HOW RAINBOWS ARE FORMED

TOPIC:

Reflection and Refraction of Light

SCIENTIST:

Theodoric of Freibourg c.1250–c.1310

INTRODUCTION:

Theodoric of Freibourg attempted to show how rainbows are formed. He did this by shining light through an "artificial raindrop"—a glass flask (probably a medical urine flask) filled with water. He observed how light was *refracted* and was split up into its constituent colors. He also observed how light was *reflected* inside the raindrop. In this way he demonstrated why the uppermost color of the rainbow is red, and the lowest blue. His explanation was not "correct" in terms of our modern understanding but his experimental design and interpretation of results were ahead of their time; in fact, the transmission of light through materials was not investigated in detail until three centuries later by Willebrord Snell (see 1.045), Isaac Newton (see 1.034), and René Descartes (1596–1650). Theodoric published his results, including ray diagrams, sometime after 1304 in *De iride et radialibus impressionibus* (On the rainbow and "radiant impressions"). This work also included an explanation of the shape and elevation of rainbows. Here you will repeat Theodoric's experiment.

TIME NEEDED:

1 hour

MATERIALS:

Note: This experiment must be performed in a room that can be darkened.

250-ml florence flask
high-intensity flashlight
masking tape
duct tape
2 pieces of white cardboard 15 cm x 10 cm
pencil
X-acto® knife
cutting board
scissors
metric ruler
black construction paper (if required)

Original Materials:

Theodoric would have used a narrow beam of sunlight in his original experiments.

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Be careful when cutting with the knife.

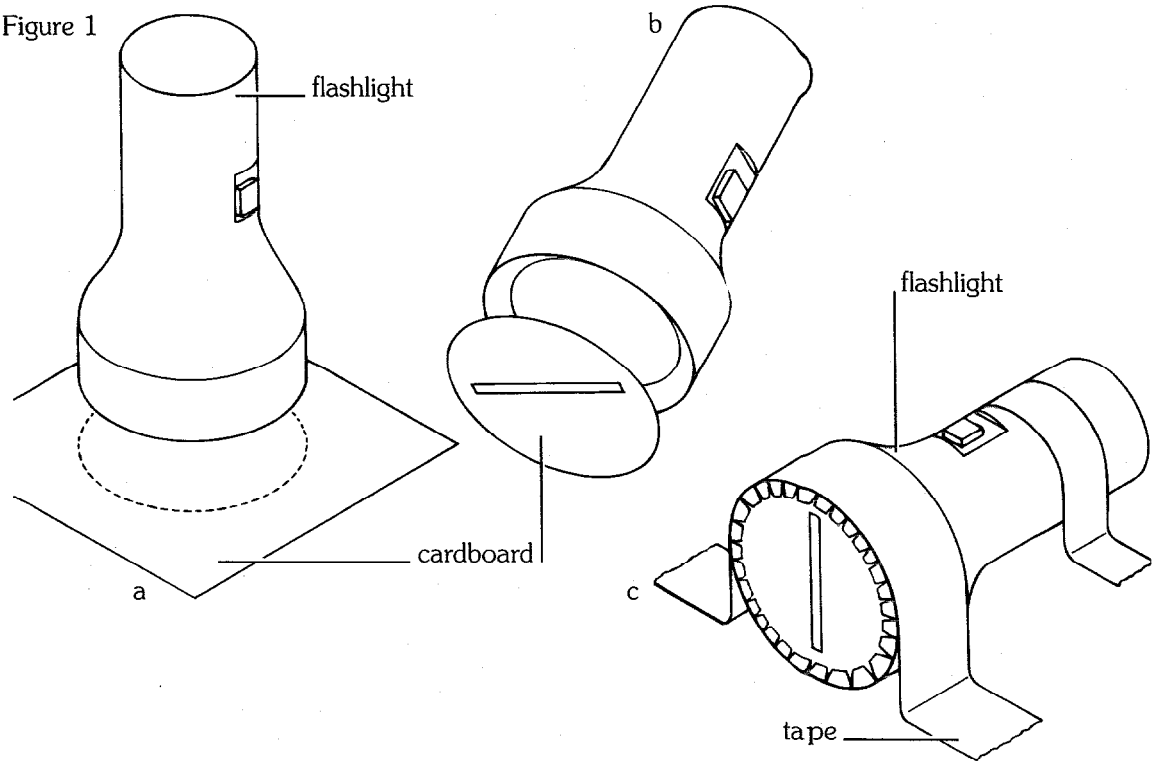
PROCEDURE:

1. Take one piece of white cardboard. Put the flashlight, lens down, on the cardboard (see figure 1a).
2. Use a pencil to draw the outline of the flashlight lens on the cardboard. Cut out the shape you have just drawn.
3. Put the cardboard shape on the cutting board. Carefully cut a central slit 1–2 mm wide and 5 cm long using the X-acto® knife and the ruler.

4. Cover the lens of the flashlight with the piece of cardboard with the slit (see figure 1b). Use masking tape to hold the cardboard in place, being careful not to cover the slit with tape.

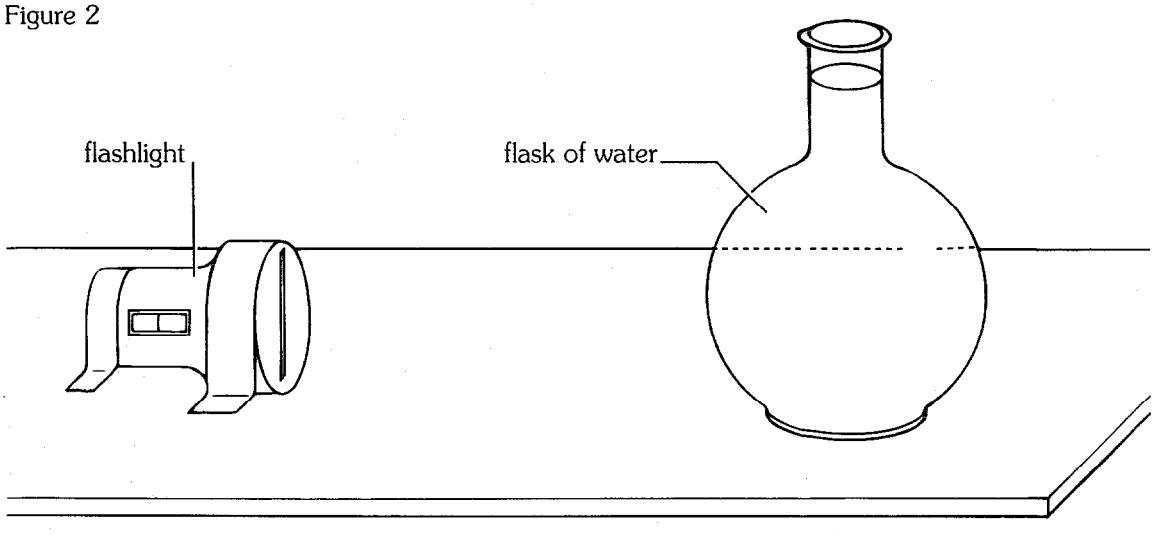
5. Position the flashlight on its side at one end of the table, with the lens facing toward the middle of the table. Make sure that the slit in the cardboard is vertical, and that the on/off switch is accessible. Secure the flashlight to the table using duct tape so that it does not move during the experiment (see figure 1c).

Figure 1



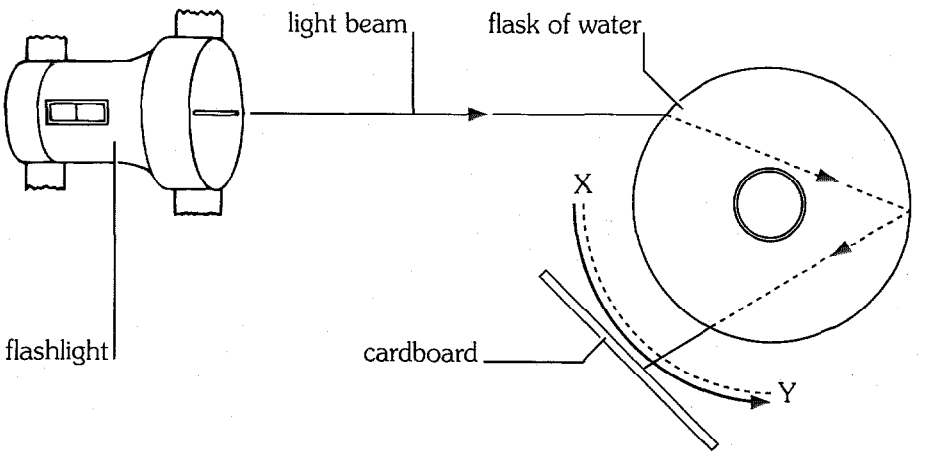
6. Fill the flask with cold water. Position it so that it is resting on the table in front of the flashlight (see figure 2).

Figure 2



7. Darken the room, taping black construction paper over the windows if necessary. Switch on the flashlight. Move the flask so that the strip of light from the flashlight hits the flask slightly off center (see figure 3).

Figure 3



8. Stand to the side of the flask, holding the second piece of white cardboard (see figure 3).
9. Move the piece of cardboard around the flask from point X to point Y. Record which colors are projected on the card and in what order. If colors are not visible, return to step 7 and carefully adjust the angle at which the light beam hits the flask until you can see colors projected onto the white cardboard.
10. Turn off the flashlight.

ANALYSIS:

1. What happened when you moved the white cardboard in step 9?
2. In what order did the colors appear from point X to point Y?
3. Do some research. Can you explain what you observed during the experiment? How do your observations relate to the formation of rainbows?

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO EXPERIMENTERS

Each experiment includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are performing the experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each experiment you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning experiments
—Read the instructions before you start
—Know the hazards of the experiments and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one experiment at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Don't use your mouth to pipette; use a suction bulb
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not use reflected sunlight to illuminate your microscope
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES