***P19.1** (a) The mass of an average neutral hydrogen atom is 1.007 9u. Losing one electron reduces its mass by a negligible amount, to

$$1.007\,9\left(1.660\times10^{-27}\text{ kg}\right)-9.11\times10^{-31}\text{ kg}=\boxed{1.67\times10^{-27}\text{ kg}}.$$

Its charge, due to loss of one electron, is

$$0-1\left(-1.60\times10^{-19}\text{ C}\right)=\boxed{+1.60\times10^{-19}\text{ C}}.$$

(b) By similar logic, charge $=\boxed{+1.60\times10^{-19}\text{ C}}$

$$\text{mass}=22.99\left(1.66\times10^{-27}\text{ kg}\right)-9.11\times10^{-31}\text{ kg}=\boxed{3.82\times10^{-26}\text{ kg}}$$

(c) charge of $Cl^{-}=\boxed{-1.60\times10^{-19}\text{ C}}$

$$\text{mass}=35.453\left(1.66\times10^{-27}\text{ kg}\right)+9.11\times10^{-31}\text{ kg}=\boxed{5.89\times10^{-26}\text{ kg}}$$

(d) charge of $Ca^{++}=-2\left(-1.60\times10^{-19}\text{ C}\right)=\boxed{+3.20\times10^{-19}\text{ C}}$

$$\text{mass}=40.078\left(1.66\times10^{-27}\text{ kg}\right)-2\left(9.11\times10^{-31}\text{ kg}\right)=\boxed{6.65\times10^{-26}\text{ kg}}$$

(e) charge of $N^{3-}=3\left(-1.60\times10^{-19}\text{ C}\right)=\boxed{-4.80\times10^{-19}\text{ C}}$

$$\text{mass}=14.007\left(1.66\times10^{-27}\text{ kg}\right)+3\left(9.11\times10^{-31}\text{ kg}\right)=\boxed{2.33\times10^{-26}\text{ kg}}$$

(f) charge of $N^{4+}=4\left(1.60\times10^{-19}\text{ C}\right)=\boxed{+6.40\times10^{-19}\text{ C}}$

$$\text{mass}=14.007\left(1.66\times10^{-27}\text{ kg}\right)-4\left(9.11\times10^{-31}\text{ kg}\right)=\boxed{2.32\times10^{-26}\text{ kg}}$$

(g) We think of a nitrogen nucleus as a seven-times ionized nitrogen atom.

$$\text{charge}=7\left(1.60\times10^{-19}\text{ C}\right)=\boxed{1.12\times10^{-18}\text{ C}}$$

$$\text{mass}=14.007\left(1.66\times10^{-27}\text{ kg}\right)-7\left(9.11\times10^{-31}\text{ kg}\right)=\boxed{2.32\times10^{-26}\text{ kg}}$$

(h) charge $=\boxed{-1.60\times10^{-19}\text{ C}}$

$$\text{mass}=\left[2(1.007\,9)+15.999\right]1.66\times10^{-27}\text{ kg}+9.11\times10^{-31}\text{ kg}=\boxed{2.99\times10^{-26}\text{ kg}}$$

P19.2 (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 $\boxed{2.38\text{ electrons for every }10^{9}\text{ already present}}$.

P19.3 If each person has a mass of $\approx 70\text{ kg}$ and is (almost) composed of water, then each person contains

$$N = \left(\frac{70\,000\text{ grams}}{18\text{ grams/mol}}\right)\left(6.02\times10^{23}\ \frac{\text{molecules}}{\text{mol}}\right)\left(10\ \frac{\text{protons}}{\text{molecule}}\right) = 2.3\times10^{28}\text{ protons}.$$

With an excess of 1% electrons over protons, each person has a charge

$$q = 0.01\left(1.6\times10^{-19}\text{ C}\right)\left(2.3\times10^{28}\right) = 3.7\times10^{7}\text{ C}.$$

So $$F = k_e\frac{q_1q_2}{r^2} = \left(9\times10^9\right)\frac{\left(3.7\times10^7\right)^2}{0.6^2}\text{ N} = 4\times10^{25}\text{ N}\ \boxed{\sim10^{26}\text{ N}}.$$

This force is almost enough to lift a weight equal to that of the Earth:

$$Mg = 6\times10^{24}\text{ kg}\left(9.8\text{ m/s}^2\right) = 6\times10^{25}\text{ N} \sim 10^{26}\text{ N}.$$

P19.4 The force on one proton is $\vec{\mathbf{F}} = \frac{k_eq_1q_2}{r^2}$ away from the other proton. Its magnitude is

$$\left(8.99\times10^9\text{ N}\cdot\text{m/C}^2\right)\left(\frac{1.6\times10^{-19}\text{ C}}{2\times10^{-15}\text{ m}}\right)^2 = \boxed{57.5\text{ N}}.$$

P19.5 $$F_1 = k_e\frac{q_1q_2}{r^2} = \frac{\left(8.99\times10^9\text{ N}\cdot\text{m}^2/\text{C}^2\right)\left(7.00\times10^{-6}\text{ C}\right)\left(2.00\times10^{-6}\text{ C}\right)}{(0.500\text{ m})^2} = 0.503\text{ N}$$

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

$$F_x = 0.503\cos60.0° + 1.01\cos60.0° = 0.755\text{ N}$$
$$F_y = 0.503\sin60.0° - 1.01\sin60.0° = -0.436\text{ N}$$
$$\vec{\mathbf{F}} = (0.755\text{ N})\hat{\mathbf{i}} - (0.436\text{ N})\hat{\mathbf{j}} = \boxed{0.872\text{ N at an angle of }330°}$$

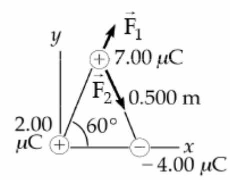

FIG. P19.5

P19.7 (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

$$F = \frac{k_eq_1q_2}{r^2} = \left(8.99\times10^9\text{ N}\cdot\text{m}^2/\text{C}^2\right)\frac{\left(12.0\times10^{-9}\text{ C}\right)\left(18.0\times10^{-9}\text{ C}\right)}{(0.300\text{ m})^2} = \boxed{2.16\times10^{-5}\text{ N}}.$$

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

$$F = \frac{k_eq_1q_2}{r^2} = \left(8.99\times10^9\text{ N}\cdot\text{m}^2/\text{C}^2\right)\frac{\left(3.00\times10^{-9}\text{ C}\right)\left(3.00\times10^{-9}\text{ C}\right)}{(0.300\text{ m})^2} = \boxed{8.99\times10^{-7}\text{ N}}.$$

***P19.8** Let the third bead have charge Q and be located distance x from the left end of the rod. This bead will experience a net force given by

$$\vec{\mathbf{F}} = \frac{k_e(3q)Q}{x^2}\hat{\mathbf{i}} + \frac{k_e(q)Q}{(d-x)^2}\left(-\hat{\mathbf{i}}\right).$$

The net force will be zero if $\dfrac{3}{x^2} = \dfrac{1}{(d-x)^2}$, or $d - x = \dfrac{x}{\sqrt{3}}$.

This gives an equilibrium position of the third bead of $x = \boxed{0.634d}$.

The equilibrium is $\boxed{\text{stable if the third bead has positive charge}}$.

P19.10 For equilibrium, $\vec{\mathbf{F}}_e = -\vec{\mathbf{F}}_g$

or $q\vec{\mathbf{E}} = -mg\left(-\hat{\mathbf{j}}\right)$.

Thus, $\vec{\mathbf{E}} = \dfrac{mg}{q}\hat{\mathbf{j}}$.

(a) $$\vec{\mathbf{E}} = \frac{mg}{q}\hat{\mathbf{j}} = \frac{\left(9.11\times10^{-31}\text{ kg}\right)\left(9.80\text{ m/s}^2\right)}{\left(-1.60\times10^{-19}\text{ C}\right)}\hat{\mathbf{j}} = \boxed{-\left(5.58\times10^{-11}\text{ N/C}\right)\hat{\mathbf{j}}}$$

(b) $$\vec{\mathbf{E}} = \frac{mg}{q}\hat{\mathbf{j}} = \frac{\left(1.67\times10^{-27}\text{ kg}\right)\left(9.80\text{ m/s}^2\right)}{\left(1.60\times10^{-19}\text{ C}\right)}\hat{\mathbf{j}} = \boxed{\left(1.02\times10^{-7}\text{ N/C}\right)\hat{\mathbf{j}}}$$

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

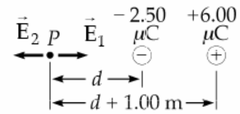

FIG. P19.11

$$E_1 = \frac{k_e q}{r^2} = \frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(2.50 \times 10^{-6} \text{ C})}{d^2} \quad (1)$$

$$E_2 = \frac{k_e q}{r^2} = \frac{(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(6.00 \times 10^{-6} \text{ C})}{(d + 1.00 \text{ m})^2} \quad (2)$$

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

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

or $d + 1.00 \text{ m} = \pm 1.55 d$

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

P19.13 (a)

$$\vec{E}_1 = \frac{k_e |q_1|}{r_1^2}(-\hat{j}) = \frac{(8.99 \times 10^9)(3.00 \times 10^{-9})}{(0.100)^2}(-\hat{j}) = -(2.70 \times 10^3 \text{ N/C})\hat{j}$$

$$\vec{E}_2 = \frac{k_e |q_2|}{r_2^2}(-\hat{i}) = \frac{(8.99 \times 10^9)(6.00 \times 10^{-9})}{(0.300)^2}(-\hat{i}) = -(5.99 \times 10^2 \text{ N/C})\hat{i}$$

$$\vec{E} = \vec{E}_2 + \vec{E}_1 = \boxed{-(5.99 \times 10^2 \text{ N/C})\hat{i} - (2.70 \times 10^3 \text{ N/C})\hat{j}}$$

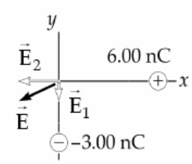

FIG. P19.13

(b)

$$\vec{F} = q\vec{E} = (5.00 \times 10^{-9} \text{ C})(-599\hat{i} - 2\,700\hat{j}) \text{ N/C}$$

$$\vec{F} = (-3.00 \times 10^{-6}\hat{i} - 13.5 \times 10^{-6}\hat{j}) \text{ N} = \boxed{(-3.00\hat{i} - 13.5\hat{j})\ \mu\text{N}}$$