Topic 5: Electricity and magnetism

5.2 – HEATING EFFECTS OF ELECTRIC CURRENTS - DAY 2 Ohm’s Law

Ohm's law

- The German Ohm studied resistance of materials in the 1800s and in 1826 stated:

"Provided the temperature is kept constant, the resistance of very many materials <u>is constant</u> over a wide range of applied potential differences, and therefore the current is proportional to the potential difference ."

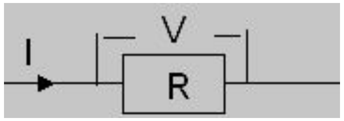
Ohm's law: Current through resistor (conductor) is proportional to potential difference on the resistor if the temperature/resistance of a resistor is constant.

- In formula form Ohm's law looks like this:

$I \propto V$ *or* $I = \frac{V}{R}$ $\text{current} = \frac{\text{voltage}}{\text{resistance}}$

I – current through R
V – potential difference across R

$I \propto V$ if resistance R is constant / temperature is constant



- Ohm's law applies to components with constant *R*.

Examples

- If a 3 volt flashlight bulb has a resistance of 9 ohms, how much current will it draw?
  - $I = V / R = 3\ V / 9\ \Omega = 0.33\ A$
- If a light bulb draws 2 A of current when connected to a 120 volt circuit, what is the resistance of the light bulb?
  - $R = V / I = 120\ V / 2\ A = 60\ \Omega$

Effects of electric current on the BODY- electric shock

Current (A)	Effect
0.001	can be felt
0.005	painful
0.010	involuntary muscle contractions (spasms)
0.015	loss of muscle control
0.070	if through the heart, serious disruption; probably fatal if current lasts for more than 1 second

questionable circuits: live (hot) wire ? how to avoid being electrified?

1. keep one hand behind the body (no hand to hand current through the body)
2. touch the wire with the back of the hand. Shock causing muscular contraction will not cause their hands to grip the wire.

human body resistance varies:
100 ohms if soaked with salt water;
moist skin - 1000 ohms;
normal dry skin – 100 000 ohms,
extra dry skin – 500 000 ohms.

What would be the current in your body if you touch the terminals of a 12-V battery with dry hands?

$I = V/R = 12\ V/100\,000\ \Omega = 0.000\,12\ A$ quite harmless

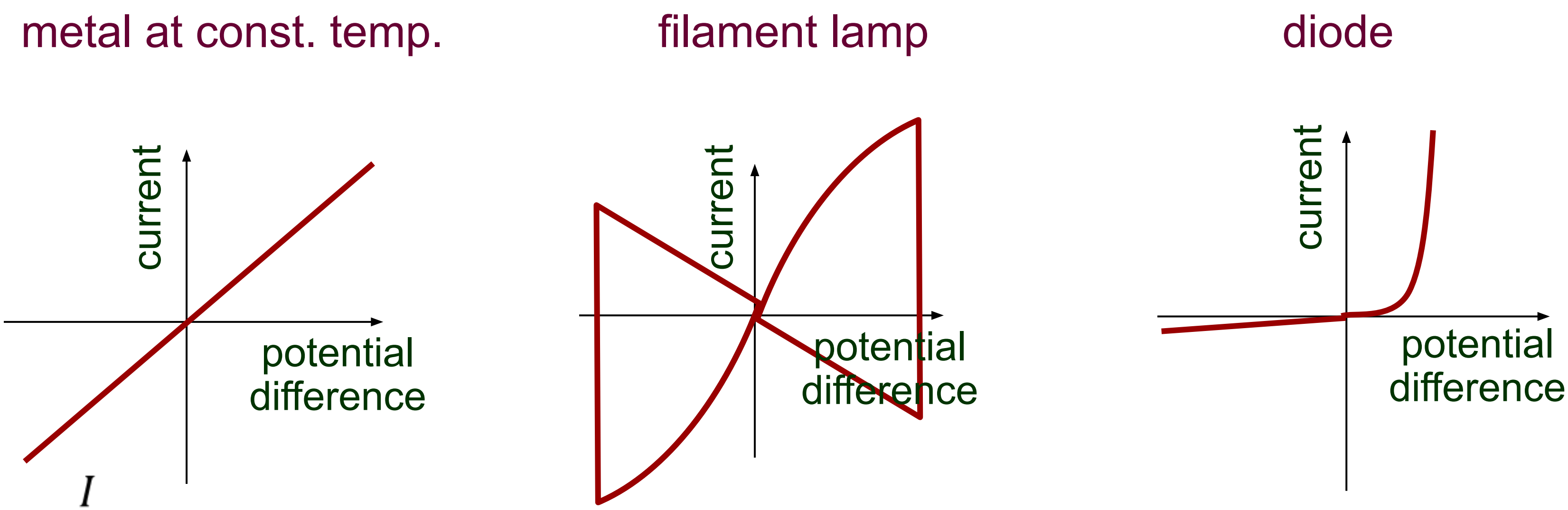
But if your hands are moist (fear of IB test?) and you touch 24 V battery, how much current would you draw?

$I = V/R = 24\ V/1000\ \Omega = 0.024\ A$

a dangerous amount of current.

Ohmic and Non-Ohmic behaviour

How does the current varies with potential difference for some typical devices?



$$as\ \frac{I}{V}\ is\ constant,$$

$$so\ is\ R = \frac{V}{I}$$

devices are non-ohmic if resistance changes

There are very few devices that are truly ohmic. However, many useful devices obey the law at least over a reasonable range.

Example

A copper wire has a length of 1.60 m and a diameter of 1.00 mm. If the wire is connected to a 1.5-volt battery, how much current flows through the wire?

The current can be found from Ohm's Law, V = IR. The V is the battery voltage, so if R can be determined then the current can be calculated. The first step, then, is to find the resistance of the wire:

L = 1.60 m.
r = 0.5 mm
$\rho = 1.72 \times 10^{-8}\ \Omega m$, copper - books

The resistance of the wire is then:

$R = \rho L/A = (1.72 \times 10^{-8}\ \Omega m)(1.60)/(7.9 \times 10^{-7} m^2) = 3.50\ \Omega$

The current can now be found from Ohm's Law:

I = V / R = 1.5 / 3.5 = 0.428 A

Ohmic and Non-Ohmic behaviour

EXAMPLE: The graph shows the applied voltage V vs resulting current I through a tungsten filament lamp.

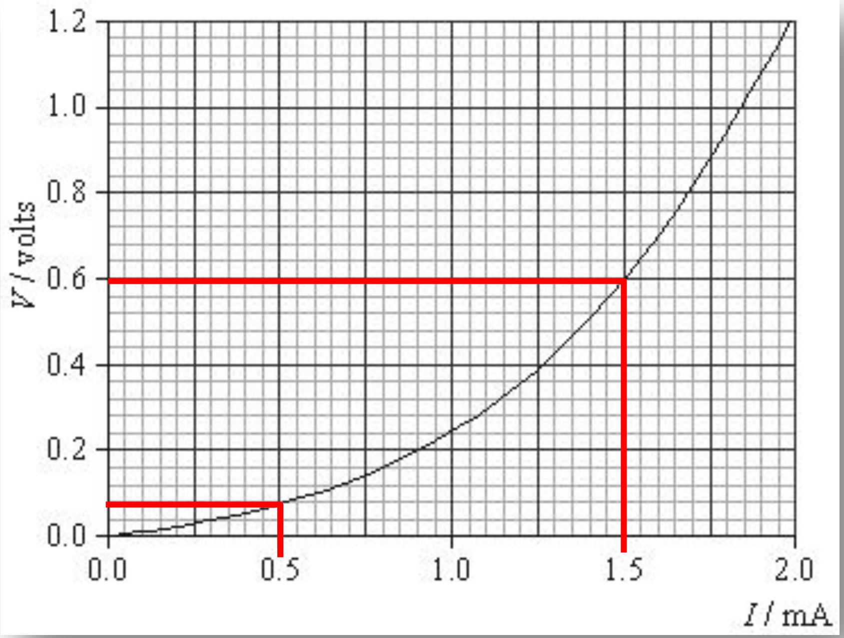
a. Find R when I = 0.5 mA and 1.5 mA. Is this filament ohmic or non-ohmic?

- At 0.5 mA: $V = 0.08$ V

  $R = V / I = 0.08 / 0.5\times10^{-3} = 160\ \Omega$.

- At 1.5 mA: $V = 0.6$ V

  $R = V / I = 0.6 / 1.5\times10^{-3} = 400\ \Omega$.



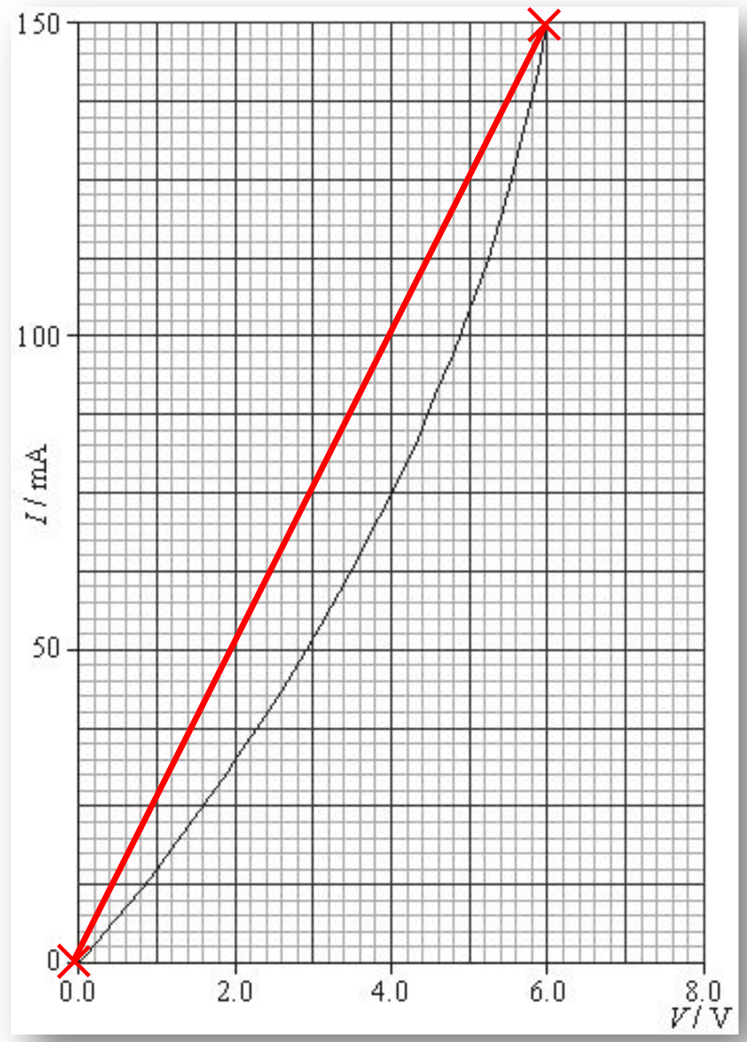
Since R is not constant the filament is non-ohmic.

b. Explain why a lamp filament might be non-ohmic.

- tungsten is a conductor.
- Therefore, the hotter the filament the higher R.
- But the more current, the hotter a lamp filament burns.
- Thus, the bigger the I the bigger the R.

Ohmic and Non-Ohmic behaviour

EXAMPLE: The *I-V* characteristic is shown for a non-ohmic component.
Sketch in the *I-V* characteristic for a 40 Ω ohmic component in the range of 0.0 V to 6.0 V.



- "Ohmic" means $V = IR$ and R is constant (and the graph is linear).
- Thus $V = I \times 40$ or $I = V / 40$.
- If $V = 0$, $I = 0 / 40 = 0.0$.
- If $V = 6$, $I = 6 / 40 = 0.15$ A.
- 0.15 A = 150 mA.

Power dissipation

- Power is the rate at which electric energy is converted into another form such as mechanical energy, heat, or light. It is rate at which the work is done.

- $P = W / t$
- $P = qV / t$
- $P = (q / t)V$

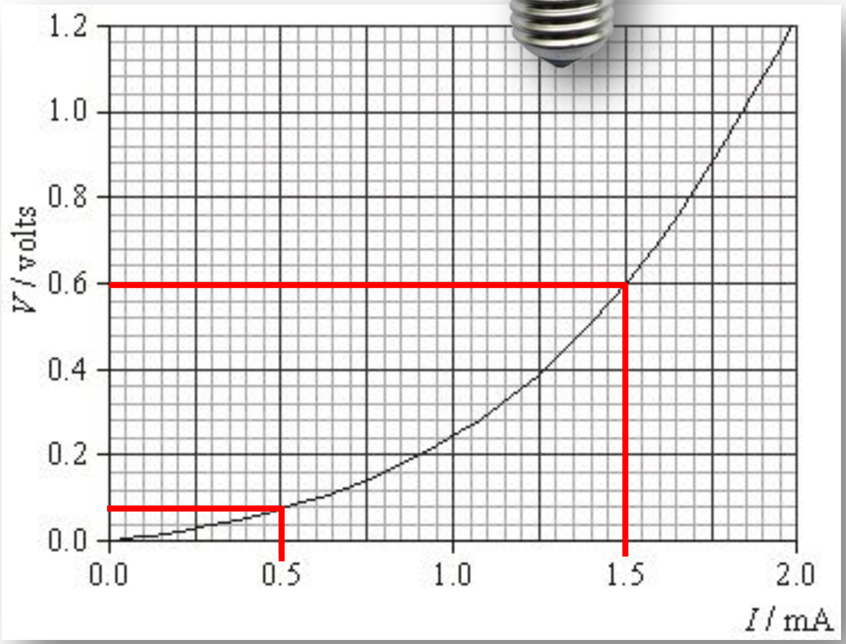
$$1\text{W} = \frac{1\text{J}}{1\text{s}} = 1\text{A} \cdot 1\text{V}$$

$$P = I\,V$$

- This power represents the energy per unit time delivered to, or consumed by, an electrical component having a current *I* and a potential difference *V*.

Power dissipation

PRACTICE:
The graph shows the *V-I* characteristics of a tungsten filament lamp.
What is its power consumption I = 0.5 mA and at I = 1.5 mA?



- At 0.5 mA, V = 0.08 V.
- $P = IV = (0.5\times10^{-3})(0.08) = 4.0\times10^{-5}$ W.
- At 1.5 mA, V = 0.6 V.
- $P = IV = (1.5\times10^{-3})(0.6) = 9.0\times10^{-4}$ W.

End of Day 2