Roll No.

PRESIDENCY UNIVERSITY

BENGALURU

SCHOOL OF ENGINEERING

TEST 1

Sem & AY: Odd Sem 2019-20 — **Date**: 30.09.2019

Course Code: PET 226 — **Time**: 2.30 to 3.30 PM

Course Name: PROCESS CONTROL & INSTRUMENTATION — **Max Marks**: 40

Program & Sem: B.Tech (PET) & V — **Weightage**: 20%

Instructions:

(i) All questions are compulsory

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries two marks (4Qx2M=8M)

1. Explain the reasons why process control is required in the industry? (C.O.NO.1) [Knowledge]
2. What are the different types of input/response which can be given to the process? (C.O.NO.1) [Knowledge]
3. Explain the difference and similarities, between a control variable, set point and measured variable? (C.O.NO.1) [Knowledge]
4. What are the advantages of closed loop system? (C.O.NO.1) [Knowledge]

Part B [Thought Provoking Questions]

Answer the Questions. Each Question carries four marks. (3Qx6M=18M)

5. What are the elements of the control systems? Explain in detail? (C.O.NO.1) [Knowledge]
6. What do you understand by positive feedback system? Take any hypothetical example and explain the positive feedback system with a block diagram and also state the condition when the positive feedback will come to a halt? (C.O.NO.1) [Knowledge]
7. What do you mean by open and closed loop system? Explain giving your own unique example of closed system, with the help of a block diagram.(Ps-examples of car is not be used) (C.O.NO.1) [Knowledge]

Part C[Problem Solving Questions]

Answer the Question. The Question carries fourteen marks. **(1Qx14M=14M)**

8. What do you mean by order of the system. Derive the transfer function equation for a thermometer? (C.O.NO.2) [Comprehension]

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Date: 30-09-19

Semester: V

Time: 1 HOUR

Course Code: PET 226

Max Marks: 40

Course Name: PROCESS CONTROL & INSTRUMENTATION

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K			K/C			C/A			
1	1	1	8									8
2	1	1				6						6
3	1	1				6						6
4	1	1				6						6
5	2	2							14			14
	Total Marks											40

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SOLUTION

Semester: V
Course Code: PET 226
Course Name: PROCESS CONTROL & INSTRUMENTATION

Date: 30-09-19
Time: 1 HOUR
Max Marks: 40
Weightage: 20%

Part A (4Q x 2M = 8)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1(a)	1. Production Rate 2. Product Quality 3. Safety 4. Economy	2	2
1(b)	1. Step input 2. Impulse input2 3. Pulse input	2	2
1(c)	Set point is the desired value in the process. Control variable is the variable which needs to be changed to achieve the set point Measured variable is the instantaneous value of the control variable	2	2
1(d)	**i)** Automatically reduce errors **ii)** Improve stability **iii)** Increase robustness against external disturbances **iv)** Reliable and repeatable	2	2

Part B (3Q x 6M = 18)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
2	i)Controllers ii)Variables iii)Final control element iv)Measuring device	6	10

Measurements

A wide range of on-line measuring devices (sensors) exists in the process industries, the most common being those for flow rate, pressure, liquid level, temperature, pH, and other selective measures of chemical composition. There is a continuing development in this area all provide summaries of many types of sensors currently available.

Controllers

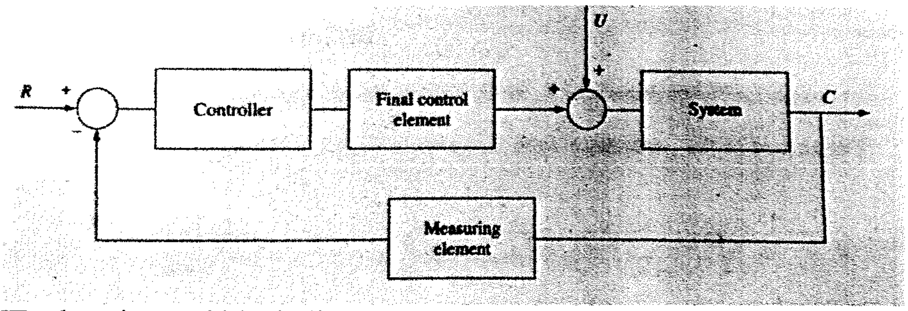
Classical PID *(proportional-integral-derivative) controllers* still dominate feedback strategy in industrial applications. Here, the signal to the final control element, p, is related to its nominal value, p_s, and to the "error" signal, e, by the equation

Final Element

The control action signal calculated by the controller is sent to the final control element, a device which implements the change of a suitable input to the system. This variable input is typically a flow rate (of fuel, air, coolant, reactant, etc.). Hence, an automatic control valve, either electrically or pneumatically operated, is usually appropriate

3		6	10

It is also possible to implement a ***positive feedback system.*** For this system, the error is generated by adding the measured variable and the set point. As we shall see later, in most cases, the output of the controller increases when the input is increased. Hence a positive feedback system will cause a signal of higher magnitude to be fed to the controller. This results in a higher value of the manipulated variable, and hence a higher value of the control variable, and consequently, a higher value of measured variable. This again gets added to the set point and fed to the controller which results in higher output and this chain of events continues till the system breaks down (we have an unstable system) or the output reaches saturation and does not change in spite of the signals from the controller (which means there is no control). Because of these problems, positive feedback control systems are not acceptable. However, under some circumstances, even negative feedback systems may behave like positive feedback systems.



[Explanation and block diagram according to the individual example]

4		6	10

Water heater

Consider a water heater consisting of a tank which has been provided with an inlet and an outlet for water to flow through the tank. The water is heated by steam condensing in a coil immersed in the water. This is shown in Figure 1.6.

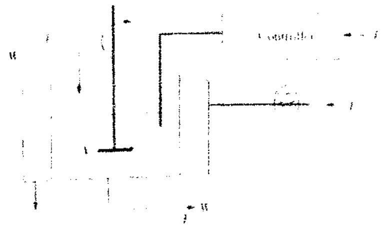


Figure 1.6 Water heater control system

The exit temperature of water T_o is the control variable. It is desired to keep the exit water temperature constant at T_R (the set point). The inlet temperature of water is T_i and the mass flow rate of water is W. We assume, the water flow rate to be constant. The contents of the tank are well mixed and hence we can assume that the water temperature is uniform at T_o throughout the tank. T_o is measured by a thermocouple and this value is fed to a controller. The controller is also given the set point T_R. The controller controls the exit water temperature by manipulating the steam temperature (by changing the steam pressure). The steam pressure is changed by opening/closing the steam valve.

Let us examine the control action. The value of T_o is continually read by the thermocouple. The controller monitors the difference between the set point T_R and the actual value of the control variable T_o. If the system is at a steady state, the error is zero. In other words, the values of T_R and T_o are the same.

Suppose the exit water temperature T_o is less than desired value due to some reason (loss of heat to the surroundings, change in the pressure of steam etc.). The thermocouple reports this lower value to the controller. The controller determines the difference between the set point T_R and the actual value of the exit water temperature T_o, i.e., the error. Since the value of T_o has decreased, the difference is positive ($T_R > T_o$). The controller, therefore, increases its output. This increase in the controller output results in opening the steam valve to a greater extent. More steam is admitted to the jacket thereby increasing the pressure. This increases the steam temperature T_v. Due to the increase in the driving force ($T_v - T_o$), more heat is transferred to the water and its temperature T_o is increased. If the water temperature is more than the desired value, exactly the same sequence is gone through except that the steam temperature is decreased thereby decreasing the heat transfer rate and hence the exit water temperature.

The components of the water heater system connected in a logically correct sequence are shown in Figure 1.7.

Suppose the system is now at steady state (the exit water temperature is the same as the set point). Let the inlet temperature of water changes. This will change the exit water temperature T_o also. The thermocouple reports this lower value to the controller. The controller again determines the difference between the set point T_R and the actual value of the exit water temperature T_o. Since the value of T_o has decreased, the difference is positive ($T_R > T_o$). The controller, therefore, increases the steam pressure, more heat is transferred to the water and its

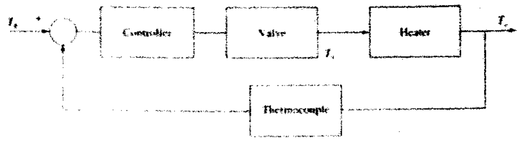


Figure 1.7 Block diagram for water heater control without load.

temperature T_o is increased. Thus, we see that since the controller can not directly change the value of the load variable T_i, it neutralizes the change in T_o by changing T_v. To repeat, the controller has no control over the load variable but can nullify the effect of the load variable on the system indirectly (by changing the manipulated variable). This is depicted in the block diagram shown in Figure 1.8.

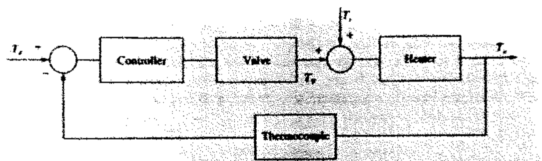


Figure 1.8 Block diagram for water heater control with load.

The control loop in the generic form is shown in Figure 1.9.

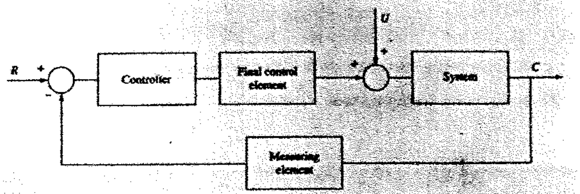
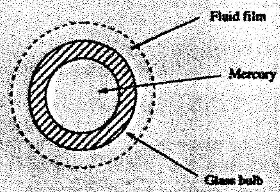


Figure 1.9 Generalised block diagram.

	[Explanation and block diagram according to the individual example]		

Part C (1Q x 14M = 14)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
5	**3.2 THERMOMETER** A liquid-in-glass thermometer is used to measure temperatures. Thermocouples, thermistors, resistance thermometers, bimetallic thermometers (enclosed in metal tubes) are also used very widely in the industry. In every case, there is a small part which gets heated or cooled when exposed to the environment. This heating or cooling is due to heat transferred from or to the surroundings. The mode of action for the different instruments is the same. The temperature of the active part of the thermometer is changed. This change is shown by the instrument in some way. In case of the liquid-in-glass thermometer, the result of the temperature change is the expansion of the liquid, while for the thermocouple, the result of temperature change in the thermocouple bead is the change in the emf produced. The following analysis is made using the liquid-in-glass thermometer but is valid for the other types of temperature sensing instruments. Figure 3.3 shows a section of the bulb of the thermometer. The innermost circle is the liquid which is enclosed in the glass envelope. The outermost layer is the film of fluid in which the thermometer is immersed.  **Figure 3.3 Top view (section) of a thermometer bulb.**	14	22

Assume that the thermometer is at the same temperature as the surroundings. This is to say that the temperature of the thermometric liquid and the temperature of the surroundings is the same. Let x be the temperature of the surroundings and y be the temperature of the thermometric liquid in the bulb. Then at steady state, $x = y$.

At a certain instant of time ($t = 0$), the temperature is increased. Heat will now start flowing into the thermometric liquid across the glass envelope till the temperatures are again equal. The change in the value of y with time can be obtained from the energy balance. The balance is

$$\text{Energy coming in} - \text{Energy going out} = \text{Rate of energy accumulation}$$

$$\text{Energy in} = hA\,(x - y)$$

$$\text{Energy out} = 0$$

$$\text{Energy accumulation rate} = mC_p \frac{dy}{dt}$$

where h is the heat transfer coefficient, A is the area for heat transfer (surface area of the glass bulb), m and C_p are the mass of the thermometric liquid and its specific heat respectively. The energy out term is zero since all the heat transferred into bulb is absorbed by the thermometric liquid.

$$hA(x - y) = mC_p \frac{dy}{dt} \tag{3.9}$$

At steady state, there is no change in y with time and $x = y$. Using the subscript s to indicate steady state, Eq. (3.9) is written as:

$$x_s - y_s = 0 \tag{3.10}$$

Here x_s and y_s are the steady state values of x and y respectively.

Subtracting Eq. (3.10) from Eq. (3.9), we get

$$hA\,[(x - x_s) - (y - y_s)] = mC_p \frac{dy}{dt} \tag{3.11}$$

or

$$hA\,(X - Y) = mC_p \frac{dy}{dt} \tag{3.12}$$

The term X represents the change in the inlet temperature. In other words, this is the deviation variable representing the change in the temperature of the surroundings (inlet temperature), while Y is the deviation variable representing the change in the temperature of the thermometric liquid (outlet temperature). We must note again that the value of the deviation variable at time $t = 0$ is zero.

Equation (3.12) now can be written as:

$$hA\,(X - Y) = mC_p \frac{dY}{dt} \tag{3.13}$$

Since $Y = y - y_s$, and the steady state value y_s is constant with respect to time, the terms (dy/dt) and (dY/dt) are the same.

Equation (3.13) governs the relationship between the input X and the output Y of the thermometer and is a first order differential equation. Hence, the thermometer is an element with first order dynamics.

Taking Laplace transforms and dividing by hA, we can write Eq. (3.13) as:

$$X(s) - Y(s) = \frac{mC_p}{hA}\, s\,Y(s) \tag{3.14}$$

The term mC_p/hA has the dimensions of time and is called the time constant of the thermometer. The time constant is generally represented by the letter T.

The ratio of the Laplace transform of the output, $Y(s)$ to that of the input $X(s)$ is called the *transfer function* of the thermometer. The transfer function is represented by $G(s)$.

$$G(s) = \frac{Y(s)}{X(s)} = \frac{1}{1 + Ts} \tag{3.15}$$

We see that Eqs. (3.15) and (3.8) are identical. We can state therefore, that *the transfer function of a first order element is simply 1 / (1 + Ts) irrespective of the physical form of the element.*

The time constant T is equal to mC_p/hA. While m, C_p, and A are constants for the given instrument, the heat transfer coefficient h, depends upon the flow rate of the fluid and its physical properties. Thus, the values of T will be different when the thermometer is placed in the region where the flow is turbulent as compared to the value if the flow is less (for example, near the wall of the pipe). It is to be remembered that although T is called the time constant, it can change depending upon its position.

The block diagram representation of the thermometer is shown in Figure 3.4.

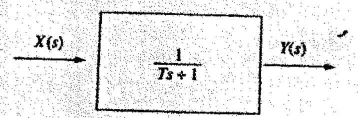


Figure 3.4 Block diagram for a thermometer.

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SCHOOL OF ENGINEERING

TEST – 2

Sem & AY: Odd Sem 2019-20
Course Code: PET 226
Course Name: PROCESS CONTROL & INSTRUMENTATION
Program & Sem: B.Tech. (PET) & V Sem

Date: 18.11.2019
Time: 2.30 PM to 3.30 PM
Max Marks: 40
Weightage: 20%

Instructions:

(i) *All Questions are Compulsory.*

Part A [Memory Recall Questions]

Answer all the Questions. Each question carries two marks. (6Qx2M=12M)

1. (C.O.NO.2)[Comprehension]

a. What are the two things that we should know or observe to give second step input?
b. Can we give impulse input in single tank? If yes, explain.
c. What are the different types of actuators used?
d. In which case, a derivative controller used?
e. Define controller gain.
f. Write short notes on analog controller.

Part B [Thought Provoking Questions]

Answer all the Questions. Each question carries six marks. (3Qx6M=18M)

2. What do you mean by controllers? Explain the different types of controllers. (C.O.NO.2)[Comprehension]
3. Explain with a relevant graph: (C.O.NO.2)[Comprehension]
   a. Dead Time
   b. Rise Time
   c. Peak Time
   d. Overshoot
   e. Settling Time
4. Which is the term used for showing Oscillatory motion in transfer function? Explain them. Explain the different oscillatory nature with the change of value of that particular term. (C.O.NO.2)[Comprehension]

Part C [Problem Solving Questions]

Answer the Questions. The question carries ten marks. (1Qx10M=10M)

5. Mr. John Wick wants a 1000 litre water supply system in his home. As 1000 litre Sintex tank was unavailable, he buys two 500 litre Sintex. Suggest him how the tanks are to be connected and state your reason. Find the transfer function of the system.
(C.O.NO.2)[Comprehension]

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Semester: V

Course Code: PET 226

Course Name: PROCESS CONTROL & INSTRUMENTATION

Date: 18-11-19

Time: 1 Hour

Max Marks: 40

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K/C			K/C			C/A			
1	2	2	12									12
2	2	2				6						6
3	2	2				6						6
4	2	2				6						6
5	2	2							10			10
	Total Marks		12			18			10			40

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SOLUTION

Date: 18-11-19

Semester: V

Time: 1 HOUR

Course Code: PET 226

Max Marks: 40

Course Name: PROCESS CONTROL & INSTRUMENTATION

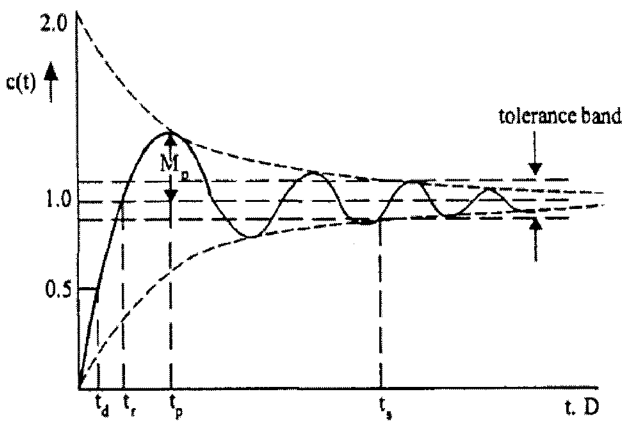
Weightage: 20%

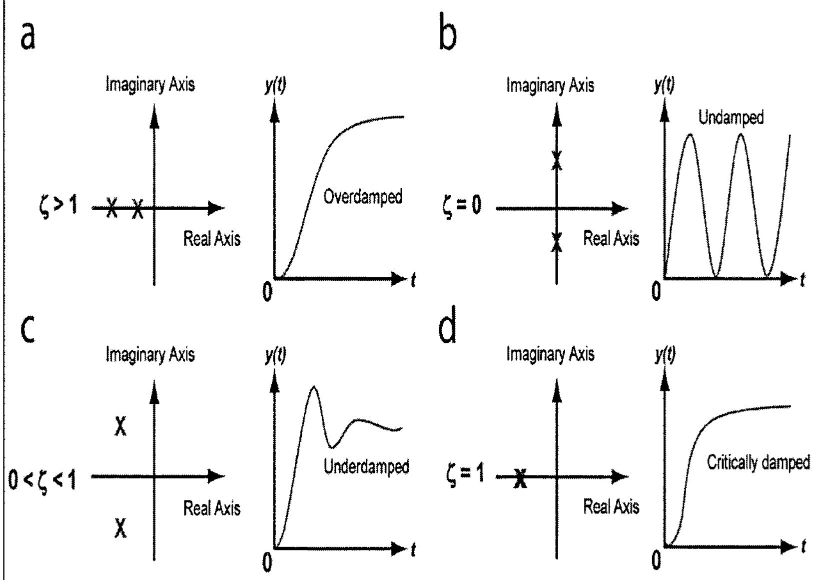
Part A (6Q x 2M = 12)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1(a)	i)It should be steady state ii) Magnitude of the step input	2	2
1(b)	Yes , by increasing and decreasing the flowrate valve at the same rate?	2	2
1(c)	Pneumatic Electro Hydrauic Electric	2	2
1(d)	The **derivative control** mode gives a **controller** additional **control** action when the error changes consistently	2	2
1(e)	The controller gain defines the strength of controller response experienced in relation to a deviation between the input and output signal. In a control loop, the controller gain is the strength of action a controller will take at a particular point below or above the setpoint.	2	2
1(f)	• They deal with continuous signals that can take a wide range of values. • The transfer function is given by differential equation in s-domain. • It use Laplace Transform techniques. • Noise , interference and distortion is comparatively more.	2	2

Part B (3Q x 6M = 18)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
2	Types of controlers 1. **Proportional controllers.** 2. **Integral controllers.** 3. **Derivative controllers.** ow we are in a condition to discuss proportional controllers, as the name suggests in a proportional controller the output (also called the actuating signal) is directly proportional to the error signal. Now let us analyze proportional controller mathematically. As we know in proportional controller output is directly proportional to error signal, writing this mathematically we have, $A(t) = K_p \times e(t)$ Advantages of Proportional Controller 1. Proportional controller helps in reducing the steady state error, thus makes the system more stable. 2. Slow response of the over damped system can be made faster with the help of these controllers Integral Controllers As the name suggests in **integral controllers** the output (also called the actuating signal) is directly proportional to the integral of the error signal. Now let us analyze integral controller mathematically. As we know in an integral controller output is directly proportional to the integration of the error signal, writing this mathematically we have, $A(t) \propto \int_0^t e(t)dt$ Derivative Controllers Now, as the name suggests in a derivative controller the output (also called the actuating signal) is directly proportional to the derivative of the error signal. Now let us analyze derivative controller mathematically. As we know in a derivative controller output is directly proportional to the derivative of the error signal, writing this mathematically we have, $A(t) \propto \frac{de(t)}{dt}$	6	10

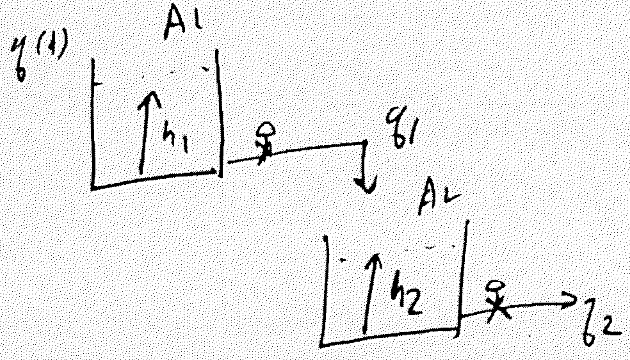
3	1. *Delay time td:* It is the time required for the response to reach 50% of the steady state value for the first time 2. *Rise time tr:* It is the time required for the response to reach 100% of the steady state value for under damped systems. However, for over damped systems, it is taken as the time required for the response to rise from 10% to 90% of the steady state value. Generally the formula of equating Rise time 3. *Peak time tp:* It is the time required for the response to reach the maximum or Peak value of the response. 4. *Peak overshoot M* : It is defined as the difference between the peak value of the response and the steady state value. It is usually expressed in percent of the steady state value. If the time for the peak is *tp'* percent peak overshoot is given by, *5.Settling time ts* : It is the time required for the response to reach and remain within a specified tolerance limits (usually ± 2% or ± 5%) around the steady state value. 	6	10
4		6	10

	The **damping ratio** is a dimensionless measure describing how oscillations in a system decay after a disturbance. Many systems exhibit oscillatory behavior when they are disturbed from their position of static equilibrium. he  damping ratio is a system parameter, denoted by ζ (zeta), that can vary from **undamped** ($\zeta = 0$), **underdamped** ($\zeta < 1$) through **critically damped** ($\zeta = 1$) to **overdamped** ($\zeta > 1$)		

Part C (1Q x 10M = 10)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
5	The tanks should be connected in same was as two tank non interacting system	10	18

as this system is more responsive.



$$\rho q(t) - \rho q_1 = \rho A \frac{dh_1}{dt}$$

$$q(t) - q_1 = A_1 \frac{dh_1}{dt} \quad —1$$

$$S.S - \quad q_s - \frac{h_{1s}}{R_1} = 0 \quad —2$$

$$(1)-(2) = (q(t) - q_s) - \frac{1}{R_1}(h_1 - h_{1s}) = A_1 \frac{dh_1}{dt}$$

$$Q(t) - \frac{1}{R_1} H_1(t) = A_1 \frac{d}{dt} H_1(t)$$

Laplace Transf $Q(s) - \frac{1}{R_1} H_1(s) = A_1 S H_1(s)$

$$Q(s) = \left(A_1 S + \frac{1}{R_1}\right) H_1(s)$$

$$\frac{H_1(s)}{Q(s)} = \frac{R_1}{R_1 A_1 S + 1} \quad \cdots \quad \frac{R_1}{\tau_1 S + 1}$$

$$\frac{H_1(s)}{Q(s)} = \frac{R_1}{T_1 s+1} \quad — 3$$

$$q_1 = \frac{h}{R_1} \quad , \quad q_s = \frac{h_s}{R_1}$$

~~SS~~ $Q_1(t) = \frac{h_1(t)}{R_1}$

L.T. — $Q_1(s) = \frac{H_1(s)}{R_1}$, $H_1(s) = R_1 Q_1(s)$ — 4

Substitute eq (4) in (3)

$$\frac{R_1 Q_1(s)}{Q(s)} = \frac{R_1}{T_1 s+1}$$

$$\boxed{\frac{Q_1(s)}{Q(s)} = \frac{1}{\tau s+1}}$$

MB Tank 2

$$q_1 - q_2 = A \frac{d}{dt} h_2$$

$$q_1 - \frac{h_2}{R_2} = A_2 \frac{d}{dt} h_2$$

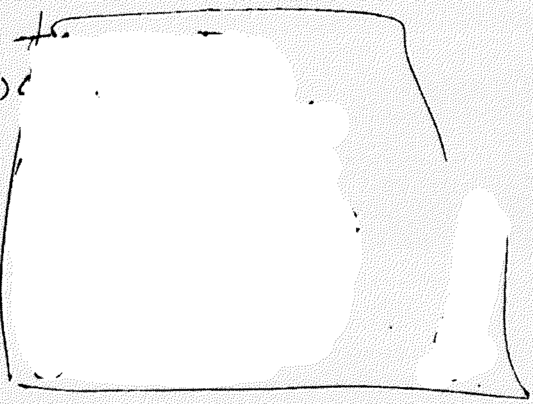
S.S — $q_{1s} - \frac{h_{2s}}{R_2} = 0$

$$(q_1 - q_{1s}) - \frac{1}{R_2}(h_2 - h_{2s}) = A_2 \frac{dh_2}{dt}$$

$$Q_1(t) - \frac{1}{R_2} H_2(t) = A \frac{dH_2(t)}{dt}$$

TF

$$Q_1(s) - \frac{1}{R_2} H_2(s) = A s H_2(s)$$



$$Q_1(s) = \left(A_2 s + \frac{1}{R_2}\right) H_2(s)$$

$$\frac{H_2(s)}{Q_1(s)} = \frac{1}{A_2 s + \frac{1}{R_2}}$$

$$= \frac{R_2}{A_2 R_2 s + 1}$$

$$\boxed{\frac{H_2(s)}{Q_1(s)} = \frac{R_2}{\tau_2 s + 1}}$$

$$q_2 = \frac{h_2}{R_2}$$

$$\frac{Q_2(s)}{Q_1(s)} = \frac{1}{\tau_2 s + 1}$$

$$\frac{H_2(s)}{Q(s)} = \frac{R_2}{(\tau_1 s + 1)(\tau_2 s + 1)}$$

$$\frac{Q_2(s)}{Q_1(s)} = \frac{1}{(\tau_1 s + 1)(\tau_2 s + 1)}$$

Roll No												

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END TERM FINAL EXAMINATION

Semester: Odd Semester: 2019 - 2020
Date: 26 December 2019

Course Code: PET 226
Time: 9:30 AM to 12:30 PM

Course Name: PROCESS CONTROL & INSTRUMENTATION
Max Marks: 80

Program & Sem: B.Tech (PET) & V
Weightage: 40%

Instructions:

(i) Read the all questions carefully and answer accordingly.
(ii) Question paper consists of 3 parts.
(iii) Scientific and Non-programmable calculators are not permitted.

Part A [Memory Recall Questions]

Answer all the Questions. Each Sub Question carries 2 marks. (1Qx20M=20M)

1. Briefly answer the questions.

a. What do you mean by controlled variable and measured variable? (C.O.No.1) Knowledge]

b. What do understand by open loop systems? (C.O.No.2) [Knowledge]

c. If the transfer function is given by $\frac{X+5X+8}{3X^4-7X+4}$ then what will be the order of the system. Justify your answer. (C.O.No.1) [Knowledge]

d. What do you understand by peak time ? (C.O.No.3) [Knowledge]

e. What is the type of oscillation that occurs in the manometer? (C.O.No.2) [Knowledge]

f. Define rangebility. (C.O.No.3) [Knowledge]

g. Define the rule for overall transfer function for loop reduction. (C.O.No.4) [Knowledge]

h. What do you understand by pulse input? (C.O.No.2) [Knowledge]

i. What are the disadvantages of feedforward control system? (C.O.No.4) [Knowledge]

j. What is the control variable and manipulated variable for a manometer system?

(C.O.No.3) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries 6 marks. **(5Qx6M=30M)**

2. Explain the rotary stem type of valve body with suitable diagram?
(C.O.No.3) [Comprehension]

3. What are the different inputs that can give to the single tank system, when it is control is aided by computer? Explain all inputs.
(C.O.No.2) [Comprehension]

4. Explain the feedback loop control system taking the example of a single tank? Write down all the process variable. (C.O. NO. 2) [Comprehension]

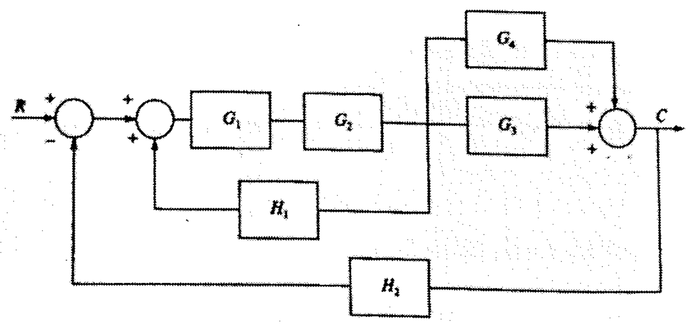
5. Describe the control valve characteristics with suitable diagram?
(C.O.No.3) [Comprehension]

6. Explain the cascade control system with suitable example?
(C.O.No.4) [Comprehension]

Part C [Problem Solving Questions]

Answer the Questions. Each Question carries 10 marks. **(3Qx10M=30M)**

7. The following block diagram is a process used in an industry. Find out the overall transfer function by loop reduction methods. (C.O.No.3) [Comprehension]



8. Actuators are an integral part of the final control element. Explain the different types actuators used in the working of the valves with suitable diagram.
(C.O.No.4) [Comprehension]

9. As a process engineer, suggest and explain the controllers to be used in the following condition. (C.O.No.3) [Comprehension]

   a) In the process where the error is changing

   b) In the process where no error is required

   c) In the process where the error is very small

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE REACH GREATER HEIGHTS

Semester: V

Course Code: PET 226

Course Name: PROCESS CONTROL & INSTRUMENTATION

Date: 26-12-2019

Time: 9:30am-12:30am

Max Marks: 80

Weightage: 40%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels	Problem Solving type [Marks allotted]	Total Marks
			K	C	C/A	
1	1-4	1-4	20			20
2	3	3		6		6
3	2	2		6		6
4	2	2		6		6
5	3	3		6		6
6	4	4		6		6
7	3	3		10	10	10
8	4	4		10	10	10
9	3	3		10	10	10
	Total Marks		20	30	30	80

Single Column Single Column Single Column

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

2, where is signature part?

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SOLUTION

Semester: V

Course Code: PET 226

Course Name: PROCESS CONTROL & INSTRUMENTATION

Date: 26-12-2019

Time: 9:30am-12:30am

Max Marks: 80

Weightage: 40%

Part A (10Q x 2M = 20)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1(a)	Control variable is the variable which needs to be changed to achieve the set point Measured variable is the instantaneous value of the control variable	2	2
1(b)	In an open-loop controller, also called a non-feedback controller, the control action from the controller is independent of the "process output", which is the process variable that is being controlled.	2	2
1(c)	4,as the highest power of the denominator of the transfer function is 4	2	2
1(d)	*Peak time tp:* It is the time required for the response to reach the maximum or Peak value of the response	2	2
1(e)	underdamped	2	2
1(f)	Ratio of the largest flow to the smallest flow permitted by valve	2	2
1(g)	To obtain the overall transfer function, put the product of all the transfer functions in the forward path in the numerator. In the denominator, put the product of all the transfer functions in the entire loop (in the forward path as also feedback path) plus 1.	2	2

1(h)	Pulse change when the value of the input is at steady state and then at a certain instant of time it is increased to a new value and held there for some time and then brought back to the original value and held there the input is said to be pulse input	2	2
1(i)	Load variable must be measured A process model is required Errors in modeling can result in poor control	2	2
1(j)	Control variable –height Manipulated variable – pressure valve	2	2

Part B (5Q x 6M = 30)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
2	Rotary Stem: Butterfly Valve, Ball Valve Rising/Non-Rising Stem: Globe Valve, Gate Valve ***Rotary stem values*** ***Butterfly valve:*** A butterfly valve is a type of flow control device, typically used to regulate a fluid flowing through a section of pipe. A flat circular disc is positioned in the centre of the pipe. The disc has a rod through it connected to an actuator on the outside of the valve. Rotating the actuator turns the disc either parallel or perpendicular to the flow. Since the disc is always present within the flow, a pressure drop is always induced in the flow regardless of valve position. However, the valve provides high capacity with low pressure loss across the valve (see Figure 7.7). There are different kinds of butterfly valves, each adapted for different pressures and different usage. The *resilient butterfly valve*, which uses the flexibility of rubber, has the lowest pressure rating. The *high performance butterfly valve*, used in slightly higher-pressure systems, features a slight offset in the way the disc is positioned, which increases the valve's ***Ball valve:*** A ball valve is a valve that opens by turning a handle attached to a ball insic the valve. The ball has a hole, or port, through the middle so that when the port is in line wit both ends of the valve, the fluid will flow. When the valve is closed, the hole is perpendicul to the ends of the valve, and flow is blocked. Ball valves are durable and usually work to achieve perfect shutoff even after years o disuse. They are, therefore, an excellent choice for shutoff applications and are often preferrec to globe valves and gate valves for this purpose. They do not offer the fine control that may be necessary in throttling applications but are sometimes used for this purpose (see Figure 7.8). Ball valves are used extensively in industry because they are very versatile. They operate at pressures up to 700 bar and temperatures up to 200°C. Sizes from 5 mm to 300 mm are readily available. They are easy to repair, operate manually or by actuators. The body of ball valves may be made of metal, plastic or metal with a ceramic centre. ***Rising/non-rising stem valves*** ***Gate valve:*** A *gate valve*, or *sluice valve*, as it is sometimes known, is a valve that opens by lifting a round or rectangular gate/wedge out of the path of the fluid. The distinct feature of a gate valve is the sealing surfaces between the gate and seats are planar. The gate faces can form a wedge shape or they can be parallel. Gate valves are sometimes used for regulating flow, but many are not suited for that purpose, having been designed to be fully opened or closed. When fully open, the typical gate valve has no obstruction in the flow path, resulting in very low friction loss.	6	12

3

3.8.1 Step Change

When the value of the input is at steady state and then at a certain instant of time it is increased to a new value and held constant there, the input is said to be subjected to a step change. This is shown in Figure 3.16.

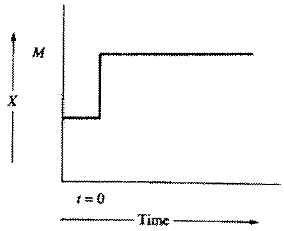


Figure 3.16 Pictorial representation of a step change.

The change in the input X as a function of time is

$$X(t) = M \tag{3.58}$$

The Laplace transform is

$$X(s) = \frac{M}{s} \tag{3.59}$$

Pulse change

When the value of the input is at steady state and then at a certain instant of time it is increased to a new value and held there for some time and then brought back to the original value and again held there, the input is said to be subjected to a pulse change. This is shown in Figure 3.17.

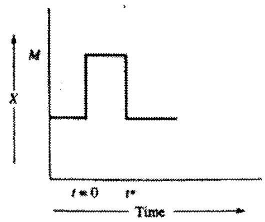


Figure 3.17 Pictorial representation of a pulse change.

The change in the input X as a function of time is

$$X(t) = M\left[u(t) - u(t - t^*)\right] \tag{3.60}$$

The Laplace transform is

$$X(s) = \frac{M}{s}(1 - e^{-t^*s}) \tag{3.61}$$

3.8.2 Impulse Change

When the value of the input is at steady state and then at a certain instant of time it is increased to a new value and at the same instant of time returned to the original value, the input is said to be subjected to an impulse change. This is shown in Figure 3.18.

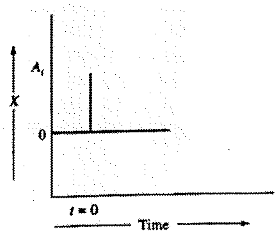


Figure 3.18 Pictorial representation of an impulse change.

The change in the input X as a function of time is given in Eq. (3.62). This is also called the delta function.

$$X(t) = A_i \tag{3.62}$$

The Laplace transform of the delta function is

$$X(s) = A_i \tag{3.63}$$

6

12

3.8.3 Ramp Change

When the value of the input is at steady state and then at a certain instant of time it is increased continuously and linearly with respect to time, the input is said to be subjected to a ramp change. This is shown in Figure 3.19.

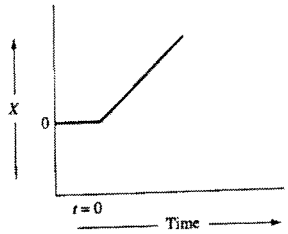


Figure 3.19 Pictorial representation of a ramp change.

The change in the input X as a function of time is

$$X(t) = Bt \tag{3.64}$$

The Laplace transform is

$$X(s) = \frac{B}{s^2} \tag{3.65}$$

3.8.4 Sinusoidal Change

When the value of the input is at steady state and then at a certain instant of time it is varied sinusoidal with an amplitude of A and a radian frequency of ω, the input is said to be subjected to a sinusoidal change. This is shown in Figure 3.20.

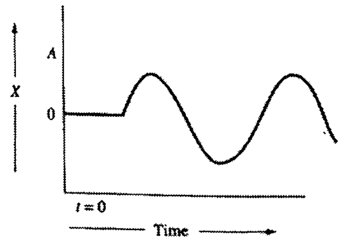


Figure 3.20 Pictorial representation of a sinusoidal change.

The change in the input X as a function of time is

$$X(t) = A \sin \omega t \tag{3.66}$$

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Let us consider one more control situation. The requirement is to maintain the flow rate of a fluid flowing through a pipeline at some particular value.

To meet this requirement, we use an orifice meter to measure the actual flow rate, Q. The flow rate as measured by the orifice meter is sent to the controller. Depending upon the error (difference between the desired flow rate, Q_D and the actual flow rate), the controller acts on the valve in the pipeline to increase or decrease the flow rate of the fluid. This arrangement is shown in Figure 1.10.

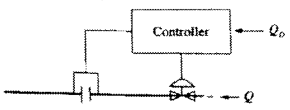


Figure 1.10 Flow control scheme.

As we know, the flow measured by the orifice meter depends on the pressure differential across the meter provided the upstream pressure remains constant. If the upstream fluid pressure changes because of some demands (for example; a partial blockage of the line), the flow through the pipeline changes. Hence, the upstream pressure can be considered to be a load variable. The loop incorporating the load is shown in Figure 1.11.

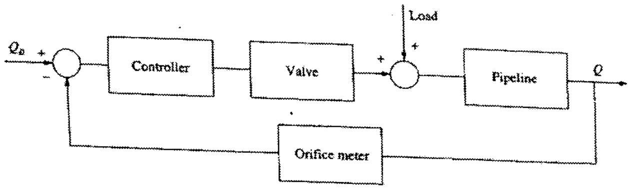
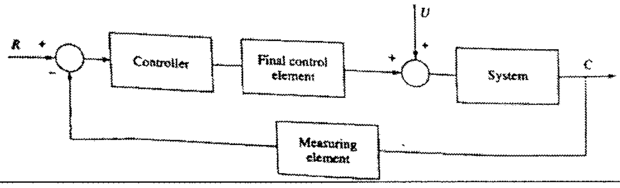


Figure 1.11 Block diagram for flow control.

The control in the generalised form is shown in Figure 1.12 below.



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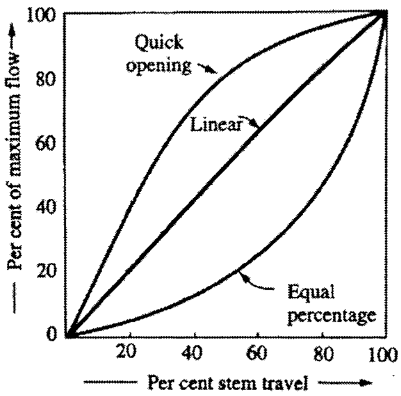

Figure 7.6 Control valve characteristics.

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	Linear characteristic: In this type of trim or characteristic, the flow capacity increases linearly with valve travel. The linear flow characteristic curve shows that the flow rate is directly proportional to the valve travel. This proportional relationship produces a characteristic with a constant slope so that with constant pressure drop, the valve gain will be the same at all flows. The linear valve plug is commonly specified for liquid level control. ***Equal percentage characteristic:*** In the equal percentage flow characteristic, equal increments of valve travel produce equal percentage changes in the existing flow. The change in flow rate is always proportional to the flow rate just before the change in valve plug, disk, or ball position is made. When the valve plug, disk, or ball is near its seat, the flow is small; with a large flow, the change in flow rate will be large. Valves with an equal percentage flow characteristic are generally used on pressure control applications and on other applications where a large percentage of the pressure drop is normally absorbed by the system itself, with only a relatively small percentage available at the control valve. Valves with an equal percentage characteristic should also be considered where highly varying pressure drop conditions can be expected. ***Quick opening characteristic:*** Quick opening valve provides large changes in flow for very small changes in lift. It usually has too high a valve gain for use in modulating control. So, it is limited to on-off service, such as sequential operation in either batch or semi-continuous processes. The quick opening flow characteristic provides for maximum change in flow rate at low valve travels with a nearly linear relationship. Additional increases in valve travel give sharply reduced changes in flow rate, and when the valve plug near the wide open position, the change in flow rate approaches zero. In a control valve, the quick opening valve plug is used primarily for on-off service; but it is also suitable for many applications where a linear valve plug would normally be specified. Valve gain is defined as the ratio of an incremental change in valve plug position to change in flow. Gain is a function of valve size and configuration system operating conditions and valve plug characteristics.		
6	In cascade control a process is contrloed by two controllers in such way that both are acting for each other. • Cascade control is technique which contains two closed loop control cascade to each other in such way that first loop controller output will be set point for second loop controller .it is called remote set point for second controller. • In cascade control **First Loop** called **Master Controller** and **second loop** called **Slave Controller**. Master controller generate the set point for the slave controller. • Finally slave controller control the process depends upon the remote set point provide by the master controller.	6	12

Part C (3Q x 1OM= 30)

Q No	Solution	Scheme of Marking	Max. Time required for each Question

7	***Solution*** The loop containing G_1, G_2 and H_1 is a positive feedback loop and hence, can be reduced by using the rule stated in Section 9.1.3. The relevant part is shown in Figure 9.10(a)	10	30

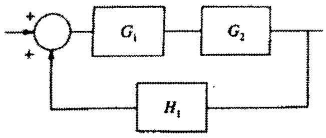

Figure 9.10(a)

This is equivalent to

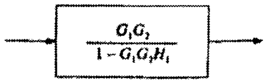

Figure 9.10(b)

We replace the inner loop with a single block containing the transfer function $\frac{G_1G_2}{1-G_1G_2H_1}$. We then get the block diagram as shown in Figure 9.11(a) and (b).

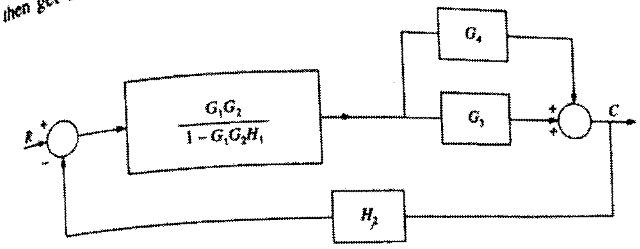

Figure 9.11(a)

The part containing G_4 and G_5 together with the summing junction can also be reduced.

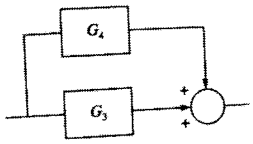

Figure 9.11(b)

It can be easily verified that this gets reduced to $G_3 + G_4$. The block diagram is, therefore, as shown in Figure 9.12.

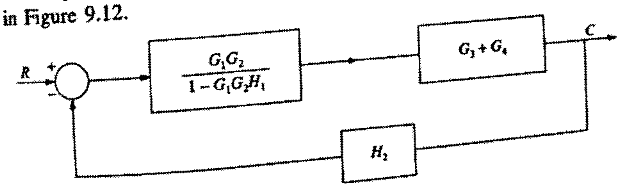

Figure 9.12

Hence, the ratio C/R is now

$$\frac{C}{R} = \frac{\dfrac{G_1G_2(G_3+G_4)}{1-G_1G_2H_1}}{1+\dfrac{G_1G_2(G_3+G_4)H_2}{1-G_1G_2H_1}}$$

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Spring-and-diaphragm actuators: Diaphragm actuators have compressed air applied to a flexible diaphragm. The operating force is derived from compressed air pressure, which is applied to the diaphragm. The actuator is designed so that the force resulting from the air pressure, multiplied by the area of the diaphragm, overcomes the force exerted by the spring. These types of actuators are single acting, in that air is only supplied to one side of the diaphragm, and they can be either direct acting (Air-to-close) or reverse acting (air-to-open) as shown in Figure 7.2.

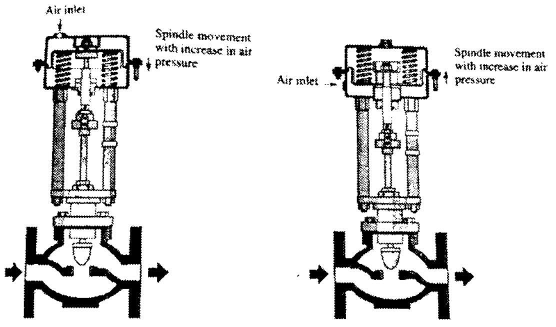

Figure 7.2 (a) Air-to-close and (b) Air-to-open valves.

Direct-acting Actuators for rotary valves increase air pressure which pushes down the diaphragm, which may either open or close the valve, depending on orientation of the actuator lever on the valve shaft. The diaphragm is pushed upwards, pulling the spindle up, and if the spindle is connected to a direct acting valve, the plug is opened. The actuator is designed so that with a specific change of air pressure, the spindle will move sufficiently to move the valve through its complete stroke from fully-closed to fully-open. As the air pressure decreases, the spring(s) moves the spindle in the opposite direction. The range of air pressure is equal to the stated actuator spring rating, for example, 0.2–1 bar.

Piston Actuators: Piston actuators are pneumatically operated using high-pressure plant air to 10 bar. Piston actuators furnish maximum thrust output and fast stroking speeds (see Fi

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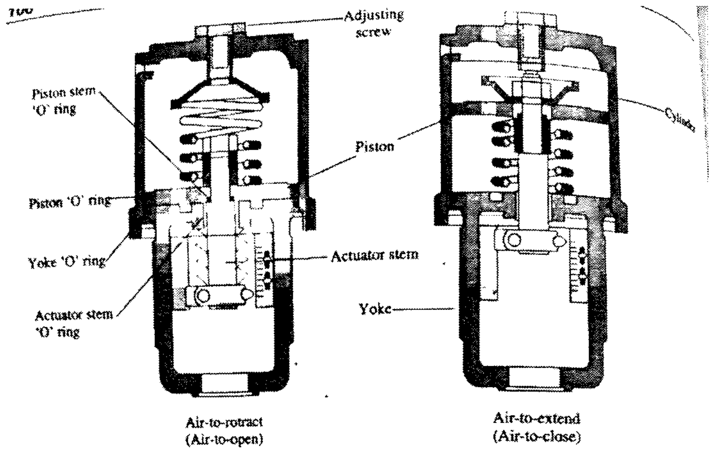

Figure 7.3 Piston actuated valves.

Piston actuators are generally used where the stroke of a diaphragm actuator would b short or the thrust is too small. The compressed air is applied to a solid piston contained v a solid cylinder. Piston actuators can be single acting or double acting, can withstand h input pressures and can offer smaller cylinder volumes, which can act at high speed.

Figure 7.4 shows another implementation of the piston-type actuator.

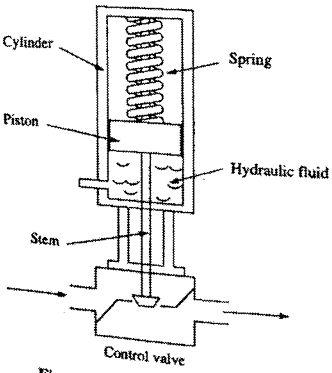

Figure 7.4 Piston-type actuator.

Electrohydraulic actuators

Electrohydraulic actuators require only electrical power to the motor and an electrical input signal from the controller. Electrohydraulic actuators are ideal for isolated locations where pneumatic supply pressure is not available but where precise control of valve plug position is needed. They consist of a motor, pump, and double-acting hydraulically operated piston within a weatherproof or explosion-proof casing.

Electric actuators

Traditional electric actuator designs use an electric motor and some form of gear reduction to move the valve. Electric actuators are more expensive than pneumatic for the same performance levels. Electric actuators use an electric motor with voltage requirements in the range: 230 V ac, 110 V ac, 24 V ac and 24 V dc. There are two types of electrical actuators; VMD (Valve Motor Drive) and Modulating. The VMD version of the electric actuator has three states: Driving the valve open, Driving the valve closed, and No movement (see Figure 7.5).

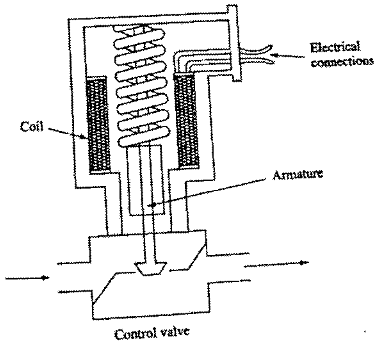

Figure 7.5 Valve with electrical actuator.

9 | **i) Derivative Controllers** | 10 | 30

Now, as the name suggests in a derivative controller the output (also called the actuating signal) is directly proportional to the derivative of the error signal. Now let us analyze derivative controller mathematically. As we know in a derivative controller output is directly proportional to the derivative of the error signal, writing this mathematically we have,

$$A(t) \propto \frac{de(t)}{dt}$$

ii) Integral Controllers

As the name suggests in **integral controllers** the output (also called the actuating signal) is directly proportional to the integral of the error signal. Now let us analyze integral controller mathematically. As we know in an integral controller output is directly proportional to the integration of the error signal, writing this mathematically we have,

$$A(t) \propto \int_0^t e(t)dt$$

iii) **Proportional controllers**.

as the name suggests in a proportional controller the output (also called the actuating signal) is directly proportional to the error signal. Now let us analyze proportional controller mathematically. As we know in proportional controller output is directly proportional to error signal, writing this mathematically we have,

$$A(t) = K_p \times e(t)$$

Advantages of Proportional Controller

1. Proportional controller helps in reducing the steady state error, thus makes the system more stable.
2. Slow response of the over damped system can be made faster with the help of these controllers