FLINN STEM

Powered by IMSA FUSION
igniting teaching and learning

IMSA Fusion — Living in a Material World STEM Curriculum Module

Table of Contents

Curricular Objectives and Background Information..........1
National Standards..........3
Unit Summaries and Objectives..........7
Materials List..........9
Unit 1: Setting the Stage..........13
Unit 2: Ages of Stone and Bronze..........27
Unit 3: Wood Works..........33
Unit 4: The Iron Age..........47
Unit 5: Silicates and Light..........61
Unit 6: I'm Rubber, You're Glue..........67
Unit 7: Plastic Dreams..........77
Unit 8: Textiles..........87
Unit 9: Outta This Material World..........99
Resources..........107

Materials Science – Living in a Material World

Curricular Objectives

Students completing this curriculum will understand that:

- The course of human civilization often hinged on developments in materials science.
- Technology and engineering require an understanding of quantifiable material properties.
- Material properties are determined by chemical composition and small-scale structure.
- Unknown materials may often be identified by testing their material properties.

Students will arrive at these understandings through a process on hands-on scientific inquiry. In the process, students will gain valuable experience with the process skills identified in the Common Core math standards as well as the Next Generation Science Standards.

Logistics

Students: 30 students in grades 6 – 8

Location: Activities are suitable for standard classrooms if laptop carts are available. Otherwise frequent visits to a computer lab will be required.

Time: This curriculum is designed for 32 content hours. Times for individual activities are typically 1 to 2 hours and detailed estimates are found at the beginning of each activity.

Background Information

Materials science is an interdisciplinary field concerned with the understanding and application of the properties of matter. Materials scientists study the connections between the underlying structure of material, its properties, its processing methods, and its performance in applications.

Scholars have long classified eras of ancient civilizations by their progress in materials science, coining such terms the Stone Age, Bronze Age and Iron Age. What is known about ancient cultures, especially those without written records, often comes from a scientific examination of the artifacts they left behind. Advances in materials science often went hand-in-hand with other cultural developments. In many cases it was the development of new materials that enabled advances in other realms of human accomplishment. When neighboring nations and cultures came into conflict, whether economic or military, dominance was often achieved by employing more advanced materials.

Although its importance goes back to antiquity, the concept of material science, as a discipline of study, is rather new. Educational programs at the college level now abound and career opportunities in this field are very rewarding for those with the passion and ability to pursue them.

Materials Science – Living in a Material World

National Standards

Next Generation Science Standards:

MS-ESS3-3: *Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment*

MS-ETS1-1: *Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions*

MS-ETS1-2: *Evaluate competing design solutions using a systemic process to determine how well they meet the criteria and constraints of the problem.*

MS-ETS1-3: *Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success*

MS-PS1-1: *Develop models to describe the atomic composition of simple molecules and extended structures*

MS-PS1-2: *Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred*

MS-PS1-3: *Gather and make sense of information to describe that synthetic materials come from natural resources and impact society*

MS-PS1-4: *Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed*

MS-PS1-5: *Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved*

MS-PS2-5: *Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact*

MS-PS4-2: *Develop and use a model to describe how waves are reflected, absorbed, or transmitted through various materials*

MS-LS1-1: *Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells*

MS-LS1-3: *Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.*

MS-LS1-5: *Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms*

NGSS Science and Engineering Practices:

SEP1: *Asking questions and defining problems*
SEP2: *Developing and using models*
SEP3: *Planning and carrying out investigations*
SEP4: *Analyzing and interpreting data*

SEP5: *Using mathematics and computational thinking*
SEP6: *Constructing explanations and designing solutions*
SEP7: *Engaging in argument from evidence*
SEP8: *Obtaining, evaluating, and communicating information*

Next Generation Science Standards Reference:
NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Mathematics Common Core Standards
CCSS.Math.Content.5.OA.B *Analyze patterns and relationships*
CCSS.Math.Content.6.EE.A *Apply and extend previous understandings of arithmetic to algebraic expressions*
CCSS.Math.Content.6.EE.A.2 *Write, read, and evaluate expressions in which letters stand for numbers*
CCSS.Math.Content.6.EE.B *Reason about and solve one-variable equations and inequalities*
CCSS.Math.Content.6.NS.C.8 *Solve real world and mathematical problems by graphing points in all four quadrants of the coordinate plane*
CCSS.Math.Content.6.RP.A *Understand ratio concepts and use ratio reasoning to solve problems*
CCSS.Math.Content.6.SP.B *Summarize and Describe Distributions*
CCSS.Math.Content.7.G.A.1 *Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.*
CCSS.Math.Content.7.EE.B *Solve real-life and mathematical problems using numerical and algebraic expressions and equations*
CCSS.Math.Content.7.NS.A.3 *Solve real-world and mathematical problems involving the four operations with rational numbers*
CCSS.Math.Content.7.G.B *Solve real-life and mathematical problems involving angle measure, area, surface area, and volume*
CCSS.Math.Content.7.RP.A *Analyze proportional relationships and use them to solve real-world and mathematical problems*
CCSS.Math.Content.7.RP.A.2 *Recognize and represent proportional relationships between quantities*
CCSS.Math.Content.HSN.Q.A.1 *Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays*

Mathematical Practices:
CCSS.Math.Practice.MP1: *Make sense of problems and persevere in solving them*
CCSS.Math.Practice.MP2: *Reason abstractly and quantitatively*

CCSS.Math.Practice.MP3: *Construct viable arguments and critique the reasoning of others*
CCSS.Math.Practice.MP4: *Model with mathematics*
CCSS.Math.Practice.MP5: *Use appropriate tools strategically*
CCSS.Math.Practice.MP6: *Attend to precision*
CCSS.Math.Practice.MP7: *Look for and make use of structure*
CCSS.Math.Practice.MP8: *Look for and express regularity in repeated reasoning*

Common Core English Language Arts (ELA) Standards

6-8.RH.7: *Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts*
6-8.SL.1: *Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on middle school topics, texts, and issues, building on others' ideas and expressing their own clearly.*
6-8.SL.4: *Present claims and finding, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details*
SL.6-8.6: *Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate*
6-8.RST.1: *Cite specific textural evidence to support analysis of primary and secondary sources; connecting insights gained from specific details to an understanding of the text as a whole*
6-8.RST.2*: Determine the central ideas or information of a primary or secondary source; provide an accurate summary*
6-8.RST.3: *Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks*
6-8.RST.7: *Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually*
6-8.RST.8: *Evaluate an author's premises, claims and evidence by corroborating or challenging them with other information*
6-8.RST.9: *Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic*
6-8.W.1: *Write arguments to support claims with clear reasons and relevant evidence*
6-8.W.2: *Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content*
6-8.WHST.2: *Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content*
6-8.WHST.7: *Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of*
6-8.WHST.9: *Draw evidence from informational texts to support analysis, reflection, and research*

Materials Science – Living in a Material World

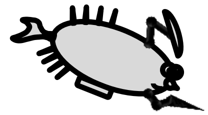
Common Core Mathematics and ELA Standards Reference

Authors: National Governors Association Center for Best Practices, Council of Chief State School Officers Title: Common Core State Standards Publisher: National Governors Association Center for Best Practices, Council of Chief State School Officers, Washington D.C. Copyright Date: 2010

Materials Science – Living in a Material World

Unit Objectives and Summaries

Unit 1 – Setting the Stage

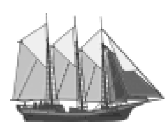


This unit introduces students to the importance of material properties by having them select appropriate materials for the design of a complex machine operating in a severe environment. Next, students construct a timeline for the wall of their Fusion classroom. In all subsequent activities, developments in the field of materials science will be placed in historical context using this timeline. Finally, students begin to understand the importance of small-scale structure by performing a kinesthetic simulation of atoms forming a crystal. A conceptual understanding of crystalline structure is important to several subsequent activities.

Unit 2 – Ages of Stone and Bronze

This unit begins with an activity in which students examine rocks with differing fracture characteristics which depend on crystalline structure. Students design methods for evaluating which rocks make the best tools for cutting and scraping simulated animal hide. Stone tools were replaced by copper and bronze as soon as people discovered how to smelt ores into metals. Students will study the process of copper smelting and then evaluate the material properties of copper, tin, and bronze.

Unit 3 – Wood Works



Wood has many useful properties, including flexibility. Students will experiment with different techniques for making a permanent bend in wooden craft sticks. Once they master the process, students will design and construct a small wooden ship, using curved timber, which must float and hold a cargo. To keep things water-tight, students will make a tar-like caulking compound.

Unit 4 – The Iron Age

This unit begins with an experiment in which students simulate the heat treatment of steel in an attempt to improve the temper of pasta "sword blades". The next activity examines the chemistry of iron. After examining the smelting of iron ore, student look at the reverse reaction of iron corroding into rust. They will exploit a catalyst's material properties to drastically increase the rate of rust formation. Armed with this experience, students will perform an exercise in forensic engineering to determine why a bridge in Wisconsin recently failed. Finally, they learn about make techniques to make corrosion resistant steel and use their knowledge to identify several samples of unknown metals.

Materials Science – Living in a Material World

Unit 5 – Silicates and Light

This unit begins be examining the interactions of matter and light. Students will experiment with a model to learn why materials have such a wide range of visual appearances. Then students will learn about stained glass. After observing patterns in the design work of architect Frank Lloyd Wright, students will use linear equations to design and create their own work of art.

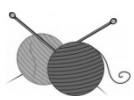
Unit 6 – I'm Rubber, You're Glue

Students will learn why different formulations of rubber have unique material properties. They will make super balls, from both natural and synthetic rubber, and evaluate their performance. Finally they will learn about the deadly ball games played in ancient Mezzo America. Students will build scale models of a ball court and experiment with the rules of these games as an exercise in experimental archaeology.

Unit 7 – Plastic Dreams

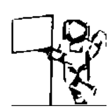
Plastics have revolutionized our manufactured world but they have also raised serious environmental issues. Students will examine the chemical and material structure of different plastics. They will perform research before engaging their peers in a debate about one of the many environmental aspects of plastics production, recycling, and biodegradation.

Unit 8 – Textiles



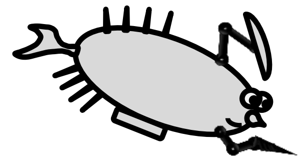
Students take on the role of clothing designers in this problem-centered unit. Customers need fabrics which meet their specific requirements. Before making the best possible recommendations, students will need to perform many experiments to determine the material properties of both natural and synthetic fibers and fabrics.

Unit 9 – Outta this Material World



In this final unit, students examine familiar classroom objects with the eye of a materials engineer. They relate the object's function with its designer's choice of materials. Moving beyond the familiar, students research the most challenging task for a materials scientist, the design of a space suit which protects an astronaut in the extreme environment of space.

Unit 1: Setting the Stage



NOTES

Introduction

The last 8,000 years of human history was shaped by many events, but none more influential than the development of science and technology. Advances in technology often hinged on the creation of new materials or discovery of previously unknown material properties.

Most of the materials properties we will study in this curriculum are determined by:

- the type of atoms in a substance.
- the crystalline structure formed by those atoms.

Every element on the periodic table is composed of a unique type of atom. Gold and silver have different properties because their atoms are different. Some materials, such as diamonds, graphite, and charcoal, have different properties due to the manner in which their atoms are assembled together. All three of these materials are made from identical carbon atoms. In each, the carbon atoms are arranged in a different pattern. Such patterns are known as a material's crystalline structure.

The atoms in a liquid are constantly interacting with each other but are still free to move. The average speed of those moving atoms is a function of the liquid's temperature. If the temperature falls below a critical "freezing point", the motion of the atoms will drop dramatically. Although they are still free to vibrate, they no longer move past each other. The liquid has become a solid.

If the change of phase happens slowly, atoms will naturally arrange themselves into a pattern which contains the least possible amount of stored energy. This pattern, repeated many times through a certain volume, is called a crystal. Crystals have specific geometries which give the solid material some of its properties.

The formation of crystals usually begins in many places at once, leading to the simultaneous formation of multiple crystals. The faster the liquid cools, the smaller these crystals will be as it takes time for larger crystals to organize. If the liquid cools very rapidly, it may freeze into a solid before any detectible crystalline patterns have a chance to form. Such a material is called an amorphous solid. Window glass is a familiar example of an amorphous solid.

NOTES

Inquiry Overview

In the first activity, students work with a set of fictional materials which have very real properties. They will examine these materials and make decisions about which material is best for a number of applications related to an underwater robot. Then they will begin to explore why different materials have different properties.

In the second activity, the class will construct a timeline to mount on the wall. Throughout the curriculum, this will serve as a reference for putting into historical context various developments in materials science.

The third activity delves into crystalline structures by having the students move about the room in a kinesthetic simulation.

Activities

Activity 1: Diving into Material Properties

Estimated Time: 90 minutes
Student Grouping: groups of 3

Objectives:

The students will:

- Select materials to serve a specific purpose based on their material properties.
- Examine why materials have differing properties.

Standards:

NGSS	MS-PS1-1, MS-ETS1-1, MS-ETS1-2, SEP (1,2)
CCSS Math	MP (7,8)

Materials for this Activity

Per group of three students:

- Student Pages
- 1 Diagram of a submarine robot
- 26 Plastic chips (labelled A through Z)
- 3 copies of Anodami Materials List
- *1 computer with internet access*

Advanced Preparation: none

Suggested Inquiry Approach:

Point to some object in the room and challenge students to **name the materials from which it is made**.

Now ask **why these materials, and not some others?**

Encourage them to **debate the suitability of other materials which might have been used**.

Help students form groups of three and obtain their materials.

Give them their student pages and, as a class, read the story about the Anodami. Allow them to continue through the first part of the activity to select suitable material for their robot. As they work, you can get the computers/laptops ready for the second part.

Students will have questions about vocabulary. Allow them to use an online dictionary for help.

As soon as you see that all groups have placed their material markers on their robots, start a class discussion. Go through each part of the robot and ask students what material they selected and why. There are many good answers and students will have different opinions. Encourage them to debate the merits of each choice. There is no single "correct" answer. Every choice has trade-offs. This is an important aspect of engineering design.

Following this discussion you may allow them to complete the remaining questions in Part 1 either independently or as a class, as you prefer.

Part 2 requires students to access an online computer simulation. They will build atoms of the first six elements. Finally they will read about different structures of carbon atoms.

Debrief:

- **What two things determine the properties of a material?**

NOTES

Activity 2: Timeline of Materials Science

Estimated Time: 85 minutes
Student Grouping: groups of 2 or 3

Objectives:

Students will establish a reference timeline which will be used throughout the curriculum for placing developments in Materials Science into a historical perspective.

Standards:

CCSS Math	6.NS.B, MP (1,2,4)
CCSS ELA	6-8.RI.9, 6-8.RST.3

Materials for this Activity

Per group of 2 or 3 students:

- Student Pages
- ≈ 10 Post-it notes
- *1 computer with internet access*

For the class:

- 1 roll of blue tape
- Timeline (12 sections)

Advanced Preparation: Select a wall on which to maintain a 15 foot-long timeline.

Suggested Inquiry Approach:

Explain that the class will be assembling a timeline on the wall. The timeline is divided into pieces like a puzzle. Each group will get one piece. **Without talking**, students will need to assemble the timeline, in correct order, and attach each piece to the designated wall.

1. Have students form groups of two or three.
2. Give each group a section of the timeline (there are 12 sections).
3. Give the roll of blue tape to a student who will assist with attaching pieces to the wall.
4. Each group sends one member, with their piece of the timeline, to work in silence with others at the wall.

   Remaining group members can get the computers up and running. Each group will need one.

NOTES

5. Once the timeline is correctly assembled, each group makes a list of significant events to plot on the timeline. If a group needs help, you might suggest any of the following to add to their list:
   - First writing, or alphabet
   - First block printing or printing press
   - Construction of the pyramids of Egypt, Stonehenge, Great Wall, etc
   - Domestication of wheat, corn, horses, etc
   - Invention of gunpowder, steam engine, telephone, etc
   - First paved road, suspension bridge, skyscraper, railroad, etc
   - First human flight

6. Facilitate a class discussion in which students share what their group thinks should go on the timeline. As a class, come to a consensus on 10 to 20 appropriate historic events for the timeline. These events do not need to be Materials Science related. That will come later.
7. Working in their groups, students use the internet to find when these events occurred. Rather than use calendar dates, the timeline will measure everything in "years ago". Students will have to translate 3,500 BCE into 5,515 ya and mid-fifteenth century into 565 ya. If you feel calendar dates are important you may have students add those labels above the timeline.
8. Students can put their results on sticky notes to attach to the timeline. Expect there to be some discrepancies between groups. Different sources may give different dates for some events. Highlight discrepancies and moderate a discussion toward consensus. Once everyone is in agreement on the timing of their important events, the sticky notes could be replaced with more permanent (and attractive) markers or labels could be written on the timeline itself using a marker.

Debrief:

- Were you surprised by the sequence of these events? Did anything happen sooner or later than you would have guessed?

- Pick some famous inventions or construction projects on your timeline and ask the questions:
  - Could this event have happened 100 years sooner?
  - 500 years sooner?
  - If not, what was missing that had to be accomplished first before the event on your timeline would be possible?

- Stone Age hunters began exploiting the material properties of rocks to make sharp-edged tools about 1.7 million years ago. How far to the left would you have to extend your timeline to document that important event? (The scale of this timeline is 50 years per centimeter.)

NOTES

Activity 3: Crystallography

Estimated Time: 45 minutes
Student Grouping: pairs

Objectives:

- Simulate the motion of atoms in a liquid as it transitions to a solid.
- Explain what causes the formation of three crystalline structures:
  1. Amorphous
  2. Crystalline
  3. Polycrystalline

Standards:

NGSS	MS-PS1-1, MS-PS1-4
CCSS ELA	6-8.W.1

Materials for this Activity

Per group of two:

- Student Pages
- 1 Fruit candy
- 1 White mint candy

Advanced Preparation: none

Suggested Inquiry Approach:

The following script is offered. There is no need to use it verbatim. Rather it is an example of how to coach students toward an understanding of the three crystalline structures.

Part 1 – forming an Amorphous Solid

- “Imagine that you are an atom of a liquid.”
- “You are free to move slowly about the room.”
- “Walk slowly, but never come to a stop.”
- “Slowly bounce away from any obstacle you encounter.”
- *Let students get used to this motion. To help manage their behavior, tell them as often as necessary:*
  - “Atoms that move too fast will have to sit down and watch!”
  - “Atoms are silent. They listen but don’t make noise!”
- “You feel electrical forces from the other atoms nearby.”

NOTES

- “These forces pull you closer until you are within arm’s reach, but push you apart if you get any closer.”
- “You feel most comfortable when you are one arm’s length from other atoms.”
- “If you find yourself too close or too far away, slowly adjust the direction of your motion.”
- “You will seldom be exactly one arm’s reach away from the nearest atoms but try to maintain that as your average.”
- “Your walking speed will vary but your average speed is a reflection of your temperature.”
- “How do you think the movement of atoms changes when the temperature drops?” *Give students a moment to answer: the atoms move more slowly*
- “If I reduced the temperature in this room far enough, the liquid which you are simulating would freeze into a solid.”
- “What will happen to your movement if the temperature drops to freezing?” *Give students a moment to answer: we stop completely*
- “When I say “now” I want you all to freeze in-place.”
- “Now!”
- “You used to be part of a liquid. Now what have you become?” *Give students a moment to answer: a solid.*
- “Without moving your feet, look around the room at the other atoms.”
- “Are you all facing the same direction?” *Give students a moment to answer: no*
- “Were you all moving in the same direction?” *Give students a moment to answer: no*
- “Are you all equally spaced around the room?” *Give students a moment to answer: no*
- “Are you exactly one arm’s length from your neighbors?” *Give students a moment to answer: no*

- "Can anyone give examples from the real world in which a liquid freezes very quickly into a solid?" *Give students a moment to answer. Lava flowing into water would be one example.*
- "The solid substance of which you are now a part is referred to as an **amorphous solid**. It has no repeating pattern or geometry. You are a somewhat random arrangement of atoms."
- "Everybody say the word "**amorphous**"!"

Part 2 – forming a Crystalline Solid

- "Now I am turning up the heat in this room so that you melt back into a liquid. Begin walking around slowly as you did before."
- "I am about to drop the temperature again but this time I will do so <u>very slowly</u>."
- "As the temperature drops there will be one atom in the room which will be the first to stop moving."
- "I am about to call out the name of that one atom."
- "If you hear your name called, freeze in-place. The rest of you keep moving but do so very slowly."
- *Call the name of one student who is close to the center of the room.*
- "_________ is now motionless and facing in a particular direction."
- "_________, please raise your hand so everyone can see you."
- "The rest of you will continue to move ever more slowly as the temperature drops."
- "The atoms which are closest to _________ finally have a chance to park themselves exactly one arm's length from a neighbor."

NOTES

- "_________ is no longer a moving target so I want the four people currently surrounding _________ to come to rest one arm-length away from him/her and facing in the same direction in which _________ faces."
- "A **crystal** has begun to form."
- "The rest of the atoms are still moving about very slowly."
- "If you find yourself within reach of any of the stationary atoms, park yourself exactly one arm's length away and face the same direction as everyone else in the crystal."
- "The crystal begins with _________ and grows outward until all the atoms have joined it."
- *All students should come to rest one arm-length from their neighbors, and all facing the same direction.*
- "Once again you have become a solid. You are not an amorphous solid now, but a **crystalline solid**."
- "Everybody say "**crystalline**"!"
- "How is a crystalline solid different from an amorphous solid?" *Give students a moment to answer: spaced equally, facing same direction, more organized*

Part 3 – forming a Polycrystalline Solid

- "Some crystalline solids are formed from a single, large crystal, such as snowflakes. More commonly, multiple crystals begin forming at the same instant and they grow until they reach the edges of the other crystals forming around them. Such a substance is called a **polycrystalline solid**."
- "I am turning up the temperature again, so melt back into a liquid and resume moving."
- "This time I am going to call three names. If you hear your name, raise your hand and stop moving."

- "Everyone else join a crystal as soon as your motion brings you within arm's reach of an atom which has already stopped. Be sure you are one arm-length away and facing in the same direction as the atom you are joining."
- *Call the names of any three students. The others should come to rest, aligned with the nearest of the three names you called.*
- "Once again you are a solid, made up of crystals, but this time you are polycrystalline solid."
- "Everybody say "**polycrystalline**"!"
- "How many crystals have you formed?" *Give students a moment to answer: 3*
- "Are all three crystals facing in the same direction?" *Give students a moment to answer: the 3 crystals are probably not facing the same direction but all the atoms within each crystal are all facing the same.*

Now have students work in pairs to answer questions on their Student Pages. Each pair will need one fruit candy and one white candy.

Debrief:

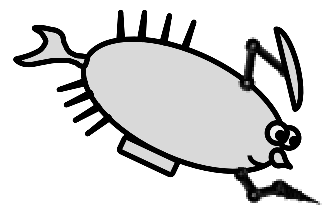
Crystalline structures are important for a broad range of solids including everything from sugar to steel. As a class, share answers to the questions on the Student Pages.

Extensions:

- During this activity, students were told that atoms like to stay "an arm's length" apart. The attractive and repulsive forces which contribute to this behavior may be examined using a web-based computer simulation here: http://phet.colorado.edu/en/simulation/atomic-interactions
- If your school has the necessary equipment (glassware and hot plate), there is an interesting experiment in crystallography outlined by Northwestern University at this site: http://www.earth.northwestern.edu/public/seth/demos/XTAL/xtal.html

Student Pages

Unit 1, Activity 1, Diving into Material Properties



Problems:

- Select materials to serve a specific purpose based on their material properties.
- Why do materials have different properties?

Materials for this Activity:

Per group of 3:

- 1 Diagram of a submarine robot
- 26 Plastic chips (labelled A through Z)
- 3 copies of Anodami Materials List
- A computer with access to the internet

Our Story:

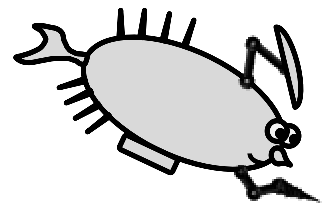
Far from Earth, the inhabitants of a planet called Anodam have a problem. The Anodami obtain all their food from the sea. Lately, it has become difficult to catch fish. Seaweed harvests have fallen dramatically. These difficulties are thought to be related to recently detected changes in the seawater.

Anodami scientists have hypothesized that volcanic activity on the sea floor might be responsible for these unfortunate changes. This possibility must be investigated immediately! The Anodami must design a submarine robot which will dive to an undersea volcano to obtain a sample of newly formed rock. An examination of that rock will help determine if the volcanoes are responsible for the damaging changes to the sea.

In this activity you will play the role of an Anodami engineer. Your task is to select appropriate materials from which to construct a submarine robot.

Student Pages

Unit 1, Activity 1, Diving into Material Properties



Procedure:

Form groups of three for this activity.

1. The Submarine Robot

Examine the diagram of the submarine robot. Read the description of each labelled part. How many labelled parts are there?

Examine the plastic chips. Verify that you have 26 chips, labelled A through Z.

Each chip represents one type of material which is available for use on your robot. Supplies are limited, however, so each material can only be used for one part of the robot. Some materials will not be used at all.

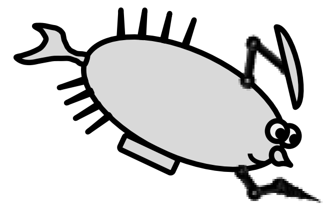
Read the information on your Materials List which explains the properties of each material.

Select a material for each labelled part of your robot and place the appropriate chip on that part.

As a class, compare your designs. Discuss why you chose these particular materials for each part of your robot.

The chips come in four different colors. In the boxes below, record any similarities you notice in the materials of each color.

Red:	Green:
Blue:	Yellow:



Unit 1, Activity 1, Diving into Material Properties

Characterize each group of materials with a label or name that contains as few words as possible:

Red:	Green:
Blue:	Yellow:

Think of some materials that might be available to engineers here on Earth. List a few materials that might fit into each category:

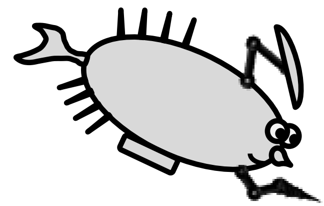
Red:	Green:
Blue:	Yellow:

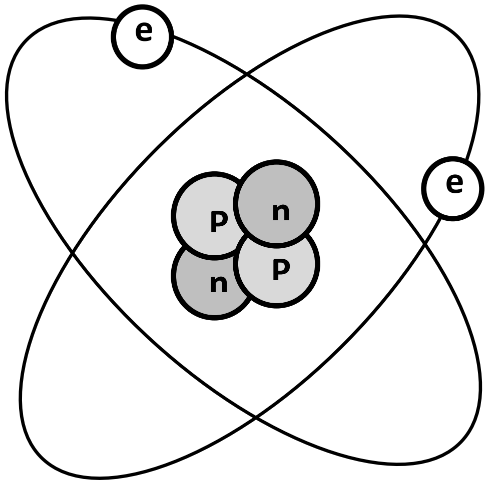
2. Material Properties

What gives a material its particular properties? There are two factors:

1) The chemical elements from which it is made.
2) The structural arrangement of its atoms.

Unit 1, Activity 1, Diving into Material Properties





Atoms are made of three different types of subatomic particles. Can you name them?

1)

2)

3)

Atoms of different elements behave differently due to having a different number of these subatomic particles. At your computer, open your browser to the following website: http://phet.colorado.edu/en/simulation/build-an-atom

Click the green "Run Now!" button to start the simulation.

Drag a single proton into the nucleus (marked with an "x").

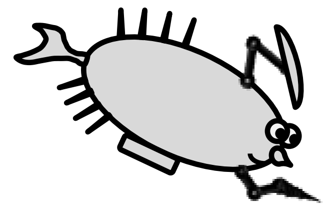
Is your nucleus stable or unstable?

Now add an electron.

With one proton and one electron, you have created an atom of hydrogen, the most basic element in the Universe. Congratulations!

Add another proton to your atom.

Is your nucleus stable? If not, add a neutron and keep adding neutrons until your nucleus is stable.



Add another electron to keep the charge of your atom neutral.

What element have you created with this atom?

Can you think of any similarities between the two elements you have created so far?

Add a third proton, a third electron, and as many neutrons as you need to stabilize the nucleus.

This is an atom of lithium. Unlike hydrogen and helium, lithium is a solid. It is a light metal often used in batteries. When matter first formed in the early universe, it was mostly hydrogen, with some helium and a tiny bit of lithium. These three elements formed the first stars. All of the other elements formed later, inside stars, where small atoms are sometimes crushed together, forming larger atoms.

Continue adding protons, electrons, and neutrons to form larger atoms. In the space below, record the element composed of each atom:

An atom with 4 protons is: ___________

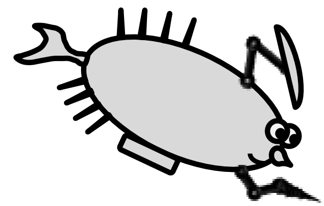
An atom with five protons is: ___________

An atom with six protons is: ___________

All atoms are composed of the same three "building blocks". What distinguishes one atom from another is how many of those blocks it has. Many of the properties of a material are due to those differences. But some properties require another explanation.

Student Pages

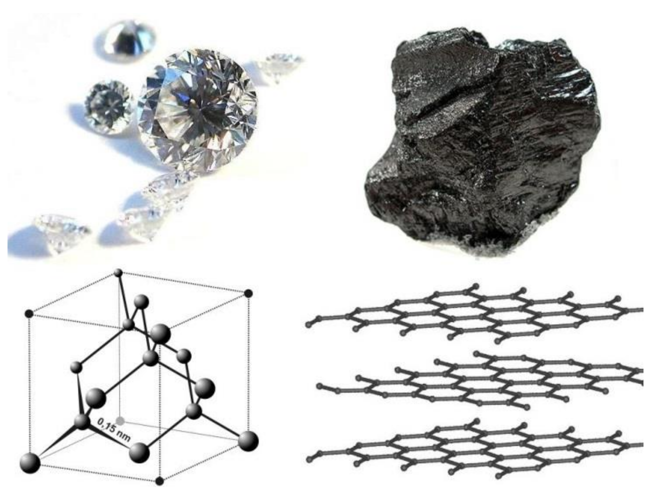
Unit 1, Activity 1, Diving into Material Properties



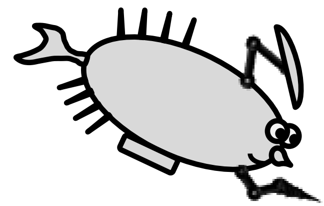
Your pencil point, which we often call “lead”, is not really made of lead. It is made of graphite. In the space below, record some observable properties of graphite:

As you know from writing with a pencil, graphite is not that hard. The hardest material in nature is diamond. In the space below, record some properties of diamond:

Obviously these two materials are very different. Surprisingly, each is composed entirely of carbon atoms. How those atoms are attached to each other makes a big difference. Graphite and diamond atoms are arranged in very different structures.

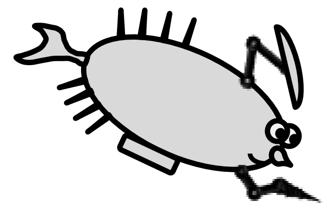


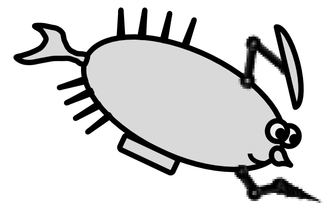
Unit 1, Activity 1, Diving into Material Properties



The carbon atoms in diamond are locked into a rigid crystalline structure. The carbon atoms in graphite are stacked in thin sheets of hexagons. Carbon atoms can be arranged in many other structures as well, each with unique properties.

Materials throughout the universe are made from the same types of atoms and structures. Whether you are on Earth or sailing the seas of Anodam, the same rules apply.





Unit 1, Activity 2, Timeline of Materials Science

Problem: Create a timeline for your class on which you can track the developments in materials science which influenced the course of human history.

Materials: You and your partner(s) will need:

- 1 Computer with internet access
- Post-It notes
- 1 section of the class timeline

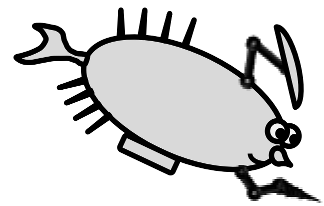
Procedure:

The entire timeline will span 8,400 years, but your group will be given just a small section of the total. Your teacher will indicate the wall on which you are to assemble the timeline.

1. Send one person from your group up to the wall with your small section of the timeline. The challenge is to assemble the entire timeline in the correct order, and fix it to the wall, without speaking!

   While one member of your group is up at the wall, the others should get a computer up and running. Later in the activity you will need to do some research using the internet.

2. You and your partners will now make a list of events that could be placed on the timeline. Think of the most important events from human history. These might be important inventions or accomplishments, the rise and fall of civilizations, the birth of important people, or other important "firsts".



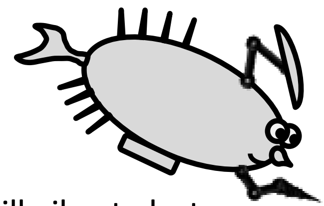
3. Share your list with the class and, together, decide on 10 to 20 events to plot on the timeline.

4. Search the internet to see when those events happened. When you find the information, use a small post-it note to record the event, the year, and your name. Place the note on the appropriate year of the timeline.

5. After all the events are placed on the timeline, check the results which other groups found. Once the class agrees on the dates you may wish to label the timeline with something nicer than post-it notes.

Student Pages

Unit 1, Activity 3, Crystallography



Atoms in a liquid are in constant motion. In a solid, atoms can still vibrate but their locations are generally fixed. Depending on how quickly they transitioned from a liquid to a solid, the atoms may be arranged randomly or in regular, geometric patterns.

Problem: What different types of crystalline structures may be formed by a liquid material as it cools and becomes a solid?

Procedure:

In this activity, you will simulate an atom of a liquid material as it cools and freezes into a solid. Your teacher will guide you on the procedure. Your liquid will freeze into a solid three times, forming different types of patterns. After completing the activity, answer the following:

1. What type of cooling produced an amorphous solid?

2. What type of cooling produced a crystalline solid?

3. How is the size of individual crystals related to the rate of cooling?

Look at the diagram of four solid materials on the next page.

4. Which object(s) are amorphous solids?

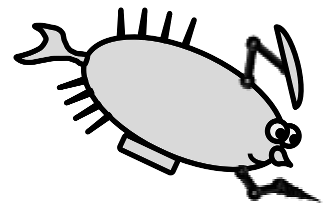
5. Which object(s) are crystalline solids?

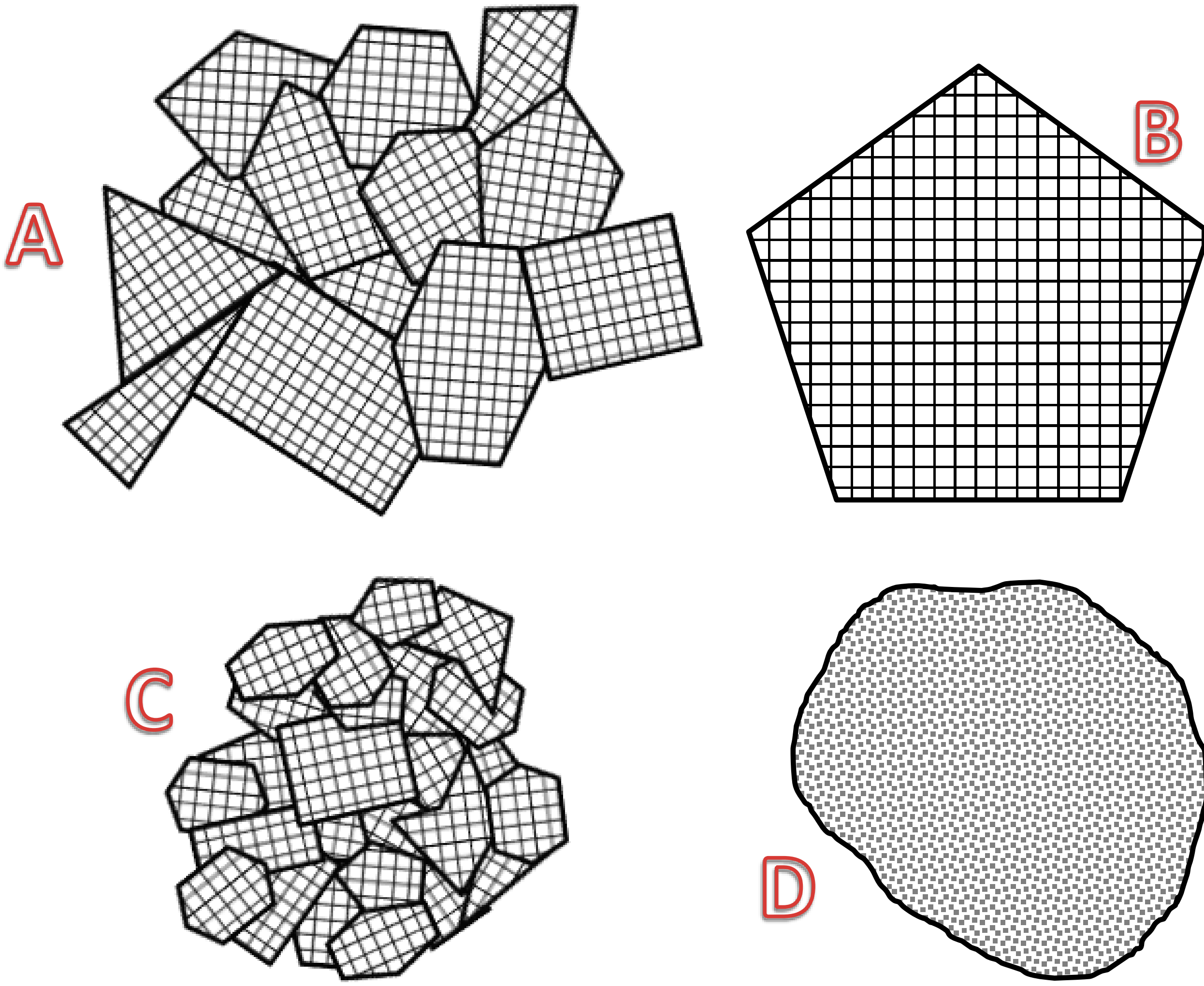
6. Which object(s) are polycrystalline solids?

7. List the objects in the order of which cooled the fastest to which cooled the slowest:

   ___________ ___________ ___________ ___________

Unit 1, Activity 3, Crystallography



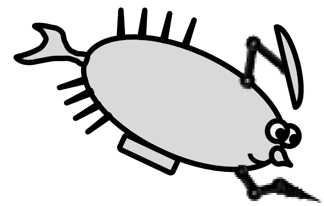


8. Imagine you held these objects in your hand. Some would feel smoother than others. List the objects in order from smoothest to roughest:

   ___________ ___________ ___________ ___________

9. Take one fruit flavored candy and one white candy. Break each candy in half. Examine the interior surfaces where the candy broke. Use a hand lens as well as your finger tips.
10. Which candy is an example of a polycrystalline solid?

11. Which candy is an example of an amorphous solid?



12. Both candies are made from the same type of sugar. Which candy cooled more slowly during production?

13. This form of candy, using crystallized sugar from the sugar cane plant, was invented in India around 500 CE. Ask your teacher for the marker representing the first hard candy. Place it on your timeline.