P25.3 (a) Energy of the proton-field system is conserved as the proton moves from high to low potential, which can be defined for this problem as moving from 120 V down to 0 V.

$$K_i + U_i = K_f + U_f: \qquad 0 + qV = \frac{1}{2}mv_p^2 + 0$$

$$\left(1.60\times10^{-19}\ \text{C}\right)(120\ \text{V})\left(\frac{1\ \text{J}}{1\ \text{V}\cdot\text{C}}\right) = \frac{1}{2}\left(1.67\times10^{-27}\ \text{kg}\right)v_p^2$$

$$v_p = \boxed{1.52\times10^{5}\ \text{m/s}}$$

(b) The electron will gain speed in moving the other way,

from $V_i = 0$ to $V_f = 120$ V: $K_i + U_i = K_f + U_f$

$$0 + 0 = \frac{1}{2}mv_e^2 + qV$$

$$0 = \frac{1}{2}\left(9.11\times10^{-31}\ \text{kg}\right)v_e^2 + \left(-1.60\times10^{-19}\ \text{C}\right)(120\ \text{J/C})$$

$$v_e = \boxed{6.49\times10^{6}\ \text{m/s}}$$

P25.7 We use the energy version of the isolated system model to equate the energy of the electron-field system when the electron is at $x = 0$ to the energy when the electron is at $x = 2.00$ cm. The unknown will be the difference in potential $V_f - V_i$. Thus, $K_i + U_i = K_f + U_f$ becomes

$$\frac{1}{2}mv_i^2 + qV_i = \frac{1}{2}mv_f^2 + qV_f$$

or
$$\frac{1}{2}m\left(v_i^2 - v_f^2\right) = q\left(V_f - V_i\right),$$

so
$$V_f - V_i = \Delta V = \frac{m\left(v_i^2 - v_f^2\right)}{2q}.$$

(a) Noting that the electron's charge is negative, and evaluating the potential difference, we have

$$\Delta V = \frac{\left(9.11\times10^{-31}\ \text{kg}\right)\left[(3.70\times10^{6}\ \text{m/s})^2 - (1.40\times10^{5}\ \text{m/s})^2\right]}{2\left(-1.60\times10^{-19}\ \text{C}\right)}$$

$$= \boxed{-38.9\ \text{V}}$$

(b) The negative sign means that the 2.00-cm location is lower in potential than the origin:

$$\boxed{\text{The origin is at the higher potential.}}$$

P25.14 The potential due to the two charges is given by $V = k_e \sum_i \frac{q_i}{r_i}$.

(a) The electric potential at point A is

$$V = k_e \sum_i \frac{q_i}{r_i} = \left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)$$

$$\times \left(\frac{-15.0 \times 10^{-9} \text{ C}}{2.00 \times 10^{-2} \text{ m}} + \frac{27.0 \times 10^{-9} \text{ C}}{2.00 \times 10^{-2} \text{ m}} \right)$$

$$= \boxed{5.39 \text{ kV}}$$

(b) The electric potential at point B is

$$V = k_e \sum_i \frac{q_i}{r_i} = \left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)$$

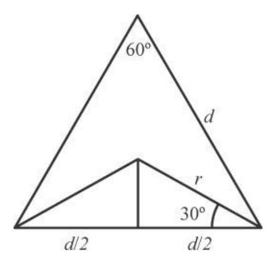
$$\times \left(\frac{-15.0 \times 10^{-9} \text{ C}}{1.00 \times 10^{-2} \text{ m}} + \frac{27.0 \times 10^{-9} \text{ C}}{1.00 \times 10^{-2} \text{ m}} \right)$$

$$= \boxed{10.8 \text{ kV}}$$

P25.15 By symmetry, a line from the center to each vertex forms a 30° angle with each side of the triangle. The figure shows the relationship between the length d of a side of the equilateral triangle and the distance r from a vertex to the center:

$$r \cos 30.0° = d/2$$

$$\rightarrow r = d/(2 \cos 30.0°)$$



ANS. FIG. P25.15

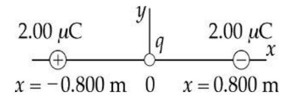
The electric potential at the center is

$$V = k_e \sum_i \frac{q_i}{r_i}$$

$$= k_e \left(\frac{Q}{d/(2 \cos 30.0°)} + \frac{Q}{d/(2 \cos 30.0°)} + \frac{2Q}{d/(2 \cos 30.0°)} \right)$$

$$V = (4)\left(2 \cos 30.0° \, k_e \frac{Q}{d} \right) = \boxed{6.93 k_e \frac{Q}{d}}$$

P25.19 (a) Since the charges are equal and placed symmetrically, $\boxed{F = 0}$.



ANS. FIG. P25.19

(b) Since $F = qE = 0$, $\boxed{E = 0}$.

(c) $V = 2k_e \dfrac{q}{r}$

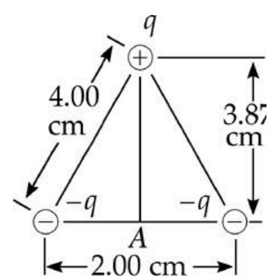
$$= 2\left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(\frac{2.00\times10^{-6}\ \text{C}}{0.800\ \text{m}}\right)$$

$$V = 4.50\times10^4\ \text{V} = \boxed{45.0\ \text{kV}}$$

P25.22 The charges at the base vertices are $d/2 = 0.010\,0$ m from point A, and the charge at the top vertex is

$$\sqrt{(2d)^2 - \left(\frac{d}{2}\right)^2} = \frac{\sqrt{15}}{2}d$$

from point A.



ANS. FIG. P25.22

$$V = \sum_i k_e \frac{q_i}{r_i}$$

$$= k_e\left(\frac{-q}{d/2} + \frac{-q}{d/2} + \frac{q}{d\sqrt{15}/2}\right) = k_e \frac{q}{d}\left(-4 + \frac{2}{\sqrt{15}}\right)$$

$$V = \left(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(\frac{7.00\times10^{-6}\ \text{C}}{0.020\,0\ \text{m}}\right)\left(-4 + \frac{2}{\sqrt{15}}\right)$$

$$= \boxed{-1.10\times10^7\ \text{V}}$$

P25.39 (a) $V = 5x - 3x^2y + 2yz^2$, where x, y and z are in meters and V is in volts.

$$E_x = -\frac{\partial V}{\partial x} = -5 + 6xy$$

$$E_y = -\frac{\partial V}{\partial y} = +3x^2 - 2z^2$$

$$E_z = -\frac{\partial V}{\partial z} = -4yz$$

which gives

$$\boxed{\vec{\mathbf{E}} = (-5 + 6xy)\hat{\mathbf{i}} + \left(3x^2 - 2z^2\right)\hat{\mathbf{j}} - 4yz\hat{\mathbf{k}}}$$

(b) Evaluate E at (1.00, 0, −2.00) m, suppressing units,

$$E_x = -5 + 6(1.00)(0) = -5.00$$
$$E_y = 3(1.00)^2 - 2(-2.00)^2 = -5.00$$
$$E_z = -4(0)(-2.00) = 0$$

which gives

$$E = \sqrt{E_x^2 + E_y^2 + E_z^2} = \sqrt{(-5.00)^2 + (-5.00)^2 + 0^2} = \boxed{7.07\ \text{N/C}}$$

P25.41 (a) For $r < R$, $V = \dfrac{k_e Q}{R}$

$$E_r = -\frac{dV}{dr} = \boxed{0}$$

(b) For $r \geq R$, $V = \dfrac{k_e Q}{r}$

$$E_r = -\frac{dV}{dr} = -\left(-\frac{k_e Q}{r^2}\right) = \boxed{\frac{k_e Q}{r^2}}$$

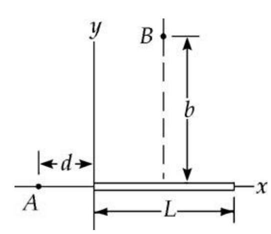
P25.44 $V = \displaystyle\int dV = \frac{1}{4\pi \in_0}\int \frac{dq}{r}$

All bits of charge are at the same distance from O. So

$$V = \frac{1}{4\pi \in_0}\left(\frac{Q}{R}\right) = \left(8.99 \times 10^9\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(\frac{-7.50 \times 10^{-6}\ \text{C}}{0.140\ \text{m}/\pi}\right)$$
$$= \boxed{-1.51\ \text{MV}}$$

P25.45 (a) As a linear charge density, l has units of C/m. So $\alpha = \lambda/x$ must have units of C/m²:

$$[\alpha] = \left[\frac{\lambda}{x}\right] = \frac{\text{C}}{\text{m}}\cdot\left(\frac{1}{\text{m}}\right) = \boxed{\frac{\text{C}}{\text{m}^2}}$$



ANS. FIG. P25.45

(b) Consider a small segment of the rod at location x and of length dx. The amount of charge on it is $\lambda\, dx = (\alpha x)\, dx$. Its distance from A is $d + x$, so its contribution to the electric potential at A is

$$dV = k_e \frac{dq}{r} = k_e \frac{\alpha x\, dx}{d + x}$$

Relative to $V = 0$ infinitely far away, to find the potential at A we must integrate these contributions for the whole rod, from $x = 0$ to $x = L$. Then

$$V = \int_{\text{all } q} dV = \int_0^L \frac{k_e \alpha x}{d + x}\, dx.$$

To perform the integral, make a change of variables to

$u = d + x$, $du = dx$, $u(\text{at } x = 0) = d$, and $u(\text{at } x = L) = d + L$:

$$V = \int_d^{d+L} \frac{k_e \alpha (u - d)}{u}\, du = k_e \alpha \int_d^{d+L} du - k_e \alpha d \int_d^{d+L} \left(\frac{1}{u}\right) du$$

$$V = k_e \alpha u \Big|_d^{d+L} - k_e \alpha d \ln\, u \Big|_d^{d+L}$$

$$= k_e \alpha (d + L - d) - k_e \alpha d \left[\ln(d + L) - \ln\, d\right]$$

$$V = \boxed{k_e \alpha \left[L - d \ln\left(1 + \frac{L}{d}\right)\right]}$$

P25.47 $$V = k_e \int_{\text{all charge}} \frac{dq}{r} = k_e \int_{-3R}^{-R} \frac{\lambda dx}{-x} + k_e \int_{\text{semicircle}} \frac{\lambda ds}{R} + k_e \int_R^{3R} \frac{\lambda dx}{x}$$

$$V = -k_e \lambda \ln(-x)\Big|_{-3R}^{-R} + \frac{k_e \lambda}{R} \pi R + k_e \lambda \ln x \Big|_R^{3R}$$

$$V = k_e \lambda \ln \frac{3R}{R} + k_e \lambda \pi + k_e \lambda \ln 3 = \boxed{k_e \lambda (\pi + 2 \ln 3)}$$

P25.50 For points on the surface and outside, the sphere of charge behaves like a charged particle at its center, both for creating field and potential.

(a) Inside a conductor when charges are not moving, the electric field is zero and the potential is uniform, the same as on the surface, and $E = \boxed{0}$.

$$V = \frac{k_e q}{R} = \frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(26.0 \times 10^{-6} \text{ C}\right)}{0.140 \text{ m}} = \boxed{1.67 \text{ MV}}$$

(b) $$E = \frac{k_e q}{r^2} = \frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(26.0 \times 10^{-6} \text{ C}\right)}{(0.200 \text{ m})^2}$$

$$= \boxed{5.84 \text{ MN/C}} \text{ away}$$

$$V = \frac{k_e q}{R} = \frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right)\left(26.0 \times 10^{-6} \text{ C}\right)}{0.200 \text{ m}} = \boxed{1.17 \text{ MV}}$$

(c) $E = \dfrac{k_e q}{R^2} = \dfrac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2\right)\left(26.0 \times 10^{-6} \text{ C}\right)}{(0.140 \text{ m})^2}$

$= \boxed{11.9 \text{ MN/C}}$ away

$V = \dfrac{k_e q}{R} = \boxed{1.67 \text{ MV}}$

P25.62 $W = \int_0^Q V dq$, where $V = \dfrac{k_e q}{R}$. Therefore, $W = \boxed{\dfrac{k_e Q^2}{2R}}$.

P25.65 In Equation 25.3, $V_2 - V_1 = \Delta V = -\int_1^2 \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}}$, think about stepping from distance r_1 out to the larger distance r_2 away from the charged line. Then $d\vec{\mathbf{s}} = dr\hat{\mathbf{r}}$, and we can make r the variable of integration:

$$V_2 - V_1 = -\int_{r_1}^{r_2} \frac{\lambda}{2\pi \in_0 r} \hat{\mathbf{r}} \cdot dr\, \hat{\mathbf{r}} \quad \text{with} \quad \hat{\mathbf{r}} \cdot \hat{\mathbf{r}} = 1 \cdot 1 \cos 0^\circ = 1$$

The potential difference is

$$V_2 - V_1 = -\frac{\lambda}{2\pi \in_0} \int_{r_1}^{r_2} \frac{dr}{r} = -\frac{\lambda}{2\pi \in_0} \ln r \Big|_{r_1}^{r_2}$$

and $$V_2 - V_1 = -\frac{\lambda}{2\pi \in_0}\left(\ln r_2 - \ln r_1\right) = \boxed{-\frac{\lambda}{2\pi \in_0} \ln \frac{r_2}{r_1}}$$