Workshop Tutorials for Introductory Physics

EI4: **Voltage and Current**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
downwards, tap, parallel, less, current, amps, volts, bottom, towers, decreasing, gravitational, greater

Voltage, Current and Resistance

Taps are always placed at the _________ of water tanks rather than at the top or halfway down. This is so that when the tap is turned on water will flow out. Unless some other force is provided, like pressure from a pump, water will always flow _________, from a region of high gravitational potential to one of lower gravitational potential. This is why water tanks are often placed up on stands or _________, so the water can run down to the houses. The difference in _________ potential is what makes the water flow and gives you a current. In a similar way a battery provides an electrical potential difference, (PD or voltage, measured in _________), to produce a current in a circuit. In a plumbing system there is a current of water, in a circuit it is a current of charge (electrons) which flows *through* the circuit. The current, I, at some place in a circuit is equal to the rate at which charge flows past that place. If the flow is steady then $I = q / t$. The SI unit of current is the ampere, A (often called the _________).

When you open a _________, so that water can flow out, you are _________ the resistance to flow. The more you open the tap, the less the resistance and the greater the current of water. For an electrical current flow, the _________ the resistance, the smaller the current. Almost any path, for either water or charge, will have some resistance which will depend on the width of the channel, its length and the nature of any stuff inside which may impede the flow. For example, narrow pipes have greater resistance than wide pipes and allow _________ water to flow. Less conductive materials, which have greater resistance, allow less charge to flow.

In electric circuits the current, I, through a component, depends on its resistance, defined as $R = V / I$, where V is the potential difference between the ends of the component. Any device whose resistance stays the same when the potential difference across it is changed is said to obey Ohm's law, which says $V = IR$. If you have only a single path, then the more resistance you put in, the greater the total resistance and the less current will flow for a given potential difference.

If you want to get a lot of water quickly from a tank you open more than one tap, and put a bucket under each one, so that there are multiple paths for the current to flow along. Similarly, when you connect resistors in _________ in a circuit the current is larger than if you use only a single resistor, because just as with plumbing there are many paths for the _________ to take.

Discussion question
If electrical potential energy is "lost" in resistors, where does it go?

B. Activity Questions:

1. Ohm's law
Use the variable voltage supply and the current meter to find the resistance of the mystery resistor.
Check your result with the resistor colour code provided.

2. 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 internal resistance. Why do you think this is important?
Would you expect the voltmeter to have a high or low resistance? Why?

3. Batteries II

Examine the circuits containing the batteries.
In which direction is the current flowing in each circuit? In which direction are the electrons moving?
What is the role of the battery?

4. Current, potential and resistance - a fluid model

How can you measure the current here?
How does changing the gravitational potential change the current?
How can you change the resistance? What effect does increasing the resistance have?

C. Qualitative Questions:

1. Many devices use a power supply or charger, such as mobile phones and electronic toys. The power supply uses gives the voltage and current that it supplies to the device.

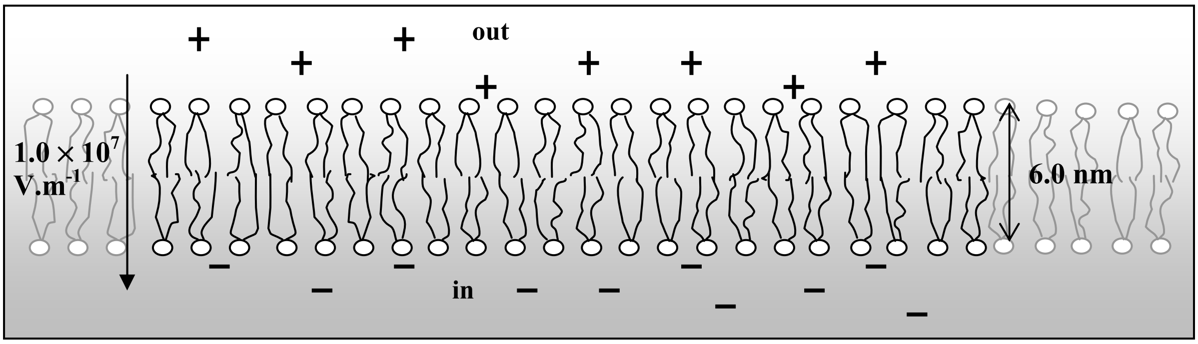
a. What is the difference between voltage and current?
b. Can you have a voltage without a current? If yes, give an example.
c. Can you have a current without a voltage? If yes, give an example.
d. What are the conditions required for a current to flow?

2. Rebecca has gotten home from university after dark and accidentally left her headlights on, so that the next morning her car battery is flat. Brent kindly offers to recharge her battery using his car's battery. He first gets out a multimeter to check that the problem is with the battery. He measures the potential across Rebecca's battery terminals to be 10 V, and that across his own battery to be 12.5 V.

a. To which terminal of Rebecca's car battery should Brent connect the positive terminal of his car's battery? Why?
b. Draw a circuit diagram showing how the batteries should be connected. Show how the current will flow in this circuit.

D. Quantitative Question:

Cell membranes are made up of a double layer of fats, about 6.0 nm thick, as shown below.
Inside the cell there is an excess of negative ions, mostly Cl^-, and outside there is an excess of positive ions, mostly Na^+. A nerve cell maintains an electric field of around 1.0×10^7 V.m^{-1}across its cell membrane.



a. What is the potential difference across the cell membrane?
Cells can adjust their membrane resistance by opening and closing channels in the membrane which allow ions to flow through them.
b. If a current of 0.10 mA is flowing through the membrane, what is the resistance of the membrane?
c. If the membrane had a resistance of 100 Ω, what current would flow?