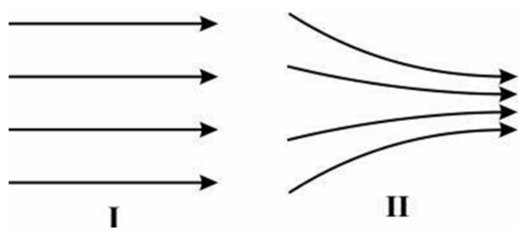
# 1. ELECTROSTATICS

<table>
<tr><th>Q. No</th><th>Question</th><th>Marks</th></tr>
<tr><td colspan="3">Multiple Choice Questions</td></tr>
<tr><td>Q.1</td><td>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.<br><br>Which of the following explains the effect of the dielectric slab in the above situation?<br><br>A. The electric field between the plates of the capacitor rises.<br>B. The potential difference between the plates falls.<br>C. The total charge on the capacitor increases.<br>D. The ability of the capacitor to store charge decreases.</td><td>1</td></tr>
<tr><td>Q.2</td><td>The image below shows two examples of electric field lines.<br><br><br>Which of the following statements is true?<br><br>A. The electric fields in both I and II arise due to a single positive point charge located somewhere on the left.<br>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.<br>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.<br>D. As you move from left to right, the electric fields in both I and II become stronger.</td><td>1</td></tr>
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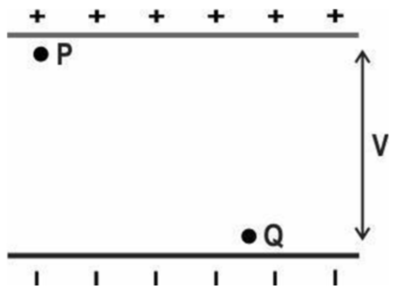
| Q.3 | In a given region, electric potential varies with position as $V(x) = 3 + 2x^2$.<br>Identify which of the following statements is correct.<br>A. Potential difference between the two points x = 2 and x = -2 is 2 V.<br>B. A charge of 1 C placed at x = 2 experiences a force of 6 N.<br>C. The force experienced by the above charge is along +x - axis.<br>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.<br><br><br>Which one of the statements is correct?<br>A. The forces on the two protons are identical.<br>B. The force on proton P near the positive plate is more than the force on proton Q.<br>C. The force on proton Q near the negative plate is more than the force on proton P.<br>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.<br>What is the requirement for the total flux through the closed container to be zero?<br>A. The field must be uniform.<br>B. The container must be symmetric.<br>C. The container must be oriented in a particular direction.<br>D. There is no such requirement. The total flux through the container is zero no matter what. | 1 |

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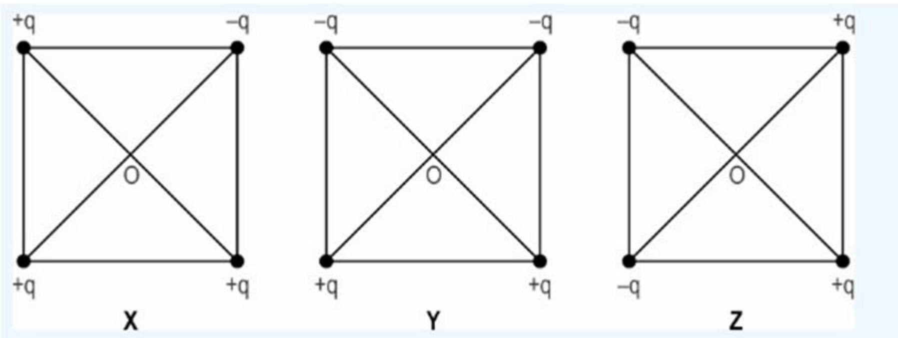
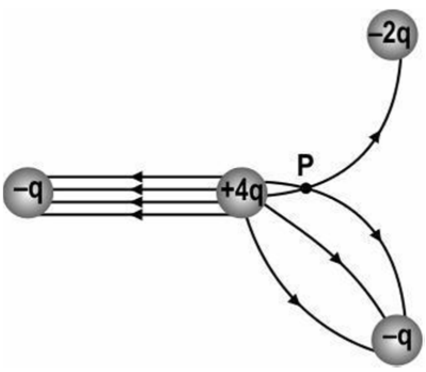
| Q.6 | A uniform electric field of 5000 V/m exists in a certain region. What volume of this space will contain energy equal to $10^{-6}$ J? (Take $\in o$ = 8.8 x$10^{-12}$ SI units)<br>A. 9 $m^3$<br>B. 9 x $10^{-3}$ $m^3$<br>C. 9 x $10^{-6}$ $m^3$<br>D. 9 x $10^3$ $m^3$ | 1 |
| **Free Response Question/Subjective Question** | | |
| Q.7 | Given are three different square arrangements of charges.<br><br><br>(a) Draw relevant vector diagrams to represent the resultant electric field ER at the center of the square in each case.<br>(b) Identify the arrangement in which the resultant electric field is the smallest at the center of the square. | 4 |
| Q.8 | The figure below shows an arrangement of four charges along with some electric field lines drawn between the charges.<br><br><br>(a) Identify three things that are incorrect in this figure.<br>(b) Draw a correct diagram representing the electric field lines for this system of charges. | 4 |

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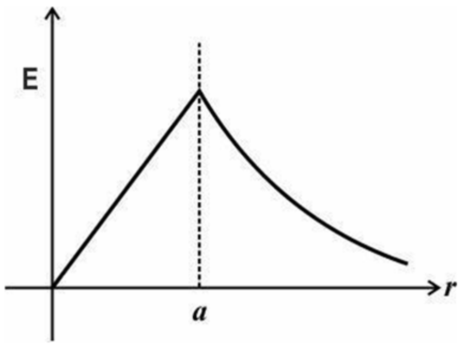
| Q.9 | In the case of a spherical charged conductor of radius R, hollow or solid, the electric potential is constant and maximum inside and on the surface.<br>On the outside, the electric potential varies as,<br>$V \propto \frac{1}{r}$<br>where r is the distance from the center of the sphere.<br>(a)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

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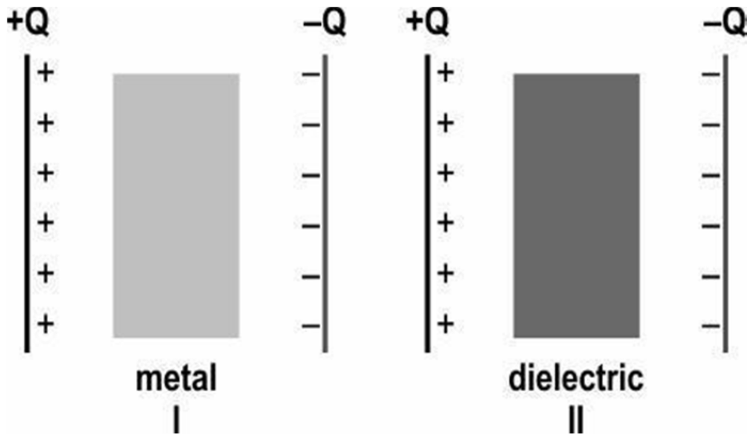
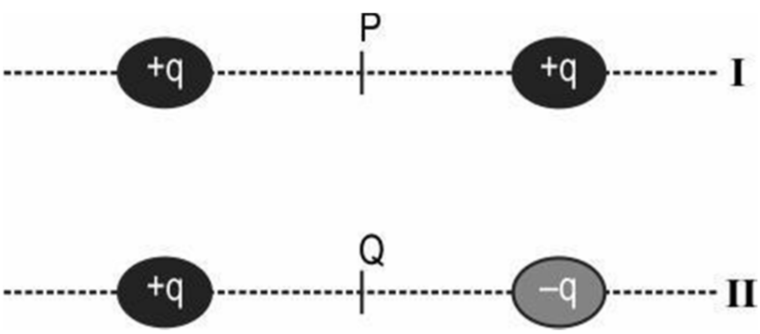
| Q.12 | Given is a pair of parallel charged metal plates in the arrangement as shown.<br><br>(a) Sketch the electric field lines between the plates in I and II.<br>(b) Mention whether net electric field intensity is zero or non-zero in each case. | 3 |
| Q.13 | The dielectric strength of a medium is the minimum electric field required to cause ionization of the medium. For air, this value is taken as 3 million V/m.<br>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.<br>(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.<br> | 2 |

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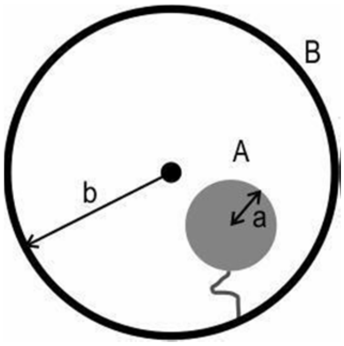
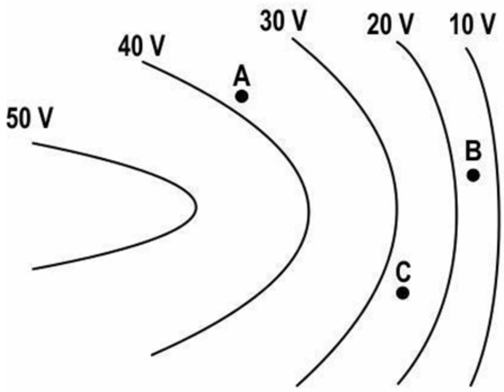
| Q.15 | A metal sphere A of radius a is charged to a potential V. It is enclosed inside a hollow metal shell B of radius b.<br><br><br>What will be the potential of A if it is connected to shell B by a conducting wire? Show the working. | 2 |
| Q.16 | Two hollow spherical conductors of different sizes are charged positively. The smaller one is at 50 V and the larger one is at 100 V.<br>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.<br>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.<br><br><br>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 |

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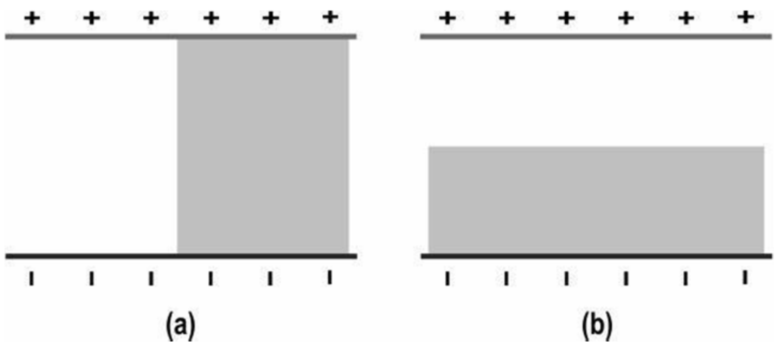
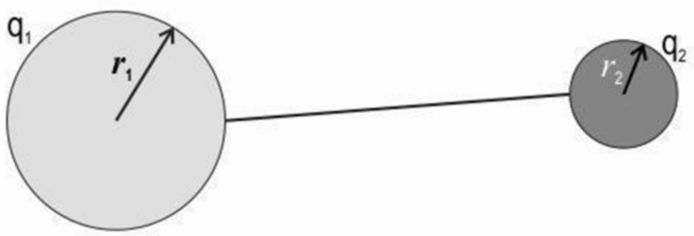
| Q.18 | The capacitance of an infinite parallel capacitor without any dielectric between the plates is C. It is then half-filled with a dielectric medium of K = 4 as in Fig (a) and then as in Fig (b).<br><br><br>Show that capacitance in Fig (a) becomes 5C and in Fig (b) the capacitance becomes (4/5)C 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.<br>(a) What will be the angle between the two strings?<br>(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.<br><br><br>Find the ratio of the magnitudes of the electric fields at the surfaces of the two spheres. | 2 |

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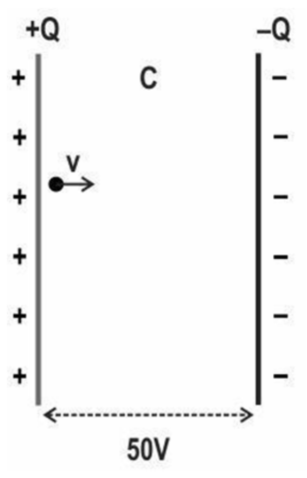
| Q.21 | A parallel plate capacitor of capacitance C is charged to a potential V by a battery. Q is the charge stored on the capacitor. Without disconnecting the battery, the plates of the capacitor are pulled apart to a larger distance of separation.<br><br>What changes will occur in each of the following quantities? Will they increase, decrease or remain the same? Give an explanation in each case.<br><br>(a) Capacitance<br>(b) Charge<br>(c) Potential difference<br>(d) Electric field<br>(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.<br><br>If the dielectric is withdrawn from the capacitor,<br>(a) Will the energy stored in the capacitor increase or decrease? What causes the change in energy?<br>(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.<br><br><br><br><br>Will the ball strike the negative plate? Give mathematical working for the answer. | 3 |

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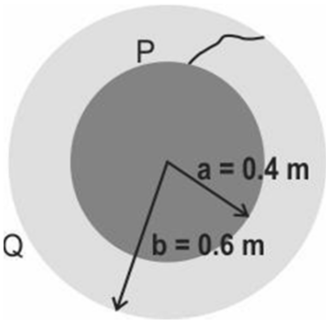
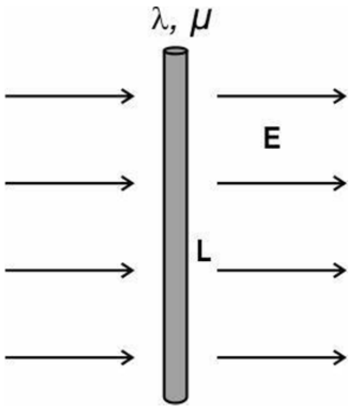
| Q.24 | An isolated capacitor of unknown capacitance C is charged to a potential difference V. It is then connected in parallel to an uncharged capacitor of capacitance Co such that the potential difference across the combination becomes V/3.<br><br>Determine the unknown capacitance C. | 2 |
| Q.25 | P and Q are two concentric conducting hollow shells connected to each other by a conducting wire.<br><br><br><br><br>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.<br><br>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.<br><br><br><br><br>Determine the speed of the rod after it travels through 1 m of distance. Ignore all external forces except the electrostatic forces. | 3 |

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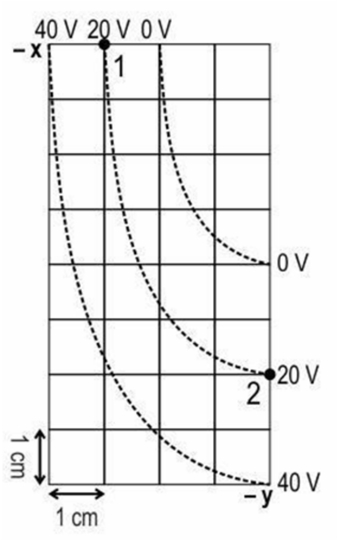
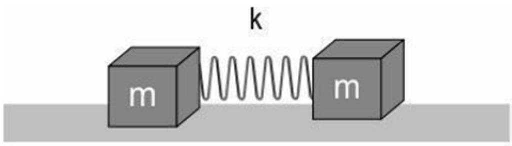
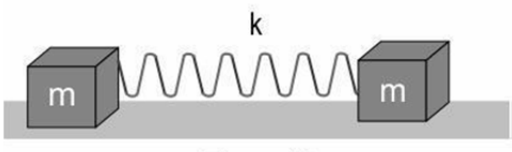
| Q.27 | A thundercloud carries a charge of +50 C at a height of 4000 m and a charge of -50 C at a height of 2000 m from the ground. An airplane crosses through the charged thundercloud at a height of 3000 m from the ground.<br><br>Find the magnitude and the direction of the electric field acting on 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.<br><br><br> | 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).<br><br><br><br>Figure (i)<br><br><br><br>Figure (ii)<br><br>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).<br><br>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 |

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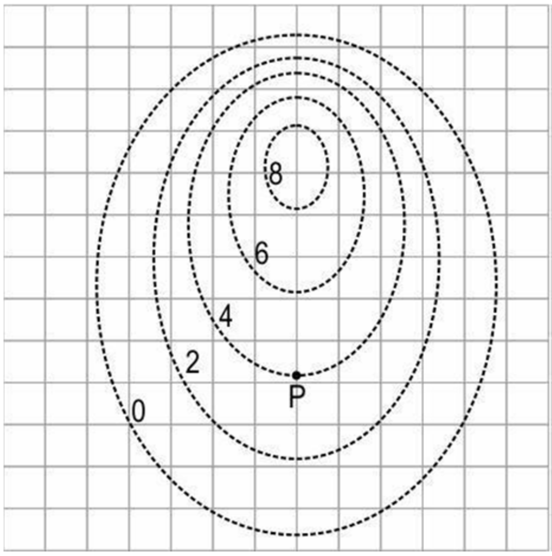
| Q.30 | The diagram below shows an arrangement of a set of equipotential lines in a given region. Each line is marked with the potential it represents. The background gridlines are squares of each side equal to 1 cm.<br><br><br>(a) Determine electric field at point P.<br>(b) Draw 6 field lines to represent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

## Answer Key & Marking Scheme

| Q. No | Answers | Marks |
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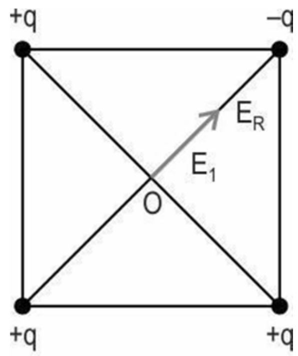
| Q.1 | C. The total charge on the capacitor increases. | 1 |
| Q.2 | C. The electric field in I is the same everywhere but the electric field in II becomes stronger as we move from left to right. | 1 |
| Q.3 | D. The electric field in the given region is non-uniform along x - axis. | 1 |
| Q.4 | A. 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. $9 \times 10^{-3}\ m^3$ | 1 |
| Q.7 | (a) 1 mark each for the correct vector representation of the electric field in the three cases:   X | 4 |

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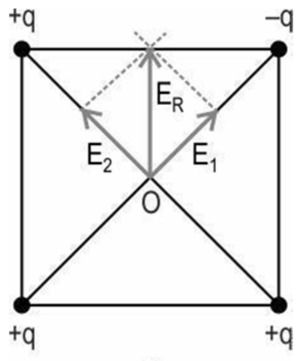
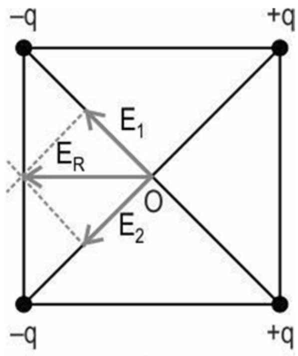
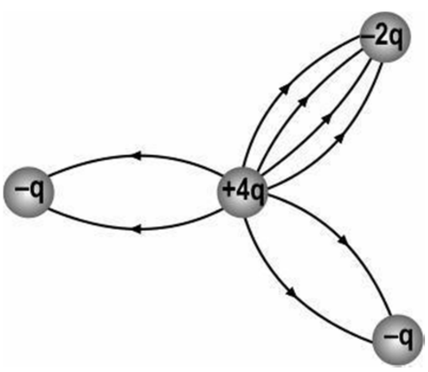
| | <br><br>Y<br><br><br>Z<br><br>(b) $E_R$ vector in X is the smallest in length. | |
| Q.8 | (a) 1 mark for each correct point:<br>- Electric field lines cross each other as shown at point P.<br>- Number of field lines that end on the negative charges is not proportional to their charges.<br>- The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

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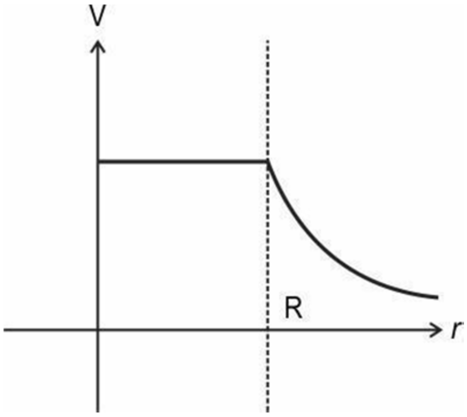
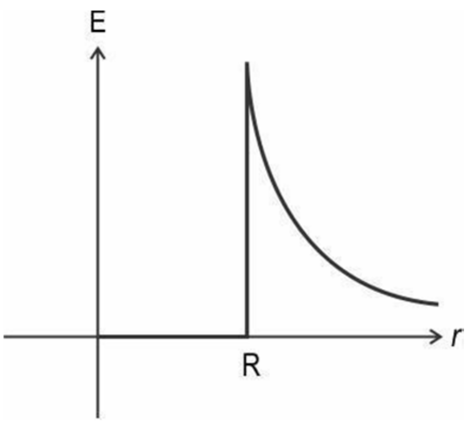
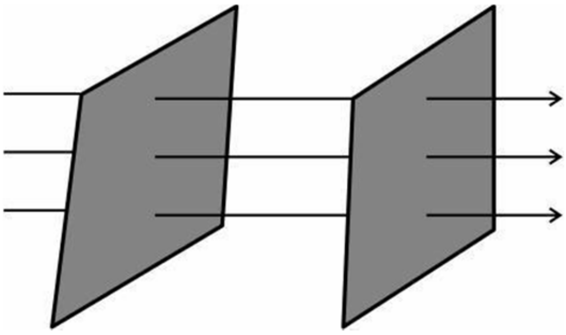
| Q.9 | (a)<br><br>[1 mark for the correct graph]<br>(b) Electric field intensity is zero inside the charged sphere. Maximum at the surface. On the outside of the sphere, it falls as E proportional to $1/r^2$<br>[1 mark for the correct statement of variation of E with r]<br>(c)<br><br>[1 mark for the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

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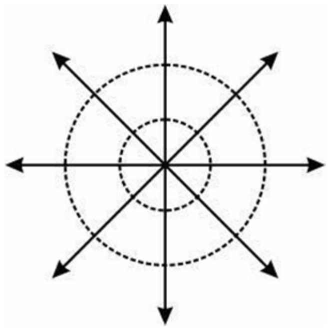
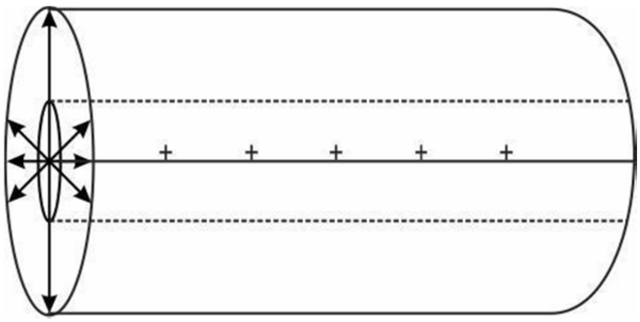
| | [1 mark for the correct drawing of two equipotential surfaces]<br>(b) A point charge<br><br>[1 mark for the correct drawing of two equipotential surfaces]<br>(c) An infinite straight line of charge<br><br>[1 mark for the correct drawing of two equipotential surfaces] | |
| Q.11 | E = 0 at r = 0.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

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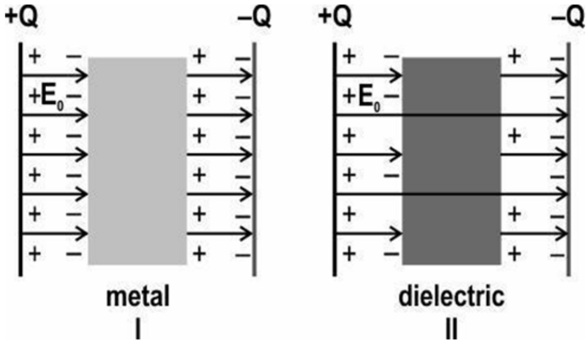
| Q.12 | (a)<br><br><br>[1 mark for correct representation of electric field inside metal]<br>[1 mark for correct representation of electric field inside dielectric]<br>(b) The net electric field intensity inside a metal is zero.<br>The net electric field intensity inside a dielectric is non-zero.<br>[0.5 mark for each point] | 3 |
| Q.13 | Electric field on the surface of a metal sphere:<br>$$E = \frac{Q}{4\pi\epsilon_0 R^2} = 9 \times 10^9 \frac{1}{(1 \times 10^{-2})^2} = 9 \times 10^{13} \text{ V/m}$$<br>[1 mark for the correct formula and calculation]<br>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.<br>[1 mark for the correct interpretation and conclusion] | 2 |
| Q.14 | (a) As<br>$$E = -\frac{\Delta V}{\Delta r}$$<br>If E =0, at a given point, then<br>$$\frac{\Delta V}{\Delta r} = 0$$<br>i.e., V = 0 or constant at that point.<br>[1 mark for correct explanation]<br>(b) At mid-point P in Fig I, E is zero, but V is non-zero.<br>At mid-point P in Fig II, E is non-zero, but V adds up to zero.<br>[0.5 mark for each point] | 2 |

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| Q.15 | Potential on the surface of sphere A:<br>$V_A = \frac{q}{4\pi\epsilon_0 a} = V$<br>On connecting sphere, A with shell B, the charge will now reside on the surface of the shell.<br>Potential on the surface of shell B:<br>$V_B = \frac{q}{4\pi\epsilon_0 b}$<br>[0.5 mark for each correct formula]<br>Comparing the two equations:<br>$V_B = \frac{a}{b} V$<br>Since sphere A is inside the shell B, so its potential now becomes the same as that of B, that is,<br>$V_A^{'} = \frac{a}{b} V$<br>[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.<br>[1 mark for the correct arrangement of the two conductors]<br>Potential on the surface of the smaller conductor placed inside the bigger conductor will be<br>$V_i$ = 50 V + 100 V = 150 V<br>[0.5 mark for the correct formula]<br>Potential on the surface of the outer conductor will be:<br>$V_o = 100 + \frac{1}{4\pi\epsilon_0 R} \times \text{charge on conductor inside}$<br>$= 100 + \frac{1}{4\pi\epsilon_0 R} \times 4\pi\epsilon_0 r \times 50 = [\,100 + 50\frac{r}{R}\,] < 150V$<br>[1 mark for the correct formula and calculation]<br>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.<br>[0.5 mark for the correct conclusion] | 3 |

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

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

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

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| Q.23 | Kinetic energy of the ball<br>$= \frac{1}{2}mv^2$<br>KE = 0.5 x 2x10$^{-16}$ x (3x10$^{6}$)$^{2}$ = 9 x 10$^{-4}$ J<br>[1 mark for the correct calculation of KE value]<br>For the ball to move through the electric field, work to be done against the electric field is<br>W = U = qV = 2 x 10$^{-6}$ x 50 = 10$^{-4}$ J<br>[1 mark for the correct calculation of electrostatic energy required]<br>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.<br>[1 mark for the correct conclusion] | 3 |
| Q.24 | Charge on unknown capacitor = Charge on the combination<br>[1 mark for a correct statement of equality of charge on the two capacitors]<br>CV = (C parallel Co)$_{eqv}$ .V/3<br>CV= (C + Co).V/3<br>C = Co/2<br>[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.<br>[1 mark for the correct charge distribution]<br>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.<br>OR<br>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.<br>[1 mark for the correct charge explanation] | 2 |

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

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

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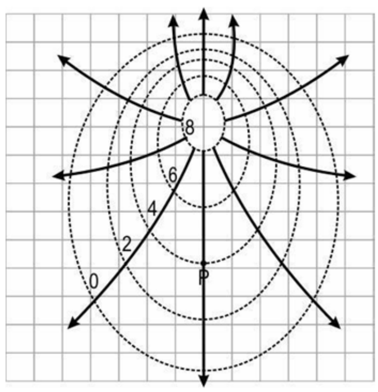
| Q.29 | Force of electrostatic repulsion Fe between the two blocks is balanced by restoring force Fr due to spring,<br>$$F_e = \frac{k_e \cdot \frac{Q}{2} \cdot \frac{Q}{2}}{L_2^2}$$<br>$$F_r = k\,(L_2 - L_1)$$<br>[0.5 mark each for the correct formula of the forces]<br>At equilibrium,<br>$F_e = F_r$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

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