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Competency Focused Practice Questions

Physics (Volume 2) | 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 179 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

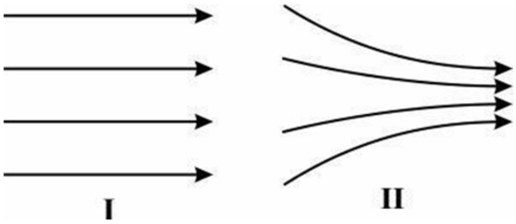
Students can also use this document to understand different kinds of questions and practice specific concepts and competencies. There will be further additions in the future to provide competency focused questions on all chapters.

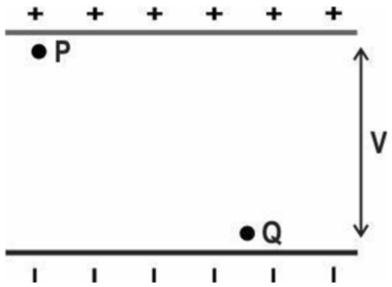
Please write back to us to give your feedback.

Team CBSE

CONTENTS

1. ELECTROSTATICS

Q. No	Question	Marks
Multiple Choice Questions		
Q.1	The capacitance of a capacitor is Co. It is connected to a battery of voltage V which charges the capacitor. With the capacitor still connected to the battery, a slab of dielectric material is introduced between the plates of the capacitor. Which of the following explains the effect of the dielectric slab in the above situation? A. The electric field between the plates of the capacitor rises. B. The potential difference between the plates falls. C. The total charge on the capacitor increases. D. The ability of the capacitor to store charge decreases.	1
Q.2	The image below shows two examples of electric field lines.  Which of the following statements is true? A. The electric fields in both I and II arise due to a single positive point charge located somewhere on the left. B. The electric fields in both I and II can be created by negative charges located somewhere on the left and positive charges somewhere on the right. C. The electric field in I is the same everywhere but the electric field in II becomes stronger as we move from left to right. D. As you move from left to right, the electric fields in both I and II become stronger.	1

Q.3	In a given region, electric potential varies with position as $V(x) = 3 + 2x^2$. Identify which of the following statements is correct. A. Potential difference between the two points x = 2 and x = -2 is 2 V. B. A charge of 1 C placed at x = 2 experiences a force of 6 N. C. The force experienced by the above charge is along +x - axis. D. The electric field in the given region is non-uniform along x - axis.	1
Q.4	A parallel plate capacitor is charged to a potential difference V. Two protons P and Q are placed at the two locations inside the capacitor as shown.  Which one of the statements is correct? A. The forces on the two protons are identical. B. The force on proton P near the positive plate is more than the force on proton Q. C. The force on proton Q near the negative plate is more than the force on proton P. D. The forces on both the protons are zero.	1
Q.5	In a given region of an electric field, there is no charge present. A closed container is placed in this region of the electric field. What is the requirement for the total flux through the closed container to be zero? A. The field must be uniform. B. The container must be symmetric. C. The container must be oriented in a particular direction. D. There is no such requirement. The total flux through the container is zero no matter what.	1

Q.6

A uniform electric field of 5000 V/m exists in a certain region. What volume of this space will contain energy equal to 10^{-6} J? (Take $\in o = 8.8 \times 10^{-12}$ SI units)

1

A. 9 m^3

B. $9 \times 10^{-3} \text{ m}^3$

C. $9 \times 10^{-6} \text{ m}^3$

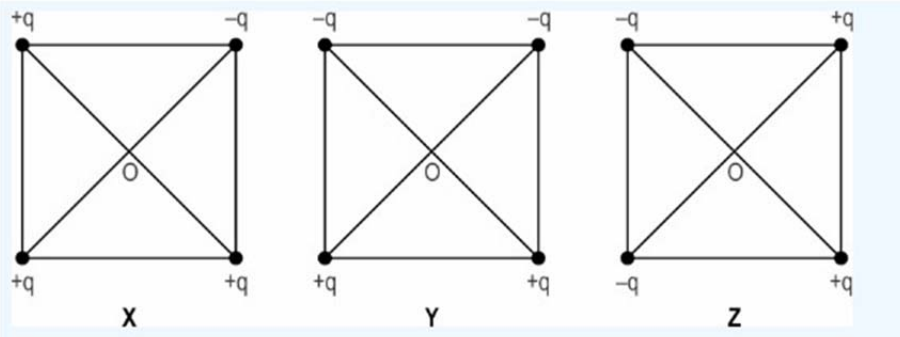
D. $9 \times 10^{3} \text{ m}^3$

Free Response Question/Subjective Question

Q.7

Given are three different square arrangements of charges.

4



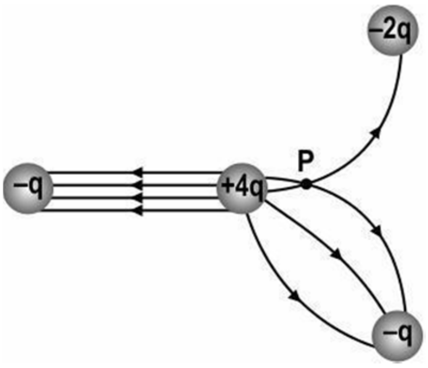
(a) Draw relevant vector diagrams to represent the resultant electric field ER at the center of the square in each case.

(b) Identify the arrangement in which the resultant electric field is the smallest at the center of the square.

Q.8

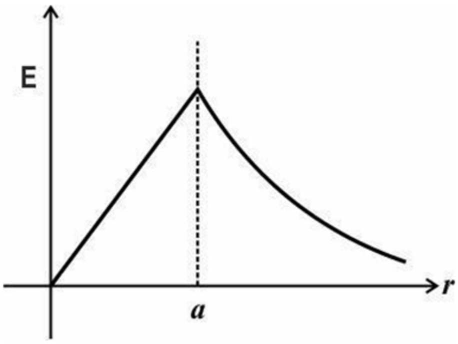
The figure below shows an arrangement of four charges along with some electric field lines drawn between the charges.

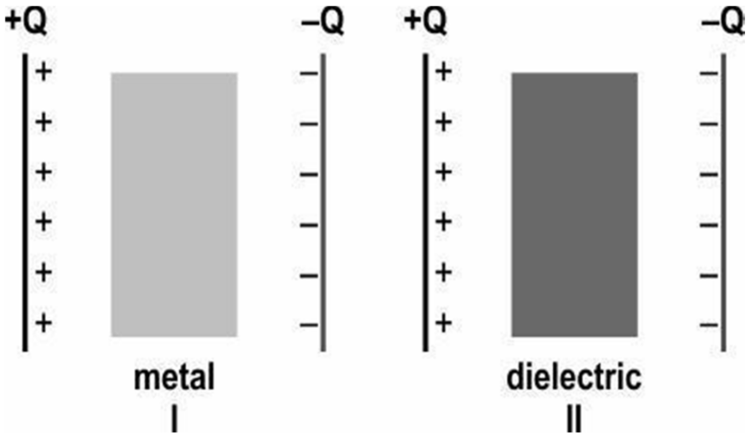
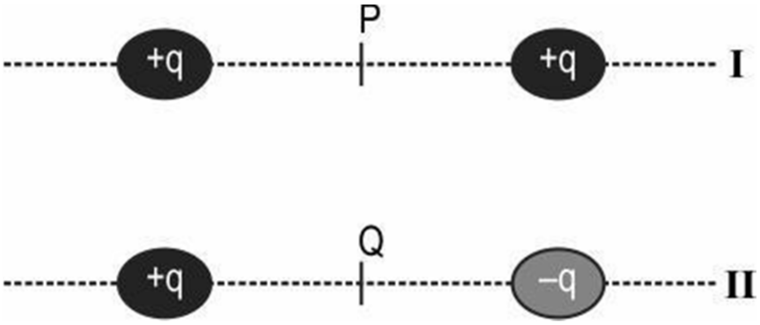
4

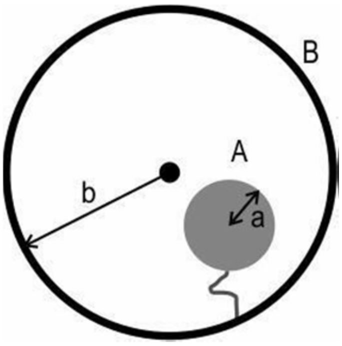
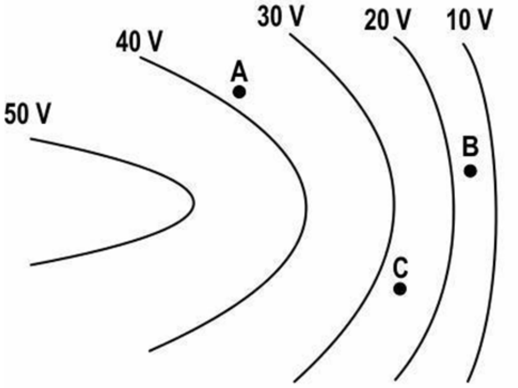


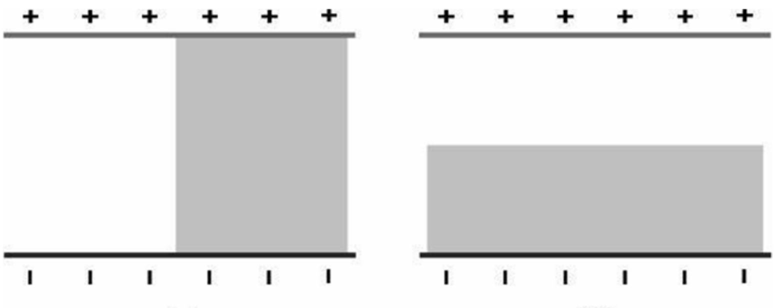
(a) Identify three things that are incorrect in this figure.

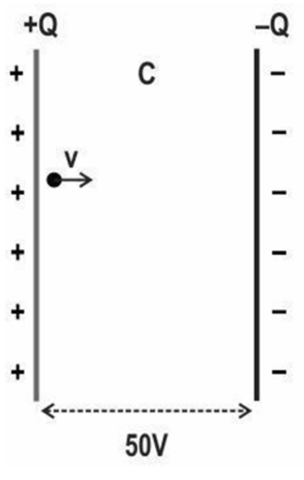
(b) Draw a correct diagram representing the electric field lines for this system of charges.

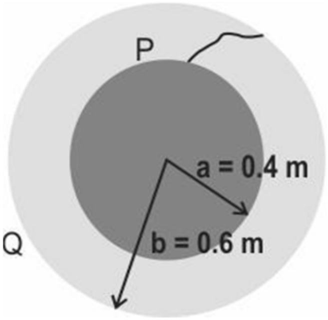
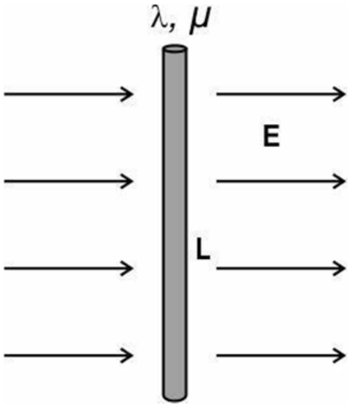
Q.9	In the case of a spherical charged conductor of radius R, hollow or solid, the electric potential is constant and maximum inside and on the surface. On the outside, the electric potential varies as, $V \propto \frac{1}{r}$ where r is the distance from the center of the sphere. (a) Represent the variation of electric potential due to a charged sphere with distance graphically. (b) How does the electric field intensity due to a charged sphere vary with distance r from the center in the above case? (c) Represent the variation of electric field intensity due to a charged sphere with distance graphically.	3
Q.10	For a given charge distribution, an equipotential surface is the locus of all points having the same potential. Draw two equipotential surfaces for each of the following: (a) a uniform electric field (b) a point charge (c) an infinite straight line of charge	3
Q.11	Study the graph between electric field intensity E versus the distance r.  (a) Describe the nature of variation of electric field intensity between r = 0 and r ≤ a. (b) Describe the nature of variation of electric field intensity for r > a. (c) Give an example of the body of charge distribution that can exhibit the above studied electric field distribution.	3

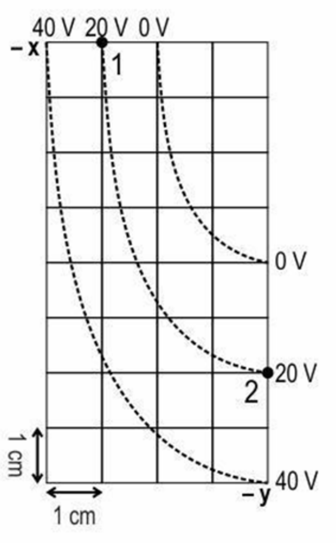
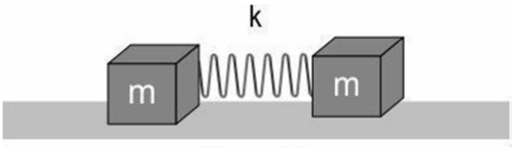
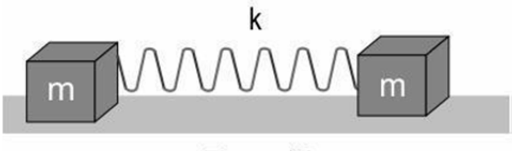
Q.12	Given is a pair of parallel charged metal plates in the arrangement as shown.  (a) Sketch the electric field lines between the plates in I and II. (b) Mention whether net electric field intensity is zero or non-zero in each case.	3
Q.13	The dielectric strength of a medium is the minimum electric field required to cause ionization of the medium. For air, this value is taken as 3 million V/m. With this information, find out if a metal sphere of radius 1 cm, surrounded by air, can hold a charge of 1 coulomb.	2
Q.14	(a) If electric field strength at a point is zero at a given point, then what can you say about the electric potential at that point? Explain. (b) In the two instances below, state whether electric field intensity and electric potential are zero or non-zero at the mid-point joining the two-point charges.  	2

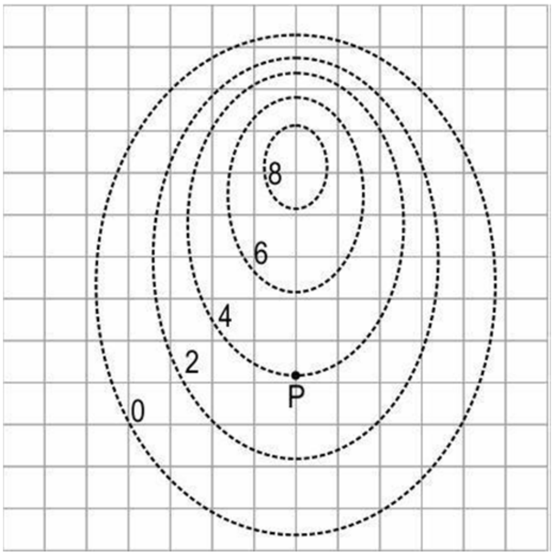
Q.15	A metal sphere A of radius a is charged to a potential V. It is enclosed inside a hollow metal shell B of radius b.  What will be the potential of A if it is connected to shell B by a conducting wire? Show the working.	2
Q.16	Two hollow spherical conductors of different sizes are charged positively. The smaller one is at 50 V and the larger one is at 100 V. Suggest a method in which the two conductors can be arranged so that the charge flows from the smaller to the bigger conductor when connected by a wire. Give a mathematical working to justify the arrangement.	3
Q.17	The figure below shows lines of constant potentials in a region in which an electric field is present.  Using the relation between potential difference and electric field intensity, find which of the three points, A, B or C will have the greatest electric field intensity.	2

Q.18	The capacitance of an infinite parallel capacitor without any dielectric between the plates is C. It is then half-filled with a dielectric medium of K = 4 as in Fig (a) and then as in Fig (b).  (a) (b) Show that capacitance in Fig (a) becomes 5C and in Fig (b) the capacitance becomes (4/5)C due to the introduction of the dielectric medium.	3
Q.19	Two small balls, each with a charge Q, hang from the same point by insulating strings of length L from a fixed support. Consider the setup in a region of zero gravity and in equilibrium. (a) What will be the angle between the two strings? (b) What will be the tension in each of the strings?	2
Q.20	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

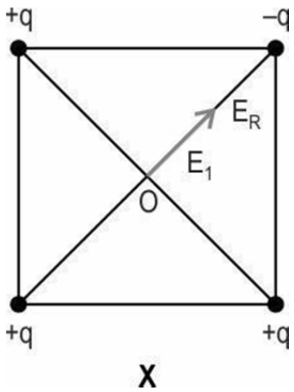
Q.21	A parallel plate capacitor of capacitance C is charged to a potential V by a battery. Q is the charge stored on the capacitor. Without disconnecting the battery, the plates of the capacitor are pulled apart to a larger distance of separation. What changes will occur in each of the following quantities? 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	5
Q.22	A parallel plate capacitor C with a dielectric in between the plates is charged to a potential V by connecting it to a battery. The capacitor is then isolated. If the dielectric is withdrawn from the capacitor, (a) Will the energy stored in the capacitor increase or decrease? What causes the change in energy? (b) Will the potential difference across the capacitor plates increase or decrease? Give an explanation.	3
Q.23	A small ball of mass 2 x 10^{-16} kg carrying a charge q = - 2 µC is fired from the positive plate of the capacitor towards the negative plate with a speed of 3 x 10^6 m/s.  Will the ball strike the negative plate? Give mathematical working for the answer.	3

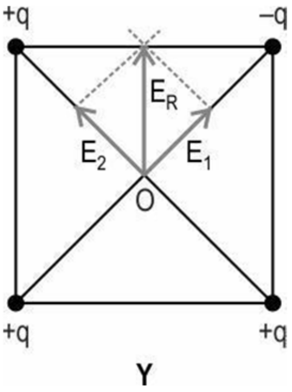
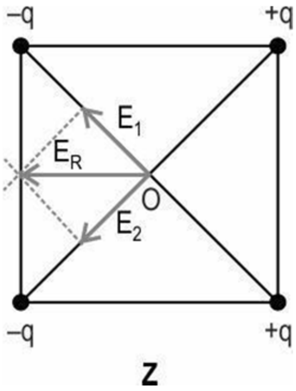
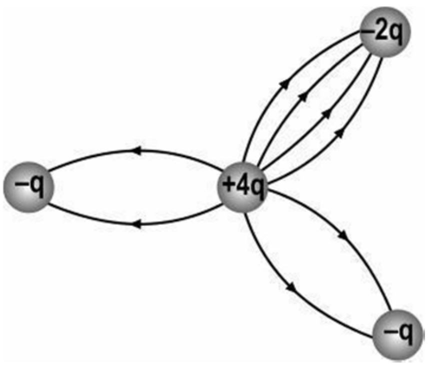
Q.24	An isolated capacitor of unknown capacitance C is charged to a potential difference V. It is then connected in parallel to an uncharged capacitor of capacitance Co such that the potential difference across the combination becomes V/3. Determine the unknown capacitance C.	2
Q.25	P and Q are two concentric conducting hollow shells connected to each other by a conducting wire.  If a total charge of 10 C is given to this system of two concentric shells, how much charge will settle on each shell? Explain.	2
Q.26	A thin rod of length L of the uniform mass density of μ kg/m and linear charge density λ C/m is initially at rest. A uniform electric field E is applied in the direction perpendicular to the length of the rod. The rod begins to move in the direction of the applied electric field.  Determine the speed of the rod after it travels through 1 m of distance. Ignore all external forces except the electrostatic forces.	3

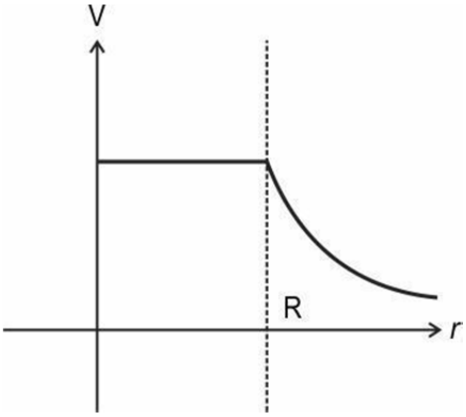
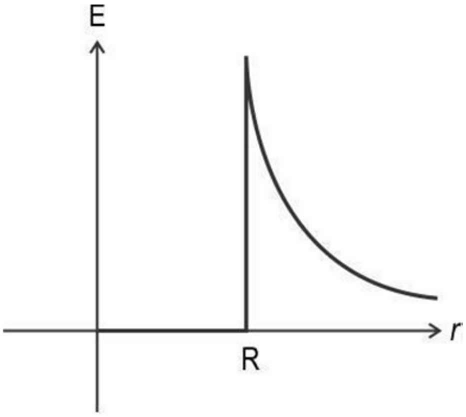
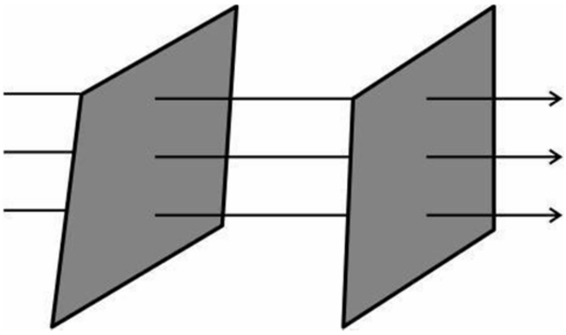
Q.27	A thundercloud carries a charge of +50 C at a height of 4000 m and a charge of -50 C at a height of 2000 m from the ground. An airplane crosses through the charged thundercloud at a height of 3000 m from the ground. Find the magnitude and the direction of the electric field acting on the airplane as its crosses through the charged-up thundercloud.	2
Q.28	Given below is the representation of equipotential lines in a given electric field region. Determine the strength and direction of electric field vectors at points 1 and 2.  	3
Q.29	Two identical small metal blocks each of mass m are held to each other by a metallic spring of force constant k. The block-spring system is placed on a frictionless surface and the spring has an unstretched length L_1 as in Fig (i).  Figure (i)  Figure (ii) A total charge Q is slowly given to the block-spring system resulting in the spring getting stretched to an equilibrium length L2 as in Fig (ii). Assume that the entire charge gets distributed only on the two blocks and consider the two blocks as point charges. Determine the charge Q.	2

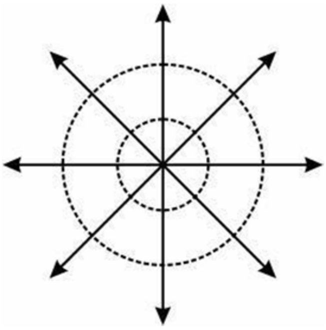
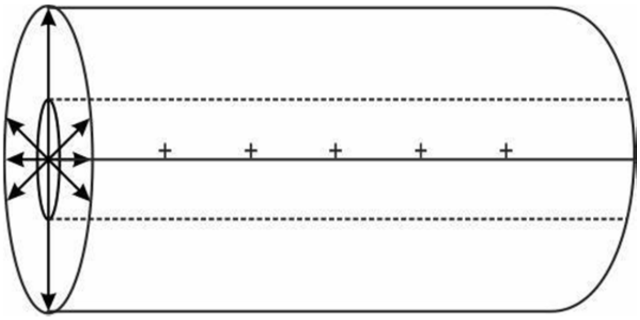
Q.30	The diagram below shows an arrangement of a set of equipotential lines in a given region. Each line is marked with the potential it represents. The background gridlines are squares of each side equal to 1 cm.  (a) Determine electric field at point P. (b) Draw 6 field lines to represent the electric field in this region.	2
Q.31	The area of each of the plates of a parallel plate air capacitor is 7 cm^2. (a) Determine the maximum charge this capacitor can store without breakdown. (b) A material of dielectric constant 2 and dielectric strength 15 x 10^6 V/m is inserted into the capacitor. Find the percentage change in the maximum charge that can be stored in the capacitor with the dielectric material. (Take Dielectric strength of air = 3 x 10^6 V/m, $\in_o = 8.8 \times 10^{-12}$ C_2/Nm^2)	3

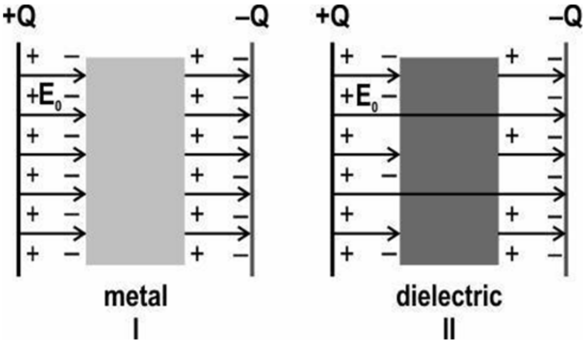
Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.1	C. The total charge on the capacitor increases.	1
Q.2	C. The electric field in I is the same everywhere but the electric field in II becomes stronger as we move from left to right.	1
Q.3	D. The electric field in the given region is non-uniform along x - axis.	1
Q.4	A. The forces on the two protons are identical.	1
Q.5	D. There is no such requirement. The total flux through the container is zero no matter what.	1
Q.6	B. 9 x 10^{-3} m^3	1
Q.7	(a) 1 mark each for the correct vector representation of the electric field in the three cases: 	4

	  (b) E_R vector in X is the smallest in length.	
Q.8	(a) 1 mark for each correct point: - Electric field lines cross each other as shown at point P. - Number of field lines that end on the negative charges is not proportional to their charges. - The field lines drawn between +4q and –q are shown as parallel and equidistant. (b) The correct representation:  [1 mark for the correct representation of the electric field lines]	4

Q.9	(a)  [1 mark for the correct graph] (b) Electric field intensity is zero inside the charged sphere. Maximum at the surface. On the outside of the sphere, it falls as E proportional to $1/r^2$ [1 mark for the correct statement of variation of E with r] (c)  [1 mark for the correct graph]	3
Q.10	(a) A uniform electric field 	3

	[1 mark for the correct drawing of two equipotential surfaces] (b) A point charge  [1 mark for the correct drawing of two equipotential surfaces] (c) An infinite straight line of charge  [1 mark for the correct drawing of two equipotential surfaces]	
Q.11	E = 0 at r = 0. Between r = 0 and r < a, the electric field intensity increases linearly.E is maximum at r = a. [0.5 mark for each point] (b)For r > a, the electric field intensity decreases as $1/r^2$. [0.5 mark for this point] (c) A uniformly charged insulating solid sphere. [1 mark for the example]	3

Q.12	(a)  [1 mark for correct representation of electric field inside metal] [1 mark for correct representation of electric field inside dielectric] (b) The net electric field intensity inside a metal is zero. The net electric field intensity inside a dielectric is non-zero. [0.5 mark for each point]	3
Q.13	Electric field on the surface of a metal sphere: $E = \frac{Q}{4\pi\epsilon_0 R^2} = 9 \times 10^9 \frac{1}{(1 \times 10^{-2})^2} = 9 \times 10^{13}$ V/m [1 mark for the correct formula and calculation] As this field is much higher than the dielectric strength of the surrounding air (=3 x 10^6 V/m), a sphere of radius 1 cm CANNOT hold 1 C of charge in air. [1 mark for the correct interpretation and conclusion]	2
Q.14	(a) As $E = -\frac{\Delta V}{\Delta r}$ If E =0, at a given point, then $\frac{\Delta V}{\Delta r} = 0$ i.e., V = 0 or constant at that point. [1 mark for correct explanation] (b) At mid-point P in Fig I, E is zero, but V is non-zero. At mid-point P in Fig II, E is non-zero, but V adds up to zero. [0.5 mark for each point]	2

Q.15	Potential on the surface of sphere A: $V_A = \frac{q}{4\pi\in_0 a} = V$ On connecting sphere, A with shell B, the charge will now reside on the surface of the shell. Potential on the surface of shell B: $V_B = \frac{q}{4\pi\in_0 b}$ [0.5 mark for each correct formula] Comparing the two equations: $V_B = \frac{a}{b} V$ Since sphere A is inside the shell B, so its potential now becomes the same as that of B, that is, $V_A' = \frac{a}{b} V$ [1 mark for the correct explanation]	2
Q.16	The smaller conductor can be enclosed inside the larger conductor and the two are connected by a conducting wire. [1 mark for the correct arrangement of the two conductors] Potential on the surface of the smaller conductor placed inside the bigger conductor will be $V_i = 50\ V + 100\ V = 150\ V$ [0.5 mark for the correct formula] Potential on the surface of the outer conductor will be: $V_o = 100 + \frac{1}{4\pi\in_0 R} \times \text{charge on conductor inside}$ $= 100 + \frac{1}{4\pi\in_0 R} \times 4\pi\in_0 r \times 50 = [\ 100 + 50\frac{r}{R}\ ] < 150V$ [1 mark for the correct formula and calculation] Hence when the inner conductor is connected by a conducting wire to the outer conductor, the charge flows from the higher potential surface of the inner conductor to the lower potential surface of the outer conductor. [0.5 mark for the correct conclusion]	3

Q.17	Relation between E and V is $E=-\frac{\Delta V}{\Delta r}$ Here ΔV between successive lines is constant, that is 10V. [1 mark for correct formula] Therefore, $E\propto\frac{1}{\Delta r}$ The smaller the distance of separation between two successive lines, the more is the electric field. So point B has the greatest electric field intensity. [1 mark for correct explanation]	2
Q.18	In Fig (a), the two capacitors are in parallel combination. So the equivalent capacitance = C + KC = C [1+K] = 5C [0.5 mark for correct identification of capacitor combination] [1 mark for correct calculation of equivalent capacitance] In Fig (b), the two capacitors are in a series combination. Equivalent capacitance = $C\frac{KC}{C+KC}=\frac{KC^2}{C(1+K)}=\frac{KC}{(1+K)}=\frac{4C}{5}$ [0.5 mark for correct identification of capacitor combination] [1 mark for correct calculation of equivalent capacitance]	3
Q.19	(a) The angle between the two strings will be 180^o. [1 mark for the correct angle] (b) Tension in each string will be equal to the electrostatic force of repulsion between the two charged balls. $F=\frac{Q^2}{4\pi\epsilon_0(2L)^2}$ [1 mark for the correct formula and substitution]	2

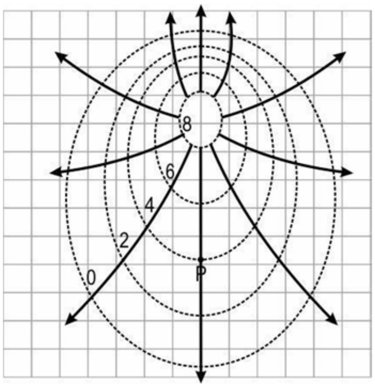
Q.20	At equilibrium, the potential on the surface of a larger sphere = potential on the surface of a smaller sphere. $V = \frac{kq_1}{r_1} = \frac{kq_2}{r_2}$ So, $\frac{q_1}{q_2} = \frac{r_1}{r_2}$ [1 mark for the correct ratio of q_1 to q_2] Since the two charges are very far from each other, the electric 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 E_1 to E_2]	2
Q.21	(a) Capacitance decreases. Capacitance is inversely proportional to the distance of separation. [0.5 mark for correct change] [0.5 mark for correct explanation] (b) Charge decreases. From Q=CV, C decreases and V remains the same, so Q decreases. [0.5 mark for correct change] [0.5 mark for correct explanation] (c) Potential difference remains the same As the capacitor is connected to the battery, the potential V of the capacitor will remain the same as that of the battery. [0.5 mark for correct change] [0.5 mark for correct explanation] (d) Electric field decreases.	5

	E due to a plane sheet of charge = σ/ϵ_o is independent of the distance from the sheet. But charge density σ on the plate decreases, so E decreases. OR: Alternatively, As $E = V/d = Q/Cd = Q/\epsilon_o A$ Since Q decreases, E also decreases. [0.5 mark for correct change] [0.5 mark for correct explanation] (e) Energy stored in the capacitor decreases. Energy stored is proportional to both Q and V. Charge Q decreases but potential V is constant. [0.5 mark for correct change] [0.5 mark for correct explanation]	
Q.22	(a) The energy of the capacitor will increase. The work done on the capacitor while removing the dielectric results in an increase in energy stored in the capacitor. (or) Energy of the capacitor after the dielectric is removed: $E' = Q^2/2C'$ The charge on the plates remains the same as the capacitor is isolated. But since the capacitance decreases when the dielectric is removed, the energy of the capacitor will increase. [0.5 marks for the correct change] [1 mark for correct explanation] (b) Potential difference will increase. Potential difference after the dielectric is removed is $V' = Q/C'$ where C' is capacitance without the dielectric. Since $C' < C$ and the charge Q remains the same in an isolated capacitor, the potential difference $V' > V$. [0.5 marks for the correct change] [1 mark for correct explanation]	3

Q.23	Kinetic energy of the ball $= \frac{1}{2}mv^2$ KE = 0.5 x 2x10^{-16} x (3x10^{6})^{2} = 9 x 10^{-4} J [1 mark for the correct calculation of KE value] For the ball to move through the electric field, work to be done against the electric field is W = U = qV = 2 x 10^{-6} x 50 = 10^{-4} J [1 mark for the correct calculation of electrostatic energy required] Since the KE of the ball > Energy required to move through the field between the plates of the capacitor, the ball will strike the negative plate. [1 mark for the correct conclusion]	3
Q.24	Charge on unknown capacitor = Charge on the combination [1 mark for a correct statement of equality of charge on the two capacitors] CV = (C parallel Co)$_{eqv}$ .V/3 CV= (C + Co).V/3 C = Co/2 [1 mark for correct calculation]	2
Q.25	There will be no charge on the inner sphere P. The entire charge of 10 C will be on the outer shell Q. [1 mark for the correct charge distribution] In case some charge does appear on the inner sphere P, it creates an electric field between the inner and the outer shell causing the charge to move to the outer shell. So only the outer sphere gathers all the charge. OR In case some charge does appear on the inner sphere P, the inner shell will be at a higher potential than the outer shell Q. This will cause the entire charge to move from P to Q, so that potentials on both the shells becomes the same. [1 mark for the correct charge explanation]	2

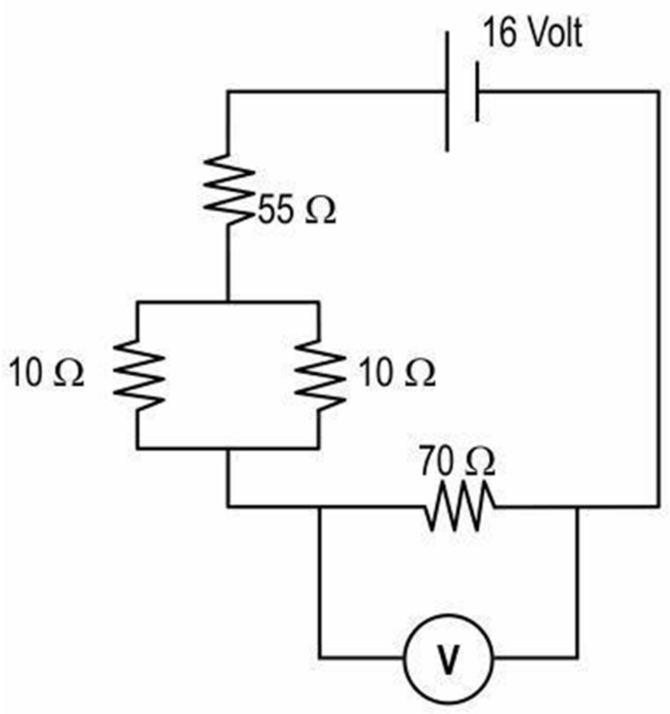
Q.26	Take potential V = 0 at initial point. After distance d, Potential V = - Ed [1 mark for correct potential difference] The electrostatic potential energy of the rod after traveling through a distance d, U_f = charge x potential difference = - λL.Ed [1 mark for correct final energy] Comparing initial and final energies of the rod, $(KE + U)_i = (KE + U)_f$ $0 + 0 = 1/2\,\mu L v^2 - \lambda LEd$ $1/2\,\mu L v^2 = \lambda LEd$ $v = \sqrt{\frac{2\lambda Ed}{\mu}} = \sqrt{\frac{2\lambda E}{\mu}}$ OR Alternatively, F = qE = ma where q = λL and m = μL substituting, for q and m, acceleration a = Eλ/μ. Using the equation of motion, $v = \sqrt{2aS} = \sqrt{\frac{2\lambda E}{\mu}}$ [1 mark for correct final result]	3

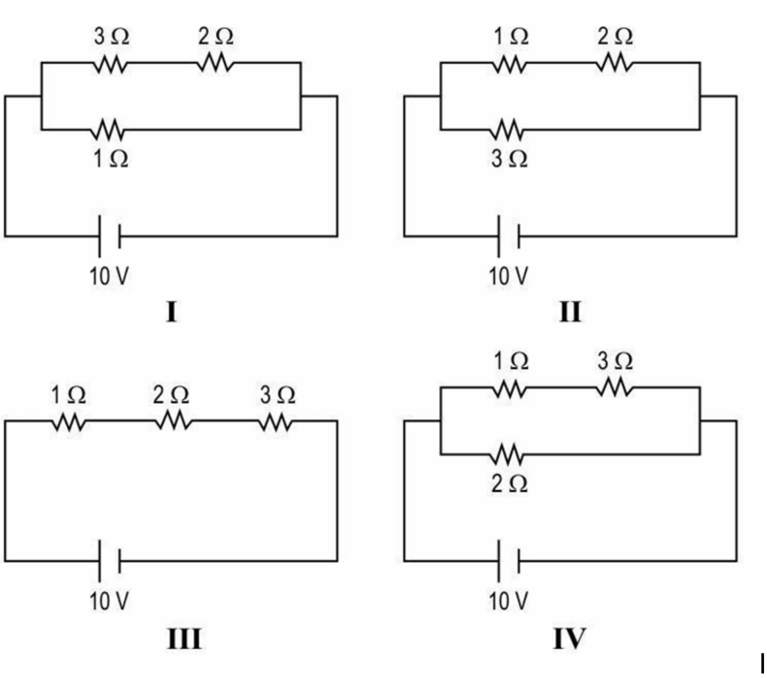
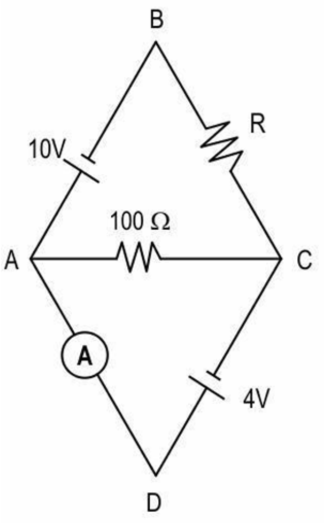
Q.27	Electric field due to +50 C above the airplane: $k\frac{q}{r^2} = 9 \times 10^9\left(\frac{50}{1000^2}\right)$ = 4.5 x 10^5 N/C, acting downwards. [0.5 mark for the correct value of electric field] Electric field due to -50 C above the airplane: $k\frac{q}{r^2} = 9 \times 10^9\left(\frac{50}{1000^2}\right)$ = 4.5 x 10^5 N/C, acting downwards. [0.5 mark for the correct value of electric field] So, the total electric field acting on the airplane = 4.5 x 10^5 N/C + 4.5 x 10^5 N/C = 9 x 10^5 N/C, acting downwards. [1 mark for the correct value of the final electric field]	2
Q.28	At point 1: 40 V change over a distance 2 cm. So electric field at point 1: E1 = 40/0.02 = 2000 V/m The direction of E_1 will be along +x axis. [1 mark for correct calculation of the E_1 value] [0.5 mark for a correct direction of E_1] At point 2: 40 V change over a distance of 4 cm. So electric field at point 2: E_2 = 40/0.04 = 1000 V/m The direction of E_2 will be along +y axis. [1 mark for correct calculation of the E_2 value] [0.5 mark for a correct direction of E_2]	3

Q.29	Force of electrostatic repulsion Fe between the two blocks is balanced by restoring force Fr due to spring, $F_e = \frac{k_e \cdot \frac{Q}{2} \cdot \frac{Q}{2}}{L_2^2}$ $F_r = k(L_2 - L_1)$ [0.5 mark each for the correct formula of the forces] At equilibrium, $F_e = F_r$ Solving for Q, $Q = \sqrt{\frac{4kL_2^2(L_2 - L_1)}{k_e}}$ [1 mark for correct final result]	2
Q.30	(a) Electric field at P = $- \frac{\Delta V}{\Delta x} = - \frac{6-2}{0.04}$ = - 100 N/C , directed downwards. [0.5 mark for the correct formula] [0.5 mark for the correct result] (b)  [1 mark for the correct drawing of electric fields lines]	2

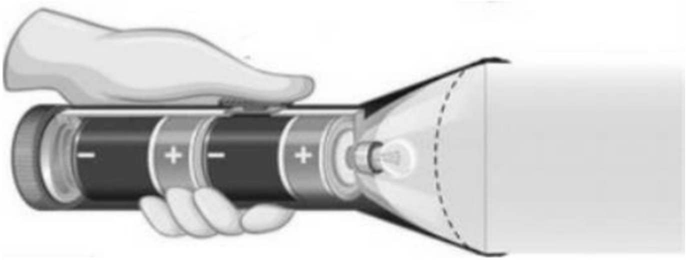
Q.31	(a) $Q_{max} = C\,V_{max}$ $Q_{max} = \frac{K \in_0 A}{d}(E_{max}d) = K \in_0 AE_{max}$ Q_{max} = 1 x 8.8 x10^{-12} x 7 x 10^{-4} x 3 x 10^{6} = 184.8 x 10^{-10} = 18.48 x 10^{-9} = 18.48 nC [0.5 mark for the correct formula] [1 mark for the correct result] (b) Q_{max} = 2 x 8.8 x$10-^{12}$ x 7 x 10^{-4} x 15 x 10^{6} = 1848 x 10^{-10} = 184.8 x 10^{-9} = 184.8 nC The change in maximum charge that can be stored = (change in charge / original charge) % = 900% [1 mark for the correct calculation and result] [0.5 mark for the correct calculation of % change]	3

2. CURRENT ELECTRICITY

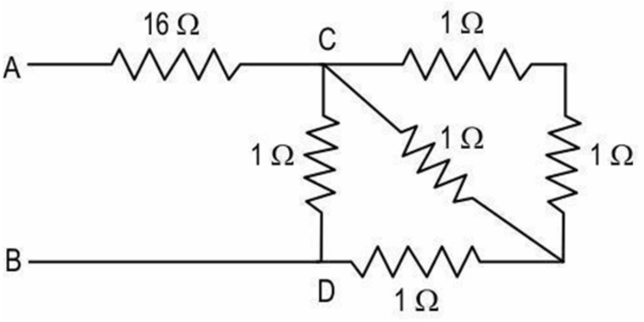
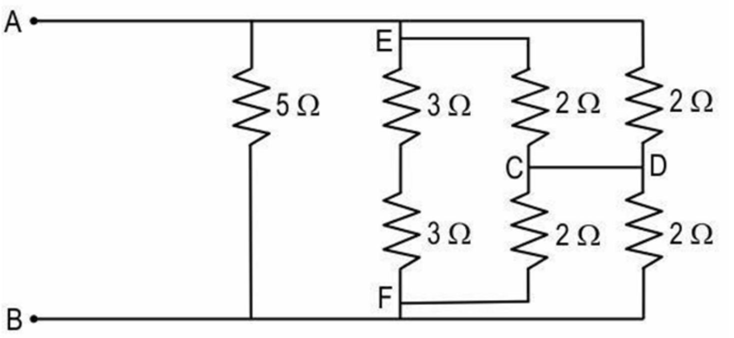
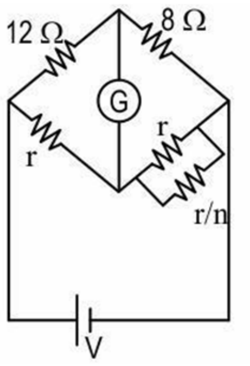
<table>
<tr><th>Q. No</th><th>Question</th><th>Marks</th></tr>
<tr><td colspan="3">Multiple Choice Question</td></tr>
<tr><td>Q.32</td><td>If the voltmeter in the given circuit reads 8 V, what is the resistance of the voltmeter?

A. 70/4119 Ω
B. 70 Ω
C. 420 Ω
D. 4200 Ω</td><td>1</td></tr>
</table>

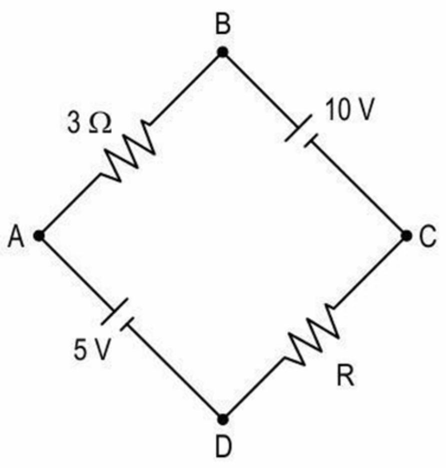
Q.33	Which combination of the three resistors will dissipate maximum power from a 10 V battery?  A. II B. III C. IV	1
Q.34	If the ammeter reading in the given circuit is zero, find the value of the resistance R.  A. 50 ohm B. 100 ohm C. 150 ohm	1

	D. 200 ohm	
Q.35	Resistances 10 Ω and R Ω are connected in the two gaps of a metre bridge. The null point is obtained at 30 cm on the metre scale from the zero end. What resistance must be connected in parallel to R so that the null point is at the mid-point of the metre wire? A. 10 Ω B. 70/3 Ω C. 70/4 Ω D. 3/70 Ω	1
Free Response Question/ Subjective Question		
Q.36	Accelerated alpha particles, constituting a beam current of 0.64 mA, are released by a cyclotron onto a target. Find the number of alpha particles that strike the target in one second.	2
Q.37	Alloys like Nichrome, whose temperature coefficient of resistance is ~ 0.4×10^{-3} /^{o}C at 20 ^{o}C, are used widely in the making of wire-bound standard resistors as their resistance changes very little with changes in temperature. (i) Find the temperature at which the resistance of a given Nichrome wire would be reduced to half its value at 20 ^{o}C. (ii) State an anomaly regarding the temperature value obtained in (i).	2
Q.38	A battery of 6 V drives a current of 60 mA through an electric lamp. Another battery of 10 V drives a current of 70 mA through the same lamp. Is the lamp an ohmic device? Explain.	2
Q.39	A dimmer is a device that is connected to a light bulb and is used to lower the brightness of the light from the bulb. It introduces a resistance in series with the bulb for this purpose. A 44 W bulb in a household circuit is connected across a 220 V power supply. (a) How much current does the bulb draw initially without the dimmer in action? (b) What resistance in series would the dimmer introduce in order to drive a current of 0.1 A through this bulb?	3

Q.40	Eva needs a 3 V power supply for her electronic circuit experiment. There is a 10 V battery in the lab that she can use. Eva decides to make a voltage divider using this battery and two different resistors, the larger value resistor being 300 ohm. What value of the smaller resistor should Eva use to make the desired voltage divider?	2
Q.41	A flashlight uses two batteries, each of emf 2 V and internal resistance 0.1 ohm, in series. The flashlight bulb has a resistance of 10 ohm.  (a) What is the current drawn by the flashlight bulb? (b) How much power is dissipated through the flashlight bulb? (c) If the two batteries have zero internal resistances, will the power dissipated through the flashlight bulb be more or less? Calculate the difference.	4
Q.42	In order to discourage the use of personal electrical appliances by the guests in the rooms of a motel in a small town, each 220 V socket in the room is wired with a circuit breaker on a 5 A line. Sam wishes to iron his clothes using his 1200 W, 220 V portable steam iron box in his motel room. (a) Will Sam be able to use his iron box without tripping the circuit breaker? Explain. (b) Find the resistance of his iron box.	2

Q.43	Tim is a music enthusiast who wishes to create good sound effects for his stereo system using his two sets of speakers at home. The first set consists of two speakers of resistance 10 Ω each. The second set consists of two speakers with resistances 5 Ω and 10 Ω respectively. Initially, he connects the first set of two 10 Ω speakers in series to the 10 V stereo output. Later, he connects the second set of speakers such that each of them is parallel to the first set of speakers. (a) What is the current through each of the 10 Ω speakers BEFORE the second set of speakers were connected? (b) What is the new current through each of the 10 Ω speakers AFTER the second set of speakers are connected? (c) If the loudness of the music is directly proportional to the amount of power used by the speaker, how has the loudness of the first set of speakers changed due to the introduction of the second set of speakers? (d) What is the impact of connecting the second set of speakers in the circuit here?	3
Q.44	Rene uses a portable electric lamp to light up her keyboard when working on her computer at night. The lamp consists of two small bulbs each of resistance 2 ohm connected in series and is powered by a 20 V battery. (a) How much current is drawn by the portable lamp? (b) Each of the two bulbs in the portable lamp is rated for continuous use of 10 hours only before they burn out. If the battery can supply total energy of 4000 kJ, which of the two occurs first: the lamp burns out or the battery drains out? Show the working.	2
Q.45	In the given network of resistors, the 16-ohm resistor burns out as soon as it begins to dissipate 100 W of power.	3

	 What MAXIMUM voltage can be applied across terminals A and B, in order to avoid the burn out of the 16-ohm resistor?	
Q.46	Determine the equivalent resistance of the following combination of resistors. Show the working (include diagrams if required). 	2
Q.47	A Wheatstone's bridge employs 5 resistors as shown. Find the value of n that will ensure that the bridge is always in a balanced condition, irrespective of the value of r. 	2

Q.48	Determine the value of R in the given network for each of the conditions separately.  i. If $V_B – V_D = 8$ V ii. If $V_A - V_C = 8$ V	4

Answer Key & Marking Scheme

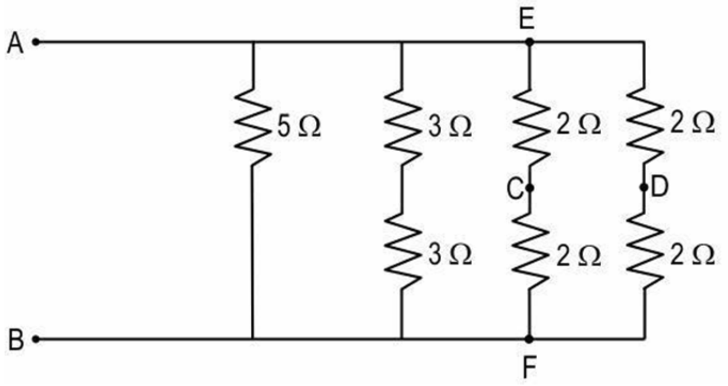
Q.No	Answers	Marks
Q.32	C. 420 Ω	1
Q.33	A. I	1
Q.34	C. 150 ohm	1
Q.35	C. 70/4 Ω	1
Q.36	Current I = nQ/t = n x 2e/1 [1 mark for the correct formula] $n = I/2e = \frac{0.64 \times 10^{-3}}{2 \times 1.6 \times 10^{-19}} = 2 \times 10^{15}$ alpha particles [1 mark for the correct calculations]	2
Q.37	(i) Using $R = Ro\ (1 + \alpha\ \Delta T)$ $Ro\ /2 = Ro\ (1 + \alpha\ \Delta T)$ $\Delta T = -\ 1250\ ^{o}C$ $T - To = -1250\ ^{o}C$ $T = -\ 1230\ ^{o}C$ [0.5 marks for the correct formula] [0.5 marks for the correct calculations] (ii) Anomaly: Since the T = - 1230 ^{o}C, is below 0 K or -273 ^{o}C, it is physically impossible to arrive at this temperature. [1 mark for the correct point]	2

Q.38	It’s a non-Ohmic device. [0.5 mark for correct conclusion] Explanation: Voltage change: v_2/v_1 = 10/6 = 0.6 Current change: I_2/I_1 = 70/60 = 1.16 When the voltage rises by a factor of 0.6, the corresponding current rises by the factor, 1.16. Since the proportion change in voltage and the current is not the same, the electric lamp is a NON-Ohmic device. [1 mark for the correct calculations of voltage and current change] [0.5 mark for the correct explanation of the conclusion] OR Resistance of the circuit in the first case= V/I = 6/60 x 10-3 = 100 ohm Resistance of the circuit in the second case= V/I = 10/70 x 10-3 = 1000/7 = 142.8 ohm. The resistance represents the slope of V-I graph for the circuit and from the above calculations, it doesn’t remain constant. It implies that V-I graph is not a straight line. Hence the lamp used in the circuit is a non-ohmic device. [1 mark for the correct calculations of resistance values] [0.5 mark for the correct explanation of the conclusion]	2
Q.39	(a) Initially, without any dimmer in action, current through the bulb: P = VI I = P/V = 44/220 = 1/5 = 0.2 A [1 mark for the correct calculation of the current] (b) Resistance of the bulb: P= V_2 /R_1 R = 220 x 220 / 44 = 1100 ohm With the introduction of the resistance in series by the dimmer, V = I R R = 220 /(0.1) = 2200 ohm	3

	$R = R_1 + R_2$ where R_2 is the resistance in series introduced by the dimmer So $R_2 = 2200 – 1100 = 1100$ ohm. [1 mark for the correct value of resistance R_1] [1 mark for the correct value of resistance R_2]	
Q.40	Two resistors R_1 (= 300 ohm) and R_2 are connected in series for making the voltage divider. $R_1 = 300$ ohm, $v_1 = I R_1$ $7 = 300.I$ ……(1) [0.5 mark each for writing equation (1)] Across the combination of two resistors, $10 = (R_1 + R_2) I$ …..(2) Solving for smaller resistor R_2 $R_2 = 900/7$ ohm = 128.6 ohm [0.5 mark each for writing equation (2)] [1 mark for calculation and correct result]	2
Q.41	(a) Total voltage across the two batteries in series = 2 + 2 = 4 V Total resistance in circuit = 0.1 + 0.1 + 10 = 10.2 ohm Current through the flashlight bulb = $I = V/R = 4/10.2$ A [1 mark for the correct value of the current] (b) Power dissipated through the flashlight bulb = $I_2 R = (4/10.2)^2 \times 10 = 1.52$ W [1 mark for the correct value of the current] (c) If the two batteries have zero internal resistances, the power dissipated through the flashlight bulb will increase. The current through the flashlight bulb, $I = V/R = 4/10 = 0.4$ A Power dissipated through the flashlight bulb = $I_2 R = (0.4)^2 \times 10 = 1.6$ W The difference = 1.60 – 1.52 = 0.08 W	4

	[1 mark for the correct value of the current] [1 mark for the correct value of the difference in the power] [Note: Depending on number of decimal places taken, the answer to the sub-question (b) may vary between 1.52 and 1.54 and accordingly the answer to this question may vary between 0.08 - 0.06. Award marks accordingly.]	
Q.42	(a) No, he will not be able to. P = VI Current drawn I = P/V = 1200/220 = 5.45 A Since the current drawn by steam iron is more than 5A, the circuit breaker will trip. [1 mark for the correct calculation of current] [0.5 mark for the correct conclusion] (b) The resistance of iron box: $P = V^2/R$ R = 220 x 220 /1200 = 40.3 ohm [0.5 mark for the correct result]	2
Q.43	(a) BEFORE the second set of speakers were connected: Total resistance = 10 + 10 = 20 Ω Current drawn from the stereo output = I = 10/20 = 0.5 A Since the two 10 Ω speakers are in series, the current through each one of them is 0.5 A. [1 mark for the correct value of current through the series combination] [0.5 mark for the correct conclusion]	3

	(a) AFTER each of the two speakers of the second set was connected in parallel to the first set of speakers: The total voltage across the first set of speakers remains the same as earlier, that is, 10 V. So the current through each of the two 10 Ω speakers of the first set remains the same as earlier. That is, 0.5 A. [0.5 mark for the correct result] (b) No change in the loudness of the first set of speakers, as the current and the power dissipated through each one of them remains unchanged even after the second set of speakers are connected. [0.5 mark for the correct conclusion] (c) Any ONE of the following points: - The amount of current drawn from the stereo output increases. - Additional power is dissipated through the two speakers of the second set. [0.5 mark for anyone correct point]	
Q.44	(a) Resistance of the lamp, R = 2 + 2 = 4 ohm Current through each lamp = I = V/R = 20/4 = 5 A. [1 mark for the correct value of current] (b) Energy consumed by the lamp in one second = VI = 20 x 5 = 100 J 4000 kJ of battery energy will last for 4000000/100 = 40000 s ~ 11 hours. So the bulbs burn out before the battery drains out. [1 mark for the correct result]	2

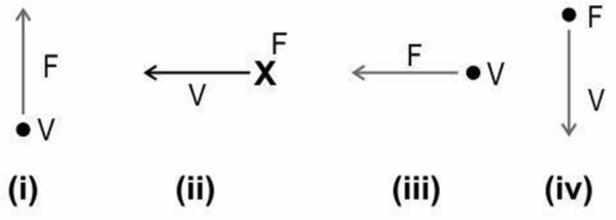
Q.45	The maximum voltage that can appear across 16 ohms: $P = V_1^2/R_1$ $V_1 = \sqrt{PR_1} = \sqrt{100 \times 16}$ = 40 volt [0.5 marks for correct calculation of maximum voltage that can appear across 16 ohms] Equivalent resistance R_2 across C and D: R_2 = 5/8 ohm [1 mark for correct calculation of equivalent resistance between C and D] As R_1 and R_2 are in series, $V_1/R_1 = V_2/R_2$ $V_2 = \frac{V_1}{R_1} R_2$ = 40 x 5/(16 x 8) = 25/16 = 1.56 volt [1 mark for correct calculation of V_2] So the maximum voltage that can be applied across A and B, $V_1 + V_2 = 40 + 1.56 = 41.5$ volt [0.5 marks for correct final result]	3
Q.46	From the symmetry, the terminals C and D are at the same potential. So the network can be reduced to the following:  [1 mark for the simplification point of the network]	2

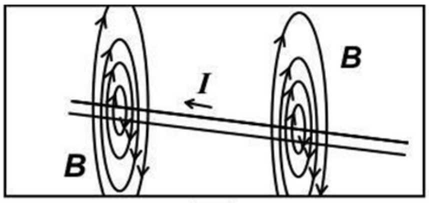
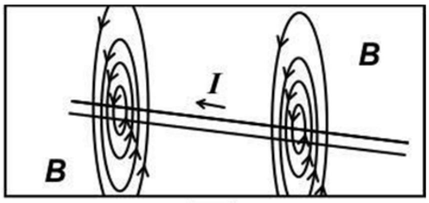
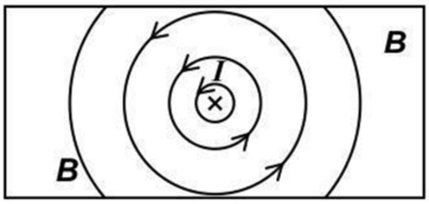
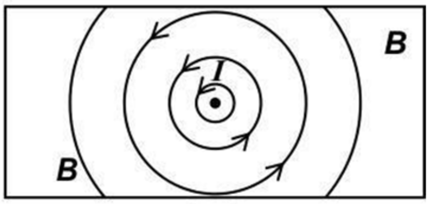
	So 5 Ω, 6 Ω, 4 Ω, 4 Ω are in parallel. $\frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{6} + \frac{1}{4} + \frac{1}{4}$ Substituting and solving, $1/R_{eq} = 13/15$ $R_{eq} = 15/13$ [1 mark for correct calculation of Req]	
Q.47	For balanced condition, $\frac{12}{8} = \frac{3}{2} = \frac{r}{r_{eq}}$ **where,** $\frac{1}{r_{eq}} = \frac{1}{r} + \frac{n}{r} = \frac{1+n}{r}$ $r_{eq} = \frac{r}{1+n}$ [1 mark for the calculation of the correct value of r_{eq}] $\frac{3}{2} = \frac{r\,(1+n)}{r}$ Solving for n, n = 1/2 [1 mark for the calculation of the correct value of n]	2
Q.48	i. For VB – VD = 8 V: Let i be the current through the loop in the anticlockwise direction, Applying Voltage rule along the arm BAD -3i – 5 = - 8 So i = 1 A [1 mark for correct application of the voltage rule] Applying Voltage rule along the arm BCD -10 + iR = -8 -10 + R = -8	4

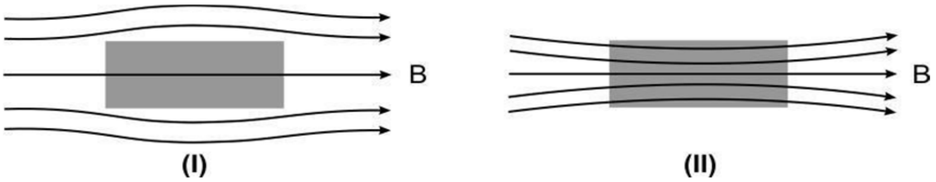
	so $R = 2\ \Omega$ [1 mark for correct application of the voltage rule] ii. For $V_A - V_C = 8$ V : Let i' be the current through the loop in the anticlockwise direction, Applying Voltage rule along the arm ABC $3i' - 10 = -8$ So $i' = 2/3$ A [1 mark for correct application of the voltage rule] Applying Voltage rule along the arm ADC $-5 - i'R = -8$ $-5 - 2R/3 = -8$ so $R = 9/2\ \Omega$ [1 mark for correct application of the voltage rule]	

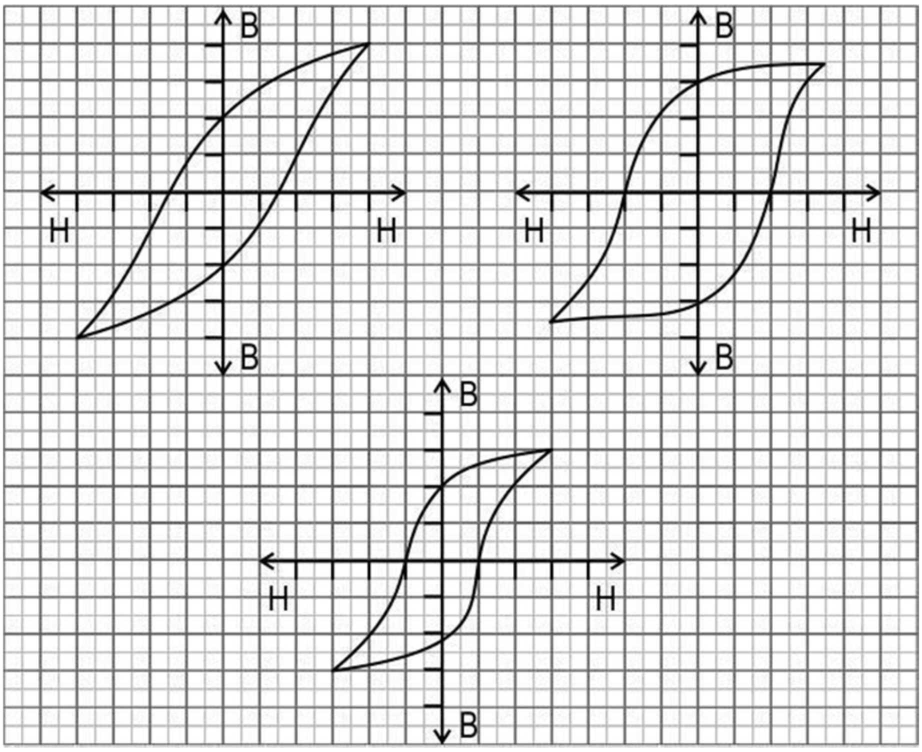
3. MAGNETIC EFFECTS OF CURRENT AND MAGNETISM

Q. No	Question	Marks
Multiple Choice Question		
Q.49	Read the following points of comparison between electric and magnetic fields carefully. i. Both Coulomb's law and Biot- Savart's laws follow inverse square law. ii. Both electric and magnetic field values depend upon the angle between the displacement vector and the field source. iii. Electric field is produced by a scalar source whereas magnetic field is produced by a vector source. iv. The direction of the magnetic field is along the displacement vector joining the field source and field point. On the other hand, the electric field is perpendicular to the plane containing the displacement vector joining the field source and the field point. Identify the correct statements. A. only i and ii B. only iii and iv C. only ii and iv D. only i and iii	1
Q.50	A deuteron and an alpha particle move with the same kinetic energy under the effect of identical magnetic fields. What will be the ratio of the radii of their paths followed? A. 1 B. √2 C. 1/2 D. 2	1
Q.51	A particle of charge q and mass m projected with a speed v into a uniform magnetic field B undergoes circular motion under the effect of magnetic force. Identify an INCORRECT statement.	1

	A. Both KE and PE of this charged particle remain constant. So no work is done by the magnetic field on it. B. An identical charged particle projected at an angle other than 90o with magnetic field B will undergo helical motion. C. Another charged particle of a different specific charge, projected with the same speed will still have the same angular frequency. D. An identical charged particle projected with double the speed in the same magnetic field will follow a circular path of larger circumference than the earlier one but with the same time period.	
Q.52	A negatively charged particle moves with velocity v through a magnetic field B and experiences a magnetic force F. In each of the diagrams below, the representation of magnetic field lines is missing.  Identify the probable direction of magnetic field lines in each case as Left, Right, Upwards or Downwards. A. i-Right, ii-Upwards, iii-Upwards, iv-Right B. i-Left, ii-Downwards, iii-Downwards, iv-Left C. i-Downwards, ii-Right, iii-Upwards, iv-Upwards D. i-Left, ii-Right, iii-Upwards, iv- Downwards	1
Q.53	Each of the diagrams represents magnetic field lines around a wire carrying current I from different perspectives. Identify which of the following representations are correct.	1

	 i  ii  iii  iv A. only i and iv B. only ii and iii C. only i and iii D. only ii and iv	
Q.54	A rod of insulating material of length 0.5 m carries a static charge of 1 C at one end. The rod is rotated in a vertical plane about a horizontal axis passing through the other end with an angular frequency of 10π rad/s. What is the magnetic field at the center of the circular path? A. $2\pi \times 10^{-6}$ T B. $4\pi^2 \times 10^{-6}$ T C. 0.4×10^{-7} T D. Zero	1
Q.55	A wire of length L carrying a current I can be turned into a circular coil of N turns. For what turned value of N, will the magnetic moment of this current carrying coil be maximum? A. one B. 4πL C. infinite D. (Magnetic moment is a constant for a given L and is independent of N)	1

Q.56	Which of the following statements is INCORRECT for a magnetic dipole? A. A freely suspended magnetic dipole in a uniform magnetic field always turns to align parallel to the external magnetic field. B. A magnetic dipole that is free to move in a non-uniform magnetic field can slide as well as rotate. C. The torque required to hold a freely suspended magnetic dipole is maximum when the dipole is perpendicular to the direction of the external magnetic field. D. A small angular displacement given to a magnetic dipole result in a simple harmonic motion about its original position, irrespective of its orientation in a uniform magnetic field.	1
Q.57	Two blocks of different materials are placed in a uniform magnetic field B. The magnetic field lines passing through the two blocks are represented as follows.  Identify the suitable values of relative permeability μ_r and magnetic susceptibility χ for the materials I and II. A. For I : $\mu_r > 1, \chi < 0$, For II : $\mu_r < 1, \chi > 0$ B. For I : $\mu_r < 1, \chi = 0$, For II : $\mu_r > 1, \chi = 0$ C. For I : $\mu_r = 0, \chi = 1$, For II : $\mu_r = 1, \chi = 0$ D. For I : $\mu_r < 1, \chi < 0$, For II : $\mu_r > 1, \chi > 0$	1
Q.58	An electromagnet is a current-carrying solenoid with a core as a magnetic material. Given below are B-H (net field Vs. magnetizing field) curves of three different magnetic materials.	1

	 Identify the most suitable magnetic material using their B-H curves, that can be used for the purpose of an electromagnet core. A. I is better than II and III B. II is better than I and III C. III is better than I and II D. II and III are better than I	
Q.59	Read the following statements carefully: I. Steel has high retentivity, high coercivity, and high permeability. II. Soft iron has higher permeability, lower retentivity, and lower hysteresis loss compared to steel. III. Amorphous metals are non-crystalline solids of very high resistivity and allow very less hysteresis losses (example: an alloy of Fe, Ni, Co and glass). Their B-H (net field Vs. magnetizing field) curve is very narrow. Based on the above material-specific properties, identify which materials are MOST suitable for the given electrical applications.	1

I. Steel	A. Transformer core
II. Soft iron	B. Permanent magnets
III. Amorphous metals	C. Electromagnet

A.

I – A, B	II – B, C	III – C, A

B.

I – B	II – C	III – A

C.

I – B	II – C, A	III – A, B

D.

I – A	II – C	III – B

E.

Q.60 Consider the standard values of magnetic properties of three unknown metals. 1

Metal P	$\mu_r = 1.0003$	$\chi = 3 \times 10^{-4}$ SI units
Metal Q	$\mu_r = 0.99$	$\chi = - 9.63$ SI units
Metal R	$\mu_r = 5000$	$\chi = 4.9 \times 10^{3}$ SI units

Identify which of the following does NOT suggest the expected behaviour of these metals.

A. With the rise in temperature, the μ_r value of R changes whereas for Q, it remains constant.

B. When placed in an identical external magnetizing field, the lines of magnetic field through metal R become denser as compared to metal P.

C. When placed in identical external magnetizing field B, the net magnetic field inside Q is more than B whereas the net magnetic field inside P is less than B.

D. If the applied external magnetizing field B is non-uniform and the metals are free to move, Q moves from stronger to weaker field points whereas R moves from weaker to stronger field points.

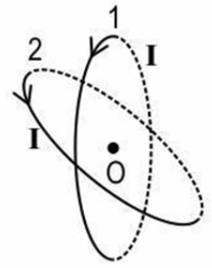
Q.61	A freely suspended magnetic dipole is aligned along the magnetic meridian. Four points A, B, C and D are located at equal distances from the centre of the magnetic dipole towards the north, east, south, and west of the dipole respectively. i. Direction of the magnetic field due to the dipole is same at A and C. ii. Direction of the magnetic field due to the dipole is same at A and D. iii. Direction of the magnetic field due to the dipole is opposite at B and D. iv. Direction of the magnetic field due to the dipole is opposite at C and D. v. Direction of the magnetic field due to the dipole is same at B and D. vi. Direction of the magnetic field due to the dipole is opposite at A and C. Select the correct option. A. Statements (iii) & (vi) are correct B. Statements (iv) & (v) are correct C. Statements (i), (ii) & (iii) are correct D. Statements (i), (iv) & (v) are correct	1
Q.62	When a ferromagnetic material goes through the hysteresis loop of magnetization, which of the following changes in magnetic susceptibility value is/are possible? (i) Magnetic susceptibility of a ferromagnetic material is independent of magnetizing field. (ii) Magnetic susceptibility of a ferromagnetic material is zero through the entire loop. (iii) Magnetic susceptibility of a ferromagnetic material is infinite through the entire loop. (iv) Magnetic susceptibility of a ferromagnetic material is negative through the entire loop. (v) Magnetic susceptibility of a ferromagnetic material can be zero, negative, positive, or infinity at different parts of the loop. A. Only (i) is correct. B. Only (ii) is correct. C. Only (v) is correct. D. Either (ii) or (iii) or (iv) could be correct depending upon the material.	1

Free Response Question/Subjective Question

Q.63

Two identical coils with a common centre are oriented at an angle of 45^o to each other. Both the coils have the same radius 'a', the same number of turns 'n', and carry the same current 'I'.

What is the value of the resultant magnetic field at their center O?



2

Q.83

Three particles are projected into identical magnetic fields.

Particle	Proton	Deuteron	Alpha particle
Speed of projection	10^6 m/s	10^6 m/s	10^6 m/s
Angle between v and B	30^o	90^o	60^o
Charge q	e	e	2e
Mass M	m	2m	4m

Answer the following. Show the working in each case.

i. Which of the particles will revolve along the circular paths with maximum frequency?

ii. Identify the particle/s that will follow a spiral path.

iii. Which particle/s revolves around the curved path of maximum radius?

5

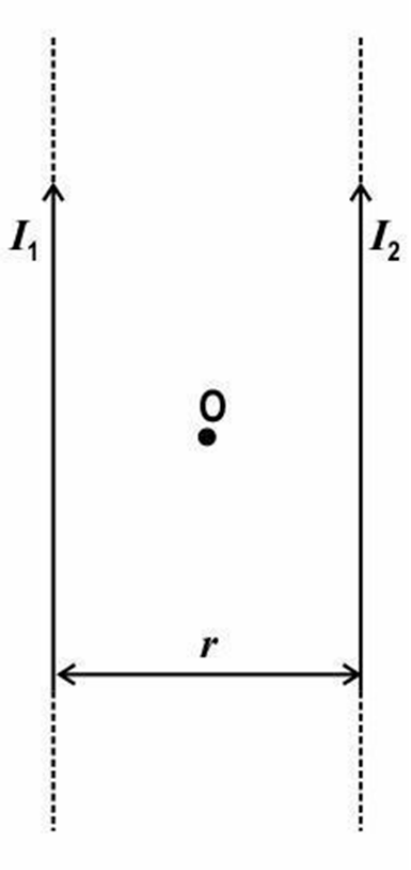
Q.65

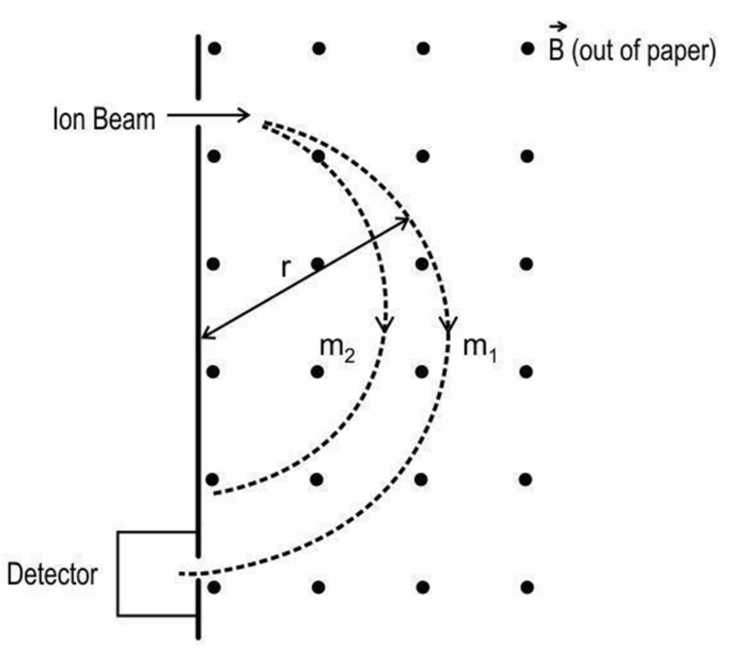
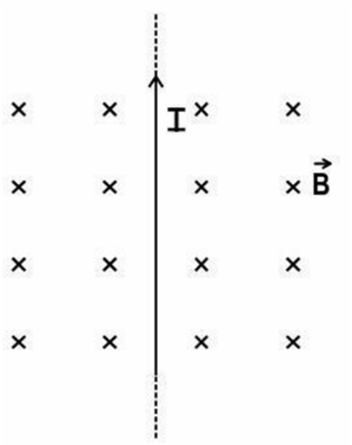
Two parallel current-carrying wires are placed at a perpendicular distance of r from each other.

a. Find the net magnetic field at the midpoint O if current $I_1 > I_2$.

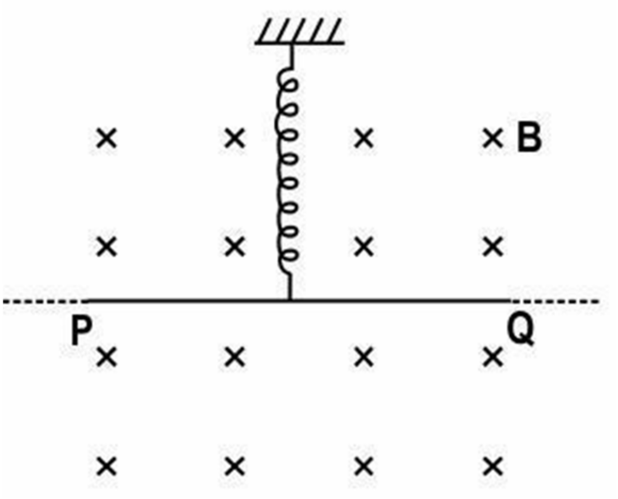
b. What is the effect on the net magnetic field at O in case if current $I_1 < I_2$?

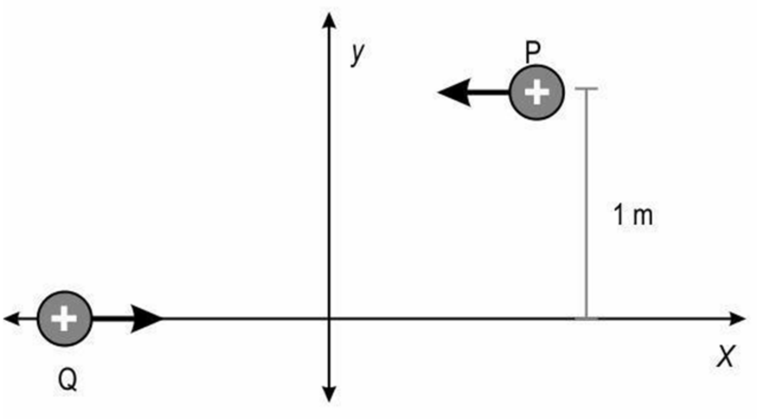
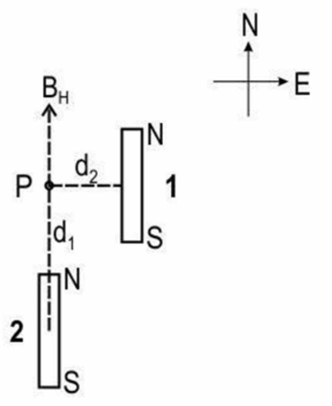
3

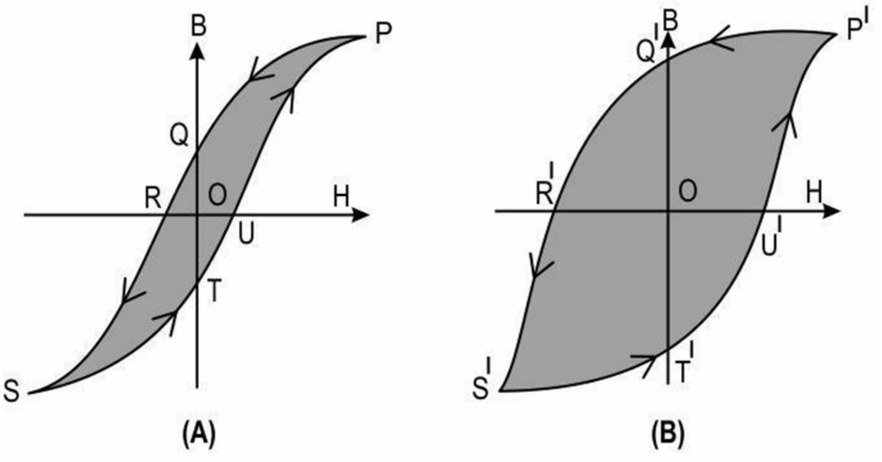
		
Q.66	A straight wire of length 4 m carrying a current of 0.5 A can be turned into either a square or a circular loop of 2 turns, before placing it in a magnetic field of intensity 0.1 T. Which loop do you think will require less counter torque in order to hold it in a position such that the axis of the 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 x 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

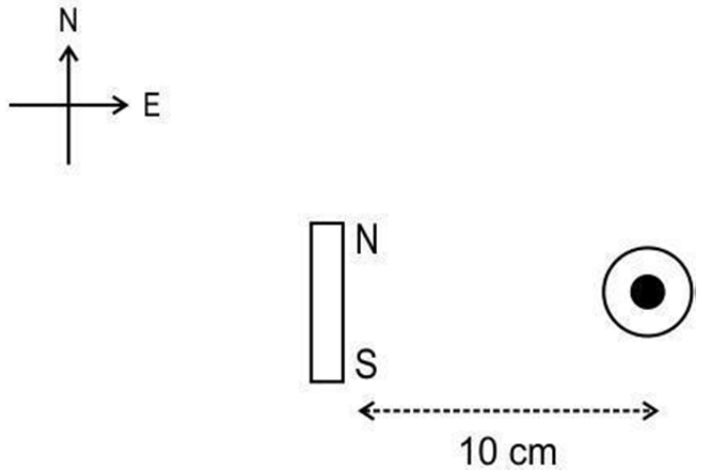
	 Another stream of singly charged particles of mass $m_2 = 0.2 \times 10^{-26}$ kg, projected through the same accelerating potential and into the same magnetic field B_1, fail to reach the detector. To what value should the magnetic field be changed so that this stream of particles strikes the detector?	
Q.68	A wire carrying a current I = 200 A in the upward direction is placed in a magnetic field $B = 2 \times 10^{-3}$ T as shown in the figure.  A null point represents the location of a point with zero net magnetic field. (a) On which side of the wire will a null point be located? (b) On which side of the wire will a null point be located if the direction of applied magnetic field B is reversed? Calculate the perpendicular distance of the null point from the wire.	3

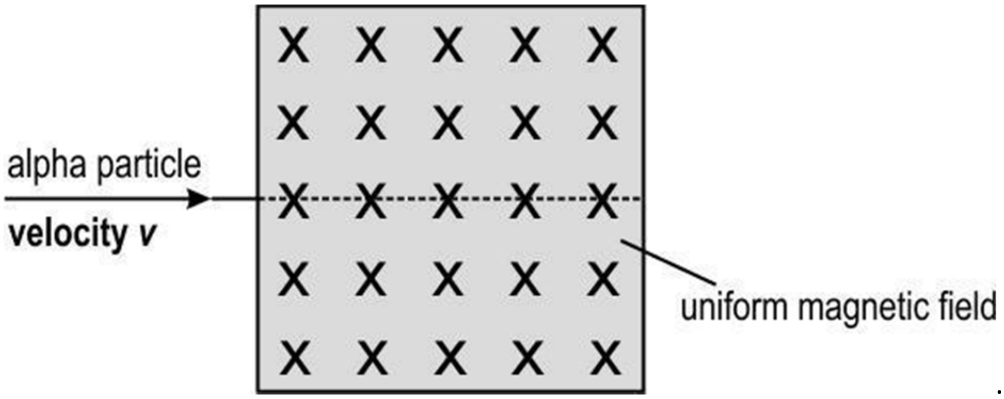
Q.69	An electric field E = 2000 N/C is directed vertically downwards and a horizontal magnetic field B is directed eastwards in a given velocity selector. A stream of charged particles projected southwards at a speed of 2×10^3 m/s is able to pass through this velocity selector completely undeflected. A different particle of charge +3 µC, when projected southwards with a speed v in the above magnetic field, experiences a net force of 2×10^{-3} N, pointing vertically downwards. Find v.	2
Q.70	A uniform magnetic field B, directed along negative z-axis and of value 2×10^{-3} T extends through 1 meter along x-axis, beyond which it becomes non-uniform. A singly charged ion of mass 1.6×10^{-26} kg is projected along the positive x-axis into the magnetic field. What should be the maximum velocity v of projection of the ion such that it just fails to enter the non-uniform part of the magnetic field region, but instead emerges out of the uniform magnetic field region with a velocity v along the negative x-axis?	2
Q.71	A loop of area A carrying a current I when placed in an external magnetic field B experiences torque. (a) What is the direction of the torque with respect to the plane of the loop? (b) Can the loop rotate around itself like a spin wheel due to this torque? Give a reason for the answer. (c) What is the shape of the graph between torque and angle θ, as it varies between 0 and 180^o? Represent it pictorially. (d) State the orientation of the current-carrying loop with respect to the external magnetic field in which the total magnetic flux through its area is minimum. Does this orientation constitute the stable or unstable equilibrium of the loop?	4
Q.72	A long straight current-carrying wire is placed in proximity to a current-carrying solenoid of 100 turns per unit length. (a) Identify suitable orientation of the current-carrying solenoid with respect to the current-carrying wire, such that the net magnetic field along the axis of the solenoid is zero. State the suitable directions of the current in each one also. (b) If the ratio of the currents through the straight wire and solenoid is 200, find the perpendicular distance between the straight current-carrying wire and the axis of the solenoid, which ensures a net zero magnetic field along the axis of the solenoid.	4

Q.73	A uniform magnetic field B = 0.002 T acts on a 2 cm long section PQ of an insulated wire. The wire is attached to a spring of spring constant 0.8 N/m as shown in the figure.  (a) What value of current should flow through PQ such that the spring is stretched by 2 x 10^{-4} m? (b) Identify the possible direction of current through section PQ.	3
Q.74	A rotating table of diameter 0.5 m has a wire stretched across its surface passing through its center. An electric current of 0.25 A flows through this wire and a magnetic field of 0.8 T is applied in the plane of the rotating table. (a) Does the magnetic force acting on the wire depend on the angle between the wire and magnetic field? (b) Find an angle between the wire and magnetic field such that the magnetic force on the wire is equal to 0.05N. (c) What is the effect on the magnetic force in case the magnetic field is applied perpendicular to the plane of the table? Give a reason for your answer.	2
Q.75	P and Q are two identical charged particles of mass 4 x 10^{-26} kg and charge 4.8x 10^{-19} C, each moving with the same speed of 2.4 x 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.	2

	 Find (a) the direction of the magnetic field and (b) the magnitude of the magnetic field applied in the region.	
Q.76	Two magnets of magnetic moment m1 = 1 Am2 and m2 = 4 Am2 respectively are directed along the magnetic meridian as shown.  If the point P, along the magnetic meridian at a distance d_1 = 20 cm from the center of magnet 1, must be maintained at a zero magnetic field intensity due to magnets 1 and 2, then, (a) Find the suitable perpendicular distance d2 at which magnet 2 should be placed without disturbing magnet 1. Take the horizontal component due to Earth's magnetic field as BH = 0.3 x 10-4T. The final answer may be expressed in fraction. (b) Describe the consequence of reversing the polarities of the magnet 2 on point P and the distance d_2 from magnet 2.	3
Q.77	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.78	A magnet of magnetic moment m is tied to another magnet of moment 3m, with similar poles above each other. The combination is freely suspended by a string in a steady magnetic field and upon disturbance oscillates with a time period of 5 s. Now if the magnet of moment 3m has its polarities reversed in the above combination, determine the time period of the oscillation.	3
Q.79	At place A, where the angle of dip is 45^o, a magnet oscillates with a frequency of 12 oscillations per minute and at place B, where the angle of dip is 60^o, the magnet oscillates with a frequency of 10 oscillations per minute. If the total magnetic field strength of Earth's field at A is 0.3×10^{-4} T, find its value at place B.	2
Q.80	Given below are the hysteresis loops or B-H (net magnetic field Vs. magnetizing field) curves of two magnetizing materials.  (a) How do the residual magnetic field in (A) and (B) compare when the external magnetizing field H is reduced to zero? (b) In which specimen is the magnetic field required to destroy the residual magnetism higher? (c) Which of the two materials will undergo a greater loss of energy for every cycle of magnetization? Give a reason for your answer. (d) Which of the two materials is suitable for the making of electromagnets? Give a reason for your choice.	3

Q.81	A freely suspended bar magnet aligned in the magnetic meridian oscillates in the horizontal plane with a time period of 0.2 s. A vertical current-carrying wire is placed at a perpendicular distance of 10 cm from the centre of the magnet.  If a current of 6 A flows through the wire upwards, what is the new time period of oscillation of the bar magnet? Take horizontal component of Earth's magnetic field = 24 μT.	3
Q.82	The magnetic field inside a current-carrying toroid is Bo. When the space inside the toroid is filled with a material of susceptibility χ, the magnetic field along its core becomes B. Show that the percent increase in the magnetic field inside the toroid is 100 times χ.	2

Q.83	An alpha particle is moving with a velocity v. It enters a magnetic field (B) as shown below. The magnetic field is perpendicular and into the plane of paper.  . A uniform electric field is applied in the same region as the magnetic field so that the alpha particle passes undeviated through the combined fields. (a) What should be the direction of the electric field? (b) Without any change in the electric and magnetic field, the alpha particle is replaced by the following particles: (i) proton moving with a velocity v (ii) electron moving with a velocity v/2 Will there be any change a deviation in the path of the particles? Give a reason for your answer.	2

Answer Key & Answer Scheme

Q. No	Answers	Marks
Q.49	D. only i and iii	1
Q.50	B. $\sqrt{2}$	1
Q.51	C. Another charged particle of a different specific charge, projected with the same speed will still have the same angular frequency.	1
Q.52	B. i-Left, ii-Downwards, iii-Downwards, iv-Left	1
Q.53	A. only i and iv	1
Q.54	A. 2π x 10^{-6} T	1
Q.55	A. one	1
Q.56	D. A small angular displacement given to a magnetic dipole results in a simple harmonic motion about its original position, irrespective of its orientation in a uniform magnetic field.	1
Q.57	D. For I : $\mu_r < 1$, $\chi < 0$, For II : $\mu_r > 1$, $\chi > 0$	1
Q.58	A. I is better than II and III	1
Q.59	B. I – B II – C III – A	1
Q.60	C. When placed in identical external magnetizing field B, the net magnetic field inside Q is more than B whereas the net magnetic field inside P is less than B.	1
Q.61	D. Statements (i), (iv) & (v) are correct	1
Q.62	C. Only (v) is correct.	1

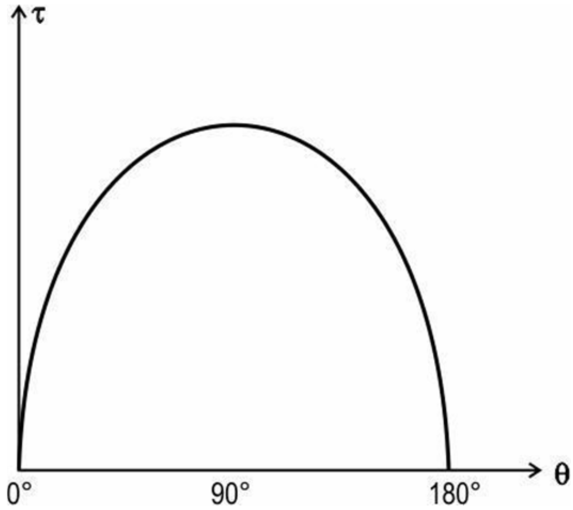
Q.63	The magnetic field at the center O of coil 1 : $B_1 = \frac{\mu_0 nI}{2a}$ The magnetic field at the center O of coil 2: $B_2 = \frac{\mu_0 nI}{2a}$ [0.5 mark for each correct formula] The resultant magnetic field at the center O: $B = \sqrt{B_1^2 + B_2^2 + 2B_1B_2\cos\theta}$ Substituting and taking angle θ = 45, $B = \frac{\mu_0 nI}{2a}\sqrt{2+\sqrt{2}}$ [1 mark for correct calculation and final result]	2
Q.64	i. Frequency of revolution $n = \frac{qB}{2\pi m}$ Since B is the same for all, Frequency n is proportional to q/m np proportional to e/m nd proportional to e/2m nα proportional to 2e/4m, that is, e/2m Proton will have a maximum frequency of revolution. (1 mark for the correct conclusion) ii. The particle that has velocity component parallel to magnetic field direction will have a spiral path. [0.5 mark for a correct statement of the condition for a particle to move along spiral path] Proton is projected at 30^o to B: The velocity component parallel to B, that is, v cos30 = √3.v/2. So proton will follow a spiral path. The deuteron is projected at 90^o to B: The velocity component parallel to B, that is, v cos90 = 0. So deuteron will follow a circular path.	5

	Alpha particle is projected at 60^o to B: The velocity component parallel to B, that is, v cos60 = v/2. So the alpha particle will follow a spiral path. [0.5 mark for each conclusion] iii. Radius of the circular path = $R = \frac{mv\perp}{qB}$ Since B is same for all particle, For proton, $R \alpha \frac{mv \sin 30}{e} = \frac{mv}{2e}$ For deuteron, $R \alpha \frac{2\ mv \sin 90}{e} = \frac{2\ mv}{e}$ For alpha particle, $R \alpha \frac{4\ mv \sin 60}{2e} = \sqrt{3} \cdot \frac{mv}{e}$ Deuteron has the maximum radius. [0.5 mark for each of the correct statement of radius] [0.5 mark for the correct conclusion]	
Q.65	a. B_1 at O due to I_1 is $= \frac{2\mu_0 I_1}{2\pi r}$ acting into the plane of the paper. B_2 at O due to I_2 is $= \frac{2\mu_0 I_2}{2\pi r}$ acting out of the plane of the paper. [0.5 mark each for correct formula and the direction of the magnetic field due to each current-carrying wire] If $I_1 > I_2$, then $B_1 > B_2$ and net magnetic field,B $= B_1 - B_2 =$	3

	$= \frac{\mu_0}{\pi r}(I_1 - I_2)$ acting into the plane of the paper. [1 mark for the correct formula of the net magnetic field along with the direction] b. If $I_1 < I_2$, then $B_2 > B_1$ and net magnetic field changes its direction.B $= B_2 – B_1 =$ $= \frac{\mu_0}{\pi r}(I_2 - I_1)$ acting out of the plane of the paper. [1 mark for the correct formula and direction of net magnetic field]	
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 $\tau = MB \sin 90 = n\,I\,A\,B = 2 \times 0.5 \times (\text{side} \times \text{side}) \times 0.1$ Side of square = perimeter /4 = 2/4 = 0.5 m $\tau = 2 \times 0.5 \times (0.5 \times 0.5) \times 0.1$ = 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, $\frac{1}{2} mv^2 = qV$ $v = \sqrt{\frac{2qV}{m}}$	3

	[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) On the left side of the wire. [0.5 mark for the correct location of null point] (b) On the right side of the wire. [0.5 mark for the correct location of null point] Null point is the point where the magnetic field due to the current-carrying wire is equal to the external magnetic field and is opposite in direction. $\mathbf{B} = \frac{\mu_0}{2\pi}\frac{I}{r}$ $r = \frac{4\pi \times 10^{-7} \times 200}{2\pi \times 2 \times 10^{-3}} = \frac{2}{100}$ r = 0.02 m [1 mark for correct statement of condition and the formula] [1 mark for correct calculation and final result]	3
Q.69	In the first case, for the charged particles to go undeviated, $qE = qvB$ So $B = E/v = 2000/2 \times 10^3 = 1$ T [1 mark for correct calculation of magnetic field B] In the second case, Net force, $F_N = F_E - F_B = q(E - vB)$	2

	Substituting, v = 4000/3 = 1.3 x 10^3 m/s [1 mark for the correct calculation and final result]	
Q.70	In order that the ion just fails to enter the non-uniform part of the magnetic field region, it should follow a circular path of radius, not more than 1 m. So the radius of the path followed by the ion in magnetic field B, $r = \frac{mv}{qB} \leq 1$ [1 mark for the correct statement of the condition and the formula] Substituting, $\frac{1.6 \times 10^{-26} \times v}{1.6 \times 10^{-19} \times 2 \times 10^{-3}} \leq 1$ Solving for v, v ≤ 2 x 104 m/s [1 mark for correct calculation and final result]	2
Q.71	(a) Torque on the current-carrying loop in the magnetic field always acts in the plane of the loop. [0.5 mark for the correct direction of torque] (b) No. For the loop to rotate around itself, it requires a torque that is along its vertical axis. But in this case, the torque is along the plane of the loop. So the loop cannot rotate like a spinwheel. [0.5 mark for the correct answer] [1 mark for the correct reason] (c) It is sinusoidal.	4

	 [0.5 mark for correct shape] [0.5 mark for the correct representation] (d) The magnetic flux is minimum when the area vector of the current-carrying loop is antiparallel to the magnetic field. This orientation constitutes unstable equilibrium. [0.5 mark for the correct orientation] [0.5 mark for the identification of this orientation as unstable]	
Q.72	(a) Consider a straight current-carrying wire in the plane of paper with the current in the upwards direction. Place the solenoid on the right side of the wire, such that its axis is perpendicular to the plane of the paper. The current in the solenoid should flow in an anticlockwise direction when looked at from above. In the above orientation, at a specific perpendicular distance between them, the net magnetic field along the axis of the solenoid can be zero. [1 mark for the correct description of the orientation and 1 mark for the correct directions of the current] OR Alternatively., Consider a straight current-carrying wire in the plane of paper with the current in the downwards direction. Place the solenoid on the left side of the wire, such that its axis is perpendicular to the plane of the paper.	4

	The current in the solenoid should flow in an anticlockwise direction when looked at from above. In the above orientation, at a specific perpendicular distance between them, the net magnetic field along the axis of the solenoid can be zero. [1 mark for the correct description of the orientation and 1 mark for the correct directions of the current] (b) If the perpendicular distance of separation between the wire and axis of the solenoid is r, B due to current-carrying wire, $= \frac{\mu_0 I_w}{2\pi r}$ B due to current carrying solenoid along its axis = $\mu_o n I_s$ [0.5 mark for each correct formula] For net magnetic field along the axis to be zero, $\frac{\mu_0 I_w}{2\pi r} = \mu_0 n I_s$ Substituting, $I_w / I_s = 200$, n = 100 r = (1/π) m [1 mark for the correct calculation and final result]	
Q.73	(a) When the spring is stretched, the restoring force on the spring upwards= the magnetic force acting on the wire PQ downwards [1 mark for the correct equation of the spring force with magnetic force] kx = BIL $I = kx/BL = 0.8 \times 2 \times 10^{-4}/(0.002 \times 0.02) = 4$ A [1 mark for the correct calculation and final result] (b) Direction of current is from Q to P [1 mark for the correct direction of the current]	3
Q.74	(a) Magnetic force on the wire is dependent on the angle between wire and magnetic field. [0.5 mark]	2

	(b) Force F = B I L sinθ $\sin\theta = \frac{F}{BIL} = \frac{0.05}{0.8 \times 0.25 \times 0.5} = 0.5$ $\theta = 30^{o}$ [1 mark for calculation and correct final result] (c) The value of magnetic force on the wire will remain constant as irrespective of the rotation of the table, the angle between the direction of the current and the magnetic field will always be 90^{o}. [0.5 mark for correct explanation]	
Q.75	(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. $r = \frac{mv}{qB} = 0.5\text{ m}$ $B = \frac{mv}{qr} = \frac{4 \times 10^{-26} \times 2.4 \times 10^{5}}{4.8 \times 10^{-19} \times 0.5}$ Solving for B = 0.04 T [0.5 mark for determining the value of r] [1 mark for correct calculations & result]	2
Q.76	(a) Magnetic field B_1 due to m1 at point P, $B_1 = \frac{\mu_0}{4\pi}\frac{2m_1}{d_1^3}$ $= 10^{-7}$ x 2 x 1/(0.2)3 = 0.25 x 10^{-4} T Net magnetic field along horizontal direction at P (due to m1 and BH), B_1 + BH = 0.55 x 10^{-4} T [0.5 mark for expression of net field at P due to B_1 and BH] Magnetic field B_2 due to m2 at point P, $B_2 = \frac{\mu_0}{4\pi}\frac{m_2}{d_2^3}$ $= 10^{-7}$ x 4/(d2)3	3

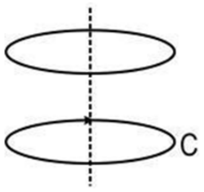
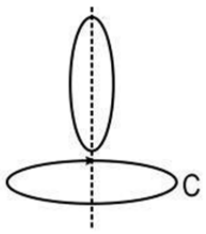
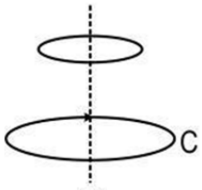
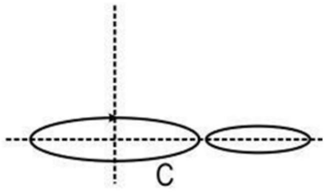
	[0.5 mark for expression of B_2] For net field intensity at P to be zero, 10^{-7} x 4/(d2)3 = 0.55 x 10^{-4} T $d_2 = \left[\frac{4}{0.55 \times 10^3}\right]^{\frac{1}{3}} m$ d_2 = 0.193m = 19.3 cm [1 mark for final equation and calculation] (b) If the polarities of magnet 2 are reversed, the magnetic field B_2 due to magnet 2 will point in the same direction as the resultant of BH and B_1. Hence the magnetic field at point P will no longer remains zero, irrespective of the distance d_2.	
Q.77	Work done to rotate from parallel to 60^o, $W = \lvert mB (\cos\theta_2 - \cos\theta_1) \rvert$ $= \lvert mB (\cos 60 – \cos 0) \rvert$ $= \lvert mB (1/2 – 1) \rvert$ = mB/2 [1 mark for correct formula and final expression of W] Counter torque required to hold the dipole at angle 60^o , τ = mBsinθ = mB sin60 = √3mB/2 τ = √3 x W = √3 x 0.25 = √3/4 N-m [1 mark for correct calculation and final result]	2
Q.78	In the first arrangement, the net magnetic moment of the combination is m_1 = m + 3m = 4m [0.5 mark for net magnetic moment] The initial time period of oscillation, $T_1 = 2\pi\sqrt{\frac{I}{m_1 B}} = 2\pi\sqrt{\frac{I_1 + I_2}{4mB}}$ [0.5 mark for the correct formula of T_1] The net magnetic moment of the combination with reversed polarities is m_2 = 3m - m = 2m	3

	[0.5 mark for net magnetic moment] The time period of oscillation after reversing the polarities, $T_2 = 2\pi\sqrt{\frac{I}{m_2B}} = 2\pi\sqrt{\frac{I_1+I_2}{2mB}}$ [0.5 mark for correct formula of T_2] $\frac{T_1}{T_2} = \sqrt{\frac{4}{2}} = \sqrt{2}$ $T_2 = 5\sqrt{2}$ s [1 mark for correct final result]	
Q.79	The frequency of oscillation by a magnetic dipole in presence of external magnetic field B is $f_1 = 2\pi\sqrt{\frac{mB}{I}}$ here $B = B_1\cos45$ where $B_1 = 0.3 \times 10^{-4}$ T and $f_1 = 12/60$ $f_2 = 2\pi\sqrt{\frac{mB}{I}}$ here $B = B_2\cos60$ and $f_2 = 10/60$ [0.5 mark each for correct formula and denoting correct values of magnetic field B] So $\frac{f_1}{f_2} = \sqrt{\frac{B_1\cos 45}{B_2\cos 60}}$ $\frac{B_1}{B_2} = \frac{f_1^2}{f_2^2}\frac{\cos 60}{\cos 45} = \frac{18\sqrt{2}}{25}$ $B_2 = \frac{0.3 \times 10^{-4} \times 25}{18\sqrt{2}}$ $B_2 = \frac{0.3\ x10^{-4}x25}{18\sqrt{2}}$ $= 0.294 \times 10^{-4}$ T [1 mark for correct calculation and final result]	2
Q.80	(a) When H = 0, the residual field in (A) is OQ. When H = 0, the residual field in (B) is OQ’	3

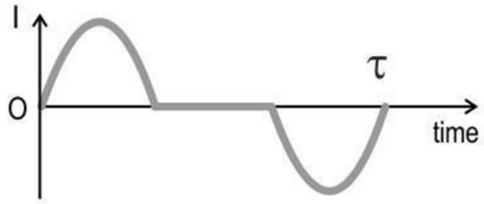
	Hence, residual field in (A) < residual field in (B) [0.5 mark for correct comparison] (b) Specimen B [0.5 mark for correct answer] (c) Material (B) undergoes greater hysteresis loss than (A). Hysteresis loss is energy dissipated per cycle per unit volume of the specimen and is given by the area enclosed by the B-H loop. [0.5 mark for correct identification of the material] [0.5 mark for a correct reason] (d) Material (A) is suitable for the making of electromagnets. Material (A) has lower retentivity as compared to material (B). [0.5 mark for correct identification of the material] [0.5 mark for a correct reason]	
Q.81	Magnetic field due to a current-carrying wire at a distance r, B = (µo i)/2πr = 2 x 10-7 x 6 / 0.1 = 12 x 10-6 T = 12 µT This field due to the current-carrying wire acts from N to S, that is, opposite to BH. So the net magnetic field under which the bar magnet oscillates: B' = BH – B = 24 – 12 = 12 µT [0.5 mark for the correct calculation of B due to current-carrying wire] [0.5 mark for correct net magnetic field acting on bar magnet] The time period of oscillation of bar magnet in presence of a magnetic field, $T_1 = \sqrt{\frac{I}{mB_H}}$ and $T_2 = \sqrt{\frac{I}{mB'}}$ $\frac{T_2}{T_1} = \sqrt{\frac{B_H}{B'}} = \sqrt{\frac{24}{12}} = \sqrt{2}$ [1 mark for the correct formula of time periods] $T_2 = T_1\sqrt{2}$ = 0.2 x √2 = 0.2 x 1.414 = 0.28 s [1 mark for correct calculation and final result]	3

Q.82	A magnetic field without the core: $Bo = \mu oH$ Magnetic field with the core: $B = \mu H = \mu o\ (1 + \chi)\ H$ [0.5 mark each for correct formula] Change in a magnetic field, $B – Bo = \mu o\ \chi\ H$ % increase in a magnetic field, $\frac{B - B_0}{B_0} \times 100 = \frac{\mu_0 \chi H}{\mu_0 H} \times 100 = 100\ \chi$ Hence proved. [1 mark for the correct final result]	2
Q.83	(a) downwards in the plane of the paper (or) perpendicular to B and v, downwards (b) (i) proton moving with a velocity v No deviation (0.5 marks) $qE = qvB$ Force does not depend on mass and the charge cancels out. So the proton will also pass undeviated. (0.5 marks for correct explanation) (ii) electron moving with a velocity v/2 The electron will deviate upwards. (0.5 marks) Since velocity is halved, electric force > magnetic force. (0.5 marks for correct explanation)	2

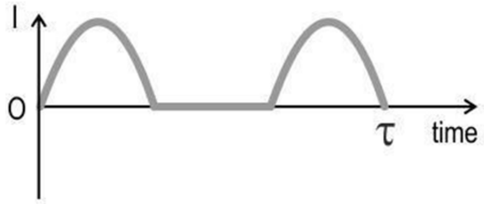
4. ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT (AC)

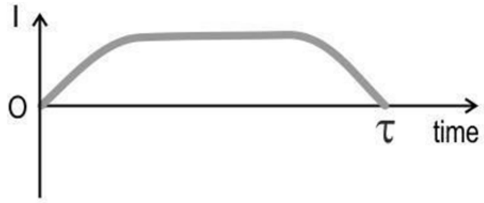
Q. No	Question	Marks
	Multiple Choice Question	
Q.84	A current-carrying coil C_1 is paired with another coil. An emf ε is induced in coil C_2 when the current through C_1 drops to zero from a non-zero value within 1 s. If the coil C_1 is paired with C3, an emf 0.7ε is induced in it, for the same rate of drop in the current through C_1 as earlier. What is the ratio of mutual inductance M_{12} (for the pair of coils C_1 and C_2) to that of mutual inductance M_{13} (for the pair of coils C_1 and C_3)? A. 0.7 B. 1 C. 1.42 D. 7	1
Q.85	Coil C carries a steady current. A second coil is placed in close proximity to coil C in different configurations as shown.  (i)  (ii)  (iii)  (iv) Which of the following options represents the correct order of the mutual inductance values for the pair of coils in given configurations?	1

	A. (i) > (iii) > (iv) > (ii) B. (iv) > (iii) > (i) > (ii) C. (ii) > (iv) > (iii) > (i) D. (iii) > (i) > (ii) > (iv)	
Q.86	A long solenoid S has length l_1, area of cross-section A and number of turns N_1. A coil C of shorter length l_2, number of turns N_2 but same area of cross-section is wound over solenoid S. If a current I flows through the coil C, then which of the following represents the flux linked with the solenoid S? A. $\frac{\mu_0 N_1 N_2 A I}{l_2} l_1$ B. $\frac{\mu_0 N_1 N_2 A I}{l_1} l_2$ C. $\frac{\mu_0 N_1 N_2 A I}{l_1}$ D. $\frac{\mu_0 N_1 N_2 A I}{l_2}$	1
Q.87	There is a pair of concentric and coplanar conducting loops of radii R_1 and R_2 such that $R_2 = 0.01 R_1$. To which of the following is the mutual inductance M for this pair directly proportional? A. $1/R_1^2$ B. R_1^2 C. $1/R_1$ D. R_1	1
Q.88	A small conducting metal ring falls vertically down with its plane parallel to y-z plane. During the fall, the ring crosses a small region of the uniform magnetic field directed along the x-axis between the times t=0 and t = τ seconds. Which of the following graphs represent the variation of current induced in the ring during the fall?	1



A.

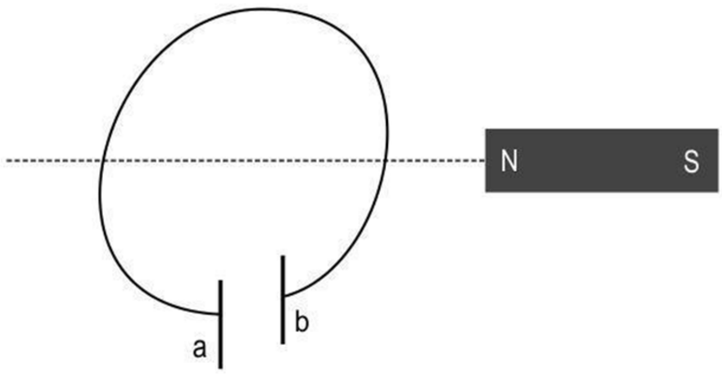




B.

C.

Q.89 A capacitor is short-circuited as shown. 1



Match the possible motions listed in [A] of the bar magnet relative to the loop with the suitable responses listed in [B] due to the induced current, if any.

[A]
I. Magnet with N facing the loop moves towards the coil
II. Magnet with N facing the loop moves away from the coil
III. Magnet NS is stationary
IV. Magnet with S facing the loop moves towards the coil
V. Magnet with S facing the loop moves away from the coil

[B]
i. Excess electrons accumulate on plate a
ii. Excess electrons accumulate on plate b
iii. The plates a and b stay neutral

A. [I - i] , [II - ii], [III - iii], [IV - i], [V - ii]

B. [I - iii] , [II - ii], [III – i], [IV – ii], [V – i]

C. [I -ii] , [II - i], [III - iii], [IV - i], [V -ii]

D. [I - i] , [II - ii], [III - iii], [IV - ii], [V - i]

Q.90 A square loop of a single turn is placed with its plane perpendicular to a uniform magnetic field. The magnetic flux through the square loop is 0.002 W_b. — 1

The square loop is now reshaped into a circular loop. What is the flux (in W_b) through the circular loop?

A. π/4

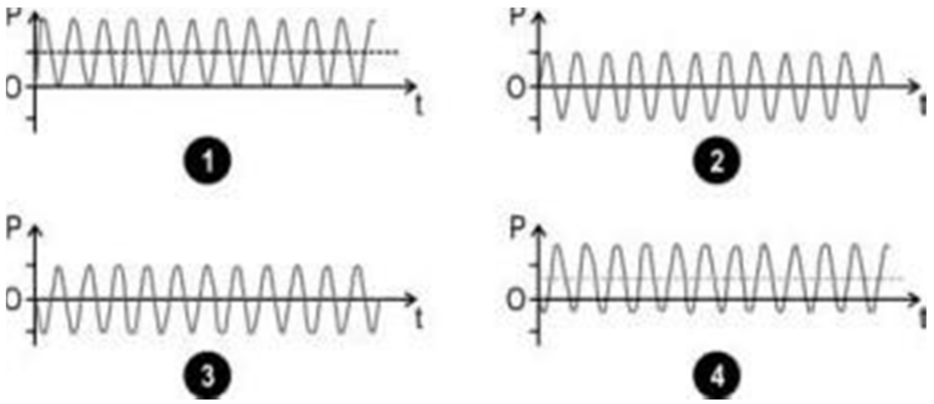
B. 0.002

C. 0.008/π

D. 0.0005π

Q.91 If P_{av} represents average power dissipated and i_{av} is the average current through a resistor over one cycle of the input sinusoidal voltage, which of the — 1

	following statements is correct for an ac circuit with resistor only? A. $P_{av} = 0$ & $i_{av} > 0$ B. $P_{av} > 0$ & $i_{av} = 0$ C. $P_{av} > 0$ & $i_{av} > 0$ D. $P_{av} = 0$ & $i_{av} = 0$	
Q.92	An LCR series circuit is connected to an ac supply of $\omega = 100$ rad/s. Given the values as R = 100-ohm, L = 500 mH, C = 5 µF, study the following statements carefully. I. The given circuit (LCR) is dominantly capacitive II. The instantaneous current in the circuit leads Vmax. III. If w greater than $200\sqrt{10}$ rad/s, the circuit becomes dominantly inductive IV. The LCR circuit can be made capacitive or inductive by simply changing the angular frequency of the input ac supply, keeping the voltage V_{max} constant. Identify the correct option. A. Only statement IV is correct B. Only statements I and II are correct C. Only statements I and III are correct D. All statements are correct	
Q.93	In an ac circuit containing a resistor R, the power dissipated is P_1. If a capacitor C is added to the above circuit, the power dissipated through the resistor changes to P_2. If an inductor L replaces the capacitor C, the power dissipated through the resistor changes to P_3. If the capacitive reactance offered by the capacitor equals the inductive reactance offered by the inductor, then which of the following represents the correct relation between P_1, P_2 and P_3? A. $P_1 = P_2 = P_3$ B. $P_3 > P_1 > P_2$ C. $P_1 < [P_2 = P_3]$ D. $P_1 > [P_2 = P_3]$	1

Q.94	A 5-ohm resistor, a 5 mH inductor and a 5 µF capacitor, joined in series resonate with an ac source of frequency ω_o. If only the resistance is changed to 10 ohm, the circuit resonates at a frequency ω_1. If only the inductor is changed to 20 mH, the circuit resonates at a frequency ω_2. Find the ratio ω_1/ω_2. A. 0.5 B. 1 C. 2 D. 4	1
Q.95	Which of the ac circuits with the following input voltage and current dissipates maximum power P? A. Input voltage V_o = 2 volt, I_o = 4 ampere and phase angle $\Phi = \pi/4$. B. Input voltage $V = V_o \sin\omega t$ volt and the current $I = I_o \sin(\omega t - \pi/2)$ ampere C. Input voltage $V = 2 \cos\omega t$ volt and the current $I = 4 \sin\omega t$ ampere D. Input voltage $V = 100 \sin 100t$ volt and the current $I = 100 \sin(100t + \pi/3)$ milliampere	1
Q.96	The four graphs below represent instantaneous power dissipated across various circuit elements such as resistor, capacitor & inductor connected either individually or in a combination to an ac supply.  Study the following statements carefully and select the correct option. I. Average power dissipated in (2) & (3) is zero. II. Average power dissipated in (1) is that in a resistor and is given as $P_{av} = I_{rms}.V_{rms}$ III. Average power dissipated in (4) is that in an LCR combination circuit and is always positive.	1

IV. Graphs (1), (2) & (3) represent power dissipation in resistor, capacitor, and inductor in an ac circuit respectively

A. Only I & II are correct

B. Only III & IV are correct

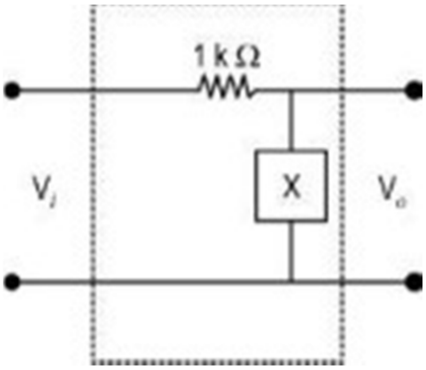
C. Only I, III & IV are correct

D. Only I, II & IV are correct

Q.97

In a circuit, a resistor of 1 kilo-ohm is connected to an element X as shown. An ac input voltage of V_i = 10 mV is applied at variable frequencies.

1



Given below is the data observed for output voltage V_o and total impedance Z of the circuit as a function of input voltage frequency v.

v	z	Vo
10 kHz	3 x 10^3 ohm	16.1 mV
100 kHz	1.04 x 10^3 ohm	1.6 mV
1 MHz	1.003 x 10^3 ohm	0.16 mV
10 MHz	10^3 ohm	16 mV

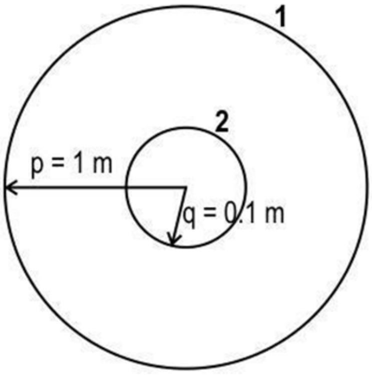
Study the following statements carefully and select the correct option given below.

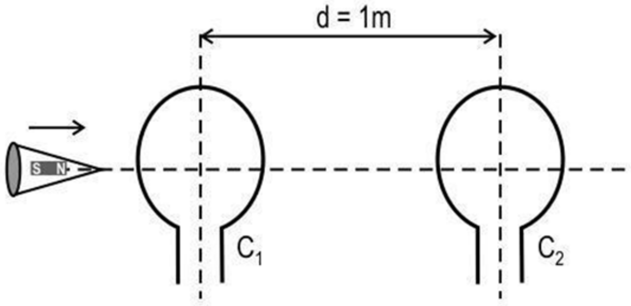
I. The output current is expected to increase with the increase in input frequency.

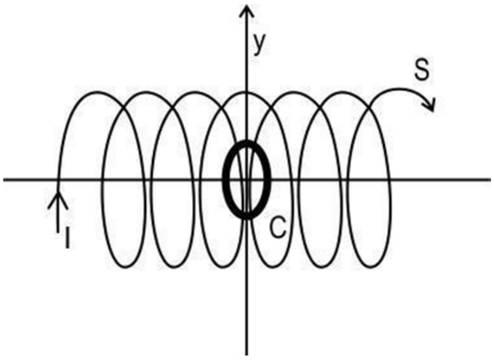
II. The reactance offered by X increases with the increase in input frequency.

III. If the ac input is replaced by dc input of the same voltage, the output voltage V_o becomes zero.

IV. The circuit element X could be either a capacitor or an inductor.

	A. Only statements I & II are correct B. Only statements III & IV are correct C. Only statements I & III are correct **D.** Only statements II & IV are correct	
	Free Response Question/ Subjective Question	
Q.98	A constant magnetic field $B = 1$ T acts perpendicularly on a static square copper coil of 100 turns with each side of 10 cm. The coil is removed from the magnetic field within 0.5 s and then replaced in another 0.5 s. a. Calculate an average emf that develops in the coil during the entire motion lasting for 1 s. b. Find the net thermal energy dissipated in the coil during the entire motion. Take resistance of the coil as 1 ohm.	2
Q.99	Given two coplanar and concentric loops 1 and 2 as shown.  A time-varying voltage (3 + 2t) is applied to the larger loop 1. If the resistance of the loops is $R_1 = 10$ ohm and $R_2 = 1$ ohm, then determine the current induced in the smaller loop.	2
Q.100	Coil 1 has self-inductance L_1 which is 3 times the self-inductance L_2 of coil 2. If during a certain instant, the rate of increase in current and the power dissipated in these two coils is the same, then determine the ratio of (a) their induced voltages (b) currents (c) energy stored in the two coils at that instant.	3

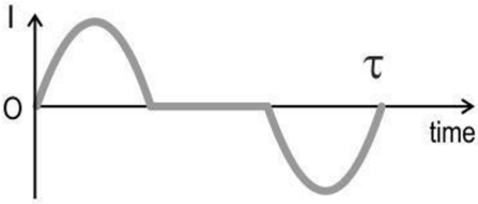
Q.101	Sam wants to generate 10 mV of EMF by moving a wire at 5m/s through a steady magnetic field region of 0.06 T. a. What should be the angle between the magnetic field and direction of motion so that the wire can be of the shortest length? b. What should this shortest length of the wire be?	1
Q.102	The Earth's magnetic field in the northern hemisphere has a downward component that can be assumed to be uniform. Consider an airplane flying through this magnetic field from India towards Russia in the north. A motional emf develops across the tips of its two wings. (a) Identify the polarities developed on the left-wing and the right-wing. Explain the answer. (b) An insulated wire along with a light bulb connects the tips of the right and the left-wing of the airplane. Will the bulb glow due to the induced emf? Explain the answer.	2
Q.103	A projectile with an enclosed tiny magnet is projected with a speed v through a pair of identical coaxial coils C_1 and C_2 as shown.  (a) Plot a graph of induced emf ∈ versus time t for the period of passage of the projectile through two successive coils. Take the counter-clockwise direction of the induced current in a coil as seen from the starting point of the incoming projectile as positive. (b) If the time interval between two emf pulses observed in C_1 and C_2 respectively is 3 ms, determine the speed of the projectile.	2

Q.104	A solenoid S of radius 50 cm with 100 turns per unit length is aligned along the x-axis carrying a current of 10 A. A coil C of radius 10 cm is coaxially placed inside the solenoid such that it can rotate about its diameter directed along the y-axis. Refer to the diagram below.  If the coil C of 50 turns revolves with a constant angular speed of π rad/s, determine the emf generated in coil C. (Note: The final answer may be written in terms of constants μ_o and π)	2
Q.105	In a given LCR series ac circuit, the inductive and capacitive reactance are given as 400 ohm and 600 ohm respectively. If resistance R in the circuit is 100 ohm and the maximum input voltage of the ac supply is 100 V, then determine the following: (a) net impedance of the circuit. (b) the maximum current in the circuit. (c) the maximum voltages across each of the elements. (d) the sum of the maximum voltages across the three elements. (e) Is it possible to attain the value as obtained in part (d) in the given circuit? Give a reason for your answer.	5
Q.106	A series LCR circuit is capacitive if the ac supply is at angular frequency ω_1 with the phase angle Φ = -30. The circuit becomes inductive if the ac supply is changed to angular frequency ω_2 while keeping the maximum value of source voltage constant and the corresponding phase angle becomes Φ = 30. What is the change in power delivered in the circuit due to a change in angular frequency from ω_1 to ω_2? Explain your answer.	3

Q.107	An LCR circuit is connected to an ac voltage of fixed V_{max} and angular frequency. Current through the circuit is I_{max} and the resistance R equals the inductive reactance X_L in the circuit. Now if the distance of separation between the capacitor plates is doubled, the current I_{max} in the circuit is reduced to half. Determine the initial relation between resistance R and capacitive reactance Xc.	2
Q.108	An ac source with V_{max} = 100 V and frequency 50 Hz is connected across a 1 μF capacitor. Assuming that at time t = 0, the energy stored in the capacitor is zero, determine the following: (a) the current in the capacitor at time t = 1/100 s. (b) maximum current in the circuit.	2
Q.109	The ratio of the turns in the primary and the secondary coil in a given transformer is 1:10. If the load resistor draws a current of 1.2 A from the secondary coil, determine the current in the primary coil, assuming that the transformer has an efficiency of only 90%.	2
Q.110	A given ac power supply has a voltage rating of 80 V. An LCR series circuit draws a current of 5A when connected to this ac power supply. Determine the range of values of the average power that can be delivered by the ac power source to the circuit.	2
Q.111	The household power supply is at 200 V and 60 Hz. Find the time required for: a. the value of current to change from 0 to its rms value b. the value of voltage to change from its rms value to 0.	2
Q.112	An alternating current is sent through a 100 km long telephone wire of capacitance 0.01 μF/km at a frequency of 8 kHz. Find out what value of an inductor that must be connected in series to this wire, so that the current through the wire is maximum.	2
Q.113	Given is a coil of resistance R and inductance L connected to a power supply. If the power supply is 50 V dc, a current of 0.5 A flows through the coil. If the power supply is 50 V ac of frequency 50 Hz, a current of 0.2 A flows through the coil. Determine the resistance R and inductance L of the coil.	2

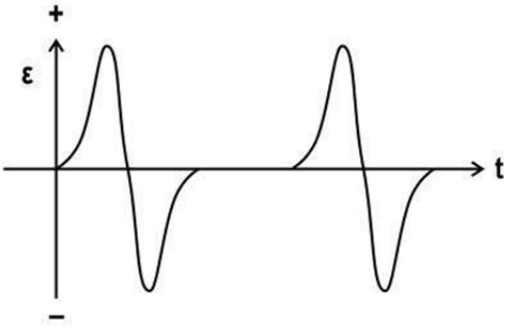
Q.114	An inductor L is connected to an ac power source of frequency 'v' Hz. The inductor L undergoes alternate cycles of magnetization and demagnetization due to sinusoidal variation of current through L. If the time taken for a successive magnetization and demagnetization of the inductor is 8 ms, determine the frequency 'v' of the input ac power source.	2
Q.115	The rating of a filament bulb is given as 50W, 100V. This bulb is to be used in a house where the power supply is at 200 V, 50 Hz. Determine the inductance of the coil that must be connected in series to the bulb, so that it glows to its maximum power rating, but doesn’t fuse.	2

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.84	C. 1.42	1
Q.85	A. (i) > (iii) > (iv) > (ii)	1
Q.86	C. $\frac{\mu_0 N_1 N_2 A I}{l_1}$	1
Q.87	D. R_1	1
Q.88	A. 	1
Q.89	C. [I -ii] , [II - i], [III - iii], [IV - i], [V -ii]	1
Q.90	C. 0.008/π	1
Q.91	B. $P_{av} > 0$ & $i_{av} = 0$	1
Q.92	D. All statements are correct	1
Q.93	D. $P_1 > [P_2=P_3]$	1
Q.94	C. 2	1
Q.95	A. Input voltage V_o = 2 volt, Io = 4 ampere and phase angle Φ = π/4.	1
Q.96	D. Only I, II & IV are correct	1
Q.97	C. Only statements I & III are correct	1

Q.98	a. Emf during removal Φ_1 = nBA = 100 x 1 x 0.1 x 0.1 = 1 Wb Φ_2 = 0 Time = 0.5 s Induced emf $\lvert\varepsilon\rvert = \Delta\Phi/\Delta t$ = 1/0.5 = 2 V Emf during return path Φ_1 = 0 Φ_2 = nBA = 100 x 1 x 0.1 x 0.1 = 1 Wb Time = 0.5 s Induced emf $\lvert\varepsilon\rvert = \Delta\Phi/\Delta t$ = 1/0.5 = 2 V Average emf during the entire motion = 0 Alternatively, Φ_1 = nBA = 100 x 1 x 0.1 x 0.1 = 1 Wb Φ_2 = nBA = 100 x 1 x 0.1 x 0.1 = 1 Wb Change in flux = 0 Time = 1 s Average induced emf during the entire motion = 0 [1 mark for the correct calculation of average induced emf] b. Thermal energy dissipated = $i^2rt = \varepsilon^2t/r$ Energy dissipated during withdrawal: 2^2 x 0.5/1 = 2 J Energy dissipated during return path: 2^2 x 0.5/1 = 2 J Total energy dissipated during the entire motion = 4 J [1 mark for the correct calculation of total energy dissipated]	2

Q.99	Current in loop 1 $I_1 = V/R_1 = (3+2t)/10$ Magnetic field at the center of the loop 1 due to current I_1, $B_1 = \mu_o I_1/2p = \mu_o(3+2t)/20$ [0.5 mark for correct result of magnetic field] Flux linked with loop 2, $\varphi_2 = B_1 A_2 = \frac{\mu_0}{20}(3 + 2t)\pi(0.1)^2$ Emf induced in loop 2, $e_2 = \frac{d\varphi_2}{dt} = \frac{\mu_0\pi}{2000}\frac{d(3 + 2t)}{dt} = \frac{\mu_0\pi}{1000}$ Induced current in loop 2, $I_2 = \frac{e_2}{R_2} = \frac{\mu_0\pi}{1000}$ A [0.5 mark for each of the correct results]	2
Q.100	(a) As $e = L\, dI/dt$ $e_1/e_2 = L_1/L_2 = 3L/L = 3$ [1 mark for the correct ratio] (b) As power $P = eI$ $I_1/I_2 = P_1e_2/P_2e_1 = e_2/e_1 = 1/3$ [1 mark for the correct ratio] (c) Energy stored in a coil, $U = ½\, LI^2$ $U_1/U_2 = ½\, L_1I_1^2/½\, L_2I_2^2 = 3(1/3)^2 = 1/3$ [1 mark for the correct ratio]	3
Q.101	a. The wire can be of the shortest length if it is moved perpendicular to the magnetic field [0.5 mark for the correct identification of the angle] b. $EMF = Bl_v$	1

	. l = EMF / B_v = 10 x 10^{-3} / 0 x 5 = 1/30 m = 3.3 cm [0.5 mark for the correct calculation of the length]	
Q.102	(a) As the plane flies northwards, the right-hand rule indicates that the positive charge experiences a force directed toward the west. Thus, the left wingtip becomes positively charged and the right wingtip negatively charged. [1 mark for the correct identification of the polarities] (b) The light bulb will not glow. The wings with the connecting insulated wire and the bulb constitute a single-loop circuit. As the plane flies through a uniform Earth's magnetic field, the magnetic flux through this loop is constant and net emf generated is zero. [0.5 mark for the correct conclusion] [0.5 mark for the correct reason]	2
Q.103	 (a) [1 mark for the correct graph] (b) Speed of the projectile = d/t = 1/(3 x 10^{-3})=333.3 m/s [1 mark for the correct calculation of the speed of the projectile]	2

Q.104	Magnetic field along axis of solenoid = B = μ_o x 100 x 10 = 1000μo Magnetic flux through coil C, Φ = NB.A = NBA cosωt [0.5 mark each for magnetic field and flux] Emf induced in the coil due to its rotation, ∈ = -dΦ/dt = NBAω sinωt Upon substitution, ∈ = 500 μ_o π^2 sinπt [1 mark for correct induced emf]	2
Q.105	(a) Impedance $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{100^2 + (400 - 600)^2}$ =100√5 ohm [1 mark for correct result] (b) $i_{max} = V_{max}/Z$ = 100/100√5 = 1/√5 A [1 mark for correct result] (c) $VR,_{max} = i_{max}$ x R = 100/√5 volt $VL,_{max} = i_{max}$ x XL = 400/√5 volt $VC,_{max} = i_{max}$ x X_C = 600/√5 volt [0.5 mark for each correct result] (d) The sum of $VR,_{max} + VL,_{max} + VC,_{max}$ = 100/√5 + 400/√5 + 600/√5 = 1100/√5 ~ 493 V [0.5 mark for correct result] (e) The sum of voltages across the three elements (= 493 V) in LCR series circuit exceeds the maximum input voltage (100 V) of the circuit. This is physically impossible. [0.5 mark for correct conclusion] The voltages across each of the elements need to be added after considering their respective phase angles. Each of the maximum values across the elements L, C and R is attained at different instants of time. Hence the net voltage equal to 493 V is never achievable at any given instant during any one ac cycle of circuit. [0.5 mark for correct reason statement]	5

Q.106	Power dissipated in the circuit remains unchanged. [0.5 mark for correct conclusion] As Power, $P_{av} = I_{rms}.\ V_{rms}.\ \cos\Phi$ Power factor cos Φ remains unchanged. With the change in ω_1 ->ω_2 Φ -> -Φ $\cos\Phi = \cos(-\Phi)$, so power factor is unchanged. [1 mark for proving that cosΦ remains unchanged] Also, V_{rms} remains unchanged as the source voltage is constant. [0.5 mark for proving that V_{rms} remains unchanged] I_{rms} remains unchanged. When $\Phi = -30$ $\tan -30 = (X_L - X_C)/R$ $X_L - X_C = -R/\sqrt{3}$ When $\Phi = 30$ $\tan 30 = (X_L - X_C)/R$ $X_L - X_C = R/\sqrt{3}$ Since impedance is $\mathbf{Z = \sqrt{R^2 + (X_L - X_C)^2}}$ In both cases $Z = 2R/\sqrt{3}$. Since $I_{rms} = V_{rms}/Z$ So I_{rms} also remains unchanged. [1 mark for proving that I_{rms} remains unchanged] Hence the Power, $P_{av} = I_{rms}.V_{rms}.\cos\Phi$ remains unchanged.	3

Q.107	For the distance between the plates doubled, C' = kA/d = C/2 So capacitive reactance $X'_c = 2X_C$ [1 mark for getting the correct relation between X_C and X_C'] For the current I_{max} to be reduced to half, Impedance Z' = 2Z $\sqrt{R^2 + (X_L - X'_C)^2} = 2\sqrt{R^2 + (X_L - X_C)^2}$ $R^2 + (X_L - X'_C)^2 = 4\,[R^2 + (X_L - X_C)^2]$ $R^2 + (X_L - 2X_C)^2 = 4\,[R^2 + (X_L - X_C)^2]$ Substituting $R = X_L$ and solving, we get $X_C = 3R/2$ [1 mark for correct calculations and final result]	2
Q.108	(a) $X_C = 1/C_\omega$ $= 1/(10^{-6} \times 2\pi \times 50) = 10^4/\pi$ ohm $i_c = \frac{V_{max}\sin(\omega t + \varphi)}{X_c} = \frac{100\sin(2\pi \times 50 \times \frac{1}{100} + \frac{\pi}{2})}{\frac{10^4}{\pi}}$ [0.5 mark for correct formulae] $i_c = (\pi/100).\ \sin(\pi + \pi/2)$ $= -(\pi/100)\sin\pi/2$ $i_c = -\ \pi/100$ A [1 mark for correct calculations and result] (b) $i_{max} = V_{max}/X_C = V_{max}.\ \omega_C$ $= 100 \times 2\pi \times 50 \times 10^{-6} = \pi/100$ A [0.5 mark for correct result]	2

Q.109	Efficiency = Output power / Input power 0.90 = $(V_s I_s)/(I_pV_p)$ [1 mark for correct formulation] I_p = 100 V_s Is /90.V_p Substituting and solving, I_p = 13.3 A [1 mark for correct substitution and calculation]	2
Q.110	Average power drawn by LCR circuit = P_{av} = V_{rms}. I_{rms}. cosΦ = 80 x 5 cosΦ = 400 cosΦ [1 mark for correct representation of P_{av}] In a series LCR circuit: The maximum value of the power factor, cosΦ is 1, in the case of resonance wherein Φ is 0. The minimum value of the power factor, cosΦ approaches 0 as the value of Φ approaches either -90 or 90 depending upon whether the circuit is inductive or capacitive. [0.5 mark for the correct reasoning of variation of the value of power factor in an LCR circuit] P_{av} values range between 0 and 400. $0 \leq P_{av} \leq 400$ [0.5 mark for determination of the correct range of values]	2
Q.111	a. Current i = i_o sin2πνt At t = 0, i = 0 At time = t, i = i_{rms} = $i_o/\surd 2$ $i_o/\surd 2$ = i_o sin2πνt π/4 = 2πνt Solving for t, t = 1/480 = 2 x 10-3 s [0.5 mark for correct formula and 0.5 mark for correct result] b. Time taken by current to change from 0 to rms value	2

	= Time taken by the voltage to change from 0 to rms value = Time taken by voltage to change from rms value to 0. So t = 2 x 10-3 s as above. [0.5 mark for correct reasoning & 0.5 mark for correct final result]	
Q.111	c. Current $i = i_o \sin 2\pi\nu t$ At t = 0, i = 0 At time = t, i = irms = $i_o/\sqrt{2}$ $i_o/\sqrt{2} = i_o \sin 2\pi\nu t$ $\pi/4 = 2\pi\nu t$ Solving for t, t = 1/480 = 2 x 10-3 s [0.5 mark for correct formula and 0.5 mark for correct result] d. Time taken by current to change from 0 to rms value = Time taken by the voltage to change from 0 to rms value = Time taken by voltage to change from rms value to 0. So t = 2 x 10-3 s as above. [0.5 mark for correct reasoning & 0.5 mark for correct final result]	2
Q.112	In an LC circuit, the current is maximum when impedance Z is minimum, that is, $X_L = X_C$ [0.5 mark for correct identification of a condition of resonance] $\omega_L = 1/C\omega$ $L = 1/C\omega^2$ Here C = 100 x 0.01 x 10-6 F = 10-6 F $\omega = 2\pi \times 8000$ rad/s $L = 1/[10^{-6} \times (2\pi \times 8000)^2]$ Solving, $L = 125/32\pi^2$ mH [0.5 mark for correct value substitution] [1 mark for correct calculation]	2

Q.113	When dc is applied: $\omega = 0$, and $Z = R$ $I = V/R$ $R = V/I = 50 / 0.5 = 100$ ohm [0.5 mark for correct value of R] When ac is applied: $I = V/Z$ $Z = V/I = 50/0.2 = 250$ ohm [0.5 mark for correct value of Z]. As $Z_2 = R_2 + \omega_2 L_2$ $\omega_2 L_2 = Z_2 - R_2$ $= (250)^2 – (100)^2 = 150 \times 350$ Solving for L, $L = \sqrt{21}/2\pi$ H [1 mark for correct calculation of L]	2
Q.114	The time taken for half a cycle of sinusoidal variation of current corresponds to a pair of successive magnetization and demagnetization of the inductor. [0.5 mark for identification of the relation between the magnetization cycle of the inductor and the sinusoidal variation of the current] So, 8×10^{-3}s = half the time period of the ac cycle So $T/2 = 8 \times 10^{-3}$ $T = 16 \times 10^{-3}$s [1 mark for correct calculation of time period] Frequency $\nu = 1/T = 103/16 = 62.5$ Hz [0.5 mark for correct calculation of frequency]	2

Q.115	Resistance R of the bulb, $P = V^2/R$ $R = V^2/P = 100 \times 100/50 = 200$ ohm [0.5 mark for correct value of R] With the choke coil in series to the bulb, the current in the circuit, $I = E/Z = \frac{200}{\sqrt{R^2 + (\omega L)^2}} = \frac{200}{\sqrt{200^2 + (100\pi L)^2}}$ [0.5 mark for correct equation of I] Voltage drop across the bulb must be 100 V, So 100= IR $100 = \frac{200 \times 200}{\sqrt{200^2 + (100\pi L)^2}}$ Transposing and solving $\sqrt{200^2 + (100\pi L)^2} = 400$ $L_2 = 12/\pi 2$ $L = \sqrt{12}/\pi$ H = 1.10 H (approx) [1 mark for the correct value of L]	2

5. ATOMS AND NUCLEI

Q. No	Question	Marks
Multiple Choice Question		
Q.116	If an electron in a hydrogen atom undergoes transition from 1st to 3rd energy level, by what factor does the time period of revolution undergo a change? A. remains the same B. becomes 3 times the initial value C. becomes 9 times the initial value D. becomes 27 times the initial value	1
Q.117	Hydrogen atom at its ground state is excited by incident photons of energy 12.75 eV. What is the expected count of the distinct spectral lines emitted by this hydrogen atom? A. 3 B. 5 C. 6 D. 8	1
Q.118	An electron in the Bohr model atom is in the nth orbit of radius r and has kinetic energy KE. Which of the following statements does not comply with the postulate of Bohr's model of atom? A. Radius of the orbit in terms of de Broglie wavelength is given as $n\lambda/2\pi$ B. In going from lower to higher orbit, both PE and TE increases but KE decreases. C. If KE = 3.4 eV, the corresponding potential energy PE is 6.8 eV and Total energy TE is 10.2 eV D. If the ionization potential of the given Bohr model atom is 13.6 V, the energy required to remove the electron from its second orbit is 3.4 eV.	1

Q.119

Choose the only correct statement.

A. In a stable nucleus, the number of neutrons ≥ number of protons.

B. Nuclei with atomic number greater than 82 show a tendency to fuse.

C. A stable nucleus in general has even number of protons and odd number of neutrons.

D. The proton-proton nuclear force > proton-neutron nuclear force > neutron-neutron nuclear force.

1

Q.120

Binding energy values of a few nuclei are given in the table below.

Lithium-7	**Iron -56**	**Lead - 206**	**Deuterium -2**
40.1 MeV	492.2 MeV	1622 MeV	2.2 MeV

The least and the most stable nuclei respectively are:

A. Lead and Lithium

B. Lithium and Deuterium

C. Deuterium and Iron

D. Iron and Lead

1

Q.121

Study the following statements carefully and identify the correct statement/s.

I. The nuclear pairs, $_7N^{14}$ and $_6C^{13}$ & $_{15}P^{30}$ and $_{14}Si^{30}$, both constitute isobars.

II. $_7N^{14}$ can absorb a neutron and transform into $_3Li^7$ after emitting 2 alpha particles and a proton.

III. If 5.6 MeV is required to remove 1 neutron from $_3Li^7$ and transform it to $_3Li^6$, then it is also the BE per nucleon of $_3Li^6$

IV. If M is the mass of the nucleus $_{13}Al^{27}$, and m_p & m_n are the masses of protons and neutrons respectively, the binding energy of the nucleus is $[|M - 13m_p - 14m_n|c^2]$

A. Only statement III

B. Only statements I and III

C. Only statements II and IV

D. Only statements III and IV

1

<table>
<tr><td>Q.122</td><td>Which of the following statements are INCORRECT for atomic nuclei?
A. As mass number A increases, the density of the nucleus does not change.
B. Heavier nuclei tend to have larger Z/N ratio as Coulomb forces have longer range compared to nuclear forces.
C. For nuclei with A > 100, the binding energy per nucleon of the nucleus decreases on an average as A increases.
D. Two Lithium nuclei do not combine to form carbon nuclei at room temperature because Coulomb repulsions do not allow them to come very close.</td><td>1</td></tr>
<tr><td colspan="3">Free Response Question / Subjective Question</td></tr>
<tr><td>Q.123</td><td>Particles like electron, protons and alpha particles can be used to ionize hydrogen atom. If the ionization energy of hydrogen atom is Ei and all these striking particles carry same kinetic energies, then determine which of these particles will be most effective in ionizing the hydrogen atom?
Assume that the collisions are perfectly inelastic and it’s the excess KE that is used for ionisation.</td><td>3</td></tr>
<tr><td>Q.124</td><td>An ultraviolet radiation falls on a H atom.
(a) If the H atom is in the ground state when the incident photon of wavelength 80 nm falls on it, will the H atom get excited to the higher energy levels? OR will the H atom
get ionized?
Justify your answer.
(b) Post your answer of part (a),
Determine EITHER the quantum number of the energy level to which the H atom gets excited OR determine the KE of the electron emitted out of the H atom.
Use value of hc = 1240 eV-nm</td><td>2</td></tr>
</table>

Q.125	(a) Show that it takes more energy, in general, to remove a neutron from a nucleus than a proton. Use the example of ${}_{Z}^{A}X$ and the below data for the purpose-of-explanation. Mass-of ${}_{Z}^{A}X$=63.546u $\text{Mass}_{\text{proton}}$ =1.0073u $\text{Mass}_{\text{neutron}}$ =1.0087u Massof ${}_{Z}^{A-1}X$=62.5493u Mass of ${}_{Z-1}^{A-1}Y$ = 62.5467 u (b) Give reason: Why does it take more energy to separate a neutron from the nucleus than a proton?	3

Answer Key & Marking Scheme

Q.No	Answers	Marks
Q.116	D. becomes 27 times the initial value	1
Q.117	C. 6	1
Q.118	C. If KE = 3.4 eV, the corresponding potential energy PE is 6.8 eV and Total energy TE is 10.2 eV	1
Q.119	A. In a stable nucleus, the number of neutrons ≥ number of protons.	1
Q.120	C. Deuterium and Iron	1
Q.121	D. only statements III and IV	1
Q.122	B. Heavier nuclei tend to have larger Z/N ratio as Coulomb forces have longer range compared to nuclear forces.	1
Q.123	The momentum conservation during the collision: mu = (m + mH)v where m is the mass of the ionizing particle and mH is mass of hydrogen atom Initial KE, Ki = (1/2) mu2 Final KE, Kf = (1/2) (m+mH)v_2 [0.5 mark for each of initial and final KE] The decrease in KE is used for ionization of the H atom So (1/2) mu2-(1/2)(m+mH)v_2 = Ei Substituting for v = mu/(m+mH) and transposing, Ei = [mH/(m+mH)] Ki [1 mark for correct expression for ionisation energy] Since Ki is same for all types of striking particles, the particles with minimum mass will be most effective in ionizing the Hydrogen atom. Amongst the given list, electrons having minimum mass will be most effective. [1 mark for the correct conclusion and reason]	3

Q.124	(a) Energy of the incident 80 nm photon E = hc/λ = 1240/80 = 15.5 eV As the ionization energy of the H atom is +13.6eV, it is less than the energy 15.5 eV absorbed from the incident photon, so the H atom gets ionized. [0.5] mark for the calculation of energy of incident photon] [0.5 mark for the correct conclusion] (b) KE of the emitted electron = Energy of the incident 80 nm photon – Ionization energy = 15.5 – 13.6 = 1.9 eV [1 mark for the correct calculation of the KE of the emitted electron]	2
Q.125	(a) Removing a neutron from ZAX : ZAX -> ZA-1X + 01n The binding energy of the missing neutron = mass defect x 931 MeV Mass defect = [Mass of ZA-1X + Massneutron] - Mass of ZAX = 62.5493 u + 1.0087 u - 63.546 u= 0.012 u BE = 0.012 x 931 = 11.172 MeV [0.5 mark for the correct calculation of mass defect] [0.5 mark for the correct calculation of the BE] Removing a proton from ZAX : ZAX -> Z-1A-1Y + 11p The binding energy of the missing proton = mass defect x 931 MeV Mass defect = [Mass of Z-1A-1Y + Massproton] - Mass of ZAX = 62.5467 u + 1.0073 u - 63.546 u= 0.008u BE = 0.008 x 931 = 7.48 MeV Hence BE to remove a neutron is more than that of the proton. [0.5 mark for the correct calculation of mass defect] [0.5 mark for the correct calculation of the BE] b) Protons are bounded by attractive nuclear forces and also experience repulsion due to electrostatic forces. Neutrons are bounded by attractive nuclear forces only. Hence they require greater energy to get separated from the nucleus. [0.5 mark for each correct statement of p and n]	3

6. DUAL NATURE OF RADIATION AND MATTER

Q.No	Question	Marks
Multiple Choice Question		
Q.126	Select the correct statement regarding photoelectric emission. A. The number of photoelectrons is proportional to the frequency of the light. B. The work function of the metal varies as a function of the depth from the surface. C. Photoelectrons are ejected from the metals only if the incident radiation has a certain minimum wavelength. D. The photoelectrons produced by a monochromatic incident light incident on the metal surface have a spread of kinetic energies.	1
Q.127	ASSERTION: A photon is different from a normal particle. REASON 1: Energy of the photon in motion is purely kinetic as it has no rest energy. REASON 2: A photon travels with the speed of light in vacuum. REASON3: Energy of the photon at rest becomes purely potential as its rest mass is zero. Select the correct option. A. Assertion is correct. Only reason 3 is correct. B. Assertion is incorrect. Only Reason 2 is correct. C. Assertion is correct. Only reasons 1 and 2 are correct. D. Assertion is incorrect. Only Reasons 1 & 3 are correct.	1
Q.128	Light from a source of frequency $f > f_o$ (threshold frequency) is incident on a metal surface. If the intensity of incident radiations from the light source is increased keeping the frequency f of light constant, which of the following quantities associated with emitted photoelectrons DOESNOT remain the same? A. only photoelectric current B. only de Broglie wavelength C. both momentum and maximum KE D. both de Broglie wavelength and the photo current	1

<table>
<tr><td>Q.129</td><td>Given are the maximum speeds of the photoelectrons corresponding to a wavelength of incident light on a certain metal surface.
Wave length Maximum speed of theemitted electrons
λ_1 v_1
λ_2 v_2
If $v_2 < v_1$, then, which of the following is/are CORRECT?
I. Wavelength λ_1 > Wavelength λ_2
II. Frequency f1 < Frequency f_2
III. Maximum KE due to wavelength λ_1 > Maximum KE due to wavelength λ_2
A. All are correct
B. Only III is correct
C. Only I and II are correct
D. Only II and III are correct</td><td>1</td></tr>
<tr><td colspan="3">Free Response Question / Subjective Question</td></tr>
<tr><td>Q.130</td><td>Given are the work functions of two materials.
<table>
<tr><th>Material</th><th>Work function (eV)</th></tr>
<tr><td>Sodium</td><td>2.4</td></tr>
<tr><td>Zinc</td><td>4.3</td></tr>
</table>
A radiation of wavelength 400 nm is made to fall on each of the above materials. In which of the two materials is the photoelectric emission observed? Take h = 4.1×10^{-15} eV-s</td><td>3</td></tr>
<tr><td>Q.131</td><td>A light of wavelength 330 nm causes photoelectric emission from a metal of work function 1 eV. What value of collector potential would stop the photoemission? Take h_c = 1240 eV- nm</td><td>2</td></tr>
</table>

Q.132	A light of wavelength 3000 Angstrom emits photoelectrons of maximum KE of 0.5 eV. What will be the maximum KE of photoelectrons if the wavelength is changed to 2000 Angstrom? Take hc = 12400 eV-Å	2
Q.133	A powerful UV laser emits radiation of wavelength 300 nm with a power of 5 mW. Determine the number of photons of this beam that strikes a metal surface every second. Take h_c ~ 2 x 10-16 J-nm	2

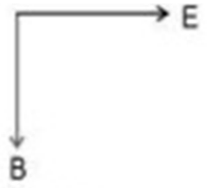
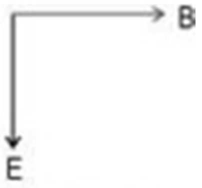
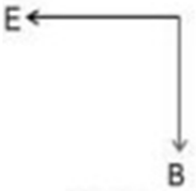
Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.126	D. The photoelectrons produced by a monochromatic incident light incident on the metal surface have a spread of kinetic energies.	1
Q.127	C. Assertion is correct. Only reasons 1 and 2 are correct.	1
Q.128	A. only photoelectric current	1
Q.129	B. Only III is correct	1
Q.130	Threshold wavelength, $\lambda = \frac{hc}{\Phi_o} = \frac{4.1 \times 10^{-15} \times 3 \times 10^{8}}{\Phi_o} = \frac{12.3 \times 10^{-7}}{\Phi_o} m$ [1 mark for the correct formula for threshold wavelength] For sodium, $\lambda = \frac{12.3 \times 10^{-7}}{2.4}$ = 5.12 x 10-7 m = 512 nm Since the λincident < λthreshold , there will be a photoelectric emission observed in sodium. [1 mark for the correct calculation and final result] For Zinc, $\lambda = \frac{12.3 \times 10^{-7}}{4.3}$ = 286 nm Since the $\lambda_{incident} > \lambda_{threshold}$, there will be no photoelectric emission observed in zinc. [1 mark for the correct calculation and final result]	3

Q.131	Equation: $\Phi_o = h\nu - KE_{max} = (h\,c/\lambda) - KEmax$ Here $KE_{max} = eV_o$ where V_o is the stopping potential applied to the collector plate $\Phi_o = (h\,c/\lambda) - eV_o$ [1 mark for the correct relation between work function and collector stopping potential] So $V_o = \frac{hc}{e\lambda} - \frac{\Phi_o}{e} = \frac{1240\ eV - nm}{330\ nm \times e} - \frac{1eV}{e} = [3.75 - 1] = 2.75$ volt [1 mark for the correct calculation ofthe collector potential]	2
Q.132	Using $\Phi_o = \frac{hc}{\lambda} - K_{max}$ In the first case, $\Phi_o = (12400/3000) – 0.5$ In the second case, $\Phi_o = (12400/2000) – K$ [0.5 mark for each equation] Equating and solving for K $\frac{12400}{3000} - 0.5 = \frac{12400}{2000} - K$ We get K = 2.57 eV for wavelength 2000 Å [1 mark for correct final result]	2
Q.133	Energy of each photon = h_v Power of the beam = n h_v = n h_c/λ [1 mark for the correct formulae of Energy and power in terms of frequency] $5 \times 10^3 = \frac{n \times 2 \times 10^{16}}{300}$ Upon calculating, $n = 7.5 \times 10^{15}$ photons per second [1 mark for the correct final result]	2

7. ELECTROMAGNETIC WAVES

Q. No	Question	Marks
Multiple Choice Question		
Q.134	Study the following statements carefully. A. Electric and magnetic fields have zero average value in a plane em wave. B. For an em wave, the ratio k/ω is independent of wavelength. C. In an em wave, the E and B fields vary with the same frequency and are in opposite phase. D. Since E = cB, the energy associated with the electric field is much greater than that associated with the magnetic field. Identify the correct option. A. only A and B are correct B. only C and D are correct C. only A and C are correct D. only B and D are correct	1
Q.135	Which of the following statement/s are incorrect? A. The displacement current flows in a dielectric of the capacitor when the potential difference across its plates is decreasing with time. B. The direction of propagation of electromagnetic waves is given by $\vec{E} \times \vec{B}$ C. The dimensions of $\epsilon_0 \frac{d\phi_E}{dt}$ are the same as that of electric voltage. D. Instantaneous energy flow rate is a constant for an electromagnetic wave. E. Light of uniform intensity shines perpendicularly on a totally absorbing surface. On decreasing the area of the surface, the intensity remains the same. A. Only statements A & B B. Only statements C & D C. Only statements D & E D. Only statements A, C & D	1

Q.136	The diagrams below show the electric and magnetic field components of an electromagnetic wave at a certain time and location. Which of these electromagnetic waves are travelling towards you?  Fig I  Fig II  Fig III  Fig IV A. only the em wave in Fig I B. only the em wave in Fig I and II C. only the em wave in Fig II and III D. only the em wave in Fig II, III and IV	1
Free Response Question / Subjective Question		
Q.137	An electromagnetic wave of frequency 1 GHz travels through an empty space along the z-direction. At a specific point in space, the electric field E attains a maximum value of 50 V/m. If the electric wave is polarized along x-axis, then, (a) explain and identify the plane in which the magnetic field B will lie. (b) express the electric and magnetic fields as a function ofz and t.	3
Q.138	In a spaceship orbiting around the Earth, two astronauts stationed 2 m apart are speaking to each other. The conversation is transmitted to Earth via electromagnetic waves. Given that the sound waves travel through the air between the two astronauts in exactly the same time as the em waves take to reach the Earth ground station. Calculate the distance of the spaceship from the ground station. Take speed of sound in the air between the two astronauts as 340 m/s.	2

Q.139	An unfortunate nuclear explosion leaves behind the residual gamma radiations in the vicinity of the explosion site with an average energy density of 4 × 10−14 J/m3. (a) What is the rms value of the electric field of the radiation? (b) Compare the electric field strength with the magnetic field strength in this residual radiation.	2
Q.140	A dish antenna with a circular aperture of a radius 20 cm, receives digital TV signals from a satellite. The average intensity of the em waves that carry a particular TV program is 5 x 10^{-14} W/m2. Determine the following: (a) electromagnetic energy delivered to the dish during the telecast of 30 minutes of a programme. (b) average energy density of the em wave.	2
Q.141	A laser emits a sinusoidal em wave of wavelength 10 µm along the x-axis. The E field of the wave is parallel to the –ve z-axis with a maximum value of 1 MV/m. Express the wave equation for E and B for this wave with all appropriate values and directions.	3
Q.142	A satellite at a height of 100 km from the Earth’s surface detects a radio signal emitted by a radio station on the ground. If the average power of the signal received is 100 kW, find the amplitudes E0 and B0 of the incoming signal.	3

Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.134	A. only A and B are correct	1
Q.135	B. Only statements C & D	1
Q.136	D. only the em wave in Fig II, III and IV	1
Q.137	(a) Since E wave is polarized along x-direction and the em wave propagates along z-direction, the magnetic field vector has to be perpendicular to both E wave and the direction of propagation of the wave. So, B vector is aligned along y axis and lies in y-z plane. [1 mark for correct explanation and the direction] (b) The standard waveforms of E and B vector in an em wave are: $E = E_o \sin (kz - \omega t)$ $B = B_o \sin (kz - \omega t)$ $B_o = E_o/c = 50/c$ T $k = 2\pi/\lambda = 2\pi \nu/c = 2\pi \times 10^9/c$ $E = 50 \sin (\frac{2\pi \times 10^9 z}{C} - 2\pi \times 10^9 .t)$ $E = 50 \sin [2\pi \times 10^9. (z/c - t)]$ $B = (50/c).\sin [2\pi \times 10^9. (z/c - t)]$ [1 mark for each correct final equation of E and B]	3
Q.138	For the travel of sound waves between the two astronauts: 2 / 340 = t ….(1) For the travel of em waves from the spaceship to the Earth station: d/(3 x 108) = t ….(2) [0.5 mark for each of the equations for sound and em waves] Equating (1) and (2) and solving for d, $d \approx 1765$ km [1 mark for correct final result]	2

Q.139	a. As energy density $u = \varepsilon_0 E_2$ $E_{rms} = \sqrt{\frac{u}{\varepsilon_0}} = \sqrt{\frac{4 \times 10^{-14}}{8.85 \times 10^{-12}}}$ = 0.067 N/C [1 mark for the correct finalresult] b. In any em radiation, the ratio E/B = c, is always constant [1 mark for the correct application of the ratio between E to B in any em wave]	2
Q.140	(a) Average intensity I = average power P /area A Average power P = I. A = I. πr^2 Average energy delivered during the telecast = I. πr^2. t [0.5 mark for correct formula of energy in terms of intensity, area and time] $E = 5 \times 10^{-14} \times \pi \times (0.2)^2 \times 1800$ $= 11.3 \times 10^{-12}$ J [0.5 mark for correct value of energy] (b) Energy density $u = I/c = 5 \times 10^{-14} / 3 \times 10^8 = 1.66 \times 10^{-22}$ J/m^3[1 mark for correct result of energy density]	2
Q.141	The standard wave equations: E-z = E_o sin(kx - ωt) … direction of E field will be along –z-axis By = Bo sin(kx - ωt) .. direction of B field will be along y-axis Where $B_o = E_o/c = 10^6/3 \times 10^8 = 3.3 \times 10^{-3}$ T $k = 2\pi/\lambda = 2 \pi / 10 \times 10^{-6} = 2\pi \times 10^5$ /m $\omega = ck = 3 \times 10^8 \times 2\pi \times 10^5 = 6\pi \times 10^{13}$ rad/s [0.5 mark for correct representation of E and correct values of B_o, k and ω] Equations: E-z = - k (10^6 V/m) sin(2π x 10^5. x - 6π x 10^{13} .t) By = j (3.3 x 10^{-3} T) sin(2π x 10^5. x - 6π x 10^{13} .t) [0.5 mark for each of E and B equations]	3
Q.142	Surface area of the hemisphere on the ground through which the signal is emitted by the radio station A = $2\pi R^2$ = 2π (100 x 1000)2 = 2π x 1010 m [0.5 mark for correct calculation of surface area]	

	Intensity of the signal received by the satellite = I = Average power/ Area = 100 x 1000 / 2π x 1010 = 10-5/2π W/m_2 [1 mark for correct calculation of Intensity of signal] As I = $\in_o E^2_{rms}$ c $E_{rms} = \sqrt{\frac{I}{\in_0 c}}$ $E_0 = \sqrt{\frac{2I}{\in_0 c}} = \sqrt{\frac{2 \times 10^{-5}}{2\pi \times 8.85 \times 10^{-12} \times 3 \times 10^{8}}}$ E_o = 0.034 V/m [1 mark for correct calculation of E_o] $B_o = E_o/c$ = 0.0115 x 10-8 T [0.5 mark for correct calculation of B_o]	

8. OPTICS

Q.No	Question	Marks
Multiple Choice Question		
Q.143	An object is moved towards a concave mirror at a constant speed, from infinity to its focus. Which of the following statements correctly describe the corresponding motion in the image formed by the concave mirror? A. The image moves slower initially and faster later on, away from the mirror. B. The image moves faster initially and slower later on, towards the mirror. C. The image moves at a constant speed, faster than the object, away from the mirror. D. The image moves at a constant speed, slower than the object, towards the mirror.	1
Q.144	Read the statements given here carefully. Each statement is in reference to spherical mirrors. Here u, v and f denote the object distance, the image distance and the focal length of the spherical mirror respectively. I. A graph plotted between u and v is a hyperbola and when u = f, v = Infinity. II. A graph plotted between u and v is a straight line and when u = Infinity, v = f. III. A graph plotted between (1/u) and (1/v) is a straight line with an intercept of each axis as (1/f). IV. A graph plotted between (1/u) and (1/v) is a hyperbola with an intercept of each axis as f. Select the correct option. A. Statements I and III are correct B. Statements II and IV are correct C. Statements I and II are correct D. Statements III and VI are correct	1
Q.145	Read the following statements carefully: I. A drop of an oil in water or in a glass, both behave as convergent lens. II. A water drop in air and a glass sphere in water, both behave as convergent	1

	lens. III. An air bubble in water and a water bubble in glass, both behave as a divergent lens. IV. A frozen ice crystal inside a glass sphere and a bromine liquid drop inside a glass sphere, behave as divergent lens. [Reference values of refractive indices of common substances: Air = 1.001; Water = 1.33; ice = 1.31; Glass = 1.51; Oil = 1.4; Bromine = 1.66] Select the correct option. A. Statements I and II are correct. B. Statements I and III are correct. C. Statements II and III are correct. D. Statements II and IV are correct.	
Q.146	An incident light ray falls on a glass prism at an angle of 60o and emerges with an angle of 30o with its initial incident direction. If the angle of the prism is 30o, then which of the following is an INCORRECT statement? A. Refractive index of the prism is √3. B. The light undergoes minimum deviation through the prism (i.e., $r_1 = r_2$). C. The emergent ray is perpendicular to the face from which it emerges. D. Angle of refraction r_1 at the incident face is same as angle of the prism.	1
Q.147	Which of the following actions will lead to an increase in the magnifying power of an astronomical telescope? A. Increase in the length of the telescope tube. B. Interchange the objective and the eyepiece of the telescope. C. A small piece of paper on the objective of the telescope pointed towards the moon. D. Increase in the focal length of the objective and decrease in the focal length of the eye piece.	1
Q.148	In a glass prism of refractive index n, identify the condition for which an incident light emerges out of the prism with a non-zero deviation. A. Angle of prism is zero	1

B Angle of incidence is equal to angle of emergence

C. The n of the material of the prism is same as its surroundings

D. Sum of angle of incidence and angle of emergence is equal to angle of prism

Q.149 Study the data related to refractive index and critical angle as given here. 1

Glass-air	**Glass-water**	**Water-air**	**Diamond-air**
Refractive index, nGA = 1.5	Refractive index, nGW = 1.125	Refractiveindex, nWA = 1.33	Refractiveindex, nDA = 2.5
Critical angle, θc = sin-1[1/1.5]= 42^{o}	Critical angle, θc = sin-1[1/1.125]= 63^{o}	Critical angle, θc = sin 1[1/1.33]= 49^{o}	Critical angle, θc =sin- 1[1/2.5]= 24^{o}

Identify an INCORRECT conclusion.

A. Lesser is the value of n, greater is the critical angle.

B. Greater is the wavelength of the incident light, greater is the corresponding critical angle in a given pair of media.

C. For given beam of incident light containing all angles of incidences, maximum total internal reflection is observed at glass-water interface.

D. Incident light with angle of incidence equal to 50oin the denser medium will be total internally reflected in all the above media except on glass-water interface.

Q.150 A real image of size p times the size of an object is formed by a concave mirror of focal length f. 1

What is the object distance from the mirror?

A. (p+1)*f/p

B. (p-1)*f/p

C. p*f/(p+1)

D. p*f/(p-1)

<table>
<tr>
<td>Q.151</td>
<td>Two superimposing waves are of amplitudes a_1 and a_2 and intensities are I_1 andI_2 respectively. If the ratio $I_1:I_2$ is 1:16, what will be the ratio of their maximumto minimum intensities upon super-imposition?
A. 1/4
B. 4/1
C. 25/9
D. 9/25</td>
<td>1</td>
</tr>
<tr>
<td>Q.152</td>
<td>Two waves from a pair of coherent sources strike the screen at a point. For which of the following cases will the intensity of superimposed waves be maximum and hence resulting in constructive interference at the given point of observation?
<table>
<tr><td>Path difference</td><td>Path difference</td><td>Path difference</td><td>Phase difference</td><td>Phase difference</td><td>Phase difference</td></tr>
<tr><td>3λ</td><td>$3\lambda/2$</td><td>$4\lambda/2$</td><td>-2π</td><td>$+5\pi$</td><td>0</td></tr>
</table>
A. Path difference = $3\lambda/2$; $4\lambda/2$ & Phase difference = 5π
B. Path difference = $4\lambda/2$ & Phase difference = $0,+5\pi$
C. Path difference = 3λ; $3\lambda/2$ & Phase difference = -2π, 5π
D. Path difference = 3λ; $4\lambda/2$ & Phase difference = 0, -2π</td>
<td>1</td>
</tr>
<tr>
<td>Q.153</td>
<td>A 5% change in wavelength is observed in the light received from a distant star. What is the speed of the moving star?
A. c
B. 0.05 c
C. 20.0 c
D. 0.02 c</td>
<td>1</td>
</tr>
<tr>
<td>Q.154</td>
<td>Which of the following statements DOES NOT correctly comply with Huygens ' Principle of constructing a secondary wavefront from a primary wavefront?
A. After some time interval, the new position of the wave front is the surface</td>
<td>1</td>
</tr>
</table>

	tangent to the secondary wavelets. B. Secondary wavelets propagate outward through a medium with speeds characteristic of waves in that medium. C. A secondary wavefront is always a plane wavefront irrespective of whether the primary wavefront is planar or spherical. D. All points on a given primary wave front are taken as point sources for the production of spherical secondary waves, called wavelets.	
Q.155	Which of the following statements related to forming of interference patterns are correct? I. The light-wave interference pattern exists in three dimensions. II. There is a net energy flow from the slits to the screen in an interference pattern. III. The light waves from the two slits overlap as they spread out and produce interference fringes on a screen placed opposite to the slits. IV. Two different but identical powered white light bulbs placed side by side would fail to produce an interference pattern on the screen. A. All are correct B. Only I and II are correct C. Only I, II and III are correct D. Only II, III and IV are correct	1
Q.156	When coherent light waves interfere to produce alternate bands of dark and bright interference bands, which of the following statement/s correctly identify the energy and intensity distribution across the interference bands? (I) Energy conservation is violated because energy disappears in the dark bands. (II) Intensity at the bright bands is four times the square of the amplitude of the individual waves. (III) The total energy leaving the slits is distributed among bright and dark bands and energy is conserved. (IV) Energy transferred by the light sources at the bright bands is same as carried by each of the individual waves. A. Statement I and II only	1

B. Statement I and IV only

C. Statement II and III only

D. Statement II and IV only

Q.157 Loud music being played on the TV in the adjacent room can be heard through the slightly open door of your study room. But you cannot see what is happening outside your room. Why is it that you can hear the sounds but unable to see through the narrow opening of the door? 1

A. Sound waves can pass right through the walls, but light waves cannot.

B. The open door is a small slit for sound waves, but a large slit for light waves.

C. Light waves diffract efficiently through the single slit of the open doorway, but sound waves cannot.

D. Light waves can travel only along straight lines whereas sound waves can travel along curved paths.

Free Response Question / Subjective Question

Q.158 A yellow light of wavelength 6000 Å enters from air into water. Refractive index for water is n = 4/3. 5

(a) Which of the following quantities for the yellow light change/s? velocity, wavelength & frequency.

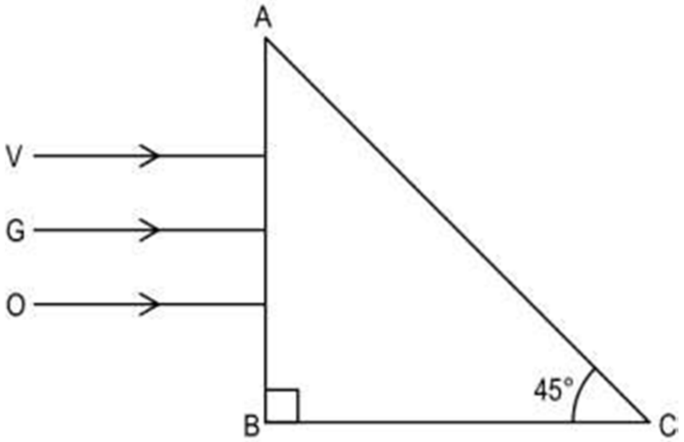
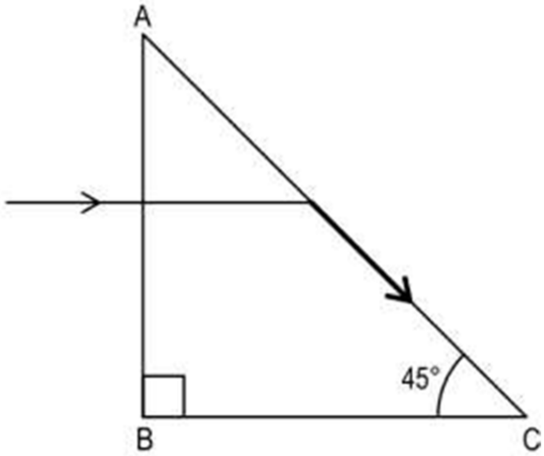
(b) What colour does the yellow light change into upon entering water? Explain your choice of the colour.

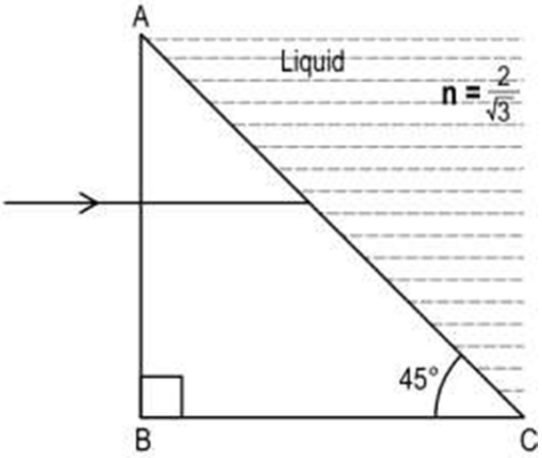
(c) Study each of the characteristics of incident and refracted yellow ray carefully. Identify if the individual combination of values (v, λ, ν and the colour) are possible for the yellow light in air undergoing refraction as it enters optically denser media.

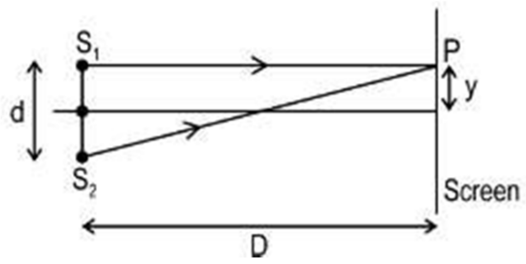
	Speed, v m/s	**Wavelength, λ Å**	**Frequency, ν Hz**	**Colour**
(i) Incident Light in air	3 x 10^{8}	6000	~5 x 10^{14}	Yellow
(ii) Refracted light in media 1	2.25 x 10^{8}	4500	~5 x 10^{14}	Yellow
(iii) Refracted light in media 2	2 x 10^{8}	7000	~5 x 10^{14}	Red

Explain your answer in each of the cases.

Q.159	An object is placed on the optical bench at a distance of 40 cm from the convex mirror of focal length 10 cm. A plane mirror is placed in between the object and the convex mirror such that it covers the lower half of the convex mirror. Find the distance from the object where the plane mirror be placed, so that no parallax is observed between the two images formed by the two mirrors.	2
Q.160	A beam of yellow light falls with a certain angle of incidence at the interface of the two media and experiences an angle of refraction of 90o. Red and blue light beams then replace the yellow light successively, keeping all other conditions same. One of the two colours, red or blue, undergoes total internal reflection. (a) Identify the colour of light that undergoes TIR. Give reason for your choice. (b) Also give reason why the other colour doesn't undergo TIR.	3
Q.161	A thin convex and a thin concave lens are placed along the same axis on an optical bench. A parallel beam of light falls on the convex lens. The distance d between the two lens is adjusted by moving the concave lens so that the light emerging out of the concave lens is parallel. (a) Draw a suitable ray diagram to represent the flow of light through the lens system. (b) State the condition that ensures that the emergent beam is parallel. If the focal length (convex) = 20 cm and focal length (concave) = 8 cm, find d.	2
Q.162	Lens Q when placed in contact with a converging lens P of focal length = 20 cm makes a combination that behaves as a converging lens system of focal length 30 cm. Lens Q when placed in contact with another lens R makes a combination that behaves as a diverging lens system of focal length 10 cm. Identify the nature of lens Q and R and determine their focal lengths.	3
Q.163	An object placed at a distance of x from the first focus of a convex lens forms a real image at a distance of y from its second focus. Show that the product xy is equal to the square of the focal length f of the lens.	2
Q.164	A beam of light consisting of violet (V), green (G) and orange (O) colours is incident on a right-angled prism as shown.	2

	 If the refractive indices of the material of the prism with respect to these three colours are 1.55, 1.45 and 1.35 respectively, which of these colours are able pass through the face AC?	
Q.165	A light ray entering a right-angled prism undergoes refraction at the face AC as shown. (Fig I) (a) What is the refractive index of the prism in Fig I?  Fig I (b) i. If the side AC of the above prism is now bounded by a liquid of refractive index 2/√3, (Fig II), determine if the light ray continues to graze along the interface AC OR undergoes total internal reflection OR undergoes refraction into the liquid.	3

	 Fig II ii. Draw the ray diagram to represent the path followed by the incident ray with the corresponding angle values. Given sin-1 √2/√3 = 54.6	
Q.166	A lens made of glass (nG) is placed in a medium of refractive index (nM). (a) Show that for nM < nG , the nature of the lens remains unchanged but its focal length increases. (b) Show that for nM > nG , the nature of the lens changes (i.e., convergent lens behaves as divergent and vice versa).	2
Q.167	An object is placed at a distance of 10 cm from first focus of a biconvex lens of focal length f. It forms an image at a distance of 10 cm from its second focus on the other side of the lens. Determine the focal length f of the given biconvex lens.	2
Q.168	In a Young's double slit experiment arrangement, each slit is illuminated with a light containing two wavelengths, 5890 Å and 5895 Å. Due to the dual wavelengths, the fringe patterns due to individual wavelengths overlap on the screen. Determine up to what order the fringes can be seen on the screen. (Note: Here the order of the fringes implies the nth fringe of each wavelength beyond which the interference patterns appear as continuous).	2
Q.169	A monochromatic light produces a fringe pattern on the screen in a double slit experimental set up. As the screen is moved towards the slits through a distance of 0.05 m, the fringe width on the screen changes by 3 x 10- 5 m.	2

	a. Does this change represent an increase or decrease in the fringe width of the pattern? b. Keeping the wavelength and separation between the slit's constant, determine the change in fringe width produced in case the screen is moved through a distance of 0.02 m from its initial position.	
Q.170	Fringe width of the interference pattern on the screen in a double slit experiment is β. Determine the fringe width if the whole apparatus is immersed in a liquid of refractive index n = 6/5.	2
Q.171	A visible light source constituted of two wavelengths: λ = 520 nm and λ' = 420 nm is used in a double-slit interference experiment. Also given are distance between slits and the screen, D = 1.50 m and the slit width d = 0.025 mm. Find the order n of maxima of light of λ that will overlap with n' of light of λ' on the screen.	2
Q.172	A light of wavelength 500 nm is used to illuminate a double slit experiment. For a double slit with a separation of 0.4 mm, determine how far the screen should be placed from the slits in order that a dark fringe appears directly opposite to both the slits and only one bright fringe in between them.	2
Q.173	A coherent light beam of 500 nm wavelength strikes two slits, producing an interference pattern. The two slits are separated by 0.3 mm and the distance between the slits and the screen is 0.3 m. Determine the number of maxima observed across the perpendicular distance of y = -1 mm to y = +1 mm on the screen.	2
Q.174	In the double slit experiment, given that, d = 0.140 mm, D = 140 cm, λ = 600 nm, and y = 1.80 cm.  (a) Determine the path difference δ for the rays from the two slits arriving at P. (b) Express this path difference in terms of wavelength λ.	3

	(c) Does the position P correspond to maxima, minima, or an intermediate condition?	
Q.175	Two cars following each other enter a short tunnel. Car 1 plays music on FM station at frequency 100 MHz whereas Car 2 plays music on AM station at frequency 1000 kHz. Which radio station will continue to play the music while the car passes through the short tunnel? Explain your answer.	2
Q.176	A blue coloured alternate bands of diffraction pattern appears on a screen due to the blue light of wavelength λ passing through a single slit of width w. If the blue light is replaced with a green light of wavelength 1.5 λ, to what width should you change the slit in order to get the original pattern back?	1
Q.177	Sea waves of wavelengths 25 m keep splashing at a 60 m wide opening in the wall barrier near the shore. The racing boats are parked on the other side of the wall barrier. a. Determine two consecutive angles to the incident direction at which the boats can be parked, so that they experience minimum rocking motion. b. Which of these two angles will receive least disturbance?	2
Q.178	Monochromatic light produces a diffraction pattern through slit of width 1 mm on a screen that is 2 m away from the slits. If the width of central maxima in the diffraction pattern is 2 cm, determine the wavelength of the incident monochromatic light.	2
Q.179	A combination of multiple convex lens kept in contact with each other has an equivalent focal length of 0.02 m. An object is placed at a distance of 0.03 m from the combination lens system. If one of the component lens of focal length 0.1 m is removed from the combination, by what distance is the image of the object shifted from its initial position?	3

Answer Key & Marking Scheme

Q.No	Answers	Marks
Q.143	A. The image moves slower initially and faster later on, away from the mirror.	1
Q.144	A. Statements I and III are correct	1
Q.145	C. Statements II and III are correct.	1
Q.146	B. The light undergoes minimum deviation through the prism (i.e., $r_1 = r_2$).	1
Q.147	D. Increase in the focal length of the objective and decrease in the focal length of the eye piece.	1
Q.148	B. Angle of incidence is equal to angle of emergence	1
Q.149	C. For given beam of incident light containing all angles of incidences, maximum total internal reflection is observed at glass-water interface.	1
Q.150	A. (p+1)*f/p	1
Q.151	C. 25/9	1
Q.152	D. Path difference = 3λ; 4λ/2 & Phase difference = 0, -2π	1
Q.153	B. 0.05 c	1
Q.154	C. A secondary wavefront is always a plane wavefront irrespective of whether the primary wavefront is planar or spherical.	1
Q.155	A. All are correct	1
Q.156	C. Statement II and III only	1
Q.157	B. The open door is a small slit for sound waves, but a large slit for light waves.	1
Q.158	(a) velocity& wavelength [1 mark for correct choice of characteristics]	5

(b) The colour of the light is function of its frequency and not its wavelength. Frequency of light does not change with the change in medium. Hence the yellow light remains yellow in water as well.

[0.5 mark for correct answer and 0.5 mark for the correct explanation]

(c)

		Speed m/s	**Wavelength Å**	**Frequency Hz**	**Colour**	
i	Incident Light	3 x 10^8	6000	~5 x 10^{14}	Yellow	Possible
ii	Refracted light	2.25 x 10^8	4500	~5 x 10^{14}	Yellow	Possible
iii	Refracted light	2 x 10^8	7000	~5 x 10^{14}	Red	Not possible

i. Possible

c = vλ = 6000 x 10^{-10} x 5 x 10^{14} = 3 x 10^8 m/s .. which is correct.

ii. The speed decreases to 2.25 x 108, implies that the light has entered another medium.

$\lambda / \lambda_o = v/c$

λ_o = 6000 x 10^{-10} x 2.25 x 10^8/3 x 10^8 = 4500 Å

Since the frequency doesn’t change, the colour of the light remains as yellow in the medium.

So (ii) is possible.

iii. The speed decreases to 2 x 10^8, implies that the light has entered another medium.

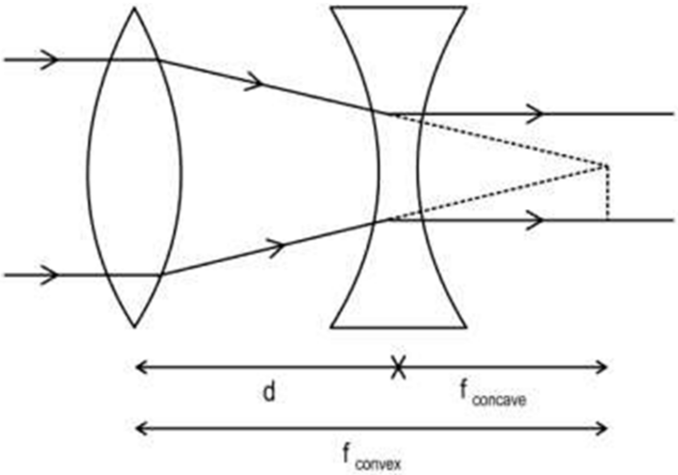
As $\lambda / \lambda_o = v/c$, the wavelength cannot increase.

The colour of light does not change with the change in medium. So (iii) is not possible.

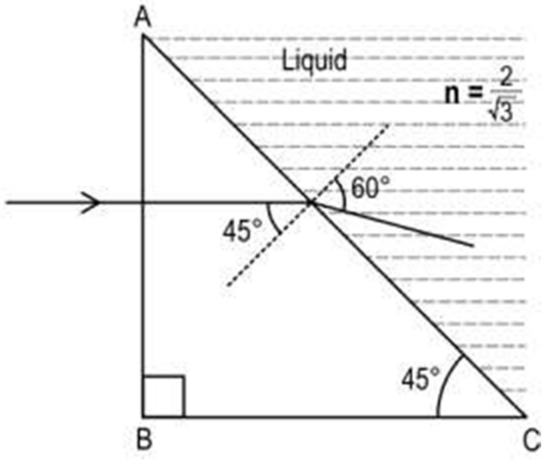
[0.5 mark for each correct identification]

[0.5 mark for each correct corresponding explanation]

Q.159	Using mirror formula for the convex mirror, 1/f = 1/v + 1/u 1/10 = 1/v + 1/(-40) Solving for v, v = 8 cm [0.5 mark for the correct value of image distance] For no parallax, the position of the image formed by plane mirror should coincide with position of the image formed by the convex mirror. [0.5 mark for identifying the condition of parallax] Hence, Total distance between object and image formed by convex mirror = 40 + 8 = 48 cm Plane mirror has to be placed at 48/2 = 24 cm from the object. [1 mark for the correct final result]	2
Q.160	(a) Blue colour undergoes TIR. As n is proportional to 1/λ and sin c = 1/n Since $\lambda_b < \lambda_y$, $n_b > n_y$ So Critical angle $C_b < C_y$ In the present situation, since at the given angle of incidence i, the yellow light has angle of refraction = 90, at the same angle of incidence i, the blue light will undergo total internal reflection since $C_b < C_y$. [0.5 mark for the correct colour identification] [1 mark for the correct reasoning] (b) Red colour does not undergo TIR. It passes through the interface with angle of refraction < 90. As n is proportional to 1/λ and sin c = 1/n Since $\lambda_r > \lambda_y$, $n_r < n_y$, So critical angle $C_r > C_y$ In the present situation, since at the given angle i, the yellow light has angle of refraction = 90, at the same angle of incidence i, the red light simply passes through into the rarer medium at an angle of refraction < 90. [0.5 mark for the correct colour identification] [1 mark for the correct reasoning]	3

Q.161	(a)  (b) Parallel beam that enters the convex lens converges at its focus after refraction. If the emergent beam from the concave lens is to be parallel, then the rays coming from convex lens must virtually meet at the focus of concave lens. [1 mark for the correct reasoning] Distance d = f_{cx} - f_{cv} = 20 – 8 = 12 cm [1 mark for the correct result]	2
Q.162	P & Q combination: $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ $\frac{1}{30} = \frac{1}{20} + \frac{1}{f_2}$ Calculating f2= -60 cm [1 mark for the correct result of focal length of lens Q] That is, Lens Q is a diverging lens. [0.5 mark for correct identification of lens Q] Q & R combination: $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$ $\frac{1}{-10} = \frac{1}{-60} + \frac{1}{f_2}$ Calculating f2 = -12 cm [1 mark for the correct result of focal length of lens R] That is, Lens R is also a diverging lens.	3

	[0.5 mark for correct identification of lens R]	
Q.163	Using lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ $\frac{1}{f} = \frac{1}{y+f} - \frac{1}{-(x+f)}$ $\frac{1}{f} = \frac{x+f+y+f}{(y+f)(x+f)}$ [1 mark for correct formula and substitution] $f(x + 2f + y) = x_y + f_y + f_x + f_2$ Transposing and solving $xy = f_2$ [1 mark for correct proof]	2
Q.164	Angle i at face AB is 0. So each colour passes through AB and strikes the face AC at an angle of 45. The light ray will pass through AC if, Angle, $i < \theta_c$ Or get total internally reflected from AC if $i \geq \theta_c$ [0.5 mark for correct identification of condition for TIR] $\sin i \geq \sin \theta_c$ $\sin 45 \geq \sin \theta_c$ $1/\sqrt{2} \geq \sin \theta_c$ $1/\sqrt{2} \geq 1/n$ $n \geq \sqrt{2} = 1.41$ [0.5 mark for correct value of n] So, the light colour with $n > 1.41$, that is, violet and green are total internally reflected by the face AC. Red colour however passes through the face AC as it $n < 1.41$. [0.5 mark for correct identification of colours that pass through and the colour that undergo TIR]	2
Q.165	(a) Since the light ray enters perpendicular to the face AB, the angle of incidence on face AC will be 45. So, $n = 1/\sin \theta_c$ $\sin \theta_c = 1/n$ $\sin 45 = 1/n = 1/\sqrt{2}$ So $n = \sqrt{2}$	3

	[0.5 mark for the correct calculation of value of n] (b) In Fig II, the face AC of the prism surrounded by a liquid. n = ng /nl = √2 / (2/√3) = √3/√2 $\sin\theta_c$ = 1/n = √2/√3 θ_c = sin-1 √2/√3 = 54.6. Since the angle of incidence on the surface AC is 45, which is less than the critical angle for the pair of media (glass and the liquid), the ray NEITHER undergoes grazing along surface AC, NOR does it undergo TIR. [1 mark for concluding that the ray does not undergo TIR at AC] Instead it passes through the surface AC and undergoes refraction in the liquid. For refracting interface AC, n1sini = n2sinr n2. sin45 = (2/√3) sinr sinr = √3/2 r = 60. [1 mark for concluding that the ray undergoes refraction and calculation of angle of refraction at AC]  [0.5 mark for the correct diagram of the path of the refracted ray]	
Q.166	(a) As 1/f = (n-1) [$1/R_1 + 1/R_2$] = (n-1)K Here n = nG/nM >1 And since 1/f is proportional to (n-1), 1/f decreases and f(focal length) increases. And there is no change in the nature of the lens. [1 mark for the correct	2

	explanation] (b) Here $n = nG/nM < 1$ And since $1/f$ is proportional to $(n-1)$ --> f becomes negative The nature of the lens changes. A convergent lens behaves as divergent. A divergent lens behaves as convergent. [1 mark for the correct explanation]	
Q.167	Given, $u = (10+f)$ $v = -(10+f)$ Using lens formula, $1/f = 1/(10+f) - 1/(-(10+f))$ $1/f = 2/(10+f)$ $10 + f = 2f$ $f = 10$ cm [1 mark for correct formula and use of correct sign conventions] [1 mark for correct calculation and result]	2
Q.168	The fringes appear till the point where a maxima of one wavelength coincides with minima of the other. [0.5 mark for the statement of the correct condition] That is, $5895 \times n = 5890 (n + ½)$ [0.5 mark for the statement of the correct equation] Solving, we get, $n = 589$ So fringes will be visible up to order of 589 of 5895 Å. [1 mark for the correct final result] OR The fringes appear till the point where a maxima of one wavelength coincides with minima of the other. [0.5 mark for the statement of the correct condition] $5890 \times n = 5895 (n + ½)$ [0.5 mark for the statement of the correct equation] Solving $n = 589.5$	2

	So fringes will be visible upto order of 589 of 5890 Å. [1 mark for the correct final result]	
Q.169	a. Decrease in fringe width. [0.5 mark for the correct conclusion] b. As $\beta = (D/d)\ \lambda$ Change in fringe width as a function of D, $\Delta\beta = \Delta D/d\ .\ \lambda$ [0.5 mark for the correct relation between the changes in β and D] In the first case, $\Delta\beta_1$ proportional to ΔD_1 $\Delta\beta_2$ proportional to ΔD_2 Finding the ratio and calculating, $\Delta\beta_2 = (\Delta D_2)/(\Delta D_1)\ .\ \Delta\beta_1$ $= (0.02/0.05) \times 3 \times 10^{-5}$ $= 1.2 \times 10^{-5}$ m [1 mark for the correct final result]	2
Q.170	As $\beta = (D/d)\ \lambda$ When immersed in a liquid, D and d remain constant. The wavelength of the light from the source changes to λ' as the frequency f of the light remains constant, speed of light and its wavelength change in the liquid. [1 mark for the correct statement on changes in λ, v and f due to change in medium] $\lambda' = v/f\ \lambda = c/f$ So, $\beta'/\beta = \lambda'/\lambda = v/c = 1/n$ Hence, $\beta' = \beta/n = 5\beta/6$ [1 mark for the correct finalresult]	2
Q.171	Condition for nth fringe of maxima of light of λ to overlap with n' th fringe of light of λ' on the screen:	2

	nλD/d =n'λ'D/d [1 mark for the statemnet of correct condition and its equation] λ/λ'= n'/n= 520/420=26/21 So 26th bright fringe of light of 420 nm overlaps with the 21st bright fringe of light of 520 nm. [1 mark for the correct finalresult]	
Q.172	For the first dark fringe to appear right in front of the slits, $y = (n + \frac{1}{2})\frac{\lambda D}{d}$ here n = 0, y= 0.2 x 10-3 m, λ = 500 x 10-9 m [1 mark for the correct formula and values] $D = \frac{2yd}{\lambda} = \frac{2 \times 0.2 \times 10^{-3} \times 0.4 \times 10^{-3}}{500 \times 10^{-9}}$ = 0.32 m = 32 cm [1 mark for the correct final result]	2
Q.173	Given D = 0.3 m, d = 0.3 x 10-3 m; λ = 500 x 10-9 m To determine the no. of maxima between of y = -1 mm to y = +1 mm. As y = n λD/d At y = 1 mm = 1 x 10-3 m, $n = \frac{yd}{D\lambda} = \frac{1 \times 10^{-3} \times 0.3 \times 10^{-3}}{0.3 \times 500 \times 10^{-9}} = 2$ [1 mark for the correct calculation of n value for the given y] So, it implies that 2 maxima are formed on the either side of the central maxima. So the total count of number of maxima across y = -1 mm to y = +1 mm on the screen is 2 + 1 +2 = 5. [1 mark for the correct final count of the maxima fringes]	2
Q.174	a. Path difference, $\delta = \frac{yd}{D} = \frac{1.8 \times 10^{-2} \times 0.14 \times 10^{-3}}{1.4} = 1.8\ \mu m$	3

	[1 mark for the correct calculation of the path difference] b. $\frac{\delta}{\lambda} = n = \frac{1.8 \times 10^{-6}}{600 \times 10^{-9}} = 3$ [1 mark for the correct calculation of n as the coefficient of wavelength] c. Since n is an integer, the position P would correspond to a maxima. [1 mark for the correct conclusion on the nature of the fringe]	
Q.175	FM station radiates waves at wavelength: $\lambda = \frac{3 \times 10^{8}}{100 \times 10^{6}} = 3 \text{ m}$ AM station radiates waves at wavelength: $\lambda = \frac{3 \times 10^{8}}{1 \times 10^{6}} = 300 \text{ m}$ [0.5 mark for the calculation of each wavelength] The width of the tunnel is of the order of wavelength of FM waves. So FM waves can diffract and enter the tunnel. Thereby the Car 1 continues to play the music. On the other hand the AM waves are way more than average width of the tunnel and fail to diffract at the opening of the tunnel. So, the AM radio signal fades away as soon as the car enters the tunnel and the music in the Car 2 dies away inside the tunnel. [0.5 mark for each of the correct explanation]	2
Q.176	Answer: The angle of diffraction θ depends on the ratio of wavelength to slit width. sinθ = +/- n λ/a In order to keep the angle same, if wavelength rises by a factor of 1.5, the slit width also to increase by the same factor of 1.5. Then the fringe widths of diffraction pattern due to green light will stay same as that with blue light. [0.5 mark for the correct formula] [0.5 mark for the correct final result]	1

Q.177	a. The sea waves undergo diffraction at the 60 m wide opening. For minimum rocking of the racing boats, they need to be parked along the angle where the first or second minima of the diffraction pattern are produced. [0.5 mark for the correct identification of the points where the boats should be parked for minimum disturbance] Using the equation sinθ = nλ/a , where n = 1, we can determine the angle for first minimum: sin θ = 25/60 = 0.416 θ = sin-1(0.416) [0.5 mark for the correct result of the first minimum angle] The angle of the second minimum, sinθ = nλ/a , where n = 2, sinθ= 2 x 25/60 = 0.83 θ = sin-1(0.83) [0.5 mark for the correct result of the second minimum angle] b. At the second minimum, the disturbance on the boats will be negligible. [0.5mark for the correct conclusion]	2
Q.178	For small diffraction angles, $\theta = \frac{\text{Width of maxima / 2}}{\text{Distance between screen \& slit}} = \frac{1 \times 10^{-2}}{2} = 0.5 \times 10^{-2}$ [1 mark for the correct formula and angle value] Also using λ = d x θ = 1 x 10-3x 0.5 x 10-2 = 0.5 x 10-5 m So λ = 5000 nm [1 mark for the correct final result]	2

Q.179	Initially, $1/v_1 - 1/u = 1/F$ $1/v_1 - 1/(-3) = 1/2$ So initially the image is formed at $v_1 = +6$ cm [1 mark for finding the initial position of the image] For the combination lens system, $1/F = 1/f_1 + 1/f_2 + 1/f_3 + \cdots . = 1/f_1 + 1/F'$, here f_1 is the focal length of the lens that is removed from the combination, $1/F' = 1/F - 1/f_1 = 1/2 - 1/10$ $F' = 2.5$ cm. This is focal length of the remaining combination after the removal of one lens. [1 mark for finding the focal length of the combination after the removal of the lens] $1/v_2 - 1/u = 1/F'$ $1/v_2 - 1/(-3) = 1/2.5$ $v_2 = + 15$ cm So the final image of the object is shifted away from the lens system by a distance of 9 cm. [0.5 mark for finding the image position in the new combination] [0.5 mark for the correct shift in the position of the image]	3

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