Elastic-Plastic Deformation

Northwestern University MRSEC
Lesson Plan for Middle School Students
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Lesson Goals:

1) Learn definitions of elastic and plastic deformation, failure
2) Connect deformation definitions to real-life experiences
3) Practice laboratory skills
    a. measurement
    b. data recording
    c. using correct metric units
    d. plotting data points on Cartesian coordinate graph

Target Age Group:
This lesson has been used in after-school science club settings at middle schools.

Duration:
45-60 minutes

Beginning Discussion:
Start off with definitions of terms:
Elastic deformation: when you remove force, object goes back to original shape
Plastic deformation: when you remove force, object stays deformed
Failure: object breaks, cannot go back to original shape even if you apply restoring force

When do each of these processes occur in everyday life? Bouncing ball: elastic, folding paper: plastic, open bag of chips: failure. When would these be useful?

Demonstration:
Take Q-tip: if you bend it a little, it comes back, bend it more, it stays bent, even more, it breaks. Plastic forks: same exercise.

Hands-on Experiment:
Students should work in groups of 2-4. Take metal wire (thick magnet wire works great) and wind it around thick nail to make a spring. (Use 4-inch length nails that have diameters of a few millimeters.) Leave 5-10cm of wire not wound on each end. It's important to wind it nicely so the wire makes a tight helix. Twist the free ends of the wire to create loops. (Figure 1) Remove nail to create free-standing spring. The force meter will hook into one of these loops. Measure the orinal length of the spring with a ruler. Students should record the measurement in their notebooks using metric units (typically centimeters). Hold the loop on one end with fingers, attach the force meter to the loop on the other end. The whole setup should be horizontal. Students should make a table in their notebooks so they can record the length of the spring as a

function of applied force. Increase applied force in 1 N increments, measure length. Release the stress after each force point and see if spring goes back to original length (this is basically the definition of elastic deformation). (Figure 2) After about 6N, students will hit the plastic regime and the spring will stretch significantly with little extra applied force. (Exact yield force will depend on specific wire used and diameter of the nail.) Each group should plot Force on X axis, Length on Y axis on a square grid paper, and find yield point. (Note: this is not the typical engineering stress-strain curve where stress is on the Y axis. Since the independent variable is force in the experiment, it should be plotted on the X axis to avoid confusing students who have been taught in school that independent variables go on the X axis.) The two regimes should be clearly visible on the graph and the turn-over point should correspond to the force where students see large deformations with small increments in the force (Figure 3).

Wrap-up Activity:
Hand out gummy worms: observe elastic, plastic regimes and failure when stretching. Note: gummy worms relax slowly, so you have to pull them pretty far to actually hit the plastic regime. You are still in the elastic regime if it eventually regains its original length. The failure happens when it starts breaking: note that you are past the fail point if any tear is visible, the gummy worm does not have to completely separate for the material to "fail."

Materials:
Q-tips, magnet wire, nail, force-meter, rulers or meter sticks, graph paper, gummy worms, plastic forks, pliers (to help making loops).

Notes: Any thick-gauge non-stranded wire will work, we used copper. You can change the diameter of the spring if the specific wire and force meter you are using do not allow you to clearly see both the elastic and the plastic regime.

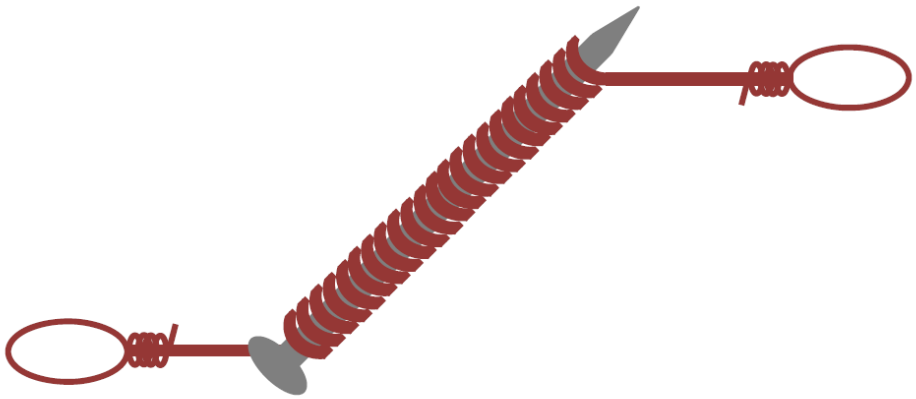

Figure 1

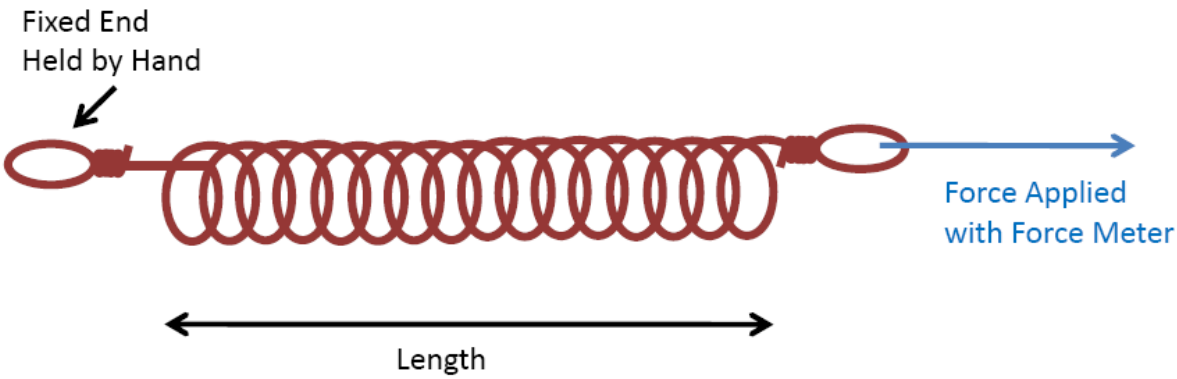

Figure 2

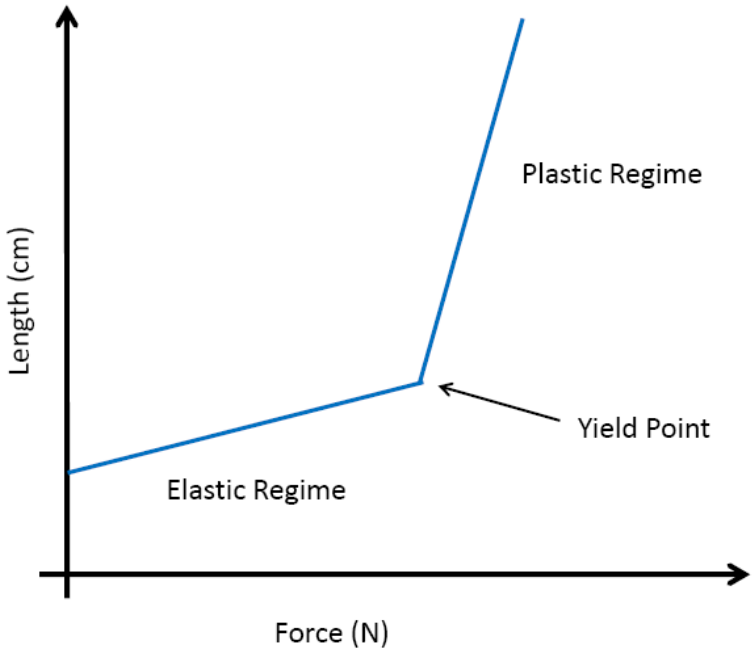

Figure 3