Tutorial   Name _____
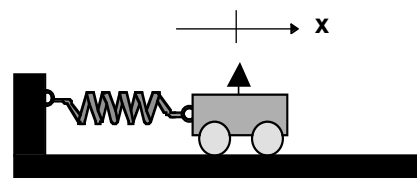
Harmonic oscillation

I.   Cart on a Horizontal Spring

Consider a small cart attached to the end of a spring that is attached
to a steel frame, as shown in the diagram. Assume the wheels are
good enough so you can ignore friction.

The cart's displacement, x, is given by the coordinate system
shown. The origin is chosen so that when the cart is at rest and the spring is unstretched, its marker is at
the origin of the coordinate system ($x = 0$).

A.   Consider the cart at the position $x = 0$.

   1.   Suppose the cart is sitting **at rest**.

      i.   Draw a free-body diagram for the cart in the box at right.
            Label all forces by identifying: a) the type of force, b) the
            object on which the force is exerted, and c) the object
            exerting the force.

      ii.   What is the magnitude and direction of the net force on
            the cart? (If it is zero, state so explicitly.) Explain.
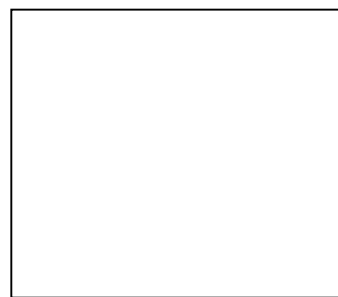
   2.   Suppose the cart is at the position $x = 0$ but is **moving to the
        right with a velocity v**.

      i.   Draw a free body diagram of the cart for this instant in
            time in the box to the right. Label all forces by
            identifying: a) the type of force, b) the object on which
            the force is exerted, and c) the object exerting the force.

      ii.   What is the magnitude and direction of the net force on
            the cart? (If it is zero, state so explicitly.) Explain.

B.   Now consider that the cart is located at $x = x_0$ where $x_0 > 0$.

   1.   Suppose that the cart is held **at rest** by the experimenter's
        hand.

      i.   Draw a free-body diagram for the cart at this position.
            Label all forces by identifying: a) the type of force, b) the
            object on which the force is exerted, and c) the object
            exerting the force.

      ii.   What is the direction of the net force on the cart?

      iii. Does the cart have a non-zero acceleration? Explain.

2. Suppose that the cart is released by the experimenter's hand at time $t = t_0$.

    i.   Draw a free-body diagram for the cart. Label all forces as before. What forces did you add to or remove from your last free-body diagram? Explain.
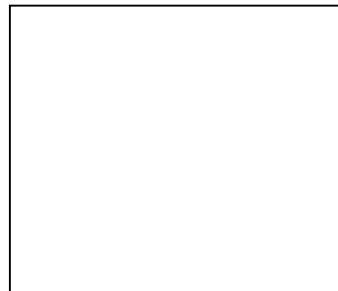
    ii. Indicate the direction of the velocity of the cart at time t_0. Explain.

    iii. Indicate the direction of the acceleration of the cart at time t_0. Explain.

II. A Mass Hanging on a Spring

An iron weight is hung from the end of a very light spring which is attached to a heavy steel frame as shown in the diagram. The weight is at rest in the position indicated. The spring is hanging from a force probe and the weight is above a motion sensor which measures the vertical distance y between the weight and the sonic ranger. (See figure.) Output from the motion sensor and force probe are displayed on your computer.

Note that with this arrangement, $y = 0$ corresponds to the location of the ranger and the upward direction is positive.
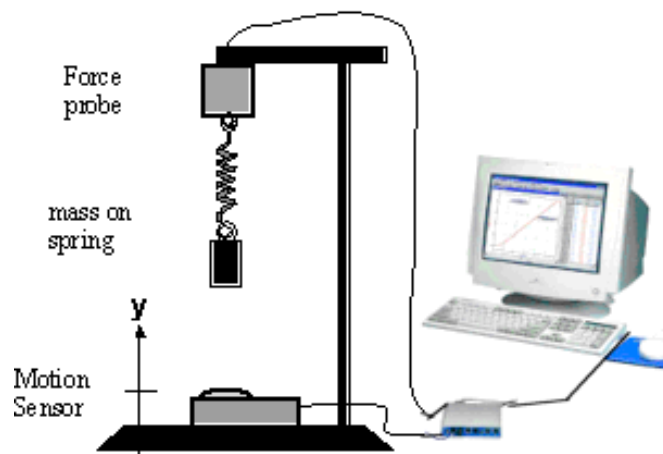
If your computer screen is not showing the graph window of the data acquisition program, ask a facilitator for help.

A. **Motion**: Open one graph window for distance *vs.* time

   1. On the graph at right, sketch your **prediction** for the shape of the graph *y* vs *t* (where *t* is time) after the weight is pulled down slightly and released.

   2. **After** sketching your prediction, perform the experiment. On the graph at right, sketch the actual shape of the graph.

   3. Resolve any discrepancies between your prediction and the experiment. Describe your resolutions, if any, in the space below.

Prediction

Observation
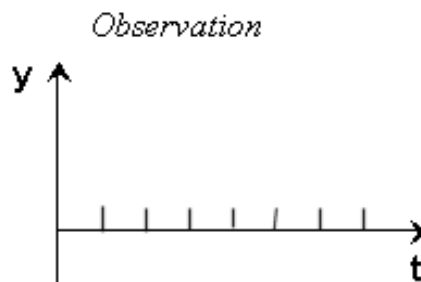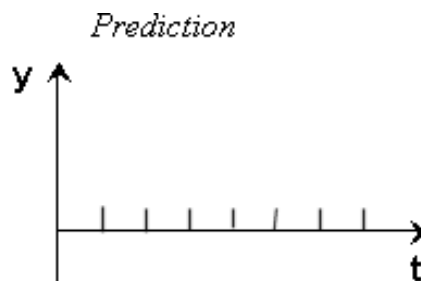
B. **Force and Motion:** Open a second graph window and change it to Force *vs.* time.

   1. On the following graphs, **first** sketch your **prediction** for the shape of the graphs of *F* vs. *t* and *y* vs. *t* after the weight is pulled down slightly and released. Be careful to match up any features in the two graphs that occur at the same time. As before, *y* = 0 corresponds to the location of the ranger and the upward direction is positive.

   2. **After** sketching your prediction, perform the experiment. Sketch the actual shapes of the graphs in the given location.
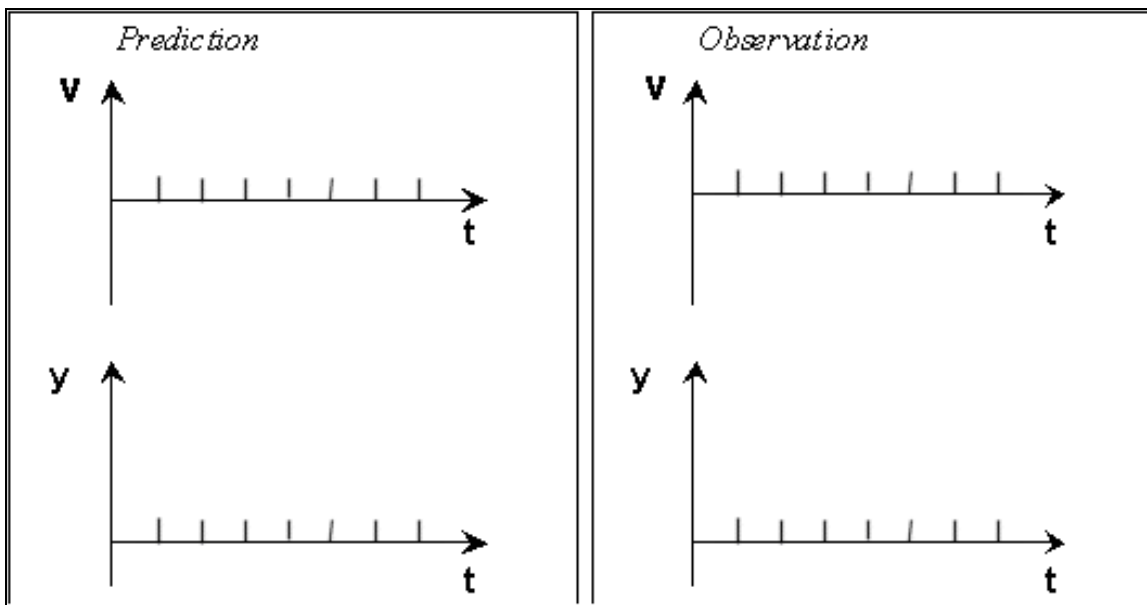
Prediction   *Observation*
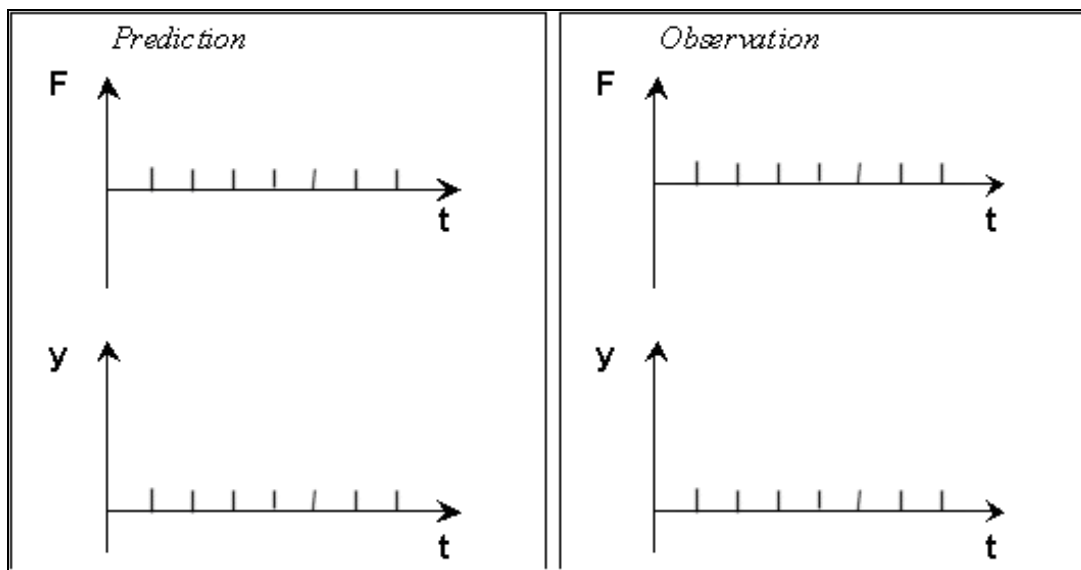
   3. Resolve any discrepancies between your prediction and the experiment. Describe the discrepancies, if any, and your resolutions in the space below.

C. Position and Velocity

    1. On the following graphs, **first** sketch your **prediction** for the shape of the graphs of *v vs. t* and *y vs. t* after the weight is pulled down slightly and released. Be careful to match up any features in the two graphs that occur at the same time. As before, *y* = 0 corresponds to the location of the ranger and the upward direction is positive.

    2. **After** sketching your prediction, perform the experiment. Sketch the actual shapes of the graphs in the given location.

    3. Pay particular attention to the association between velocity and position. What is the velocity when the position is a maximum? What is the position when the velocity is a maximum? Why?

    4. Resolve any discrepancies between your prediction and the experiment. Describe the discrepancies, if any, and your resolutions in the space below.

D. Other Variables and Plots

    1. If you have time, look at the acceleration. How does it correlate with position and force? You might try plotting position against force or velocity against position to see if you can interpret what the resulting graph is telling you.