DISCOVERY OF THE DIFFRACTION OF LIGHT

TOPIC:
Light

SCIENTIST:
Francesco Grimaldi 1618–1663

INTRODUCTION:
In the seventeenth century there were two schools of thought concerning the nature of light. Isaac Newton (see 1.034) favored the corpuscular theory. This visualized light as a stream of tiny and invisible particles. Dutch physicist Christiaan Huygens (1629–1695), on the other hand, suggested that light consists of waves in ether, a substance that was thought to fill the whole of space. Francesco Grimaldi's research provided the first evidence to support Huygens' wave theory of light. Grimaldi found that when light passes obstacles or through narrow openings, it spreads out to form wave fronts, as indicated by the presence of light and dark fringes. This "bending" of light around corners we now call "diffraction." It occurs most readily when the obstacle or opening is approximately the same size as the wavelength of the light. What made Grimaldi's observations so notable, then and now, was that they were accomplished close to the limits of what could be observed with the equipment that was available at the time.

TIME NEEDED:
1½ hours

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

- high-intensity flashlight
- black cardboard approximately 30 cm x 30 cm
- masking tape
- magnifying glass
- needle, pin, and any other small, solid objects with sharp edges
- ring stand with clamp
- clothespin
- pencil
- black construction paper (if necessary)
- metric ruler
- scissors

Original Materials:
Grimaldi did his experiment on a much larger scale. He built a room-sized *camera obscura* and, through a pinhole in a large sheet of material which blacked out the room, projected an image of the sun onto a large screen. He then placed various objects in the path of the light and observed the resulting shadows projected onto the screen.

Safety Precautions
Please read and copy the safety precautions at the beginning of this book.

PROCEDURE:
1. Put the flashlight, lens downward, on the black cardboard. Trace the outside of the lens on the cardboard. Repeat this three more times at different places on the cardboard to produce four outlines.
2. Cut out the four circles using the scissors. Make a pinhole through the center of one of the cardboard disks using the point of a needle.

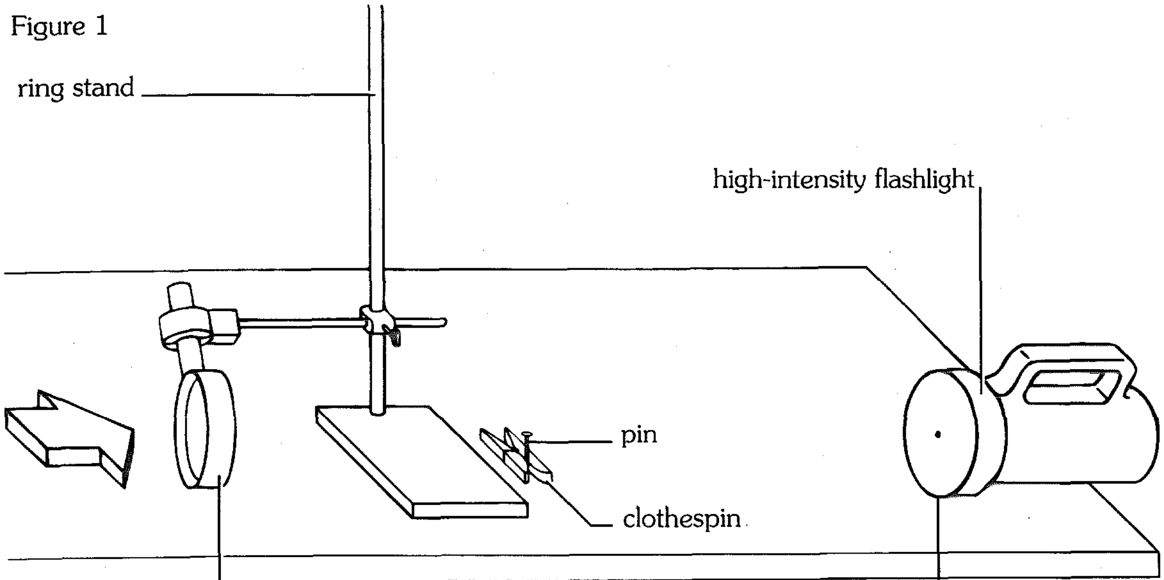
3. Cover the flashlight lens with the cardboard disk with the pinhole. Make sure the pinhole is over the center of the lens. Secure the disk in position using masking tape, being careful not to cover the pinhole.

4. Position the flashlight so that it projects a near horizontal beam of light along a tabletop.

5. Clamp a pin in a vertical position with its head upwards using the clothespin placed flat on the tabletop. Clamp the magnifying glass vertically using the ring stand and clamp.

6. Arrange the magnifying glass, pin, and flashlight so they are in a line, with the pin standing between the flashlight and the magnifying glass (see figure 1). Position the pin approximately 1 m from the flashlight.

Figure 1



7. Darken the room; if it has windows, cover them using the construction paper and masking tape. Switch on the flashlight. Adjust the position of the pin held by the clothespin so that the head of the pin is illuminated by light coming through the pinhole. If the pinhole is too small, enlarge it; if the pinhole is too large, take one of the other cardboard disks and make a small pinhole in the center of it.

8. Look through the magnifying glass. Start with the magnifying lens a few centimeters away from the pin. Gradually move it backwards so the magnification increases. Continue this movement to obtain the greatest possible magnification of the pinhead. Move your head from side to side or squint to increase the magnification.

9. Carefully examine the pinhead. Make a note of whether the outline of the silhouetted object is sharp or not, and of the appearance of the illuminated pinhead.

10. Repeat steps 5 to 9, using a needle (so that the eye of the needle is illuminated) clamped in the clothespin, then using any other suitable small, sharp objects.

ANALYSIS:

1. What did you see when the object was illuminated? Were the outlines of the silhouettes sharp or not? If they were not sharp, was it because they were spread out, or because there were patterns of outlines?

2. Do some research. If you saw patterns around the objects through the magnifying lens, how do you think they were caused?

OUR FINDINGS:

Click on above link to see what we found.

Our Findings

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1. The outlines of the objects should not be sharp. The observer should see patterns of light and dark fringes surrounding the objects.

2. The fringes are caused by diffraction. This occurs because the light waves take different routes around the obstacle. If, when they meet up again having passed around the object, they are not in phase (*i.e.*, vibrations of the wave motion are not occurring simultaneously), they can "add up" to make patterns of light and dark—the frinaes observed during the experiment.

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