23.4a) \( V_i = \frac{k \cdot 9.1 \cdot 8.2}{r_{i2}} \)  \( V_f = \frac{k \cdot 8.1 \cdot 8.2}{r_{i2f}} \)

\[ W_{i\rightarrow f} = V_i - V_f = k \cdot 9.1 \cdot 8.2 \left( \frac{1}{r_i} - \frac{1}{r_f} \right) = (9 \times 10^9) (1.6 \times 10^{-9})^2 \left( \frac{1}{2 \times 10^{-10}} - \frac{1}{3 \times 10^{-10}} \right) \]

\( W_{i\rightarrow f} = -7.68 \times 10^{-14} \text{ J} \)

This is the work done by the electric force. Work by external agent is therefore +7.68 \times 10^{-14} \text{ J}

b) \( A U < K_1 + K_2 \approx 2K \) (equal masses so same K)

\[ K_2 \quad \frac{1}{2} \frac{dU}{dz} = \frac{1}{2} \frac{dU}{m} \]

\[ v = \sqrt{\frac{dU}{m}} = 6.78 \times 10^6 \text{ m/s} \]

23.5 a) \[ \quad \]

\[ \begin{align*}
\frac{1}{2} m V_f^2 &= \frac{1}{2} m V_i^2 + k \cdot 9.1 \cdot 8.2 \left( \frac{1}{r_i} - \frac{1}{r_f} \right) \\
V_f^2 &= V_i^2 + 2 \cdot k \cdot 9.1 \cdot 8.2 \left( \frac{1}{r_i} - \frac{1}{r_f} \right)
\end{align*} \]

\[ V_f = \sqrt{(22)^2 + 2(9 \times 10^9)(2.8 \times 10^{-9})(7.8 \times 10^{-9}) (\frac{1}{0.8} - \frac{1}{0.4})} \]

\[ V_f = 12.5 \text{ m/s} \]

b) When \( V_f = 0 \)

From above \( \frac{k \cdot 9.1 \cdot 8.2}{r_f} = \frac{1}{2} m V_f^2 + k \cdot 9.1 \cdot 8.2 \left( \frac{1}{r_i} - \frac{1}{r_f} \right) \)

\[ r_f = \frac{k \cdot 9.1 \cdot 8.2}{\left( \frac{1}{2} m V_f^2 + k \cdot 9.1 \cdot 8.2 \left( \frac{1}{r_i} - \frac{1}{r_f} \right) \right) = 0.32 \text{ m} } \]
\[ U = \frac{9 \times 10^9 (4 \times 10^{-9}) (2 \times 10^{-9})}{0.1} + \frac{9 \times 10^9 (2 \times 10^{-9}) (3 \times 10^{-9})}{0.2} + \frac{9 \times 10^9 (2 \times 10^{-9}) (-3 \times 10^{-9})}{0.1} \]

\[ U \approx 3.6 \times 10^{-7} \, \text{J} \]

b) \[ U = \frac{9 \times 10^9 r_1}{0.2} + \frac{9 \times 10^9 r_3}{0.2 - r_{13}} + \frac{9 \times 10^9 r_2}{r_{13}} = 0 \]

\[ \frac{-12 \times 10^{-8}}{0.2} + \frac{8 \times 10^{-8}}{r_{13}} = 0 \]

\[ -60 + \frac{8}{r_{13}} - \frac{6}{0.2 - r_{13}} = 0 \]

\[ -60 \left( r_{13} (0.2 - r_{13}) + 8 (0.2 - r_{13}) - 6 r_{13} \right) r_{13} (0.2 - r_{13}) = 0 \]

Therefore,

\[ -60 (0.2 r_{13} - r_{13}^2) + 1.6 - 8 r_{13} - 6 r_{13} = 0 \]

\[ 60 r_{13}^2 - 26 r_{13} + 1.6 = 0 \]

\[ r_{13} = \frac{26 \pm \sqrt{26^2 - 4 \times 240 \times 1.6}}{120} = \frac{26 \pm 17.1}{120} \]

\[ r_{13} = 0.36 \, \text{m} \, \text{or} \, r_{13} = 7.42 \, \text{cm} \]

not between 0 - 20 cm so \[ r_{13} = 7.42 \, \text{cm} \] is correct
b) For $x > a$ 
\[ V = \frac{kq}{x} - \frac{2kq}{x-a} = kq \left[ \frac{1}{x} - \frac{2}{x-a} \right] \]

\[ V = \frac{kq}{x} \left[ \frac{x-a-2x}{x(x-a)} \right] = -\frac{kq}{x} \frac{(x+a)}{x(x-a)} \]

For $0 < x < a$ 
\[ V = \frac{kq}{a-x} - \frac{2kq}{x-a} = kq \left[ \frac{a-x-2x}{x(a-x)} \right] \]

\[ V = \frac{kq}{a} \left[ \frac{(a-3x)}{x(a-x)} \right] \]

For $x < 0$ 
\[ V = -\frac{kq}{x} - \frac{2kq}{x+a} = -kq \left[ \frac{1}{x} + \frac{2}{x+a} \right] \]

\[ V = -\frac{kq}{x} \left[ \frac{(x+a)+2x}{x(x+a)} \right] = +\frac{kq}{x} \frac{x+a}{x(x+a)} \]

or more generally 
\[ V = \frac{kq}{x} - \frac{kq}{x-a} \]

c) \[ V = 0 \]

For $x > 0$ 
\[ \lambda = -q \text{ not possible} \]

For $0 < x < a$ 
\[ x = \frac{a}{3} \text{ OK} \]

For $x < a$ 
\[ x = -a \text{ OK} \]

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23.28 \[ \frac{r}{q} \]

\[ V = \frac{kq}{r} \]

\[ E = \frac{kq}{r^2} \]

a) \[ E/V = \frac{1}{r} \Rightarrow V/\frac{E}{r} = 4.98/12 = 0.42 \text{ m} \]

b) \[ V = \frac{kq}{r} \Rightarrow q = Vr/k = 2.30 \times 10^{-10} \text{ C} \]

c) Since $V > 0$, $q > 0$ so $E$ away from $q$. 

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[Note: The handwritten content is not clearly legible in all parts, especially in the lower section of the page. The interpretation is based on the visible and legible parts.]
e) \[ V = \frac{kq}{x} - \frac{2kq}{|x-a|} \xrightarrow{x \to \infty} -\frac{kq}{x} \] which is potential for a pt. charge \(-q\) at the origin.
1. An electron is released from rest in a uniform electric field. The electron then moves under the influence of the electric field. Which of the following is true for the electron?
   [A] Its potential energy increases and it moves toward higher electric potential,
   [B] Its potential energy decreases and it moves toward higher electric potential,
   [C] Its potential energy increases and it moves toward lower electric potential,
   [D] Its potential energy decreases and it moves toward lower electric potential.

2. A uniformly charged insulating sphere of radius \( R = 1.00 \text{ m} \) and total charge \( Q = 4.60 \mu \text{C} \) is held centered at the origin. A point charge \( q = 1.20 \mu \text{C} \) with mass \( 2.80 \times 10^{-3} \text{ kg} \) is placed on the \( x \)-axis a distance of 2.00 m from the origin.

   a) What is the electric potential energy of the system?

   \[
   U = \frac{kqQ}{r} = \frac{(9 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(4.6 \times 10^{-6} \text{ C})(1.2 \times 10^{-6} \text{ C})}{2} \\
   U = 2.48 \times 10^{-2} \text{ J}
   \]

   b) If the point charge \( q \) is released from rest what is its speed when it is a distance of 50.0 m from the origin?

   \[
   \Delta K = -\Delta U \\
   \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 = -(\frac{kqQ}{r_f} - \frac{kqQ}{r_i}) = kQq \left( \frac{1}{r_i} - \frac{1}{r_f} \right)
   \]

   \[
   v_f^2 = \frac{2kQq}{m} \left( \frac{1}{r_i} - \frac{1}{r_f} \right)
   \]

   \[
   v_f = \sqrt{\frac{2kQq}{m} \left( \frac{1}{r_i} - \frac{1}{r_f} \right)}
   \]

   \[
   v_f = 13.1 \text{ m/s}
   \]