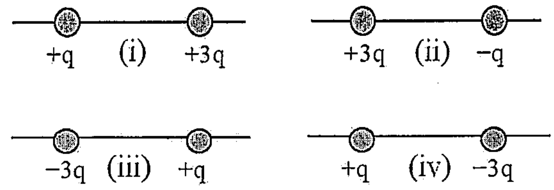
Q.1 For questions (I to VI), circle the correct answer: *(1 pt each question)*

(I) The figure shows four different arrangements of two point charges. In which situation is there a point to the left of the arrangement where an electron will be at equilibrium?



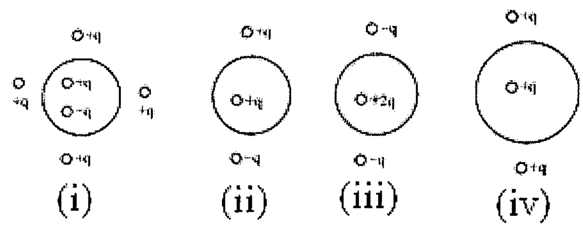
a. i b. ii

c. iii d. iv e. none of them

(II) Three identical conducting spheres A, B, and C initially have charges of + 6q, +2q, and − 10q, respectively. Thin conducting wire connects two spheres at a time in the following sequence: (1) spheres A and B, then (2) spheres A and C. The final charge on sphere A will be?

a. **Zero** b. **+ 3q** c. **− 3q** d. **− 6q** e. none of them

(III) In the shown figures, in which configuration is the electric-field flux through the surface of the sphere the highest?



a. i

b. ii

c. iii

d. iv

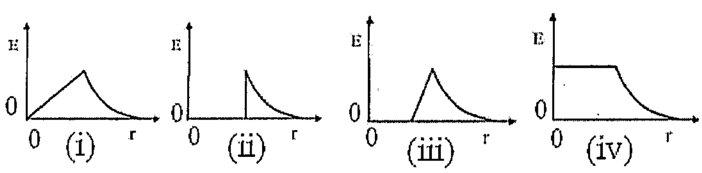
(IV) An insulating sphere has a uniform volume charge density (ρ). Which one of the following diagrams represents the magnitude of the electric field due to the sphere as a function of the distance r from the center of the sphere?

a. i

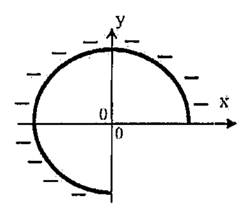
b. ii

c. iii

d. iv



(V) A negative charge distributed uniformly on a circular wire as shown in the figure. The wire is in the xy-plane and centered at the origin. The x-component and the y-component of the electric field at the origin are:



a. $E_x > 0$ and $E_y > 0$ b. $E_x < 0$ and $E_y > 0$

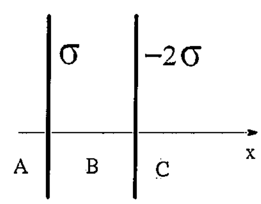
c. $E_x > 0$ and $E_y < 0$ d. $E_x < 0$ and $E_y < 0$

e. Zero, Zero

(VI) Two parallel insulating sheets with surface charge densities σ and −2σ are perpendicular to the x-axis, as shown in the figure. In which region of the three regions (A, B, C) the magnitude of the electric field has the largest value?

a. A b. B

c. C d. the electric field has the same magnitude in all three regions



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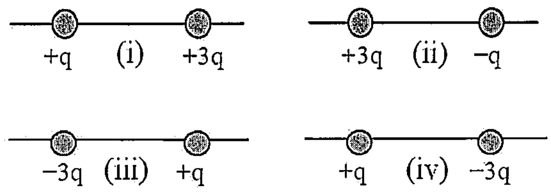


a. iv　　b. iii

c. ii　　d. i　　e. none of them

(II) Three identical conducting spheres A, B, and C initially have charges of + 6q, +2q, and − 10q, respectively. Thin conducting wire connects two spheres at a time in the following sequence: (1) spheres A and B, then (2) spheres A and C. The final charge on sphere A will be?

a. **Zero**　　b. **− 3q**　　c. **+ 3q**　　d. **− 6q**　　e. none of them

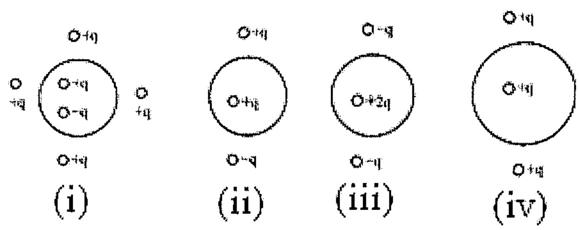
(III) In the shown figures, in which configuration is the electric-field flux through the surface of the sphere the highest?

a. ii

b. iii

c. i

d. iv



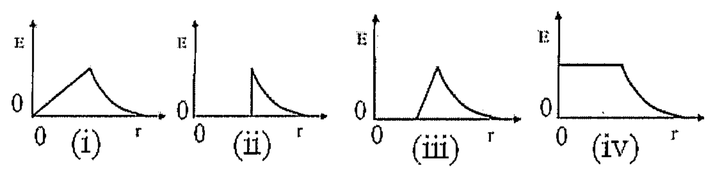
(IV) An insulating sphere has a uniform volume charge density (ρ). Which one of the following diagrams represents the magnitude of the electric field due to the sphere as a function of the distance r from the center of the sphere?

a. ii

b. iii

c. i

d. iv

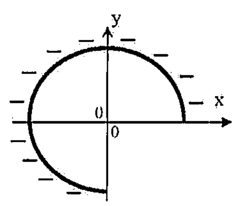


(V) A negative charge distributed uniformly on a circular wire as shown in the figure. The wire is in the xy-plane and centered at the origin. The x-component and the y-component of the electric field at the origin are:

a. $E_x > 0$ and $E_y > 0$　　b. $E_x < 0$ and $E_y < 0$

c. $E_x > 0$ and $E_y < 0$　　d. $E_x < 0$ and $E_y > 0$

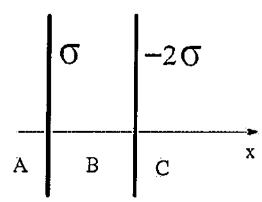
e. Zero, Zero



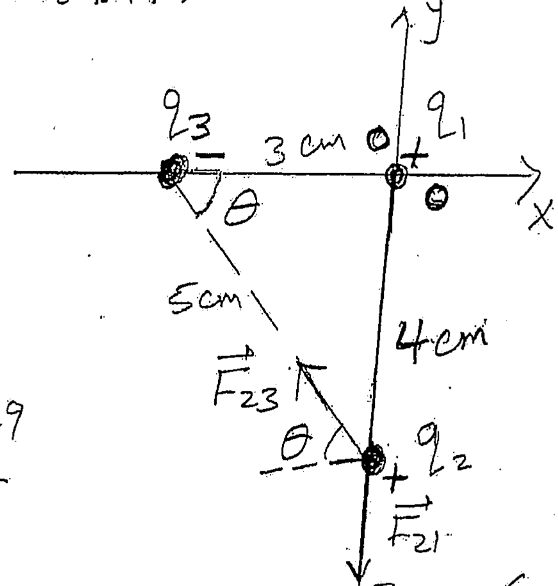
(VI) Two parallel insulating sheets with surface charge densities σ and −2σ are perpendicular to the x-axis, as shown in the figure. In which region of the three regions (A, B, C) the magnitude of the electric field has the largest value?

a. C　　b. the electric field has the same magnitude in all three regions

c. A　　d. B



Q.2 Three point charges are placed on the xy-plane, with $q_1 = +32\ nC$ located at the point (0, 0), $q_2 = +48\ nC$ located at the point (0, − 4 cm), and $q_3 = -.24\ nC$ located at the point (-3 cm, 0). Find the magnitude and the direction of the net electric force on the point charge q_2? *(6 pts)*



$$F_{21} = k\frac{|q_2||q_1|}{r_{12}^2}$$

$$= 8.99\times10^{9}\ \frac{48\times10^{-9}\times32\times10^{-9}}{(0.04)^2}$$

$$= 8.63\times10^{-3}\ N$$

$$F_{23} = 8.99\times10^{9}\ \frac{48\times10^{-9}\times24\times10^{-9}}{(0.05)^2}$$

$$= 4.14\times10^{-3}\ N$$

$$\cos\theta = \frac{3}{5} = 0.6$$

$$\sin\theta = \frac{4}{5} = 0.8$$

$$\vec{F}_{21} = -8.63\times10^{-3}\ \hat{j}\ (N)$$

$$\vec{F}_{23} = -4.14\times10^{-3}\cos\theta\ \hat{i} + 4.14\times10^{-3}\sin\theta\ \hat{j}$$

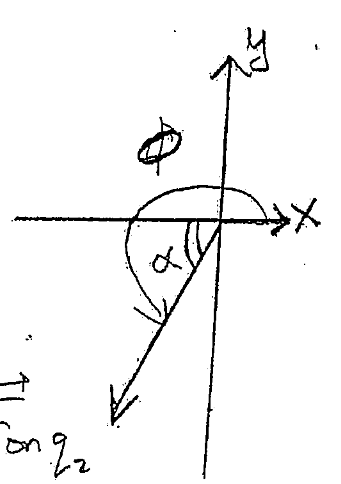
$$\vec{F}_{23} = [-2.49\times10^{-3}\ \hat{i} + 3.31\times10^{-3}\ \hat{j}]\ (N)$$

$$\vec{F}_{on\,q_2} = \vec{F}_{21} + \vec{F}_{23} = -2.49\times10^{-3}\ \hat{i} - 5.32\times10^{-3}\ \hat{j}\ (N)$$

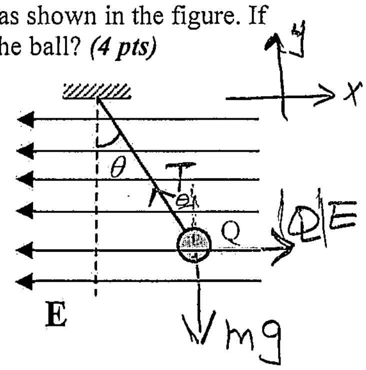
$$F_{on\,q_2} \cong 5.87\ (N)$$

direction $\quad \alpha = \tan^{-1}\frac{5.32}{2.49} \simeq 64.92^\circ$

$$\phi = 180^\circ + \alpha \simeq 244.92^\circ$$



Q.3 (A) A small ball of mass m = 1.3 g has a charge Q is suspended by a negligible mass string and placed in a uniform electric field of magnitude E = 8×10^5 N/C directed leftward as shown in the figure. If the ball is at equilibrium when $\theta = 40°$, find the charge (magnitude and sign) on the ball? ***(4 pts)***



equilibrium $\Sigma F_x = 0$, $\Sigma F_y = 0$

$T \sin\theta = QE$

$T \cos\theta = mg$

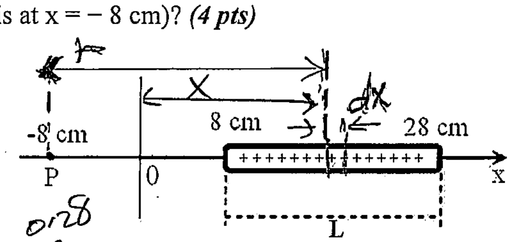
$\tan\theta = \frac{QE}{mg}$

$Q = mg \tan\theta / E = 1.3 \times 10^{-3} \times 9.8 \tan 40° / 8 \times 10^5$

$= 1.34 \times 10^{-8}$ (C)

$\vec{F}_{electric\ on\ Q}$ is opposite to $\vec{E} \Rightarrow$ Q has to be negative

Q.3 (B) A positive charge (Q = + 64 (*n*C)) distributed uniformly along a thin insulating rod located between x = 8 cm and x = 28 cm, as shown in the figure. Find (by deriving the formula) the magnitude and the direction of the electric field at the point P (along the *x*-axis at x = − 8 cm)? ***(4 pts)***



$d\vec{E} = K \frac{dq}{r^2} (-\hat{i})$

$E = K \int_{0.08}^{0.28} \frac{\lambda\, dx}{(x+0.08)^2} = K\lambda \int_{0.08}^{0.28} \frac{dx}{(x+0.08)^2}$; $\lambda = \frac{Q}{L}$

let $u = (x+0.08) \rightarrow du = dx$

$E = K\lambda \int \frac{du}{u^2} = K\lambda \frac{-1}{u} = K \frac{Q}{L} \left. \frac{-1}{(x+0.08)} \right|_{x=0.08}^{0.28}$

$= \frac{8.99 \times 10^9 \times 64 \times 10^{-9}}{0.2} \left\{ \frac{-1}{0.36} - \frac{-1}{0.16} \right\}$

$E = 9,988.9$ (N/C)

direction: since Q is (+ve), then $\vec{E}$ is in the $(-\hat{i})$ direction