Lecture 2

EMT1150
Introduction to Circuit Analysis

Department of Computer Engineering Technology

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Review

- Syllabus
- Unit of measurements
- Unit conversions
- Accuracy, significant figures

Unit Conversion

1. Set up the conversion factor to form a numerical value of 1
2. Perform the required mathematics to the proper magnitude

Example 1: Convert 5yards to centimeter (cm)

1yard = 3 feet $1=\frac{3ft}{1yard}$

1ft = 12inch $1=\frac{12inch}{1ft}$

1 meter=39.37 in $1=\frac{1m}{39.37\ inch}$

1meter = 100 cm $1=\frac{100cm}{1m}$

5yard = 5yard $\times\frac{3ft}{1yard}\times\frac{12inch}{1ft}\times\frac{1m}{39.37\ inch}\times\frac{100cm}{1m}$ =457.20 (cm)

Powers of Ten

- 10, 100, 1000,
- 1,000,000,000

$1 = 10^0$
$10 = 10^1$
$100 = 10^2$
$1000 = 10^3$
$1000000000 = 10^9$

$1/10 = 0.1 = 10^{-1}$
$1/100 = 0.01 = 10^{-2}$
$1/1000 = 0.001 = 10^{-3}$
$1/10,000 = 0.0001 = 10^{-4}$

Example 1: Express $\frac{1}{1000}, \frac{1}{0.00001}$ in power of ten format.

$$a.\ \frac{1}{1000} = \frac{1}{10^{+3}} = 10^{-3}$$

$$b.\ \frac{1}{0.00001} = \frac{1}{10^{-5}} = 10^{+5}$$

Example 2: Calculate (a) (1000)(10,000), (b) (0.00001)(100)

a. $(1000)(10{,}000) = (10^3)(10^4) = 10^{(3+4)} = 10^7$
b. $(0.00001)(100) = (10^{-5})(10^2) = 10^{(-5+2)} = 10^{-3}$

Basic Arithmetic Operations

When adding or subtracting numbers in a powers-of-ten format, be sure that the power of ten is the same for each number. Then separate the multipliers, perform the required operation, and apply the same power of ten to the results.

Example 3: **Calculate (a) 6300 + 75,000, (b) 0.00096 – 0.000086**

a. 6300 + 75,000 = (6.3)(1000) + (75)(1000)

$= 6.3 \times 10^3 + 75 \times 10^3$

$= (6.3 + 75) \times 10^3$

$= 81.3 \times 10^3$

b. 0.00096 – 0.000086 = (96)(0.00001) – (8.6)(0.00001)

$= 96 \times 10^{-5} - 8.6 \times 10^{-5}$

$= (96 - 8.6) \times 10^{-5}$

$= 87.4 \times 10^{-5}$

Ex.4 Calculate (a) (0.0002)(0.000007),
(b) (340,000)(0.00061)

a. (0.0002)(0.000007) = [(2)(0.0001)] [(7)(0.000001)]

$= (2 \times 10^{-4})(7 \times 10^{-6})$

$= (2)(7) \times (10^{-4})(10^{-6})$

$= 14 \times 10^{-10}$

b. (340,000)(0.00061) $= (3.4 \times 10^{5})(61 \times 10^{-5})$

$= (3.4)(61) \times (10^{5})(10^{-5})$

$= 207.4 \times 10^{0}$

$= 207.4$

Exp 5. Calculate (a) $\frac{0.00047}{0.002}$ (b) $\frac{690,000}{0.00000013}$

$$a.\ \frac{0.00047}{0.002} = \frac{47\times10^{-5}}{2\times10^{-3}} = \left(\frac{47}{2}\right)\times\left(\frac{10^{-5}}{10^{-3}}\right) = 23.5\times10^{-2}$$

$$b.\ \frac{690,000}{0.00000013} = \frac{69\times10^{4}}{13\times10^{-8}} = \left(\frac{69}{13}\right)\times\left(\frac{10^{4}}{10^{-8}}\right) = 5.31\times10^{12}$$

Exp 6. Calculate (a) $(0.00003)^3$
(b) $(90,800,000)^2$

a. $(0.00003)^3$ $= (3 \times 10^{-5})^3 = (3 \times 10^{-5})^3 = (3)^3 \times 10^{-15}$
b. $(90,800,000)^2$ $= (9.08 \times 10^7)^2 = (9.08)^2 \times (10^7)^2$
$= 82.4464 \times 10^{14}$

Fixed-point and floating point

- Fixed-point format requires that the decimal point appear in the same place each time.
- In the floating-point format the decimal point appears in a location defined by the number to be displayed.

$$\frac{1}{3} = 0.333, \qquad \frac{1}{3} = 0.33333333333333$$

Scientific /engineering notation

- Scientific notation: the decimal point appear directly after the first digit greater than or equal to 1 but less than 10.
- Engineering notation: all powers of ten must be 0 or multiples of 3, and the coefficient must be greater than or equal to 1 but less than 1000.

Scientific /engineering notation

Example 4: express 1/3, 1500, 255 in two notations with two-place accuracy

$\frac{1}{3}$ = 0.333

$\frac{1}{3}$ = 3.33E-1 Scientific notation

$\frac{1}{3}$ = 333.33E-3 Engineering notation

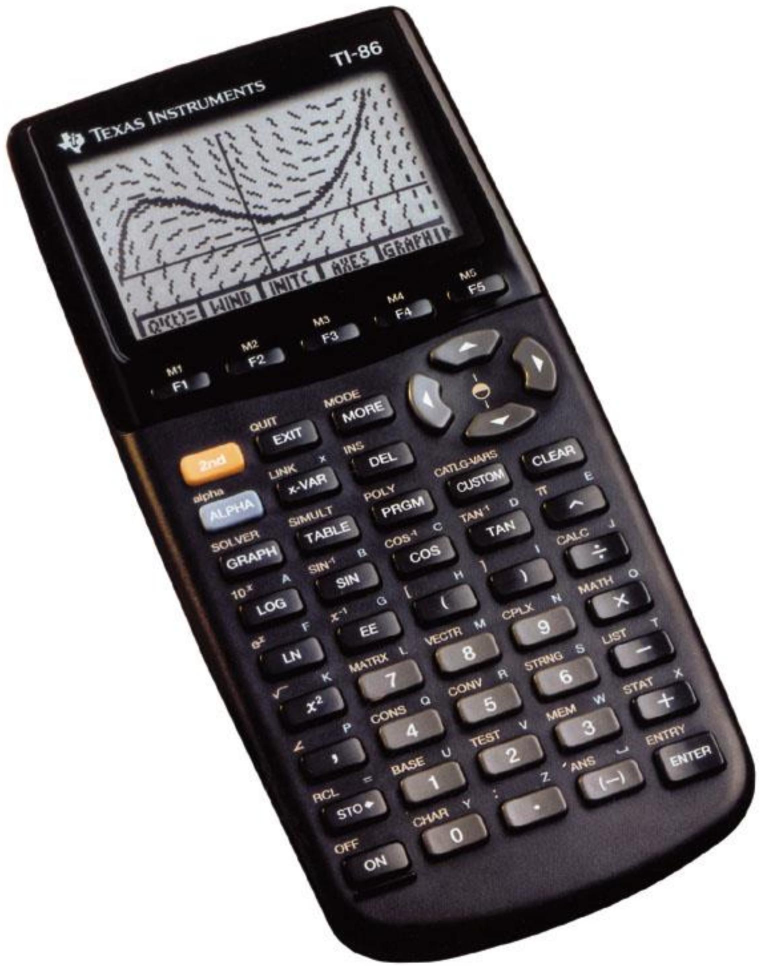
1500= 1.50E3 Scientific notation

1500= 1.50E3 Engineering notation

255= 2.55E2 Scientific notation

255= 255E0 Engineering notation

Calculators and Order of Operation

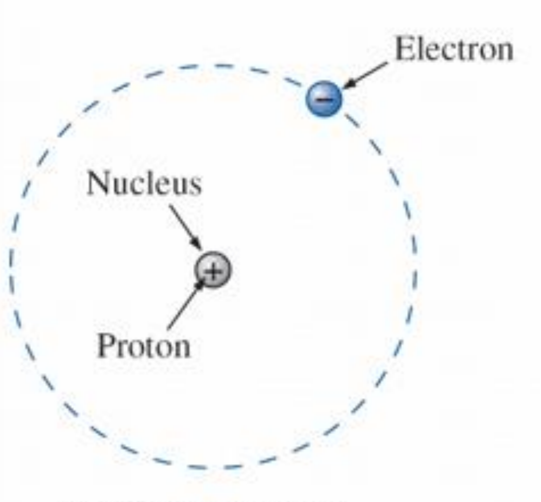


Chapter 2 Voltage and Current

- **Atoms and Their Structure**
- **Current**
- **Voltage**
- **Fixed (DC) Supplies**
- **Conductor, insulator, Semiconductors**
- **Ammeters and Voltmeters**

Atoms and Their Structure

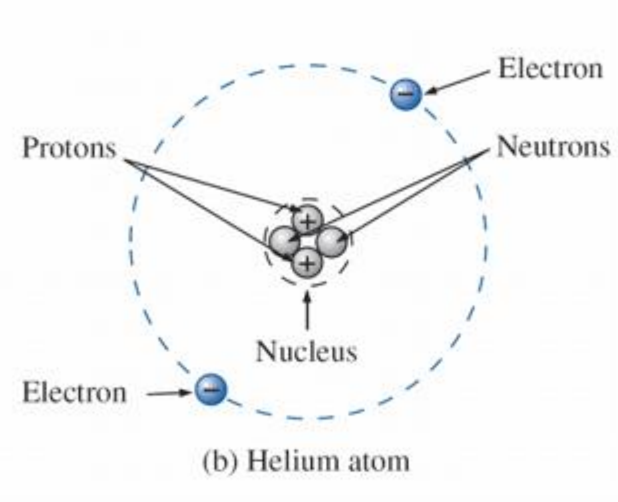
- The simplest of all atoms is the hydrogen atom, made up of two basic particles, the proton and the electron.



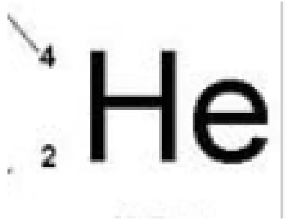
(a) Hydrogen atom

Atoms and Their Structure

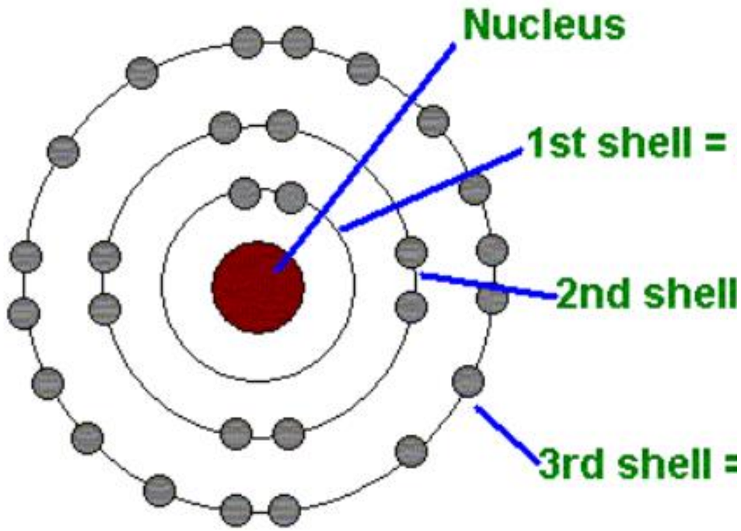
- In other elements, the nucleus also contain the neutrons, which has no electrical charge.
- In periodic table, atomic number corresponds to the number of protons, and mass number is the sum of proton and neutron.



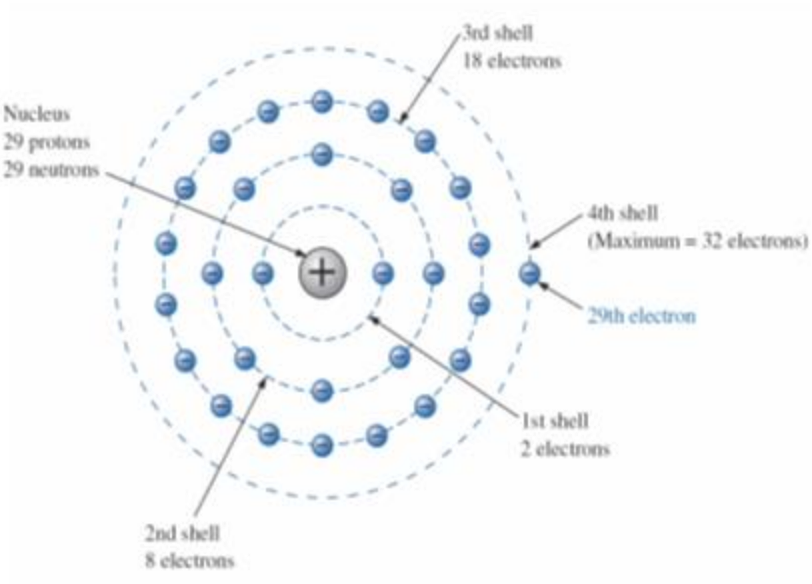
(b) Helium atom



- The atomic structure of any stable atom has an equal number of electrons and protons.
- The electrons are distributed in different shells around the nucleus.
- The number of electrons in each succeeding shells is determined by $2n^2$, where n is the shell number.

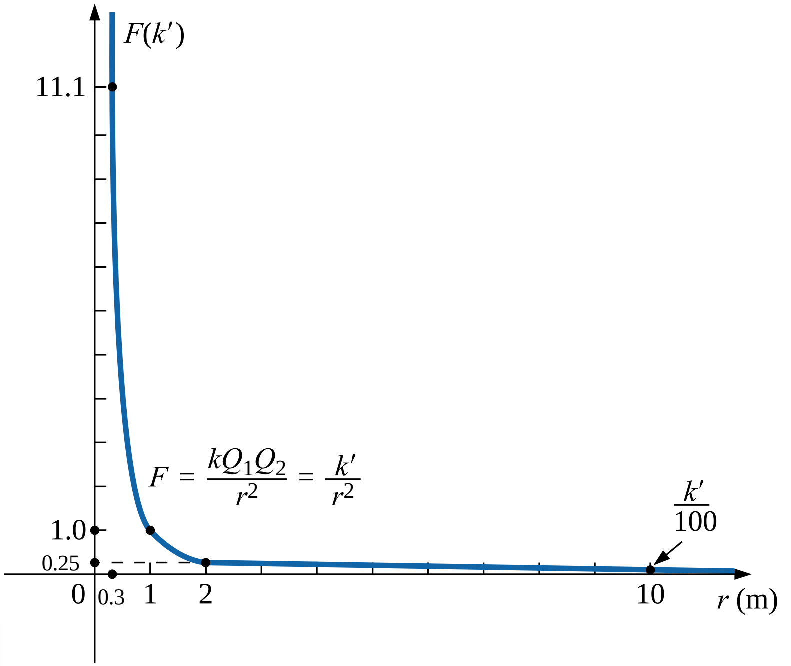


- Copper is the most commonly used metal in the electrical/electronics industry.
- Why? It has 29 electrons in orbits around the nucleus.



Coulomb's law

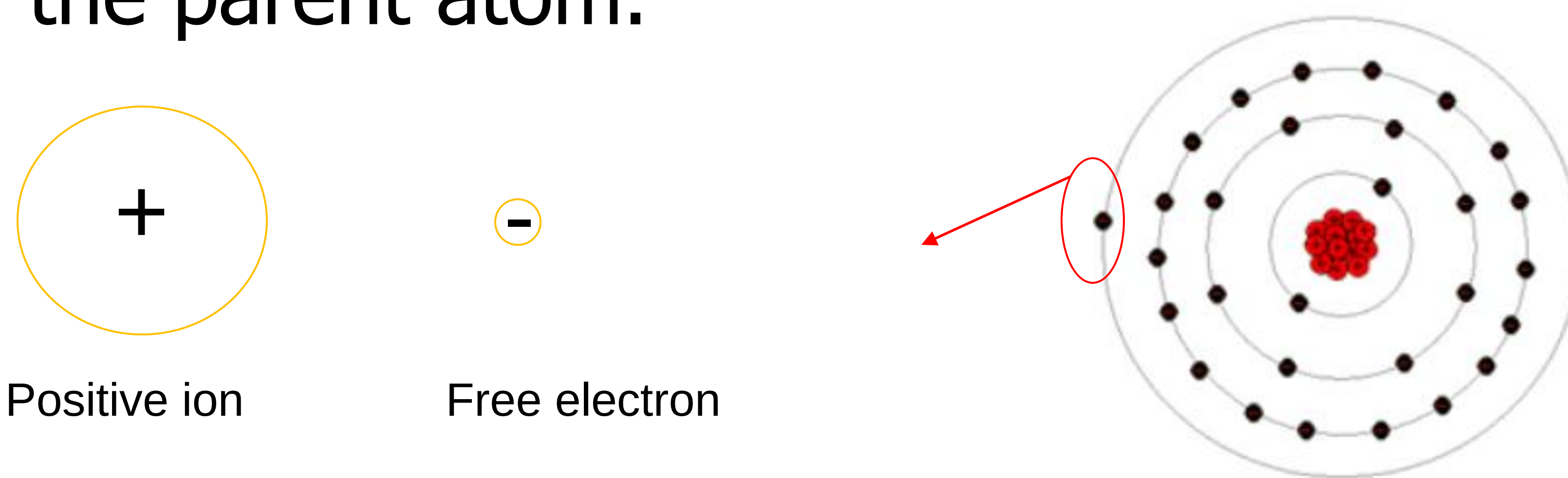
- The magnitude of the electrostatic force of interaction between two point charges is directly proportional to the scalar multiplication of the magnitudes of charges and inversely proportional to the square of the distance between them.



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

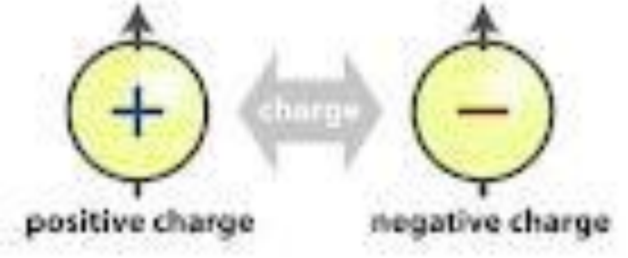
- F = electrostatic force
- q = electric charge
- r = distance between charge centers
- k = Coulomb constant $9.0 \times 10^9\ N \cdot m^2/C^2$

- As a result, the attraction force between the 29th electron and the nucleus is significantly less than the force between other electrons and nucleus.
- The 29th electron is loosely bound to the atomic structure, can become a free electron if it gains sufficient energy from the surrounding medium to leave the parent atom.



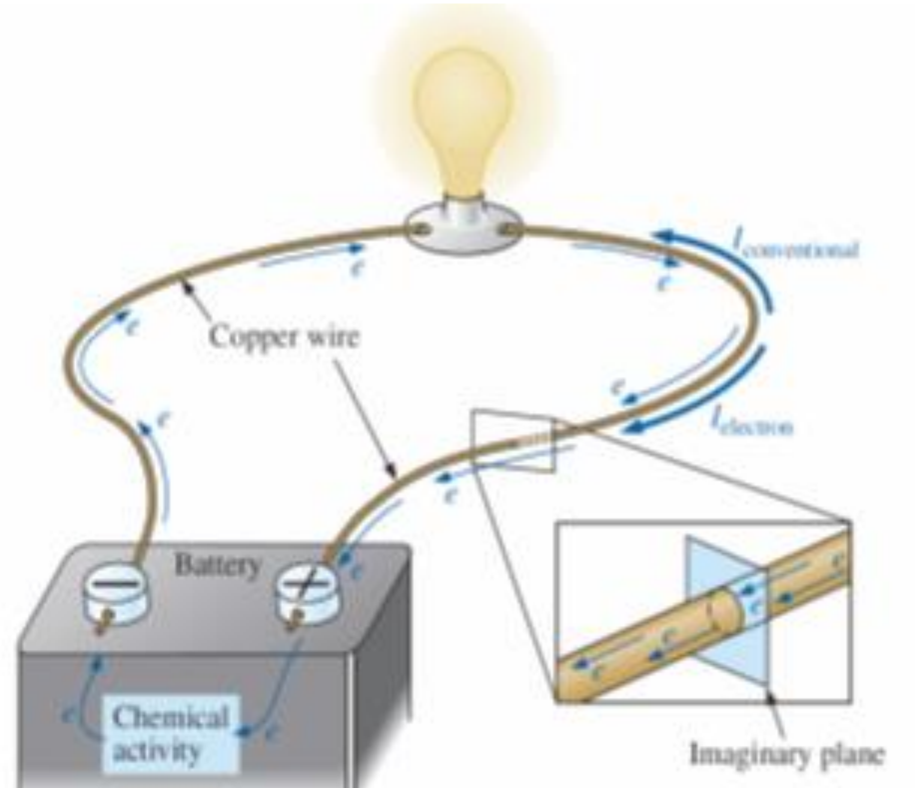
Charge

- Unit: Coulomb (C)
- Quantized value
- electron=-1.602×10^{-19} C
- 1C=1/(-1.602×10^{-19})e=-6.242×10^{18} e
- Q, q(t)



Current

- The electrical effects caused by charges in motion depend on the rate of charge flow. The rate of charge flow is known as the **electrical current**.



Current

- If 6.242×10^{18} *electrons* drift at uniform velocity through the imaginary circular cross section in 1 *second*, the flow of charge, or **current**, is said to be 1 **ampere** (A).
- The current in amperes can now be calculated using the following equation:

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

I = amperes (A)
Q = coulombs (C)
t = seconds (s)

Example 1: The charge flowing through the imaginary surface is 0.16 C every 64 ms. Determine the current in ampere.

$$I = \frac{Q}{t} = \frac{0.16C}{64\times10^{-3}s} = \frac{160\times10^{-3}C}{64\times10^{-3}s} = 2.50A$$

Example2: Determine the time required for 4 × 10^{16} electrons to pass through the imaginary surface if the current is 5 mA.

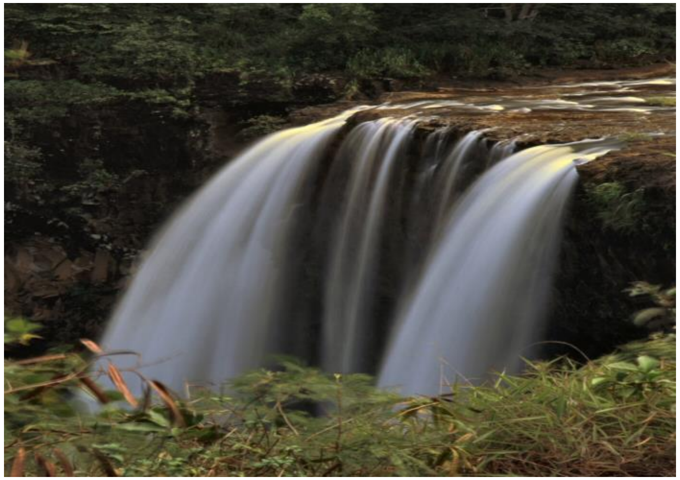
$$4\times10^{16} electron\left(\frac{1C}{6.242\times10^{18} electrons}\right)$$

$$=0.641\times10^{-2}C=0.00641C=6.41mC$$

$$t=\frac{Q}{I}=\frac{6.41\times10^{-3}C}{5\times10^{-3}A}=1.282s$$

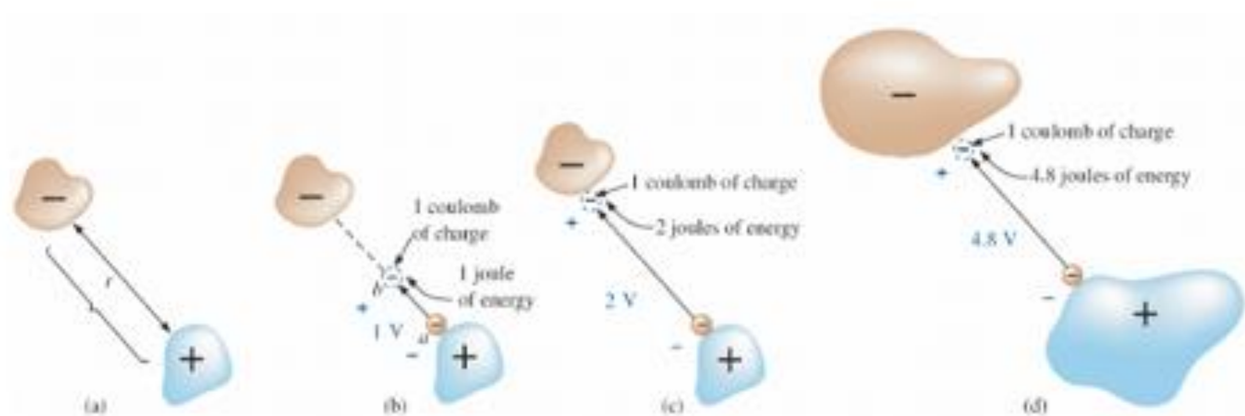
Voltage

- Voltage represents the work per unit charge associated with moving a charge between two points.



Voltage

- If a total of 1 joule (J) of energy is used to move the negative charge of 1 coulomb (C), there is a difference of 1 volt (V) between the two points.

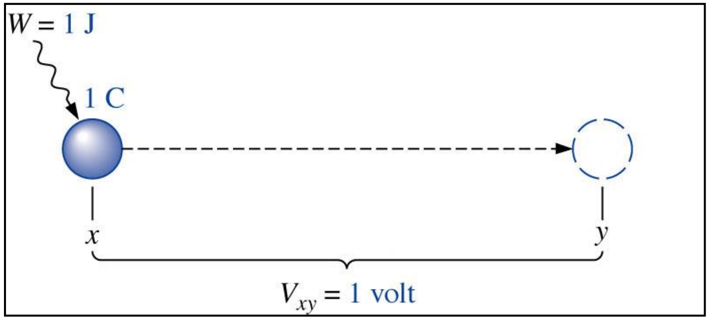


Voltage

- The **voltage** across an element is the work (energy) required to move a unit positive charge from the – terminal to the + terminal. The unit of voltage is the volt, V, also called the potential difference between two points.

$$V = \frac{W}{Q}$$

V = voltage (V)
Q = coulombs (C)
W = potential energy (J)



Example3: Find the potential difference between two points in an electrical system if 60 J of energy are expended by a charge of 20 C between these two points.

$$V = \frac{W}{Q} = \frac{60J}{20C} = 3V$$

Example 4: Determine the energy expended moving a charge of 50 μC through a potential difference of 6 V.

$$W = Q \cdot V = \left(50 \times 10^{-6}\right)\left(6V\right) = 300 \times 10^{-6} J = 300 \mu J$$

Checking Understanding

1. A current is said to exist whenever _____.
   a. a wire is charged
   b. a battery is present
   c. electric charges are unbalanced
   d. electric charges move in a loop

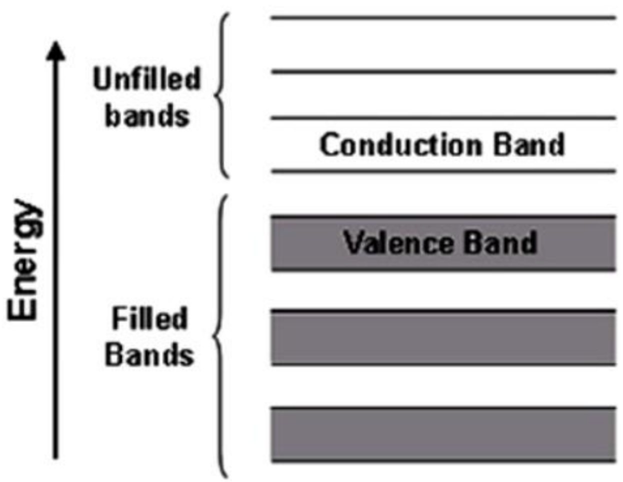
Answer: (d). Electric current is a flow of electric charge through the circuit.

2. If an electric circuit could be compared to a water circuit at a water park, then the current would be analogous to the ____.
   a. water pressure
   b. gallons of water flowing down slide per minute
   c. water
   d. bottom of the slide
   e. water pump
   f. top of the slide

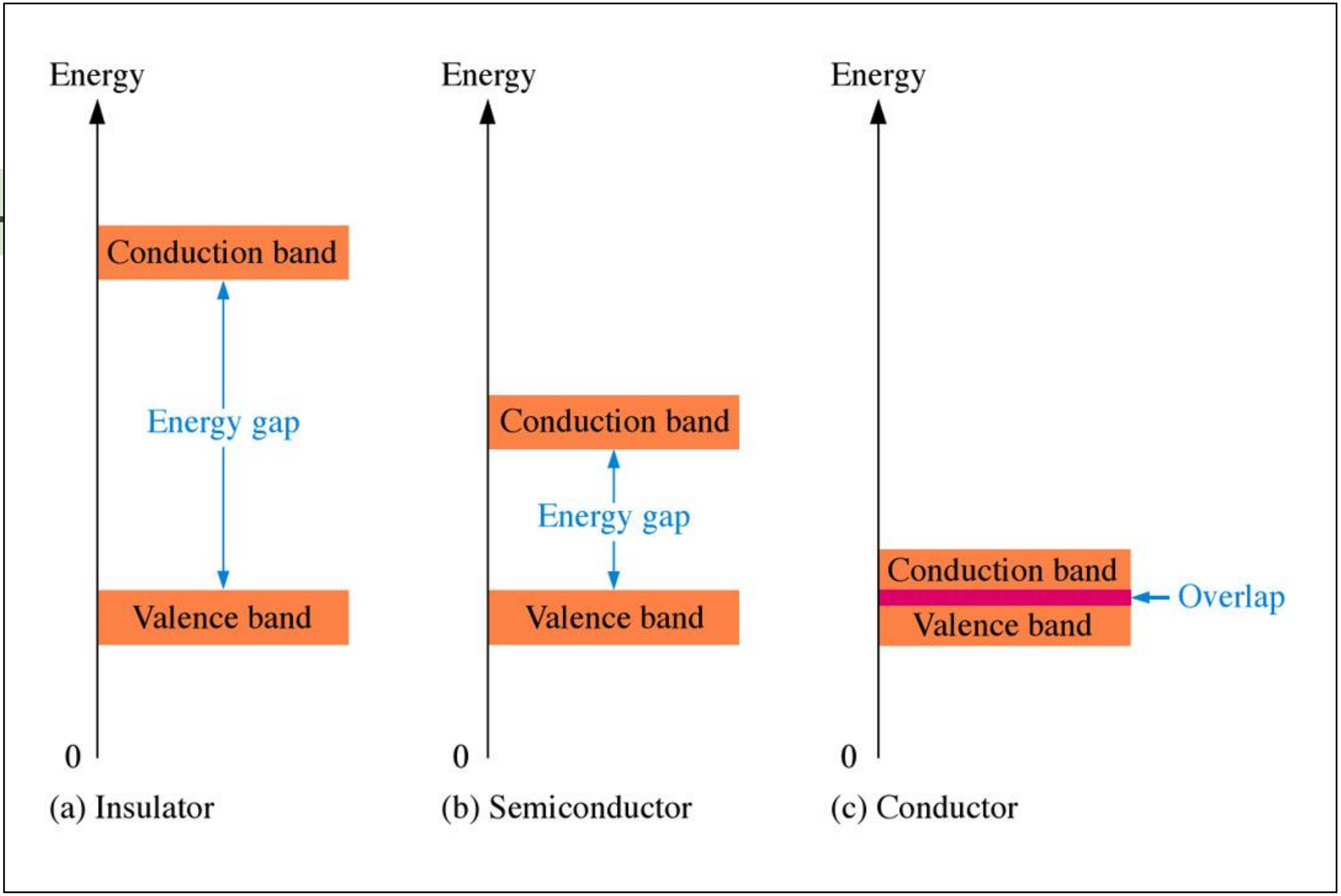
Answer: (b). $i(t)=Q/t$, current is defined as the rate at which the charges pass through a given point in a specific time.

Conductors, Insulators, and Semiconductors

- In solid physics, the outmost shell is known as the Valence band and electrons in this shell are called valence electrons.
- Outside the valence band, there is the conduction band which has higher energy and is generally empty.

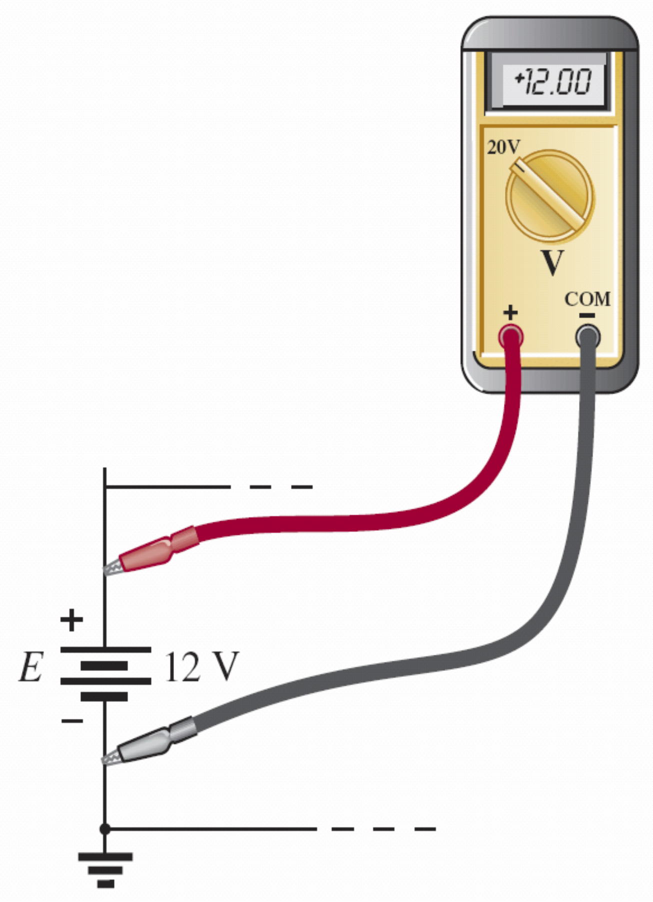


- A **conductor** is a material that easily conducts electrical current. The best conductors are single-element material, such as copper, gold, and aluminum, which are characterized by atoms with only one valence electron very loosely bound to the atom.
- An **insulator** is a material that does not conduct electrical current under normal conditions. Valence electrons are tightly bound to the atoms.
- A **semiconductor** is a material that is between conductors and insulators in its ability to conduct electrical current. The most common single –element semiconductors are silicon, germanium, and carbon

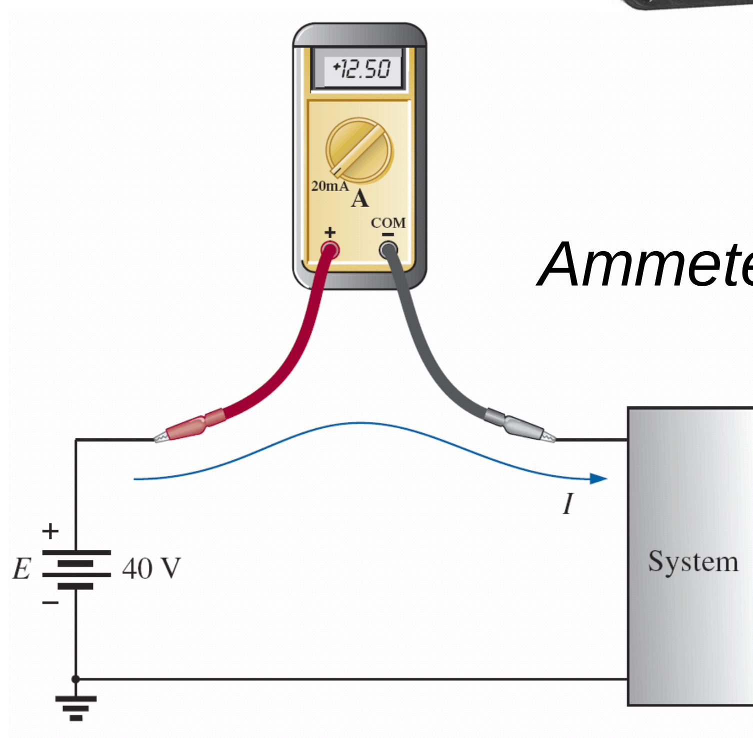

Energy
Conduction band
Energy gap
Valence band
0
(a) Insulator
Energy
Conduction band
Energy gap
Valence band
0
(b) Semiconductor
Energy
Conduction band
Overlap
Valence band
0
(c) Conductor

Ammeters and Voltmeters

- It is important to be able to measure the current and voltage levels of an operating electrical system to check its operation, isolate malfunctions, and investigate effects impossible to predict on paper.
- Ammeters are used to measure current levels; voltmeters, the potential difference between two points.



Voltmeter connection.



Ammeter connection.

Example5: Will a fuse rated at 1 A “blow” if 86 C pass through it in 1.2 min?

$$I = \frac{Q}{t} = \frac{86C}{(1.2)(60s)} = 1.194A$$ > 1 A (yes)

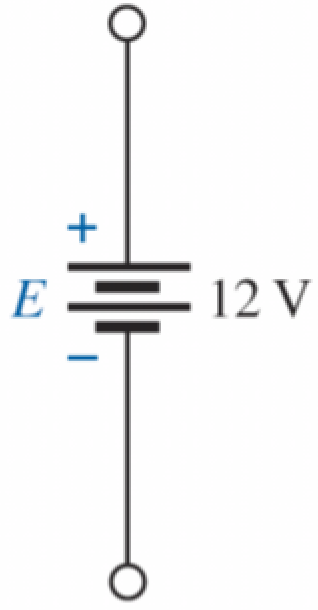
Example6: Potential difference between points in an electric current is 24 V. If 0.4 J of energy were dissipated in a period of 5 ms, what would the current be between the two points?

$$Q = \frac{W}{V} = \frac{0.4J}{24V} = 0.0167C$$

$$I = \frac{Q}{t} = \frac{0.0167C}{5\times10^{-3}s} = 3.34A$$

Voltage source

- The terminology **dc** is an *abbreviation* for **direct current**, which encompasses the various electrical systems in which there is a unidirectional (“one direction”) flow of charge.



Voltage source

- In general, dc voltage sources can be divided into three basic types:
  - Batteries (chemical action or solar energy)
  - Generators (electromechanical), and
  - Power supplies (rectification—a conversion process to be described in your electronics courses).