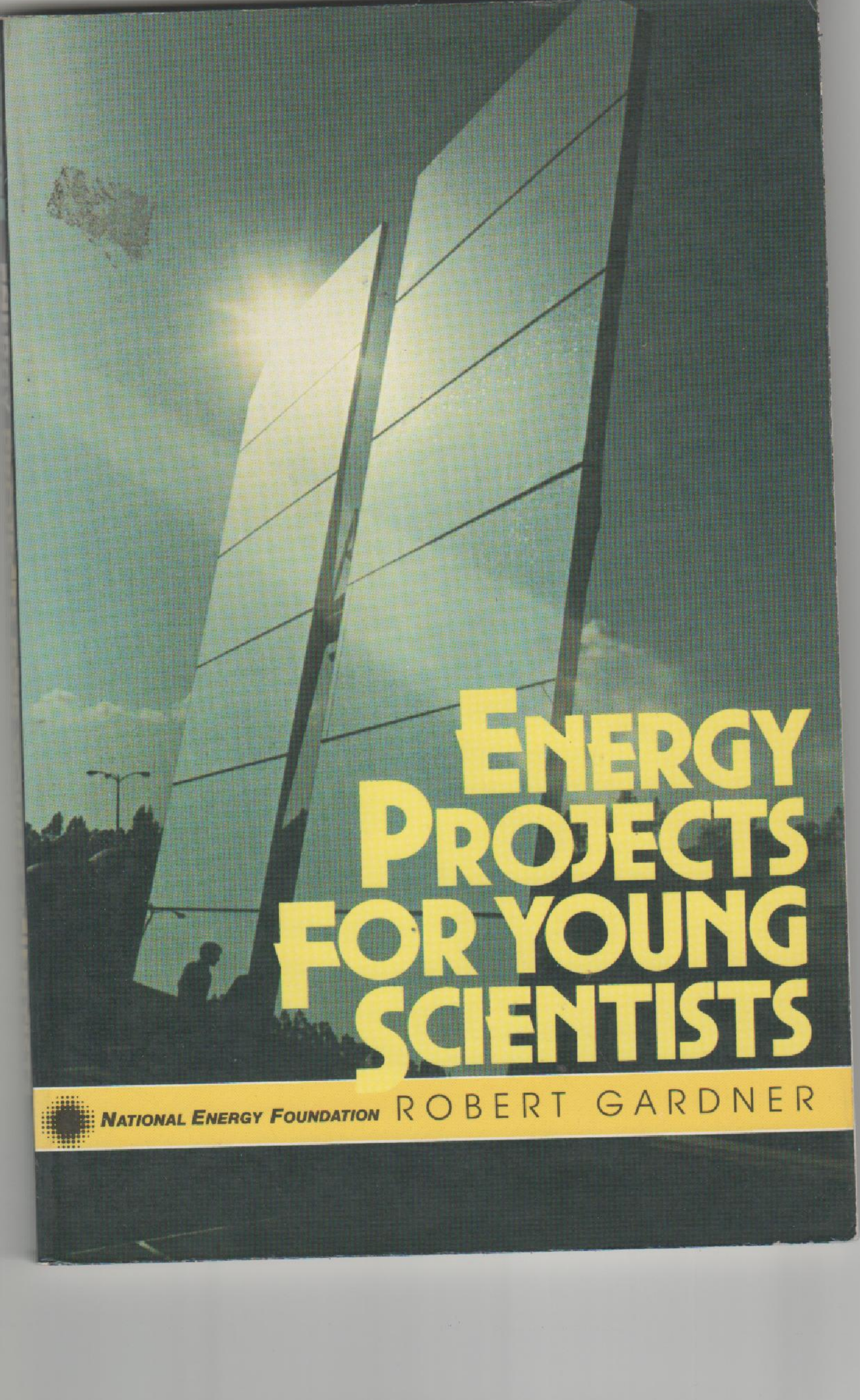

ENERGY PROJECTS FOR YOUNG SCIENTISTS

NATIONAL ENERGY FOUNDATION

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vertical axis versus the voltmeter reading, in volts. What does the graph tell you? What does a voltmeter measure?

Write an equation relating heat, current, time, and voltage.

The product of voltage × current × time is called electric work and is measured in joules. If you measure heat in joules, write the equation relating heat, current, time, and voltage. How many joules are equal to 1 cal?

Notice that you may now write 1 V = 1 J/A-s.

Charge is also measured in another unit called a coulomb (C). One coulomb is the same amount of charge as 1 A-s; hence, you can also write:

$$1\ V = 1\ J/C$$

PROJECT 22: Meters in your home and school

Most of the electricity used in homes and commerce is purchased from a utility company. To determine how much to charge each month, the utility company puts a meter in the line leading to each building for which a bill is rendered.

If you can find the place where the electric power line enters your house, apartment, or school, it will be connected to a meter. Current flowing through the meter causes the disk inside the meter to turn. Through a series of gears, the spinning disk turns the meter dials and thus gives a reading of the electrical energy entering the building. The dial on the right records kilowatt-hours, the next dial indicates tens of kilowatt-hours, the next, hundreds of kilowatt-hours, and so on.

As you probably know, a watt is a unit of power equal to 1 J/s. An ampere of current is a flow of 1 C/s. Hence, you may write:

$$1\ C/s \times 1\ J/C = 1\ J/s \text{ or } 1\ W$$

A kilowatt is 1000 J/s, and an hour is equal to 3,600 s; therefore, a kWh is: 1,000 J/s × 3,600 s = 3,600,000 J.

The power ratings on various appliances, when multiplied by the time they are used, will indicate how much electrical energy these devices require. For example, a 100-W light bulb when turned on for 1 h will require: 0.10 kW × 1.0 h = 0.10 kWh. If the power company charges you $0.10 per kilowatt-hour, operating the light bulb for 1 h will cost 0.10 kWh × $0.10/kWh = $0.01, or one cent.

Make a survey of the electrical appliances in your home or school. How many hours or minutes per day does each one operate? How much energy does each appliance require over a year's time? On the back of your family's or school's electric bill you will find the cost of a kilowatt-hour. Use this figure to determine the cost of operating each appliance for one year.

THE DIRECTION OF CURRENT FLOW

The fact that electric current disappears when a circuit is broken at any point is good evidence to support the idea that charge flows all the way around a circuit. But which way does charge flow? Does positive charge flow from the positive to the negative end of a battery? Or does negative charge flow in the opposite direction? Or does charge of both signs flow in both directions?

Physicists *defined* the direction of electric current to be the direction that positive charge would flow in a circuit long before the actual direction was determined. That definition still holds, and, as you will see, that definition is sometimes valid.

PROJECT 23: A vacuum tube and the direction of charge flow

Vacuum tubes were common in electronic devices prior to the development of solid state physics. You can buy one at a radio store or from a mail order supplier (see your science teacher), or you can dismantle old radios or other devices, which might have such tubes. Tube type 12D4 works well, but you can also use types 6AX4 or 6W4G. These tubes, which are well evacuated, will conduct electric charge under certain conditions.

Set up the circuit shown in Figure 7A. With the 12D4 tube inverted to reveal its pins as shown in Figure 7B, the connections to the heater and to the cathode and plate can be made using alligator clips.

You will note that there are really two circuits. The circuit containing the heater consists of a 12-V battery or a DC power source connected to a heating wire coiled within the cathode. This circuit is used solely to warm the cathode. The second circuit consists of a 12-V battery or DC power source with its positive and negative electrodes connected to either the cathode or the plate within the vacuum tube. It also contains an ammeter (0–1 A) to detect any current that might flow between the cathode and plate.

With the heater circuit disconnected, connect the positive lead from the battery to the plate and the negative lead to the cathode. Is there any current? Reverse the leads. Does current flow now?

Now connect the heater circuit so that the cathode is hot. You should be able to see a red glow coming from the cathode. Once the cathode is hot, connect the positive lead from the battery in the other circuit to the plate. Connect the negative end of this battery to the cathode. Is there any evidence that charge is flowing across the vacuum? What happens if you disconnect the cathode heater?

Repeat the experiment, but this time connect the cathode to the positive end of the battery and the plate to the negative end. What do you find now?

From your observations, what conditions are required for charge to flow across the vacuum between cathode and plate? Can you offer an explanation as to why there is a current given the required conditions but no current otherwise?

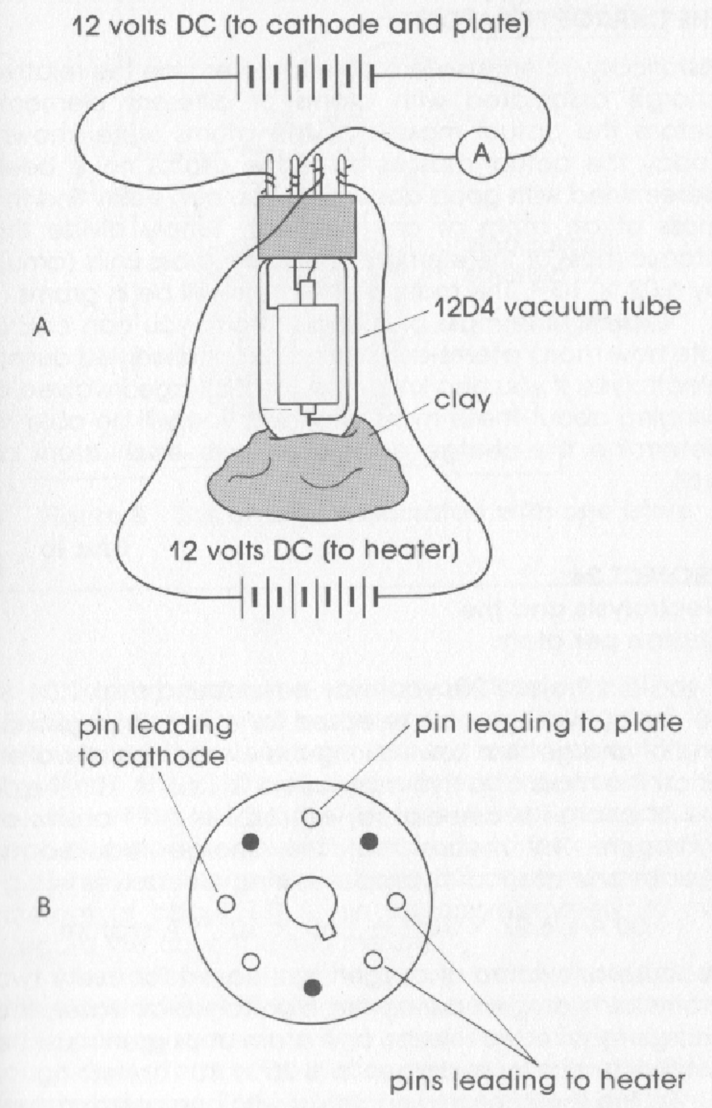

Figure 7 Connections to a vacuum tube