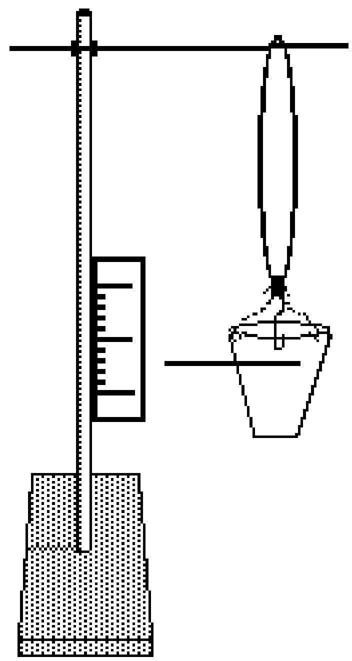
# MEASUREMENT OF MASS

**PROBLEM PRESENTATION:**

A. The CHALLENGE in this activity is for students to build a spring balance to find the unknown mass of an object. A commercial spring balance should be available for them to examine. Also, a previously constructed spring balance like they will be building should be on display.

B. Station Setup

1. Five stations will be identically equipped with a 3 ounce paper cup, four paper clips, a large elastic rubber band, a metric ruler, a couple of metal washers, and a toothpick (Bag #1). These materials will be used to construct and calibrate a spring balance (see diagram).



2. Our unit of mass will be nontraditional; we will measure mass in "penny units." (Use pennies minted after 1982 because the composition of pennies, and therefore their weight, changed in 1982.)

3. The students should be instructed to build a spring balance from the materials found in bag #1 so that they can determine the unknown mass of the object provided, in "penny units." This can be done by determining the stretch for zero pennies, 5 pennies, 10 pennies, etc. By plotting # pennies on the x axis and the "stretch", on the y axis a simple calibration curve can be made. The stretch can be indicated by the graduations on the ruler for zero pennies, 5 pennies, etc.

4. Each of the groups should attempt to find the mass of the same object. Because all rubber bands will not stretch the same, the calibration curves may look different for different groups. But the value determined from each calibration curve should result in the same mass for the common object being considered.

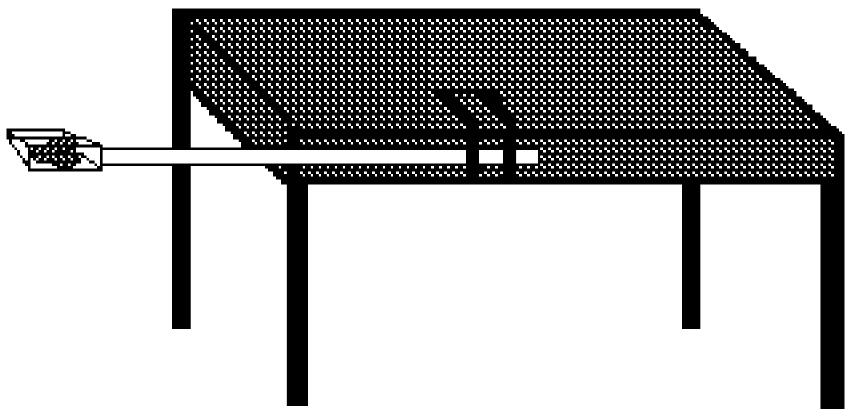
| Mass (pennies) | 0 | 5 | 10 | 15 | 20 | 25 |
|---|---|---|---|---|---|---|
| Stretch (cm) | 43 | 53 | 65 | 75 | 88 | 9 |

5. Instruct the students that once they know the stretch of the unknown object they should locate this position on the Y axis (for example, 85 cm). Then, starting at this position and moving right in a line parallel to the X axis they will reach the calibration line. Now, if they go down from here parallel to the Y axis until the line crosses the X axis, they will instantly have determined the mass of the unknown object (19 pennies).

**CLASS RESPONSE / CONCEPT INVENTION**

A. After a reasonable mass of the unknown object has been determined, ask whether this process would work to find out the mass inside the NASA's shuttle while in space. Point out that since there is no gravity in the shuttle, the spring balance would register **0 penny units** when the unknown mass was attached to the spring balance. To solve this problem we need to construct an inertia balance.

1. How could they determine the mass of the object in space by using the materials in bag #2? Indicate that as in the previous determination, a calibration curve will have to be constructed.
2. Bag #2 should contain a hacksaw blade, a clamp, an empty paper clip box. The box should be secured to the hacksaw blade with tape. By then clamping the blade to the table it should be free to swing back and forth. (As in the case of the spring balance, an inertia balance should be constructed ahead of time and put on display to help guide the students in their construction of their inertia balance. See diagram below.)



3. The inertial mass can be determine by the effect of the object on the oscillation of the blade. Perhaps the easiest way to do this is to determine the period of oscillation (the time that it takes for the blade to oscillate back and forth once.) To get a good period of oscillation, count the number of oscillations in a given number of seconds (say, 10 seconds), and then divide the number of seconds by the number of oscillations. Remember one oscillation is one swing left to right and back to left, and the period is the time per oscillation.

| Pennies Added | Number of Oscillations | Time for 10 Oscillations (seconds) | Period (sec/oscillation) |
|---|---|---|---|
| 0 | 10 | | |
| 10 | 10 | | |
| 20 | 10 | | |
| 30 | 10 | | |
| 40 | 10 | | |
| 50 | 10 | | |
| Unknown Mass 1st Trial | 10 | | |

| | | | |
|---|---|---|---|
| Unknown Mass 2nd Trial | 10 | | |

Now plot on the y axis your experimentally determined period and on the x axis the mass in "penny units." This is now a calibration curve for determining the inertial mass of an object. It should be a straight line. It can be used to find the mass of an unknown by putting the unknown mass in the box, finding its period, and reading its mass off the calibration curve.

B. Would you expect the inertial mass and gravitational mass to be the same for a given object? Are they? What is the ratio of the inertial mass to the gravitational mass? How do we explain this? What would the gravitational mass be on the moon? (The gravity on the moon is 1/6 that of gravity on the earth.) What would be the gravitational mass on Jupiter? (The gravity on Jupiter is 2.37 times that of gravity on the earth.) What would be the ratio of inertial mass to gravitational mass on the moon? on Jupiter?

**CONCEPT EXTENSION**

A. In answering the questions in part B. under CLASS RESPONSE / CONCEPT INVENTION we assumed that inertial mass stayed constant while gravitational mass changed depending on location.

1. Are these assumptions true?
2. We know that Astronauts train in airplanes where there is zero gravity before they go into space. Without going into space, can we simulate a change in our gravitational mass? For example, what happens to apparent gravitational mass when we descend in an elevator? What happens to our inertial mass when descending in the same elevator?
3. Ask students to reason out how common bathroom scales work. If someone has an old set of scales, take it apart so that they students can see that there is a spring inside that responds to different amounts of mass placed on it. In other words, it can be thought of as acting somewhat like the spring balance that they build in class. What effect would the downward movement of the elevator have on the apparent mass registered on the scales? [It should simulate less gravity such as would be found on the moon, however, not to the same extent.]
4. Have students go to a building that has an elevator (the speedier the elevator, the better.) Have them place a working set of bathroom scales (one with digital readout would be best) on the floor of the elevator and have one student stand on it while the elevator is motionless. Have another student record the gravitational mass. As the elevator starts to move have the student recorder call out the gravitational mass until the elevator comes to rest. Did the gravitational mass change? [Yes]
5. Transport the spring balance and the inertial balance to the elevator and determine whether the gravitational mass and the inertial mass can be detected to change as the elevator descends. These determinations should only be attempted after the students are relatively accomplished in using their spring and inertial balances. [The gravitational mass will change but not the inertial mass.]
6. Because everyone may not have access to an elevator, see if you can get a student to ride along with the experimenters and videotape the events so that the rest of the class can experience the extension of the relationship of gravitational mass and inertial mass.