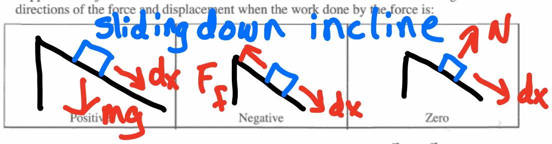
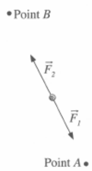
I. **Review of work**

A. Suppose an object moves under the influence of a force. Sketch arrows showing the relative directions of the force and displacement when the work done by the force is:



B. An object travels from point A to point B while two constant forces, $\vec{F}_1$ and $\vec{F}_2$, of equal magnitude are exerted on it.



1. Is the total work done on the object by $\vec{F}_1$ *positive*, *negative*, or *zero*?

   $W_1 < 0$

2. Is the total work done on the object by $\vec{F}_2$ *positive*, *negative*, or *zero*?

   $W_2 > 0$

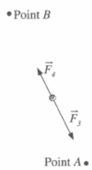
3. Is the net work done on the object *positive*, *negative*, or *zero*? Explain.

   $W_{net} = 0$

4. Is the speed of the object at point B *greater than*, *less than*, or *equal to* the speed of the object at point A? Explain how you can tell.

   $|V_B| = |V_A|$

C. An object travels from point A to point B while two constant forces, $\vec{F}_3$ and $\vec{F}_4$, of *unequal* magnitude are exerted on it as shown.



1. Is the total work done on the object by $\vec{F}_3$ *positive*, *negative*, or *zero*?

   $W_3 < 0$

2. Is the total work done on the object by $\vec{F}_4$ *positive*, *negative*, or *zero*?

   $W_4 > 0$

3. Is the net work done on the object *positive*, *negative*, or *zero*? Explain.

   $W_{net} < 0$

4. Is the speed of the object at point B *greater than*, *less than*, or *equal to* the speed of the object at point A? Explain how you can tell.

   $|V_B| < |V_A|$

remember $dW = \vec{F} \cdot d\vec{x}$

$|W_1| = |W_2| \Rightarrow W_{net} = 0$

Calculation example of $V = kq/r$ using PheT simulation

$q_1 = -1\,nC$ $\quad$ $q_2 = +1\,nC$ $\quad$ $q_3 = +1\,nC$

$r_1 = 1.0\,m$ $\quad$ $r_2 = 1.5\,m$ $\quad$ $r_3 = 2.5\,m$

$$V_{total} = V_1 + V_2 + V_3 = k\left(\frac{-1\,nC}{1.0\,m} + \frac{1\,nC}{1.5\,m} + \frac{1\,nC}{2.5\,m}\right) = 0.6\ V \checkmark$$

Finishing the example from Monday

b) $V_b - V_a = -(V_a - V_b) = -\int_a^b \vec{E} \cdot d\vec{l} = -E\Delta x = -120V$

That's the change in potential, not potential energy

$$\Delta U = \Delta V q \Rightarrow U_b - U_a = (V_b - V_a) q = (-120V)(1.6 \cdot 10^{-19} C) = -1.92 \cdot 10^{-17} J$$

c) $V_i = 0$ $\quad V_f = ?$ $\quad \Delta K + \Delta U = 0$

cons. of energy!

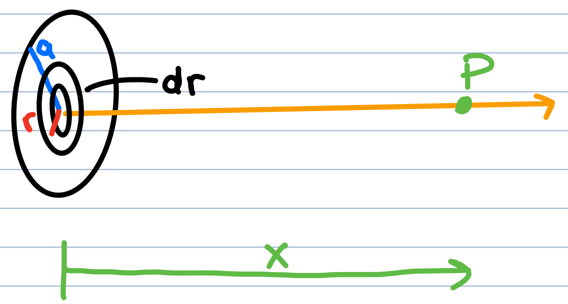
$\Delta K = -\Delta U$

$\rightarrow \frac{1}{2} m_p v_f^2 - \frac{1}{2} m_p v_i^2 = 1.92 \cdot 10^{-17}\ \text{J} \Rightarrow v_f = 152\ \text{km/s}$

Task: Go to PhET sim "charges and fields", make two parallel horizontal lines of charge (one +, one -). Explore the "lines of equipotential"

example The potential due to a uniformly-charged disk

σ charge density



$dU = \frac{k\,dq}{\text{distance}}$

$\text{distance} = \sqrt{r^2+x^2}$ $\quad dq = \sigma\, dA$
$= \sigma 2\pi r\, dr$

$$V = \int_{r=0}^{r=a} dV = \pi k \sigma \int_0^a \frac{2r\,dr}{\sqrt{r^2+x^2}} = \frac{\pi k \sigma}{1/2}\left[(a^2+x^2)^{1/2} - (0^2+x^2)^{1/2}\right]$$
$$= 2\pi k \sigma\left[\sqrt{a^2+x^2} - x\right]$$

Is this sensible? Take limiting case

$$V = 2\pi k \sigma x\left[\left(\left(\frac{a}{x}\right)^2+1\right)^{1/2} - 1\right] \xrightarrow[\frac{a}{x} \ll 1]{} 2\pi k \sigma x\left[1 + \frac{1}{2}\left(\frac{a}{x}\right)^2 + 1\right]$$

recall Taylor expansion $\quad f(y)_{@0} \approx f(0) + f'(0)(y-0)$

$\rightarrow f(y) = (1+y)^n \quad f'(y) = n(1+y)^{n-1}$

$\rightarrow f(y)_{@0} \approx 1 + ny$

$\rightarrow V = \frac{k\pi a^2 \sigma}{x} = \frac{kQ}{x}$ ✓