.4×10^5 m/s as shown in the figure. The two particles are equidistant from the vertical y-axis. At some instant, a magnetic field B is switched on so that the two particles undergo head-on collision.  Find (a) the direction of the magnetic field and (b) the magnitude of the magnetic field applied in the region.	2
Q.69	A magnetic dipole of dipole moment m is aligned parallel to an external magnetic field B. Work of 0.25 J has to be done in order to turn it through angle of 60^o. Find the external counter torque that is required in order to maintain the dipole at this angle.	2

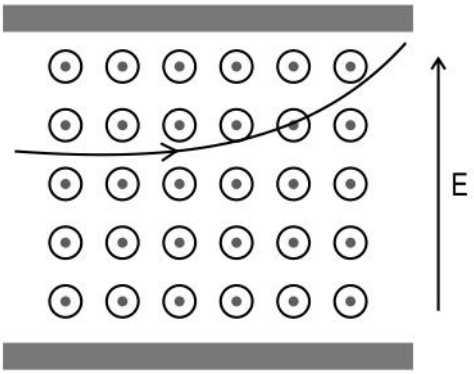
Q.70	Two identical metal loops A and B lie close to each other on the same plane without touching each other. If a current begins to flow through loop A, whose magnitude increases with time, state if the two loops attract or repel each other. Give a reason for your answer.	2
Q.71	A charged particle '+q' moving with a velocity 'v' enters region I of crossed electric and magnetic field as shown below.  Represent the various paths that can be described by the particle in the region I. Also, specify the condition under which it describes each path. (*Neglect the effect of gravity acting on the particle*)	3
Q.72	A bar magnet pivoted at its centre rests in a uniform magnetic field. 4 J of work is done in rotating the bar magnet through an angle of 60° from its stable equilibrium position as shown below.  Calculate the force F that should be applied at right angles to the axis of the magnet at a distance of 5 cm from the pivot to hold the magnet at 60°.	2
Q.73	A current-carrying solenoid of 50 turns/cm carries a current of 2 A. a. Find the magnetic intensity H at the center of the solenoid.	3

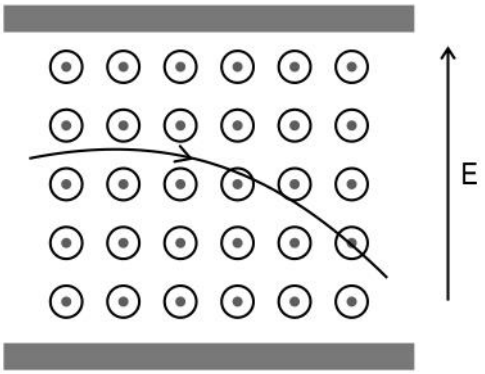
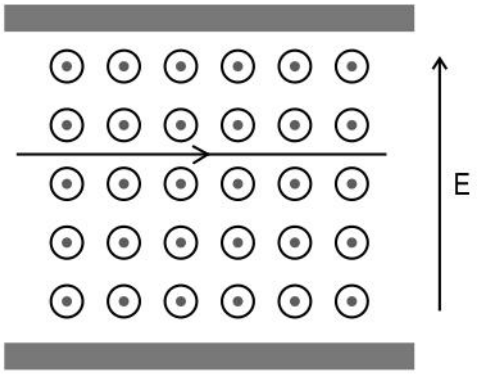
	b. A material P of magnetic susceptibility $\chi_p = 5 \times 10^{-3}$ is introduced as the core of the solenoid. Is the material P diamagnetic, paramagnetic or ferromagnetic? Find the magnetization M developed in the core. c. The material P is now replaced by the material Q of magnetic susceptibility $\chi_q = 5 \times 10^{3}$. Is the material Q diamagnetic, paramagnetic or ferromagnetic? d. Mention the type of magnetic material that has (i) M >> H (ii) M << H	

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.61	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.62	D. Assertion is false but the reason is true.	1
Q.63	D. Assertion is false but reason is true.	1
Q.64	D. $(\sqrt{3} \times IL^2)/36$	1
Q.65	A. Both A and R are true and R is the correct explanation of A	1
Q.66	Length of wire = 4 m The perimeter of the coil with 2 turns = 2 m For a given perimeter, a circular loop will have more area than the square loop. Torque on the loop is directly proportional to the area of the loop. Therefore, the counter-torque required to hold the coil in a position such that the axis of the loop is perpendicular to the magnetic field will be less for square loop than for the circular loop. [1 mark for the correct conclusion of lesser counter-torque with correct argument] The counter torque required is τ = MB sin 90 = n I A B = 2 x 0.5 x (side x side) x 0.1 Side of square = perimeter /4 = 2/4 = 0.5 m τ = 2 x 0.5 x (0.5 x 0.5) x 0.1 = 0.0250 Nm. [1 mark for the correct calculation of the counter torque]	2
Q.67	Equating the kinetic energy of charged particles to the energy gained due to accelerating potential V,	3

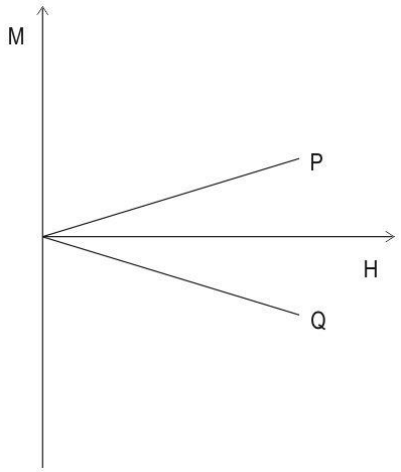
	$\frac{1}{2}mv^2 = qV$ $v = \sqrt{\frac{2qV}{m}}$ [1 mark for the correct expression of speed] Equating the magnetic force on the charged particles to the centripetal force acting on them, $qvB = \frac{mv^2}{r}$ $B = \frac{1}{r}\sqrt{\frac{2mv}{q}}$ [1 mark for the correct expression of magnetic field] For same accelerating potential V, radius r and charge q, $\frac{B_2}{B_1} = \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{0.2}{0.8}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$ $B_2 = B_1/2 = 0.2/2 = 0.1$ T [1 mark for correct calculation of value of B_2]	
Q.68	(a) Perpendicular and into the page. [0.5 mark] (b) For a head-on collision to take place, the radius of the path of each ion should be equal to 0.5 m. $\mathbf{r = \frac{mv}{qB} = 0.5\ m}$ $\mathbf{B = \frac{mv}{qr} = \frac{4 \times 10^{-26} \times 2.4 \times 10^{5}}{4.8 \times 10^{-19} \times 0.5}}$ Solving for B = 0.04 T [0.5 mark for determining the value of r] [1 mark for correct calculations & result]	2
Q.69	Work done to rotate from parallel to 60^o , $W = \lvert mB(\cos\theta_2 - \cos\theta_1) \rvert$ $= \lvert mB(\cos 60 - \cos 0) \rvert$ $= \lvert mB(1/2 - 1) \rvert$	2

	= mB/2 [1 mark for correct formula and final expression of W] Counter torque required to hold the dipole at angle 60^o, $\tau = mB\sin\theta = mB \sin 60 = \sqrt{3}mB/2$ $\tau = \sqrt{3} \times W = \sqrt{3} \times 0.25 = \sqrt{3}/4$ N-m [1 mark for correct calculation and final result]	
Q.70	Due to increasing current through loop A, magnetic field lines through loop B also increase. This induces an emf in loop B so that current through loop B is in the direction opposite to that in loop A. [1 mark for the reason] This is as per Lenz's law. Since the currents are in opposite direction, loop B is repelled by loop A. [1 mark for the conclusion]	2
Q.71	The particle experiences a force due to an electric field along the + y direction and magnetic force along the - y direction. $F_E = qE$ $F_B = qvB$ The various paths described by the particle depend on the relation between F_E and F_B **Case 1**: $F_E > F_B$  **Case 2:** $F_E < F_B$	3

	 **Case 3:** $F_E = F_B$  (*1 mark each for representing each case correctly along with the condition*)	
Q.72	A magnet is in stable equilibrium in a uniform magnetic field when its magnetic moment is aligned with the direction of the magnetic field ie when θ = 0° Let M be the dipole moment of the magnet and B be the magnetic field. Work done in rotating the bar magnet through 60° = $U_f - U_i$ = - MBcos60° + MB cos0° = MB/2 4 = MB/2 MB = 8 units (1 mark) The force applied at 5cm from the pivot should provide the necessary torque required to hold the magnet at 60°. Torque acting on dipole at 60° = MBsin 60° = 8 × √3/2 = 4√3 N m 4√3 = F × 5/100 F = 400√3/5 =80√3 N (1 mark)	2
Q.73	a. Magnetic intensity, H = n I = 50 x 100 x 2 = 10^4 A/m [0.5 mark for correct value of H]	3

	b. Since $\chi_p = 5 \times 10^{-3}$ is small and positive, the material P is paramagnetic. [0.5 mark for correct identification of the material P] Magnetization M developed in P, $M = \chi_p H = 5 \times 10^{-3} \times 10^4 = 50$ A/m [0.5 mark for correct value of M] c. Since $\chi_q = 5 \times 10^3$ is large and positive, the material Q is ferromagnetic. [0.5 mark for correct identification of the material Q] d. (i) Ferromagnetic material has magnetization M >> H (ii) Paramagnetic material has magnetization M << H. [0.5 mark for the correct statements]	

5. Chapter: Magnetism and Matter

Q.No	Question	Marks
	Multiple Choice Question	
Q.74	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): Paramagnetic substances are weakly attracted to magnets. Reason(R): The individual atoms of a paramagnetic substance do NOT possess a permanent magnetic dipole moment. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation of assertion. C. Assertion is true but reason is false. D. Both assertion and reason are false.	1
Q.75	The graph below represents the variation of intensity of magnetisation (M) with magnetic field strength (H) for substances P and Q.  Which of the two substances is most likely to be attracted when taken near a magnet? A. Only P B. Only Q C. Both P and Q D. Neither P nor Q	1

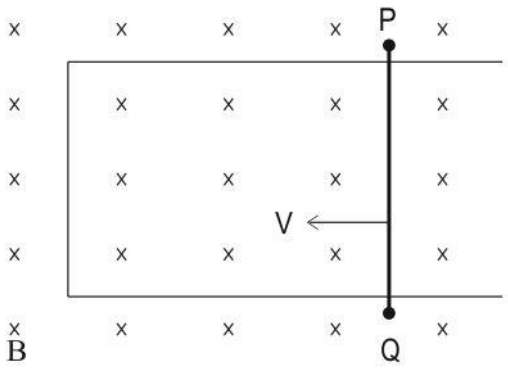
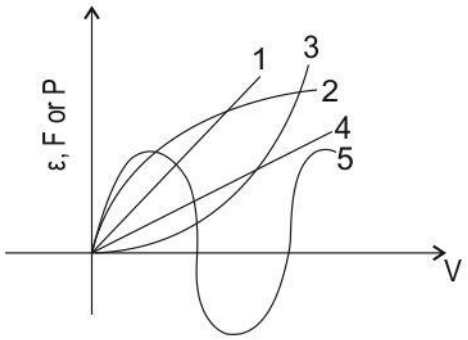
Q.76	Assertion: Monopoles exist only as electric charges, not in magnetism. Reason: Gauss law states that the net magnetic or electric flux through any closed surface is always zero. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true and but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Free Response Questions/Subjective Questions		
Q.77	Read the following information. Each of the orbiting electrons in an atom contributes towards the orbital magnetic moment. In a diamagnetic material, the resultant magnetic moment of each atom is zero. When exposed to an external magnetic field, the diamagnetic substance experiences repulsion. Answer the following: (a) Why are diamagnetic materials repelled when placed in an external field? Give an explanation basis the changes that occur to the orbital magnetic moment of the electrons. (b) In contrast to a diamagnetic material, how does a material with each individual atom having a non-zero magnetic dipole moment but all atoms aligned in random directions, respond to an external magnetic field? What are such materials known as? (c) In the material identified in (b) what is the effect of fall in temperature and rise in applied magnetic field intensity? (d) What does the value $\mu_r = 0$ signify in a magnetic material? Find χ of such material. What are such materials known as?	4
Q.78	Earth's magnetic field is assumed to be due to a small magnetic dipole located at its core. Considering the distance of either of the poles from the centre of the Earth to be about 6400 km and the measure of the Earth's magnetic field at the poles as 0.6×10^{-4} T, what is the magnetic dipole moment of the assumed magnetic dipole located at the centre?	2

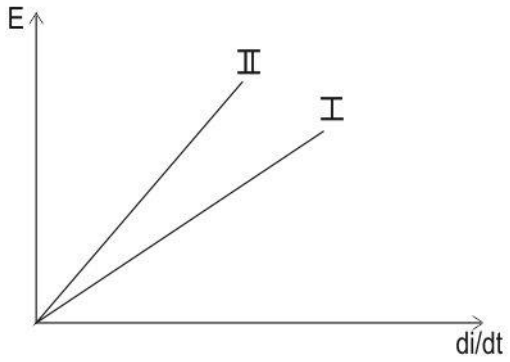
Answer key and Marking Scheme

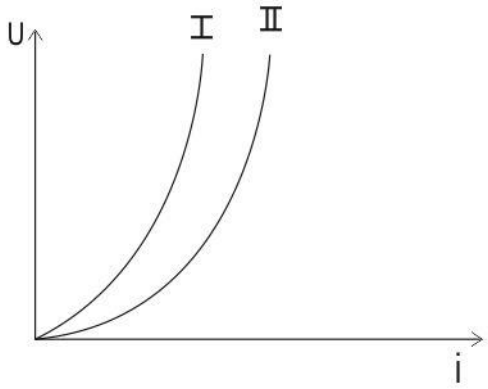
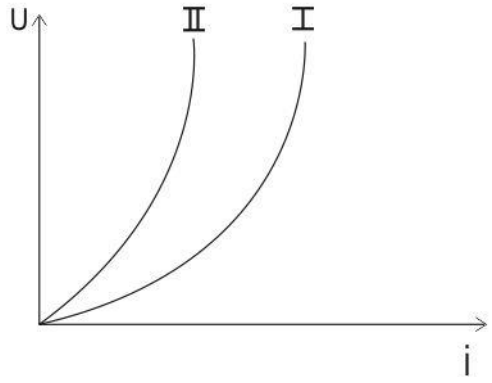
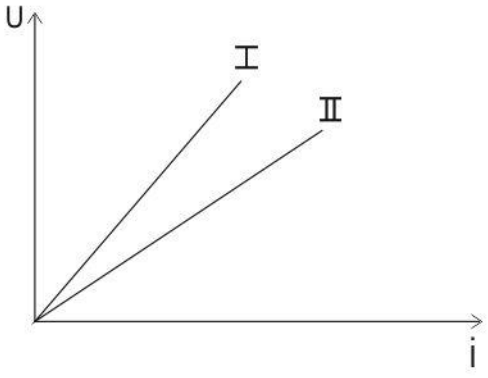
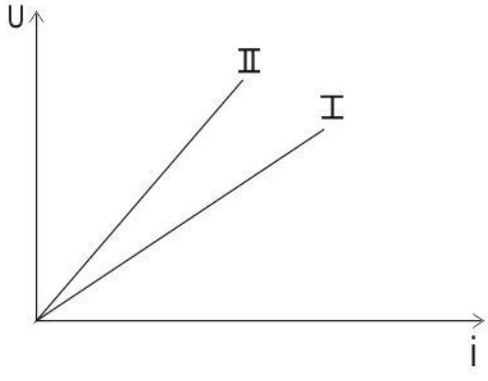
Q.No	Answers	Marks
Q.74	C. Assertion is true but reason is false.	1
Q.75	A. Only P	1
Q.76	C. A is true but R is false	1
Q.77	(a) When an external magnetic field B is applied to a diamagnetic material, the electrons with an orbital magnetic moment in the direction same as B, slow down whereas the ones in the direction opposite to B, speed up. The diamagnetic material develops a net non-zero magnetic moment in the direction opposite to the applied B. This results in repulsion. [1 mark for correct explanation] (b) Each atom with a net non-zero magnetic moment aligns parallel to the applied magnetic field B. The material will experience attraction. [0.5 mark for correct explanation] They are known as paramagnetic materials. [0.5 mark for correct identification] (c) With the fall in temperature and rise in the applied magnetic field intensity B, the magnetization intensity M of paramagnetic material increases until all dipole moments are perfectly aligned to B. The material is said to have reached its magnetic saturation. [0.5 mark for correct description] (d) As $\mu_r = 1+ \chi$, if $\mu_r = 0$, it implies $\chi = -1$. If such a material is placed in an external magnetic field, it will repel all the field lines. The net magnetic field inside the material, that, $B = \mu H = \mu_0\mu_r H = 0$. [0.5 mark for correct interpretation] [0.5 mark for correct value of χ] Such materials are known as perfectly diamagnetic materials or superconductors. [0.5 mark for identification of material]	4

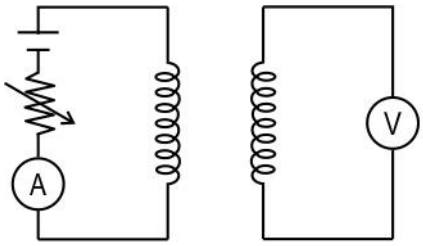
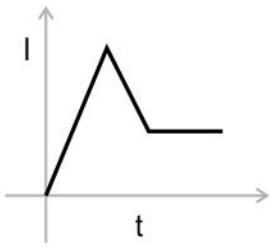
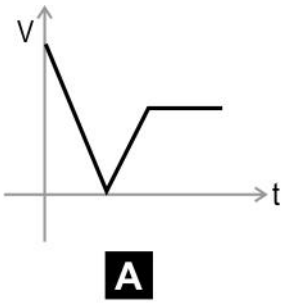
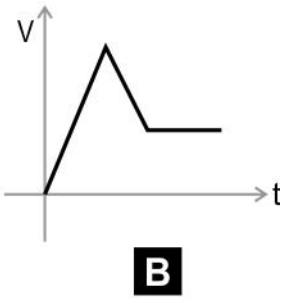
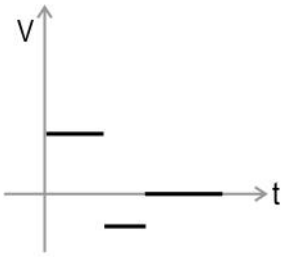
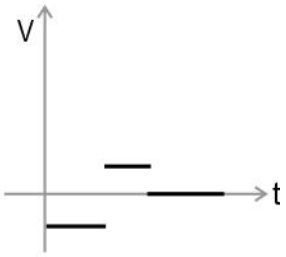
Q.78	The magnetic field due to magnetic dipole at the center, aligned along the magnetic meridian (end-on position), $B = \frac{\mu_o}{4\pi}\frac{2m}{R^3}$ for R >> length of earth's dipole [0.5 mark for correct formula & 0.5 mark for the correct identification of the end on-position of the Earth's poles with respect to Earth's magnetic dipole] For R >> length of earth's dipole $0.6 \times 10^{-4} = 10^{-7} \times 2m/(6400 \times 10^3)^3$ $m = \frac{0.6 \times 10^{-4} \times (6400 \times 10^3)^3}{2 \times 10^{-7}} = \frac{0.6 \times 64^3}{2} \times 10^{18}$ $m = 7.8 \times 10^{22}\ Am^2$ [1 mark for correct calculation and final result]	2

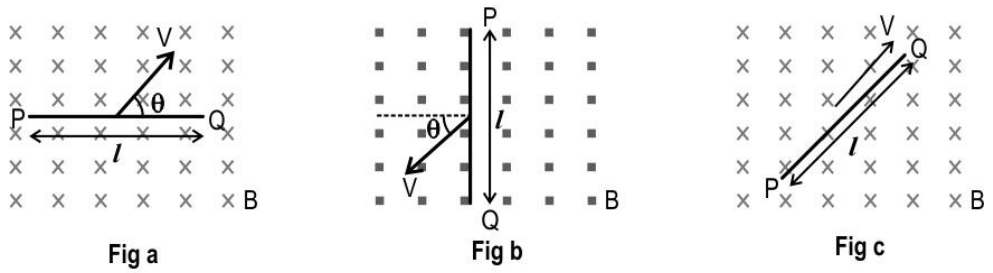
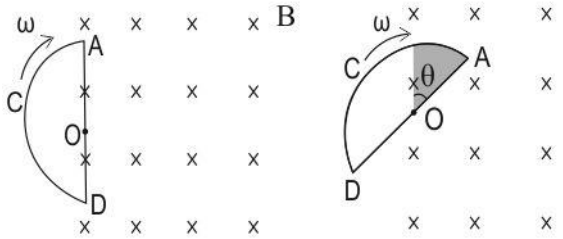
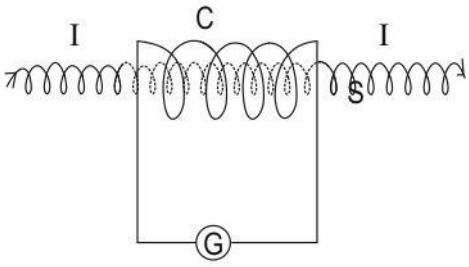
6. Chapter: Electromagnetic Induction

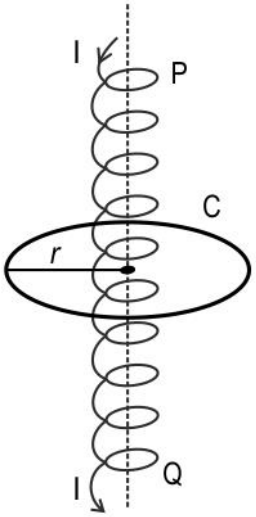
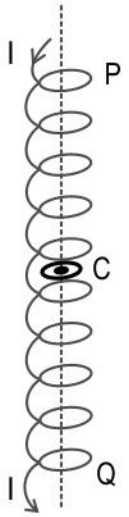
Q.No	Question	Marks
	Multiple Choice Question	
Q.79	A conducting rod PQ of a small resistance is moved at a constant velocity v under the effect of a constant force F through a region of the constant magnetic field as shown. Assume no energy losses.  If the emf induced across PQ is ε and a force F and power P is used to move the rod, then which of the following graphs correctly represent ε, F, and P as a function of speed v respectively?  A. Graphs 5, 3 and 1 B. Graphs 2, 4 and 5 C. Graphs 4, 1 and 3 D. Graphs 3, 2 and 4	1
Q.80	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The charge induced in a closed circuit increases if the rate of change of flux associated with the circuit increases rapidly.	1

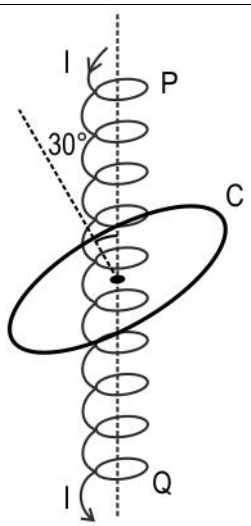
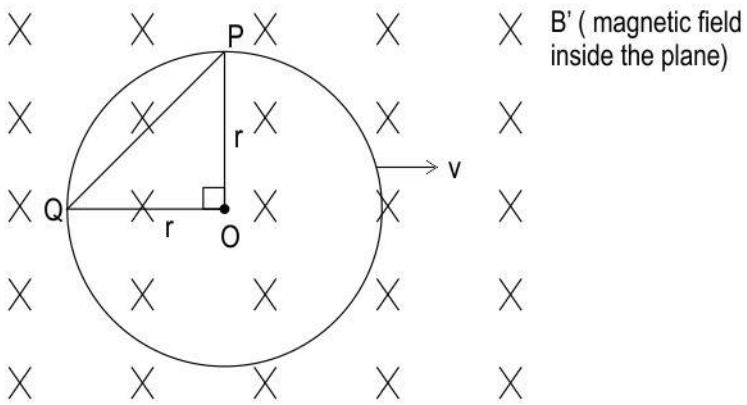
	Reason (R): The emf induced in a closed circuit is directly proportional to the rate of change of flux associated with the coil. A. Both assertion and reason are true and reason is the correct explanation of assertion. B. Both assertion and reason are true but reason is NOT the correct explanation of assertion. C. Assertion is true but reason is false. D. Assertion is false but reason is true.	
Q.81	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The induced emf in a coil increases if the resistance of the coil is increased. Reason (R): Higher the resistance, the less the current through a coil. Select the correct option. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true.	1
Q.82	The following graphs represent emf induced with the rate of change of current for two different inductors.  Which of the given options correctly represents the energy stored versus current through these inductors?	1

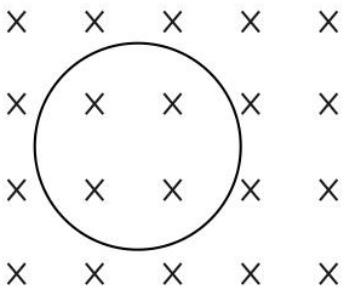
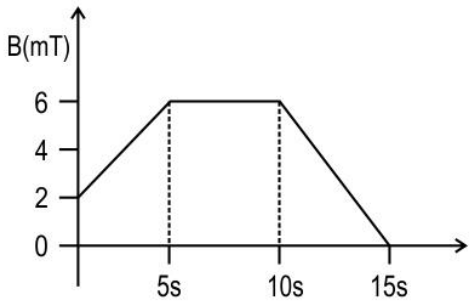
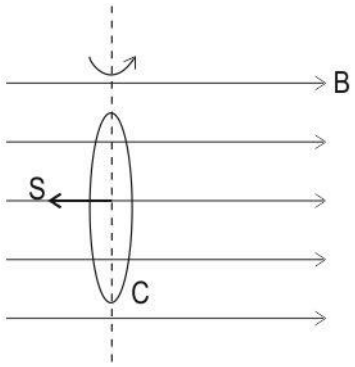
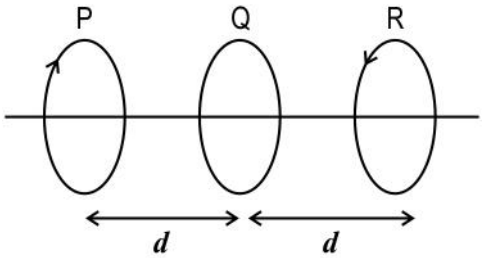
	A.  B.  C.  D.  	**4**
Q.83	Circuit I consists of a coil of wire, a battery, a rheostat, and an ammeter. Another coil connected to a voltmeter is placed close to the circuit I as shown below. As the resistance of the rheostat is changed, the current in the coil of the circuit I changes. The graph below shows this change in current with time.	1

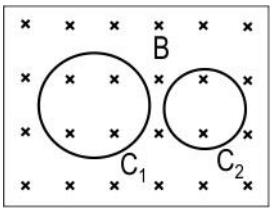
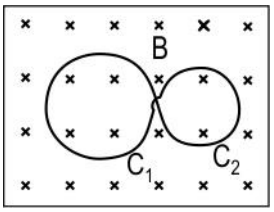
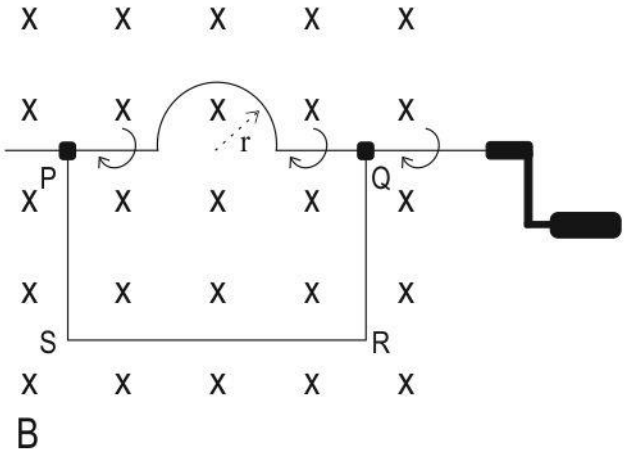
	  Which of the graphs correctly shows the voltage measured by the voltmeter with time?  A  B  C  D A. A B. B C. C D. D	
Q.84	Assertion (A): For a sustained induced motional emf across a metal rod, a constant work has to be done on the rod by an external agency for moving it with constant speed through the external magnetic field. Reason (R): Work done by the external force keeps the charges in motion through the rod for a sustained induced current. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1

Free Response Questions/Subjective Questions		
Q.85	A uniform magnetic field B exists in a direction perpendicular to the plane of motion of a conductor of length l translating at a velocity v as shown in the figures below.  Fig a Fig b Fig c Write an expression for induced emf in each case. Draw a figure representing the induced emf by an equivalent battery in each case.	3
Q.86	ADC is a semi-circular loop of conducting wire of radius r and centred at O. The initial position of the loop with respect to the magnetic field is shown in fig 1. The loop is then pulled into the magnetic field (fig 2.) and makes two complete rotations about point O.  (a) Plot a graph between the induced current I and the angle of rotation θ for two complete periods of rotations. (b) Depict the above graph in case the loop ADC revolves with angular frequency ω' > ω. Keep all other conditions fixed as earlier. Give a reason for the change depicted in the graph.	3
Q.87	A current-carrying solenoid S of radius r with 100 turns per unit length is placed coaxially inside coil C of 100 turns and twice the radius of the solenoid as shown.  Current I through the solenoid S changes from 2 A in one direction to 2 A in the opposite direction within an interval of 2 seconds.	3

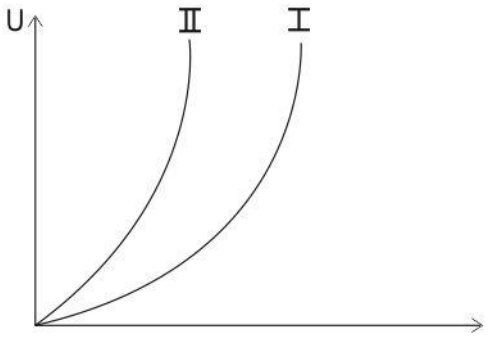
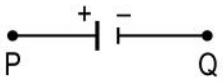
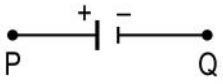
	(a) What is the rate of change in current that occurs in the solenoid? (b) Calculate the rate of change in flux experienced by coil C due to a change in current in solenoid S in terms of radius r of solenoid S. (c) If the total resistance of the coil C is 5 ohm, what is the induced current through the coil C? (d) By what factor does the induced current in coil C in part (c) change if the radius of the solenoid is changed from r to 3r/2? Keep all other conditions the same as earlier.	
Q.88	A long and an ideal solenoid of length l, radius R and number of turns N carries a steady current I. Determine the flux linked with a circular surface C of radius r in each of the following cases:  Fig i : r > R , Plane of coil ⊥ axis of the solenoid  Fig ii : r < R , Plane of coil ⊥ axis of the solenoid	3

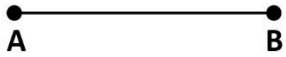
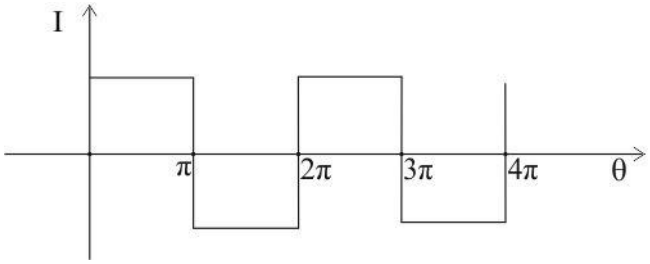
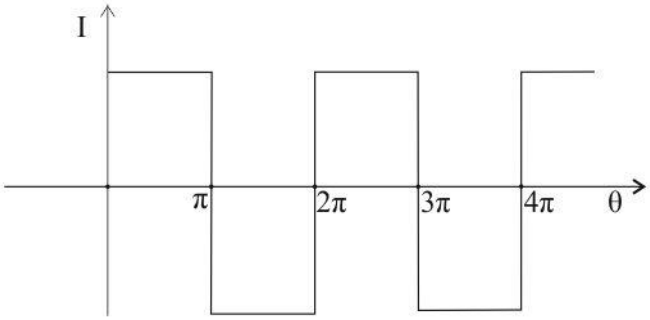
	 Fig iii : r >R , Normal to the plane of coil subtends an angle 30° with the axis of the solenoid	
Q.89	A long straight wire carrying a current of 0.1 A is placed at a distance of 10 m from a small conducting square loop in the same plane. The side of the square is 11 mm and the resistance of the square is 3 ohms. An external agent gradually changes the shape of the square loop to nearly a circle in 2 seconds. What is the average induced current in the loop?	3
Q.90	A conducting circular coil of radius 2 cm translates with a uniform velocity of 'v' in a uniform magnetic field as shown below.  (a) If ∠POQ is 90°, what is the induced potential difference between points P and Q? (b) Draw a figure representing the induced potential difference between points P and Q by an equivalent battery. (c) What is the net-induced emf in the conducting circular coil when the coil is moved within the magnetic field? Justify your answer.	4
Q.91	A circular loop of conducting wire is placed in a time-varying magnetic field such that the plane of the loop is perpendicular to the magnetic field. The graph below represents the variation of the magnetic field with time.	5

	  (a) In which time interval will the current induced in the coil be in the clockwise direction? Give reason. (b) Calculate the induced emf in the coil for the time interval t = 0s to t = 15s, if the area of the loop is 5×10^{-4} m^2. (c) Graphically represent the induced emf as a function of time.	
Q.92	A coil C of N turns and area S is placed normal to the magnetic field B as shown.  Determine the rate of change in flux linked with coil C as it turns about its diameter from the initial position as shown in the figure through an angle of 180° with angular velocity ω.	2
Q.93	Given three identical coils P, Q and R placed coaxially as shown. Equal and opposite currents flow through the coils P and R.  a. Coil P is moved to the right keeping the coils Q and R fixed. i. Will the flux linked with coil Q increase or decrease? Give reason. ii. Using Lenz's law, identify the direction of induced current through coil Q.	2

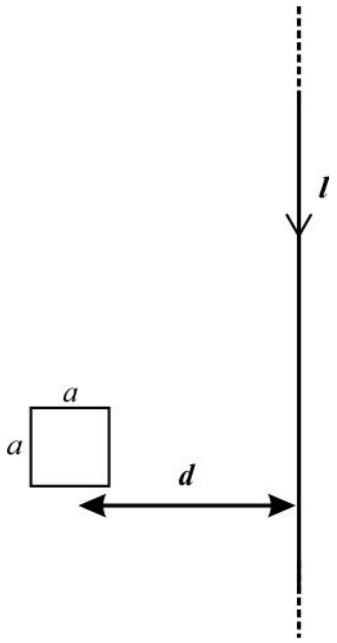
	b. Coil P is moved to the left keeping the coils Q and R fixed. i. Will the flux linked with coil Q increase or decrease? Give reason. ii. Using Lenz's law, identify the direction of induced current through coil Q.	
Q.94	(a) Two static coils C_1 and C_2 are placed in the same plane in a region of uniform magnetic field B. If the magnetic field begins to increase at a constant rate, identify the directions of the induced currents in the two coils as seen from above.  (b) The two coils C_1 and C_2 of the above arrangement are now connected as shown below keeping all other conditions the same as earlier.  Identify the directions of the induced current through the coils C_1 and C_2 as seen from above. Give an appropriate reason for the answer.	2
Q.95	Part of the wire belonging to the loop PQRS is bent into a semicircle of radius r = 0.2 m as shown in the diagram.  Initially, the plane of the loop is perpendicular to the magnetic field B = 0.5 T. Find the change in the flux linked with the loop PQRS, when the wire PQ is rotated from the starting position as shown in the figure to the final position attained after half a rotation.	2

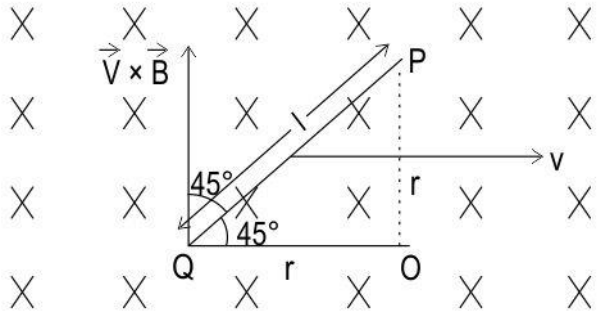
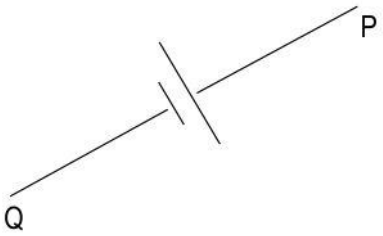
Answer key and Marking Scheme

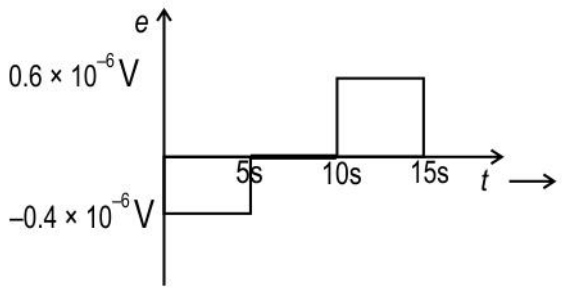
Q.No	Answers	Marks
Q.79	C. Graphs 4, 1 and 3	1
Q.80	D. Assertion is false but reason is true.	1
Q.81	D. Assertion is false but the reason is true.	1
Q.82	 B.	1
Q.83	D. D	1
Q.84	C. A is true but R is false	1
Q.85	For Fig a : $\varepsilon = v_{\perp} l B = vlB \sin\theta$  [0.5 mark for correct formula and 0.5 mark for correct representation of the battery] For Fig b : $\varepsilon = v_{\perp} l B = vlB \cos\theta$  [0.5 mark for correct formula and 0.5 mark for correct representation of the battery] For Fig c : $\varepsilon = 0$	3

	 [0.5 mark for correct formula and 0.5 mark for correct representation of the battery]	
Q.86	(a) The graph between I and angle of rotation θ when the loop revolves with angular frequency ω :  (1 mark for the correct graphical representation) (b) The graph between I and angle of rotation θ when the loop revolves with higher angular frequency ω' :  (1 mark for the correct graphical representation) Reason: As angular frequency increases, the rate of change in the flux linked with the loop increases. This increases the induced emf and hence the corresponding value of the induced current also increases. (1 mark for the correct statement of the reason)	3
Q.87	a. Rate of change in current, $\Delta I/\Delta t = 4/2 = 2$ A/s [0.5 mark for correct value] b. Let n be the number of turns per unit length of coil S and N be the number of turns for coil C. Flux through S $\Phi_s = BA = (\mu_o nI)(\pi r^2)$ Rate of change in flux linked to coil C, $\Delta\Phi_C/\Delta t$ $= N \cdot \Delta\Phi_s/\Delta t$ $= N\, \mu_o\, n\pi r^2 \cdot \Delta I/\Delta t$	3

	= 100 x 4π x 10^{-7} x 100 x π x r^2 x 2 = $8\pi^2r^2$ x 10^{-3} [1 mark for the correct result of rate of change in flux of C] c. Induced emf in coil C ε = $\Delta\Phi_C/\Delta t$ = $8\pi^2r^2$ x 10^{-3} V Induced current I through coil C = ε / R = ($8\pi^2$ r^2 x 10^{-3})/5 [1 mark for the correct result of induced current in C] d. Induced Current I' = [$8\pi^2(3r/2)^2$ x 10^{-3}]/5 I'/I = $(3/2)^2$ = 9/4 I' = 9I/4 = 2.25 I The induced current increases by a factor of 2.25 [0.5 mark for correct final answer]	
Q.88	Fig i : Here θ = 0, $\phi_{in} = B_{in}A\cos\theta$ $\phi_{in} = \frac{\mu_0 NI}{l}\pi R^2 \cos 0$ $\phi_{in} = \frac{\mu_0 NI}{l}\pi R^2$ Φ_{out} = 0 (Magnetic field outside the solenoid is zero.) $\phi_c = \phi_{in} + \phi_{out}$ $\phi_c = \frac{\mu_0 NI}{l}\pi R^2$ [1 mark for the correct result] Fig ii : $\phi_{in} = B_{in}A\cos\theta$ $\phi_{in} = \frac{\mu_0 NI}{l}\pi r^2 \cos 0$ $\phi_{in} = \frac{\mu_0 NI}{l}\pi r^2$ [1 mark for the correct result] Fig iii : $\phi_{in} = B_{in}A\cos\theta$ $\phi_{in} = \frac{\mu_0 NI}{l}\pi R^2 \cos 30$ $\phi_{in} = \frac{\sqrt{3}\mu_0 NI}{2l}\pi R^2$ [1 mark for the correct result]	3

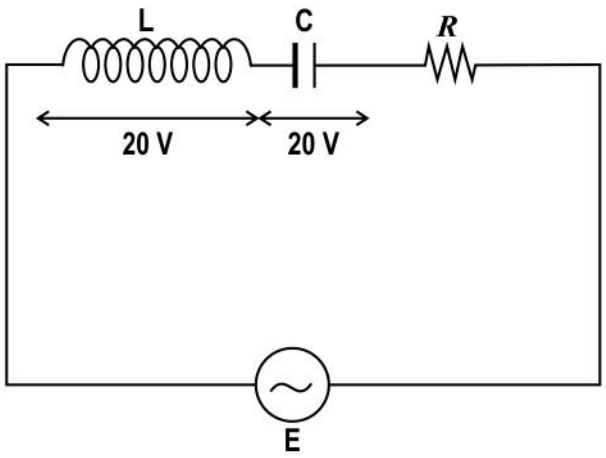
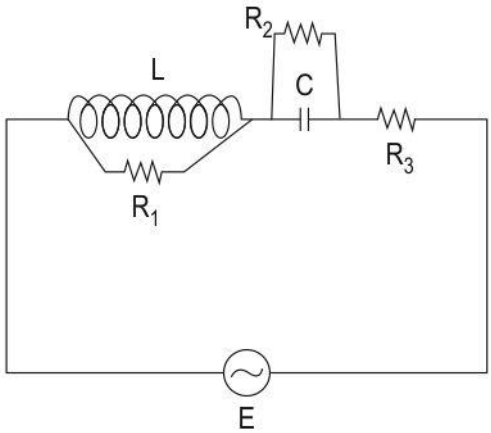
Q.89	 Given: Distance between wire and the centre of the loop, d = 10 m Current in the wire, I = 0.1 A Side of the square loop, a = 11 mm Resistance of the loop, R = 3 ohm Time taken for changing from square to circle, Δt = 2 s To find: Average induced current = I_{avg} = (Average induced EMF)/Resistance = $\Delta\Phi/R\Delta t$ .....(i) $\Delta\Phi = B\Delta A = (\mu_0 I/2\pi d) \times \Delta A$ (B is magnetic field due to the long straight wire) Substituting the known values we get, $\Delta\Phi = (\mu_0 \times 0.1/2\pi \times 10) \times \Delta A = 2\ 10^{-9} \times \Delta A$ .....(ii) [0.5 marks for writing correct formula of flux change and 0.5 marks for correct formula of magnetic field due to long straight wire] When the square changes to circle its perimeter will remain the same so we can say $2\pi r = 4a$ $r = 2a/\pi$ Now, $\Delta A = \pi r^2 - a^2 = \pi(2a/\pi)^2 - a^2$ $= (4a^2/\pi) - a^2$ Substituting the value of a	3

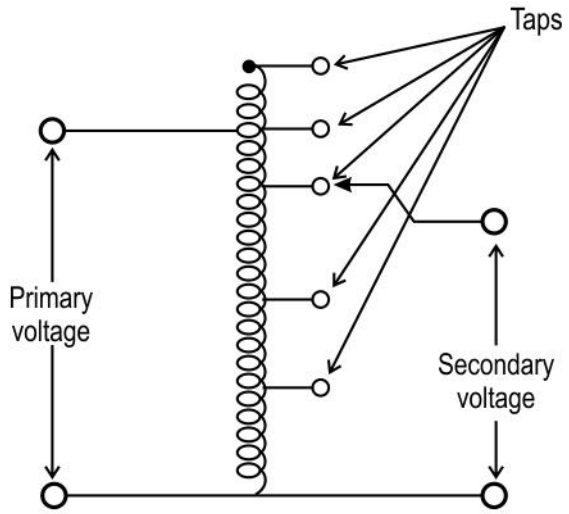
	$\Delta A = (4 \times 11 \times 11 \times 7/22)-(11 \times 11) = 33\ mm^2 = 33 \times 10^{-6}\ m^2$ Substituting value of ΔA in (ii) we have $\Delta\Phi = 2 \times 10^{-9} \times 33 \times 10^{-6} = 6.6 \times 10^{-14}\ T.m^2$ [1 mark for finding change in area] Substituting values in equation (i) $I_{avg} = 6.6 \times 10^{-14}/(3 \times 2) = 1.1 \times 10^{-14}\ A$ [1 mark for final answer]	
Q.90	(a) Δ POQ is right angled triangle at O. By Pythagoras theorem, the displacement vector between points A and B has a magnitude of √2r. $\left\vert\vec{l}\right\vert = \sqrt{2}r$ (1 mark) $e = (\vec{v} \times \vec{B}).\vec{l}$ The angle between $(\vec{v} \times \vec{B})$ and $\vec{l}$ is 45° as shown below.  e = (vBsin90°) lcos 45° e = vlB/√2 = vBr (1 mark) (b)  (c) Since neither the area of the loop nor the magnetic field linked with the field is changing, there is no change in the flux through the coil.	4
Q.91	(a) For the induced current to be clockwise, the magnetic flux associated with the circular coil should decrease. (1 mark) The flux associated with the coil decreases when the magnetic field associated with the coil decreases as ϕ =B.A	5

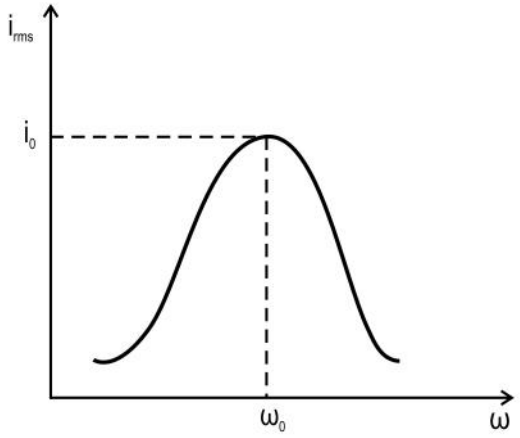
	Hence, in the time interval t=10s to t=15s, the induced current will be clockwise. (1 mark) (b) $e = -d\phi/dt$ (0.5 marks) For t = 0s to t = 5 s $d\phi = dB.A = (6-2) \times 10^{-3} \times 5 \times 10^{-4}$ $d\phi = 2 \times 10^{-6}$ Wb $e = -2 \times 10^{-6}/5 = -0.4 \times 10^{-6}$ V (0.5 marks) Induced emf from t= 5 s to t = 10s = 0 as there is no change in magnetic flux. (0.5 marks) induced emf from t = 10s to t = 15 s $d\phi = (0 - 6) \times 10^{-3} \times 5 \times 10^{-4}$ $d\phi = -3 \times 10^{-6}$ Wb $e = -d\phi/dt$ $e = 3 \times 10^{-6}/5 = 0.6 \times 10^{-6}$ V (0.5 marks) (c)  	
Q.92	Flux linked with a coil is given by the formula, $\phi = \vec{B}.\vec{A} = BA\cos\theta$ Here, B is the magnetic field strength and A is the area of the coil and θ is the angle between the magnetic field and the area vector. Initial flux linked with coil, $\Phi_1 = BNS \cos 180 = -BNS$ Final flux linked with coil, $\Phi_2 = BNS \cos 0 = BNS$ Change in flux = $\Delta\Phi = BNS - (-BNS) = 2BNS$ [1 mark for correct result of change in flux] Time duration, $\Delta t = \pi/\omega$ Rate of change in flux $\Delta\Phi/\Delta t = 2BNS\omega/\pi$ [0.5 mark for time formula] [0.5 mark for correct final result]	2

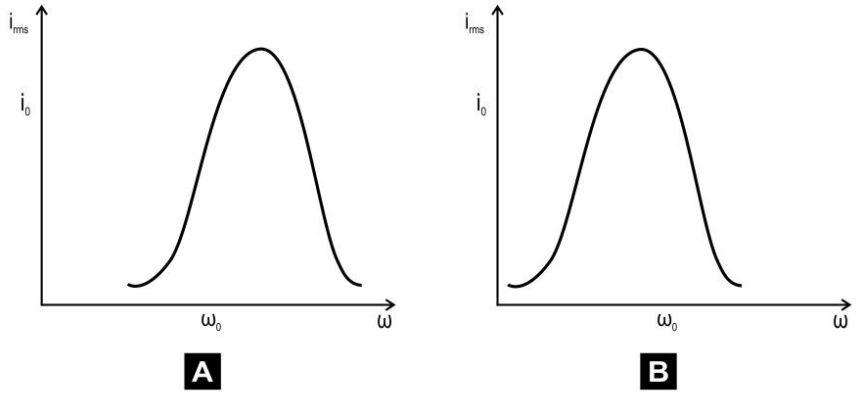
Q.93	a. i. Flux linked with coil Q due to coil P increases. Flux linked with coil Q due to coil R remains the same. So the overall flux linked with the coil Q increases. [0.5 mark for correct conclusion of overall change in flux linked with Q] ii. Induced current through Q flows in the direction opposite to that in P, that is anti-clockwise direction. [0.5 mark for correct conclusion of the direction of induced current through coil Q] b. i. Flux linked with coil Q due to coil P decreases. Flux linked with coil Q due to coil R remains the same. Overall flux linked with the coil Q decreases. [0.5 mark for correct conclusion of overall change in flux linked with Q] ii. Induced current through Q flows in the direction same as that in P, that is clockwise direction. [0.5 mark for correct conclusion of the direction of induced current through coil Q]	2
Q.94	(a) The direction of the induced current through C_1 : Anticlockwise The direction of the induced current through C_2 : Anticlockwise [0.5 mark for the correct identification of directions through C_1 and C_2] (b) The direction of the induced current through C_1 : Anticlockwise The direction of the induced current through C_2 : Clockwise [0.5 mark for the correct identification of directions through C_1 and C_2] C_1 is a coil of a larger area, hence it will experience higher induced emf in comparison to the coil C_2 of a smaller area. Since coils C_1 and C_2 are connected to each other, the induced emf across coil C1 will drive the current through the closed-loop. So the direction of the current in C_1 remains as anticlockwise, whereas C_2 becomes clockwise. [1 mark for the correct statement of reason]	2
Q.95	Change in flux, $\Delta\Phi = B.\Delta A$ Here B = 0.5 T $\Delta A = (Area)_{Rectangle} + \pi r^2/2 - [(Area)_{Rectangle} - \pi r^2/2] = \pi r^2$ [1 mark for correct calculation of change in the area] So change in flux, $\Delta\Phi = 0.5 \times \pi (0.2)^2 = 0.2 \pi$ Wb [1 mark for correct calculation of change in flux]	2

7. Chapter: Alternating Current

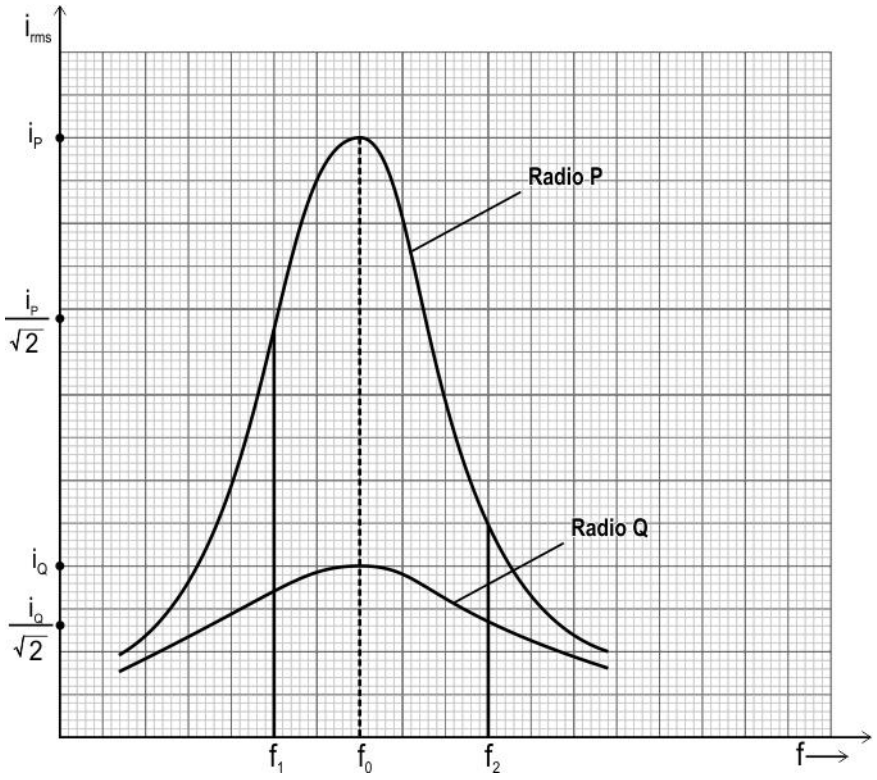
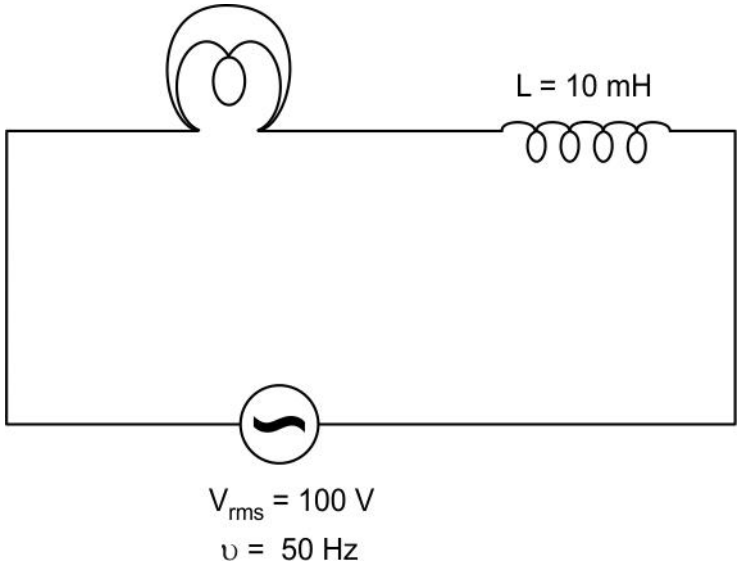
Q.No	Question	Marks
	Multiple Choice Question	
Q.96	Shown below is a series LCR circuit connected to an ac source of emf E. The voltage drop across the inductor and the capacitor is 20 V.  Which of the following will happen if the value of R is doubled? A. The voltage across L will be doubled. B. The voltage across C will remain the same. C. The voltage across the LC combination will be halved. D. The voltage across the LC combination will remain the same.	1
Q.97	A very high frequency AC source of peak EMF 200 V is connected across a circuit as shown in the figure. The components of the circuit are L = 1 mH, C = 1 μF, R_1=10 ohm, R_2 = 40 ohm, R_3 = 30 ohm. What is the approximate value of the peak current flowing through this circuit?  A. 0 A	1

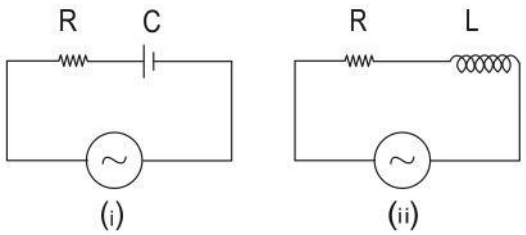
	B. 2.5 A C. 5 A D. 6.67 A	
Q.98	A capacitor has a dielectric of dielectric constant 6, that completely occupies the space between its plates. If a current I flows through this capacitor when connected to an AC source, what will be the current in the circuit when this dielectric is removed? A. I/6 B. I - 6 C. I D. 6I	1
	An autotransformer is a special transformer that has a single winding with an iron core. In an autotransformer, portions of the same winding act as both the primary and secondary. It has two end terminals and one or more terminals at intermediate tap points. The input voltage is applied across two of the terminals. The output voltage is taken across two terminals, one terminal of which is usually in common with the input voltage terminal. They are generally used in home applications with small voltage conversions. The figure below shows an autotransformer with several 'taps'.  	
Q.99	Which of the following is an advantage of an autotransformer compared to an ordinary two-winding transformer? A. Lower cost B. No hysteresis loss C. Copper loss is negligible D. Better isolation of primary and secondary	1
Q.100	In the transformer shown in the image above, if the number of turns between the points where the input voltage is connected is 800 and the maximum output	1

	voltage that can be obtained is 115% of the input voltage, what is the total number of turns in the coil? *(The turns ratio of an autotransformer is calculated with the same formula as two-winding transformers.)* A. 685 B. 695 C. 915 D. 920	
Q.101	In the autotransformer shown in the image above, the output terminal shown by the arrow can be connected to any of the taps. For a given input voltage, how many different stepped-down voltages can be obtained? *(Consider the transformer to be ideal.)* A. 2 B. 3 C. 4 D. 5	1
Q.102	The graph below shows the frequency response of an LCR circuit when connected to an AC source.  Which of the following graphs CORRECTLY represents the change in the frequency response of the LCR circuit if the capacitance and the inductance of the circuit are increased and resistance is decreased?	1

	 A. A B. B C. C D. D	
Q.103	Assertion (A): Current drawn through a long wire of finite resistance connected across an ac generator decreases when that wire is wound into a coil of many loops. Reason (R): Inductor offers back emf to the time varying ac current whereas a resistor doesn't. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Q.104	Assertion (A): Resonant frequencies of two different LCR series circuits with different L, C and R values may be same. Reason (R): Resonant frequency of an LCR series circuit is independent of R, L and C values of a circuit.	1

	Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	
Q.105	Assertion (A): Greater average power is consumed by the resistor-only ac circuit than by the resistor–inductor (RL) series combination in the same ac circuit. Reason (R): For the same ac circuit, the R-L reactance is less than resistance offered to the current flow. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Free Response Questions/Subjective Questions		
Q.106	For designing a high-quality sound delivery system, Anne includes two speakers in the sound system that is connected to an input ac supply. The speakers are connected separately. She connects an inductor in series to both of the speakers individually, so that speaker 1 delivers low-frequency signals and speaker 2 delivers high-frequency signals. (a) Will speaker 1 deliver low-frequency signals? (b) Will speaker 2 deliver high-frequency signals as desired? (c) Give a reason for your answer in (a) and (b). If need be, suggest correction(s) with appropriate reason.	3
Q.107	The graph below shows the variation in current flowing through two LCR circuits used in radios P and Q, with the change in frequency. To prevent adjacent-channel interference while tuning the radio to a particular frequency it is desirable that the frequency of adjacent channels does not lie in the bandwidth region of the selected frequency.	3

	 (a) Which radio will allow a person to hear a radio channel of frequency f_o, without the interference of other frequencies? Give reason. (*Assume f_1, f_o and f_2 are the only radio frequencies available and to prevent adjacent-channel interference on the band*) (b) Compare the resistance and capacitance of LCR circuit used in radios P and Q, if both the circuits have the same inductance. Give reason.	
Q.108	Consider a small bulb with negligible resistance connected to an inductor L = 10 mH in an ac circuit with an input rms voltage of 100 V.  If the frequency of input ac voltage is increased from 50 Hz to 50 kHz,	3

	a. What is the percentage change in the rms current in the ac circuit? b. Will the bulb glow brighter or dimmer? Explain your answer.	
Q.109	The output emf of an ac generator is 10sin100πt. The ac generator is connected to the following circuit elements individually: a. 100-ohm Resistor b. 10μF Capacitor c. 10mH Inductor. Determine the instantaneous voltage and current through each one of them.	4
Q.110	Given are two ac circuits, each connected to identical power supplies.  The ac source is of angular frequency ω in both the circuits (i) and (ii) initially. If the frequency is changed to ω/3, maintaining the same voltage, the current in the circuit (i) is halved whereas the current in the circuit (ii) is doubled. Determine the initial ratio of capacitive reactance in a circuit (i) to the inductive reactance in the circuit (ii), that is, when the angular frequency in both the circuits was ω.	3

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.96	D. The voltage across the LC combination will remain the same.	1
Q.97	C. 5 A	1
Q.98	A. I/6	1
Q.99	A. Lower cost	1
Q.100	D. 920	1
Q.101	B. 3	1
Q.102	B. B	1
Q.103	A. Both A and R are true and R is the correct explanation of A	1
Q.104	C. A is true but R is false	1
Q.105	C. A is true but R is false	1
Q.106	(a) Yes. (0.5 marks) (b) No. (0.5 marks) (c) Since both the speakers are connected to an inductor, the current in an inductive circuit decreases with increasing frequency. Thus, an inductor connected in series with a speaker blocks high-frequency signals and allows low-frequency signals. So both speaker 1 and 2 will deliver low-frequency signals. (1 mark) Correction: If speaker 2 is connected to a capacitor instead of an inductor, the capacitor blocks low-frequency signals and passes high-frequency signals. This is because the current in a capacitive circuit increases with increasing frequency. So speaker 2 connected to a capacitor in series will deliver high-frequency signals, as desired. (1 mark)	3
Q.107	(a) Radio P will allow the person to hear the radio channel of frequency f_o, without the interference of other frequencies. (0.5 marks)	3

	Both f_1 and f_2 do not lie in the bandwidth of the radio P while frequency f_1 lies in the bandwidth of radio Q. (0.5 marks) (b) The maximum current at resonance in an LCR circuit is given by $i_{max} = V/R$ Since $i_P > i_Q$, the resistance of circuit used in radio P is less than the resistance of the circuit used in radio Q. (*0.5 marks for correct answer and 0.5 marks for correct reason*) The resonance frequency $f_o = 1/(2\pi\sqrt{LC})$ As L and f_o is the same for both circuits the capacitance of both circuits will be the same. *(0.5 marks for correct answer and 0.5 marks for correct reason.)*	
Q.108	a. For angular frequency ν = 50 Hz Inductive reactance $X_L = \omega L = 2\pi \times 50 \times 10 \times 10^{-3} = \pi$ ohm $I_{rms} = V_{rms}/X_L = 100/\pi$ A [0.5 mark for correct value of I_{rms}] For angular frequency ν = 50 kHz Inductive reactance $X'_L = \omega L = 2\pi \times 50 \times 10^3 \times 10 \times 10^{-3} = 1000\pi$ ohm $I'_{rms} = V_{rms}/X_L = 1/10\pi$ A [0.5 mark for correct value of I'_{rms}] % decrease in I_{rms} $= |\Delta I_{rms}|/I_{rms} \times 100$ $= 999\pi/(10\pi \times 100) \times 100$ = 99.9 % [1 mark for correct calculation of % decrease of I_{rms}] b. Bulb glows dimmer. [0.5 mark for correct conclusion]	3

	Increase in angular frequency increases the inductive reactance that further results in the decrease in I_{rms} current flowing through the bulb. Hence the bulb glows dimmer. [0.5 mark for correct reason explanation]	
Q.109	a. 100 ohm Resistor: Voltage across R = 10sin100πt Current i = V/R = 10sin100πt /100 = 0.1 sin100πt [0.5 mark for voltage & 0.5 mark for correct expression of current] b. 10μF Capacitor: Voltage across C = 10sin100πt Current i = 10sin100πt /X_c Here $X_c = 1/C\omega = 1000/\pi$ ohm Current through C = i = V/X_c = 10sin(100πt + π/2) / (1000/π) $= \frac{10 \sin\left(100\pi t + \frac{\pi}{2}\right)}{\left(\frac{1000}{\pi}\right)} = \frac{\pi}{100} \sin\left(100\pi t + \frac{\pi}{2}\right)$ [0.5 mark for voltage & 1 mark for correct expression of current] c. 10mH Inductor : Voltage across L = 10sin100πt Inductive reactance, $X_L = L\omega = 10 \times 10^{-3} \times 100\pi = \pi$ ohm Current through an inductor, i = V/X_L $= \frac{10}{\pi} \sin\left(100\pi t - \frac{\pi}{2}\right)$ [0.5 mark for voltage & 1 mark for correct expression of current]	4
Q.110	In circuit (i):	3

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}}$$

$$I/2 = \frac{V}{Z'} = \frac{V}{\sqrt{R^2 + \left(\frac{3}{C\omega}\right)^2}}$$

Substituting for I,

$$\frac{V}{\sqrt{R^2 + \left(\frac{1}{c\omega}\right)^2}} = \frac{2V}{\sqrt{R^2 + \left(\frac{3}{c\omega}\right)^2}}$$

[1 mark for expression for currents]

Transposing and solving:

$3R^2 = 5\,(1/C\omega)^2 = 5X_C^2$

$X_C/R = \sqrt{3}/\sqrt{5}$

[0.5 mark for correct ratio X_C/R]

In circuit (ii):

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + \left(L\omega\right)^2}}$$

$$2I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + L^2\omega^2/9}}$$

Substituting for I,

$$\frac{2V}{\sqrt{R^2 + \left(L\omega\right)^2}} = \frac{V}{\sqrt{R^2 + L^2\omega^2/9}}$$

[1 mark for expression for currents]

Transposing and solving,

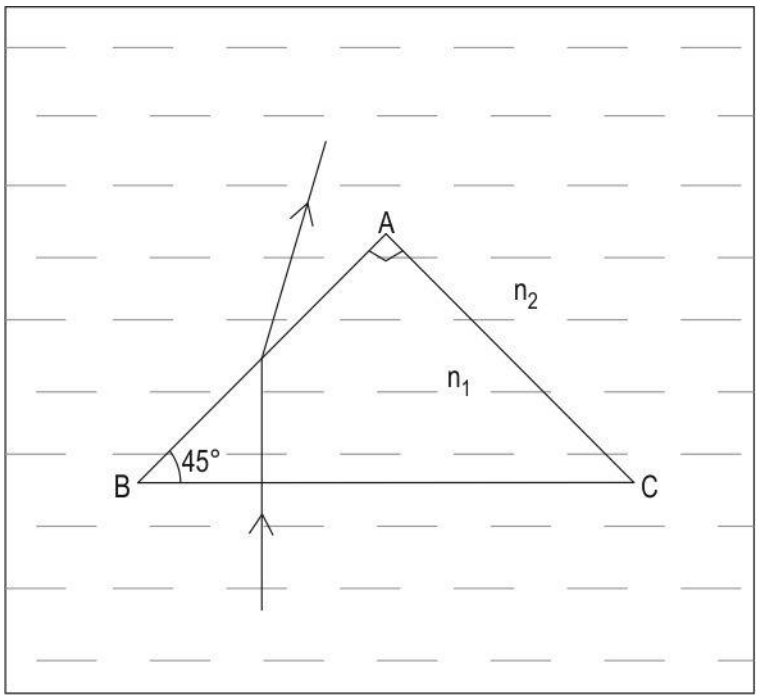
$X_L/R = 3\sqrt{3}/\sqrt{5}$

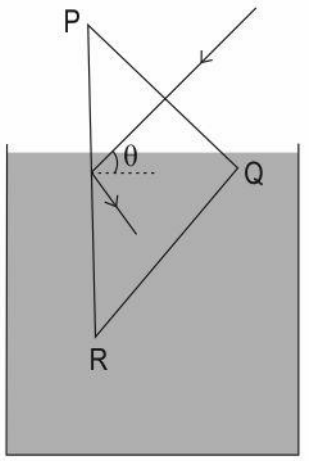
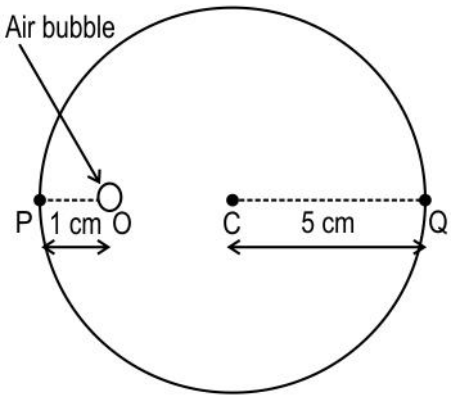
So the ratio:

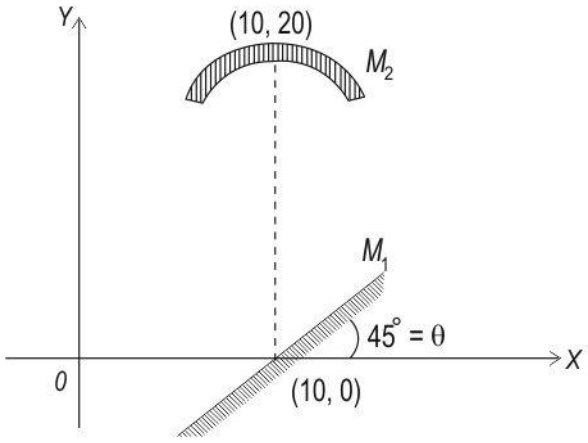
$X_C / X_L = 1/3$

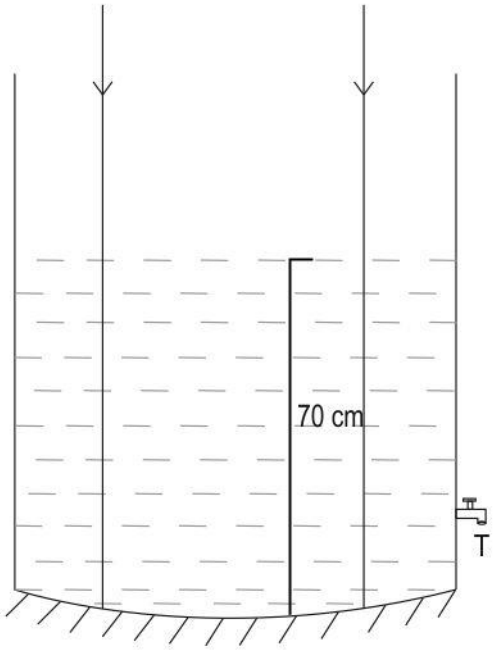
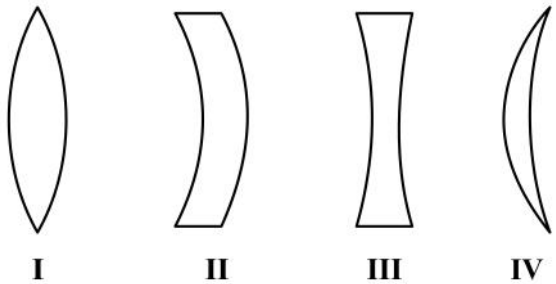
[0.5 mark for correct final ratio]

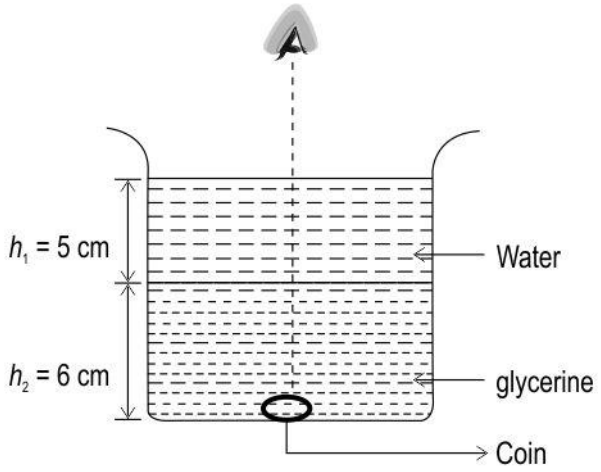
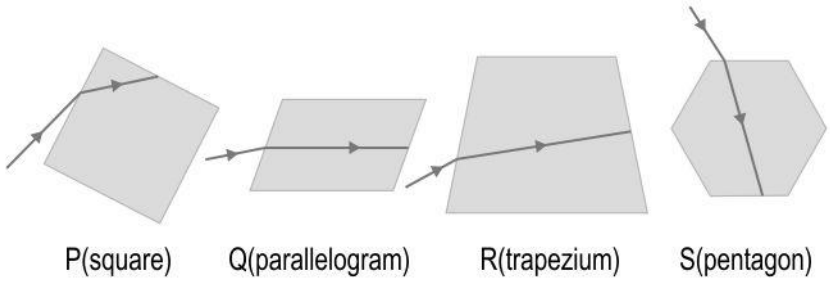
8. Chapter: Ray Optics and Optical Instruments

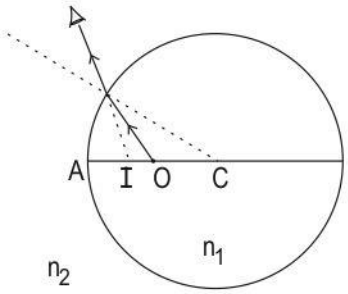
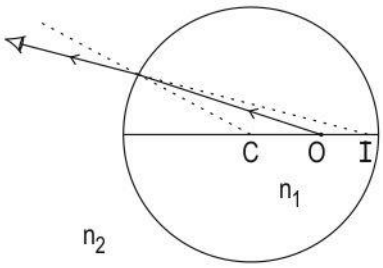
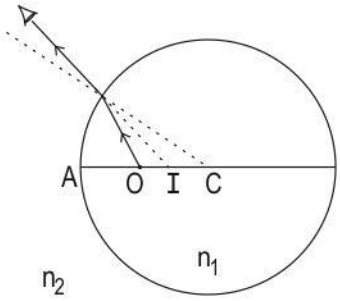
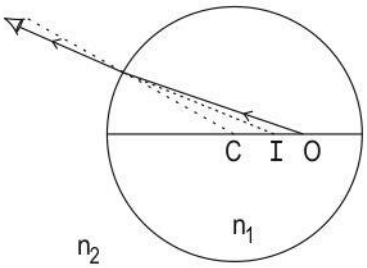
Q.No	Question	Marks
	Multiple Choice Question	
Q.111	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): A ray of light travelling from one media to another always changes its path. Reason(R): The speed of light changes when it travels from one medium to another. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation of assertion. C. Assertion is true but reason is false. D. Assertion is false but reason is true.	1
Q.112	A right-angled isosceles prism of refractive index n_1, is placed in a medium whose refractive index is n_2. The path of a ray of light that falls normally on side BC of the prism is shown in the image below.  	1

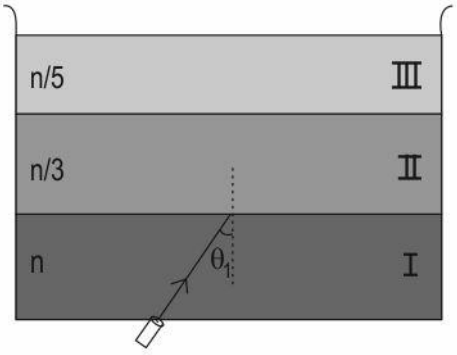
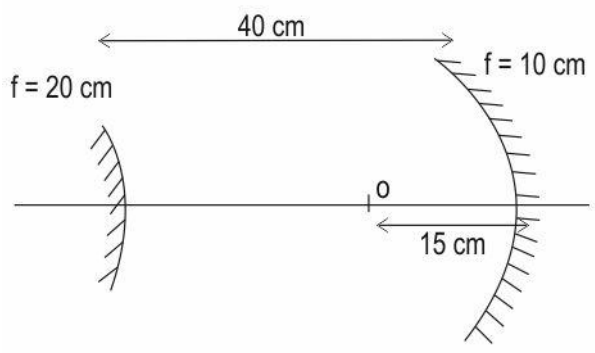
	If $n_2 = \sqrt{2}$, then what could be the possible value of n_1? (take $\sqrt{2}$ =1.414) A. 1.3 B. 1.6 C. 2 D. 2.5	
Q.113	A ray of light enters perpendicularly into the prism PQR that is partially immersed in the liquid. Given the refractive indices of prism and liquid as n_g = 3/2 and n_l = 5/4.  Which one of the following conditions ensures that the ray of light undergoes total internal reflection at the surface PR? A. sin θ = 1 B. sin θ ≥ 5/6 C. sin θ ≤ 8/15 D. 2/3 > sin θ > 4/5	1
Q.114	An air bubble is trapped at position O that is 1 cm inside the surface of glass sphere of radius 5 cm. C is the centre of the glass sphere. The air bubble is viewed from side P and then from side Q.  Which of the following statements is correct?	1

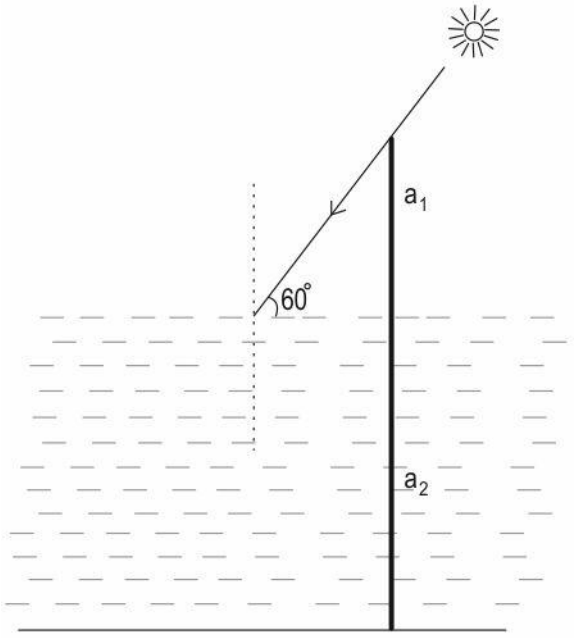
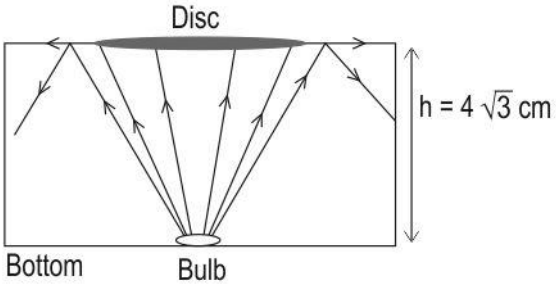
	A. The bubble appears to be on the surface of the sphere when seen from side P. B. The bubble appears to be at the center of the sphere when seen from side Q. C. The bubble appears at a position that is beyond 9 cm from the surface of the sphere when seen from side Q. D. The bubble appears at a position that is more than 1 cm from the surface of the sphere when seen from side P.	
Free Response Questions/Subjective Questions		
Q.115	M_1 is the plane mirror initially placed at angle $\theta = 45^o$ to the x-axis at (10,0) coordinates. M_2 is the concave mirror of focal length 10 cm with its center coinciding with coordinates (10, 20). Also, its principal axis coincides with the centre of the plane mirror as shown in the figure.  A beam of light parallel to x-axis is incident on the plane mirror. Determine the coordinates of the image formed by M_2 for the initial angle $\theta = 45^o$ of the plane mirror. Explain how you arrived at the answer.	2
Q.116	The base of a tank of water is a concave mirror of radius of curvature equal to 100 cm. The initial level of the water in the tank is 70 cm.	3

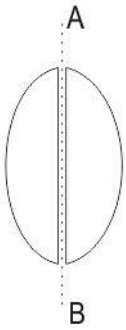
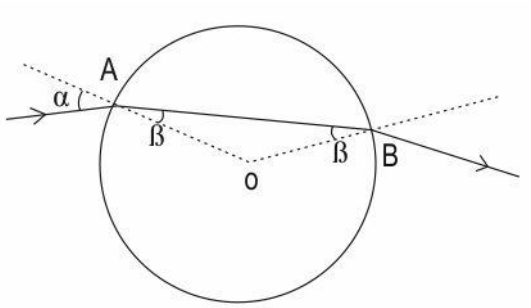
	 (a) Draw a ray diagram to show the image formation due to the incident parallel beam of sun's rays falling perpendicular to the water surface. (b) Determine the position of the image formed. (c) Tap T of the tank is opened and the water begins to drain out of the tank. How does the position of the image change as the water level in the tank drops from 70 cm to 40 cm?	
Q.117	A plano concave lens forms a virtual image at a distance of 5 cm in front of the lens of an object placed in front of it. The image formed is 1/2 times the size of the object. If the speed of light in the Plano concave lens is 2/3 times the speed of light in air, then find (a) the refractive index of the lens. (b) the radius of curvature of the curved surface of the lens.	4
Q.118	Each of the four lenses shown below is constructed by a material of refractive index n which is bounded by two curved surfaces of radii of curvatures R_1 and R_2 respectively. 	4

	For all four lenses identify if the two radii of curvature and the focal length are positive or negative when kept in air.	
Q.119	A coin is placed at the bottom of a beaker. The beaker is then filled with a layer of glycerine followed by a layer of water as shown below. When viewed normally by an observer in air, the coin appears to be at a depth of 7.9 cm.  (a) If the refractive index of water is 1.3, calculate the refractive index of the glycerine. (b) If the observer slowly moves the eye away from the normal, the object suddenly disappears at a certain position. Explain the observation.	3
Q.120	Shown below are the cross-sections of four transparent objects. The direction of the incident ray and the refracted ray are shown.  (a) In which of the case(s) will the emergent ray be parallel to the direction of the incident ray? Explain why. (b) In each of the four cases draw the direction of the emergent ray. (Note: TIR does not take place for the given angles of incidence on the second surface.)	3
Q.121	An air bubble is stuck inside a glass ball of refractive index n_1. The surrounding medium outside the glass ball is of refractive index n_2. Each of the ray diagrams given here depict the virtual position of bubble as seen from outside the glass ball.	4

	In Fig I and II the bubble is nearer to the viewing surface and in Fig III & IV, the bubble is away from the viewing surface.  Fig I  Fig III  Fig II  Fig IV a. Identify the correct ray diagrams depicting the virtual position of the air bubble as seen from outside the glass ball in each of the following cases. i. $n_1 > n_2$ ii. $n_1 < n_2$ b. State true or false: When viewed from outside: i. For $n_1 > n_2$ and the bubble to the left of C, the apparent position of the bubble is closer to viewing surface. ii. For $n_1 > n_2$ and the bubble is to right of C, the apparent position of the bubble is farther away from viewing surface. iii. For $n_1 < n_2$, and the bubble is to left of C, the apparent position of the bubble is closer to viewing surface. iv. For $n_1 < n_2$, and the bubble is to right of C, the apparent position of the bubble is farther away from viewing surface.	
Q.122	A transparent container contains layers of 3 immiscible transparent liquids of different refractive indices. A laser beam is pointed at the layer I as shown in the figure.	2

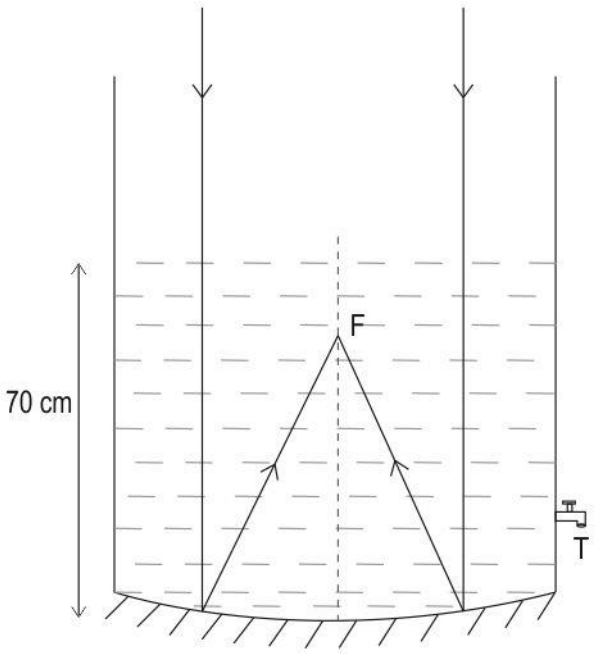
	 What minimum angle of θ_1 will ensure that laser beam does not enter region III at all?	
Q.123	A thin convex lens of focal length 10 cm and refractive index $n_1 = 1.5$ is immersed in a medium of refractive index n_2. In each of the following instances, determine whether the lens behaves as a converging lens, plane glass or a diverging lens. Also find the focal length of the lens in each case. (a) $n_2 = 1.2$ (b) $n_2 = 1.5$ (c) $n_2 = 2$	4
Q.124	A concave mirror and a convex mirror of focal lengths 10 cm and 20 cm respectively are placed coaxially as shown. The distance of separation between the two mirrors is 40 cm.  If an object O is placed in between them as shown, at a distance of 15 cm from the concave mirror, find the position of final image that is formed by two successive reflections, (a) first by concave mirror, and (b) then by convex mirror.	3
Q.125	A pole stands in a pool of water such that the sun shines at an angle as shown in the diagram. The ratio of the height of the pole above the water, a_1 to that inside the water, a_2 is √3/ √55.	3

	 *NOTE:Image not to scale.* (a) Complete the ray diagram to show the formation of the shadows of the pole on the water surface and at the bottom of the pool. (b) Show that the ratio of length of the shadow of the pole on the water surface to that at the bottom of the pool is 1/4. Take n for the pool water as 4/3.	
Q.126	Wide aromatic liquid containers with bulbs glowing at the bottom are used for decoration purposes in a garden. At night, instead of switching off the bulbs, the caretaker chooses to place a floating opaque disc at the center of each of the containers. In doing so, the bulbs become invisible from the surface!  Determine the minimum diameter of the circular opaque disc that the caretaker should place on surface of the liquid in each of the containers. The height of liquid in each container is 4√3 cm and the refractive index of the liquid is 2/√3.	2
Q.127	A small piece of paper is stuck on the surface of the glass sphere of radius 10 cm and refractive index 1.5. The paper is viewed from diametrically opposite side. a. Represent the image formation using a ray diagram. b. Determine the image position.	3

Q.128	A biconvex lens of glass (n=3/2) is shifted from air (n=1) to water (n = 4/3). Determine the factor by which the focal length of the lens changes.	2
Q.129	A thin equi-convex lens of focal length f is sliced into two equal parts by a vertical plane AB.  What is the focal length of each of the sliced part?	2
Q.130	Light falling on a glass sphere of refractive index n, at angle of incidence α refracts at angle of refraction β.  Refer to the given diagram above. a. Show that angle of emergence is equal to angle of incidence. b. Complete the given diagram to represent the deviation produced in the incident ray. c. Determine the angle of deviation produced in the incident light as it passes through the glass sphere in terms of α and β.	3
Q.131	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): The degree of convergence of a convex lens made of glass decreases when it is placed in water. Reason(R): The relative refractive index of the glass with respect to water is less than that of glass with air. A. Both assertion and reason are true and reason is the correct explanation for assertion.	1

	B. Both assertion and reason are true but reason is not the correct explanation of assertion. C. Assertion is true but reason is false. D. Both assertion and reason are false.	

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.111	D. Assertion is false but reason is true.	1
Q.112	B. 1.6	1
Q.113	B. $\sin\theta \geq 5/6$	1
Q.114	C. The bubble appears at a position that is beyond 9 cm from the surface of the sphere when seen from side Q.	1
Q.115	For angle $\theta = 45^{o}$ of the plane mirror, the reflected rays that fall on M_2 are all parallel to principal axis. So the reflected rays converge at the focus F of the M_2. (1 mark for the correct argument of image formation) The coordinates of the image formed by concave mirror : (10, 10) (1 mark for the correct value of coordinates)	2
Q.116	(a)  The image is formed at the position of the principal focus of the mirror inside the water. [1 mark for the correct representation of the diagram with clear indication of the location of the image formed]	3

	(b) Using mirror formula: As R = -100 cm, f = - 50 cm of the concave mirror. $1/v+1/(-\infty)=1/(-50)$ Calculating, v = -50 cm It's a real image of the sun. [1 mark for the correct determination of the actual position of the image] (c) For the water level in between 70 cm till 50 cm, the image continues to be fixed at the position of the principal focus of the mirror, that is, at a distance of 50 cm from the mirror. As the water level falls below, 50 cm, the rays begin to refract at water-air interface before meeting at the image point. Since the rays refract away from the normal, the image position will be below the earlier position of 50 cm (at F) mark. As the level drops further, the image position continues to shift downwards. [1 mark for the correct description of the change in position of the image due to falling level of the liquid and the corresponding explanation]	
Q.117	(a) Refractive index = c/v $n = c /(2/3c) =1.5$ (b) v = - 5.0 cm $m = v/u = h_i/h_o$ (0.5 marks) $-5/u = (1/2h_o)/h_o$ u = - 5 × 2 = -10 cm (0.5 marks) 1/f = 1/v - 1/u (0.5 marks) 1/f = -1/5 + 1/10 = -1/10 f = - 10 cm (0.5 marks) By lens maker formula $1/f = (n - 1)(1/R_1 - 1/R_2)$ (0.5 marks) $-1/10 = (1.5 - 1)(1/R_1 - 1/-\infty)$	4

<table>
<tr><td></td><td>R_1 = - 10 × 0.5 cm = - 5 cm (0.5 marks)</td><td></td></tr>
<tr><td>Q.118</td><td>
<table>
<tr><th></th><th>R_1</th><th>R_2</th><th>f</th></tr>
<tr><td>lens 1</td><td>positive</td><td>negative</td><td>positive</td></tr>
<tr><td>lens 2</td><td>negative</td><td>negative</td><td>converging if $|R_1| > |R_2|$
diverging if $|R_1| < |R_2|$</td></tr>
<tr><td>lens 3</td><td>negative</td><td>positive</td><td>negative</td></tr>
<tr><td>lens 4</td><td>positive</td><td>positive</td><td>diverging if $|R_1| > |R_2|$
converging if $|R_1| < |R_2|$</td></tr>
</table>
(1 mark for each lens)
</td><td>4</td></tr>
<tr><td>Q.119</td><td>(a) The height by which the coin appears to be displaced when viewed normally = 11 - 7.9 = 3.1 cm

The displacement due to water

$d_w = h_1 (1 - 1/n_w)$

$d_w = 5 (1 -1/1.3)$

On solving

d_w = 1.15 cm (1 mark)

The displacement due to glycerine

$d_g = h_2 (1 - 1/n_g)$

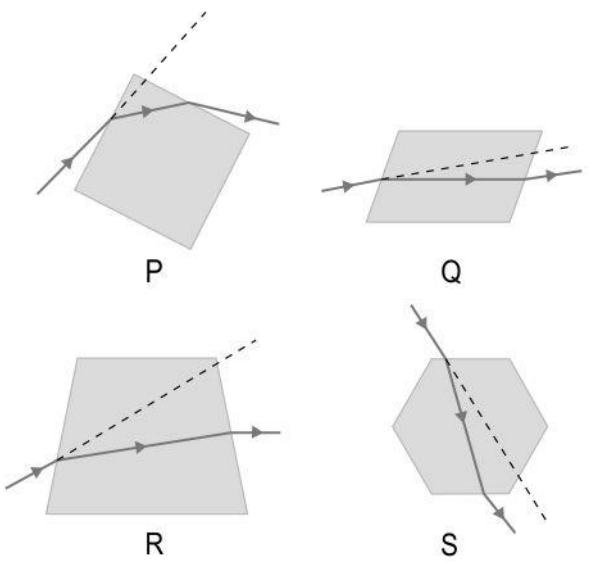
d_g = 3.1 - 1.15 = 1.95 cm

$1.95 = 6 (1-1/n_g)$

On solving

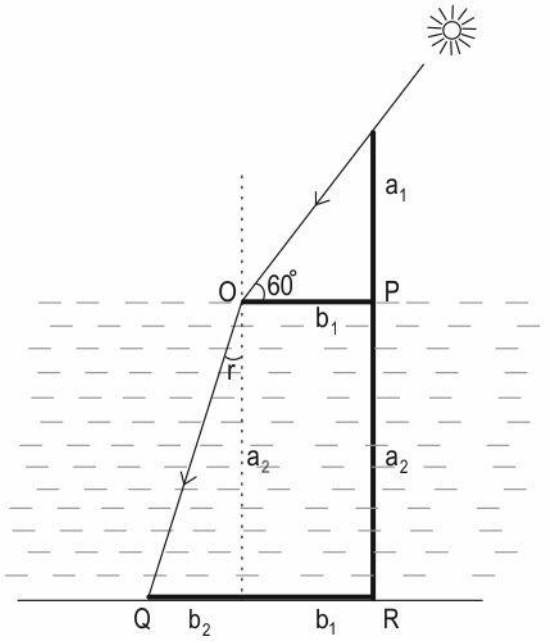
n_g = 1.48 (1 mark)

(b) As the ray travels from glycerine to air, it refracts at two surfaces, glycerine-water, and water-air. Since, at both surfaces the ray of light travels from denser media to rarer, for a particular angle of incidence the ray of light will undergo total internal reflection at either of the interfaces, and hence the coin becomes invisible.</td><td>3</td></tr>
<tr><td>Q.120</td><td>(a) In Q and S, the emergent ray will be parallel to the incident ray because the two refracting surfaces are parallel.</td><td>3</td></tr>
</table>

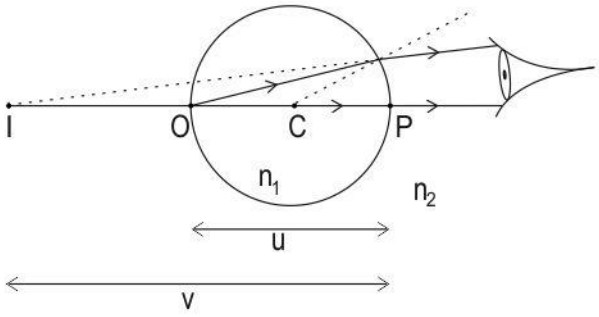
	In P and R, the refracting surfaces are not parallel.(1 mark) (b)  (0.5 marks for each correct diagram)	
Q.121	a. i. $n_1 > n_2$: Fig I & Fig III ii. $n_1 < n_2$: Fig II & Fig IV [0.5 mark each for the correct identification of the diagrams] b. State true or false: i. For $n_1 > n_2$, the apparent position of the bubble is closer to viewing surface in case the bubble is to left of C. TRUE ii. For $n_1 < n_2$, the apparent position of the bubble is closer to viewing surface in case the bubble is to right of C. TRUE iii. For $n_1 > n_2$, the apparent position of the bubble is closer to viewing surface in case the bubble is to right of C. FALSE iv. For $n_1 < n_2$, the apparent position of the bubble is farther to viewing surface in case the bubble is to left of C. FALSE [0.5 mark for each correct answer]	4
Q.122	Snell's law for each of the interfaces: $n \sin\theta_1 = n/3 \,.\, \sin\theta_2 = n/5.\, \sin(90)$	2

	[1 mark for the correct representation of Snells law at each of the interfaces] $n \sin\theta_1 = n/5. \sin(90) = n/5 \times 1$ $\sin\theta_1 = 1/5$ $\theta_1 = \sin^{-1}(1/5)$ [1 mark for the correct final result]	
Q.123	(a) $\frac{n_2}{f_1} = (n_1 - n_2)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ for lens of refractive index n_1 & focal length f_1 surrounded by medium of refractive index n_2 $\frac{1}{f_1} = (1.5 - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \ldots(1)$ Here $n_1 = 1.5$, $f_1 = 10$ cm, $n_2 = 1$ (air) [1 mark for correct formula and substitution] $\frac{1.2}{f_2} = (1.5 - 1.2)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \ldots(2)$ Here $n_1 = 1.5$, $f_1 = 10$ cm, $n_2 = 1.2$ Ratio of equations (1) and (2) $\frac{f_2}{1.2 \times f_1} = \frac{(1.5 - 1)}{(1.5 - 1.2)} = \frac{0.5}{0.3}$ Solving for f_2, $f_2 = +20$ cm. The lens behaves as converging. [1 mark for each correct result and calculation] (b) $\frac{n_2}{f_2} = (n_1 - n_2)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$	4

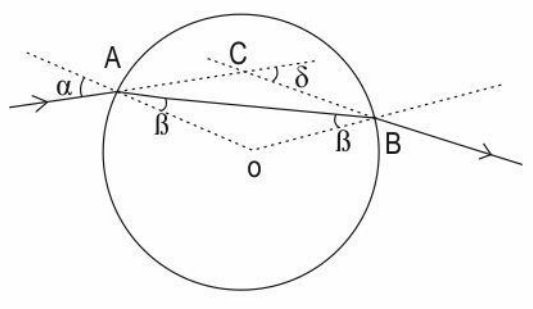
	Here $n_1 = 1.5$, $f_1 = 10$ cm, $n_2 = 1.5$ $n_2/f_2 = 0$ f_2 = infinite. The lens behaves as a plane glass. [1 mark for each correct result and calculation] (c) $\frac{2}{f_2} = (1.5 - 2)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$ ...(4) Here $n_1 = 1.5$, $f_1 = 10$ cm, $n_2 = 2$ Solving (1) and (4) $f_2 = -2\ f_1 = -2 \times 10 = -20$ cm The lens behaves as a diverging lens. [1 mark for each correct result and calculation]	
Q.124	(a) First by concave mirror: u = -15 cm f = -10 cm Using lens formula, 1/f = 1/v + 1/u Substituting and calculating v = -30 cm. [1 mark for correct calculation of image distance of I_1] Image is real. This image I_1 formed by concave mirror acts as an object. [0.5 mark for identifying that image I_1 behaves as an object for convex mirror] (b) And then by convex mirror, u = +10 cm	3

	f = - 20 cm Using lens formula, and substituting, v = -20/3 cm [1 mark for correct calculation of image distance of I_2] Final image I_2 is formed behind the convex mirror at a distance of 20/3 = 6.66 cm. [0.5 mark for stating the correct position of the image by the convex mirror]	
Q.125	(a)  *NOTE:Image not to scale.* OP is shadow on water surface. QR is the shadow at the bottom of the pool. [1 mark for the correct representation of the two shadows] (b) Given $a_1/a_2 = \sqrt{3}/\sqrt{55}$ To find: $b_1/(b_1 + b_2)$ From the figure, $\tan 60 = a_1/b_1$	3

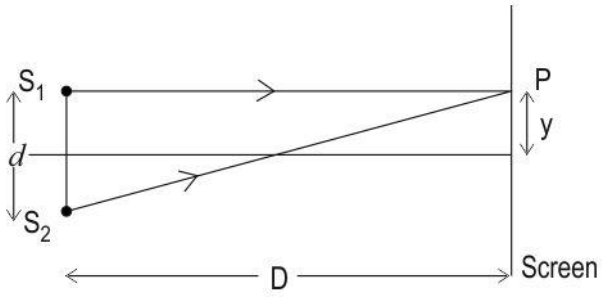
	So $b_1 = a_1/\sqrt{3}$ Also, $n_1 \sin 30 = n_2 \sin r$ $\sin r = \sin 30/n = (3/4) \times (1/2) = 3/8$ $\cos r = \sqrt{(1 - \sin^2 r)} = \sqrt{(1 - 9/64)} = \sqrt{55}/8$ $\tan r = b_2/a_2$ $b_2 = a_2 \tan r = a_2 \sin r/\cos r$ $= 3 a_2/\sqrt{55}$ [1 mark for the correct calculation of values for b_1 and b_2] Ratio, $\frac{b_1}{b_1+b_2} = \frac{a_1/\sqrt{3}}{\left(\frac{a_1}{\sqrt{3}} + \frac{3a_2}{\sqrt{55}}\right)}$ Resolving and substituting for $a_2/a_1 = \sqrt{55}/\sqrt{3}$ Ratio, $\frac{b_1}{b_1+b_2} = ¼$ [1 mark for the correct final proof]	
Q.126	Light will not emerge from the liquid if at the edge of the disc, $i > \theta_c$ $\sin i > \sin\theta_c$ [0.5 mark for the correct condition of TIR] If R is the radius of the opaque disc and h is the depth of the bulb, $\sin i = R/\sqrt{(R^2+h^2)}$ and $\sin\theta_c = 1/n$ $R/\sqrt{(R^2+h^2)} > 1/n$ [0.5 mark for the correct equation using the ray diagram of the ray undergoing TIR]	2

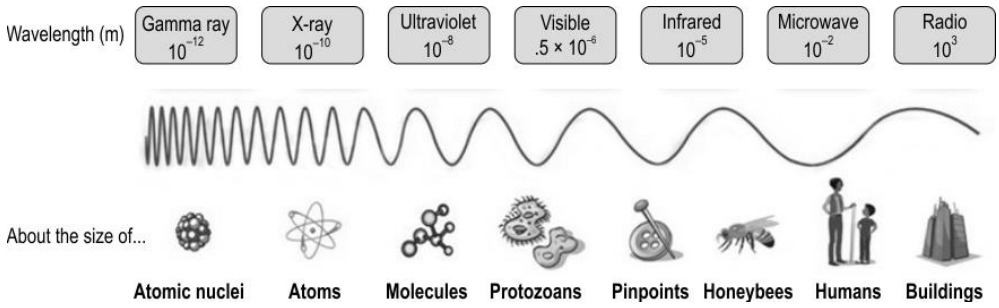
	Transposing and solving, $R > h/\sqrt{(n^2-1)}$ $R_{min} = h/\sqrt{(n^2-1)}$ $R_{min} = \frac{h}{\sqrt{n^2-1}} = \frac{4\sqrt{3}}{\sqrt{(2/\sqrt{3})^2-1}} = 12\ cm$ Diameter of the required opaque disc = 24 cm [1 mark for the correct calculation and final result]	
Q.127	a.  [1 mark for the correct ray diagram depicting the location of the image] b. Using, $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2-n_1}{R}$ Here, u = -20 cm, R = -10 cm, n_1 = 1.5, n_2 = 1 [1 mark for correct formula and identify correct values with signs] Upon substituting and calculating 1/v = -1/40 v = -40 cm Image is formed 20 cm behind the glass ball. [1 mark for the correct final value]	3

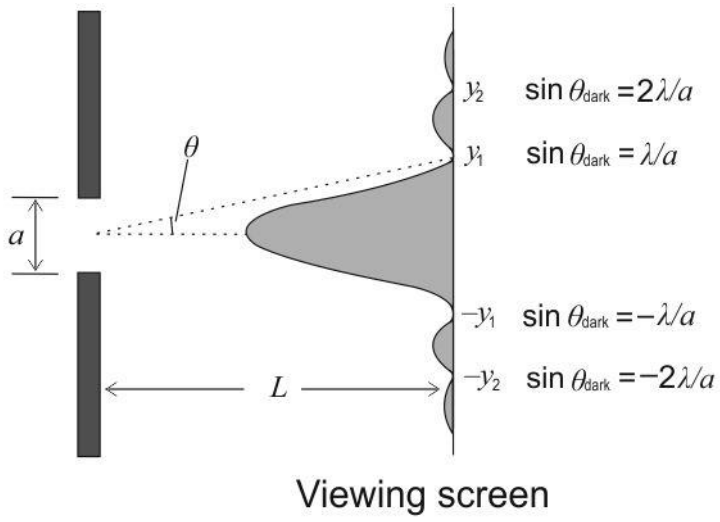
Q.128	As, $\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} + \frac{1}{R_2}\right] = \left(\frac{n_2}{n_1} - 1\right)K$ $\frac{1}{f_A} = \left(\frac{3/2}{1} - 1\right)K = \frac{1}{2}K$ $\frac{1}{f_W} = \left(\frac{3/2}{4/3} - 1\right)K = \left(\frac{1}{8}\right)K$ $\frac{1/f_A}{1/f_W} = \frac{1/2}{1/8}$ [1 mark for the correct formulae] $f_W/f_A = 4$ Focal length of the lens increases by a factor of 4 as it is shifted from air into water. [1 mark for the correct result]	2
Q.129	For biconvex lens, $\frac{1}{f} = (n-1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right] = (n-1)\left[\frac{1}{R} - \frac{1}{-R}\right] = \frac{2(n-1)}{R}$ For sliced lens, $\frac{1}{f'} = (n-1)\left[\frac{1}{R} - \frac{1}{\infty}\right] = \frac{n-1}{R} = \frac{1}{2f}$ f' = 2f The focal length of each sliced part is double the focal length of the undivided biconvex lens. [1 mark for the correct relations for biconvex lens and sliced plano convex lens] [1 mark for the correct calculations and final result]	2
Q.130	a. For refraction at A, 1 sin α = n sin β …(1) For refraction at B, n sinβ = 1 sin γ ….(2), here γ is the angle of emergence at interface B Comparing equations (1) and (2), γ = α	3

	[1 mark for the correct proof] b. Completed ray diagram representing angle of deviation.  [1 mark for the correct representation of angle of deviation} c. Angle of deviation, $\delta = (\alpha - \beta) + (\alpha - \beta) = 2(\alpha - \beta)$ (As Exterior angle of a triangle = sum of opposite interior angles) [1 mark for the correct final result of angle of deviation]	
Q.131	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1

9. Chapter: Wave Optics

Q.No	Question	Marks
	Multiple Choice Question	
Q.132	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): When monochromatic light passes through a narrow opening, a pattern of alternate bright and dark fringes is produced. Reason (R): The edges of the opening become sources of secondary waves, which superpose to produce the pattern. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Both assertion are reason are false.	1
	Free Response Questions/Subjective Questions	
Q.133	A white light is used to illuminate the two slits in a Young's double slit experiment. It results in the overlapping interference patterns on the screen as each wavelength corresponds to one interference pattern. [Refer to the diagram below for the various parameters of the experimental setup.]  At a point P, that is directly opposite to the slit S_1, find the series of wavelengths that will result in minima.	2
Q.134	In a Young's double slit experiment; the source of light consists of wavelengths in the range 3000 – 8000 Å. The distance of the screen from slits is 2 m and distance of separation between the two slits is 10^{-3} m.	2

	Determine the wavelengths in the visible range (400 nm -700 nm) present at a position that is 10^{-3} m from the central maxima.	
Q.135	A lamp sends out a plane wave through a slit of width 2 μm. The light from the lamp is composed of two spectral lines of wavelengths D_1 = 5896 Å and D_2 = 5900 Å. Determine the distance between the first secondary maxima of each of the spectral lines in the diffraction pattern formed on the screen that is 2 m away from the slits.	2
Q.136	Read the passage carefully and answer the questions given below. Diffraction of incoming beams by an obstacle or aperture is convincing proof of the wave nature of light. Diffraction takes place for all types of waves, mechanical or non-mechanical, transverse or longitudinal. However, its effects are perceptible only if the wavelength of radiation is comparable to the dimensions of the diffracting device. In the case of diffraction of light through apertures and obstacles instead of sharp shadow or uniform illumination, we get a fringe pattern called a diffraction pattern that depends on the nature of the diffracting device and the wavelength of the incoming light used. Given here is the representation of wavelengths of light waves in comparison to the sizes of various objects.  a. If the spacing of atoms in crystals is of the order of few Å, then can visible light waves be used to study the arrangement of atoms in a crystal? Give reason. b. Identify the waves that are most suitable for studying arrangements of atoms in a crystal. c. State true or false & give reason for your answer: Both a clap sound and a radio electromagnetic wave can be heard or received around the corner of a building. (Consider the wavelength of a clap to be about 0.1 m.) d. In the single slit diffraction arrangement, how would the image on the screen appear in case the wavelength λ of the incident light is much less than the aperture width d?	4

Q.137	Study the intensity distribution diagram for a diffraction pattern from a single slit of width 'a'. The positions of two minima on each side of the central maximum are labeled. (Drawing not to scale.)  Answer the following questions: a. Determine the ratio of width of the central bright maximum to the width of the second secondary maxima above it. b. What is sine of an angle at which the second secondary maxima is produced above the central maxima? c. If the slit width in Figure is made half as wide, what will be effect on the width of its central bright fringe? Explain your answer.	3

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.132	C. Assertion is true but the reason is false.	1
Q.133	The distance y from center: y = (D/d) Δx , where Δx is the path difference between two light waves reaching point P. For the missing wavelengths (or minima points) at P, $\Delta x = (n + \frac{1}{2})\lambda$, with n = 0,1,2,3..... So $y = \frac{D}{d}\frac{(2n+1)}{2}\lambda$ [1 mark for the correct relation between for missing wavelength] As per the given diagram, $\frac{d}{2} = \frac{D}{d}\frac{(2n+1)}{2}\lambda$ $\lambda = \frac{d^2}{D\,(2n+1)}$ for n = 0,1,2,3... So all $\lambda = d^2/D$, $d^2/3D$, $d^2/5D$,… will form minima at point P. [1 mark for correct result of series of wavelengths]	2
Q.134	For a point that is at a distance y from central maxima, $y = \frac{D}{d}\Delta x = \frac{D}{d}n\lambda$ Here Δx is the path difference = nλ …. for the maxima at the position that is at a distance y from central maxima. λ = yd/nD where n = 1,2,3… [0.5 mark for the correct formula for wavelength in terms of y and other parameters] Substituting,	2

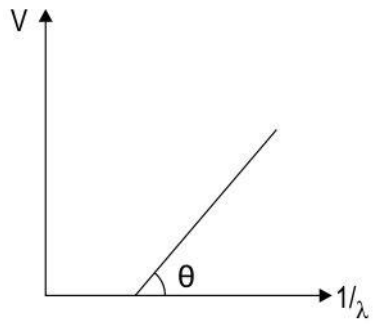
	$\lambda = \frac{10^{-3}\, x\, 10^{-3}}{n\,.\,2}$ = 0.5 x 10^{-6} /n = 5000/n Å with n = 1,2,3… So the following wavelengths are present at the given position: λ = 5000 Å, 2500 Å, 1666 Å,…. [1 mark for correct calculation of the range of wavelengths present at the given position] Out of these only the wavelength 5000 Å is in visible range. [0.5 mark for the correct identification of the wavelength in visible range present at the given position]	
Q.135	$sin\theta = (n + \frac{1}{2})\frac{\lambda}{d} = \frac{x}{D}$ here d = slit width, x is the distance of the maxima from the central line and D is the perpendicular distance of the screen from the slit. $x = (n + \frac{1}{2})\frac{\lambda D}{d}$ For the first secondary maxima $x = (1 + \frac{1}{2})\frac{\lambda D}{d}$ (1 mark) Distance between the two secondary maximas of the two spectral lines: $\Delta x = \frac{3D}{2d}(5900 - 5896)x10^{-10}$ $\Delta x = \frac{3\times2}{2\times2\times10^{-6}} \times 4x10^{-10}$ $\Delta x = 6 \times 10^{-4}m$ (1 mark)	2
Q.136	a. Wavelength of visible light waves ~4000 -7000Å is much higher than the spacing of atoms, which is few Å. Hence visible light cannot be used to study the arrangement of atoms in a crystal using the diffraction principle. [*0.5 marks for the correct answer and 0.5 marks for the reason.*] b. X rays [1 mark] c. True. In both cases the wavelengths of the clap sound and radio waves is comparable to the dimensions of the building.	4

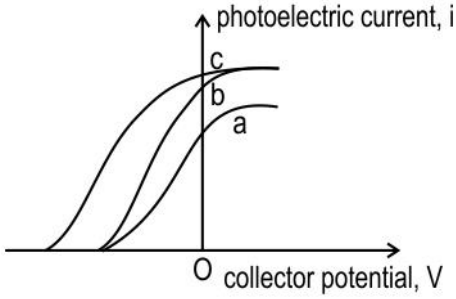
	[1 mark] d. There will be a uniform illumination of the screen in the case of the wavelength of the light is much less than the slit width of the diffraction apparatus. [1 mark]	
Q.137	a. Width of the central maxima : $\frac{\lambda}{a} - \frac{-\lambda}{a} = \frac{2\lambda}{a}$ Each of the secondary maxima are of same width, that is , λ/a So the ratio = 2 : 1 [1 mark for the correct final result] b. Condition for the maxima : sinθ = (n + ½)λ/a , where n = +/- 1, +/- 2, …. For the second secondary maxima : n = +2 So sinθ = (2 + ½)λ/a = 5λ/2a [1 mark for the correct final result] c. As the angles on the either side of the central maxima: sinθ =+/- λ/a With the decrease in slit width a, the angle θ on the either side of the central maxima will increase, hence the width of the central maxima will increase. [0.5 mark for the correct change in width of central maxima & 0.5 mark for the correct reason]	3

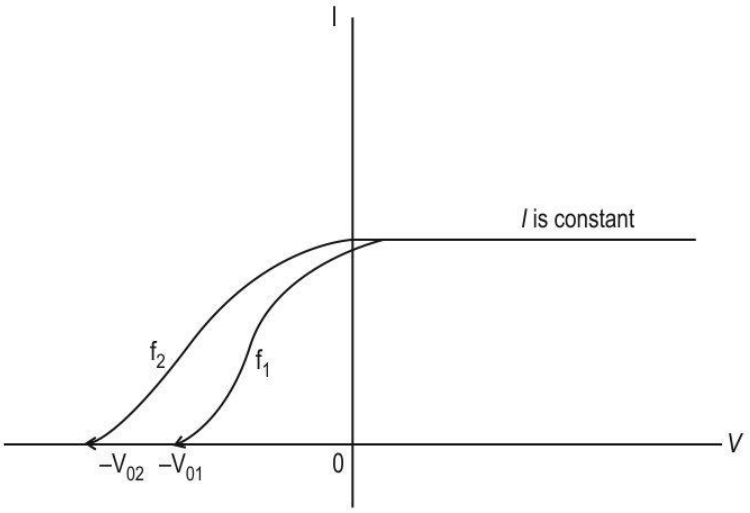
10. Chapter: Dual Nature of Radiation and Matter

Q.No	Question	Marks
	Multiple Choice Question	
Q.138	An electron and proton when accelerated through a certain potential difference get associated with de Broglie wavelengths λ_e and λ_p respectively. Consider the ratio of the mass of the proton (m_p) to the mass of the electron (m_e), m_p/m_e= 1837 Read the following statements carefully. I. If the two given particles have equal energies, then $\lambda_p/\lambda_e = 1/\sqrt{1837}$ II. If the velocities of the two particles is v_e and v_p respectively, then $\lambda_p/\lambda_e = \sqrt{(v_e/1837v_p)}$ III. If the accelerating potential V is the same for the two particles, then $\lambda_p/\lambda_e = 1/\sqrt{1837}$ Select the correct option. A. All statements are true B. All statements are false C. Only statements i & ii are correct D. Only statements I & III are correct	1
Q.139	A light of wavelength belonging to the blue region of the visible spectrum causes photoelectric emission in a metal. When light of wavelength belonging to the red region is incident on the metal, photoelectric emission does not take place. When an em wave belonging to IR region is incident on the metal, will photoelectric emission take place? Why/ why not? A. Yes, because IR rays are highly energetic. B. No, because IR rays cannot cause photoelectric emission. C. Yes, because IR rays have a higher frequency than red light. D. No, because IR rays have a longer wavelength than red light.	1
Q.140	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.	1

	Assertion (A): De Broglie's wavelength of a freely falling body keeps decreasing with time. Reason (R): The momentum of the freely falling body increases with time. Select the correct option: A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but reason is false. D. Assertion is false but reason is true.	
Q.141	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The photoelectric effect supports the wave nature of light. Reason (R): There exists a maximum wavelength above which photoelectric emission does NOT take place. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true.	1
Q.142	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): If electrons pass through a double-slit, an interference pattern is produced. Reason (R): Electrons behave as both particles and waves. Select the correct option. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true.	1

Q.143	In a photoelectric effect experiment, the graph of stopping potential V versus reciprocal of wavelength λ of incident light for a given material is plotted below.  If the existing material is replaced with another material and the intensity of the light is increased, which of the following is most likely to happen? A. The slope theta of the line will increase. B. The slope theta of the line will decrease. C. There will not be any change in the graph. D. The line will cut the 1/λ axis at a different point.	1
Q.144	A certain device is designed that can generate current using the heat radiations emitted by the surrounding bodies. The frequency range of heat radiations is between 3×10^{11} Hz to 4×10^{14} Hz. What should be the maximum work function of this device so that it can generate current corresponding to all possible heat radiations? (Plank constant h = 4.14×10^{-15} eV Hz^{-1}) A. 0.1242×10^{-2} eV B. 12.42×10^{-2} eV C. 1.656 eV D. 16.56 eV	1
Q.145	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): The number of photoelectrons ejected from a metal increases if the intensity of the light source is increased for a frequency greater than the threshold frequency. Reason(R): An increase in the intensity of light increases the energy of each photon. A. Both assertion and reason are true and reason is the correct explanation for assertion.	1

	B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true.	
Q.146	Study the following graphs between photoelectric current (i) vs. collector potential (V) for three different radiations a, b, and c of frequencies f_a, f_b, f_c respectively with corresponding intensities I_a, I_b, and I_c respectively falling on a given photosensitive surface.  Select the correct option. A. $f_a \neq f_b$; $I_a = I_b$ B. $f_b = f_c$; $I_b = I_c$ C. $f_a = f_b$; $I_a \neq I_c$ D. $f_b \neq f_c$; $I_b \neq I_c$	1
Q.147	ASSERTION: Electromagnetic wave picture of light can also explain the photoelectric effect in addition to the particle nature of light. REASON: Electric field of an em wave would cause the electrons in the metal to oscillate and tear free from the surface when the amplitude of the oscillation becomes large enough. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true and R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Free Response Questions/Subjective Questions		
Q.148	The following graph shows the variation of photoelectric current (I) with a change in collector potential (V) for two different incident waves in a photoelectric effect experiment.	3

	 (a) Which of the two frequencies are greater, f_1 or f_2? Give reason. (b) The photoelectric current becomes constant and same for both the waves after a certain collector potential. What does this indicate?	
Q.149	Photoelectrons are emitted from a neutral spherical metal ball when it is illuminated by a light of wavelength 4×10^{15} Hz. The power of the light source is 3.313 mW. What is the maximum charge that can be acquired by this sphere in 2 s assuming there is no dielectric breakdown of the surrounding medium? (Assume that all the light is incident on the metal ball) ($h = 6.626 \times 10^{-34}$ J.s)	2
Q.150	Ambient light sensors are used in mobile phone devices to auto-adjust the brightness of the screen based on the surrounding brightness. A light sensor has to be able to detect a wide range of frequencies. A sensor can react with a photon energy of 1.82×10^{-19} J to 5.71×10^{-19} J to create mobile electrons. What will be the range of frequencies that the sensor is sensitive to? ($h = 6.67 \times 10^{-34}$ Js, $c = 3 \times 10^{8}$ m/s)	2
Q.151	(a) How does Einstein's photoelectric equation provide an explanation for the concept of the threshold frequency in the context of the photoelectric effect? (b) Why do all the electrons emitted during a photoelectric emission not have the same kinetic energy? Give any TWO reasons.	3
Q.152	A photoelectric emission apparatus with an unknown metal is irradiated with 200 nm light. The photocurrent becomes zero at the collector plate potential of –0.80 V. Determine the work function of the unknown metal. Take $h = 4.13 \times 10^{-15}$ eV-s.	2
Q.153	A monochromatic light of wavelength 240 nm falls on sodium metal surface that has threshold wavelength value as 360 nm. Determine the speed of the photoelectrons emitted from the sodium metal surface. Take $hc \sim 2 \times 10^{-16}$ J-nm and mass of photoelectron = 9×10^{-31} kg	2

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.138	D. Only statements I & III are correct	1
Q.139	D. No, because IR rays have a longer wavelength than red light.	1
Q.140	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.141	D. Assertion is false but the reason is true.	1
Q.142	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.143	D. The line will cut the $1/\lambda$ axis at a different point.	1
Q.144	A. 0.1242×10^{-2} eV	1
Q.145	C. Assertion is true but the reason is false.	1
Q.146	C. $f_a = f_b$; $I_a \neq I_c$	1
Q.147	D. A is false and R is also false	1
Q.148	(a) Higher the magnitude of stopping potential higher will be the frequency of incident wave. Thus $f_2 > f_1$. [0.5 marks for correct reason] [0.5 marks for identifying greater frequency] (b) Constant current indicates that all the emitted electrons are collected by the collector plate and thus the current cannot increase further. The current being same for both the waves indicates that intensity of both the waves is the same. [1 mark for explaining why current becomes constant] [1 mark for explaining why current is same]	3
Q.149	Given: Frequency of light = $v = 4 \times 10^{15}$ Hz Power of source = P = 3.313 mW Time = t = 2 s	2

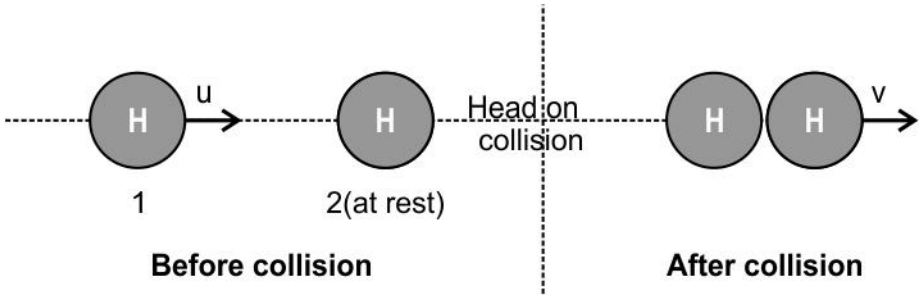
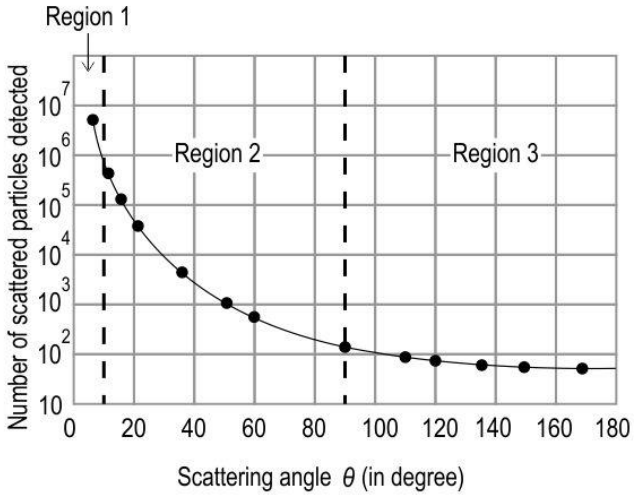
	Energy of each photon = hv = $6.626 \times 10^{-34} \times 4 \times 10^{15}$ J Total energy incident on sphere in 2 s = E = Pt = 3.313 mW × 2 s = 6.626×10^{-3} J Number of incident photons = n = E/ hv = $6.626 \times 10^{-3}/(6.626 \times 10^{-34} \times 4 \times 10^{15}) = 25 \times 10^{14}$ Maximum number of electrons that can be emitted by the sphere = Number of incident photons = 25×10^{14} Maximum charge that can be acquired by the sphere q = ne = $25 \times 10^{14} \times 1.6 \times 10^{-19}$ C = 400 μC [1 mark for calculating number of photons] [1 mark for calculating charge on sphere]	
Q.150	λ = hc/E λ1=6.67 x 10-34 x 3 x 108/1.82 x 10-19 = 1099.50 nm λ2=6.67 x 10-34 x 3 x 108/5.45 x 10-19 = 350.43 nm The sensor will be sensitive to wavelengths in the range of 350.43 nm to 1099.50 nm. (1 mark for the correct use formula and 1 mark for the correct answer.)	2
Q.151	(a) Einstein's photoelectric equation: KE_{max} = hv-Φ If hv < Φ, then the emitted electron's maximum kinetic energy (KE_{max}) would be negative, which is not physically meaningful. Thus, v > Φ/h for the photoelectric effect to take place. and we can also say v_{th} = Φ/h = Threshold frequency In summary, Einstein's photoelectric equation explains the threshold frequency by demonstrating that only photons with a frequency greater than this can cause a photoelectric effect which is in line with the experimental results. [1 mark for the correct explanation. Look for kinetic energy cannot be negative and thus v> Φ/h or Threshold frequency = Φ/h] (b) (i) Electrons in a material are bound to the atoms by different amounts of energy. Electrons closer to the surface have weaker binding energies compared	3

	to those deeper within the material. When a photon is absorbed, it needs to provide enough energy not just to overcome the work function (the energy required to escape the material) but also to overcome the electrons binding energy. (ii) Electrons might lose some of their kinetic energy due to interactions with other particles in the material before escaping. [1 mark for each correct reason]	
Q.152	Maximum KE of the emitted photoelectrons: $KE_{max} = e\,\Delta V = e \times 0.8 = 0.8$ eV [0.5 mark for correct calculation of KE_{max}] Work function = $h\nu - KE_{max}$ $= (h\,c/\lambda) - KE_{max}$ $= \frac{(4.13 \times 10^{-15} \times 3 \times 10^{8})}{\lambda} - KE_{max}$ $= \frac{12.40 \times 10^{-7}\ \text{eV} - \text{m}}{\lambda} - 0.8\ \text{eV}$ $= \frac{1240\ \text{eV} - \text{nm}}{200\ \text{nm}} - 0.8\ \text{eV} = 5.4\ \text{eV}$ [0.5 mark for correct formula of work function in terms of stopping potential] [1 mark for the correct final result of work function]	2
Q.153	Given $\lambda_o = 360$ nm and $\lambda = 240$ nm KE of the emitted photoelectrons $K = \frac{1}{2} mv^2 = E - \Phi_o$, where E is the energy of the incident light [1 mark for the correct equations] $\frac{1}{2} mv^2 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right] = hc\left[\frac{1}{240} - \frac{1}{360}\right] = \frac{hc}{720}$ $v = \sqrt{\frac{2 \times hc}{m \times 720}} = \sqrt{\frac{2 \times 2 \times 10^{-16}}{9 \times 10^{-31} \times 720}}$ $v = 7.8 \times 10^5$ m/s [1 mark for the correct final result]	2

11. Chapter: Atoms

Q.No	Question	Marks
	Multiple Choice Question	
Q.154	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): The mass of a nucleus is less than the mass of the constituent particles. Reason (R): Energy is absorbed when the nucleons are bound together to form the nucleus. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation of assertion. C. Assertion is true but reason is false. D. Both assertion and reason are false.	1
Q.155	The angular momentum of a hydrogen atom in the excited state is $8.28/\pi \times 10^{-15}$ eVs. What should be the minimum energy of light which can excite the electron from the ground state to this excited state? ($h = 4.14 \times 10^{-15}$ eVs) A. 0.85 eV B. 12.75 eV C. 13.6 eV D. 14.45 eV	1
Q.156	The potential energy of an electron in an excited state of the hydrogen atom is about –3 eV. How many emission spectral lines are possible for this excited electron? A. 1 B. 2 C. 3 D. 6	1

Q.157	The ionization energy of the hydrogen atom is 13.6 eV. For a hydrogen-like atom, the transition from n = 2 to n = 1 has 81.6 eV more energy than that of hydrogen's same transition. What is the ionization energy of this hydrogen-like atom? A. 13.6 eV B. 40.8 eV C. 105.4 eV D. 122.4 eV	1
Q.158	In a hydrogen atom, the electron makes a transition from n_1 to n_2 state. Considering classical electromagnetic theory, the initial frequency of light emitted by the electron in n_1 state is 8 times as that in state n_2. What are the possible values of n_1 and n_2? A. $n_1 = 1, n_2 = 2$ B. $n_1 = 2, n_2 = 1$ C. $n_1 = 8, n_2 = 1$ D. $n_1 = 1, n_2 = 8$	1
Q.159	A hydrogen atom is in its third excited state. It de-excites by releasing a photon of the longest wavelength. What is the ratio of the velocity of the electron in the third excited state to the new state? A. 4/3 B. 3/4 C. 4/1 D. 1/4	1
Q.160	The second line of the Balmer series has a blue-green colour. Which of the given transitions may lead to violet colour? (n is principal quantum number) A. n = 3 to n = 2 B. n = 4 to n = 2 C. n = 5 to n = 2 D. n = 6 to n = 1	1
Free Response Questions/Subjective Questions		
Q.161	After a head-on inelastic collision between two hydrogen atoms that were initially in the ground states, the two atoms combine and move together into the excited state.	3

	 Determine the minimum velocity of the first H atom that can result in the minimum possible excitation in the second H-atom in this collision. Assume that in perfectly inelastic collisions between the atoms, the excess KE is used for the excitation. Use: 1 eV = 1.6 x 10^{-19} J and Mass of H-atom = 1.6 x 10^{-27} kg	
Q.162	In a Geiger Marsden experiment, an alpha particle of energy ½ mv^2 bombards the heavy target nucleus of charge Ze. In the modified version of the Geiger Marsden experiment, a bombarding particle of 3 times the mass and 2 times the charge of the alpha particle moving with the same speed as earlier, is used as the bombarding particle, keeping the heavy target nucleus the same as earlier. If the distance of closest approach in the first case is r_0, then determine by what factor does the distance of closest approach changes in the modified version of the experiment.	2
Q.163	Angular momentum of an electron in a hydrogen atom is $3h/2\pi$, here h is the plank constant. Find the wavelength of the emitted photon in terms of R (Rydberg constant) when the atom de-excites to emit visible radiations.	2
Q.164	The below graph represents the variation in the number of alpha particles scattered and the scattering angle in Rutherford's alpha particle scattering experiment. The graph is divided into three regions (separated by two dashed lines). What can be concluded about the structure of atoms from the behavior of particles observed in Region 1 and Region 3? 	2

<table>
<tr><td>Q.165</td><td>An electron excites from first orbit to the second orbit of a hydrogen atom. By what factor will the magnetic dipole moment of the revolving electron change? Show calculations.</td><td>3</td></tr>
<tr><td>Q.166</td><td>The table below represents the energies corresponding to a few allowed energy levels of a doubly ionized hydrogen-like atom with Z=3.

<table><tr><th>Energy level</th><th>Energy</th></tr><tr><td>n=1</td><td>-122.4 eV</td></tr><tr><td>n=2</td><td>-30.6 eV</td></tr><tr><td>n=3</td><td>-13.6 eV</td></tr><tr><td>n=4</td><td>-7.65 eV</td></tr><tr><td>n=5</td><td>-4.9 eV</td></tr><tr><td>n=∞</td><td>0 eV</td></tr></table>
(a) What is the ionisation energy of the hydrogen-like atom? The transition of electron between which two energy levels corresponds to ionisation energy?

(b) What will be the energy of the photon absorbed when the electron in the n = 2 state jumps to the n = 4 state?

(c) The energy of the electron in the excited state of this hydrogen-like atom drops from – 13.6 eV to -122.4 eV. Specify the different ways in which this transition can occur.</td><td>3</td></tr>
<tr><td>Q.167</td><td>An atom can be attain three possible excited states such that,

- energy of excited atom in the 3rd state is 2 times the energy in ground state

- energy of excited atom in the 2nd excited state is 5/4 times the energy in ground state

Radiation of wavelength λ_1 is emitted during the transition from 2nd excited state to the ground state.

Radiation of wavelength λ_2 is emitted during the transition from 3rd excited state to the 2nd excited state.

Show that wavelength λ_1 is thrice the wavelength λ_2.</td><td>3</td></tr>
<tr><td>Q.168</td><td>In a Bohr model of an atom, upon de-excitation of the electron, the wavelength of radiation emitted is given as:</td><td>2</td></tr>
</table>

	$\lambda = \frac{n^2}{R\left[\frac{n^2}{9} - 1\right]}$ Here R is Rydberg constant and n represents the unknown energy level from which the electron falls to the energy level n = 3. a. State the condition at which radiation of maximum wavelength is emitted. Determine this maximum wavelength. b. State the condition at which radiation of minimum wavelength is emitted. Determine this minimum wavelength.	
Q.169	a. State true or false: For every spectral line of Balmer series, an additional photon of wavelength corresponding to a Lyman spectral line is released so that the H atom reaches its ground state. b. Identify the quantum numbers across which the transition of the excited electron results in the emission of the maximum wavelength of Lyman spectral series of (a). c. Determine this maximum wavelength of the photon emitted in (b). [Use $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ where λ is wavelength of th radiation emitted due to transition from n_2 to n_1 level and Rydberg constant R ~ 1 x 10^7 m^{-1}]	2
Q.170	An excited Hydrogen atom is in a state n = 5. It de-excites through two consecutive transitions to reach the ground state. A photon of energy 0.967 eV is released during the first transition. a. Determine the quantum number of the in-between energy level of the atom after the first transition. b. Determine the energy of the photon released during the second transition.	3
Q.171	The emission spectra of a certain gas X indicates only three spectral lines of wavelengths 36 nm, 72 nm and 100 nm. Assuming that the energy of the highest energy level is zero, determine, a. the energy level of the ground state. b. the energy level of the first excited state.	3

	[Consider that as in case of H atom, the difference between successive energy levels in the gas X atoms also keeps decreasing as the energy increases. Take value of hc = 1240 eV-nm]	
Q.172	When a gas is heated, the thermal energy is absorbed for the purpose of either the excitation or ionization of the gas atoms. The average kinetic energy of Hydrogen gas molecules at absolute temperature T is given as 3kT/2, where k is Boltzmann constant of value 8.6×10^{-5} eV/K. Using the above information, find out if the hydrogen atoms get ionized or stay in the excited state at a temperature of 10^5 K.	2
Q.173	Two spectral lines of minimum and maximum energy transitions, constituting the Balmer series, fall on two metals X and Y of work functions as given below. Which of these metals will exhibit photoelectric emission? a. Metal X with work function 1.7 eV. b. Metal Y with work function 3.1 eV.	3

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.154	C. Assertion is true but reason is false.	1
Q.155	B. 12.75 eV	1
Q.156	C. 3	1
Q.157	D. 122.4 eV	1
Q.158	A. $n_1 = 1$, $n_2 = 2$	1
Q.159	B. 3/4	1
Q.160	C. n = 5 to n = 2	1
Q.161	Minimum excitation energy required by second H atom for excitation from n = 1 to n = 2 state, with energy levels as $E_1 = -13.6$ eV $E_2 = -3.4$ eV So minimum excitation energy required = -3.4 – (-13.6) = 10.2 eV (1 mark for the correct excitation energy required) During inelastic collision, Mu = 2Mv, where v is velocity of the two atoms moving together after the collision v = u/2 Loss in KE during the collision = minimum excitation energy required by the second H-atom So, $\frac{1}{2}Mu^2 - \frac{1}{2}(2M)v^2 = \frac{1}{4}Mu^2 = 10.2eV$ (1 mark for the correct condition of energy exchange during the collision) Hence, $\frac{1}{4}Mu^2 = 10.2eV = 10.2 \times 1.6 \times 10^{-19}J$	3

	$u^2 = \frac{4\times10.2\times1.6\times10^{-19}}{1.6\times10^{-27}}$ Solving for u = 6.3 x 10^4 m/s (1 mark for the correct final result)	
Q.162	In the first case: $\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze.2e}{r_0}$ $r_0 \propto \frac{2e}{m}$ [1 mark for identifying the correct dependence of distance of closest approach on the mass and charge of the bombarding particle] In the modified version, $r \propto \frac{2.2e}{3.m}$ So, $\frac{r}{r_0} = \frac{4e}{3m}.\frac{m}{2e} = \frac{2}{3}$ Therefore, $r = \frac{2}{3}r_0$ The distance of closest approach becomes 0.66 times the earlier value of r_o. [1 mark for the correct final result]	2
Q.163	Comparing 3h/2π with nh/2π, the initial state of the hydrogen atom is $n_1 = 3$ As visible radiations are emitted the electron would de-excite to $n_2 = 2$ (Balmer series) Using, $\frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{n^2})$ We have $\frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{3^2}) = \frac{5R}{36}$ Hence, $\lambda = \frac{36}{5R}$	2

	[0.5 marks for identifying the excited state $n_1 = 3$ and 0.5 marks for identifying $n_2 = 2$] [1 mark for finding correct wavelength]	
Q.164	Region 1: This region shows that the majority of the alpha particles passed without deflecting or deflecting by a small angle. This indicates that most of the space in an atom is empty. Region 3: This region shows that only a small portion of alpha particles have a large deflection angle ($>90^0$). This indicates that all the positive charge and mass of an atom are concentrated in a very small volume within the atom.	2
Q.165	Magnetic dipole moment is given by = M = IA Current = I = Charge/Time period = $= e \times v/2\pi r$ Area = $A = \pi r^2$ (r = radius of orbit, v = speed of electron in that orbit) Thus, $M = e \times v/2\pi r \times \pi r^2 = evr/2$ [1 mark for finding or writing correct expression of M in terms of v and r] $M = evr/2$ We know $mvr = nh/2\pi$ Therefore, $M = enh/4\pi m$ i.e. $M \propto n$ So, when the electron excites to the second orbit the magnetic dipole moment becomes 2 times that in the first orbit. [1 mark for finding correct dependence of M on n] [1 mark for correct answer]	3
Q.166	(a) The ionisation energy of this hydrogen-like atom is 122.4 eV. (0.5 marks) Ionisation energy corresponds to the transition of the electron from the ground state to $n = \infty$. (0.5 marks) (b) The energy of the photon absorbed = - 7.65 - (- 30.6) = 22.95 eV (c) -1.5 eV and -13.6 eV corresponds to n=3 and n=1 state.	3

	There are two possible ways in which the electron can jump from n=3 to n=1 states 1. n=3 to n=1 (0.5 marks) 2. n=3 to n=2 to n=1 (0.5 marks)	
Q.167	For the transition 2nd excited state to the ground state of the atom: $\frac{5E}{4} - E = \frac{hc}{\lambda_1}$ $\frac{E}{4} = \frac{hc}{\lambda_1}$ $\lambda_1 = \frac{4hc}{E}$ .....(1) [1 mark for the correct relation between energy and wavelength of radiation emitted] For the transition 3rd excited state to the 2nd excited state of the atom, $2E - \frac{5E}{4} = \frac{hc}{\lambda_2}$ $\frac{3E}{4} = \frac{hc}{\lambda_2}$ $\lambda_2 = \frac{4hc}{3E}$ .....(2) [1 mark for the correct relation between energy and wavelength of radiation emitted] Ratio $\lambda_1 : \lambda_2 = 3 : 1$ [1 mark for the correct final relation]	3
Q.168	a. Simplifying the given equation: $\frac{1}{\lambda} = \frac{R}{n^2}\left[\frac{n^2}{9} - 1\right] = R\left[\frac{1}{3^2} - \frac{1}{n^2}\right]$ For maximum wavelength (least energetic photon) to be emitted, $n_f = 3$, $n_i = 4$	2

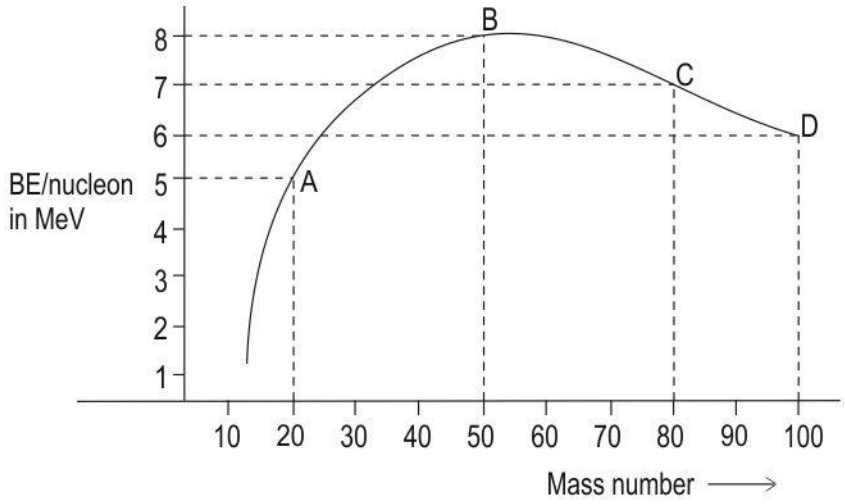
	$\frac{1}{\lambda_{max}} = R\left[\frac{1}{3^2} - \frac{1}{4^2}\right] = \frac{7R}{144}$ $\lambda_{max} = \frac{144}{7R}$ [0.5 mark for the correct condition] [0.5 mark for the correct final wavelength] b. For minimum wavelength (most energetic photon) to be emitted, $n_f = 3$, n_i = infinity So $\frac{1}{\lambda_{min}} = R\left[\frac{1}{3^2} - \frac{1}{\infty}\right] = \frac{R}{9}$ $\lambda_{min} = 9/R$ [0.5 mark for the correct condition] [0.5 mark for the correct final wavelength]	
Q.169	a. True. [0.5 mark for correct answer] b. For maximum wavelength Lyman series, the transition is between $n_f = 1$ and $n_i = 2$. [0.5 mark for the correct values of n_f and n_i] c. Using $\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = 1 \times 10^7 \times \frac{3}{4}$ $\lambda = 1.33 \times 10^{-7} = 133 \times 10^{-9}$ m = 133 nm	2
Q.170	a. The initial excited energy level of H atom: $E_5 = -13.6/n^2 = -13.6/52 = -0.544$ eV Energy of photon released during the first transition = 0.967 eV	3

	Energy level of the in-between level occupied by the atom after the first transition = -0.544 – 0.967 = -1.511 eV [1 mark for the correct value of energy of the intermediate level] Quantum number of in-between level occupied by the atom after the first transition, $E_n = -1.511 = -13.6/n^2$ $n^2 = -13.6/-1.511$ n = 3 [1 mark for the correct value of n] b. Energy of the photon released during the second transition: -1.511 – (-13.6) = 12.089 eV [1 mark for the correct value of the energy of photon released]	
Q.171	a. Only three emission spectral lines imply only three possible energy states, that is, ground, first and second, i.e., n = 1,2,3 respectively. [0.5 mark for recognising the 3 possible states] Given that $E_3 = 0$ λ_{min} = 36 nm is emitted for transition from n = 3 to n = 1 (ground state) [0.5 mark for identifying the correct quantum numbers for λ_{min}] So $E_1 = \frac{hc}{\lambda_{min}} = \frac{1240}{36}$ = 34.44 eV (energy level of the ground state) [1 mark for the correct value of energy level of the ground state] b. λ_{max} = 100 nm is emitted for transition between n = 3 (second excited state) to n = 2 (first excited state) [0.5 mark for identifying the correct quantum numbers for λ_{max}] So	3

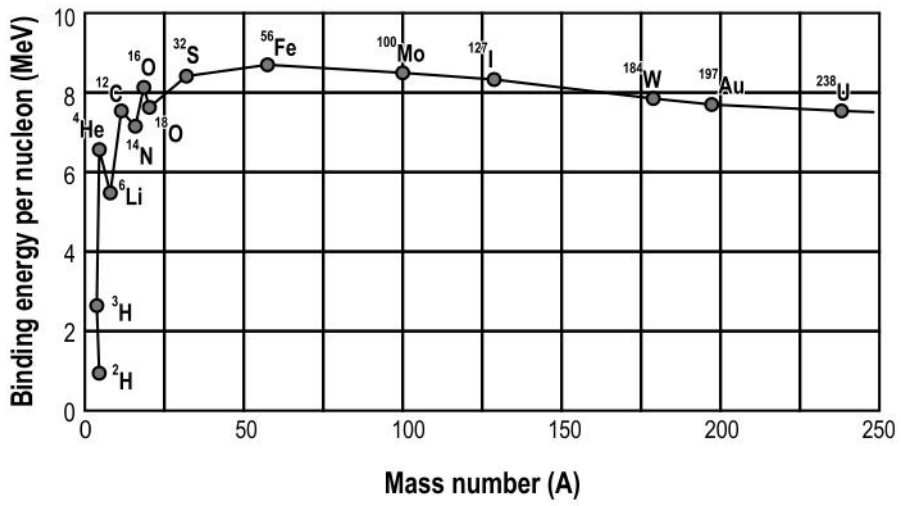
	$E_2 = \frac{hc}{\lambda_{max}} = \frac{1240}{100}$ = 12.4 eV (energy level of the first excited state) [0.5 mark for the correct value of energy level of the ground state]	
Q.172	Total thermal energy absorbed by the H atom at 10^5 K = 3kT/2 $= \frac{3 \times 8.6 \times 10^{-5} \times 10^5}{2} = 12.9 \text{ eV}$ [1 mark for the correct calculation of energy value] As the ionization energy of H atom being 13.6 eV > Absorbed thermal energy of 12.9 eV, the H atom will be in the excited state. They fail to get ionized. [1 mark for the correct conclusion]	2
Q.173	Energy of photon emitted can be calculated by the formula $E = 13.6 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ The first Balmer spectral line (of minimum energy) emission could be due to the transition between $n_1 = 2$ and $n_2 = 3$ The energy of this photon $= 13.6 \left[\frac{1}{2^2} - \frac{1}{3^2}\right] = 1.9 \, eV$ [1 mark for the correct calculation of energy of photon] As the energy of an incident photon is greater than the work function of metal X but less than the work function of metal Y, this photon can result in photoelectric emission in only metal X. [0.5 mark for the correct conclusion on the metal] The second Balmer spectral line (of maximum energy) emission corresponds to the transition: $n_1 = 2$ and n_2 = infinity The energy of this photon	3

	$= 13.6 \left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] = 3.4\ eV$ [1 mark for the correct calculation of energy of photon] As the energy of the incident photon exceeds the work functions of both the metal X & Y, this photon can result in photoelectric emission in both metals X and Y. [0.5 mark for the correct conclusion on the metal]	

12. Chapter: Nuclei

Q.No	Question	Marks
	Multiple Choice Question	
Q.174	A, B, C and D are four different nuclei with different binding energies and mass numbers.  Considering that the below equations (I-IV) are possible, identify the equation/s that would be exothermic. I. D -> B +C II. C -> B + A III. D -> 2B IV. B -> 2A A. only I B. only IV C. only I and III D. only II and III	1
Q.175	A certain nucleus M decays into N which further decays to R by undergoing the reactions shown below. $M \rightarrow N + \beta^-$ $N \rightarrow R + \alpha$	1

	Which of the following options is correct about the above reactions? A. M and R are isotopes. B. N has less number of protons than M. C. The mass number of N is more than that of M. D. Atomic number of R is one less than that of M.	
Q.176	Two alpha particles P and Q deflect by 10° and 120° angles in Rutherford's gold foil experiment. Which of the following is DEFINITELY true about the two particles? A. Impact parameter of P > Impact parameter of Q B. Impact parameter of P < Impact parameter of Q C. Kinetic Energy of P > Kinetic Energy of Q D. Kinetic Energy of P < Kinetic Energy of Q	1
Q.177	Consider the following reaction $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$ Which of the given options is correct for the above reaction if U was initially at rest? A. Momentum of Th will be less than that of He B. Kinetic energy of Th will be less than that of He C. Momentum of Th will be more than that of He D. Kinetic energy of Th will be more than that of He	1
Q.178	The distance of closest approach of an alpha particle is *d* when it moves with a speed *v* towards a nucleus. Another alpha particle is projected with higher energy such that the new distance of the closest approach is d/2. What is the speed of projection of the alpha particle in this case? A. v/2 B. √2v C. 2v D. 4v	1
Q.179	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R.	1

	Assertion(A): If an atom has a filled valence shell, the atomic nucleus is stable. Reason(R): The atom with a filled valence shell does not react with other elements. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but reason is true.	
Q.180	An element with an unstable nucleus decays by emitting an α particle and two β^- particles to become a stable atom. Which of the following is true about the new stable atom? A. It is an isobar of the original element. B. It is an isotone of the original element. C. It is an isotope of the original element. D. It has the same proton and neutron number as the original atom.	1
	Free Response Questions/Subjective Questions	
Q.181	Given here is BE/nucleon vs. Mass number curve.  (a) Arrange the following nuclei in the ascending order of the ease with which a nucleon can be taken out of the atomic nucleus:^{6}Li, ^{16}O, ^{56}Fe, and ^{238}U. State the condition basis on which the arrangement is done. (b) If 8 protons and 8 neutrons are combined into the following nuclei/combination of nuclei, estimate which one of them will release the most energy. Show the working.	4

<table>
<tr><td></td><td>i. One ^{12}C nucleus and one ^{4}He nucleus

ii. Four ^{4}He nuclei

iii. One ^{16}O nuclei

(Use BE/A of ^{12}C = 7.6 MeV; BE/A of ^{4}He = 6.8 MeV; BE/A of ^{16}O = 8.2 MeV)</td><td></td></tr>
<tr><td>Q.182</td><td>A pair of nucleons were attracted to each other when they were separated by a distance d, however, when the distance was increased, after a certain separation they started repelling each other. Identify this pair and explain this behavior.</td><td>2</td></tr>
<tr><td>Q.183</td><td>The table below represents the binding energy per nucleon and mass number of a few elements.

<table><tr><th>Element</th><th>Mass Number</th><th>Binding energy per nucleon (MeV)</th></tr><tr><td>Hydrogen</td><td>1</td><td>0</td></tr><tr><td>Helium`</td><td>2</td><td>7.4</td></tr><tr><td>Lithium</td><td>6</td><td>4.9</td></tr><tr><td>Iron</td><td>56</td><td>8.8</td></tr><tr><td>Gold</td><td>197</td><td>7.7</td></tr><tr><td>Uranium</td><td>238</td><td>7.5</td></tr></table>
Study the table and answer the following questions.
(a) What does the binding energy per nucleon of hydrogen signify?
(b) Which element has the highest mass defect per nucleon among the given elements? Give reason.
(c) Of lithium and gold which element has a more tightly bound nucleus? Give reason.</td><td>3</td></tr>
<tr><td>Q.184</td><td>Given below are two probable nuclear reactions:

$_{Z}^{A}X$ ----------> $_{Z}^{A-1}X + {}_{0}^{1}n$ (1)

$_{Z}^{A}Y$ ----------> $_{Z-1}^{A-1}Z + {}_{1}^{1}p$ (2)

a. State the condition under which nuclear reactions can occur spontaneously without any external energy input.

b. Using the following data of nuclear masses, identify which of the given reactions can occur spontaneously without any external energy input.</td><td>3</td></tr>
</table>

	Mass of ${}_{Z}^{A}X$ = 230.033927 u $Mass_{proton}$ = 1.0078 u $Mass_{neutron}$ = 1.0087 u Mass of ${}_{Z}^{A-1}X$ = 229.033496 u Mass of ${}_{Z}^{A}Y$ = 230.049289 u Mass of ${}_{Z-1}^{A-1}Z$ = 229.032089 u	
Q.185	Removing one proton from ${}_{12}^{23}Mg$ results in the formation of ${}_{11}^{22}Na$. If the binding energy per nucleon for ${}_{12}^{23}Mg$ nucleus is 7.9 MeV/A and that of ${}_{11}^{22}Na$ is 8.11 MeV/A, determine the energy required to remove one proton from ${}_{12}^{23}Mg$.	2
Q.186	The heaviest stable nucleus is ${}_{83}^{209}Bi$ and the lightest stable nucleus is ${}_{1}^{1}H$. Find the ratio of: a. Volume of the two nuclei b. Density of the two nuclei	2
Q.187	The carbon-13 nucleus has one additional neutron as compared to nucleus of carbon-12. The difference in the BE of these two nuclei is approx. 5 MeV. Take mass of neutron = 1.0086 u. Using this information, determine the difference in the atomic masses of these two nuclei.	2

Answer key and Marking Scheme

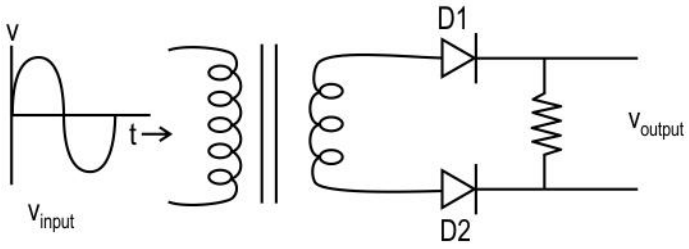
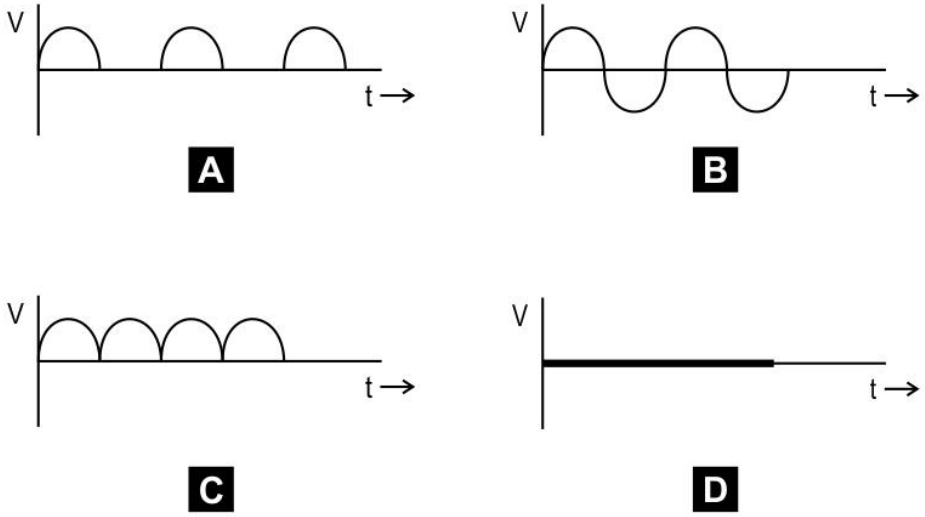
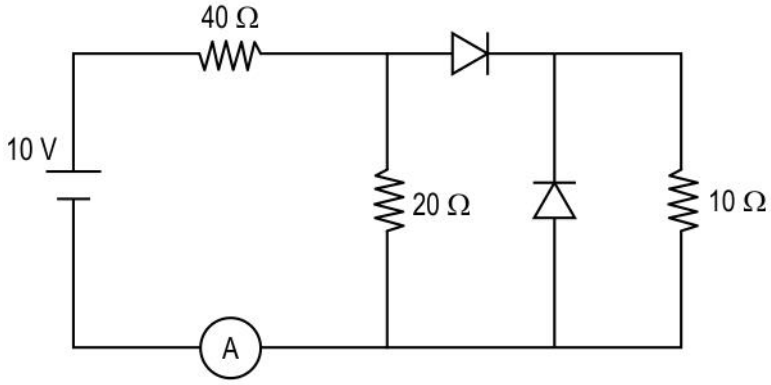
Q.No	Answers	Marks
Q.174	C. only I and III	1
Q.175	D. Atomic number of R is one less than that of M.	1
Q.176	A. Impact parameter of P > Impact parameter of Q	1
Q.177	B. Kinetic energy of Th will be less than that of He	1
Q.178	B. √2v	1
Q.179	D. Assertion is false but reason is true.	1
Q.180	C. It is an isotope of the original element.	1
Q.181	(a) ^{6}Li , ^{238}U, ^{16}O, ^{56}Fe Lesser is the BE/nucleon, lesser is the energy required, hence it is easier to remove the nucleon from the nucleus. [0.5 mark for the correct arrangement][0.5 mark for the correct condition] (b) i. One ^{12}C nucleus and one ^{4}He nucleus BE/A of ^{12}C = 7.6 MeV BE/A of ^{4}He = 6.8 MeV Total BE = 12 x 7.6 + 4 x 6.8 = 118.4 MeV This is the total energy released in the case of forming One ^{12}C nucleus and one ^{4}He nucleus. [1 mark for the correct calculation of energy released in the reaction] ii. BE/A of ^{4}He = 6.8 MeV Total BE = 4 x 6.8 x 4 = 108.8 MeV [1 mark for the correct calculation of energy released in the reaction] iii. BE/A of ^{16}O = 8.2 MeV Total BE = 16 x 8.2 = 131.2 MeV	4

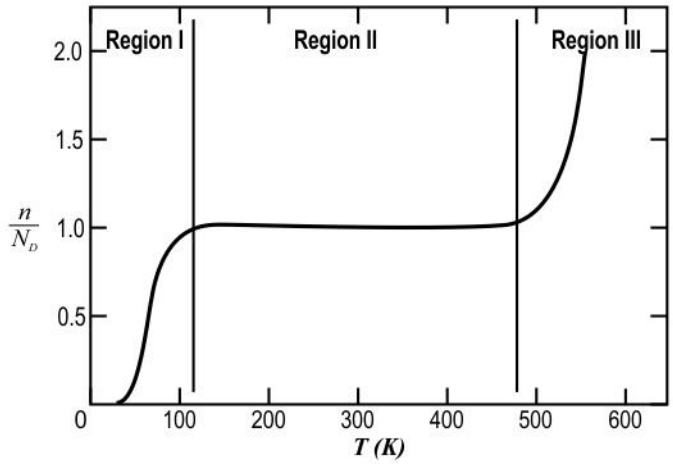
	Maximum energy is released in case of formation of one ^{16}O nucleus using 8 p and 8 n. [1 mark for the correct calculation of energy released in the reaction]	
Q.182	These particles are likely to be protons. The change in behaviour from attraction to repulsion is due to the nuclear force and the electromagnetic force. Initially, when the protons are close together (at a distance 'd'), the strong nuclear force, which is attractive, overcomes the electromagnetic repulsion between the positively charged protons. However, as the protons move farther apart (beyond a certain distance), the strong nuclear force diminishes because it acts only over short distances and the electromagnetic repulsion dominates as the distance between the protons increases.	2
Q.183	(a) Binding energy per nucleon of hydrogen is 0 MeV which signifies it does not require energy to separate the nucleons in the nucleus of hydrogen as it has only 1 proton and no neutrons. (b) The binding energy per nucleon of iron is the maximum. (0.5 marks) This implies that its mass defect per nucleon is the maximum. (0.5 marks) (c) The higher the binding energy per nucleon, the more tightly bound will be the nucleus. (0.5 marks) Thus gold has a more tightly bound nucleus as it has greater binding energy than lithium. (0.5 marks)	3
Q.184	a. The nuclear reaction that occur spontaneously without any external energy input, are possible, if the Q value of the reaction is positive. Alternatively, sum of the reactant masses exceeds the sum of product masses. [1 mark for the statement of the correct condition] b. Reaction 1: $_{Z}^{A}X$ ---------> $_{Z}^{A-1}X + {}_{0}^{1}n$ Mass of the reactant $_{Z}^{A}X$: 230.033927 u Sum of the masses of the products = 229.033496 u + 1.0087 u = 230.042196 u Since the sum of product masses exceeds the mass of the reactant , reaction 1 is not possible. [1 mark for the correct result] Reaction 2: $_{Z}^{A}Y$ ---------> $_{Z-1}^{A-1}Z + {}_{1}^{1}p$ Sum of the masses of the products = 229.032089 u + 1.0078 u = 230.039889 u	3

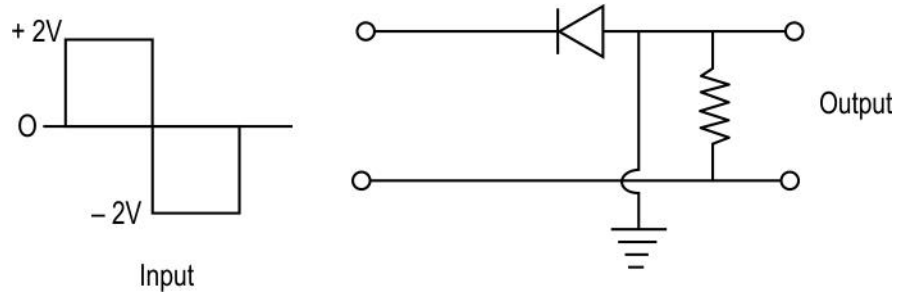
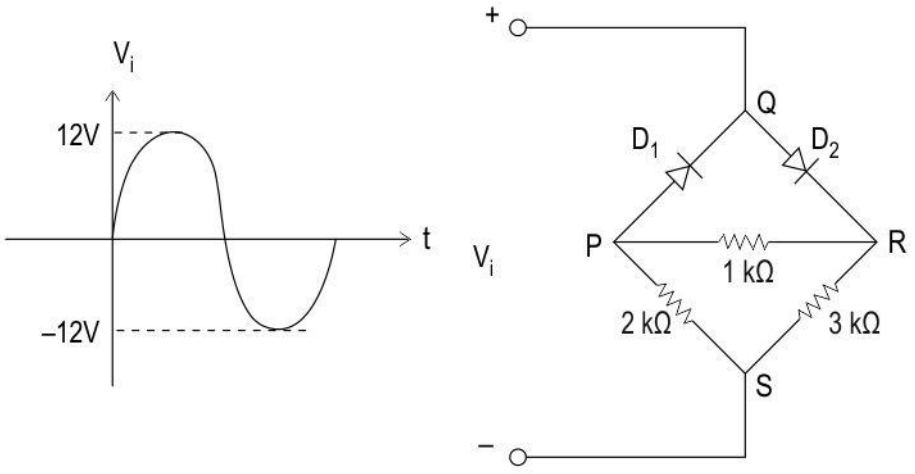
	Mass of the reactant ${}_{Z}^{A}Y$: 230.049289 u Since the sum of product masses is less than the mass of the reactant , reaction 2 is possible. [1 mark for the correct result]	
Q.185	Total BE of ${}_{12}^{23}Mg$ = 7.9 x 23 MeV Total BE of ${}_{11}^{23}Na$ = 8.11 x 22 MeV [0.5 mark for each expression for BE] Energy required to remove one proton from ${}_{12}^{23}Mg$ is (7.9 x 23) – (8.11 x 22) = 181.7 – 178.4 = 3.28 MeV [1 mark for correct final result]	2
Q.186	a. Radius of nucleus, $r = r_o A^{1/3}$ where $r_o = 1.2 \times 10^{-15}$ m Volume of the nucleus = $= (4/3)\pi r^3 = (4/3)\pi r_0^3.A$ Ratio, $\frac{volume\ of\ 209Bi}{volume\ of\ 1H} = \frac{209}{1} = 209$ [1 mark for correct formula & final result] b. Density of a nucleus = mass/volume = $m_n A/(4/3)\pi r_0^3.A$ = constant and independent of A. Ratio of densities of Bi and H is 1 [1 mark for correct final result]	2
Q.187	Difference in BE of C12 and C13 is 5 MeV The corresponding Mass defect that resulted in the above difference in BE = 5/931 = 0.0054u [1 mark for the calculation of mass defect] Since C13 nucleus has one extra neutron of mass 1.0086 u as compared to C12 nucleus, the difference in atomic masses between C12 and C13 is given as, 1.0086 u - 0.0054u = 1.0032 u. [1 mark for the correct final result]	2

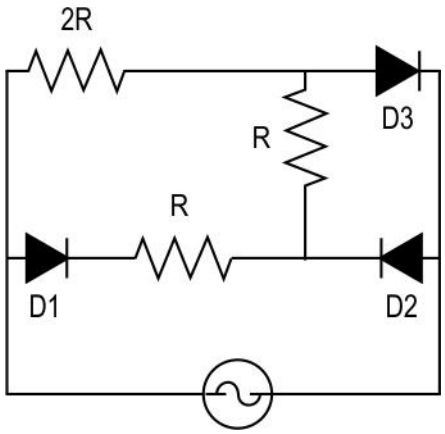
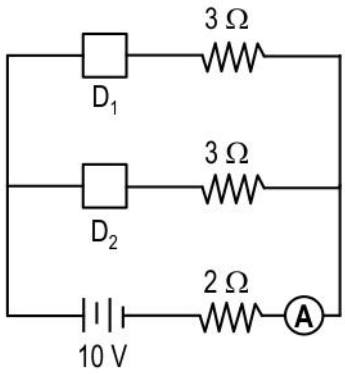
13. Chapter: Semiconductor Electronics: Materials, Devices and Simple Circuits

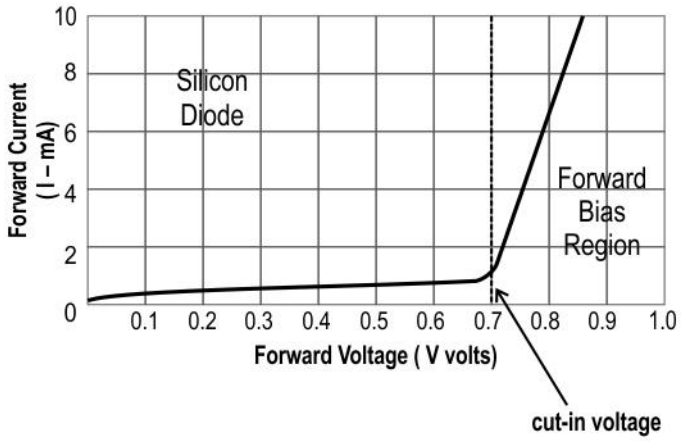
Q.No	Question	Marks
	Multiple Choice Question	
Q.188	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion (A): For the same doping concentrations, n-type Si material has a higher conductivity than p-type Si material. Reason (R): In a semiconductor the electrons are less tightly bounded than holes. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true.	1
Q.189	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): n-type semiconductors of silicon are electrically charged. Reason(R): In n-type semiconductors, the doped atom has 1 more valence electron than silicon. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true.	1
Q.190	In an unbiased p-n junction at equilibrium, which of the following statements is true about diffusion current and drift current? A. Diffusion current is equal to drift current B. Drift current exists while diffusion current is zero C. Diffusion current exists while drift current is zero D. Neither drift current nor diffusion current exists	1

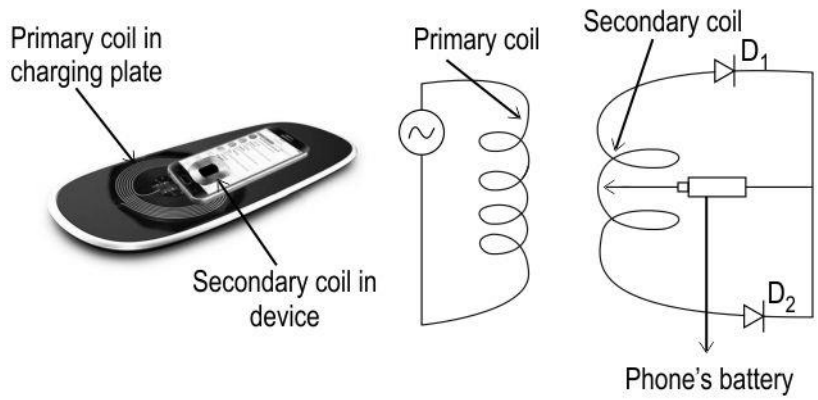
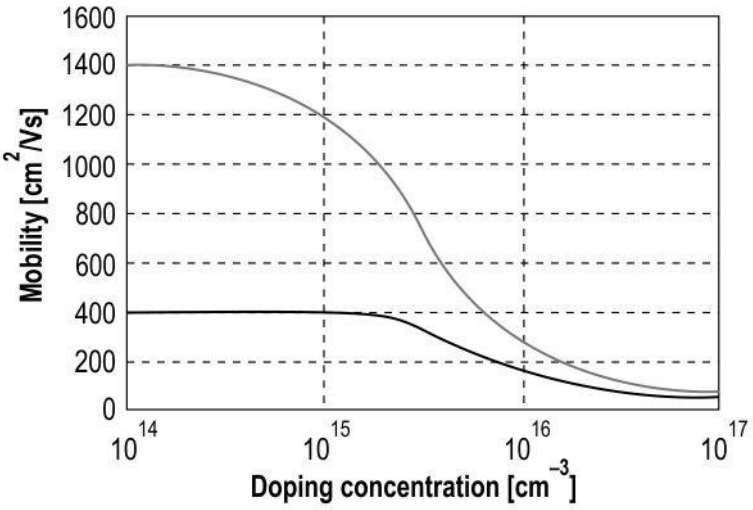
Q.191	The diagram below shows a transformer whose output terminals are connected to two diodes D_1 and D_2.  Which of the following represents the waveform obtained at the output terminals of the transformer correctly?  A. A B. B C. C D. D	1
Q.192	A 10V battery is attached to 3 resistors and two ideal diodes as shown below. What will be the reading of the ammeter?  A. 1/6 A B. 1/5 A C. 1/4 A	1

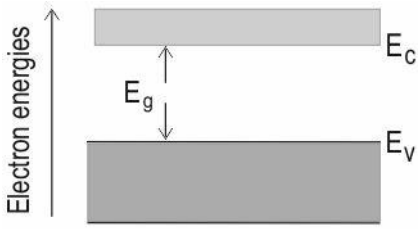
	D. 3/14 A	
	The graph below represents the variation of n/N_D with temperature for an extrinsic n-type semiconductor. The temperature range indicated on the X-axis is divided into three regions, Regions I, II and III.  *n*: number of majority carriers N_D: number of donor electrons Study the graph and answer the following questions.	
Q.193	Which region(s) has the maximum number of unionized donor atoms? A. Only region I B. Only region II C. Only region III D. Only regions I and III	1
Q.194	Which of the following relation is definitely TRUE for the semiconductor in region II? (n_e - concentration of free electrons; n_h – concentration of holes) A. $n_e > n_h$ B. $n_e < n_h$ C. $n_e = n_h$ D. $n_e > n_h$ and $n_h = 0$	1
Q.195	In which region(s) are thermally generated electrons comparable to donor electrons? A. Only region I B. Only region II C. Only region III D. Only regions 1 and II	1
Q.196	An ideal diode and a resistor are connected to an ac source as shown.	1

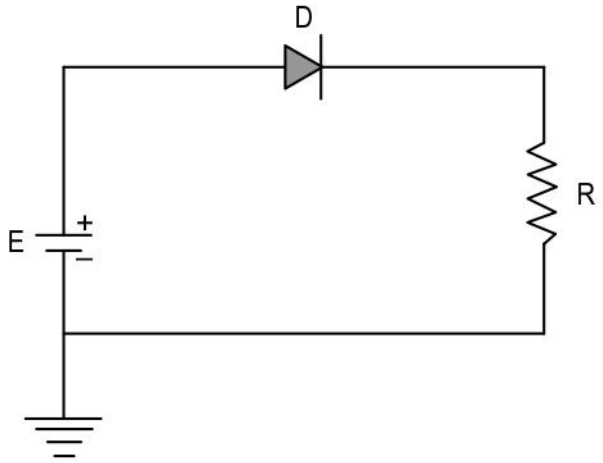
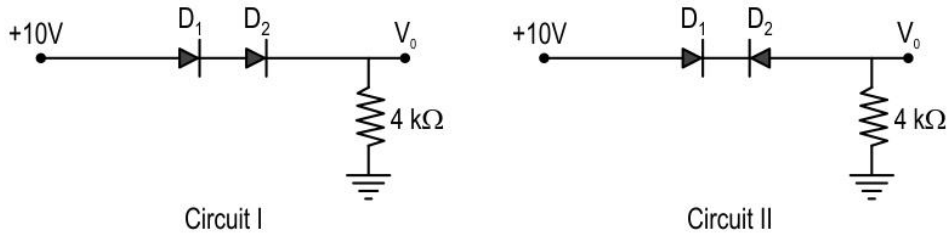
	 The input voltage is a square wave as shown above. What will be output across the resistor? A. Only +2 V B. Only -2 V C. Either 0 V or +2 V D. Either 0 V or -2 V	
Q.197	An electron with an initial energy of 0.9eV diffuses from the n-side to the p-side of a diode whose potential barrier is 0.7eV. What is the energy of the electron when it just diffuses from the n-side to the p-side? A. 1.5eV B. 0.9eV C. 0.7eV D. 0.2eV	1
Free Response Questions/Subjective Questions		
Q.198	A sinusoidal input voltage V_i is applied across a network of 2 ideal diodes and the 3 resistors as shown below.  Study the given network carefully. Considering the period when the positive half of the input voltage V_i is fed into the network, answer the following questions: (a) Identify which of the diodes would be conducting.	3

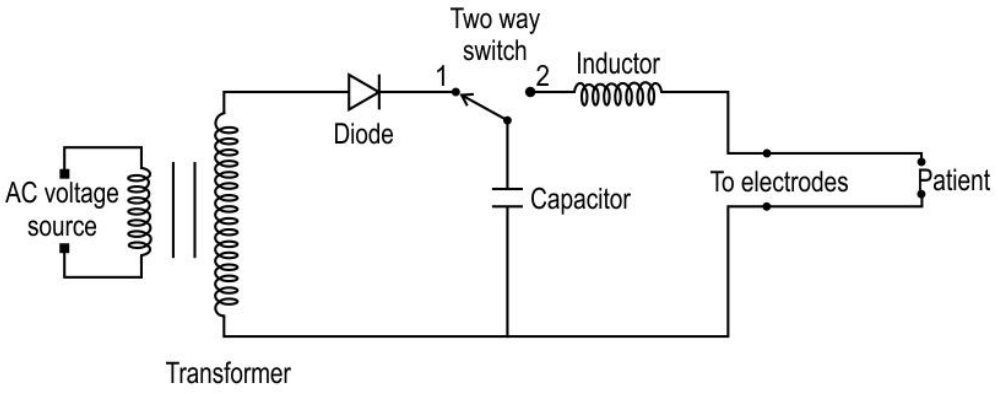
	(b) Redraw an equivalent circuit diagram to show the flow of current and voltage drops across each of the circuit elements. Consider that ideal diodes offer zero resistance when forward-biased & infinite resistance when reverse-biased. (c) Determine the output voltage V_o across 1 kΩ, 2 kΩ and 3 kΩ respectively when the input voltage $V_{i,max}$ = 12V.	
Q.199	A germanium sample at T = 300 K is doped with pentavalent impurity. If the concentration of the pentavalent impurity is 12 x 10^{17} cm^{-3} , calculate the number of electrons and holes. Assume, complete ionisation of the impurity atom. Given, intrinsic carrier concentration = 2.4 x 10^{13} cm^{-3}.	2
Q.200	The image below shows a circuit with three diodes and three resistors connected to an AC source with an rms voltage V.  What is the average power delivered over one full cycle of AC in the above circuit? Show your calculations and arrive at the final answer in terms of V and R. (*Assume the diode is ideal.*)	5
Q.201	D_1 and D_2 represent the position of two ideal diodes that are connected in an electric circuit.  If the ammeter reading is 2A, then with the help of diagram(s) show the possible orientation of D_1 and D_2. Explain.	2
Q.202	The hole and electron concentration in the intrinsic semiconductor of germanium at room temperature is 2 x 10^{18} m^{-3}. After doping with an element	2

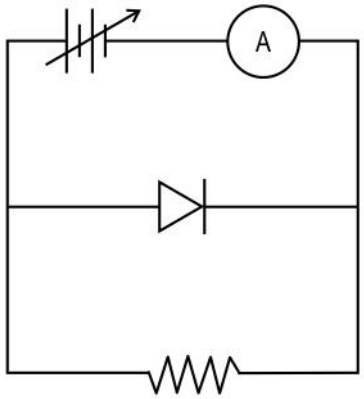
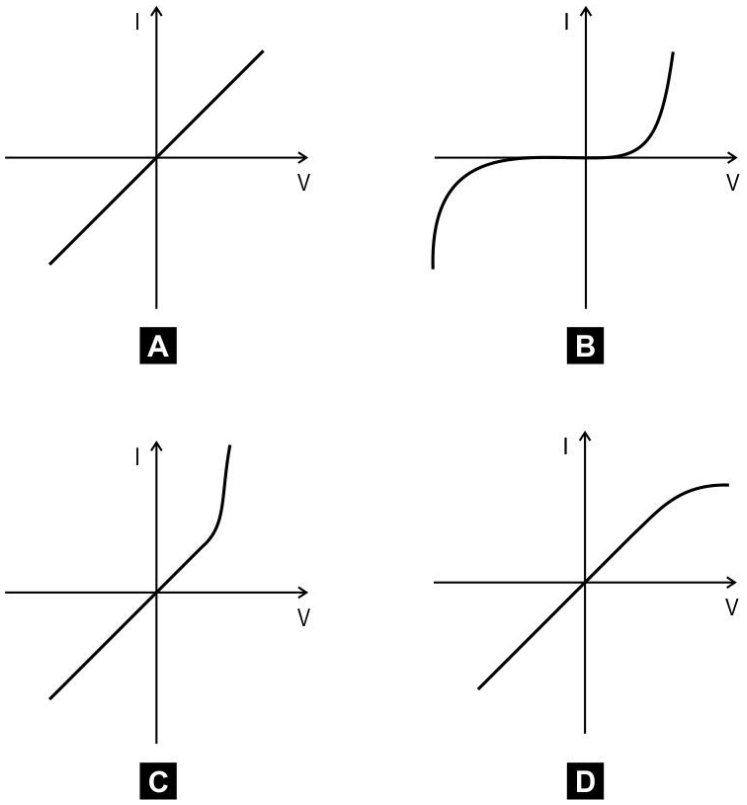
	Q, the concentration of electrons in the doped semiconductor becomes 6 x $10^{22}m^{-3}$. The concentration of germanium atoms is 6 x $10^{30}m^{-3}$. (a) Is Q trivalent or pentavalent element? Give reason. (b) What is the ratio of atoms of element Q and germanium in the doped semiconductor?	
Q.203	When a p-n junction is forward-biased and the voltage supplied exceeds the potential barrier the diffusion current increases exponentially as the number of holes diffusing into the n-region increases. Will the concentration of the holes become equal in p-region and n-region after some time and diffusion current become zero? Give a reason for your answer.	2
Q.204	Shown below is the V-I characteristics curve for a forward-biased Si diode.  A Si diode along with a resistor R is connected in series to a battery of 2 V. If the value of R is 1000 Ω, will the diode now operate above its cut-in voltage? Justify your answer by showing the necessary mathematical calculations.	2
Q.205	A diode is connected in series with a 3 V battery and a 30 Ω resistor. A drift current of 10 μA flows through the diode. (a) What is the potential drop across the diode? (b) Is the diode forward-biased or reverse-biased? Draw a circuit diagram to represent the above connections.	3
	Wireless charging of smartphones makes use of two coils, the primary coil present in wireless chargers and the secondary coil present in smartphones. The energy is transferred from one coil to the other during the charging of the phone. Together, these two coils work like an electrical transformer. The output of the secondary coil is fed into a full wave rectifier which is connected to the battery of the smartphone. A simplified circuit diagram of this arrangement is shown in the image below.	

		
Q.206	If the power rating of the wireless charger is 220V-10W and the current induced in the secondary coil is 1.25 A, then calculate the peak voltage which acts as an input to the full wave rectifier circuit. Assume the efficiency of the wireless charger is 70%.	2
Q.207	How will the charging of the phone be affected if the phone's battery is directly connected to the output of the secondary coil? Give reason.	2
Q.208	If the frequency of the AC input fed to the primary coil is 50Hz, then what is the frequency fed to the phone's battery? Give a reason.	1
Q.209	The graph below shows the variation in the mobility of electrons and holes for a Si semiconductor with doping concentration at 300 K.  The pentavalent doping concentration is 10^{15} cm^{-3} and the concentration of intrinsic charge carriers at 300 K is about 10^{10} cm^{-3}. (a) Find the concentration of majority and minority charge carriers. (b) What is the conductivity of silicon at 300 K? *(Calculate conductivity assuming majority charge carriers only.)* The magnitude charge on an electron/hole is 1.6 x 10^{-19} C. Assume complete dopant ionization.	3
Q.210	In a representation of energy band diagram of a material X, the energy band that includes the energy levels of the valence electrons is the valence band, E_v	4

	whereas the energy band above the valence band is the conduction band, E_c. The gap between the conduction and the valence band is represented by the energy gap, E_g. For the given sample material, the energy gap, E_g is about 2.8 eV. If the given sample material has N atoms with 'p' number of valence electrons in each atom, then there would be a total of pN, the total number of electrons in its valance band.  (a) Identify the nature of the sample material X. What happens to the electrons in the valence energy band at a temperature, say 40 ^oC, that is, slightly above the room temperature? If N_e are the number of electrons in the conduction band at a given temperature of the material X and v_d is their corresponding drift speed, comment what happens to these two parameters upon the increase in temperature of the material X? Explain. (b) With the increase in the temperature of material X, both the number of charge carriers as well the extent of thermal vibrations in the lattice increase. Is the temperature coefficient of resistivity of material X - Negative, Zero OR positive? Give reason for your answer. (c) Represent energy band diagram of a material with E_g more than that of given material X OR Represent energy band diagram of a material with $E_g \leq 0$	
Q.211	In a forward biased, ideal pn diode, the applied forward potential is opposite to the potential barrier of the depletion region. A small forward voltage is sufficient to overcome the potential barrier. Once eliminated, the junction resistance is reduced to zero and an ideal pn junction has zero ohmic potential drop across itself. The voltage at which the current starts to increase rapidly is called threshold voltage or cut in voltage or knee voltage of the pn diode. If the diode voltage is more than knee voltage, it conducts easily otherwise it conducts poorly. For a silicon diode, $V_{(threshold)} = 0.7$ V a. In the circuit given here, determine the voltage across an ideal silicon diode D and resistor R and the current through the diode and resistor, if E = 3 V and R = 2 k-ohm.	4

	 b. How will the values in part (a) change in case E is made 0.3 V? OR How will the values in part (a) change in case the terminals of E are reversed?	
Q.212	The threshold voltage for diodes D_1 and D_2 are 0.3 V and 0.7 V respectively.  In circuit I, both the diodes D_1 and D_2 are forward biased. In circuit II, D_1 is forward biased whereas D_2 is reverse biased. Determine current through the diodes in series, I_D and voltage V_o in each of the two given circuits.	2
Q.213	A p-n junction diode has a depletion layer of thickness 500 nm and an electric field 16 x 10^5 V/m. a. Find the barrier potential created. b. Determine the minimum kinetic energy (in eV) that the conduction electrons must have so that they can diffuse from n-side onto p-side, in case of: i. the junction is unbiased ii. the junction is forward biased at 0.5 V iii. the junction is reverse biased at 0.5 V	2
Q.214	A non-ideal diode causes a voltage drop of 0.2 V when in forward bias. The diode burns out if the current through it exceeds 8 mA through it. In which of the following instances will this diode run the risk of burning out? Show the working. a. A battery of 4.2 V and resistor of 1 k-ohm connected in series to the diode. b. A battery of 6.2 V and a resistor of 0.6 k-ohm connected in series to the diode.	3

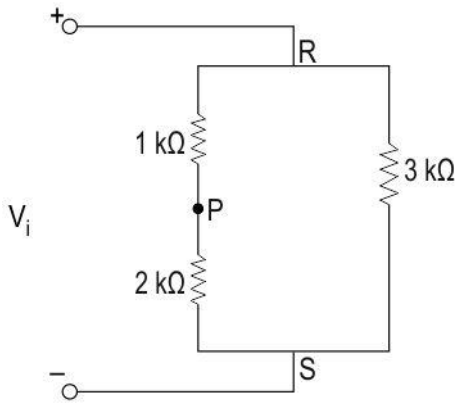
Q.215	Almost a constant electric current of 20 μA flows through a given pn junction diode in reverse bias. The current becomes 4 times in case the pn junction diode is forward biased. Determine the diffusion current that flows through the given diode in case it is: a. unbiased b. reverse biased c. forward biased	2
Q.216	A certain biasing voltage is applied across the pn junction with an initial potential barrier of V_o. The holes approach the pn junction with a non-zero initial kinetic energy from either p or the n- side depending upon the nature of biasing applied. a. If the holes approach the pn junction from p-side, i. What type of biasing must have been applied across the pn junction? ii. Will the kinetic energy of the holes increase or decrease while crossing the junction? Give reason for your answer. b. If the holes approach the pn junction from n-side, i. What type of biasing must have been applied across the pn junction? ii. Will the kinetic energy of the holes increase or decrease while crossing the junction? Give reason for your answer.	3
	Defibrillators are devices that deliver a high dose of electric current to the human heart to restore a normal heartbeat. Defibrillation can be a life-saver for someone in cardiac arrest. To deliver a high dose of electric current, a capacitor is used to store a large quantity of charge. The capacitor then delivers this charge to the human heart in a very short time interval. The image below shows a simplified defibrillator circuit. 	
Q.217	(a) Identify the type of transformer used in the circuit and its purpose. (b) What happens when the switch is in position 1 and position 2?	2
Q.218	(a) Why is a diode used in the circuit? (b) How will the device be affected if the diode is NOT included in the circuit?	2

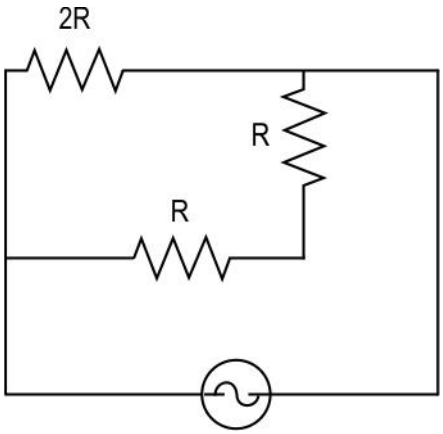
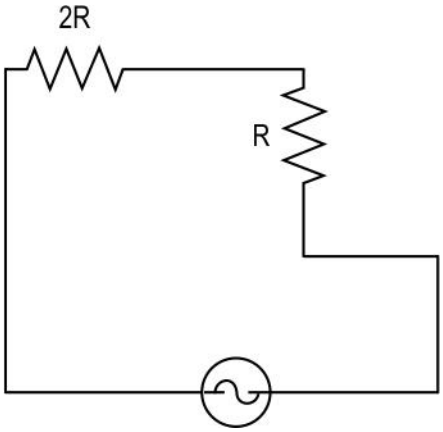
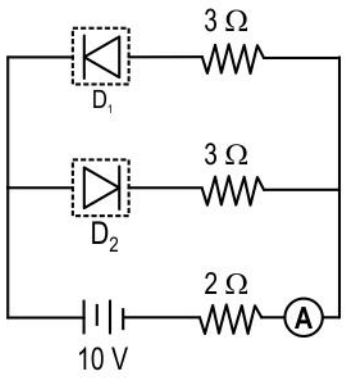
Q.219	(a) If the capacitor has a capacitance of 40 µF, charged to 2500 V, what is the energy stored in the capacitor? (b) If 60% of this energy is passed through the patient in a pulse of about 3 ms, how much electrical power is delivered to the patient? (c) Using the power calculated in part(b), calculate the current flowing from the capacitor plates to the patient's heart. (d) What is the resistance of the path? *(The path of current from the capacitor plates through the patient's heart.)*	4
Q.220	A diode and a resistor are connected in parallel to a variable DC power supply. An ammeter is connected to measure the current in the circuit.  Which of the following graphs correctly shows how the ammeter reading (I) varies with the voltage (V) supplied by the power supply?  A. A	1

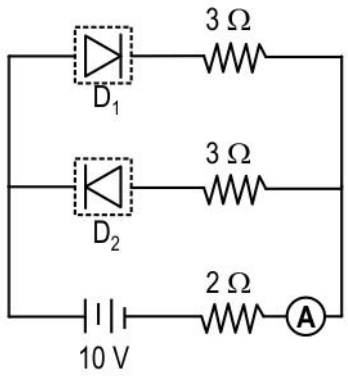
	B. B C. C D. D	

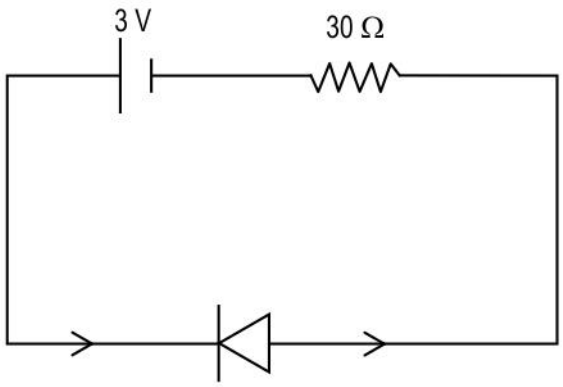
Answer key and Marking Scheme

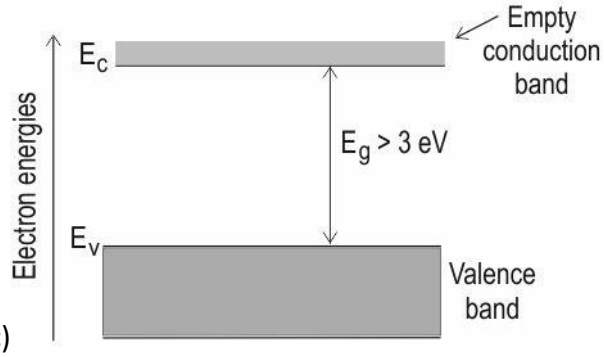
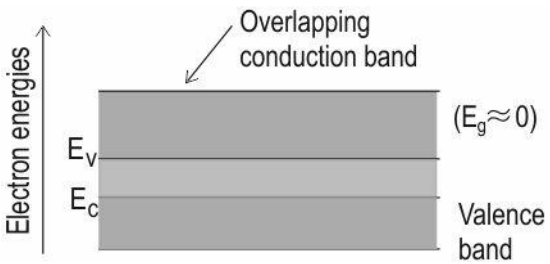
Q.No	Answers	Marks
Q.188	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.189	D. Assertion is false but the reason is true.	1
Q.190	A. Diffusion current is equal to drift current	1
Q.191	D. D	1
Q.192	D. 3/14 A	1
Q.193	A. Only region I	1
Q.194	A. $n_e > n_h$	1
Q.195	C. Only region III	1
Q.196	D. Either 0 V or -2 V	1
Q.197	B. 0.9eV	1
Q.198	(a) Only D_2 will be conducting [0.5 mark for correct statement] (b) D1 will offer infinite resistance (open circuit). D2 will offer zero resistance (forward biased) Equivalent circuit will be :	3

	 [1 mark for the correct layout of the resistors in the equivalent network] (c) Voltage across R and S = 12 V $V_1 + V_2 = 12$ (here V_1 is p.d across 1 k-ohm and V_2 is p.d across 2 k-ohm) Also $V_1/V_2 = R_1/R_2 = 1/2$ $2V_1 = V_2$ Substituting and solving, $V_1 = 4$ V $V_2 = 8$ V These will be output voltages across 1kΩ and 2kΩ respectively. The output voltage across 3 kW, will be same as that of V_i that is, 12 V. [0.5 mark for each correct voltage value across the resistors]	
Q.199	Intrinsic carrier concentration $n_i = 2.4 \times 10^{13}$ cm^{-3} Donor concentration $N_D = 12 \times 10^{17}$ cm^{-3} Number of electrons = 12×10^{17} cm^{-3} (0.5 marks) Number of holes = n_i^2/N_D (0.5 marks) Number of holes = $(2.4 \times 10^{13})^2/(12 \times 10^{17}) = 0.48 \times 10^9$ cm^{-3} (1 mark)	2
Q.200	During the positive half cycle, diodes D1 and D3 conduct while D2 does not. The circuit can be redrawn as follows:	5

	 Total resistance = R (1 mark) Power delivered = 1/2(V^2/R) (0.5 marks) During the negative half cycle, diodes D1 and D3 do not conduct while D2 conducts. The circuit can be redrawn as follows:  Total resistance = 3R (1 mark) Power delivered = 1/2(V^2/3R) (0.5 marks) Total power delivered = 1/2(V^2/R) + 1/2(V^2/3R) = 2V^2/3R (1 mark)	
Q.201	I = 2 A this implies that the total resistance of the circuit is 10/2 = 5 Ω. This is possible when one of the diodes is forward-biased and the other is reverse-biased. (1 mark)  **Possible orientation 1**	2

	 **Possible orientation 2** (*1 mark to be allocated only if both diagrams are drawn*)	
Q.202	(a) Since the concentration of electrons increases on doping, it makes germanium an n-type semiconductor. Hence, Q is a pentavalent element. (1 mark) (b) Doped semiconductor is n-type. One electron is provided by 1 donor atom, Q. Concentration of Q atoms = 6×10^{22} m^{-3} Ratio of Q atoms and germanium in doped semiconductor = $(6 \times 10^{22})/(6 \times 10^{30})$ = $1 : 10^{8}$ (1 mark)	2
Q.203	The concentration of the holes never becomes equal in the p-region and n-region and hence diffusion current does not become zero. (1 mark) This is because as the holes diffuse into the n-region they recombine with the electrons. Hence, the decrease in the concentration of holes from the p-region to the n-region is maintained by the recombination of holes and electrons. (1 mark)	2
Q.204	We shall find the maximum value of R for which the diode operates at a voltage just above its cut-in voltage. Since the diode and resistor are connected in series we get $V = V_R + V_D$ $V_R = 2 – 0.7 = 1.3$ V (0.5 marks) At cut-in voltage the current through the diode is 1mA $\therefore R_{max} = V_R/I$ $R_{max} = 1.3/1 \times 10^{-3} = 1.3 \times 1000 = 1300\ \Omega$ (1 mark) Hence, at 1000 Ω the diode will operate above its cut-in voltage. (0.5 marks)	2
Q.205	(a) The potential drop across the 30 Ω resistor = $30 \times 10 \times 10^{-6}$ V = 300×10^{-6} = 0.0003 V (0.5 marks) Potential drop across the diode = 3 - 0.0003 = 2.9997 V (0.5 marks) (b) The diode is reverse-biased in the circuit (1 mark)	3

	 (1 mark for circuit diagram.)	
Q.206	Efficiency = P_{output} / P_{input} (0.5 marks) P_{output} = (70 × 10) /100 = 7 W For secondary coil P = VI (0.5 marks) V = 7/1.25 = 5.6 V (0.5 marks) V_{rms} = 5.6 V V_{peak} = 5.6 × √2 = 7.9 V (0.5 marks)	2
Q.207	The phone's battery will not get charged. (1 mark) The output of the secondary coil is ac. Thus the battery will charge during one half of the ac cycle and discharge during the next cycle. (1 mark)	2
Q.208	The full wave rectifier rectifies both the half cycles of the AC input. (0.5 marks) Hence, the frequency fed to the phone's battery is 100 Hz. (0.5 marks)	1
Q.209	(a) Intrinsic concentration = $n_i = 10^{10}\ cm^{-3}$ Since the doped atom is pentavalent, majority charge carriers are electrons. Concentration of electrons (majority charge carriers) n_e = doping concentration = $10^{15}\ cm^{-3}$ (0.5 marks) Concentration of holes (minority charge carriers) $n_h = n_i^2/n_e = 10^{20}/10^{15} = 10^5\ cm^{-3}$ (0.5 marks) (b) $\sigma = \mu n_e e$ (0.5 mark) Since the concentration of holes is much less than the concentration of electrons, conductivity can be calculated assuming only electron concentration. $\mu = 1200\ cm^2/Vs$ for the given doping concentration of $10^{15}\ cm^{-3}$. (0.5 mark) $\sigma = \mu n_e e$ $\sigma = 1200 \times 10^{15} \times 1.6 \times 10^{-19}$ $\sigma = 1920 \times 10^{-4}$ S/cm (1 mark)	3

Q.210	(a) Semiconductor [0.5 mark] The valence electrons will gain energy equal to or more than E_g and jump from the valence band onto the conduction band. [0.5 mark] With the rise in temperature of the semiconductor, the conductivity increases due to increase in the number of electrons N_e in the conduction band. From the expression, $v_d = 1/N_e eA$, as N_e increases, the drift speed v_d of the electrons decreases. [0.5 mark for the correct mention and reason of change in N_e and v_d] (b) Temperature coefficient of resistivity of material X is Negative. [0.5 mark for the correct answer] The effect of an increase in the number of charge carriers (electrons and holes) exceeds the effect of increased lattice thermal vibrations, hence the resistivity decreases with the rise in temperature of material X. [0.5 mark for the correct explanation] (c)  OR  [1 mark for the correct representation of energy and valence band and correct labels of E_c, E_v and E_g]	4
Q.211	a. For E = 3 V and R= 2 k-ohm, The pn diode is forward biased. [0.5 mark for the correct identification of the bias of the pn] $V_D = 0.7$ V [0.5 mark for the correct value of V_D] $V_R = 3 - 0.7 = 2.3$ V	4

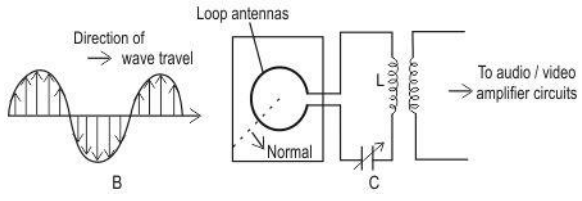
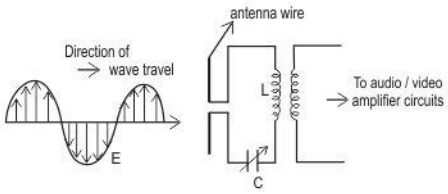
	[0.5 mark for the correct value of VR] $I_D = I_R = V_R/R = 2.3/2 \times 10^{-3} = 1.15$ mA [0.5 mark for the correct values of I_D and I_R] b. For E = 0.3 V and R= 2 k-ohm, The pn diode doesn't reach its threshold voltage value. [0.5 mark for the correct identification of the bias of the pn] So V_D = 0.3 V, so the pn diode is in open condition. It will not conduct. [0.5 mark for the correct value of V_D] $I_D = 0 = I_R$ [0.5 mark for the correct values of I_D and I_R] $V_R = 0$ [0.5 mark for the correct value of V_R] OR If the terminals of the applied E are reversed, at E = 3 V, the pn diode is in reverse bias. [0.5 mark for the correct identification of the bias of the pn] So $I_D = 0 = I_R$ [0.5 mark for the correct values of I_D and I_R] $V_R = 0$ [0.5 mark for the correct value of V_R] V_D = 3V (voltage across the pn diode can be non-zero in open circuit condition) [0.5 mark for the correct value of V_D]	
Q.212	In circuit I : V_{D1} = 0.3 V V_{D2} = 0.7 V So $V_o = 10 - V_{D1} - V_{D2} = 10 - 0.3 - 0.7 = 9$ V $I_D = V_o/R = 9/(4 \times 10^{-3}) = 2.25$ mA [0.5 mark for correct value of V_o and I_D] In circuit II: D_1 is forward biased whereas D_2 is reverse biased, this means that the overall circuit is open circuit. So $I_D = 0$ $V_o = 0$ [0.5 mark for correct value of V_o and I_D]	2

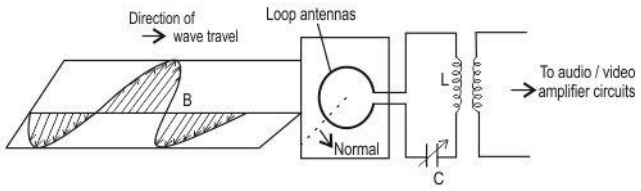
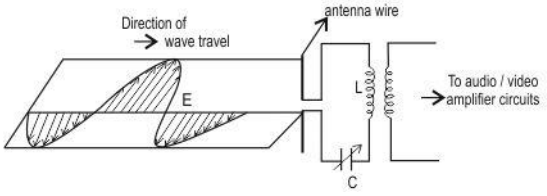
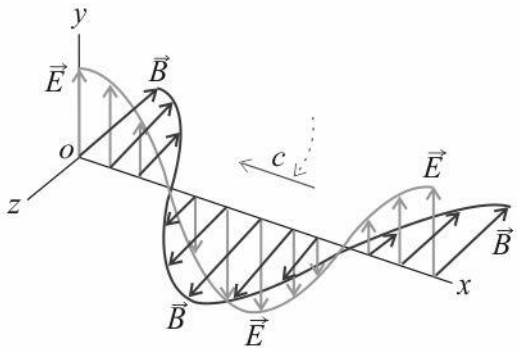
Q.213	a. Electric field = V/d V = E. d = 16 x 10^5 x 500 x 10^{-9} volt = 0.8 volt [0.5 mark for the correct value] b. i. if the junction is unbiased : KE required = eV = 0.8 eV ii. if the junction is forward biased at 0.5 V KE required = (0.8 – 0.5) eV = 0.3 eV iii. if the junction is reverse biased at 0.5 V KE required = (0.8 + 0.5) eV = 1.3 eV [0.5 mark for the correct value of each of the KE values]	2
Q.214	a. The given non-ideal diode causes a voltage drop of 0.2 V. So when a battery of 4.2 V and resistor of 1 k-ohm connected in series to the diode, the voltage drop across the resistor will be: 4.2 – 0.2 = 4 V Current through resistor & diode = I = 4/1000 = 0.004 = 4 mA. The diode does not burn out in this case. [1 mark for the correct calculation of current flowing through the diode] [0.5 mark for the correct conclusion] b. When a battery of 6.2 V and resistor of 0.6 k-ohm connected in series to the diode, the voltage drop across the resistor will be: 6.2 – 0.2 = 6 V Current through resistor & diode = I = 6/600 = 0.01 A = 10 mA. The diode will burn out in this case as the current exceeds the max. safe limit of 8 mA. [1 mark for the correct calculation of current flowing through the diode] [0.5 mark for the correct conclusion]	3
Q.215	a. Given is the drift current = 20 µA and forward biasing current of 4 x 20 = 80 µA In case of unbiased condition, Diffusion current = drift current = 20µA [0.5 mark for the correct value] b. In case of reverse biased, Diffusion current = 0 [0.5 mark for the correct value] c. In case of forward biased, Diffusion current – drift current = Biasing current Diffusion current – 20 = 80	2

	Diffusion current = 100 μA [1 mark for the correct value]	
Q.216	a. i. Forward biasing ii. Decreases. Holes are pushed through the pn junction in the direction opposite to the electric field across the barrier potential of the depletion region. [0.5 mark for each point] b. i. Reverse biasing ii. Increases. Holes are swept through the pn junction in the direction same as the electric field across the barrier potential of the depletion region. [0.5 mark for each point]	3
Q.217	(a) Step-up transformer. It is used to increase the output voltage across the secondary coil. (1 mark) (b) When the switch is in position 1, the capacitor gets charged and when the switch is in position 2, the capacitor gets discharged. (1 mark)	2
Q.218	(a) The diode is used for rectification. OR The diode is used to convert AC to DC. (1 mark) (b) For the device to work properly, the capacitor needs to be fully charged. If the diode is NOT included in the circuit, the capacitor will get continuously charged and discharged and will not be fully charged when needed. (1 mark)	2
Q.219	(a) C = 40 μF; V = 2500 V E = CV2/2 E = 40 x 10-6 x 2500 x 2500 / 2 E = 125 J (1 mark) (b) 60% of E = 125 x 60/100 = 75 J (0.5 marks) Power = E/t Power = 75/(3 x 10-3) = 25000 W (0.5 marks) (c) Power = 25000 W V = 2500 V I = P/V = 25000/2500 = 10 A (1 mark) (Please note this is a really high current which can be fatal in general. But in the case of a defibrillator, the current passes for an extremely small interval of time and can help save a person.)	4

	(d) R = V/I = 2500/10 = 250 ohm (1 mark)	
Q.220	C. C	1

14. Chapter: Electromagnetic Waves

Q.No	Question	Marks
	Multiple Choice Question	
Q.221	Two statements are given below. One is labelled Assertion (A) and the other is labelled Reason (R). Read the statements carefully and choose the option that correctly describes statements A and R. Assertion(A): An oscillating electric charge loses energy. Reason(R): An oscillating electric charge radiates em waves. A. Both assertion and reason are true and reason is the correct explanation for assertion. B. Both assertion and reason are true but reason is not the correct explanation for assertion. C. Assertion is true but the reason is false. D. Assertion is false but the reason is true.	1
Q.222	Radio and television reception involves a process wherein broadcasted waves reach receiving antennae and interact with the electric charges in the antenna. Depending upon the shape, the antenna either interacts with the oscillating electric field vectors or magnetic field vectors of the em wave. In either case, the electrons experience force (electric or magnetic), and are set into alternating motion, thereby inducing the time varying current that is transmitted through the antennae as the signals. Study the figures carefully. In each of the following figures, either E or B waves are omitted in the receiving wave for simplicity. Study the following orientations of the antennae (wire & the loop). I.  II. 	1

	III.  IV.  Select the orientations that result in the best reception of the incoming signals by the antennae. A. Only I and IV B. Only II and III C. Only II and IV D. Only I and III	
Q.223	The diagram below shows a single EM wave of wavelength λ. For different values of x given as x = 0, λ/4, λ/2, 3λ/4 and λ, which of the following statements are correct.  I. Energy density is maximum at x = 0, λ/2 and λ II. Magnitude of instantaneous intensity is minimum at x = λ/4, 3λ/4 III. Energy density and the magnitude of instantaneous intensity have minimum values at positions where E and B are both zero. A. Only I is true B. Only II is true C. Only III is true D. All statements I, II & III are true	1
Free Response Questions/Subjective Questions		
Q.224	A 2 mW laser beam is pointed on a 1 mm^2 area. (a) What is the intensity of the beam in W/m^2?	4

	(b) If a 1 nC static charge is intercepted by this beam, what is the maximum electric force that the charge experiences? (c) What is the maximum magnetic force that acts on this charge if it is set into a motion at 500 m/s? (d) Justify that the electric force exerted by the em wave on the static charge is $\sim 10^6$ times the magnetic force on the moving charge as in the part (c).	
Q.225	(a) Given the direction of electric and magnetic fields, how is the direction of an em wave determined? (b) Suggest a pair of varying Electric (E_x or E_y or E_z) and magnetic field (B_x or B_y or B_z) vectors that would generate a plane electromagnetic wave travelling along –z direction.	2
Q.226	Consider a radiation whose magnetic field component is given by $B = 10^{-3}\cos(4 \times 10^{10}\pi x + 12\pi \times 10^{18}t)$ Wb m^{-2}. What will be the mass of a particle whose momentum is the same as that of the photon of this radiation and whose speed is 1000 times smaller than that of the photon? ($h = 6.626 \times 10^{-34}$ J s)	3

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.221	A. Both assertion and reason are true and reason is the correct explanation for assertion.	1
Q.222	B. Only II and III	1
Q.223	D. All statements I, II & III are true	1
Q.224	(a) Intensity of the em beam I = Power/area = 2 x 10^{-3} / 10^{-6} = 2000 W/m^2 (1 mark for the correct value of the intensity]) (b) Intensity I of the em beam is also given as = ½ $c\in_o E_o^2$ (= ½ of electric field energy density x c) $E_0 = \sqrt{\frac{2I}{c\epsilon_0}} = \sqrt{\frac{2\times2000}{3\times10^8\times8.85\times10^{-12}}}$ E_0 = 1.22 x 10^3 N/C (0.5 mark for the correct value of E_0) Maximum force of the static charge, F = qE_o = 1 x 10^{-9} x 1.22 x 10^3 = 1.22 x 10^{-6} N (0.5 mark for the correct value of F) (c) Max. magnetic force of a moving charge, $F_B = qvB_o = qvE_o/c$ = 1 x 10^{-9} x 500 x 1.22 x 10^3 / 3 x 10^8 = 2 x 10^{-12} N (1 mark for the correct value of F_B) (d) Ratio F_E/F_B = 1.22 x 10^{-6} / 2 x 10^{-12} ~ 10^6 So the electric force exerted by the em wave on the static charge is ~ 10^6 times the magnetic force on the moving charge. (1 mark for the correct relation between F_E and F_B)	4
Q.225	(a) The direction of the em wave is given by the cross product of electric and magnetic vectors (E x B) (1 mark) (b) E_y and B_x would generate an em wave along –z direction. (1 mark)	2

Q.226	The momentum (p) of a photon is given by the equation: $p = E/c$ Where, E = energy of the photon c = speed of light The energy of a photon is related to its frequency (f) by the equation: $E = hf$ Where: E = energy, h = Planck's constant, f = frequency Thus, $p = hf/c$ The momentum of the particle is given by mv and as per the question we need $mv = hf/c$ $mc/1000 = hf/c$ $m = 1000hf/c^2$ Comparing the equation of B with $B = B_0 \cos(2\pi x/\lambda + 2\pi ft)$ We have, $f = 6 \times 10^{18}$ Hz $m = 1000 \times 6 \times 10^{18} \times h/(3 \times 10^8)^2$ $= 2/3 \times 10^5 \times 6.626 \times 10^{-34}$ $= 4.42 \times 10^{-29}$ kg [0.5 marks each for the formula of momentum of photon and that of energy of photon] [0.5 mark for finding frequency from the equation of B and 0.5 mark for writing an expression for the momentum of a particle] [1 mark for final answer]	3

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