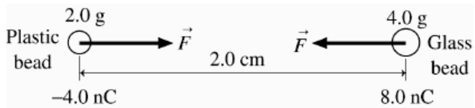
26.32. Model: The beads are point charges.

Visualize:



Solve: The beads are oppositely charged so are attracted to one another. The force on each is the same by Newton's third law, and is

$$F = K\frac{|q_1||q_2|}{r^2} = \left(9.0\times10^{-9}\ \text{Nm}^2/\text{C}^2\right)\frac{\left(4.0\times10^{-9}\ \text{C}\right)\left(8.0\times10^{-9}\ \text{C}\right)}{\left(2.0\times10^{-2}\ \text{m}\right)^2} = 7.2\times10^{-4}\ \text{N}$$

The beads accelerate at different rates because their masses are different. By Newton's second law, the acceleration of the bead on the left is

$$a_{\text{left}} = \frac{F}{m} = \frac{\left(7.2\times10^{-4}\ \text{N}\right)}{\left(2.0\times10^{-3}\ \text{kg}\right)} = 0.36\ \text{m/s}^2\ \text{to the right.}$$

For the bead on the right, the acceleration is

$$a_{\text{right}} = \frac{\left(7.2\times10^{-4}\ \text{N}\right)}{\left(4.0\times10^{-3}\ \text{kg}\right)} = 0.180\ \text{m/s}^2\ \text{to the left.}$$

26.44. Model: The charges are point charges.

Visualize: Please refer to Figure P26.44.

Solve: Placing the 1.0 nC charge at the origin and calling it q_1, the q_2 charge is in the first quadrant, the q_3 charge is in the fourth quadrant, the q_4 charge is in the third quadrant, and the q_5 charge is in the second quadrant. The electric force on q_1 is the vector sum of the electric forces from the other four charges q_2, q_3, q_4, and q_5. The magnitude of these four forces is the same because all four charges are equal in magnitude and are equidistant from q_1. So,

$$F_{2\text{ on }1} = F_{3\text{ on }1} = F_{4\text{ on }1} = F_{5\text{ on }1} = \frac{\left(9.0\times10^{9}\ \text{N m}^2/\text{C}^2\right)\left(2.0\times10^{-9}\ \text{C}\right)\left(1.0\times10^{-9}\ \text{C}\right)}{\left(0.50\times10^{-2}\ \text{m}\right)^2 + \left(0.50\times10^{-2}\ \text{m}\right)^2} = 3.6\times10^{-4}\ \text{N}$$

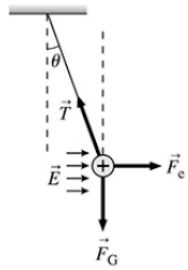
Thus, $\vec{F}_{\text{on }1}$ = (3.6 × 10^{-4} N, away from q_2) + (3.6 × 10^{-4} N, away from q_3) + (3.6 × 10^{-4} N, toward q_4) + (3.6 × 10^{-4} N, toward q_5). In component form,

$$\vec{F}_{\text{on }1} = F_{\text{on }1}\left[\left(-\cos45°\hat{i} - \sin45°\hat{j}\right) + \left(-\cos45°\hat{i} + \sin45°\hat{j}\right) + \left(-\cos45°\hat{i} - \sin45°\hat{j}\right) + \left(-\cos45°\hat{i} + \sin45°\hat{j}\right)\right]$$

$$= \left(3.6\times10^{-4}\ \text{N}\right)\left(-4\cos45°\hat{i}\right) = -1.02\times10^{-3}\hat{i}\ \text{N}$$

26.68. Model: The charged ball attached to the string is the point charge.

Visualize:



The charged ball is in static equilibrium in the external electric field when the string makes an angle θ with the vertical. The three forces acting on the charge are the electric force due to the electric field, the gravitational force on the ball, and the tension force.

Solve: In static equilibrium, Newton's second law for the charged ball is $\vec{F}_{net} = \vec{T} + \vec{F}_G + \vec{F}_3 = \vec{0}$. In component form,

$$(F_{net})_x = T_x + 0\text{ N} + qE = 0\text{ N} \qquad (F_{net})_y = T_y - mg + 0\text{ N} = 0\text{ N}$$

These two equations become $T\sin\theta = qE$ and $T\cos\theta = mg$. Dividing the equations gives

$$\tan\theta = \frac{qE}{mg} = \frac{(25\times10^{-9}\text{ C})(200{,}000\text{ N/C})}{(2.0\times10^{-3}\text{ kg})(9.8\text{ N/kg})} = 0.255 \Rightarrow \theta = 14.3°$$

27.3. Model: The electric field is that due to superposition of the fields of the two 3.0 nC charges located on the y-axis.

Visualize: Please refer to Figure EX27.3. We denote the top 3.0 nC charge by q_1 and the bottom 3.0 nC charge by q_2. The electric fields ($\vec{E}_1$ and $\vec{E}_2$) of both the positive charges are directed away from their respective charges. With vector addition, they yield the net electric field $\vec{E}_{\text{net}}$ at the point P indicated by the dot.

Solve: The electric fields from q_1 and q_2 are

$$\vec{E}_1 = \left(\frac{1}{4\pi\varepsilon_0}\frac{|q_1|}{r_1^2}, \text{ along } +x\text{-axis}\right) = \frac{(9.0\times10^9 \text{ N m}^2/\text{C}^2)(3.0\times10^{-9} \text{ C})}{(0.05 \text{ m})^2}\hat{i} = 10{,}800\hat{i} \text{ N/C}$$

$$\vec{E}_2 = \left(\frac{1}{4\pi\varepsilon_0}\frac{|q_2|}{r_2^2}, \theta \text{ above } +x\text{-axis}\right)$$

Because $\tan\theta = 10 \text{ cm}/5 \text{ cm}$, $\theta = \tan^{-1}(2) = 63.43°$. So,

$$\vec{E}_2 = \frac{(9.0\times10^9 \text{ N m}^2/\text{C}^2)(3.0\times10^{-9} \text{ C})}{(0.10 \text{ m})^2 + (0.050 \text{ m})^2}(\cos 63.43°\,\hat{i} + \sin 63.43°\,\hat{j}) = (966\hat{i} + 1127\hat{j}) \text{ N/C}$$

The net electric field is thus

$$\vec{E}_{\text{net at P}} = \vec{E}_1 + \vec{E}_2 = (11{,}766\hat{i} + 1127\hat{j}) \text{ N/C}$$

To find the angle this net vector makes with the x-axis, we calculate

$$\tan\phi = \frac{1127 \text{ N/C}}{11{,}766 \text{ N/C}} \Rightarrow \phi = 5.5°$$

Thus, the strength of the electric field at P is

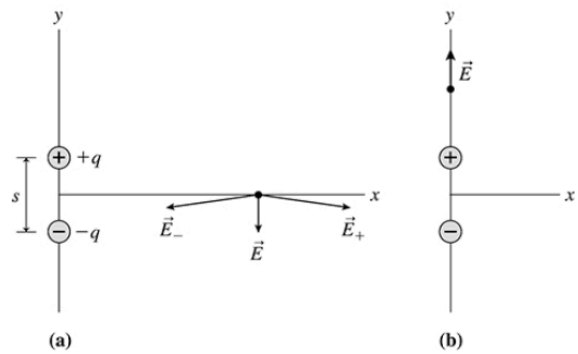
$$E_{\text{net}} = \sqrt{(11{,}766 \text{ N/C})^2 + (1127 \text{ N/C})^2} = 11{,}820 \text{ N/C} = 1.18\times10^3 \text{ N/C}$$

and $\vec{E}_{\text{net}}$ makes an angle of $5.5°$ above the $+x$-axis.

Assess: Because of the inverse square dependence on distance, $E_2 < E_1$. Additionally, because the point P has no special symmetry relative to the charges, we expected the net field to be at an angle relative to the x-axis.

27.5. Model: The distances to the observation points are large compared to the size of the dipole, so model the field as that of a dipole moment.

Visualize:



The dipole consists of charges $\pm q$ along the y-axis. The electric field in (a) points down. The field in (b) points up.

Solve: **(a)** The dipole moment is

$$\vec{p} = (qs,\text{ from} - \text{to} +) = (1.0\times10^{-9}\text{ C})(0.0020\text{ m})\hat{j} = 2.0\times10^{-12}\hat{j}\text{ C m}$$

The electric field at (10 cm, 0 cm), which is at distance r = 0.10 m in the plane perpendicular to the electric dipole, is

$$\vec{E} = -\frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3} = -(9.0\times10^9\text{ N m}^2/\text{C}^2)\frac{2.0\times10^{-12}\hat{j}\text{ C m}}{(0.10\text{ m})^3} = -18.0\hat{j}\text{ N/C}$$

The field strength, which is all we're asked for, is 18.0 N/C.

(b) The electric field at (0 cm, 10 cm), which is at r = 0.10 m along the axis of the dipole, is

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{r^3} = (9.0\times10^9\text{ N m}^2/\text{C}^2)\frac{2(2.0\times10^{-12}\hat{j}\text{ C m})}{(0.10\text{ m})^3} = 36\hat{j}\text{ N/C}$$

The field strength at this point is 36 N/C.