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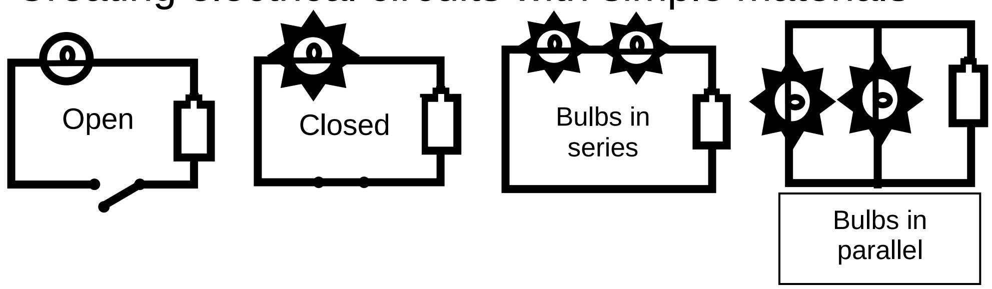
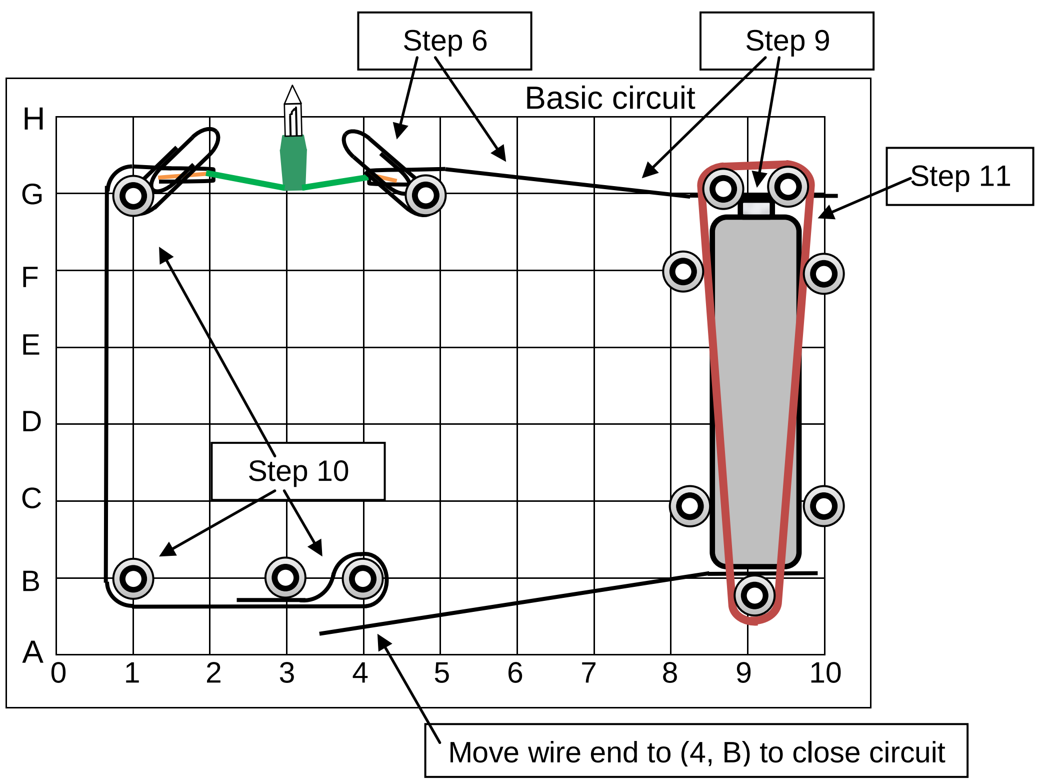
BREADBOARD CIRCUITS

Creating electrical circuits with simple materials



Provide students with opportunities to create a basic circuit, build a portable version, and explore parallel and series circuits!



Curriculum topics:

- Electricity
- Conductors
- Parallel and Series Circuits

Subject:
Physical Science

Grade range: 4 – 12

Who we are:

Resource Area for Teaching (RAFT) helps educators transform the learning experience through affordable "hands-on" activities that engage students and inspire the joy and discovery of learning.

For more ideas and to see RAFT Locations

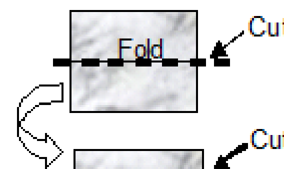
www.raft.net/visit-raft-locations

Materials required for each student or group

- 1 Foam base
- 1 Paper template – ¼ of blackline master (see page 6 for a master; download a master of 4 copies of the basic circuit at www.raft.net/raft-idea?isid=5)
- 12 Plastic pipette tips
- 1 Aluminum foil strip 7 cm x 30 cm (3" x 12")
- 1 Thin stiff cardboard strip ~1 cm x 30 cm (~½" x 12")
- 2 Paperclips, regular size (#1)
- 1 **Clear** bulb and socket from a holiday mini-light set (bulbs are cut apart and pre-stripped as part of the supplied kit materials)
- **1 AA battery (not supplied in the kit)** (AAA, C, or D can also be used)
- Optional: Scissors and rulers since the foil strips can be easily torn and folded to size
- Optional: A paper cutter makes cutting the foil sheets easier

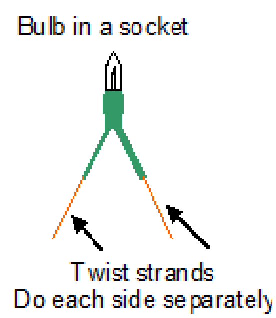
Note: After 10 sets of the above materials are distributed there will be left over sets of pipette tips, foil strips, and bulbs in sockets. These extra items can used to create circuit variations such as series and parallel circuits that require an additional bulb.

Materials preparation



1. Cut the foil sheets in half **along the fold** and then cut each half again to make strips 7 cm x 30 cm (3" x 12"). See illustration.

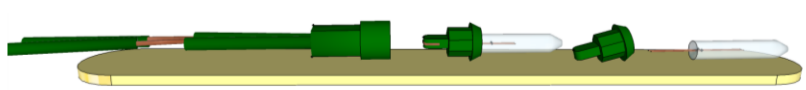
2. (Suggestion: Have students do the following instead of the instructor.) For each mini bulb, **twist** and pull off the cut section of insulation, if present, from the end of each wire lead. Take the exposed thin wires on one side of the bulb and gently twist the thin strands together, as needed, giving the wire a "rope" like appearance. Repeat for the exposed thin wires on the other side of the bulb. Do this for each lead of all the mini bulbs. (Optional: To protect the fingers from being poked during twisting, place the wire strands in a folded piece of cardstock or a business card.)



Safety issue: A short circuit, a low resistance path from one end of a battery to the other, can heat up a thin wire enough to become burning hot. Twisting the thin wire strands together reduces that risk when working with the bulb and battery.

Teaching tips:

Create a disassembled bulb display by pulling out a spare bulb from the socket. Next straighten the wires coming from the glass bulb so the plastic base can be removed. Glue each of the glass bulb, plastic base, and socket to cardboard or a craft stick so that the students can see how the straight wires inside the glass bulb connect to the 2 wire leads of the bulb socket through metal to metal contact. Review the concepts and some examples of **conductors** (bare wires and metal pieces) and **nonconductors** (glass and plastic) that make up the bulb, socket, and wire leads.



The **How to build it** section could be preceded by giving each activity station just a battery and a bulb and the instructions to examine each closely. What parts could be conductors and what parts could be insulators (non-conductors)? Next find different ways to connect the battery and bulb together that make the bulb light and that do not make the bulb light (equally important). Draw pictures of the different situations. Later the students could build the breadboard circuit to reinforce the concepts learned and to build more complex circuits (See the **Learn more** section on page 4).

How to build it (a basic circuit)

(See the Learn more section on page 4 for other circuits to build)

Teaching tip: Decide if the students are to use a blank template or one showing the layout of the parts. In either case, to help show students where the parts are to be placed, create a transparency of the template for use on an overhead projector. Note the letters could be replaced with numbers to provide students practice with using coordinates and ordered pairs.
Safety tip: Hands should be washed after handling electrical components such as the light bulbs. Note: Batteries can corrode and leak over time.

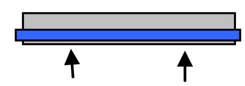
1. Center the selected paper template on the foam base. Poke 1 pipette tip through the paper and into the foam at each of points (10, F) and (10, C). When inserting tips into the foam, insert **only** 1/3 of the tip length.

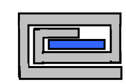
2. Place the battery against the 2 tips as shown and add 2 more tips on the other side of the battery, opposite the first pair of tips, at (8, F) and (8, C).

3. Insert 2 tips on either side of the bump at the positive end of the battery at (8.5, G) and (9.5, G), and one tip against the flat end of the battery. Next, insert a tip into locations (1, B), (3, B), and (4, B).

4. **To make a folded foil wire:** Place the narrow cardboard strip near a long edge of the foil strip as shown in figure 1. Fold the edge of the foil over the cardboard strip and then fold the cardboard strip upward to wrap the foil around the strip to make a narrow foil ribbon about 1 cm (3/8") wide. Pull the cardboard strip out, from one end or the other, for later reuse.

Figure 1





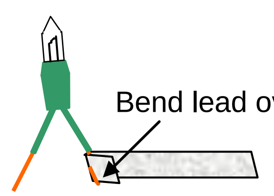
Enlarged side view of Folded Foil Wire

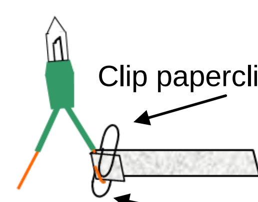
5. Tear or cut the folded foil wire in the middle to make 2 sections each 15 cm (6") long. Take one of the halves (and only one!) and tear the half in half. There will then be 1 long and 2 short foil wires.

6. Put a stripped bulb lead in a fold created by bending over 1 cm (~½") of a short foil wire. See illustration below and on the first page. Bend the end of the wire lead over the bottom edge of foil to hold the wire in place.

7. Place a paperclip over the folded foil wire and bare copper of the bulb lead as shown to the right.

8. Insert a pipette tip into the bottom loop of the paperclip. Insert tip into the foam base at (5, G), see the first page and the illustration to the right.





9. Insert the end of the short foil wire between the battery's top end and the 2 tips, see diagram on the first page.

10. Repeat steps 7 and 8 for the second bare bulb lead using the long foil wire, but insert the tip into (1, G). Loop the rest of the long foil wire around the tips in row "B" as shown on the first page.

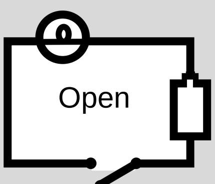
11. Insert the end of the remaining short foil wire between the bottom of the battery and the tip. Add a rubber band around the 3 tips at the ends of the battery as shown on the first page. The rubber band will press the foil wires onto the ends of the battery to ensure a good electrical connection. Double wrap the rubber band if needed to press the tips to the battery.

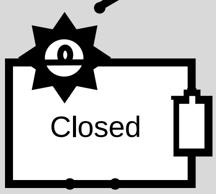
Curriculum Standards:

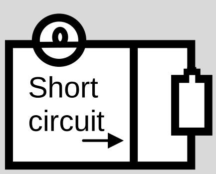
Energy can be transferred from place to place and converted from one form to another (Next Generation Science Standard:, Grade 4, Physical Science 3-2 & 3-4; High School, Physical Science 3-3)

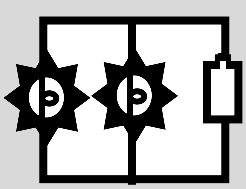
Test variables (Next Generation Science Standards: Grades 3-5, Engineering Design 1-3)

Science & Engineering Practices (Next Generation Science Standards Grades 4 – 12)









Additional standards at: http://www.raft.net/raft-idea?isid=5

To do and notice

1 Close the switch by moving the end of the foil wire coming from the battery at row “B” to touch the wire at (4, B).The bulb should light up. If a bulb will not light up, check that the battery is good and that the circuit is not broken due to an incomplete connection to the battery or bulb.

> **Teaching tip** If the bulb still will not light up, gently remove the bulb from the socket, cleaning the wires coming from the bulb with the eraser end of a pencil, and then reseating the bulb.

2 Let go of the foil wire from the battery at (4, B).The bulb should go out. If the bulb stays lit, then move and/or straighten the foil wire coming from the battery, as needed, to separate the wires so they are not in contact.

3 To explore the effect of removing a bulb from a circuit – disconnect the bulb from the foil wires – rather than pulling directly on the bulb (which may cause damage the bulb and/or fragile wires).

Learn more

- Draw a circuit using symbols. See the RAFT idea sheets ***Make-a-Circuit*** and ***Circuits – An Electron Maze*** for illustrations of the symbols.
- Use the same techniques to create more complex circuits (see page 6 and the illustrations to the left):
  - Use 2 bulbs connected in series or parallel. Note: Two bulbs in series will glow very dimly when connected to a single battery.
  - Use 2 batteries connected in series or parallel or larger sized batteries.
  - Use 2 batteries and 2 bulbs. Using 2 batteries in series will make bulbs wired in a series glow brighter.
  - Model a hall light that is controlled by two switches (“3-way” switches).
  - Model circuits in which the bulb(s) do not light up as challenges for students to find the reason(s) the bulb(s) do not glow. Examples would be a burnt out bulb; a dead battery; a loose connection; and/or an incorrectly wired circuit.
  - Create a circuit where closing a switch turns a bulb off.

Note that more complex circuits may require additional materials such as more wires, bulbs, and batteries.

Related activities:
See these RAFT Idea Sheets to introduce and expand on Breadboard Circuits:

Light Up Your Life **-** www.raft.net/ideas/Light up Your Life.pdf
Folded Foil Wires **-** www.raft.net/ideas/Folded Foil Wires.pdf
Circuits – An Electron Maze **-** www.raft.net/ideas/Circuits an Electron Maze.pdf

Resources

Visit www.raft.net/raft-idea?isid=5 for “how-to” video demos & more ideas!
See these websites for more information on the following topics:

- **Breadboards** – http://en.wikipedia.org/wiki/Breadboard
- **Bulbs** – http://home.howstuffworks.com/light-bulb.htm/printable
- **Batteries** – http://electronics.howstuffworks.com/battery.htm/printable
- **Three-way switch -** http://home.howstuffworks.com/three-way.htm/printable

The science behind the activity

Battery: A battery contains stored potential chemical energy which is transformed into potential electrical energy. When the battery is connected to a bulb or motor (a **load)** the electrical energy can push/pull on the nearby electrons in the wires. A battery does not create electrons, but it does create a push/pull force on the electrons that are always present in the battery, wire, and bulb. The potential chemical energy in the battery decreases as more of the chemical energy is converted into electrical energy. To be accurate, 1-½ volt "batteries" should really be referred to as 1-½ volt "cells" as the chemistry involved creates a "push" (**voltage**) of 1-½ volts. A "battery" implies more than one cell. 6 and 9 volt batteries contain 4 and 6 of the 1-½ volt cells (4 x 1½ =6, 6 x 1½ =9, respectively).

Wires: Metals are **conductors** because some electrons in the metal can move about easily, unlike **non-conductors** (insulators) such as plastic and glass. Metals will vary in how easily electrons can move about (e.g. in how much the movement of electrons is resisted). Aluminum and copper are both metals with a low resistance to the movement of electrons. Copper is commonly used inside the wires found in homes and cars. Aluminum is used in some wires and is the basis for the folded foil wires as the foil can be easily cut, joined, and can be folded neatly. The foil wires from different ends of the battery must be kept from touching because the foil wires lack the insulated covering found on most other wires. Crossing the foil wires could lead to a short circuit, a very low resistance path from one end of the battery to the other. A short circuit can heat up the wire and battery and run down the battery.

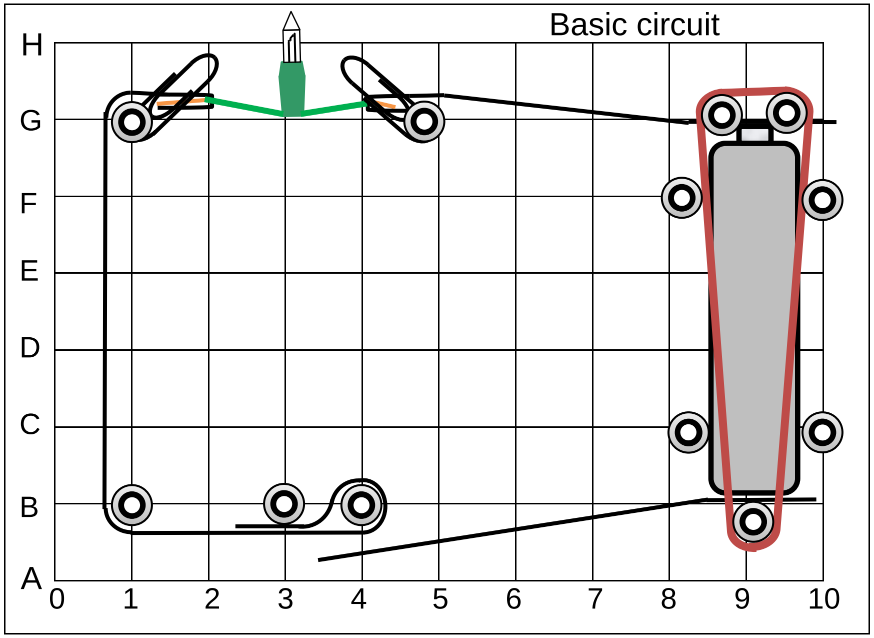
Light Bulb: An **incandescent bulb**, such as the mini-holiday bulb, produces light when the wire filament inside becomes hot enough to glow. The filament contains the metal tungsten which has a relatively high resistance to the movement of electrons. When the bulb is connected to the battery, the electron movement occurs easily in the aluminum wires but is resisted in the coiled filament of the bulb. The friction from the resistance heats up the coil to over 2,000 degrees C (4,000º F). Heating energizes metal atoms and causes the atoms to vibrate or "jiggle". When the atoms are hot enough these vibrating atoms can give off visible light. Light produced by heating is called **incandescent light.**

Switch: To turn the light on and off, a part of the circuit needs to be moveable so that the conductive path can be broken (separated) and reconnected as needed. A single pole, single throw switch is a switch with a single "on" position, as was constructed in the basic circuit. A hall light with 2 switches makes use of a more complex switch having 2 possible circuits and is called a double pole, double throw switch. See the **Resources** section for more details.

Breadboarding: The making of experimental circuits is called "**breadboarding**" and originally involved a breadboard! Most homes had a board for cutting bread, especially before sliced bread became commonly available. Early experimenters found the breadboard's flat wooden surface an ideal nonconductive base for building electrical circuits. Early circuits used nails hammered into the board to create connection points for electrical components. This is why the term "breadboarding" has come to mean the easy and rapid creation of electrical circuits.

Series Circuits: When batteries are positioned with the positive end of one connected to the negative end of another, the batteries are said to be in series ("one after the other"). Batteries in series will provide more electrical push/pull, called **voltage**, than a single battery. Two 1-1/2 volt batteries in series can provide 3 volts to a circuit. Bulbs can also be connected in series. Bulbs in series will glow less brightly than a single bulb in the same circuit as the 2 bulbs have to share the voltage.

Parallel Circuits: Batteries connected with the positive ends together and, separately, the negative ends connected together are said to be in parallel. The voltage remains unchanged but more potential chemical energy is available so the circuit can be powered longer. Bulbs connected so that each bulb has one lead connected to the positive battery end and the other to the negative battery end are said to be connected in parallel. Bulbs in series will glow as bright as a single bulb in the same circuit as long as the battery can supply the same voltage. Manufacturing differences can vary a bulb's brightness.


Basic circuit
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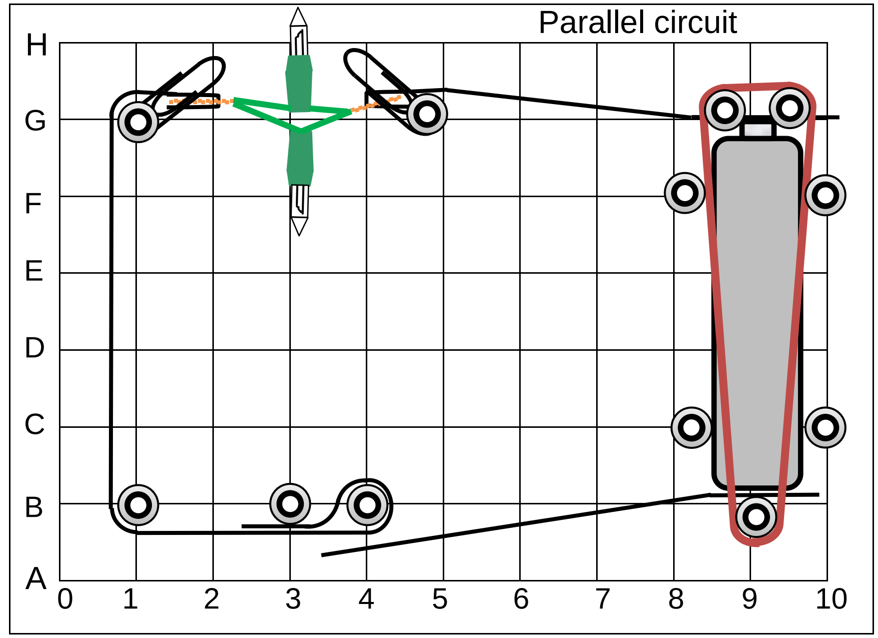
Parallel circuit
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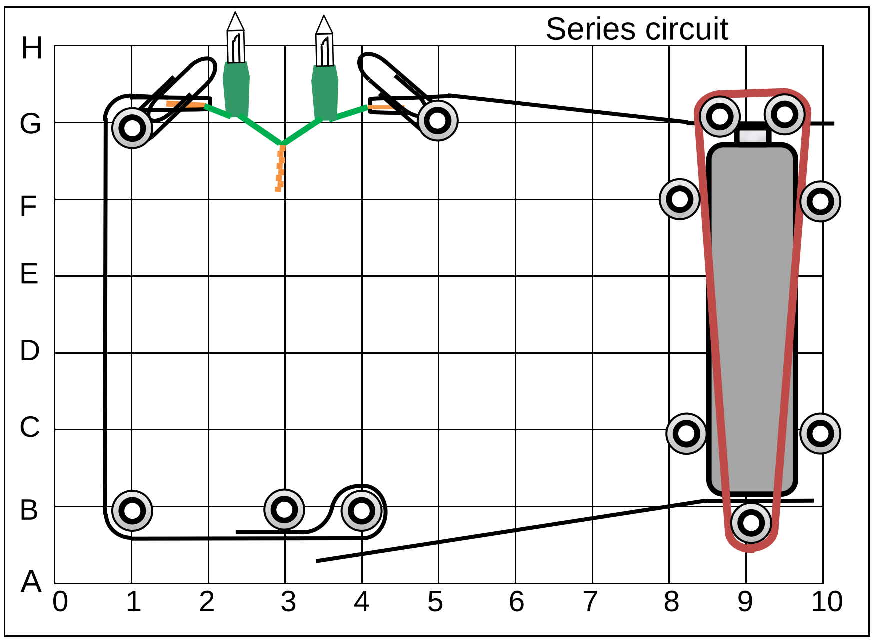
Series circuit
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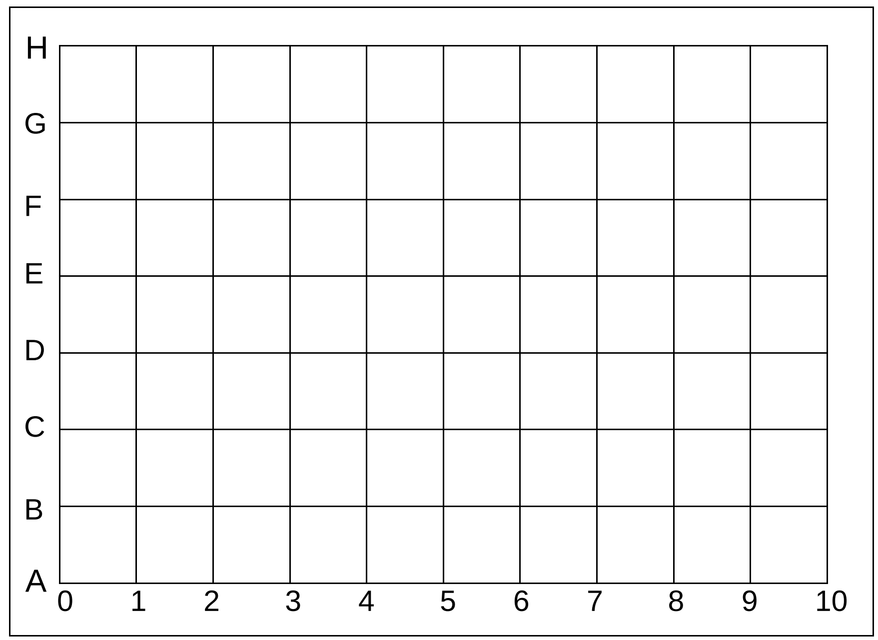
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