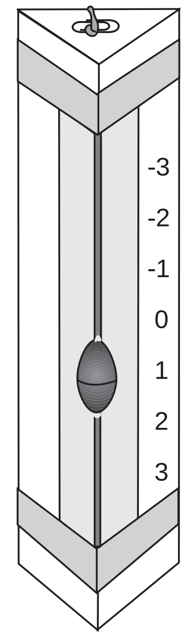
Accelerometers



Students construct a device that can measure acceleration environments from +3 to -3 g.

Objective:

• To measure the acceleration environments created by different motions.

Science Standards:

Physical Science
- position and motion of objects

Unifying Concepts and Processes
Change, Constancy, & Measurement

Science and Technology
- abilities of technological design

Science Process Skills:

Communicating
Measuring
Collecting Data

Mathematics Standards:

Communication
Number & Number Relationships
Measurement Computation & Estimation

Materials and Tools

Lightweight poster board (any color)
3 “drilled egg” lead fishing sinkers, 1 ounce size
Masking tape
Rubber band, #19 size
4 small paper clips
Scissors
Straightedge
Ballpoint pen
Pattern
Hot glue (low temperature)

Activity Management:

This activity provides students with the plans for making a one-axis accelerometer that can be used to measure acceleration in different environments ranging from +3 g to -3 g. The device consists of a triangular shaped poster board box they construct with a lead fishing sinker suspended in its middle with a single strand of a rubber band. Before using the device, students must calibrate it for the range of accelerations it can measure.

The pattern for making the accelerometer box is included in this guide. It must be doubled in size. It is recommended that several patterns be available for the students to share. To save on materials, students can work in teams to make a single accelerometer. Old file folders can be substituted for the poster board. The student reader can be used at any time during the activity.

The instructions call for three egg (shaped) sinkers. Actually, only one is needed for the accelerometer. The other two are used for caiibrating the accelerometer and can be shared between teams.

When the boxes are being assembled, the three sides are brought together to form a prism shape and held securely with masking tape. The ends should not be folded down yet. A rubber band is cut and one end is inserted into a hole punched into one of the box ends. Tie the rubber band to a small paper clip. This will prevent the end of the rubber band from sliding through the hole. The other end of the rubber band is slipped through the sinker first and then tied off at the other end of the box with another paper clip. As each rubber band end is tied, the box ends are closed and held with more tape. The two flaps on each end overlap the prism part of the box on the outside. It is likely that the rubber band will need some adjustment so it is at the right tension. This can be easily done by rolling one paper clip over so the rubber band winds up on it. When the rubber band is lightly stretched, tape the clip down.

After gluing the sinker in place on the rubber band, the accelerometer must be calibrated. The position of the sinker when the box is standing on one end indicates the acceleration of 1 gravity (1 g). By making a paper clip hook, a second sinker is hung from the first and the new position of the first sinker indicates an acceleration of 2g9. A third sinker indicates 3 g. Inverting the box and repeating the procedure yields positions for negative 1, 2, and 3 g. Be sure the students understand that a negative g acceleration is an acceleration in a direction opposite gravity's pull. Finally, the half way position of the sinker when the box is laid on its side is 0 g.

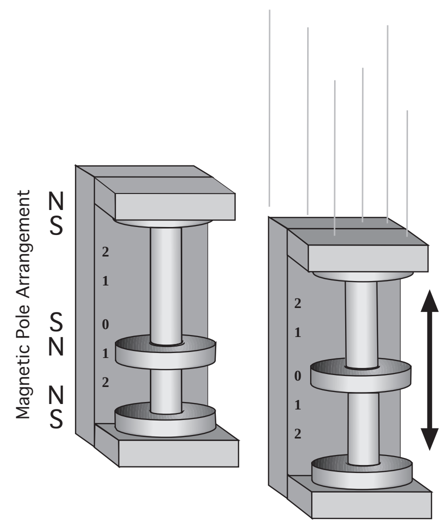
Students are then challenged to use their accelerometers to measure various accelerations. They will discover that tossing the device or letting it fall will cause the sinker to move, but it will be difficult to read the scale. It is easier to read if the students jump with the meter. In this case, they must keep the meter in front of their faces through the entire jump. Better still would be to take the accelerometer on a fast elevator, on a trampoline, or a roller coaster at an amusement park.

Assessment:

Test each accelerometer to see that it is constructed and calibrated properly. Collect and review the student sheets.

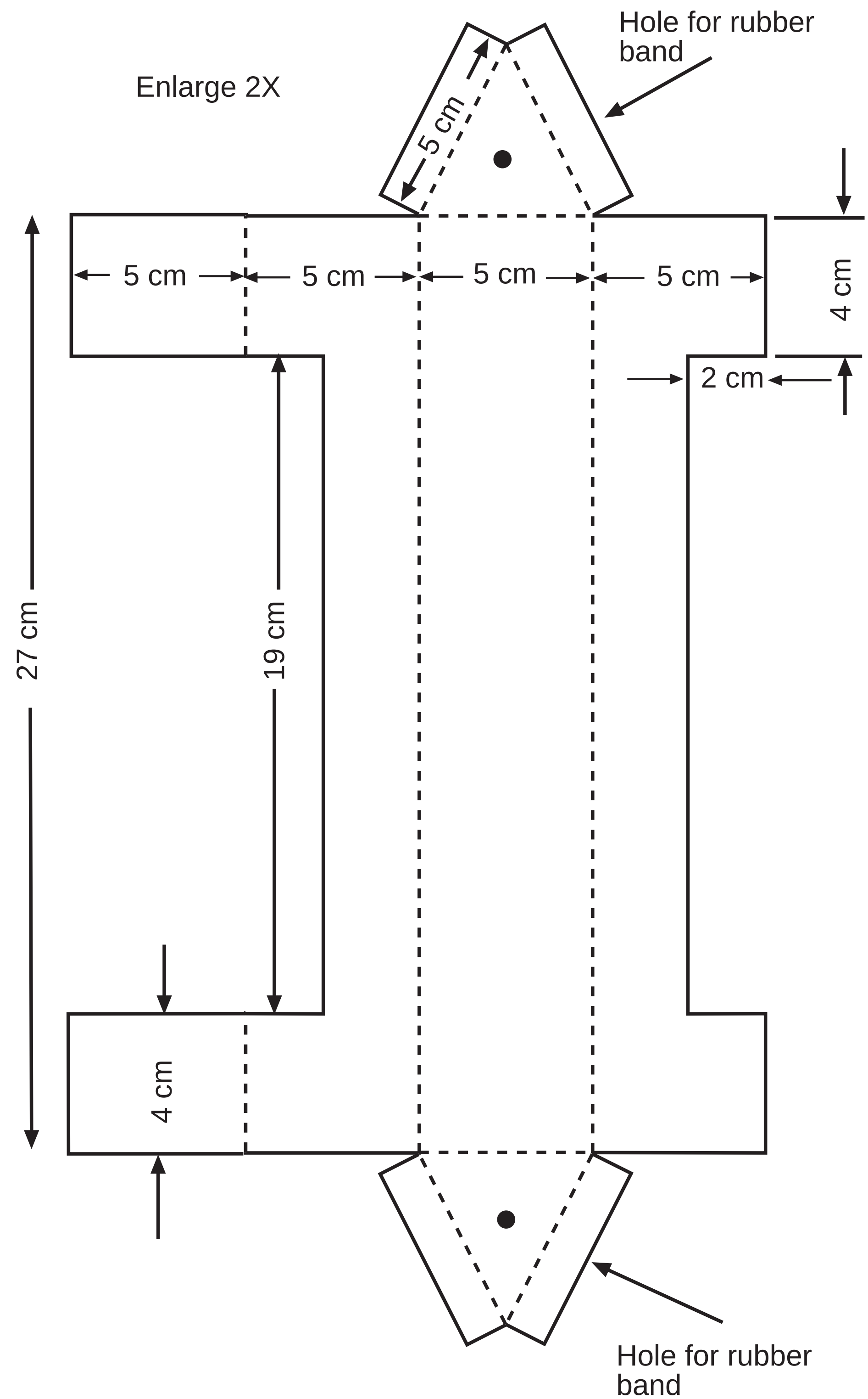
Extensions:

1. Take the accelerometer to an amusement park and measure the accelerations you experience riding a roller coaster and other fast rides.
2. Construct a magnetic accelerometer.
3. Design and construct an accelerometer for measuring very slight accelerations such as those that might be encountered on the Space Shuttle.



Magnetic Accelerometer
Three ring magnets with like poles facing each other.

Accelerometer Box Pattern



Acceleration

Acceleration is the rate at which an object's velocity is changing. The change can be in how fast the object is moving, a direction change, or both. If you are driving an automobile and press down on the gas pedal (called the accelerator), your velocity changes. Let's say you go from 0 kilometers to 50 kilometers per hour in 10 seconds. Your acceleration is said to be 5 kilometers per hour per second. In other words, each second you are going 5 kilometers per hour faster than the second before. In 10 seconds, you reach 50 kilometers per hour.

You feel this acceleration by being pressed into the back of your car seat. Actually, it is the car seat pressing against you. Because of the property of *inertia*, your body resists acceleration. You also experience acceleration when there is a change in direction. Let's say you are driving again but this time at a constant speed in a straight line. Then, the road curves sharply to the right. Without changing speed, you make the turn and feel your body pushed into the left wall of the car. Again, it is actually the car pushing on you. This time, your acceleration was a change in direction. Can you think of situations in which acceleration is both a change in speed and direction?

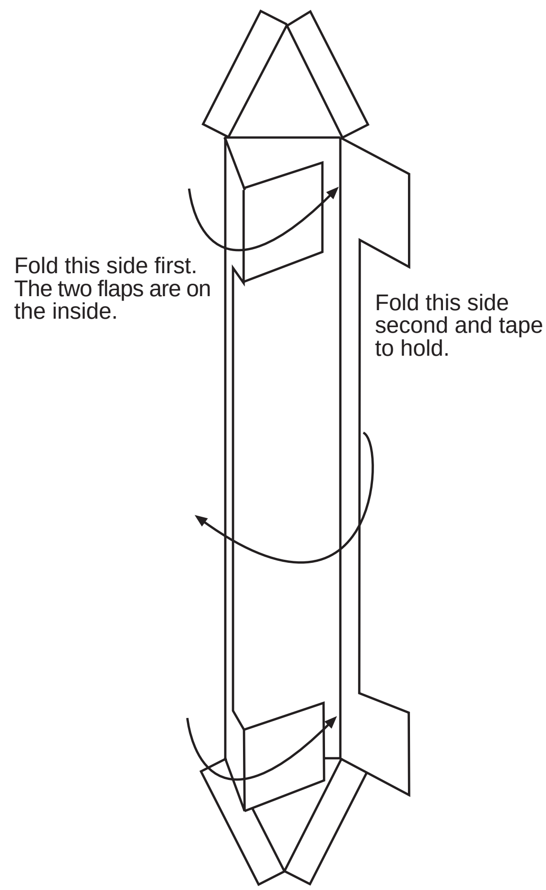
The reason for this discussion on acceleration is that it is important to understand that the force of gravity produces an acceleration on objects. Imagine you are standing at the edge of a cliff and you drop a baseball over the edge. Gravity accelerates the ball as it falls. The acceleration is 9.8 meters per second per second. After 5 seconds, the ball is traveling at a rate of nearly 50 meters per second. To create a microgravity environment where the effects of gravity on an experiment are reduced to zero, NASA would have to accelerate that experiment (make it fall) at exactly the same rate gravity does. In practice, this is hard to do. When you jump into the air, the microgravity environment you experience is about 1/100th the acceleration of Earth's gravity. The best microgravity environment that NASA's parabolic aircraft can create is about 1/1000th g. On the Space Shuttle in Earth orbit, microgravity is about one-millionth g. In practical terms, if you dropped a ball there, the ball would take about 17 minutes just to fall 5 meters!

Accelerometer Construction and Calibration

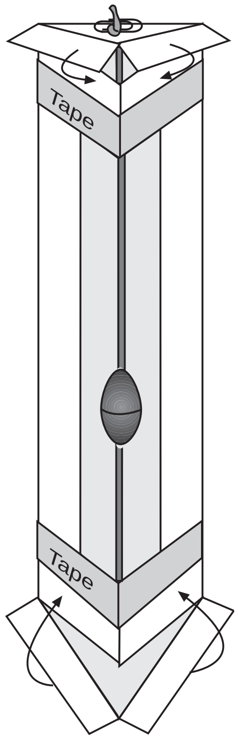
The instructions below are for making a measuring device called an accelerometer. Accelerometers are used to measure how fast an object changes its speed in one or more directions. This accelerometer uses a lead weight suspended by a rubber band to sense changes in an object's motion.

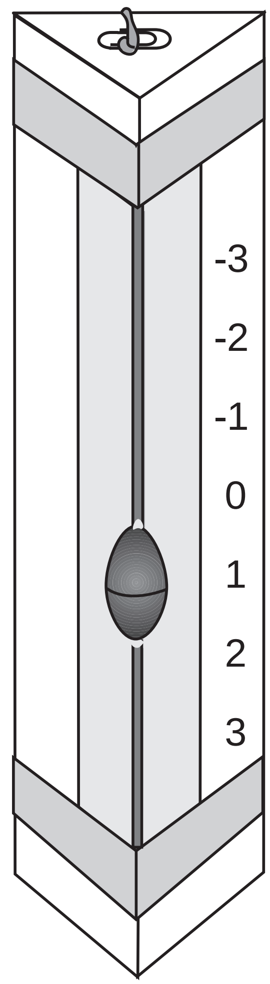
Building the Accelerometer:

1. Trace the pattern for the accelerometer on a piece of poster board. Cut out the pattern.
2. Use a ruler and a ballpoint pen to draw the fold lines on the poster board in the same place they are shown on the pattern. As you draw the lines, apply pressure to the poster board. This will make the poster board easier to fold.
3. Fold the two long sides up as shown in the first illustration. The left side with the tabs is folded over first. The right side is folded second. This makes a long triangle shape. Use tape to hold the sides together.
4. Punch a small hole in one of the end triangles. Cut the rubber band to make one long elastic band. Tie one end of the band to a small paper clip. Thread the other end through the hole.
5. Slip the lead weight on the band. Punch a hole in the other end triangle. While stretching the band, slip the free end through the second hole and tie it to a second paper clip.
6. Set the triangular box on its side so the window is up. Slide the weight so it is in the middle of the elastic band. Put a dab of hot glue on each end of the weight where the elastic band enters the holes.
7. If the elastic band sags inside the box, roll the elastic around one of the paper clips until it is snug. Then tape the paper clip in place. Tape the other triangular end in place.



Fold ends after rubber band and weight are attached. The two flaps on each end are folded to the outside.





Finished Accelerometer

Calibrating the Accelerometer:

1. Stand the accelerometer on one end. Using a pencil, mark one side of the accelerometer next to the middle of the weight. Identify this mark as 1 g.
2. Using a small paper clip as a hook, hang a second weight on the first. Again, mark the middle of the first weight on the accelerometer. Identify this mark as 2 g. Repeat this step with a third weight and identify the mark as 3 g.
3. Remove the two extra weights and stand the accelerometer on its other end. Repeat the marking procedure and identify the marks as -1 g, -2 g, and -3 g.
4. The final step is to mark the midway position between 1 and -1 g. Identify this place as 0 g. The accelerometer is completed.

Accelerometer Tests

Instrument Construction Team:

Test your accelerometer by jumping in the air with it a few times. What happens to the position of the sinker?

What g forces did you encounter in your jumps?

Where else might you encounter g forces like these?

Explain how your accelerometer measures different accelerations.

Design Activity:

How can this accelerometer be redesigned so it is more sensitive to slight accelerations? Make a sketch of your idea below and write out a short explanation.