1. To **"displace"** an object means to move it from one place to another. In Chapter II you learned that the **"displacement"** of the object is the distance to the object *from the origin of a coordinate system.* To be perfectly clear when describing a displacement, you must also describe its *direction.*
   a. If you drive eastward at 60 mph for two hours, your change in displacement is _____ miles *east*.
   b. If you walk 20 yards north and then go *back* 5 yd. then your change in displacement is 15 yd ____.

2. Something that can be described completely only by giving both a numerical value and a direction is called a *vector*. Displacements, velocities, accelerations, and forces are examples of vectors because they can be *measured* and because they always have *directions* such as eastward, northward, or upward. Is temperature a vector? ____ If so, what is the direction of the temperature in this room?

3. We have often described directions in a crude way by using *signs***.** For example, in Ch. II forward displacements were "____tive" and _____ward displacements were said to be "negative". Signs are a good language for describing directions in *one-dimensional* situations, where only two directions are possible. An elevator's displacement can be described conveniently by a number with a sign and a unit, because it can move only up or down. But signs are not *always* adequate, as in these examples:
   a. What is your final displacement if you go 4.0 meters north, turn right, and then go 4.0 m east? (Give a number in *decimal form*, units, and direction. Round off properly.) _____ ____ _____
   b. While riding northward at 20.0 mph, Dennis the Menace shoots a pebble out of the car window at 20.0 mph eastward relative to the car. With what velocity does the pebble hit its target? ___ ___ __
   c. The answer to 3b has _____ significant digits than the answer to 3a. (more, fewer)

4. Problems 3a and 3b are both solved by a procedure called "**vector addition**". Here are the steps:
   a. Each vector is represented by an arrow drawn on a map. As on any map, a **scale** is necessary. For example, in 3a you might let one inch represent one mile. In 3b, 1 cm. could represent 1 mph. In each case the length of the arrow corresponds to the **magnitude** (amount) of the vector.
   b. The arrows representing the given vectors are drawn **tail-to-head** on the map.
   c. The **"vector sum"** is represented on the map by a new arrow drawn from the *tail* of the first arrow to the *head* (pointed end) of the last one. It is a good idea to make that new arrow look different from the others by drawing it as a *dotted line,* or by using a different color.
   d. You can use geometry or trigonometry to *calculate* the length of the new arrow. If you prefer, you may *measure* it with a ruler. Just remember to use the scale that you chose in part "a" to express that magnitude in terms of the original units that were given in the question.
   e. In physics we use *decimal notation*. (Answering with a radical would imply that your answer had perfect precision. That's not possible because the given values must have some uncertainty.)
   f. The last blanks in 1b, 3a and 3b are for *direction* words, such as "up" or "southwest". Words which describe directions are *not* units. *When you multiply two vectors you always multiply their units but you never multiply their directions!*

5. Most automobiles have a speedometer, an odometer, a gas gauge, and a clock.
   a. Which of those instruments can measure displacement? _____
   b. Does it always measure displacement, or does it do so only under certain conditions? ____
   c. What are those special conditions? (Clue: *The answer to 3a is not eight miles!*)

6. "Average velocity" is defined as Δdisplacement/Δtime. If I drive 70.7 miles northeast and then 70.7 miles southeast, starting at 1 PM and finishing at 5 PM on the same day then my average *speed* is ___ mph, but my average *velocity* is _____ _____ _____. *Begin with a diagram. Round off properly.*

7. What is my average velocity if I stand still for two hours at a spot 100 miles south of my home?

8. When you calculate a speed or a velocity do you use a *time*, or a time *interval*? _____
   -Do you use a displacement, or a *change* in displacement? _____
   -Does this agree with your answer to #7? ___

1. Obtain an 8.5 by 11-inch sheet of paper with square corners. (The back of this paper will do.)
   a. Let the upper-left-hand corner be "point A".
   b. Make dot "B" on the upper edge of the paper exactly one centimeter to the right of A.
   c. Draw a line segment just two centimeters long down from B, parallel to the left edge of the paper. Label its lower endpoint with the letter "C".
   d. Draw a straight line from A through C.
   e. Extend it to intersect the bottom edge of the paper at point "D".
   f. Let the lower-left-hand corner be "E": Measure and record distance ED: **ED = _____ ____**

2. Turn the paper around 180^{o} and repeat the process: **New ED value = _____ ____**

3. Collect the results from everyone in the class and make a *histogram*, as on page 2.

4. If we were able to draw and measure with perfect accuracy, then we would all get the same length for ED. What does #3 tell us about our drawing and measuring abilities?

5. Using the "olympic rule", make a rough circle around the central region of your histogram, surrounding about two-thirds of the data points.
   a. According to that rule, the **SLV** of length ED is ____ ____, and the **GLV** is ____ ___.
   b. The **Uncertainty** (or **"Standard Deviation"**) of length ED = _____ ___. (See RS I.)
   c. To convert that uncertainty into percentage form you must divide it by the _____ of length ED (in _____s), multiply by ___, and round off properly. The **MLV** of length ED is ____ ____.
   d. We conclude that ED = _____ ± ____ cm, or ____ cm ± ____%.

6. Triangle AED was just a magnified picture of triangle ABC. When you magnify a picture, you multiply each of its linear measurements by a certain "magnification factor". There is some important information about such multiplication in #21 on RS I. Please copy it here:

7. According to that rule, magnifying a picture _____ alter the relative uncertainty of its width. (does, doesn't) -Does #11 on page 20R agree? _____ -After rounding off properly, we conclude that **AB = ___ cm ± ____%, or ___ ± ___ cm.**

8. On page 1 and in #14 on p. 3 we *guessed* that the uncertainty of a ruler measurement was roughly ±___ cm. Today's *experiment* shows that the uncertainty of such a measurement is roughly ±___cm.

9. We *could* have drawn triangle ABC *ten times bigger*:
   a. Using the same pencil and ruler to draw the *new* triangle, we would find that
      new AB = ____ ± ____ cm. (See #13 on page 1.)
   b. The new *relative* uncertainty of AB would be **(± ____cm) ÷ (____cm) = ± ___ %.**

10. Comparing the *new* percentage uncertainty (in 9b) with the *original* one (in 5c) we see that **increasing the length of a line segment by a factor of N enables us to draw it or measure it with ___ times better precision, so its relative uncertainty is _____ed by ___.**
    -Does #9 illustrate that rule? ___ If not, why hasn't it been corrected?

11. To get a precision of ± 1% or better, we must make the vectors in our diagram more than ____ centimeters long. This discovery is recorded in #__ on RS III.