Stress-Strain

WHAT YOU WILL NEED

From Kit
- 11” Clear Balloon
- 9” Colour Balloon
- Skewer

CLEANUP

- Balloons: Garbage

LEARNING OBJECTIVE

To demonstrate a physical representation of an elastomer stress-strain curve.

WHAT TO DO

Part 1- Inflating one balloon in another
1. Watch the video demonstration before the activity
2. Stretch out each balloon before you attempt to blow them
3. Blow each balloon individually and release the air
4. Observe the change in difficulty as you are blowing the balloon, and any physical change
5. Blow up the clear balloon until it is about halfway full (around 8” should be fine). Hold it closed by pinching it, **Do not tie it off**
6. Insert the uninflated colour balloon into the first balloon so that the opening sticks out of the large balloon. If this is too difficult by hand, use the blunt side of the skewer to help you. (Insert the skewer into the small balloon and twist the balloon around the skewer. Use this to insert the small balloon into the large balloon before removing the skewer)
7. Blow up the smaller balloon and tie it off
8. Push the small balloon completely in the first balloon and blow the larger balloon up more before tying it closed

Part 2- Skewer
1. Orient the inside balloon so that it is perpendicular to the large balloon (refer to the video)

The pointed end of the skewer is sharp! Be careful to point away from your body when in use.

2. Using the skewer, pierce the large balloon from the top (the side that it is tied off) and into the small balloon. Observe what happens.

Stress-Strain

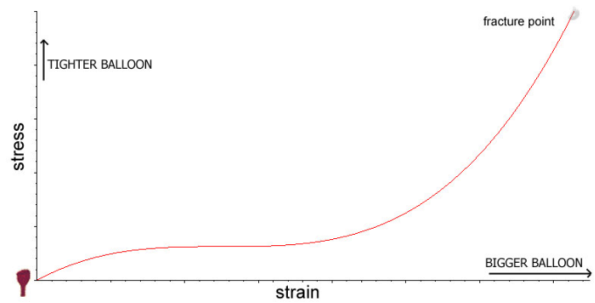
WHAT YOU WILL NEED

<u>From Kit</u>

- 11” Clear Balloon
- 9” Colour Balloon
- Skewer

THINGS TO THINK ABOUT

The stress-strain curve of a typical elastomer



http://members.tripod.com/the_common_loon/phyx.html

1. Compare the stress strain curve to the different levels of difficulty you experienced while blowing the balloons in Part 1.
2. The Young’s modulus is a measure of the stiffness of a material. Where can you find the Young’s modulus on a stress strain curve?
3. Does the Young’s modulus on the curve above support the difficulty levels you experienced during the activity?
4. Why were you able to pierce the balloon from the top and not the side? Sketch the stress distribution of the balloon

ALWAYS WEAR YOUR

Many thanks to Amy Chiu and Luis Zhuo for their creativity and tireless efforts in planning these activities, to Robyn McNeil for many of the initial concepts, to Dayna Lau for her initial graphic design work, to Tait Watt for many improvements and a new activity.

Crystal Structure

WHAT YOU WILL NEED

<u>From Kit</u>

- Polystyrene Balls
- Glue Gun
- Glue Stick

CLEANUP

- Polystyrene Balls: Garbage
- Glue Gun: E-Waste
- Glue Sticks/Shape: Garbage

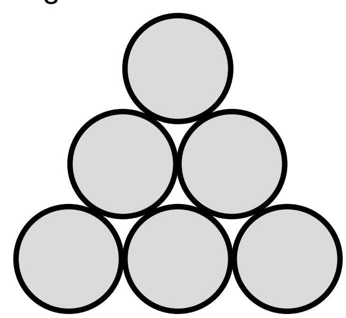
TIP: Isopropyl Alcohol weakens glue bond

LEARNING OBJECTIVE

To show a physical representation of the different crystal structures

WHAT TO DO

1. Start by making a triangle with six polystyrene balls as in the illustration
2. Put a ball in the center of the triangle
3. Repeat steps 1-2 so you have two identical structures
4. Place them together but with one of the structures up side down (it should fit perfectly to form one of the unit cells discussed in class)



DISCUSSION

1. What crystal structure did the polystyrene balls form in this lab activity?
2. The unit cell was formed by stacking close packed planes. what other stacking sequence will create the same structure?
3. If the polystyrene balls represents atoms and the glue represents the bonds between them, what did the space between the atoms represent?
4. Approximately how big would an interstitial atom have to be to fit into the spaces between the polystyrene balls?

POST LAB

As there are still some polystyrene balls remaining, try making various structures such as: BCC, HCP, tetrahedral, octahedral, graphite, a pyramid, or others that you can come up with and post it on social media (i.e. Facebook, Instagram, Twitter, Myspace…) with the hashtag #unitcellballer

Polymers

WHAT YOU WILL NEED

From Kit
- Sodium Polyacrylate
- Plastic Container
- Glass Jar
- Elmer's Glue
- Borax
- Skewer
- Salt

Other
- Water

Note: This activity may get a little messy so be sure to have a clean and clear workspace.

CLEANUP

Part 1: Put sodium polyacrylate in the garbage. Wipe plastic container with damp tissue to remove sodium polyacrylate, place tissue in garbage
Part 2: Put slime in the garbage. Wash the glass jar with warm water and soap.

LEARNING OBJECTIVE

To show some of the more interesting properties of certain polymers, and their possible effects on materials.

WHAT TO DO

Part 1 - Hydrophilic Polymer
1. Fill ¾ of the cup with room temperature tap water
2. Slowly pour in the sodium polyacrylate powder while mixing and observe what happens
3. Add a little salt (a teaspoon or so –save most of the salt for the salt bath activity) to the gel and wait at least ten seconds. Observe what happens to the solution

Part 2- Slime
1. Empty the container of glue into the plastic container
2. Mix the glue with another container full of water while stirring (the vial is 50 mL)
3. In the glass jar, mix 100mL of warm water with borax until it is saturated (a table spoon should be fine)
4. Pour the glue solution into the borax solution while stirring
5. Remove the polymer from the container and store in a plastic bag, if you like. Work with the polymer to get a feel of the properties

DISCUSSION

Part 1
1. How did the water and polymer react?
2. What microstructure properties within this polymer caused this reaction with water?
3. What would happen if a hydrophobic polymer was used in this experiment?
4. What happens when the salt is added to the solution and why does it react that way?

Part 2
1. What is the purpose of the borax? What would happen if not enough was added?
2. How are these polymers different and similar?

Plastic Deformation

WHAT YOU WILL NEED

<u>From Kit</u>

- 2 Rubber Bands
- Mechanical Pencil
- Glass Jar

<u>Other</u>

- Paper
- Tape

CLEANUP

- Rubber Band: Garbage
- Paper: Recycling

LEARNING OBJECTIVE

To show the viscoelastic properties of polymers when experiencing stress over a period of time.

WHAT TO DO

1. Tape a piece of paper to the bottom of the glass jar, to be marked with the pencil. Place this on a flat surface.
2. Place one of the rubber bands around the glass jar, being careful to hold it securely to avoid injury.
3. Slip the pencil through the band so that it is held against the jar, perpendicular to the surface. The writing end should face the paper.
4. Holding the jar securely, use the pencil to stretch out the rubber band across the paper as far as you easily can.
5. Use the pencil to mark this location on the paper.
6. Leave the rubber band on the jar for 1 week.
7. Repeat steps 4 & 5.

DISCUSSION

1. Was there a difference between the maximum deformations of the rubber band during step 4 and step 7?
2. Was there a difference between the ease of deformation of the rubber band during step 4 and step 7?
3. Compare the two rubber bands. What differences do you notice?
4. What properties of polymers contributed to the observations from questions 1, 2, and 3? Hint: look at the polymer stress-strain curve from Lab 1.
5. If you were to leave the rubber band for another week and repeat the experiment, what results would you expect to see? What if you left it until your final exams?
6. Based on your knowledge of polymers, what could be done to modify these results?
7. If you were using a similar material for a gasket, what could you expect to happen to the seal over time, based on your observations? How could this be solved?

Thermoplastic

WHAT YOU WILL NEED

<u>From Kit</u>

- Mechanical Pencil Tube

<u>Other</u>

- Candle (TA will Provide)
- Lighter(TA will Provide)

CLEANUP

- Mechanical Pencil Tube: Garbage

ACKNOWLEDGMENT

The content of this lab was developed by the University of Alberta

LEARNING OBJECTIVE

To show the effects of heat on a thermoplastic polymer, and the changes in its stress-strain behavior.

WHAT TO DO

1. Light a candle using the lighter
   → **Be careful with the lighter, don’t burn yourself**
2. Hold one end of the plastic tube and heat the center of the tube by holding it 2 - 3 cm away from the candle
3. Rotate the plastic tube slowly, heating the circumference of the tube evenly
4. Remove the tube from the heat source when you see a bit of shiny discoloration and bulging around the center of the tube (make sure it is not burning or dripping and blow out the candle)
5. Slowly pull apart both ends of the tube until it re-hardens, creating a thin filament in the center of the tube. Make the filament as long as you can without snapping it
6. Once the filament has completely hardened, try to stretch the filament slightly (just enough so that it will bounce back and retain its original shape)
7. Now stretch the filament until it plastically deforms (it can no longer return to its original shape)
8. Finally, stretch the filament until it breaks

DISCUSSION

1. A thermoplastic polymer is a plastic material that becomes more mouldable above a specific temperature. What are some applications for this material?
2. The glass transition temperature T_g is the temperature at which a hard glassy polymer turns into a soft rubbery one. What is the T_g relative to room temperature?
3. Sketch the stress-strain curve of the material before T_g and after T_g but before T_m
4. Think about the stress-strain curves for both the original tube and filament we created. How does the elastic region differ?

Steel Spring

LEARNING OBJECTIVE

To show affects of heat treating processes as well as the properties and formation of the phases in steel.

WHAT YOU WILL NEED

<u>From Kit</u>

- Mechanical Pencil
- Plastic Container

<u>Other</u>

- Water
- Candle (TA will Provide)
- Lighter(TA will Provide)

WHAT TO DO

1. Fill a container with cold water and set it aside for later use
2. Disassemble the mechanical pencil and take out the spring and graphite. Save the clear plastic tube for another lab
3. Stretch and squeeze the spring in your hands without deforming it. Write down the physical properties of the steel. (i.e. malleability, ductility, etc.)
4. Slip the spring on one end of the graphite
5. While holding the other end of the graphite, ignite the candle and hold the spring to the flame until it is red hot
   → **Be careful with the lighter, don't burn yourself**
6. Let the spring cool in still air for 1 min & repeat steps 3-5.
7. Quickly drop the hot spring in the ice water bath until it is completely cool (A couple of seconds should be fine)
8. Take the spring out of the water and repeat step 3

CLEANUP

- Mechanical Pencil Spring: Garbage

DISCUSSION

1. Quenching is the rapid cooling of a material, while tempering* is the slow cooling of a material in still air. Both are heat treatment processes to achieve different properties. When would you want to use each process?
   * Refers to tempering a metal. Tempering glass is different, but unfortunately, the same term is used.
2. Why did the spring only break after quenching? What affect does tempering and quenching have on the microstructure of the spring? (Hint: Think about the phases in steel)
3. When austenite transforms into martensite the crystal structure changes from face center cubic to a highly strained body-centered tetragonal structure. What type of defect does this stress introduce? (Hint: think 0-D, 1-D, 2-D, and 3-D defect).

ACKNOWLEDGMENT

The content of this lab was developed by the University of Alberta.

Crystal Growth

WHAT YOU WILL NEED

From Kit
- Borax
- Glass Jar
- 2 Pipe Cleaners
- Skewer
- Paper Clip

Other
- Water
- Kettle

CLEANUP

- Leftover liquid solution: Pour down drain, rinse for several minutes with hot water
- Crystal structure: Place in hot water to dissolve the crystal, dispose of liquid as listed above
- Pipe Cleaners: Garbage
- Skewer: Garbage

LEARNING OBJECTIVE

To demonstrate the difference between nucleation and crystal growth, and to show the effect of the contact surface for nucleation.

WHAT TO DO

1. Create a web with the pipe cleaner so that you have an oval shape roughly 1.5”x1.5” (Refer to the video)
2. Slip the pipe cleaner shape onto one of the loops of the paper clip, and place the skewer through the other loop. It should hang about ½” from the skewer
3. Using a kettle or stove, boil 250mL of water
4. Into the glass container containing Borax, pour the 250mL of water. Stir while you pour the water, most of the borax should completely dissolve
   →The glass container can potentially crack due to thermal shock. Do this over a sink
5. Balance the skewer over the glass container so that that pipe cleaner web is completely submerged in the solution
6. Cover to top with a magazine or a piece of cardboard and leave for 8hrs or over night.

DISCUSSION

1. Why does the solution need to be super saturated? What will happen to a seed crystal and how does it affect the growth of new crystals on the pipe cleaner
2. How does temperature affect the crystal formation?
3. What will happen if you leave the crystal in the solution for a shorter amount of time? I.e. 4hrs
4. At what point will the crystals stop growing?
5. If a coffee filter was used instead of a pipe cleaner, the crystals would have been smaller but in a larger quantity. Why would the crystal growth change even if both borax solutions were equally saturated? (Hint think about the driving force for crystallization and nucleation)

Supercooling (OPTIONAL)

WHAT YOU WILL NEED

From Kit
- N/A

Other
- Unopened store-bought water bottle or distilled water (do not use tap water, and don't use the distilled water from your kit as you'll need it for the salt bath experiment)
- Refrigerator – Freezer

CLEANUP

- Water: Pour down drain
- Bottle: Recycling

LEARNING OBJECTIVE

To show the supercooled portion of the water phase diagram, as well as the effect of crystallization sites.

WHAT TO DO

1. Put the water bottle in the freezer
2. Set a timer for 2 hours
3. Don't disturb the freezer, any disturbance (i.e. opening the door, bumping the freezer) will make it unsuccessful
4. Take the water carefully out of the freezer
5. If the water is frozen after 2 hours, allow it to melt and try doing the experiment once again but with 10 minutes less cooling time
6. Shake the bottle of water and see what happens to the water

DISCUSSION

1. What happened when you shook the water bottle?
2. In terms of the water phase diagram, explain how the water reached the point of supercooling.
3. What factors caused the water to instantly freeze?
4. Why does the water have to be distilled? What would happen if you tried the process with tap water?

CHALLENGE

Catch a great video or still of your experiment and post it on social media (i.e. Facebook, Instagram, Twitter, Myspace…) with the hashtag #supercool

Gorilla® Glass

WHAT YOU WILL NEED

<u>From Kit</u>

- Corning® Gorilla® Glass
- Resqme®
- Plastic Bag (originally containing the alligator clips)

CLEANUP

- Glass: Wrap bag in paper, carefully place in garbage

LEARNING OBJECTIVE

To demonstrate the properties of tempered glass.

WHAT TO DO

Warning: This activity involves shattering glass and gloves and goggles must be warn throughout the procedure. Ensure that you are away from other people.

1. Place the Corning® Gorilla® Glass in the plastic bag
2. Put the Corning® Gorilla® Glass on a hard surface within a bowl or a container and shatter it using the Resqme ® tool.

DISCUSSION

1. Tempered glass is made by rapidly cooling the surface and leaving the interior to self cool. When the material cools, is the interior of the glass in compression or tension?
2. Why does tempered glass break into many small pieces, while regular glass breaks into a few large pieces? (watch a video on Youtube of regular glasses breaking)
3. If damage to the surface of the tempered glass causes it to shatter, how do we manufacture products and components out of this material?

Nitinol Memory Wire

WHAT YOU WILL NEED

<u>From Kit</u>
- Memory Wire (Nitinol)

<u>Other</u>
- Large Container
- Hot Water
- Candle (TA will Provide)
- Lighter(TA will Provide)

CLEANUP

- Nitinol: Garbage

LEARNING OBJECTIVE

To demonstrate the effect of temperature and phase changes in a material.

WHAT TO DO

1. Observe the original shape of the wire
2. Fill a cup with warm water (hot coffee temperature is fine, use a kettle)
3. Bend the wire in half and lower it into the hot water. Observe any changes in the shape.
4. Remove the wire from the water and bend it in half again
5. Light a candle and make sure it is stable
6. While holding the wire steady, hold the bent portion of the wire over the flame until you feel a release in stress in the wire. (Hold the other end as tightly as you can). Immediately remove it from the flame and set it to cool
7. Repeat steps 1-3 with the wire

DISCUSSION

1. The properties observed are due the nitinol wire undergoing a phase change. How can a phase change be happening if there is no visible change of state?
2. How do you think the absorbed energy is being used by the Nitinol at the nanoscale?
3. Unlike most alloys, nitinol exhibits the unique property of shape memory effect. Explain this by considering the crystal structure. (Hint: Nitinol is simple cubic at high temperatures and symmetric body centered tetragonal at low temperature).
4. What's the difference between deforming the metal at room temperature as opposed to a high temperature (i.e. over the candle)? What causes this difference?

Corrosion

WHAT YOU WILL NEED

From Kit
- Stainless Steel Plate
- Galvanized (zinc coated) Steel Plate
- Stainless Steel Nut and Bolt
- Zinc Coated Steel Nut and bolt
- Salt
- 2 Plastic Containers

Other
- Water

LEARNING OBJECTIVE

To demonstrate the importance of material selection and the effect it has on the rate of corrosion.

WHAT TO DO

1. Fill two cups with water and mix salt in each to create a salt water bath. Stir the solution and add salt until it is saturated
2. Taking the stainless steel plate, fasten the galvanized (zinc coated) steel bolt through the hole and tighten it with the nut (finger tight is okay, but if you have a wrench or pliers, go ahead and make it tight!)
3. Repeat step 2 using the galvanized steel plate and stainless steel bolt
4. Place each plate in a separate salt water for a few days
5. Return after 2 days and observe the difference

CLEANUP

- Plates, bolts, and nuts: Wrap in newspaper, place in garbage
- Salt Water (stainless steel): Pour down drain
- Salt water (zinc-coated steel): Pour down drain, run water for several minutes

DISCUSSION

1. What type of corrosion is this?
2. What is the purpose of the salt water bath? Would the same thing happen if we just left both plates on a table?
3. Why did one combination corrode more than the other? (Hint: Look at the voltage series you created)
4. If you were to design a boat using only tin and zinc, which material should be used for majority of the boat, and which should be used as fasteners (i.e. screws and rivets). Note: only consider corrosion as the deciding factor for this exercise

Galvanic Cell

WHAT YOU WILL NEED

From Kit
- 3 Galvanized Nails
- 3 Copper Wires
- 2 Tin Wires
- Led Light
- 4 Alligator Clip Wires
- Salt
- 2 Plastic Containers
- Glass Jar

Other
- Water

CLEANUP

- Nails: Wrap securely in newspaper, place in garbage
- Wires: Garbage
- Alligator Clips: Garbage
- Salt Water: Down drain
- Containers: Follow info on bottom

LEARNING OBJECTIVE

To demonstrate the properties of electrochemistry and how it is used on batteries.

WHAT TO DO

1. Take two alligator clip wires and connect them on one end with a copper wire and the other end with a galvanized nail. For one of the other two alligator clips, connect one end to the long leg of the LED and the other end to a copper wire. For the last alligator clip wire, connect one end to the shorter leg of the LED and the other end to the galvanized nail.
2. Take one plastic container and glass jar and fill it with tap water and put around one tbsp of salt in it
3. Take the plastic container with distilled water and place it among the other containers, don't confuse it with the container with salt
4. Place one copper wire and one galvanized nail in each container; make sure that they are not from the same alligator clip wire (watch video for reference)
5. Connect the wire that ends with the copper wire with the longest leg of the LED and the galvanized nail to the shortest leg of the LED; notice if the LED lights up or not
6. Slowly put some salt into the container with distilled water and see the brightness of the LED's light
7. Replace two galvanized nails with the tin wires provided in the kit and repeat the observation

DISCUSSION

1. What is the role of the salt in this lab activity and why does this make the LED light up?
2. Is the type of material important in this lab? (zinc and copper)
3. Why won't the LED light up when the nail is replaced with tin?
4. How does a battery work and how is that related to this lab activity? Explain