24.2 $\Phi_E = EA\cos\theta = (2.00\times10^4\ \text{N/C})(18.0\ \text{m}^2)\cos 10.0° = \boxed{355\ \text{kN}\cdot\text{m}^2/\text{C}}$

***24.10** (a) $E = \dfrac{k_e Q}{r^2}$

$$8.90\times10^2 = \frac{(8.99\times10^9)Q}{(0.750)^2},$$ But Q is negative since **E** points inward.

$$Q = -5.56\times10^{-8}\ \text{C} = \boxed{-55.6\ \text{nC}}$$

(b) The $\boxed{\text{negative}}$ charge has a $\boxed{\text{spherically symmetric}}$ charge distribution.

23.42 (a) $|a| = \frac{qE}{m} = \frac{(1.602\times10^{-19})(6.00\times10^{5})}{(1.67\times10^{-27})} = 5.76\times10^{13}\ \text{m/s}$ so $\quad \mathbf{a} = \boxed{-5.76\times10^{13}\,\mathbf{i}\ \text{m/s}^2}$

(b) $v = v_i + 2a(x - x_i)$

$0 = v_i^{\,2} + 2(-5.76\times10^{13})(0.0700) \qquad \boxed{\mathbf{v}_i = 2.84\times10^{6}\,\mathbf{i}\ \text{m/s}}$

(c) $v = v_i + at$

$0 = 2.84\times10^{6} + (-5.76\times10^{13})\,t \qquad t = \boxed{4.93\times10^{-8}\ \text{s}}$

23.48 $a_y = \frac{qE}{m} = \frac{(1.602\times10^{-19})(390)}{(9.11\times10^{-31})} = 6.86\times10^{13}\ \text{m}/\text{s}^2$

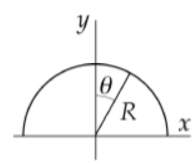
(a) $t = \frac{2v_i\sin\theta}{a_y}$ from projectile motion equations

$t = \frac{2(8.20\times10^{5})\sin 30.0°}{6.86\times10^{13}} = 1.20\times10^{-8}\ \text{s}) = \boxed{12.0\ \text{ns}}$

(b) $h = \frac{v_i^{\,2}\sin^2\theta}{2a_y} = \frac{(8.20\times10^{5})^2\sin^2 30.0°}{2(6.86\times10^{13})} = \boxed{1.23\ \text{mm}}$

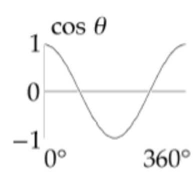
(c) $R = \frac{v_i^{\,2}\sin 2\theta}{2a_y} = \frac{(8.20\times10^{5})^2\sin 60.0°}{2(6.86\times10^{13})} = \boxed{4.24\ \text{mm}}$

23.61 $Q = \int \lambda\, d\ell = \int_{-90.0°}^{90.0°} \lambda_0\cos\theta\, R\,d\theta = \lambda_0 R\sin\theta\Big|_{-90.0°}^{90.0°} = \lambda_0 R\,[1-(-1)] = 2\lambda_0 R$



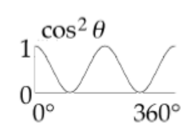
$Q = 12.0\ \mu\text{C} = (2\lambda_0)(0.600)\ \text{m} = 12.0\ \mu\text{C} \qquad$ so $\qquad \lambda_0 = 10.0\ \mu\text{C/m}$

$dF_y = \frac{1}{4\pi\epsilon_0}\left(\frac{(3.00\ \mu\text{C})(\lambda\, d\ell)}{R^2}\right)\cos\theta = \frac{1}{4\pi\epsilon_0}\left(\frac{(3.00\ \mu\text{C})\left(\lambda_0\cos^2\theta R\,d\theta\right)}{R^2}\right)$



$F_y = \int_{-90.0°}^{90.0°}\left(8.99\times10^{9}\ \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}\right)\frac{(3.00\times10^{-6}\ \text{C})(10.0\times10^{-6}\ \text{C/m})}{(0.600\ \text{m})}\cos^2\theta\, d\theta$

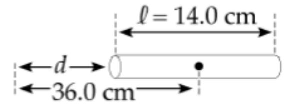
$F_y = \frac{8.99(30.0)}{0.600}\left(10^{-3}\ \text{N}\right)\int_{-\pi/2}^{\pi/2}\left(\tfrac{1}{2}+\tfrac{1}{2}\cos 2\theta\right)d\theta$



$F_y = (0.450\ \text{N})\left(\tfrac{1}{2}\pi + \tfrac{1}{4}\sin 2\theta\Big|_{-\pi/2}^{\pi/2}\right) = \boxed{0.707\ \text{N}}$ Downward.

Since the leftward and rightward forces due to the two halves of the semicircle cancel out, $F_x = 0$.

23.24 $E = \frac{k_e \lambda \ell}{d(\ell + d)} = \frac{k_e (Q/\ell)\ell}{d(\ell + d)} = \frac{k_e Q}{d(\ell + d)} = \frac{(8.99 \times 10^9)(22.0 \times 10^{-6})}{(0.290)(0.140 + 0.290)}$



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

23.28 $E = \frac{k_e Q x}{(x^2 + a^2)^{3/2}}$

For a maximum, $\frac{dE}{dx} = Qk_e \left[\frac{1}{(x^2 + a^2)^{3/2}} - \frac{3x^2}{(x^2 + a^2)^{5/2}} \right] = 0$

$x^2 + a^2 - 3x^2 = 0$ or $x = \frac{a}{\sqrt{2}}$

Substituting into the expression for E gives

$$E = \frac{k_e Q a}{\sqrt{2}\left(\frac{3}{2}a^2\right)^{3/2}} = \frac{k_e Q}{3\frac{\sqrt{3}}{2}a^2} = \boxed{\frac{2k_e Q}{3\sqrt{3}\,a^2}} = \boxed{\frac{Q}{6\sqrt{3}\pi \epsilon_0 a^2}}$$

23.30 (a) From Example 23.9: $E = 2\pi k_e \sigma \left(1 - \frac{x}{\sqrt{x^2 + R^2}}\right)$

$\sigma = \frac{Q}{\pi R^2} = 1.84 \times 10^{-3}\ \mathrm{C/m^2}$

$E = (1.04 \times 10^8\ \mathrm{N/C})(0.900) = 9.36 \times 10^7\ \mathrm{N/C} = \boxed{93.6\ \mathrm{MN/C}}$

appx: $E = 2\pi k_e \sigma = \boxed{104\ \mathrm{MN/C}\ \text{(about 11\% high)}}$

(b) $E = (1.04 \times 10^8\ \mathrm{N/C})\left(1 - \frac{30.0\ \mathrm{cm}}{\sqrt{30.0^2 + 3.00^2}\ \mathrm{cm}}\right) = (1.04 \times 10^8\ \mathrm{N/C})(0.00496) = \boxed{0.516\ \mathrm{MN/C}}$

appx: $E = k_e \frac{Q}{r^2} = (8.99 \times 10^9)\frac{5.20 \times 10^{-6}}{(0.30)^2} = \boxed{0.519\ \mathrm{MN/C}\ \text{(about 0.6\% high)}}$

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

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

23.10 The top charge exerts a force on the negative charge $\frac{k_e qQ}{(d/2)^2 + x^2}$ which is directed upward and to the left, at an angle of $\tan^{-1}(d/2x)$ to the x-axis. The two positive charges together exert force

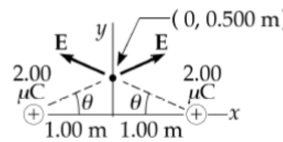
$$\left(\frac{2k_e qQ}{\left(d^2/4 + x^2\right)}\right)\left(\frac{(-x)\mathbf{i}}{\left(d^2/4 + x^2\right)^{1/2}}\right) = m\mathbf{a} \qquad \text{or for } x << d/2, \qquad \mathbf{a} \approx \frac{-2k_e qQ}{md^3/8}\mathbf{x}$$

(a) The acceleration is equal to a negative constant times the excursion from equilibrium, as in $\mathbf{a} = -\omega^2\mathbf{x}$, so we have Simple Harmonic Motion with $\omega^2 = \frac{16k_e qQ}{md^3}$.

$$T = \frac{2\pi}{\omega} = \boxed{\frac{\pi}{2}\sqrt{\frac{md^3}{k_e qQ}}}$$, where m is the mass of the object with charge $-Q$.

(b) $$v_{\max} = \omega A = \boxed{4a\sqrt{\frac{k_e qQ}{md^3}}}$$

23.18 (a) $$E = \frac{k_e q}{r^2} = \frac{(8.99\times10^9)(2.00\times10^{-6})}{(1.12)^2} = 14,400 \text{ N/C}$$



$E_x = 0$ and $E_y = 2(14,400)\sin 26.6° = 1.29\times10^4$ N/C

so $$\boxed{\mathbf{E} = 1.29\times10^4\,\mathbf{j}\text{ N/C}}$$

(b) $$\mathbf{F} = \mathbf{E}q = (1.29\times10^4\,\mathbf{j})(-3.00\times10^{-6}) = \boxed{-3.86\times10^{-2}\,\mathbf{j}\text{ N}}$$