Assuming energy is conserved, we have:

\[(K+U)_i = (K+U)_f\]  
Since they are "far apart" initially, \(U_i = 0\). \(K_i = K_{\text{He}}\) since \(K_{\text{Au}} = 0\) (initially). The point of closest approach is given by: \(U_f = \frac{K_{\text{He}}q_2}{r_{\text{min}}}\). Finally, \(K_f\) is determined by the conservation of momentum.

Let \(m\) be the helium mass and \(M\) be the Au mass: \(m v_{\text{He}}^2 = (m+M) v_f^2\) so we have:

\[\frac{1}{2} m v_{\text{He}}^2 = \frac{1}{2} (m+M) v_f^2 + \frac{k q_{\text{He}} q_{\text{Au}}}{r}\]

\[\frac{1}{2} m v_{\text{He}}^2 = \frac{1}{2} (m+M) \left(\frac{m}{m+M}\right)^2 v_{\text{He}}^2 + \frac{k q_{\text{He}} q_{\text{Au}}}{r}\]

\[\frac{1}{2} m v_{\text{He}}^2 \left[1 - \frac{m}{m+M}\right] = \frac{k q_{\text{He}} q_{\text{Au}}}{r}\]
\[
\frac{17.50 \text{ cm}^1}{\frac{1}{2} \mu_{\text{He}}^2 \left[ \frac{M}{m+M} \right]} = \frac{\frac{q_{\text{He}} q_{\text{Av}}}{r}}{r}
\]

So \( r = \frac{k q_{\text{He}} q_{\text{Av}}}{K_{\text{He}} \left[ \frac{1}{1 + \frac{m}{M}} \right]} \)

\[
= \frac{(9.10^7 \text{ keV} \text{ m}^2)}{2} \left( \frac{2}{1} \right) (1.6 \times 10^{-19} \text{ C})^2 \left[ \frac{1}{1 + \frac{m}{M}} \right]
\]

\[
= \frac{3.2 \times 10^{-26}}{7.54 \times 10^{-3}} \left[ 0.98 \right] \text{ m}
\]

\[
= 4.9 \times 10^{-14} \text{ m} \approx 50 \text{ fm}
\]

**NOTE:** Their assumption that the Au nucleus is fixed amounts to assuming that \( \frac{m}{M} \approx 0 \). How much difference does it make to assume this? [ANS: 2%]

These are two extremes of the possible
17.50 cm$^{-1}$ case: The Au recoils independent of its neighbors or the entire Au foil recoils as one. Can you think of a way to see which is more like reality?

**ANS:** I can think of a couple of ways and there are probably more I haven't thought of... here's one.

Let's estimate how long the He$^+$ Au interact and how far the Au moves in that time, assuming the Au is alone.

The He slows in distance about equal to the radius of the Au atom - once it penetrates the electrons around Au.

This distance is $\approx 10^{-10}$ m. So the time is $st = \frac{4x}{c} \approx \frac{10^{-10}}{1.5 \times 10^7 \text{m/s}} \approx 10^{-17}$ s!

the Au moves (at most) at the U$_{com}$, so $v_{Au} = \frac{m}{m + M} v_{He} \approx 3 \times 10^5$ m/s
\[ 17.50\text{cm}^{-1} \text{ so the Au moves: } \Delta x = v \Delta t \]
\[ = (3 \times 10^5 \text{ cm/s})(10^{-7} \text{ s}) = 3 \times 10^{-12} \text{ m} \]

This is much less than the Au bond length.

\[ \text{The size of the Au nucleus is: } R \approx 1.2 \text{ fm}, \]
\[ (197)^{1/3} \approx 7 \text{ fm}. \]

So the Au moves much more than its size, but much less than its distance from its neighbors.

So I think it's not CLEARLY in either case (stationary or freely moving). At least by this calculation,

• Look up Red Rover on Wikipedia
\[ 17.64 \quad |E| = \frac{\Delta V}{\Delta x}, \text{ so } \Delta x = \frac{\Delta V}{|E|} \]

\[ = \frac{1.5 \times 10^4}{10^{-6} \text{ N/m}} = 1.5 \times 10^6 \text{ m} \]

\[ = 1500 \text{ km} \approx 1000 \text{ mi} \]

17.74 I assume all the dielectric sheets are \( \geq 120 \text{ cm}^2 \) in area. The \( C \) is then:

\[ C = \frac{x\varepsilon_0 A}{d} = \frac{k}{d}(\varepsilon_0 A) \]

\[ = \frac{k}{d}(8.85 \times 10^{-12} \frac{\text{C}^2}{\text{Nm}^2})(120 \times 10^{-4} \text{ m}^2) \]

\[ = \frac{k}{d}(10^{-13} \frac{\text{C}}{\text{V}_m}) \]

So we're interested in the largest \( \frac{k}{d} \) smallest ratio \( \rho \frac{k}{d} \).
17.74 cm$^2$

Paper: \( \frac{3.5}{10^{-4} \text{m}} = 3.5 \times 10^4 \text{ m} \) - LARGEST

Glass: \( \frac{7}{2 \times 10^{-3} \text{m}} = 3.5 \times 10^3 \text{ m} \)

Paraffin: \( \frac{2}{10^2 \text{m}} = 2 \times 10^{-2} \text{ m} \) - SMALLEST

\[ C_{\text{LARGE}} = (3.5 \times 10^4 \text{ m})(10^{13} \frac{\text{C}}{\sqrt{\text{m}}}) \]
\[ = 3.5 \times 10^{-7} \text{ F} = 3.5 \text{ nF} \]

\[ C_{\text{SMALL}} = (2 \times 10^{-2} \text{ m})(10^{13} \frac{\text{C}}{\sqrt{\text{m}}}) \]
\[ = 2 \times 10^{-11} \frac{\text{C}}{\text{V}} \]
\[ = 20 \text{ pF} \]
17.88 \text{ J} \quad u = \frac{1}{2} cy^2 \quad \sigma \\
\sigma 
\begin{align*}
V &= \sqrt{\frac{2(300 \text{ J})}{9 \times 10^{-6} \text{ C}}} = \sqrt{6.67 \times 10^7 \frac{\text{J} \cdot \text{C}}{\text{C}}} \\
&= 8165 \text{ V} = 8 \text{ kV} \\
\text{How much charge is delivered?} \\
\text{(ANS: 0.07 C)}
\end{align*}
17.94a) From Table 17.1, \( E = 4 \frac{kV}{mm} = \frac{4V}{ax} \)

So \( \Delta x \geq \frac{5V}{4 \times 10^{-3} V} = 1.25 \times 10^{-6} m \)

b) \( C = \frac{\varepsilon_0 A}{d} \Rightarrow A = \frac{Cd}{\varepsilon_0} \)

\[
A \geq \frac{(1F)(1.25 \times 10^{-6} m)}{(90)(8.85 \times 10^{-12} F/m)}
\]

\[
= 1570 \text{ m}^2
\]

\[= (40 \text{ m})^2 \]

Inside: There's a 1F cap in PH 116 - ask your lab teacher to look at it, don't play with it!