Q23.23 Linear charge density, λ, is charge per unit length. It is used when trying to determine the electric field created by a charged rod.

Surface charge density, σ, is charge per unit area. It is used when determining the electric field above a charged sheet or disk.

Volume charge density, ρ, is charge per unit volume. It is used when determining the electric field due to a uniformly charged sphere made of insulating material.

Q23.28 In special orientations the force between two dipoles can be zero or a force of repulsion. In general each dipole will exert a torque on the other, tending to align its axis with the field created by the first dipole. After this alignment, each dipole exerts a force of attraction on the other.

P23.30 $E = 2\pi k_e \sigma\left(1 - \frac{x}{\sqrt{x^2 + R^2}}\right)$

$$E = 2\pi\left(8.99 \times 10^9\right)\left(7.90 \times 10^{-3}\right)\left(1 - \frac{x}{\sqrt{x^2 + (0.350)^2}}\right) = 4.46 \times 10^8\left(1 - \frac{x}{\sqrt{x^2 + 0.123}}\right)$$

(a) At $x = 0.050\,0$ m, $E = 3.83 \times 10^8$ N/C $=$ $\boxed{383 \text{ MN/C}}$

(b) At $x = 0.100$ m, $E = 3.24 \times 10^8$ N/C $=$ $\boxed{324 \text{ MN/C}}$

(c) At $x = 0.500$ m, $E = 8.07 \times 10^7$ N/C $=$ $\boxed{80.7 \text{ MN/C}}$

(d) At $x = 2.00$ m, $E = 6.68 \times 10^8$ N/C $=$ $\boxed{6.68 \text{ MN/C}}$

P23.33 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, $E_x = 2.16 \times 10^7 \text{ N/C}$.

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

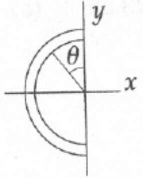

FIG. P23.33

P23.40 (a) $\frac{q_1}{q_2} = \frac{-6}{18} = \boxed{-\frac{1}{3}}$

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

P23.42 $F = qE = ma \qquad a = \dfrac{qE}{m}$

$$v_f = v_i + at \qquad v_f = \frac{qEt}{m}$$

electron: $v_e = \dfrac{(1.602\times10^{-19})(520)(48.0\times10^{-9})}{9.11\times10^{-31}} = \boxed{4.39\times10^{6}\ \text{m/s}}$

in a direction opposite to the field

proton: $v_p = \dfrac{(1.602\times10^{-19})(520)(48.0\times10^{-9})}{1.67\times10^{-27}} = \boxed{2.39\times10^{3}\ \text{m/s}}$

in the same direction as the field

P23.44 (a) $|a| = \frac{qE}{m} = \frac{(1.602\times10^{-19})(6.00\times10^{5})}{(1.67\times10^{-27})} = 5.76\times10^{13}$ m/s so $\mathbf{a} = \boxed{-5.76\times10^{13}\,\hat{\mathbf{i}}\ \text{m/s}^2}$

(b) $v_f = v_i + 2a(x_f - x_i)$

$0 = v_i^2 + 2(-5.76\times10^{13})(0.070\,0)$ $\boxed{\mathbf{v}_i = 2.84\times10^{6}\,\hat{\mathbf{i}}\ \text{m/s}}$

(c) $v_f = v_i + at$

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

P23.49 $v_i = 9.55 \times 10^3 \text{ m/s}$

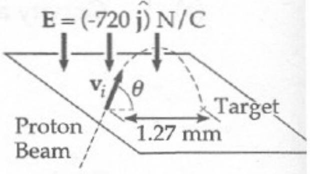

FIG. P23.49

(a) $$a_y = \frac{eE}{m} = \frac{(1.60 \times 10^{-19})(720)}{(1.67 \times 10^{-27})} = 6.90 \times 10^{10} \text{ m/s}^2$$

$$R = \frac{v_i^2 \sin 2\theta}{a_y} = 1.27 \times 10^{-3} \text{ m so that}$$

$$\frac{(9.55 \times 10^3)^2 \sin 2\theta}{6.90 \times 10^{10}} = 1.27 \times 10^{-3}$$

$$\sin 2\theta = 0.961 \qquad \theta = \boxed{36.9°} \qquad 90.0° - \theta = \boxed{53.1°}$$

(b) $$t = \frac{R}{v_{ix}} = \frac{R}{v_i \cos\theta}$$ If $\theta = 36.9°$, $t = \boxed{167 \text{ ns}}$. If $\theta = 53.1°$, $t = \boxed{221 \text{ ns}}$.