CHAPTER 22 | Electric Fields

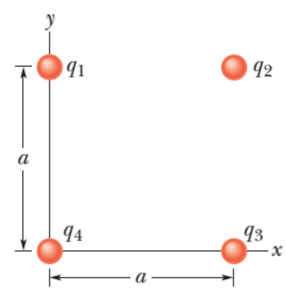
1 | The nucleus of a plutonium-239 atom contains 94 protons. Assume that the nucleus is a sphere with radius $6.64\ fm$ and with the charge of the protons uniformly spread through the sphere. At the surface of the nucleus, what are

(a) magnitude (Ans: $\mathrm{E} = 3.07 \times 10^{21}\ N/C$) and

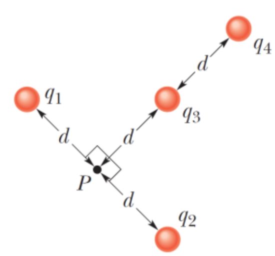
(b) direction (radially inward or outward) of the electric field produced by the protons? (Ans: $Outward$)

2 | In the figure, the four particles form a square of edge length $a = 5.00\ cm$ and have charges $q_1 = +10.0\ nC$, $q_2 = -20.0\ nC$, $q_3 = +20.0\ nC$, and $q_4 = -10.0\ nC$. In unitvector notation, what net electric field do the particles produce at the square's center?

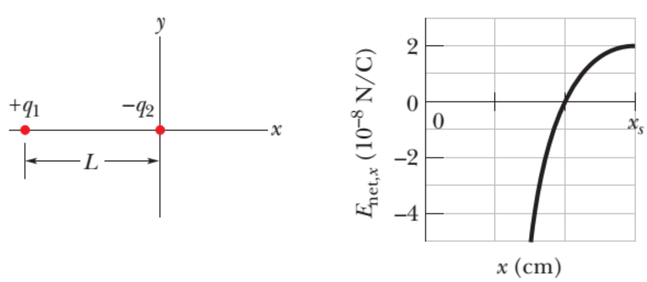
(Ans: $\vec{E} = 1.02 \times 10^5\ (\hat{j})\ N/C$)



3 | In the figure, the four particles are fixed in place and have charges $q_1 = q_2 = +5e$, $q_3 = +3e$, and $q_4 = -12e$. Distance $d = 5.0\ \mu m$.What is the magnitude of the net electric field vector at point P due to the particles? (Ans: $zero$)



4 | Figure (a) shows two charged particles fixed in place on an x axis with separation L. The ratio q_1/q_2 of their charge magnitudes is 4.00. Figure (b) shows the x component $E_{net,x}$ of their net electric field along the x axis just to the right of particle 2.The x axis scale is set by $x_s = 30.0\ cm$.



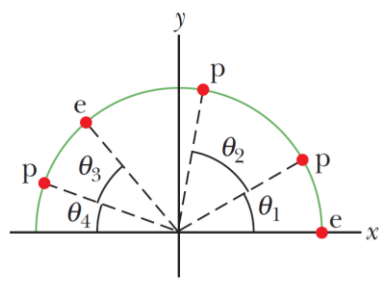
(a) (b)

(a) At what value of $x > 0$ is $E_{net,x}$ maximum? (Ans: $x = 34\ cm$)

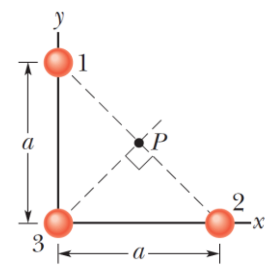
(b) If particle 2 has charge $-q_2 = -3e$, what is the value of that maximum? (Ans: $E_{net,x} = 2.2 \times 10^{-8}\ N/C$)

5 | Two charged particles are fixed to x axis:
Particle 1 of charge $q_1 = 2.1 \times 10^{-8}\ C$ is at position $x = 20\ cm$ and particle 2 of charge $q_2 = -4.00 q_1$ is at position $x = 70\ cm$. At what coordinate on the axis (other than at infinity) is the net electric field produced by the two particles equal to zero? $(Ans{:}\ x = -30\ cm)$

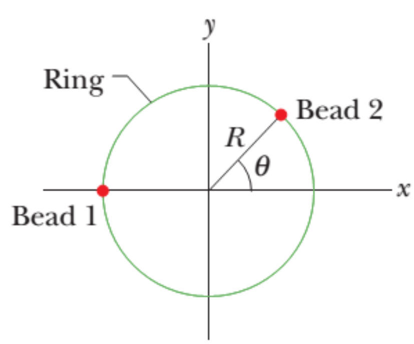
6 | The given figure shows an uneven arrangement of electrons (e) and protons (p) on a circular arc of radius $r = 2.00\ cm$, with angles $\theta_1 = 30.0°$, $\theta_2 = 50.0°$, $\theta_3 = 30.0°$, and $\theta_4 = 20.0°$. What are the magnitude and direction (relative to the positive direction of the x axis) of the net electric field produced at the center of the arc? $(Ans{:}\ 3.93 \times 10^{-19} \frac{N}{C}, -76.4°)$



7 | In the figure ahead, the three particles are fixed in place and have charges $q_1 = q_2 = +e$ and $q_3 = +2e$. Distance $a = 6.0\ \mu m$. What are the magnitude and direction of the net electric field at point P due to the particles? $(Ans{:}\ 160 \frac{N}{C}, 45°)$

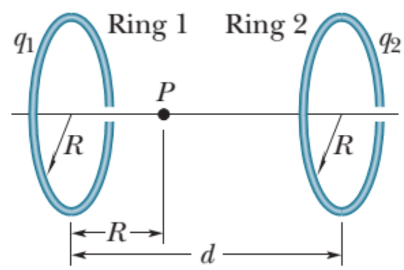


8 | Following figure shows a plastic ring of radius $R = 50.0\ cm$. Two small charged beads are on the ring: Bead 1 of charge $+2.00\ mC$ is fixed in place at the left side; bead 2 of charge $+6.00\ mC$ can be moved along the ring. The two beads produce a net electric field of magnitude E at the center of the ring. At what



(a) positive $(Ans{:}\ \theta = 67.8°)$ and
(b) negative value of angle θ should bead 2 be positioned such that $E = 2.00 \times 10^5\ N/C$? $(Ans{:}\ \theta = -67.8°)$

9 | Figure shows two parallel nonconducting rings with their central axes along a common line. Ring 1 has uniform charge q_1 and radius R; ring 2 has uniform charge q_2 and the same radius R. The rings are separated by distance $d = 3.00R$. The net electric field at point P on the common line, at distance R from ring 1, is zero. What is the ratio q_1/q_2? $(Ans: 0.506)$



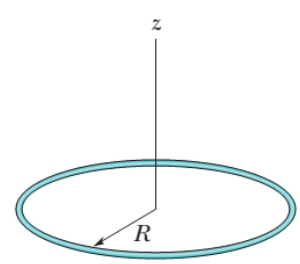
10 | At some instant, the velocity components of an electron moving between two charged parallel plates are $v_x = 1.5 \times 10^5\ m/s$ and $v_y = 3.0 \times 10^3\ m/s$. Suppose the electric field between the plates is uniform and given by $\vec{E} = (120\ N/C)\hat{j}$. In unit-vector notation, what are

(a) the electron's acceleration in that field $Ans: \vec{a} = -(2.1 \times 10^{13}\ m/s^2)\hat{j}$ and

(b) the electron's velocity when its x coordinate has changed by 2.0 cm?

$Ans: \vec{v} = (1.5 \times 10^5\ m/s)\hat{\imath} - (2.8 \times 10^6\ m/s)\hat{j}$

11 | A thin nonconducting rod with a uniform distribution of positive charge Q is bent into a complete circle of radius R. The central perpendicular axis through the ring is a z axis, with the origin at the center of the ring. What is the magnitude of the electric field due to the rod at



(a) $z = 0$ $(Ans: E = 0)$ and

(b) $z = \infty$? $(Ans: E = 0)$

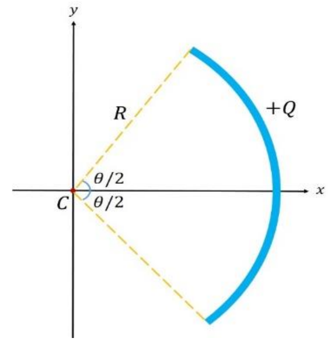
(c) In terms of R, at what positive value of z is that magnitude maximum?

$(Ans: z = 0.707R)$

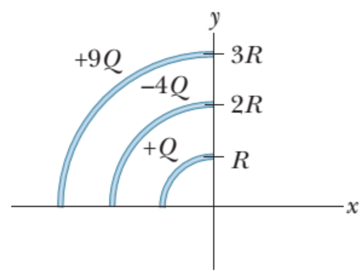
(d) If $R = 2.00\ cm$ and $Q = 4.00\ mC$, what is the maximum magnitude?

$(Ans: E_{max} = 3.46 \times 10^7\ N/C)$

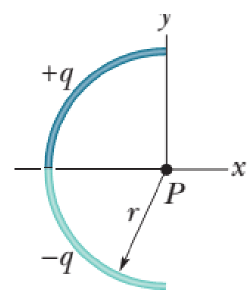
12 | In the figure below, the charge $+Q$ is spread uniformly along a circular arc that has radius R and subtends an angle θ. Find the magnitude of the electric field due to the arc at the center of it.
$(Ans\text{: } \vec{E}_C = \frac{2kQ}{R^2\theta}\sin(\frac{\theta}{2})\ (-\hat{\imath}))$



13 | Figure shows three circular arcs centered on the origin of a coordinate system. On each arc, the uniformly distributed charge is given in terms of $Q = 2.00\ mC$. The radii are given in terms of $R = 10.0\ cm$. What are the
(a) magnitude $(Ans\text{: } E_{net} = 1.62 \times 10^6\ N/C)$ and
(b) direction (relative to the positive x direction) of the net electric field at the origin due to the arcs? $(Ans\text{: } -45°\ from + x)$

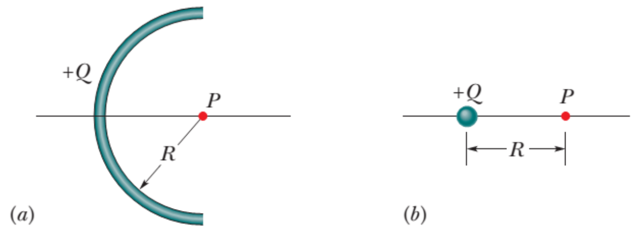


14 | In the figure below, a thin glass rod forms a semicircle of radius $r = 5.00\ cm$. Charge is uniformly distributed along the rod, with $+q = 4.50\ pC$ in the upper half and $-q = -4.50\ pC$ in the lower half. What are the
(a) magnitude $(Ans\text{: } E_{net} = 20.6\ N/C)$ and
(b) direction (relative to the positive direction of the x axis) of the electric field $\vec{E}$ at P, the center of the semicircle? $(Ans\text{: } -\hat{\jmath})$

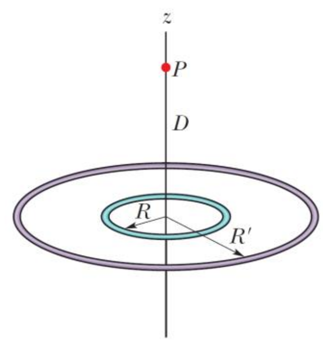


15 | Charge is uniformly distributed around a ring of radius $R = 2.40\ cm$, and the resulting electric field magnitude E is measured along the ring's central axis (perpendicular to the plane of the ring). At what distance from the ring's center is E maximum? $(Ans\text{: } z = 1.7\ cm)$

16 | Figure (a) shows a nonconducting rod with a uniformly distributed charge Q. The rod forms a half-circle with radius R and produces an electric field of magnitude E_{arc} at its center of curvature P. If the arc is collapsed to a point at distance R from P (figure (b)), by what factor is the magnitude of the electric field at P multiplied? $\left(Ans\text{: } E_{particle}/E_{arc} = \pi/2\right)$



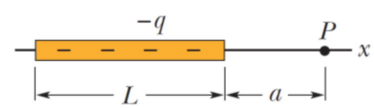
17 | The figure in front shows two concentric rings, of radii R and $R = 3.00R$, that lie on the same plane. Point P lies on the central z-axis, at distance $D = 2.00R$ from the center of the rings. The smaller ring has uniformly distributed charge $+Q$. In terms of Q, what is the uniformly distributed charge on the larger ring if the net electric field at P is zero? $(Ans\text{: } -4.19Q)$



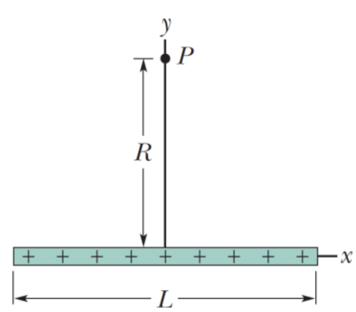
18 | In the following figure, a non-conducting rod of length $L = 8.15\ cm$ has a charge $-q = -4.23\ fC$ uniformly distributed along its length.

(a) What is the linear charge density of the rod? $(Ans\text{: } -5.19 \times 10^{-14}\ C/m)$

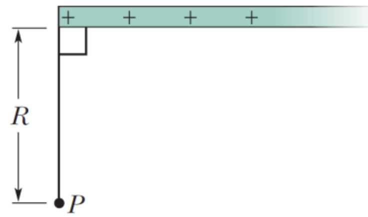
(b) What are the magnitude and direction (relative to the positive direction of the x axis) of the electric field produced at point P, at distance $a = 12.0\ cm$ from the rod? $(Ans\text{: } 1.57 \times 10^{-3}\ \frac{N}{C}, 180°)$



19 | In the figure, positive charge $q = 7.81\ pC$ is spread uniformly along a thin nonconducting rod of length $L = 14.5\ cm$ .What are the magnitude and direction (relative to the positive direction of the x axis) of the electric field produced at point P, at distance $R = 6.00\ cm$ from the rod along its perpendicular bisector? $(Ans\text{: } 12.4\ \frac{N}{C}, +90°)$



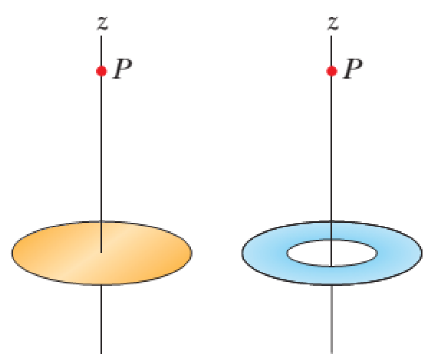
20 | In the figure, a "semi-infinite" non-conducting rod (that is, infinite in one direction only) has uniform linear charge density λ. Show that the electric field $\vec{E}_P$ at point P makes an angle of $45°$ with the rod and that this angle is independent of the distance R.



(Hint: Separately find the component of $\vec{E}_P$ parallel to the rod and the component perpendicular to the rod.)

21 | At what distance along the central perpendicular axis of a uniformly charged plastic disk of radius $0.600\ m$ is the magnitude of the electric field equal to one-half the magnitude of the field at the center of the surface of the disk? $(Ans: z = 035\ m)$

22 | Suppose you design an apparatus in which a uniformly charged disk of radius R is to produce an electric field. The field magnitude is most important along the central perpendicular axis of the disk, at a point P at distance $2.00R$ from the disk (figure (a)). Cost analysis suggests that you switch to a ring of the same outer radius R but with inner radius $R\ /2.00$ (figure (b)). Assume that the ring will have the same surface charge density as the original disk. If you switch to the ring, by what percentage will you decrease the electric field magnitude at P? $(Ans: 28\%)$



(a) (b)