Get Critical! STEM Kit Use Instructions

Note: This kit is intended for students 4th grade and higher in a supervised classroom setting. It is strongly recommended that instructors try the kit themselves before using it with students. This kit covers the scientific practices of Analyzing & Interpreting Data; Using Mathematics & Computational Thinking; Constructing Explanations & Designing Solutions; and Engaging in Argument from Evidence. (https://www.nap.edu/read/13165/chapter/7#50)

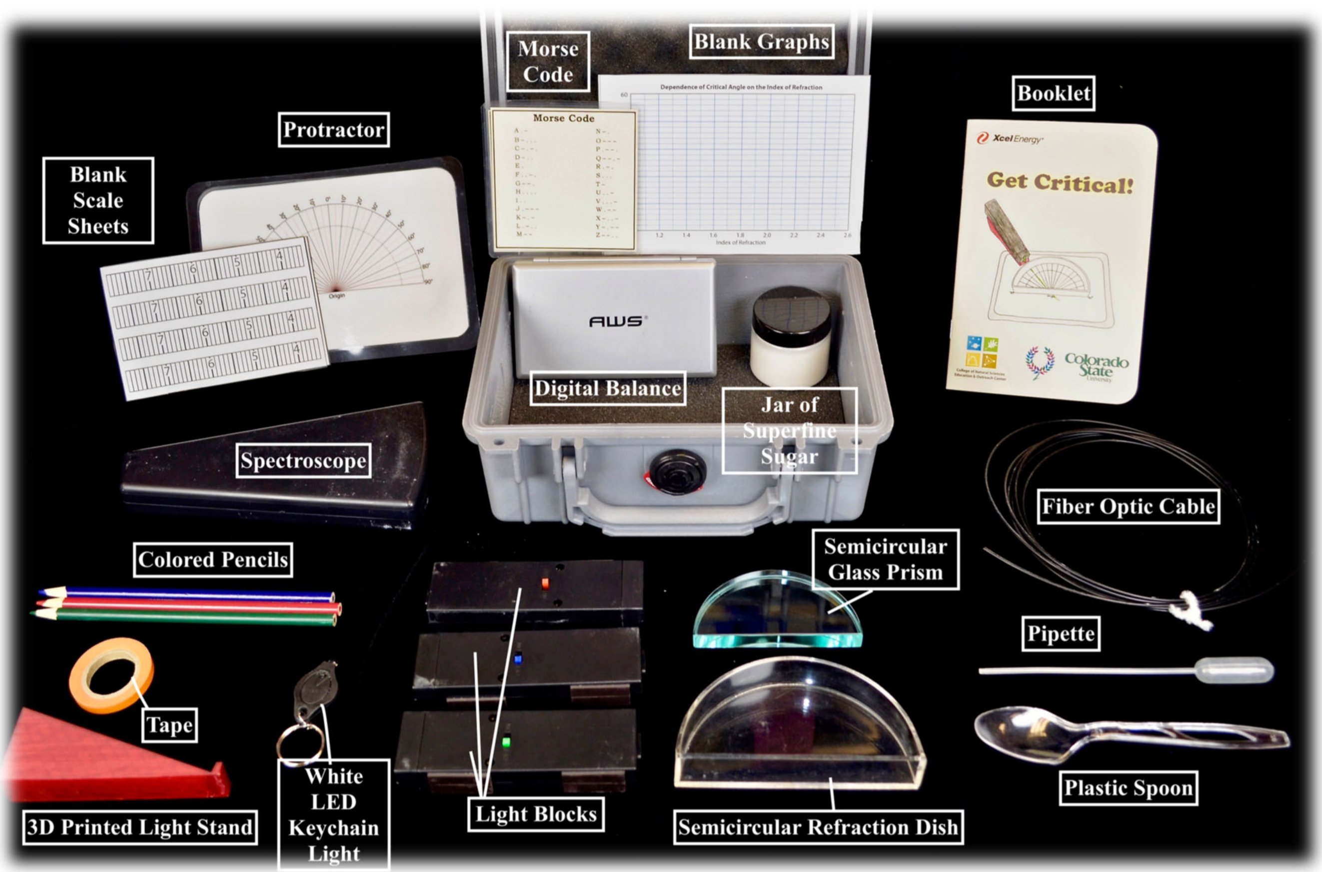
Unpacking Instructions

One classroom set of 15 kits is inside one large green case. Also included is a teacher's kit (different color) with extra supplies in case they are needed.

Kit Contents

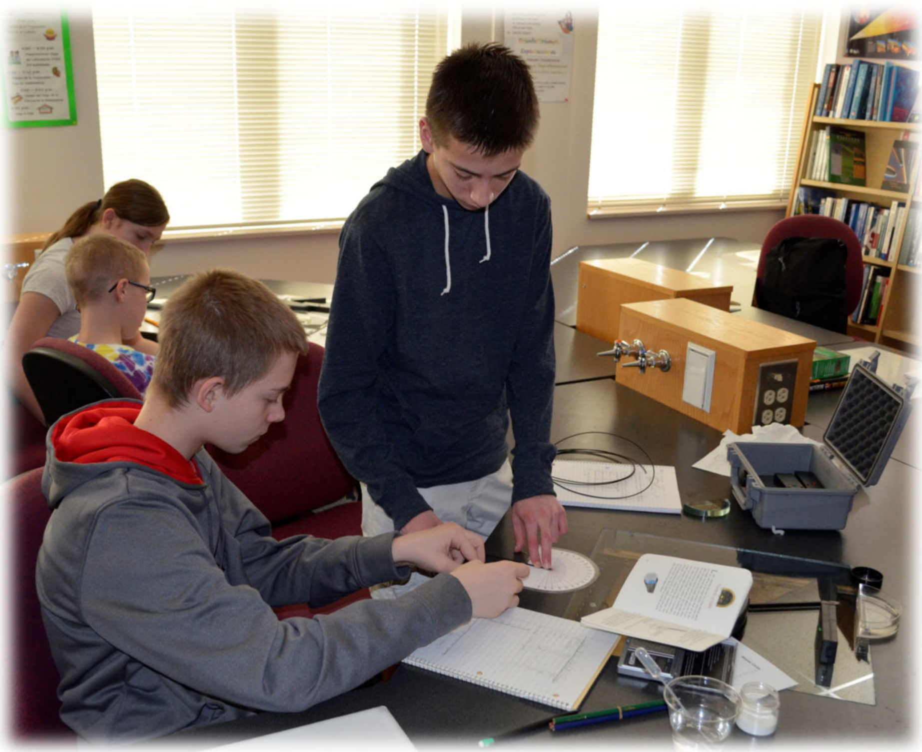
Each individual kit should contain:

- 3D Printed Light Stand
- Digital Balance
- Fiber Optic Cable
- Jar of Superfine Sugar
- Laminated Protractor
- Light Blocks (Blue, Red & Green)
- Morse Code Laminated Cards (2)
- Pipette
- Plastic Spoon
- Red, Green, and Blue Colored Pencils
- Semicircular Glass Prism
- Semicircular Petri Dish
- Spectroscope
- Tape
- White LED Keychain Light
- Blank Graph Templates (1 per student)
- Blank Scale Sheet Templates (1 per student)
- Get Critical! Booklet



Room Setup

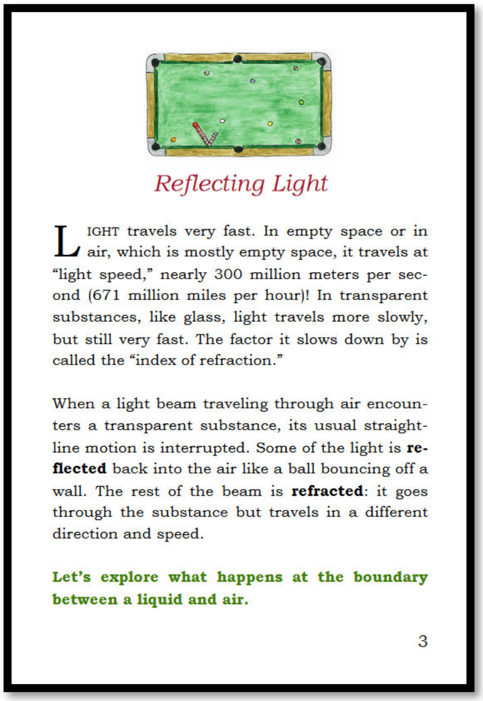
1. Arrange tables and chairs so students can work in pairs



2. Make sure to have the following supplies on hand:
   - Water
   - Plastic Cup (for water)
   - Paper Towels
   - Science Notebook
   - Tape (for taping data tables into Science Notebooks)
3. Have each pair of students obtain a kit, a paper towel for their workspace and a cup full of water.

Begin Lesson

1. Students should start by opening their science notebooks to a new page. Notebook should be labeled "Get Critical!" with the date and the name of their lab partner.
2. They should then open the kit and take out the Get Critical! Booklet and begin reading on page 3.



Reflecting Light

LIGHT travels very fast. In empty space or in air, which is mostly empty space, it travels at "light speed," nearly 300 million meters per second (671 million miles per hour)! In transparent substances, like glass, light travels more slowly, but still very fast. The factor it slows down by is called the "index of refraction."

When a light beam traveling through air encounters a transparent substance, its usual straight-line motion is interrupted. Some of the light is **reflected** back into the air like a ball bouncing off a wall. The rest of the beam is **refracted**: it goes through the substance but travels in a different direction and speed.

Let's explore what happens at the boundary between a liquid and air.

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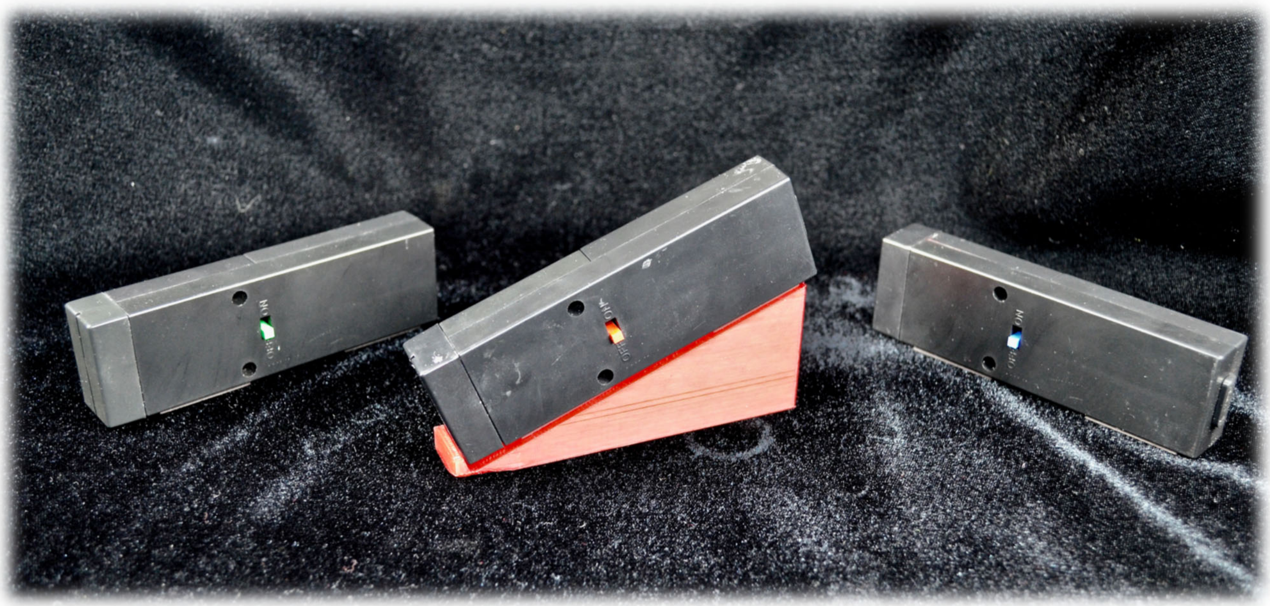
3. The words 'Science Notebook', accompanied by a pencil icon, are located throughout the booklet, which indicates that the students should **stop and respond** to the prompt in their notebooks.
4. Blank graph templates and scale sheets that are supplied in the kit can be used by the students and taped into their science notebooks in the appropriate place. Extra copies of the templates can be downloaded from the EOC website at: https://www.cns-eoc.colostate.edu/stem-kits/get-critical.
5. Pairs of students should be allowed to proceed at their own pace. Make sure to encourage students to read the text rather than just looking at the pictures.
6. Walk around the classroom and check on students, especially if they are younger. Clarify any parts that the students do not understand.

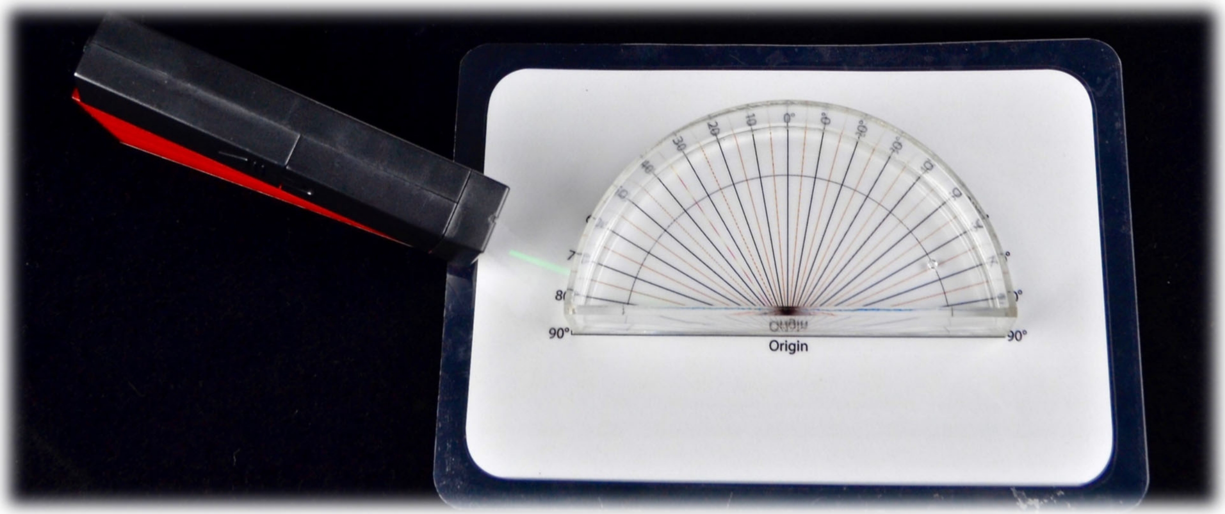
Part 1: Reflecting Light

1. Make sure students are pressing the "TARE" button with empty semicircular dish on it. Students should be weighing out exactly 50 grams of just water (page 4). They should work quickly with weighing out the water, as the digital balance will turn off if not in use after a short period of time.

2. Students should start out using the green light block. It needs to be placed on the red colored light stand so that the end producing the light is sloped downward. This makes it easier to see the rays of light.

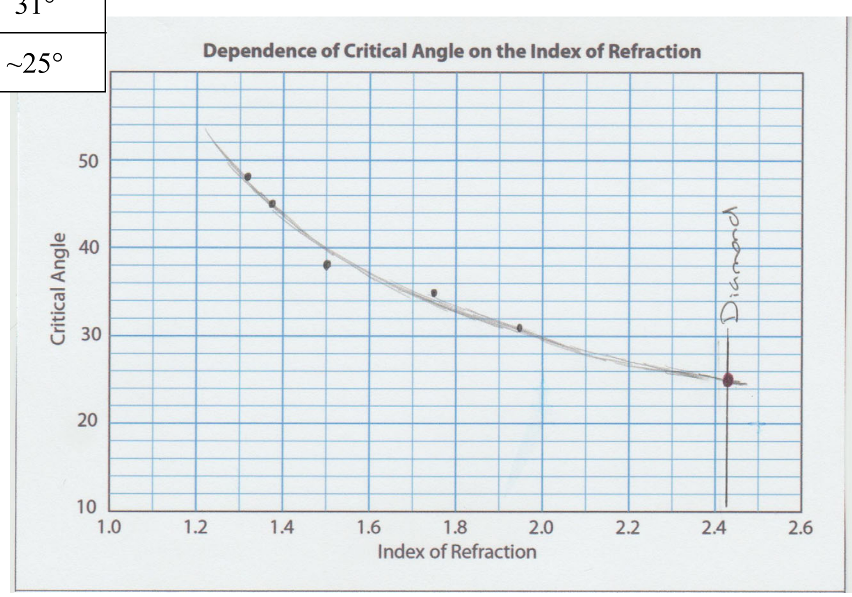


3. When using the light blocks, the light beam should be pointed towards the origin of the protractor. Students should pay close attention to what degree they are on and in which direction they are moving them.



4. Make sure students are accurately identifying the incident ray and the reflected ray and recording it in their science notebooks.
5. Critical angles and index of refraction should be recorded in order to complete "Dependence of Critical Angle on the Index of Refraction" graph.

Substance	Index of Refraction	Critical Angle
Water	1.33	~48°
30% Sugar Solution	1.38	~45°
Glass	1.50	~38°
Ruby	1.76	35°
Zircon	1.96	31°
Diamond	2.42	~25°



Part 2: Tunnels of Light

1. When taping fiber optic cable down, it should be perpendicular to the 90-degree line on the protractor (page 11). The red light should be used and once again propped on the red light stand.
2. Let students have the autonomy to make fun messages, but make sure it's appropriate!

Part 3: Diffraction

1. When students are using the spectroscope, make sure they are holding it horizontally and looking straight through the square hole. *Note: The spectroscope measures in nanometers (x100) so use the provided scales! Provide help reading the scales if needed.*

2. Students should do their best to get all three colors (blue, green and red) to shine through the fiber optic cable at the same time. It might help to rearrange the order of the colors to make it work. The fiber optic cable should be taped down before trying to shine lights through it (page 15).
3. When using cable to block hole on the wider side of spectroscope, the cable might not fully fit. If this is true, have students tape the cable to the spectroscope in order for students to observe the effects of shining colors through it (page 16).

Clean Up

1. All lights and the digital balance need to be turned off.
2. Loosely roll up the fiber optic cable & tie with piece of pipe cleaner. Throw away any used tape.

3. The semicircular Petri dish should be emptied into the sink and washed thoroughly then dried with a soft cloth.
4. Clean any sugar water off of the glass prism and protractor.
5. ***Make sure everything is completely dry before putting away in the kit.***
6. Place the semicircular glass prism inside the semicircular dish.

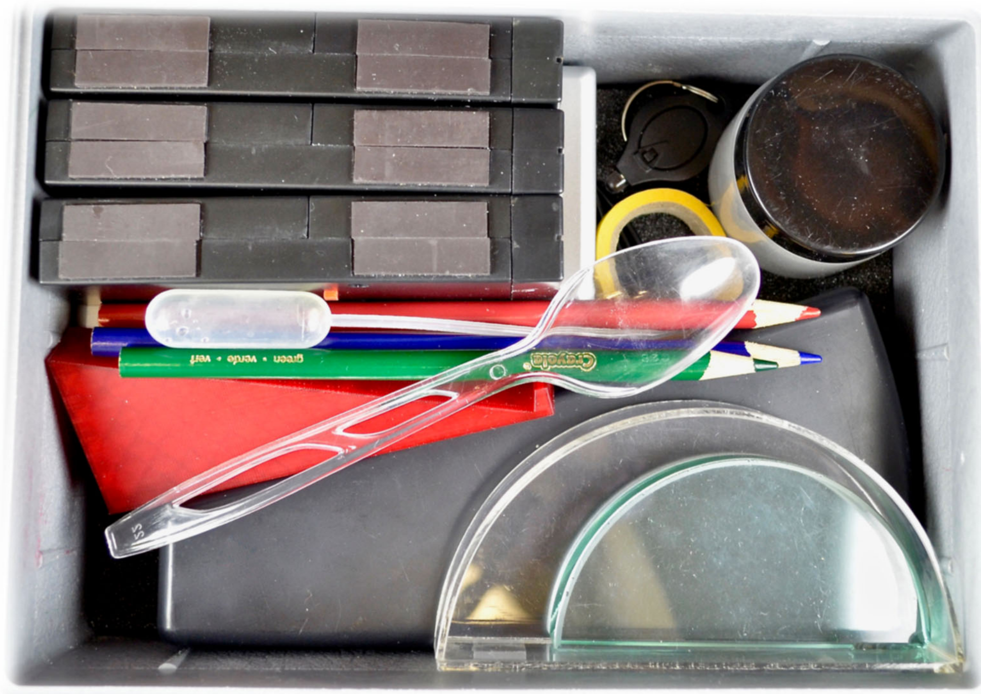
Packing Instructions

Step 1: Place the rolled-up fiber optic cable on the bottom of the case and the jar of sugar in the upper right corner.

Step 2: Obtain the spectroscope, tape, white keychain light and digital balance. Place the digital balance in the upper left corner of the case. The tape and white keychain light should be placed directly to the right of the digital balance. The spectroscope should be placed in the lower left corner.

Step 3: Obtain the red, blue, and green light blocks and place horizontally on top of the digital balance in the upper left corner of the case. Place the red light stand and put directly below the digital balance. The semicircular glass prism should be placed inside the semicircular dish. Both the semicircular glass prism and dish should be placed on top of the spectroscope towards the bottom right side of the case.

Step 3: Place the colored pencils, pipette and spoon directly below the light blocks. Lastly, place the Morse code sheets, protractor and Get Critical! booklet on top of it all and close case, making sure the latches are snapped shut. **CAUTION:** ***Do not force the case shut – it should close with ease!***



Class Discussion Questions

Note: The questions provided below are guide questions that students can discuss as a class in order to determine what they learned/took away from the kit.

Reflecting Light:

1. Explain the difference between reflected and refracted.
   Reflected light is light that involves a change in direction of waves when they bounce off of a barrier. Refracted light involves change in direction as the light passes from one medium to another.
2. What happened to the boundaries between liquid and air when shining light on the water? The sugar solution?
   The light changed direction when shining light on the water. Due to the sugar solution being denser, the ray of light reflected and refracted differently compared to just water.
3. Why do you suppose the critical angle changed when using a sugar solution rather than just water?
   Adding sugar to the water makes the solution denser, thus changing the critical angle.
4. Compare the critical angles for the water, 45% sugar solution, and glass prism.
   The addition of sugar makes the water more dense and therefore slows down the light waves. When light passes from a more dense to a less dense substance, the light is refracted away from the origin.
5. Why do jewelers shape diamonds into polygonal shaped faces?
   Jewelers shape diamonds into polygonal shaped faces in order to take advantage of the reflection of light. This shape prevents light from escaping, making the diamond appear shiny and bright.

Tunnels of Light:

1. What will happen if light is shone through a long skinny glass rod?
   The shape causes the angle to be greater than the critical angle. This means that nearly all of the light that enters one end of the rod will exit the other end through a series of bounces.

Diffraction of Light:

1. What does peering through the two pencils vertically and shining a light represent? How does this compare to using the spectroscope?
   Peering through the two pencils vertically and shining a light is another way to make light bend due to the very narrow slit. As light passes through the narrow opening, the light waves fan out as they bend. Spectroscopes help to magnify the effect of one slit and is much easier to use compared to the pencils.
2. When shining the three lights through the fiber optic cable, how is it possible for the light to travel to the other side of the cable?
   The light in the fiber optic cable travels by constantly bouncing from one mirror lined wall to the next. This internal reflection occurs because there is no refraction of the light wave.

Teacher Feedback Survey:

http://dat.cns-eoc.colostate.edu/STEMkits/stem_kit_survey.php

Thank You!