Workshop Tutorials for Introductory Physics

EI5: **Circuits**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
blood, energy, voltage, current, sound, current, thermal, power, less, electrons, watts

Power, energy and electrical circuits

When you switch on a battery-powered radio, you're using electrical ______. You can often find the rate of energy consumption written on the back of the radio as so many ______. This rate at which the radio uses energy is called ______ (P) and it depends on both the ______ (V) supplied by the battery and the total ______ (I) from the battery, through the relation: $P = VI$. If the power consumption is constant then the energy (E) used in a time interval (Δt) is given by $E = P\Delta t$.

Similar relations hold for appliances which run on mains electricity, which supplies an alternating current, AC. Although the AC voltage and current vary very rapidly, the average voltage, average current and average power consumption are still connected via the relation $P = VI$.

A radio uses electrical energy to produce ______ and quite a lot of ______ energy which leaves the radio as heat. As far as energy consumption goes, we can treat most appliances, like radios and toasters, as pure resistors. You can work out the effective resistance of an appliance by using the relation that voltage equals current $\times$ resistance, $V=IR$.

From this relation you can see that for a given voltage, the more resistance you have, the ______ the current will be, which seems very sensible. A resistor is like a fatty deposit in an artery, slowing down the flow of ______, or speed humps slowing down the flow of traffic. When you have resistors in parallel, their total resistance is less, because it's like having two lanes instead of one, so more traffic can flow. When you have two parallel electrical paths the ______can flow down two paths, so you get more ______, even though there are more resistors!

Discussion questions

Can you have a voltage without a current? If yes, give an example.
Can you have a current without a voltage? If yes, give an example.

B. Activity Questions:

1. Torch – a simple circuit

Dismantle the torch and examine its components.
Draw a circuit diagram for the torch, labelling each component and showing its function.

2. Toaster man – resistors in series

The ammeter (which measures current) is connected where the heart would be.
What do you notice when you change the position of the connection from the "boot" to the "skin"?

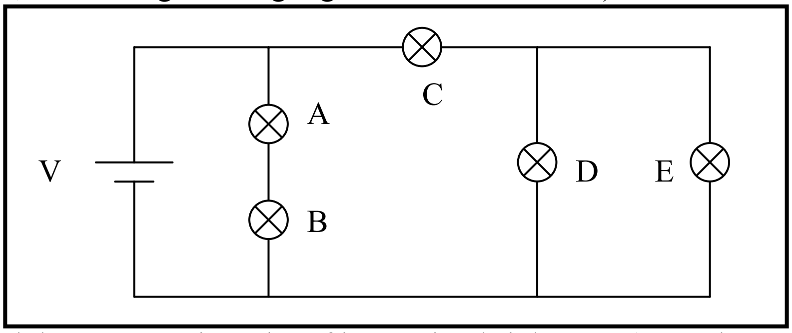
3. Measuring current and voltage

Examine the simple circuit set up to measure current and voltage.
Why is the voltmeter connected in parallel with the resistor?
Why is the current meter connected up in series with the resistor.
Current meters have very low resistance. Why do you think this is important?
Would you expect the voltmeter to have a high or low resistance? Why?

4. Simple membrane model – resistors in parallel
Cell membranes have channels through them which can open and close allowing current (ions) to flow into or out of the cell. This can be modeled as switches and resistors in parallel.
Close one of the switches, leaving the rest open. Measure the resistance of the membrane.
Close each of the switches, and measure the resistance each time you add another resistor in parallel.
What is happening to the total resistance? Why?
What effect does this have on the total current flow through the membrane?

C. Qualitative Questions:

1. Consider the circuit containing 5 identical globes shown below. (Treat the globes as if they obey Ohm's law, even though real light globes are not Ohmic.)

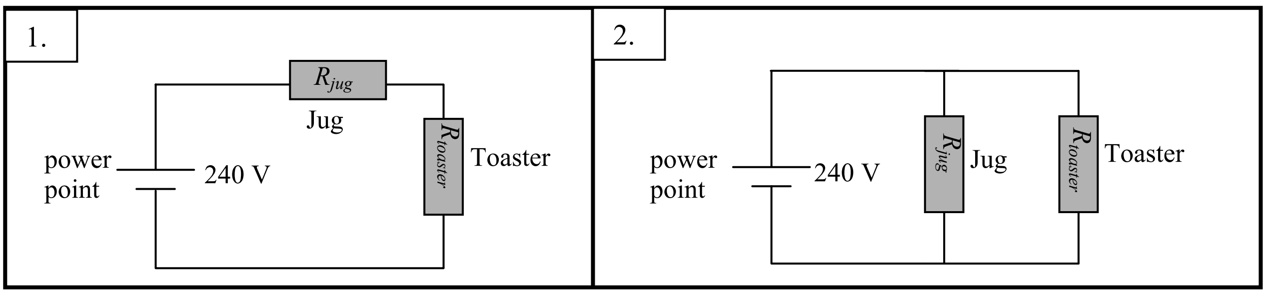


Rank the globes, A to E, in order of increasing brightness. (Note that some may have equal brightness.) You may want to redraw the circuit.

2. Rebecca is helping Brent study for a test on circuit theory. Brent is having trouble remembering Kirchhoff's rules. Kirchhoff's rule for junctions states that the total currents going into a junction must be equal to the total currents coming out of a junction. Kirchhoff's rule for loops says that the sum of all the potential changes around a loop must be zero. Rebecca tells him that these things are pretty obvious, and are really just statements of conservation of charge and conservation of energy. How can Rebecca justify this claim? (Hint: the potential difference (or voltage) between two points is the difference in potential energy per unit charge at those points.)

D. Quantitative Question:

Two simple circuits containing a power supply and appliances which act as resistors are shown below. In Australia the power supplied to households is an alternating (oscillating) voltage which we will treat as a 240 V battery.



The toaster has an operating resistance of 30 Ω and the electric jug has a resistance of 40 Ω.
a. Calculate the total resistance of each circuit.
b. What is the current flowing through the toaster in each circuit?
c. What is the current flowing through the jug in each circuit?
d. Circuit 1 is wired in series with the power source. What would happen if the toaster burnt out? Why are houses usually wired in parallel with the power source, as in circuit 2?