Name: _____
Lab Partners: _____
_____

Building Physical Intuition – Kinematics

Kinematics is the *description* of motion. Motion can be described using the quantities: time, distance and displacement, speed and velocity, and acceleration. These exercises are designed to improve your observation and physical intuition for describing motion. Strive to improve your ability to make estimates of reasonable kinematics magnitudes.

Groups: form groups of three (or whatever number your instructor suggests)
Equipment: each group should have a one meter stick, a two meter stick, and a watch with a second hand and/or a stopwatch.

Distance vs. Displacement

There are important distinctions between what we mean by **distance** and **displacement**. In both cases, however, the amounts are measured in the same units as lengths.

	Amount	Direction
Distance	The amount traveled along a path.	Direction does *not* matter! It is not included in our definition.
Displacement	The length of the straight line from the earlier position to the later position, regardless of path.	Points **from** the earlier position straight **to** the later position.

1. *Measured Walks.* Place a small object on the ground to mark a starting spot (origin). (A piece of tape works well since it will stay in place.) Stand back to back with your partners so that you all walk at the same time, but in different directions. Without looking at your partners, walk straight ahead a distance that you think is 4 m. Mark your final position. Measure how far you walked from the origin. (Don't be concerned if you are off by quite a bit. This is a learning exercise to familiarize you with metric distances.) Enter your group's results in the table below.

	Person A_____	Person B _____	Person C_____
Experimental Attempt			
Ideal Distance			
Percent Error			

The **Percent Error** gives you a quantitative way to say how far off you were. Perform this calculation for each person as follows:

$$\text{Percent Error} = \frac{\text{Experimental - Ideal}}{\text{Ideal}} \times 100\%$$

Notice that the **Percent Error** is positive (+) if you walked too far (experimental exceeds the ideal) and is negative (–) if you did not walk far enough. Be sure to follow rules for significant figures

If everyone in your group walked exactly 4 meters, would your displacements all be the same? Be careful to check and use the definition for **displacement** when answering this question! _____, because _____

_____.

2. *Forward & Back Walks [1-D Motion].* Have each member of the group take the walks described below. Place a small object on the ground to mark a starting spot (origin). Choose one direction to be the positive x-direction (+ x-direction). Put something on the ground to clearly show your choice for the + x-direction. The opposite direction is called the negative x-direction (– x-direction).

   For each walk, you will: Sketch the walk showing the origin and positive direction. Measure and record the distances traveled for each of the stages. Also record the displacements for each of the stages including a +/- sign to indicate direction. Calculate the total distance and total displacement by addition. Measure all quantities to the nearest 0.01 m.

   - WALK A: Walk 5 steps in the + x-direction and mark the spot. Walk 3 steps in the -x-direction and mark the spot.
   - WALK B: Walk 5 steps in the -x-direction and mark the spot. Walk 3 steps in the +x-direction and mark the spot.
   - WALK C: Make up your own 3-stage walk.

     Stage 1: _____

     Stage 2: _____

     Stage 3: _____

	Person A_____	Person B _____	Person C_____
Walk A Sketch:	distance 1 = _____m distance 2 = _____m total dist. = _____ m displace. 1 = _____m displace. 2 = _____m total displ. = _____m	distance 1 = _____m distance 2 = _____m total dist. = _____m displace. 1 = _____m displace. 2 = _____m total displ. = _____m	distance 1 = _____m distance 2 = _____m total dist. = _____m displace. 1 = _____m displace. 2 = _____m total displ. = _____m
Walk B Sketch:	distance 1 = _____m distance 2 = _____m total dist. = _____m displace. 1 = _____m displace. 2 = _____m total displ. = _____m	distance 1 = _____m distance 2 = _____m total dist. = _____ m displace. 1 = _____ m displace. 2 = _____ m total displ. = _____ m	distance 1 = _____m distance 2 = _____m total dist. = _____m displace. 1 = _____m displace. 2 = _____m total displ. = _____m

	Person A_____	Person B _____	Person C_____
Walk C Sketch:	distance 1 = _____m distance 2 = _____m distance 3 = _____m total dist. = _____m displace. 1 = _____m displace. 2 = _____m displace. 3 = _____m total displ. = _____m	distance 1 = _____m distance 2 = _____m distance 3 = _____m total dist. = _____m displace. 1 = _____m displace. 2 = _____m displace. 3 = _____m total displ. = _____m	distance 1 = _____m distance 2 = _____m distance 3 = _____m total dist. = _____m displace. 1 = _____m displace. 2 = _____m displace. 3 = _____m total displ. = _____m

- Is distance ever negative? _____, because _____
  _____.

In the case of 1-D motion (motion along a line), the magnitude of a displacement is the absolute value of the displacement.

- In general, is the total distance equal to the magnitude of the total displacement? _____, because _____
  _____.
- In what special case is the total distance equal to the magnitude of the total displacement?
  _____
  _____.

Using walks A, B and C, find the average length of a single step for each person. Show how you used your data to obtain this result.

	Person A_____	Person B _____	Person C_____
Average Step Length:			

Method of calculation of average step length:

3. *2-D Motion Preview.* Place a small object on the ground to mark a starting spot (origin). Walk 4 steps in one direction and mark your new position. Turn and walk 3 steps in a direction 90° from the direction you just walked. Mark your final spot. Keep these marked positions on the ground until you are done with the questions below.

   - Draw a picture showing the origin and the two parts of your walk.

   - Measure all lengths. On your diagram, label the lengths of the two parts of the walk you have drawn.

   - Total distance traveled = _____

   - On your diagram, draw an arrow from your starting point to your ending point to show your total displacement.

   - Using the positions marked on the ground, measure the magnitude (numerical value with units) of your total displacement. _____

   - Is the total distance equal to the magnitude of the total displacement? _____

     In general, can you add distances to obtain the magnitude of the total displacement? In what special case could you add distances to obtain the magnitude of the net displacement?

Speed vs. Velocity

The difference between the **average speed** of an object and the **average velocity** is effectively the same as the difference between **distance** and **displacement**. This is evident from the definitions:

- average speed $\overset{is}{\equiv} \dfrac{\text{distance}}{\text{time to travel that distance}}$
- average velocity $\overset{is}{\equiv} \dfrac{\text{displacement}}{\text{time for that displacement}}$

4. *From the definitions*:

   - Does average speed have direction? _____ Why or why not? _____
     _____
     _____.
   - Does average velocity have direction? _____Why or why not?_____
     _____
     _____.
   - Can average speed be negative? _____Why or why not? _____
     _____
     _____.
   - Can average velocity be negative? _____Why or why not? _____
     _____
     _____.
   - In general, is average speed equal to the magnitude of average velocity? _____Why or why not?
     _____
     _____.
   - In what special case is average speed equal to the magnitude of average velocity?_____
     _____
     _____.

5. *Human Speeds.* Along a straight line, mark a starting point (origin) and an ending point 10 m away. Choose one person to be a walker/runner, one person to be a timer with stopwatch, and the third person to be the recorder. The timer should be at the 10 m mark. Have the walker/runner start well behind the origin to get her/him up to a steady speed. When the walker/runner passes the origin, the timer should start the stopwatch.

   Take turns being walker/runner, timer and recorder for the following different motions. Units are placed in the column headings and should not be included with numerical values you record in the table.

	Time (s)	Distance (m)	Displacement (m)	Ave. Speed(m/s)	Ave. Velocity (m/s)
slow walk					
normal walk					
fast walk					
jog					
run					

- In this special case where you do not change direction, what do you notice? _____
  _____
  _____
- To get a sense of how fast your speeds were, we can use the rough conversion of 1 m/s is about 2 mi/h. Using this rough conversion and the table above, fill in the blanks below. How many significant figures should you keep?

  slow walking speed ≈ _____ m/s ≈ _____ mi/h

  normal walking speed ≈ _____ m/s ≈ _____ mi/h

  fast walking speed ≈ _____ m/s ≈ _____ mi/h

  jogging speed ≈ _____ m/s ≈ _____ mi/h

  running speed ≈ _____ m/s ≈ _____ mi/h

Do these numbers seem to be about right? _____.

6. *Race Walking!* In this contest you will take turns walking as quickly as you can—do not run or jog. Select and mark an origin. Choose a positive direction and measure 5.00 m from the origin in that direction. Clearly mark the spot. Measure and mark 10.00 m from the origin in the negative direction. Start from the origin, timer says "go," walk as fast as you can to the +5.00 m mark, turn around and walk as fast as you can to the finish line at the – 10.00 m mark.

Add units to the column headings and record your values in the table.

Name	Time ( )	Distance ( )	Displacement ( )	Ave. Speed ( )	Ave. Velocity ( )

- Aside from the time to finish, which number would you use to determine the fastest walker? _____
- What does the sign of the average velocity tell you? _____
  _____
- What would your average velocity be if you started and stopped at the same spot?
  _____
  In that case, would your average speed be positive, negative or zero? _____