Electrical Current

Electrical current refers to the movement of electrons. As previously mentioned, we use a unit called Coulombs to keep track of how many electrons are moving.

1 Coulomb is approximately 6.241×10^{18} electrons.

The charge on one electron is 1.6×10^{-19} C (inverses)

An AMPERE (A) is a fundamental unit, and it is the number of Coulombs that pass a point in 1 second.

$$I = \frac{Q}{\Delta t}$$

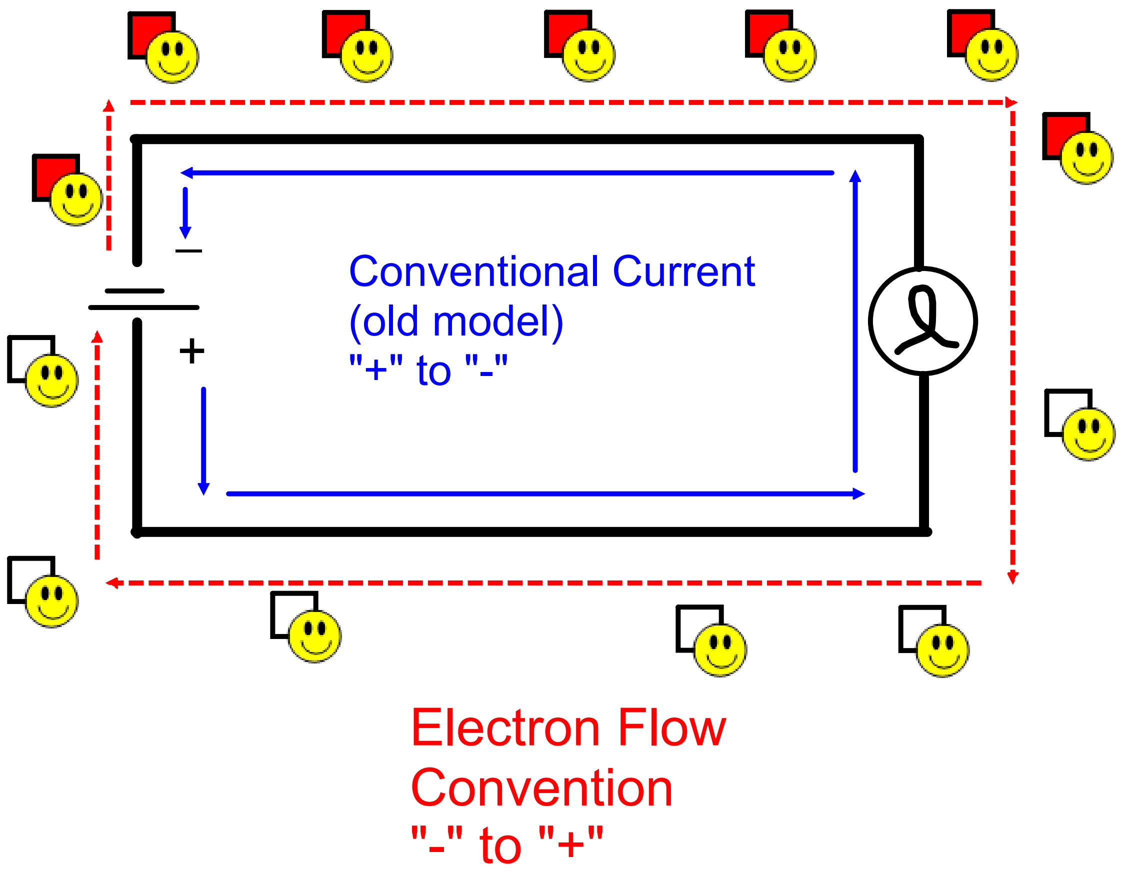
I - "intensity"

Q - number of coulombs

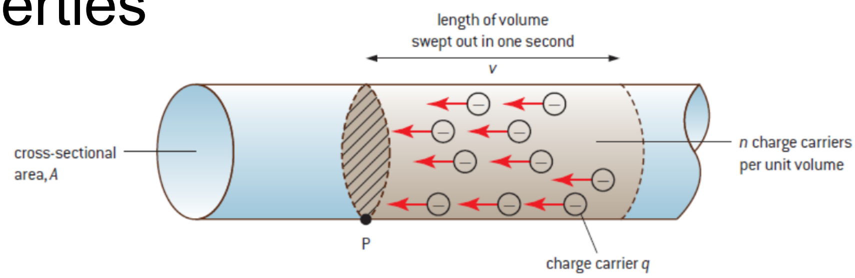
t - time in seconds

Electric Current

The FLOW (movement) of electrons is required for electric devices to operate; the electric current is what is responsible for the transfer of electrical energy along a conducting wire.



Current Properties



The figure above shows charge carriers, each of charge *q*, moving past point P at a speed *v*.

In one second, a volume of *Area x velocity (Av)* of charge carriers passes P.

The total number of charge carriers in this volume is *nAv* and therefore the total charge in the volume is *nAvq*.

However, this is the charge that passes point P in one second, which is what we mean by the electric current.

$$I = nAvq$$

I = amperes (C/s)

n = charge density (number of carriers/m^3)

ie. Copper has ~ 8.5x10^{28} electrons / m^3

A = cross section area (m^2)

v = velocity of charge movement (m/s)

(drift speed)

q = charge on each carrier

(electron is 1.6x10^{-19}C / carrier)

Noteworthy - "guage" of a wire affects area, type of metal used affects charge density

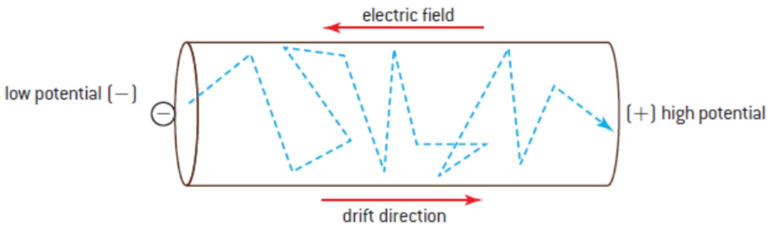
What happens to I when A or n changes?

Drift Speed

When a field is applied to a wire, and the electrons start to move, they actually move relatively slowly down the wire compared to their random motion.

Factors that affect the drift speed of electrons down a wire are as follows:

The energy transfer in a conductor arises as follows:



▲ Figure 15

A typical drift speed of an electron: 10^{-4} m/s or 0.1 mm/s
(5A current in metal conductor of cross section 1 mm^2)

The speeds of the electrons due to their random motion: 10^6 m/s

The speed of an electrical signal down a conductor: approx. 3×10^8 m/s

DC - Direct Current

Current flows in one direction.

Used in most hand held items, ie see transformer attached to your phone charger, laptop, etc.

AC - Alternating Current

Current oscillates back in forth.

Used for long distance transmission and large tools and machines.

Effects of Current on Your Body

The nerve cells in your body communicate with each other by creating very small electric currents. If a larger current is transmitted through your body it can overload your nervous system. By touching a wire with a current flowing through it, you can affect the current in your body (**Table 1**). Muscles will contract and you may not be able to let go of the wire. The electric current will also cause burns, because some of the electrical energy will be transformed into thermal energy. An electric shock can burn tissue deep inside the body, not just on the surface.

The standard electrical breaker for your home is a 15 Amp rating, that means it will turn itself off when more than 15 Amperes of current are requested (a safety feature).

Table 1 Effects of Current on Your Body

Direct current (A)	Sensation
0.0008	slight tingling
0.051	painful but can still control muscles
0.064	painful but can let go of wires
0.075	severe pain with difficulty breathing
0.50	possible heart fibrillation

Measuring Electric Current

An ammeter is a device that measures electric current. An electrician uses an ammeter to determine the current in a home circuit. Too much current can be dangerous because moving electrons cause wires to heat up. Ammeters must be connected in series in a circuit (**Figure 2**), so that all the electrons flowing through the wire also have to flow through the ammeter, giving an accurate reading of the current. If the ammeter were connected in parallel, there would be more than one path for the current to flow along: one path would be into the circuit while the other path would be through the ammeter. You would not be sure how much of the current went through the path. The symbol for an ammeter is —(A)— .

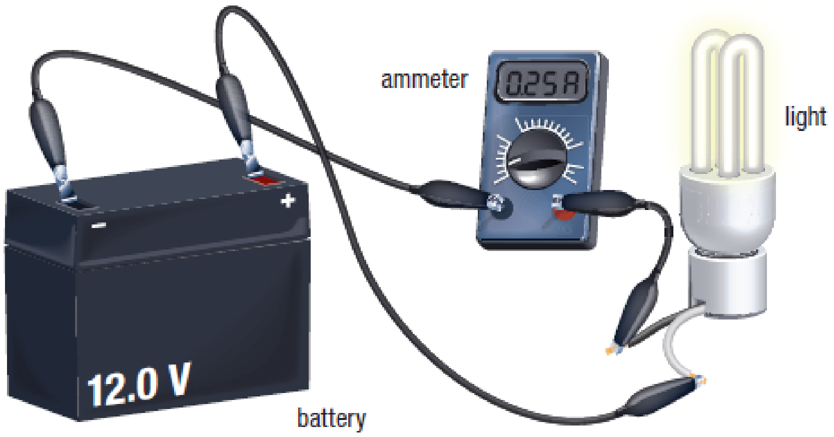


Figure 2 An ammeter is connected in series to measure electric current.

Sample Problem 1

Calculate the amount of current through a wire that has 0.85 C of electrons passing a point in 2.5 min.

Given: $Q = 0.85$ C; $\Delta t = 2.5$ min

Required: I

Analysis: $I = \dfrac{Q}{\Delta t}$

Practice

1. What is the current travelling through a cellphone charger when 0.20 mC of electrons pass a point in 0.75 min? Answer in amperes and microamperes (μA).
   T/I [ans: [redacted]
2. How many electrons, measured in coulombs, result from a current of 15 A for 24 h?
   T/I [redacted]

Power Ratings - Big Items

The power rating is how many joules of energy are required per second to run the machine.

This value gives you a snapshot of the power required to operate an appliance, but it doesn't tell you how much energy was consumed during its use.

Table 1 Power Ratings

Electrical device	Power rating (W)
MP3 player	0.4
charger for an MP3 player	120
laptop computer	20–75
52 in. LCD TV	220
50 in. plasma TV	380
central air conditioner	7000
stove	6000–10 000

Electrical energy is measured in units of kilowatt hours (kWh) because the joule (J) is sometimes too small to be a convenient measurement. One kilowatt hour is equal to 3.6 million joules. A typical home in Ontario uses 1000 kWh of electrical energy each month.

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

$$1\,kWh = \frac{1000J}{\text{sec}} \bullet \frac{3600\,\text{sec}}{hr} \bullet 1hr$$

$$1\,kWh = 3,600,000J$$

$$1\,kWh = 3.6MJ$$

Power a second way

Power = voltage x current

Units	J/s	J/C	C/s

$$P = V*I$$

11.5 Summary

- Direct current is the flow of electrons in one direction only.
- The symbol for current is I and current is measured in units of amperes (A).
- The equation that describes current is $I = \frac{Q}{\Delta t}$.
- An ammeter is used to measure current in a circuit and must be connected in series. An ammeter has the circuit symbol —(A)— .

11.5 Questions

1. What is direct current? In which direction does current go according to the electron flow convention? K/U
2. What is the current if 2.5 C of charge (electrons) passes a point in a circuit in 4.6 s? T/I C
3. Calculate the amount of charge travelling through a car battery when a current of 800.0 A is produced for 1.2 min. T/I
4. For how long can a battery produce a current of 250 mA if 1.7×10^2 C of charge passes through it? Answer in seconds and minutes. T/I
5. LED lights require less power than incandescent lights. Calculate the time required for 150 µC of charge (electrons) to pass through an LED light if the current is 0.21 mA. T/I
6. Batteries have a rating system that includes the current and the time. A rechargeable AA battery might have a rating of 2650 mAh. That is, the battery can produce a current of 2650 mA for 1 h before it is depleted. For how long could it produce a current of 883 mA? T/I
7. A student connects an ammeter in parallel and notices that the reading is a very large number. Provide a possible explanation for the high reading. K/U C
8. Is it possible to produce an electric current in a material that does not have any free electrons? Explain your answer. K/U
9. Refer to Table 1 on page 517. Electricians routinely work on household circuits that have current ratings of 15 A or more. Why do you suppose they turn off the power before working on the circuit? K/U