P19.11 The point is designated in the sketch. The magnitudes of the electric fields, E_1, (due to the -2.50×10^{-6} C charge) and E_2 (due to the 6.00×10^{-6} C charge) are

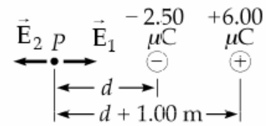

FIG. P19.11

$$E_1=\frac{k_eq}{r^2}=\frac{\left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(2.50\times10^{-6}\ \text{C}\right)}{d^2} \qquad (1)$$

$$E_2=\frac{k_eq}{r^2}=\frac{\left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(6.00\times10^{-6}\ \text{C}\right)}{(d+1.00\ \text{m})^2} \qquad (2)$$

Equate the right sides of (1) and (2)

to get	$(d+1.00\ \text{m})^2=2.40d^2$
or	$d+1.00\ \text{m}=\pm1.55d$
which yields	$d=1.82$ m
or	$d=-0.392$ m .

The negative value for d is unsatisfactory because that locates a point between the charges where both fields are in the same direction.

Thus, $\boxed{d=1.82\ \text{m to the left of the } -2.50\ \mu\text{C charge}}$.

P19.13 (a)

$$\vec{E}_1=\frac{k_e|q_1|}{r_1^2}\left(-\hat{j}\right)=\frac{\left(8.99\times10^9\right)\left(3.00\times10^{-9}\right)}{(0.100)^2}\left(-\hat{j}\right)=-\left(2.70\times10^3\ \text{N/C}\right)\hat{j}$$

$$\vec{E}_2=\frac{k_e|q_2|}{r_2^2}\left(-\hat{i}\right)=\frac{\left(8.99\times10^9\right)\left(6.00\times10^{-9}\right)}{(0.300)^2}\left(-\hat{i}\right)=-\left(5.99\times10^2\ \text{N/C}\right)\hat{i}$$

$$\vec{E}=\vec{E}_2+\vec{E}_1=\boxed{-\left(5.99\times10^2\ \text{N/C}\right)\hat{i}-\left(2.70\times10^3\ \text{N/C}\right)\hat{j}}$$

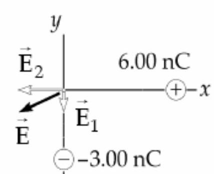

FIG. P19.13

(b)

$$\vec{F}=q\vec{E}=\left(5.00\times10^{-9}\ \text{C}\right)\left(-599\hat{i}-2\,700\hat{j}\right)\ \text{N/C}$$

$$\vec{F}=\left(-3.00\times10^{-6}\,\hat{i}-13.5\times10^{-6}\,\hat{j}\right)\ \text{N}=\boxed{\left(-3.00\hat{i}-13.5\hat{j}\right)\ \mu\text{N}}$$

P19.15 (a) $\vec{E} = \frac{k_e q_1}{r_1^2}\hat{r}_1 + \frac{k_e q_2}{r_2^2}\hat{r}_2 + \frac{k_e q_3}{r_3^2}\hat{r}_3 = \frac{k_e(2q)}{a^2}\hat{i} + \frac{k_e(3q)}{2a^2}\left(\hat{i}\cos 45.0° + \hat{j}\sin 45.0°\right) + \frac{k_e(4q)}{a^2}\hat{j}$

$$\vec{E} = 3.06\frac{k_e q}{a^2}\hat{i} + 5.06\frac{k_e q}{a^2}\hat{j} = \boxed{5.91\frac{k_e q}{a^2}\text{ at } 58.8°}$$

(b) $\vec{F} = q\vec{E} = \boxed{5.91\frac{k_e q^2}{a^2}\text{ at } 58.8°}$

P19.17 $E = \frac{k_e \lambda \ell}{d(\ell + d)} = \frac{k_e (Q/\ell)\ell}{d(\ell + d)} = \frac{k_e Q}{d(\ell + d)} = \frac{(8.99\times 10^9)(22.0\times 10^{-6})}{(0.290)(0.140 + 0.290)}$

$\vec{E} = \boxed{1.59\times 10^6\ \text{N/C, directed toward the rod.}}$

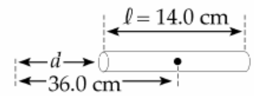

FIG. P19.17

P19.21 Due to symmetry $E_y = \int dE_y = 0$, and $E_x = \int dE\sin\theta = k_e\int \frac{dq\sin\theta}{r^2}$

where $dq = \lambda ds = \lambda r d\theta$,

so that, $E_x = \frac{k_e\lambda}{r}\int_0^{\pi}\sin\theta d\theta = \frac{k_e\lambda}{r}(-\cos\theta)\Big|_0^{\pi} = \frac{2k_e\lambda}{r}$

where $\lambda = \frac{q}{L}$ and $r = \frac{L}{\pi}$.

Thus, $E_x = \frac{2k_e q\pi}{L^2} = \frac{2(8.99\times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(7.50\times 10^{-6}\ \text{C})\pi}{(0.140\ \text{m})^2}$.

Solving, $E_x = 2.16\times 10^7$ N/C.

Since the rod has a negative charge, $\vec{E} = \left(-2.16\times 10^7\hat{i}\right)$ N/C $= \boxed{-21.6\hat{i}\ \text{MN/C}}$.

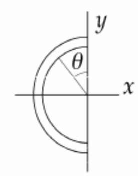

FIG. P19.21

***P19.24** (a) $\frac{q_1}{q_2} = \frac{-6}{18} = \boxed{-\frac{1}{3}}$

(b) $\boxed{q_1 \text{ is negative, } q_2 \text{ is positive}}$

P19.27 (a) $a=\frac{qE}{m}=\frac{1.60\times10^{-19}(640)}{1.67\times10^{-27}}=\boxed{6.13\times10^{10}\ \text{m/s}^2}$

(b) $v_f=v_i+at$ $\quad 1.20\times10^6=\left(6.13\times10^{10}\right)t$ $\quad t=\boxed{1.95\times10^{-5}\ \text{s}}$

(c) $x_f-x_i=\frac{1}{2}\left(v_i+v_f\right)t$ $\quad x_f=\frac{1}{2}\left(1.20\times10^6\right)\left(1.95\times10^{-5}\right)=\boxed{11.7\ \text{m}}$

(d) $K=\frac{1}{2}mv^2=\frac{1}{2}\left(1.67\times10^{-27}\ \text{kg}\right)\left(1.20\times10^6\ \text{m/s}\right)^2=\boxed{1.20\times10^{-15}\ \text{J}}$

Section 19.8 Electric Flux

P19.30 $\Phi_E=EA\cos\theta=\left(2.00\times10^4\ \text{N/C}\right)\left(18.0\ \text{m}^2\right)\cos10.0°=\boxed{355\ \text{kN}\cdot\text{m}^2/\text{C}}$

P19.31 $\Phi_E=EA\cos\theta$ $\quad A=\pi r^2=\pi(0.200)^2=0.126\ \text{m}^2$

$5.20\times10^5=E(0.126)\cos0°$ $\quad E=4.14\times10^6\ \text{N/C}=\boxed{4.14\ \text{MN/C}}$

Section 19.9 Gauss's Law

P19.32 (a) $E=\frac{k_eQ}{r^2}$: $\quad 8.90\times10^2=\frac{\left(8.99\times10^9\right)Q}{(0.750)^2}$

But Q is negative since $\vec{E}$ points inward. $\quad Q=-5.57\times10^{-8}\ \text{C}=\boxed{-55.7\ \text{nC}}$

(b) The $\boxed{\text{negative}}$ charge has a $\boxed{\text{spherically symmetric}}$ charge distribution, concentric with the spherical shell.

P19.33 (a) With δ very small, all points on the hemisphere are nearly at a distance R from the charge, so the field everywhere on the curved surface is $\frac{k_e Q}{R^2}$ radially outward (normal to the surface). Therefore, the flux is this field strength times the area of half a sphere:

$$\Phi_{\text{curved}} = \int \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = E_{\text{local}} A_{\text{hemisphere}}$$

$$\Phi_{\text{curved}} = \left(k_e \frac{Q}{R^2}\right)\left(\frac{1}{2} 4\pi R^2\right) = \frac{1}{4\pi \epsilon_0} Q(2\pi) = \boxed{\frac{+Q}{2 \epsilon_0}}$$

(b) The closed surface encloses zero charge so Gauss's law gives

$$\Phi_{\text{curved}} + \Phi_{\text{flat}} = 0 \quad \text{or} \quad \Phi_{\text{flat}} = -\Phi_{\text{curved}} = \boxed{\frac{-Q}{2 \epsilon_0}}.$$