Competency Based Practice Questions

Physics - XII

Co-created by
Board of School Education Haryana
and
Educational Initiatives

HOW TO USE THIS BOOKLET

Dear Teachers and Students,

The **Board of School Education Haryana** is pleased to present the **Competency-Based Practice Questions** booklet. This resource has been thoughtfully designed to help you deepen your understanding of key concepts and enhance your problem-solving skills. It includes **50 exemplar questions** carefully aligned with the curriculum to familiarize students with the format of **Competency-Based Questions**. These questions are intended to support targeted practice and develop the skills necessary to confidently approach a variety of question types in assessments.

Best Ways for Teachers to Utilise This Resource

1. Integrate into Classroom Teaching

- Use these questions to demonstrate how theoretical concepts translate into practical applications.
- Encourage group discussions to explore reasoning and understanding of concepts taught.

2. Scaffold Student Learning

- Start with simpler questions and guide students through the thought process.
- Gradually introduce more complex questions to build confidence and familiarity.

3. Incorporate into Assessments

- Use these questions in classroom quizzes or homework to help students adapt to the format.
- Provide feedback that emphasises reasoning over correctness, encouraging students to refine their understanding.

4. Focus on Skill Development

- Highlight how these questions nurture understanding, analysis and critical thinking.
- Use student responses to identify and address misconceptions effectively.

Best Ways for Students and Parents to Utilise This Resource

1. Focus on Conceptual Understanding

- Approach each question as a way to understand *why* and *how* a concept works, rather than simply finding the correct answer.

2. Practice Purposefully

- Don’t rush—break down the question, identify the concept it addresses, and plan your approach before solving it.

3. Use Feedback to Improve

- Treat mistakes as learning opportunities. Review incorrect answers to understand *what went wrong* and *how to improve*.
- Revisit similar questions to build confidence and mastery over the topic.

Best Ways for Parents to Utilise This Resource

1. Encourage Critical Thinking

- Spend time discussing questions and concepts, asking “Why?” and “How?”.

2. Create a Positive Environment

- Celebrate effort and curiosity, not just grades.
- Help your child view mistakes as opportunities to learn and grow.

3.Collaborate with Teachers

- Stay informed about competency-based assessments through school communications.
- Share observations and work with teachers to address any concerns or challenges.

Final Message

These practice questions are an excellent opportunity to strengthen your conceptual understanding and boost your confidence in solving competency-based questions. For students, each question builds skills that will help you tackle similar challenges with ease. For teachers, this is a chance to mentor students in developing their thinking and problem-solving skills.

Start today—every effort you invest will prepare you not only for exams but for a lifetime of meaningful learning and success. Let’s make this journey toward competency-based education a meaningful and successful one!

Board of School Education, Haryana

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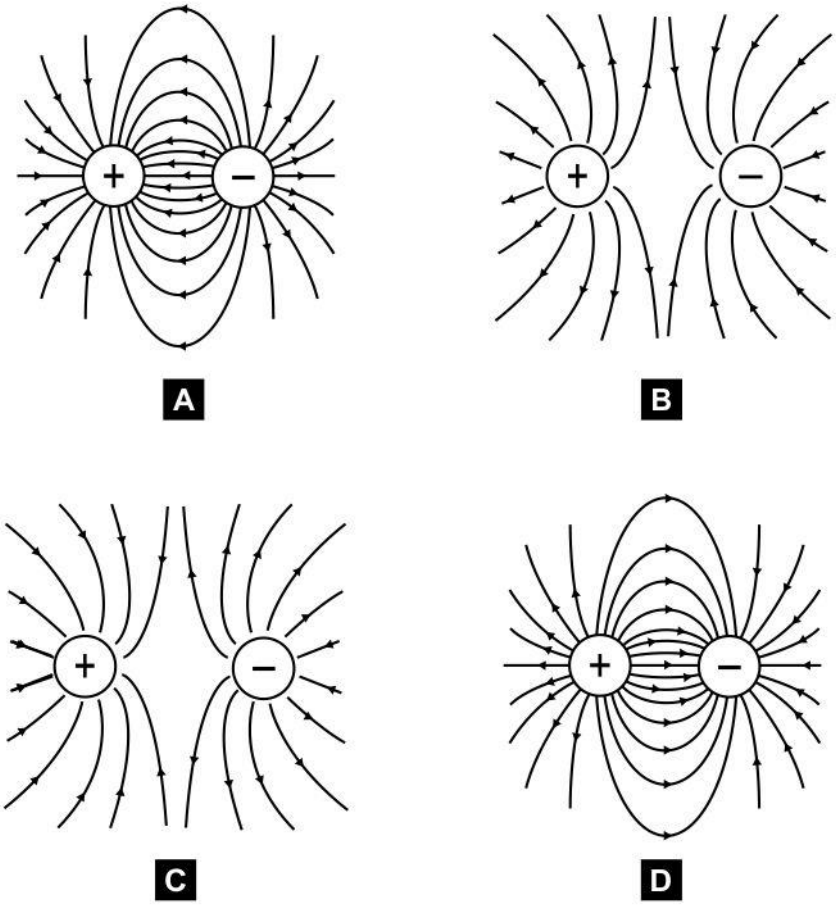
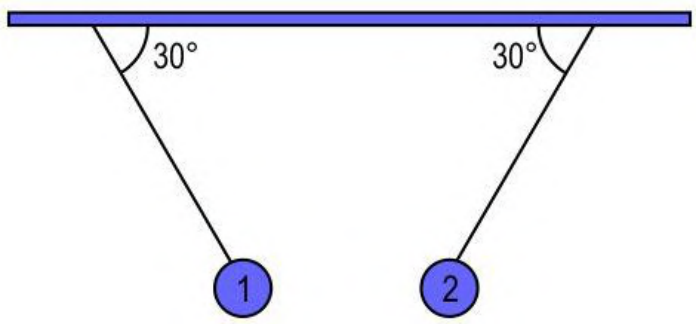
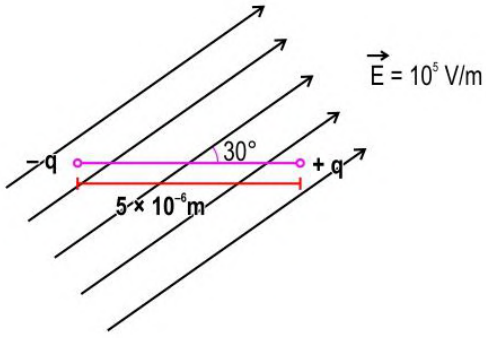
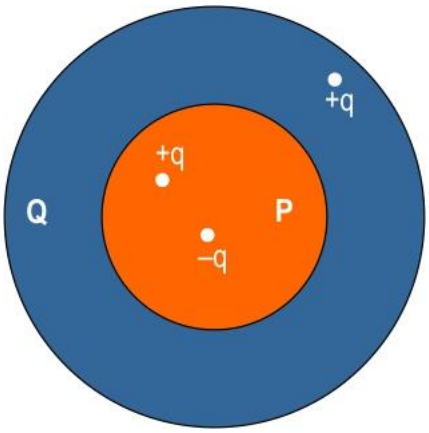
Electric Charges and Fields

Q.No	Question	Marks
1	Which of the diagrams correctly represent the electric field due to a pair of equal and opposite charges separated by a distance?  ***[Skill: Mechanical]***	1
2	Fill up the blank in the statement below: The number of electric field lines crossing an area A at a distance r from a positive charged particle is _____the electric field lines crossing an area A/4 at a distance r/2 from the charged particle. ***[Skill: Application]***	1

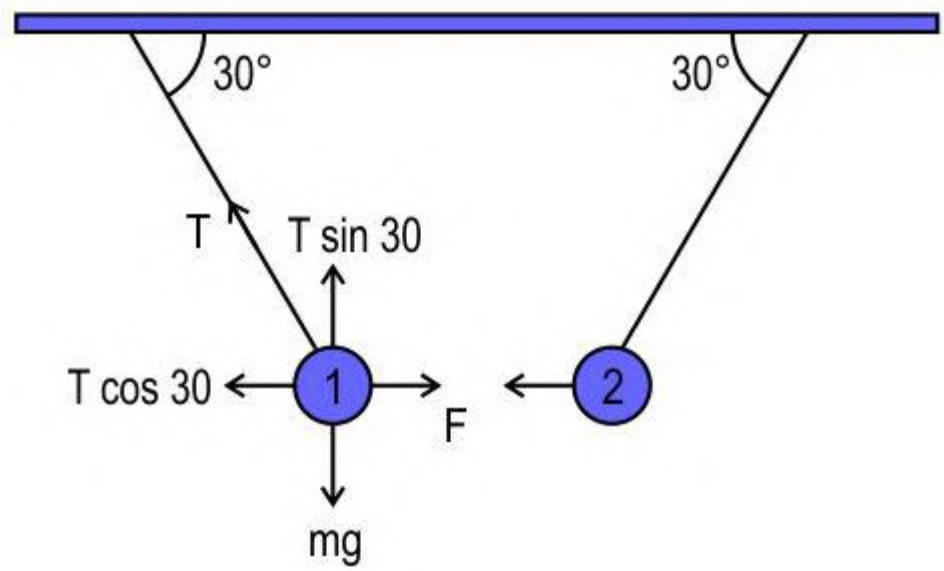
3	Two metallic spheres, each weighing 200 g, are suspended using identical, non-stretchable strings (P and Q). At rest, the spheres are positioned such that their centers align along the same horizontal axis, as depicted in the diagram below.  Sphere 1 carries a charge of +1μC while sphere 2 carries a charge of -1μC. Considering the spheres to be point charges, and drawing a relevant diagram answer the following questions. (a) What is the tension in the string attached to the sphere 1? (b) Calculate the coulomb force between the two spheres. *(Given: g = 10m/s^2 and k = 9 x 10^9 Nm^2/C^2)* ***[Skill: Understanding]***	2+1
4	(a) Radius of the 'K' shell of hydrogen atom is approximately 5.0 x 10^{-11}m. Charges on electron and proton are -1.6 x 10^{-19} C and 1.6 x 10^{-19}C, respectively. Calculate the magnitude of centripetal force acting on the electron in ground state. *(Take k = 9 x 10^{9}Nm^2/C^2)* (b) A dipole is placed in a region of space having a uniform electric field, as shown below, the distance of separation between the charges is 5 x 10^{-6} m. Calculate the torque acting on the electric dipole.  (c) Two concentric spheres, P and Q, enclose 3 charges as shown below.	1.5+1.5+ 2



If $|q| = 1\mu C$, what is the electric flux through sphere P and sphere Q? Show the necessary calculations. *(take* $\frac{1}{8.85} = 1.12 \times 10^{-1}$ *)*

[Skill: Application]

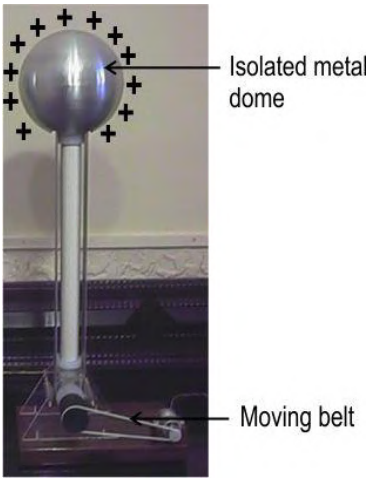
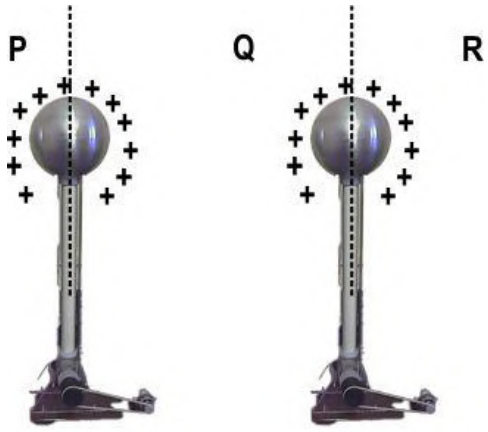
Marking Scheme

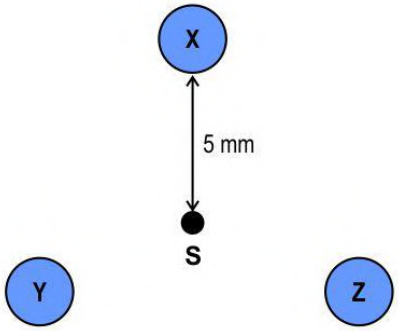
Q No.	Rubric	Marks
1	**Correct Answer:** D The electric field lines move from positive charge to negative charge. Thus, diagram D shows the correct representation of electric fields due to a dipole.	1
	A: The student does not have a correct understanding of electric field due to a dipole.	
	B: The student does not have a correct understanding of electric field due to a dipole.	
	C: The student does not have a correct understanding of electric field due to a dipole.	
2	the same as/equal to	1
3	(a)  *[1 mark for the diagram, depicting tension, force and weight]* From the diagram, Tsinθ = mg *[0.5 marks]* T = (0.2 × 10)/sin 30^o T = 2 × 2 = 4 N *[0.5 marks]*	2
	(b) From the diagram, the horizontal component of tension is balanced by the coloumb force acting between the sphere. Tcosθ= |F| *[0.5 marks]* F = $4\sqrt{3}/2$ = 3.46 N *[0.5 marks]*	1

4	(a) (i) The electrostatic force between the electron and proton acts as the centripetal force that keeps the electron in its circular orbit around the nucleus. *[0.5 marks]* The electrostatic force is given by F = $k\|q_1q_2\|/r^2$ *[0.5 marks]* r in this case will be equal to the radius of 'K' shell of the H-atom. Substituting all the values, we get $\frac{\left(9\times10^{9}\times1.6\times10^{-19}\times\left(-1.6\times10^{-19}\right)\right)}{\left(5\times10^{-11}\right)^{2}}$ F = 9.2 x 10^{-8} N *[0.5 marks]*	1.5
	(b) Torque = P x E where P is the dipole moment of the dipole and E is the external electric field. Magnitude of torque = $pEsin30^o$ *[0.5 marks]* = qd$Esin30^o$ *[0.5 marks]* = $(1.6 \times 10^{-19} \times 5 \times 10^{-6} \times 10^{5} \times 0.5)$ $\tau = 4 \times 10^{-20} N \cdot m$ *[0.5 marks]*	1.5
	(c) According to Gauss's law: $\varphi = \frac{q}{\epsilon_o}$ *[0.5 marks]* As net charge enclosed by sphere P is zero, so electric flux through sphere P is zero. *[0.5 marks]* Net charge enclosed by sphere Q is q. so electric flux = $\frac{10^{-6}}{8.85\times10^{-12}}$ *[0.5 marks]* =1.12 x 10^{-6} x 10^{11} = 1.12 x 10^{5} Nm^2C^{-1} *[0.5 marks]*	2

Electrostatic Potential and Capacitance

Q No.	Question	Marks
5	The question below consists of two statements, Assertion (A) and Reason (R). Assertion(A): Work done in moving a charged particle along the equipotential surface is zero. Reason(R): The electric field is always perpendicular to the equipotential surface at every point. Answer the question by selecting the appropriate option given below. (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. ***[Skill: Understanding]***	1
6	(a) Two identical parallel plate capacitors each with plate area A and separation d, are connected in series. A dielectric material with a dielectric constant k is inserted between the plates of both capacitors. Find the resultant capacitance of the circuit in terms of k, A, d, and ϵ_o. (b) If a DC battery of 12 V is connected across the capacitors, what will be the charge on the plates of the capacitor (in terms of k, A, d, and ϵ_o) when the capacitors are fully charged? ***[Skill: Understanding]***	1.5+0.5

7	(a) The Van de Graaff generator is a device designed to generate high voltage. It works by using a continuous moving belt to collect electrostatic charge from a source and transfer it to a large, isolated metal dome, where the charge accumulates.  Assuming that the metal dome is spherical, answer the following: (i) What will be the shape of equipotential surface due to the metal dome? (ii) Two Van de Graaff generators are kept 100 cm apart. In which region—P, Q, or R—can the net electric potential due to both the generators be zero? Give reason.  (b) Three point charges, X, Y, and Z, have charges of magnitude $2\mu C, 0.5\mu C$, and $-1\mu C$, respectively. The three charges are kept at an equal distance from point 'S' in an arrangement as shown below. *(Given k = 9 x 10^9 Nm^2 C^{-2})*	3+2



Calculate the net potential due to all three charges at point S.

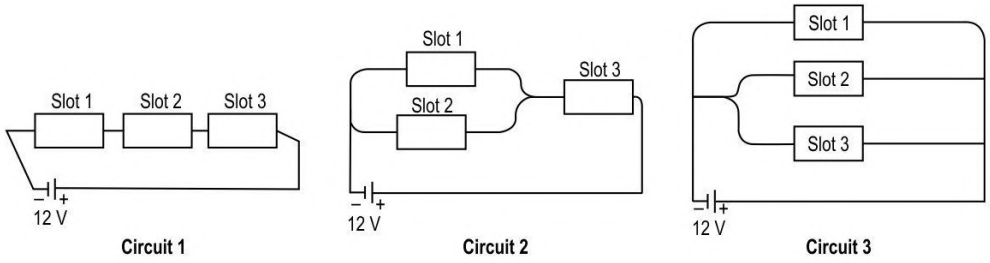
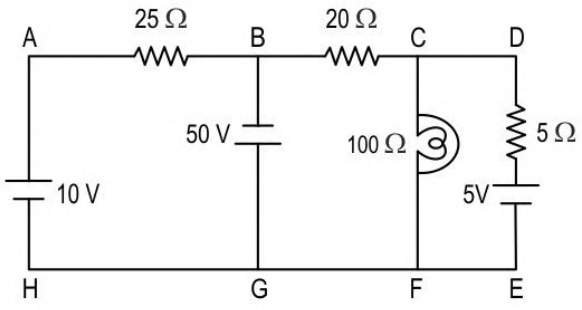
[Skill: Application]

Marking Scheme

Q No.	Rubric	Marks
5	**Correct Answer:** A Both the statements are true. Work done in moving a charged particle along the equipotential surface is zero because electric field is always perpendicular to the equipotential surface and the force due to electric field along the tangent to the surface is zero. So, reason is a correct explanation of the assertion.	1
	B: Students choosing this may lack understanding of work done along equipotential surfaces.	
	C: Students choosing this may lack understanding of work done along equipotential surfaces.	
	D: Students choosing this may lack understanding of work done along equipotential surfaces.	
6	(a) The capacitance of each capacitor is given by: $C_1 = C_2 = kA\epsilon_o / d$ *[0.5 marks]* for series combination, net capacitance is $\frac{1}{C_{net}} = \frac{1}{C_1} + \frac{1}{C_2}$ *[0.5 marks]* $\frac{1}{C_{net}} = \frac{d}{k\epsilon_o A} + \frac{d}{k\epsilon_o A}$ $C_{net} = \frac{k\epsilon_o A}{2d}$ *[0.5 marks]*	1.5
	(b) $Q = C_{net}V = \frac{6 \cdot k\epsilon_o A}{d}$ *[0.5 marks]*	0.5
7	(a) (i) Concentric spheres with center same as that of the metal dome. *[1 mark]* (ii) As the electric potential at any point is a scalar quantity and both the Van de Graaff generators have identical charge, potential due to two like charges will never cancel out. *[1 mark]* So, the potential will not be zero for any of the regions. *[1 mark]* *[Accept any other valid reason.]*	3
	(b) The net electric potential at point S is: Potential at any point is given as V = k Q/r *[0.5 marks]* $V_{net} = \frac{(kQ_X)}{r} + \frac{(kQ_Y)}{r} - \frac{(kQ_Z)}{r}$ *[0.5 marks]*	2

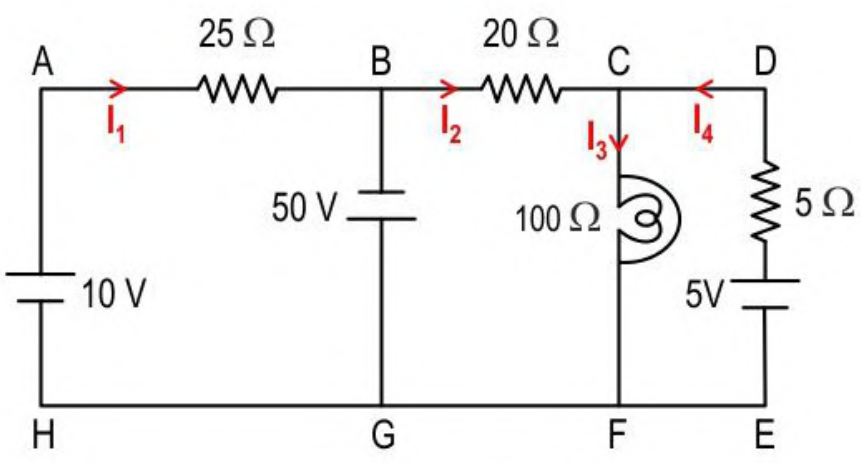
	$V_{net} = \frac{(9\times10^{9})}{5\times10^{-3}}\left(2\times10^{-6}+0.5\times10^{-6}-1\times10^{-6}\right)$ *[0.5 marks]* $V_{net} = 2.7 \times 10^{6}$ V *[0.5 marks]*	

Current Electricity

Q No.	Question	Marks
8	Fill up the blanks in the statement given below. For low temperatures, the temperature versus resistivity graph for metals is _____. ***[Skill: Mechanical]***	1
	Answer questions 9-10 based on the information given below. In a physics laboratory session, students are provided with three plug-and-play circuits (shown below). Each circuit has slots where one electrical component can be inserted or removed. The students have resistors with the following resistances available: R_X=1 Ω, R_Y=2 Ω, and R_Z=3 Ω. 	
9	Identify the circuit(s) in which (a) changing the position of the resistors does not affect the total current flowing through the circuit. (b) the current flowing is maximum. Give reason. *(No mathematical calculations needed.)* ***[Skill: Application]***	1+1
10	For circuit 2, calculate the value of lowest possible current. Show the mathematical calculations involved. ***[Skill: Application]***	3
11	In a circuit, 3 batteries, 3 resistors and a bulb of resistance 100Ω, are connected as shown below.  Calculate: (a) the current and voltage drop through 25Ω resistor.	2+3

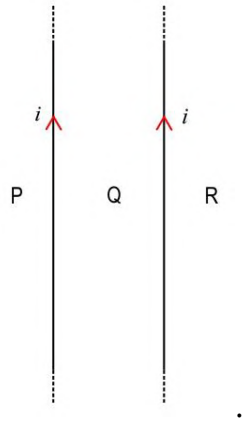
	(b) the power dissipated by the bulb. ***[Skill: Understanding]***	

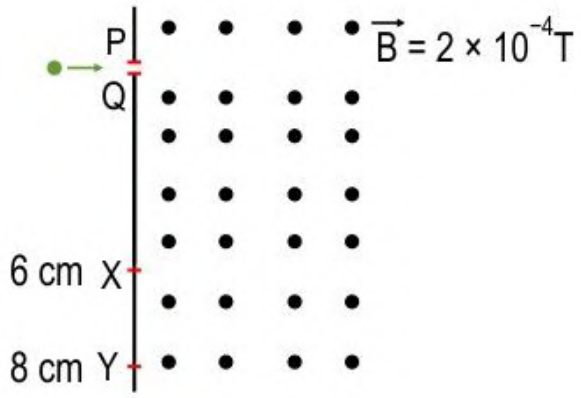
Marking Scheme

Q No.	Rubric	Marks
8	straight line/linear	1
9	(a) Circuit 1 and circuit 3 *[0.5 marks for each correct answer]*	1
	(b) in circuit 3 *[0.5 marks]* The net resistance is least when the resistances are connected in parallel, so current flowing will be maximum. *[0.5 marks]*	1
10	To have the least current flowing in the circuit, we should maximize the resistance of the circuit. *[0.5 marks]* This is possible if we have R_X and R_Y in parallel and this combination in series with R_Z. $\frac{1}{R} = \frac{1}{R_X} + \frac{1}{R_Y}$ *[0.5 marks]* On solving R = 0.67 Ω *[0.5 marks]* when this is in series with R_Z we get the greatest total resistance = 3.67 Ω *[0.5 marks]* Given that V=12 V, The resulting current is I = V/R *[0.5 marks]* = 3.2 A *[0.5 marks]*	3
11	(a) Drawing the circuit to indicate the the currents, we get:  *[0.5 marks for the circuit]* Considering the loop ABGHA and applying Kirrchoff's voltage rule we get:	2

	10 - 25I_1 + 50 = 0 *[0.5 marks]* I_1= 12/5 = 2.4 A *[0.5 marks]* Voltage drop = 2.4 x 25 = 60 V *[0.5 marks]* *[Accept any other method of arriving at the correct answer.]*	
	(b) Considering the loop BCFGB and applying Kirrchoff's voltage rule we get: -20I_2 -100I_3- 50=0 *[0.5 marks]* Considering the loop CDEFC and applying Kirrchoff's voltage rule we get: 5 - 5I_4- 100I_3= 0 *[0.5 marks]* According to Kirrchoff's law, $I_3 = I_2 + I_4$ $I_4 = I_3 - I_2$ substituting I_4 and solving the equations for I_2 and I_3 we get I_3 = -3/52 A *[1 mark]* Power dissipated by the bulb is P=IV= I^2 R *[0.5 marks]* P = $(3/52)^2$ (100) = 0.33 W *[0.5 marks]* *[Accept any other method of arriving at the correct answer.]*	3

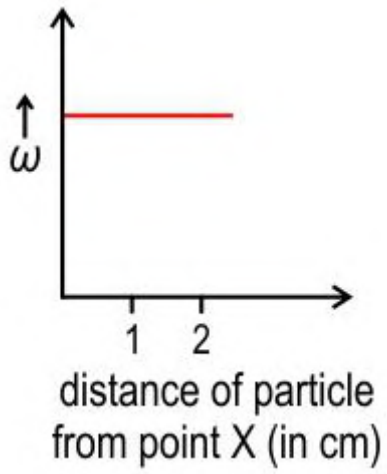
Moving Charges and Magnetism

Q No.	Question	Marks
12	Two infinitely long wires carrying current are positioned as shown below.  If the magnitude of current in both wires is the same, in which region: P, Q, or R is it possible to obtain a point where total magnetic field intensity is zero? (A) only region P (B) only region Q (C) both regions P and R (D) (*The magnetic field will never be zero.*) ***[Skill: Understanding]***	1
13	Two charged particle, P and Q , moving with constant velocities, v_P and v_Q, enter a uniform magnetic field applied perpendicular to the plane of motion of the particles. The particle P is moves in a circular path while particle Q moves in a helical path within the uniform magnetic field. (a) Will the angle between the velocity and the force acting on particles P (say θ_P), and Q (say θ_Q) be the same? Justify your answer. (b) What does the difference in their paths tell about their initial velocity directions right before entering the magnetic field? Explain. ***[Skill: Understanding]***	1+1

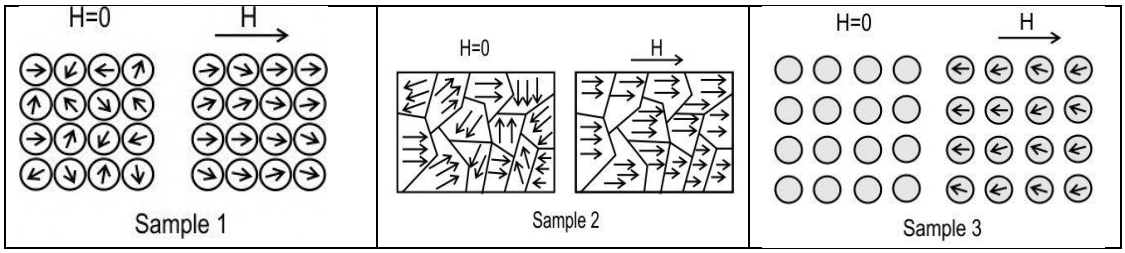
14	A beam of particles having a range of velocities are projected normally through the slit PQ into a uniform magnetic field $B = 2 \times 10^{-4} T$. The mass and charge of the particles are $2 \times 10^{-26} kg$ and $1.6 \times 10^{-19} C$, respectively. A particle detector can detect particles from point X to point Y as shown in the image below.  The distances of point X and Y from point Q are 6 cm and 8 cm, respectively. (a) For what range of velocity will the particle detector be able to detect the particle? (b) Calculate the minimum change in the magnetic field required to detect a particle of velocity 70 m/s. (c) Plot the variation in angular frequency of the particles versus distance at which the particle is detected from point X. ***[Skill: Application]***	2+1.5 +1.5

Marking Scheme

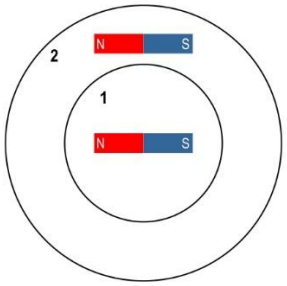
Q No.	Rubric	Marks
12	**Correct Answer:** B The magnetic fields due to current carrying wires are acting in opposite directions in region Q. So, the magnetic field will be zero at midpoint between the two wires.	1
	A: Students choosing this option may not understand the direction of magnetic field due to current carrying wire.	
	C: Students choosing this option may not understand the direction of magnetic field due to current carrying wire.	
	D: Students choosing this option may not understand the direction of magnetic field due to current carrying wire.	
13	(a) Yes, because the Lorentz force acting on a particle moving in a magnetic field is given by $\vec{F}$= q($\vec{v} \times \vec{B}$), where **v** and **B** are the velocity vector and the magnetic field vector, respectively. The resultant of the cross product will always lie in the direction perpendicular to both velocity and magnetic field. So, the angle between force and resultant velocity will be 90° for both the particles. *[1 mark]* *[Accept any other valid answer.]*	1
	(b) Particle P moves in a circular path, indicating that its initial velocity vector is perpendicular to the magnetic field. *[0.5 marks]* Particle Q moves in a helical path, indicating that its initial velocity vector is at an angle θ with the magnetic field and $\theta \neq 90^o$. *[0.5 marks]*	1
14	(a) We know that, radius a charged particle moving in a uniform magnetic field is given by: $r = \frac{mv}{qB}$ Rearranging the terms: $v = \frac{rqB}{m}$ *[0.5 marks]* substituting the value of q, B, and m, we get $v = \frac{\left(r \times 1.6 \times 10^{-19} \times 2 \times 10^{-4}\right)}{2 \times 10^{-26}}$ $v = 1.6 \times 10^3 \times r$ minimum velocity for which the particle can be detected will be for r = 3 cm. i.e, when the particle is detected at point X. $v_{min} = 48$ m/s *[0.5 marks]* Maximum velocity for which the particle can be detected will be for r = 4 cm. i.e, when the particle is detected at point Y. $v_{max=64}$ m/s *[0.5 marks]*	2

	So, the range of velocity should be, $48 \leq v \leq 64$ m/s. *[0.5 marks]*	
	(b) $B = \frac{mv}{qr}$ *[0.5 marks]* The change in magnetic field will be minimum when the particle is detected at point Y, i.e, r = 4 cm $B = \frac{\left(2\times10^{-26}\times70\right)}{1.6\times10^{-19}\times4\times10^{-2}}$ $B = 2.19 \times 10^{-4}T$ *[0.5 marks]* Change in magnetic field=$\left(2.19 \times 10^{-4}\right) - \left(2 \times 10^{-4}\right) = 1.9 \times 10^{-5}T$ *[0.5 marks]*	1.5
	(c) $\omega = \frac{qB}{m}$ *[0.5 marks]* The angular frequency is independent of radius of circular path covered by the particle.  *[1 mark for correct graph]*	1.5

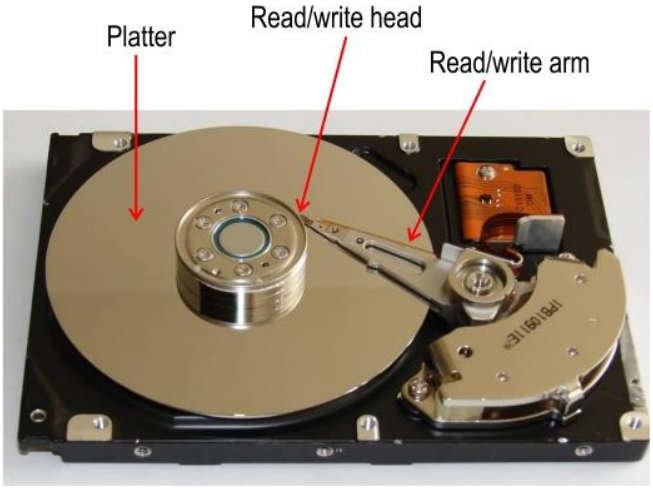
Magnetism and Matter

<table>
<tr><th>Q.No.</th><th>Question</th><th>Marks</th></tr>
<tr><td>15</td><td>The domain orientations for three different material samples, both before and after the application of an external magnetic field, are provided below.
 

Which of the following options correctly identifies the substances?
<table>
<tr><th>Option</th><th>Sample 1</th><th>Sample 2</th><th>Sample 3</th></tr>
<tr><td>A</td><td>Diamagnetic</td><td>Ferromagnetic</td><td>Paramagnetic</td></tr>
<tr><td>B</td><td>Paramagnetic</td><td>Ferromagnetic</td><td>Diamagnetic</td></tr>
<tr><td>C</td><td>Ferromagnetic</td><td>Paramagnetic</td><td>Diamagnetic</td></tr>
<tr><td>D</td><td>Ferromagnetic</td><td>Diamagnetic</td><td>Paramagnetic</td></tr>
</table>

[Skill: Application]</td><td>1</td></tr>
<tr><td>16</td><td>Two spheres are enclosing two bar magnets as shown below.
 

What is the magnetic flux through the sphere 2? Justify your answer.
[Skill: Understanding]</td><td>1</td></tr>
</table>

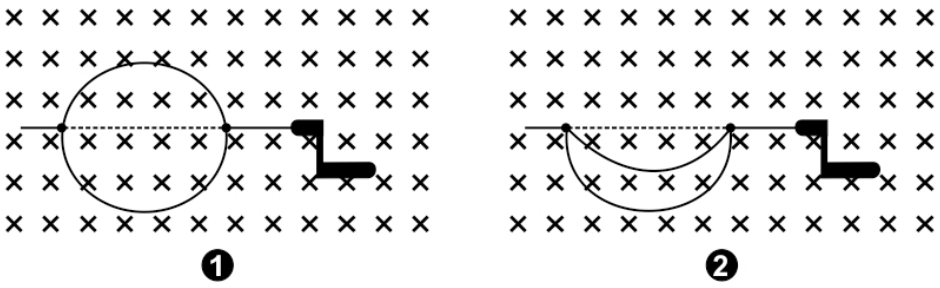
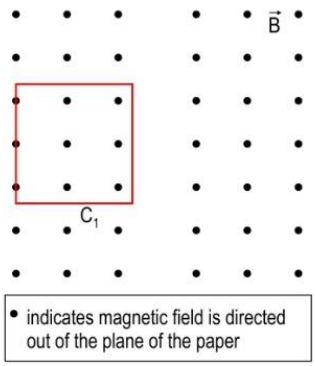
17	A Hard Disk Drive (HDD) is a data storage device that uses a rapidly spinning rigid disk coated with a magnetic material. This material can be magnetised by an external magnetic field and retains the magnetisation even after the field is removed, enabling the storage of digital information. In modern HDDs, data is written to and read from the disk using a read/write head. This head is supported by a thin layer of air, known as a gas bearing, as the disk spins beneath it.  The read/write head is a solenoid, through which current can be passed through in two directions to generate magnetic field in two direction, opposite to each other. *(Assume $\mu_0 = 4\pi \times 10^{-7}$ H/m)* (a) What type of magnetic material is most likely to be used to coat the magnetic disc? Justify your answer. (b) Can the read/write head read when the disc and the head are stationary? Justify your answer. (c) If the number of windings per meter length of the solenoid in read/write head is 50 and the current flowing through the wire is 0.1 A, (i) Calculate the magnetic field inside the solenoid. (ii) If a material kept inside the solenoid, increases the magnetic field inside it, what can be said about the magnetic susceptibility of the material? (iii) Derive the formula for total magnetic field inside the core in terms of magnetic susceptibility of the material. ***[Skill: Application]***	1+1+3

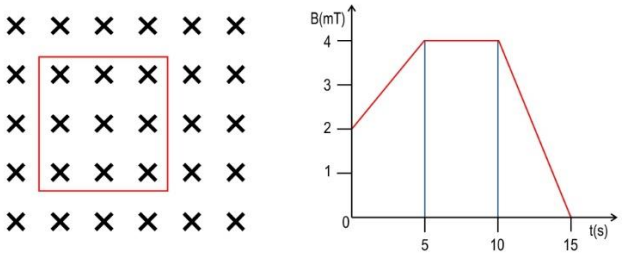
Marking Scheme

Q No.	Rubric	Marks
15	**Correct Answer:** B In sample 1,the randomly oriented magnetic dipoles align themselves in the direction of the external field. Hence, the sample is paramagnetic material. In sample 2, the magnetic domains oriented randomly, align themselves in the direction of external field. Hence the sample is ferromagnetic. In sample 3, the induced dipoles align themselves opposite to the external field. Hence, the sample is diamagnetic.	1
	A: Students choosing this option may have inadequate understanding of paramagnetic, ferromagnetic and diamagnetic materials.	
	C: Students choosing this option may have inadequate understanding of paramagnetic, ferromagnetic and diamagnetic materials.	
	D: Students choosing this option may have inadequate understanding of paramagnetic, ferromagnetic and diamagnetic materials.	
16	The magnetic flux through sphere 2 is zero. *[0.5 marks]* Gauss' law states that magnetic flux through any closed curve is zero. *[0.5 marks]*	1
17	(a) The material is most likely a ferromagnetic material because it can be magnetised easily with the help of an external magnetic field and holds the magnetisation even if the magnetic field is removed. *[1 mark]* *[Accept any other valid reason.]*	1
	(b) No, because the read/write head reads using the phenomenon of induced current due to changing magnetic flux. If both the head and the disc are stationary, the change in flux will be zero. *[1 mark]* *[Accept any other valid reason.]*	1
	(c) (i) B=$\mu_0 ni$ *[0.5 marks]* $B = 4\pi \times 10^{-7} \times 50 \times 0.1$ $B = 6.2 \times 10^{-6} T$ *[0.5 marks]* (ii) The magnetic susceptibility of the material is more than zero, or a positive number. *[0.5 marks]* (iii) Let the M be the magnetization of the material, χ_m be the magnetic susceptibility and B be the magnetic field due to current carrying solenoid. $H = \frac{B}{\mu_o}$	3

Q No.	Rubric	Marks
	$M = \chi_m \cdot H$ *[0.5 marks]* Total magnetic field inside the solenoid will be $B_T = \mu_o (H + M)$ $B_T = \mu_o (1 + \chi_m) H$ *[0.5 marks]* $B_T = (1 + \chi_m) B$ $B_T = (1 + \chi_m) \cdot 6.2 \times 10^{-6} T$ *[0.5 marks]*	

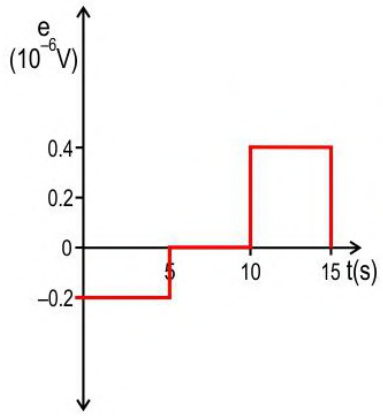
Electromagnetic Induction

Q No.	Question	Marks
18	A 0.5 A current is passed through a solenoid with a length of 10 mm, 50 turns, and a cross-sectional area of 314 cm². What is the energy required to build up the current in the solenoid? *(Use $\mu_o = 4\pi \times 10^{-7} H/m$)* (A) 1.23×10^{1} J (B) 1.23×10^{-3} J (C) 1.23×10^{-4} J (D) (*Energy cannot be calculated because inductance is not given*.) ***[Skill: Mechanical]***	1
19	A conducting loop is kept in a uniform magnetic field $B = 5 \times 10^{-4} T$ as shown below. The upper part of the loop is rotated clockwise so that the configuration of the loop changes.  If area of loop in configuration 1 is 0.4 m^2 and in configuration 2 is 0.1m^2 and the times taken to rotate the upper part is 5 sec, calculate the EMF induced in the loop. ***[Skill: Application]***	2
20	A coil C_1 is placed in a constantly varying magnetic field as shown below.  Giving reason, state the direction of current induced in the coil when: (i) magnetic field increases? (ii) magnetic field decreases? ***[Skill: Understanding]***	2

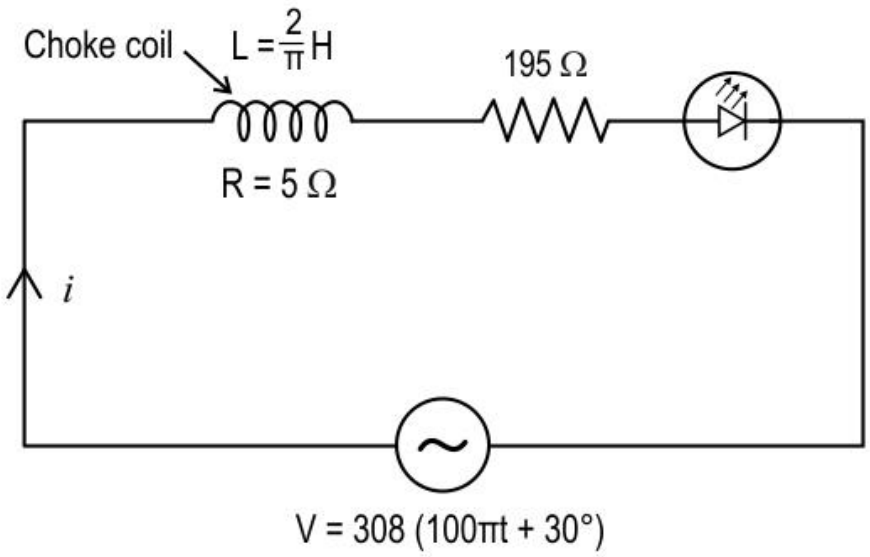
21	A square loop of conducting wire is placed in a time-varying magnetic field such that the plane of the loop is perpendicular to the magnetic field. The graph below represents the variation of the magnetic field with time.  (a) In which time interval(s) will the current induced in the coil be in the anti-clockwise direction? Give reason. (b) Calculate the induced emf in the coil for the parts in the graph labelled as I(t = 0s to t = 5s), II(t = 5s to t =10s) and III (t= 10 s 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. ***[Skill: Understanding]***	1+2+2

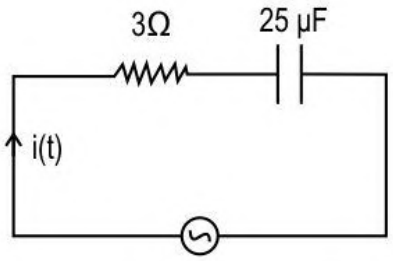
Marking Scheme

Q No.	Rubric	Marks
18	**Correct Answer:** B $U=(LI^2)/2$ $L= \mu_o N^2 A/L$ $U=(4\pi\times10^{-7}\times (50)^2\times314\times10^{-4}\times (0.5)^2) /(2 \times10^{-2})= 1.23\times10^{-3}$ J	1
	A: Students choosing this option may have used wrong formula.	
	C: Students choosing this option may not have converted length into m.	
	D: Students choosing this option may have inadequate understanding of energy stored in an inductor.	
19	$d\phi = B\,(A_2 - A_1)$ *[0.5 marks]* $d\phi = -5 \times 10^{-4} \times 0.3 = -1.5 \times 10^{-4} Wb$ *[0.5 marks]* $\epsilon = -\frac{d\phi}{dt}$ *[0.5 marks]* $\epsilon = 3 \times 10^{-5} V$ *[0.5 marks]*	2
20	(i) Direction of induced current in C_1 will be clockwise. (ii) Direction of induced current in C_1 will be anti-clockwise. *[0.5 marks for each correct answer]* According to Lenz's law, the direction of induced current will always oppose the change in the magnetic field. *[1 mark]*	2
21	(a) For the induced current to be anti-clockwise, the magnetic flux associated with the loop should increase, in accordance with Lenz's law. *[0.5 marks]* The flux associated with the coil increases when the magnetic field associated with the coil increases as $\varphi = B.A$ Hence, in the time interval t=0s to t=5s, the induced current will be anti-clockwise. *[0.5 marks]*	1
	(b) $e = -d\varphi/dt$ *[0.5 marks]* For t = 0s to t = 5 s $d\varphi = dB.A = (4-2) \times 10^{-3} \times 5 \times 10^{-4}$ $d\varphi = 1 \times 10^{-6}$ Wb $e = -\frac{10^{-6}}{5} = -0.2 \times 10^{-6}$ 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]*	2

	Induced emf from t = 10s to t = 15 s $d\varphi = (0 - 4) \times 10^{-3} \times 5 \times 10^{-4}$ $d\varphi = -2 \times 10^{-6} Wb$ $e = -d\varphi/dt$ $e = \frac{(2 \times 10^{-6})}{5} = 4 \times 10^{-7} V$ *[0.5 marks]*	
	(c)  *[1 mark for correctly labelled axis and 1 mark for the correct representation .]*	2

Alternating Current

Q No.	Question	Marks
	Answer questions 22-23 based on the information given below. In most parts of India, the V_{rms} and frequency of household electric supply are 220V and 50 Hz, respectively. However, some devices are unable to operate at such high voltages. To reduce the voltage supplied to these devices, using a large resistor in series is avoided as it would lead to significant power wastage. Instead, we use a choke coil. The circuit shown below demonstrates the use of a choke coil (inductor) connected to a voltage source described by V = 308(100πt + 30^o), where 308 represents the peak voltage. 	
22	Given that the inductance of the inductor is $\frac{2}{\pi}$ H and the resistance offered by the material of the inductor is 5Ω. (a) Calculate the inductive reactance of the inductor and impedance of the circuit. (b) If the inductor is replaced with a resistor having the same resistance as the inductive reactance, calculate the power consumption of the circuit. ***[Skill: Application]***	1+1
23	(a) Calculate the power consumption in the original circuit. (b) In part (a), suggest a method to reduce the power consumption of the circuit without changing the current flowing through it. *(Take* $\frac{1}{\sqrt{2}} = 0.71$*)* ***[Skill: Application]***	2+1

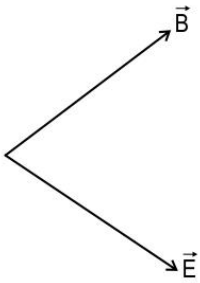
24	In the circuit given below a resistor of resistance 3 Ω and a capacitor of capacitance 25 μF are connected in series. The current flowing through the circuit at time 't' is given by $i(t)=2\sin(10^4 t)$.  (a) Calculate the voltage drop across the resistor and the capacitor at time 't'. Show the mathematical steps. (b) Calculate the phase difference between current and voltage supplied by the source, and the expression for voltage supplied by the AC source at a given time 't'. *(Assume* $\tan^{-1}\left(\frac{4}{3}\right) = 53^\circ$ *)* ***[Skill: Understanding]***	2.5+ 2.5

Marking Scheme

Q No.	Rubric	Marks
22	(a) $X_L = \omega L = 100\pi \times \frac{2}{\pi} = 200\Omega$ *[0.5 marks]* $Z=\sqrt{X_L^2 + R^2}=\sqrt{200^2 + 200^2} = 200\sqrt{2}\Omega$ *[0.5 marks]*	1
	(b) Total resistance of circuit = 200 + 195 = 395Ω $P = V_{rms} . I_{rms}$ *[0.5 marks]* = 220 x 0.557 = 122.54 W *[0.5 marks]* *[Accept any other valid method.]*	1
23	(a) $V_{rms} = \frac{V_o}{\sqrt{2}} = 308/1.4 = 220V$ *[0.5 marks]* $I_{rms} = V_{rms}/Z = \frac{220}{200\sqrt{2}} = 0.78A$ $\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$ $\phi = \tan^{-1}\left(\frac{200}{200}\right) = 45^\circ$ *[0.5 marks]* Power consumption $= V_{rms}.I_{rms}\cos(\phi)$ *[0.5 marks]* $P = 220 \times 0.71 \times \frac{1}{\sqrt{2}} = 110.3$ watt *[0.5 marks]*	2
	(b) To decrease the power consumption, the power factor should decrease, keeping the impedance of the circuit, the same. This can be achieved by increasing the inductive reactance of the inductor and decreasing the resistance of the resistor. *[1 mark]*	1

24	(a) From the given equation $\boldsymbol{\omega} = 10^4$ Inductive reactance= $X_c = \frac{1}{\omega C} = \frac{1}{10^4 \cdot 25 \cdot 10^{-6}} = 4\Omega$ *[0.5 marks]* Peak voltage across resistor $(V_0)_R = i_o \times R = 2 \times 3 = 6V$ *[0.5 marks]* Peak voltage across capacitor $(V_O)_C = i_o \times X_C = 2 \times 4 = 8V$ *[0.5 marks]* For resistor, voltage and current are in same phase. So, $V_R(t) = 6\sin(10^4 \cdot t)$ *[0.5 marks]* For capacitor, voltage lags behind current by π/2. So, $V_c(t) = 8\sin\left(10^4 \cdot t - \frac{\pi}{2}\right)$ *[0.5 marks]* *[Accept any other valid method of arriving the answer.]*	2.5
	(b) $Z = \sqrt{\{4^2 + 3^2\}} = 5\ \Omega$ *[0.5 marks]* phase difference $\phi = \tan^{-1}\left(\frac{X_c}{R}\right)$ $\phi = \tan^{-1}\left(\frac{4}{3}\right) = 53^\circ$ *[0.5 marks]* peak voltage: $V_o = i_o Z$ =2 x 5=10V *[0.5 marks]* for capacitive circuit, voltage lags behind the current by φ so, $V(t) = V_o \sin(\omega t - \phi)$ *[0.5 marks]* $V(t) = 10\sin(10^4 \cdot t - 53^\circ)$ *[0.5 marks]* *[Accept any other valid method of arriving the answer.]*	2.5

Electromagnetic Waves

Q No.	Question	Marks
25	The directions of electric and magnetic field associated with an electromagnetic wave are given below.  What is the direction of propagation of the given electromagnetic wave? (A) going into the plane of the paper (B) emerging out of the plane of the paper (C) along the direction of the resultant of electric and magnetic field vectors (D) opposite to the direction of the resultant of the electric and magnetic field vectors ***[Skill: Understanding]***	1
26	A parallel plate capacitor has an area A and a distance between the plates d. If the rate of accumulation of charge is 15μC/s, calculate the displacement current through the capacitor. ***[Skill: Understanding]***	1
27	In a plane electromagnetic wave, the magnetic field is oscillating sinusoidally. The expression for magnetic field at time (t) is given by $B(t) = 10^{-4} \sin\left(\omega t - \frac{\pi}{2}\right)$ (a) What is the peak value of electric field associated with the electromagnetic wave? (b) What is the phase difference between electric and magnetic field associated with the EM wave? (c) Write the expression for electric field at any given time 't'? ***[Skill: Mechanical]***	1+0.5 +0.5

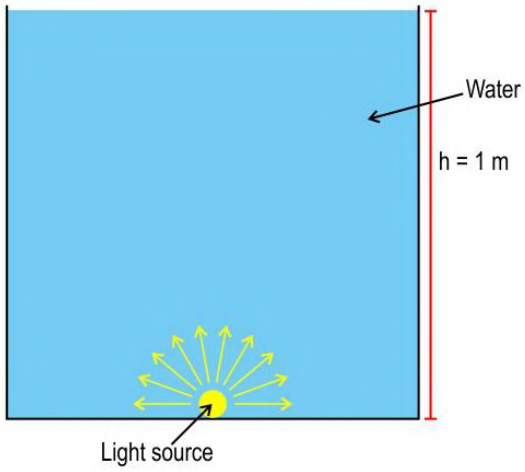
28	The Giant Metrewave Radio Telescope (GMRT) is India's largest radio telescope. It consists of 30 parabolic dishes, each with a diameter of 45 meters, spread over an area of 25 km². It is one of the most sensitive radio telescope arrays in the world at low frequencies.  Consider that the radio telescope receives a radio signal of normally incident waves with an intensity of 2×10^{-15} W/m². (a) Calculate the average power incident on each of the dishes. (b) If the wavelength of the incident waves is 1 m, calculate the number of photons falling on each dish per minute. *(Given that* $\frac{1}{hc} = 5.05 \times 10^{24} J^{-1} m^{-1}$ *)* (c) Assume that the body of the dish is reflective, at what point will the intensity of radio waves be the maximum? Calculate the distance of that point from the center of the dish. ***[Skill: Application]***	1+2+2

Marking Scheme

Q No.	Rubric	Marks
25	**Correct Answer:** B The direction of propagation of the EM wave is perpendicular to both electric and magnetic field, and is given by $\vec{E} \times \vec{B}$.	1
	A: The students choosing this option may think take the direction of EM wave as $\vec{B} \times \vec{E}$ instead of $\vec{E} \times \vec{B}$.	
	C: The students choosing this option may have inadequate knowledge of direction of propagation of EMW.	
	D: The students choosing this option may have inadequate knowledge of direction of propagation of EMW.	
26	(a) Displacement current through the capacitor is $I_d = \frac{d(\phi_E)}{dt}$ $i_d = \epsilon_o \cdot \frac{d(\phi_E)}{dt}$ *[0.5 marks]* $\phi_E = E \cdot A = \frac{\sigma}{\epsilon_o} \cdot A$ $\phi_E = \frac{Q}{\epsilon_o A} \cdot A$ $\frac{\epsilon_o \cdot d(\phi_E)}{dt} = \frac{d(Q)}{dt}$ I_d=15μA *[0.5 marks]* *[Accept any other valid method.]*	1
27	(a) Peak value of magnetic field is given : $B_o = 10^{-4}$ T Peak value of electric field , $E_o = B_o . c$ *[0.5 marks]* $E_o = 10^{-4} \cdot 3 \cdot 10^8 = 3 \cdot 10^4$ V/m *[0.5 marks]*	1
	(b) The phase difference between electric and magnetic field is zero. *[0.5 marks]*	0.5
	(c) Expression for electric field at any given time 't' is $E_o = 3 \cdot 10^4 \sin\left(\omega t - \frac{\pi}{2}\right)$ *[0.5 marks]*	0.5
28	(a) For normal incidence, P=I·A *[0.5 marks]* $P = 2 \times 10^{-15} \times \left(\pi \times \left(\frac{45}{2}\right)^2\right)$ $P = 3.18 \times 10^{-12} W$ *[0.5 marks]*	1
	(b) Energy = power × time *[0.5 marks]* Energy = $3.18 \times 10^{-12} \times 60$ Energy = $1.9 \times 10^{-10} J$ *[0.5 marks]*	2

	Let 'n' be the number of photons falling on each dish per minute, $E = n\left(\frac{hc}{\lambda}\right)$ *[0.5 marks]* $n = \frac{E\lambda}{hc}$ $n = 9.6 \times 10^{14}$ *[0.5 marks]*	
	(c) Since the waves are incident normally, after reflection, the rays will converge at the focus of the dish.*[1 mark]* focus(f) = radius/2 *[0.5 marks]* f = 45/4 = 11.25m *[0.5 marks]*	2

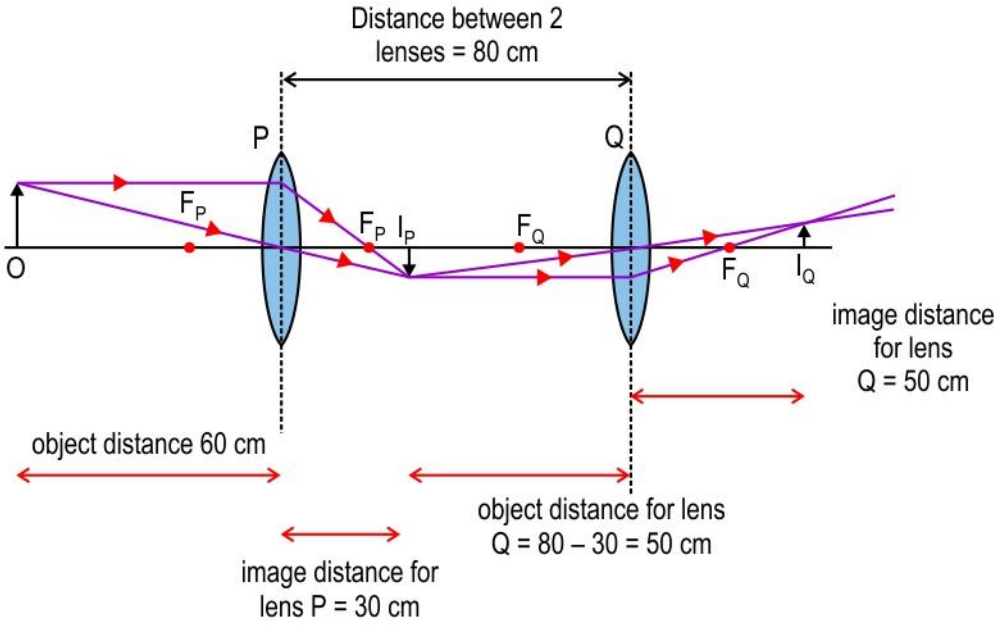
Ray Optics and Optical Instruments

Q No.	Question	Marks
29	The question below consists of two statements, Assertion (A) and Reason (R). Assertion(A): In air, concave lens made of glass always diverges the light rays falling on it. Reason(R): A diverging lens is always thinner in the middle than at the edges. Answer the question by selecting the appropriate option given below. (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. ***[Skill: Understanding]***	1
30	A spherical drop of water, when kept in air, acts like which type of lens? ***[Skill: Understanding]***	1
31	A sodium light source, emitting light in all directions, is kept inside a tank of height 1 m, completely filled with water as shown below. The walls of the tank are highly absorbing and absorb all the light falling on it.  (a) Assuming that the width of the tank is much greater than its height, calculate the range of incident angle for which the light be **refracted** while travelling from water to air. (Answer in terms of $\sin^{-1}$.) (b) What will happen to the range of the incident angle in part (a) if the water in the tank is replaced with a liquid of a higher refractive index? Explain. *(No mathematical calculations needed.)* ***[Skill: Application]***	2+1

32	Two converging lenses, P and Q, have focal lengths of f_P= 20.0 cm and f_Q= 25.0 cm respectively. They are positioned 80.0 cm apart. An object is placed 60.0 cm in front of lens P. (a) Calculate the image distance from lens Q. (b) Based on your calculations, draw a ray diagram on graph paper to illustrate the image formed by this combination of lenses, using an appropriate scale. ***[Skill: Understanding]***	2+3

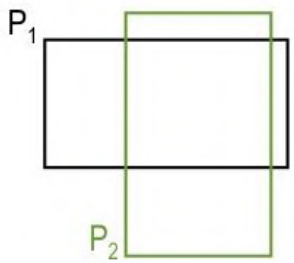
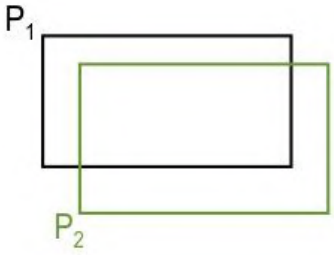
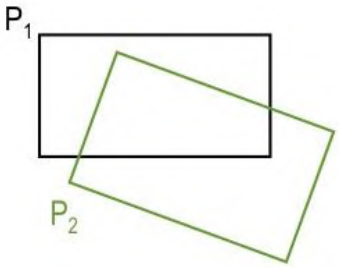
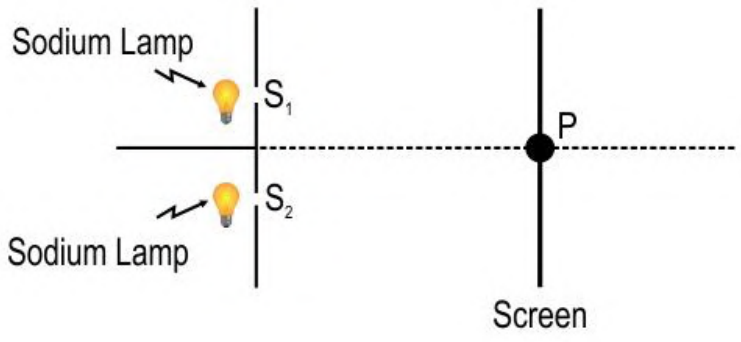
Marking Scheme

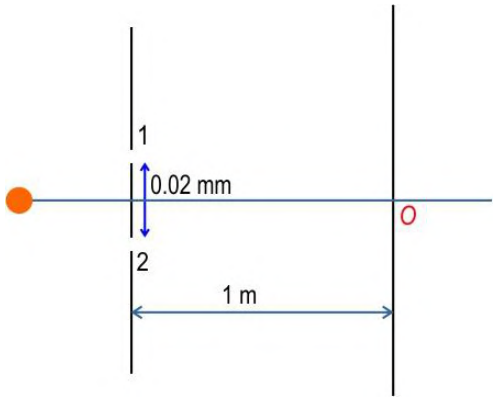
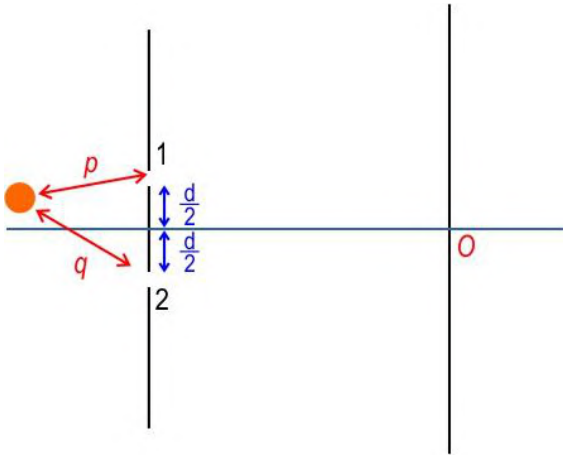
Q No.	Rubric	Marks
29	**Correct Answer:** C Concave lens will diverge light rays if the refractive index of the surrounding is less than the lens itself. So, assertion is true. When a concave lens is kept in a medium of refractive index higher than that of the material of the lens, it will act as a converging lens.	1
	A: Students choosing this option may not understand that behaviour of lens changes when put in a medium of refractive index higher than that of the material of the lens.	
	B: Students choosing this may be thinking that concave lens diverges light rays due to difference in refractive index.	
	D: Students choosing this may lack understanding of how concave lens bends light.	
30	converging lens/convex lens	1
31	(a) For any angle of incidence that is greater than critical angle, the light ray will undergo TIR, and the reflected light will be absorbed by the wall of the container. So the light will be refracted only for the incident rays whose angle is equal to or less than critical angle. *[0.5 marks]* *[Accept any other valid explanation.]* Let the critical angle be i_c, $i_c = \sin^{-1}\left(\frac{1}{\eta_{water}}\right)$ *[0.5 marks]* $i_{c=\sin^{-1}\left(\frac{1}{1.33}\right)}$ *[0.5 marks]* Range = $0 < \theta < \sin^{-1}\left(\frac{1}{1.33}\right)$ *[0.5 marks]*	2
	(b) If the water in the tank is replaced with a liquid of higher refractive index, the range of incident angles for which light is refracted into the air will decrease. *[0.5 marks]* This is because a higher refractive index decreases the critical angle. *[0.5 marks]* *[Accept any other valid reason.]*	1

32	(a) Thin lens equation $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ *[0.5 marks]* Given, f_P = 20 cm and u_P = 60 cm Image distance for the first lens (f_P) $\frac{1}{v_P}=\frac{1}{f_P}+\frac{1}{u_P}=\frac{1}{20}+\frac{1}{(-60)}$ v_P = 30 cm *[0.5 marks]* the image formed by the first lens (f_P) is the object for the second lens (f_Q). The lenses are separated by a distance of 80 cm and image distance for lens f_P is 30 cm. thus, the object distance for the second lens (f_Q) = 80-30 = 50 cm thus, u_Q = 50 cm and f_Q = 25 cm. *[0.5 marks]* the image distance for the second lens f_Q $\frac{1}{v_Q}=\frac{1}{f_Q}+\frac{1}{u_Q}=\frac{1}{25}+\frac{1}{(-50)}$ v_Q = 50 cm. *[0.5 marks]* (b) Ray diagram:  Rubric for the ray diagram. 1) For the first lens: the object is placed beyond 2f, the image formed is between f and 2f using any two convenient rays. The image formed is real, inverted and diminished. *[1 mark]*	5

	2) For the second lens: the object is placed at 2f, the image formed is at 2f, using any two convenient rays. The image formed is real, inverted, and same size as the image formed by the lens P. *[1 mark]* 3) The ray diagram drawn with appropriate scale *[1 mark]* *(Deduct 0.5 marks if the arrow-heads are not indicated.)*	

Wave Optics

Q No.	Question	Marks
33	Two identical polarizers, P_1 and P_2 are kept in front of each other in different arrangements. In which of the following arrangements will the intensity of light passing through both the them be the maximum? (A)  (B)  (C)  (D) (*The intensity will be the same for all the arrangements.*) ***[Skill: Mechanical]***	1
34	In an experiment, two coherent sodium lamps illuminate two pinholes S_1 and S_2 as shown in the image below.  (a) Write the expression for distance from 'P' where a destructive interference will be observed. (b) By what distance should the screen be moved so that the distance to the first dark spot increases by a distance equal to the wavelength (λ) of the light source? *(Answer in terms of distance between the pinholes, 'd'.)* ***[Skill: Understanding]***	0.5+ 1.5

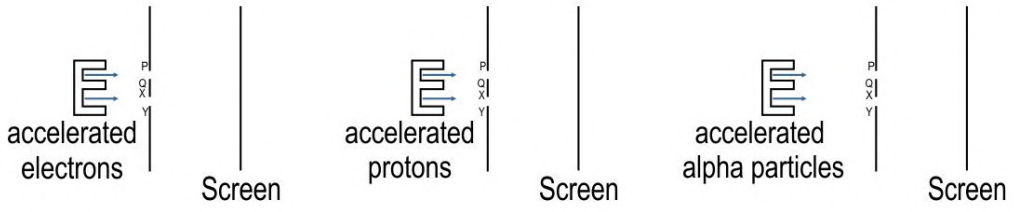
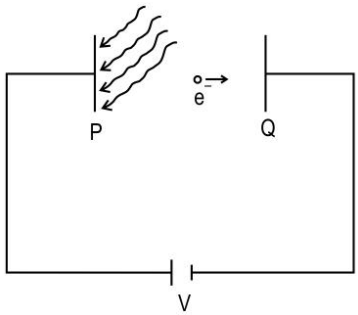
35	(a) A coherent source of light, emitting light of wavelength 650 nm, is kept in front of two small slits as shown in the image below.  The distance between the slits is 0.02 mm, and the screen is placed 1m away. (i) Calculate the distance between two adjacent bright fringes (fringe width). (ii) If the space between the slit and the screen is filled with a liquid of refractive index 1.5, determine the new fringe width. (b) A coherent source of light is kept in front of two slits such that the distance of the source from slit 1 and 2 is 'p' and 'q, respectively, as shown in the image below.  If p = 30 cm and q = 25 cm, what should be the maximum wavelength of the light to get a constructive interference at point 'O'? (Assume that the wavelength of the light and the slit width is comparable.) ***[Skill: Application]***	3.5+ 1.5

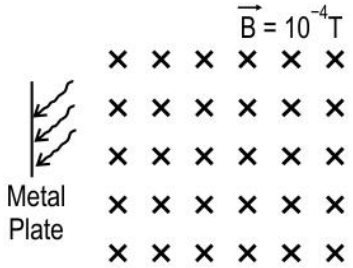
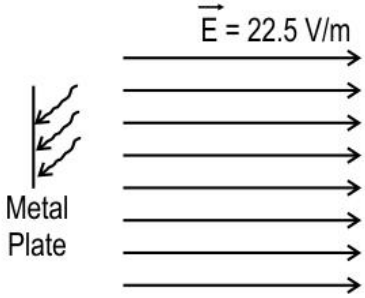
Marking Scheme

Q No.	Rubric	Marks
33	**Correct Answer:** B According to Malus' law, the intensity of the light passing through the polaroid is directly proportional to the square of cosine of the angle between them. Since, cosθ is maximum for θ=0°, the intensity of parallel arrangement will be the maximum.	1
	A: Students choosing this option do not understand malus' law.	
	C: Students choosing this option do not understand malus' law.	
	D: Students choosing this option do not understand malus' law.	
34	(a) Let x be the distance from point 'P' where n^{th} dark spot is formed, $x = \left(n + \frac{1}{2}\right) \cdot \frac{\lambda D}{d}$ *[0.5 marks]* where 'd' is the distance between two pinholes, D is the distance from center of the slits to screen.	0.5
	(b) Initial distance for first dark spot, $x = \left(\frac{1}{2}\right) \cdot \frac{\lambda D}{d}$ *[0.5 marks]* Let the new distance of screen be D_{new}, $\frac{1}{2} \cdot \frac{\lambda D}{d} + \lambda = \frac{1}{2} \cdot \frac{\lambda D_{new}}{d}$ *[0.5 marks]* $\frac{D_{new}}{2d} = \frac{D}{2d} + 1$ $D_{new} = D + 2d$ $D_{new} - D = 2d$ *[0.5 marks]*	1.5
35	(a) (i) fringe width, $\beta = \frac{\lambda D}{d}$ *[0.5 marks]* $\beta = \frac{\left(650 \times 10^{-9} \times 1\right)}{2 \times 10^{-5}}$ *[0.5 marks]* β=3.25 x 10^{-2}m *[0.5 marks]* (ii) from the equation $\eta_1 \lambda_1 = \eta_2 \lambda_2$, *[0.5 marks]* $\lambda_{oil} = \frac{\lambda_{air}}{\eta_{oil}} = \frac{650nm}{1.5} = 433.3nm$ *[0.5 marks]* $= \beta_{new} = \frac{\lambda_{oil} D}{d} = \frac{\left(433.3 \times 10^{-9} \times 1\right)}{2 \times 10^{-5}}$ = 2.16 x 10^{-2}m *[1 mark]*	3.5

	(b) To get a maxima at point O, the phase difference between the distance travelled by light rays at slit 1 and slit 2 should be multiple of the wavelength of the light. *[0.5 marks]* 30-25=nλ *[0.5 marks]* wavelength will be maximum for n=1 λ_{max}=5cm *[0.5 marks]*	1.5

Dual Nature of Radiation and Matter

Q No.	Question	Marks
36	Three types of charged particles -electrons, protons and alpha particles are accelerated such that they all have the same momentum and pass through similar small slits PQ and XY as shown below.  For which of the particles is it possible to observe an interference pattern, considering wavelength of electrons is comparable to the slit width? (A) only electrons (B) only electrons and protons (C) all-electrons, protons and alpha particles (D) (*Interference pattern can only be observed for waves and not particles.*) ***[Skill: Understanding]***	1
37	Fill up the blanks in the statement given below. For a metal undergoing photoelectric effect, the stopping potential for the metal decreases when the _____ of the incident light is decreased. ***[Skill: Understanding]***	1
38	A battery is connected across a caesium plate, P, and a collector plate, Q as shown in the diagram below.  The work function of caesium is 2.14 eV. If the maximum momentum of the incident photons is 1.33×10^{-27} kg.m/s, calculate the minimum potential of the battery required to stop the flow of photocurrent, express your answer in eV. *(Assume that internal resistance of the battery and the connecting wires is zero.)* *(Assume c=3×10^{8}m/s and 1 J=1.6 x 10^{-19} eV)* ***[Skill: Application]***	2

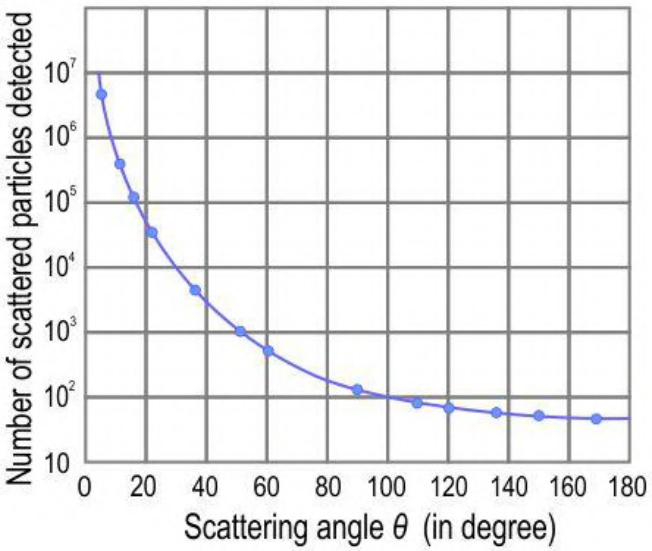
39	Work function for a certain metal is 4.1 eV. When light of frequency 3.2 x 10^{15} Hz is incident on the metal surface, photoemission of electrons occurs.  (a) A uniform magnetic field $B = 10^{-4}$ T is applied parallel to the plane of the metal sheet as shown below. Calculate the maximum radius of the path followed by the emitted photoelectrons as they move within the magnetic field. *(Assume: h = 6.6 x 10^{-34} J-s, 1 eV = 1.6 x 10^{-19} J, mass of electron=9.1 x 10^{-31} kg, $\sqrt{264.99 \times 10^{-50}} = 1.6 \times 10^{-24}$ and $\sqrt{0.79 \times 10^{-13}} = 2.81 \times 10^{-7}$)* (b) A uniform electric field E=20 V/m is applied perpendicular to the plane of the metal sheet for a distance of 1m, as shown below.  Calculate the minimum wavelength associated with the electrons after passing through the electric field. *(Assume $\sqrt{9.1 \times 10^{-48}} = 3 \times 10^{-24}$)* ***[Skill: Application]***	3+2

Marking Scheme

Q No.	Rubric	Marks
36	**Correct Answer:** C Due to dual nature of matter, particles also behave as waves. Since the momentum of all three particles is the same, the wavelength associated with all three will be the same. Hence, it is possible to observe a diffraction pattern for all three.	1
	A: Students choosing this option may think that since mass of the electron is the least, wavelength associated with the particle be the smallest but since momentum of all three particles is the same, the waves associated with all three will be the same.	
	B: Students choosing this option may think that since electron and protons are elementary particles, they will show a diffraction pattern.	
	D: Students choosing this option do not understand dual nature of particles.	
37	frequency/energy	1
38	Maximum energy of the incident photon $E_{max} = pc$ *[0.5 marks]* $E_{\max} = 1.33 \times 10^{-27} \times 3 \times 10^{8} = 3.99 \times 10^{-19} J$ $E_{\max} = \frac{(3.99 \times 10^{-19})}{1.6 \times 10^{-19}}$ = 2.49 eV *[0.5 marks]* Stopping potential $V = E_{\max} - \phi$ *[0.5 marks]* where ϕ is the work function of caesium. V = 2.49 - 2.14 = 0.35eV *[0.5 marks]*	2
39	(a) Energy of incident photons: E=hϑ where ϑ is the frequency of the incident light. E= $\frac{(6.6 \times 10^{-34} \times 3.2 \times 10^{15})}{1.6 \times 10^{-19}}$ =13.2eV *[0.5 marks]* $KE_{\max} = E - \phi$ where E is the energy of photons and ϕ is the work function. KE_{max}=13.2 - 4.1 = 9.1 eV *[0.5 marks]* The radius will be maximum when electron with maximum K.E. will enter perpendicular to the magnetic field. *[0.5 marks]* $r_{\max} = \frac{mv}{qB}$ *[0.5 marks]* $r_{\max} = \frac{\sqrt{2mKE_{\max}}}{qB}$ *[0.5 marks]* $r_{\max} = \frac{\sqrt{(2 \times 9.1 \times 10^{-31} \times 9.1 \times 1.6 \times 10^{-19})}}{1.6 \times 10^{-19} \times 10^{-4}}$ $= \frac{(1.6 \times 10^{-24})}{1.6 \times 10^{-23}} = 0.1\text{m}$ *[0.5 marks]* *[Accept any other method of arriving at the same answer.]*	3

	(b) Maximum KE of the photoelectrons is 9.1 eV= $9.1 \times 1.6 \times 10^{-19} = 1.4 \times 10^{-18} J$ gain in KE after passing through electric potential: U = eV= eEl *[0.5 marks]* where l is the length for which electron is under the influence of electric field. $U=\frac{(1.6\times10^{-19}\times22.5)}{1}=3.6 \times 10^{-18} J$ *[0.5 marks]* Energy of electron after passing through the electric field is $E = 5 \text{ x } 10^{-18}\text{J}$ $\lambda = \frac{h}{\sqrt{2mE}}$ *[0.5 marks]* $\lambda = \frac{(6.6\times10^{-34})}{\sqrt{2\times9.1\times10^{-31}\times5\times10^{-18}}}$ $\lambda = \frac{(6.6\times10^{-34})}{3\times10^{-24}} = 2.2 \times 10^{-10} m$ *[0.5 marks]*	2

Atoms

Q No.	Question	Marks
40	A hydrogen atom makes a transition from the higher energy state with principle quantum number 3 to the lower energy state with principle quantum number 1. What is/are all the possible energy/energies (**in eV**) of the photon(s) emitted during the transition? (A) only 10.2 (B) only 12.09 (C) only 12.09 and 1.89 (D) all - 12.09, 10.2 and 1.89 ***[Skill: Mechanical]***	1
41	Fill up the blank in the statement given below. In a hydrogen atom, the ionization energy for an electron in 1st excited state is _____than the ionization energy for 2nd excited state. ***[Skill: Mechanical]***	1
42	The graph below presents experimental data on the scattering of α particles by a thin gold foil at various angles, as obtained by Geiger and Marsden.  (a) What inference can you draw about the structure of atoms by looking at the data for scattering angle between 0° and 20°? (b) What can you conclude about the structure of atoms by looking at the data for scattering angle between 160° and 180°? ***[Skill: Application]***	1+1

43	An alpha particle with impact parameter b=0, approaches an atom of atomic number 72, with an initial velocity of 3 x 10^4m/s. (a) At what distance from nucleus will the alpha particle momentarily come to rest before getting repelled in the opposite direction? *(Assume k=*$9 \times 10^9 Nm^2C^{-2}$ *,mass of alpha-particle =* 6.6×10^{-27} *kg and charge on a proton =* $1.6 \times 10^{-19}C$*)* (b) How does the distance get impacted if the alpha particle approaches the atom with a greater velocity? Explain. (c) Why does the alpha particle momentarily come to rest at the distance calculated in subpart (a)? ***[Skill: Understanding]***	1+1+1

Marking Scheme

Q No.	Rubric	Marks
40	**Correct Answer:** D The energy of a hydrogen atom in a state with principal quantum number n is given by $E_n = -13.6/n^2$. The transitions that can take are from n=3 to n=1, n = 3 to n= 2 and n = 2 to n= 1. E_1 = -13.6 eV E_2 = -3.4 eV E_3 = -1.51 eV So energy of photons released would be: -1.51 + 13.6 = 12.09 eV -1.51 + 3.4 = 1.89 eV -3.4 + 13.6 = 10.2 eV	1
	A: Students choosing this option may have not considered the possibility of transition from n=3 to n=2 and then from n=3 to n=2.	
	B: Students choosing this option may have not considered the possibility of transition from n=3 to n=2 and then from n=2 to n=1.	
	C: Students choosing this option may have not considered the possibility of transition from n=2 to n=1.	
41	more/greater/higher	1
42	(a) Most of the alpha-particles suffer a deviation less than 20°, suggesting that most of the space in the atom is empty. *[Accept any other valid answer.]*	1
	(b) Very few alpha particles suffer a deviation between 160° and 180° suggesting that all the positive charge of the atoms is concentrated at the center of the atom in a volume very small compared to the total volume of the atom. *[Accept any other valid answer.]*	1
43	(a) $r = \frac{2kZe^2}{KE}$ *[0.5 marks]* $r = \frac{\left(2\times9\times10^{9}\times72\times1.6\times10^{-19}\times1.6\times10^{-19}\right)}{(6.6\times10^{-27}\times3\times10^{4}\times3\times10^{4})}$ x 2 r = 11.1 x 10^{-9} m *[0.5 marks]*	1
	(b) $r = \frac{2kZe^2}{KE} = \frac{4kZe^2}{mv^2}$ As we can see in the above equations that r is inversely proportional to v^2, the distance r will decrease with increase in velocity. *[0.5 marks each for correct answer and reason.]*	1

	(c) The motion of the alpha particle is governed by the principle of conservation of energy. As the particle approaches the nucleus its kinetic energy gets converted into potential energy. *[0.5 marks]* At a particular distance from the nucleus, the entire kinetic energy of the alpha particle gets converted into potential energy and as a result the alpha particle momentarily comes to rest at this distance. *[0.5 marks]* *[Accept any other valid reason.]*	1

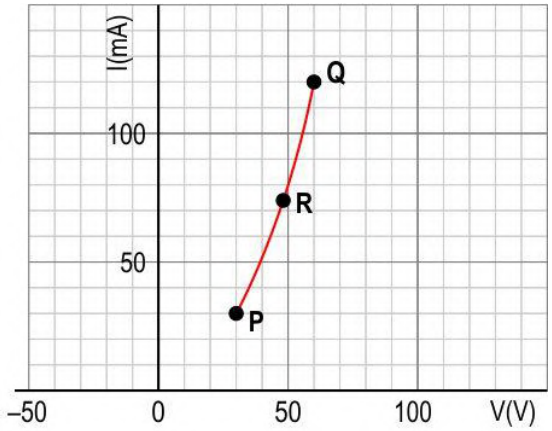
Nuclei

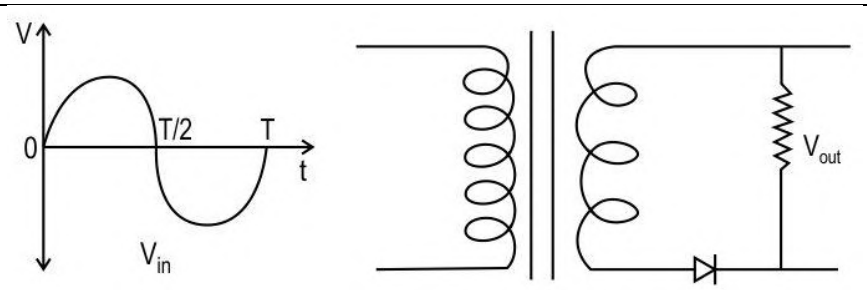
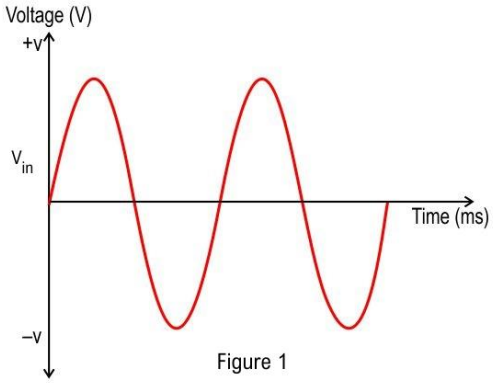
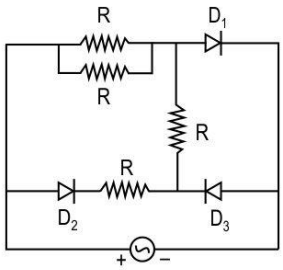
Q.No.	Question	Marks
44	The question below consists of two statements, Assertion (A) and Reason (R). Assertion(A): Higher binding energy always means the nucleus is more stable. Reason(R): Higher energy per nucleon means the more energy is required to remove a nucleon from the nucleus. Answer the question by selecting the appropriate option given below. (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. ***[Skill: Understanding]***	1
45	A nuclear fission reaction is given below. $Po_{84}^{212} \rightarrow Pb_{82}^{208} + \chi$ Identify the particle χ. ***[Skill: Mechanical]***	1
46	(a) If the mass of the nucleus of neon(Ne_{10}^{20}) is 19.99244 u, calculate the binding energy per nucleon in MeV/c^2 . *(Given that mass of neutron is 1.008665 u, mass of proton is 1.007825 and 1 u = 931.5 MeV/c^2)* (b) What is the significance of binding energy per nucleon in the stability of nucleus. ***[Skill: Mechanical]***	2+1

Marking Scheme

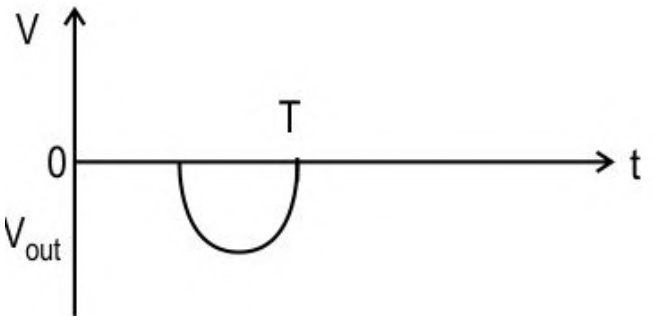
Q No.	Rubric	Marks
44	**Correct Answer:** D Higher binding energy does not always mean more stability but it is higher binding energy per nucleon always means more stability. So, assertion is incorrect but reason is correct.	1
	A: Students choosing this may lack understanding of relation between binding energy and stability of the nucleus.	
	B: Students choosing this may lack understanding of relation between binding energy and stability of the nucleus.	
	C: Students choosing this may lack understanding of relation between binding energy and stability of the nucleus.	
45	The particle is alpha particle/nucleus of helium atom.	1
46	(a) Number of neutrons and protons in neon is 10 each. Mass of 10 neutrons=10.08665u Mass of 10 protons=10.07825u Total mass of constituent particles of nucleus of neon = (m_{n+p})=10m_n + 10m_p = 20.16490 u *[0.5 marks]* Mass defect= (total mass of constituent particle) - (mass of nucleus) Δm=20.16490 - 19.99244 = 0.17246 u *[0.5 marks]* given that, 1 u = 931.5 MeV/c^2 0.17246 u = 160.6465 MeV *[0.5 marks]* B.E. per nucleon= 160.6465/20 = 8.032325 *MeV [0.5 marks]*	2
	(b) Binding energy per nucleon represents the average energy required to remove a nucleon (proton or neutron) from the nucleus. The higher the binding energy per nucleon, the more tightly bound the nucleons are, making the nucleus more stable. *[1 mark]* *[Accept any other valid answer.]*	1

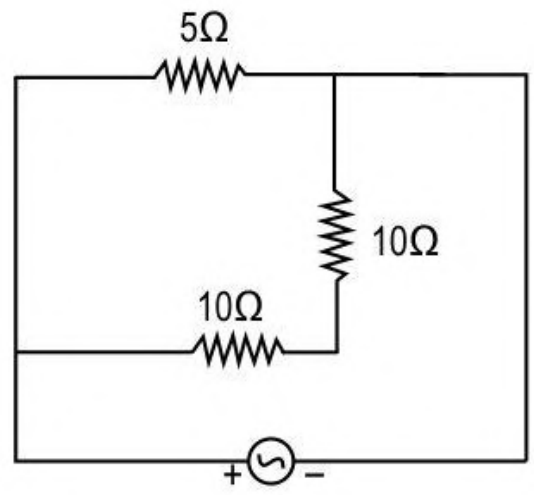
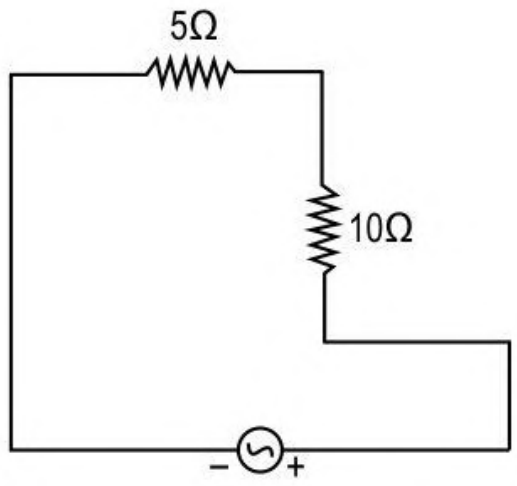
Semiconductor Electronics: Materials, Devices and Simple Circuits

Q No.	Question	Marks
47	The graph below shows the V-I characteristic of a diode.  What is the dynamic resistance of the diode at point R? (A) 333.3Ω (B) 0.333 Ω (C) 0.003 Ω (D) 3 Ω ***[Skill: Application]***	1
48	The question below consists of two statements, Assertion (A) and Reason (R). Assertion(A): The number of free electrons in p-type semiconductors is zero. Reason(R): p-type semiconductors contain holes that act as majority charge carriers. Answer the question by selecting the appropriate option given below. (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. ***[Skill: Understanding]***	1
49	(a) Silicon wafers are doped with aluminum to create p-type semiconductors. In a sample of p-type semiconductor, 2×10^{16} aluminum atoms/cm³ are added to the silicon wafers. Given that the intrinsic carrier concentration of silicon at room temperature is 1.1×10^{10} cm^3, what is the number of electrons per cm³ in the p-type silicon wafer? (b) The diagram below shows a transformer whose output terminal is connected to a diode.	1 + 2

	 Draw the output voltage obtained across the resistor connected to output terminals of the transformer for one input cycle. Explain your answer. ***[Skill: Understanding]***	
50	Figure 2 below, shows a circuit consisting of three diodes and four resistors connected to an alternating input voltage (V_{in}), represented in figure 1, having a peak voltage of 20 V. All resistors have the same resistance value of 10 Ω.  Figure 1  Figure 2 (a) During positive half and negative cycle, which diodes will be forward biased? Draw the effective circuit for both positive and negative half cycle. (b) 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. (*Assume the diode to be ideal.*) ***[Skill: Application]***	3+2

Marking Scheme

Q No.	Rubric	Marks
47	**Correct Answer:** A R=ΔV/ΔI=(60-30)/(0.12-0.03) =333.3Ω	1
	B: Students choosing this option may have taken current in A instead of mA.	
	C: Students choosing this option may have used the formula R=ΔI/ΔV	
	D: Students choosing this option may have used the formula R=ΔI/ΔV and have taken current in A instead of mA.	
48	**Correct Answer:** D In p-type semiconductors, holes are the majority charge carriers so reason is true. But free electrons are also present acting as minority charge carriers so assertion is incorrect.	1
	A: Students choosing this option may not understand majority and minority charge carriers in extrinsic-semiconductors.	
	B: Students choosing this option may not understand majority and minority charge carriers in extrinsic-semiconductors.	
	C: Students choosing this option may think that in p-type semiconductors, because the number of valence electrons in dopant is fewer than the semiconductor material and valence shell is incomplete, so they do not have free electrons.	
49	(a) In thermal equilibrium, for a p-type semiconductor: $n_h = N_d = 2 \times 10^{16}\ atoms \cdot cm^{-3}$ So, electron concentration, $n_e = \frac{n_i^2}{n_h}$ *[0.5 marks]* $n_e = \frac{(1.1\times10^{10})^2}{2\times10^{16}} = 6 \times 10^3 cm^{-3}$ *[0.5 marks]*	1.5
	(b) In positive half cycle, the diode will be in reverse bias so, no output will be obtained at the output terminals. *[0.5 marks]* In negative half cycle, the diode is in forward bias so, an output voltage will be obtained at the output terminals. *[0.5 marks]*  *[1 mark for correct representation.]*	1

50	(a) During positive half cycle, diodes D_1 and D_2 are in forward bias but D_3 is in reverse bias. *[0.5 marks]* So, D_1 and D_2 will conduct while D_3 does not. The effective circuit will be as follows:  *[1 mark for drawing the circuit correctly.]* During negative half cycle, diodes D_1 and D_2 are in reverse forward bias but D_3 is in forward bias. *[0.5 marks]* So, D_3 will conduct while D_1 and D_2 do not. The effective circuit will be as follows:  *[1 mark for drawing the circuit correctly]*	3

	(b) Power dissipated $P = \frac{(V_o)^2}{2R}$ *[0.5 marks]* The effective resistance during positive half cycle is R_{eff}=4Ω The power dissipated during positive half cycle will be $P_1 = \frac{(V_o)^2}{2R_{eff}} = \frac{20^2}{2\times4}$ = 50 Watt *[0.5 marks]* Effective resistance during negative half cycle is R_{eff}=15Ω The power dissipated during negative half cycle will be $P_2 = \frac{(V_o)^2}{2R_{eff}} = \frac{20^2}{2\times15}$ *[0.5 marks]* $P_2 = 13.33$ Watt total power dissipated during one full cycle $P = P_1 + P_2$ = 50 + 13.33 = 63.33 Watt *[0.5 marks]*	2

Board of School Education Haryana, Bhiwani