[SINGLE CORRECT CHOICE TYPE]

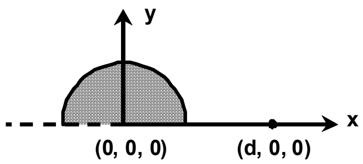
Q.1 A positive point charge Q is placed at a point P, which is at a distance L from the centre C of an uncharged metallic ball of radius R (L>R). There is a point G on the line PC, at a distance R/2 from C. Then, the electric potential at G is **[3]**

(A*) $\frac{Q}{4\pi\varepsilon_0 L}$ (B) $\frac{Q}{4\pi\varepsilon_0} \times \left(\frac{1}{L}-\frac{1}{R}\right)$ (C) $\frac{Q}{4\pi\varepsilon_0} \times \left(\frac{1}{L}-\frac{2}{R}\right)$ (D) None

Q.2 A tiny electric dipole (H_2O molecule) of dipole moment $\vec{p}$ is placed at a distance r from an infinitely long wire ,with its $\vec{p}$ normal to the wire. If the linear charge density of the wire is λ, the electrostatic force acting on the dipole is equal to **[3]**

(A) $\frac{\lambda P}{4\pi\varepsilon_0 r}$ (B) $\frac{\lambda P}{\pi\varepsilon_0 r}$ (C) $\frac{2\lambda P}{\pi\varepsilon_0 r}$ (D*) $\frac{\lambda P}{2\pi\varepsilon_0 r^2}$

Q.3 A solid hemispherical uniformly charged body having charge Q is kept symmetrically along the y-axis as shown in the figure. The electric field at a distance d from the origin along the x–axis will be **[3]**



(A*) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{d^2}$ (B) less than $\frac{1}{4\pi\varepsilon_0}\frac{Q}{d^2}$

(C) more than $\frac{1}{4\pi\varepsilon_0}\frac{Q}{d^2}$ and less than $\frac{1}{4\pi\varepsilon_0}\frac{2Q}{d^2}$ (D) $\frac{1}{4\pi\varepsilon_0}\frac{2Q}{d^2}$

Q.4 Two particles, each of mass m and charge Q, are separated by some distance. They are in equilibrium under mutual gravitational and electrostatic forces. **[3]**

(A) Q/m is of the order of 10^{-15} C/kg. (B) Q/m is of the order of 10^{-20} C/kg.
(C) The equilibrium is stable. (D*) The equilibrium is neutral.

Q.5 A solid sphere of radius R is charged uniformly throughout the volume. At what distance from its surface is the electric potential $\frac{1}{4}$ of the potential at the centre ?

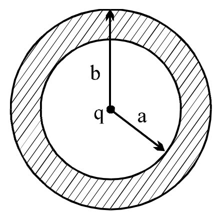
(A) $\frac{8R}{3}$ (B) $\frac{R}{3}$ (C*) $\frac{5R}{3}$ (D) $\frac{2R}{3}$

Q.6 Two concentric spherical shells have radii R_1 and R_2 [$R_2 > R_1$]. The inner shell carries a charge –q coulombs. The velocity of an electron (charge e, mass m) starting from rest from the inner shell and striking the outer shell is **[3]**

(A*) $\sqrt{\frac{qe}{2\pi\varepsilon_0 m}\frac{(R_2-R_1)}{R_1R_2}}$ (B) $\sqrt{\frac{qe}{4\pi\varepsilon_0 m}\frac{(R_2-R_1)}{R_1R_2}}$

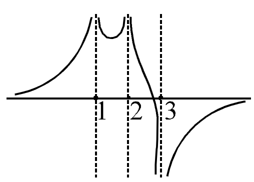
(C) $\sqrt{\frac{qe}{4\pi\varepsilon_0}\left(\frac{1}{R_1^2}-\frac{1}{R_2^2}\right)}$ (D) $\sqrt{\frac{qe}{4\pi\varepsilon_0 m}\frac{R_2-R_1}{R_1^2}}$

Q.7 In the figure shown, charge q is at the centre of the conducting neutral spherical shell of inner radius a and outer radius b. Find the electric potential energy of the system. (Ignore self energy of point charge) **[3]**



(A) 0 (B) $\frac{kq^2}{2b}$ (C*) $\frac{kq^2}{2b}-\frac{kq^2}{2a}$ (D) $\frac{kq^2}{2a}-\frac{kq^2}{2b}$

Q.8 Three charges lie on the x-axis each at distance a apart from the nearest one. The charges are numbered from 1 to 3 moving from left to right. A representation of the electric potential V of the three charges at different points is shown above. Which one of the following statements is true? **[3]**

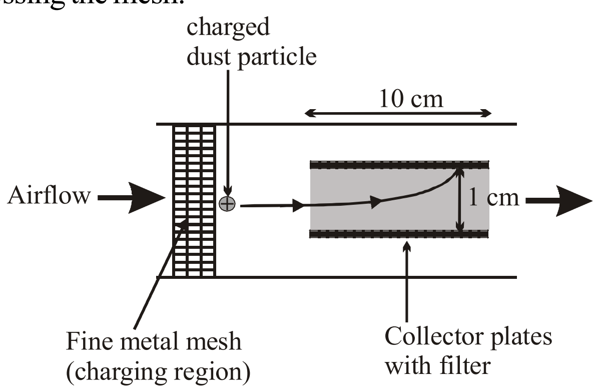


(A) The electric field is zero at some point between charges 1 and 2 and also at some point between charges 2 and 3.
(B*) The electric field is zero at some point between charges 1 and 2 but it is never zero between charges 2 and 3.
(C) the electric field is never zero between charges 1 and 2 but it is zero at some point between charges 2 and 3.
(D) The electric field is never zero between charges 1 and 2 and it is never zero between charges 2 and 3.

[PARAGRAPH TYPE]

Paragraph for question nos. 9 to 11

An air ionizer filters particles of dust, pollen, and other allergens from the air using electric forces. In one type of ionizer (see diagram), a stream of air is drawn in with a speed of 3.0 m/s. The air passes through a fine, highly charged wire mesh that transfers electric charge to the particles. Then the air passes through parallel "collector" plates that attract the charged particles and trap them in a filter. Consider a dust particle of radius 6.0 μm, mass 1.0×10^{-13} kg, and charge 100e. The plates are 10 cm long and are separated by a distance of 1.0 cm. Ignore gravity. Assume that the speed of dust particles does not change after crossing the mesh.



Q.9 Ignoring drag force, what would be the minimum potential difference between the plates to ensure that all the particles get trapped by the filter? **[3]**
(A) 2250 V (B) 3750 V (C) 1500 V (D*) 1125 V

Q.10 Consider a particle injected in the lowest point of the plates at the above potential difference. Ignoring air drag, at what speed would the particle be moving relative to the stream of air just before hitting the filter? **[3]**
(A*) 0.6 m/s (B) 3.6 m/s (C) 3 m/s approx. (D) 6 m/s approx.

Q.11 Taking air drag into consideration **[3]**
(A) the potential difference required would be lesser and speed of striking would be more
(B) the potential difference required would be more and speed of striking would be lesser
(C*) the potential difference required would be lesser and speed of striking would be also lesser
(D) the potential difference required would be more and speed of striking would also be more

[REASONING TYPE]

Q.12 **Statement 1 :** If potential of a point is zero, then electric field must be zero at that point. **[3]**
Statement 2 : Electric field intensity is equal to negative of potential gradient.
(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1.
(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1.
(C) Statement-1 is true, statement-2 is false.
(D*) Statement-1 is false, statement-2 is true

[MULTIPLE CORRECT CHOICE TYPE]

Q.13 A simple pendulum consists of a small sphere of mass m suspended by a thread of length L. The sphere carries a charge of modulus q. The pendulum is made to oscillate in uniform electric field of strength E. The time period of oscillation will be **[4]**

(A) $T = 2\pi\sqrt{\dfrac{L}{g + \dfrac{qE}{m}}}$, if E is directed vertically downward and charge is negative.

(B*) $T = 2\pi\sqrt{\dfrac{L}{g + \dfrac{qE}{m}}}$, if E is directed vertically upward and charge is negative.

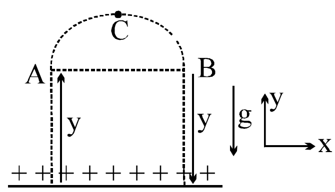
(C*) $T = 2\pi\sqrt{\dfrac{L}{\left[g^2 + \left(\dfrac{qE}{m}\right)^2\right]^{1/2}}}$, if E is horizontal

(D) $T = 2\pi\sqrt{\dfrac{L}{g}}$ in all the cases.

Q.14 Three equal point charges (Q) are kept at the three corners of an equilateral triangle ABC of side a. P is a point having equal distance a from A, B and C. If E is the magnitude of electric field and V is the potential at point P, then **[4]**

(A) $E = \dfrac{3Q}{4\pi\varepsilon_0 a^2}$ (B*) $E = \dfrac{\sqrt{6}Q}{4\pi\varepsilon_0 a^2}$ (C*) $V = \dfrac{3Q}{4\pi\varepsilon_0 a}$ (D) $E = 0$

Q.15 An infinitely long uniformly charged nonconducting rod is placed along x-axis. A test charge is slowly taken from point A to B in the X-Y plane along semi a circular path A→ C → B as shown in the figure, then which alternative (s) may be correct **[4]**

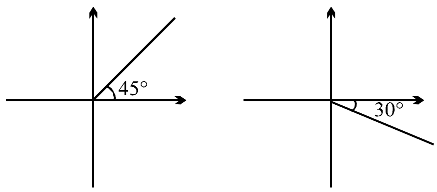


(A*) work done by external agent is zero
(B*) the workdone by external agent is path independent
(C) $W_{A\to C} = -W_{B\to C}$
(D) At point C, the force applied by external agent is maximum

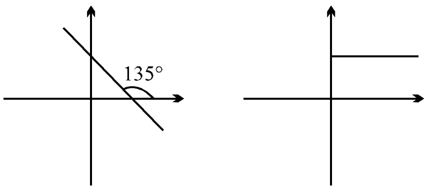
[MATRIX TYPE]

Q.16 Column I shows graphs of electric potential V versus x and y in a certain region for four situations. Column II shows the range of angle which the electric field vector makes with positive x-direction. **[6]**

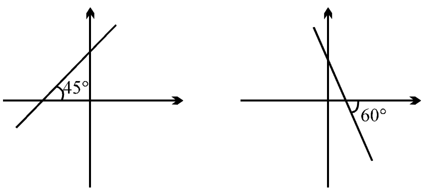
Column I **(V versus x)** (V versus y) — **Column II**

(A)


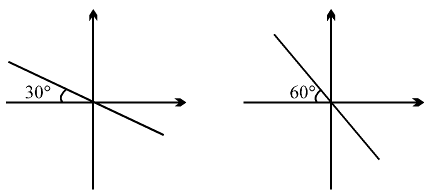
(P) $0 \le \theta < 45°$

(B)


(Q) $45° \le \theta < 90°$

(C)


(R) $90° \le \theta < 135°$

(D)


(S) $135° \le \theta \le 180°$

[Ans. (A) – S; (B) – P; (C) – R; (D) – Q]

[SUBJECTIVE TYPE]

Q.17 Two nonconducting spherical shell A and B of same radius are kept on a horizontal rough surface. Each shell has uniformly distributed charge Q on the surface. Initially they are separated by a distance r (centre to centre). They move without sliding away from each other due to electrostatic repulsion. The shell A has mass m and B has mass 2m. Find the speed of the shell B when the separation becomes 2r. **[5]**

[Ans. $Q\sqrt{\dfrac{K}{10RM}}$]

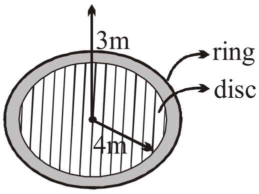
Q.18 A conducting sphere S_1 of radius r is attached to an insulating handle . Another conducting sphere S_2 of radius R is mounted on an insulating stand . S_2 is initially uncharged . S_1 is given a charge Q, brought into contact with S_2 & removed, S_1 is recharged such that the charge on it is again Q & it is again brought into contact with S_2 & removed. This procedure is repeated n times.

(a) Find the electrostatic energy of S_2 after n such contacts with S_1.

(b) What is the limiting value of this energy as $n \to \infty$? **[5]**

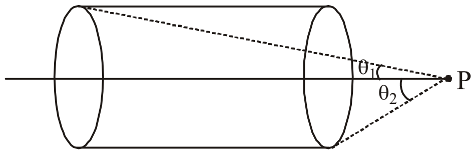
Ans (a) $U_2 = \dfrac{a^2Q^2}{8\pi\epsilon_0 R}\left(\dfrac{1-a^n}{1-a}\right)^2$ where $a = \dfrac{R}{r+R}$, (b) $U_2\,(n \to \infty) = \dfrac{RQ^2}{8\pi\epsilon_0 r^2}$

Q.19 A disc of radius 4 m is uniformly charged with the charge of 1 μC. On the periphery of the disc, we stick a thin ring which has a uniform charge of – 1 μC. What is the Electric field (in N/C) due to the combination at a point 3 m away from the centre of combination on the common axis ? **[5]**



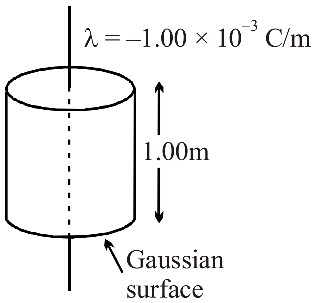
[Ans. 0234]

Q.20 A cylinder is uniformly charged on its curved surface with surface charge density σ. Radius of the cylinder is R. Calculate the electric field on the axis of the cylinder at point P, as shown in the figure. **[5]**



[Ans. $(\sigma/2\varepsilon_0)(\sin\theta_2 - \sin\theta_1)$]

Q.21 The visible portion of a lightning strike is preceded by an invisible stage in which a column of electrons extends downward from a cloud to the ground. Assume the linear charge density along the column is 1.00×10^{-3} C/m. Treat the column of charge as if it were straight and infinitely long. At what distance (in m) from the column of electrons does the electric field have a magnitude of 3.00×10^6 V/m , the dielectric strength for air? This is an estimate of the radius of a visible lightning bolt. (Round off to nearest integer) (value of $\in_0$ is 8.85×10^{-12} C^2/Nm^2) **[5]**



[Ans. 6 m]