Section	Group	Name	Signature
Grade			
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Materials: • *PhET simulation "Circuit Construction Kit DC" https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html*

After this activity you should know: • *the definition of current.* • *how the current is related to the microscopic motion of the charge carriers..*

The current I is the rate, in Coulombs per second, at which charge moves pass point in a wire. If Q is the total amount of charge that has gone pass the point in time t, the current is defined as

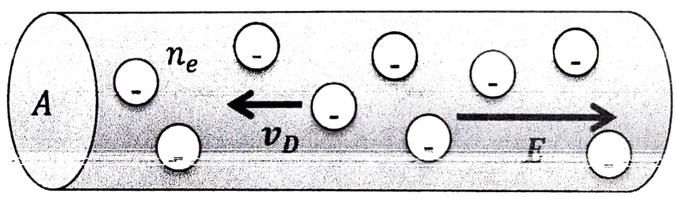
$$I = \frac{dQ}{dt}$$

If the current is constant in time, this simplifies to $I = \Delta Q/\Delta t$. The SI unit of current is an ampere = coulomb/second.

1. A wire of cross-sectional area A has n_e conduction electrons per volume. The electrons are moving to the left with drift speed v_D. Each electron has charge $-e$. *The direction of the electric current is defined as the direction that positive charge carriers would move and is therefore opposite the direction the electrons move.*

   a. The motion to the left is caused by an electric field to the right. (Note that the electric field in a conductor is zero only if the conductor is in electrostatic equilibrium.) All conduction electrons within a length $v_D\Delta t$ of the left end of the wire will pass through the left end in time Δt. How many electrons pass through the left end in time Δt? Answer in terms of n_e, A, Δt and v_D.

   $A \cdot n_e \cdot V_D \cdot \Delta t$



   b. What is the magnitude of the charge that passes through the left end in time Δt? Note that the same amount of charge enters the right end so the cylinder remains neutral. Answer in terms of n_e, A, Δt, e, and v_D.

   $A\, n_e V_D \Delta t\, e$

   c. What is the magnitude and direction of the electric current I in terms of n_e, A, v_d and e?

   $A\, n_e V_D\, e$ Right

   d. A typical househild copper wire has a diameter of 3 mm. Copper has one conduction electron per atom or 8.5×10^{28} conduction electrons per m^3. Determine the drift speed of the conduction electrons if the wire carries 1.5 Amps of current. *Comment: You will find that the drift speed is very small.*

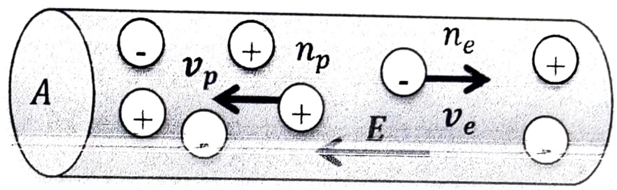
   $1.5 = .0015^2 \pi \cdot 8.5 \cdot 10^{28} \cdot V_D$?

e. With such a small drift speed, it will take on a long time for an electron to travel from a wall switch to a light. Why does the light turn on almost immediately after you flip a wall switch? *Hint: think about the difference between what happens to a full water hose versus an empty water hose when you turn on a water faucet.*

the electron at the end of the wire is the one which moves into the bulb.

2. In ionic liquids and semi-conductors, the free charge carriers can be positive as well as negative. Consider a tube of cross sectional area A of an ionic liquid which contains both mobile positive and negative ions.

The negative ions are singly charged (charge $-e$) with n_e ions per volume and drift speed v_e to the right. The positive ions are also singly charged (charge $+e$) with n_p ions per volume and drift speed v_p to the left.



a. What is the direction of the electric current due to the positive ions?

Right

b. What is the direction of the electric current due to the negative ions?

Left

c. What is the total electric current?

Left

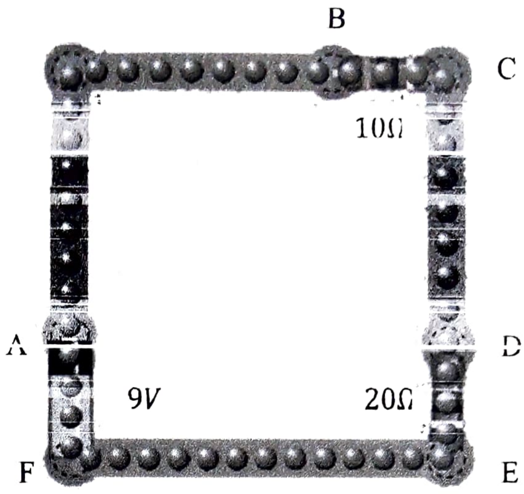
3. Assume a constant current of 3 Amps going through a copper wire. How many electrons go through the wire in 5 seconds.

$I = n_q A v_d$

$I \Delta t = A n_e e v_d \cdot \Delta t$

$= 15\,C \cdot \frac{1 \text{ electron}}{1.6 \cdot 10^{-19}\,C} = 9.375 \cdot 10^{19}$ electrons

4. Open https://phet.colorado.edu/sims/html/circuit-construction-kit-dc/latest/circuit-construction-kit-dc_en.html and build the following circuit consisting of a battery and two resistors. Left click on the resistors and set the resistances to 10 and 20 ohms (Ω). Set the EMF (i.e., the battery) to 9 Volts.



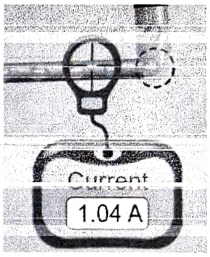
a. Use the voltmeter to measure the voltage differences at the points shown. The voltmeter measures $V_{red} - V_{black}$, i.e. the voltage at the read lead minus the voltage at the black lead.

$V_A - V_F$	$V_C - V_B$	$V_E - V_D$
9 V	~~4.5~~ -3V	-6V ~~4.5~~

b. Kirchoff's loop rule says the sum of voltage drops in any closed loop in a circuit will be zero. Based on your voltage measurements above, is Kirchoff's loop rule obeyed for this circuit?

yes

c. Use the non-contact ammeter to measure the current going through each resistor and the EMF. *Regular ammeters require you to break the circuit so that the current goes through the ammeter. Non-contact ammeters (also known as clamp-on ammeters) allow you to measure the current without breaking the circuit. However they are not as accurate as standard ammeters and reasonable quality ones are more expensive.*



Fill in the table below.

I (thru emf)	I (thru 10Ω)	I (thru 20Ω)
~~0.45~~ 0.3 A	0.3 A	0.3

d. What is true regarding the direction of the current through a resistor? Choose one!

Note: the blue dots represent the conduction electrons. The electric current is defined as the direction that positive charge carriers would move and is therefore opposite the direction of the motion of the electrons.

- The current flows from the high voltage end to the low voltage end of the resistor so that the mobile charges gain electrical potential energy as they move through the resistor.
- The current flows from the high voltage end to the low voltage end of the resistor so that the mobile charges lose electrical potential energy as they move through the resistor.
- The current flows from the low voltage end to the high voltage end of the resistor so that the mobile charges gain electrical potential energy as they move through the resistor.
- The current flows from the low voltage end to the high voltage end of the resistor so that the mobile lose gain electrical potential energy as they move through the resistor.

e. What is true of the current going through a resistor? More than one statement maybe true. Choose ***ALL*** true statements.

- Charge is used up by a resistor so there is less current coming out of a resistor than going into a resistor.
- The current going into a resistor, and coming out of a resistor is always the same.
- The mobile charges gain kinetic energy as they go thru a resistor.
- The mobile charges lose electrical potential energy as they go through the resistor so they have less ~~potential energy coming out of the resistor than when the charges went in. The charges do not speed up~~ since the lost potential energy but goes to heating up the resistor.

f. Resistors are connected in series if there are no branch points in between. What can we say about the current going through each resistor when they are connected in series?

It is the same

g. What is true of the battery in this circuit? Choose one.

- The battery has a storage of charge which is then used up by the resistors.
- The battery does work on the mobile charges as they go through the battery. Therefore the charges have ~~higher potential energy when they leave the battery than went they entered.~~

h. Place the voltmeter to measure the voltage across the battery terminals. Change the resistances of the resistors to 3 Ω and 6 Ω and measure the voltage across the battery and the current. What is true? Choose one.

- An ideal battery maintains the same voltage difference across its terminals indepedent of the resistance of the circuit. The current adjusts depending on the resistance of the circuit.
- An ideal battery maintains a constant current and the voltage adjusts depending on the resistance of the circuit.

i. The charge on a capacitor as a function of time is

$$Q(t) = 3\ \mu C - 3\mu C\ e^{-t/(2\ \mu s)}$$

What is the current at t = 4 μs?

$$I(4) = \frac{3 - 3e^{-2}}{4\ \mu s}$$