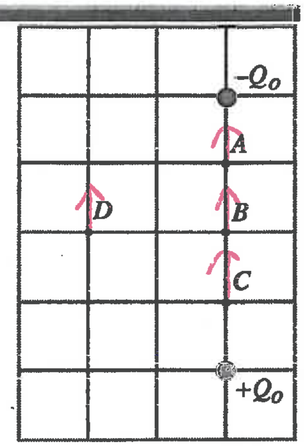
Pretest: Electric potential difference

Name ____________________

Two charges $+Q_o$ and $-Q_o$ are fixed in place at the positions shown. Four points *A*, *B*, *C*, and *D* are labeled on the diagram.



1. Sketch arrows on the diagram to indicate the direction of the electric field, if any, at each of the points *A*, *B*, *C*, and *D*.

2. A positively charged test particle is observed to move as described below. For each motion, tell whether the work done ***by the electric field*** is *positive*, *negative*, or *zero*. Explain your reasoning in each case.

   - the test charge moves from point *B* to point *A*

positive

$$W_{B\to A} = \int_B^A \vec{E}\cdot d\vec{l} = \int_B^A E\,dl\cos\theta \;\; ; \;\; \cos\theta = 1$$

   - the test charge moves from point *B* to point *C*

negative $\cos\theta = -1$

   - the test charge moves from point *B* to point *D*

zero $\cos\theta = 0$

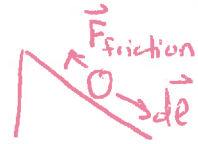
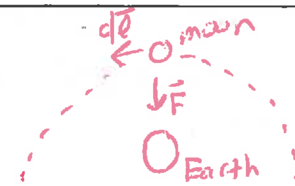
3. Rank, from highest to lowest, the electric potentials at points *A*, *B*, *C*, and *D*. Explain.

$V_C > V_B > V_A$, $V_B = V_D$

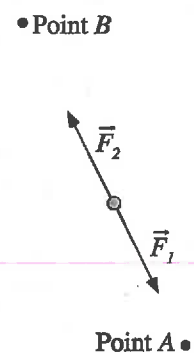
Note: just b/c $V_B = 0$ doesn't mean $E_B = 0$. similar to a ball half way down the slope of a ramp has $U = mgh = 0$ if we define $h = 0$ at that point.

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:

		
Positive	Negative	Zero

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?*

   $W_2 > 0$

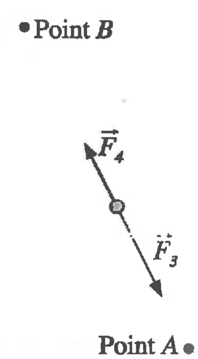
3. Is the net work done on the object *positive, negative,* or *zero?* Explain.

   $W_{net} = 0$

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.

   $|v_B| = |v_A|$ since $W_{net} = 0 \Rightarrow \Delta K = 0$

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.

   $W_{net} < 0$ since $|F_3| > |F_4|$

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.

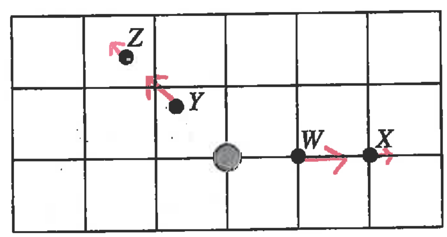
   $|v_B| < |v_A|$ $W_{net} < 0 \Rightarrow \Delta K < 0$

D. State the work-energy theorem in your own words. Are your answers in part B consistent with this theorem? Explain.

Are your answers in part C consistent with the work-energy theorem? Explain.

II. Work and electric fields

The diagram at right shows a top view of a positively charged rod. Points *W*, *X*, *Y*, and *Z* lie in a plane near the center of the rod. Points *W* and *Y* are equidistant from the rod, as are points *X* and *Z*.



A. Draw electric field vectors at points *W*, *X*, *Y*, and *Z*.

B. A particle with charge $+q_o$ travels along a straight line path from point *W* to point *X*.

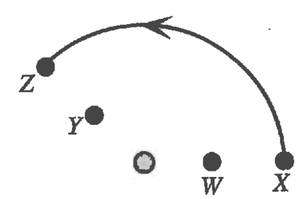
Is the work done *by the electric field* on the particle *positive, negative,* or *zero?* Explain using a sketch that shows the electric force on the particle and the displacement of the particle.

$W_{W\to X} > 0$

Compare the work done by the electric field when the particle travels from point *W* to point *X* to that done when the particle travels from point *X* to point *W*.

$W_{X\to W} = -W_{W\to X}$

C. The particle travels from point *X* to point *Z* along the circular arc shown.



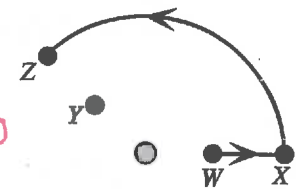
1. Is the work done *by the electric field* on the particle *positive, negative,* or *zero?* Explain. (*Hint:* Sketch the direction of the force on the particle and the direction of the displacement for several short intervals during the motion.)

$W_{net} = 0$ since $\vec{dl} \perp \vec{E}$ always

Alternatively, we know $W_{X\to W} + W_{W\to rod} = -(W_{rod\to Y} + W_{Y\to}$

and work $X\to Z$ is same independent of path

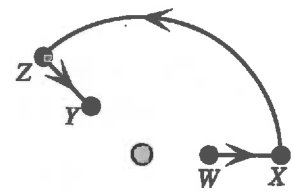
2. Compare the work done by the electric field when the particle travels from point *W* to point *X* to that done when the particle travels from point *W* to point *Z* along the path shown. Explain.



$W_{W\to X} = W_{W\to Z}$ since $W_{X\to Z} = 0$

D. Suppose the particle travels from point *W* to point *Y* along the path *WXZY* as shown.

1. Compare the work done by the electric field when the particle travels from point *W* to point *X* to that done when the particle travels from point *Z* to point *Y*. Explain.

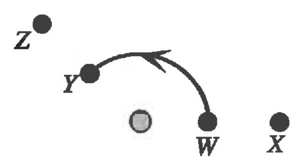


$W_{W\to X} = -W_{Z\to Y}$

What is the total work done on the particle by the electric field as it moves along the path *WXZY*?

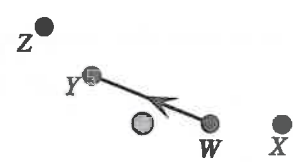
$W_{W\to X\to Z\to Y} = 0$

2. Suppose the particle travels from *W* to *Y* along the arc shown. Is the work done on the particle by the electric field *positive*, *negative*, or *zero?* Explain using force and displacement vectors.



$W_{W\to Y} = 0$ $(\cos\theta = 0)$

3. Suppose the particle travels along the straight path *WY*. Is the work done on the particle by the electric field *positive, negative,* or *zero?* Explain using force and displacement vectors. (*Hint:* Compare the work done along the first half of the path to the work done along the second half.)



$W_{W\to Y} = 0$ since work is path-independent for a conservative force

See Figure 7.18 and discussion on p. 217

E. Compare the work done as the particle travels from point *W* to point *Y* along the three different paths in part D.

It is often said that the work done by a static electric field is *path independent*. Explain how your results in part D are consistent with this statement.

III. Electric potential difference

A. Suppose the charge of the particle in section II is increased from $+q_o$ to $+1.7q_o$.

1. Is the work done by the electric field as the particle travels from *W* to *X* *greater than, less than,* or *equal to* the work done by the electric field on the original particle? Explain.

   $W = \int \vec{F} \cdot d\vec{l}$ and $F = qE$ → F larger and thus W larger

2. How is the quantity *the work divided by the charge* affected by this change?

   unchanged

The *electric potential difference* ΔV_{WX} between two points *W* and *X* is defined to be:

$$\Delta V_{WX} = -\frac{W_{elec}}{q}$$

where W_{elec} is the work done by the field as a charge q travels from point *W* to point *X*.

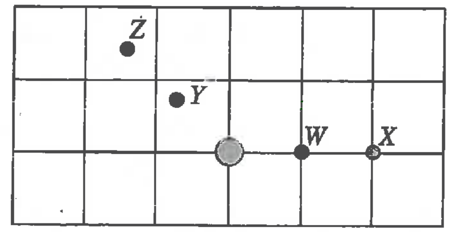
3. Does this quantity depend on the *magnitude* of the charge of the particle that is used to measure it? Explain.

   No divides out since $W \propto q$

4. Does this quantity depend on the *sign* of the charge of the particle that is used to measure it? Explain.

   No divides out

B. Shown at right are four points near a positively charged rod. Points *W* and *Y* are equidistant from the rod, as are points *X* and *Z*. A charged particle with mass $m_o = 3 \times 10^{-8}$ kg is released from rest at point *W* and later is observed to pass point *X*.



1. Is the particle positively or negatively charged? Explain.

positive

2. Suppose that the magnitude of the charge on the particle is 2×10^{-6} C and that the speed of the particle is 40 m/s as it passes point *X*.

   a. Find the change in kinetic energy of the particle as it travels from point *W* to point *X*.

   $$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}mv_f^2 = 2.4 \cdot 10^{-5}\ J = \Delta k$$

   b. Find the work done on the particle by the electric field between point *W* and point *X*. (*Hint:* See part D of section I.)

   $$W_{w \to x} = \Delta k$$

   c. Find the electric potential difference between point *W* and point *X*.

   $$\Delta V_{w \to x} = V_x - V_w = -\frac{W_{w \to x}}{q} = -\frac{\Delta k}{q} = \frac{-2.4 \cdot 10^{-5} J}{2 \cdot 10^{-6} C} = -12V$$

   d. If the same particle were released from point *Y*, would its speed as it passes point *Z* be *greater than, less than,* or *equal to* 40 m/s? Explain.

   ~~less than~~, equal to, since W & Y are equidistant from the rod, as are [illegible] X & Z

3. Suppose that a second particle with the same mass as the first but nine times the charge (*i.e.*, 18×10^{-6} C) were released from rest at point W.

   a. Would the electric potential difference between points *W* and *X* change? If so, how, if not, why not?

   No difference, since potential only based on the properties of the rod

   b. Would the speed of the second particle as it passes point *X* be *greater than, less than,* or *equal to* the speed of the first particle as it passed point *X*? Explain.

   $$\Delta V_{w \to x} = -\frac{W_{w \to x}}{q} = \frac{-\frac{1}{2}mv_f^2}{q} \to V_f = \sqrt{\frac{-2q\,\Delta V_{w \to x}}{m}} \Rightarrow 3x \text{ faster}$$

4. A particle with mass $m_o = 3 \times 10^{-8}$ kg is launched toward the rod from point Z and turns around at point Y.

   a. If the particle has charge $q_o = 2 \times 10^{-6}$ C, with what speed should it be launched? Explain.

$\Delta K = K_Y - K_Z = W_{Z \to Y} = -(V_Y - V_Z)q$

$\rightarrow -\frac{1}{2}mv_i^2 = -(V_Y - V_Z)q \rightarrow v_i = \sqrt{\frac{2}{m} q(V_Y - V_Z)} = 40 \text{ m/s}$

$(V_Y - V_Z)$: 12V

   b. If instead the particle has charge $9q_o$ (*i.e.*, 18×10^{-6} C) with what speed should it be launched? Explain.

$v_i \propto \sqrt{q} \Rightarrow 3\times$ faster