

8. (a) The individual magnitudes $|\vec{E}_1|$ and $|\vec{E}_2|$ are figured from Eq. 22-3, where the absolute value signs for q_2 are unnecessary since this charge is positive. Whether we add the magnitudes or subtract them depends on if \vec{E}_1 is in the same, or opposite, direction as \vec{E}_2 . At points left of q_1 (on the $-x$ axis) the fields point in opposite directions, but there is no possibility of cancellation (zero net field) since $|\vec{E}_1|$ is everywhere bigger than $|\vec{E}_2|$ in this region. In the region between the charges ($0 < x < L$) both fields point leftward and there is no possibility of cancellation. At points to the right of q_2 (where $x > L$), \vec{E}_1 points leftward and \vec{E}_2 points rightward so the net field in this range is

$$\vec{E}_{\text{net}} = (|\vec{E}_2| - |\vec{E}_1|) \hat{i}.$$

Although $|q_1| > q_2$ there is the possibility of $\vec{E}_{\text{net}} = 0$ since these points are closer to q_2 than to q_1 . Thus, we look for the zero net field point in the $x > L$ region:

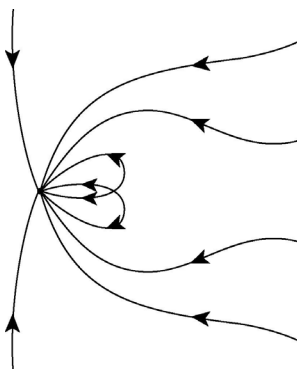
$$|\vec{E}_1| = |\vec{E}_2| \Rightarrow \frac{1}{4\pi\epsilon_0} \frac{|q_1|}{x^2} = \frac{1}{4\pi\epsilon_0} \frac{q_2}{(x-L)^2}$$

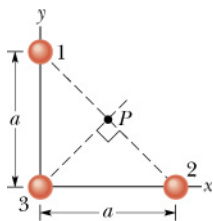
which leads to

$$\frac{x-L}{x} = \sqrt{\frac{q_2}{|q_1|}} = \sqrt{\frac{2}{5}}.$$

Thus, we obtain $x = \frac{L}{1 - \sqrt{2/5}} \approx 2.72L$.

(b) A sketch of the field lines is shown in the figure below:

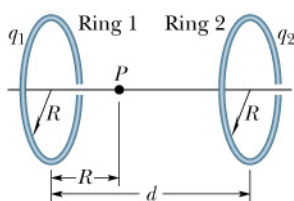




13. (a) The vertical components of the individual fields (due to the two charges) cancel, by symmetry. Using $d = 3.00$ m, the horizontal components (both pointing to the $-x$ direction) add to give a magnitude of

$$E_{x, \text{net}} = \frac{2 q d}{4\pi\epsilon_0 (d^2 + y^2)^{3/2}} = 1.38 \times 10^{-10} \text{ N/C}.$$

(b) The net electric field points in the $-x$ direction, or 180° counterclockwise from the $+x$ axis.

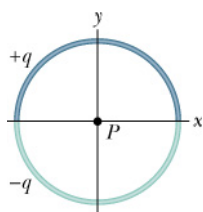


22. We use Eq. 22-3, assuming both charges are positive. At P , we have

$$E_{\text{left ring}} = E_{\text{right ring}} \Rightarrow \frac{q_1 R}{4\pi\epsilon_0 (R^2 + R^2)^{3/2}} = \frac{q_2 (2R)}{4\pi\epsilon_0 [(2R)^2 + R^2]^{3/2}}$$

Simplifying, we obtain

$$\frac{q_1}{q_2} = 2 \left(\frac{2}{5} \right)^{3/2} \approx 0.506.$$

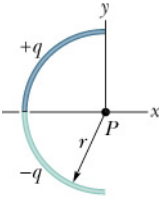


24. From symmetry, we see that the net field at P is twice the field caused by the upper semicircular charge $+q = \lambda \cdot \pi R$ (and that it points downward). Adapting the steps leading to Eq. 22-21, we find

$$\vec{E}_{\text{net}} = 2(-\hat{j}) \frac{\lambda}{4\pi\epsilon_0 R} \sin \theta \bigg|_{-90^\circ}^{90^\circ} = -\frac{q}{\epsilon_0 \pi^2 R^2} \hat{j}.$$

(a) With $R = 8.50 \times 10^{-2}$ m and $q = 1.50 \times 10^{-8}$ C, $|\vec{E}_{\text{net}}| = 23.8$ N/C.

(b) The net electric field \vec{E}_{net} points in the $-\hat{j}$ direction, or -90° counterclockwise from the $+x$ axis.



25. Studying Sample Problem 22-4, we see that the field evaluated at the center of curvature due to a charged distribution on a circular arc is given by

$$\vec{E} = \frac{\lambda}{4\pi\epsilon_0 r} [\sin \theta]_{-\theta/2}^{\theta/2} \quad \text{along the symmetry axis}$$

where $\lambda = q/r\theta$ with θ in radians. In this problem, each charged quarter-circle produces a field of magnitude

$$|\vec{E}| = \frac{|q|}{r\pi/2} \frac{1}{4\pi\epsilon_0 r} [\sin \theta]_{-\pi/4}^{\pi/4} = \frac{1}{4\pi\epsilon_0} \frac{2\sqrt{2}|q|}{\pi r^2}.$$

That produced by the positive quarter-circle points at -45° , and that of the negative quarter-circle points at $+45^\circ$.

(a) The magnitude of the net field is

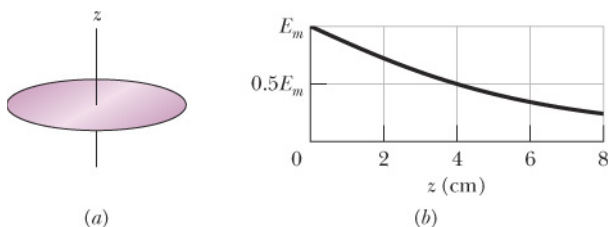
$$E_{\text{net},x} = 2 \left(\frac{1}{4\pi\epsilon_0} \frac{2\sqrt{2}|q|}{\pi r^2} \right) \cos 45^\circ = \frac{1}{4\pi\epsilon_0} \frac{4|q|}{\pi r^2} = \frac{(8.99 \times 10^9) 4(4.50 \times 10^{-12})}{\pi (5.00 \times 10^{-2})^2} = 20.6 \text{ N/C}.$$

(b) By symmetry, the net field points vertically downward in the $-\hat{j}$ direction, or -90° counterclockwise from the $+x$ axis.

26. We find the maximum by differentiating Eq. 22-16 and setting the result equal to zero.

$$\frac{d}{dz} \left(\frac{qz}{4\pi\epsilon_0 (z^2 + R^2)^{3/2}} \right) = \frac{q}{4\pi\epsilon_0} \frac{R^2 - 2z^2}{(z^2 + R^2)^{5/2}} = 0$$

which leads to $z = R/\sqrt{2}$. With $R = 2.40 \text{ cm}$, we have $z = 1.70 \text{ cm}$.

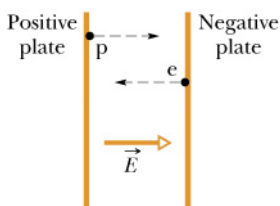


32. We write Eq. 22-26 as

$$\frac{E}{E_{\max}} = 1 - \frac{z}{(z^2 + R^2)^{1/2}}$$

and note that this ratio is $\frac{1}{2}$ (according to the graph shown in the figure) when $z = 4.0$ cm.

Solving this for R we obtain $R = z\sqrt{3} = 6.9$ cm.



45. We take the positive direction to be to the right in the figure. The acceleration of the proton is $a_p = eE/m_p$ and the acceleration of the electron is $a_e = -eE/m_e$, where E is the magnitude of the electric field, m_p is the mass of the proton, and m_e is the mass of the electron. We take the origin to be at the initial position of the proton. Then, the coordinate of the proton at time t is $x = \frac{1}{2}a_p t^2$ and the coordinate of the electron is $x = L + \frac{1}{2}a_e t^2$.

They pass each other when their coordinates are the same, or $\frac{1}{2}a_p t^2 = L + \frac{1}{2}a_e t^2$. This means $t^2 = 2L/(a_p - a_e)$ and

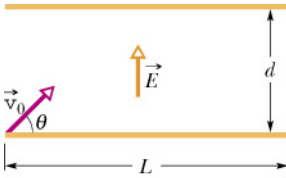
$$\begin{aligned} x &= \frac{a_p}{a_p - a_e} L = \frac{eE/m_p}{(eE/m_p) + (eE/m_e)} L = \frac{m_e}{m_e + m_p} L \\ &= \frac{9.11 \times 10^{-31} \text{ kg}}{9.11 \times 10^{-31} \text{ kg} + 1.67 \times 10^{-27} \text{ kg}} (0.050 \text{ m}) \\ &= 2.7 \times 10^{-5} \text{ m}. \end{aligned}$$

50. (a) Eq. 22-33 leads to $\tau = pE \sin 0^\circ = 0$.

(b) With $\theta = 90^\circ$, the equation gives

$$\tau = pE = (2(1.6 \times 10^{-19} \text{ C})(0.78 \times 10^{-9} \text{ m}))(3.4 \times 10^6 \text{ N/C}) = 8.5 \times 10^{-22} \text{ N} \cdot \text{m}.$$

(c) Now the equation gives $\tau = pE \sin 180^\circ = 0$.



86. (a) The electric field is upward in the diagram and the charge is negative, so the force of the field on it is downward. The magnitude of the acceleration is $a = eE/m$, where E is the magnitude of the field and m is the mass of the electron. Its numerical value is

$$a = \frac{(1.60 \times 10^{-19} \text{ C})(2.00 \times 10^3 \text{ N/C})}{9.11 \times 10^{-31} \text{ kg}} = 3.51 \times 10^{14} \text{ m/s}^2.$$

We put the origin of a coordinate system at the initial position of the electron. We take the x axis to be horizontal and positive to the right; take the y axis to be vertical and positive toward the top of the page. The kinematic equations are

$$x = v_0 t \cos \theta, \quad y = v_0 t \sin \theta - \frac{1}{2} a t^2, \quad \text{and} \quad v_y = v_0 \sin \theta - a t.$$

First, we find the greatest y coordinate attained by the electron. If it is less than d , the electron does not hit the upper plate. If it is greater than d , it will hit the upper plate if the corresponding x coordinate is less than L . The greatest y coordinate occurs when $v_y = 0$. This means $v_0 \sin \theta - a t = 0$ or $t = (v_0/a) \sin \theta$ and

$$y_{\max} = \frac{v_0^2 \sin^2 \theta}{a} - \frac{1}{2} a \frac{v_0^2 \sin^2 \theta}{a^2} = \frac{1}{2} \frac{v_0^2 \sin^2 \theta}{a} = \frac{(6.00 \times 10^6 \text{ m/s})^2 \sin^2 45^\circ}{2(3.51 \times 10^{14} \text{ m/s}^2)} = 2.56 \times 10^{-2} \text{ m}.$$

Since this is greater than $d = 2.00 \text{ cm}$, the electron might hit the upper plate.

(b) Now, we find the x coordinate of the position of the electron when $y = d$. Since

$$v_0 \sin \theta = (6.00 \times 10^6 \text{ m/s}) \sin 45^\circ = 4.24 \times 10^6 \text{ m/s}$$

and

$$2ad = 2(3.51 \times 10^{14} \text{ m/s}^2)(0.0200 \text{ m}) = 1.40 \times 10^{13} \text{ m}^2/\text{s}^2$$

the solution to $d = v_0 t \sin \theta - \frac{1}{2} a t^2$ is

$$\begin{aligned} t &= \frac{v_0 \sin \theta - \sqrt{v_0^2 \sin^2 \theta - 2ad}}{a} = \frac{4.24 \times 10^6 \text{ m/s} - \sqrt{(4.24 \times 10^6 \text{ m/s})^2 - 1.40 \times 10^{13} \text{ m}^2/\text{s}^2}}{3.51 \times 10^{14} \text{ m/s}^2} \\ &= 6.43 \times 10^{-9} \text{ s}. \end{aligned}$$

