دانشگاه صنعتی امیرکبیر
(پلی تکنیک تهران)

Electrical and Electronic Circuits

Chapter 1
Introduction and Basic Components and Electric Circuits

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عظیم فرقدان

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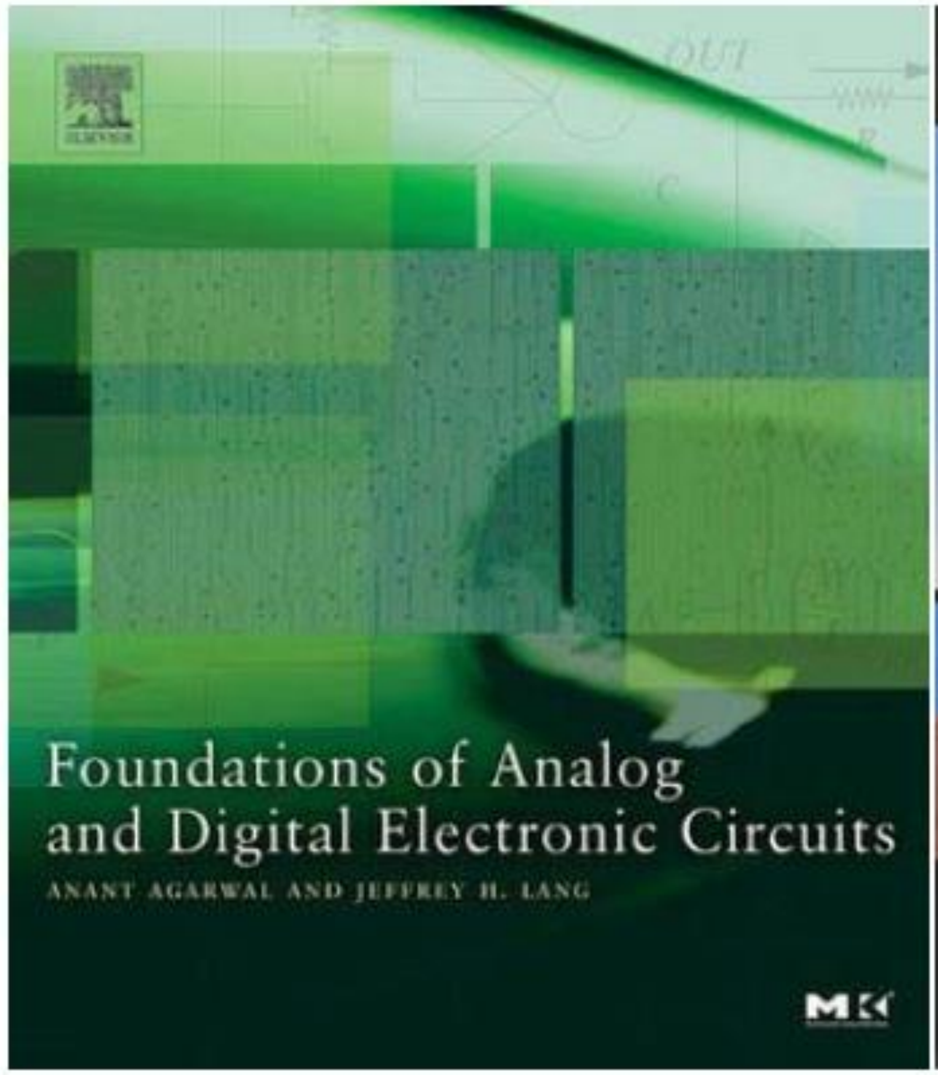
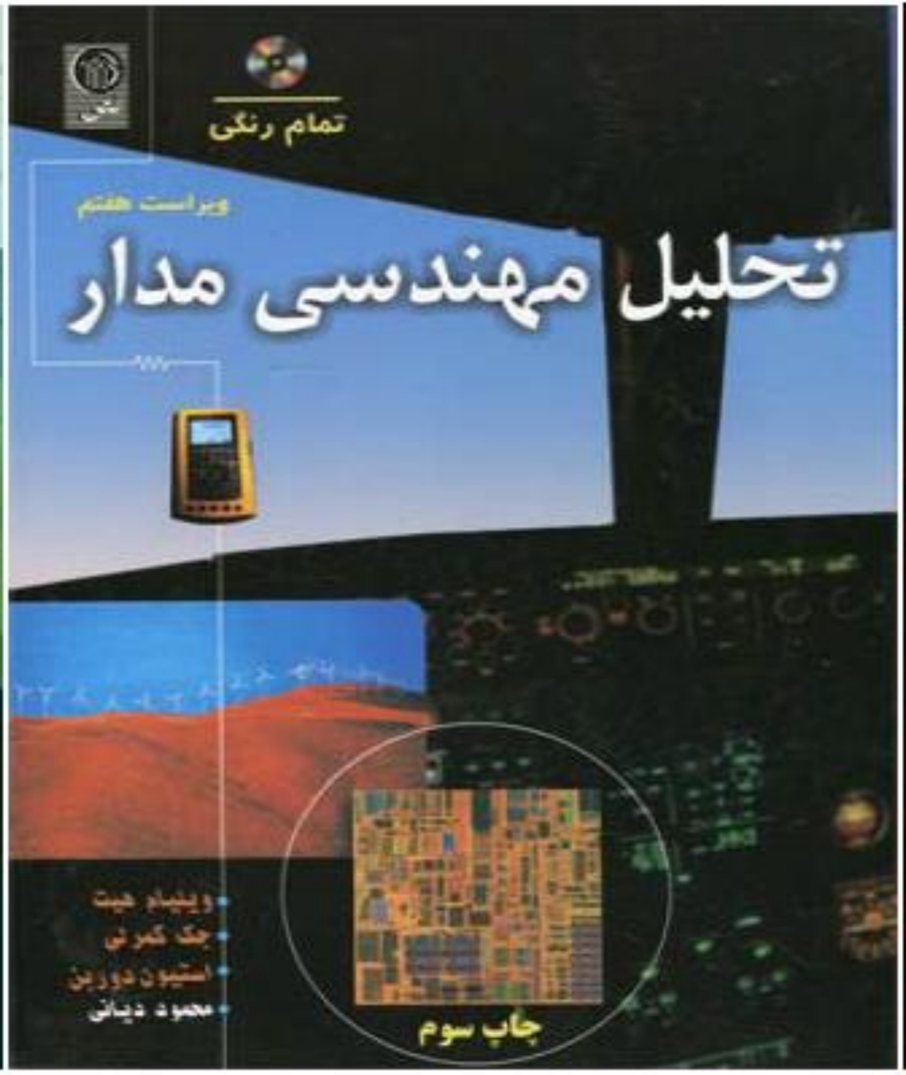
Assessment

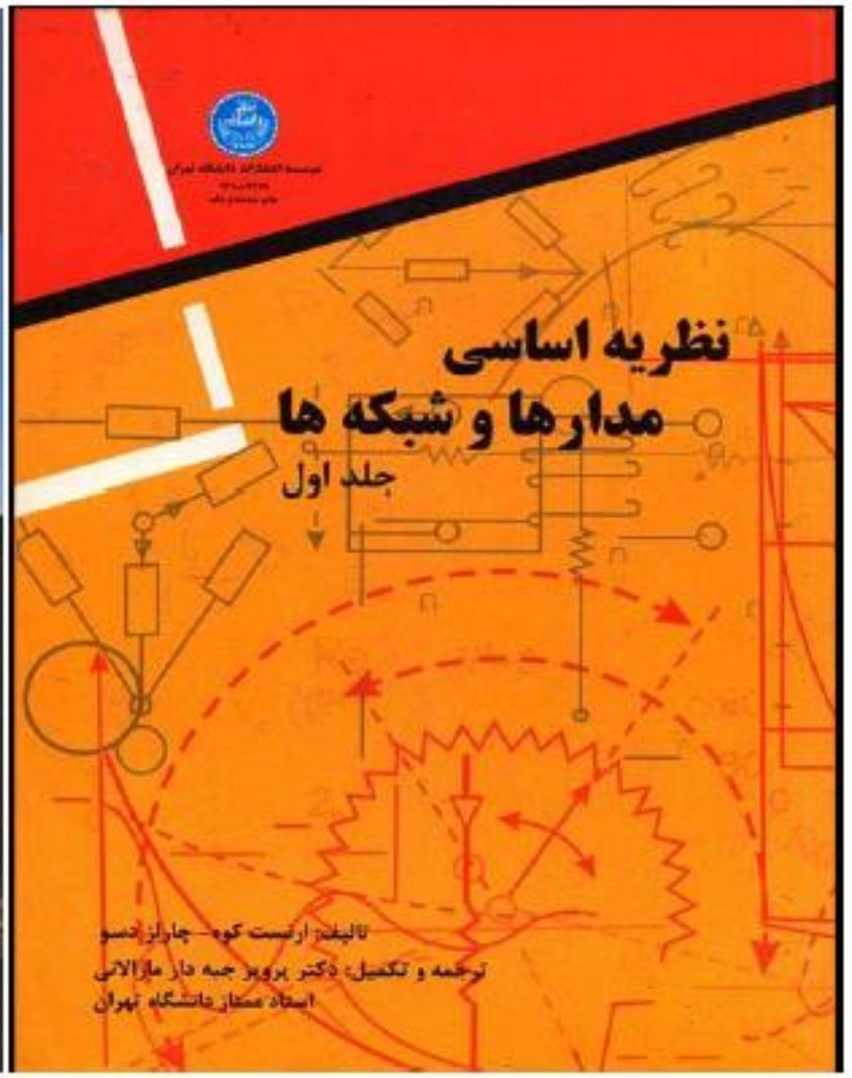
Method	Quantity	(%)	(%)
Quiz	-	5	-
Homework/Problem Solving	7	15	-
Laboratory	-	-	100
Midterm Exam	1	35	-
Final Exam	1	45	-
Attendance & participation	-	extra	-
Final Grade		75	25

Reference Books

1. C. Desoer, Basic Circuit Theory, 2nd Edition
2. W. Hayt, Engineering Circuit Analysis, 8th Edition
3. A. Agarwal, Foundations of Analog and Digital Electronic Circuits







The SI System

- Base units:
  - meter (m), kilogram (kg), second (s), ampere (A)
- Derived units:
  - work or energy: joule (J)
  - power (rate of doing work): watt (W)
  - 1 W = 1 J/s

❑ 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 x 10^{-2} W

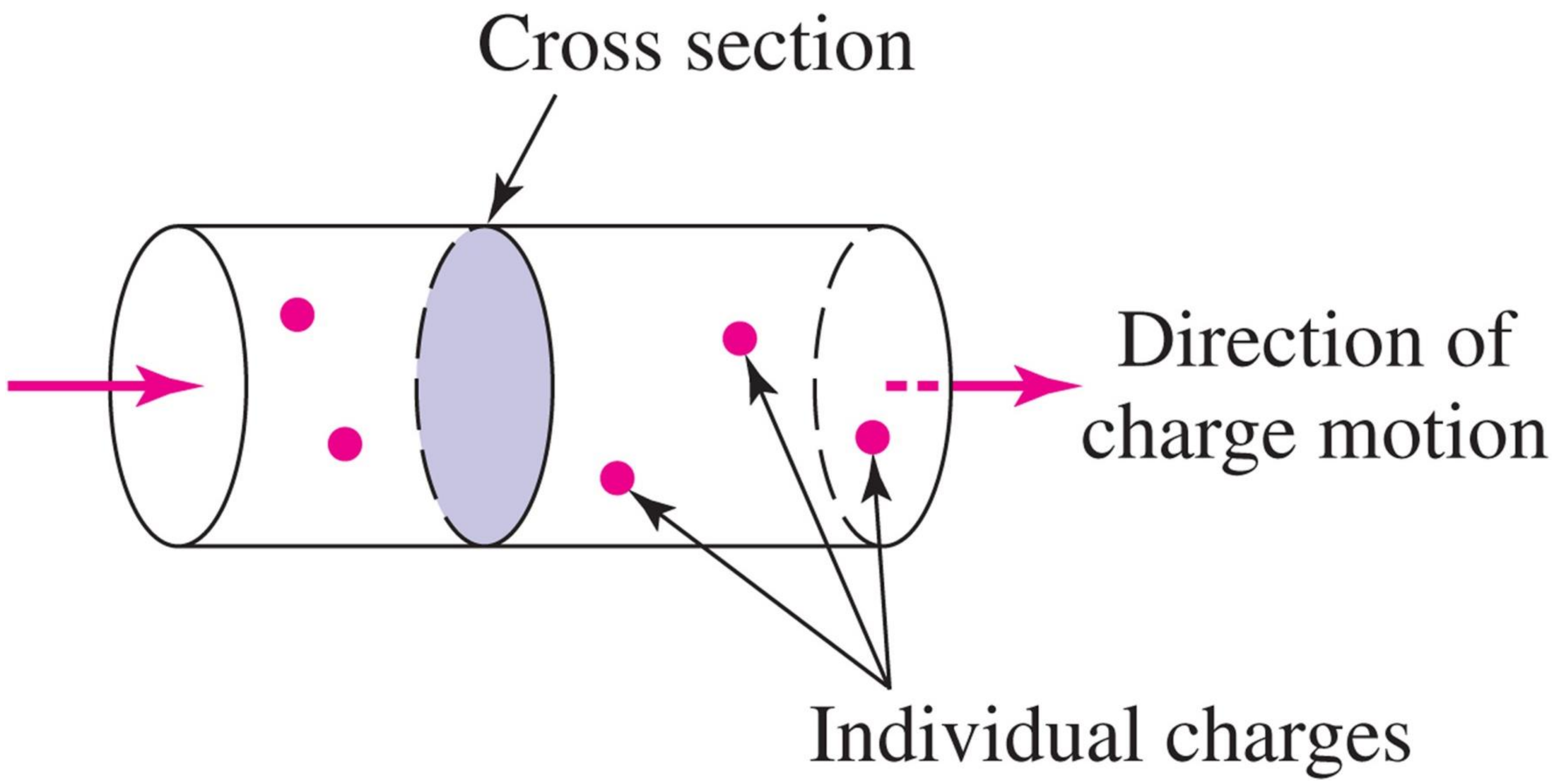
Charge

- 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

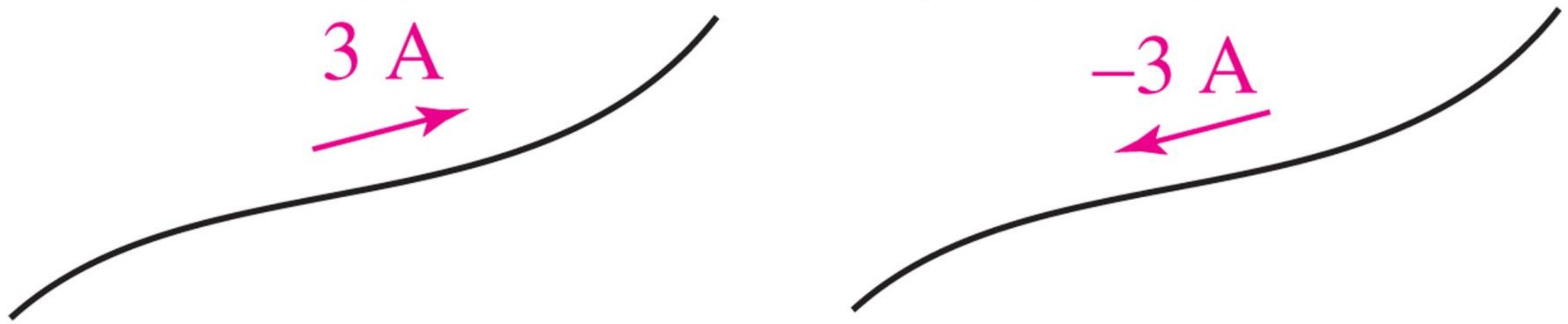
- Current is the rate of charge flow:

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

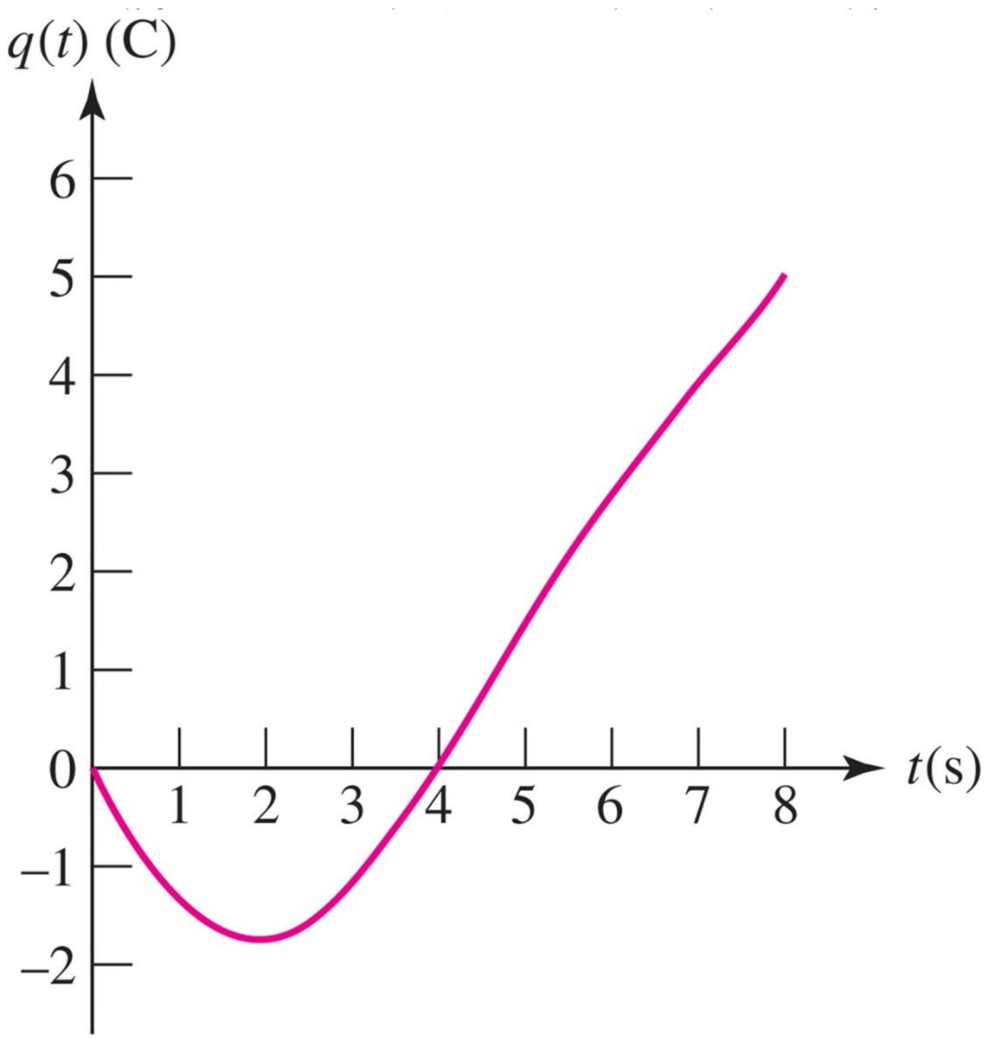


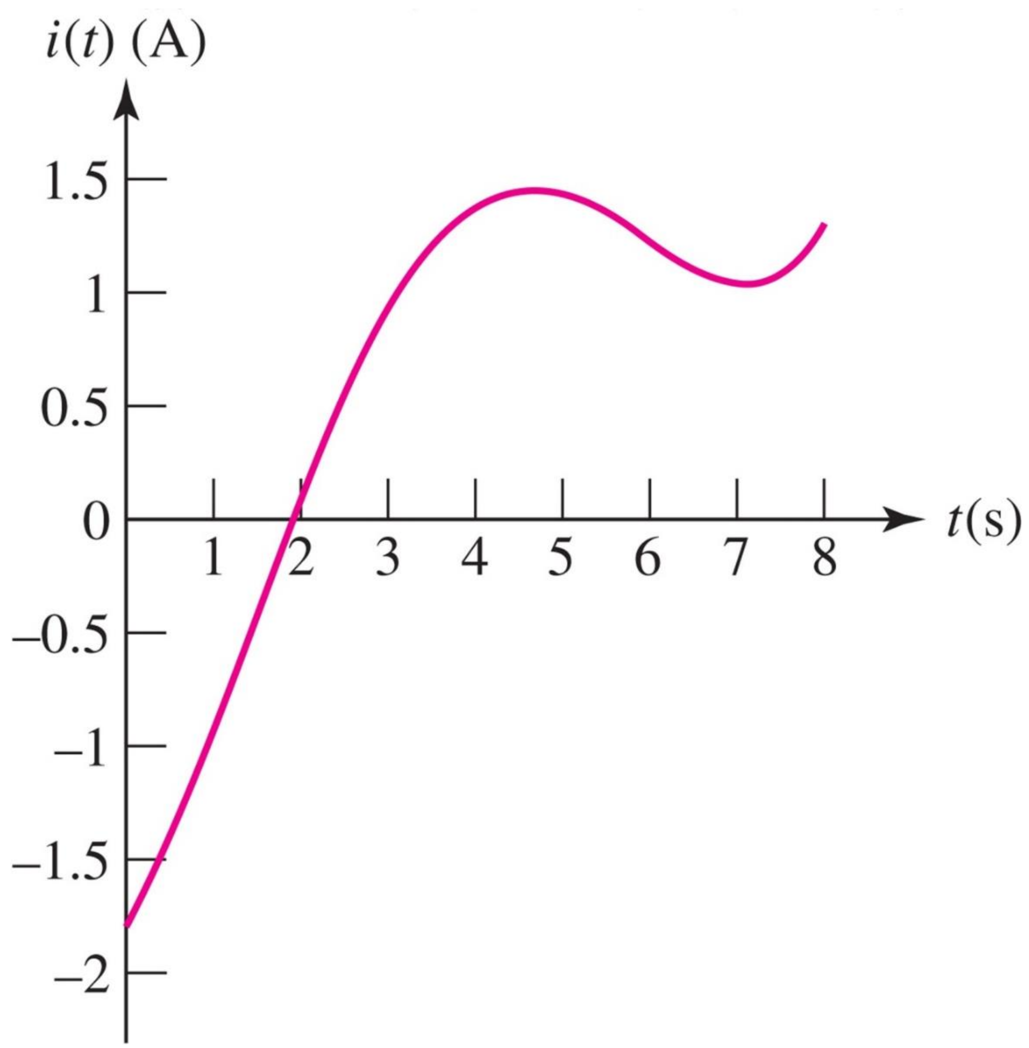
Current and Charge

- 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**:



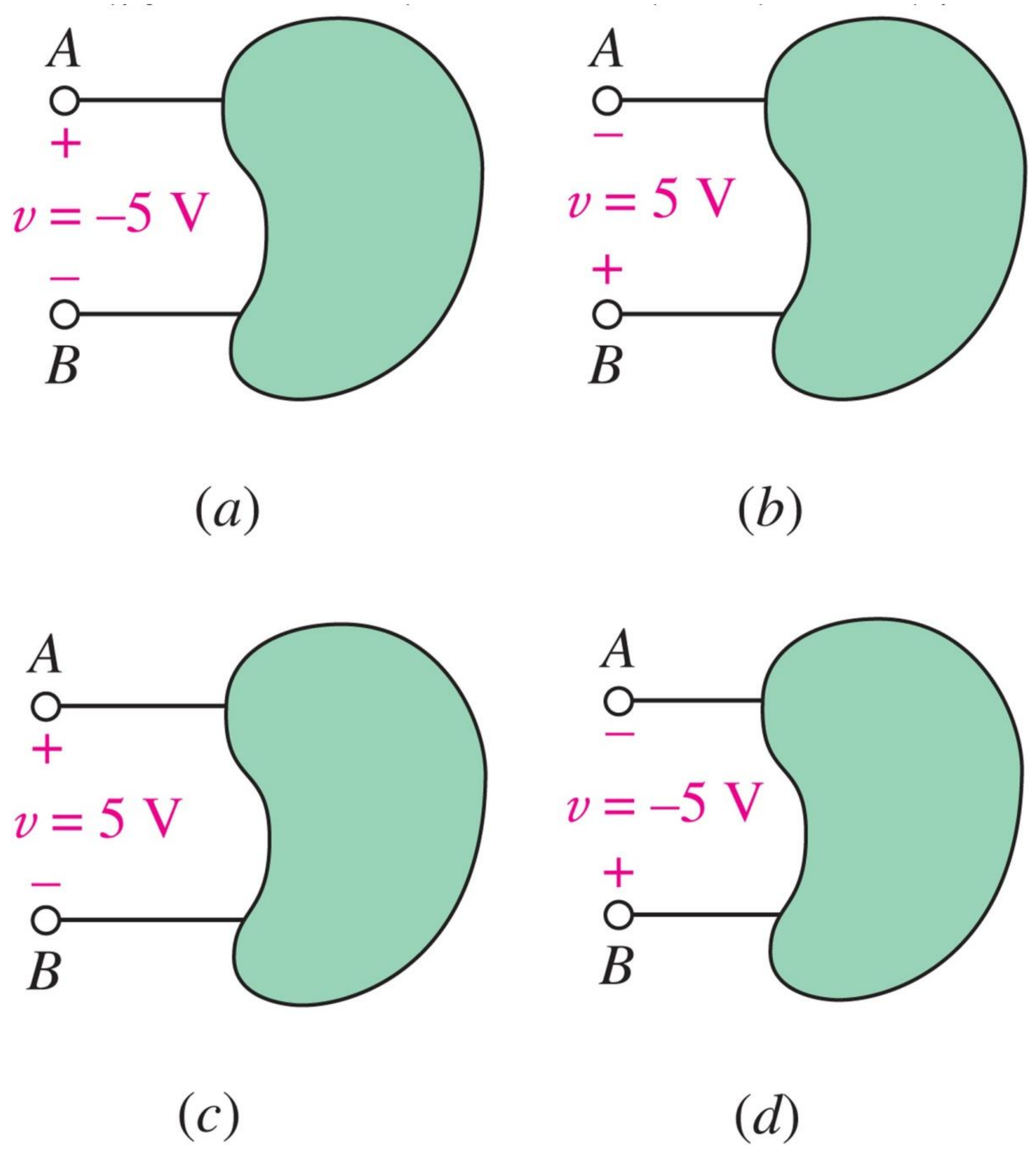
- Current is **the rate of flow of charge:** $\boldsymbol{i = dq/dt}$





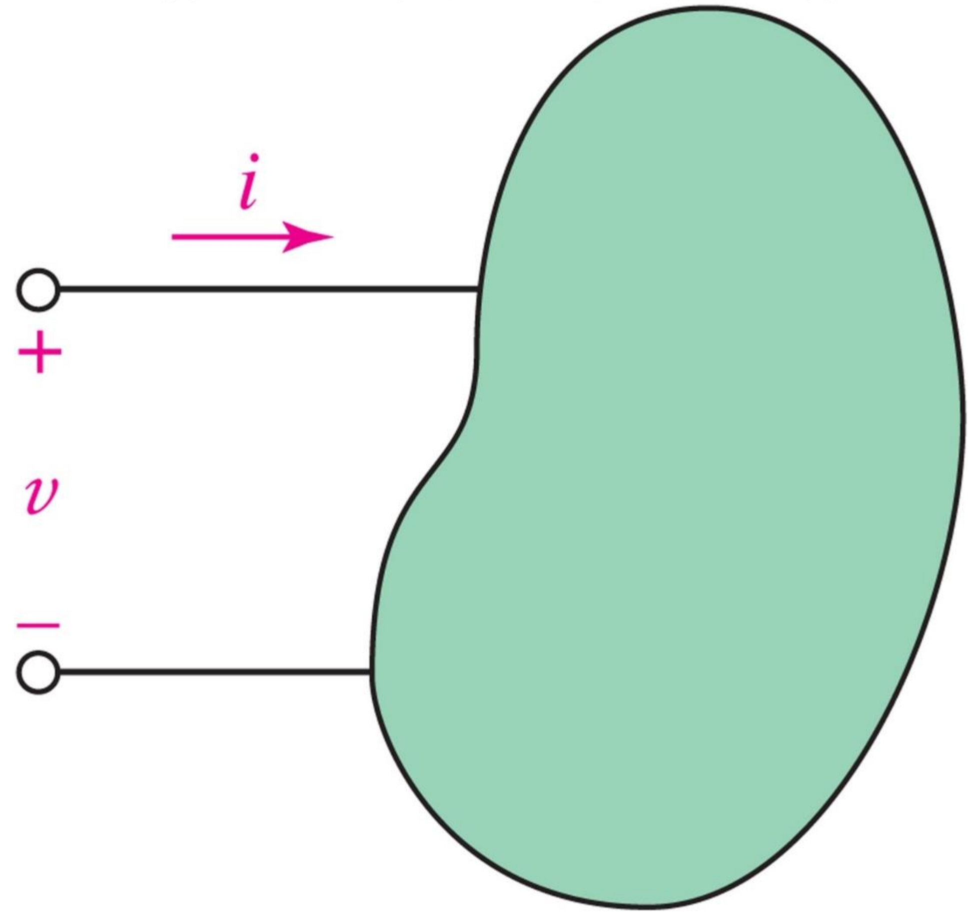
Voltage

- 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.
- $V = dW/dq$
- Example: (a)=(b), (c)=(d)



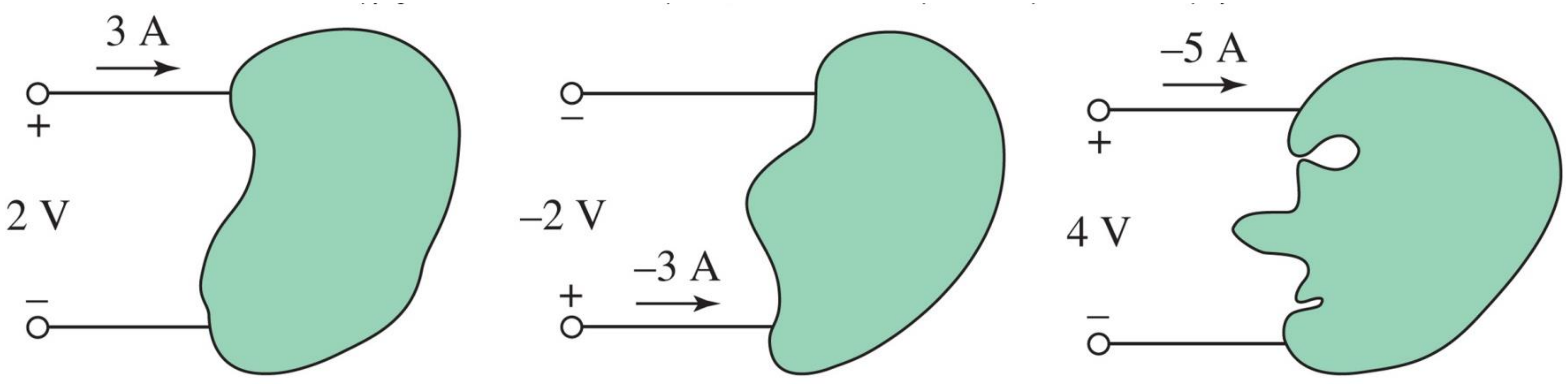
Power: $p = v\,i$

- The power required to push a current i (C/s) into a voltage v (J/C) is $p = vi$ (J/s = W).
    - ➢ ***$P = dE/dt$***
- When power is positive, the element is ***absorbing*** energy.
- When power is negative, the element is ***supplying*** energy.



- The direction of current and voltage shown in this figure is referred to as **the conventional direction**.
    - ➢ The current enters the element from the positive terminal of the voltage.

Example: Power



(a) (b) (c)

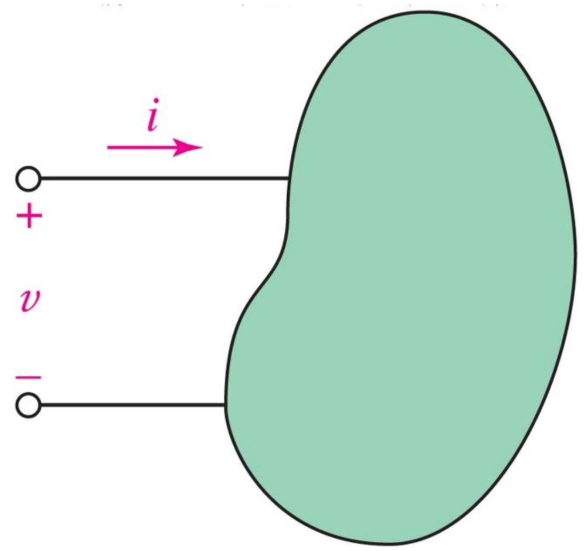
- How much power is absorbed by the three elements above?

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

Circuit Elements

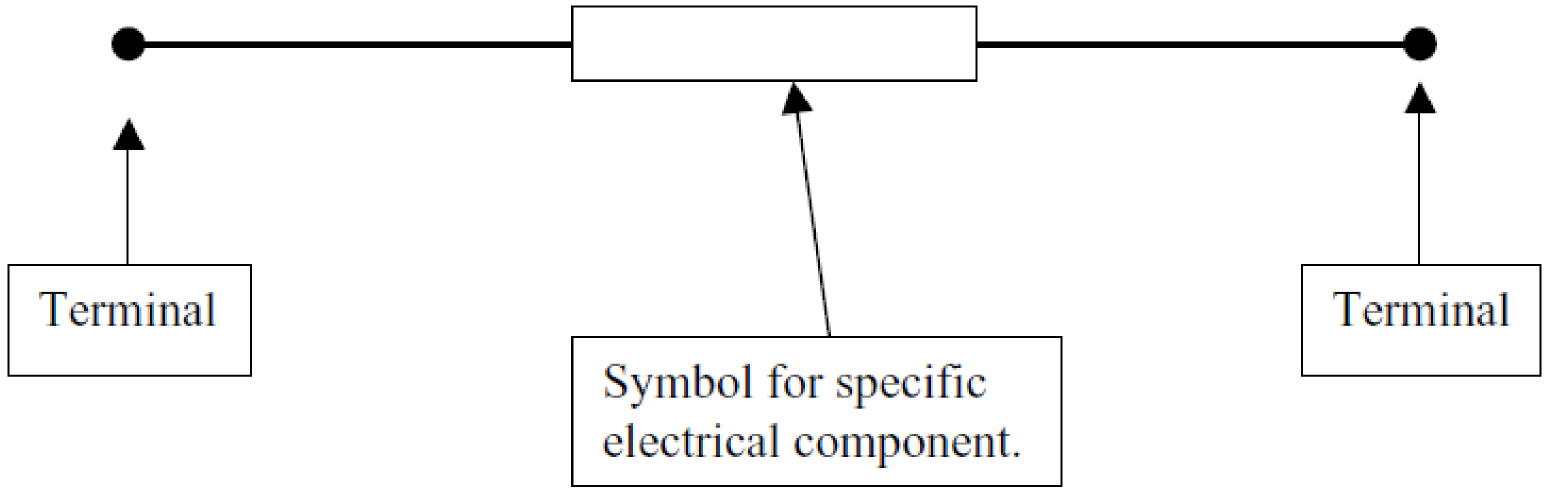
- A circuit element usually has two terminals (sometimes three or more).

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



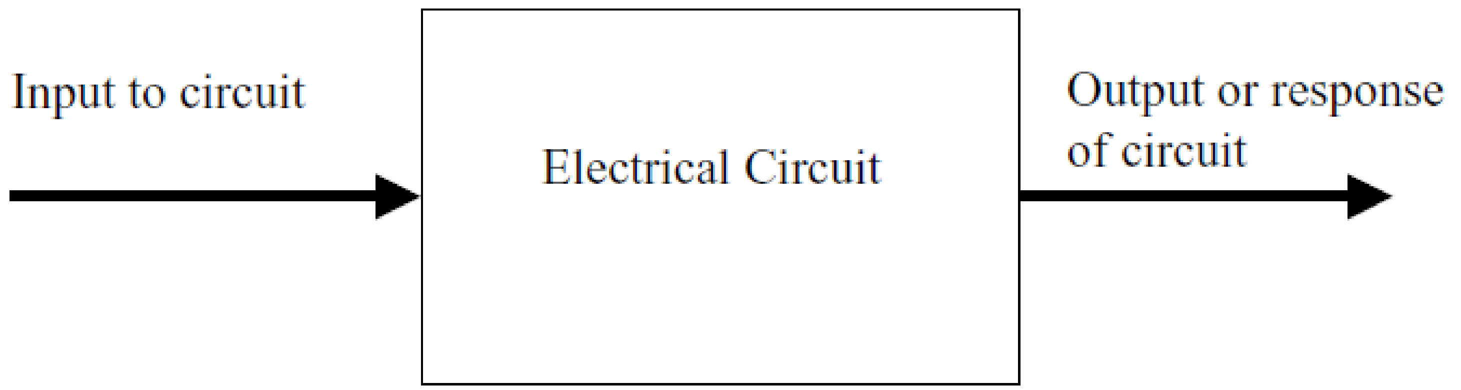
Electric Circuit

- An arrangement into a network of several connected two-terminal electrical components.
  - –Each type of component will have its own symbol.



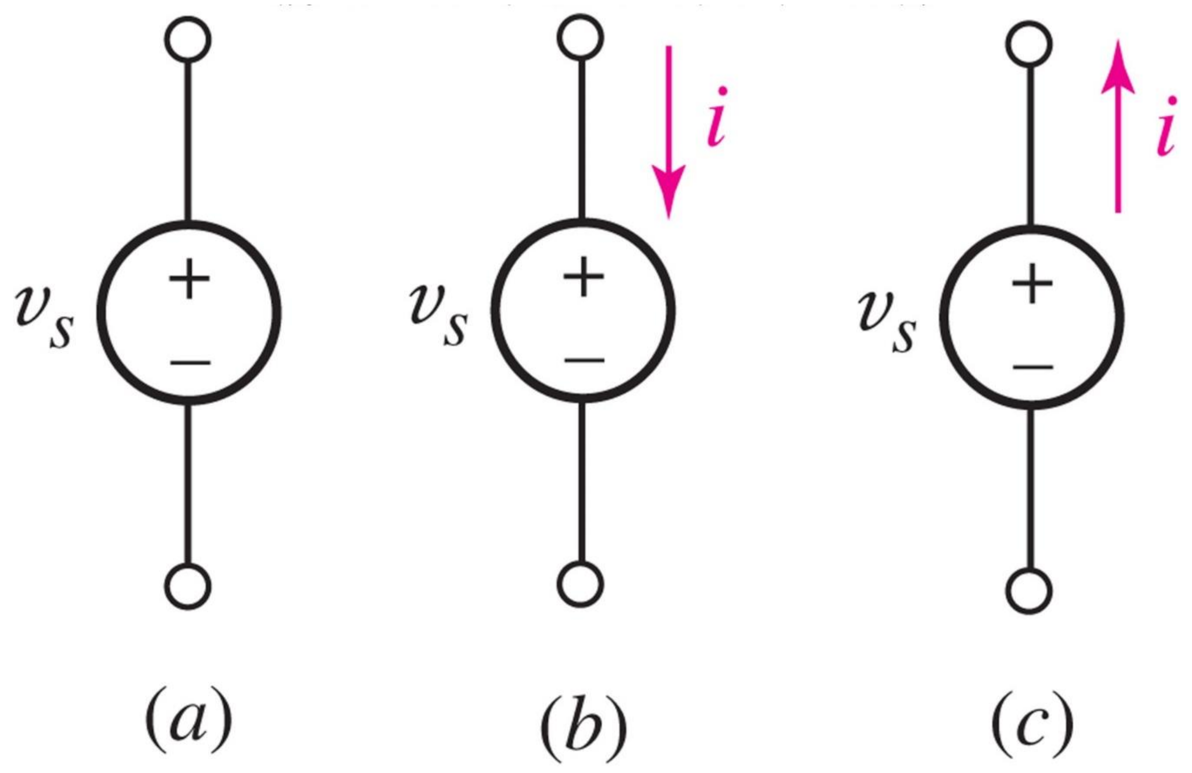
What Is Circuit Analysis?

- Art of finding out how the unique circuit we are given responds to a particular input.
  - The input could be a voltage or a current, or maybe some combination of voltages and currents.
- The response of the circuit is the output.



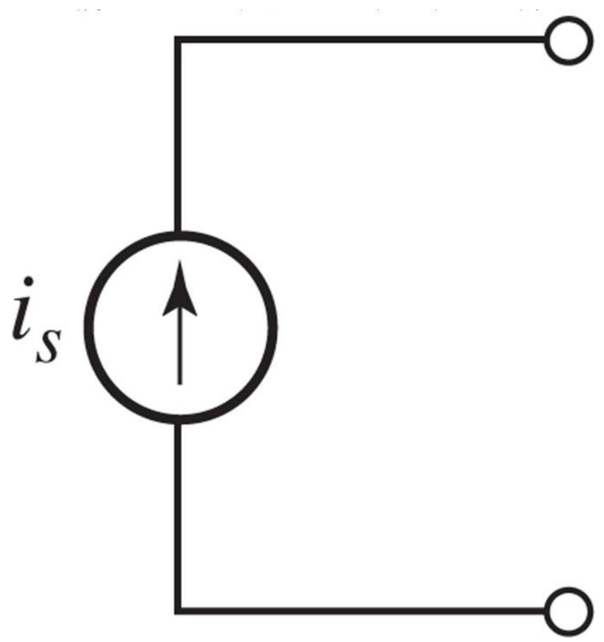
Voltage Sources

- 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.



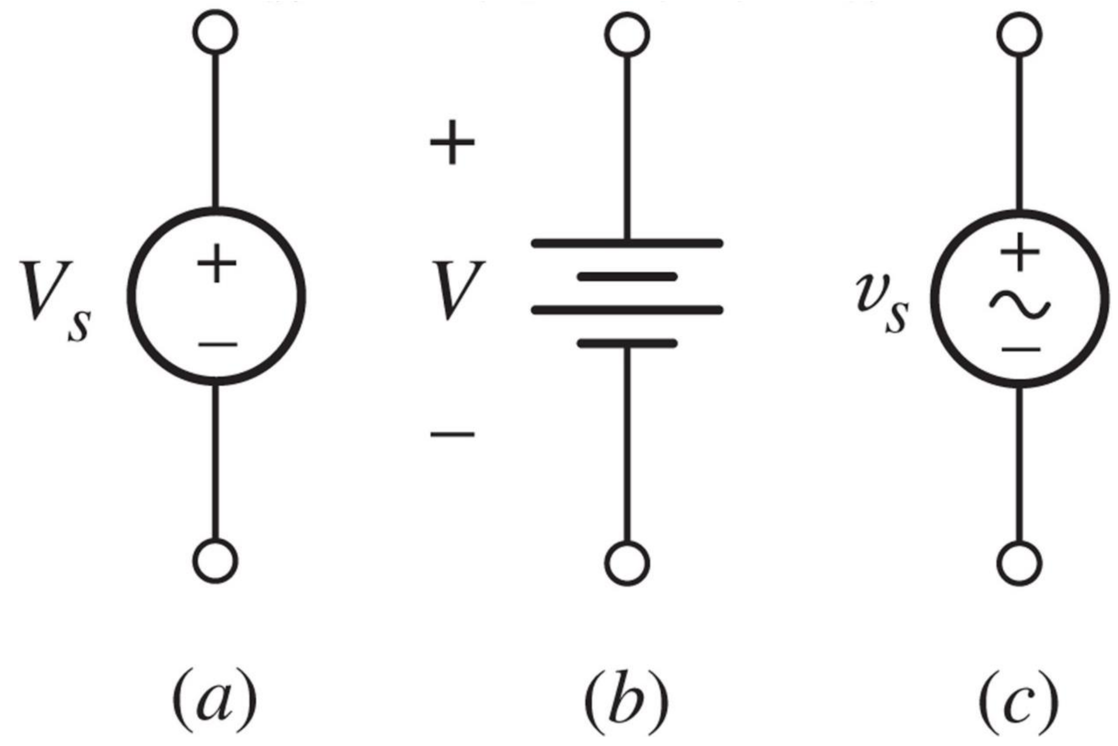
Current Sources

- 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

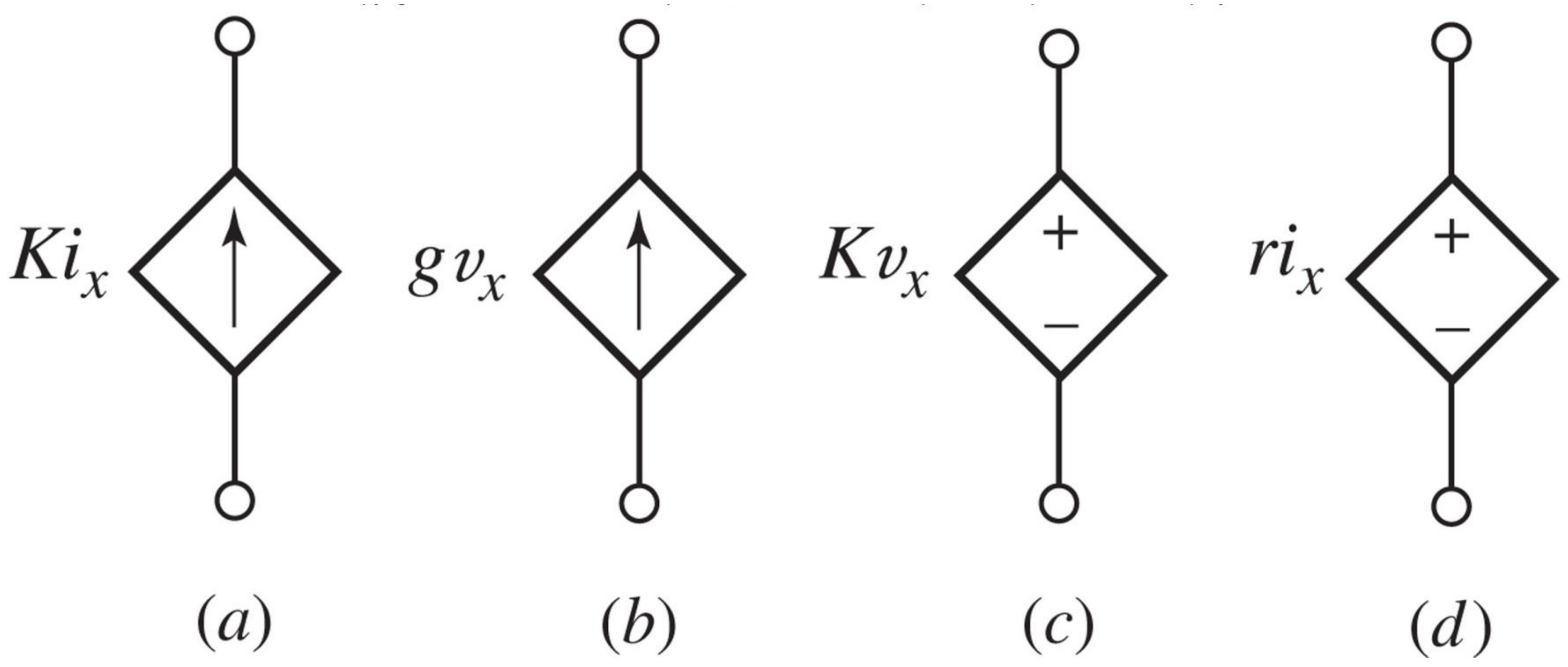
- A voltage source is an ***idealization*** (no limit on current) and ***generalization*** (voltage can be time-varying) of a battery.
- A battery supplies a constant "dc" voltage V but in practice a battery has a maximum power.



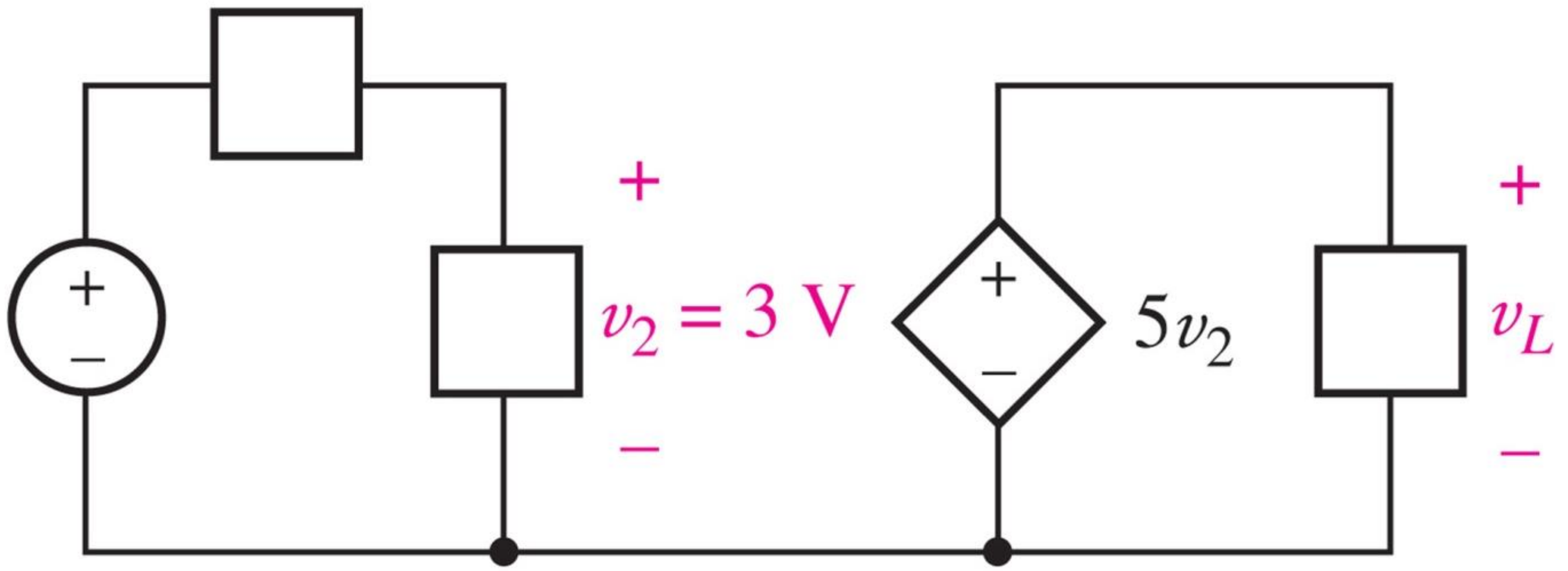
Dependent Sources

- 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.

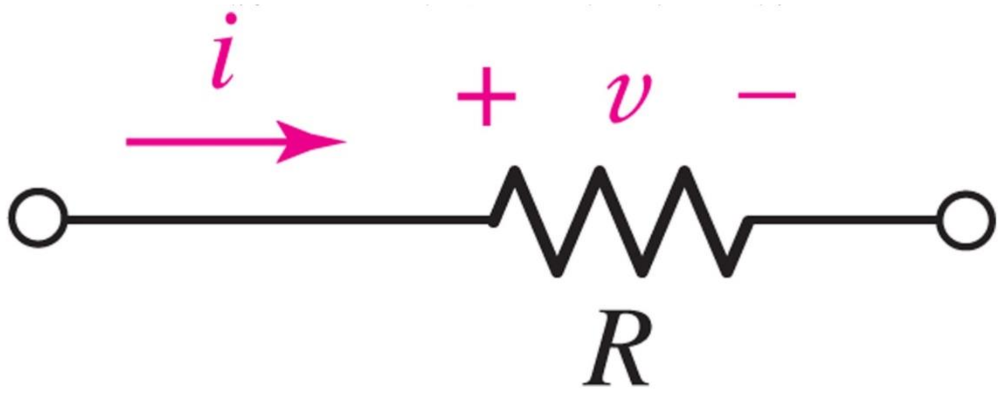


- Find the voltage v_L in the circuit below.

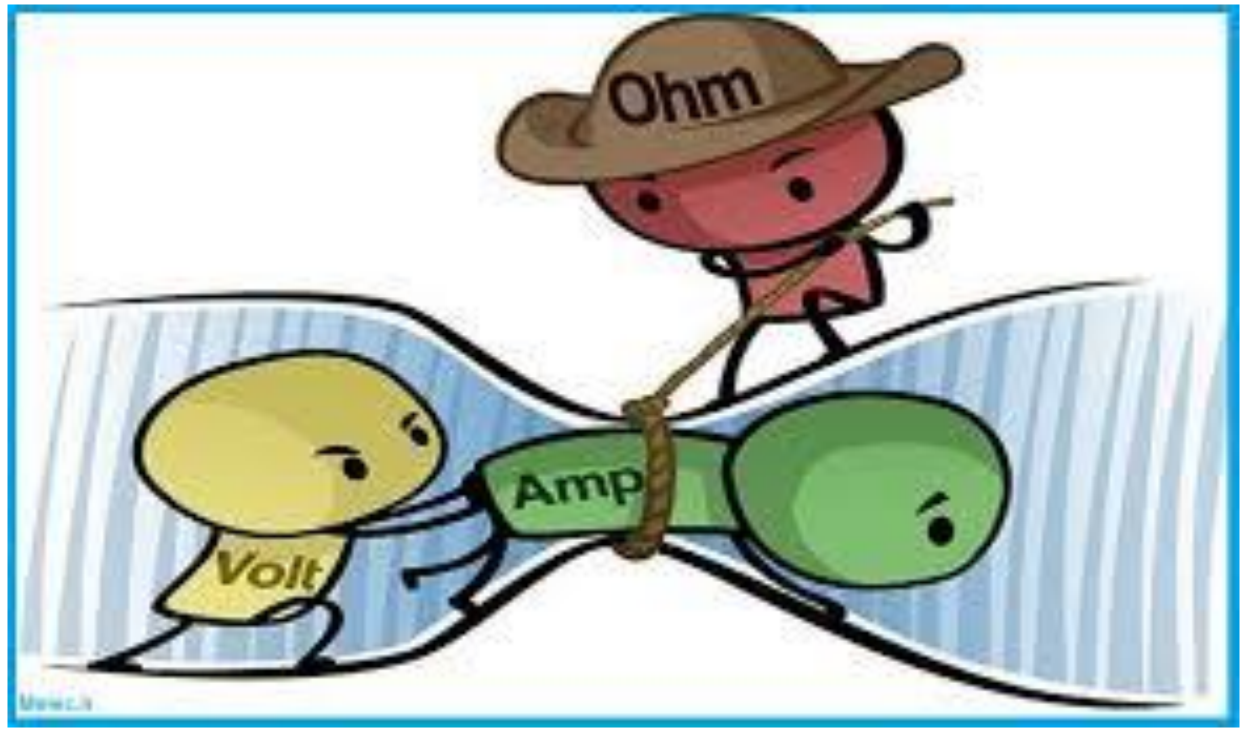


- A (linear) resistor is an element for which

$$v = iR$$



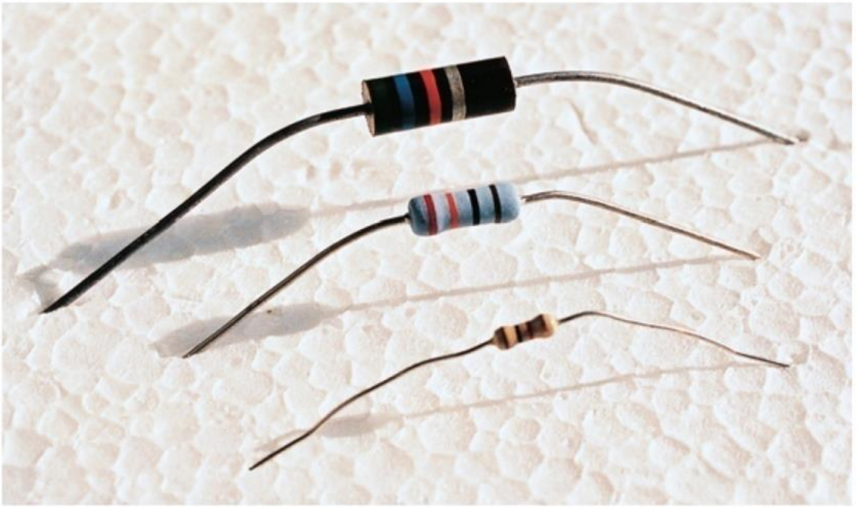
- where the constant R is a resistance.
- The equation is known as **“Ohm’s Law.”**
- The unit of resistance is **ohm (Ω).**



Resistors

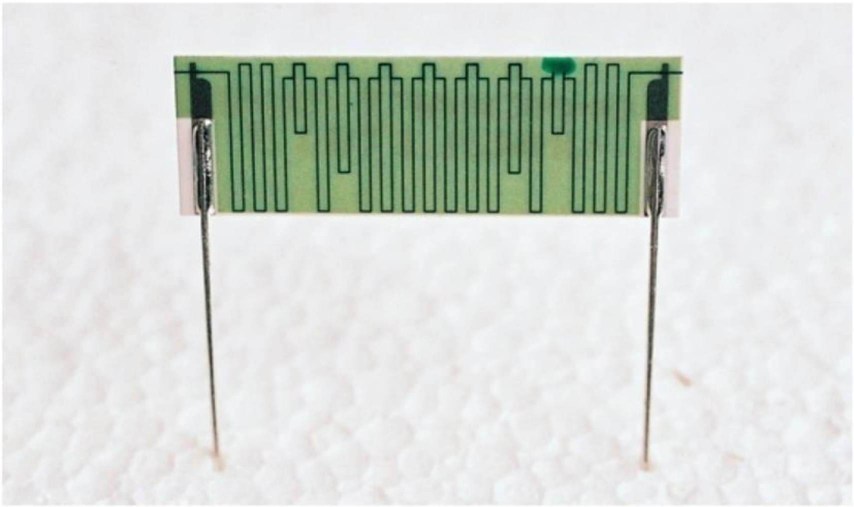
(a)typical resistors (b) power resistor

(c) a 10 TΩ resistor (d) circuit symbol

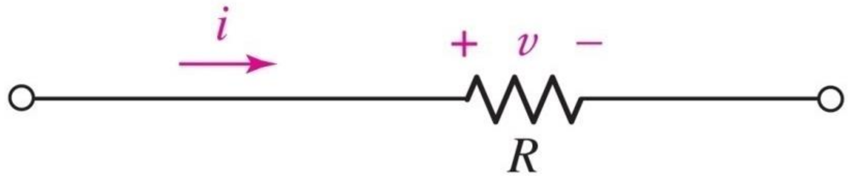


(a)

(b)

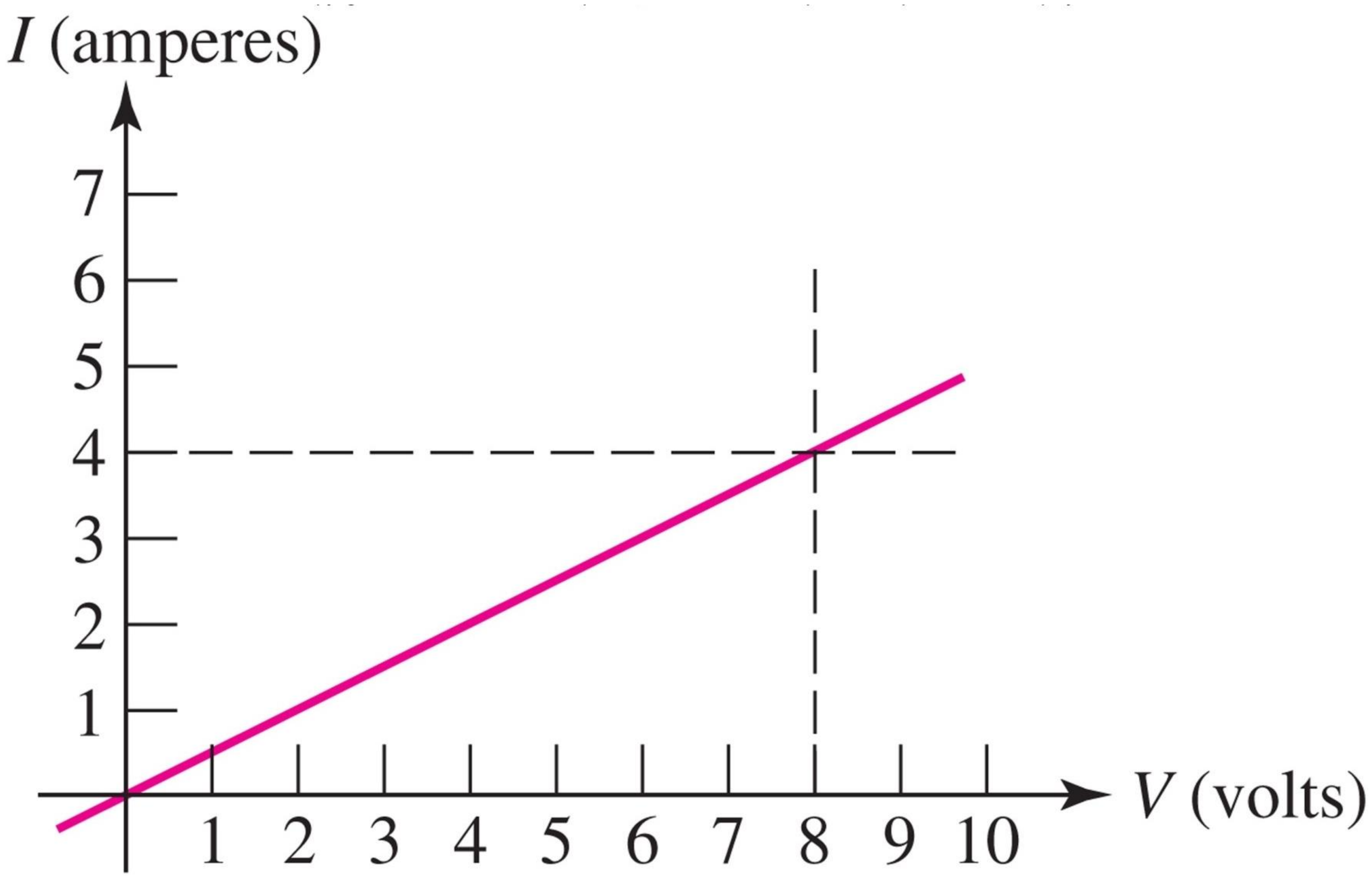


(c)



(d)

- 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}.

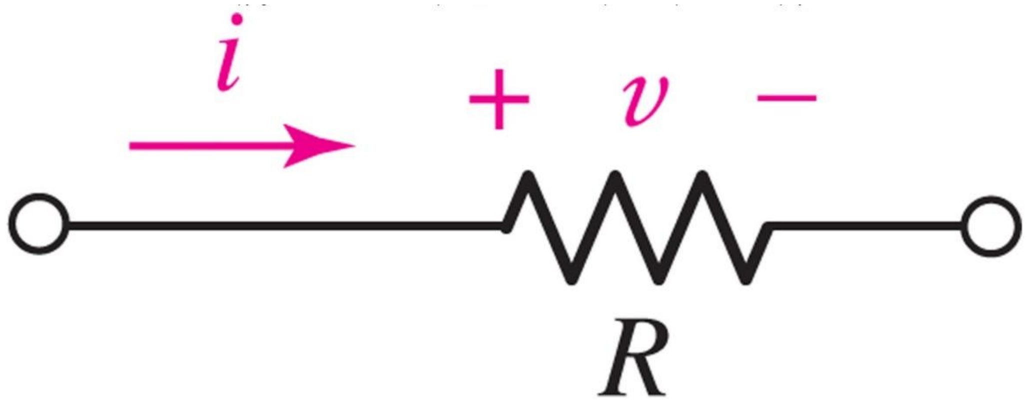
- This is the graph for a **2 ohm** resistor.

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.

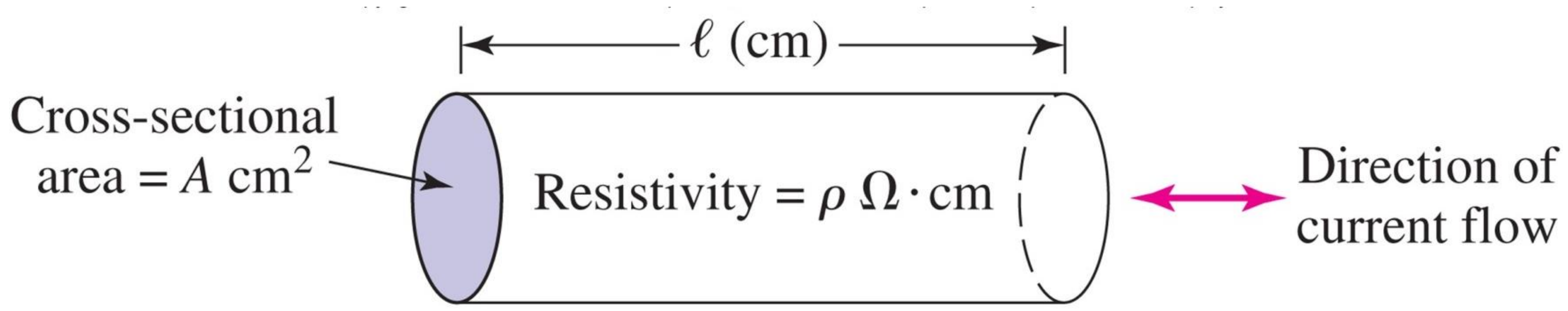
$$v = iR = (0.0424)(560) = 23.7\text{ V}$$

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

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

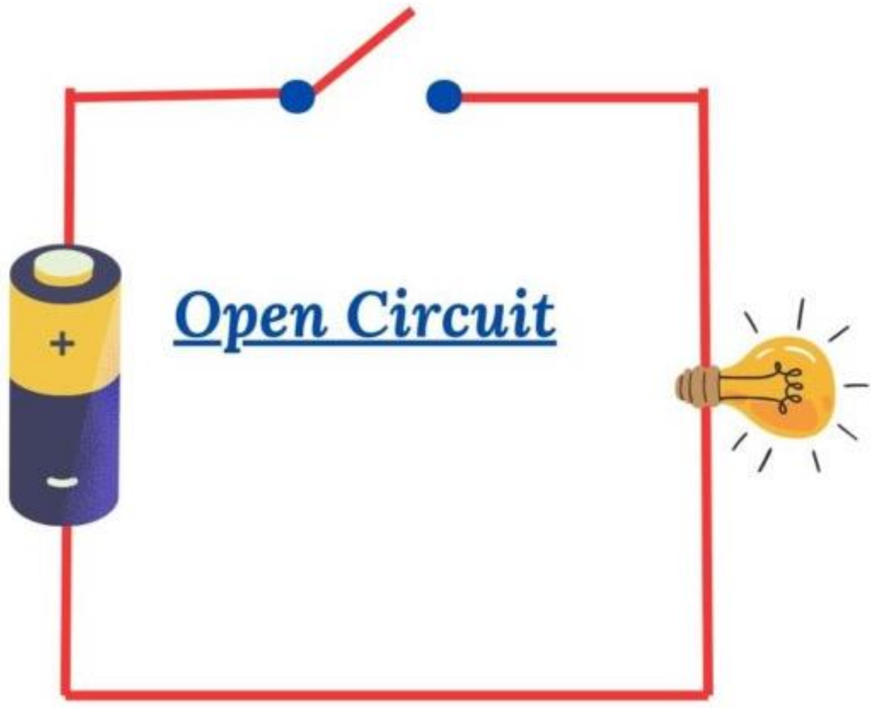
- We sometimes prefer to work with *the reciprocal of resistance* (1/R), which is called conductance (symbol G, unit siemens (S)).

- A resistor R has conductance G=1/R.

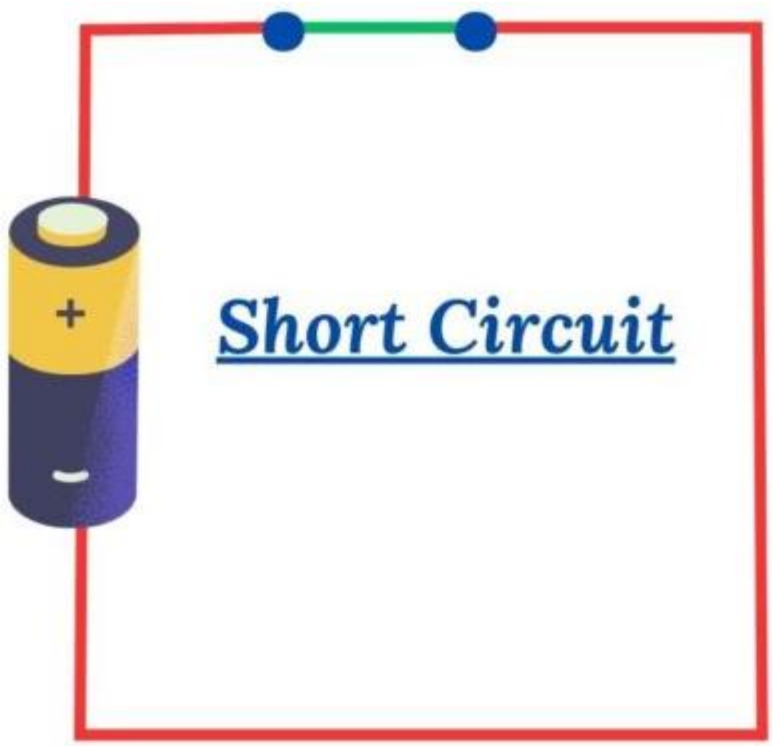
- The *i*-*v* equation (i.e. Ohm's law) can be written as

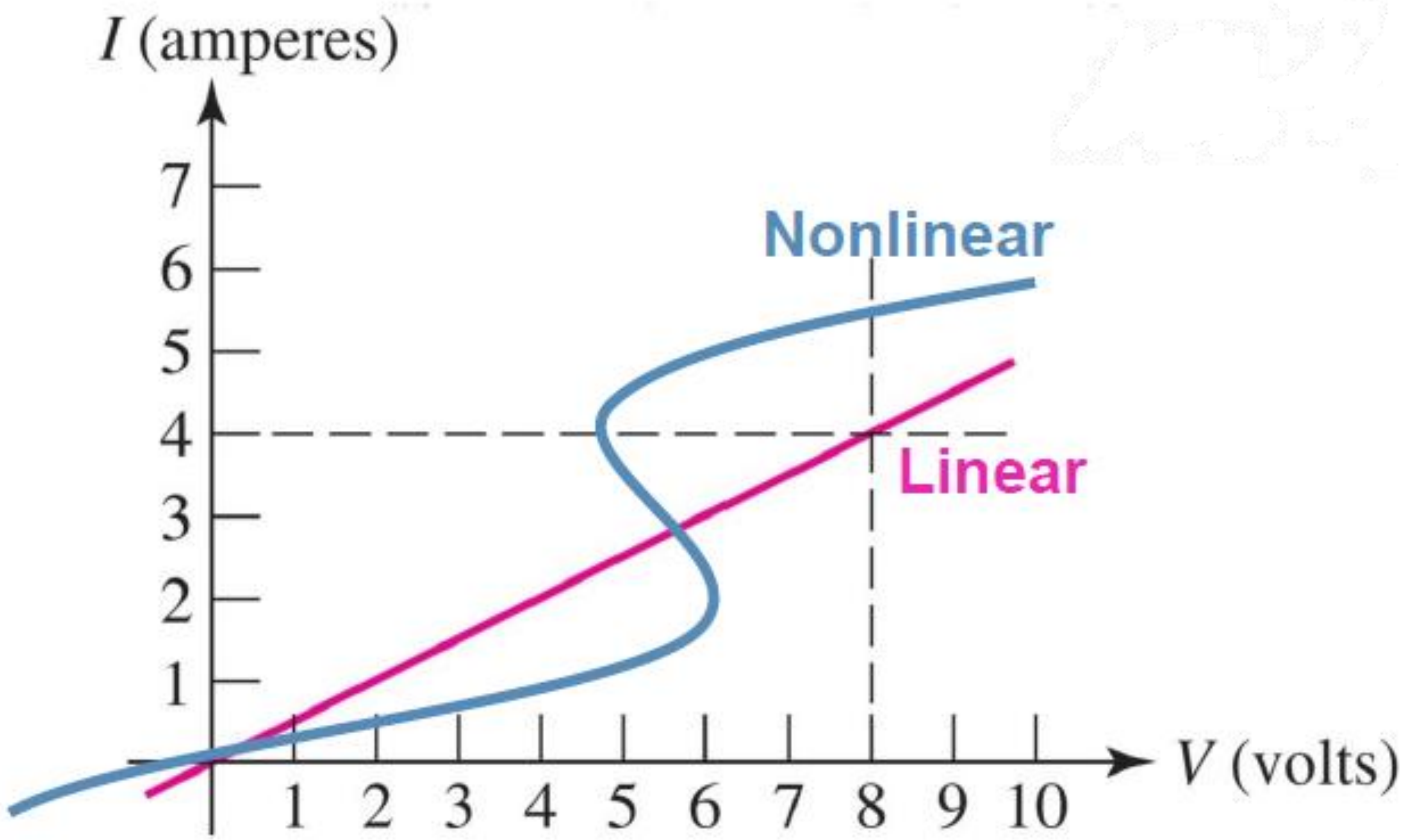
$$i=Gv$$

- 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 $R = 0\ \Omega$.





Linear function:

$$f(x_1 + x_2) = f(x_1) + f(x_2)$$

$$f(ax) = af(x)$$

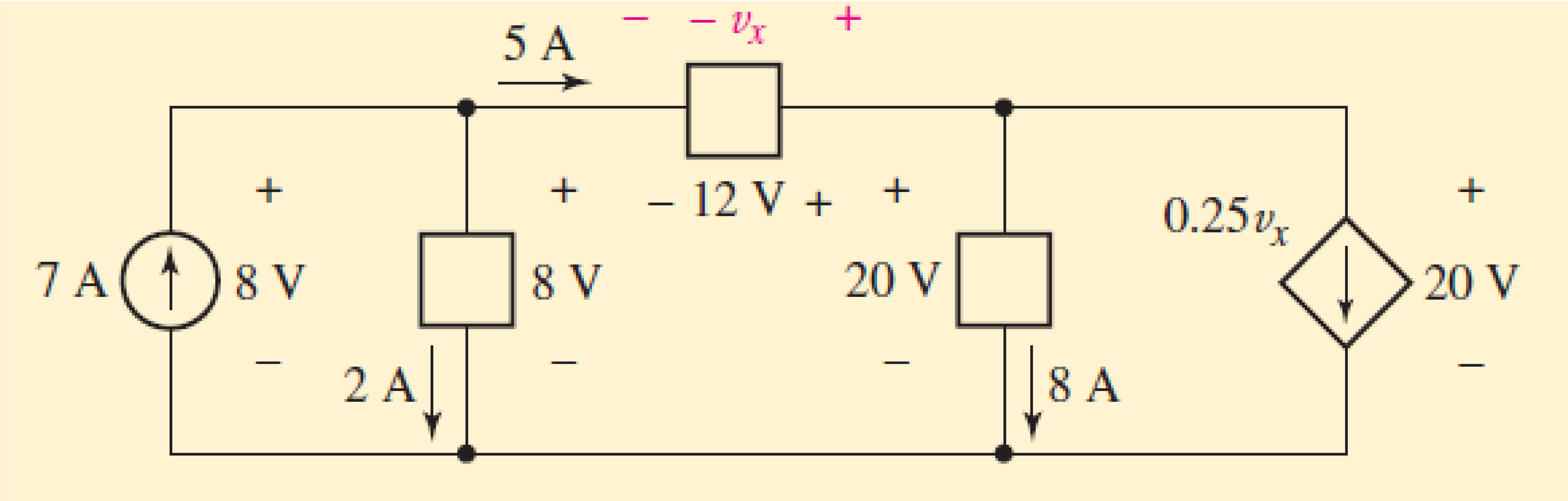
Linear resistance:

$$v = f(i) = 2\,i$$

Nonlinear resistance:

$$v = f(i) = 50\,i + 0.5\,i^3$$

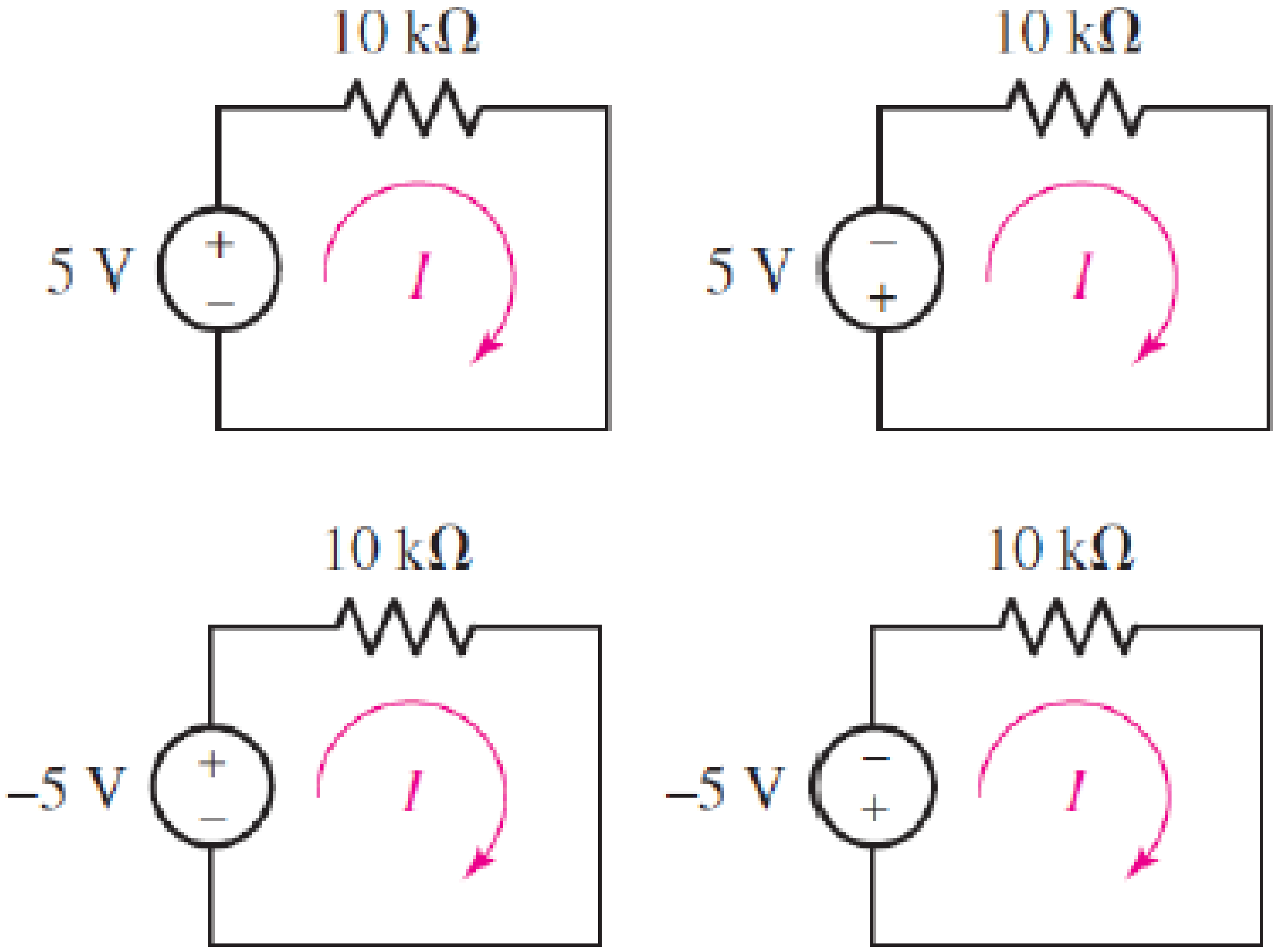
Find the power *absorbed* by each element in the circuit



Ans: (left to right) −56 W; 16 W; −60 W; 160 W; −60 W.

Practice 2

For each of the circuits, find the current I and compute the power absorbed by the resistor.

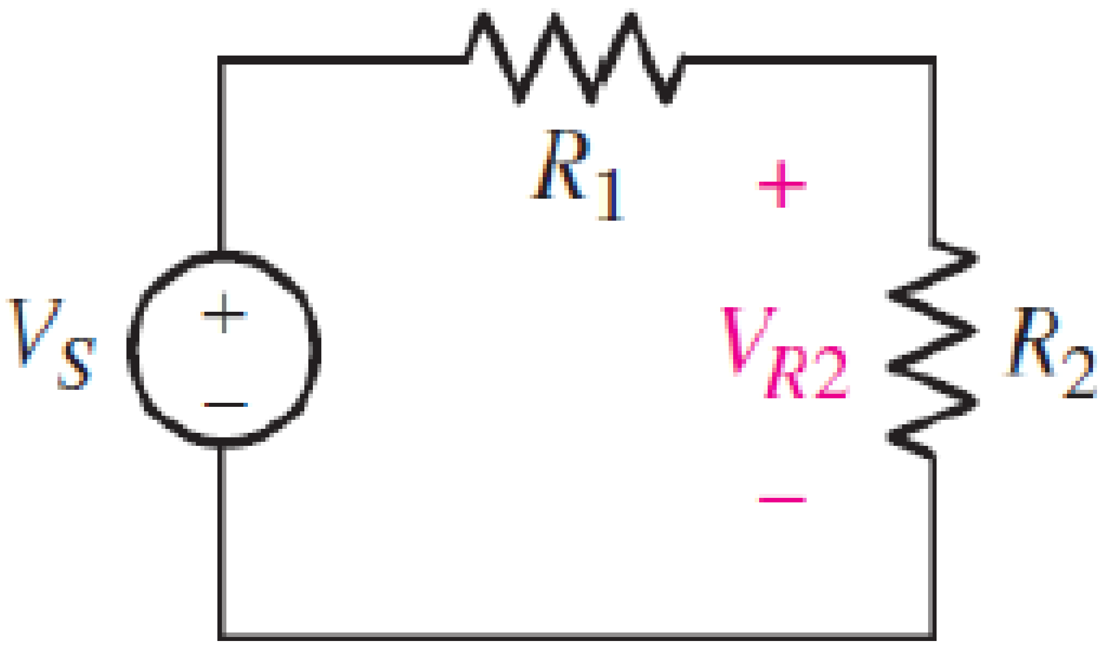


Practice 3

show that:

$$V_{R2} = V_S \cdot \frac{R2}{R1 + R2}$$

You may assume the same current flows through each element (a requirement of charge conservation).



Thanks