GENERATION
BEYOND

EDUCATOR GUIDE

TOPIC

Suit Up for Take-off!

KEY LEARNING OBJECTIVES

Students will be able to:

- Understand the different types of polymers used in specific applications
- Evaluate three examples of polymer fabric for suitability as a flight suit
- Perform laboratory simulations/tests to assess selected polymer fabric properties.

LESSON OVERVIEW

In this lesson, teams will investigate polymers in terms of how different types form, where they are found, and how they are used. Teams will investigate specific properties of selected polymer fabrics through a series of evaluative laboratory exercises. Students will use this information to select the best material or materials to be used in a flight suit.

The accompanying presentation was created with PowerPoint so that it can be used in a variety of classrooms. If you are using a laptop with an LCD projector, simply progress through the PowerPoint by clicking to advance. All of the interactive aspects of the presentation are set to occur on click. Links to the corresponding videos can be found in the notes section of the PowerPoint. If you are using an interactive whiteboard, tap on each slide with your finger or stylus to activate the interactive aspects of the presentation. It does not matter where you tap, but you can make it appear as if you are making certain things happen by tapping them. In the notes for each slide, there will be information on how to proceed.

CONTENT AREAS

Chemistry, Physical Sciences

ACTIVITY DURATION

3 class sessions (45 minutes each)

GRADE LEVEL

Grades 9–12

ESSENTIAL QUESTIONS

1. What is a polymer?
2. What are examples of natural and synthetic polymers found in daily life?
3. What properties are critical for polymer fiber materials used in flight situations?
4. What are some tests that can be applied to polymer fiber materials to test specific properties?

MATERIALS

- Test guidelines appropriate for high-school lab experiments
- “Plentiful Polymers” Student Activity Sheet
- Two 20-gallon glass aquariums with lids
- Ten each of 8”-square samples of high-grade woven DACRON®, Kevlar®, and polypropylene fabric
- Scissors
- Hole punch
- Six feet of heavy gauge wire to suspend samples
- One 20-lb bag of light-grit sand per group
- Two small high-speed fans
- Small freezer
- Empty plastic gallon jugs with perforated lids to hold water
- Tensile strength tester
- Safety glasses for all students

BACKGROUND INFO

Polymers are useful substances found in nearly every aspect of life. Not only are they found in nature as the building blocks of all organisms, they are used in many synthetic materials such as plastics and nylon.

Our understanding of polymers had its genesis in 1868, when scientists first synthesized cellulose nitrate from natural substances. Ivory to make billiard balls was in short supply, so the top billiard-ball manufacturer of the time sponsored a competition to devise a material that would have similar properties to ivory. In the United States, John Wesley Hyatt mixed cotton-based pyroxin and nitric acid with camphor. He called the resultant mixture celluloid.

The first truly synthetic plastic did not appear until 1909, when phenol-formaldehyde plastics were developed and used for cookware handles, grinding wheels, and electrical plugs. From there, other plastic polymers were developed to produce everything from toothbrushes to upholstery. During World War II, a shortage of natural silk led to the production of nylon, a strong polymer filament that has since been used in hundreds of products. The ability to form and reform the long polymer chains allow scientists to design for particular properties including flexibility, tensile strength, and resistance to fire and specific chemicals. Today, polymers are found in almost every facet of modern life.

This guide was created to give educators ideas and strategies for presenting the content in the digital lesson. It provides slide-by-slide details for educators to be prepared to engage with students as they explain, discuss, and effectively facilitate the content in the presentation. The presentation is designed to cover three 45-minute class sessions, but it is flexible, depending on the students' needs and time available.

During the lesson, students will learn about the basic chemical structure of polymers and identify where they are found in nature as well as in synthetic products. They will be introduced to the challenge of evaluating three polymer fiber fabrics for use as flight suits. Students will perform tests based on military standards and evaluate each fabric for specific properties. Based on their results, they will choose the most appropriate fabric or fabric combinations for a flight suit.

[ref: (1) Ebewele, Robert Oboigbaotor.;Polymer science and technology / Robert O. Ebewele.; © 2000; CRC Press, New York)

NATIONAL STANDARDS

Next Generation Science Standards

High School

PS2.6: Structure and Properties of Matter
Communicate scientific and technical information about why the molecular level structure is important in the functioning of designed materials.

Defining and Delimiting Engineering Problems
Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)

Developing Possible Solutions
When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)

Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4)

Optimizing the Design Solution
Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. (HS-ETS1-2)

PROCEDURE

Day 1

Engage (Slides 1–3)

Overview: Students will be presented with the challenge of evaluating the suitability of three different types of fabric for eventual use in a flight suit. They will be introduced to examples of natural and synthetic polymers and how common polymers are in daily life.

Slide 1 is the introduction for the lesson. Slides 2–3 introduce the Challenge and invite students to start thinking about how polymers play a major role in their daily lives.

Slide 1

- Introduce students to this challenge by telling them to prepare for the elements as they identify key ideas to unpack the mission!
    - Show Suit-Up for Takeoff video. Pause the video every few minutes for students to jot down their thoughts related to the following categories:
        - A = Adjective: List a word or two that describes something you saw or learned.
        - E = Emotion: Describe how a particular part of the segment made you feel.
        - I = Interesting: Write something you found interesting about the content/topic.
        - O= Oh!: Describe something that surprised you.
        - U = Um?: Write a question about something you learned or want to learn more about.
    - Pause at the predetermined points to allow students 60 seconds to add information to their list.
    - When the video concludes, have students complete a Pair & Share of their A-E-I-O-U statements.
- Clarify the requirements of the STEM Challenge Activity to students using the handout. In this challenge, students will conduct product testing to develop a flight suit that can handle all types of weather and wear.

Slide 2

- This is a click-to-reveal interactive slide. The title "Polymers" is hidden until the area is clicked on. Ask students to try to think about what all the disparate items shown on the slide have in common. Use a large sheet of paper to write down students' thoughts.
- After recording a variety of student guesses, click to reveal "Polymers."
- Ask students what they know about polymers. Have they heard the term before? What images come to mind when someone says a material is made of polymers. It is likely that some students may equate polymer with plastic. Don't correct any student feedback.

Slide 3

- Display Slide 3 to the class. Review the slide information that describes the basic chemistry of a polymer chain and emphasize that a polymer is a chain of joined structures that repeat. Point out that sometimes the bonds that hold the various atoms together are strong, and sometimes they are weak.
- The type of polymer chain will determine the characteristics of the polymer material.

Day 1

Explore (Slide 4–7)

Overview: Students will learn that polymers can occur naturally and are also created synthetically (i.e., by humans in a laboratory). They will be introduced to examples of naturally occurring polymers and synthetic polymers. They will then do an in-class exercise that will give them the opportunity to relate the idea of polymers to their personal lives.

Slide 4

- Review the examples of natural and synthetic polymers. Students may not know the term chitin. It refers to the exoskeleton of insects like the beetle shown on the slide. Cellulose is the polymer that makes up wood.
- Briefly review the synthetic polymer examples. Ask students if they have had ever used any of these items, or items similar to them.
- Distribute "Plentiful Polymers" Student Activity Sheet. Once the students have completed the exercise, ask for volunteers to share their results. Ask if students were surprised to see food items listed.
- If time permits, instruct students to research additional products that contain polymers and add these products to their chart.

Day 2

Explain (Slides 8–11)

Overview: Students will begin to focus on the polymer properties needed for the materials to make a good spacesuit. They will be introduced to the three materials they are to evaluate for specific properties.

Slides 8–10

- Show Slide 8 and share with students the reasons why scientists began to explore synthetic polymers. During the war years, silk was in short supply. As a result, chemists began to explore synthetic polymers that became the material we know as nylon. Nylon can be made in great quantities and used in a variety of applications, ranging from clothing to parachutes. Soon, more experiments with polymer chains led to the development of plastic polymers with enormous applications for daily life.
- Ask students to brainstorm properties that a material or materials should have to make a good flight suit for astronauts. Encourage them to consider the environments in which the flight suit will be used. Write student responses on a large, white sheet of paper.
- After recording a variety of student ideas, click to reveal the list on the right side of the slide. How many student responses match the properties in the list?

Slide 11

- Show Slide 11. Tell students that the three polymer fabrics shown on the screen are the materials under consideration for the flight suit in the Challenge. Many students may be familiar with Kevlar®, a particularly strong fiber used to make bulletproof vests. Some may have heard of DACRON®, which is used in a variety of bedding products, including pillows, mattresses, and comforters. Polypropylene might be familiar as the material used in many plastic bags and bottles.

Elaborate (Slides 12–14)

Overview: Students are given more detailed information about the properties of the polymer fabrics under consideration. They should have the fabric samples in hand while the details of each material are presented.

Slide 12

- Divide the class into three groups and distribute samples of each polymer to each group.
- Show Slide 12. DACRON® is an industrial term for Poly(ethylene terephthalate), known as PET. Students may recognize the term "polyester." DACRON® is a polyester synthesized through a reaction between ethylene glycol and terepthalic acid, which are shown on the slide. The chain can be short or long. Adding bonds and removing atoms as necessary changes the structure of a two-repeat-unit portion of a longer polymer chain of PET.
- Review the characteristics of DACRON® fibers. Have students take notes about how these properties would be best used in a flight suit.
- Students might not be familiar with the term "tensile strength." Explain that it refers to a material's ability to withstand tension without breaking. Tension can be from pulling or twisting the material.

Slide 13

- Show slide 13. Aramids are crystalline polymers. The crystal structure allows them to be made into fibers that "stack," or fit into each other well. Very strong chemical bonds make this polymer particularly tough when made into a fiber.
- Kevlar is an aramid® called poly-paraphenylene terephthalamide. Kevlar® is used for a wide variety of products such as special clothing, belts for radial tires, composites for airplane panels, and ironing board covers. It may best be known as a material used in bulletproof vests.

Slide 14

- Show slide 14. Polypropylene is one of the most versatile polymers. It is widely used in a variety of plastic products, like bottles, food storage containers, and indoor/outdoor carpets. Polypropylene fiber is a popular material for thermal clothing because it does not absorb water. Sweat is usually wicked away, keeping a person cooler or warmer.

Day 3

Evaluate (Slide 15)

Overview: Students will be introduced to the procedures for the Challenge activity. Students will be divided into groups to test the tensile strength of polymer fabrics that have been stressed with freeze/thaw cycles, simulated rain, and abrasion.

- Explain to students that they will be role-playing different careers in aerospace as they experiment with materials. Distribute the Career Cards randomly within the groups of four students. Ask students to summarize in their small groups the similarities and differences between the careers on the cards. Ask what conclusions they can draw about the types of careers that are part of the aerospace industry.
- Show Slide 10. Divide students into teams of 4. Each team will prepare fabrics to simulate a different type of environmental condition. Two team members will be responsible for preparing fabrics that have been frozen and thawed. The third will simulate the effects of hard rain. The fourth will simulate the effects of abrasion from sand and grit.
- After the groups have prepared the fabrics, distribute samples of the fabrics to each group. Each group will use the tensile strength tester to test the strength of each fabric.
- Have each team report the results of their tensile strength tests. Which fabric did the best?
- Ask students which fabric or combination of fabrics would make the best flight suit based on the test results.
- Provide students the opportunity to debrief the Career Cards they used throughout the lesson.
  Ask students to consider the following:
    - Which job would you like to have? Why?
    - Which job seems the most important? Why?
    - What is a common requirement among many of the jobs?
    - Which job seems the most difficult? Why?

Polymers are an unavoidable part of modern life. Changes are, you routinely use many more products that contain polymers, or that are made with polymers, than you would think. Some products will likely come as a surprise!

Look at the products listed in the chart. These products are all made of polymers! Circle all the products you have used during the last week. Then, conduct some research on other common products that use polymers; record your findings in the additional boxes in the chart.

Cell phone	Salad dressing	Hairspray
Running shorts	Eye glasses	Frozen food
Frozen whipped topping	Carpet fiber	Fast-food Container
Sun screen	Single-serving water bottles	Nail polish
Raincoats	Fishing rods	Disposable diapers

As a **Materials Analyst,** you develop, process, and test materials used to create a range of products, from computer chips and aircraft wings to shoes and skateboards. You work with metals, ceramics, plastics, composites, and other substances to create new materials that meet certain mechanical, electrical, and chemical requirements.

As the **Organic Chemist,** you study molecules that contain carbon by characterizing, synthesizing, or finding applications for these molecules. You typically use chemistry lab equipment as well as advanced computer-driven equipment.

As the **Materials Engineer,** you specialize in working with particular materials such as metals, plastics, ceramics, wood, and fabric. You develop, process, and test these materials to create products ranging from aircraft wings to computer chips.

As the **Manufacturing Manager,** you lead the design and development of new products and develop performance metrics. Your also work with market researchers to find out needs and wants.

TEST PROCEDURE: FABRIC FREEZE/THAW

Freezer with ten "swatches" of fabric laying on sheets of waxed paper on freezer shelves. The samples are not stacked (i.e., they are not touching each other)

1. Lay ten 8" × 8" pieces of fabric (DACRON®, Kevlar®, polypropylene) on pieces of wax paper on flat surfaces in the freezer.
2. Freeze swatches for 24 hours. Then have the freeze/thaw group remove the swatches from the freezer and place on a dry surface. They will cut the fabric into 30 equal pieces to serve as test swatches.
3. Distribute samples of each frozen swatch (DACRON®, Kevlar®, polypropylene) to student groups. Each group will test each of the three fabrics for tensile strength and record the data.
4. Students should run one test and write down the tensile strength for each fabric, as well as any observations.

TEST PROCEDURE: RAIN

Test stations should be set up and ready to go by the time class starts.

Rain: Fish tank with 20-gallon rectangular dimensions. At one of the narrower ends are suspended 10 pieces of fabric on wires strung across the tank. The wires are attached by dabs of epoxy. The wire is threaded through two holes punched into the top and bottom of each swatch. At the other narrow end of the tank is a plastic gallon milk jug that has been cut lengthwise and filled with water. On one side of the milk jug, a fan is positioned with its head facing at about 45 degrees towards the water. The fan is going to "blow" the water against the fabric samples at the other end of the fish tank. Show the lid over the fish tank covering everything except the fan.

1. Cut two pieces of wire that fit across the width of the end of the fish tank and secure them with epoxy. (see illustration)
2. Using a hole punch, punch four small diameter holes in each swatch, one hole per corner, with an equal gap between each swatch.
3. Cut the wire 2" from where it is secured to one wall of the aquarium. Thread the swatches onto the longer piece of wire. Avoid overlapping the edges of the swatches. Thread through the top and bottom holes. When the swatches are threaded, attach the two ends of the wire and twist the wire to secure it. This is done with both wires. The result will be the fabric attached at top and bottom. DO NOT pull the fabric taut. The face of the fabric should be towards the fan and the water.
4. Cut one empty plastic milk container in half, lengthwise. Fill with water and place it at about a 45-degree angle away from the swatches. Place the small fan behind the water and set at its highest speed. If possible, angle the head of the fan toward the water. Place the aquarium lid on the aquarium so that it covers the fan, water, and samples but its opening is wide enough so that the fan can be turned on by the student.
5. When the testing period begins, have students turn on the fan at the highest speed. The simulation will run for 20 minutes. Students should observe what is happening with the fabric.
6. At the end of the test period, have student volunteers cut the samples from the tank and lay them individually on a waxed piece of paper or any other non-absorbent material. Ask for student volunteers to cut the swatches into 30 swatches of equal size that can be tested at the tensile strength tester.
7. Students should run one test and write down the tensile strength for each fabric, as well as any observations.

TEST PROCEDURE: SAND ABRASION

Test stations should be set up and ready to go by the time class starts.

Abrasion: Fish tank with 20-gallon rectangular dimensions. At one of the narrower ends are suspended 10 pieces of fabric on wires strung across the tank. The wires are attached by dabs of epoxy. The wire is threaded through two holes punched into the top and bottom of each swatch. At the other narrow end of the tank is a plastic gallon milk jug that has been cut lengthwise and filled with sand. On one side of the milk jug, a fan is positioned with its head facing at about 45 degrees toward the sand. The fan is going to "blow" the sand against the fabric samples at the other end of the fish tank. Show the lid over the fish tank covering everything except the fan.

1. Cut two pieces of wire that fit across the width of the end of the fish tank and secure with epoxy
2. Using a hole punch, punch four small diameter holes in each swatch, one hole per corner, with an equal gap between each swatch.
3. Cut the wire 2" from where it is secured to one wall of the aquarium. Thread the swatches onto the longer piece of wire. Avoid overlapping the edges of the swatches. Thread through the top and bottom holes. When the swatches are threaded, attach the two ends of the wire and twist the wire to secure it. This is done with both wires. The result will be the fabric attached at top and bottom. DO NOT pull the fabric taut. The face of the fabric should be toward the fan and the water.
4. Cut one empty plastic milk container in half, lengthwise. Fill with light-grit sand and place it at about a 45 degree angle away from the swatches. Place the small fan behind the sand and set at its highest speed. Air flow has to be strong enough to move the sand and direct it at the fabric samples. Place the aquarium lid on the aquarium so that it covers the fan, water, and samples but its opening is wide enough so that the fan can be turned on by the student.
5. When the testing period begins, have students turn on the fan. Test will run for 20 minutes. Students should observe what is happening with the fabric while they wait to test their Freeze/Thaw samples at the tensile strength tester.
6. At the end of the test period, have student volunteers cut the samples from the tank and lay them individually on a waxed piece of paper or any other non-absorbent material. Ask for student volunteers to cut the swatches into 30 swatches of equal size that can be tested at the tensile strength tester.
7. Students should run one test and write down the tensile strength for each fabric, as well as any observations.