Teacher Tech Brief

Impact Resistance Tester

Graphic

One of the hazards of spacewalking is the presence of small high-speed particles. These particles are called micrometeoroids and usually are smaller than a grain of sand, have a mass that is only a fraction of a gram, and travel at speeds ranging from a few to as many as 80 kilometers per second. An astronaut struck by a micrometeoroid could be severely injured. Furthermore, the near-Earth space environment has the additional problem of space debris such as paint chips and metal fragments from old rocket boosters and satellites. Being struck by one of these particles is equally dangerous. As a consequence, spacesuits have to be constructed from materials that are resistant to impacts.

Purpose

This test stand measures the resistance of sample materials to impacts.

Principle

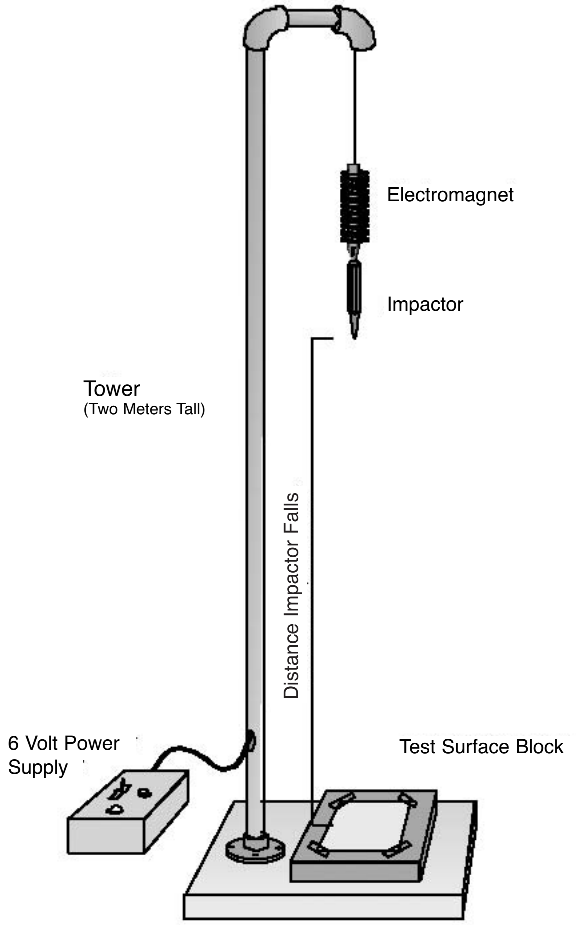
The test stand consists of a tower, made from pipe, with an electromagnet near the top. A center punch (impactor) is suspended from the magnet and drops when the electricity is cut off. The center punch falls into a test sample placed below.

Materials and Tools Checklist

- ☐ Wooden base (6" x 1" x 2')
- ☐ PVC plastic water pipe (3/4" x 10')
- ☐ Pipe elbows (2 pcs)
- ☐ Pipe flanges (1 pc)
- ☐ Screws for flange
- ☐ Bell wire
- ☐ Large eye screw
- ☐ Electronic project box
- ☐ On/off switch
- ☐ Pilot light
- ☐ Push button switch
- ☐ 6 volt battery holder
- ☐ Wooden block (1" x 6" x 6")
- ☐ Center punch
- ☐ Screw driver
- ☐ Meter stick
- ☐ Test materials
- ☐ Tape or pins

Operation

Cut the material to be tested into a small square and tape or pin it on the test surface block (1" x 6" x 6" wooden block). After positioning the test material, turn on the electromagnet and attach the impactor.



Measure the distance between the point of the electromagnet and the test material. When the impactor and magnet stop swinging, turn off the electric current to release the impactor. As it falls, the impactor will accelerate into the sample and make a dent or even penetrate it. Evaluate the resistance to impacts of various materials by comparing the damage done to them. Use a metric ruler for measuring the diameter of the dent or hole.

Mathematics Equations

In physics, the energy of a moving object is called kinetic energy. The amount of that energy is related to the object's mass and its speed. The equation below can be used to determine the kinetic energy of the falling center punch at the moment of its impact on the test surface. The answer will be in joules (unit of work equal to a force of one Newton exerted over a distance of one meter; in English units, a joule is approximately equal to 0.75 foot pounds).

$$KE = 1/2\ mv^2$$

m = mass of impactor
v = velocity at impact

To determine the velocity at the impact, use the following equation:

$$v = gt$$

g = the acceleration of gravity or $9.8 m/second^2$
t = length of time the impactor fell

To determine the length of time the impactor falls. use the following equation:

$$t = \sqrt{\frac{2d}{g}}$$

d = the distance the impactor fell, in meters

Sample Problem
d = 2 m
Impactor mass = 50 grams
What is KE?

$v = 9.8 m/s^2$
x 0.64s = 6.3m/s
KE = 1/2 x 0.05kg x (6.3m/s) 2 = 1.19 joules

Special Note

In this simulation of micrometeoroid impact we are substituting an impactor with a large mass and low velocity for a micrometeoroid with a small mass and a high velocity. The reason for this can be seen in the first two equations on the previous page. Velocity is a quadratic factor while mass is a linear factor. Because of this trade, we can achieve similar damage to the surface of a material being impacted. However, micrometeoroids usually vaporize upon impact. If the surface layer is penetrated, the gas produced disperses on the material beneath.

Safety Precautions

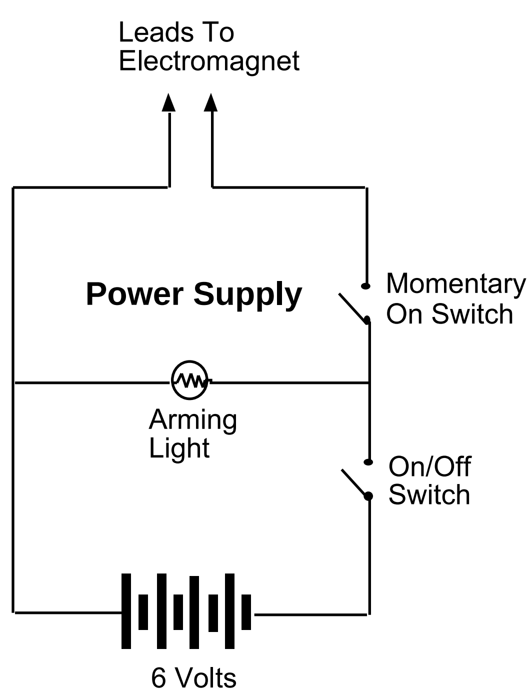
1. All operators and observers must wear eye protection during drops.

2. The materials to be tested should be placed on the test stand before the impactor is suspended from the electromagnet. Nothing but the material to be tested should under the suspended impactor.

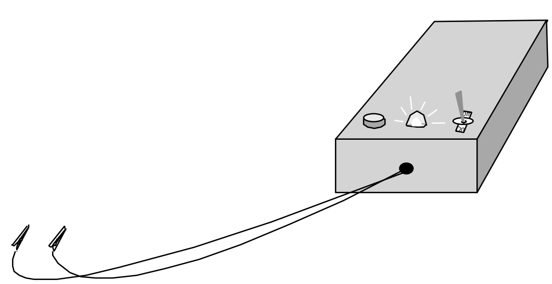
Tips

- Parts for the impactor design pictured in this activity are available from hardware stores (pipe parts, screws, eye screw, center punch) and electronic parts stores (project box, switch, battery holder, pilot light, electromagnet wire).
- Make your electromagnet by wrapping electromagnet wire about 400 times around a large eye screw. When the magnet is electrified the blunt end of the impactor will be held by the magnet. When the current is turned off, the magnet impactor will drop straight to the target.
- Have students bring in various materials for testing such as fabrics and plastics. Encourage students to create composite materials by combining two or more materials together.
- Ask students to keep a test log containing data from each test. Encourage students to predict the amount of damage a sample will receive during a test and compare that to the actual results.
- Discuss the relative merits of the materials the students tested. For example, a thick layer of

Wiring Diagram for Power Supply



Finished Power Supply



steel would make an excellent micrometeoroid shield but would probably be too heavy and too inflexible to be of use in a Martian suit.

- Before running tests on impact resistance, use Exploration Brief on Micrometeoroids and Space Debris (p. 67) with the students to introduce the topic of spacesuits and impacts. After your students have selected materials for their spacesuit, challenge them to wrap a potato in their materials and see if the materials prevent penetration in the drop test. Refer to the potato astronaut activity for more information.
- A typical micrometeoroid has a mass of 1x10-5 grams and travels at about eight kilometers per second.Upon impact, approximately three joules of work is expended.
- A drop tower is not necessary for this test. The electromagnet can be suspended from a pulley from the ceiling. The tower, however makes the unit very portable and eliminates any hazards associated with attaching a pulley to a high ceiling.
- For younger students, begin studying the mathematics of the device with observations on the speed of the impactor as it falls. It will be observed that the farther the impactor falls, the faster it falls.

Extensions

- The impactor can be dropped from any height when testing materials. At what height should the impactor be suspended to equal the impact of a micrometeoroid in space if the micrometeoroid has a mass of 1x10-5 grams and a velocity of 8,000 meters per second? Velocity of 16,000 meters per second? (Your answers will depend upon the mass of the impactor you use.)
- How much kinetic energy is expended by the micrometeoroid above?
- Challenge the students to combine the equations on the previous page into simpler mathematical statements.
- How high should the impactor be before dropping to simulate the impact of a micrometeoroid with a mass of 1x10-5 grams and a velocity of eight kilometers per second? How high should the impactor be suspended if the micrometeoroid's velocity is 16 kilometers per second?