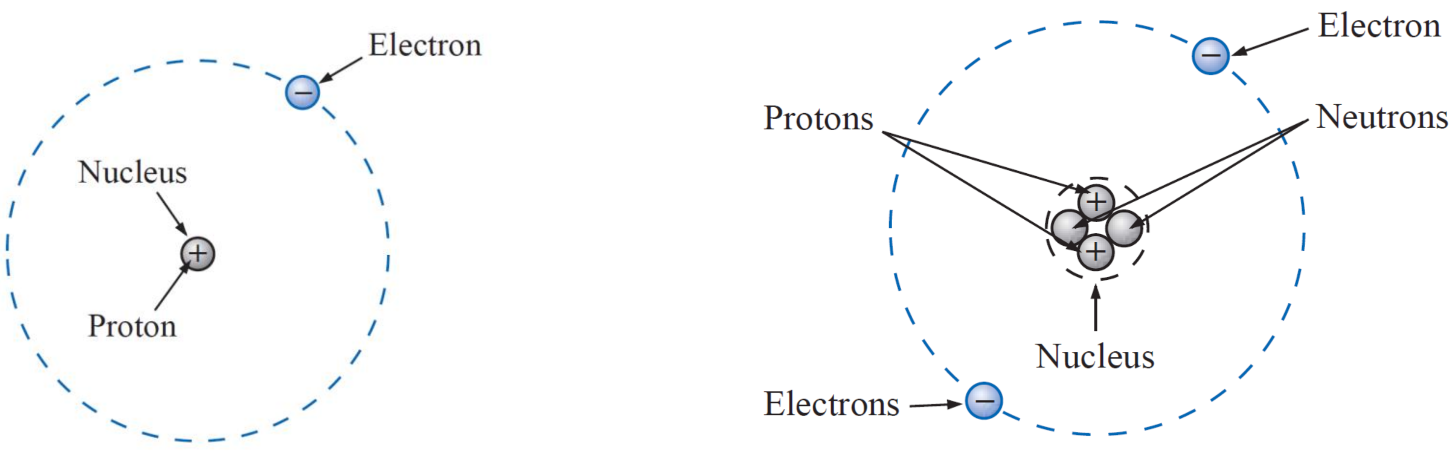
Current and Voltage

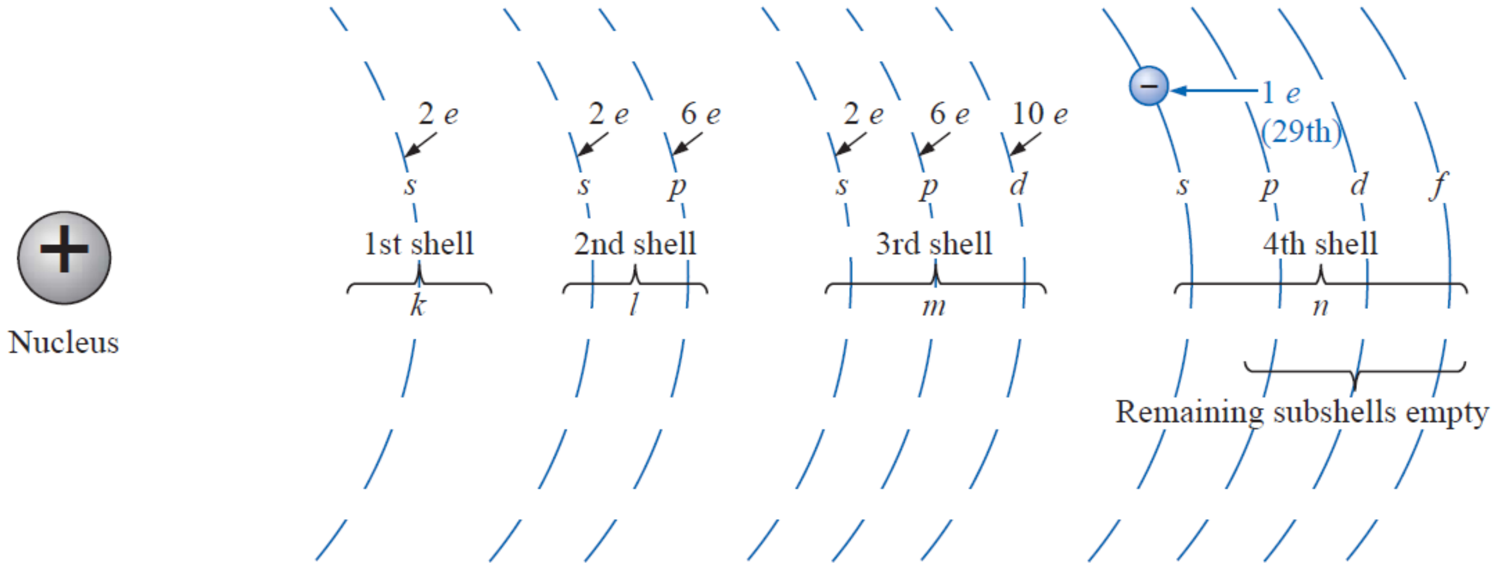
The fundamental concepts of current and voltage requires knowledge of the atom and its structure.

- Nucleus, heavy it contains:
  - **protons** positively charged
  - **neutrons** with no charge
- Orbiting negatively charged **electrons**



(a) Hydrogen atom

(b) Helium atom



The copper atom.

One electron in outer most shell it is almost free: with very small energy it becomes **free electron**.

In one cm^3 of copper there is 8.54×10^{22} such free electrons,

2.2 CURRENT

No external forces applied:

At room temperature there exists a random motion of the free electrons created by the thermal energy.

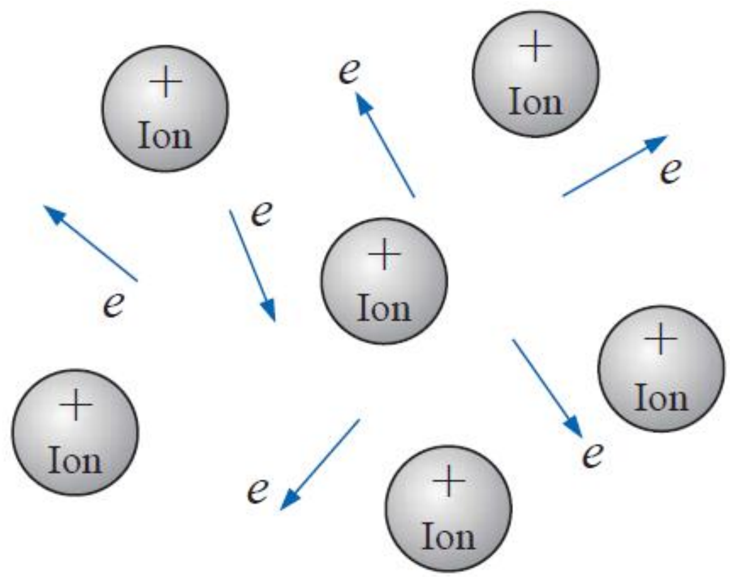
Atoms losing their electron become: **positive ions**

The free electrons are able to move within these positive ions.

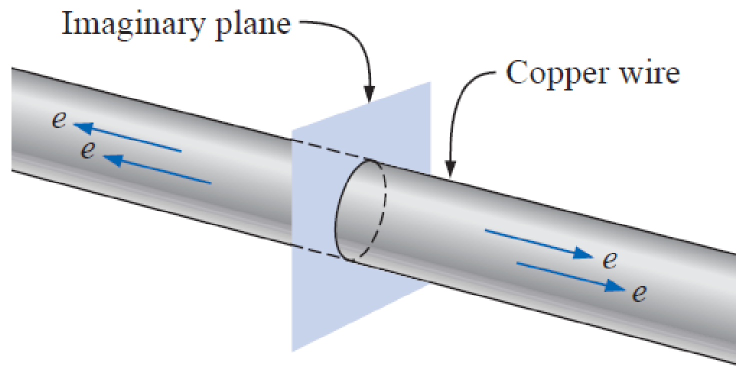
The positive ions can only oscillate around their fixed position.

The free electron is the charge carrier in a copper wire or any other solid conductor of electricity.

No External force



With no external forces applied, the net flow of charge in a conductor in any one direction is zero.



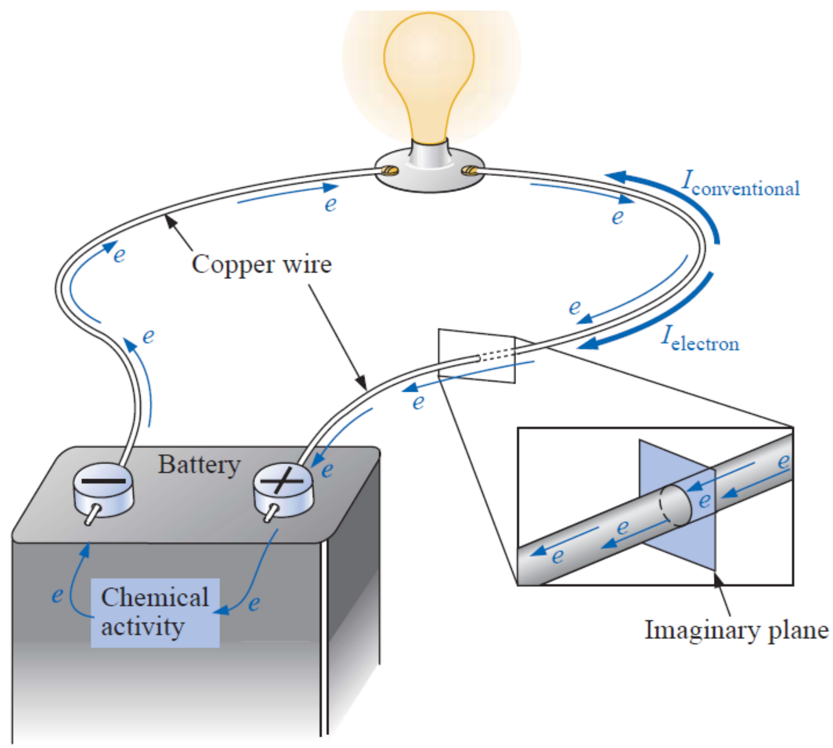
Battery: Use chemical energy to put:

- \+ charge at one terminal
- \- charge at the other

Light bulb: emit light when electrons pass through its filament.

When the circuit is closed:

- Free **e⁻** drift toward (+) terminal.
- The (-) terminal is a supply of **e⁻**
- Chemical activity of the battery:
  - Absorb **e⁻** at (+) terminal
  - Supply **e⁻** at (-) terminal



Basic electric circuit.

When 6.242×10^{18} **e⁻** drifts through the imaginary cross section in 1 s the flow of charge (current) is 1 Ampere (A).

1 Coulomb (C) = the charge of 6.242×10^{18} **e⁻**

One **e⁻** has a charge of:

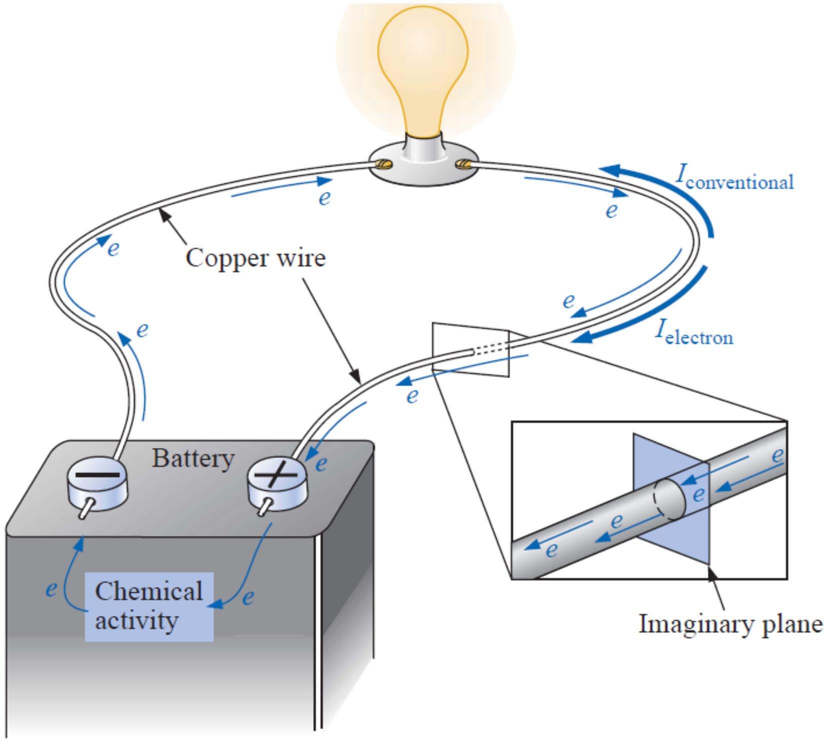
$$Q_e = \frac{1\ C}{6.242 \times 10^{18}} = 1.6 \times 10^{-19}\ C$$

The current is:

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

I = Amperes (A)
Q = Coulomb (C)
t = second (s)

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



Basic electric circuit.

Conventional flow: The direction of *I* (direction of positive charges)

Electrons flow: Inverse of conventional flow of current

EXAMPLE 2.1 The charge flowing through the imaginary surface of Fig. 2.7 is 0.16 C every 64 ms. Determine the current in amperes.

Solution: Eq. (2.2):

$$I = \frac{Q}{t} = \frac{0.16\ \text{C}}{64 \times 10^{-3}\ \text{s}} = \frac{160 \times 10^{-3}\ \text{C}}{64 \times 10^{-3}\ \text{s}} = \mathbf{2.50\ A}$$

EXAMPLE 2.2 Determine the time required for 4×10^{16} electrons to pass through the imaginary surface of Fig. 2.7 if the current is 5 mA.

Solution: Determine Q:

$$4 \times 10^{16}\ \text{ele\cancel{ct}rons} \left(\frac{1\ \text{C}}{6.242 \times 10^{18}\ \text{ele\cancel{ct}rons}} \right) = 0.641 \times 10^{-2}\ \text{C}$$

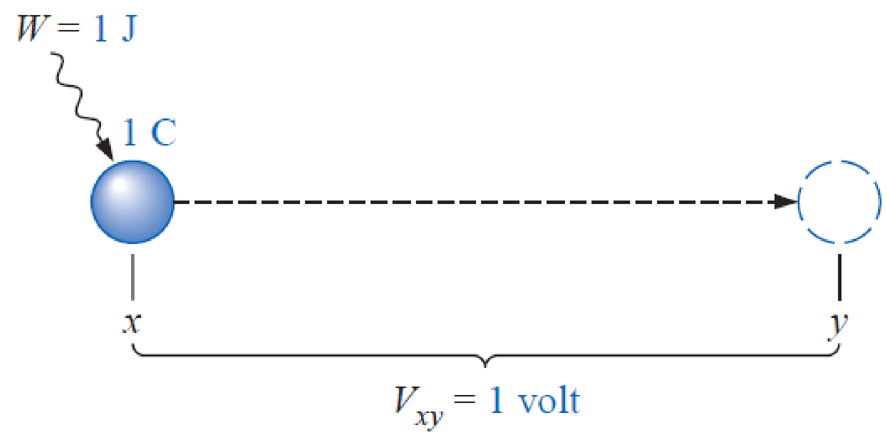
$$= 0.00641\ \text{C} = 6.41\ \text{mC}$$

Calculate t [Eq. (2.4)]:

$$t = \frac{Q}{I} = \frac{6.41 \times 10^{-3}\ \text{C}}{5 \times 10^{-3}\ \text{A}} = \mathbf{1.282\ s}$$

2.3 VOLTAGE

A potential difference of 1 volt (V) exists between two points if 1 joule (J) of energy is exchanged in moving 1 coulomb (C) of charge between the two points.



The unit of measurement is the **Volt**

Voltage is an indication of how much energy is involved in moving a charge between two points in an electrical system.

A potential difference or voltage is always measured between two points in the system. Changing either point may change the potential difference between the two points under investigation.

$$V = \frac{W}{Q}$$ (Volts, V)

$$W = QV$$ (Joules, J)

$$Q = \frac{W}{V}$$ (Coulombs, C)

EXAMPLE 2.3 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.

Solution: Eq. (2.6):

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

EXAMPLE 2.4 Determine the energy expended moving a charge of 50 μC through a potential difference of 6 V.

Solution: Eq. (2.7):

$$W = QV = (50 \times 10^{-6}\ \text{C})(6\ \text{V}) = 300 \times 10^{-6}\ \text{J} = \mathbf{300\ \mu J}$$

Distinguish between sources of voltage (batteries and the like) and losses in potential across dissipative elements:

E for voltage sources (volts)
V for voltage drops (volts)

Potential: *The voltage at a point with respect to another point in the electrical system. Typically the reference point is ground, which is at zero potential.*

Potential difference: *The algebraic difference in potential (or voltage) between two points of a network.*

Voltage: *When isolated, like potential, the voltage at a point with respect to some reference such as ground (0 V).*

Voltage difference: *The algebraic difference in voltage (or potential) between two points of the system. A voltage drop or rise is as the terminology would suggest.*

Electromotive force (emf): *The force that establishes the flow of charge (or current) in a system due to the application of a difference in potential. This term is not applied that often in today's literature but is associated primarily with sources of energy.*

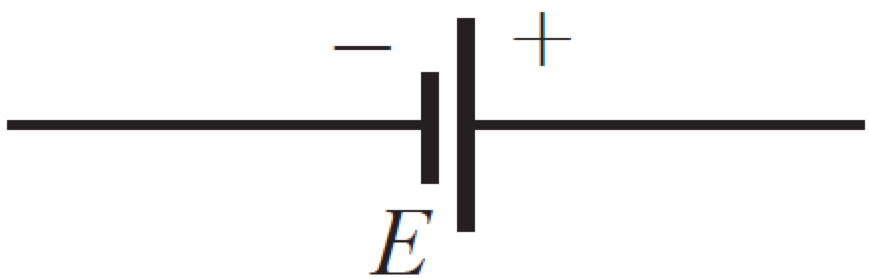
2.4 FIXED (dc) SUPPLIES

dc ≡ direct current ⟹ the flow of charge only in one direction
⟹ current only in one direction

dc Voltage Sources

Dc voltage sources can be divided into three broad categories:

(1) batteries (chemical action),
(2) generators (electromechanical), and
(3) power supplies (rectification).



Symbol for a dc voltage source.

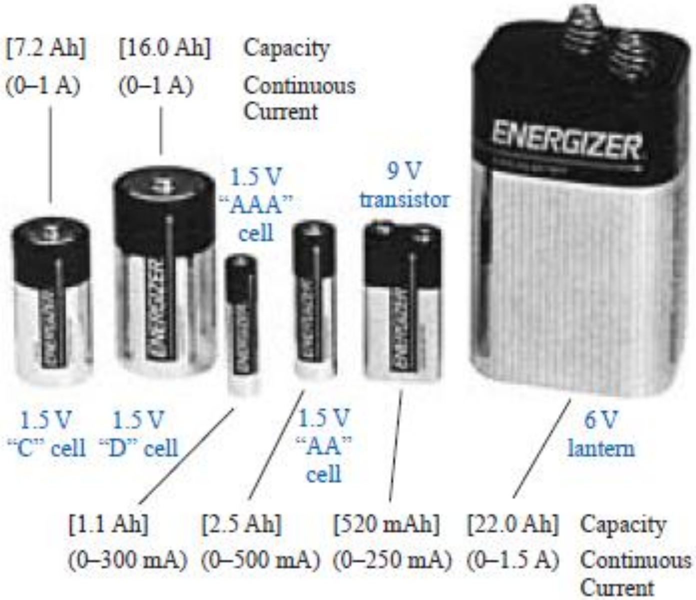
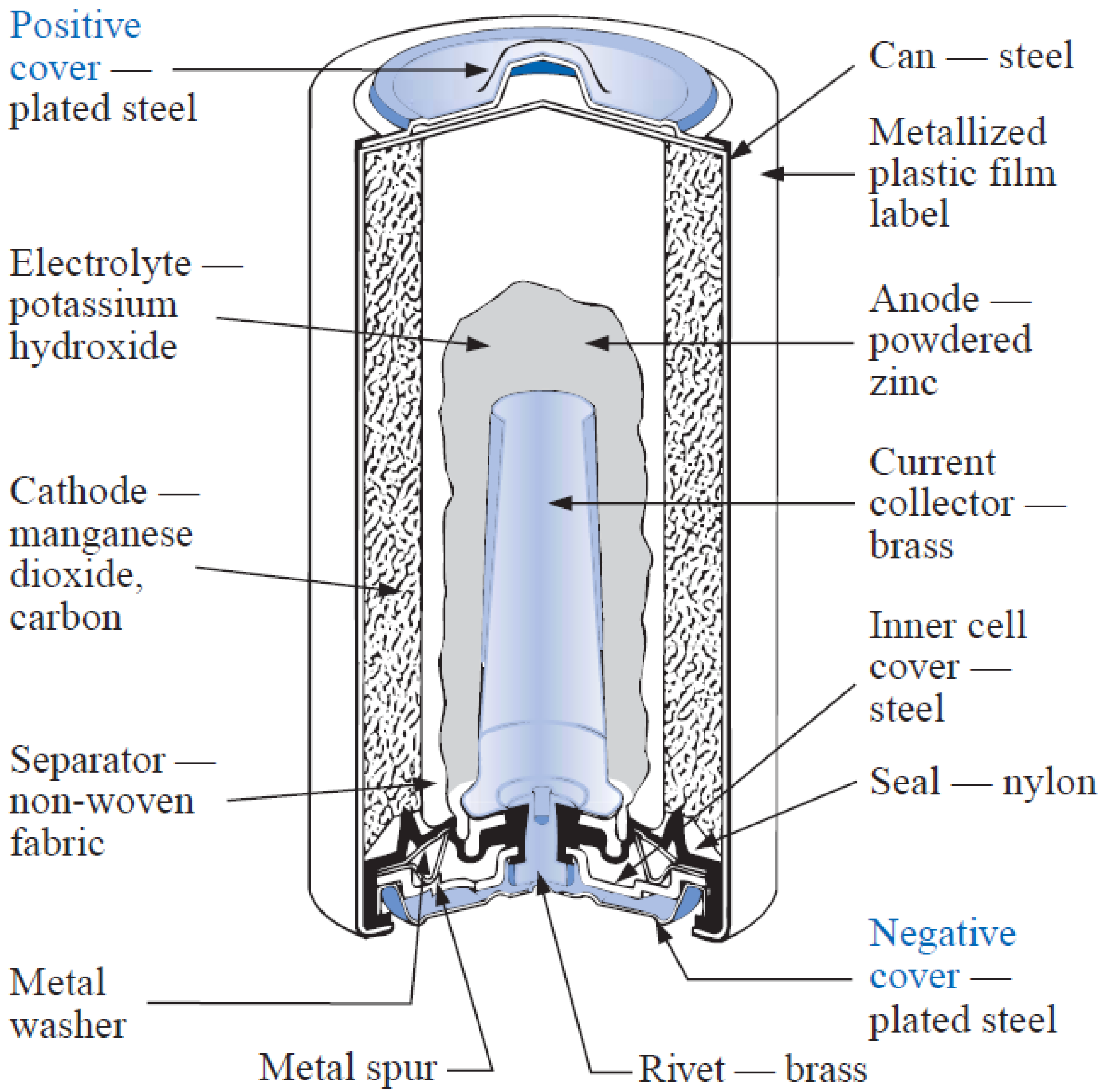


FIG. 2.15
Rechargeable nickel-cadmium batteries. (Courtesy of Eveready Batteries.)

(1) Battery is a source of electrical energy developed through the conversion of chemical or solar energy

a. Primary type
b. Secondary type (rechargeable)

Each battery has: “ + ” and “ - ” electrode and an electrolyte:



Ampere-Hour Rating

Batteries have a capacity rating given in ampere-hours (Ah) or (mAh).

A battery with 100 **Ah** rating will theoretically provide steady current of:

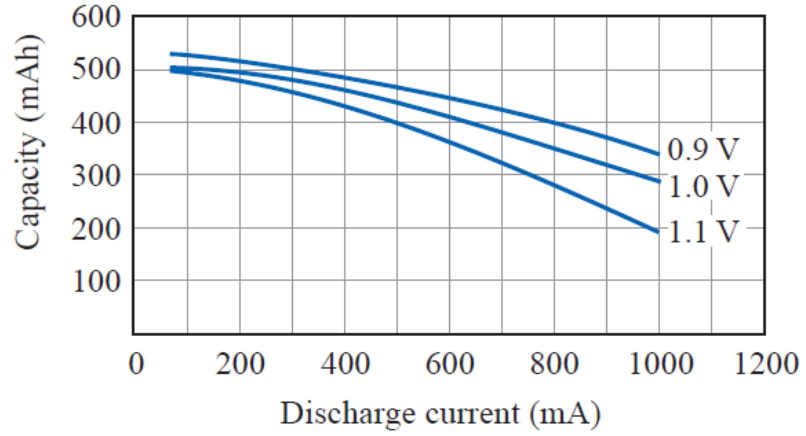
1 A for 100 h, or
2 A for 50 h, or
10 A for 10 h,
and so on, …. as determined by the following equation:

$$\text{Life (hours)} = \frac{\text{ampere-hour rating (Ah)}}{\text{amperes drawn (A)}}$$

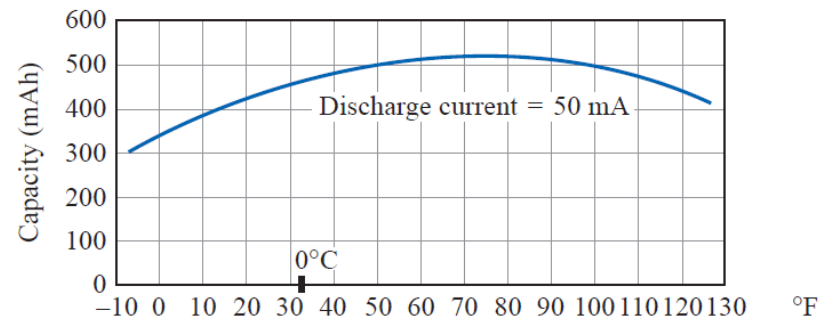
The rating is affected by two factors:

1) Temperature
2) Rate of discharge (current)

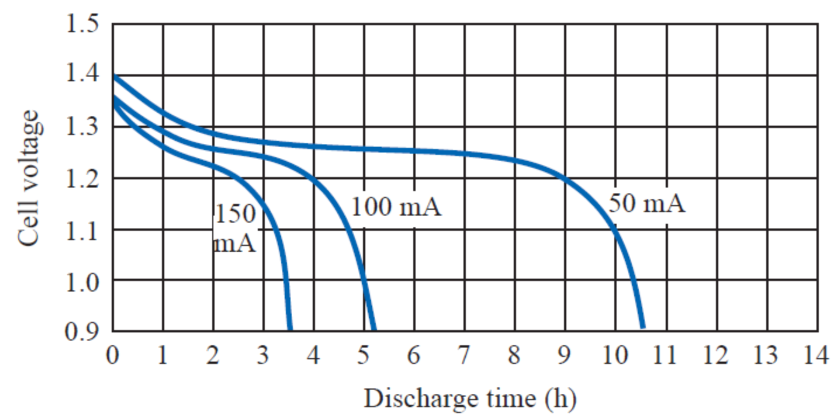
The capacity of a dc battery decreases with an increase in the current demand



The capacity of a dc battery decreases at relatively (compared to room temperature) low and high temperatures.



The terminal voltage of a dc battery decreases with the length of the discharge time at a particular drain current.



Generators $\Longrightarrow$ 120 V or 240 V

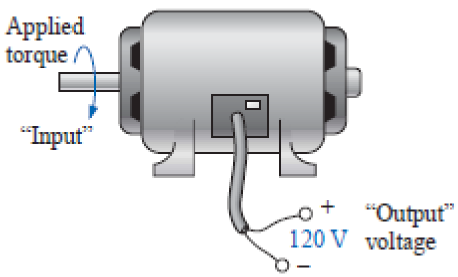


FIG. 2.20
dc generator.

Power supplies

From (AC outlet) $\Longrightarrow$ rectification and filtering $\Longrightarrow$ dc

FIG. 2.21
dc laboratory supply. (Courtesy of Leader Instruments Corporation.)

They must provide three connections: **“ + ”** and **“ - ”** and **“ground”**

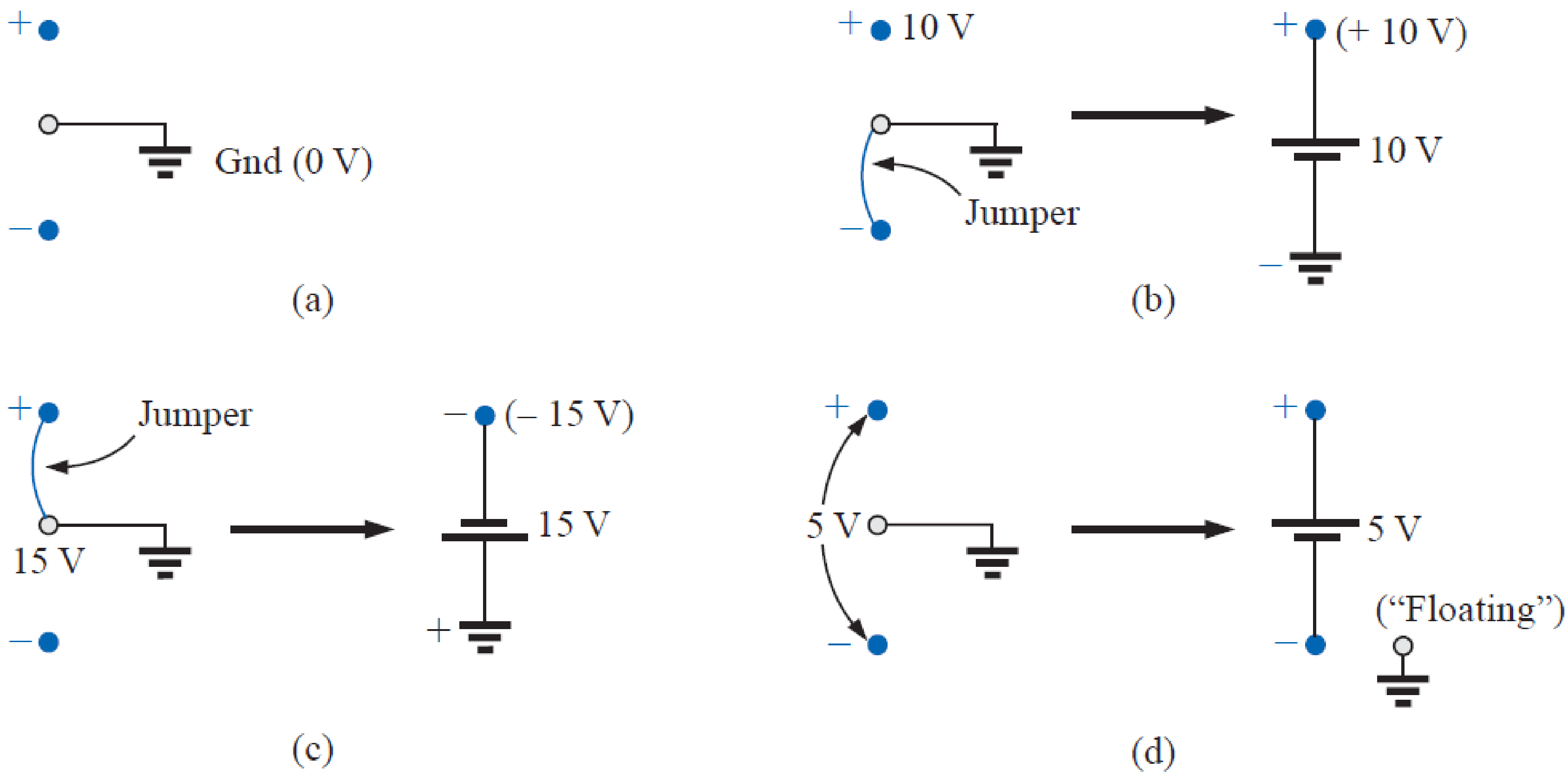


FIG. 2.22

dc laboratory supply: (a) available terminals; (b) positive voltage with respect to (w.r.t.) ground; (c) negative voltage w.r.t. ground; (d) floating supply.

dc Current Sources

dc voltage ⟹ ***fixed voltage for any current drawn***

the current source will supply, ideally, a fixed current to an electrical system, even though there may be variations in the terminal voltage as determined by the system,

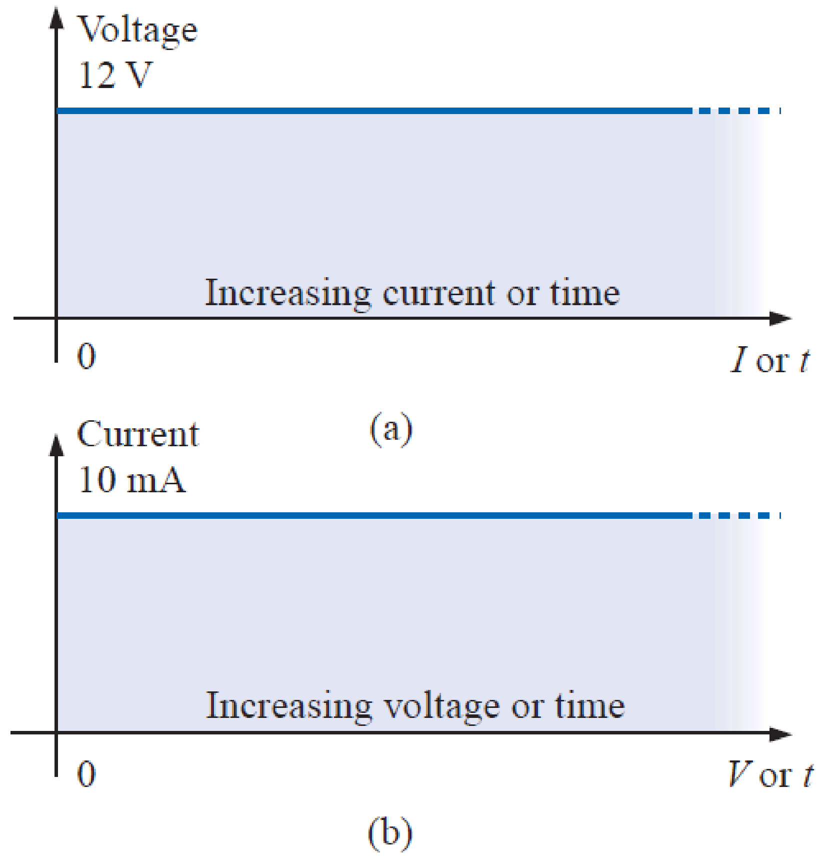


FIG. 2.23
Terminal characteristics: (a) ideal voltage source; (b) ideal current source.

CONDUCTORS AND INSULATORS

Conductors ***are those materials that permit a large flow of electrons with very little external force (voltage) applied.***

Good conductors typically have only one electron in the valence (most distant from the nucleus) ring.

Insulators ***are those materials that have very few free electrons and require a large applied potential (voltage) to establish a measurable current level.***

Insulator will break down (permit charge to flow through it) if a sufficiently large potential is applied across it.