Supplemental Experiment 1
Measuring Vector Forces

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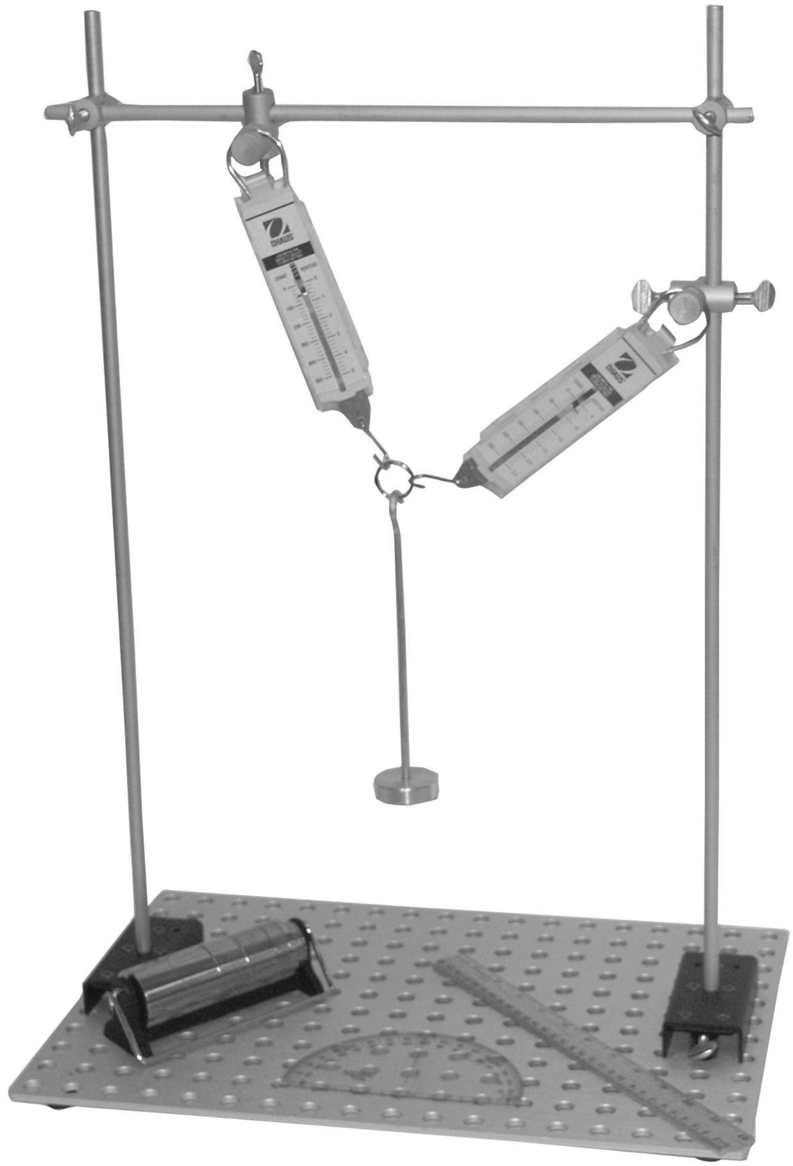

Figure 1
Setup for Supplemental Experiment 1

Supplemental
Experiment 1

Measuring Vector Forces

Experiment Objectives

- Set up a system to measure forces using spring scales.
- Measure the resultant force produced by adding two forces.
- Graphically represent the resultant force by adding two or more force vectors.

Laboratory Proficiencies

- Use a spring scale to measure force in Newtons.
- Use a protractor to measure angles to the nearest degree.

Discussion

A force is the push or pull exerted by one body on another. Sometimes two or more forces act on a body at the same time. The result of this action is called the resultant force. If the resultant force is zero, then the body experiences no net force. When this happens, the body is said to be in **equilibrium**.

Vectors are used to graphically represent forces. Their angle specifies the direction of the force, and their length specifies the magnitude of the force. Vectors can be graphically combined to determine the resultant force when two or more forces are acting on a body.

In this experiment, you will place a system of forces in equilibrium. Then you will measure the forces and graphically add them to find the resultant. The resultant of forces in equilibrium should be zero. If it is not, then there must be an unmeasured force in the system that is not being taken into account. This unmeasured force is often due to friction.

Equilibrium A state of balance between opposing forces.
Vectors A quantity that has magnitude and direction. Commonly represented by a directed line whose length equals magnitude and angle equals direction.

Equipment and Materials Required

- Metal O-Ring, 1"
- Protractor
- Ruler, 30 cm
- Small Slotted Weight Set
- Small Weight Hanger
- Spring Scale, 2.5 Newton
- Spring Scale, 5 Newton
- Support Stand Set (following parts)
  - — Long Crossbar
  - — Mechanical Breadboard
  - — Rod Connectors, 4
  - — Scale Hangers, 2
  - — Support Rods with Base, 2

Procedure

Lab Setup

The lab setup is shown in Figure 1 at the beginning of the experiment. Refer to this figure and the detailed figures that follow when assembling the equipment.

❑ 1. Use the mechanical breadboard, support rods, long crossbar, rod connectors, and scale hangers to assemble the support stand. Details of the assembly are shown in Figure 2.

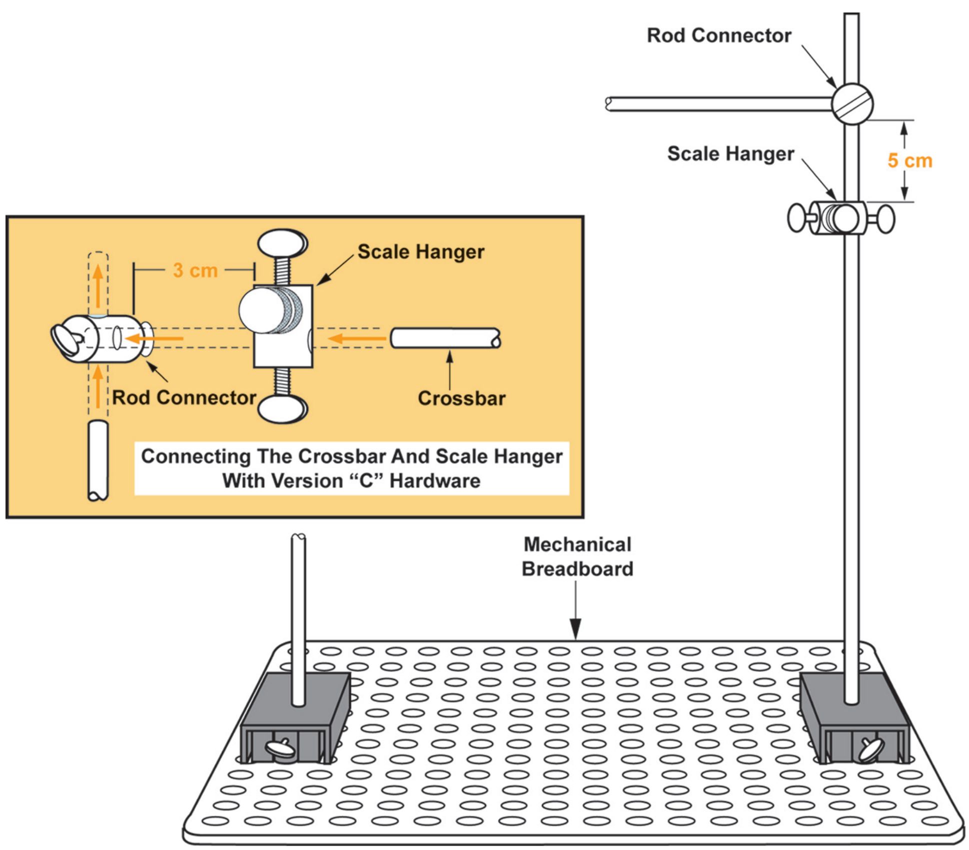

Figure 2
Assembling the support stand

❑ 2. Mount the two scale hangers. Position one on the crossbar, 3 cm from the left rod connector. Position the other hanger on the right support rod, 5 cm below the crossbar. See Figure 2.

❑ 3. Hang the 5 Newton scale from the scale hanger on the crossbar. Hang the 2.5 Newton scale from the scale hanger on the support rod. Fully extend the tongue of the 5 Newton scale. Use a pencil to draw a line down the middle of the tongue. Label the front of this scale A. Repeat for the 2.5 Newton scale and label it scale B. See Figure 3.

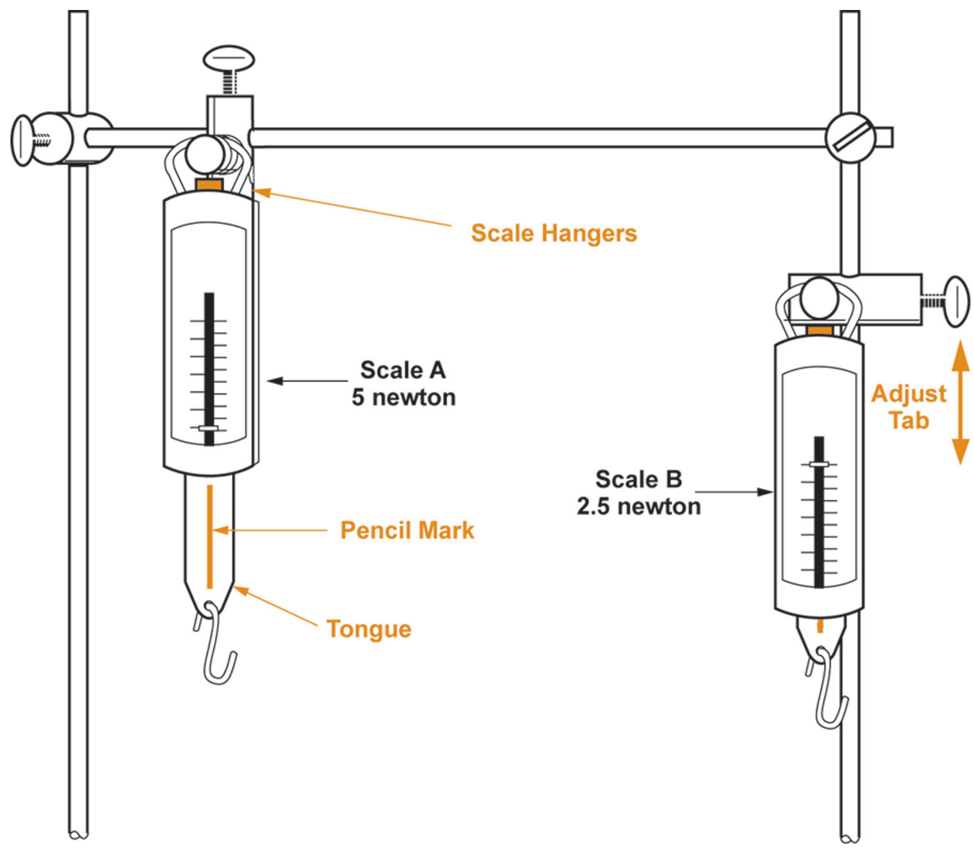

Figure 3
Marking and zeroing the spring scales

❑ 4. Adjust both scales by sliding the movable indicator plate up or down. The scales should read zero when hanging vertically. See Figure 3.

❑ 5. Attach the S-hook from each scale to the 1" O-ring. Then suspend the 50-gram weight hanger from the ring. See Figure 4.

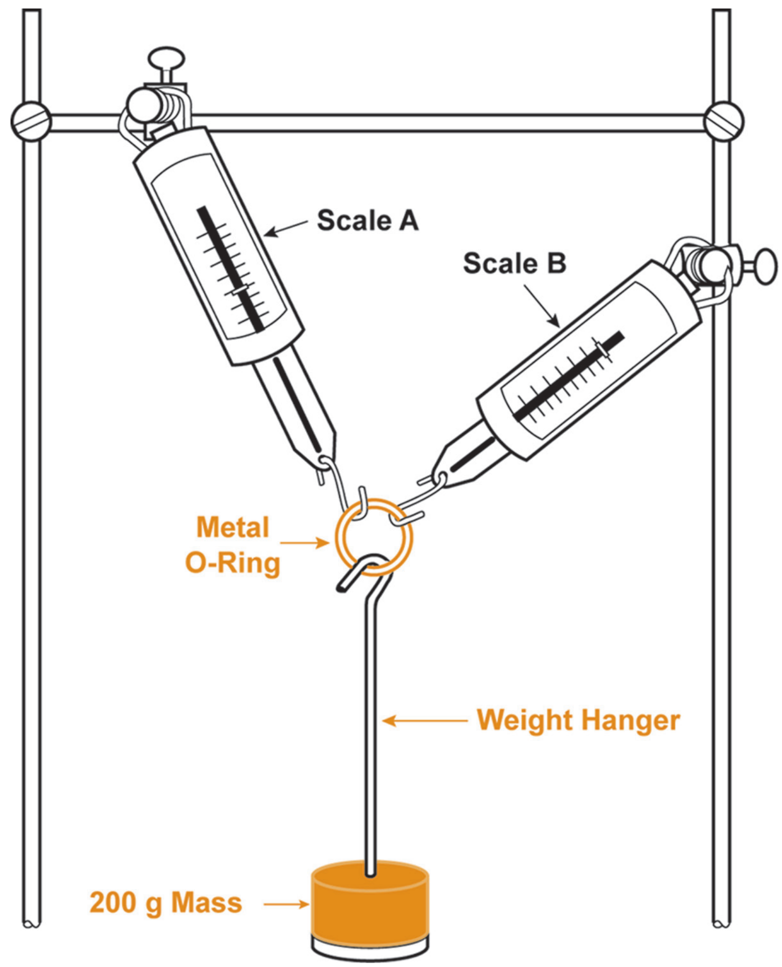

Figure 4
Weight hanger and scales setup

❑ 6. Add 200 grams of mass to the weight hanger for a total hanging mass of 250 grams.

Observations and Data Collection

The system you have assembled is in equilibrium since no motion is observed. Three forces are acting on the ring: F_A (scale A); F_B (scale B); and F_W (weight hanger.) Use the following procedure to record the forces under Observation 1, in Data Table 1, of your Student Journal.

❑ 1. Convert the mass of the hanging weights from grams to kilograms.

$$1\,\text{Gram} = \frac{1}{1000}\,\text{Kilogram}$$

Enter the value in the Student Journal.

❑ 2. Use the following conversion equation to convert the mass of the hanging weights to units of force (weight) in Newtons.

$$\text{F (Newtons)} = \text{Mass (Kilograms)} \times \frac{9.8\ \text{Newtons}}{\text{Kilograms}}$$

Record this as the value of Force F_W in Data Table 1.

❑ 3. Enter the scale readings in Data Table 1 as F_A (scale A) and F_B (scale B).

❑ 4. Use the protractor to measure the angle of each force with respect to the vertical axis. Position the protractor so that the center mark is aligned with the center of the O-ring. Align the baseline of the protractor along the shaft of the weight hanger. See Figure 5.

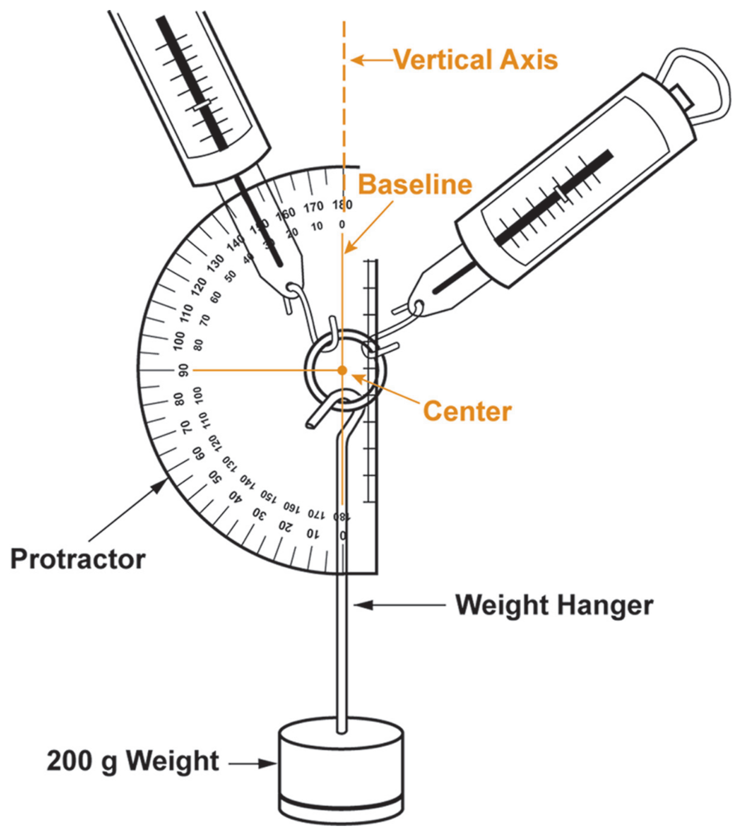

Figure 5
Positioning the protractor

❑ 5. Refer to Figure 6 for details on how to read the angles. Use a protractor to read angle *A*. Record all angles that are to the right of the vertical axis as positive angles. Record all angles that are to the left of the vertical axis as negative angles. This will produce a negative reading for angle *A*. Move the protractor to the other side and read angle *B*. Record these values in Data Table 1. Since the weight is pulling straight down on the weight hanger, angle *C* is 180°.

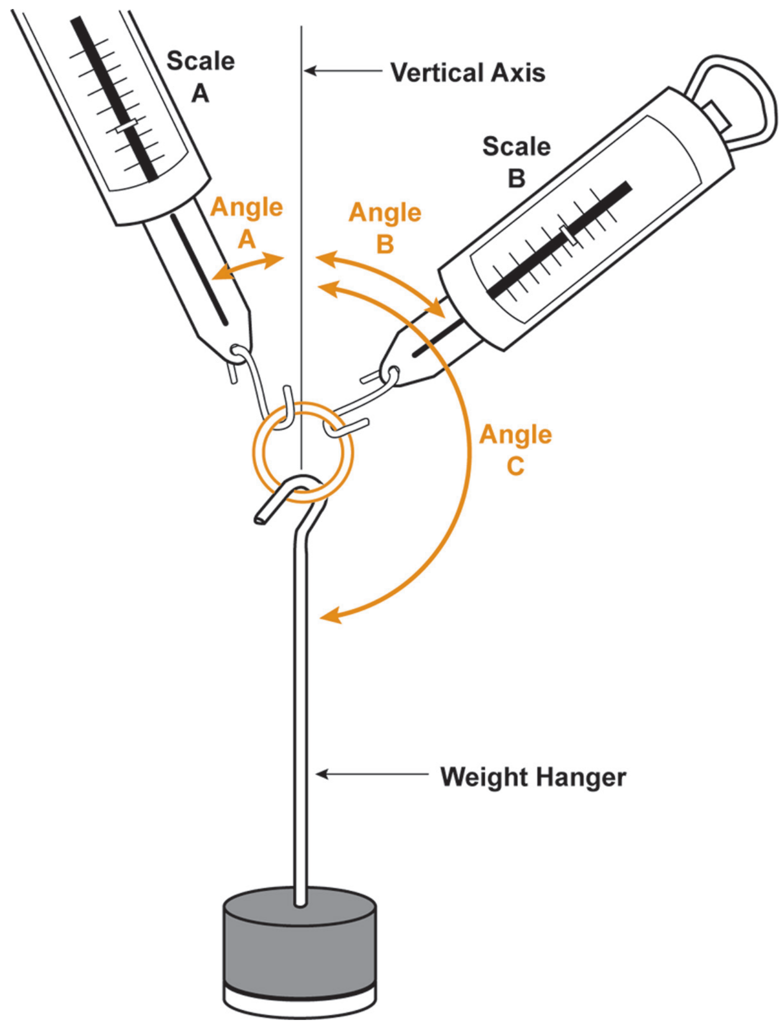

Figure 6
Force angles

Graphing the Data

You will now graphically add the forces to see if the resultant force equals zero.

❑ 1. Place the protractor center over the graph origin under Graphing the Data, Data Graph 1. Align the protractor baseline with the vertical axis of the graph. See Figure 7.

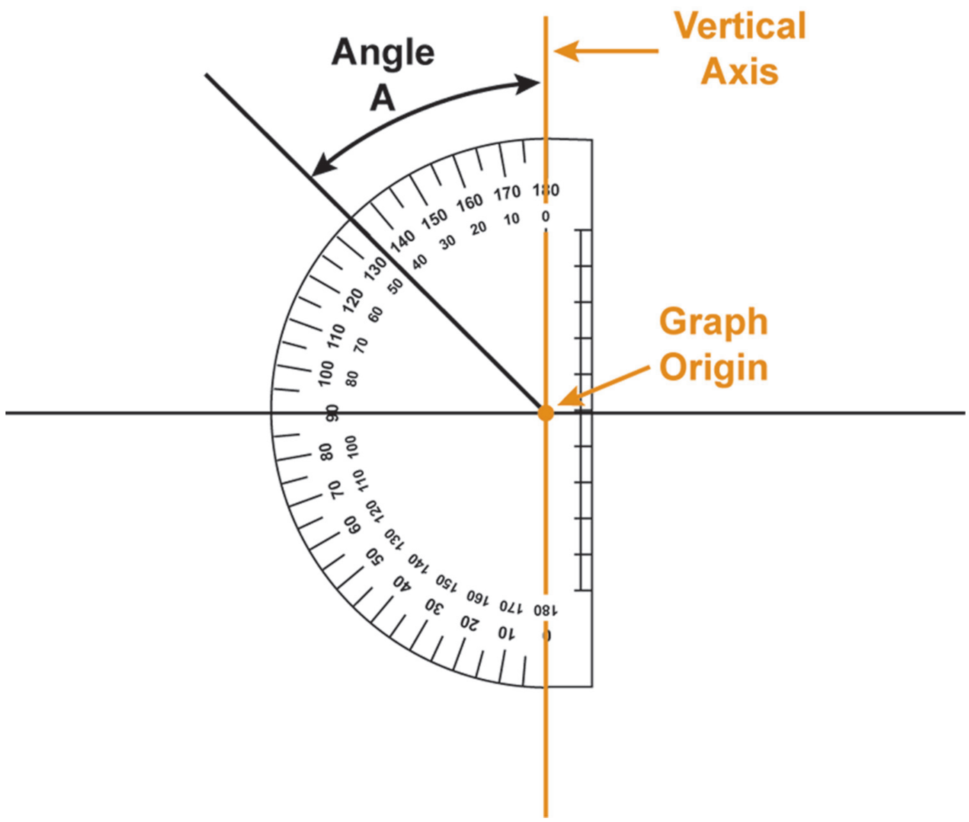

Figure 7
Plotting angle *A*

❑ 2. Locate and mark a point at the exact value of angle *A* on the graph. Since angle *A* is negative, the protractor must face to the left. See Figure 8. Use a ruler to draw a line from the origin through the point. The direction of this line represents the direction of F_A.

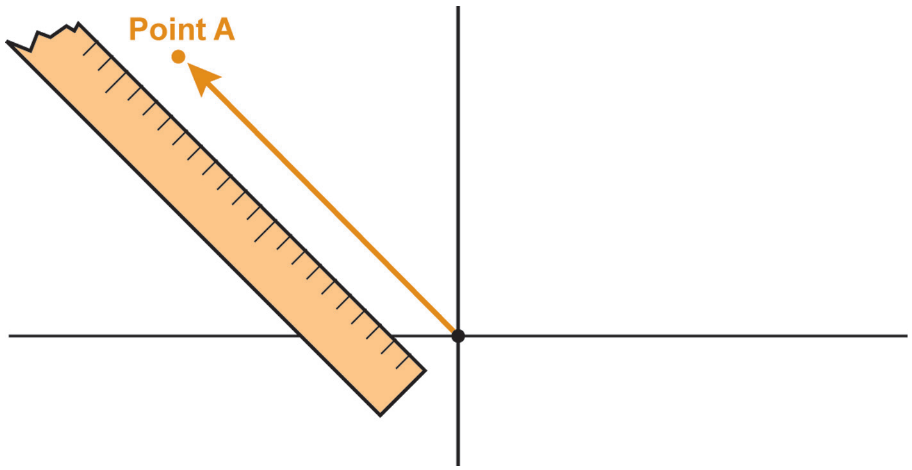

Figure 8
Graphing vector A

❑ 3. Use the following scale to find the length of this vector.

One Large Division = 1 Newton

Make a ruler from a piece of paper marked with the graph scale. Use this ruler to mark off the length of vector F_A on the line, measuring from the origin outward. Label the end point A. Draw an arrowhead at point A. Label this vector F_A. See Figure 8.

❑ 4. When adding vectors, the next vector has its origin at the arrowhead of the preceding vector. Draw a vertical axis through point A. Repeat steps 2 and 3, draw vector F_B, and label it vector F_B. See Figure 9.

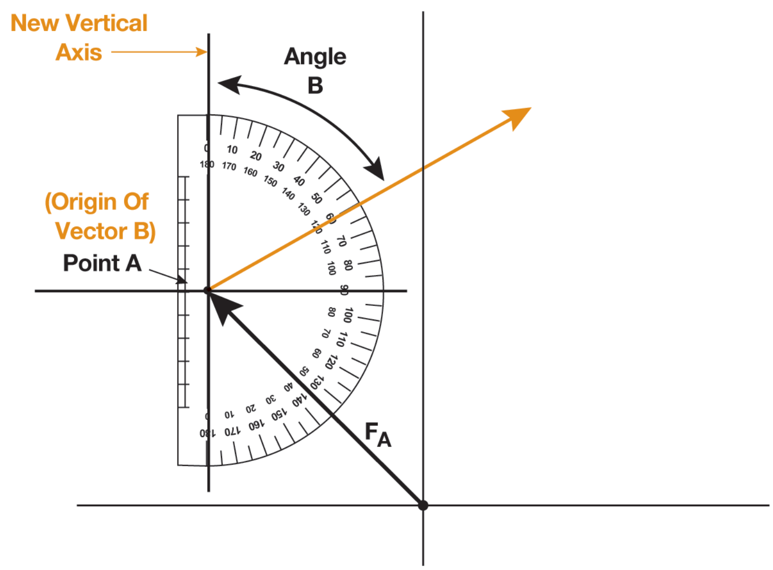

Figure 9
Locating vector B

❑ 5. Draw a vector (F_R) from the origin of vector F_A to point B. Place the arrowhead at point B. This vector is the resultant of vectors F_A and F_B. See Figure 10.

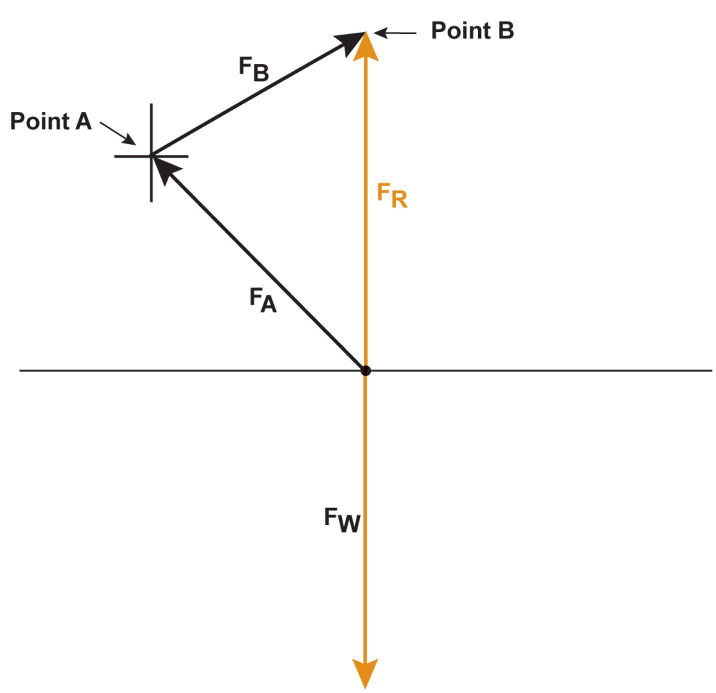

Figure 10
Locating vector C

❑ 6. Draw the vector F_W to represent the hanging weight. Start at the origin and direct this vector straight down as in Figure 11.

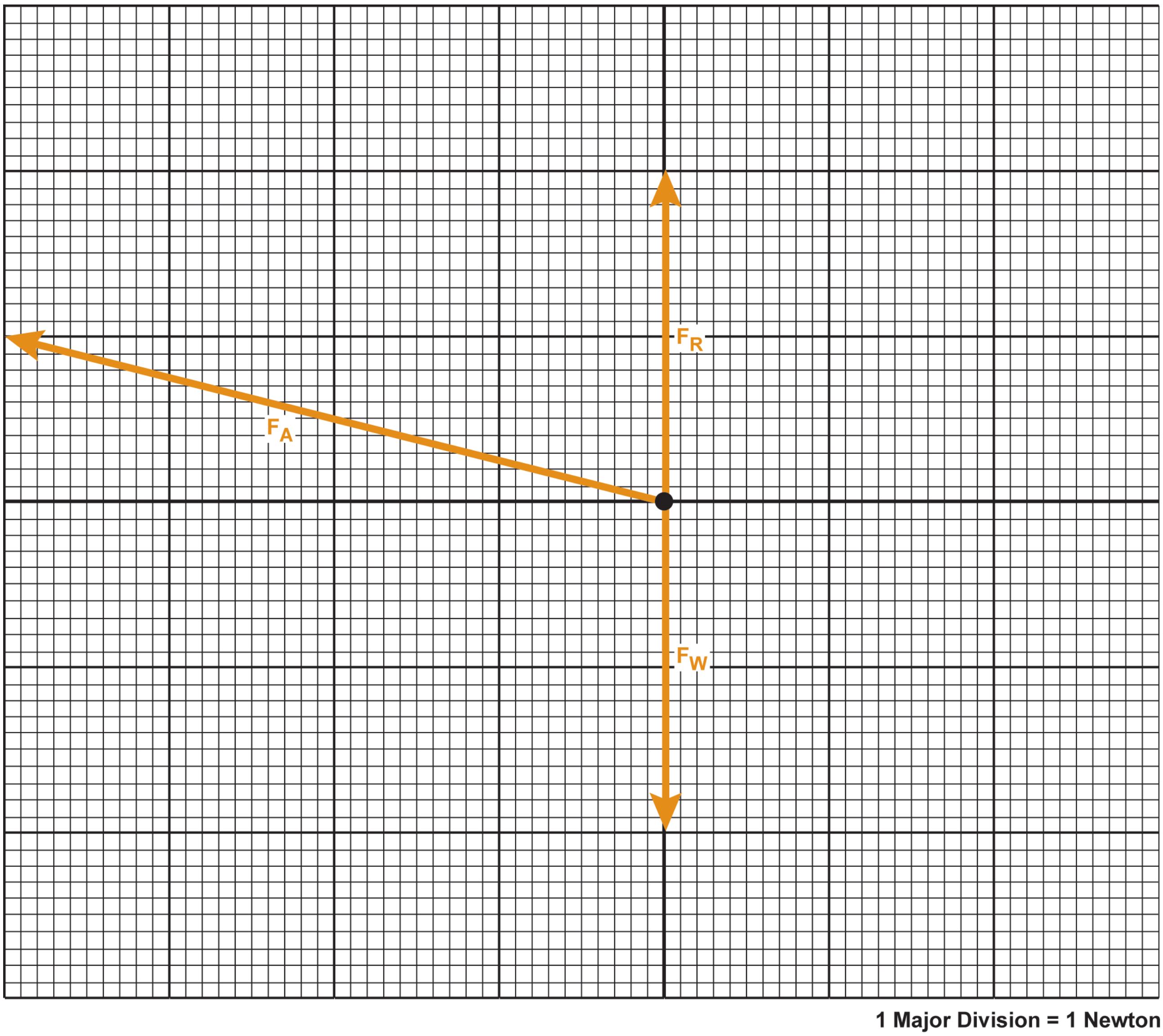

Figure 11
Graph for Question 3

❑ 7. Measure the length and angle of your resultant vector, F_R. Record the values under Graphing the Data. The length of vector F_R should be equal to the length of F_W. The angle of vector F_W is measured from the vertical axis. The angle of vector F_R should be zero degrees. However, due to friction and other factors, the length of vector F_R may not equal the length of vector F_W and neither may the angle of vector F_R be exactly zero degrees.

Questions and Interpretations

1. What should your resultant vector have been? Was it as expected?

2. Give as many reasons as you can for a non-zero resultant force.

3. Figure 11 shows vectors acting at a point, similar to the experiments you did. Vector F_R is the resultant of vectors F_A and F_B. Draw the missing vector, F_B, on the graph in your Student Journal.

4. If vector F_W in Figure 11 represents a force of 2N, what force does vector F_A represent? Record the value in your Student Journal

5. Looking at the vectors in Figure 12 below, the resultant vector can consist of the sum of vectors F_A and F_B or the sum of vectors F_C and F_D. Comparing the angles L_A and L_C, can we say that the vector (or the force that it represents) increases or decreases as the angle increases?

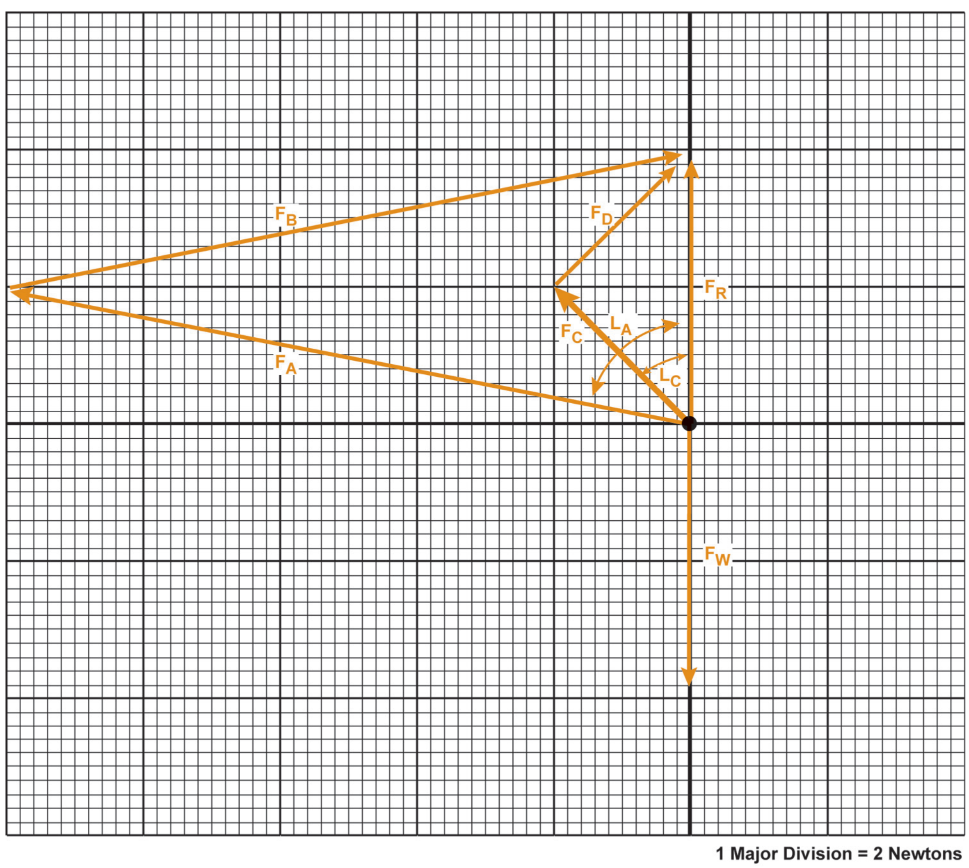

Figure 12
Graph for Question 5

Notes