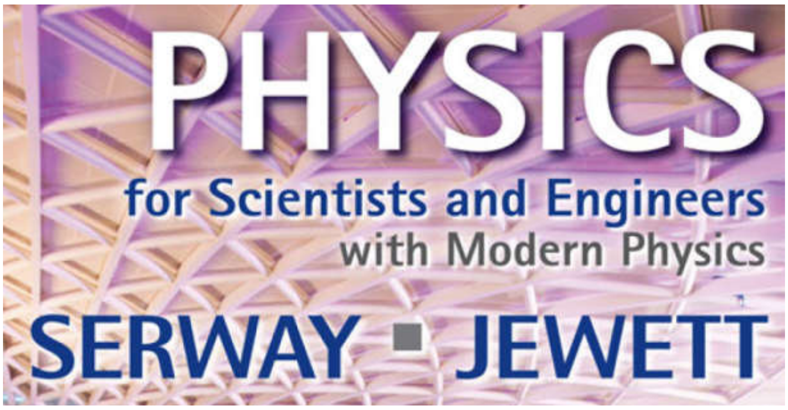
Numerical results of the following problems
Here are the specific notations in this file

$$k_e = \frac{1}{4\pi\varepsilon_0} = 9 \cdot 10^9 \frac{Vm}{As} \qquad \left[\frac{N}{C} \equiv \frac{V}{m}\right] \qquad [As \equiv C]$$



P23.11

(a) The forces are perpendicular, so the magnitude of the resultant is

$$F_R = \sqrt{(F_6)^2 + (F_3)^2} = \boxed{1.38 \times 10^{-5}\ \text{N}}$$

(b) The magnitude of the angle of the resultant is

$$\theta = \tan^{-1}\left(\frac{F_3}{F_6}\right) = 77.5^\circ$$

The resultant force is in the third quadrant, so the direction is

$$\boxed{77.5^\circ \text{ below } -x \text{ axis}}$$

P23.12

(a) The net force on the 6 μC charge is

$$F_{(6\mu\text{C})} = F_1 - F_2 = \boxed{46.7\ \text{N to the left}}$$

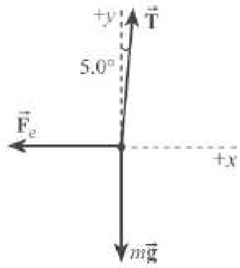
(b) The net force on the 1.5 μC charge is

$$F_{(1.5\mu\text{C})} = F_1 + F_3 = \boxed{157\ \text{N to the right}}$$

(c) The net force on the -2 μC charge is

$$F_{(-2\mu\text{C})} = F_2 + F_3 = \boxed{111\ \text{N to the left}}$$

P23.16 Consider the free-body diagram of one of the spheres shown in ANS. FIG. P23.16. Here, T is the tension in the string and F_e is the repulsive electrical force exerted by the other sphere.



ANS. FIG. P23.16

$$\sum F_y = 0 \Rightarrow T\cos 5.0° = mg$$

or $$T = \frac{mg}{\cos 5.0°}$$

$$\sum F_x = 0 \Rightarrow F_e = T\sin 5.0° = mg\tan 5.0°$$

At equilibrium, the distance separating the two spheres is $r = 2L\sin 5.0°$.

P23.21 (a) The force is one of $\boxed{\text{attraction}}$. The distance r in Coulomb's law is the distance between the centers of the spheres. The magnitude of the force is

$$F = \frac{k_e q_1 q_2}{r^2}$$

$$= \left(8.99\times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\frac{\left(12.0\times 10^{-9}\ \text{C}\right)\left(18.0\times 10^{-9}\ \text{C}\right)}{(0.300\ \text{m})^2}$$

$$= \boxed{2.16\times 10^{-5}\ \text{N}}$$

(b) The net charge of -6.00×10^{-9} C will be equally split between the two spheres, or -3.00×10^{-9} C on each. The force is one of $\boxed{\text{repulsion}}$, and its magnitude is

$$F = \frac{k_e q_1 q_2}{r^2}$$

$$= \left(8.99\times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\frac{\left(3.00\times 10^{-9}\ \text{C}\right)\left(3.00\times 10^{-9}\ \text{C}\right)}{(0.300\ \text{m})^2}$$

$$= \boxed{8.99\times 10^{-7}\ \text{N}}$$

P23.29

$x = \boxed{1.82\ \text{m}}$ to the left of the negatively-charged object.

P23.25

$$= \boxed{\frac{k_e q}{a^2}\left(3.06\hat{\mathbf{i}} + 5.06\hat{\mathbf{j}}\right)}$$

(b) The electric force on charge q is given by

$$\vec{\mathbf{F}} = q\vec{\mathbf{E}} = \boxed{\frac{k_e q^2}{a^2}\left(3.06\hat{\mathbf{i}} + 5.06\hat{\mathbf{j}}\right)}$$

***23.33** From the free-body diagram shown in ANS. FIG. P23.33,

$$\sum F_y = 0: \qquad T\cos 15.0° = 1.96 \times 10^{-2}\ \text{N}$$

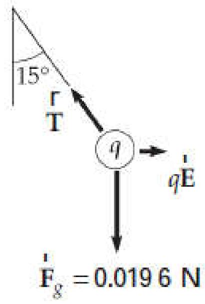
So $T = 2.03 \times 10^{-2}$ N.

From $\sum F_x = 0$, we have $qE = T\sin 15.0°$,

or

$$q = \frac{T\sin 15.0°}{E} = \frac{\left(2.03\times10^{-2}\ \text{N}\right)\sin 15.0°}{1.00\times10^{3}\ \text{N/C}}$$

$$= 5.25\times10^{-6}\ \text{C} = \boxed{5.25\ \mu\text{C}}$$



ANS. FIG. P23.33

P23.37

$$E = \boxed{1.59\times10^{6}\ \text{N/C}}$$

P23.38

(a) At x = 0.050 0 m,

$$E = 3.83\times10^{8}\ \text{N/C} = \boxed{383\ \text{MN/C}}$$

(b) At x = 0.100 m,

$$E = 3.24\times10^{8}\ \text{N/C} = \boxed{324\ \text{MN/C}}$$

(c) At x = 0.500 m,

$$E = 8.07\times10^{7}\ \text{N/C} = \boxed{80.7\ \text{MN/C}}$$

(d) At x = 2.000 m,

$$E = 6.68\times10^{8}\ \text{N/C} = \boxed{6.68\ \text{MN/C}}$$

P23.57 $\vec{E}$ is directed along the y direction; therefore, $a_x = 0$ and $x = v_{xi}t$.

(a) $t = \frac{x}{v_{xi}} = \frac{0.050\,0 \text{ m}}{4.50 \times 10^5 \text{ s}} = 1.11 \times 10^{-7} \text{ s} = \boxed{111 \text{ ns}}$

(b) $a_y = \frac{qE}{m} = \frac{(1.602 \times 10^{-19} \text{ C})(9.60 \times 10^3 \text{ N/C})}{1.67 \times 10^{-27} \text{ kg}} = 9.21 \times 10^{11} \text{ m/s}^2$

$y_f - y_i = v_{yi}t + \frac{1}{2}a_y t^2$:

$y_f = \frac{1}{2}(9.21 \times 10^{11} \text{ m/s}^2)(1.11 \times 10^{-7} \text{ s})^2$

$= 5.68 \times 10^{-3} \text{ m} = \boxed{5.67 \text{ mm}}$

(c) $v_x = 4.50 \times 10^5 \text{ m/s}$

$v_{yf} = v_{yi} + a_y t = (9.21 \times 10^{11} \text{ m/s}^2)(1.11 \times 10^{-7} \text{ s}) = 1.02 \times 10^5 \text{ m/s}$

$\vec{v} = \boxed{(450\hat{i} + 102\hat{j}) \text{ km/s}}$

P23.67

$q = \boxed{1.09 \times 10^{-8} \text{ C}}$

(b) Using the above result for q in equation [1], we find that the tension is

$$T = \frac{qE_x}{\sin 37.0°} = \frac{(1.09 \times 10^{-8} \text{ C})(3.00 \times 10^5 \text{ N/C})}{\sin 37.0°}$$

$$= \boxed{5.44 \times 10^{-3} \text{ N}}$$

P23.68

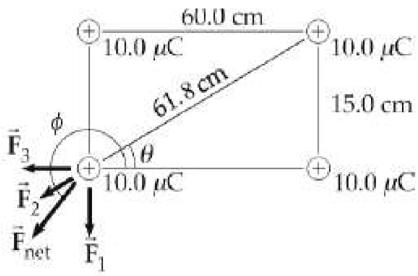
$$\boxed{q = \frac{mg}{(A\cot\theta + B)}}$$

(b) Substituting this value into equation [1], we obtain

$$\boxed{T = \frac{mgA}{(A\cos\theta + B\sin\theta)}}$$

P23.72 The magnitude of the electric force is given by $F = \frac{k_e q_1 q_2}{r^2}$. The angle θ in ANS. FIG. P23.72 is found from

$$\theta = \tan^{-1}\left(\frac{15.0}{60.0}\right) = 14.0°$$



ANS. FIG. P23.72

$$F_1 = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(10.0\times10^{-6}\ \text{C})^2}{(0.150\ \text{m})^2}$$
$$= 40.0\ \text{N}$$

$$F_2 = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(10.0\times10^{-6}\ \text{C})^2}{(0.618\ \text{m})^2} = 2.35\ \text{N}$$

$$F_3 = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(10.0\times10^{-6}\ \text{C})^2}{(0.600\ \text{m})^2} = 2.50\ \text{N}$$

$$F_x = -F_3 - F_2\cos 14.0° = -2.50 - 2.35\cos 14.0° = -4.78\ \text{N}$$
$$F_y = -F_1 - F_2\sin 14.0° = -40.0 - 2.35\sin 14.0° = -40.5\ \text{N}$$

(a) $F_{net} = \sqrt{F_x^2 + F_y^2} = \sqrt{(-4.78\ \text{N})^2 + (-40.5\ \text{N})^2} = \boxed{40.8\ \text{N}}$

(b) $\tan\phi = \frac{F_y}{F_x} = \frac{-40.5\ \text{N}}{-4.78\ \text{N}} \rightarrow \phi = \boxed{263°}$

P23.73

Thus the distance to three digits is 0.259 m = $\boxed{2.59\ \text{cm.}}$

P24.13 Consider as a gaussian surface a box with horizontal area A, lying between 500 and 600 m elevation. From Gauss's Law,

$$\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{q}{\epsilon_0}:$$

$$(+120 \text{ N/C})A + (-100 \text{ N/C})A = \frac{\rho A(100 \text{ m})}{\epsilon_0}$$

$$\rho = \frac{(20.0 \text{ N/C})(8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2)}{100 \text{ m}} = \boxed{1.77 \times 10^{-12} \text{ C/m}^3}$$

The charge is $\boxed{\text{positive}}$, to produce the net outward flux of electric field.

P24.14 (a) The total electric flux through the surface of the shell is

$$\Phi_{E,\text{ shell}} = \frac{q_{\text{in}}}{\epsilon_0} = \frac{12.0 \times 10^{-6}}{8.85 \times 10^{-12}} = 1.36 \times 10^6 \text{ N} \cdot \text{m}^2/\text{C}$$
$$= \boxed{1.36 \text{ MN} \cdot \text{m}^2/\text{C}}$$

(b) Through any hemispherical urface of the shell, by symmetry,

$$\Phi_{E,\text{ half shell}} = \frac{1}{2}(1.36 \times 10^6 \text{ N} \cdot \text{m}^2/\text{C}) = 6.78 \times 10^5 \text{ N} \cdot \text{m}^2/\text{C}$$
$$= \boxed{678 \text{ kN} \cdot \text{m}^2/\text{C}}$$

(c) $\boxed{\text{No}}$, the same number of field lines will pass through each surface, no matter how the radius changes.

P24.15 (a) The gaussian surface encloses a charge of +3.00 nC.

$$\Phi_E = \frac{q_{\text{in}}}{\epsilon_0} = \frac{3.00 \times 10^{-9} \text{ C}}{8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2} = 339 \text{ N} \cdot \text{m}^2/\text{C}$$

(b) No. The electric field is not uniform on this surface. Gauss's law is only practical to use when all portions of the surface satisfy one or more of the conditions listed in Section 24.3.

positive on one face and negative on the other.

P24.45 (a) Inside surface: consider a cylindrical gaussian surface of arbitrary length ℓ within the metal. Since E inside the conducting shell is zero, the total charge inside the gaussian surface must be zero:

$$\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{q_{\text{in}}}{\epsilon_0} \quad \rightarrow \quad 0 = \frac{(\lambda + \lambda_{\text{inner}})\ell}{\epsilon_0}$$

so $\lambda_{\text{inner}} = \boxed{-\lambda}$.

(b) Outside surface: consider a cylindrical gaussian surface of arbitrary length ℓ outside the metal. The total charge within the gaussian surface is

$$q_{\text{wire}} + q_{\text{cylinder}} = q_{\text{wire}} + (q_{\text{inner surface}} + q_{\text{outer surface}})$$

$$\lambda\ell + 2\lambda\ell = \lambda\ell + (-\lambda\ell + \lambda_{\text{outer}}\ell) \quad \rightarrow \quad \lambda_{\text{outer}} = \boxed{3\lambda}$$

(c) Gauss's law:

$$\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{q_{\text{in}}}{\epsilon_0}$$

$$E 2\pi r \ell = \frac{3\lambda\ell}{\epsilon_0} \quad \rightarrow \quad E = 2\frac{3\lambda}{4\pi\epsilon_0 r} = \boxed{6k_e\frac{\lambda}{r}, \text{ radially outward}}$$

***P24.47** (a) $\vec{\mathbf{E}} = \boxed{0}$

(b) $$E = \frac{k_e Q}{r^2} = \frac{(8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(8.00 \times 10^{-6} \text{ C})}{(0.030\,0 \text{ m})^2} = 7.99 \times 10^7 \text{ N/C}$$

$$\vec{\mathbf{E}} = \boxed{79.9 \text{ MN/C radially outward}}$$

(c) $\vec{\mathbf{E}} = \boxed{0}$

(d) $$E = \frac{k_e Q}{r^2} = \frac{(8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(4.00 \times 10^{-6} \text{ C})}{(0.070\,0 \text{ m})^2} = 7.34 \times 10^6 \text{ N/C}$$

$$\vec{\mathbf{E}} = \boxed{7.34 \text{ MN/C radially outward}}$$