BASIC CONCEPTS

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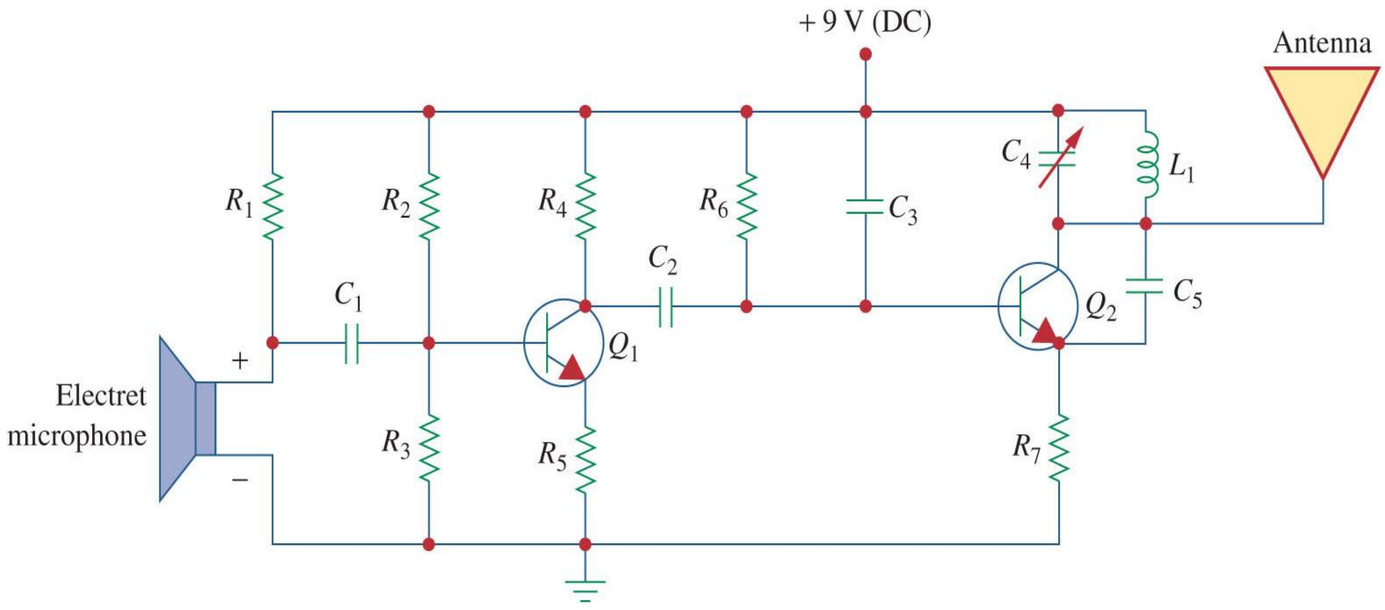
Electric Circuit

- An electric circuit is an interconnection of electrical elements.



Units and prefixes

- When taking measurements, we must use units to quantify values.
- We use the International Systems of Units (SI).
- Prefixes on SI units allow for easy relationships between large and small values

The SI Units

Quantity	Basic unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Charge	coulomb	C

The SI Prefixes

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Charge

- The most basic quantity in an electric circuit is the electric charge.
- Charge is a basic SI unit, measured in Coulombs (C)
- We also know that the charge *e* on an electron is negative and equal in magnitude to $1.602*10^{-19}$ C
- One Coulomb is quite large, $6.24*10^{18}$ electrons.

Charge

- While a proton carries a positive charge of the same magnitude as the electron.
- The charge of any number (N) of electron or proton = N * electron (proton) charge.

How much charge is represented by 4,600 electrons?

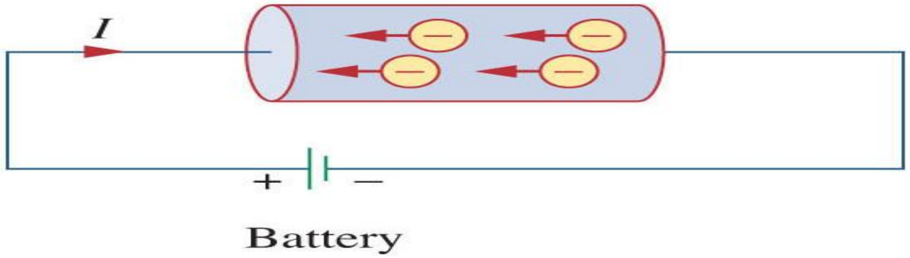
Solution:

Each electron has -1.602×10^{-19} C. Hence 4,600 electrons will have

$$-1.602 \times 10^{-19} \text{ C/electron} \times 4{,}600 \text{ electrons} = -7.369 \times 10^{-16} \text{ C}$$

Current

- The movement of charge is called a current.
- Electric current is the time rate of change of charge, measured in amperes (A).



Current

- The relationship between current *i*, charge *q*, and time *t* is:

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

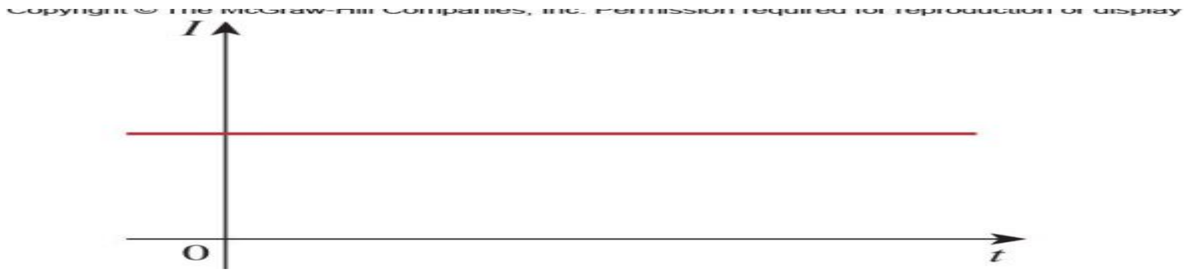
where current is measured in amperes (A), and
1 ampere = 1 coulomb/second

- The charge transferred between time t0 and *t* is obtained by integrating both sides

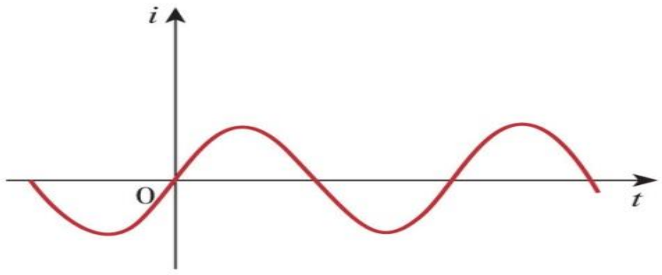
$$Q \triangleq \int_{t_0}^{t} i \, dt$$

Current

A direct current (dc) is a current that remains constant with time.



An alternating current (ac) is a current that varies sinusoidal with time.



Example1

The total charge entering a terminal is given by $q = 5t \sin 4\pi t$ mC. Calculate the current at $t = 0.5$ s.

Solution:

$$i = \frac{dq}{dt} = \frac{d}{dt}(5t \sin 4\pi t) \text{ mC/s} = (5 \sin 4\pi t + 20\pi t \cos 4\pi t) \text{ mA}$$

At $t = 0.5$,

$$i = 5 \sin 2\pi + 10\pi \cos 2\pi = 0 + 10\pi = 31.42 \text{ mA}$$

Example2

Determine the total charge entering a terminal between $t = 1$ s and $t = 2$ s if the current passing the terminal is $i = (3t^2 - t)$ A.

Solution:

$$Q = \int_{t=1}^{2} i\,dt = \int_{1}^{2} (3t^2 - t)\,dt$$

$$= \left(t^3 - \frac{t^2}{2}\right)\Bigg|_1^2 = (8 - 2) - \left(1 - \frac{1}{2}\right) = 5.5\ \text{C}$$

Voltage

- The voltage between two points a and b in an electric circuit is the energy (or work) needed to move a unit charge from a to b.

$$v_{ab} \triangleq \frac{dw}{dq}$$

where w is energy in joules (J) and q is charge in coulombs (C). The voltage v_{ab} or simply v is measured in volts (V), named in honor of

Power

- Power is the time rate of expending or absorbing energy, measured in watts (W).

$$P = \frac{dW}{dt}$$

where p is power in watts (W), w is energy in joules (J), and t is time in seconds (s).

$$\mathrm{P} = \frac{dw}{dt} = \frac{dw}{dt} \times \frac{dq}{dq} = \frac{dw}{dq} * \frac{dq}{dt} = vi$$

$$w = \int_{t_0}^{t} p\,dt = \int_{t_0}^{t} vi\,dt$$

Power

- The power absorbed or supplied by an element is the product of the voltage across the element and the current through it.
- If the power has a + sign, power is being delivered to or absorbed by the element.
- If the power has a - sign, power is being supplied by or delivered from the element.
- Current direction and voltage polarity play a major role in determining the sign of power.

Power

Passive sign convention is satisfied when the current enters through the positive terminal of an element and $p = +vi$. If the current enters through the negative terminal, $p = -vi$.

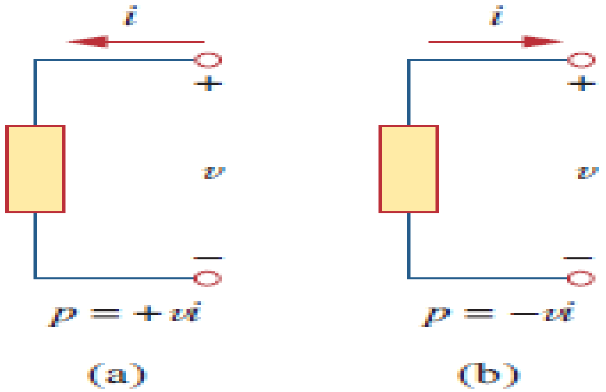


Figure 1.8
Reference polarities for power using the passive sign convention: (a) absorbing power, (b) supplying power.

Example3

An energy source forces a constant current of 2 A for 10 s to flow through a light bulb. If 2.3 kJ is given off in the form of light and heat energy, calculate the voltage drop across the bulb.

Solution:

The total charge is

$$\Delta q = i\,\Delta t = 2 \times 10 = 20\ \text{C}$$

The voltage drop is

$$v = \frac{\Delta w}{\Delta q} = \frac{2.3 \times 10^3}{20} = 115\ \text{V}$$

Example4

Find the power delivered to an element at $t = 3$ ms if the current entering its positive terminal is

$$i = 5\cos 60\pi t \text{ A}$$

and the voltage is: (a) $v = 3i$, (b) $v = 3\,di/dt$.

Solution:

(a) The voltage is $v = 3i = 15\cos 60\pi t$; hence, the power is

$$p = vi = 75\cos^2 60\pi t \text{ W}$$

At $t = 3$ ms,

$$p = 75\cos^2(60\pi \times 3 \times 10^{-3}) = 75\cos^2 0.18\pi = 53.48 \text{ W}$$

(b) We find the voltage and the power as

$$v = 3\frac{di}{dt} = 3(-60\pi)5\sin 60\pi t = -900\pi\sin 60\pi t \text{ V}$$

$$p = vi = -4500\pi\sin 60\pi t\cos 60\pi t \text{ W}$$

At $t = 3$ ms,

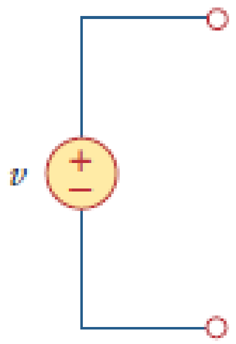
$$p = -4500\pi\sin 0.18\pi\cos 0.18\pi \text{ W}$$

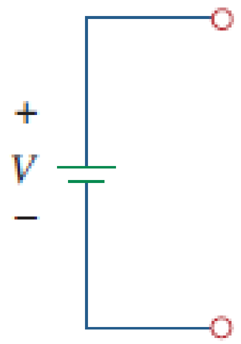
$$= -14137.167\sin 32.4^\circ\cos 32.4^\circ = -6.396 \text{ kW}$$

Circuit Sources

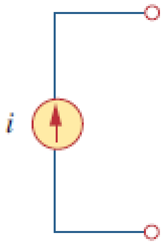
- **Independent Source:** provides a specified voltage or current that is completely independent of other circuit variables.

Independent Voltage Source:





Independent current source:

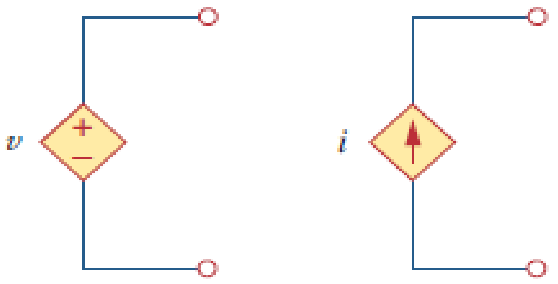


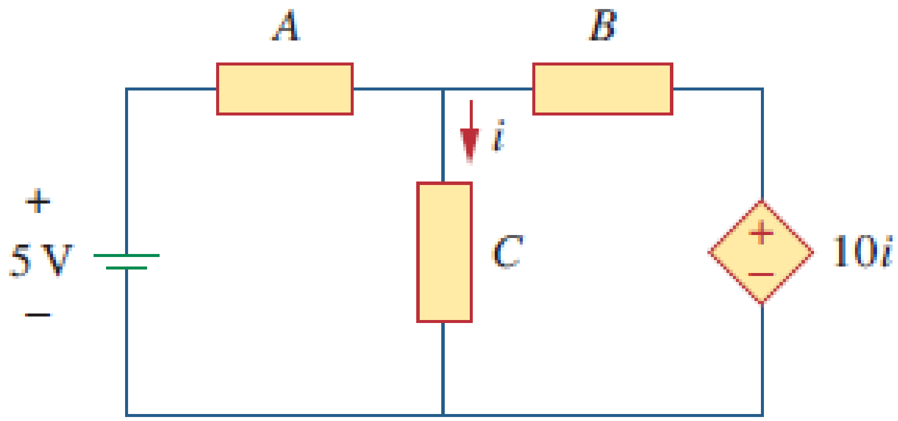
Circuit Sources

- **dependent Source:** provides a specified voltage or current that is completely dependent on other circuit variables.

dependent Voltage Source:

dependent current source:





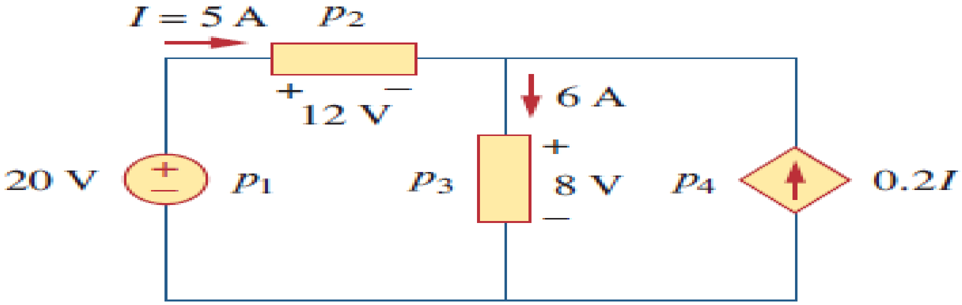
Circuit Elements

- There are four possible types of dependent sources, namely:

1. A voltage-controlled voltage source (VCVS).
2. A current-controlled voltage source (CCVS).
3. A voltage-controlled current source (VCCS).
4. A current-controlled current source (CCCS).

Example1

- Calculate the power supplied or absorbed by each element.



- P1= - 5*20=-100 supplied
- P2= +5*12= 60 absorbed
- P3= + 6*8= 48 absorbed
- P4= - 0.2*5*8= - 8 supplied