Physics 122: Electricity & Magnetism – Lecture 10 Current

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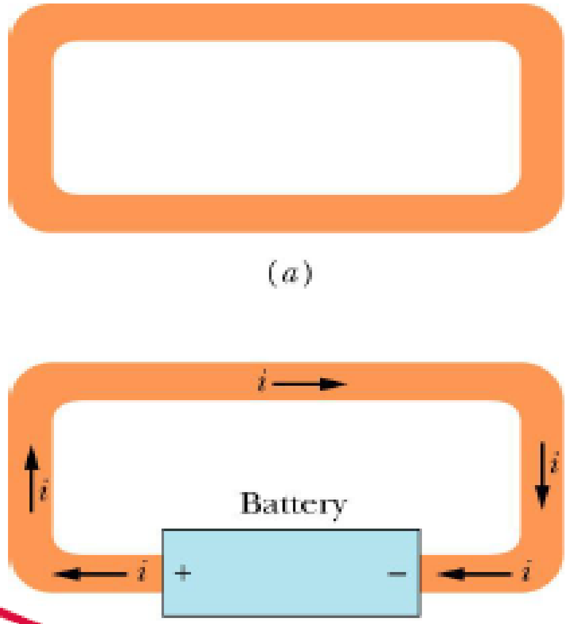
Definition of Current

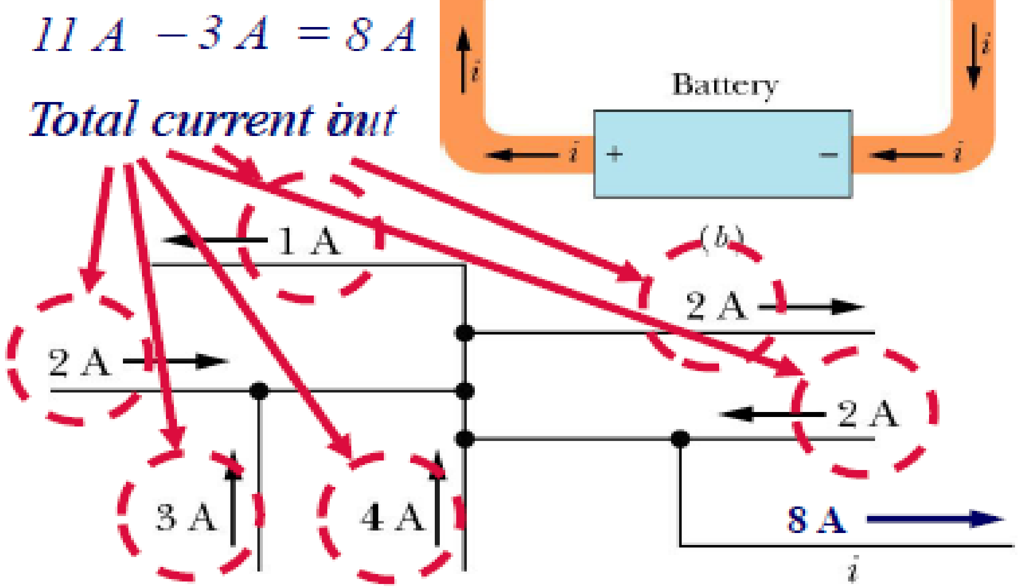
- Current is the flow of electrical charge, i.e. amount of charge per second moving through a wire, $i = dq/dt$.
- It is a scalar, not a vector, but it has a direction—positive in the direction of flow of positive charge carriers.
- Any way that you can get charges to move will create a current, but a typical way is to attach a battery to a wire *loop*.
- Charges will flow from the + terminal to the – terminal (again, it is really electrons that flow in the opposite direction, but current is defined as the direction of positive charge carriers).

Units: ampere
1 A = 1 C/s



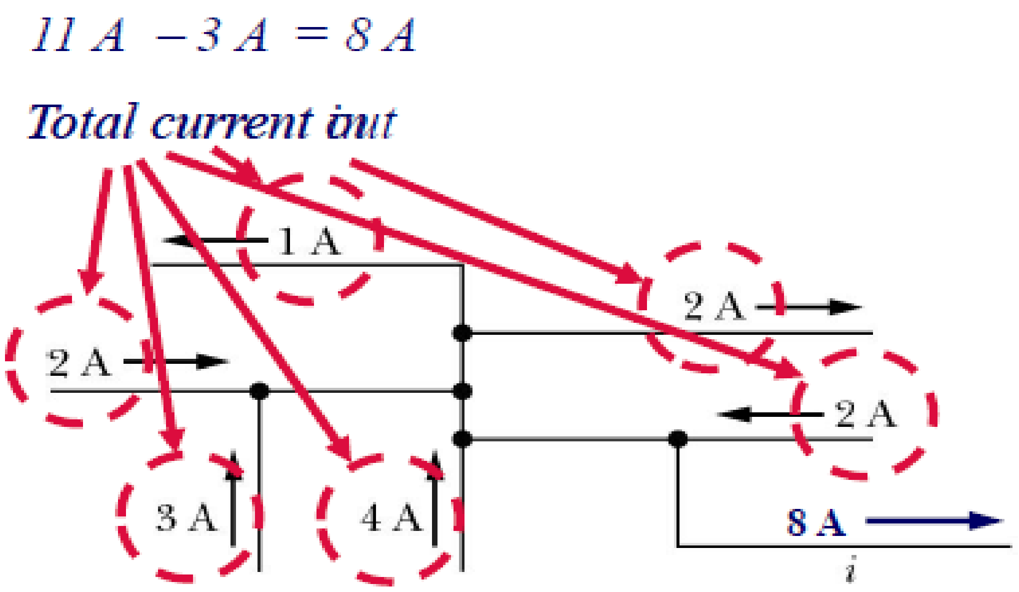
(a)

(b)



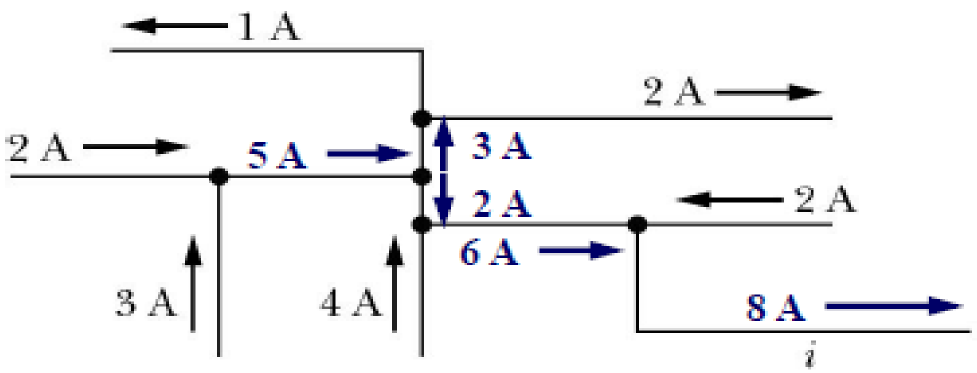
Current in a Circuit

- What is the current in the wire marked i in the figure below?



Current At Junctions

- What is the current in all of the wire sections that are not marked?

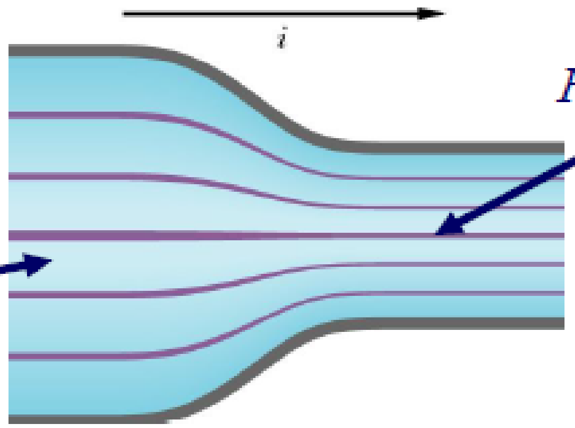


Current Density

- When we care only about the total current i in a conductor, we do not have to worry about its shape.
- However, sometimes we want to look in more detail at the current flow inside the conductor. Similar to what we did with Gauss' Law (electric flux through a surface), we can consider the flow of charge through a surface. To do this, we consider (charge per unit time) per unit area, i.e. current per unit area, or *current density*. The units are amps/square meter (A/m^2).
- Current density is a vector (since it has a flow magnitude and direction). We use the symbol $\vec{J}$. The relationship between current and current density is

$$i = \int \vec{J} \cdot d\vec{A}$$

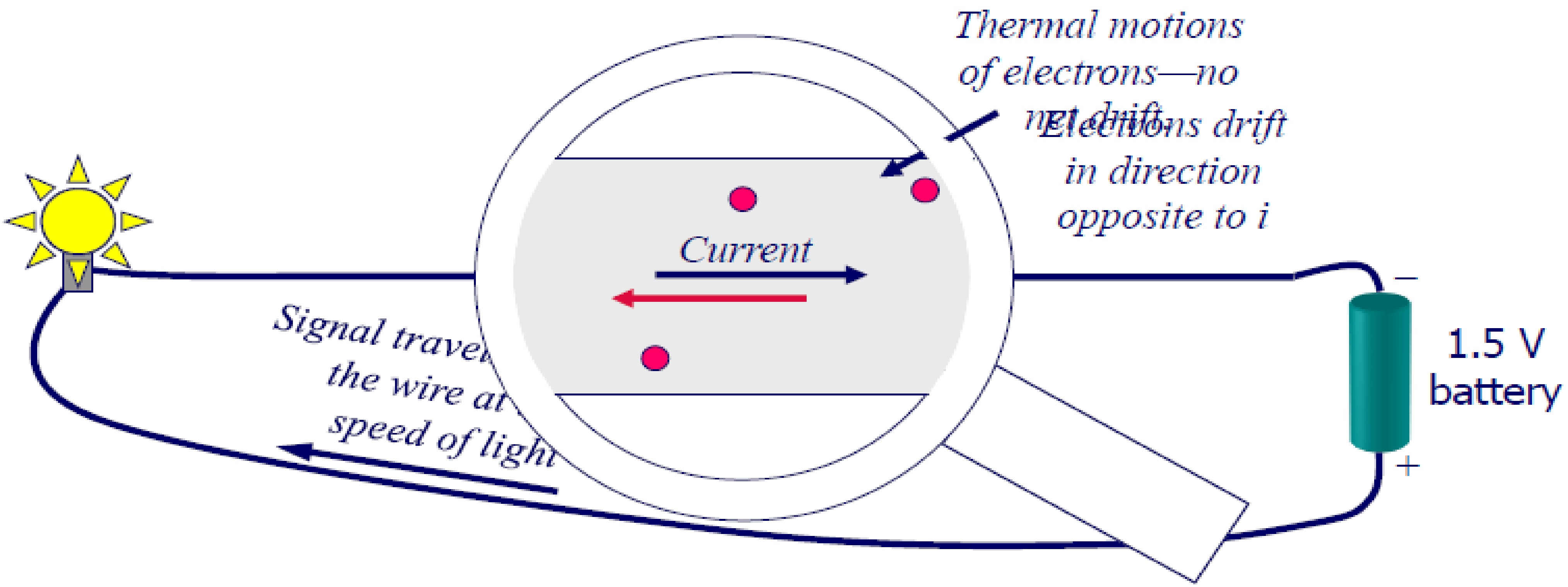
Small current density in this region



High current density in this region

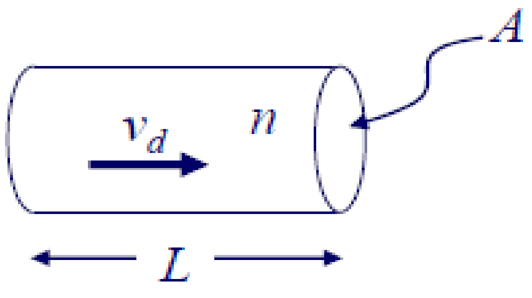
Drift Speed

- Let's look in detail at one happens when we connect a battery to a wire to start current flowing.



Drift Speed

- The drift speed is tiny compared with thermal motions.
- Thermal motions (random motions) have speed $v_{th} \approx 10^{6}\,\mathrm{m/s}$
- Drift speed in copper is $10^{-4}\,\mathrm{m/s}$.
- Let’ s relate drift speed to current density.



Total charge q in volume V

$$q = \frac{N}{V} Ve = nVe = nALe$$

density of charge carriers

$$L = v_d t \quad \therefore \quad q = nAv_d te$$

time to drift a distance L

$$i = \int \vec{J} \cdot d\vec{A} = \frac{dq}{dt} = neAv_d$$

$$\vec{J} = ne\vec{v}_d$$

$+e$ means J and v_d in same direction

$-e$ means J and v_d in opposite directions

ne is carrier charge density ρ

Summary

- Current, i, is flow of charge (charge per unit time), units, amperes (A).
- Net current into or out of a junction is zero.
- Current density, J, (current per unit area) is a vector.
- J is proportional to the density of charge carriers, ne, and the drift speed of the carriers through the material.

$$i = \int \vec{J} \cdot d\vec{A}$$

$$\vec{J} = ne\vec{v}_d$$