BASIC CONTROL SYSTEM

FIRST EDITION 2022

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BASIC CONTROL SYSTEM EBOOK

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@ JABATAN PENGAJIAN POLITEKNIK DAN KOLEJ KOMUNITI
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PREFACE

BISMILLAHIRRAHMANIRRAHIM

Alhamdulillah, all praise be to Allah who always provided ease in completing all matters until we were able to complete the first topic of the Ebook Basics of Control Systems.

Course provides student with knowledge on basic concept of control system.Control system are an intergral part of human being's daily life.This course emphasizes the type of open loop and closed loop control system.The need for control system, classification of control systems and various types illustrations of control systems used in practice are discussed in Chapter 1.

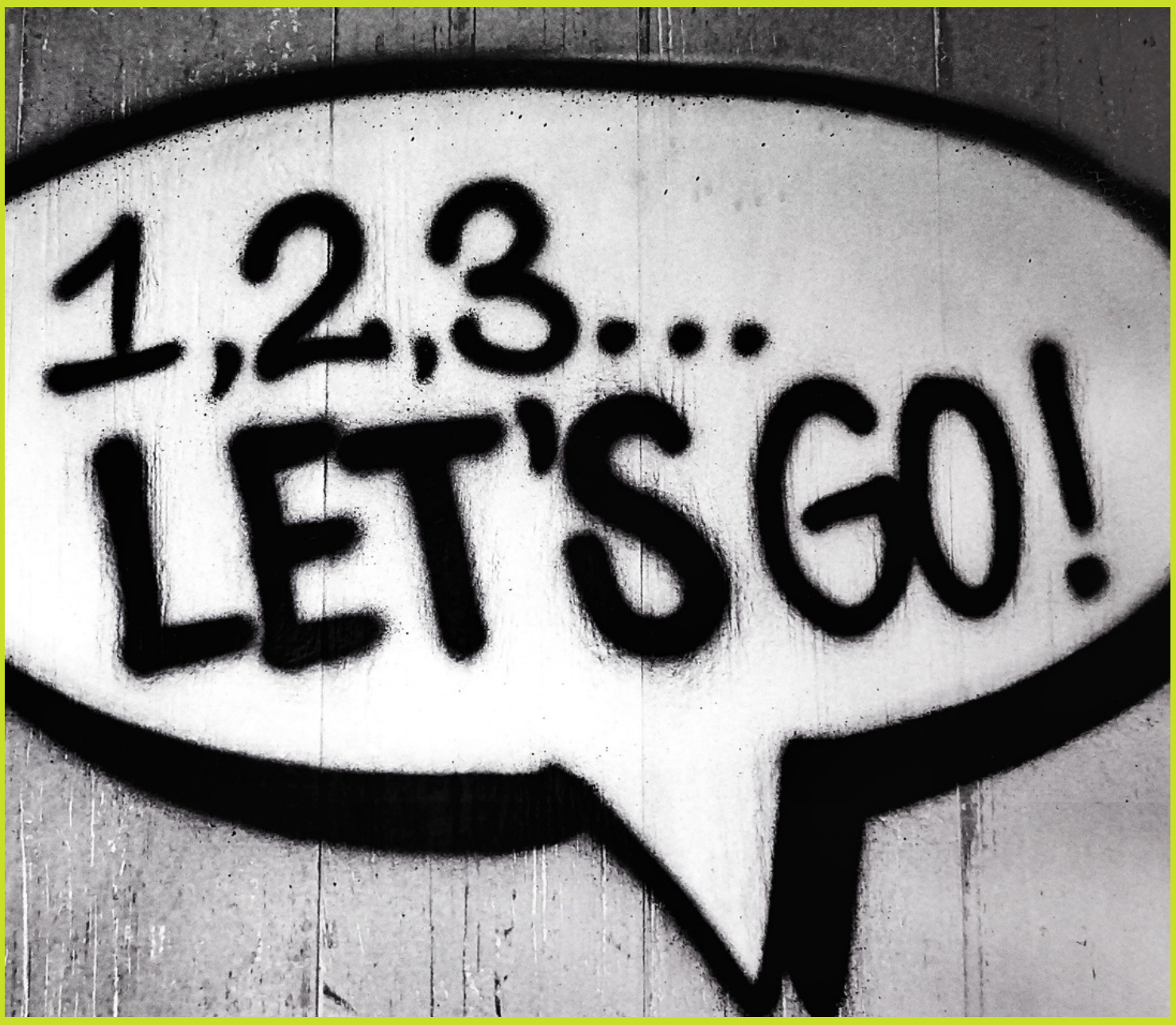
This chapter also provides sample questions to help student understand the concepts of control system.Extensive short questions and answers are given at the end of chapter to enable the student to prapare for examination very throughly.

The author expresses her high appreciation to the Department of Electrical Engineering and the Publishing Unit of the Sultan Salahuddin Abdul Aziz Shah Polytechnic, through the support given to realize the production of this book. May it be benefit to all students.

TABLE OF CONTENTS

CHAPTER 1 :
INTRODUCTION TO CONTROL SYSTEM

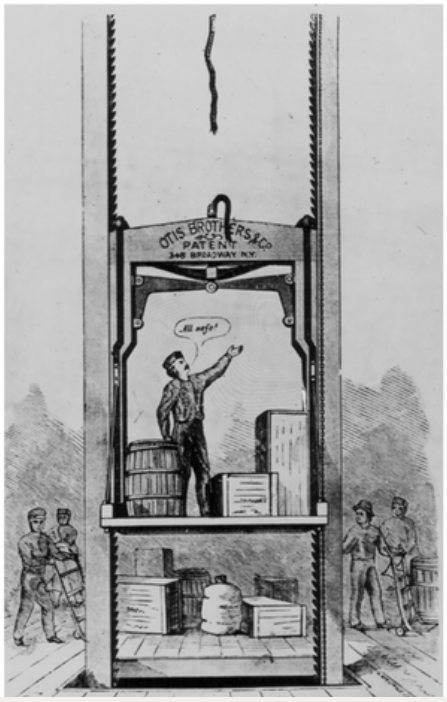
BASIC CONTROL SYSTEM introduces students to the fundamental ideas of classical control theory such as the basic concept of control system, transfer function and time domain analysis. Student will also be introduced to the concept of controller in control system. The goal is to instill the students' interests in the fields of control system and to provide a solid background for engineering applications in control system techniques

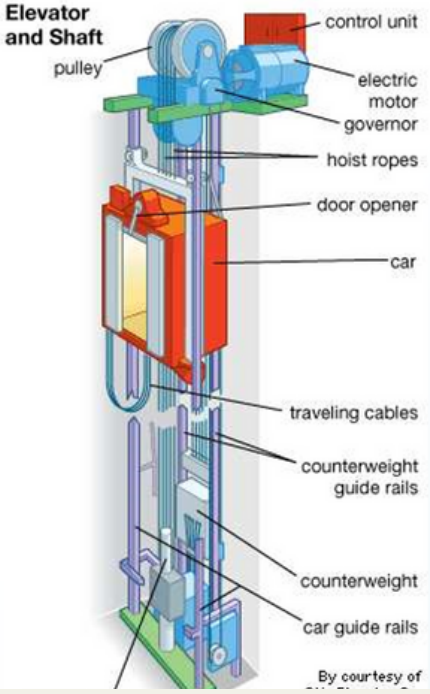


TOPIC 1: INTRODUCTION TO CONTROL SYSTEMS

HISTORY

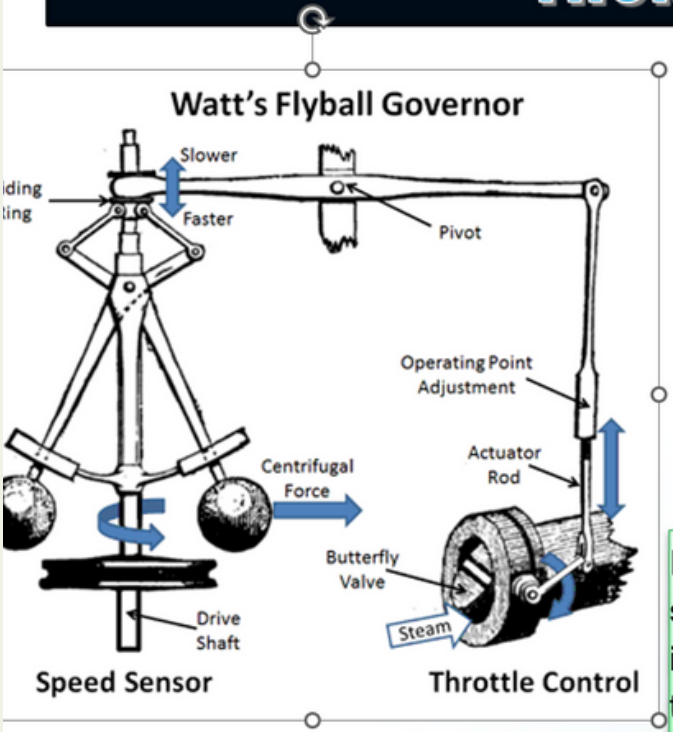
Then and Now

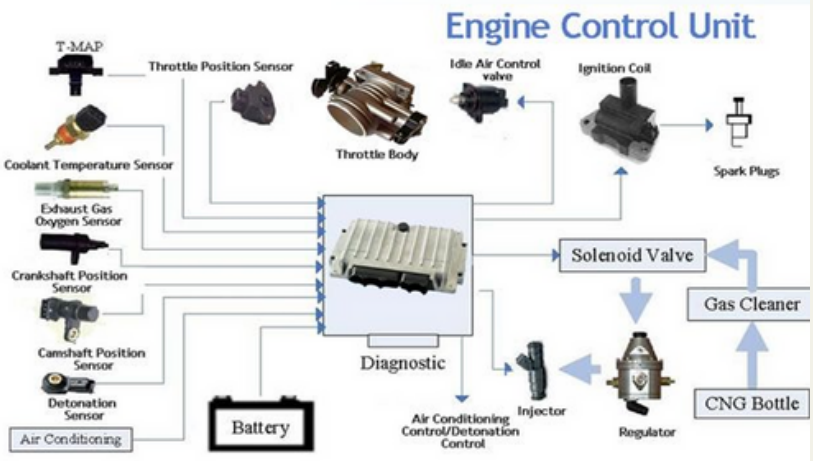




- Early elevators were controlled by hand ropes or an elevator operator. The photo shows a rope is cut to demonstrate the safety brake.
- Today elevators are fully automatic using control system to regulate position and velocity

Then and Now

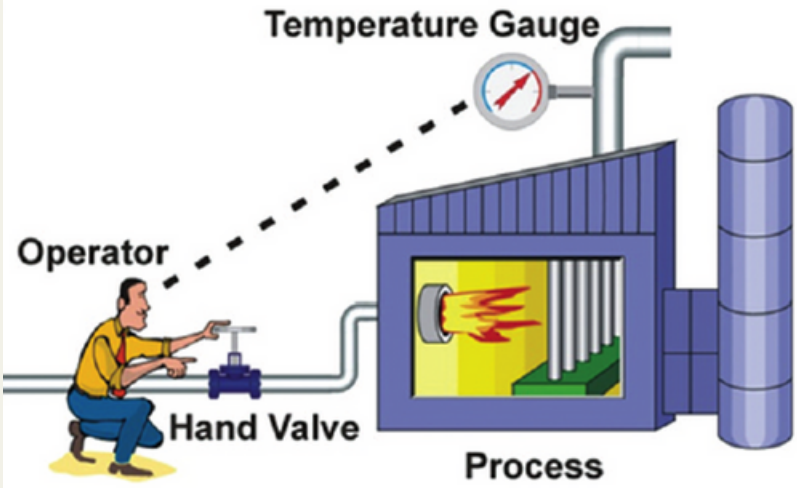




If the engine speed is too high, the centrifugal force on th sensor's weights will cause the actuator rod to be raised, in turn causing the butterfly valve to move so as to restric the flow of steam into the engine, hence reducing its speed.

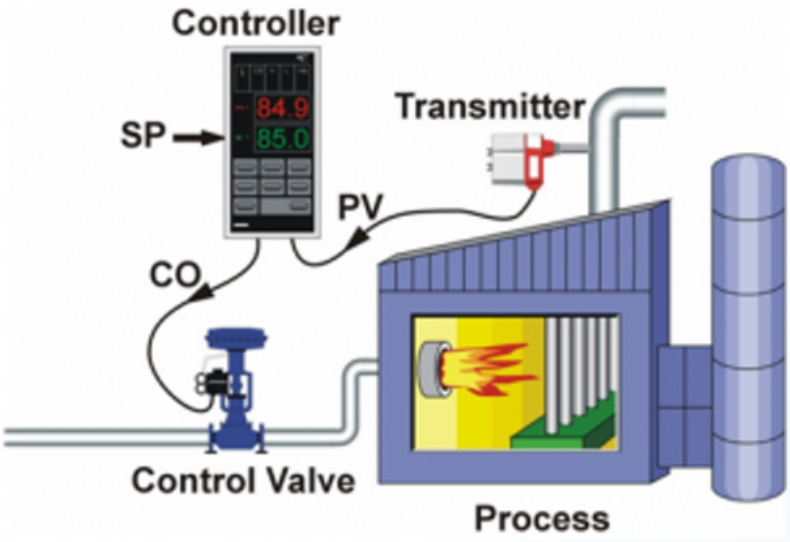
HISTORY

Manual Control System



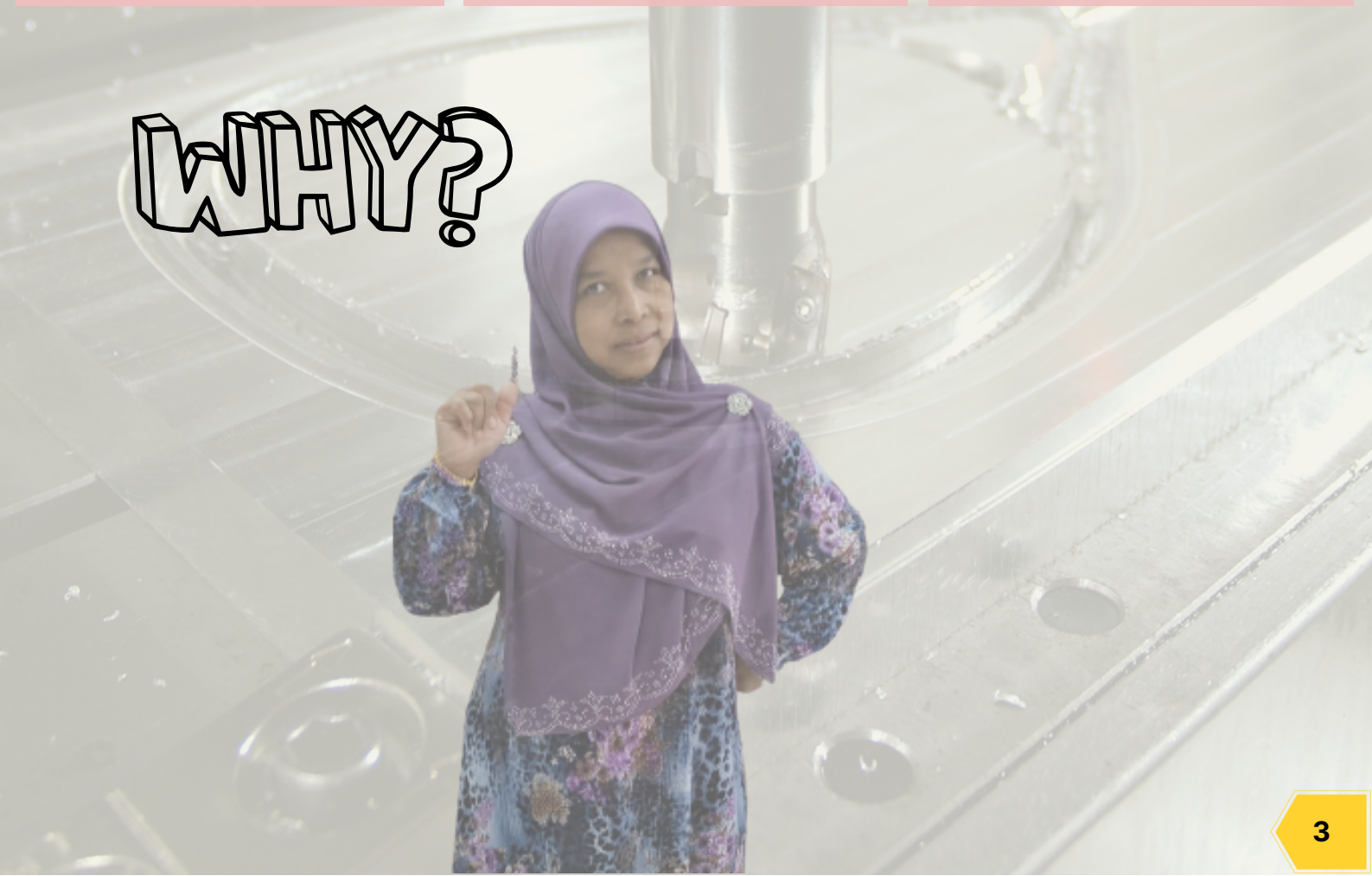
- Without automatic controllers, all regulation tasks will have to be done manually.
- For example: To keep constant the temperature of water discharged from an industrial gas-fired heater, an operator will have to watch a temperature gauge and adjust a fuel gas valve accordingly.
- If the water temperature becomes too high for some reason, the operator has to close the gas valve a bit – just enough to bring the temperature back to the desired value.
- If the water becomes too cold, he has to open the gas valve.

Auto Control System



- A setpoint of the desired temperature is set in the controller.
- Actual water temperature is measured by a temperature transmitter and transmitted to the controller continuously.
- The controller reads the temperature value, computes the appropriate electrical signal required and send the electrical signal to the control valve.
- Control valve will open at different positions based on the received signal.
- When the valve is open, the gas is released accordingly for the burning process.

Why use CONTROL SYSTEM?	Description	Example
Power amplification	We can move large/heavy equipment with precision.	Elevators can carry heavy loads and stops automatically at each floors in the building.
Remote control	Useful in remote and dangerous locations.	A remote-controlled robot arm can be used to pick up material in radioactive environment.
Convenience of input form	Provide convenience by changing the form of the input.	In temperature control system, the input is a position on the thermostat.
Compensation for disturbances	System is able to yield correct output even with a disturbance.	If wind forces an antenna from its commanded position, the system will be able to detect the deviation and corrects it.



1.1 INTRODUCTION TO CONTROL SYSTEM

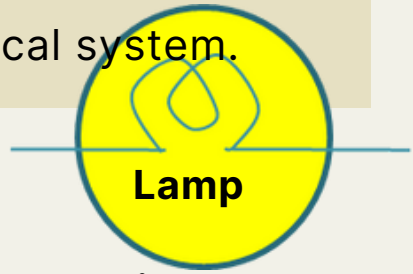
- In recent years, control systems have gained an increasingly importance in the development and advancement of the modern civilization and technology
- Control system are now integral part of the modern industrialization, industrial processes and home appliance.
- Practically our day-to-day activities are affected by some type of control systems.

1.2 BASIC CONCEPT OF CONTROL SYSTEM

SYSTEM

A system is a combination or arrangement of different physical components which act together as an entire unit to achieve certain objective.

Example: a lamp made up of glass, filament is physical system.

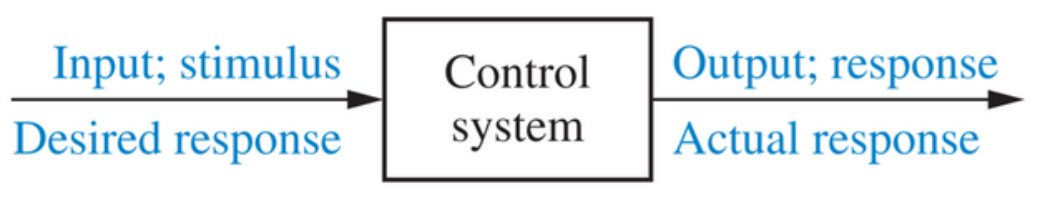


Physical system

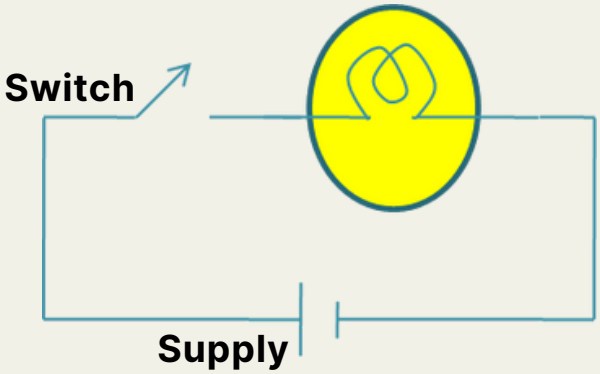
CONTROL SYSTEM

A control system is an interconnection of components forming a system configuration that will provide a desired system response.

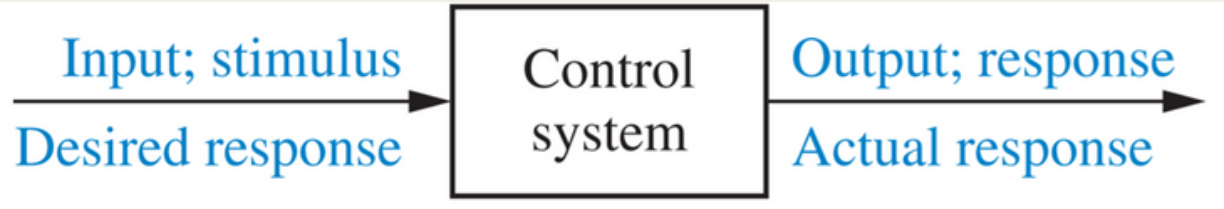
Example: Switched ON or OFF a lamp using a switch.

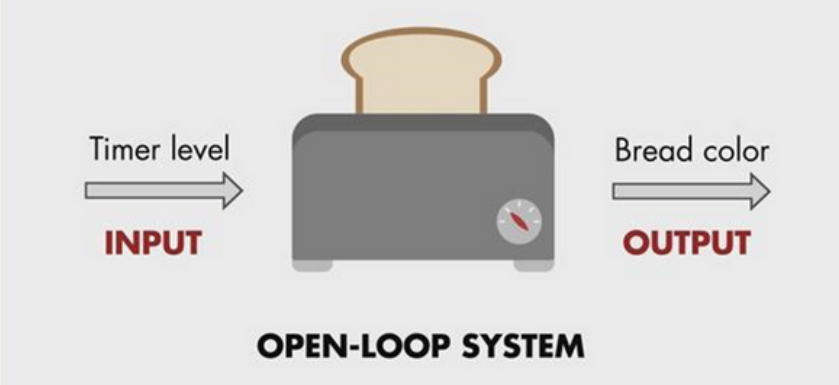


An INPUT is the stimulus, excitation or command applied to control system. The OUTPUT is the actual response resulting from a control system.



Control System



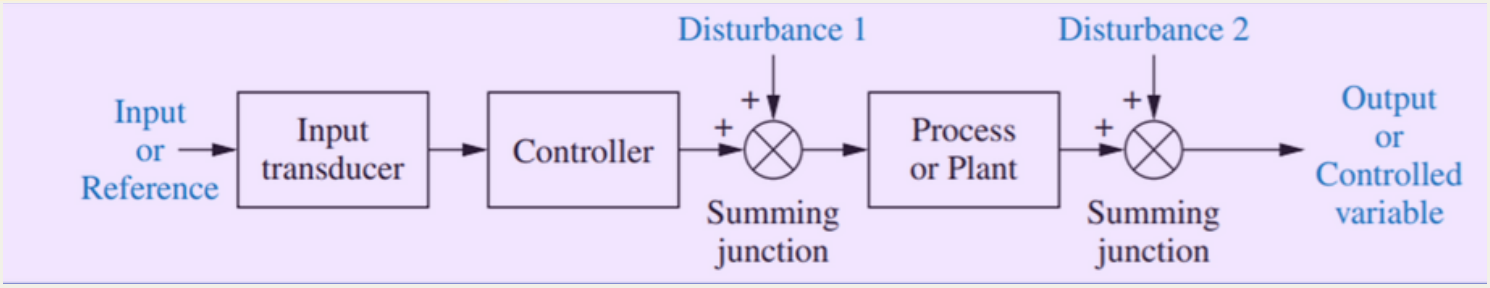


- INPUT could be *physical variables* (values measured by sensors, switch, pushbuttons) or *abstract ones* such as reference, set point or desired values.
- Control system can have more than one input or output.
- The OUTPUT / actual response may or may not be equal to the specified desired response.

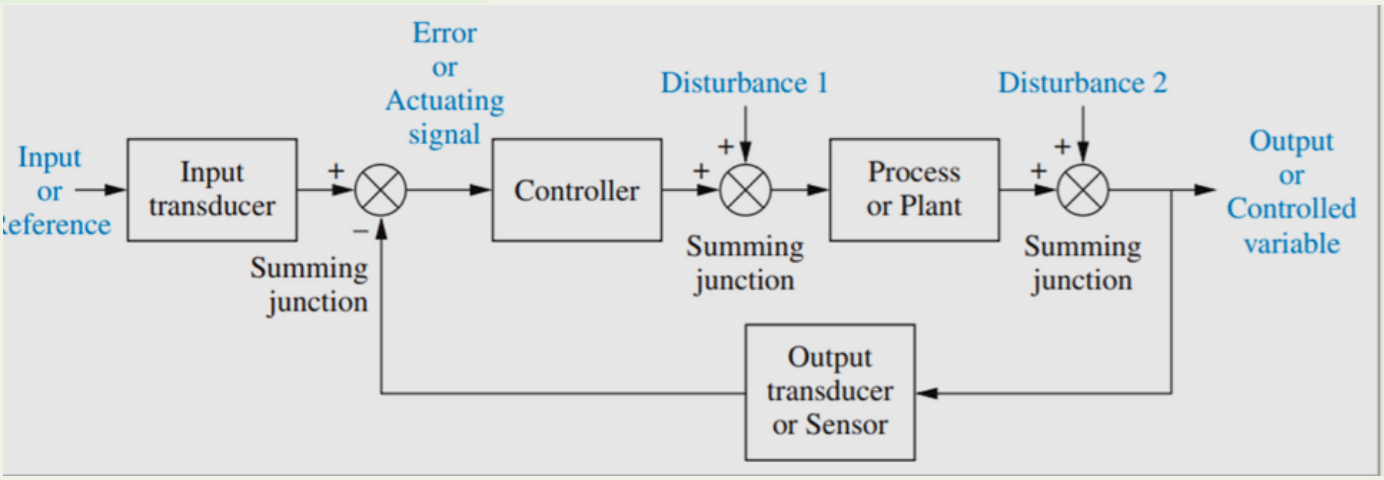
Discussion:
What is the INPUT & OUTPUT?

1.2.1 BLOCK DIAGRAM OPEN LOOP AND CLOSE LOOP CONTROL SYSTEM

OPEN LOOP CONTROL SYSTEM



CLOSED LOOP CONTROL SYSTEM



1.2.2 TERMINOLOGY IN CONTROL SYSTEM

INPUT	Desired response. Example: Heater temperature setpoint
OUTPUT	Actual response: Example: Actual heater temperature
CONTROLLED VARIABLE	The quantity or condition that is measured and controlled (another name for output).
MANIPULATED VARIABLE	The quantity or condition that is varied by the controller to adjust the controlled variable. Example: Current supplied to heater element.
CONTROLLER	Measuring the controlled variable and applying the manipulated variable to correct deviation of the measured value (output) from a desired value (input).
DISTURBANCE	External factor (signal) that affects the output. Example: Signal noise due to loose wiring.

TERMINOLOGY IN CONTROL SYSTEM

PLANT

Any physical objects to be controlled such as mechanical device, heating furnace, a chemical reactor etc.

PROCESS

Operation to be controlled. Example: Boiling process, Heating process, Painting process etc

ERROR

The difference between input and output.

SUMMING JUNCTION

- To represent addition or subtraction of signals.
- An operation to reduce error in the presence of disturbances.

INPUT TRANSDUCER

Converts the input to that used by the controller. Example: Sensor (temperature, pressure, flowrate, level etc)

OUTPUT TRANSDUCER

Converts the output to that used by the controller. Example: Sensor (temperature, pressure, flowrate, level etc)

1.3 CLASIFICATION OF CONTROL SYSTEM

- ## Natural Control Systems:

  The biological systems, systems inside human being are of natural type.

- ## Manmade Control Systems:

  The various systems, that used in day to day life are designed and manufactured by human beings. Such systems like vehicles, switches, various controller etc.

- ## Combinational Control System:

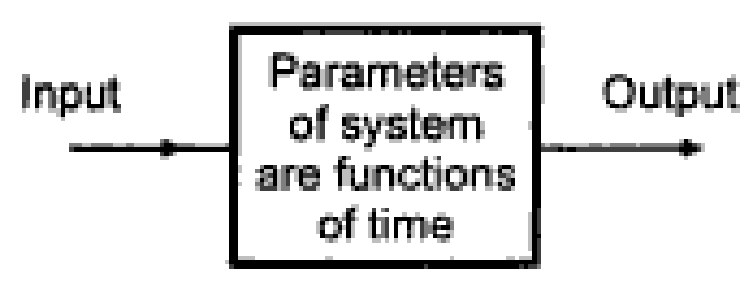
  Combinational control system is one, having combination of natural and manmade together.

CLASIFICATION OF CONTROL SYSTEM

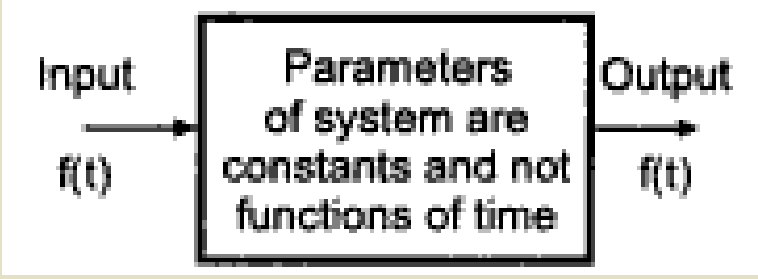
For engineering analysis :

- Time Varying and Time-Invariant Control Systems:

Time varying control systems are those in which parameters of the systems are varying with time. It is not dependent on whether input or output are functions of time or not.



Time invariant system are those the inputs and outputs are functions of time but the parameters of a systems are independent of time, which are not varying with time and are constants.



CLASIFICATION OF CONTROL SYSTEM

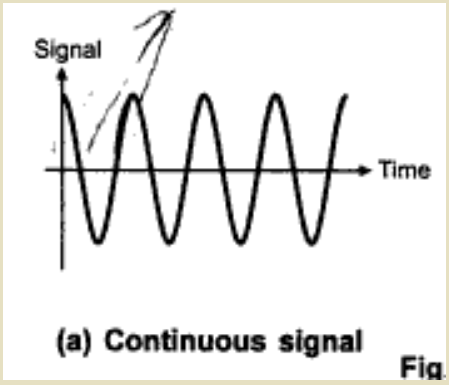
- Linear and Nonlinear Control Systems:

  A control system is said to be linear if it satisfies the principle of superposition is applicable to the system. This means the response to several inputs can be obtained by considering one input at a time and then algebraically adding the individual results.

  A control system is said to be nonlinear if :
  a) It does not satisfy the principle of superposition.
  b) The equations describing the system are nonlinear in nature

- Continuous Time and Discrete Time Control System:

  In a **continuous time control system** all system variables are the functions of a continuous time variable ‘t’.

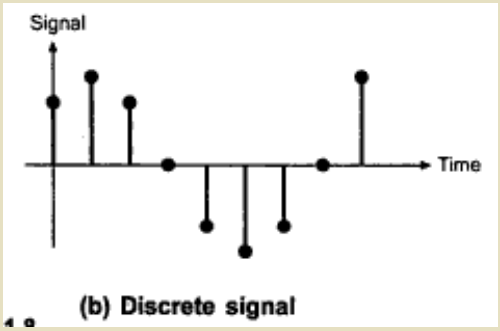


(a) Continuous signal Fig

CLASIFICATION OF CONTROL SYSTEM

Continuous Time and Discrete Time Control System:

In **discrete time systems** one or more system variables are known only at certain discrete interval of time. They are not continuously dependent on the time.



- ## Deterministic and stochastic Control Systems:

  Deterministic control systems can be described when its response to input as well as behavior to external disturbances is predictable and repeatable.

  Stochastic controls systems can be described if such response is unpredictable.

CLASIFICATION OF CONTROL SYSTEM

- ## Lump Parameter and Distributed Parameter Control Systems:

  Control system that can be described by ordinary differential equations is called **lumped parameter control system.**

  Control system that can be described by partial differential equations are called **distributed parameter control systems.**

- ## Single Input single Output (SISO) and Multiple Input Multiple Output (MIMO):

  Single input single output system is a system having only one input and one output is called.

  Single input single output systems is a system having only one input and one output.

  Multiple input multiple output systems may have multiple types of inputs and multiple outputs

CLASIFICATION OF CONTROL SYSTEM

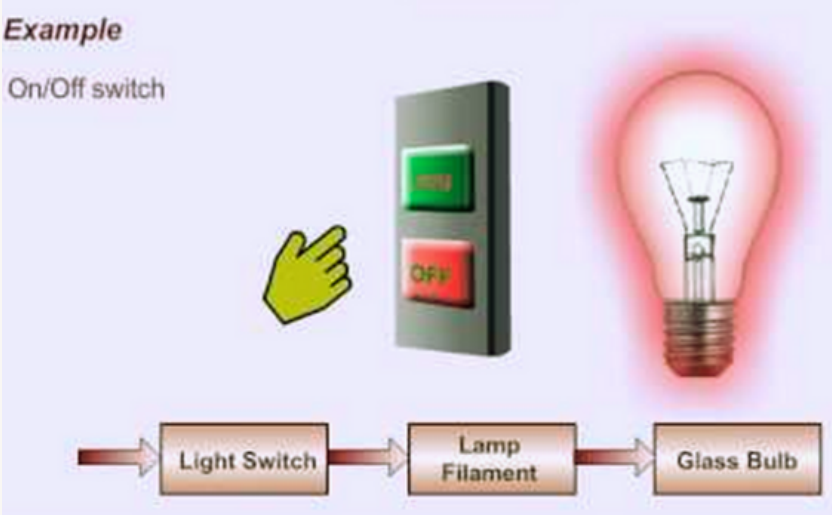
- OPEN LOOP AND CLOSED LOOP CONTROL SYSTEM

Control Systems can be classified as open loop control systems and closed loop control systems

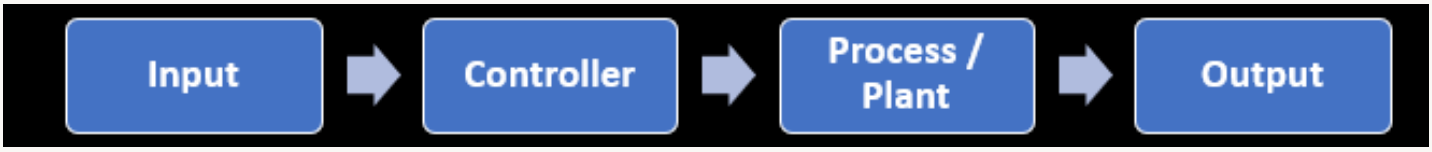
1.4 OPEN LOOP CONTROL SYSTEM

- A system which the output has no effect to the act of control i.e. output is not measured nor feedback for comparison with the input.
- It utilizes a controller or control actuator to obtain the desired response.
- Accuracy of this system depends on calibration.
- Open loop system has to be calibrated carefully and must be maintained in order to be useful.
- Useful if the relationship between output and input is determinable and there is no disturbance.
- A control system which operated according to time.
- Also called non feedback system

Open Loop Control System

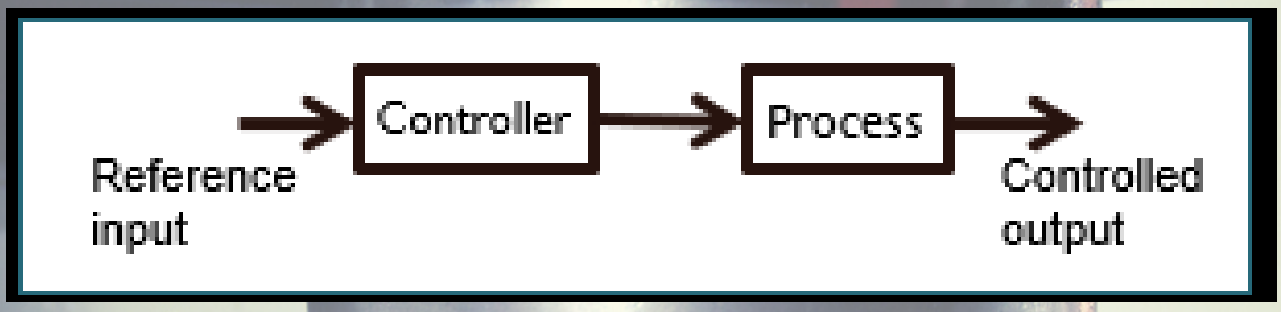


- Commanded by the input.
- Output has no effect on the control action.
- Output is not compared to the reference input (no feedback).
- Output may not be equal to the desired response if there are disturbances present in the system.



- Open loop systems **do not** make decisions based on feedback
  - A toaster heats bread for a set period of time
  - It cannot predict the perfect coloured toast
  - Why can't toasters get toast right every time?

1.4.1 Block Diagram of Open System



- **Reference Input**
  It is an applied signal or an excitation signal applied to a control system from an energy source in order to produce a specified output.

- **Controller**
  The element of the system itself or external to the system which controls the plants or the process.

- **Plant/Process**
  The portion of a system which is to be controlled or regulated

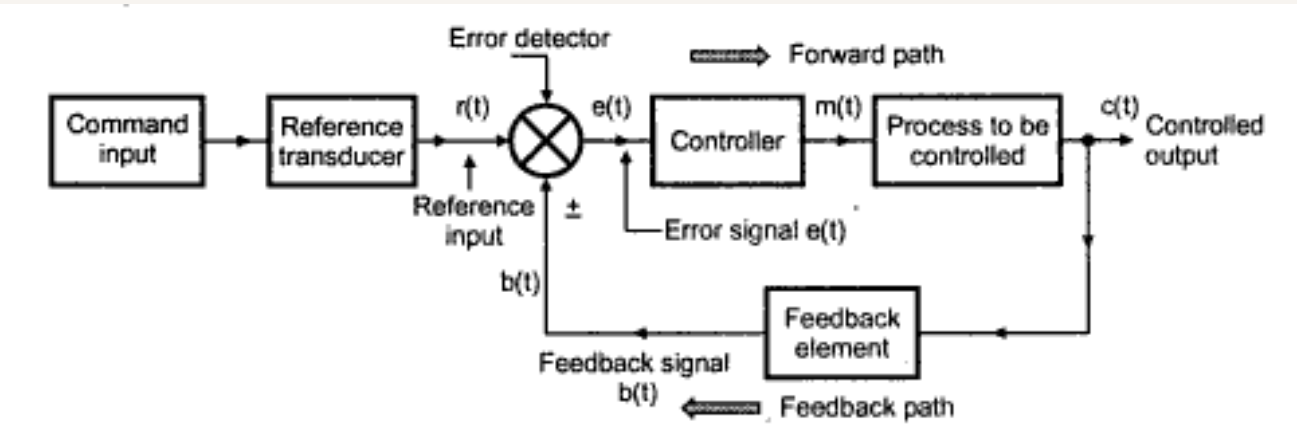
- **Controlled Output**
  It is the particular signal of interest or the actual response obtained from a control system when input is applied to it.

1.5 Advantages & Disadvantages

OPEN LOOP SYSTEM

Advantages	Disadvantages
Systems are simple in construction and design.	Inaccurate and unreliable because accuracy is dependent on accuracy of calibration.
System are simple and economical	Inaccurate results are obtained with parameter variation, internal disturbance.
Systems are easy to maintenance .	
Not much problem of stability.	
Can still operate even if output cannot be measured.	To maintain the quality and accuracy , recalibration of the system is necessary from time to time.

1.6 CLOSED LOOP CONTROL SYSTEM



The various signal are,

r(t) = Reference input e(t) = Error signal

c(t) = Controlled output m(t) = Manipulated signal b(t) = Feedback signal

Reference input: Is the desired value of the controlled variable. It also known as a setpoint.

Feedback signal: The signal which is output of feedback element and it will be compared with the reference input to give error signal.

When feedback sign is positive, systems are called positive

When feedback is negative systems are called **negative feedback systems.**

CLOSED LOOP CONTROL SYSTEM

Error signal: This error signal is then modified by controller and decides the proportional manipulated signal for the process to be controlled.

Manipulated signal: This manipulation is such that error will approach zero. This signal then actuates the actual system and produces and output.

Controlled output: The produced output after actuating the actual system.

1.6.1 : Advantages & Disadvantages

CLOSED LOOP SYSTEM

Advantages	Disadvantages
Reduced sensitivity to disturbance inputs and parameter changes.	More complicated to design hence more expensive.
Highly accurate as any error arising is corrected due to presence of feedback signal.	Require more maintenance.
Facilitates automation.	Stability is the major problem and more care is needed to design a stable closed loop system.
Less affected by noise.	
High bandwidth– fast response.	
Can stabilize an unstable open loop plant	

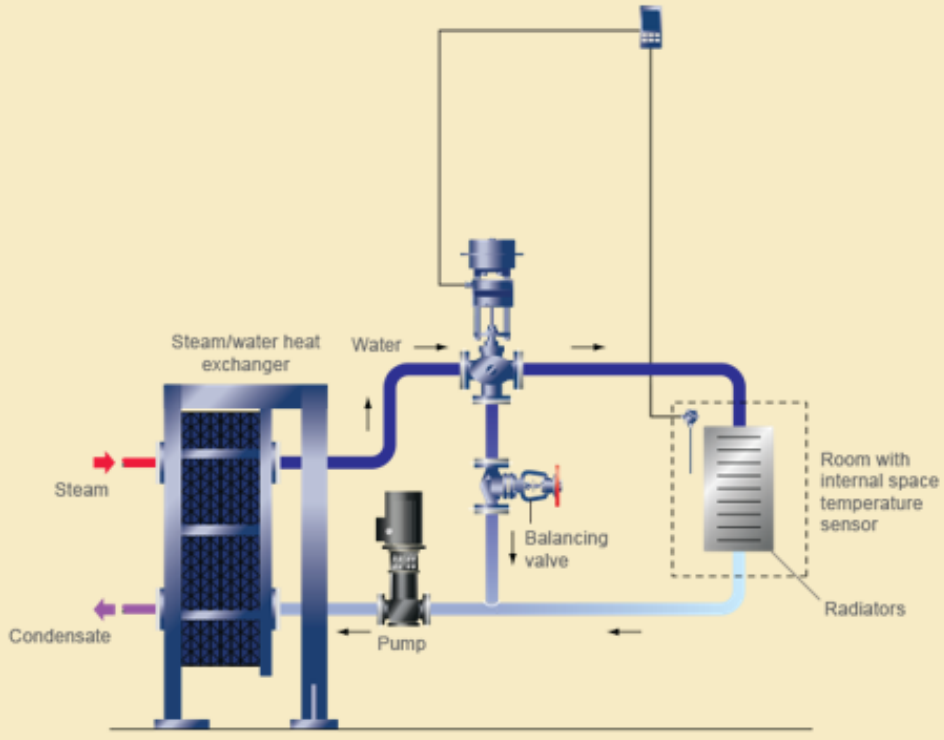
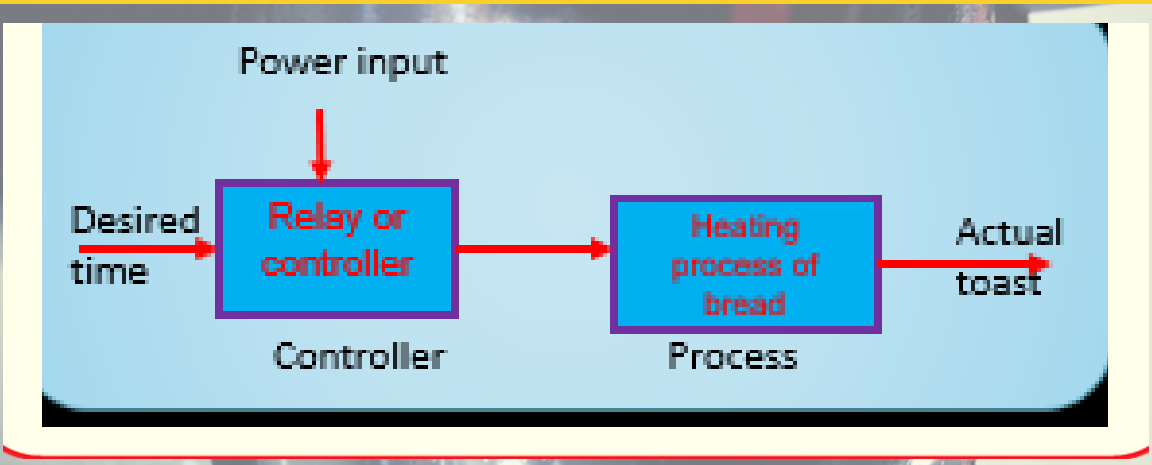


Fig. 5.3.3 Closed loop control system with sensor for internal space temperature

1.7 Examples Aplication of Open Loop Control System



- **Example 1: Automatic Toaster:**
  - **Reference input**
    Bread and setting the time of toasting required
  - **Controlled variable/Output**
    Degree of toasting
  - **Control element**
    A person making decision based on experience of the toasting degree by adjusting the setting of the toaster.
  - **Correction element**
    Control knob/switch
  - **Process**
    toasting

Examples Aplication of Open Loop Control System

Automatic Toaster-cont....

- In this system, the quality of toast depends upon the time for which the toast is heated. Depending on time setting, bread is simply heated in this system.
- The degree of toasting required is determined by adjusting the setting of the toaster and it is not altered by the condition of the bread.
- The toaster does not react to a change in the condition of the bread.
- The toast quality is to be judged by user and has no effect on the input.

Examples Aplication of Open Loop Control System

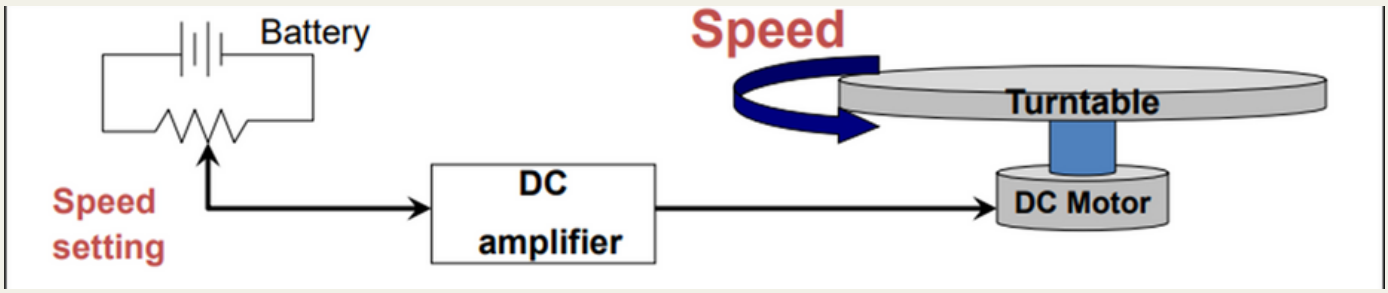
Example 2 : : Turntable speed control

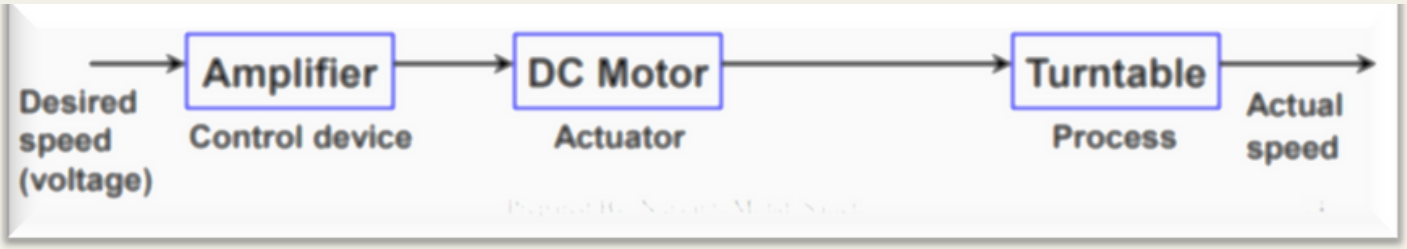
Aim: To design a system for turntable speed control that will ensure that the actual speed of rotation is within an acceptable percentage of desired speed.

Example of devices - using turntable speed control to rotate: CD player, computer disk drive.

Battery – provides voltage i.e. proportional to the desired speed. This voltage is amplified and applied to the motor.

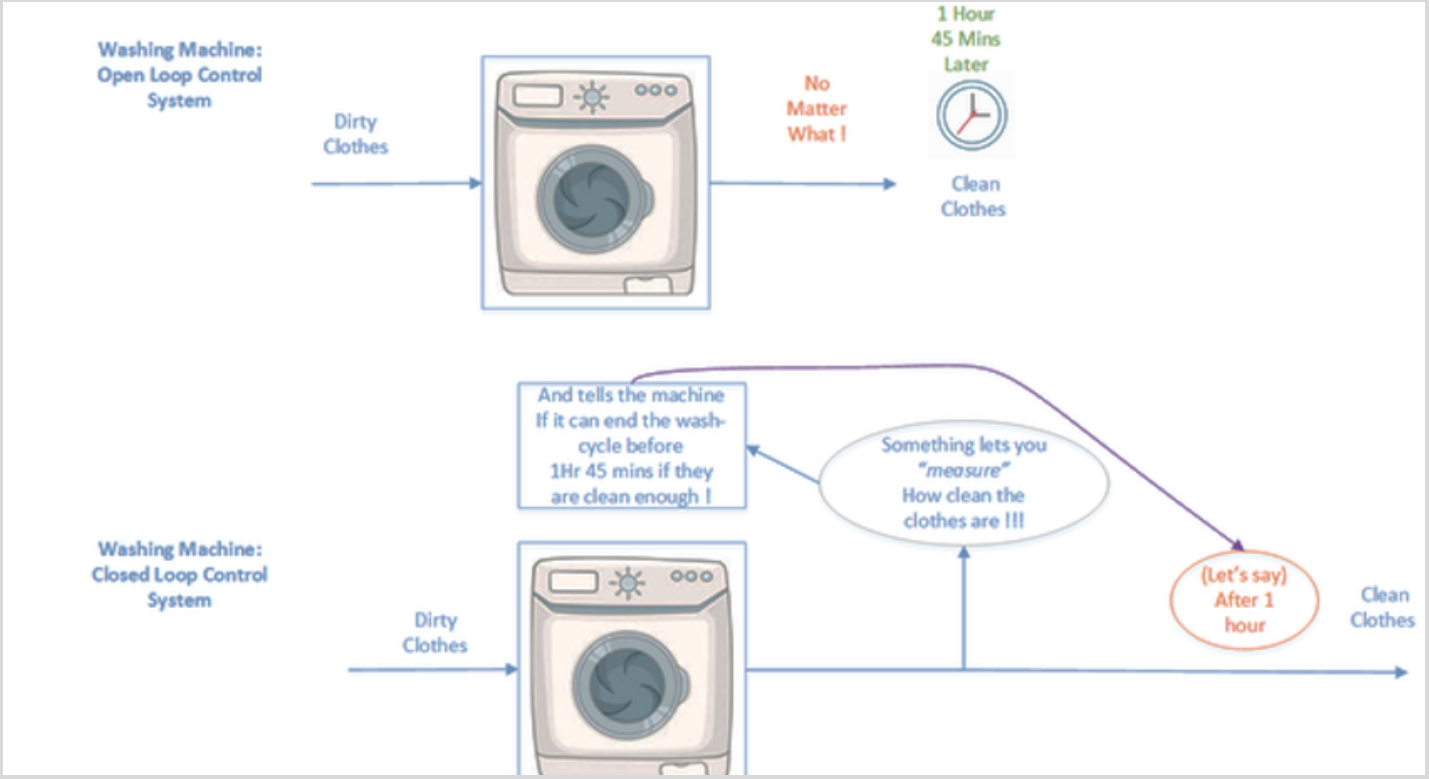
DC motor – provides speed that proportional to applied motor voltage.





Examples Aplication of Open Loop Control System

Example 3 : : Automatic Washing Machine

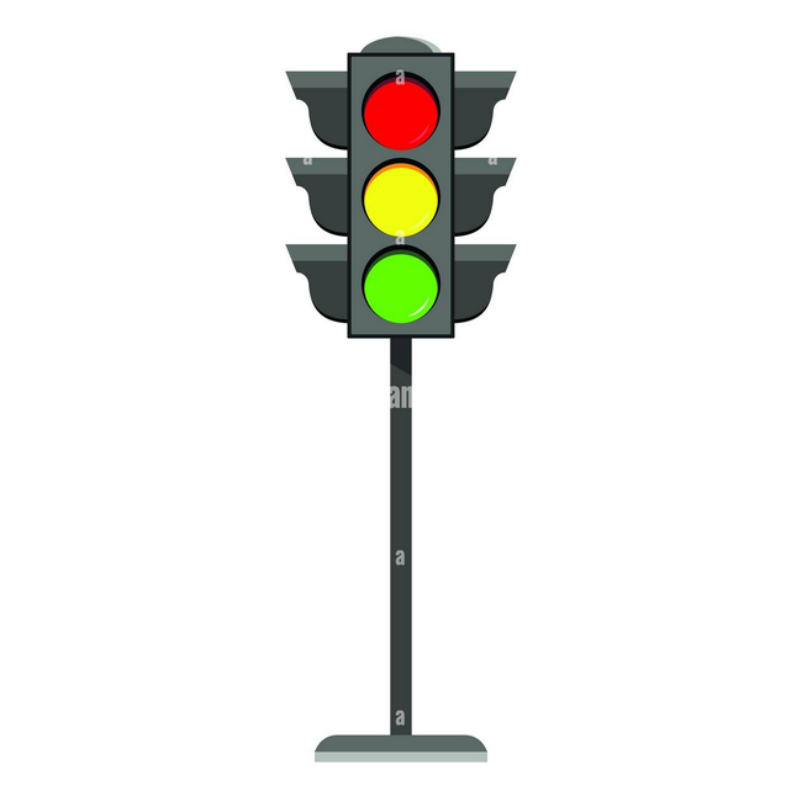


Example 4: : Microwave Oven

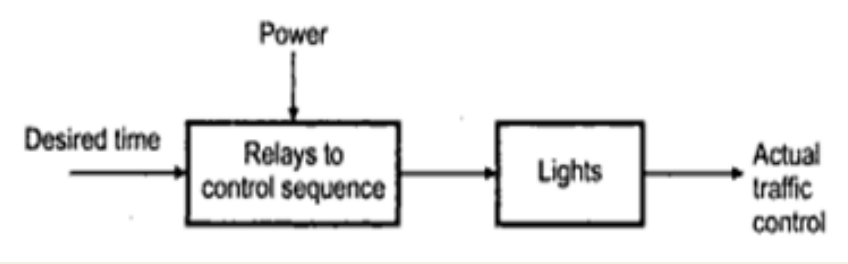
- You set the microwave oven to run for two minutes. After cooking for two minutes, the control system turns the microwave off. It has no idea whether your food is still frozen, burnt or cooked perfectly.

Examples Aplication of Open Loop Control System

Example 5 : : Traffic light Controller

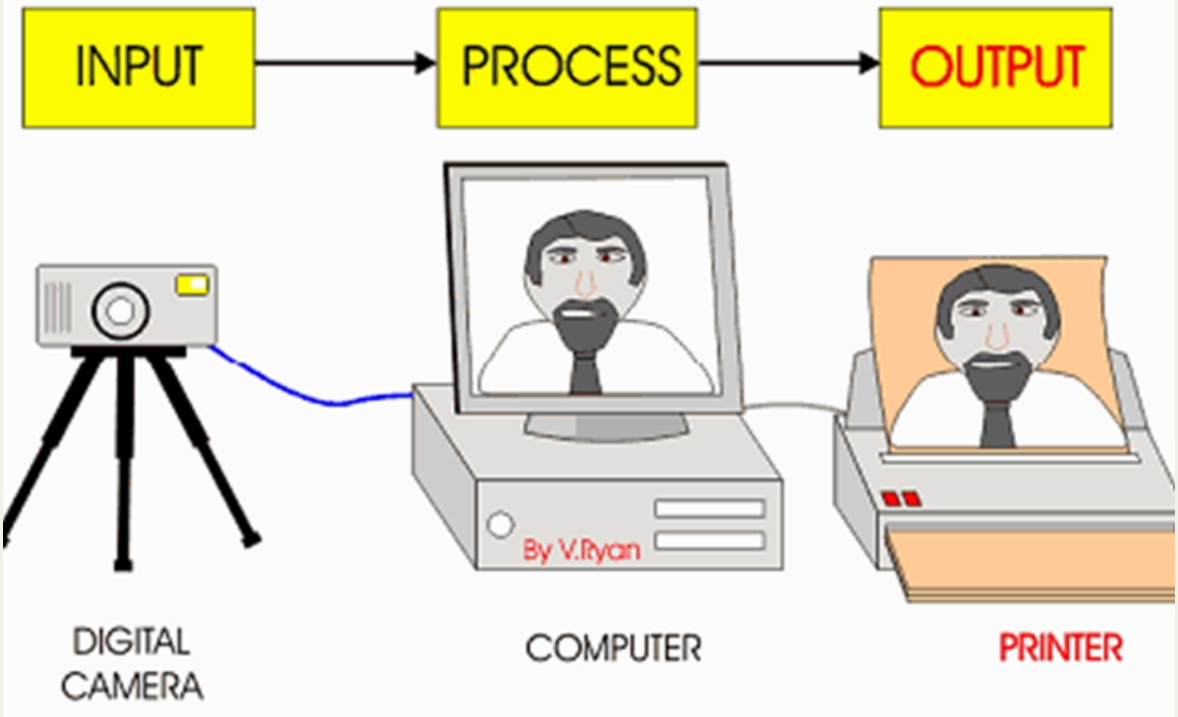


A traffic flow control system used on roads is time dependent. The traffic on the road becomes mobile or stationary depending on the duration and equence of lamp glow. The sequence and duration are controlled by relays which are predetermined and not dependent on the rush on the road.



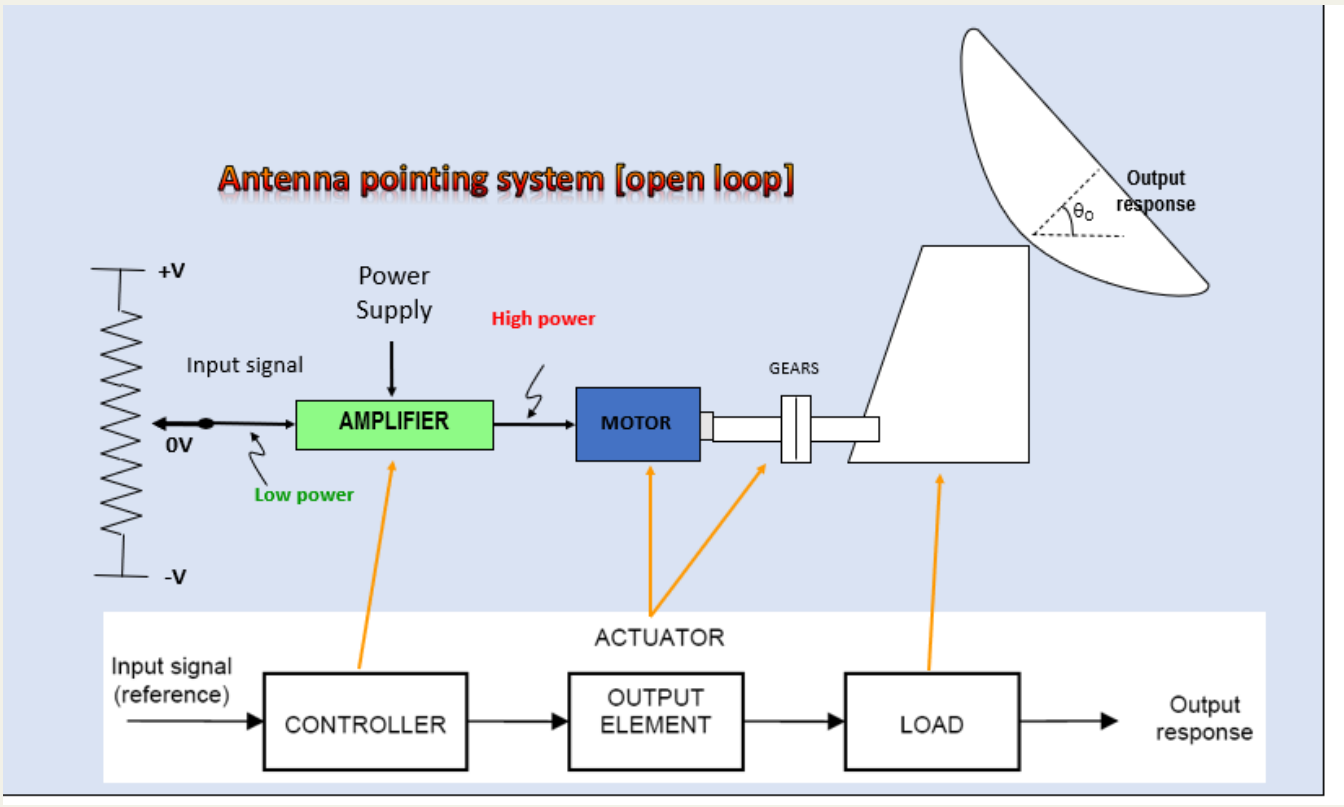
Examples Aplication of Open Loop Control System

Example 6 : Computer



Examples Aplication of Open Loop Control System

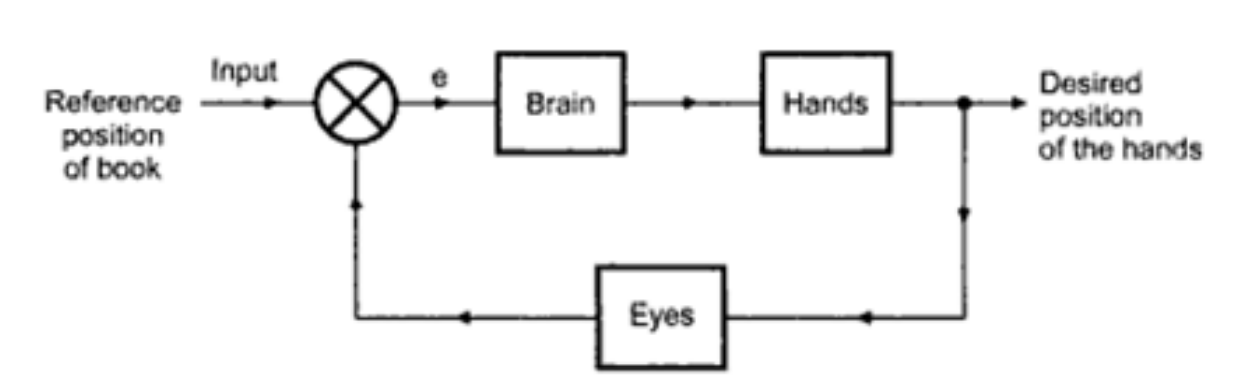
Example 7 : Antenna



1.8 Examples Aplication of Open Close Control System

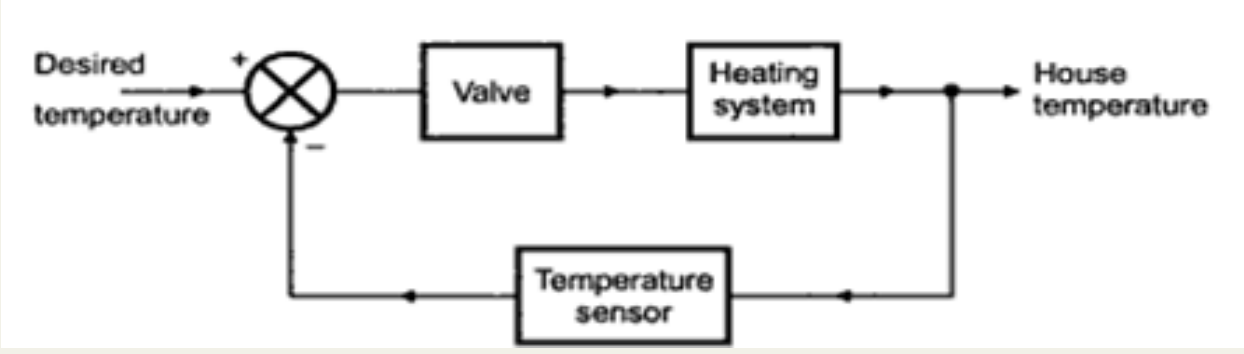
Example 1: Human Being

The best example is human being. If a person wants to reach for a book on the table, closed oop system can be represented as in figure below.



Example 2: Home Heating System

The heating system is operated by a valve. The actual temperatures is sensed by a thermal sensor and compared with the desired temperature. The difference between the two, actuates the valve mechanism to change the temperature as per the requirement.



Examples Aplication of Open Close Control System

Example 3: Temperature Control System

The aim is to maintain hot water temperature constant. Water is coming with constant flow rate. Steam is coming from a valve. Pressure thermometer 'P' is used as a feedback element which sends a signal for comparison with the set point. This error actuates the valve which controls the rate of steam, eventually controlling the temperature of the water.

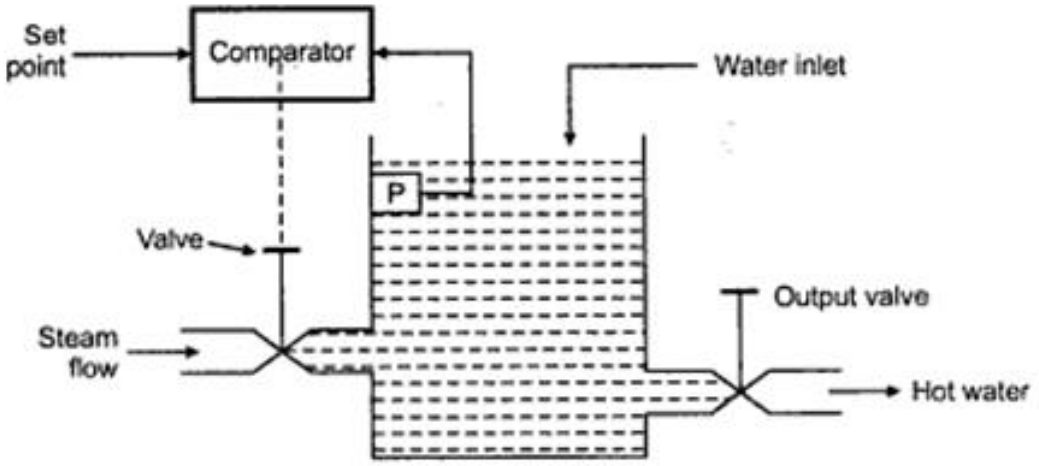
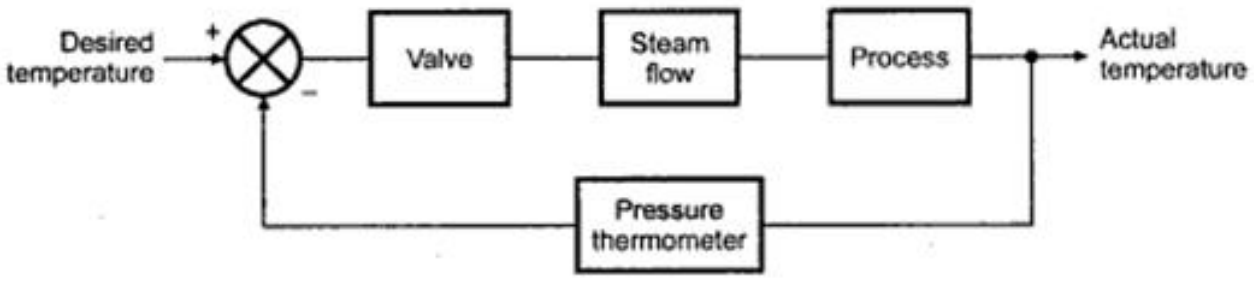
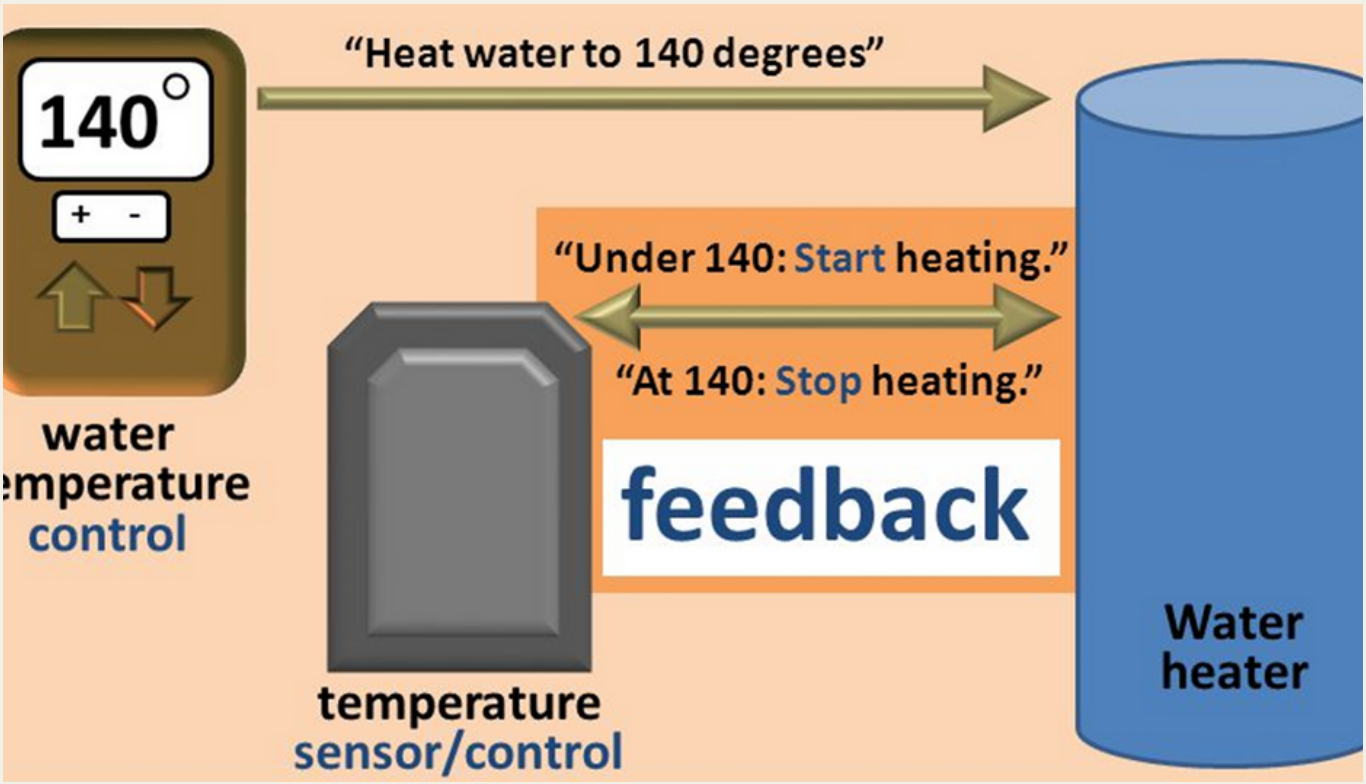


Fig. 1.20 Temperature control system

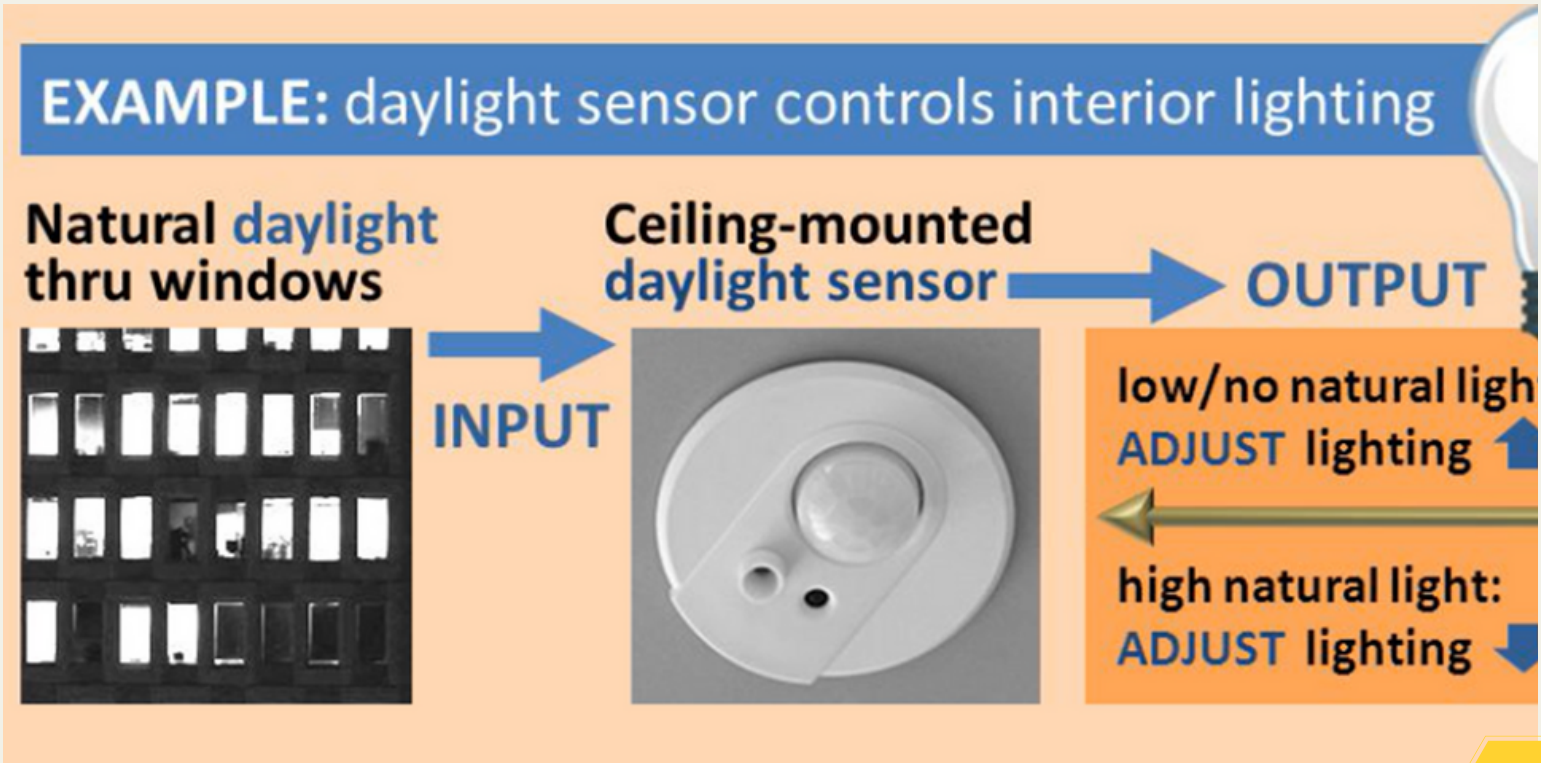


Examples Aplication of Open Close Control System

Example 4: Water Heater

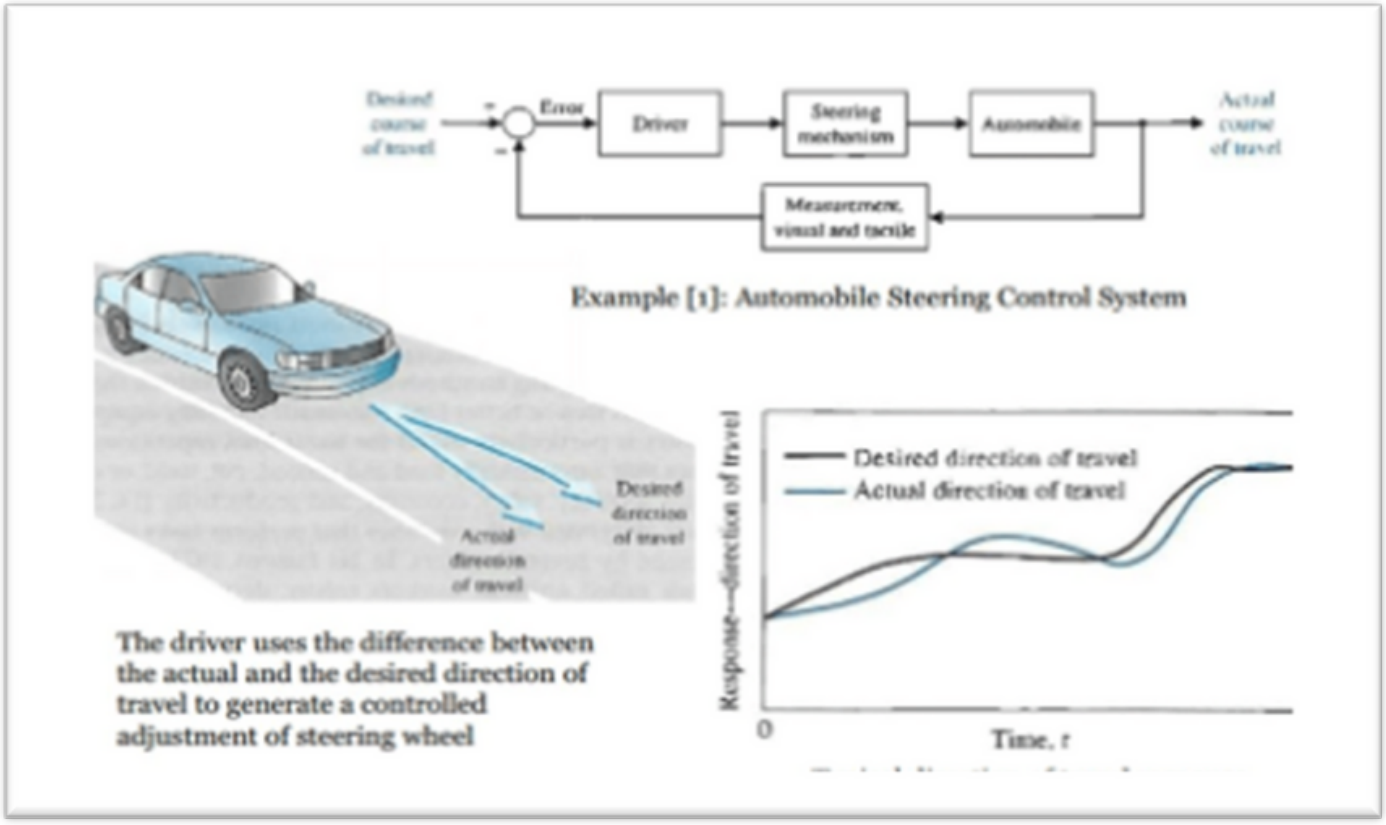


Example 5: Daylight Sensor Control

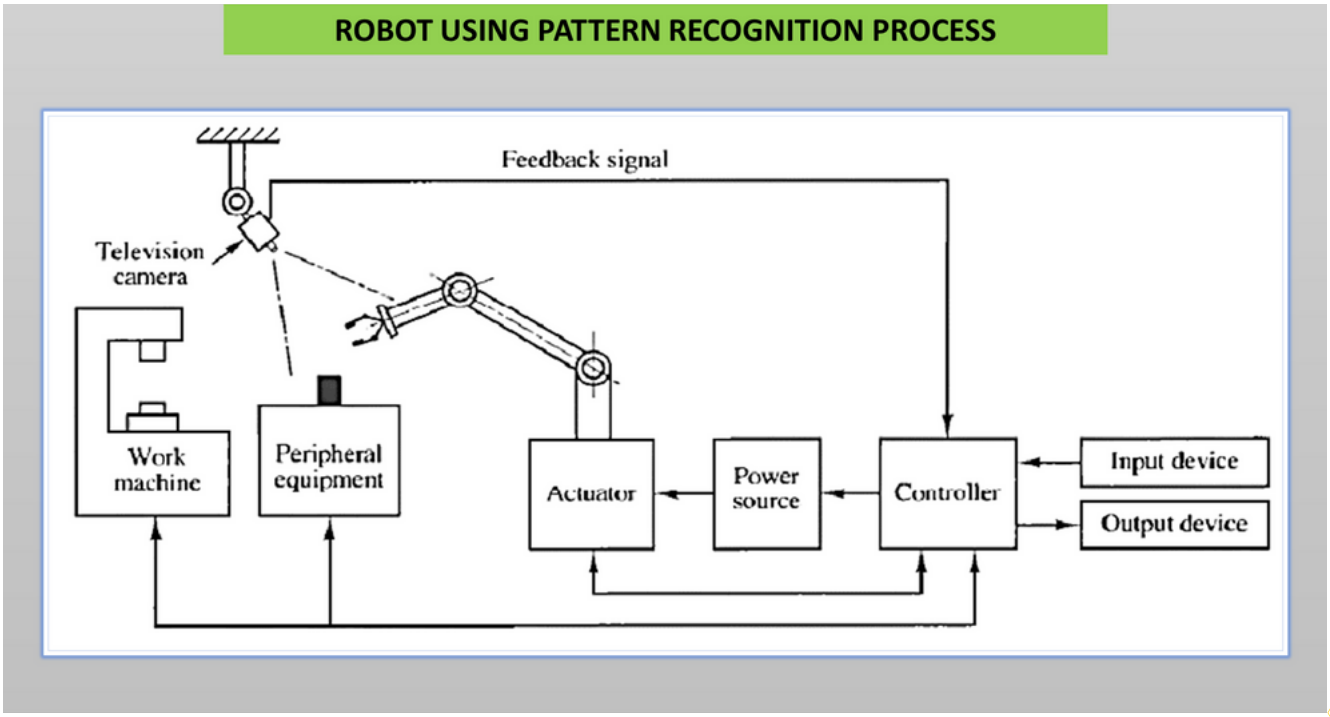


Examples Aplication of Open Close Control System

Example 6: Automobile Steering Control System

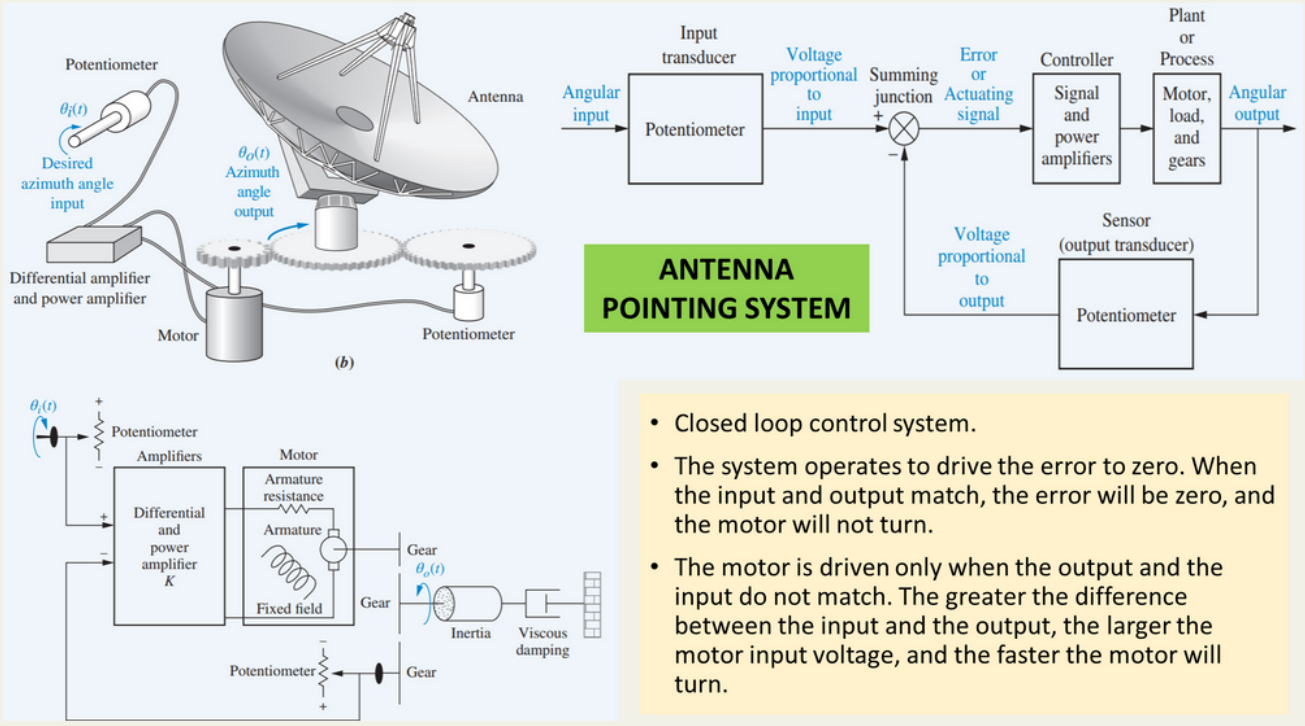


Example 7: Robot Process



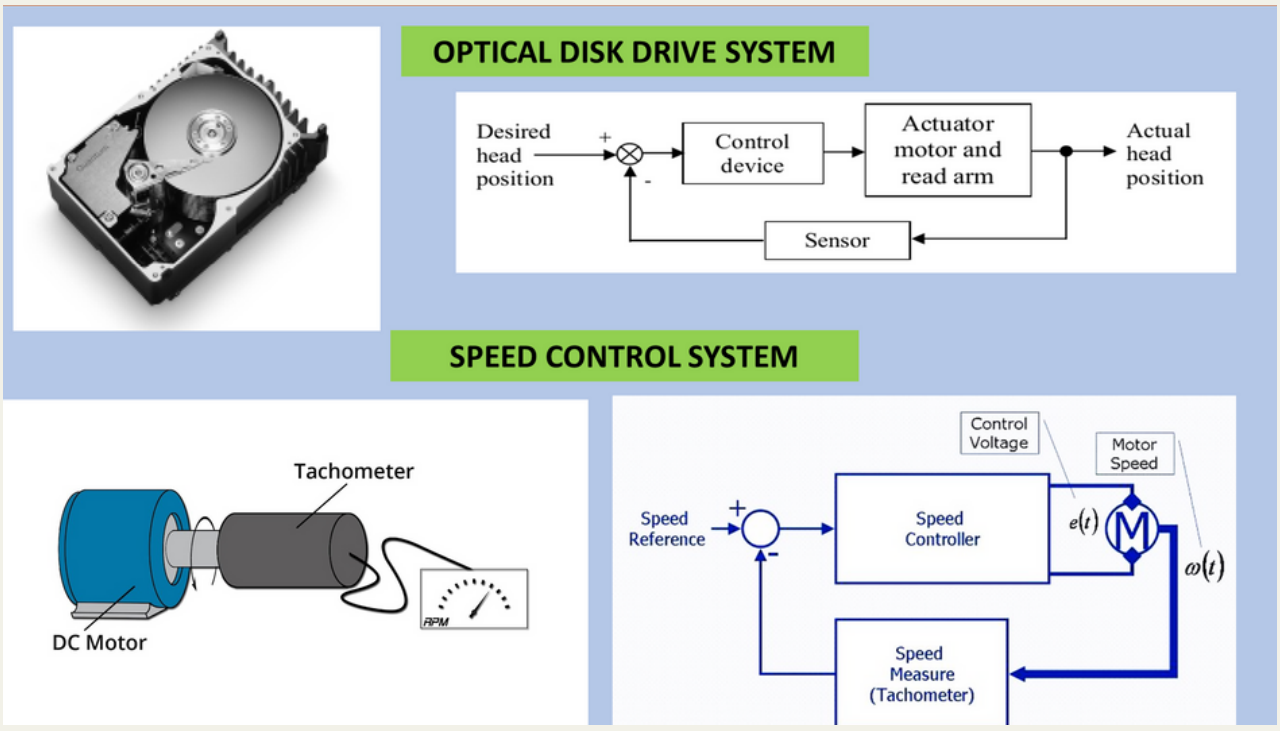
Examples Aplication of Open Close Control System

Example 7: Antenna Pointing System



- Closed loop control system.
- The system operates to drive the error to zero. When the input and output match, the error will be zero, and the motor will not turn.
- The motor is driven only when the output and the input do not match. The greater the difference between the input and the output, the larger the motor input voltage, and the faster the motor will turn.

Example 8: Speed control System

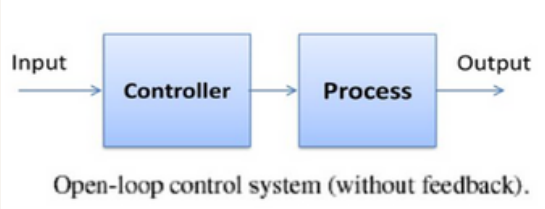


1.9 COMPARE BETWEEN OPEN LOOP AND CLOSED LOOP CONTROL SYSTEM

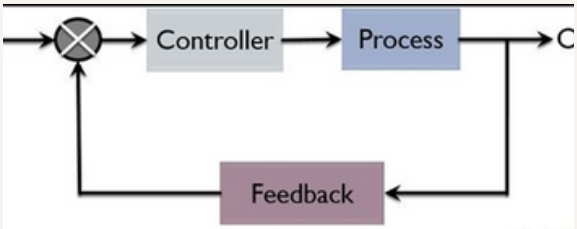
Open loop control systems

VS.

Closed loop control systems



Open-loop control system (without feedback).



Examples

- TV remote control.
- Washing Machine.
- Volume on the stereo system.
- Clothes drier.
- Servo motor or stepper motor.
- Door lock systems.
- Coffee or tea making machine.

Examples.

- Thermostat Heater.
- Modern Air Conditioner.
- Induction Cooker.
- Electric Iron.
- Water Level Controller.
- Automatic Street Light.
- Smoke Detection System.

Open Loop Control System	Closed-Loop Control System
In this system, the controlled action is free from the output	In this system, the output mainly depends on the controlled act of the system.
This control system is also called a Non feedback control system	This type of control system is also called a feedback control system
The components of this system include a controlled process and controller.	The components of this kind of system include an amplifier, controlled process, controller and feedback
The construction of this system is simple	The construction of this system is complex
The consistency is non-reliable	The consistency is reliable
The accuracy of this system mainly depends on the calibration	These are accurate due to feedback
In this system, the controlled action is free from the output	In this system, the output mainly depends on the controlled act of the system.

AN IDEAL CONTROL SYSTEM

- **Accuracy :** A good control system must be highly accurate. It should operate with as little error as possible

- **Sensitivity :** A good control system should be very insensitive to such parameter variations but sensitive to the input commands.

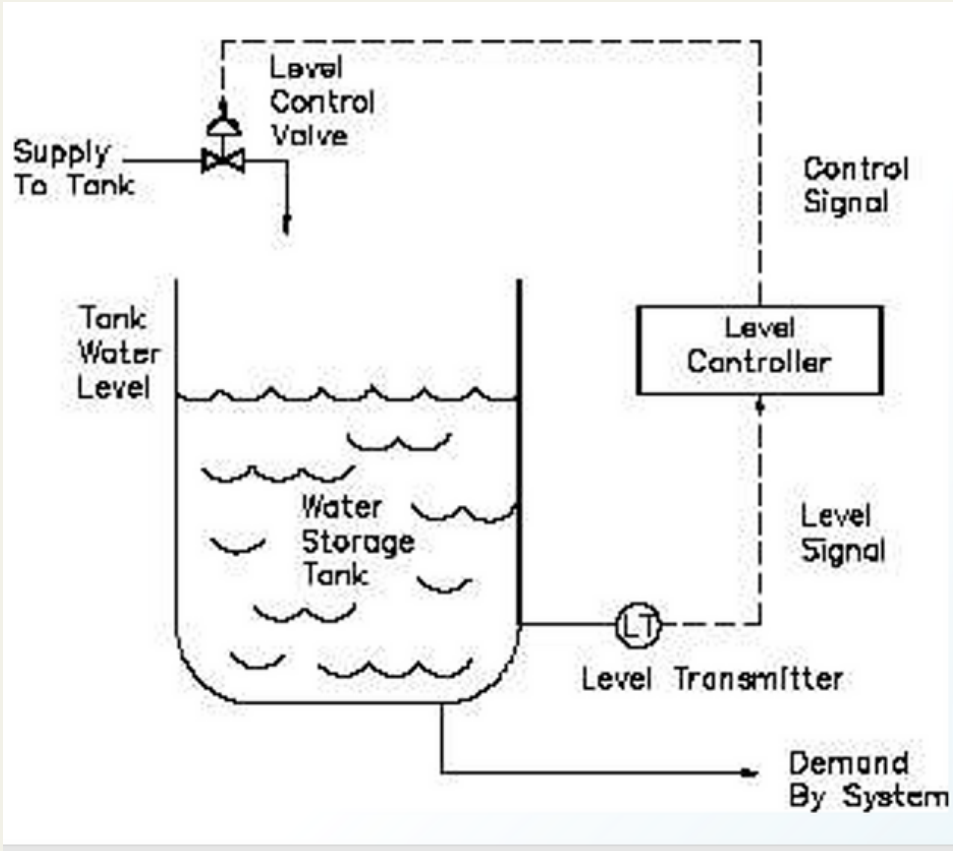
- **External Disturbance or Noise :** All the physical systems are subjected to external disturbance and noise signals ; during operation.

- **Stability :** A concept of stability means output of system must follow reference input and must produced bounded output for bounded input. However due to wrong selection of parameters it is possible that output tends to increase without bounds. This is called as unstable condition. A good system is one which in stable in nature.

- **Bandwidth:** This requirement is related to the frequency response of the system. For the input frequency range,it should give satisfactory outputs. The frequency range for which output is satisfactory is its bandwidth. The satisfactory output means maximum possible output without overshoots and it should not change with input frequency in given range.

- **Speed :**A system should have good speed. This means output of the system should approach to its desired value as fast as possible. This is measured in terms of its rise time and settling time. System should settled down to its final value as quickly as possible.

- **Oscillations:**The system should exhibits suitable damping.



Open Loop or Closed Loop?

Discuss your answer with your lecturer

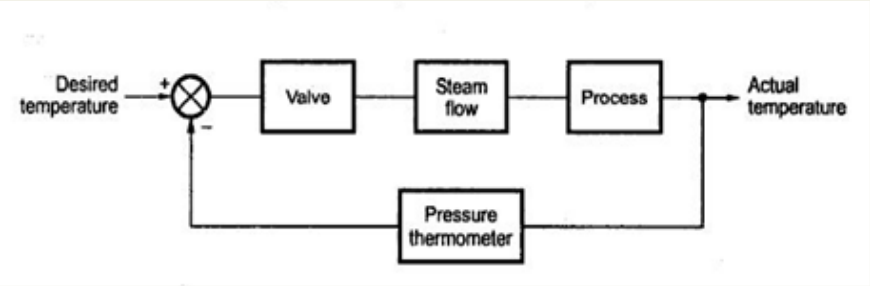
QUESTION & ANSWER

QUESTION 2

By referring to Figure A1 (c), temperature control system is one of example closed- loop control system. Draw the general block diagram of the system and explain the operations of the system .

ANSWERS

BLOCK DIAGRAM



OPERATION THE SYSTEM

Water is coming with constant flow rate.
-Steam is coming from a valve
-Pressure thermometer ‘P’ is used as a feedback element which sends a signal for comparison with the set point.
-This error actuates the valve which controls the rate of flow of steam, eventually controlling the temperature of the water.

QUESTION & ANSWER

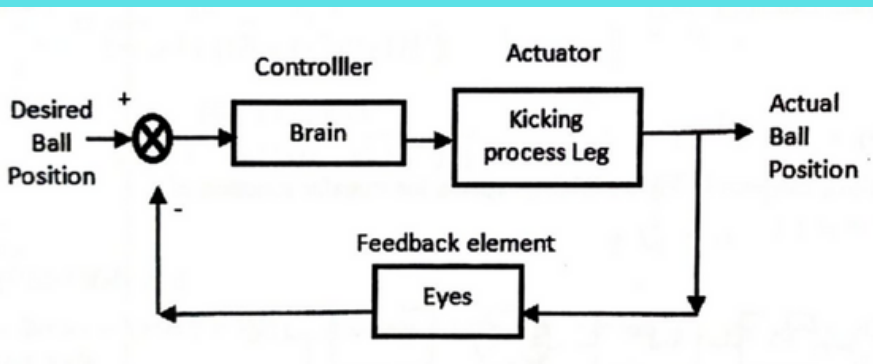
QUESTION 1

The boy is kicking a ball as show in figure 1.Write the operations in the closed loop control system with the aid of a block diagram.

figure 1.

ANSWERS

BLOCK DIAGRAM



OPERATION THE SYSTEM

A boy wants to kick a ball, presented as in the figure above. Position of a ball is given as the reference. Feedback signal from eyes compares the actual position with reference position. Error signal is given to brain. Brain manipulates this error and gives signal to the leg. Leg will control a position. This process continues till the actual position of the ball equal to the desired ball position.

Review questions

1. State FOUR (4) basic component of a control system.
2. Describe an open loop and closed loop control system.
3. Give 3 examples of open-loop and closed loop control systems.
4. Compare open loop and close loop control systems in general with an example of real time application.
5. How do we classify control systems?
6. In the past, control systems used a human operator as part of a closed loop control systems. Sketch the block diagram of the valve control system shown in figure 2.

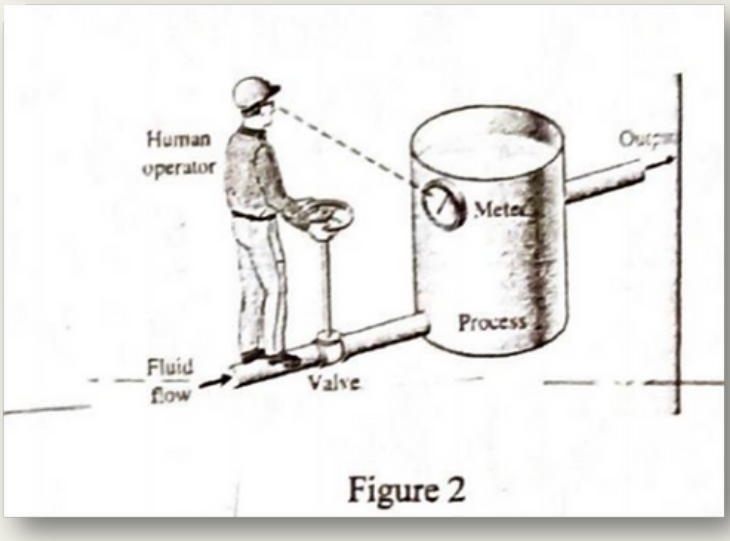


Figure 2

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BASIC CONTROL SYSTEM

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