***19.1** (a) $N = \left(\frac{10.0 \text{ grams}}{107.87 \text{ grams/mol}}\right)\left(6.02\times10^{23}\ \frac{\text{atoms}}{\text{mol}}\right)\left(47\ \frac{\text{electrons}}{\text{atom}}\right) = \boxed{2.62\times10^{24}}$

(b) $\#\text{ electrons added} = \frac{Q}{e} = \frac{1.00\times10^{-3}\text{ C}}{1.60\times10^{-19}\text{ C/electron}} = 6.25\times10^{15}$

or $\boxed{2.38 \text{ electrons for every } 10^9 \text{ already present}}$

**19.4** (a) The force is one of $\boxed{\text{attraction}}$. The distance $r$ in Coulomb's law is the distance between centers. The magnitude of the force is

$$F = \frac{k_e q_1 q_2}{r^2} = \left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\frac{\left(12.0\times10^{-9}\text{ C}\right)\left(18.0\times10^{-9}\text{ C}\right)}{(0.300\text{ m})^2} = \boxed{2.16\times10^{-5}\text{ N}}$$

(b) The net charge of $-6.00\times10^{-9}$ C will be equally split between the two spheres, or $-3.00\times10^{-9}$ C on each. The force is one of $\boxed{\text{repulsion}}$, and its magnitude is

$$F = \frac{k_e q_1 q_2}{r^2} = \left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\frac{\left(3.00\times10^{-9}\text{ C}\right)\left(3.00\times10^{-9}\text{ C}\right)}{(0.300\text{ m})^2} = \boxed{8.99\times10^{-7}\text{ N}}$$

**19.6** (a) $F = \frac{k_e e^2}{r^2} = \left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\frac{\left(1.60\times10^{-19}\text{ C}\right)^2}{\left(0.529\times10^{-10}\text{ m}\right)^2} = \boxed{8.22\times10^{-8}\text{ N}}$

(b) We have $F = \frac{mv^2}{r}$ from which

$$v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{8.22\times10^{-8}\text{ N}\left(0.529\times10^{-10}\text{ m}\right)}{9.11\times10^{-31}\text{ kg}}} = \boxed{2.19\times10^6\text{ m/s}}$$

***19.7**

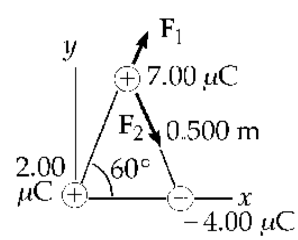
$$F_1 = k_e\frac{q_1q_2}{r^2} = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(7.00\times10^{-6}\text{ C})(2.00\times10^{-6}\text{ C})}{(0.500\text{ m})^2} = 0.503\text{ N}$$

$$F_2 = k_e\frac{q_1q_2}{r^2} = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(7.00\times10^{-6}\text{ C})(4.00\times10^{-6}\text{ C})}{(0.500\text{ m})^2} = 1.01\text{ N}$$

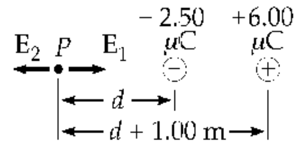
$$F_x = 0.503\cos60.0^\circ + 1.01\cos60.0^\circ = 0.755\text{ N}$$

$$F_y = 0.503\sin60.0^\circ - 1.01\sin60.0^\circ = -0.436\text{ N}$$

$$\mathbf{F} = (0.755\text{ N})\mathbf{i} - (0.436\text{ N})\mathbf{j} = \boxed{0.872\text{ N at an angle of }330^\circ}$$



**19.9** The point is designated in the sketch. The magnitudes of the electric fields, $E_1$, (due to the $-2.50\times10^{-6}$ C charge) and $E_2$ (due to the $6.00\times10^{-6}$ C charge) are




$$E_1=\frac{k_e q}{r^2}=\frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(2.50\times10^{-6}\ \text{C})}{d^2} \quad (1)$$

$$E_2=\frac{k_e q}{r^2}=\frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(6.00\times10^{-6}\ \text{C})}{(d+1.00\ \text{m})^2} \quad (2)$$

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

to get $(d+1.00\ \text{m})^2=2.40d^2$

or $d+1.00\ \text{m}=\pm1.55d$

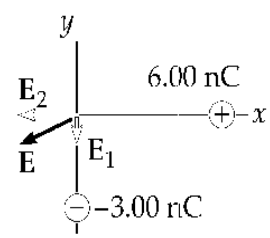
which yields $d=1.82$ m

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, $d=$ 1.82 m to the left of the $-2.50\ \mu$C charge.

***19.10** (a) $\mathbf{E}_1=\frac{k_e|q_1|}{r_1^2}(-\mathbf{j})=\frac{(8.99\times10^9)(3.00\times10^{-9})}{(0.100)^2}(-\mathbf{j})=-(2.70\times10^3\ \text{N/C})\mathbf{j}$




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

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

(b) $\mathbf{F}=q\mathbf{E}=(5.00\times10^{-9}\ \text{C})(-599\mathbf{i}-2700\mathbf{j})\ \text{N/C}$

$\mathbf{F}=(-3.00\times10^{-6}\mathbf{i}-13.5\times10^{-6}\mathbf{j})\text{N}=$ $(-3.00\mathbf{i}-13.5\mathbf{j})\ \mu\text{N}$

***19.13** (a) $\mathbf{E} = \frac{k_e q_1}{r_1^2}\hat{\mathbf{r}}_1 + \frac{k_e q_2}{r_2^2}\hat{\mathbf{r}}_2 + \frac{k_e q_3}{r_3^2}\hat{\mathbf{r}}_3 = \frac{k_e(2q)}{a^2}\mathbf{i} + \frac{k_e(3q)}{2a^2}(\mathbf{i}\cos 45.0° + \mathbf{j}\sin 45.0°) + \frac{k_e(4q)}{a^2}\mathbf{j}$

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

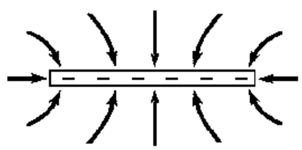
(b) $\mathbf{F} = q\mathbf{E} = \boxed{5.91\frac{k_e q^2}{a^2} \text{ at } 58.8°}$

**19.18** $E = \int \frac{k_e dq}{x^2}$, where $dq = \lambda_0 dx$

$$E = k_e\lambda_0 \int_{x_0}^{\infty} \frac{dx}{x^2} = k_e\left(-\frac{1}{x}\right)\Big|_{x_0}^{\infty} = \boxed{\frac{k_e\lambda_0}{x_0}}$$

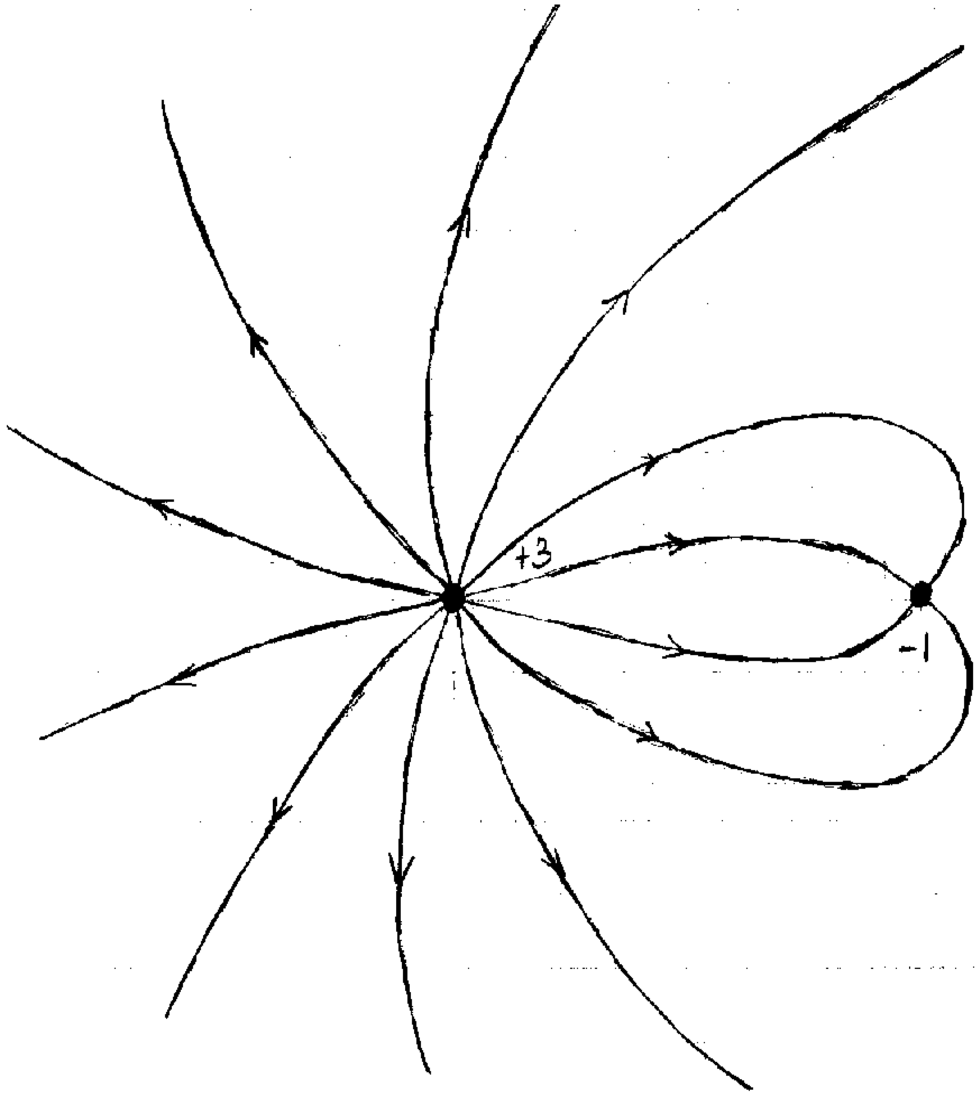
$\boxed{\text{The direction is } -\mathbf{i} \text{ or left for } \lambda_0 > 0}$

***19.21**



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

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




- The lines point outward from the + charge and inward towards the − charge
- Close to either charge the lines are evenly spaced (like they are for an isolated point charge).
- The number of field lines attached to each charge is proportional to $|q|$.
- $\frac{1}{3}$ of the field lines originating on the +3 charge loop around and end on the −1 charge. The remaining lines extend to infinity.
- At large distances the remaining field lines would be equally spaced, similar to those of a +2mC point charge

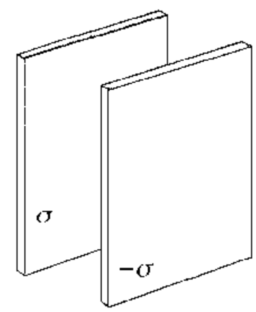
***19.26** (a) $t = \dfrac{x}{v_x} = \dfrac{0.0500}{4.50 \times 10^5} = 1.11 \times 10^{-7}\ \text{s} = \boxed{111\ \text{ns}}$

(b) $a_y = \dfrac{qE}{m} = \dfrac{\left(1.602 \times 10^{-19}\right)\left(9.60 \times 10^3\right)}{\left(1.67 \times 10^{-27}\right)} = 9.21 \times 10^{11}\ \text{m/s}^2$

$y_f - y_i = v_{yi}t + \frac{1}{2}a_y t^2$: $\quad y_f = \frac{1}{2}\left(9.21 \times 10^{11}\right)\left(1.11 \times 10^{-7}\right)^2 = 5.67 \times 10^{-3}\ \text{m} = \boxed{5.67\ \text{mm}}$

(c) $v_x = \boxed{4.50 \times 10^5\ \text{m/s}}$ $\quad v_{yf} = v_{yi} + a_y t = \left(9.21 \times 10^{11}\right)\left(1.11 \times 10^{-7}\right) = \boxed{1.02 \times 10^5\ \text{m/s}}$

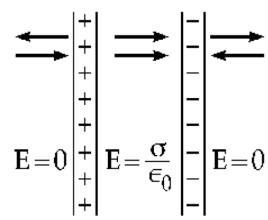
**19.60** Consider the field due to a single sheet and let $E_+$ and $E_-$ represent the fields due to the positive and negative sheets. The field at any distance from each sheet has a magnitude given by Equation 19.24:




$$\left|E_+\right| = \left|E_-\right| = \frac{\sigma}{2\epsilon_0}$$

(a) To the left of the positive sheet, $E_+$ is directed toward the left and $E_-$ toward the right and the net field over this region is $\mathbf{E} = \boxed{0}$.

(b) In the region between the sheets, $E_+$ and $E_-$ are both directed toward the right and the net field is




$$\mathbf{E} = \boxed{\frac{\sigma}{\epsilon_0}\ \text{to the right}}$$

(c) To the right of the negative sheet, $E_+$ and $E_-$ are again oppositely directed and $\mathbf{E} = \boxed{0}$.