INNOVATIVE TECHNOLOGIES CHALLENGE

HOW CAN YOU MAKE A SMARTPHONE INTO A MICROSCOPE?

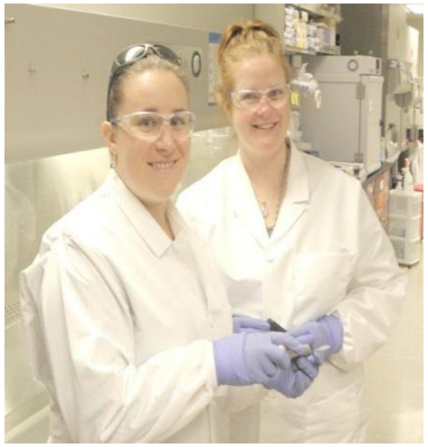


Photo from Pacific Northwest National Laboratory

Summary: This activity exposes students to a new technology called a Smartphone Microscope. Students will gain an understanding of the historical context of microscopes and their function, collect data (images) and brainstorm how this technology might be used in all STEM (science, technology, engineering and math) disciplines and careers.

Background: At the heart of innovation, creativity meets function. How did two of our engineers at the Department of Energy's Pacific Northwest National Laboratory located in Richland, Washington come up with their design for a Smartphone Microscope? Well—they were trying to solve a problem!

Rebecca Erikson and Janine Hutchison (pictured) describe in their own words how they identified a problem and created a technology to solve it: "We interviewed a lot of first responders, public health labs and civil support teams. They told us when confronted with a suspicious white powder, the first thing they do is send a sample to the lab where it is put under a microscope. An inexpensive yet powerful microscope in the field could be used to quickly determine whether the material is a threat or a hoax. Listening to their needs we were quickly reminded of a very early microscope—the Leeuwenhoek Microscope, which used a single glass sphere to provide magnification. Taking his lead, we used an inexpensive glass sphere and put it into a housing or clip that we designed and printed on a 3D Printer. Combining this microscope with the great cameras found on cell phones and tablets, we were able to create a very inexpensive microscope that has applications beyond first responders."

Learning Objectives - after this activity, students should be able to:

- Explain the historical context of the microscope and the structure of van Leeuwenhoek's instrument
- Describe how the Smartphone microscope works
- Compare and contrast the terms reflection and refraction
- Use the microscope and collect data (images), experiment with different types of specimens and analyze the different structures from patterns in the data
- Brainstorm other uses for the microscope
- Identify STEM careers that could use this microscope as a tool (Be sure to check the Women@Energy site to investigate different STEM careers at http://energy.gov/diversity/listings/women-energy)

Introduction: In the mid 1600's, van Leeuwenhoek (pictured) used his imagination and curiosity to construct a single lens microscope. Most microscopes we use now are called compound microscopes which mean they use more than one lens to magnify an image. Van Leeuwenhoek ground a bead of glass very small to be used for the lens. He was actually able to see things much clearer than scientists that used the compound microscopes at that time. When light hits an object, it can be reflected, which means the light exits the source at an angle directly back or it can be refracted which means that the light exits the substance at an angle that looks offset. Light moves differently when it passes through different substances. When light changes course, it "bends" as it moves through a glass bead and produces a point where all of the light converges. This is called the focal point and its distance from the lens is called the focal length and determines the magnification of an object. The smaller the lens, the shorter the focal length and the result is a higher magnification. The bead you will be using in your microscope magnifies 100X (100 times) and there are also beads that magnify 350X and 1000X.

*Links to open source 3D printing directions for the clips to hold these beads and a source to buy the beads are included at the end of this activity.

Activity - What is Reflection and Refraction?

Materials:

- Light source i.e., flashlight or laser pointer, or natural sunlight
- Samples to be studied
- Glass of water
- Straw
- Mirror

Procedure: In order to understand reflection, point your selected light source at a mirror. The angle of incidence (the angle at which the light hits the reflective source) is equal to the angle of reflection (the angle at which the light exits the source). For refraction, you will use a transparent glass of water and a straw. Put the straw in the water and observe. Does the straw look bent? Light moves in air at a different speed than in glass or water. Therefore, the angle of incidence is larger than the angle of refraction so the straw looks bent.

The tiny glass beads that are used in the microscope are actually put in paint that is used on roadways. Have you ever noticed that when you are driving at night that there are certain roadways which reflect the light from your headlights more intensely? That is because the roadway paint has embedded glass spheres that reflect the light from headlights at a more directed angle, back to the driver's eye. If you have access to a vial of these glass beads, shine a light on them and experience the reflective effect.

*If you want to explore further, there is a reflection animation and a virtual experiment on refraction (http://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Refraction/Refraction-Interactive)

Activity - Smartphone Microscope: What is a microscope? What does it help us do? You need to think about what you might want to look at more closely with your microscope and collect those items as samples to be studied. We have provided some suggestions for samples, but anything you can think of will be interesting. One thing to keep in mind, light needs to be able to travel through your sample to the glass bead and the lens of your camera. Also, you can use the microscope with your phone's front or rear-facing camera, but remember there is a difference in resolution between those two cameras. For example, the front camera on an IPhone6 is 1.2 Megapixels, while the rear camera is 8.0 megapixels, meaning the rear camera has a more powerful lens. If you use a camera on the back of your device, you will want to turn the flash to "ON" to illuminate your sample.

Materials

- Tablet, smartphone or digital device with a camera
- Smartphone Microscope
- Samples to examine (Suggestions)
  - Any type of leaf or grass, corn or algae
  - Flowers, butterfly wings or feathers for structural components
  - Salt, sugar, or baking soda
    - You can use a clear piece of adhesive tape to attach crystals
    - Make sure you place the crystal side of the tape directly on the microscope.
    - If you use tape, what else do you see? (You can see the adhesive that is used on tape to make things stick.)
  - Paper money
  - Strands of thread, hair, dust particles, lint
  - Different spices such as pepper, cinnamon, etc.

Procedure: Examine your microscope and clip. On the branded side of the clip you will see a glass bead. Turn on your camera App and attach the clip to your phone, tablet or digital device, placing the glass bead in line directly with the lens of your camera.

Take your sample (remember, light must be able to pass through it), and place it directly over the glass bead. Then move your sample very slowly until you think the object has the best focus. Collect your data by taking a picture of your image.

As you study your images, what patterns can you see emerging from your different samples? What would you like to look at next? What are other ways you can think about using this microscope? Which other STEM careers could use this microscope as a tool for investigation?

Enrichment: As a fun add-on to this activity, each student can send their favorite image to their educator, and the educator can share the images with the group. For each image, the group can study the image and guess the origin of the sample. Each student should present their image with the name of the sample and magnification used.

For comparative purposes, students might take a picture of their object without the magnification and then a second image using the microscope. How do these two images compare?

Putting the A in STEAM? If you would like to integrate the Arts, make a collage of all of the images taken by students and display on classroom walls or the halls of your institution.

Next Generation Science Standards (5):

4-PS3 Energy Students who demonstrate understanding can use evidence to construct an explanation relating the speed of an object to the energy of that object.

Science and Engineering Practices:

- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. (4-PS3-3)
- Use evidence (e.g., measurements, observations, patterns) to construct an explanation. (4-PS3-1)

Disciplinary Core Ideas:

- Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-2), (4-PS3-3)
- Light also transfers energy from place to place. (4-PS3-2)

Cross-cutting Concepts:

- Energy can be transferred in various ways and between objects. (4-PS3-1), (4-PS3-2), (4-PS3-3), (4-PS3-4)

Science affects everyday life. (4-PS3-4)**4-PS4** Waves and Their Applications in Technologies for Information Transfer

- PS4.B: Electromagnetic Radiation

Disciplinary Core Ideas:

- An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2)

Cross-cutting Concepts:

- Similarities and differences in patterns can be used to sort, classify, and analyze simple rates of change for natural phenomena. (4-PS4-1)

MS-PS3 Energy

Cross-cutting Concepts:

- Science knowledge is based upon logical and conceptual connections between evidence and explanations (MS-PS3-4), (MS-PS3-5)

MS-PS4 Waves and their Applications in Technologies for Information Transfer

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

Science and Engineering Practices:

- Develop and use a model to describe phenomena. (MS-PS4-2)
- Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. (MS-PS4-3)
- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1)

Disciplinary Core Ideas:

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2)

Cross-cutting Concepts:

- Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3)

Sources:

- Picture of van Leeuwenhoek: http://www.vanleeuwenhoek.com/images/Antonie van Leeuw Enhoek-Jan%20Verkolje-1632-1675.jpg
- Image for angle of incidence and angle of reflection (animation): http://www.physicsclassroom.com/mmedia/optics/lr.cfm
- The Refraction Interactive (with two activities and teacher notes): http://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Refraction/Refraction-Interactive
- Women at Energy site showcasing science and engineering women at the Department of Energy http://energy.gov/diversity/listings/women-energy
- Next Generation Science Standards http://www.nextgenscience.org/
- PNNL website for 3D print files for microscope clip and resource for glass beads http://availabletechnologies.pnnl.gov/technology.asp?id=393

Girls of Energy

INNOVATIVE TECHNOLOGIES CHALLENGE

POWER UP ACTIVITIES FOR SMARTPHONE MICROSCOPE LESSON

ACTIVITY ONE:

WHAT IS REFLECTION?

Students will use a laser pointer or flashlight and a mirror to study reflection and note angles of incidence and reflection

Materials

- Laser Pointer or Flashlight
- Dark Room with a mirror

Question:

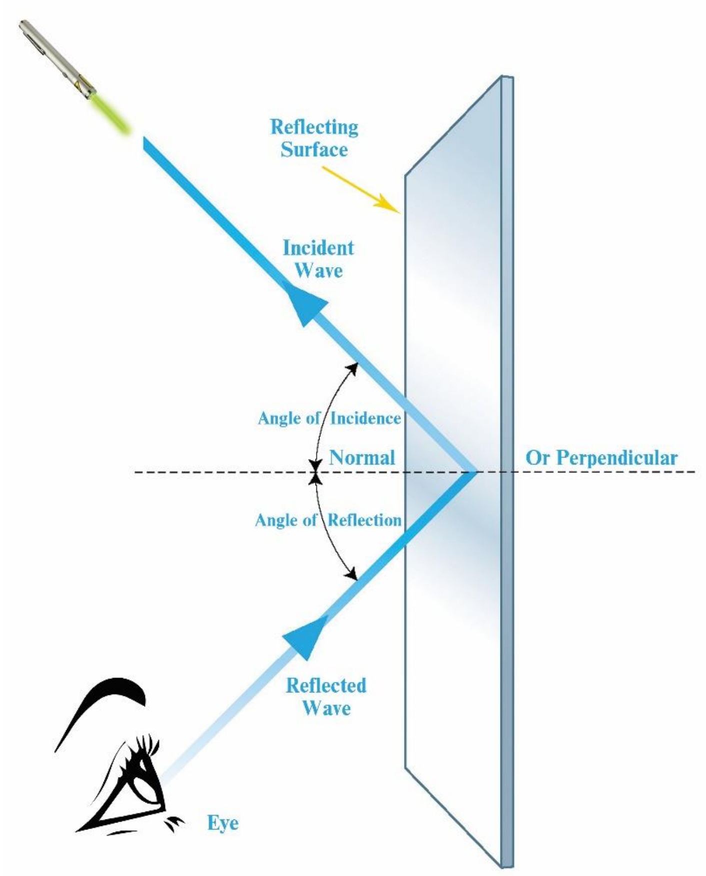
What is Reflection?

Explore:

Find a dark room that has a mirror so you can observe the light from a laser pointer (preferred) or a flashlight as it hits the mirror. Does the light bounce reflect? In which direction? How do the two angles compare? Another option would be to trace the path of the light using a white base like foam board and drawing utensil. Using a protractor, measure the angle of incidence and the angle of reflection.

Explain:

When light hits a reflective surface, it reflects at an angle equal to the incident angle. This can happen when almost all of the light is reflected, but it can also happen when only some of the light rays are reflected.



ACTIVITY TWO:

HOW IS REFRACTION DIFFERENT FROM REFLECTION?

Students will use a glass, liquids and a straw to examine how light “bends”.

Materials

- Transparent Glass
- Water
- Colored Straw

Question:

How is Refraction different from Reflection?

Explore:

Take a colored straw and place it in an empty, transparent glass. Sketch how the straw appears when you observe from the side of the glass. Now, put water in the glass until it is ¾ full. Sketch what you see now when you look through the side of the glass.

What happened? How does the straw look different? Why do you think it looks different? What other liquids could you put in the glass and observe? How would these look the same—or different?

Explain:

Light energy moves through different substances with different speeds; this is called refraction. What our eye perceives comes from the refraction or bending of light due to movement through different substances. Light moves through air, water and glass at different speeds and that is why the straw appears bent. As enrichment for this activity, try this again using salt water or sugar water (with as much solid as the water can hold), syrup or oil.

Does the straw look different in each case? You can measure each angle and you can also use images of each. Explain which substance refracts more from your data and observations.

ACTIVITY THREE:

DESIGN YOUR OWN REFRACTION VIRTUAL EXPERIMENT

Students will design their own interactive refraction virtual experiment.

Question:

Can you observe how light changes speed when moving through different substances?

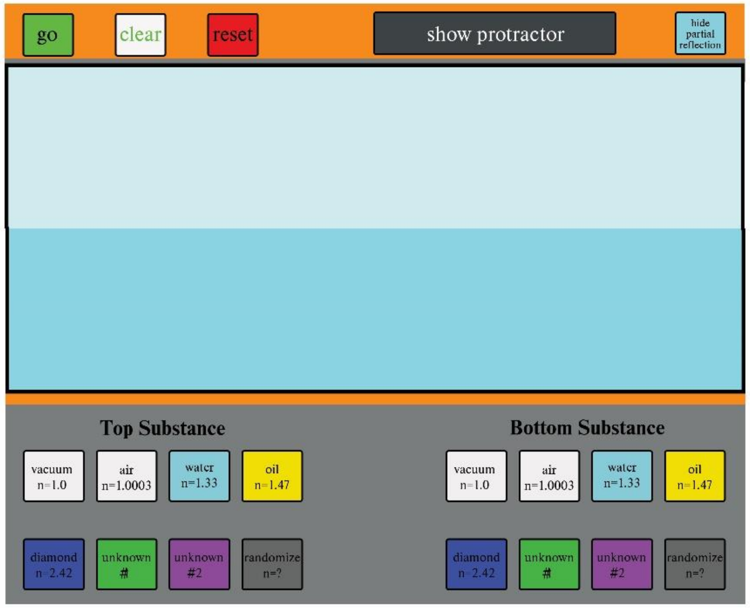
Explore:

Use this link to interactively explore how a light ray changes when passing through different substances. In order to become familiar with this interactive display, use your cursor to manipulate all of the various pieces. You can move the laser, fire the laser, use the protractor to measure angles and change the top and bottom substances to investigate varying speeds. It might work best if you select the “Hide partial reflection” button so you can see the major reflection and refraction paths of light. If you want to collect data, you can use the protractor to measure the different angles of incidence and refraction. This will help you reference how quickly light moves through different substances.

Explain:

Light moves at different speeds as it continues through different types of mediums. This interactive experiment allows students to investigate the various ways light is reflected and refracted depending on the types of materials used. This can be a simple tool to observe how light moves, but it can also be used to investigate different types of materials.

Which material bent the light at a larger angle? Which material bent the light at a smaller angle? How do those observations compare to the n value noted for each substance?



ACTIVITY FOUR:

LIGHT IS ENERGY-CAN YOU SEE THIS?

Students will use a Wint O Green Lifesaver® to examine how light is emitted when electrons are excited and return to a lower energy state.

Materials:

- Wint O Green Life Saver®
- Dark Room
- Mirror

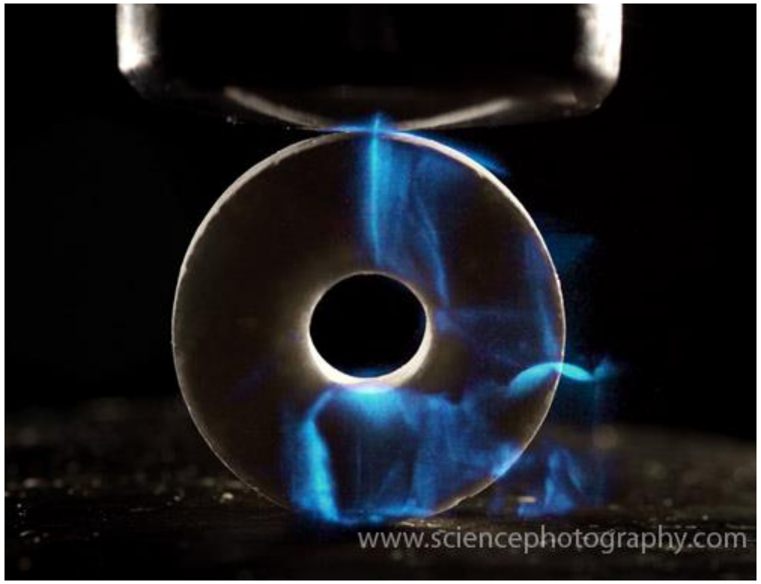
Question:

How can you see Light Energy?

Explore:

Take a Wint O Green Lifesaver® and go somewhere very dark with a mirror. Bite down on the mint and watch in the mirror to see what happens. As an alternative, you can put a few candies in a baggie and use a pair of pliers to break them.

Did you see a spark? What color was it?



Explain:

Wint O Green Lifesavers® contain a special ingredient called oil of wintergreen. This oil has a special property that absorbs energy waves we cannot see with our eyes (ultraviolet) and emits them as light that we can see. When you crunch on a candy, you disturb and excite electrons. When they lose the energy you gave them by crunching (kinetic energy), you will see that extra energy given off as blue light. Sometimes the electrons excite the nitrogen in the air as well, making the blue color more pronounced.

Light is energy and can be used in many different ways. Your Smartphone Microscope would not function without the light waves entering through the glass bead and bending to help produce an image that your eye can detect.

ACTIVITY FIVE:

REFRACTION AND CONVERGING LENSES — WHAT MAKES THE WORLD UPSIDE-DOWN?

In this activity, students will learn about converging lenses and try their hand at capturing an image that shows a converging lens.

Materials:

- Smartphone Microscope
- Digital Device with a Camera
- Transparent Glass
- Magazine or Newspaper
- Magnifying Glass
- Water
- Glass Bead

Question:

What makes the Department of Energy sign appear upside-down?

Explore:

In order to understand more about lenses and how the glass bead works as a lens in the Smartphone Microscope, we will use rounded transparent substances to demonstrate how light moves through a lens. Take a transparent glass and a magazine or newspaper and place the empty glass on top of the newspaper.

What do you see?

Now move the glass further away from the print—what happens to your image? Examine the bottom of the glass—does it appear to be the same thickness or thicker in one area?

Use a magnifying glass and look at the same newsprint. What happens? Examine the magnifying glass and see if it has a uniform thickness or if it has areas that are thicker or thinner.

Using your glass bead, look at the newsprint—what do you see? Place 1 drop of water over a letter on the newsprint—what do you observe? Do things appear larger? Are they right-side up or upside-down?

Explain:

A converging lens is thicker in the middle and thinner around the edges. As light bends around the edge of the lens, it converges at the focal point. If the sample you are studying is between the focal point and the lens, the object appears right side-up and magnified. If the sample is beyond the focal point, the image appears upside-down and magnified. If you have a camera, see if you can take pictures of things that can be used as a converging lens. Water droplets hanging on a tree branch after a rainstorm work well as converging lenses! How do your collected images compare to the picture?