

Inertial Balance

Objective:

- To demonstrate how mass can be measured in microgravity.

Science Standards:

- Science as Inquiry
- Physical Science
 - position and motion of objects
- Unifying Concepts and Processes
- Change, Constancy, & Measurement

Science Process Skills:

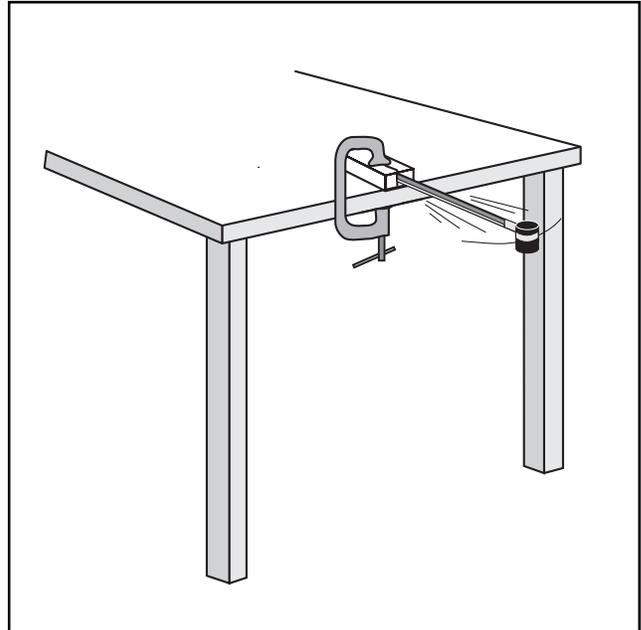
- Observing
- Communicating
- Measuring
- Collecting Data
- Making Graphs
- Interpreting Data
- Controlling Variables

Mathematics Standards:

- Communication
- Number & Number Relationships
- Computation & Estimation
- Measurement

Activity Management:

Before doing this activity, you will need to construct enough inertial balances for the entire class. Plan on having one balance for every three or four students. Except for the empty film canisters, which are free from photo processors, materials and tools for making all the balances can be obtained at a hardware store where lumber is also sold. To reduce your cost, buy hacksaw blades in multipacks. The dimensions for the wood blocks are not critical and you may be able to find a piece of scrap lumber to meet your needs. The only tools needed to construct the balances are a crosscut or backsaw to cut



Objects of unknown mass are measured with a balance that works in microgravity.

MATERIALS AND TOOLS	Hacksaw blade (12 inch) Coping saw (optional) 1 C-clamp (optional) Plastic 35mm film canister Tissue paper Masking tape Wood block (1x2.5x4 inch) Wood saws Glue Objects to be measured Graph paper, ruler, and pencil Pennies and nickels Stopwatch
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the wood into blocks and a coping saw to cut the notch for insertion of the blade. If you have access to power tools, use a table scroll saw to cut the notches. The notches should be just wide enough for the hacksaw blade to be slid in. If the notches are too wide, select a thinner blade for the coping or scroll saw.

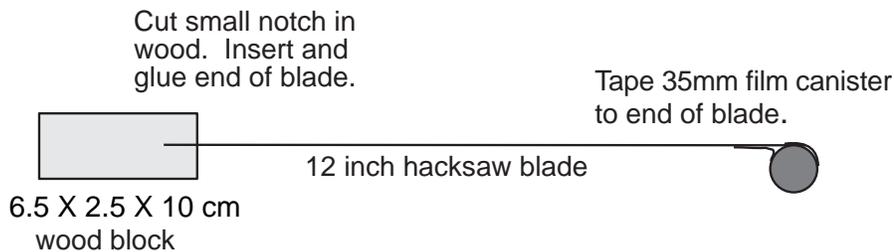
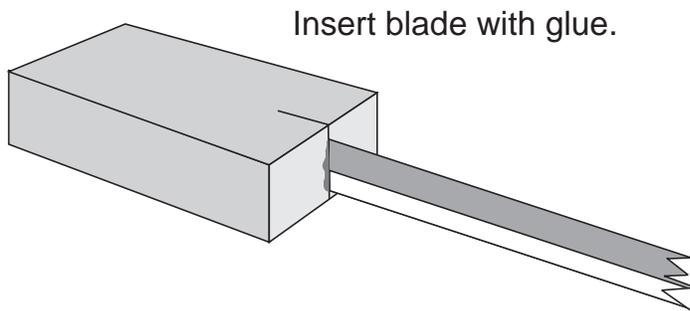
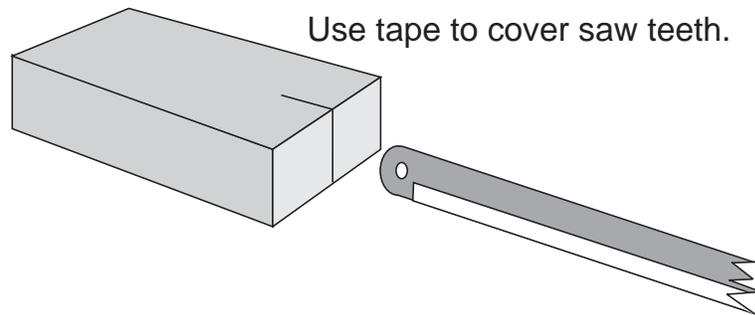


Cut the blocks, one for each balance, about 10 centimeters long. Cut a 2 centimeter deep notch in one end of each block. Slip one end of the hacksaw blade into the notch to check the fit. It should be snug. Remove the blade and apply a small amount of glue to both sides of the end and slip the blade back in place. Make sure the blade is slightly above and parallel to the bottom flat side of the block. Set the balance aside to dry.

Use tape to attach a film canister to the opposite end of each balance. Squirt hot glue into the bottom of the canister and drop in a large metal

washer. Repeat two more times. The reason for doing this is to provide extra mass to the canister end of the inertial balance. Students will be counting how long it takes the device to oscillate from side to side 25 times. A very light canister will swing faster than the students can count. Extra mass will slow the device so that counting is possible.

To use the inertial balance, students will place the wood block on the edge of a table



so the hacksaw and canister stick over the edge. The balance can be anchored with a clamp or just pressed to the tabletop by one student in the team. An object of unknown mass is placed in the canister and the students determine its mass by deflecting the blade so it swings from side to side. Unknown masses can be such things as nuts and bolts, washers, and pebbles. The tissue paper called for in the instructions anchors the unknown object in the canister so it will not slosh around and throw off the accuracy.

The first step for students is to calibrate the balance. This is done with a standard mass such as a penny. The length of time the balance takes to oscillate 25 times is measured for zero through 10 pennies. The results are plotted on a graph. When an unknown mass is placed in the canister, its time will be measured. By referring to the graph, students will be able to determine the unknown object's mass by seeing where it falls on the graph. The mass will be given in units of pennies. If desired, the balance can be calibrated in grams by measuring the pennies on a metric beam balance.

Save the student reader for use after the activity.

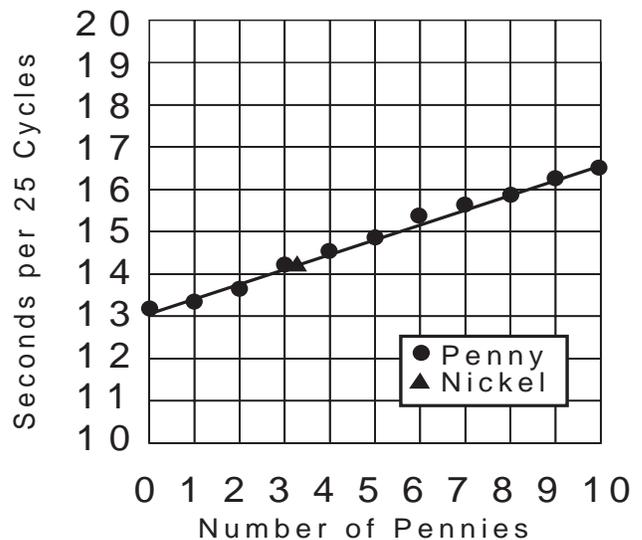
Assessment:

Collect calibration graphs and data sheets.

Extensions:

1. Construct and demonstrate inertia rods. The instructions follow. The materials list is found on the next page.
- A. Using a saw, cut the PVC tube in half. Smooth out the ends, and check to see that the caps fit the ends.
- B. Squeeze a generous amount of silicone rubber sealant into the end of one of the tubes. Slide the pipe into the tube. Using the dowel rod, push the pipe to the middle of the tube. Add sealant to the other end of the tube and insert

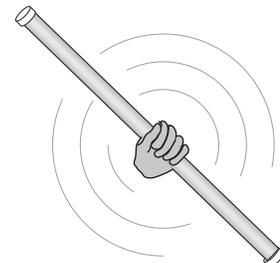
Sample Graph

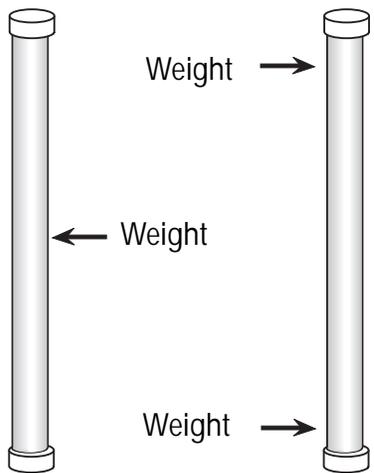


the second pipe. Position both pipes so they are touching each other and straddling the center of the tube.

Set the tube aside to dry.

- C. Squeeze sealant into the ends of the second tube. Push the remaining pipes into the ends of the tubes until the ends of the pipes are flush with the tube ends. Be sure there is enough compound to cement the pipes in place. Set the tube aside to dry.
- D. When the sealant of both tubes is dry, check to see that the pipes are firmly cemented in place. If not, add additional sealant to complete the cementing. Weigh both rods. If one rod is lighter than the other, add small amounts of sealant to both ends of the lighter rod. Re-weigh. Add more sealant if necessary.
- E. Spread some sealant on the inside of the PVC caps. Slide them onto the ends of the tubes to cement them in place.
- F. Use fine sandpaper to clean the rods.





MATERIALS AND TOOLS

- PVC 3/4 in. water tube
(about 1.5 to 2 m long)
- 4 iron pipe nipples (4-6 in. long
sized to fit inside PVC pipe)
- 4 PVC caps to fit water pipe
- Silicone rubber sealant
- Scale or beam balance
- Saw
- Very fine sandpaper
- 1/2 in. dowel rod

Demonstrate the rods by having a student pick up both of the rods from their upper ends and tell the class whether the rods feel the same. Then, the student grasps each rod by its middle, extends arms, and twists the rods side to side as rapidly as possible. One rod will be easy to twist and the other difficult. The effect is caused by the distribution of the mass in each rod. Because the ends of the rods move more rapidly than the middle during twisting, the student feels more

inertia in the rods with the masses at the ends than the rod with the masses in the middle. Relate this experience to the way the inertial balances operate.

2. Ask students to design an inertial balance that automatically counts oscillations.
3. Have students enter their calibration data into a graphing calculator and use the calculator to determine unknown masses when new measurement results are entered.



Inertia and Microgravity

The microgravity environment of an orbiting Space Shuttle or space station presents many research problems for scientists. One of these problems is measurement of mass. On Earth, mass measurement is simple. Samples, such as a crystal, or subjects, such as a laboratory animal, are measured on a scale or beam balance. In a scale, springs are compressed by the object being measured. The amount of compression tells what the object's weight is. (On Earth, weight is related to mass. Heavier objects have greater mass.) Beam balances, like a seesaw, measure an unknown mass by comparison to known masses. With both these devices, the force produced by Earth's gravitational attraction enables them to function.

In microgravity, scales and beam balances don't work. Setting a sample on the pan of a scale will not cause the scale springs to compress. Placing a subject on one side of a beam balance will not affect the other side. This causes problems for researchers. For example, a life science study on the nutrition of astronauts in orbit may require daily monitoring of an astronaut's mass. In materials science research, it may be necessary to determine how the mass of a growing crystal changes daily. How can mass be measured without gravity's effects?

Mass can be measured in microgravity by employing inertia. Inertia is the property of matter that causes it to resist acceleration. If you have ever

tried to push anything that is heavy, you know about inertia. Imagine trying to push a truck. You will quickly realize that the amount of inertia or resistance to acceleration an object has is directly proportional to the object's mass. The more mass, the more inertia. By directly measuring an object's inertia in microgravity, you are indirectly measuring its mass.

The device employed to measure inertia and, thereby, mass is the inertial balance. It is a spring device that vibrates the subject or sample being measured. The object to be measured is placed in the sample tray or seat and anchored. The frequency of the vibration will vary with the mass of the object and the stiffness of the spring (in this activity, the hacksaw blade). An object with greater mass will vibrate more slowly than an object with less mass. The time needed to complete a given number of cycles is measured, and the mass of the object is calculated.



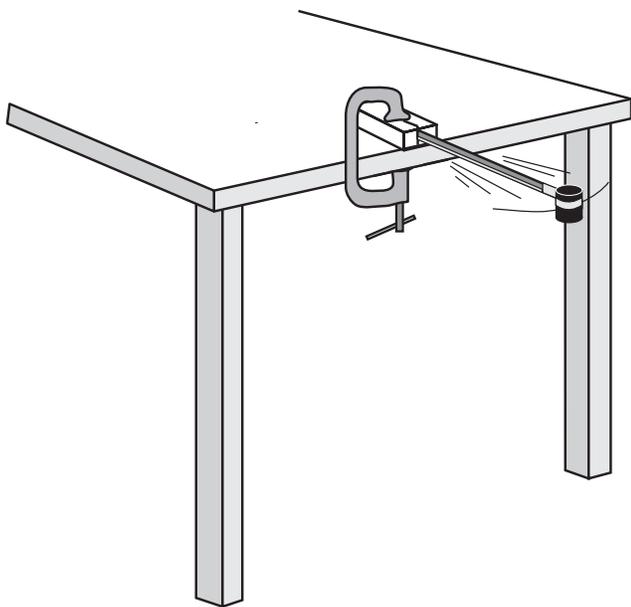
Payload Commander Dr. Rhea Seddon is shown using the Body Mass Measurement Device during the Spacelab Life Sciences 2 mission. The device uses the property of inertia to determine mass.



Measuring Mass With Inertia

Calibrating the Inertial Balance:

1. Clamp the inertial balance to the table so the spring (saw blade) and sample bucket extends over the edge of the table.
2. Pick one member of your team to be the timekeeper, another to record data, and another to count cycles. Refer to the box to the right for details on how to perform each task.
3. Begin calibration by inserting a wad of tissue paper in the bucket and deflecting the spring. Release the bucket and start counting cycles. When the time for 25 cycles is completed, enter the number in the data chart and plot the point on the graph for zero pennies. To improve accuracy, repeat the measurements several times and average the results.
4. Insert 1 penny into the bucket next to the tissue paper wad and measure the time it takes for 25 cycles. Record the data as 1 penny.
5. Repeat the procedure for 2 through 10 pennies and record the data.



Counter: Pull the sample bucket a few centimeters to one side and release it. At the moment of release, say "Now" and begin counting cycles. A cycle is completed when the sample bucket starts on one side, swings across to the other and then returns to its starting point. When 25 cycles are complete, say "Stop."

Timer: Time the number of cycles being counted to the nearest tenth of a second. Start timing when the counter says "Now" and stop when the counter says "Stop."

Recorder: Record the time for 25 cycles as provided to you by the timer. There will be 11 measurements. Plot the measurements on the graph and draw a line connecting the points.

6. Draw a line that goes through or close to all points on the graph. Your inertial balance is calibrated.

Using the Inertial Balance:

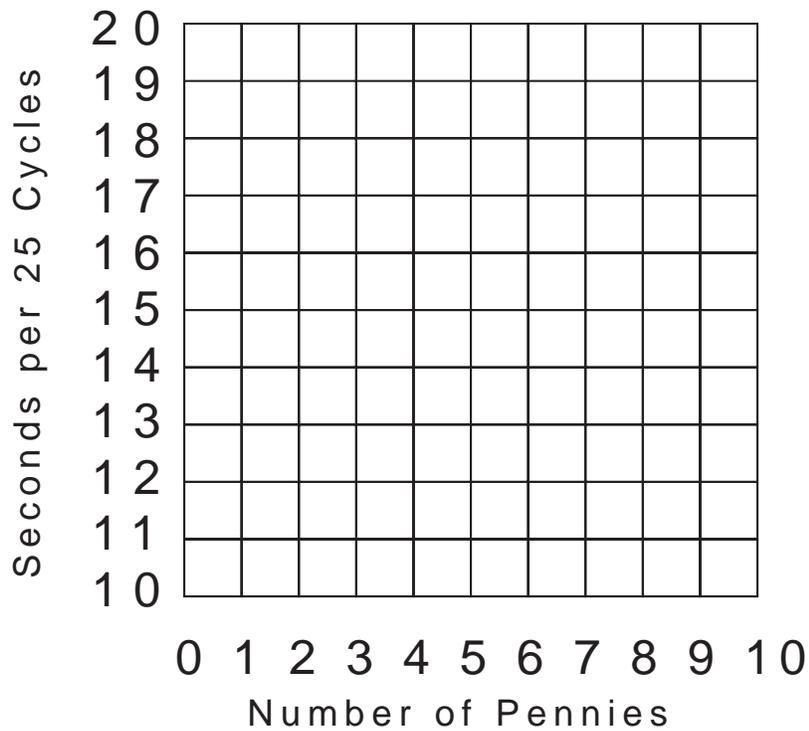
1. Place an unknown object in the inertial balance bucket. Remember to use the same tissue paper for stuffing. Measure the time for 25 cycles. And record your answer.
2. Starting on the left side of the graph, find the number of seconds you measured in step 1. Slide straight over to the right until you reach the graph line you drew in the previous activity. From this intersection point, go straight down to the penny line. This will tell you the mass of the unknown object in penny weights.



Measuring Mass With Inertia

Measurement Team: _____

Calibration Graph



Unknown Object 1

Mass: _____ pw

Unknown Object 2

Mass: _____ pw

Unknown Object 3

Mass: _____ pw

Unknown Object 4

Mass: _____ pw



Questions:

1. Will this technique for measuring mass work in microgravity? Yes_____ No_____
Explain your answer:

2. Why was it necessary to use tissue paper for stuffing?

3. How could you convert the penny weight measurements into grams?

4. Would the length of the hacksaw blade make a difference in the results?

5. What are some of the possible sources of error in measuring the cycles?

6. What does a straight line in the calibration graph imply?

