Mathematics/Physics

The Inertial Balance

Carl E. Martikean
10937 Sheephead Court
DEMOTTE IN 46310-9352
cmartikean@yahoo.com

Lew Wallace High School
415 W. 45th Ave.
GARY IN 46408
(219) 980-6305

Objective(s):

At the end of this lesson, the student will be able to:

1. Explain how either a single pan or double pan balance operates;
2. Explain the physics principle of the balance using Newton's First and Second Laws;
3. Differentiate between mass and weight;
4. Explain how mass and weights are related using Newton's First and Second Laws;
5. Explain the difference between gravitational and inertial mass.

Materials:

Triple beam balance	Centigram balance
Various masses	Two c-clamps
Metal meter stick or 1m of thin metal flat	Wooden blocks formed into an L shape to hold the meter stick in a horizontal position.
35mm film container to be attached to the end of the meter stick	Masking tape, stop watch

Strategy:

Many students confuse the concepts of mass and weight. Our purpose here is to clarify for the student, through self-discovery, the difference between mass and weight. Further, the student will be challenged to discover how to "weigh" objects in outer space with an inertial balance.

Performance Assessment:

Briefly describe the performance assessment that you would use and the expected results that should be obtained. A grading rubric would also be nice.

Background

Weighing, really massing on the surface of a planet or planetoid is easily demonstrated with either a two-pan balance or a centigram balance. Ask students what the balance is measuring (mass or weight). Then start a discussion of how the balance operates. What we ultimately are looking for are the physics principles of the balance. Among these are the fact that gravity is used and that no matter what body we were standing on the balance would operate exactly the same. But what would be different? So just what is the balance measuring- mass or weight? How do we know? So, in order to successfully use either a beam balance or a spring balance we need a gravitational force. These balances are a simple (?) demonstration of Newton's second law. So does the balance measure mass or weight? Why?

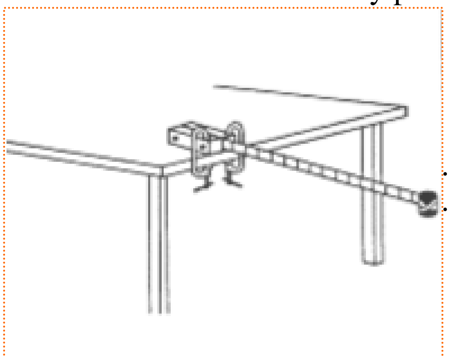
What if you were in the orbiting Space Shuttle or space station? Would this balance work? What problems would be present? The measurement of mass presents a unique problem. How do we measure mass in a microgravity environment?

In space, because of the free fall conditions neither a beam or spring balance will operate. So there must be a third method of measuring a mass of an object. This brings us back to Newton's first law. This law is the principle of inertia, the property of matter that resists acceleration. The amount of resistance (laziness) is directly proportional to the mass of the object.

To measure mass in space, scientists use an inertial balance. An inertial balance is a spring device that vibrates the sample being measured. The frequency of the vibration will vary with the mass of the object and the stiffness of the spring. In this case we are using a metal meter stick. For a given spring, an object with greater mass will vibrate more slowly than an object of lesser mass. The object to be measured is placed in the balance, and a spring mechanism starts the vibration. The time needed to complete a given number of cycles is measured, and the mass of the object is calculated.

Procedure:

1. Using a drill and bit to make the necessary holes, bolt two blocks of wood to the opposite sides of one end of the metal meter stick.
2. Tape an empty plastic film canister to the free end of the meter stick. Insert a piece of foam into the canister.
3. Anchor the wood block to the table top with C-clamps. The opposite end should swing freely from side to side.
4. Calibrate the inertial balance by placing objects of known mass (pennies) in the sample bucket (canister with foam plug). Begin with just the bucket. Push the end of the meter stick to one side and release it. Using a stopwatch or clock with a second hand, time how long it takes the stick to complete 25 cycles.



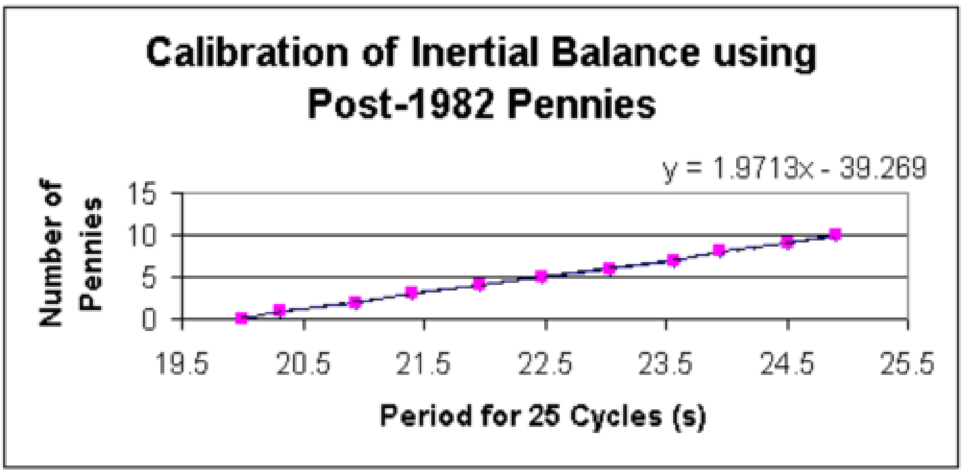
5. Make a plot of the data. (See the sample graph.)
6. Place a single penny in the bucket. Use the foam to anchor the penny so that it does not move inside the bucket. Any movement will result in an error (oscillations of the mass can cause a damping effect). Measure the time needed to complete 25 cycles. Plot this data.
7. Repeat this procedure for different number up to 10 pennies.
8. Draw a curve on the graph through the plotted points.
9. Place a nickel in the bucket and measure the time for 25 cycles. Use the pennies plot to determine the mass of the nickel in "penny" units.

Conclusions:

25 cycles (s)	Number of Pennies
19.99	0
20.31	1
20.94	2
21.4	3
21.97	4
22.47	5
23.03	6
23.57	7

23.94	8
24.5	9
24.9	10

Quarters	
20.81	1
22.06	2



Questions

1. Does the length of the meter stick make a difference in the results?
2. What are some of the possible sources of error in measuring the cycles?
3. Why is it important to use foam to anchor the pennies in the bucket?
4. Is there a difference between the nickel's inertial mass and its gravitational mass?

References:

Experiment III-3 Inertial and Gravitational Mass Physics: Laboratory Guide, Physical Science Study Committee, D.C. Heath and Company, copyright 1965.

Activity 4 : *Inertial Balance Part 1* Microgravity: a Teacher's Guide with Activities (Secondary Level) National Aeronautics and Space Administration, July, 1992