EEE-1131: Basic Electrical Circuits

Fundamental Electrical Concept and Measuring Units

Courtesy: Md. Sarwar Pervez

Syllabus

Course Code: EEE-1131
Course Title: Basic Electrical Circuits

Fundamental electrical concepts and measuring units.
Direct current: voltage, current, resistance and power. Laws of electrical circuits and methods of network analysis; Network theorem, KCl, KVl superposition theorem, Theremin's theorem, Norton theorem, Max Power transfer theorem Introduction to magnetic circuits.

Alternating current: instantaneous and r.m.s. current, voltage and power, average power for various combinations of R, L and C circuits, phasor representation of sinusoidal quantities.

Fundamental Electrical Concept and Measuring Units

ENERGY

Energy is defined as the ability to do work. For instance, we're all familiar with light, heat, and electrical energy.

TYPES OF ENERGY

Potential Energy, Kinetic Energy, Mechanical Energy, Thermal Energy, Light Energy, Chemical Energy, Nuclear Energy, **Electrical Energy**

Why Electrical Energy is chosen over other form of energy?

- **Transmission**
- **Distribution**
- **Conversion**

Fundamental Electrical Concept and Measuring Units

What Is Electrical Energy?

Electrical energy is a form of energy resulting from the flow of **electric charge.**

Unit of the electrical energy : **Joule (or watt-second).**
Example : **Lightning**, **batteries** and even **electric eels** are examples of electrical energy in action!

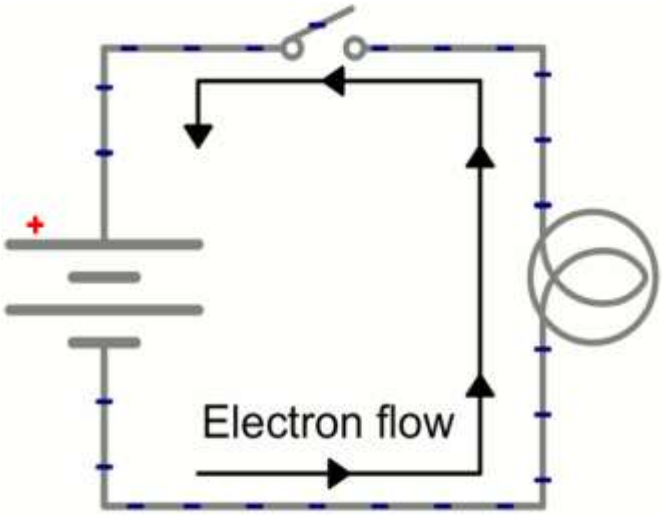
What is a Circuit? A circuit is a loop through which current can flow.

Components of a Circuit

Voltage Source : Energy sources are the active elements which supply electrical energy to the circuits

Load : An electrical **load** is an electrical component or portion of a **circuit** that consumes (active) electric power.

Conductor /Conductive Path : a conductor is an object or type of material that allows the flow of charge



Courtesy: Md. Sarwar Pervez

Fundamental Electrical Concept and Measuring Units

Atomic Structure (3 min 46 sec)

Rutherford Atomic Model

1. The positively charged particles and most of the mass of an atom was concentrated in an extremely small volume. He called this region of the atom as a nucleus.
2. Rutherford model proposed that the negatively charged electrons surround the nucleus of an atom. He also claimed that the electrons surrounding the nucleus revolve around it with very high speed in circular paths. He named these circular paths as orbits.
3. Electrons being negatively charged and nucleus being a densely concentrated mass of positively charged particles are held together by a strong electrostatic force of attraction.

Main Points of the Bohr Model

1. Electrons orbit the nucleus in orbits that have a set size and energy.
2. The energy of the orbit is related to its size. The lowest energy is found in the smallest orbit.
3. Radiation is absorbed or emitted when an electron moves from one orbit to another.

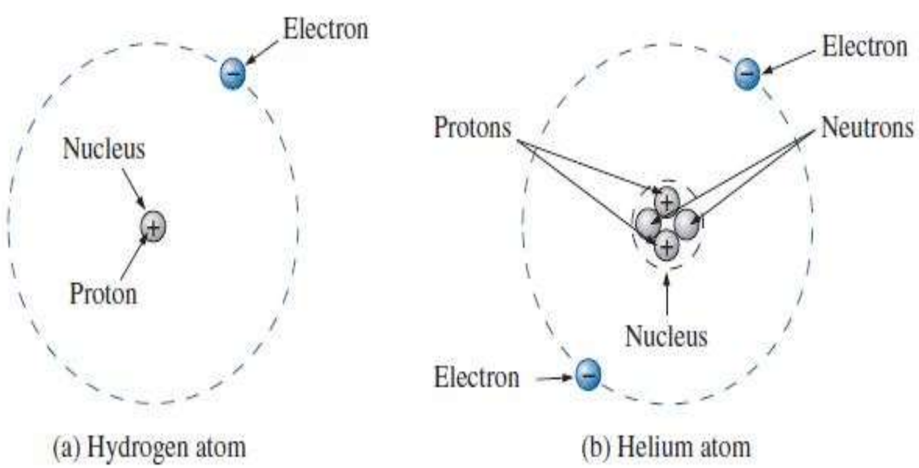


FIG. 2.1
Hydrogen and helium atoms.

Fundamental Electrical Concept and Measuring Units

Charge (6 min 32 sec)

Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

Unit Unit of Charge is **Coulomb (C)**

Types of Charge

Positive charge (Proton)
Negative Charge (electrons)

Properties of Charge :

1.Like Charges repel while unlike charges attract each other.
2.Charge is transferrabel.
3.Charge is always associated with mass

Fundamental Electrical Concept and Measuring Units

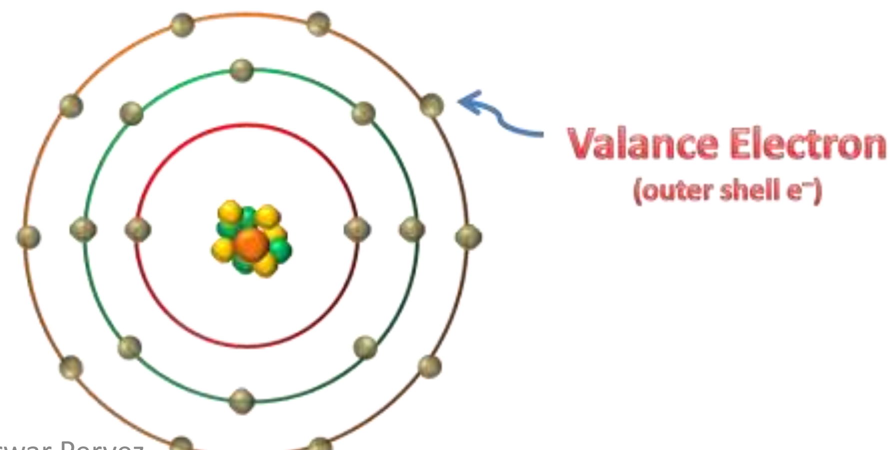
Properties of Charge :

1. The coulomb is a large unit for charges. In 1 C of charge, there are $1/(1.602 \times 10^{-19}) = 6.24 \times 10^{18}$ electrons. Thus realistic or laboratory values of charges are on the order of pC, nC, or μ C.

2. Charge is quantized :According to experimental observations, the only charges that occur in nature are integral multiples of the electronic charge $e = -1.602 \times 10^{-19}$ C.

3. The law of conservation of charge states that charge can neither be created nor destroyed, only transferred. Thus the algebraic sum of the electric charges in a system does not change

Valence Band,
Valence electrons
Conduction band ,
Conduction electrons or free electrons.
(1min 40 sec)

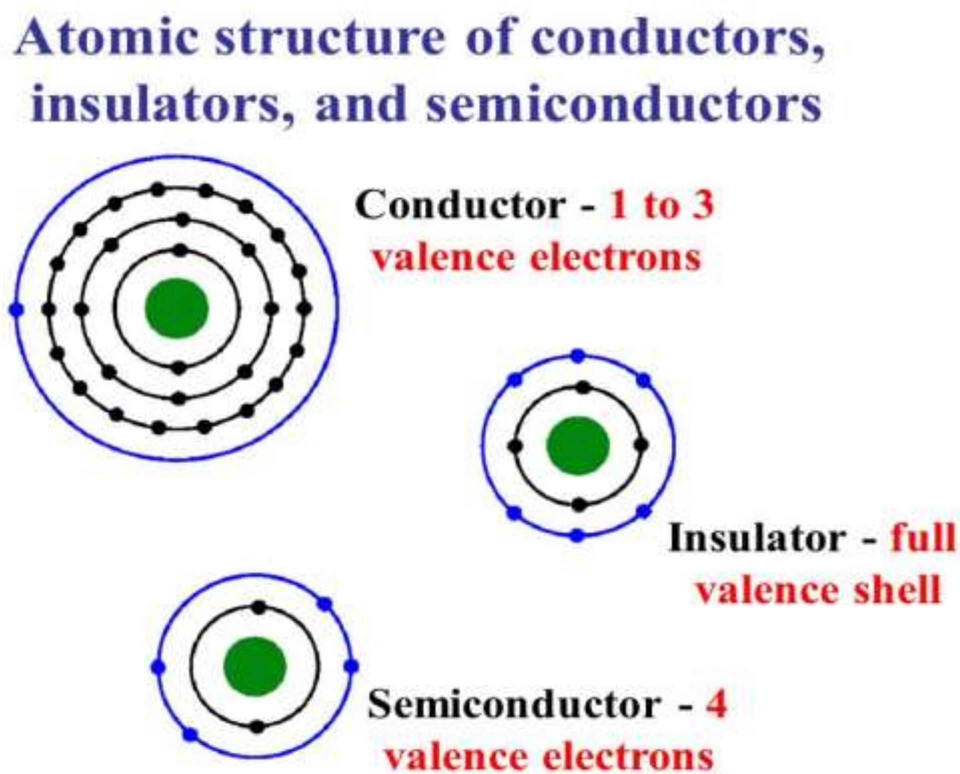


Courtesy: Md. Sarwar Pervez

Fundamental Electrical Concept and Measuring Units

Types of materials :

- Metals (< 4 electrons)
- Insulators (> 4 electrons)
- Semiconductors (4 electrons)



Courtesy: Md. Sarwar Pervez

Fundamental Electrical Concept and Measuring Units

Electric Current (1min 5sec)

Electric current Theory (2 min 34 sec)

This is the rate at which free electrons can be made to **drift** through a materials in a particular direction.

" Electric current is the time rate of change of charge, measured in amperes (A).

mathematically, I = dq / dt

$$\boxed{I = \frac{Q}{t}} \qquad \begin{aligned} I &= \text{amperes (A)} \\ Q &= \text{coulombs (C)} \\ t &= \text{time (s)} \end{aligned}$$

Voltage

Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).

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.

The defining equation is

$$\boxed{V = \frac{W}{Q}} \qquad \begin{aligned} V &= \text{volts (V)} \\ W &= \text{joules (J)} \\ Q &= \text{coulombs (C)} \end{aligned} \tag{2.2}$$

Fundamental Electrical Concept and Measuring Units

Voltage Sources:

An electromotive force (emf) is a force that establishes the flow of charge (or current) in a system due to the application of a difference in potential.

DC voltage sources can be divided into three basic types

(1) batteries (chemical action or solar energy),
(2) generators (electromechanical),and
(3) power supplies

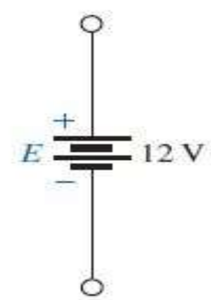


FIG. 2.11
Standard symbol for a dc voltage source.

Fundamental Electrical Concept and Measuring Units

POWER

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

We write this relationship as

$$\boxed{p \triangleq \frac{dw}{dt}} \tag{1.5}$$

where p is power in watts (W), w is energy in joules (J), and t is time in seconds (s). From Eqs. (1.1), (1.3), and (1.5), it follows that

$$p = \frac{dw}{dt} = \frac{dw}{dq} \cdot \frac{dq}{dt} = vi \tag{1.6}$$

or

$$\boxed{p = vi} \tag{1.7}$$

Fundamental Electrical Concept and Measuring Units

Circuit Analysis

Circuit analysis is the process of determining voltages across (or the currents through) the elements of the circuit

Circuit Element

An element is the basic building block of a circuit. An electric circuit is simply an interconnection of the elements.

Types of Circuit Element

There are two types of elements found in electric circuits:
passive elements and
active elements.

Active Elements

An active element is capable of generating energy Typical active elements include generators, batteries, diode, transistor and operational amplifiers

Passive Elements

Passive element is not capable of generating energy Examples of passive elements are resistors, capacitors, and inductors.

Fundamental Electrical Concept and Measuring Units

Type of sources

independent sources and
Dependent sources.

Ideal Independent Sources

An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit elements.

Ideal dependent Sources

An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current

Fundamental Electrical Concept and Measuring Units

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)

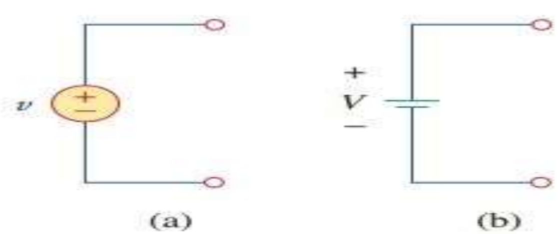


Figure 1.11
Symbols for independent voltage sources: (a) used for constant or time-varying voltage, (b) used for constant voltage (dc).

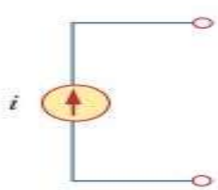


Figure 1.12
Symbol for independent current source.

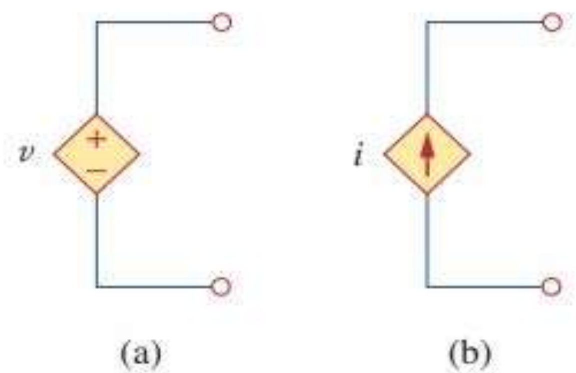


Figure 1.13
Symbols for: (a) dependent voltage source, (b) dependent current source.

Fundamental Electrical Concept and Measuring Units

Measuring Units

Physical quantity	Symbol	Unit	Symbol	Measure device
Current	I	Ampere	A	Amperemeter
Voltage	U	Volt	V	Voltmeter
Power	P	Watt	W	Powermeter
Resistance	R	Ohm	Ω	Ohmmeter
Capacitance	C	Farad	F	Capacitance meter
Inductance	L	Henry	H	Inductance meter
Frequency	f	Hertz	Hz	Oscilloscope
Period	T	Second	s	Oscilloscope
Charge	Q	Coulomb	C	Charge meter
Conductance	G	Siemens	S	Conductivity meter

RESISTOR

Resistor:

Resistor is a passive electrical component that reduces the electric current.

Resistance

The resistor's ability to reduce the current is called **resistance**

Symbol : Represented by R

Unit : ohms (symbol: Ω).

The resistance of any material is due primarily to four factors:

1.Material
2. Length
3. Cross-sectional area
4. Temperature of the material

The first three elements are related by the following basic equation:

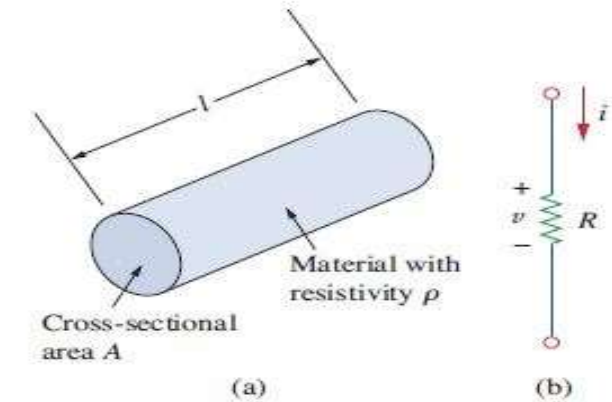
$$\boxed{R = \rho \frac{l}{A}}$$

ρ = CM-Ω/ft at T = 20°C
l = feet
A = area in circular mils (CM)

RESISTORS

Resistivity

Resistivity is a measure of the resistance of a given size of a specific material to electrical conduction



CONDUCTANCE

By finding the reciprocal of the resistance of a material, we have a measure of how well the material conducts electricity. The quantity is called conductance, has the symbol G, and is measured in siemens (S) (note Fig. 3.31). In equation form, conductance is

$$\boxed{G = \frac{1}{R}} \qquad \text{(siemens, S)}$$

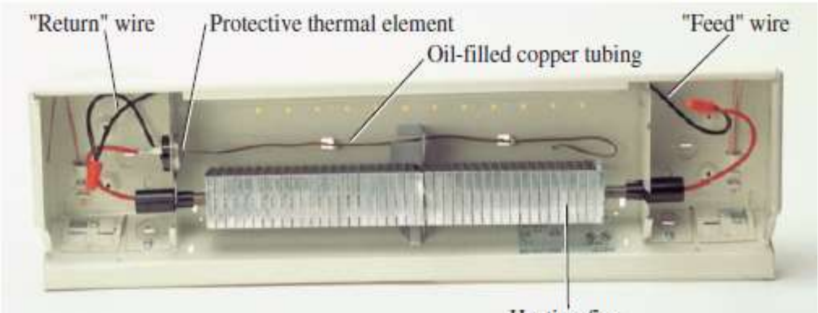
PRACTICAL APPLICATION OF RESISTOR

Resistance can be used to perform a variety of tasks, from heating to measuring the stress or strain on a supporting member of a structure. In general, resistance is a component of every electrical or electronic application.

Electric Baseboard Heating Element

One of the most common applications of resistance is in household fixtures such as toasters and baseboard heating where the heat generated by current passing through a resistive element is employed to perform a useful function.

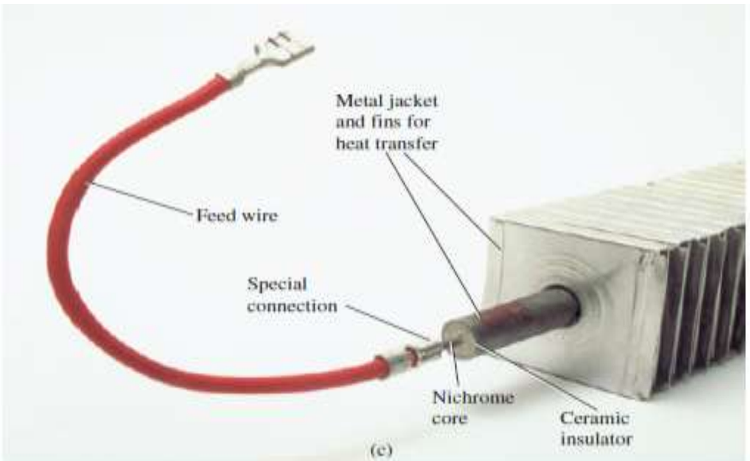
(a)

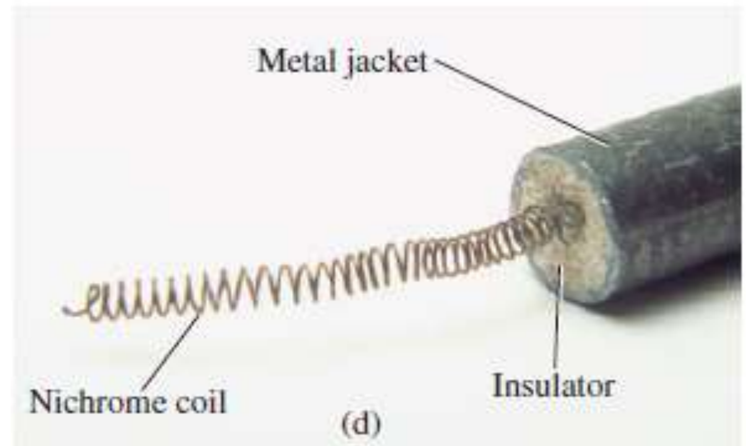


(b)

PRACTICAL APPLICATION OF RESISTOR

Electric Baseboard Heating Element





Electric baseboard: (a) 2-ft section; (b) interior; (c) heating element; (d) nichrome coil.

PRACTICAL APPLICATION OF THE MOTION OF ELECTRONS

TV Picture Tube

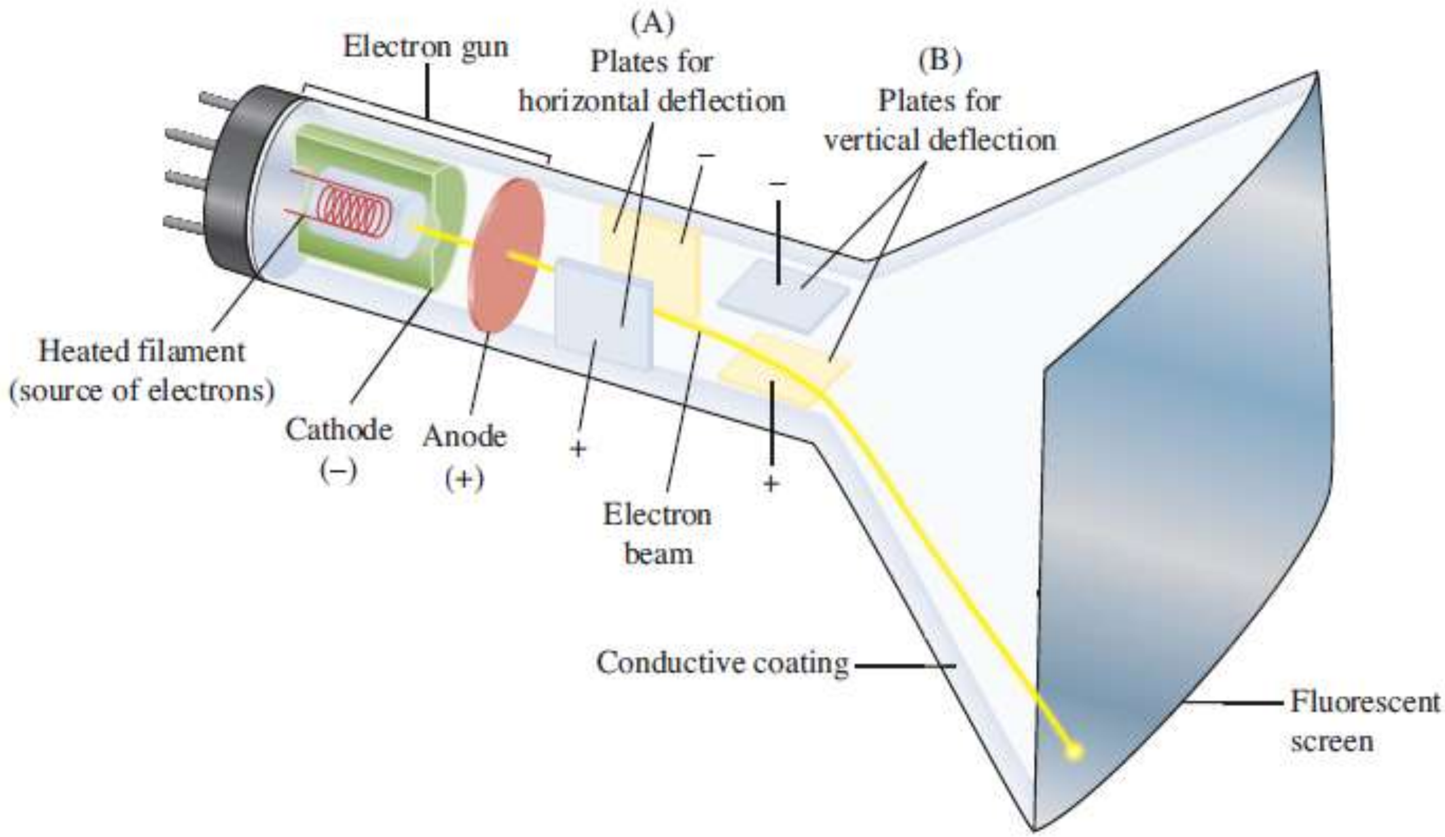


Figure 1.17
Cathode-ray tube.

PRACTICAL APPLICATION OF THE MOTION OF ELECTRONS

Electricity Bills

how an electric utility company charges their customers. The cost of electricity depends upon the amount of energy consumed in kilowatt-hours (kWh). (Other factors that affect the cost include demand and power factors; we will ignore these for now.) However, even if a consumer uses no energy at all, there is a minimum service charge the customer must pay because it costs money to stay connected to the power line. As energy consumption increases, the cost per kWh drops. It is interesting to note the average monthly consumption of household appliances for a family of five, shown in Table 1.3.

TABLE 1.3

Typical average monthly consumption of household appliances.

Appliance	kWh consumed	Appliance	kWh consumed
Water heater	500	Washing machine	120
Freezer	100	Stove	100
Lighting	100	Dryer	80
Dishwasher	35	Microwave oven	25
Electric iron	15	Personal computer	12
TV	10	Radio	8
Toaster	4	Clock	2

PRACTICAL APPLICATION OF THE MOTION OF ELECTRONS

Electricity Bills

Example Problem-1: A homeowner consumes 700 kWh in January. Determine the electricity bill for the month using the following residential rate schedule:

Base monthly charge of $12.00.

First 100 kWh per month at 16 cents/kWh.

Next 200 kWh per month at 10 cents/kWh.

Over 300 kWh per month at 6 cents/kWh.

PRACTICAL APPLICATION OF THE MOTION OF ELECTRONS

Electricity Bills

Example Problem-1: A homeowner consumes 700 kWh in January. Determine the electricity bill for the month using the following residential rate schedule:
Base monthly charge of $12.00.
First 100 kWh per month at 16 cents/kWh.
Next 200 kWh per month at 10 cents/kWh.
Over 300 kWh per month at 6 cents/kWh.

Solution:

We calculate the electricity bill as follows.
Base monthly charge =$12.00
First 100 kWh @ $0.16/k Wh = $16.00
Next 200 kWh @ $0.10/k Wh =$20.00
Remaining 400 kWh @ $0.06/k Wh = $24.00
Total charge _=$72.00
Average cost _
$72/(100 +200 +400)= 10.2 cents/kWh