Hot Air: Teacher Lesson Plan

Introduction

Light has many interesting aspects. **Refraction** is the way that light bends as it travels through different mediums. The **medium** is the substance that light is traveling through. If you are looking at the Moon while standing by a pool, the medium is air. If you are looking at the Moon from under water after you jump into the pool, the mediums are both air and water. The Moon would appear different from underwater because the light is refracted. In this experiment you are going to decide if warm air and cool air are considered to be different mediums, or if they are the same medium.

Student Product

Students produce a table of observations from both the Cool Air and Hot Air experiments, and answer questions using evidence from their experiment.

Materials:

- Candle holder (modeling clay, or sticky adhesive putty)
- Candle (birthday cake size) and matches or lighter
- Laser pointer
- Binder clip
- Graph paper (8.5 x 11 inches with 1/4 inch grid size)
- Masking tape
- Cup (8 to 12 inches high), preferably non-flammable.
- Meter stick

Texas Essential Knowledge and Skills, Grades 9-12:

Astronomy

112.33(c)-2I use astronomical technology such as telescopes, binoculars, sextants, computers, and software

Integrated Physics and Chemistry

112.38(c)-5(G) explore the characteristics and behaviors of energy transferred by waves, including acoustic, seismic, light, and waves on water as they superpose on one another, bend around corners, reflect off surfaces, are absorbed by materials, and change direction when entering new materials.

Physics

112.39(c)-7D: investigate behaviors of waves, including reflection, refraction, diffraction, interference, resonance, and the Doppler effect.

Activity

Background:

Stars twinkle because Earth's atmosphere refracts the starlight. Warm cells of air rise and cool cells fall, like the globs of goo in a lava lamp. Convection is at work in both these systems. The index of refraction of the air cells depends on the temperature and pressure of the cell: cool dense cells have higher refraction indexes than warm vacuous cells, thus refract or bend light at greater angles. The journey of starlight though interstellar space is mostly undisturbed, until it suddenly meets Earth's turbulent atmosphere. Air cells refract the starlight in many different directions, so that it follows a crooked path through the atmosphere into an observer's eye – "twinkle, twinkle little star". In this experiment you are going to decide if warm air and cool air are considered to be different mediums, or if they are the same medium.

Preparation

1. Set up a table next to a wall
2. Measure a distance of 1.10 meters (1 meter and 10 centimeters) from the wall. Mark this spot on the table on masking tape with a pen as "Cool Air".
3. Measure 1 meter from the wall. Mark this spot as "Hot Air".
4. Center the cup (overturned) on the "Cool Air" mark.
5. Practice clamping the laser pointer "on button" with the binder clip, so that the laser stays "on". The laser will sit on top of the "Cool Air" cup and direct the beam perpendicular to the wall.
6. Students will tape the graph paper to the wall, so that the laser strikes the center. Be sure they are careful, and do not turn their heads back toward the laser.
7. Students can record their observations of the laser light the provided data table, or they can make up their own data table.

Safety Cautions: During this activity, students will work with a laser and fire.

Laser: A laser beam **directed into your eye** will permanently damage it, possibly resulting in blindness. The reflected laser light off the paper screen is harmless.

Fire: Always monitor the candle while it burns. Be prepared with a fire extinguisher.

Engage

StarDate: "High-Flying Stargazer" November 19, 2003

Before listening to or reading this StarDate radio script, ask students an engagement question:

Why do you think stars twinkle in the sky?

Accept everyone's answers, but offer no explanation yet. Now try a thought experiment:

Imagine that you are an astronaut aboard the International Space Station. The station happens to be on Earth's night-side, so Earth blocks the Sun and you can see both the Earth and space. You can see lights from cities and stars. Which lights do you think twinkle?

Explore

Safety considerations: everyone stays behind the laser, unless ONE group member is marking the laser spot on the graph paper. **Never look directly at the laser beam or allow it to shine in someone's eyes.** Monitor the candle while it is burning, and be prepared with a fire extinguisher.

Cool Air experiment: This is a control condition.

1. Place the cup at the "Cool Air" mark (1.10 meters from the screen).
2. Turn the laser on. Use the binder clip to maintain the laser pointer in the ON position.
3. Place the laser pointer on top of the cup.
4. Think laser safety – do not turn your head toward the laser as you tape up the graph paper or mark the laser spot. Face the wall until you are well away from the beam.
5. Tape the graph paper to the wall, centered on the laser spot.
6. Using a pencil, mark the laser spot on the graph paper. Observe the laser spot on the graph paper. Record your observations in a data table.
7. Do not disturb the cup or laser. Proceed to the "Hot Air" experiment.

Hot Air experiment: This is the experimental condition.

1. Place the candle into candleholder and set it at the "Hot Air" (1-meter) mark.
2. Light the candle.
3. Allow the candle to burn for 2 minutes. Be prepared with a fire extinguisher.
4. Students record their observations in a data table. The laser spot will slowly sway around

   the reference point by a tiny amount, only a millimeter or two. It's shape and brightness may

   change.
5. Blow out the candle. Turn off the laser.

Explain

Ask students to answer the following questions based on their experimental results and observations:

Cool Air experiment:

1. What did the laser spot do during the Cool Air experiment?

   When the laser light went through cool air, the laser spot on the graph paper was steady.

2. What did the laser beam travel through on it's way to the graph paper?

   Cool air at classroom air temperature.

Hot Air experiment:

3. What did the laser spot do during the Hot Air experiment?

   The laser spot moved around the reference point. It also changed size, shape, and brightness.

4. What did the laser beam travel through on it's way to the graph paper?

   Cool air, hot air, then cool air.

5. What did the candle flame do to the air above it?

   The flame heated the air. It created a convection current: hot air rising, and cool air sinking.

Real world application:

6. Why do you think stars appear to twinkle at night, observing them from Earth's surface? Can you relate this to your experiment?

   The laser beam is like light from a star. The air between the laser and the paper is like our atmosphere, and the paper is like our eye. "Outer space" is nearly a perfect vacuum, but our atmosphere is dense and turbulent. Star light travels almost undisturbed through space. But once it enters our atmosphere, it encounters cells of warm air and cool air. These are two different and changing mediums, so the star light will slightly change direction. As a result, we see the star twinkle.

Elaborate

The *Elaborate* section gives students an opportunity to extend their understanding into other contexts, like ground-based vs. space-based astronomy. Keep this page of the student worksheet separate from the rest of the activity, because the StarDate FAQ explains what happens to starlight as it travels through the atmosphere. Students should have the opportunity to discover how warm/cool air affects the laser light **first**, then communicate their conclusions.

Convection: A Current Event by Alan Gould, Lawrence Hall of Science
http://lhsgems.org/GEM280.html

Ask students to read this FAQ, then explain why they think astronomers want telescopes in space, or on the Moon.

StarDate: FAQ: Why do stars twinkle?

Because stars are so incredibly distant, to our eyes they appear strictly as points in the night sky. Irregularities in Earth's atmosphere cause starlight to dance around, and the minute changes in the path the starlight takes through the atmosphere results in apparent changes in color — the familiar "twinkling" effect.

Planets, however, actually form a tiny but definite circle on the sky just large enough to counter the distorting effect of turbulence. Such extended objects only "twinkle" when their light passes through very large amounts of atmosphere, such as when they lie close to the horizon.

Assessment or evaluation

Conclusions: Are warm air and cool air considered to be different mediums, or are they the same medium? Use evidence from your lab to backup your claim.

Warm air and cool air act like different mediums. The laser beam moved and twinkled in the warm air, but not in the cool air. The important point for a telescope is not whether the air itself is hot or cold, but whether there is a boundary where hot and cold air meet – that is where refraction takes place. This is why telescope domes are often air-conditioned during the day, so that when the dome is opened, the air inside matches the temperature of the cooler nighttime air outside, eliminating or minimizing the boundary between the two air masses. Ideally, the air inside the dome and outside the dome become the same medium, with the same temperature and pressure.

High-Flying Stargazer

StarDate: November 19, 2003

Hundreds of men and women have flown in space. Almost all of them have remarked on the great view of the heavens. But few have gone to such lengths to enjoy the view as Donald Pettit, the science officer for the sixth mission aboard the International Space Station. Pettit and crewmates Ken Bowersox and Nikolai Budarin were launched a year ago this month, and spent more than five months in orbit.

Pettit is an amateur astronomer who likes to photograph the night sky. In orbit, he rigged up a dark cone over the station's biggest window to block out light from inside the station. Then he snapped pictures of stars, galaxies, aurorae, and other astronomical sights. Pettit says it took a while to get used to the view:

PETTIT: What's amazing, you look at the stars, there's no twinkling effect. However, you look at city lights and you could see twinkles. And that takes a while to get used to. Another most amazing thing is looking at meteor showers. And this shows just how polarized you get when you live as a creature on the surface of a planet. The first time I went to look for a meteor shower, my thought was, "Gosh, I need to get a window that's pointing out towards the stars, because that's where the meteors are." However, after thinking about it for a few milliseconds, I realized I needed to get an Earth-viewing window, because the atmosphere is below us, between us and the Earth, and that's where the meteors burn up, and I need to be looking up that way, not up at the stars....Stars twinkling, and the direction you look for meteors, and seeing Earth lights twinkle, all of these are some of the delightful aspects of living and working in this kind of environment.