Phys 100 2024

Lecture 25

Mon: HW by 5pm

Note that there will be a video search

Group Exercise

READ 8.4

Weds: Review

Fri: Test 2 Covers 18-26 Energy, Electricity + Magnetism.

Moving charges

We have so far considered how stationary charges interact. We can get charges to move and, in these cases, the interactions and behavior can be very different to when they are stationary.

~~DEMO: PhET Circuit Construction DC~~

~~* Show simple bulb ci~~

DEMO: Construct circuit with battery, bulb and switch.

DEMO: PhET Circuit Construction DC

* Show simple bulb circuit.

The animation indicates that a circuit like this functions because charged particles flow through the wires in the circuit loop. This type of flow of charge is an electric current

electric current = collection of moving charged particles.

Electric currents and the associated circuitry are crucial for:

* functioning of appliances
* functioning of electronics (phones, computers, ...)
* functioning of scientific equipment (MRIs, NMR, photon detectors, ...)
* transmission and reception of radio waves
* signalling inside biological systems.

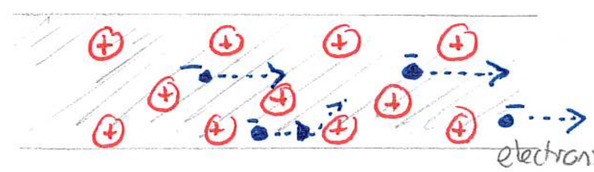
Quiz 1 80%

Quiz 2 90%

The model for current flow is then

* the nuclei are positive and stationary
* some (negative) electrons move

the moving electrons constitute the current



It is these moving charges that can be made to perform useful tasks.

* charges moving through a toaster filament collide with the material in the filament and this heats the filament.

DEMO: PhET Battery Resistor Circuit.

* charges oscillating in an antenna (e.g. radio station) produce radio waves and these cause charges in a receiver antenna to oscillate.

DEMO: PhET Radio Waves + Fields

- show basic transmission / reception
- discuss frequency variation.

Quantifying current.

If you look at the specifications on most electronic appliances, devices, there will be a place where certain quantities are specified. These include:

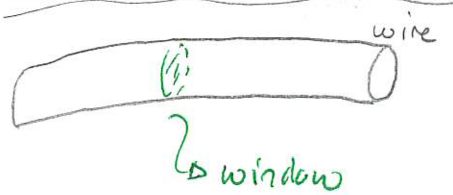
* Watts: energy consumed per second
* Volts (V)
* Amps (A)

The latter two are quantities that we usually used to understand how the device functions and these are applied to various pieces of the circuit. The study of electronics describes how to track these in various devices and circuits.

We first consider current conceptually

> Current ≈ rate at which charge flows

The way to quantify this is:



1. observe charge flowing through a cross-sectional window
2. measure charge Q that flows in time t.
3. current = $\dfrac{\text{charge flowing}}{\text{time}}$

$$I = \frac{Q}{T}$$

Q: Coulombs; T: Seconds

Units: Amperes (Amps) ≈ A

1 Electric current

Electric current in circuits consists of moving electrons. Each electron has charge -1.6×10^{-19} C. One might ask how many electrons pass through a household device in a given time. In the following, ignore the minus sign (it eventually relates to the direction of current).

a) Suppose that one billion electrons flow through a device in five seconds. Determine the total charge that flows through the device in this time and use this to determine the current flowing through the device.

The current that flows past any point in (through) a typical toaster is about 8 A.

b) Guess the number of electrons that flow through the toaster in one minute.

c) Determine the total charge that flows through the toaster in one minute.

d) Determine the number of electrons that flow through the toaster in one minute. How does it compare to your guess?

Answer: a) total charge = number of electrons × charge one electron

$$= 10^9 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-10}$$

$$\text{current} = \text{charge}/\text{time} = \frac{1.6 \times 10^{-10}}{5s} = 3.2 \times 10^{-11}\text{ A}$$

b) Must be more than 1 billion.

c) $$\text{current} = \frac{\text{charge}}{\text{time}} \Rightarrow 8A = \frac{\text{charge}}{60s}$$

$$\Rightarrow \text{charge} = 8A \times 60s = 480C$$

d) $$\text{number of electrons} = \frac{\text{total charge}}{\text{charge one electron}} = \frac{480C}{1.6 \times 10^{-19}}$$

$$= 3 \times 10^{21}$$

Quiz 3

Note that the idea of total charge enters into ratings of battery lifespans. These are usually described in terms of Amp Hrs. Then 1 Amp hr means the battery can supply 1 Amp for 3600s. Thus

$$1 \text{ Amp hr} \Rightarrow 3600\,C \text{ of charge.}$$

This determines the total amount of charge the battery can provide in its lifetime (before charging) and therefore the total number of electrons.

Examples are:

iPhone 15 battery	3.349 Ahr $\Rightarrow$	12060 C	could be supplied
Duracell AA battery	1.350 Ahr $\Rightarrow$	4860 C	" " "

Note that these do not describe how quickly the battery could provide these charges nor how much energy they supply to each charge.

However, since each electron that flows is the result of one chemical reaction in the battery, the total number of electrons that flow is limited by the number of chemical reactions that can occur and ultimately by the quantity of chemicals available for such reactions.