Wrocław University of Science and Technology

Physics

JZL1001913C

summer semester

2020/2021

Wednesday, 18:20 - 19:50

Friday, 18:20 - 19:50

virtual room (ZOOM)

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Electrostatics

- short rewiev

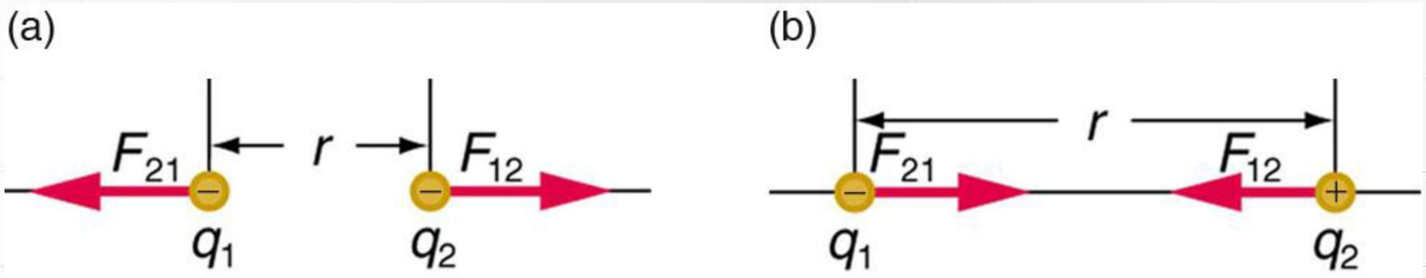
Charge	Unit 1 kg/m/s² = 1 C = 1 Coulomb
Electric field $E = k\frac{\lvert Q\rvert}{r^2}$	Unit 1N/C = 1 V/m = 1 Volt/metr
Electric potential energy $E_p = Fr = k\frac{q_1 q_2}{r}$	Unit 1J

Quantities:
- Electric charge
- Electric field
- Electric potential
- Electric potential energy

Coulomb's law

$$F = k\frac{q_1 q_2}{r^2}$$

$$k = 8.988 \times 10^9 \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}} \approx 8.99 \times 10^9 \frac{\mathrm{N \cdot m^2}}{\mathrm{C^2}}$$



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Outline

- Introduction - Physics rules the world
- Motion phenomena - Kinematics
- Motion phenomena - Dynamics
- Rotational motion
- Harmonic motion
- Gravitational field
- Relativistic phenomena
- Basics of Thermodynamics
- Principles of Thermodynamics
- Fluids Statics
- Electrostatics
- **Electric current**
- Magnetic field
- Vibrations and electromagnetic waves
- Revisions and tests

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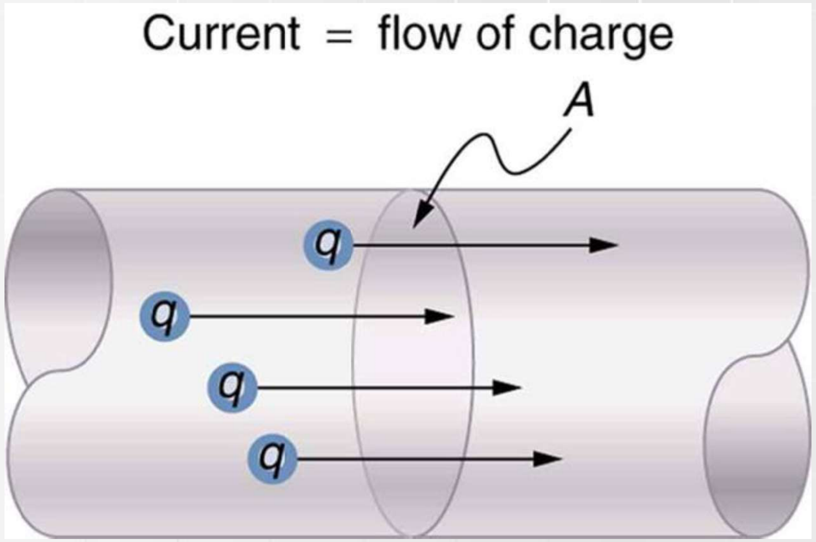
Electric current

Electric current is defined to be the rate at which charge flows. A large current, such as that used to start a truck engine, moves a large amount of charge in a small time, whereas a small current, such as that used to operate a hand-held calculator, moves a small amount of charge over a long period of time. In equation form, electric current I is defined to be

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

where ΔQ is the amount of charge passing through a given area in time Δt.



The direction of conventional current is the direction that positive charge would flow

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Example 1

(a) What is the current involved when a truck battery sets in motion 720 C of charge in 4.00 s while starting an engine?

(b) How long does it take 1.00 C of charge to flow through a handheld calculator if a 0.300-mA current is flowing?

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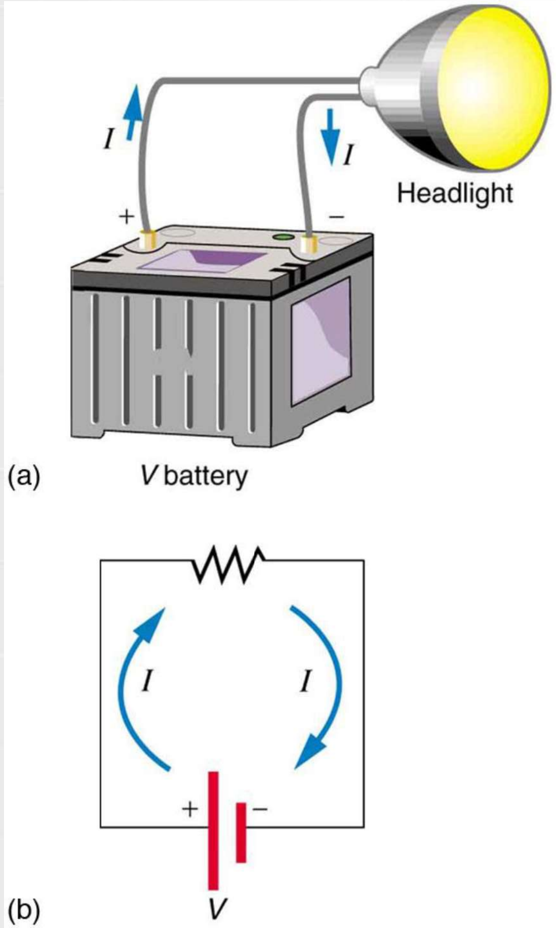
Electric circuit

Figure shows a simple circuit and the standard schematic representation of a battery, conducting path, and load (a resistor). Schematics are very useful in visualizing the main features of a circuit. A single schematic can represent a wide variety of situations. The schematic in image (b), for example, can represent anything from a truck battery connected to a headlight lighting the street in front of the truck to a small battery connected to a penlight lighting a keyhole in a door. Such schematics are useful because the analysis is the same for a wide variety of situations. We need to understand a few schematics to apply the concepts and analysis to many more situations.



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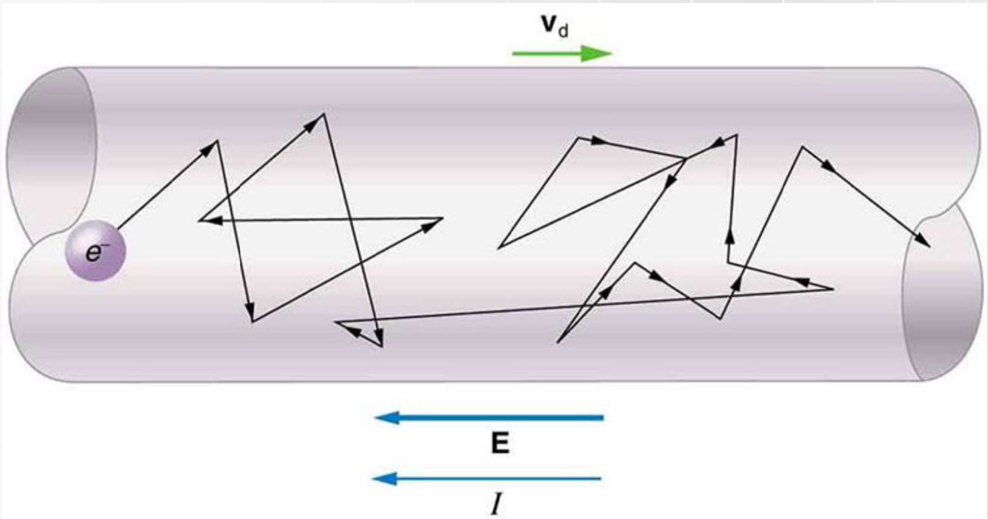
Drift Velocity

Good conductors have large numbers of free charges. In metals, the free charges are free electrons. Image shows how free electrons move through an ordinary conductor. The distance that an individual electron can move between collisions with atoms or other electrons is quite small. The electron paths thus appear nearly random, like the motion of atoms in a gas. But there is an electric field in the conductor that causes the electrons to drift in the direction shown (opposite to the field, since they are negative). The drift velocity v_d is the average velocity of the free charges. Drift velocity is quite small, since there are so many free charges. If we have an estimate of the density of free electrons in a conductor, we can calculate the drift velocity for a given current. The larger the density, the lower the velocity required for a given current.

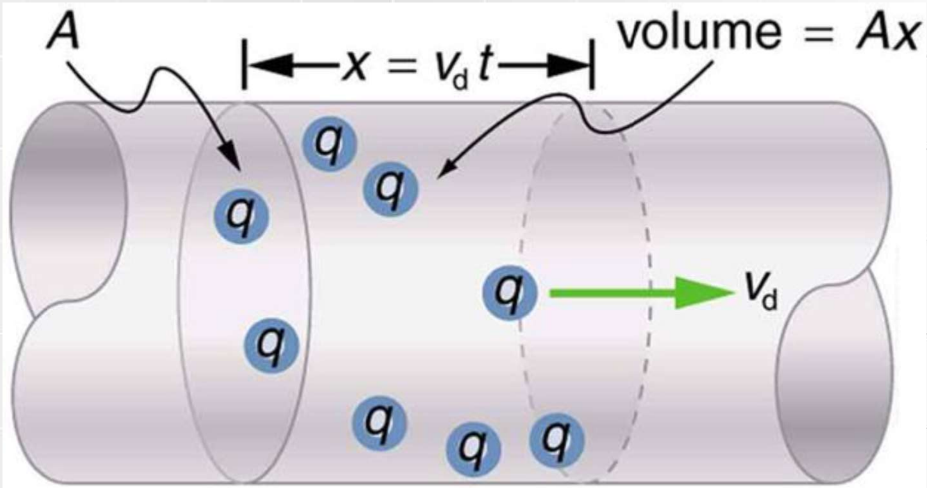


Relationship between current and drift velocity

We can obtain an expression for the relationship between current and drift velocity by considering the number of free charges in a segment of wire. The number of free charges per unit volume is given the symbol n and depends on the material. The shaded segment has a volume Ax, so that the number of free charges in it is n A_x. The charge ΔQ in this segment is thus qnAx, where q is the amount of charge on each carrier. (Recall that for electrons, q is -1.60×10^{-19}C .) Current is charge moved per unit time; thus, if all the original charges move out of this segment in time Δt , the current is

$I=\Delta Q/\Delta t=qnAx/\Delta t$

$I=nqAv_d$



Voltage source

What drives current? We can think of various devices—such as batteries, generators, wall outlets, and so on—which are necessary to maintain a current. All such devices create a potential difference and are loosely referred to as voltage sources. When a voltage source is connected to a conductor, it applies a potential difference V that creates an electric field. The electric field in turn exerts force on charges, causing current.

Ohm’s Law

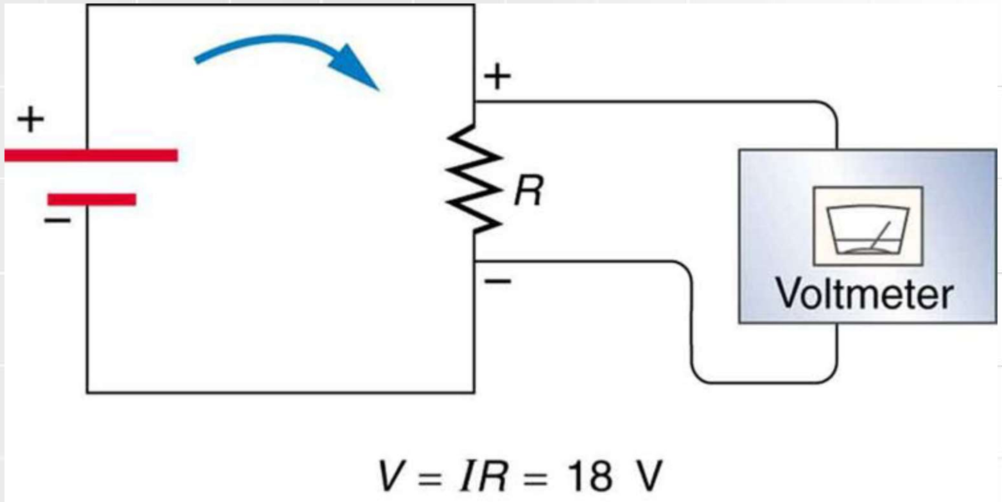
The current that flows through most substances is directly proportional to the voltage V applied to it. The German physicist Georg Simon Ohm (1787–1854) was the first to demonstrate experimentally that the current in a metal wire is directly proportional to the voltage applied.

$$I = \frac{U}{R}$$

Ohm’s law in this form really defines resistance for certain materials. Ohm’s law is not universally valid. The many substances for which Ohm’s law holds are called *ohmic*. These include good conductors like copper and aluminum, and some poor conductors under certain circumstances. Ohmic materials have a resistance R that is independent of voltage V and current I . An object that has simple resistance is called a resistor, even if its resistance is small. The unit for resistance is an ohm and is given the symbol Ω (upper case Greek omega).

Voltage source

This expression for V can be interpreted as the voltage drop across a resistor produced by the flow of current I . The phrase IR drop is often used for this voltage.



The voltage drop across a resistor in a simple circuit equals the voltage output of the battery.

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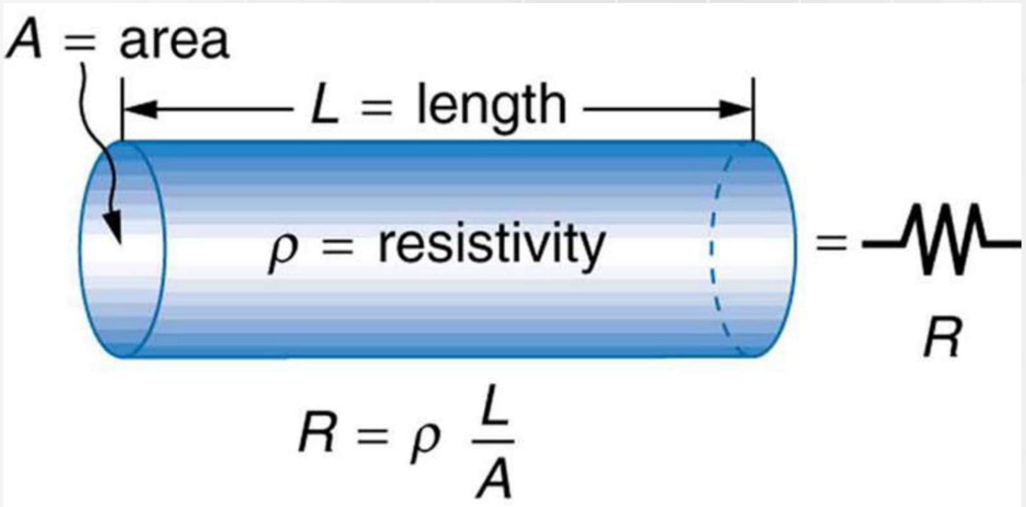
Resistivity

The resistance of an object depends on its shape and the material of which it is composed. The cylindrical resistor in is easy to analyze. We can gain insight into the resistance of more complicated shapes. As you might expect, the cylinder's electric resistance R is directly proportional to its length L, similar to the resistance of a pipe to fluid flow. The longer the cylinder, the more collisions charges will make with its atoms. The greater the diameter of the cylinder, the more current it can carry (again similar to the flow of fluid through a pipe). In fact, R is inversely proportional to the cylinder's cross-sectional area A



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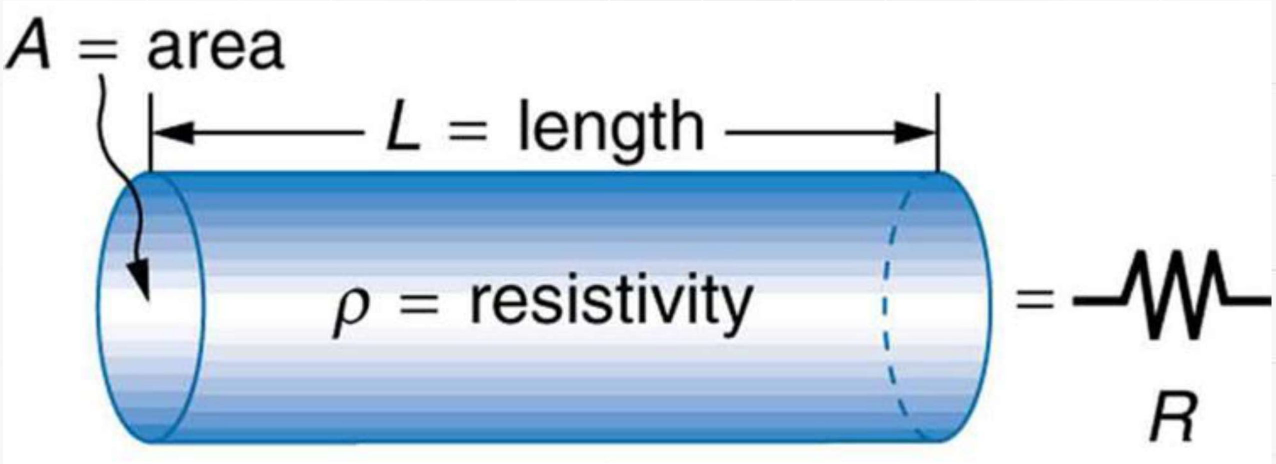
Resistivity

We define the resistivity ρ of a substance so that the resistance R of an object is directly proportional to ρ. Resistivity ρ is an intrinsic property of a material, independent of its shape or size. The resistance R of a uniform cylinder of length L , of cross-sectional area A, and made of a material with resistivity ρ, is

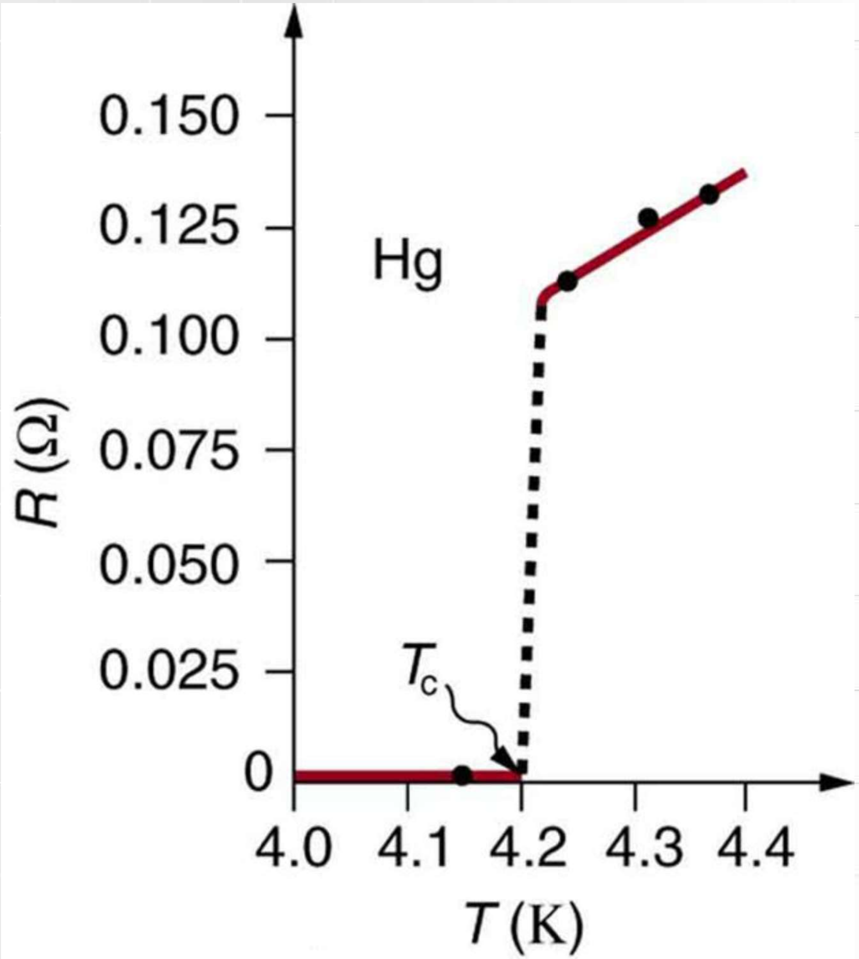


$$R = \rho \frac{L}{A}$$

Temperature Variation of Resistance

The resistance of a sample of mercury is zero at very low temperatures—it is a superconductor up to about 4.2 K. Above that critical temperature, its resistance makes a sudden jump and then increases nearly linearly with temperature.

$$\rho = \rho_0(1 + \alpha \Delta T)$$



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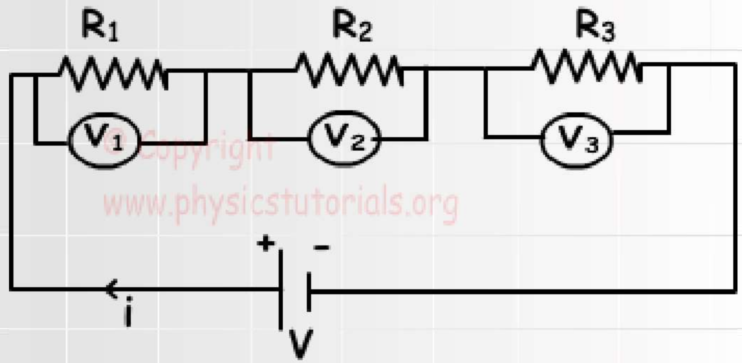
Combination of Resistors

- series

Resistors can be combined in two ways; series and parallel. Combination of more than one resistor is called equivalent resistor. We first look at the resistors in series.



a. In this types of circuit, amount of currents passing through the resistors are equal and this current comes from the battery.

$I=I_1=I_2=I_3$

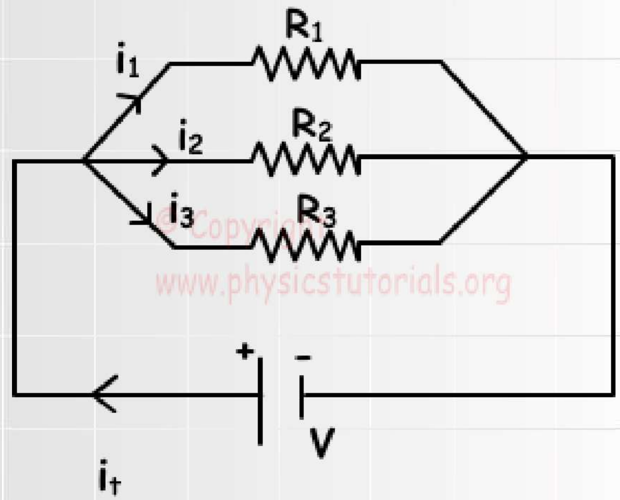
b. Sum of the potential differences of each resistor is equal to total potential difference of the circuit or potential difference between the ends of battery.

$U_t=U_1+U_2+U_3$

Combination of Resistors

- parallel

Resistors can be combined in paralel way.



a. Sum of the currents in each branch is equal to the current coming from battery.

$i_t=i_1+i_2+i_3$

b. Since the two ends of each resistor are connected to the same points, potential differences of each resistor are equal.

$U=U_1=U_2=U_3$

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Power in Electric Circuits

Electric energy depends on both the voltage involved and the charge moved. This is expressed most simply as PE=qV , where q is the charge moved and V is the voltage (or more precisely, the potential difference the charge moves through). Power is the rate at which energy is moved, and so electric power is

$$P = \frac{PE}{t} = \frac{qU}{t}$$

Recognizing that current is I=q/t (note that Δt=t here), the expression for power becomes

$$P = UI$$

Unit: 1 A·V=1 W

Cost of Electricity

The more electric appliances you use and the longer they are left on, the higher your electric bill. This familiar fact is based on the relationship between energy and power. You pay for the energy used. Since P=E/t , we see that

$$E = Pt$$

is the energy used by a device using power P for a time interval t. For example, the more lightbulbs burning, the greater P used; the longer they are on, the greater t is. The energy unit on electric bills is the kilowatt-hour (kW·h), consistent with the relationship E=Pt.

Unit: 1 kW·h = 3.6×106J

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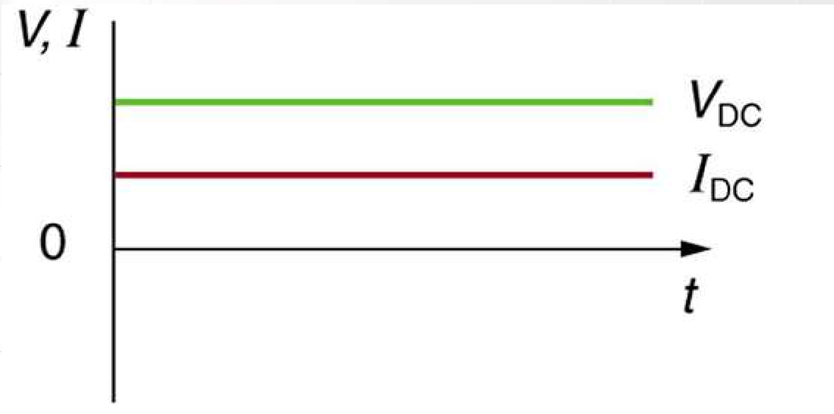
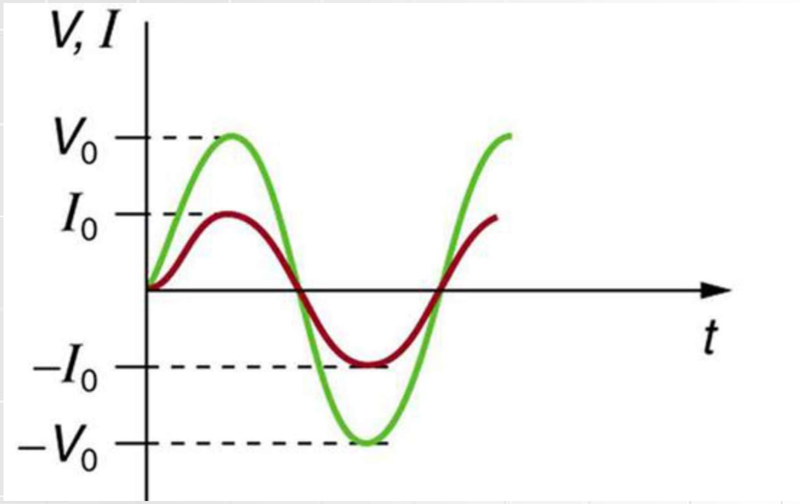
Current: DC and AC

Most of the examples dealt with so far, and particularly those utilizing batteries, have constant voltage sources. Once the current is established, it is thus also a constant. **Direct current** (DC) is the flow of electric charge in only one direction. It is the steady state of a constant-voltage circuit. Most well-known applications, however, use a time-varying voltage source. **Alternating current** (AC) is the flow of electric charge that periodically reverses direction. If the source varies periodically, particularly sinusoidally, the circuit is known as an alternating current circuit.





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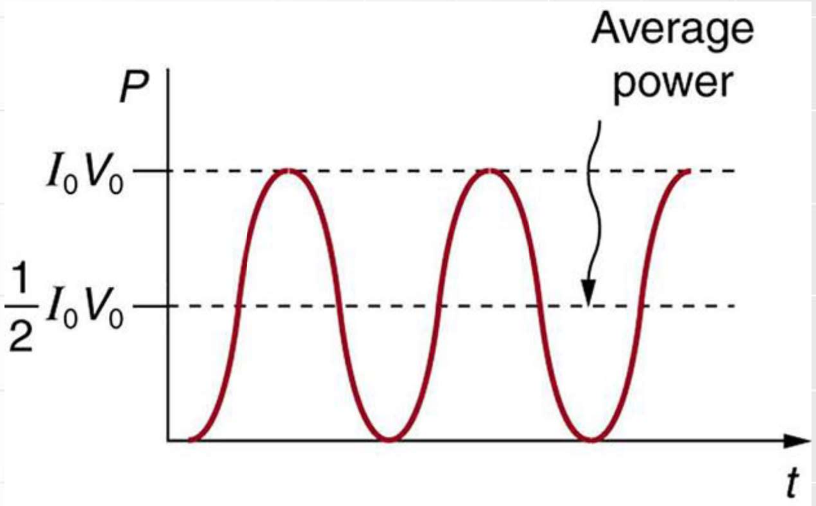
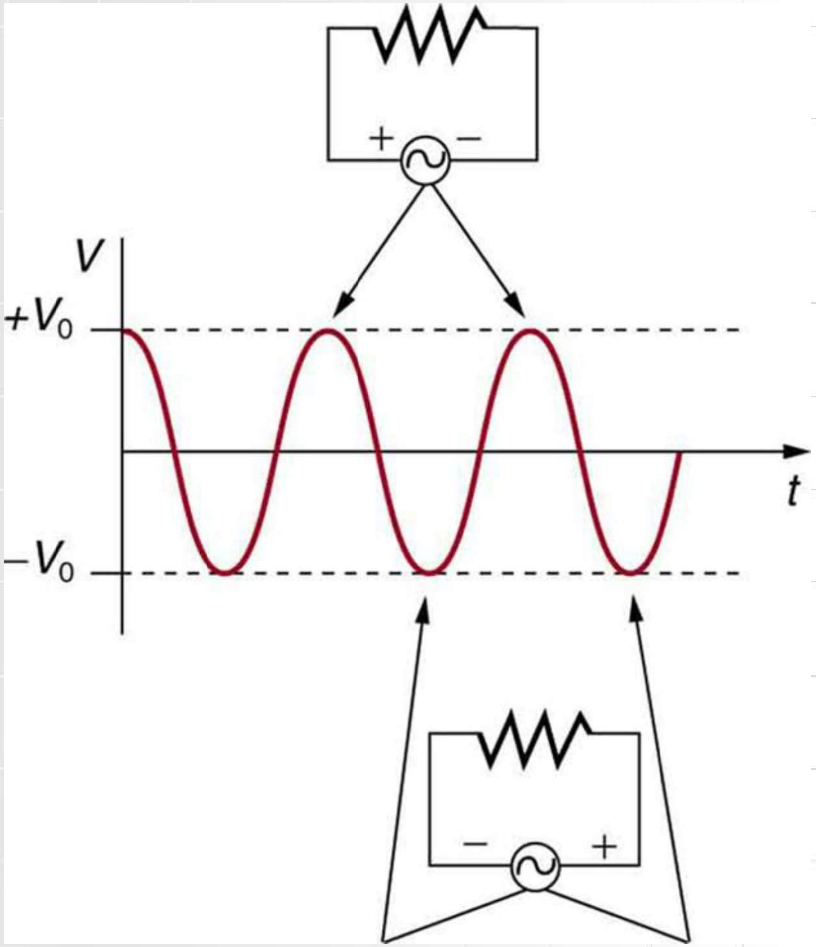
Alternating voltage and current

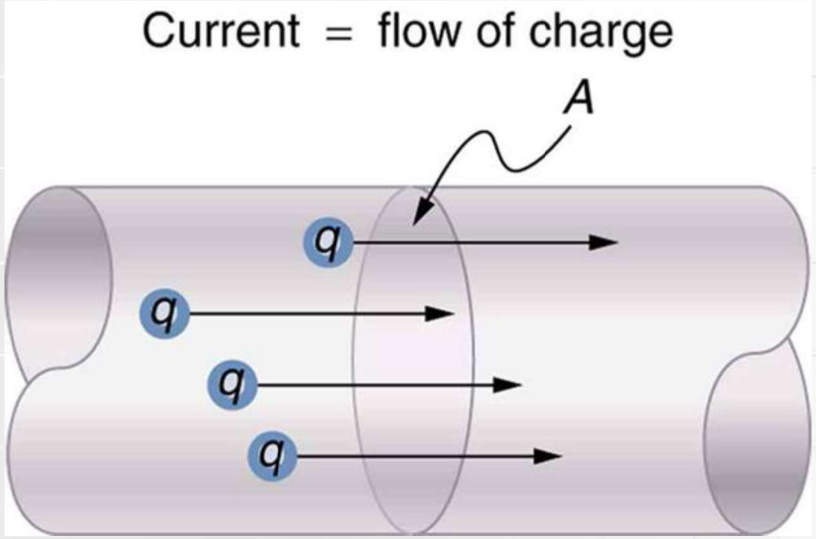
$$V = V_0 \sin 2\pi ft$$
$$I = I_0 \sin 2\pi ft$$





Electric current

All right. So if you go to our website today, you will find I've assigned some problems and you should try to do them. They apply to this chapter.



Quizz

Kahoot link: https://kahoot.it/challenge/02521304?challenge-id=459c69ba-0699-474d-ae7d-12916780bd23_1620475768723

Deadline: 19th May 2021, 18:00