Electric Circuits Variables and Components

Electric Circuit or Network

- Network - Interconnection of two or more circuit elements
- Electric Circuit – if the network contains at least one closed path, it is also an electric circuit

Units - SI System (International System of Units)

Base units:

Base Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Derived units:

- work or energy: joule (J) → $1\ J = 1\ kg\ m^2\ s^{-2}$
- power (rate of doing work): watt (W) → $1\ W = 1\ J/s$

SI: Units and Prefixes

Any measurement can be expressed in terms of a unit, or a unit with a “prefix” modifier.

FACTOR	NAME	SYMBOL
10^{-9}	nano	n
10^{-6}	micro	µ
10^{-3}	milli	m
10^{3}	kilo	k
10^{6}	mega	M

Example: $12.3\ \mathrm{mW} = 0.0123\ \mathrm{W} = 1.23 \times 10^{-2}\ \mathrm{W}$

Electric Circuit Variables

- Charge
- Current
- Voltage
- Power and Energy

Circuit Variable - Charge

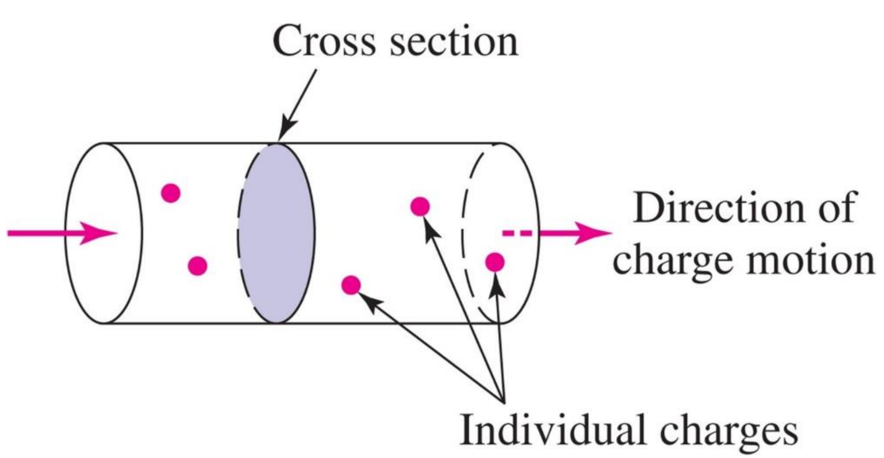
- Law of conservation of charge - Charge cannot be created or destroyed, only transferred
- Matter is made of atoms, each atom consist of electrons (negative charge), protons (positive charge), and neutrons
- Charge symbol is Q or q
- In SI system, the fundamental unit of charge is **Coulomb** (**C**). It is defined in terms of Amperes
- Counts the number of electrons (or positive charges) present
- Charge on a single electron is -1.602×10^{-19} C
- One Coulomb is large unit for charge, 6.24×10^{18} electrons
- Charge is always multiple of electron charge

Circuit Variables - Current and Charge

Coulomb is defined in terms of **Ampere** by counting the total charge that passes through an arbitrary cross section of a wire during an interval of one second

Charge in Motion - **Current** is the rate of charge flow:

1 ampere = 1 coulomb/second (or 1 A = 1 C/s)



Circuit Variables - Current and Charge

Current (designated by *I* or *i*) is the rate of flow of charge in a specified direction

$$i = \frac{dq}{dt}$$

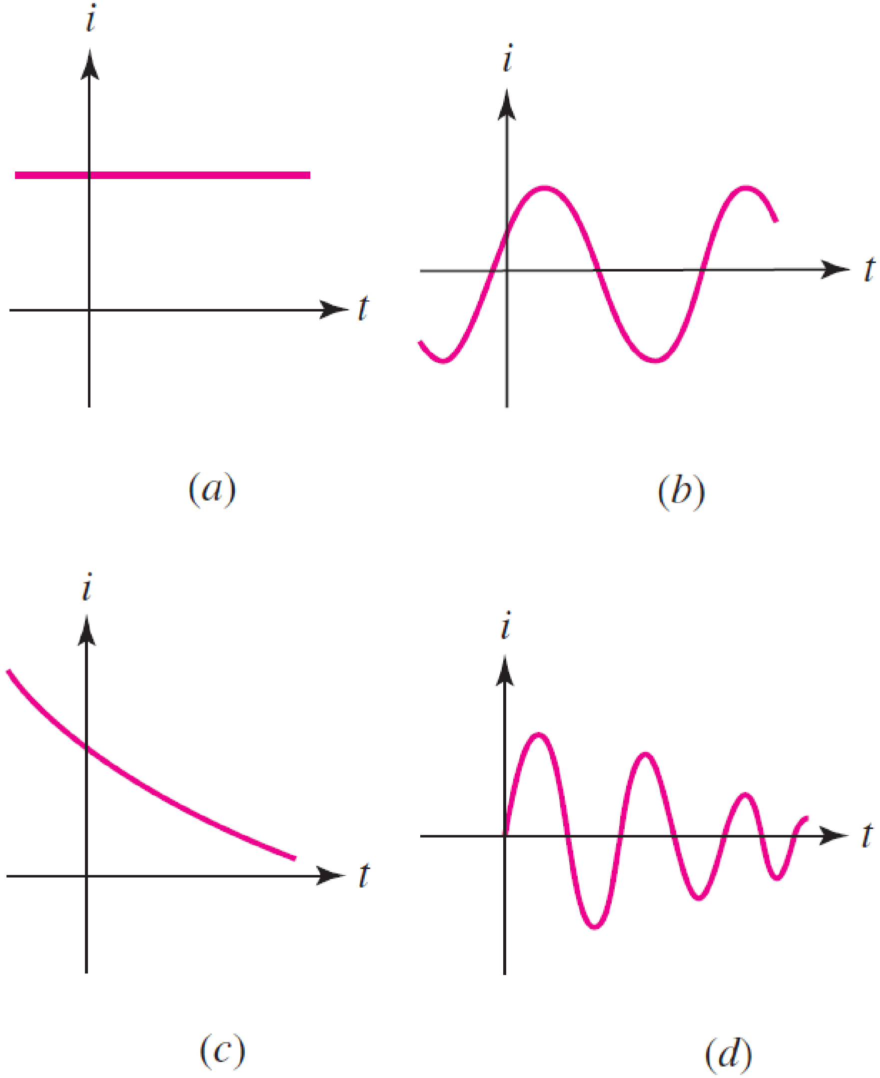
Current must be designated with both a direction and a magnitude

Unit – Ampere (A)

These two currents are the same:

$$Q = \int_{t_0}^{t} i\, dt$$

Circuit Variables - Current



Circuit Variables - Current

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2.4 In the wire of Fig. 2.7, electrons are moving *left* to *right* to create a current of 1 mA. Determine I_1 and I_2.

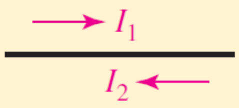


FIGURE 2.7

Circuit Variable and Component - Voltage

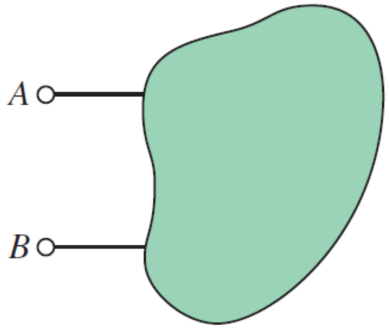


FIGURE 2.8 A general two-terminal circuit element.

DC current enters terminal A, through the element and leaves out of terminal B

Pushing charge through this element requires energy – voltage or potential difference

Voltage across the two terminals is a measure of the work required to move charge through the element

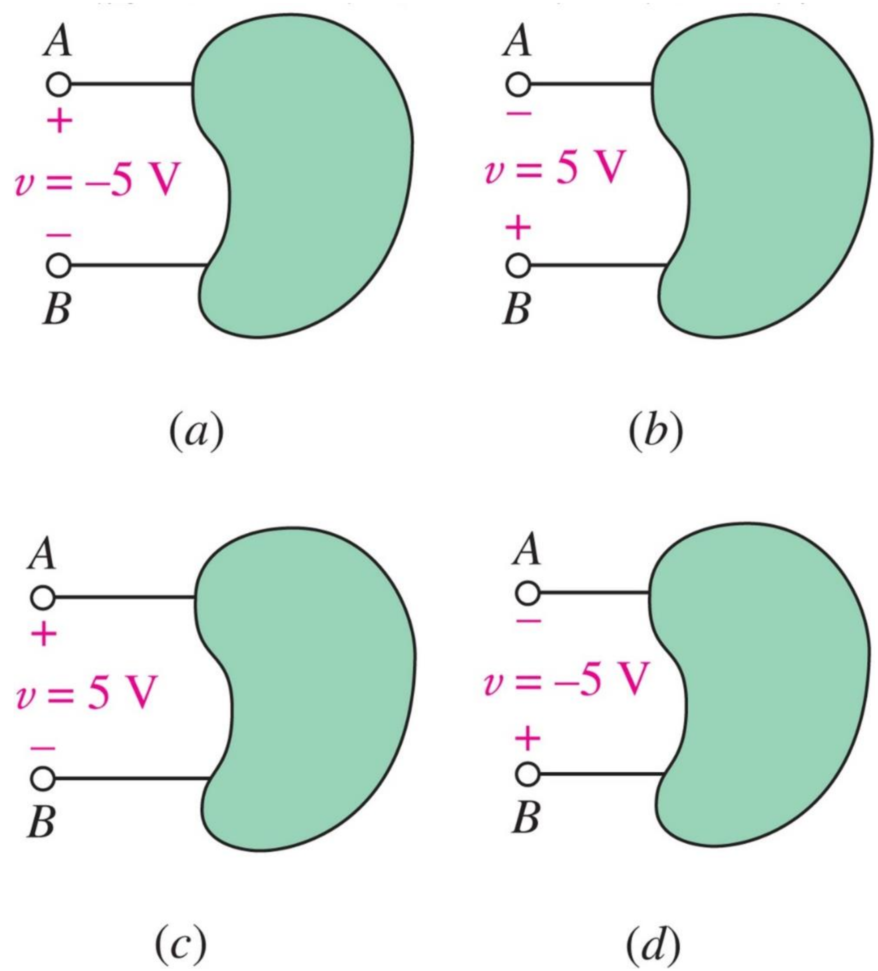
Circuit Variable - Voltage

When 1 J of work is required to move 1 C of charge from A to B, there is a voltage of 1 volt between A and B.

Unit: volt and 1 V = 1 J/C

Voltage (V or *v*) across an element requires both a magnitude and a polarity.

Example: (a)=(b), (c)=(d)



Circuit Variable - Voltage

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2.5 For the element in Fig. 2.11, $v_1 = 17$ V. Determine v_2.

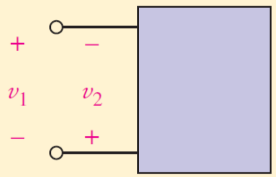


FIGURE 2.11

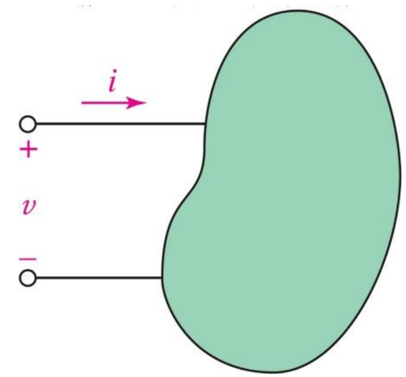
Circuit Variable - Power: $p = vi$

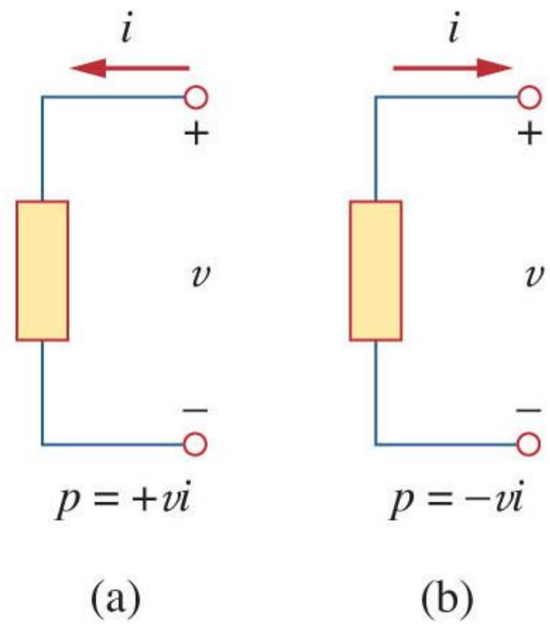
The power required to push a current i (C/s) into a voltage v (J/C) is $p = vi$ (J/s = W). Unit – Watt (W)

Positive power – Power is absorbed by the element

Negative power – Power is supplied by the element

Passive sign convention is satisfied if the direction of current is selected such that the current enters through positive terminal of the voltage and $p = +vi$ and if the current enters through the negative voltage terminal $p = -vi$



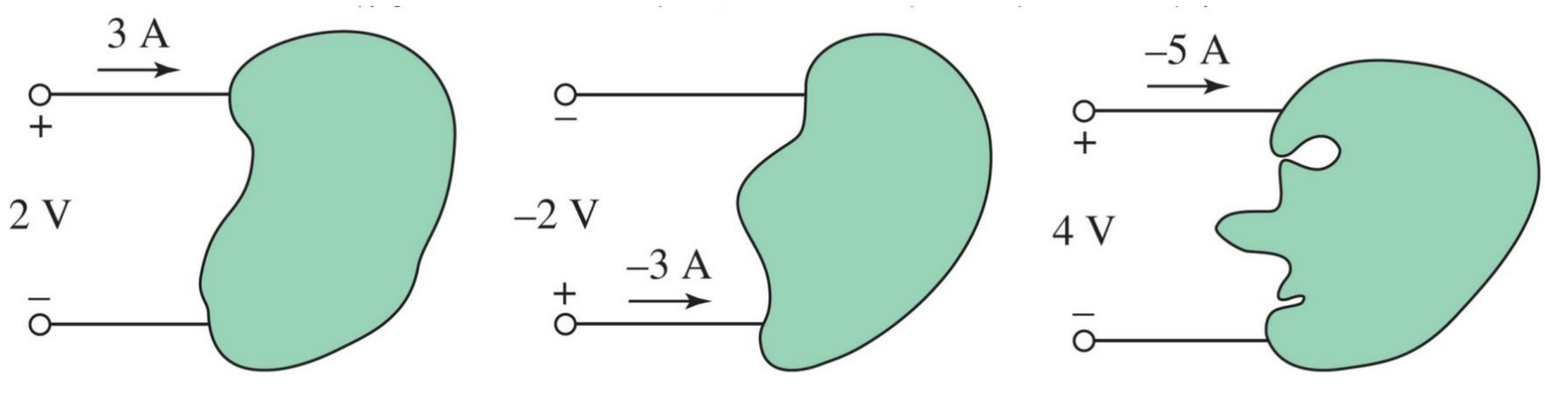


Absorbing Power Supplying Power

Circuit Variable - Power

- Law of conservation of energy – algebraic sum of power in a circuit, at any instant of time, must be ZERO
- The sum of all power supplied must be absorbed by the other element

Example: Power Absorbed



(a) (b) (c)

How much power is absorbed by the three elements above?

$P_a = +6$ W, $P_b = +6$ W, $P_c = -20$ W.

(Note: (c) is actually supplying power)

Circuit Variable - Energy (*W*)

Power is rate of work or energy $p = \frac{dw}{dt}$

Energy is integral of power

$$w(t) = \int_{t_0}^{t} p \; dt = \int_{t_0}^{t} vi \; dt$$

Energy determines total electricity need or how long your battery will last

Energy Example: Battery

Energy in units of joules (J) or watt-hours (Wh)

$$1 \text{ Wh} = 3600 \text{ J}$$

Battery capacity often given in amp-hours (Ah)

$$W = (\text{battery voltage}) \times (\text{capacity in Ah})$$

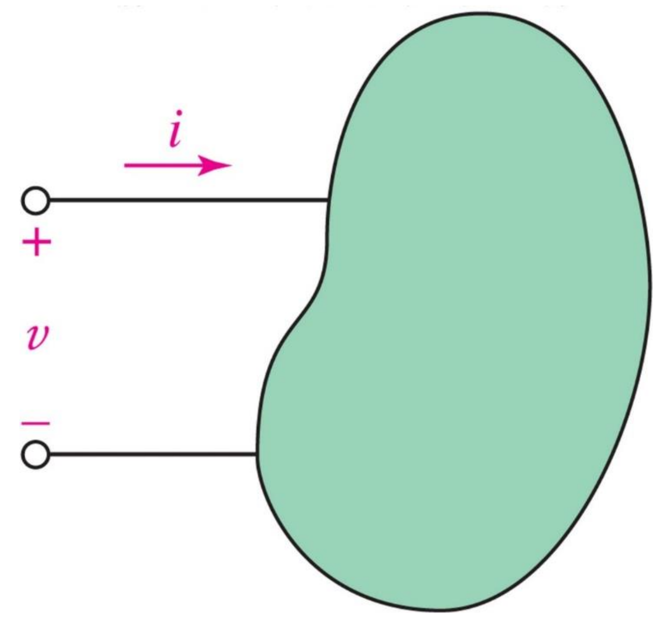
A 1.5 V battery with capacity of 2 Ah:

- Has total energy of 3 Wh = 10.8 kJ
- Can supply a circuit drawing 200 mA for 10 h

Circuit Components or Elements

A circuit element usually has two terminals (sometimes three or more).

The relationship between the voltage *v* across the terminals and the current *i* through the device defines the circuit element model.

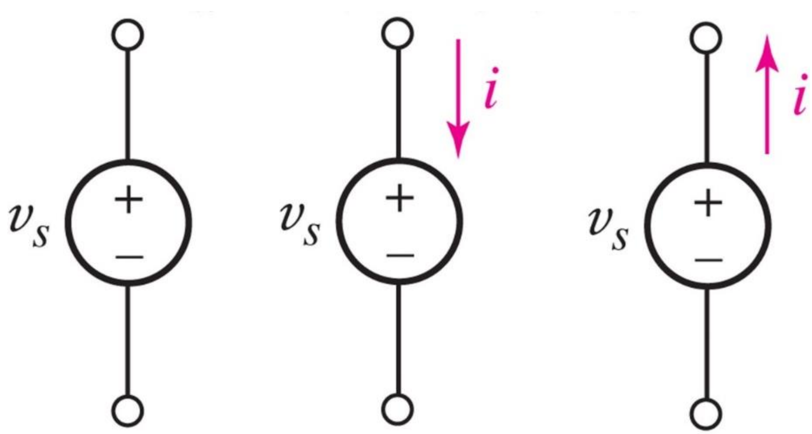


Circuit Element - Voltage Sources

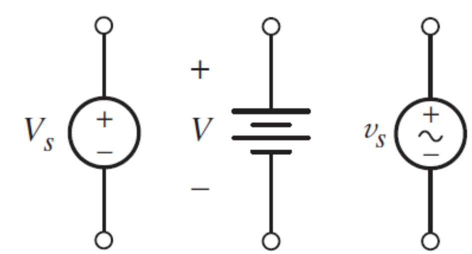
Independent Voltage Source:

An ideal voltage source is a circuit element that will maintain the specified voltage v_s across its terminals.

The current will be determined by other circuit elements.



(a) (b) (c)



(a) (b) (c)

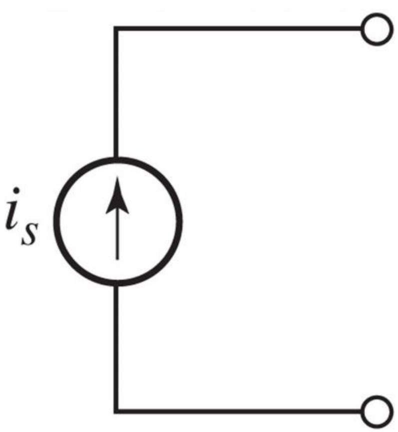
FIGURE 2.16 (*a*) DC voltage source symbol; (*b*) battery symbol; (*c*) ac voltage source symbol.

Circuit Element - Current Sources

Independent Current Source

An ideal current source is a circuit element that maintains the specified current flow i_s through its terminals.

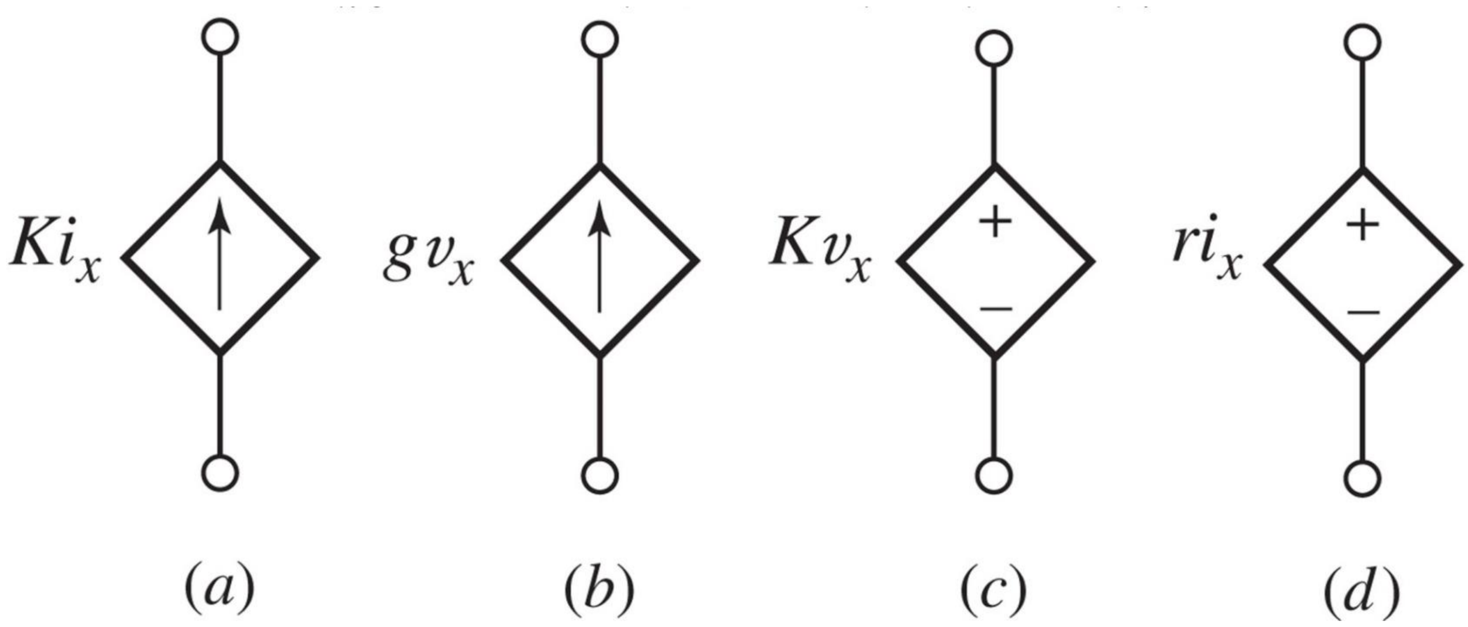
The voltage is determined by other circuit elements.



Dependent Sources

Dependent current sources (a) and (b) maintain a *current* specified by another circuit variable.

Dependent voltage sources (c) and (d) maintain a *voltage* specified by another circuit variable.



Example - Power

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2.9 Find the power *absorbed* by each element in the circuit in Fig. 2.20.

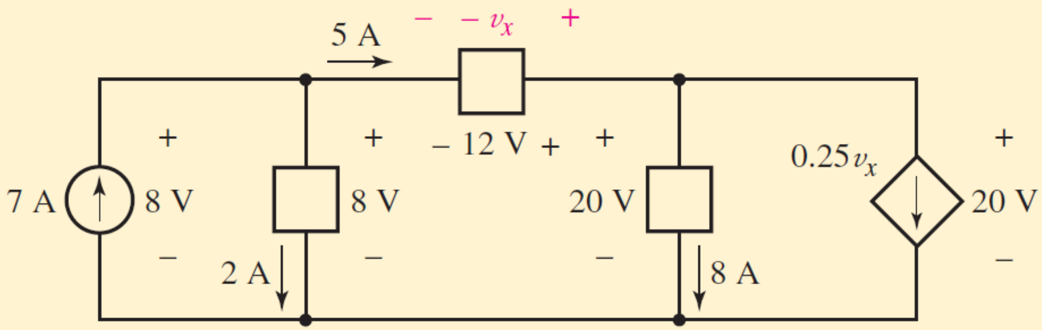


FIGURE 2.20

Resistance

Resistance (R) – is a property of a material to resist the flow of electric current

Resistance of an object is a function of its length, *l*, cross sectional area *A* and the material's resistivity

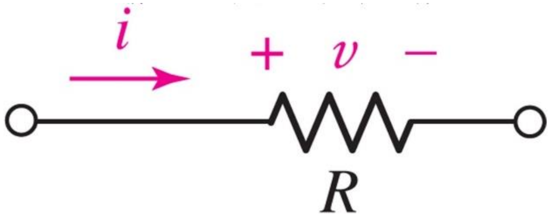
$$R = \rho \frac{l}{A}$$

The resistance is measured in Ohms (Ω)

Resistivity is in ohm-m

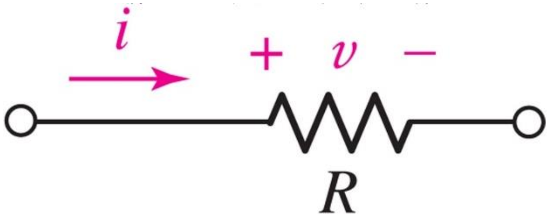
Good conductors, copper and aluminum, has low resistivities

Insulators, mica and paper, has high resistivities

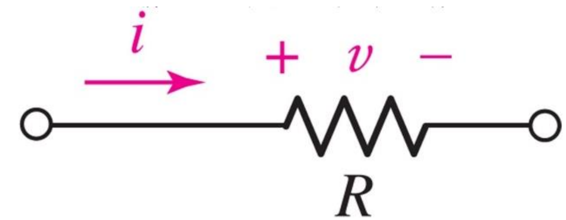


Circuit Element - Resistor

Circuit element used to model the current resisting behaviour of a material is a RESISTOR.



Ohm’s Law



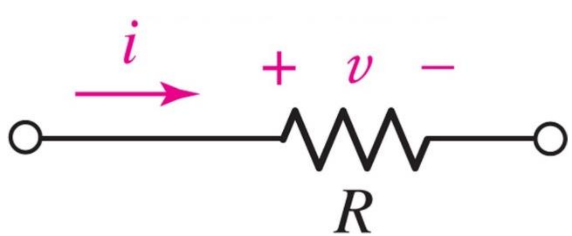
Power Absorption

Resistors absorb power: since $v = iR$

$$p = vi = v^2/R = i^2 R$$

Positive power means the device is absorbing energy.

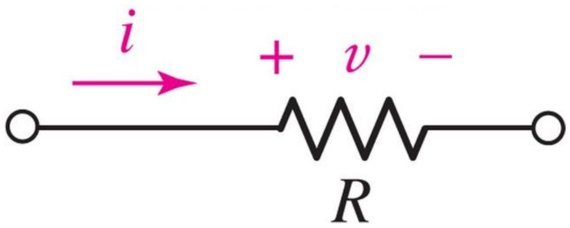
Power is always positive for a resistor!



Example: Resistor Power

A 560 Ω resistor is connected to a circuit which causes a current of 42.4 mA to flow through it.

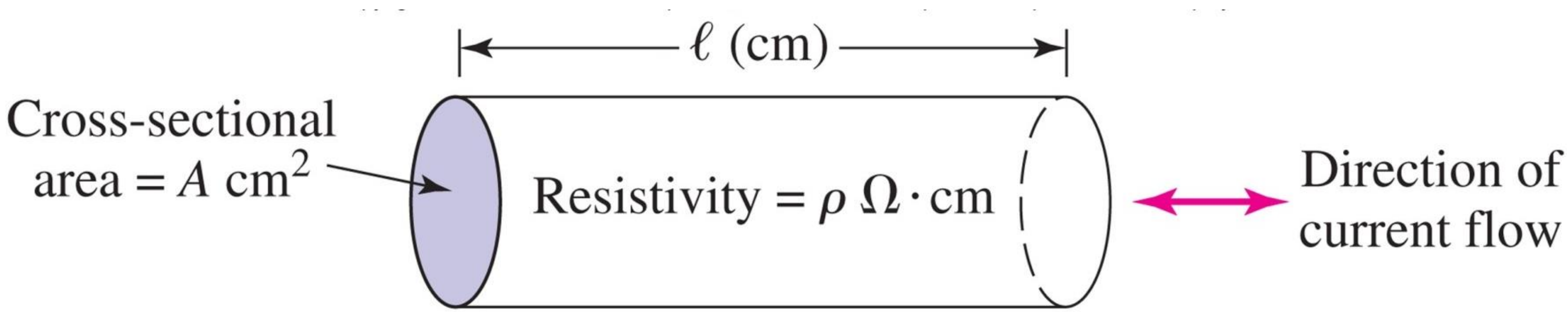
Calculate the voltage across the resistor and the power it is dissipating.



Wire Gauge and Resistivity

The resistance of a wire is determined by the resistivity of the conductor as well as the geometry:

$$R = \rho l / A$$



[In most cases, the resistance of wires can be assumed to be 0 ohms.]

Conductance

We sometimes prefer to work with *the reciprocal of resistance* (1/*R*), which is called conductance (symbol *G*, unit siemens (S)).

A resistor *R* has conductance $G = 1/R$.

Ohm's law (*i*-*v* equation) can be written as

$$i = Gv$$

Open and Short Circuits

An open circuit between A and B means $I = 0$.

Voltage across an open circuit: any value.

An open circuit is equivalent to $R = \infty\ \Omega$.

A short circuit between A and B means $v = 0$.

Current through a short circuit: any value.

A short circuit is equivalent to $R = 0\ \Omega$.