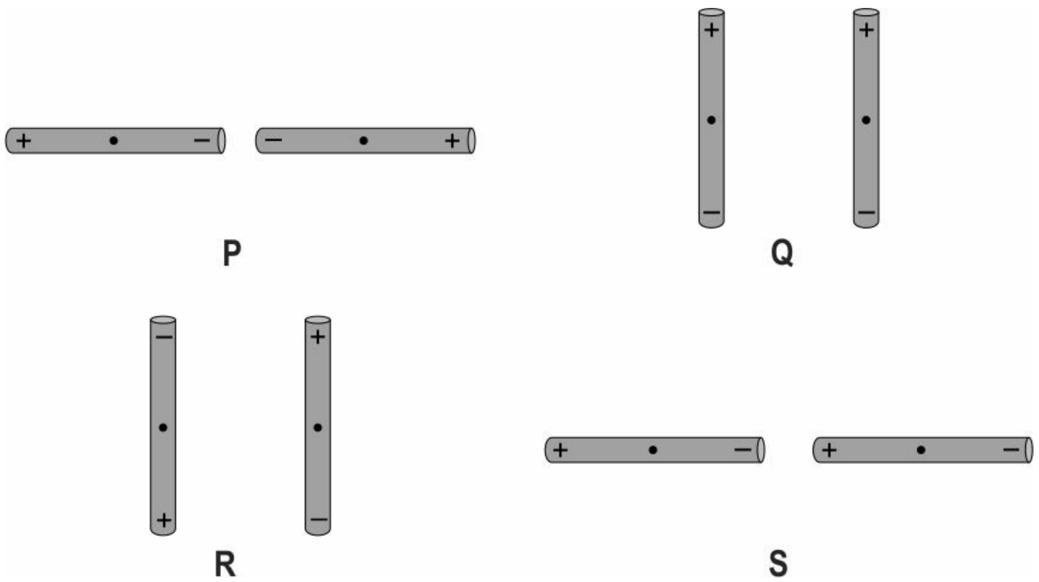
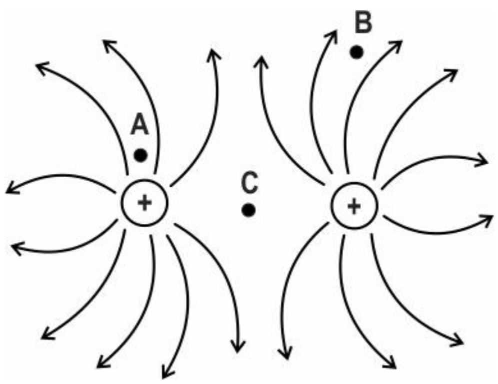
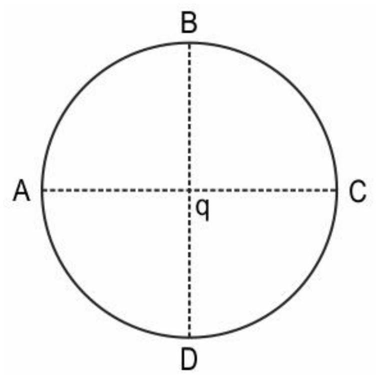
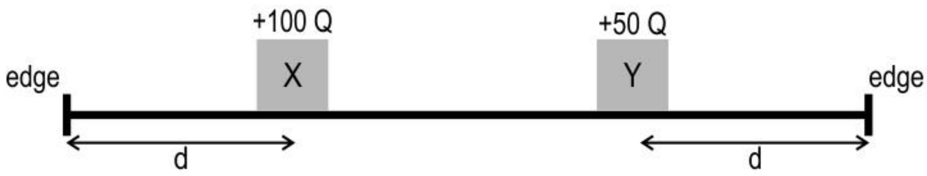
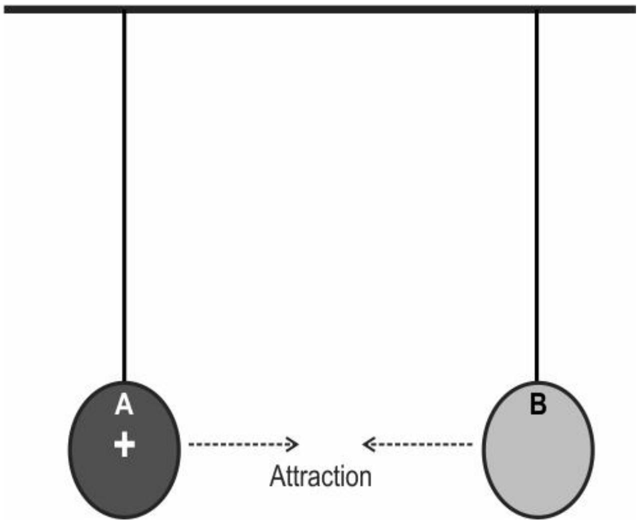
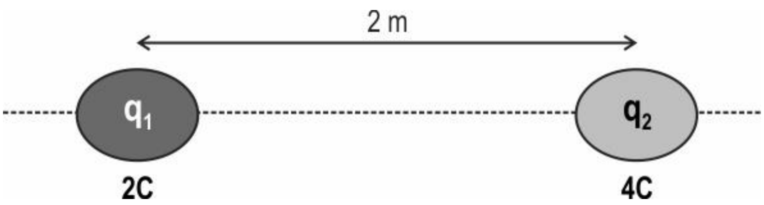
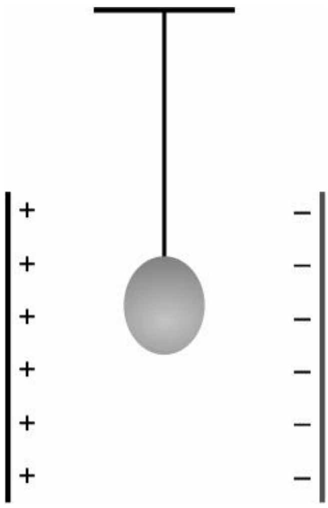
Electric Charges and Fields & Electrostatic Potential and Capacitance

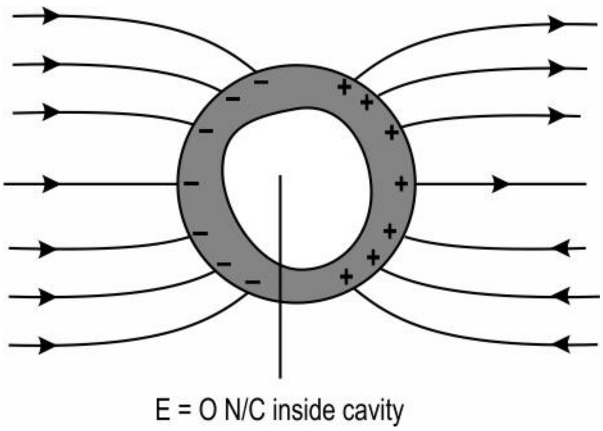
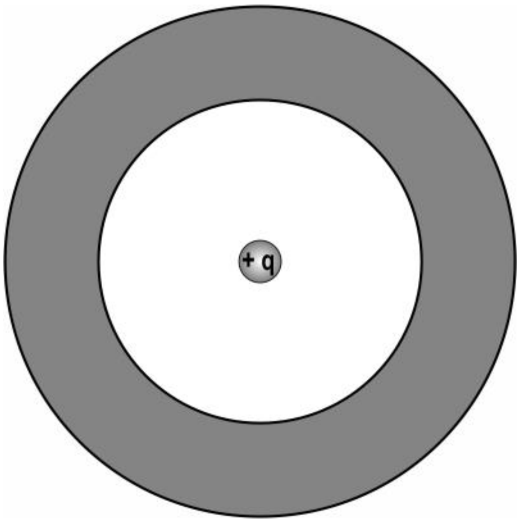
Q.No	Question	Marks
	Multiple Choice Question	
Q.1	Two insulated rods have opposite static charges at their ends. The charged rods are mounted at their centres so that they are free to rotate in the plane of the screen. The two rods can be held in the following 4 orientations as shown below.  Identify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

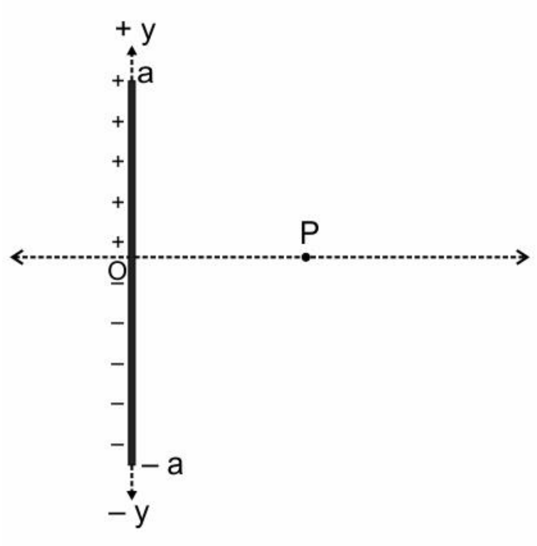
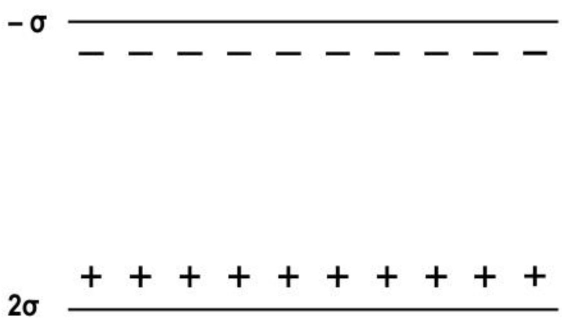
	Study the given electric field representation and identify one INCORRECT qualitative impression given by this representation. A. The electric field at point A is stronger than at point B. B. The electric field distribution is two-dimensional. C. The electric field at point C is zero. D. The electric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

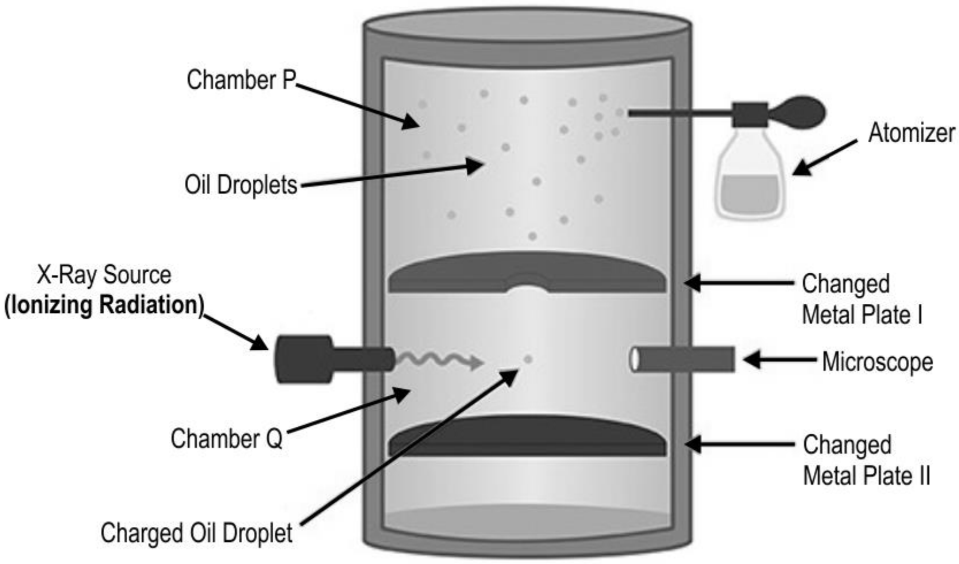
	building from lightning by either neutralizing or conducting the charge of the cloud in the sky to the ground.  Identify ONE statement from below given that DOES NOT contribute to the correct explanation of the working principle of a lightning conductor. A. Charge density on the surface of metal spikes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

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

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

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

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



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

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

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

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

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.1	C. Orientations Q and S are stable. Orientations P and R are unstable.	1
Q.2	B. The electric field distribution is two-dimensional.	1
Q.3	D. both statements Q and S	1
Q.4	D. Work done in moving a test charge between any two points along the circle is zero.	1
Q.5	B. Charges are distributed uniformly on the surface of conductors irrespective of their shapes.	1
Q.6	D. Assertion is false but reason is true.	1
Q.7	C. $9q/\epsilon_0$	1
Q.8	C. Both the blocks will reach the edge at the same time.	1
Q.9	A. Block X will reach the edge first.	1
Q.10	C. Both blocks will reach the edge at the same time.	1
Q.11	(a) The attraction between A and B could be due to the following reasons: - B is negatively charged and hence A and B attract each other. [0.5 mark] - B is neutral. The two balls attract each other due to the polarization of molecules in neutral ball B. [0.5 mark] It is not possible to determine for sure that ball B is negative or neutral from this experiment alone. (b) Possible additional experiments: - A known neutral ball can be brought near ball B (without ball A nearby). [1 mark] If the neutral ball is attracted to ball B, then ball B is negatively charged for sure. If there is no interaction between the two balls, then ball B is neutral for sure. [1 mark] OR	3

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- A known negatively charged ball is brought near ball B (without ball A nearby). [1 mark]

If ball B repels the negatively charged ball, ball B is negatively charged for sure.

On the other hand, if ball B is attracted to the negatively charged ball, then ball B is neutral for sure.[1 mark]

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<td>Q.12</td>
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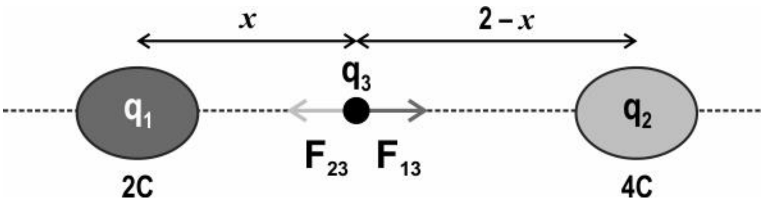
(a) For a resultant force at the location of q_3 to be zero, the net electrostatic force on q_3 due to q_1 and q_2 has to be zero.

Since q_3 is positive, it will be under the effect of repulsive force by both q_1 and q_2 as represented by F_{13} and F_{23}.



That is,

$F_{13} = F_{23}$

$$\frac{kq_1q_3}{x^2} = \frac{kq_2q_3}{(2-x)^2}$$

Substitute for values of q_1 = 2C, q_2 = 4C and solve to get,

$$(2-x)^2 = 2x^2$$

Solve for x,

$$x = \frac{2}{\sqrt{2}+1} = 0.83m$$

So q_3 placed at 0.83 m away from q1 along the straight line joining q_1 and q_2 experiences a zero resultant force.

- 1 mark for drawing the correct diagram and explanation of forces acting on charge q_3

- 1 mark for writing a correct equation for forces on q_3 using Coulombs law

- 1 mark for substituting and solving for the value of x

(b) Yes, the negative charge at the location of q_3 will experience zero resultant force.

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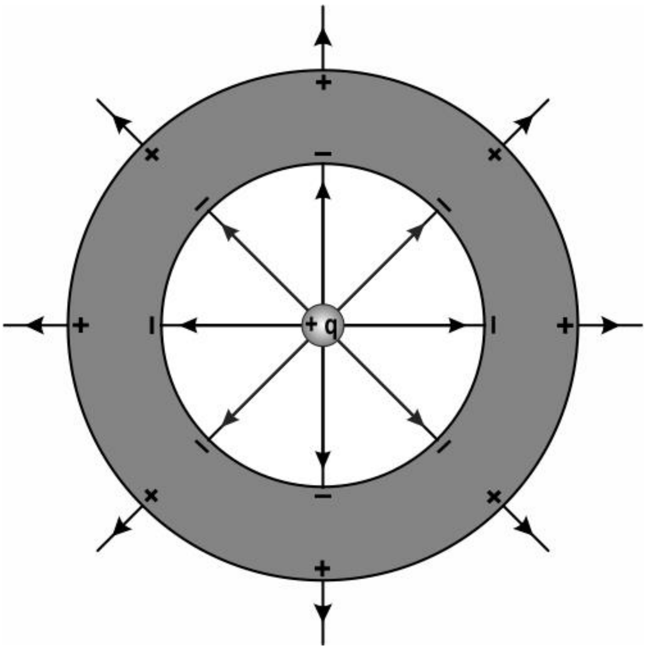
	The forces on the negative charge due to q_1 and q_2 will get reversed. [1/2 mark for the first point] [1/2 mark for correct explanation]	
Q.13	- Once the ball is brought in contact with one of the charged plates, say the negatively charged plate, some negative charge gets transferred to the ball. Soon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

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

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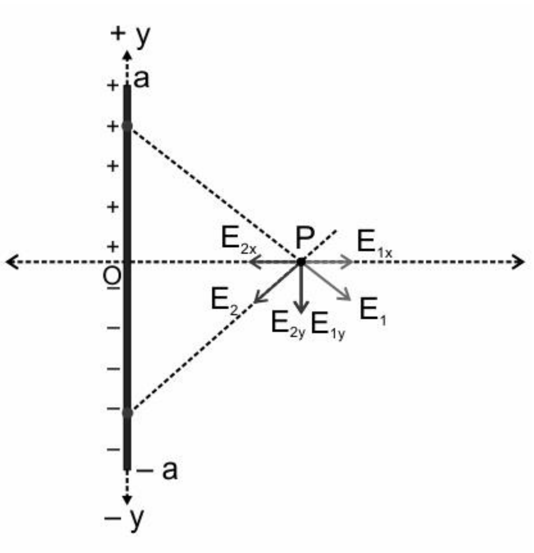
<td>(Note: Award full marks even if E_1 and E_2 is shown and it is mentioned that E_1 and E_2 are equal and direction of resultant is along the angle bisector of the two vectors.)



[1 marks for the correct representation of E_1, E_2 and the resultant.]</td>
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<td>Q.17</td>
<td>Potential on the surface of spherical conductor =

$$V = \frac{Q}{C} = \frac{Q}{4\pi\epsilon_0 R}$$
[1 mark for the correct formula of potential in terms of the radius of conductor]

The greater volume of sphere B corresponds to a greater radius R_B.

$R_A < R_B$.

So for the same charge given to the two spherical conductors, the conductor with a smaller radius, that is, B is at the lower potential.

$V_A > V_B$

The charge always flows from a body at a higher potential to a body at a lower potential.

Hence, it is impossible for the charge to flow from B to A as $V_B < V_A$.

[1 mark for correct conclusion of $V_A > V_B$]

[1 mark for the correct final result]</td>
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<td>Q.18</td>
<td>Acceleration of the particle (a) $= F_{net}/m$

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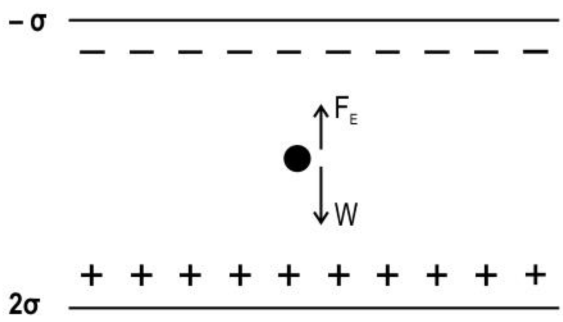 Here, $F_E=qE$ Where, E = Electric field Magnitude of electric field due to a charged sheet is given by $\sigma/2\epsilon_0$, where σ is its surface charge density. Thus, E = Electric field between the sheets = $2\sigma/2\epsilon_0 + \sigma/2\epsilon_0 = 3\sigma/2\epsilon_0$ (As fields due to both the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

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