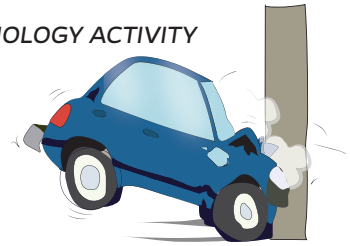
Name: _____ Class: _____ Date: _____

UNDERSTANDING CAR CRASHES: WHEN PHYSICS MEETS BIOLOGY ACTIVITY

STRESSING OVER PENCIL PRESSURE



MATERIALS NEEDED

DAY 1

Per pair of students

- One mechanical pencil with lead and an eraser (with the lead diameter written on the pencil)
- One metric ruler with millimeters marked

Per student

- One "Stressing over Pencil Pressure" Student Activity Sheet
- One calculator
- **OPTIONAL:** One sheet of notebook paper

Key Question

- How can magicians lay on a bed of sharp nails unharmed? Is it magic or science?
- How are force, pressure, and stress relevant in engineering strong and safe vehicles?

Did You Know?

The physics concepts of force, pressure, and stress are all related but all different. Automotive engineers must understand the differences between these three concepts as well as their relationships to each other in order to design strong and safe structural components for vehicles, such as roofs and body frames. In this activity you will use mechanical pencils to conduct tests similar to a bed-of-nails demonstration on a smaller scale to investigate the relationships between these concepts.

Purpose

- To explain the relationship between force and pressure.
- To describe the relationship between surface area and pressure.
- To explain how engineers differentiate between pressure and stress.
- To describe how the concepts of force, pressure, and stress are relevant when designing strong and safe vehicles.

Procedure

Part 1 - Making Observations about Pencil Pressure

Push the pencil lead out so that it is sticking out 3 mm from the tip of the pencil. Take turns conducting the pencil pressure test on your own hands and work with your partner to describe your observations.

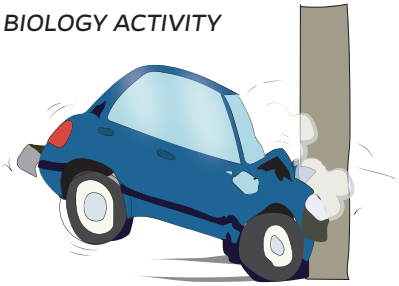
a. Pencil Pressure Test Instructions: Gently press each end of the mechanical pencil (pencil lead end and eraser end) between the centers of your palms or between the index fingers of your left and right hands (see Figures 1 and 2) and hold the pencil in place for 3 seconds. During this time, you should hold your hands or fingers steady so the pencil remains stationary (and does not move to the left or to the right).

Safety Warnings: Briefly and gently press the pencil between your palms or fingers and do not use your pencils to conduct tests on others.

Figure 1

Figure 2

STRESSING OVER PENCIL PRESSURE



Procedure (continued)

Part 1 - Making Observations about Pencil Pressure

1. Describe how the two different ends feel WITHOUT using the words force, pressure, or stress.

» Pencil lead end observations:

» Eraser end observations

Part 2 - Making Inferences about Pencil Pressure

After partners have conducted the pencil pressure test, work together to answer the following question:

2. As you gently pressed your palms together, do you think each end of the pencil applied the same amount of force to each of your palms/fingers or different amounts of force to each palm/finger? Explain why you think the forces were equal or different.

Part 3 – Recording Pencil Measurements

3. Using a metric ruler with millimeter (mm) markings, measure the diameter (the distance across a circle through its center point) of the pencil's eraser. Record it below.

» Eraser diameter = _____ **(mm)**

4. Record the diameter of the pencil lead in the space below. On most mechanical pencils, the diameter is written at the end of the pencil near the eraser (see Figure 3).

» Lead diameter = _____ **(mm)**

Figure 3

Part 4 - Calculating Radius, Surface Area, and Pressure

Your pencil pressure observations can be explained mathematically using the measurements from Part 3 to make a few calculations. Work with your partner to complete the calculations for radius, area, and pressure. NOTE: For all calculations, show your work in the margins of this activity sheet or on a separate sheet of notebook paper. Record your final calculations below

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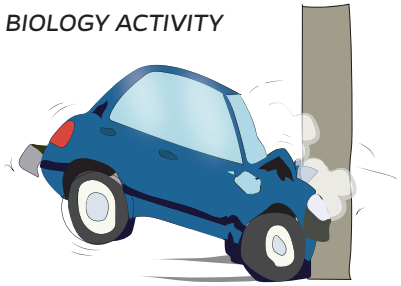


Procedure (continued)

Part 4 - Calculating Radius, Surface Area, and Pressure

5. First, calculate the radius of the eraser and the radius of the pencil lead.
Radius = Diameter ÷ 2

» Eraser radius = _____ **(mm)**

» Lead radius = _____ **(mm)**

6. Next, convert the radius of the pencil eraser and the radius of the pencil lead from millimeters (mm) to meters (m). Remember that 1 m = 1000 mm, so divide the radius in mm by 1000. For example: 5 mm ÷ 1000 = 0.005 m.

» Eraser radius = _____ **(m)**

» Lead radius = _____ **(m)**

7. Since both the pencil lead and the eraser are circular, use each radius calculated in question 6 to calculate the cross-sectional surface area of the eraser and the cross-sectional surface area of the lead using the formula for the area of a circle. NOTE: For ease of calculation in this activity, we are assuming that the shape of the eraser remained circular even after it was pressed against your skin. Area (A) = $\pi \times r^2$

A = cross-sectional surface area of a circle (m^2) = π = 3.14

» r = the radius of either the eraser or the lead (m) = _____ **(m)**

» Eraser cross-sectional surface area = _____ **(m^2)**

» Lead cross-sectional surface area = _____ **(m^2)**

8. To simplify the calculations required, assume that a force (F) of 0.5 Newtons was applied by each end of the pencil during everyone's pencil pressure tests. Use this force value and the cross-sectional surface areas calculated in item 7 to calculate the amount of pressure exerted on your palms or fingers by the eraser end and the pencil lead end in the pencil pressure test.

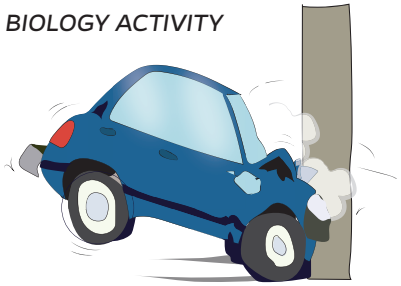
P = F ÷ A
P = Pressure (N/m^2) or Pascals (Pa)
F = Force applied to the surface (N)
A = cross-sectional surface area (m^2)

» Eraser pressure = _____ **(Pa)**

» Lead pressure = _____ **(Pa)**

Read the following paragraphs and discuss them with your partner. Then be ready to share two general conclusions you can make about pressure and stress and their engineering applications.

STRESSING OVER PENCIL PRESSURE



Procedure (continued)

Part 5 – Exploring Pressure and Stress

Is pressure the same as stress? Not really, but their amounts can be the same if the same force is applied to a material. Pressure and stress are closely related. Mathematically, they both are equal to force divided by area (F/A). But one of the biggest differences between the two is where the force is applied on a material. With pressure, the force is applied on the outside surface of the material. With stress, the force is applied inside or within the material. Pressure on the outside of a material can cause stress inside a material.

How do engineers use stress to test the strength of an object? One of the ultimate goals of mechanical and civil engineers is to design safe structures that are strong enough to withstand a wide variety of external forces such as wind, earthquakes, or collision (impact) forces. Whether designing bridges or vehicles, engineers help to ensure the safety of structures by analyzing the strength of their component parts (e.g., a bridge support pillar or the bumper of a car). One method used to test the strength of structural components is a stress test. In stress tests, pressure is applied to the outside of a component to create stress inside the component until the component reaches its stress limit and fails (i.e., breaks, fractures, crumbles, or deforms excessively).

Analysis Questions

1. Describe how the two different ends feel WITHOUT using the words force, pressure, or stress.

2. Compare your pressure calculations for the pencil eraser and the pencil lead in the pencil pressure test. Which end exerted greater pressure?

3. Compare your pressure calculations for the pencil eraser and the pencil lead in the pencil pressure test. Which end exerted greater pressure?

4. How do engineers differentiate between pressure and stress?

5. How does an understanding of force, pressure, and stress help engineers design stronger and safer vehicles?