

Problem 21.96 Two charges are placed as shown in Fig. P21.96. The magnitude of q_1 is $3.00\text{ }\mu\text{C}$, but its sign and the value of the charge q_2 are not known. The direction of the net electric field \mathbf{E} at point P is entirely in the negative y direction.

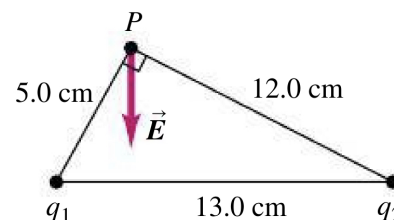
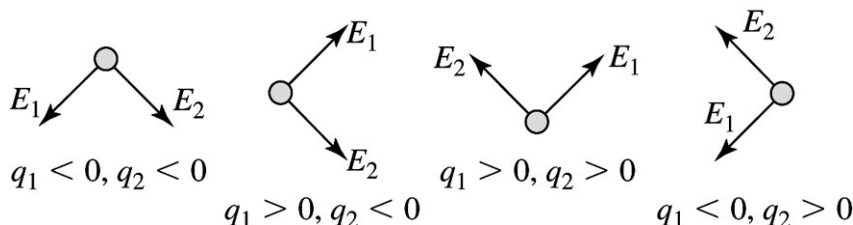


Figure P21.96

- Considering the different possible signs of q_1 and q_2 , four possible diagrams could represent the electric fields \mathbf{E}_1 and \mathbf{E}_2 produced by q_1 and q_2 . Sketch the four possible electric field configurations.
- Using the sketches from part (a) and the direction of \mathbf{E} , deduce the signs of q_1 and q_2 .
- Determine the magnitude of \mathbf{E} .

Solution.

- The four possible diagrams are:

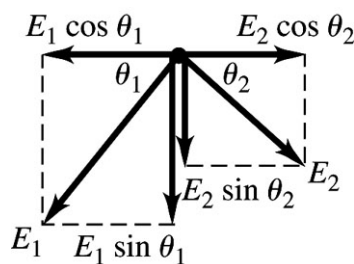


Here E_1 and E_2 indicate the electric fields of q_1 and q_2 , respectively.

- The first diagram is the only one that has the net $\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2$ pointing in the $-y$ direction like we want. This means both q_1 and q_2 are negative. (We also could have deduced this by placing a positive test charge at P , and realizing we need q_1 and q_2 to be negative in order to produce an electric field pointing down.)
- Using the expression for the electric field due to a point charge, we can find the magnitudes of E_1 and E_2 :

$$E_1 = \frac{1}{4\pi\epsilon_0} \frac{q_1}{(5.0\text{ cm})^2} = -\frac{1}{4\pi\epsilon_0} \frac{3.00\text{ }\mu\text{C}}{(5.0\text{ cm})^2}, \quad E_2 = \frac{1}{4\pi\epsilon_0} \frac{q_2}{(12.0\text{ cm})^2}.$$

Notice that we need to solve for q_2 , which we can do by force balance. We need to find and add the x and y components of \mathbf{E}_1 and \mathbf{E}_2 , which we can do by finding their angles from the horizontal. Call these angles θ_1 and θ_2 . Building off of our diagram for (a), we can make something similar to a force diagram, but for the electric field:



From Fig. P21.96, we can write down

$$\cos \theta_1 = \frac{5}{13}, \quad \sin \theta_1 = \frac{12}{13}, \quad \cos \theta_2 = \frac{12}{13}, \quad \sin \theta_2 = \frac{5}{12}.$$

First, let's balance forces in the x direction, in which we know there's 0 net electric field. This will allow us to find q_2 :

$$0 = E_x = E_{1x} + E_{2x} = E_1 \cos \theta_1 + E_2 \cos \theta_2 = -\frac{5}{13} \frac{1}{4\pi\epsilon_0} \frac{3.00 \mu\text{C}}{(5.0 \text{ cm})^2} + \frac{1}{4\pi\epsilon_0} \frac{12}{13} \frac{q_2}{(12.0 \text{ cm})^2}$$

Problem 23.82 A hollow, thin-walled insulating cylinder of radius R and length L (like the cardboard tube in a roll of toilet paper) has charge Q uniformly distributed over its surface.

- (a) Calculate the electric potential at all points along the axis of the tube. Take the origin to be at the center of the tube, and take the potential to be zero at infinity.
- (c) Use the result of part (a) to find the electric field at all points along the axis of the tube.

Problem 22.32 A cube has sides of length $L = 0.300$ m. One corner is at the origin (Fig. E22.6). The nonuniform electric field is given by $\mathbf{E} = (-5.00 \text{ N C}^{-1} \text{ m}^{-1})x \hat{\mathbf{i}} + (23.00 \text{ N C}^{-1} \text{ m}^{-1})z \hat{\mathbf{k}}$.

- (a) Find the electric flux through each of the six cube faces S_1 , S_2 , S_3 , S_4 , S_5 , and S_6 .
- (b) Find the total electric charge inside the cube.

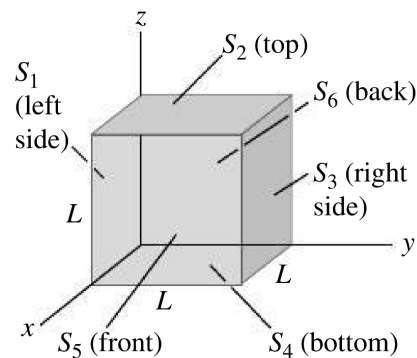


Figure E22.6

Problem 24.11

Problem 4 A spherical capacitor contains a charge of 3.30 nC when connected to a potential difference of 220 V . If its plates are separated by vacuum and the inner radius of the outer shell is 4.00 cm , calculate

- (a) the capacitance,
- (b) the radius of the inner sphere, and
- (c) the electric field just outside the surface of the inner sphere.