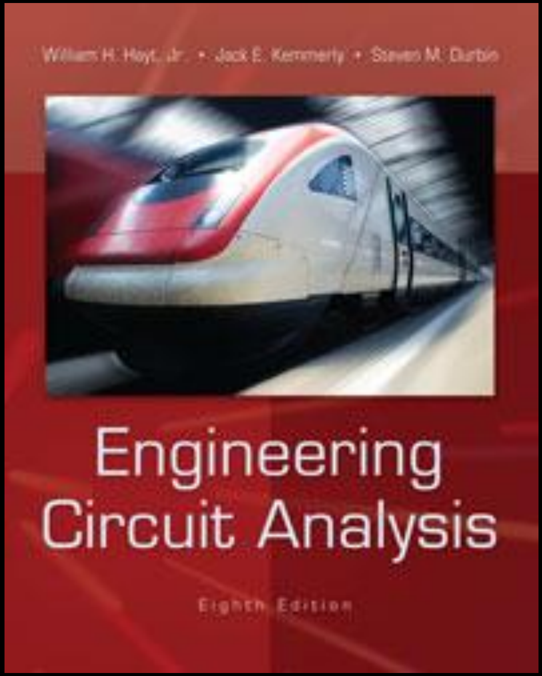
Chapter 2
Basic Components and Electric Circuits



The SI System

Base units:

- meter (m), kilogram (kg), second (s), ampere (A)
- also: kelvin, mole, and candela

Derived units:

- work or energy: joule (J)
- power (rate of doing work): watt (W)
- $1 \text{ W} = 1 \text{ J/s}$

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 mW = 0.0123 W =1.23×10^{-2} W

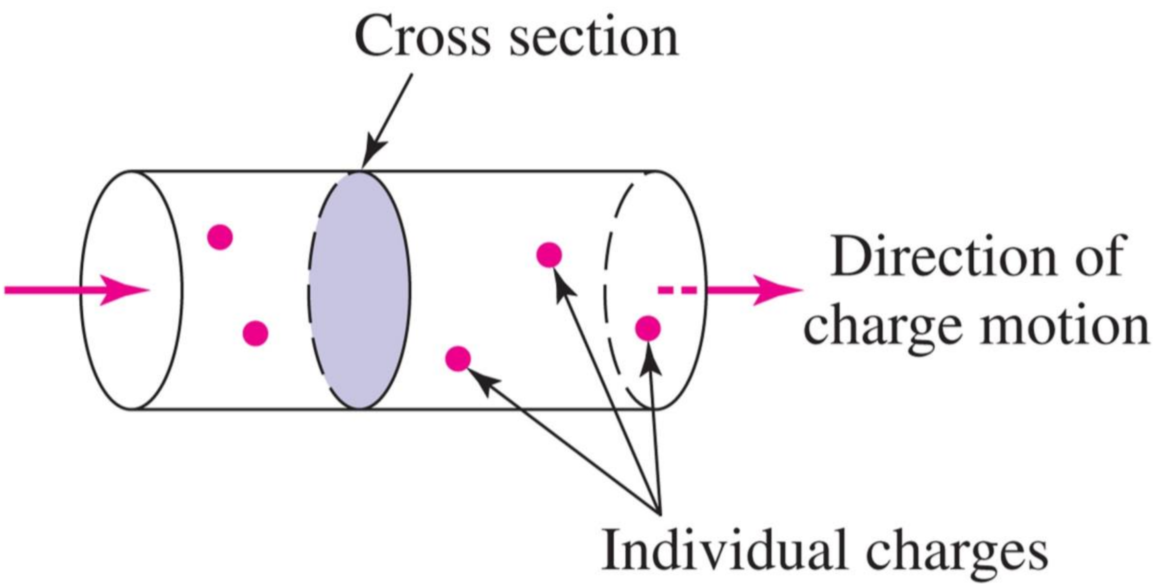
Charge

- charge is *conserved*: it is neither created nor destroyed
- symbol: Q or *q;* units are coulomb (C)
- the smallest charge, the *electronic charge*, is carried by an electron (-1.602×10^{-19} C) or a proton ($+1.602 \times 10^{-19}$ C)
- in most circuits, the charges in motion are electrons

Current and Charge

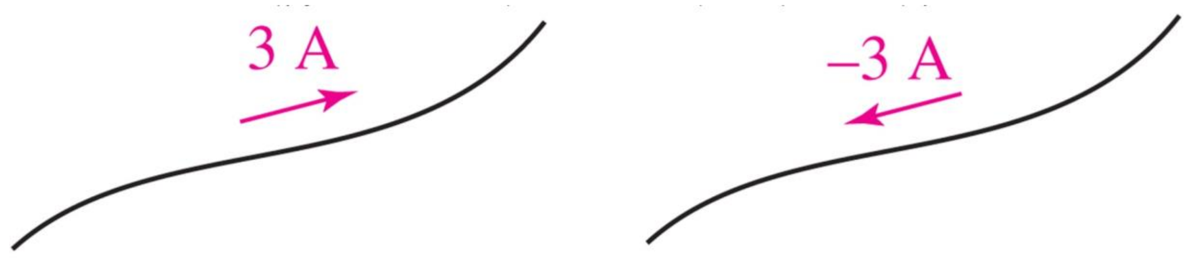
Current is the rate of charge flow:

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

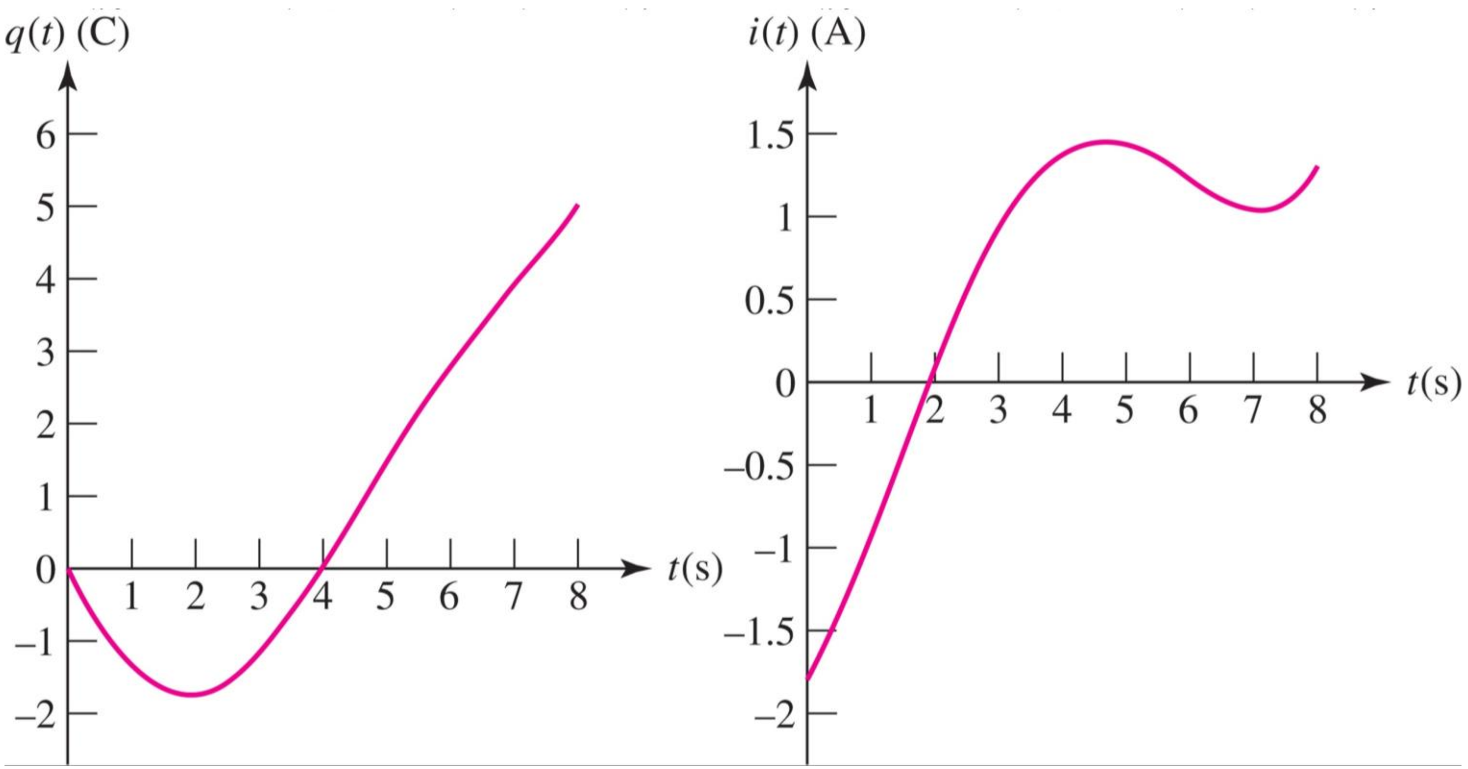


Current and Charge

- Current (designated by *I* or *i*) is the rate of flow of charge
- Current must be designated with both a direction and a magnitude
- These two currents are the same:



Current and Charge: i=dq/dt

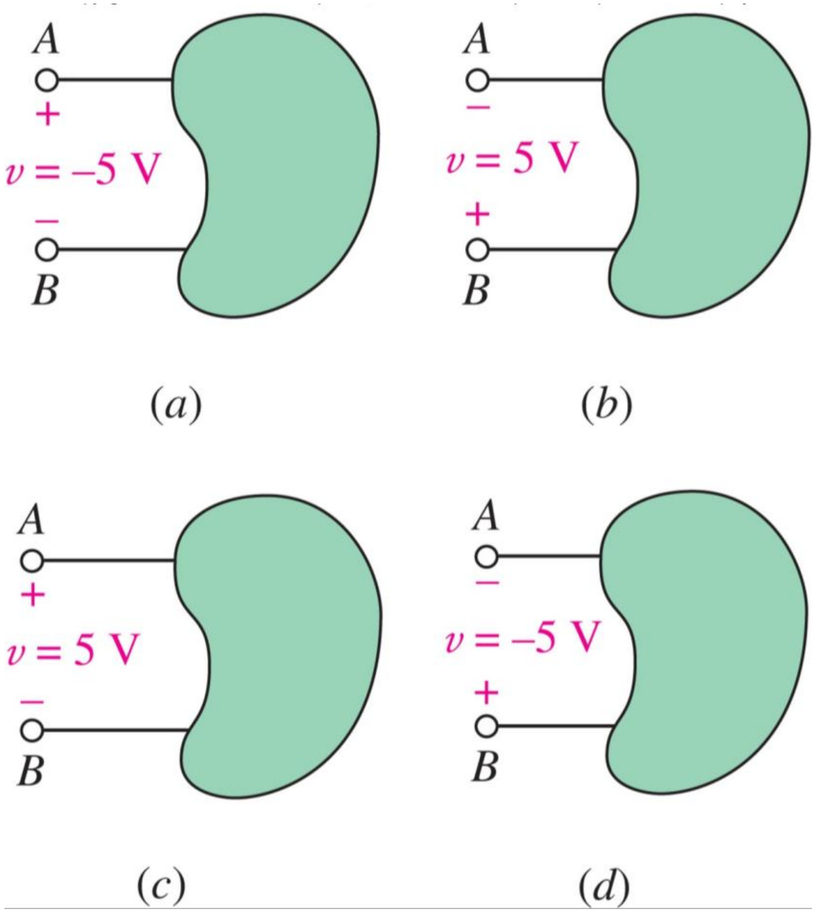


Voltage

- 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.

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

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

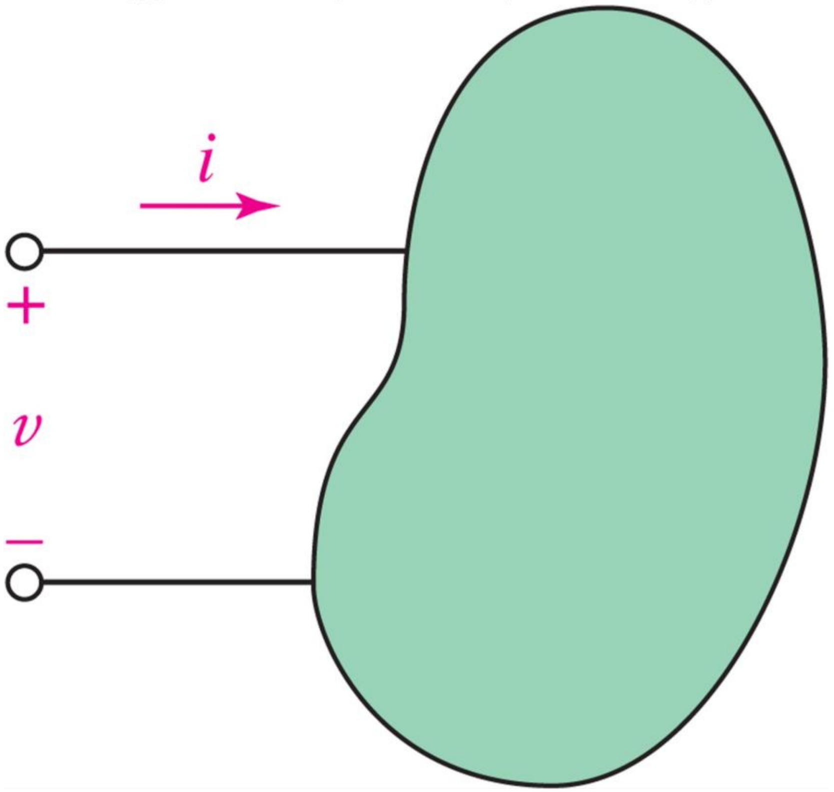


Power: $p = v\,i$

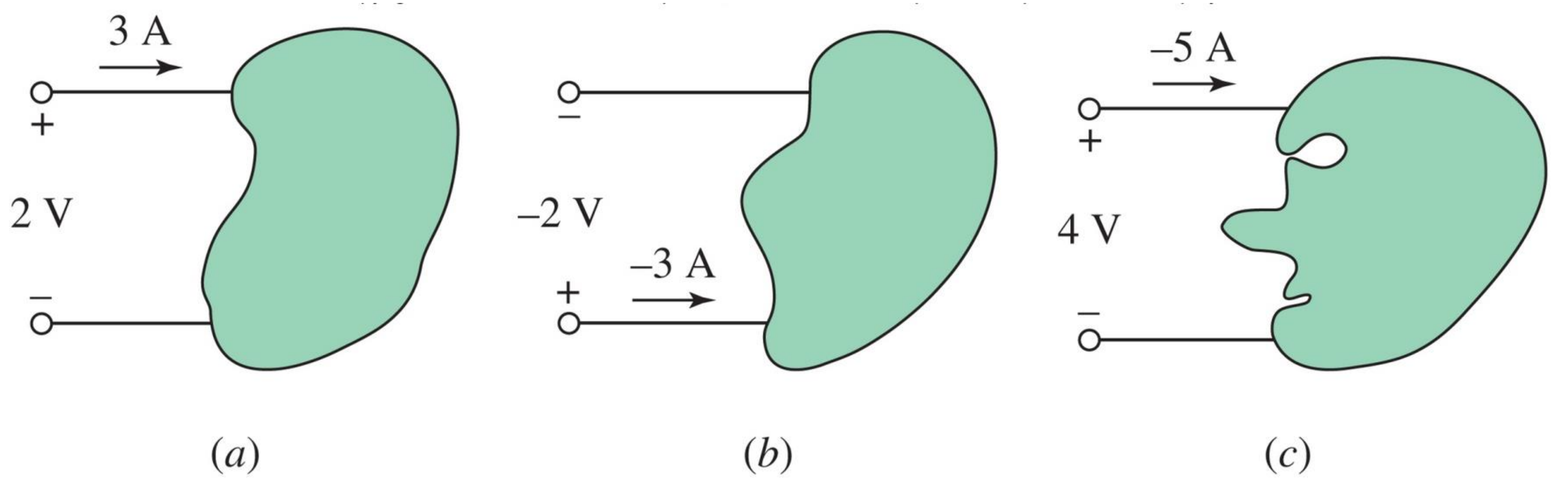
The power required to push a current i (C/s) into a voltage v (J/C) is $p = vi$ (J/s = W).

When power is positive, the element is *absorbing* energy.

When power is negative, the element is *supplying* energy.



Example: Power



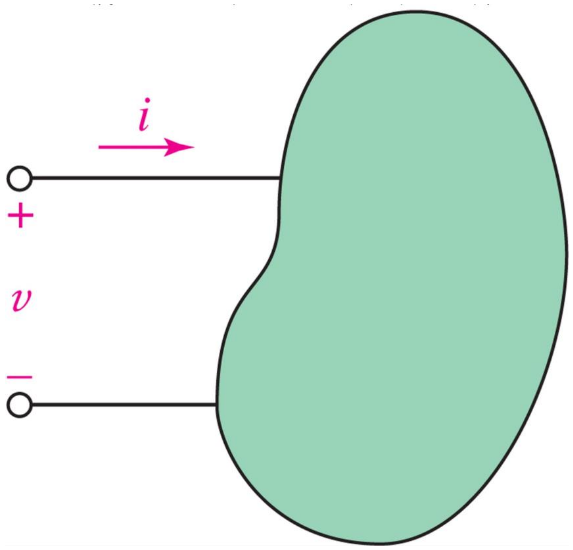
How much power is absorbed by the three elements above?

$P_a = +6$ W, $P_b = +6$ W, $P_c = -20$ W.
(Note: (c) is actually supplying power)

Circuit Elements

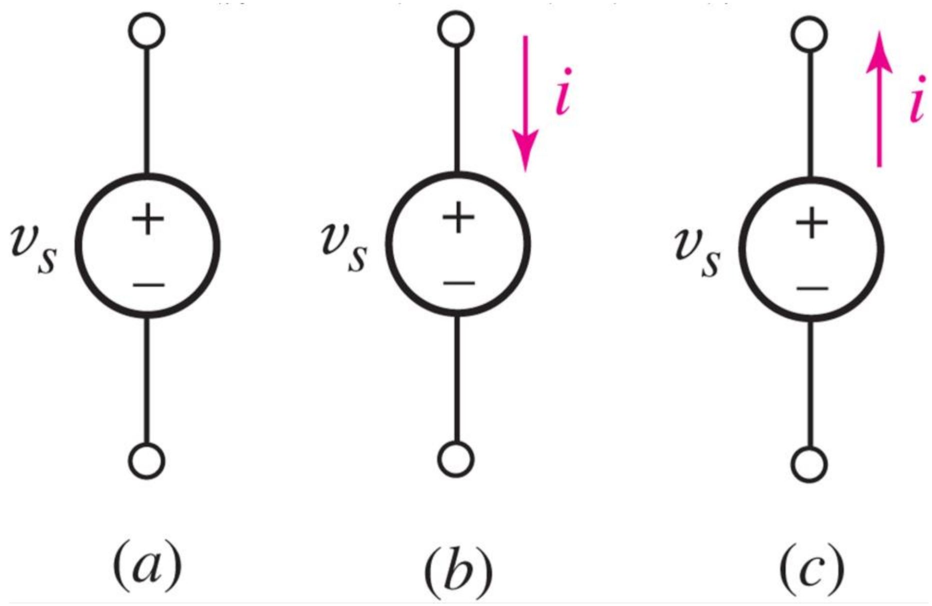
- A circuit element usually has two terminals (sometimes three or more).

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



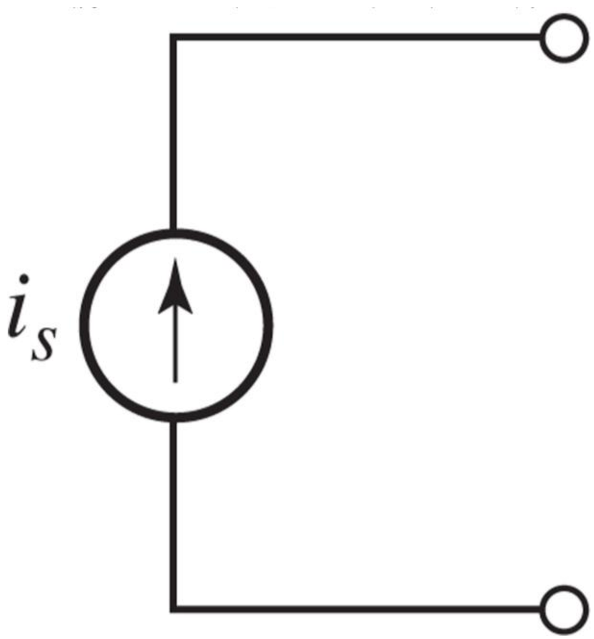
Voltage Sources

- 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.



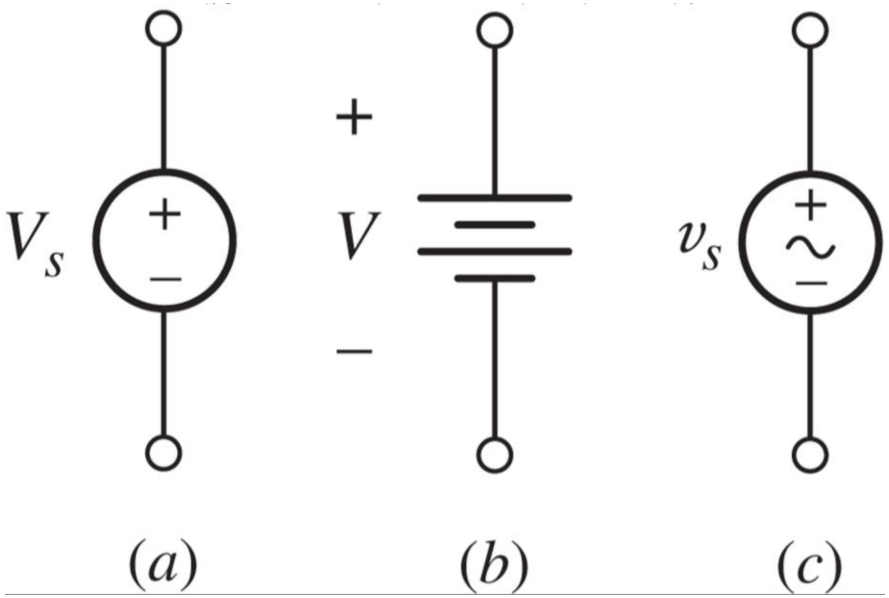
Current Sources

- 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.



Battery as Voltage Source

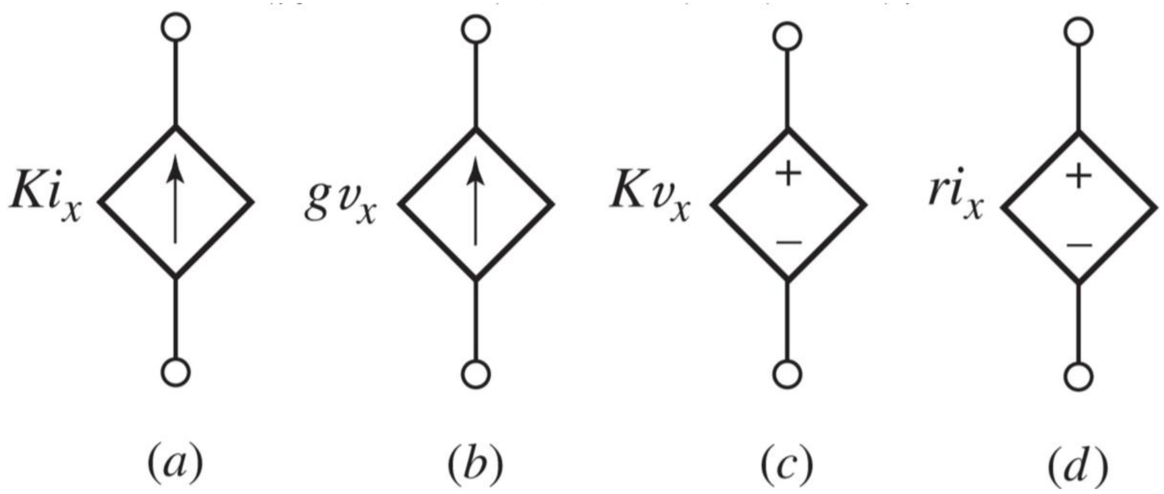
• A voltage source is an idealization (no limit on current) and generalization (voltage can be time-varying) of a battery.
• A battery supplies a constant “dc” voltage V but in practice a battery has a maximum power.



Dependent Sources

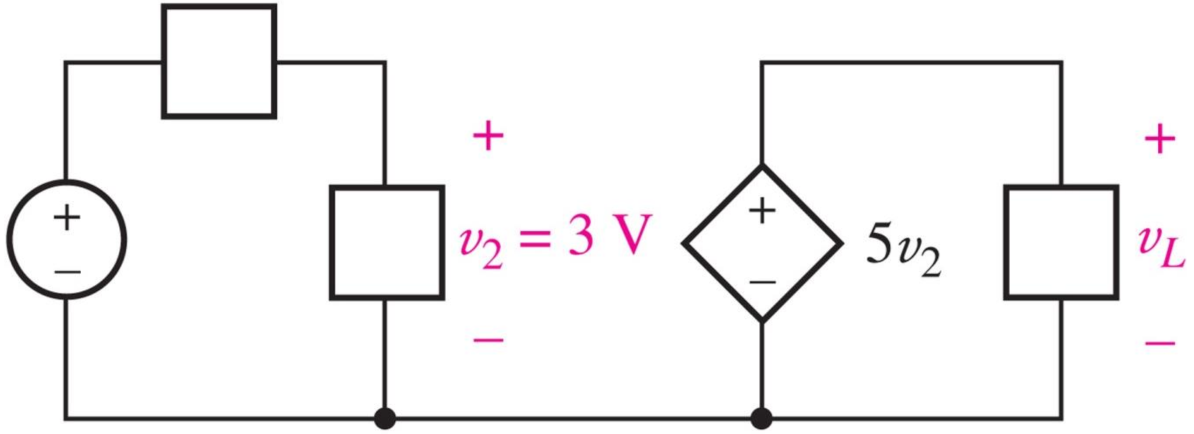
Dependent current sources (a) and (b) maintain a *current* specified by another circuit variable.

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



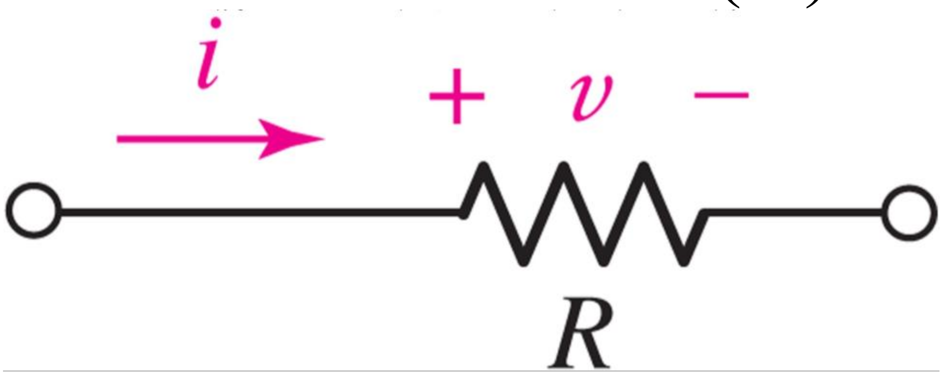
Example: Dependent Sources

Find the voltage v_L in the circuit below.



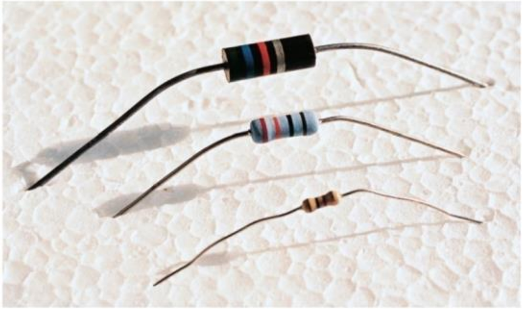
Ohm's Law: Resistance

- A (linear) resistor is an element for which
  - $v = iR$
- where the constant R is a resistance.
- The equation is known as "Ohm's Law."
- The unit of resistance is ohm (Ω).



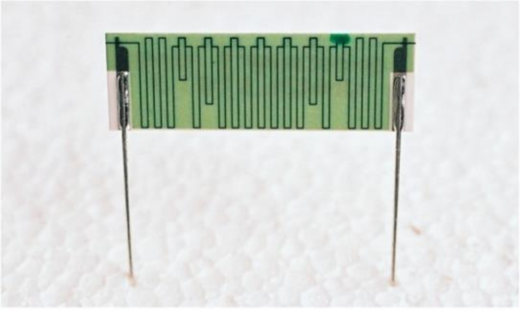
Resistors

(a) typical resistors (b) power resistor
(c) a 10 TΩ resistor (d) circuit symbol

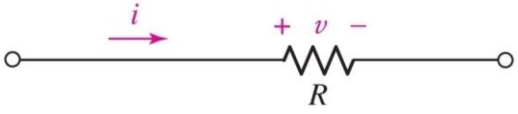


(a)

(b)



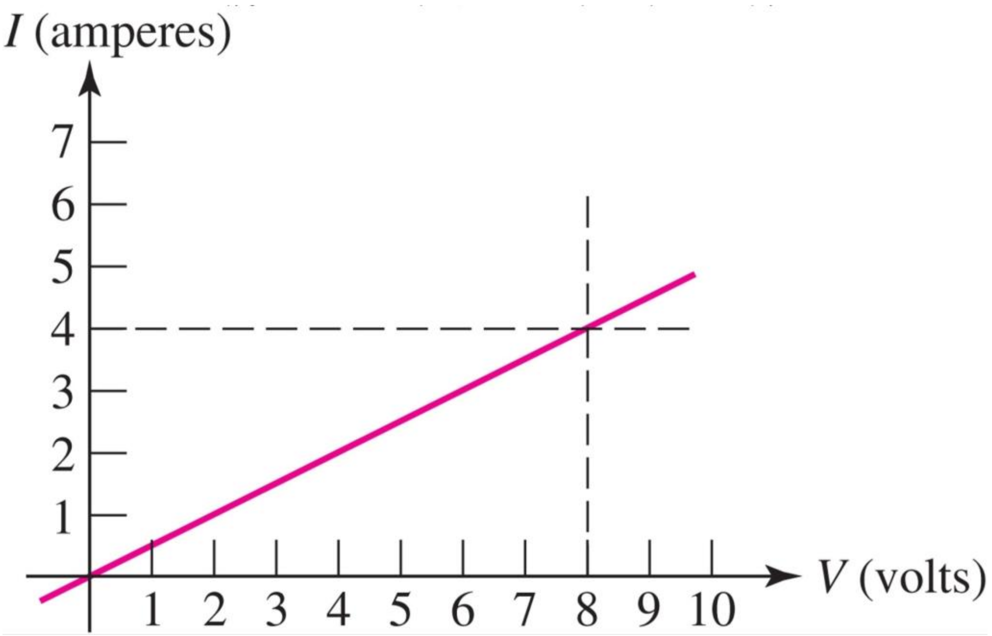
(c)



(d)

The i-v Graph for a Resistor

For a resistor, the plot of current versus voltage is a straight line:



In this example, the slope is 4 A / 8 V or 0.5 Ω^{-1}.

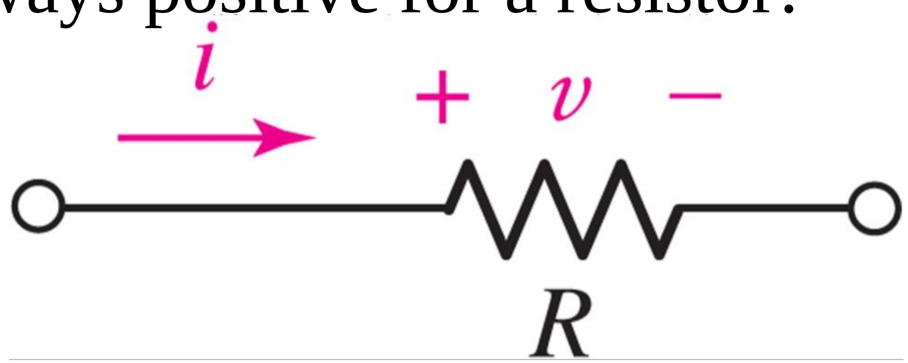
This is the graph for a 2 ohm resistor.

Power Absorption

Resistors absorb power: since $v=iR$

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

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.

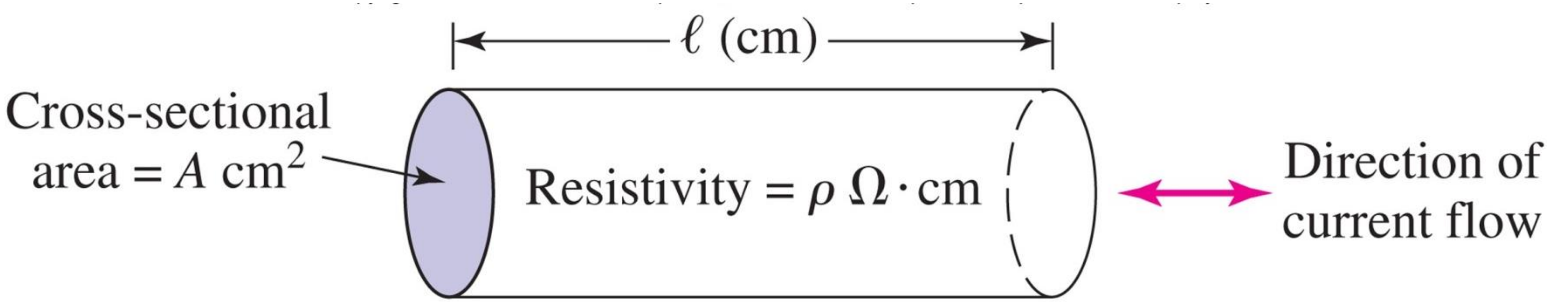
$$v = iR = (0.0424)(560) = 23.7\text{ V}$$

$$p = i^2 R = (0.0424)^2(560) = 1.007\text{ W}$$

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.

- The *i-v* equation (i.e. Ohm's law) 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 $R = 0\ \Omega$.