Phys 132 2022

Lecture 16

Weds: Discussion / quiz

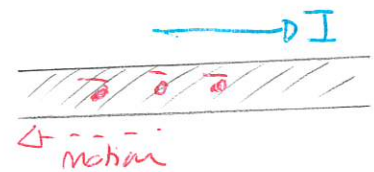
Ex 82, 83, 84, 85, 86, 87, 92, 93

Thurs: Warm Up 6 D2L

Circuit Operation

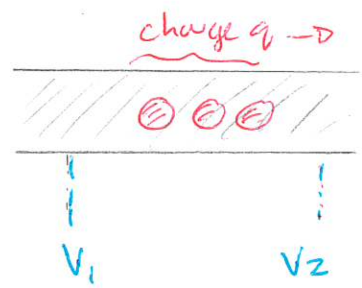
A circuit operates by having a current of charged particles flow through various circuit elements. The following quantities are useful for understanding circuits:

1) current ~ rate at which charge flows past any point



$$I = \left|\frac{\Delta Q}{\Delta t}\right|$$ Amps

2) potential difference ~ energy (per unit charge) to transport charge from one location to another.

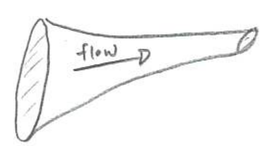


Energy to move charge q
$= q\,\Delta V$

Volts

$\Delta V = V_2 - V_1$

These have analogs with flow of water around pipes:



current ~ rate at which volume passes

potential difference ~ pressure difference between ends

Quiz 1 80% - 100%

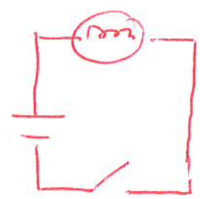
Quiz 2 30% - 70%

Ohm's Law

We are typically well-equipped with batteries and other power supplies that can produce a known potential difference. The question will then be what current results when this is connected to any particular device.

Demo: PhET circuit AC

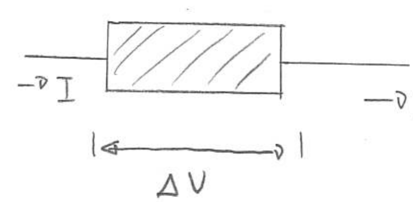
* connect for different bulbs
* observe V and I using meters



The exact relationship between the potential difference across a device and the current depends on the type of device. An experimental observation applies to a large class of devices; called Ohmic devices.

The potential difference across an Ohmic device, ΔV, and the current through the device, I, are related via:

$$\Delta V = I R$$



where R is a constant for the particular device called the resistance of the device.

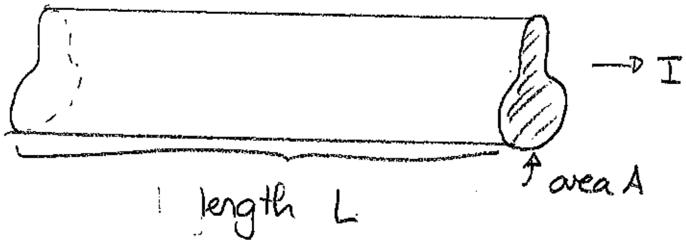
This is called Ohm's Law. The units of resistance are: Ohms $\equiv \Omega = V/A$

Examples include
* wires
* resistors

The resistance of a device depends on:

1) its configuration
2) the material from which it is constructed

A general rule applies for an Ohmic object with a cylindrical cross section. For current that flows perpendicular to the cross-section; the resistance is:



$$R = \rho \frac{L}{A}$$

where L = length of material

A = cross sectional area

ρ = resistivity of the material.

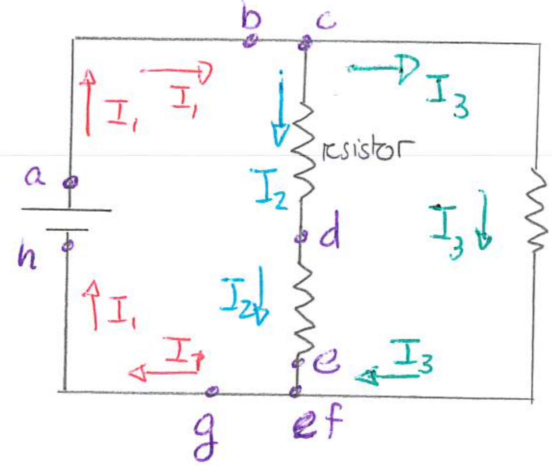
"rho"

The resistivity primarily depends on the type of material and to a lesser degree on the temperature.

Quiz3 – not done

Basic circuit laws

We can now develop quantitative laws that apply to any circuit.
First the conservation of charge implies



1) in any single arm of a circuit the current is the same

2) at any junction the current leaving equals the current entering.
In the example $I_1 = I_2 + I_3$

Second the conservation of energy implies

3) the potential differences around any single closed loop must add to zero. (Kirchoff's loop rule)

In the example, letting $\Delta V_{a\to b} = V_b - V_a$ we get

$$\Delta V_{a\to b} + \Delta V_{b\to c} + \Delta V_{c\to d} + \Delta V_{d\to e} + \Delta V_{e\to f} + \Delta V_{f\to g} + \Delta V_{g\to h} + \Delta V_{h\to a} = 0$$

Then across any section of wire $\Delta V = 0$. Thus

$$0 + 0 + \Delta V_{c\to d} + \Delta V_{d\to e} + \Delta V_{h\to a} = 0$$

$$\Rightarrow \quad \underbrace{-\Delta V_{h\to a}}_{=-\Delta V_{a\to h}} = \Delta V_{c\to d} + \Delta V_{d\to e}$$

$$\Rightarrow \quad \underbrace{\Delta V_{a\to h}}_{\text{battery}} = \underbrace{\Delta V_{c\to d}}_{\text{resistor 1}} + \underbrace{\Delta V_{d\to e}}_{\text{resistor 2}}$$

Quiz 4 - 70%

Power in Circuits

An important issue with circuit elements is the rate at which they consume or deliver energy. This is quantified by power:

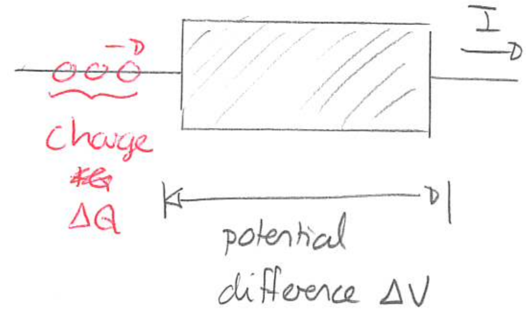
Power ~ rate at which energy is consumed/delivered

If energy ΔE is consumed/delivered in time Δt then the power is

$$P = \frac{\Delta E}{\Delta t}$$

units: Watts : $W = J/s$

This is easy to measure and compute in electric circuit elements. The energy required is



$$\Delta E = \Delta U_{elec}$$

$$= (\Delta Q)\,\Delta V$$

$$\Rightarrow \quad P = \underbrace{\frac{\Delta Q}{\Delta t}}_{I} \Delta V$$

Thus

> If current I flows through a device across which the potential difference is ΔV then
>
> $$P = I\,\Delta V$$

For Ohmic devices $\Delta V = IR$ or $I = \Delta V / R$

$$P = I(IR) \qquad\qquad P = \frac{\Delta V}{R}\Delta V$$

$$P = I^2 R \qquad\qquad P = \frac{\Delta V^2}{R}$$