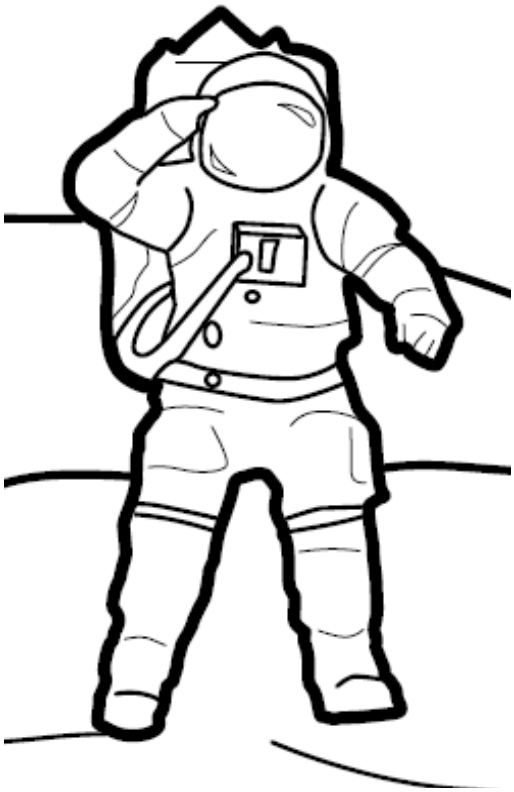

Figure 1. Extravehicular Mobility Unit outside of the International Space Station.

National Science Content Standards:

Physical Science

- Position and motions of objects
- Motions and forces

National Mathematics Content Standards:

- Number and operations
- Measurement
- Data Analysis

National Mathematics Process Standards:

- Problem Solving
- Reasoning and Proof
- Connections
- Representations

Engineering Activity 2

High Velocity Debris: Space Suit Protection

Objective

To investigate the relationship between mass, velocity, acceleration, force, and kinetic energy as described in Newton's second law of motion and the equations of motion (assuming constant acceleration).

NASA Challenge

You are a NASA Space Suit Engineer, and you need to select the best material to be used on your space suit. You need to select a material that can survive an impact by a piece of space debris the size of a marble traveling at various speeds.

Materials

Empty tissue box

Scissors

Tape

6 sheets of tissue paper

6 sheets of paper towel

3 marbles of different sizes and masses

1 meter stick

Management

This activity can be conducted in a classroom environment. This activity can be performed on a team of at least four (4) students. Tissue boxes with the top cut off work well.

Double check the taping of the paper to the tissue box to ensure the tape will not peel up. The paper needs to be tight over the opening of the tissue box. Loose paper will negatively affect the results of the exercise.

Guide the students through the paper replacement.

Background

The international Space Station (ISS) orbits between 370-460 kilometers (230 – 286 miles) above the surface of the earth. The ISS is surrounded by man-made debris which can impact the ISS or the astronauts in space suits outside of the ISS at speeds between 4 -7 kilometers per hour (8948 – 15658 mph). Debris traveling at high speeds can cause life threatening damage to the space station or the space suits.

Procedure: Making the Impact Box

1. Explain the activity to the students.
2. Remove tissue from the tissue box.
3. Using scissors, cut the top of the tissue box off.
4. Place paper (tissue or paper towel) on top of tissue box opening.
5. Use tap to tape the paper to the four sides of the tissue box. Make sure the paper is tight over the opening of the tissue box.

Procedure: Test 1A: Change Marble Velocity

1. Select an open space in the classroom to conduct the test.
2. Make sure the tissue paper is properly secured over the impact box.
3. Suit Engineer #1 will hold a meter stick along the side of the box.
4. Suit Engineer # 2 will have a timer and will record the time it takes the marble to collide with the impact box.
5. Using the smallest marble, Suit Engineer # 3 will drop the marble 25 cm above the top surface of the impact box.
6. Suit Engineer # 4 will document the time it takes the marble to collide with the impact box and whether or not the test is a pass/fail. Pass means no damage was done to the tissue paper. Fail means the marble did damage the tissue paper.
7. Repeat steps # 2 – 6 while steadily increasing the distance marble is dropped by 25 cm until marble goes through material or you reach 100 cm.

Procedure: Test 1A: Change Marble Velocity and Suit material

1. Replace damaged tissue paper with paper towel. Make sure the paper towel is properly secured over the impact box.
2. Suit Engineer #1 will hold a meter stick along the side of the box.
3. Suit Engineer # 2 will have a timer and will record the time it takes the marble to collide with the impact box.
4. Using the smallest marble, Suit Engineer # 3 will drop the marble 25 cm above the top surface of the impact box.
5. Suit Engineer # 4 will document the time it takes the marble to collide with the impact box and whether or not the test is a pass/fail. Pass means no damage was done to the tissue paper. Fail means the marble did damage the tissue paper.
6. Repeat steps # 2 – 6 while steadily increasing the distance marble is dropped by 25 cm until marble goes through material or you reach 100 cm.

Procedure: Test 2: Change Marble Size

1. If necessary, replace damaged paper towel with another paper towel. Make sure the paper towel is properly secured over the impact box.
2. Suit Engineer #1 will hold a meter stick along the side of the box.
3. Suit Engineer # 2 will have a timer and will record the time it takes the marble to collide with the impact box.
4. Using the second smallest marble, Suit Engineer # 3 will drop the marble 25 cm above the top surface of the impact box.
5. Suit Engineer # 4 will document the results. Pass means no damage was done to the tissue paper. Fail means the marble did damage the tissue paper.
6. Repeat steps # 2 – 6 while steadily increasing the distance marble is dropped by 25 cm until marble goes through material or you reach 100 cm.
7. If necessary, replace damaged paper towel with another paper towel. Make sure the paper towel is properly secured over the impact box.
8. Suit Engineer #1 will hold a meter stick along the side of the box.
9. Suit Engineer # 2 will have a timer and will record the time it takes the marble to collide with the impact box.
10. Using the largest marble, Suit Engineer # 3 will drop the marble 25 cm above the top surface of the impact box.
11. Suit Engineer # 4 will document the results. Pass means no damage was done to the tissue paper. Fail means the marble did damage the tissue paper.
12. Repeat steps # 2 – 6 while steadily increasing the distance marble is dropped by 25 cm until marble goes through material or you reach 100 cm.

Discussion

1. When the same-sized marble was dropped from a different height, did it hit the paper with the same velocity?

   Answer:

   No. The average speed of an object is defined as the total distance an object (in this case the marble) moves during a time interval Δt.

   savg= total distanceΔt

   Speed is directly related to the total distance traveled. As you increase the distance, you increase the total speed. Speed is indirectly related to the time interval. As you increase the time interval, the speed decreases. For this activity, the magnitude of the total distance increased at a greater rate than the time interval, therefore as marble was dropped from a higher distance, the average speed increased.

2. When the different sized marbles were dropped from the same height, did they hit the tissue with the same velocity?

   Answer: No.

Assessment

- Have students fill out data sheets documenting their results.
- Review student data sheets and their conclusions with the class.

Extensions

For advanced students, the following equation can be used to find the kinetic energy of each of the marble cases.

KE= 12mv2