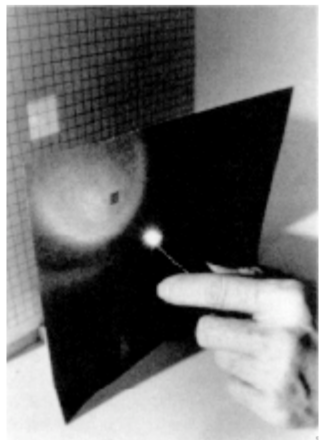
Inverse Square Law

Why the world gets dark so fast outside the circle of the campfire.



Math Light

We all know that a light, such as a candle or a streetlight, looks dimmer the farther away from it we get. The question of how much dimmer it looks was answered a long time ago. Here's an easy way to repeat that discovery.

materials

Graph Paper Version

✔ **A Mini-Maglite™ flashlight.** No substitutes! A point source of light is required for this Snack. (Or make your own economical light source with a square of heavy cardboard, a Mini-Maglite™ replacement bulb, two batteries - either AAA, AA, C, or D - and clip leads to connect them. See Assembly for details.)

✔ **Cardboard or foamcore.**

✔ **A file card.**

- **A knife or scissors.**
- **Adult help.**

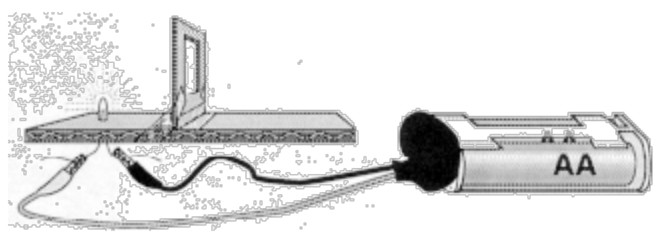
Perfboard Version

- **Perfboard** (available at Radio Shack).
- **A file card.**
- **Cardboard** to use as a screen.
- **A knife or scissors.**
- **A pencil.**
- **Adult help.**

Graph Paper Version

assembly

(15 minutes or less if you use MiniMaglite™, 30 minutes or less if you make the light source)



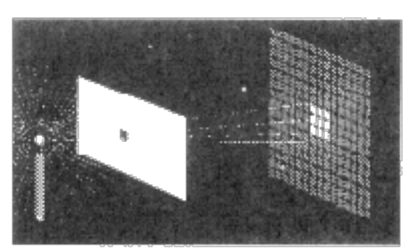
Unscrew the front reflector assembly of the Mini-Maglite™ to expose the bulb. The bulb on the MiniMaglite™ will come on and stay on when the reflector assembly is removed.

If you're making your own light source, you need a replacement bulb for the Mini-Maglite™, two batteries (either AAA, AA, C, or D), and clip leads to connect them. Using the clip leads, wire the bulb in series with the batteries (see the diagram on page 62). Cut a small hole in the cardboard. Push the bulb through the hole so that it fights tightly and gives you something to hold on to.

Now cut a l/2 x 1/2 inch (1.3 x 1.3 cm) square hole in the file card. Hold or mount the card 1 inch (2.5 cm) in front of the light source. The square of light made when the light shines through this hole will shine on the graph paper.

to do and notice

(15 minutes or more)



Keep the distance between the bulb and the card with the square hole constant at 1 inch (2.5 cm). Put the graph paper at different distances from the bulb, and count how many squares on the graph paper are lit at each distance. The results will be easier to understand if you make a table of "number of squares lit" versus "distance." Be sure to measure the distance from the bulb.

what's going on?

The light from the Mini-Maglite™ spreads out equally in all directions. As the distance from the bulb to the graph paper increases, the same amount of light spreads over a larger and larger area, and the light reaching each square becomes correspondingly less intense. For example, adjust the distance from the bulb to the graph paper to 1 inch (2.5 cm). At this distance, the graph paper touches the card. A single 1/2 inch (1.3 cm) square area will be illuminated. When the graph paper is moved 2 inches (5 cm) from the card, four 1/2 inch (1.3 cm) squares will be illuminated on the graph paper. When the graph paper is moved 3 inches (8 cm) from the card, 9 squares will be illuminated. At 4 inches (10 cm), 16 squares will be illuminated, and so on. The area illuminated will increase as the square of the distance.

The intensity of light is the power per area. Since the energy that comes through the hole you cut is spread out over a larger area, the intensity of light decreases. Since the area increases as the square of the distance, the intensity of the light must decrease as the inverse square of the distance. Thus, intensity follows the *inverse-square law*.

Perfboard Version

assembly

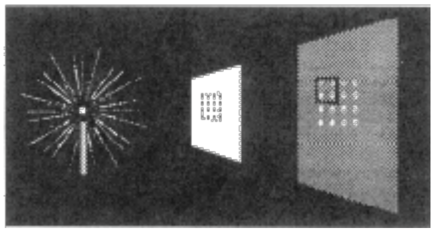
(15 minutes or less)

Follow the instructions for the light source in the Assembly instructions above. Tape a piece of perfboard to the card. Perfboard is a thin board drilled with holes 1/10 inch (2 mm) apart. Cut a hole in a card so that light shines through a square area 8 holes wide and 8 holes long, making 64 points of light. Hold a second card touching the perfboard, and with your pencil draw a square around the 64 points of light.

to do and notice

(15 minutes or more)

Mount the perfboard 1 inch (2.5 cm) from the bulb. Hold the second square different distances from the bulb and record the number of points of light that fall in the square. At 1 inch (2.5 cm), all 64 holes fit within the square. At 2 inches (5 cm), 16 points fall within the square.



what's going on?

The number of points of light is proportional to the inverse square of the distance: it follows the inverse-square law as explained above. You can also do this experiment with a piece of perfboard that has 32 holes across and 32 holes vertically. It will make 1,000 points of light.

etcetera

The inverse-square law applies not only to the intensity of light, but also to gravitational and electrical forces. The pull of the earth's gravity drops off at $1/r^2$, where r is the distance from the center of the earth. The attraction or repulsion between two electric charges decreases with the distance at $1/r^2$, where r is the distance between the two charges.

Questions? Comments? Want to share your results?
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This snack is from **"The Magic Wand - and Other Experiments on Light and Color"**, currently out of print. You can still order any of the other 3 snackbooks from the **Exploratorium Online Store**.

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