Automation

The word ‘Automation’ is derived from greek words “Auto”(self) and “Matos” (moving). Automation therefore is the mechanism for systems that “move by itself”. However, apart from this original sense of the word, automated systems also achieve significantly superior performance than what is possible with manual systems, in terms of power, precision and speed of operation.

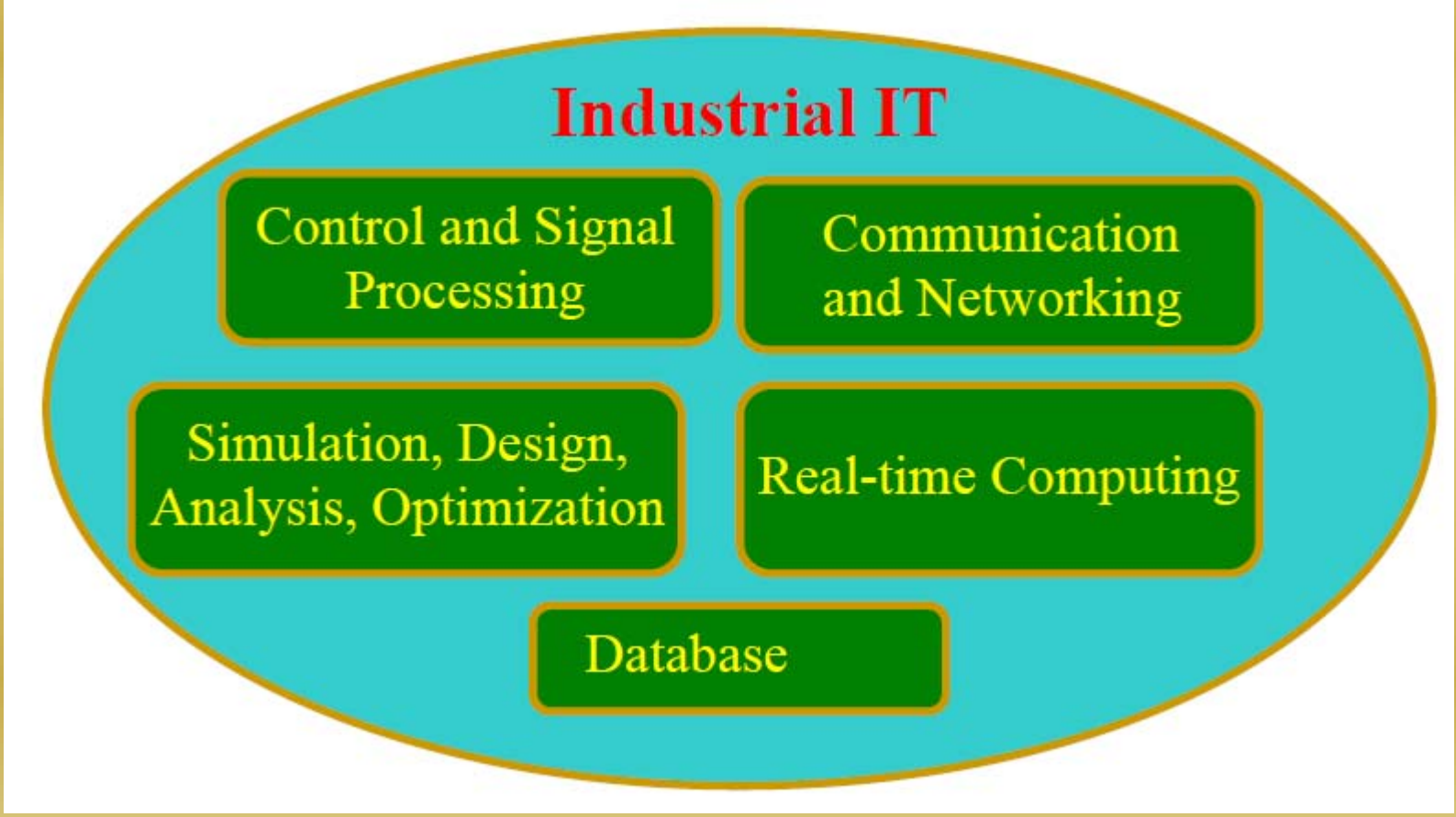
Definition: ***Automation is a set of technologies that results in operation of machines and systems without significant human intervention and achieves performance superior to manual operation***

Control

- It is perhaps correct to expect that the learner for this course has already been exposed toa course on Control Systems, which is typically introduced in the final or pre-final year of an undergraduate course in Engineering in India. The word control is therefore expected to be familiar and defined as under.

- ***Definition: Control is a set of technologies that achieves desired patterns of variations of operational parameters and sequences for machines and systems by providing the input signals necessary.***

Industrial Automation



Role of automation in industry

- Manufacturing processes, basically, produce finished product from raw/unfinished material using energy, manpower and equipment and infrastructure.
- Since an industry is essentially a “systematic economic activity”, the fundamental objective of any industry is to make profit.
- Roughly speaking,

Profit = (Price/unit – Cost/unit) x Production Volume

So profit can be maximised by producing *good quality products, which may sell at higher price, in larger volumes with less production cost and time.*

Types of Automation Systems

- *Fixed Automation: It is used in high volume production with dedicated equipment, which has a fixed set of operation and designed to be efficient for this set. Continuous flow and Discrete Mass Production systems use this automation. e.g. Distillation Process, Conveyors, Paint Shops, Transfer lines etc. A process using mechanized machinery to perform fixed and repetitive operations in order to produce a high volume of similar parts.*

- *Programmable Automation: It is used for a changeable sequence of operation and configuration of the machines using electronic controls. However, non-trivial programming effort may be needed to reprogram the machine or sequence of operations. Investment on programmable equipment is less, as production process is not changed frequently. It is typically used in Batch process where job variety is low and product volume is medium to high, and sometimes in mass production also. e.g. in Steel Rolling Mills, Paper Mills etc.*

- *Flexible Automation: It is used in Flexible Manufacturing Systems (FMS) which is invariably computer controlled. Human operators give high-level commands in the form of codes entered into computer identifying product and its location in the sequence and the lower level changes are done automatically. Each production machine receives settings/instructions from computer. These automatically loads/unloads required tools and carries out their processing instructions. After processing, products are automatically transferred to next machine.*

- *Integrated Automation: It denotes complete automation of a manufacturing plant, with all processes functioning under computer control and under coordination through digital information processing. It includes technologies such as computer-aided design and manufacturing, computer-aided process planning, computer numerical control machine tools, flexible machining systems, automated storage and retrieval systems, automated material handling systems such as robots and automated cranes and conveyors, computerized scheduling and production control.*

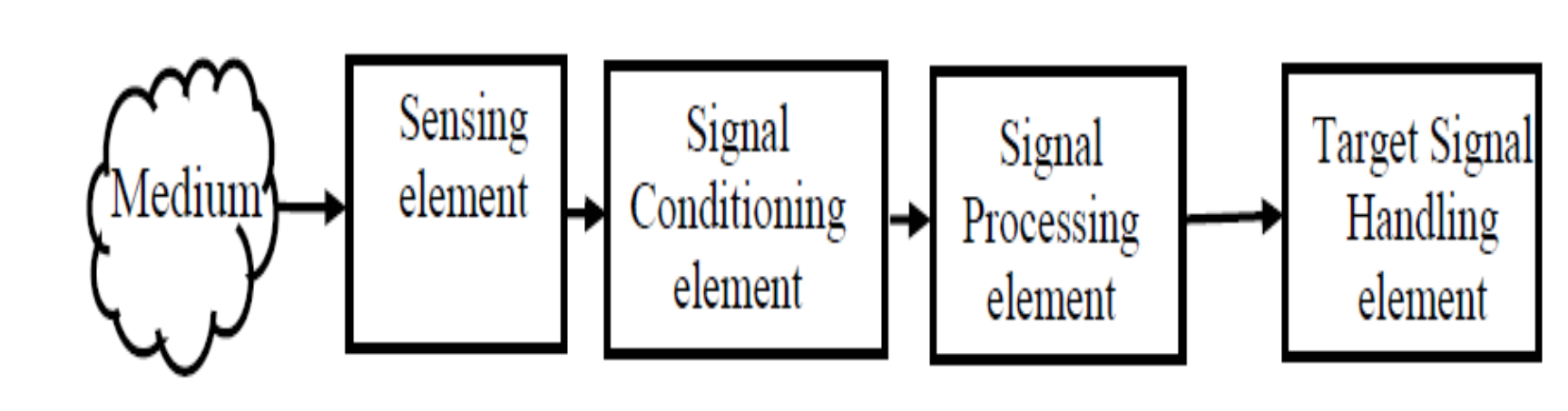
The Functional Elements of Industrial Automation

- An Industrial Automation System consists of numerous elements that perform a variety of functions related to Instrumentation, Control, Supervision and Operations Management related to the industrial process. These elements may also communicate with one another to exchange information necessary for overall coordination and optimized operation of the plant/factory/process. Below, we classify the major functional elements typically found in IA systems and also describe the nature of technologies that are employed to realize the functions.

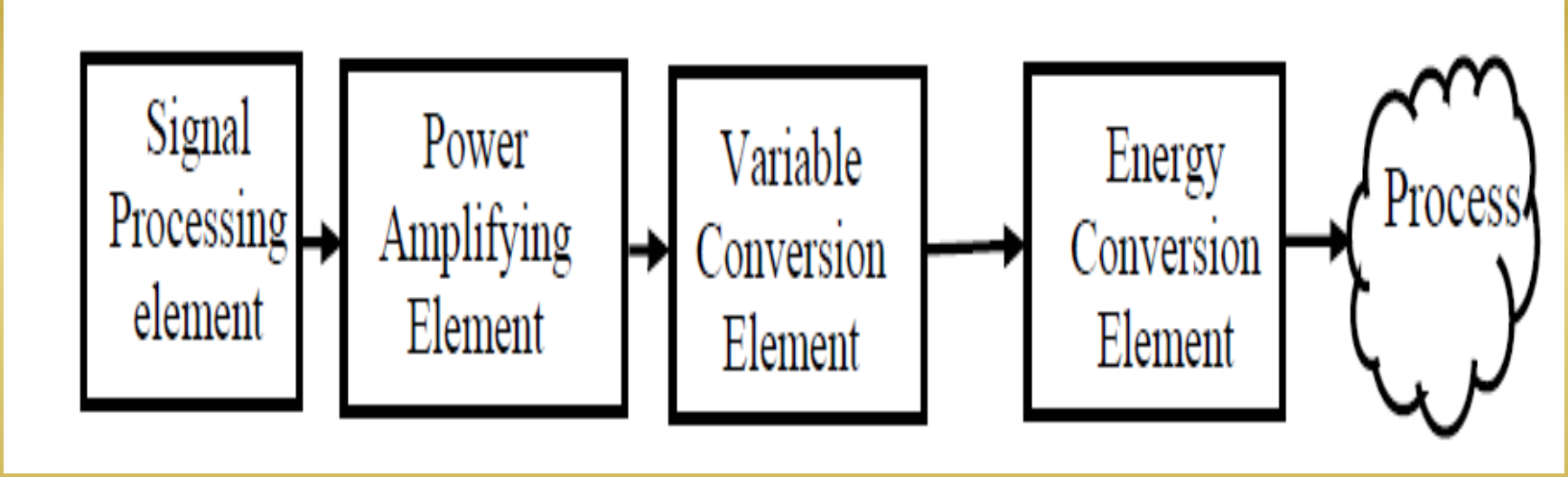
Sensing and Actuation Elements

- These elements interface directly and physically to the process equipment and machines. The sensing elements translate the physical process signals such as temperature, pressure or displacement to convenient electrical or pneumatic forms of information, so that these signals can be used for analysis, decisions and finally, computation of control inputs. These computed control inputs, which again are in convenient electrical or pneumatic forms of information, need to be converted to physical process inputs such as, heat, force or flow-rate, before they can be applied to effect the desired changes in the process outputs. Such physical control inputs are provided by the actuation elements.

Industrial Sensors and Instrument Systems



Industrial Actuator Systems



Industrial Control Systems

- By industrial control systems, we denote the sensors systems, actuator systems as a controller. Controllers are essentially (predominantly electronic, at times pneumatic/hydraulic) elements that accept command signals from human operators or Supervisory Systems, as well as feedback from the process sensors and produce or compute signals that are fed to the actuators.

Sequence / Logic Control

- Many control applications do not involve analog process variables, that is, the ones which can assume a continuous range of values, but instead variables that are set valued, that is they only assume values belonging to a finite set. The simplest examples of such variables are binary variables, that can have either of two possible values, (such as 1 or 0, on or off, open or closed etc.). These control systems operate by turning on and off switches, motors, valves, and other devices in response to operating conditions and as a function of time. Such systems are referred to as sequence/logic control systems.

Supervisory Control

- Supervisory control performs at a hierarchically higher level over the automatic controllers, which controls smaller subsystems.
- Supervisory control systems perform, typically the following functions:

♦ **Set point computation**: Set points for important process variables are computed depending on factors such as nature of the product, production volume, mode of processing. This function has a lot of impact on production volume, energy and quality and efficiency.

♦ **Performance Monitoring / Diagnostics**: Process variables are monitored to check for possible system component failure, control loop detuning, actuator saturation, process parameter change etc. The results are displayed and possibly archived for subsequent analysis.

- **Start up / Shut down / Emergency Operations** : Special discrete and continuous control modes are initiated to carry out the intended operation, either in response to operator commands or in response to diagnostic events such as detected failure modes.

♦ **Control Reconfiguration / Tuning**: Structural or Parametric redesign of control loops are carried out, either in response to operator commands or in response to diagnostic events such as detected failure modes. Control reconfigurations may also be necessary to accommodate variation of feedback or energy input e.g. gas fired to oil fired.

♦ **Operator Interface**: Graphical interfaces for supervisory operators are provided, for manual supervision and intervention.

What is a PLC ?

- PLC = Programmable Logic Controller
- Major components: power supply, processor, I/O, and network connection
- Processor uses its own operating system and application development software
- I/O cards interface with standard real-world electrical signals
  - 110 VAC inputs and outputs for motor starters
  - 24 VDC inputs for switches
  - 4-20mA for levels, pressures and flows
  - RTD and thermocouple cards for temperatures
  - 4-20 mA outputs to control valves and VFD speeds
- Ethernet networking available

What is a PLC?
(Continued)

In general, each manufacturer offers two PLC types:

- Modular design for larger applications
- Integrated "brick" design with fixed I/O for smaller applications

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History of the PLC

- Invented in the early 1970s by Modicon Corporation
- Based originally on a General Motors Specification to replace relays
- Meant to reduce capital and changeover costs
- Analog capability was added by the early 1980s

What is Ladder Logic?

- Graphic language meant to look like Relay Logic Diagrams
- Primarily comprised of:
  - Relay coils and contacts
  - Timers
  - Compares
  - Math functions
  - Program control
  - File functions

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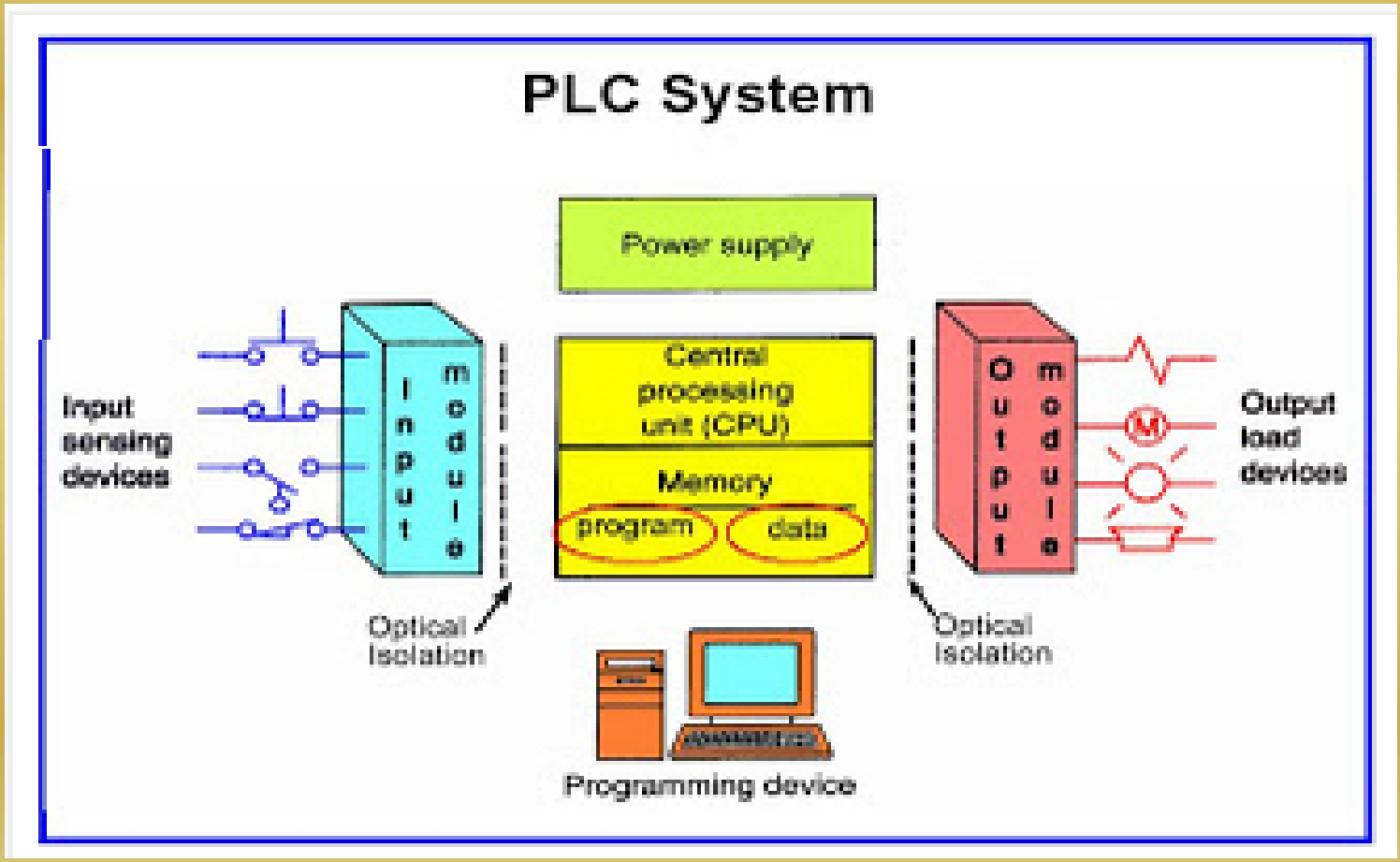
What is Function Block Programming?

- Graphic language meant to look like flow diagrams
- Preferred by chemical/process types
- Primarily comprised of:
  - Input and Output control
  - Logic functions (AND, OR, XOR)
  - Scaling, filters and control functions (PID)
  - Math functions
  - Compare functions (< > =)
  - Timers
  - Program control

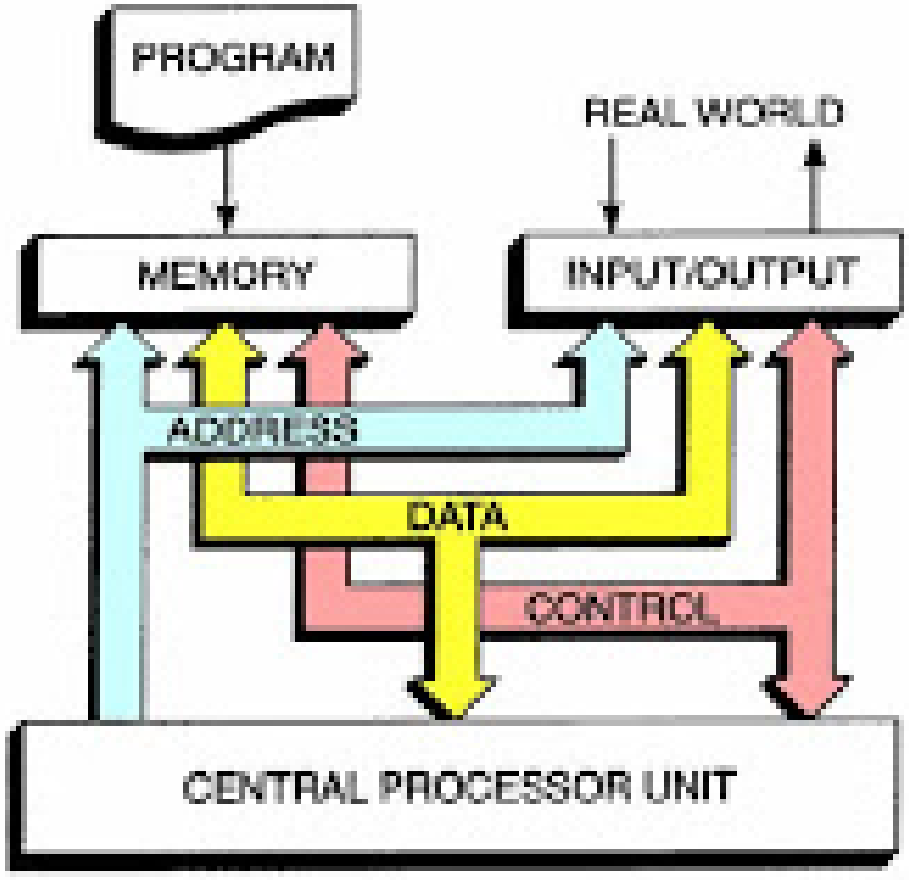
Current Major US PLC Brands

- Allen Bradley
- GE Fanuc
- Siemens
- Modicon

Over View


PLC System
Power supply
Central processing unit (CPU)
Memory
program
data
Input module
Output module
Input sensing devices
Output load devices
Optical Isolation
Optical Isolation
Programming device

Architecture



- Size
- Application
- Memory
- Sinking
- Sourcing

Networking

- **Computer network** A collection of computing devices that are connected in various ways in order to communicate and share resources

  Usually, the connections between computers in a network are made using physical wires or cables

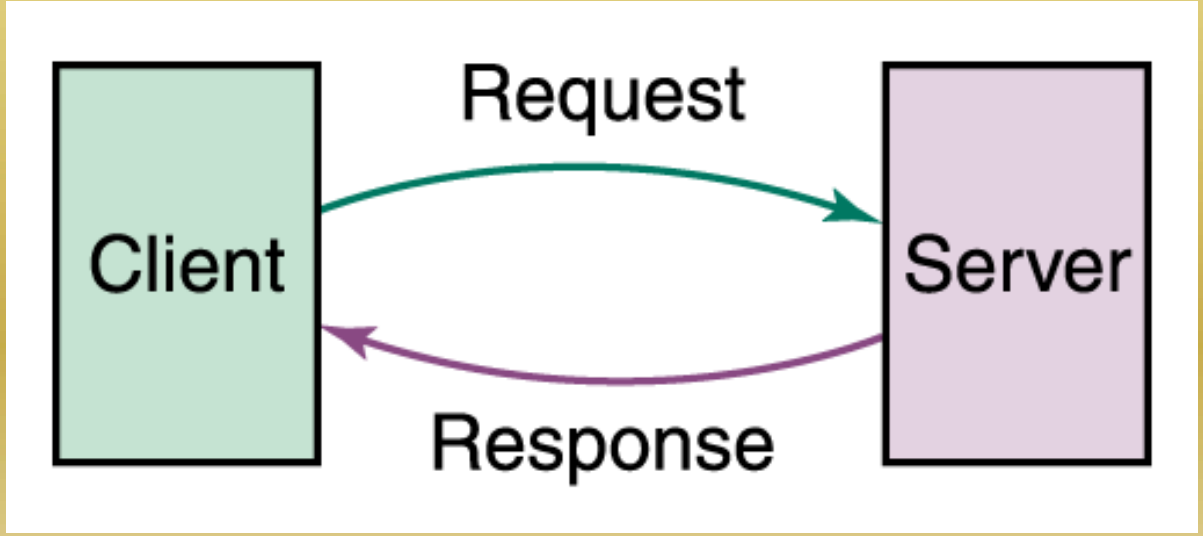
    However, some connections are **wireless**, using radio waves or infrared signals

Networking

- The generic term **node** or **host** refers to any device on a network
- **Data transfer rate** The speed with which data is moved from one place on a network to another
- Data transfer rate is a key issue in computer networks

Networking

- Computer networks have opened up an entire frontier in the world of computing called the **client/server model**



Client/Server interaction

Networking

- **File server** A computer that stores and manages files for multiple users on a network
- **Web server** A computer dedicated to responding to requests (from the browser client) for web pages

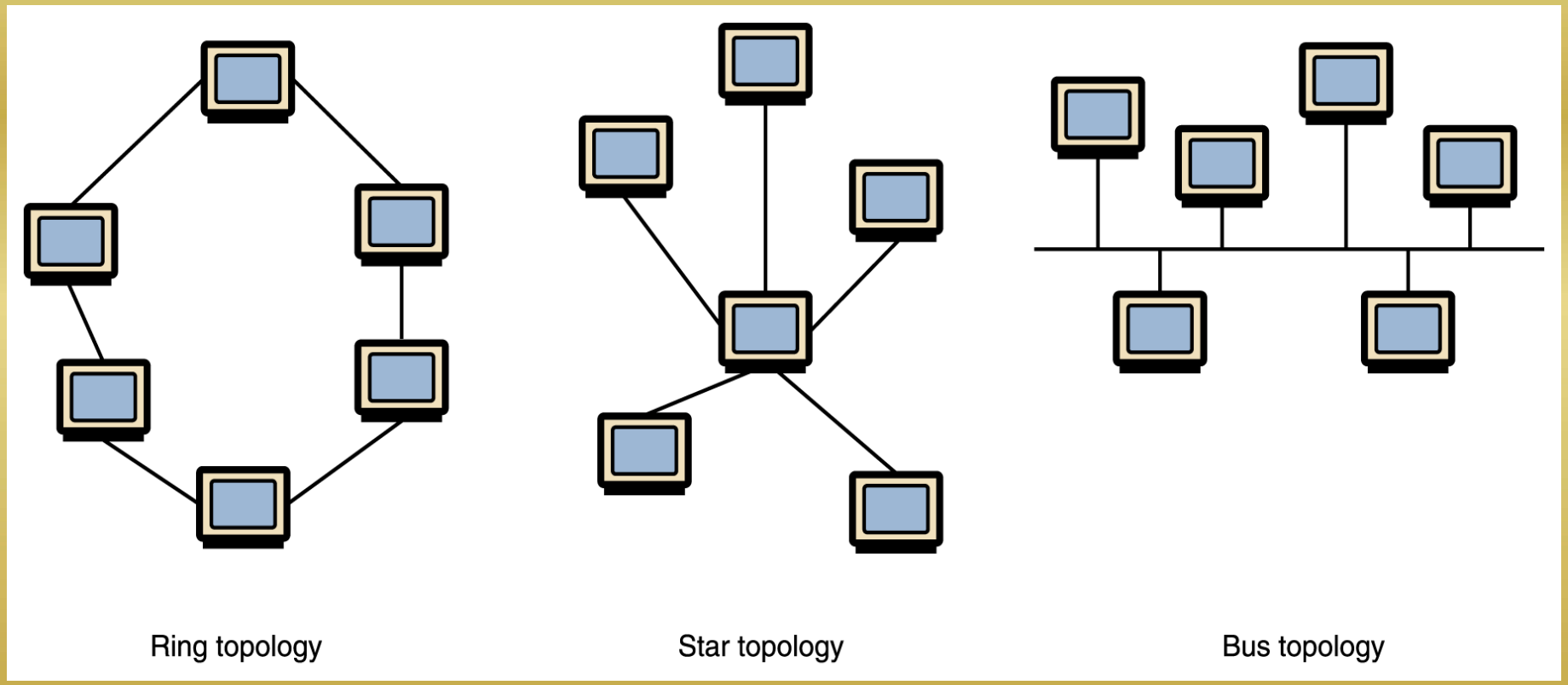
Types of Networks

- **Local-area network (LAN)** A network that connects a relatively small number of machines in a relatively close geographical area

Types of Networks

- Various configurations, called topologies, have been used to administer LANs
  - **Ring topology** A configuration that connects all nodes in a closed loop on which messages travel in one direction
  - **Star topology** A configuration that centers around one node to which all others are connected and through which all messages are sent
  - **Bus topology** All nodes are connected to a single communication line that carries messages in both directions

Types of Networks



Various network topologies

- A bus technology called **Ethernet** has become the industry standard for local-area networks

Types of Networks

- **Wide-area network (WAN)** A network that connects two or more local-area networks over a potentially large geographic distance
  - Often one particular node on a LAN is set up to serve as a **gateway** to handle all communication going between that LAN and other networks
  - Communication between networks is called internetworking
  - The **Internet**, as we know it today, is essentially the ultimate wide-area network, spanning the entire globe

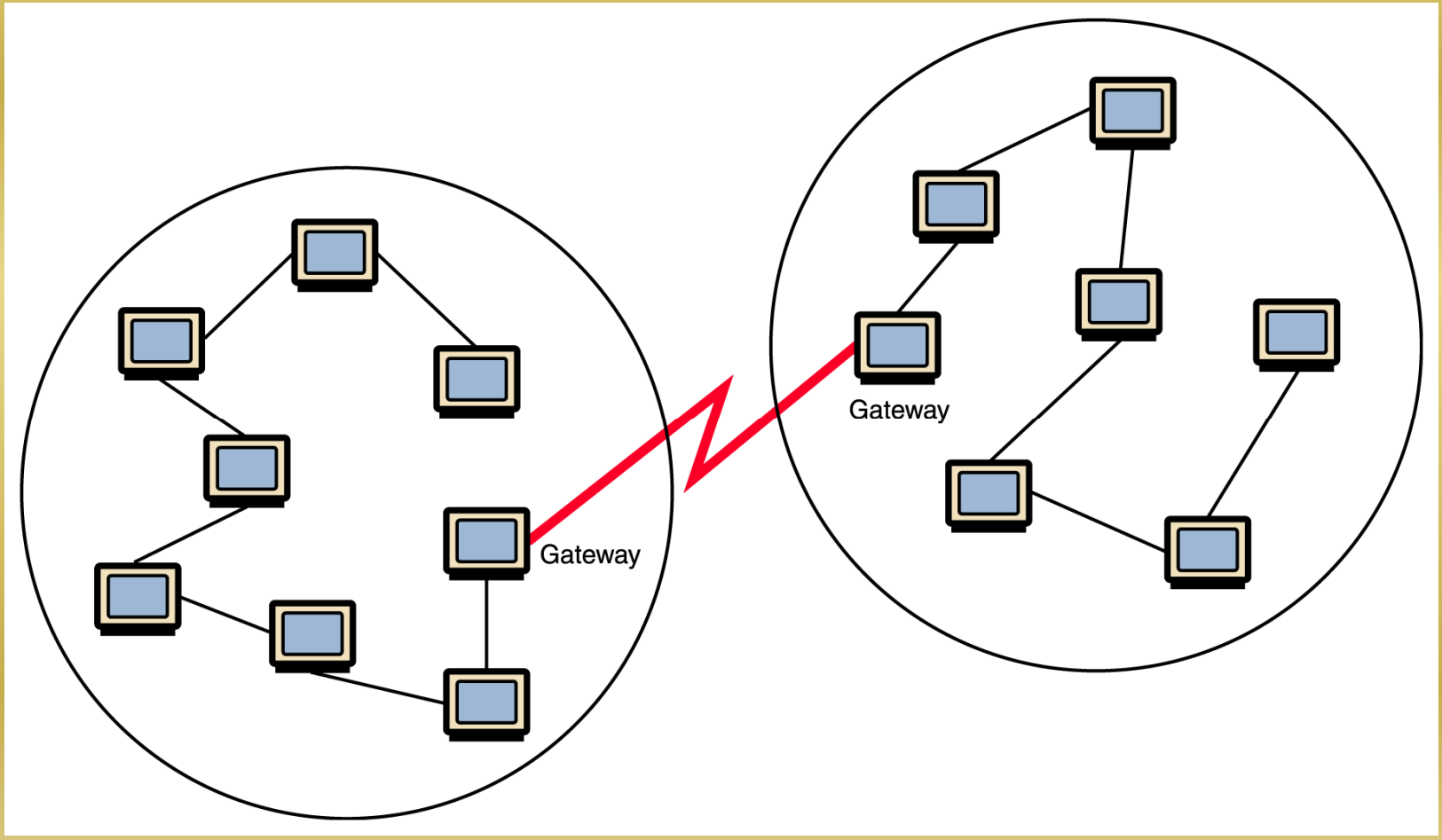
Types of Networks

- **Metropolitan-area network (MAN)** The communication infrastructures that have been developed in and around large cities

So, who owns the Internet?

Well, nobody does. No single person or company owns the Internet or even controls it entirely. As a wide-area network, it is made up of many smaller networks. These smaller networks are often owned and managed by a person or organization. The Internet, then, is really defined by how connections can be made between these networks.

Types of Networks



Local-area networks connected across a distance to create a wide-area network

Internet Connections

- **Internet backbone** A set of high-speed networks that carry Internet traffic

  These networks are provided by companies such as AT&T, GTE, and IBM
- **Internet service provider (ISP)** A company that provides other companies or individuals with access to the Internet

Internet Connections

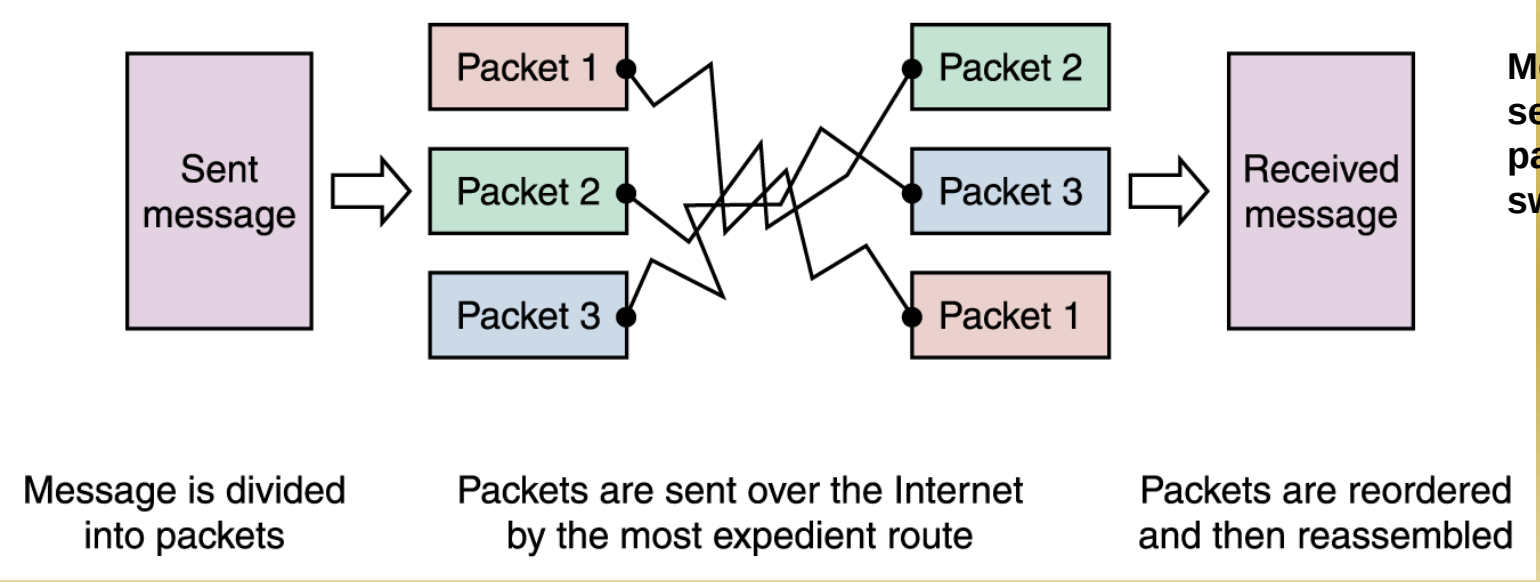
- There are various technologies available that you can use to connect a home computer to the Internet
  - A **phone modem** converts computer data into an analog audio signal for transfer over a telephone line, and then a modem at the destination converts it back again into data
  - A **digital subscriber line** **(DSL)** uses regular copper phone lines to transfer digital data to and from the phone company's central office
  - A **cable modem** uses the same line that your cable TV signals come in on to transfer the data back and forth

Internet Connections

- **Broadband** A connection in which transfer speeds are faster than 128 bits per second
  - DSL connections and cable modems are broadband connections
  - The speed for **downloads** (getting data from the Internet to your home computer) may not be the same as **uploads** (sending data from your home computer to the Internet)

Packet Switching

- To improve the efficiency of transferring information over a shared communication line, messages are divided into fixed-sized, numbered **packets**
- Network devices called routers are used to direct packets between networks



Messages sent by packet switching

Open Systems

- **Proprietary system** A system that uses technologies kept private by a particular commercial vendor

  One system couldn't communicate with another, leading to the need for

- **Interoperability** The ability of software and hardware on multiple machines and from multiple commercial vendors to communicate

  Leading to

- **Open systems** Systems based on a common model of network architecture and a suite of protocols used in its implementation

Open Systems

7	Application layer
6	Presentation layer
5	Session layer
4	Transport layer
3	Network layer
2	Data Link layer
1	Physical layer

The layers of the OSI Reference Model

- The International Organization for Standardization (ISO) established the **Open Systems Interconnection (OSI) Reference Model**
- Each layer deals with a particular aspect of network communication

7 Application
6 Presentation
5 Session
4 Transport
3 Network
2 Data Link
1 Physical

OSI REFERENCE MODEL

1. Physical Layer

a) Convert the logical 1's and 0's coming from layer 2 into electrical signals.

b) Transmission of the electrical signals over a communication channel.

Main topics:

- Transmission mediums
- Encoding
- Modulation
- RS232 and RS422 standards
- Repeaters
- Hubs (multi-port repeater)

2. Data Link Layer

a) Error control to compensate for the imperfections of the physical layer.

b) Flow control to keep a fast sender from swamping a slow receiver.

Main topics:

- Framing methods
- Error detection and correction methods
- Flow control
- Frame format
- IEEE LAN standards
- Bridges
- Switches (multi-port bridges)

OSI REFERENCE MODEL

3. Network Layer

a) Controls the operation of the subnet.

b) Routing packets from source to destination.

c) Logical addressing.

Main topics:

- Internetworking
- Routing algorithms
- Internet Protocol (IP) addressing
- Routers

OSI REFERENCE MODEL

4. Transport Layer

a) Provides additional Quality of Service.

b) Heart of the OSI model.

Main topics:

- Connection-oriented and connectionless services
- Transmission Control Protocol (TCP)
- User Datagram Protocol (UDP)

OSI REFERENCE MODEL

7 Application

6 Presentation

5 Session

4 Transport

3 Network

2 Data Link

1 Physical

5. Session Layer

a) Allows users on different machines to establish *sessions* between them.

b) One of the services is managing dialogue control.

c) Token management.

d) Synchronization.

6. Presentation Layer

a) Concerned with the syntax and semantics of the information.

b) Preserves the meaning of the information.

c) Data compression.

d) Data encryption.

7. Application Layer

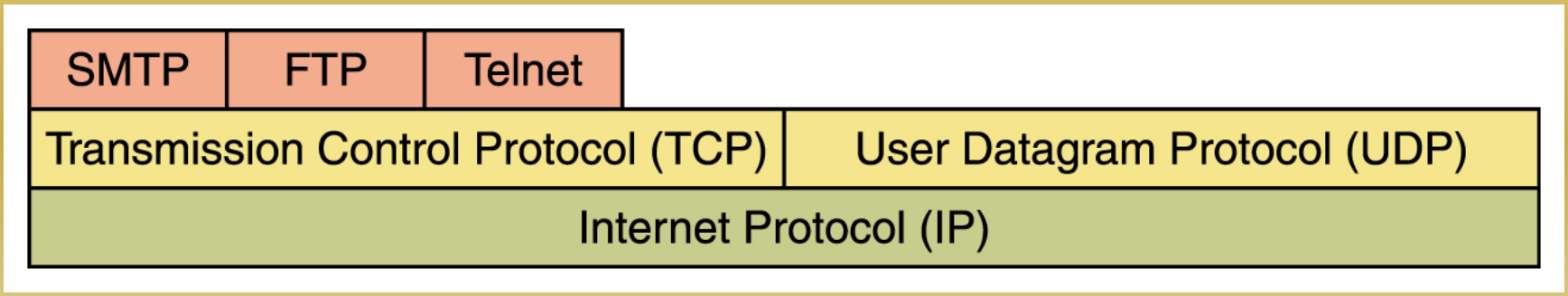
a) Provides protocols that are commonly needed.

Main topics:

- File Transfer Protocol (FTP)
- HyperText Transfer Protocol (HTTP)
- Simple Mail Transfer Protocol (SMTP)
- Simple Network Management Protocol (SNMP)
- Network File System (NFS)
- Telnet

Network Protocols

- Network protocols are layered such that each one relies on the protocols that underlie it
- Sometimes referred to as a **protocol stack**



Layering of key network protocols

Introduction

- **IEEE 802** refers to a family of IEEE standards
  - Dealing with local area network and metropolitan area network.
  - Restricted to networks carrying variable-size packets.
  - Specified in IEEE 802 map to the lower two layers
    - Data link layer
      - LLC sublayer
      - MAC sublayer
    - Physical layer

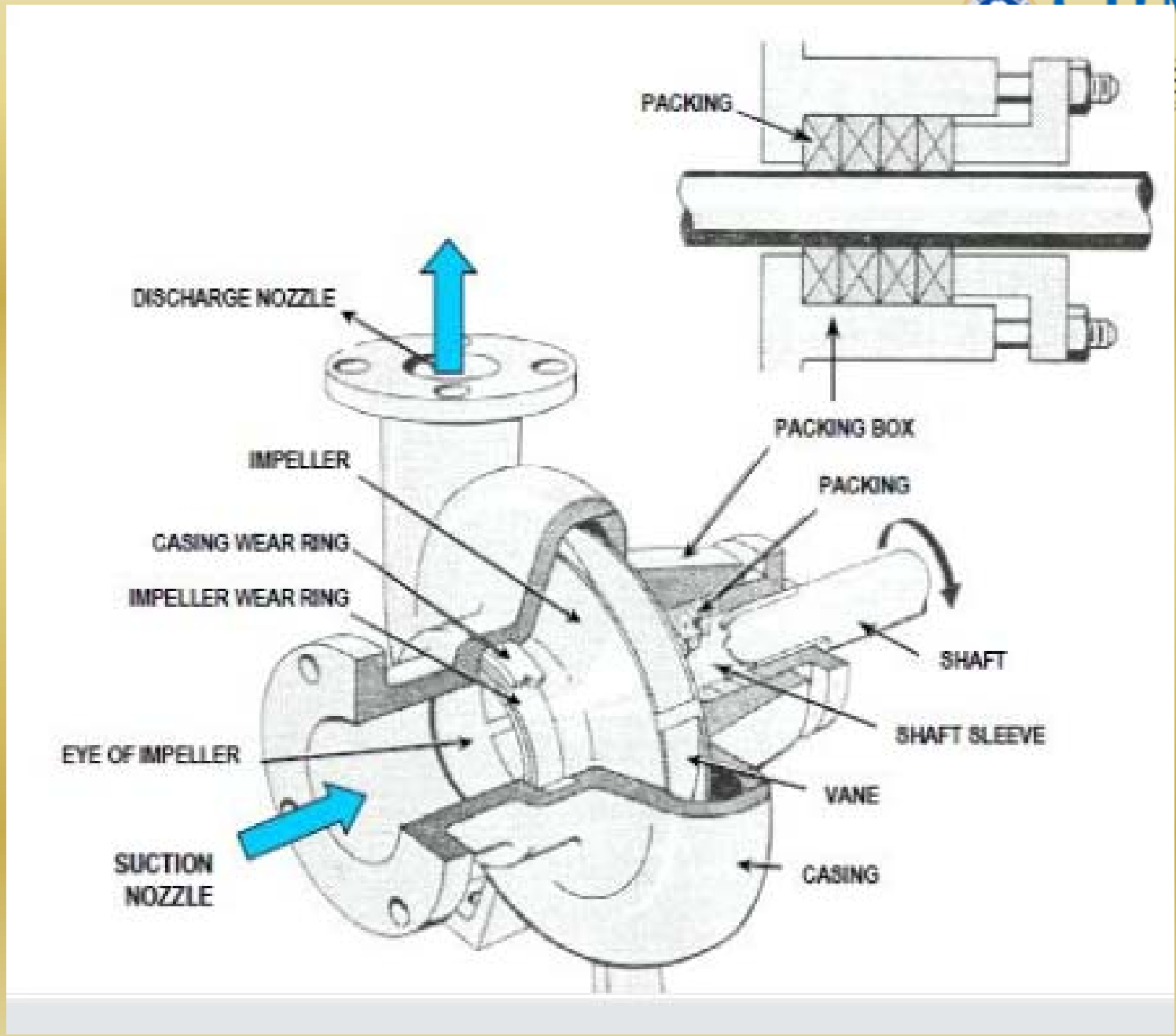
- The most widely used standards
  - The Ethernet family, Token Ring, Wireless LAN.
  - Bridging and Virtual Bridged LANs.
  - An individual Working Group provides the focus for each area.

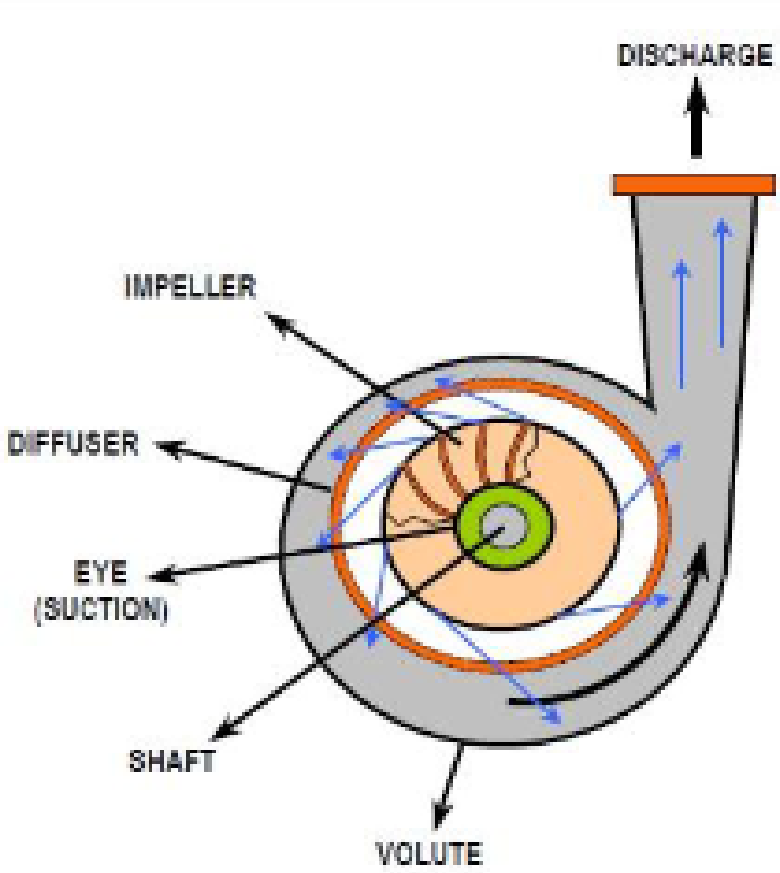
IEEE 802 Working Groups

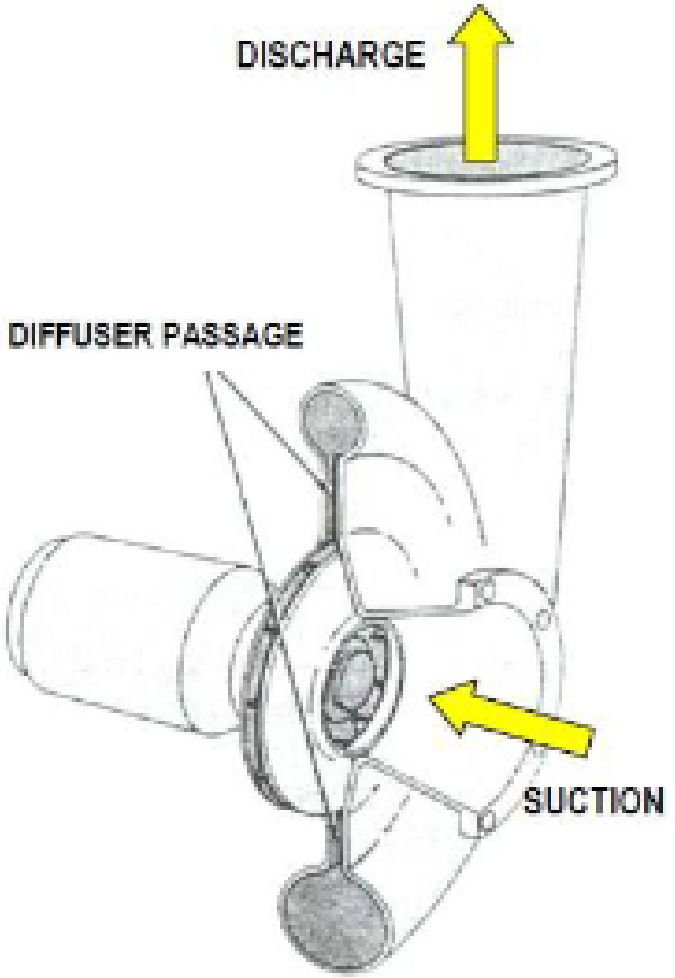
Active working groups	Inactive or disbanded working groups
802.1 Higher Layer LAN Protocols Working Group	802.2 Logical Link Control Working Group
802.3 Ethernet Working Group	802.4 Token Bus Working Group
802.11 Wireless LAN Working Group	802.5 Token Ring Working Group
802.15 Wireless Personal Area Network (WPAN) Working Group	802.7 Broadband Area Network Working Group
802.16 Broadband Wireless Access Working Group	802.8 Fiber Optic TAG
802.17 Resilient Packet Ring Working Group	802.9 Integrated Service LAN Working Group
802.18 Radio Regulatory TAG	802.10 Security Working Group
802.19 Coexistence TAG	802.12 Demand Priority Working Group
802.20 Mobile Broadband Wireless Access (MBWA) Working Group	802.14 Cable Modem Working Group
802.21 Media Independent Handoff Working Group	
802.22 Wireless Regional Area Networks	

1. The low initial cost.
2. Low maintenance costs.
3. Simple in operation.
4. Ability to operate under a wide variety of conditions.
5. Give a smooth, continuous flow, free from pulsation.

CENTRIFUGAL PUMPS


PACKING
DISCHARGE NOZZLE
PACKING BOX
IMPELLER
PACKING
CASING WEAR RING
IMPELLER WEAR RING
SHAFT
SHAFT SLEEVE
EYE OF IMPELLER
VANE
SUCTION NOZZLE
CASING


DISCHARGE
IMPELLER
DIFFUSER
EYE
(SUCTION)
SHAFT
VOLUTE


DISCHARGE
DIFFUSER PASSAGE
SUCTION

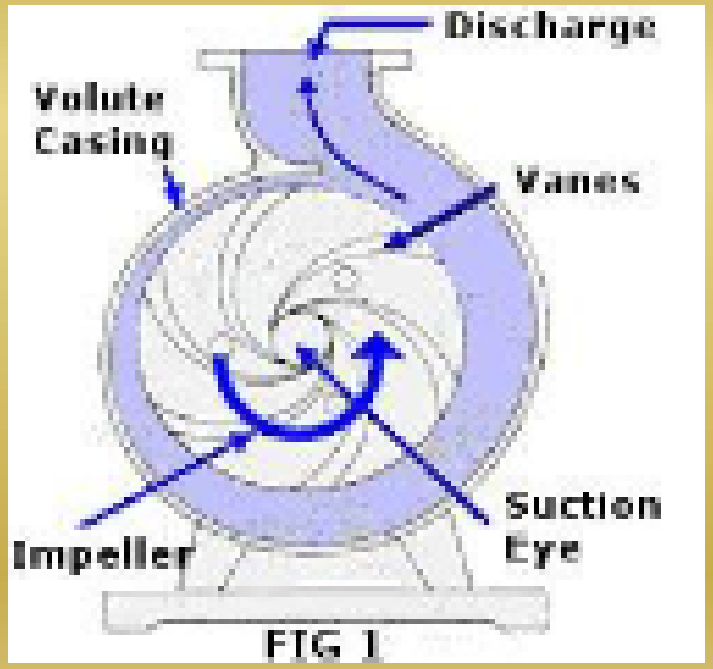
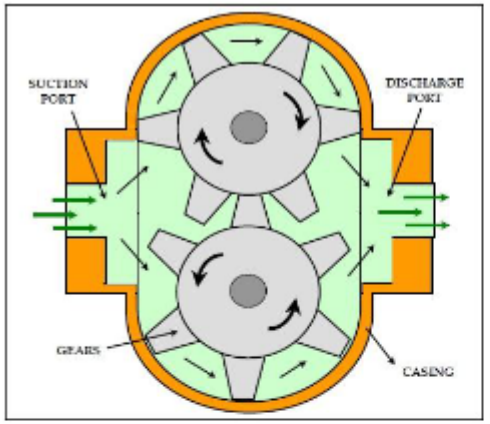
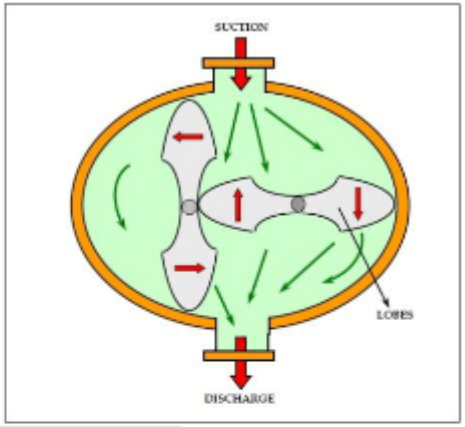


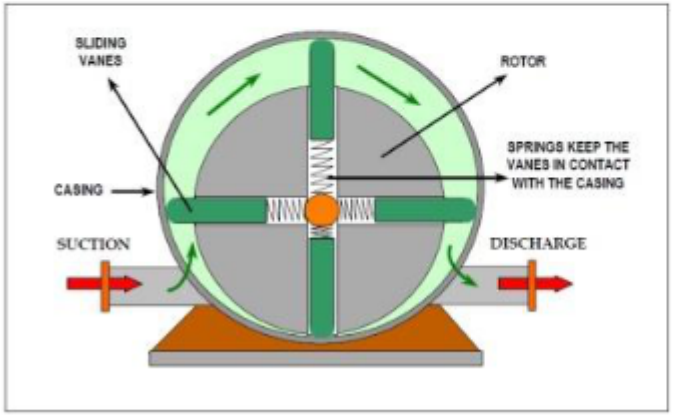
FIG 1

POSITIVE DISPLACEMENT PUMPS

- Rotary Pumps
- In Rotary pumps, movement of liquid is achieved by mechanical displacement of liquid produced by rotation of a sealed arrangement of intermeshing rotating parts within the pump casing.

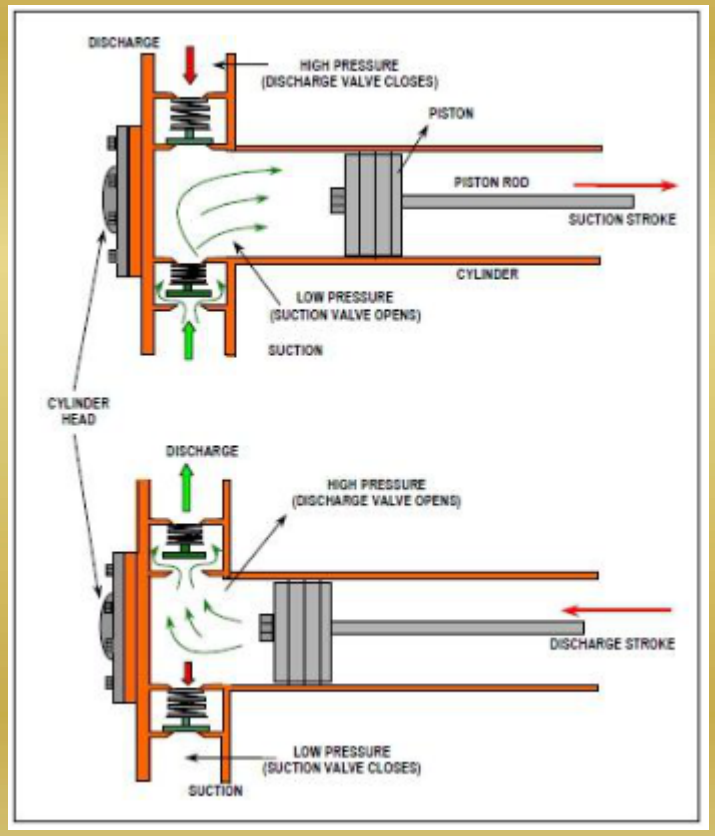


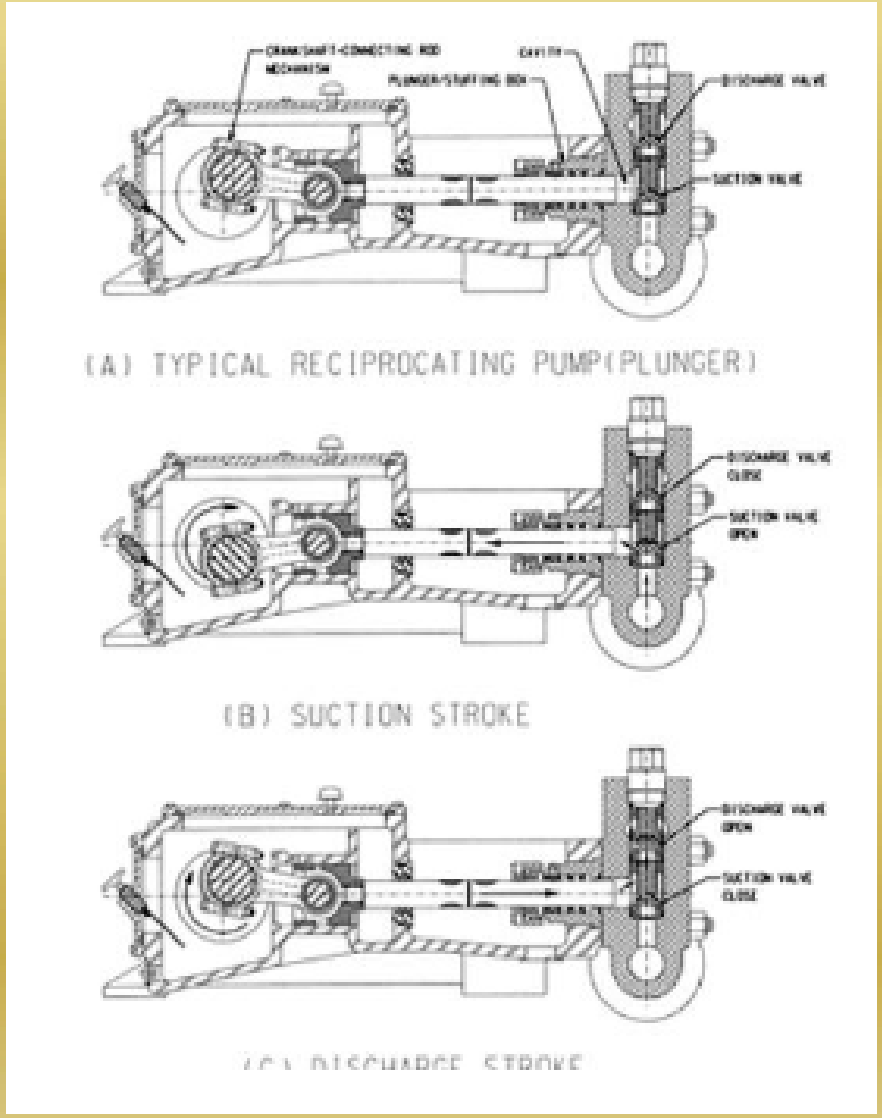




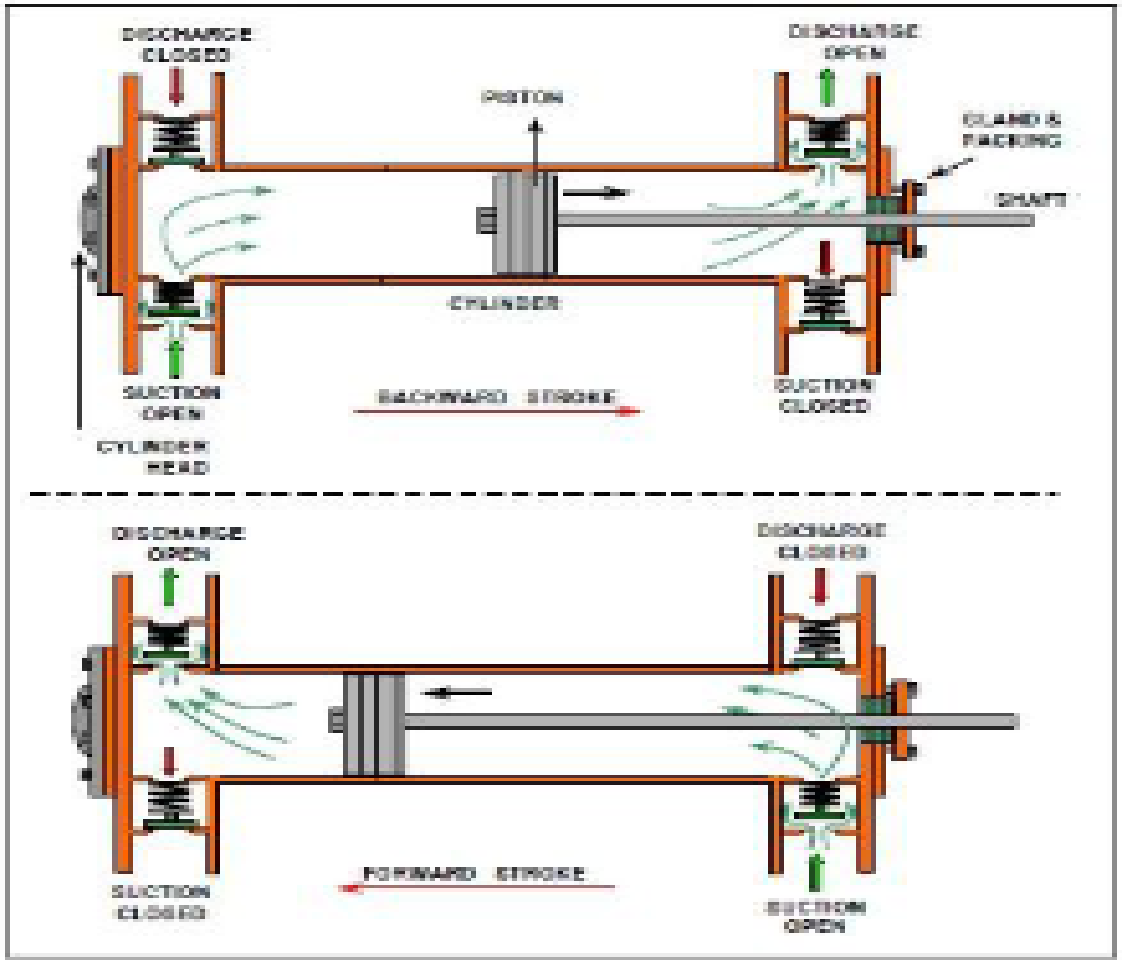
Reciprocating Pumps

Single Acting Reciprocating Pumps

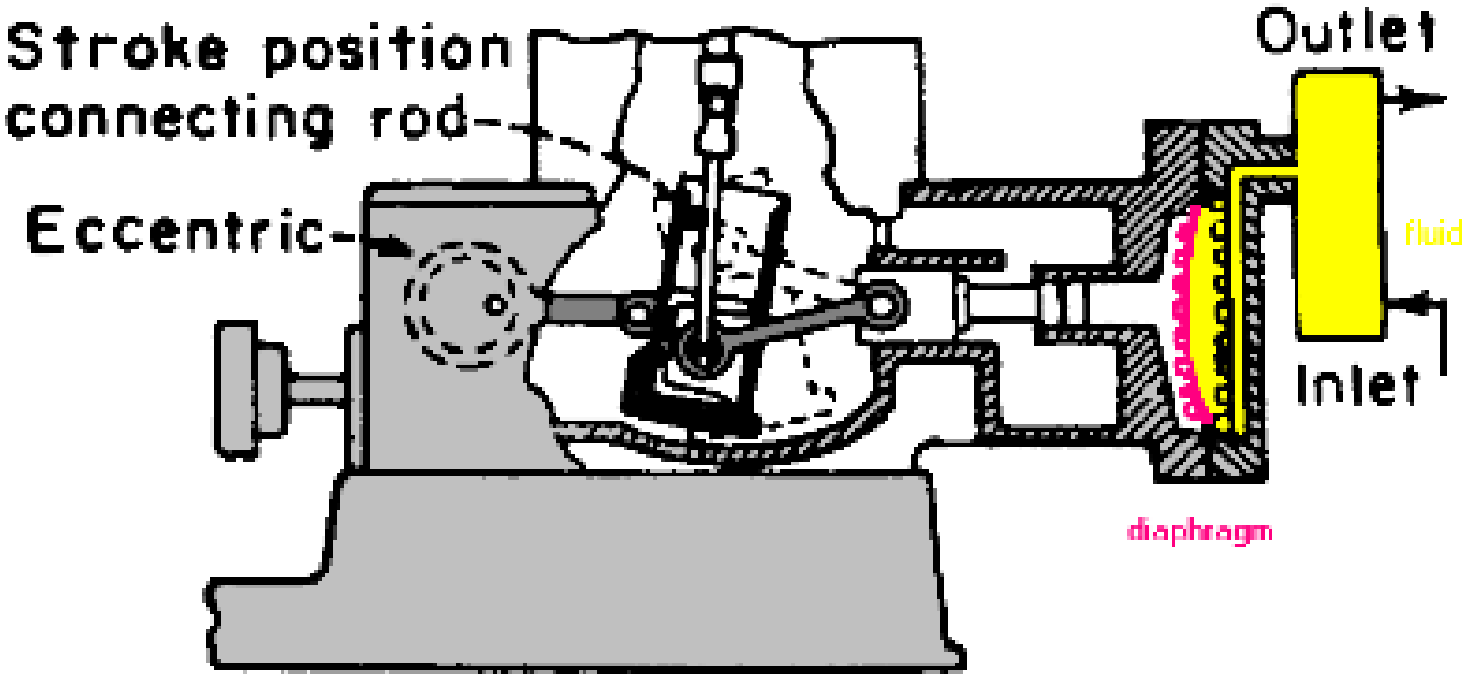


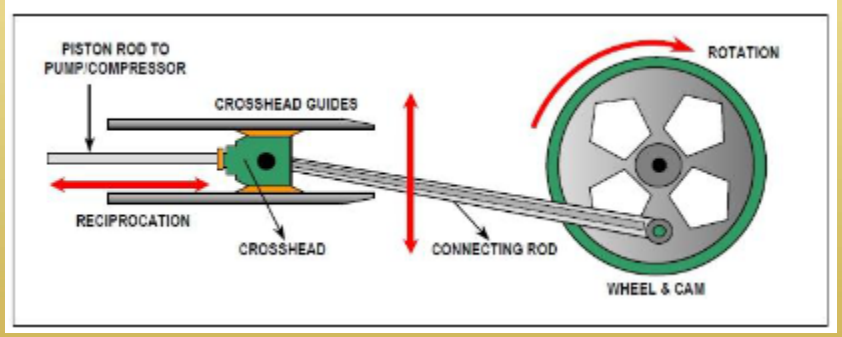


Double Acting Reciprocating Pumps

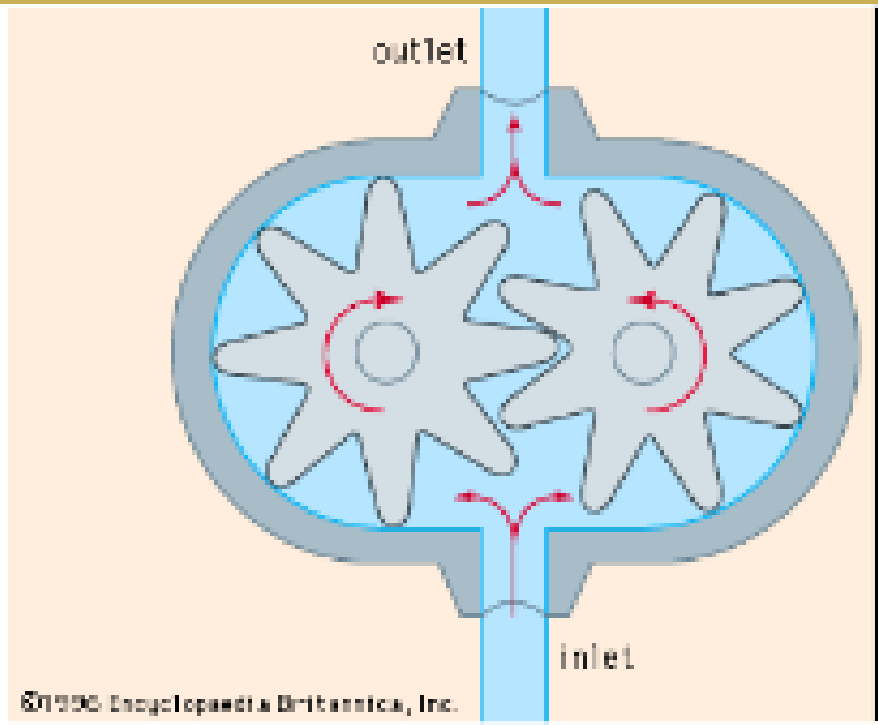


Diaphragm pump

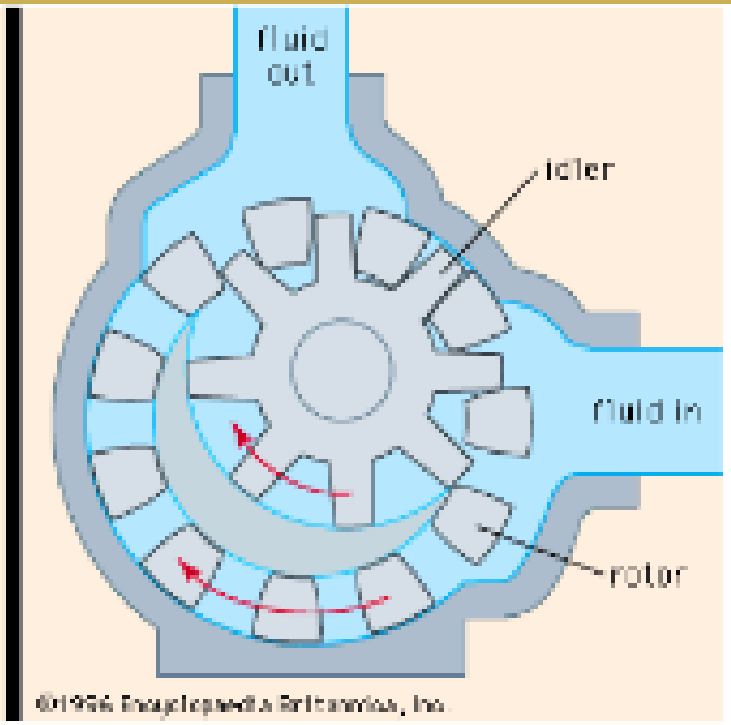



PISTON ROD TO
PUMP/COMPRESSOR
CROSSHEAD GUIDES
ROTATION
RECIPROCATION
CROSSHEAD
CONNECTING ROD
WHEEL & CAM

Rotary Pump

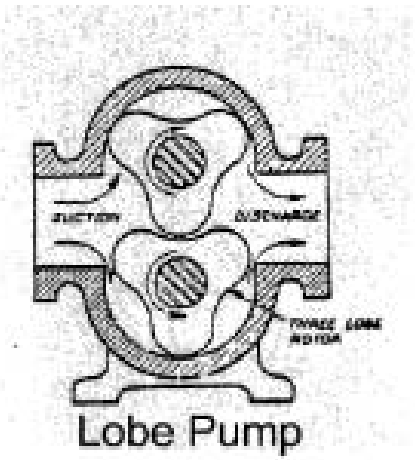


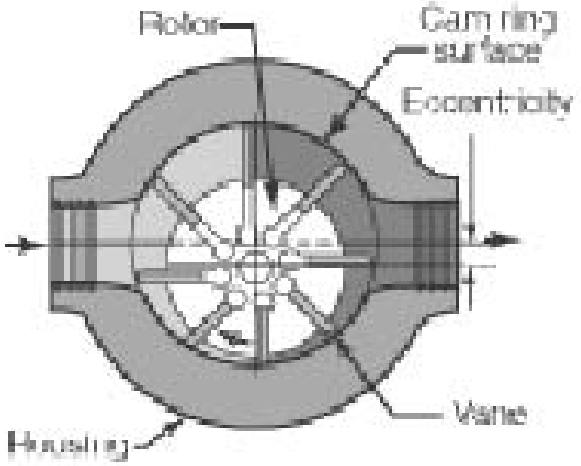
External gear Pump

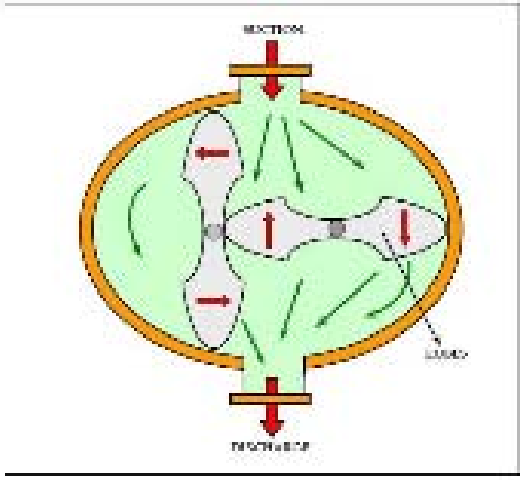


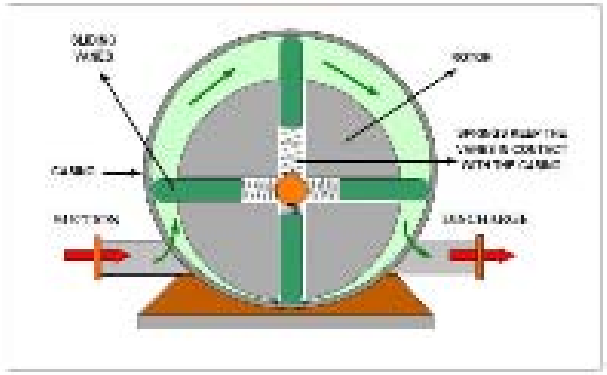
Internal gear Pump

Rotary Pump









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Advantages of Rotary Pumps

They can deliver liquid to high pressures.
Self -priming.

Give a relatively smooth output, (especially at high speed).

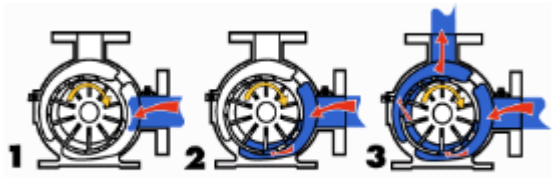
Positive Acting.

Can pump viscous liquids.

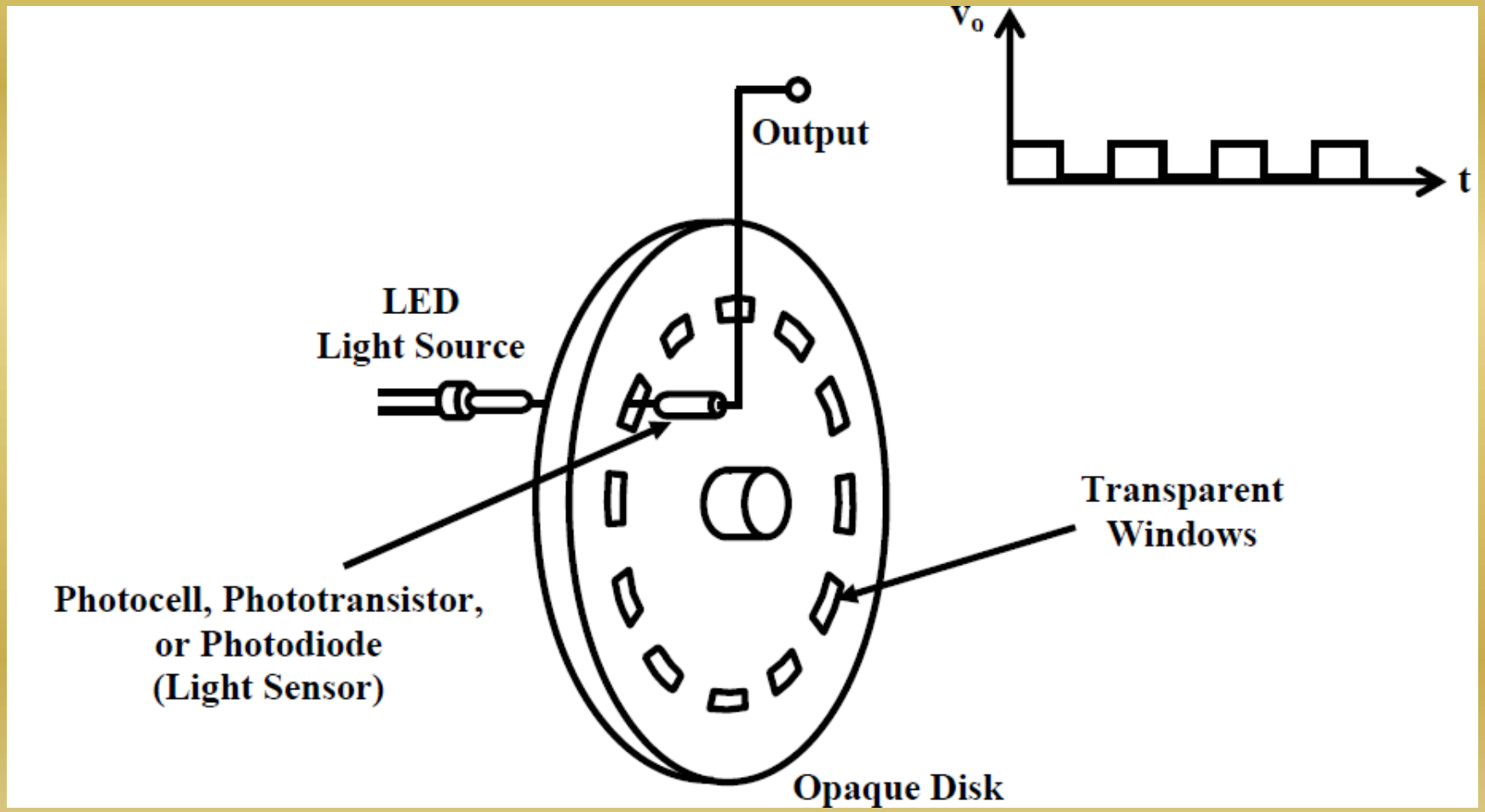
Gear Pump

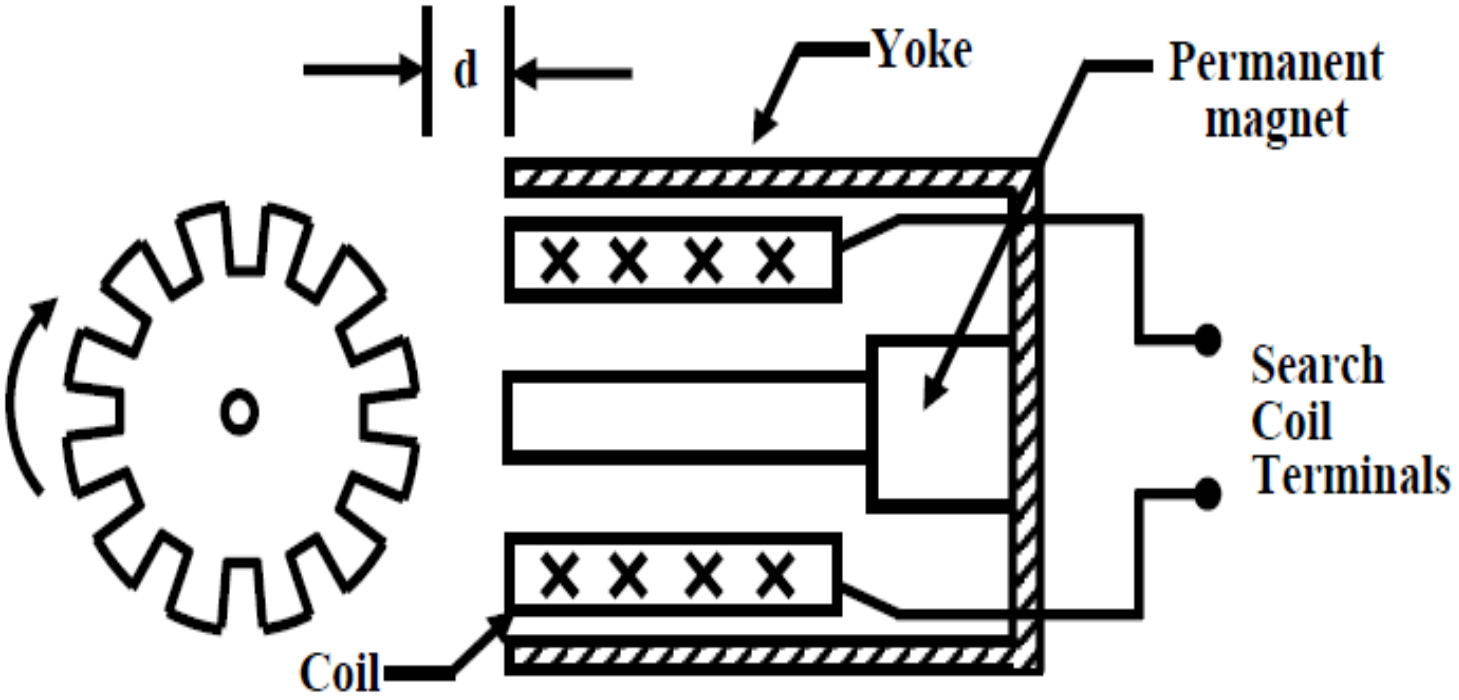
Lobe Pump

Vane Pump



Speed Measurement



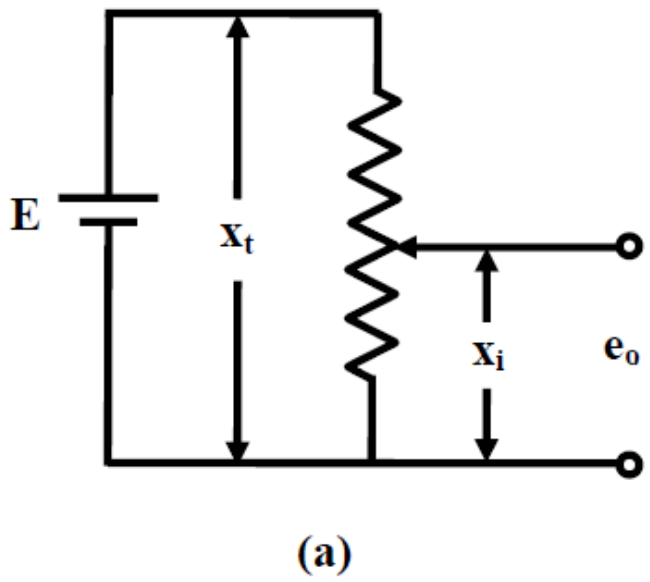


Variable reluctance type speed sensor.

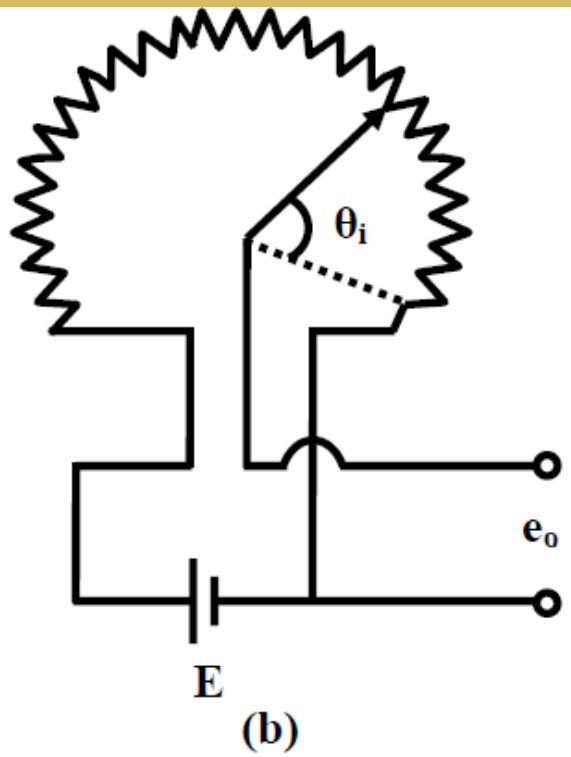
Displacement Measurement

- Broadly speaking, displacement measurement can be of two types: contact and noncontact types. Besides the measurement principles can be classified into two categories: electrical sensing and optical sensing. In electrical sensing, passive electrical sensors are used variation of either inductance or capacitance with displacement is measured. On the other hand the optical method mainly works on the principle of intensity variation of light with distance. Interferometric technique is also used for measurement of very small displacement in order of nanometers. But this technique is more suitable for laboratory purpose, not very useful for industrial applications.

Potentiometer



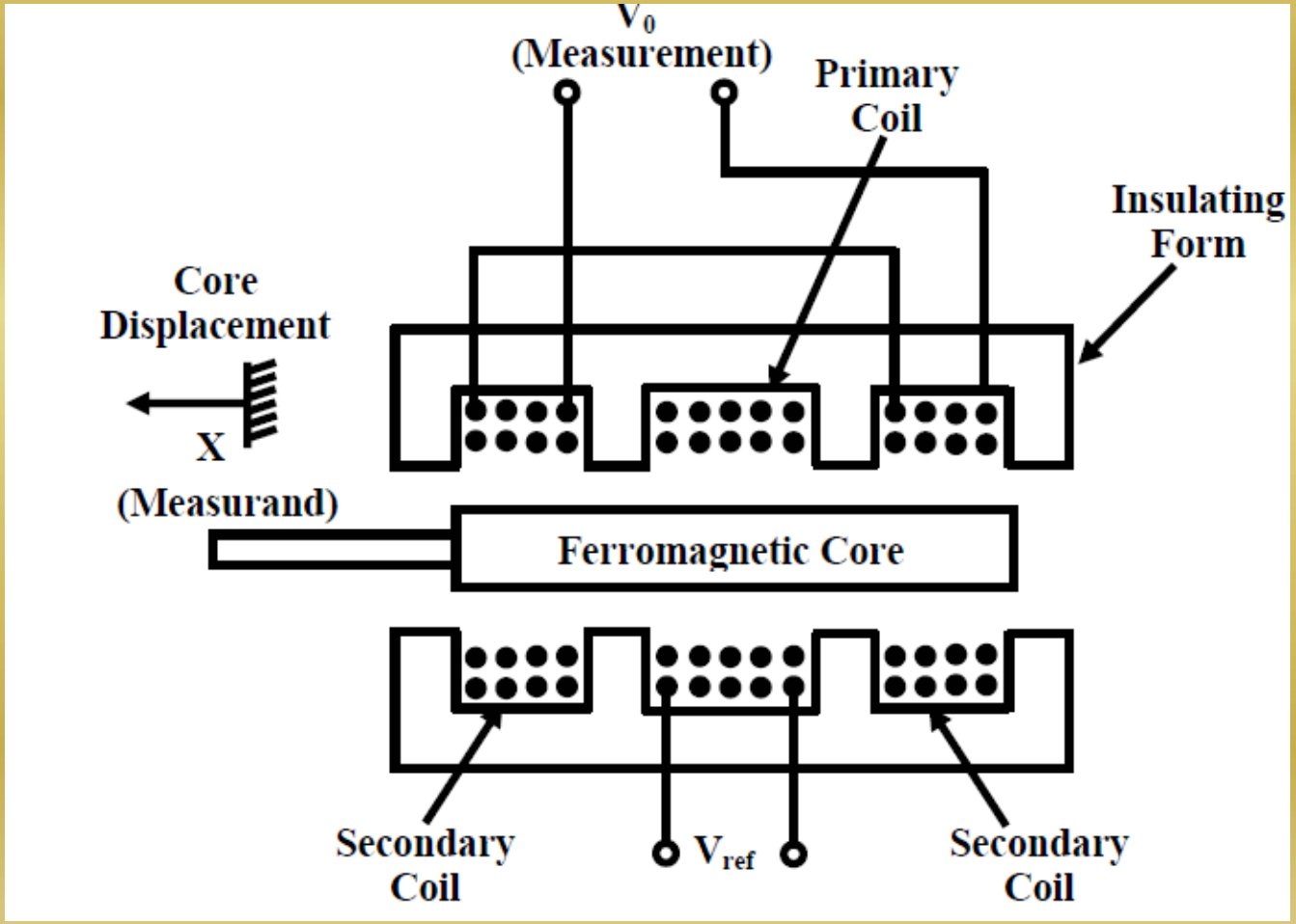
(a)



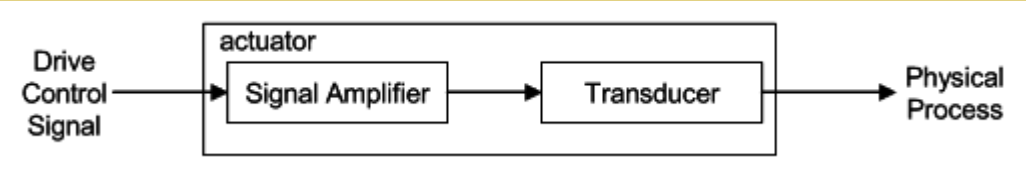
(b)

Potentiometer
(a) Linear
(b) Rotary

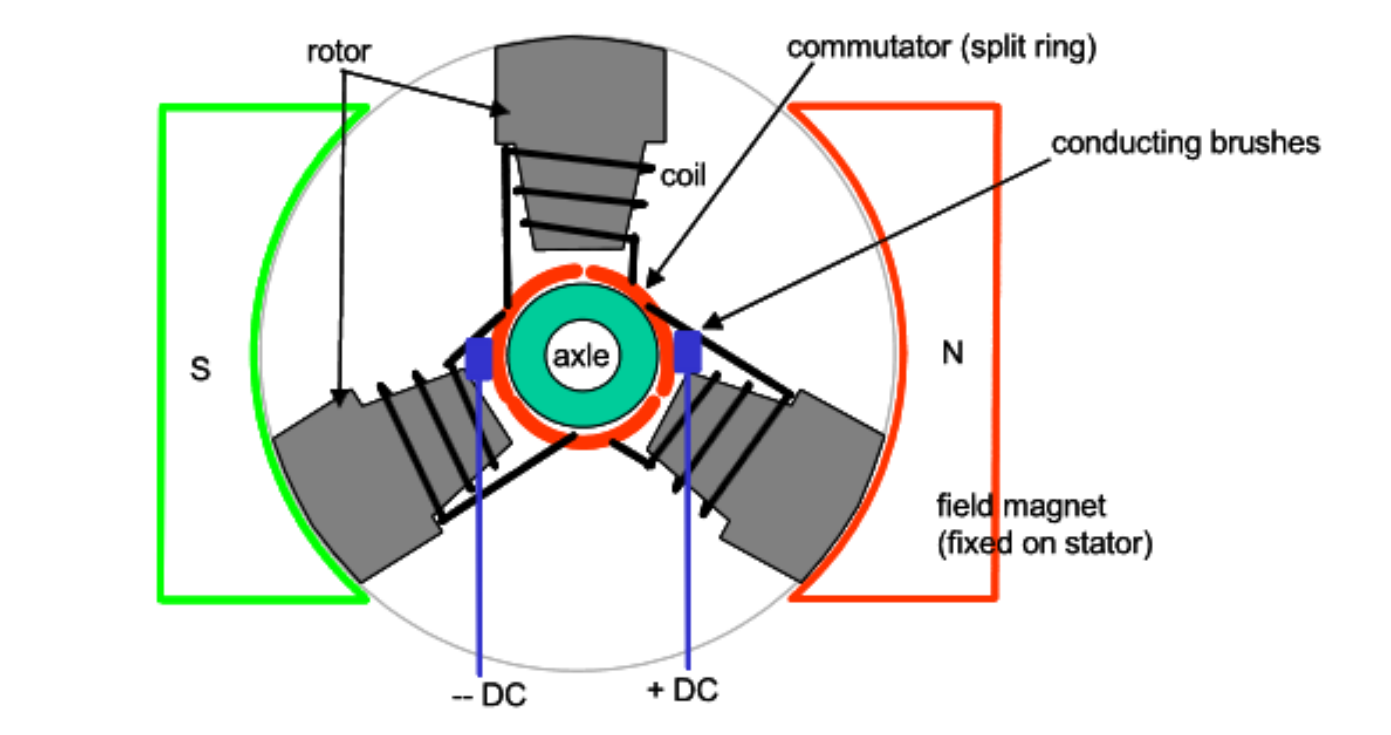
Linear Variable Differential transformer (LVDT)

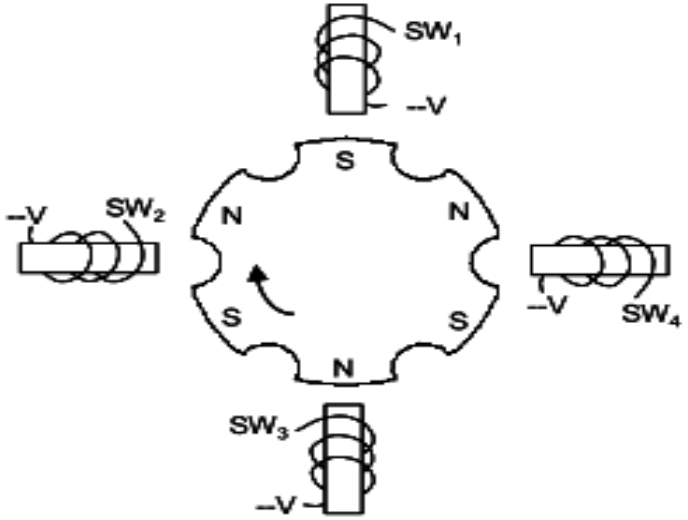


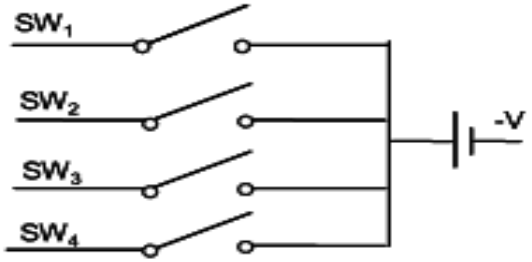
Actuator


Drive
Control
Signal
actuator
Signal Amplifier
Transducer
Physical
Process

Motor


rotor
commutator (split ring)
conducting brushes
coil
axle
S
N
field magnet
(fixed on stator)
-- DC
+ DC





Full Steps (CW)

Degs	SW_1	SW_2	SW_3	SW_4
0	ON			
30		ON		
60			ON	
90				ON
120	ON			
150		ON		

Half Steps (CW)

Degs	SW_1	SW_2	SW_3	SW_4
0	ON			
15	ON	ON		
30		ON		
45		ON	ON	
60			ON	
75			ON	ON
90				ON