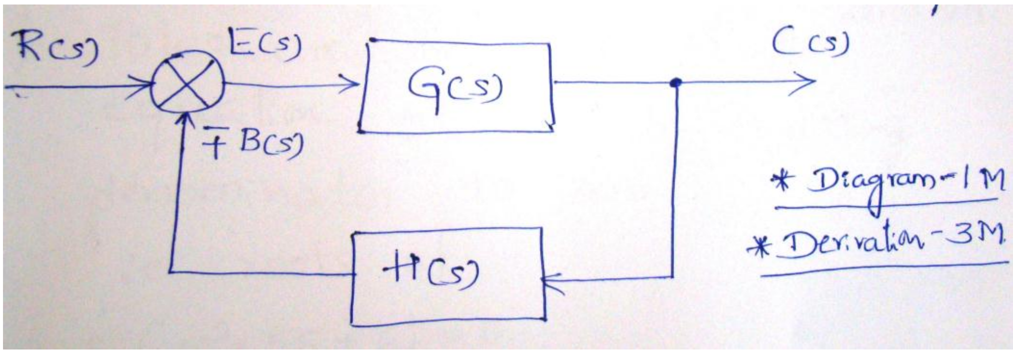

Q. 1. Answer Any Five. **(20 Marks)**

a) Derive the transfer function of closed loop system.

Ans. Transfer function of closed loop system:- (**Diagram 01 mark, derivation 03 marks**)



R(s) – Laplace of reference i/p R(t).

C(s) – Laplace of controlled o/p C(t).

E(s) – Laplace of error signal e(t).

B(s) – Laplace of feedback signal b(t).

G(s) – Equivalent forward path transfer f^n .

H(s) – Equivalent feedback path transfer function.

Referring to this Fig.

$E(s) = R(s) \mp B(s)$ -----------(1)

$B(s) = C(s)\, H(s)$ -----------(2)

$C(s) = E(s)\, G(s)$ ------------(3)

B(s) = C(s) H(s) and substituting in equation (1)

$E(s) = R(s) \mp C(s)\, H(s)$.

$E(s) = C(s) / G(s)$

$C(s) / G(s) = R(s) \mp C(s)\, H(s)$.

$C(s) = R(s)\, G(s) \mp C(s)\, G(s)\, H(s)$

Hence, $C(s)\, [1 \pm G(s)\, H(s)] = R(s)\, G(s)$

$C(s) / R(s) = G(s) / 1 \pm G(s)\, H(s)$.

b) Find out the poles and zeros of the following Tf = $S^2 - 4 / S(S^2 + 5S + 6)$.

Ans.- **(Calculation of poles – 2 mark s and zeros – 2 marks)**

Tf = $S^2 - 4 / S(S^2 + 5S + 6)$

1) Poles are the root of equation obtained by equating denominator to zero

   i. e. roots of

   $S(S^2 + 5S + 6) = 0$

   $S = 0$

   $S^2 + 5S + 6 = 0$

   $S^2 + 3S + 2s + 6 = 0.$

   $S(S + 3) + 2(S + 3) = 0$

   $(S + 2)(S + 3) = 0$

   $S = -2, S = -3.$

   So there are 3 poles S =0, -2, -3.

2) Zeros are the roots of the equation obtained by equating numerator to zero i.e. roots of

   $S^2 - 4 = 0$

   $S^2 = 4$

   $S = \pm 2.$

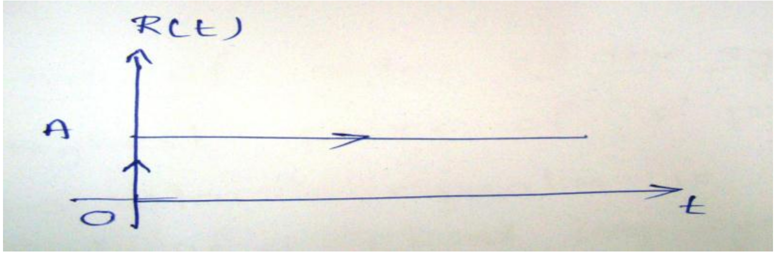
   So there are two zeros

   $S = +2, -2.$

c) Draw the standard test signals used in time domain analysis. State the mathematical expression in Laplace transform of each.

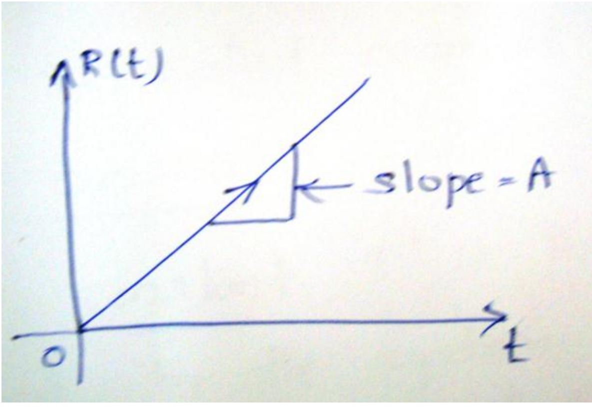
Ans.:- standard test signals used in time domain:- (**1 mark each for step**, ramp. parabolic and impulse.)

i) Step i/p (position function)



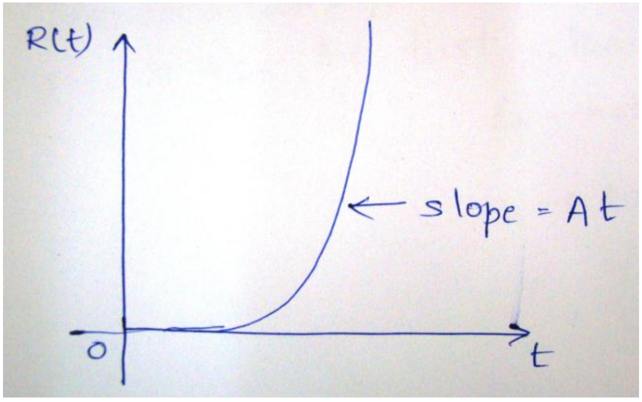
Mathematical expression of Laplace transform of step i/p is A/S.

ii) Ramp i/p (velocity function)



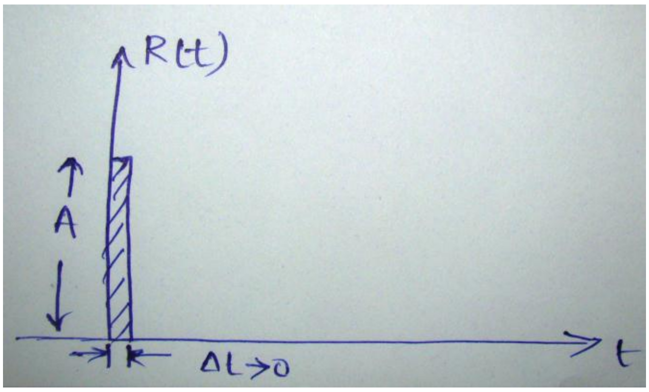
Its Laplace transform is A/S^2

iii) Parabolic i/p (Acceleration function)



Its Laplace transform is A/S^3

iv) Impulse i/p



Its Laplace transform is always 1 if A = 1, i.e. for unit impulse.

d) Define: i) order of system. ii) Time constant. Iii) Give practical example of 0^{th} , 1^{st} and 2^{nd} order system.

Ans.:-

i) Definition of order of the system:- (1mark)

The highest power of 'S' present in the characteristics equation i.e. denominator polynomial of a closed loop system transfer function is called order of the system.

ii) Time constant:- (1 mark)

Time constant 'T' is the time required by the system o/p to reach 63.2% of its final value during the first attempt.

T = 1/ Wn. ---- damping ratio.

Wn----- natural frequency.

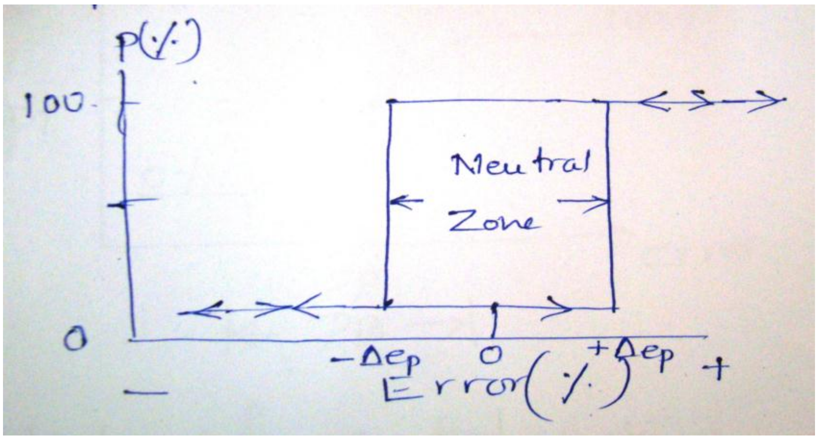
iii**) O order is simple resistance network**

1 order is RC or C network

2 order is series RLC network

e) Define: i) Neutral zone ii) proportional band and state the mode of control action.

Ans. :- Definition of Neutral zone:- **(1 ½ marks)**

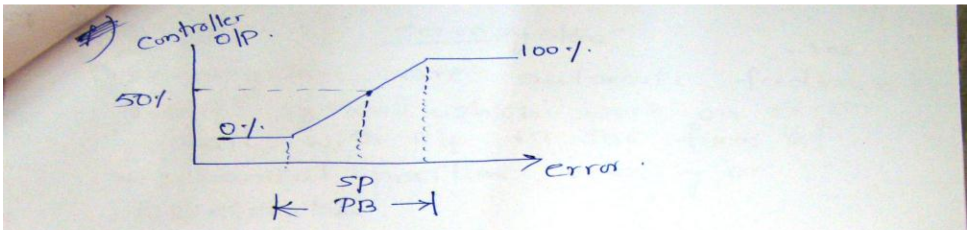


In ON-OFF controller, there is on overlap as ep increases through zero or decreases through zero. In this span, no change in controller o/p occurs.

The range 2Δep which is referred to as the neutral zone or differential gap is often purposely designed above a certain minimum quantity to prevent excessive cycling.

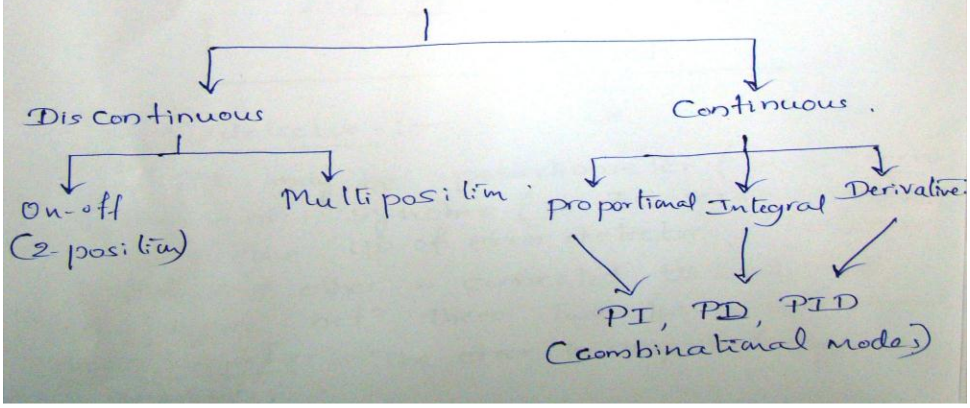
Definition of proportional Band:- **(1 ½ marks)**

PB is the percentage of full scale change in controller i/p (i. e. the error)required to change the controller o/p from 0% to 100% corresponding to full operating range of final control element.



Modes of control actions -1M-

There are two modes

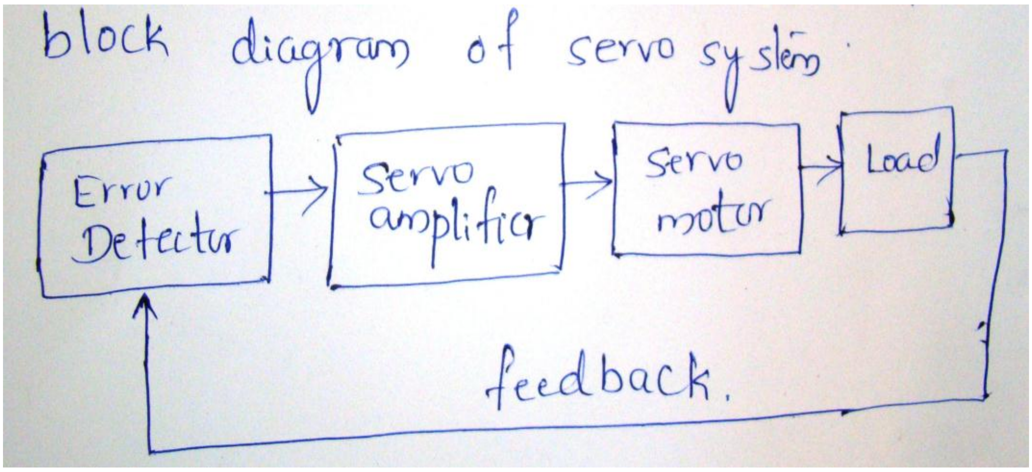


f) Draw the block diagram and explain each block of servo system. Define servo system.

Ans. :- Definition of Servo system:- **(1 mark)**

Servo system are automatic feed back control system which work on error signals with o/p in the form of mechanical position, velocity or acceleration.

Block diagram of Servo system:- **(1 mark)**



Error detection:- It may potentiometer (in DC servo system) or synchro (in AC servo system). one of the i/p of error detector is reference i/p and other is connected to load. The difference between these two i/ps is error signal.

Servo amplifier:- The error is amplified by amplifier.

Servo motor:- it may be AC, DC or stepper. Servo motor is connected to load mechanically. Thus motor can adjust the load position according to error. Thus this system automatically tries to connect any deviation to the error detector changes according to the error.

g) State any six applications of Robot.

Ans:- **(any six, 04 marks)**

1. Process industry

2 Transportation of material

3.Lifting loads in hazardous conditions

4. Used in modern toys

5. Used for CAD purposes

6 . Security purpose which can detect moving objects and transmit information to control room,

7. Robots are used in engineering projects.

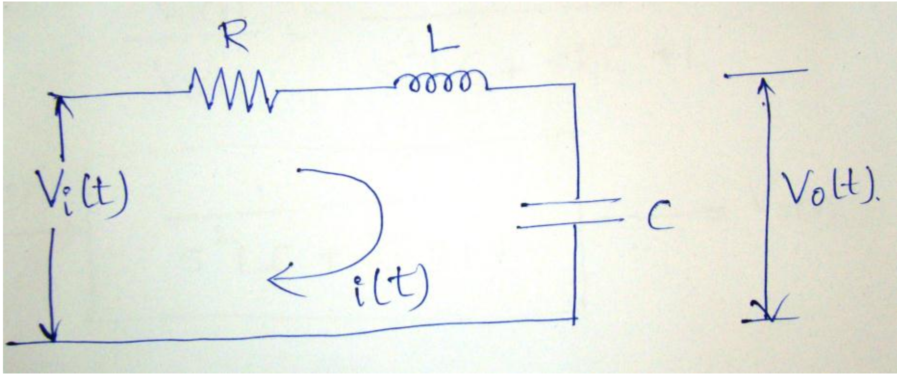
8. Space exploration

9. Nuclear plants/ chemical/ automation industries

Q. 2. Answer any FOUR. (16 marks)

a) Derive the transfer function of the following electrical circuit:-

Ans:- **(derivation – 4 marks)**



Vi = iR + Ldi / dt + 1 / c idt.

Take Laplace transform,

Vi(s) = I (s) [R + SL + 1/ SC]

I(s) / Vi (s) = 1 / [R + SL + 1/ SC] ----- (1)

Vo = 1 /C (idt)

Hence, Vo (s) = 1 / SC x I(s)

I(s) = SC Vo(s) ------(2)

Substituting value of I (s) in equation 1

SC Vo(s)/ Vi(s) = 1/ [R + SL + 1/ SC]

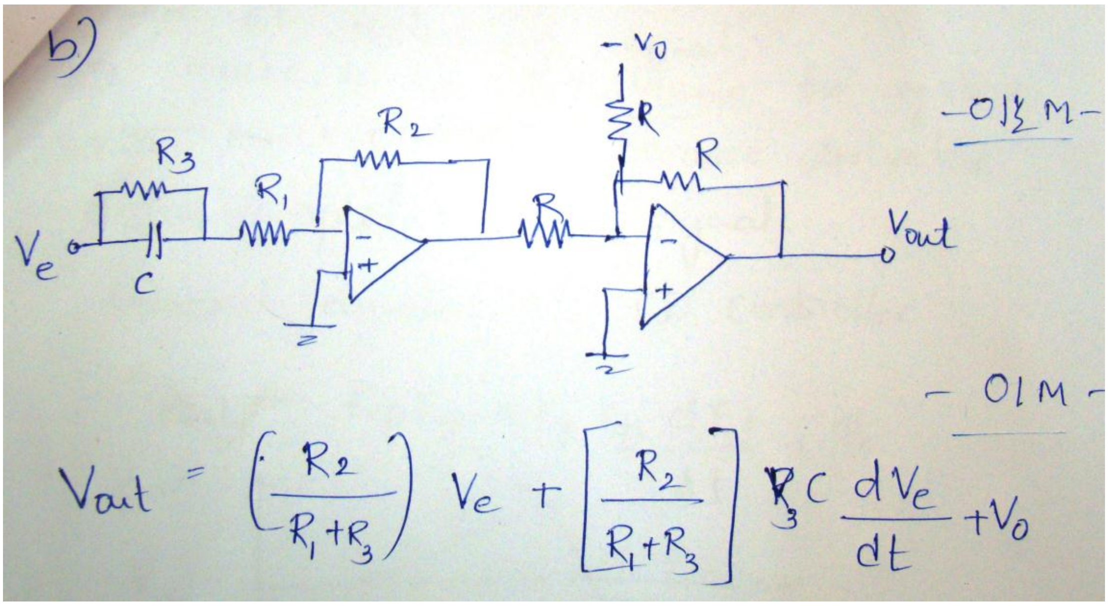
Vo(s) / Vi(s) = 1 / SC[R + SL + 1 /SC] = 1 / S^2LC + SRC + 1

Vo(s) / Vi(s) = 1 / S2 LC + SRC +1

Vi(s) → $\boxed{1 / S2LC + RCS + 1}$ → Vo(s)

b) Draw electronic PD controller. State the equation. Explain PD controller in brief.

Ans.:-



Where proportional gain Gp = $R_2 / R_1 + R_3$

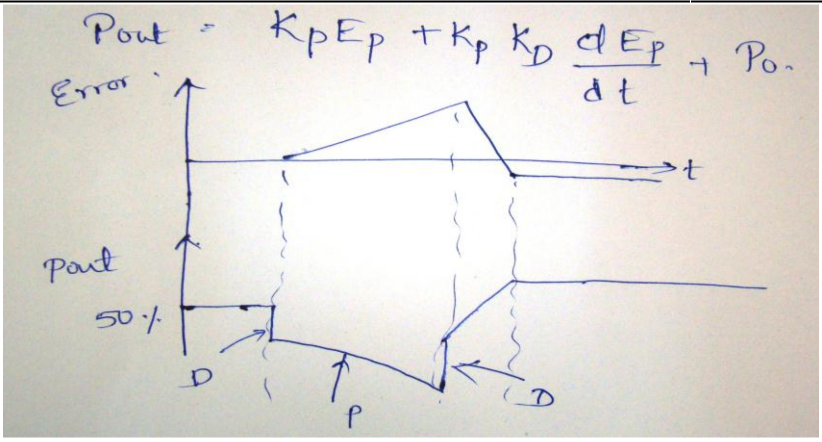
Derivation gain Gp = R_3C.

Explanation:- it is the combination of -1 ½ M proportional and derivative controller. The derivative action speed up the response of system. it enhances both speed and stability of control response especially on slow process. It cannot eliminate offset. Derivative action take place followed by proportional.

PD controller can be introduced by an amplifier which has o/p containing & terms, one is proportional to actuating signal itself, other to derivative of actuating signal.

PD mode is not suitable for system with noise problems, because derivative action amplifies noise signal.

General equation of PD controller.



Note :- Graph is optional

c) Explain the following terms w. r. to robotics.

i) Dof ii) End effector.-

Ans:-

DOF: **(2 marks)**

Degree of freedom is a term used to describe a robot's freedom of motion in 3 dimensional space specifically the ability to move forward and backward, up and down, left and right . For each DOF a joint is required.

End effector:- **(2marks)**

End effector is the robot's hand . It is a device attached to the wrist of the manipulator for the purpose of grasping, lifting, transporting or performing operations.

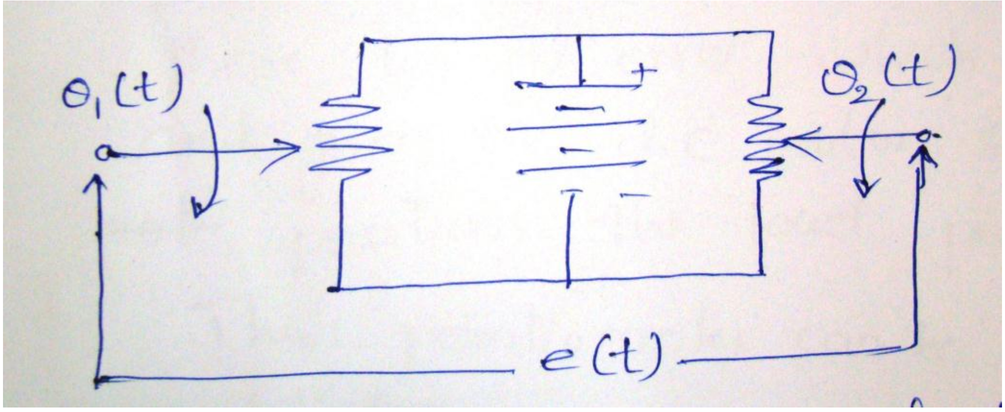
d) Explain potentiometer as error detector.

Ans.:- **(any one diagram -2 marks, working - 2 marks)**

When voltage is applied across the fixed terminals of the potentiometer the o/p voltage which is measured across the variable terminals which is proportional to the i/p displacement.

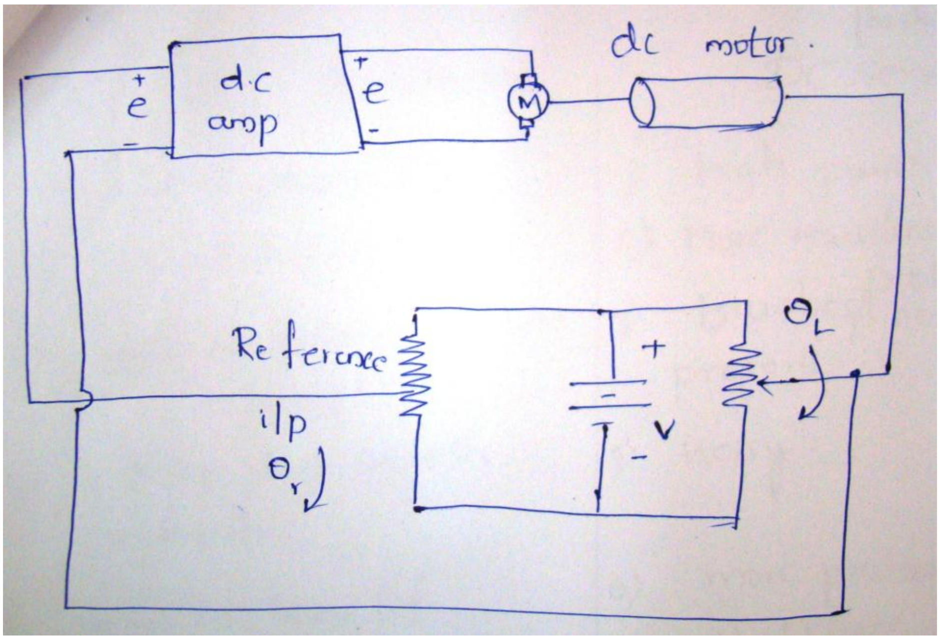
E(t) α Qc (t).

This transducer can be used as error detector.



This arrangement of two potentiometer can be used as an error detector. The o/p voltage is taken across the variable terminals of two potentiometer.

Output e(t) = Ks [Q_1(t) – Q_2 (t)]



One potentiometer displacement is to be considered as reference i/p the other is variable. The difference between these two error which is amplified and given to DC motor so that it positions the load properly.

Thus potentiometer can be used as an error detector.

e) Compare AC and DC servo motors (any six valid points)

Ans.:- Comparison between AC and DC servo motor: **(any 6 points - 4 marks)**

Sr.no	**AC servo motor**	**DC servomotor**
1.	Low power o/p	High power o/p
2.	Maintenance is less	More maintenance
3.	Brushes / commutator's absent	Brushes / problem commutator's present
4.	Stable and smooth operation	Noise
5.	Less problem of stability	More problem of stability
6.	No RF noise because of absence of brushes	Brushes produce of RF noise.
7.	Non – linear characteristics	Linear characteristics
8.	No voltage supply to rotor, Rotor current is supplied inductively by rotating magnetic field of stator.	Voltage is given through power supply to rotor.
9.	Applications:- low power(computer peripherals, recorders etc.)	Applications:- high power (machine tools, robotics)

f) Why standard test signals are required? State Laplace representation of all standard test signals.

Ans.:- Need of standard test signals**:-** **(1 mark)**

Standard test signals are step, ramp, parabolic and impulse/p.

In practice, many signals are available which are the function of time and can be used as reference i/p for various control systems, such as saw tooth, square, triangular etc. but while analyzing the system, it is highly impossible to consider each one of : t as a i/p and study the response. Hence for analysis point of view, those signals which are most commonly used as reference i/p are standard test i/p. once the system behave satisfactory to a test i/p, its time response to actual i/p is assumed to be up to the mark.

i) Step input :- (each standard 1 mark)

$R(t) = A \quad \text{for } t \geq 0$

$R(t) = 0 \quad \text{for } < 0$

R(s) = A/S.

ii) Ramp i/p:-

$R(t) = At \quad t \geq 0.$

$= 0 \quad t < 0$

Its Laplace transform is

R(s) = A/S

iii) **Parabolic i/p:-**

$R(t) = A/ 2 \times t^2 \quad$ for $t \geq 0.$

$= 0 \quad$ for $t < 0$

$R(s) = A /S^3$

iv) **Impulse :-**

R(t) = A for t = 0

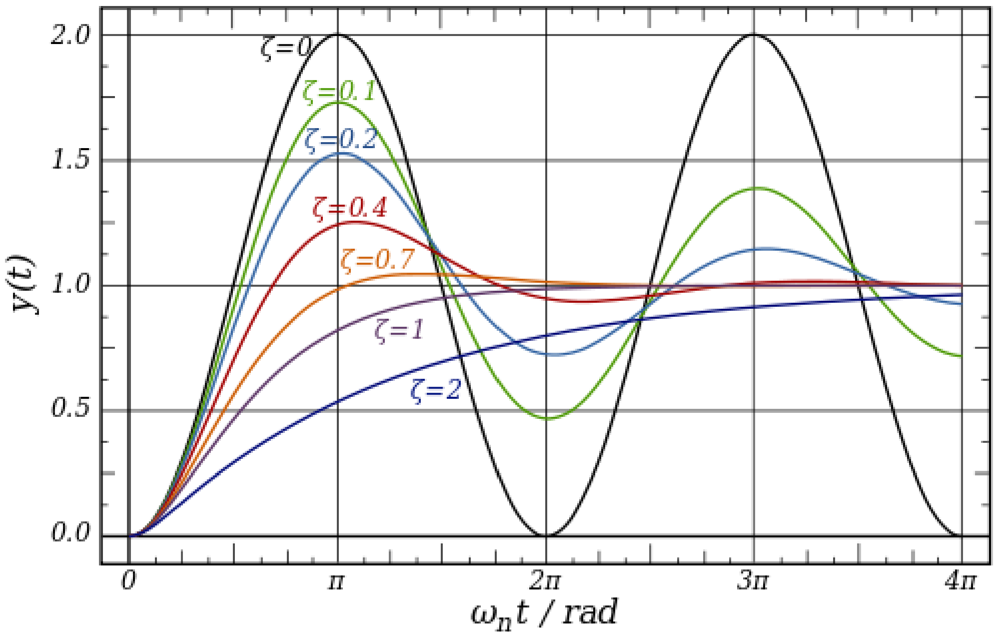
R (s) = 0 for $t \neq 0$.

R(s) = A , which is constant.

Q3) Answer any four :- (16 marks)

a) Explain the effect of damping on response of control system with neat sketch

Ans:- (Diagram 2 mark and explanation 2 mark)



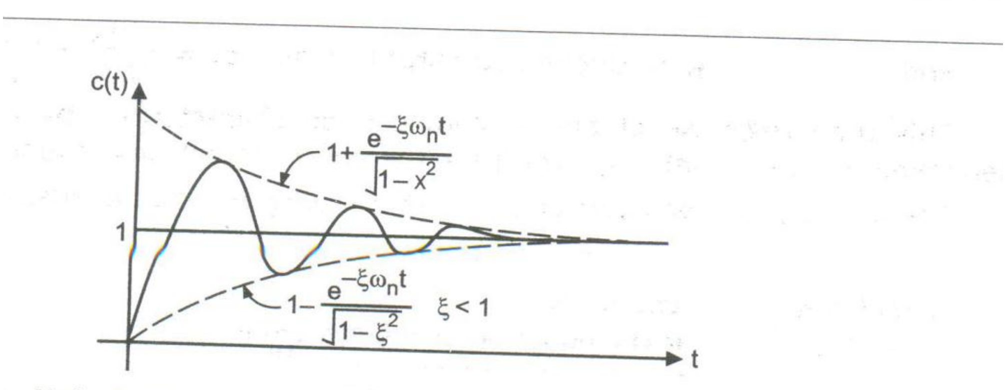
For $\zeta < 1$ ie underdamped

For $\zeta > 1$ ie overdamped

For $\zeta = 1$ ie criticallydamped

For $\zeta = 0$ ie undamped

or



: Unit-Step Response of Underdamped Second-Order System

b) Define the following frequency response specifications:

i) Resonance peak ii) Bandwidth iii) Cutt-off frequency iv) Resonant frequency

Ans:- (Each definition 1 mark each)

i) **Resonance peak M_r** - Is defined as the maximum value of $|M(jw)|$

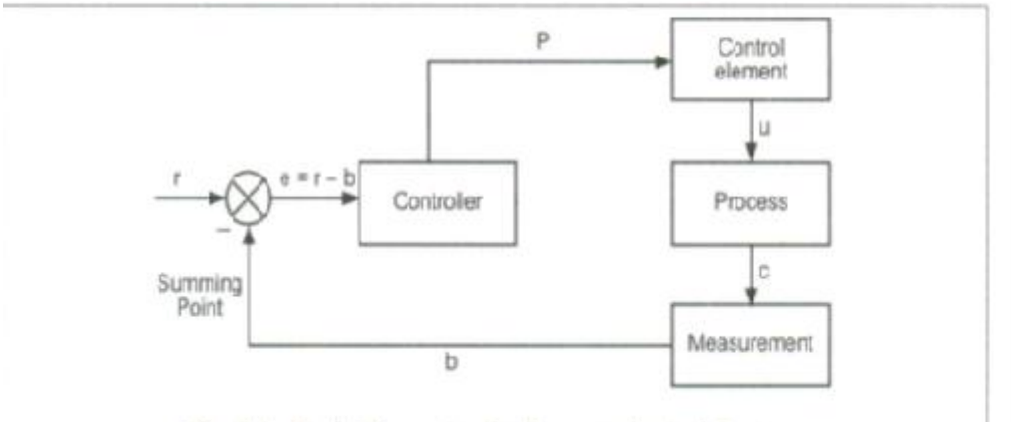
ii) **Bandwidth**: Is defined as the range of frequency at which the magnitude of $|M(jw)|$ drops to 70.7 of its zero frequency value or 3dB from the zero frequency value.

iii) Cut0ff frequency w_c is defined as a frequency where magnitude M has a value 0.707 ie 3dB on a magnitude frequency curve.

iv) Resonant frequency is the frequency where magnitude M has a peak value.

c) Draw the block diagram of process control system and describe each element

Ans:- (**Diagram 2 marks and 2 marks for elements)**



Explanation:

Process consists of several regulated operations.

Measuring element: measures or sense the actual value of the controlled variable and converts it into proportional feedback variable.

Error detector compares the feedback variable with the set point.

Controller generates the correct signal which is then applied to the final control element

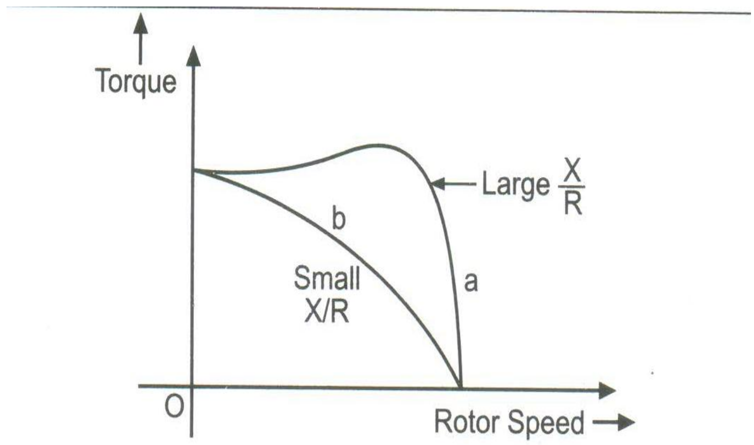
Final control element adjust the manipulated variable with the set point.

d) How is AC servomotor different from a normal 2-phasa induction motor? Explain. Draw the torque – speed characteristic of AC servomotor

Ans:- **(Difference 2 marks and characteristic 2 marks)**

- An A.C. servomotor differs in two ways from a normal induction motor.

1. The rotor resistance of the servomotor is high, so its X/R ratio is small. This makes the torque-speed characteristic nearly linear as compared to highly non-linear characteristic with large X/R ratio in induction motor.
2. The rotor construction is usually squirrel cage or drag cup type. The diameter of the rotor is kept small to reduce the insertia and thus we obtain good acceleration whereas drag-cup construction is used for very low inertia applications.



Curve a shows for two phase induction motor and curve b shows ac servo motor characteristics.

e) A system has open loop transfer function $G_{(S)} = 4 / S(S + 2)(1 + 0.5S)$ and unity feedback. Find the steady state error for r(f) = 3t

Ans:-

3 e). $H(s) = 1$; $G(s) = \dfrac{4}{s(s+2)(1+0.5s)}$

$r(t) = 3t$

$\therefore R(s) = \dfrac{3}{s^2}$ —— 1 Mark

Steady state error, $e_{ss} = \lim\limits_{t\to\infty} e(t) = \lim\limits_{s\to 0} \dfrac{s \cdot R(s)}{1+G(s).H(s)}$ —— 1 Mark

$$e_{ss} = \lim_{s\to 0} \frac{s \times \frac{3}{s^2}}{1 + \frac{4}{s(s+2)(1+0.5s)} \times 1}$$

$$= \lim_{s\to 0} \frac{\frac{3}{s}}{\frac{1}{s}\left[s + \frac{4}{(s+2)(1+0.5s)}\right]}$$

$$= \frac{3}{2}$$

$= 1.5$ —— 2 Marks.

OR error coefficient; $K_v = \lim\limits_{s\to 0} s\, G(s).H(s)$

$K_v = \lim\limits_{s\to 0} \cancel{s} \times \dfrac{4}{\cancel{s}(s+2)(1+0.5s)} \times 1$ —— 2 Mark.

$= 2$

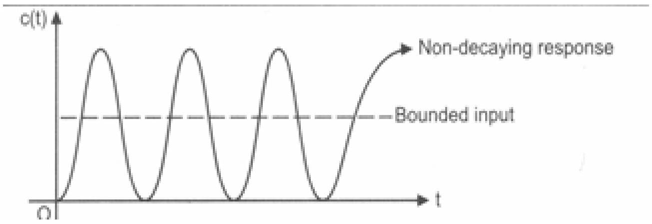
$e_{ss} = \dfrac{A}{K_v}$ for $r(t) = 3t \Rightarrow A = 3$ —— 1 Mark

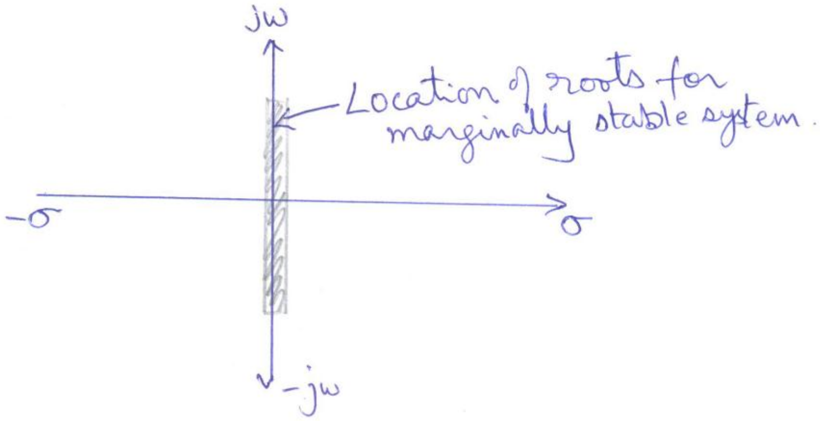
$\therefore e_{ss} = \dfrac{3}{2} = 1.5$ —— 1 Mark

f) Explain the concept of marginal stability. Draw neat sketch to represent it on

Ans: - **(concept 2 marks and any diagram 2 marks)**

The output of the system does not settle down to a constant value and keeps fluctuating within the desired output bounds. Such a system is said to be limitedly or marginally stable system.





Q4) i) Answer any 3 :- (**12 marks**)

a) State the principle of derivative control action with mathematical expression and its characteristics.

Ans:- (Principle 1 mark, mathematical expression 1 mark and any 2 characteristics 2 marks or graph may be considered.)

Principle of derivative control action: the rate of change of controlled output is proportional to the error signal. Or the output of the controller is proportional to derivative of the input signal.

Mathematical expression $P = K_D * [de_p / dt]$

Or $P(t) = K_D * [de(t) / dt]$

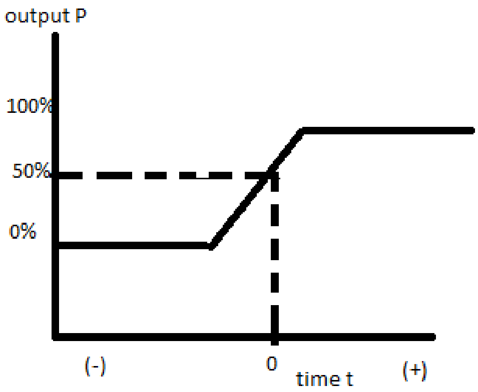
Where K_D = Derivative gain constant and $[de_p / dt]$ = rate of change of error signal

Characteristics:

1. It provides no output when the error is zero

2. It provides no output if the error is constant.

   Or graph



b) Find out the type of the system and the error coefficient for th3e system with

   G(s) H(s) = S + 3 / S(1 + 0.6S) (1 + 0.35S)

4 (i) (b). $G(s) \cdot H(s) = \dfrac{s+3}{s(1+0.6s)(1+0.35s)}$

Type of system = 1 — 1 Mark

Error coefficients

i) $K_p = \lim\limits_{s \to 0} G(s) \cdot H(s)$

$= \lim\limits_{s \to 0} \dfrac{s+3}{s(1+0.6s)(1+0.35s)}$

$K_p = \infty$ — 1 Mark

ii) $K_v = \lim\limits_{s \to 0} s\, G(s) \cdot H(s)$

$= \lim\limits_{s \to 0} \dfrac{\cancel{s}(s+3)}{\cancel{s}(1+0.6s)(1+0.35s)}$

$= 3$ — 1 Mark

iii) $K_a = \lim\limits_{s \to 0} s^2\, G(s) \cdot H(s)$

$= \lim\limits_{s \to 0} \dfrac{s^2 \cdot \times (s+3)}{s(1+0.6s)(1+0.35s)}$

$= 0$ — 1 Mark

c) State any two disadvantage and two advantage of On – OFF controller

Ans:- (**Advantages 2 marks and any 2 disadvantages 2 marks)**

Advantages of ON-OFF controller:

i) Simple in construction and economical and cheapest

Disadvantage:

i) Cannot fully eliminate errors, not a perfect controller of a process control system, not suitable for complex system and has a slow response.

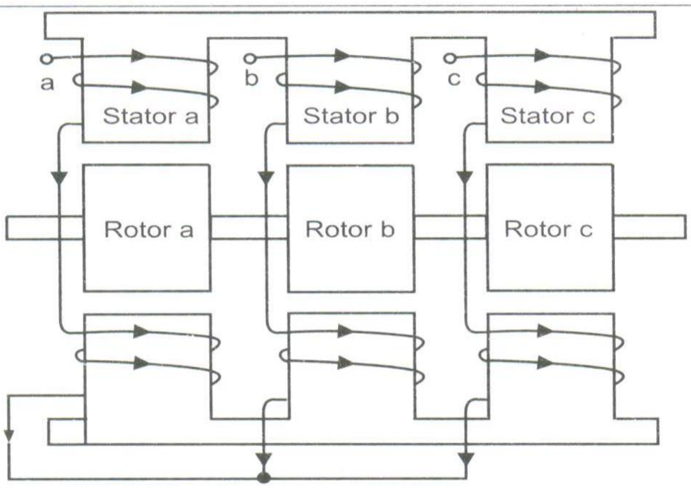
d) Draw and explain variable reluctance type stepper motor

Ans – (**diagram 2 marks and explanation 2 marks)**

A variable reluctance stepper motor consists of only one or several stacks of stators and rotors.

Stators have a common frame whereas rotors have a common shaft

shown in the cross-sectional view of Fig. 5.18 for a 3-stack motor.



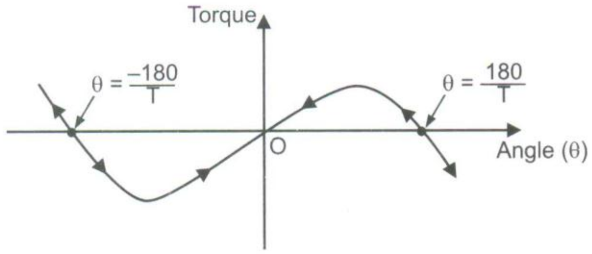


Fig. 5.18 (d) : Static Torque-Angle Characteristic

(i) Teeth aligned position $\theta = 0$, is a stable position i.e. slight disturbance from this position in either direction brings the rotor back to it.

(ii) Tooth slot aligned position $\theta = \frac{180}{T}$ is unstable i.e. slight disturbance from this position in either direction makes the rotor move away from it.

The teeth on all the rotors are perfectly aligned but the stator teeths differ by an angular displacement of,

$$\alpha = \frac{360}{nT}$$

where,

n = Number of stacks

Q4) ii) Answer any 1 :- (**04 marks**)

a) For the system with the characteristic equation $S^4 + 6S^3 + 21S^2 + 36S + 20 = 0$, find the stability of the system with Routh's stability criterion

4 (ii) a) Characteristic equation $s^4 + 6s^3 + 21s^2 + 36s + 20$

Routh's array.

s^4	1	21	20
s^3	6	36	
s^2	15	20	
s^1	28		
s^0	20		

— 3M

Since all the terms of the Routh's array first column are positive and there is no sign change – the system is stable. —1M.

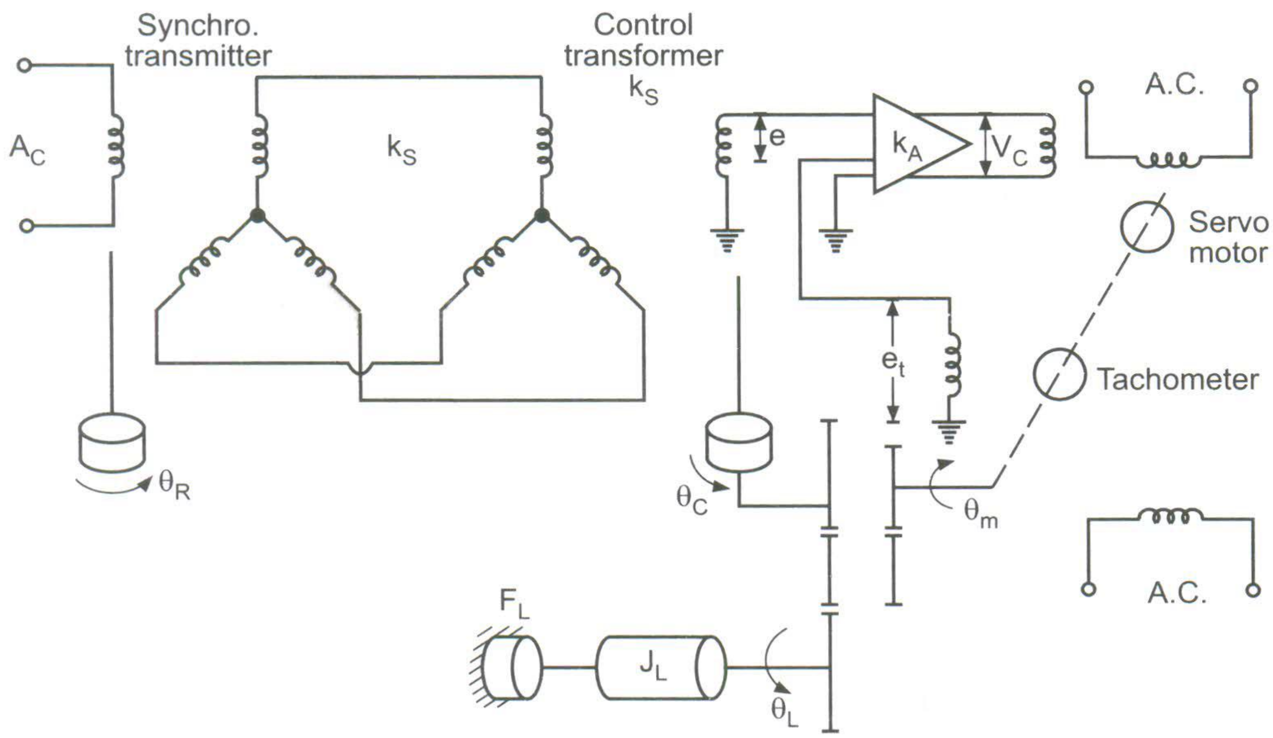
b) Draw the schematic diagram of AC servo system and label the elements. State any two advantages of it.

Ans:- **(Diagram 2 marks, label 1 mark and advantage 1 marks)**

The elements are synchro transmitter, control transformer ac servo motor, tachometer , ac amplifier and load

Advantage: smooth operation and wide applications in machine tools, etc.

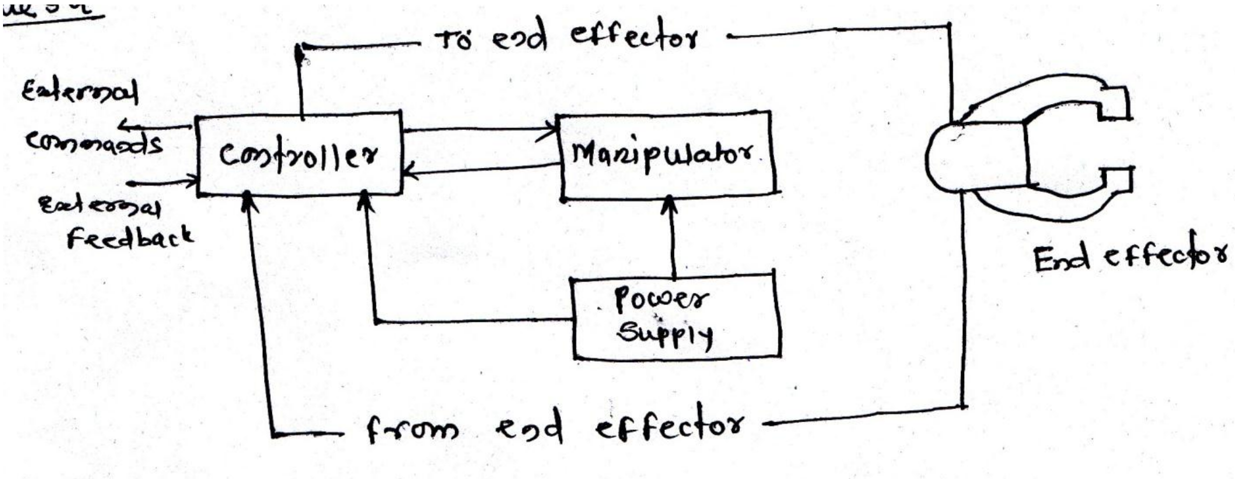
echanical load is controlled in accordance with the position of the reference sha



Q.5) Answer any 4: (16 marks)

a) Draw the B. D. of Robotics and explain.

Ans: - **Labeled B.D. – 2 mark,**



functional Diagram of Robotics.

Fig. 2

Suitable Explanation - 2 mark

- Manipulator: - It provides motion similar to human arms. It is robot arm consist of segments joined together with axis capable of motion in various directions allowing the robot to perform work.
- Rod effector: - It is ripper tools, attached to the robot arm, actually perform work.
- Power supply: - It provides and regulates the energy that is converted to motion by the robot actuators of it may be either electric, prematic or hydraulic.
- Controller: - It initiates, terminates & coordinates the motions & sequences of a robot. Also accept the necessary inputs to the robot and provides the output to interface with the outside world.

b) Derive the expression of output response of a 1st order system for unit step input.

Ans: - For input function & its Laplace – (**1 mark)**

Equation 1 and 2 – (**1 mark)**

For correct V_0 (t) – (**2 mark)**

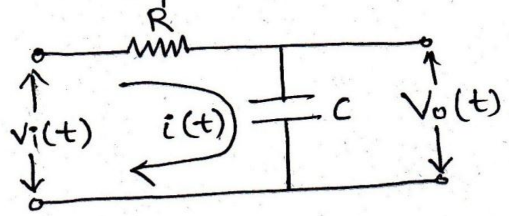
Unit Step input Function –

$$V_i(t) = 1 \quad t \geq 0$$
$$= 0 \quad t < 0$$

Therefor laplace of unit step i/p is –

$$V_i(s) = 1/s$$

first Order System:-



Apply KVL to input side, we get

$$V_i(t) - R\,i(t) - \frac{1}{C}\int i(t)\,dt = 0$$

Take Laplace of above equation

$$V_i(s) - R\,I(s) - \frac{1}{sC}I(s) = 0$$

$$V_i(s) = \left(R + \frac{1}{sC}\right)I(s) \quad \text{—— (1)}$$

Apply KVL to Output side, we get

$$V_o(t) = \frac{1}{C}\int i(t)\cdot dt$$

$$V_o(s) = \frac{1}{Cs}\,I(s) \quad \text{—— (2)}$$

Devide Equation (2) by equation (1)

$$\frac{V_o(s)}{V_i(s)} = \frac{1/Cs \cdot I(s)}{\left(R+\frac{1}{Cs}\right) \cdot I(s)}$$

$$\frac{V_o(s)}{V_i(s)} = \frac{1}{(1+sRC)}$$

Substitute $V_i(s) = 1/s$

$$V_o(s) = \frac{1}{s(1+sRC)} = \frac{A}{s} + \frac{B}{(1+sRC)}$$

$$1 = A(1+sRC) + Bs$$

$$1 = A + AsRC + Bs$$

$$1 = A + (ARC + B)s$$

$$\therefore \quad A = 1 \quad , \quad B = -RC$$

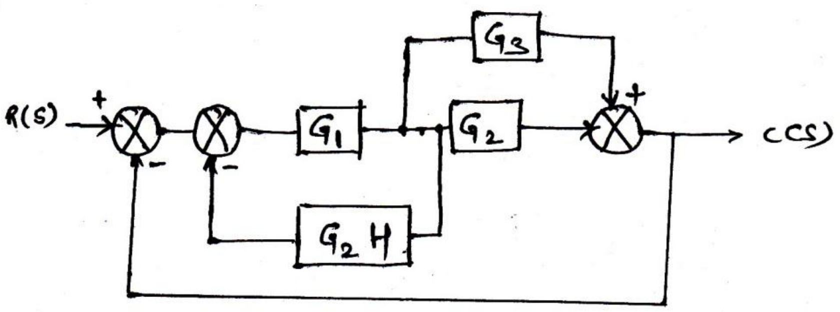
$$\therefore \quad V_o(s) = \frac{1}{s} - \frac{RC}{(1+sRC)}$$

$$= \frac{1}{s} - \frac{1}{s + 1/RC}$$

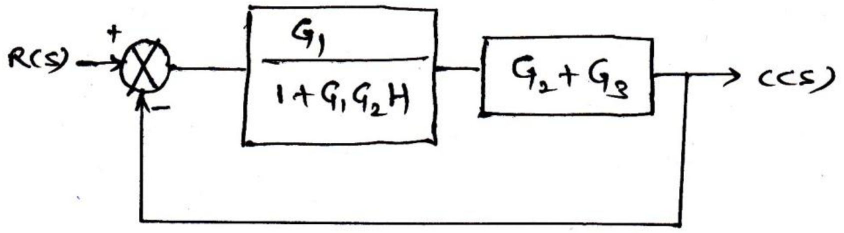
Taking laplace inverse

$$V_o(t) = 1 - e^{-t/RC}$$

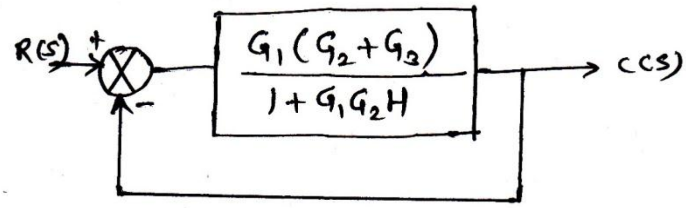
c) Derive the input function of the block diagram, shown in fig.2



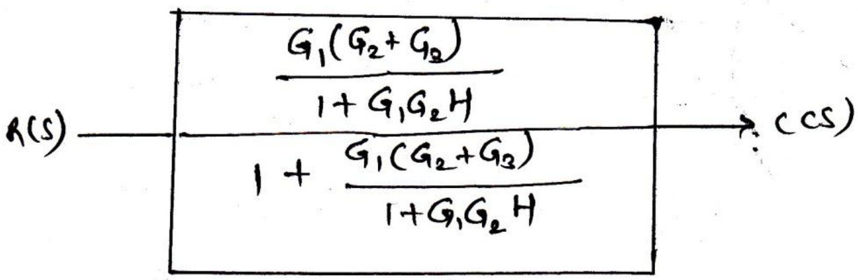
→ 1 Mark



→ 1 Mark



→ 1 Mark



After simplification

$$\frac{C(s)}{R(s)} = \frac{G_1(G_2+G_3)}{1+G_1G_2H + G_1(G_2+G_3)}$$ → 1 Mark

— transfer function.

\#

d) State any 4 advantages of frequency response analysis.

Ans: - Any 4 advantages – 1 mark each (other relivent advantages also can be consider)

1) Without the knowledge of the transfer function, the frequency response of stable open loop system can be obtained Experimentally.
2) These methods are easy to use for design of control systems and for finding absolute as well as relative stability of the system. Calculations are simple and methods of design are well tested.

3) When it is difficult to find transfer function of a given system by writing differential equation, the transfer function of the system can be determined practically in the laboratory by obtaining the frequency response of the system.
4) Frequency response tests are simple and can be made accurately by use of readily available signal generators and precise measuring instruments.
5) Frequency response can be precisely applied to the system those do not have rational transfer function.
6) The apparatus required for obtaining frequency response is simple and inexpensive, and easy to use.

e) Compare open loop and closed loop control system (6 points).

Ans: - **(Any 4 points – 4 mark (1 mark each)**

(Other relivent parameters also can be consider for comparison.)

Sr. No.	Open loop	Closed loop
1.	Any change in output has no effect on the input. i.e. feedback does not exist.	Changes in output affect the input which is possible by use of feedback.
2.	Feedback element is absent.	Feedback element is present.
3.	Error detector is absent.	Error detector is present.
4.	It is inaccurate & unreliable.	Highly accurate and reliable.
5.	Highly sensitive to disturbances.	Less sensitive to the disturbances.
6.	Bandwidth is small.	Bandwidth is large.
7.	Simple to construct & cheap.	Complicated to design and hence costly.
8.	Generally are stable in nature.	Stability is the major consideration while designing.
9.	Highly affected by non-linearities.	Reduced effect of non-linearities.

Q.6) Answer any 2: **(16 marks)**

a) For the given differential equation $d^2y/dt^2 + 4. Dy/dt + 8y\ (t) = 8\ x\ (t)$, where y = o/p, x = i/p find

1) Setting time (2 mark)
2) Rise time (2 mark)
3) Peak tome (2 mark)
4) Peak overshoot (2 mark)

Ans: -

Given differential equ^n is,

$$\frac{d^2y}{dt^2} + 4\cdot\frac{dy}{dt} + 8y(t) = 8x(t)$$

Take laplace transform

$$s^2 y(s) + 4s\, y(s) + 8y(s) = 8x(s)$$

$$y(s)[s^2+4s+8] = 8x(s)$$

$$\text{T.F. } \frac{y(s)}{x(s)} = \frac{8}{s^2+4s+8}$$

Comparing this with standard T.F. of second Order System.

$$\frac{\omega^2}{s^2 + 2\xi\omega_0 s + \omega_0^2}$$

$$\therefore \omega_n^2 = 8$$

$$\therefore W_n = 2.83 \text{ rad/sec}$$

$$2\xi W_n = 4 \quad \therefore \xi = 0.7067$$

1) Settling time $(T_s) = \frac{4}{\xi W_n} = \frac{4}{0.7067 \times 2.83}$ ---- 2M

$$\boxed{T_s = 2 \text{ sec}}$$ → 2marks

2) Rise time =

$$\theta = \tan^{-1}\left[\frac{\sqrt{1-\xi^2}}{\xi}\right] = \tan^{-1}\left[\frac{\sqrt{1-(0.7067)^2}}{0.7067}\right]$$

$$\theta = 45^\circ \; ; \; 0.78597 \text{ radians}$$

$$T_r = \frac{\pi-\theta}{\omega_d} = \frac{\pi-\theta}{W_n\sqrt{1-\xi^2}}$$

$$= \frac{\pi - 0.78597}{2.83\sqrt{1-0.7067^2}}$$

$$\boxed{T_r = 1.1769 \text{ Sec}}$$ → 2marks

b) Find the range of K for stability of a unity feedback system with

G(s) = K/S(S + 4) (S^2 + 2S + 2)

Ans: -

$$G(s) = \frac{K}{S(S+4)(s^2+2s+2)}$$

$$1 + G(S)\,H(s) = 0$$

for unity feedback $H(s)=1$

$1 + G(s) = 0 \longrightarrow$ characteristics eq^n

$$1 + \frac{K}{S(S+4)(s^2+2S+2)} = 0$$

$$S(S+4)(s^2+2s+2) + K = 0$$

$$(s^2+4s)(s^2+2s+2) + k = 0$$

$$s^4 + 2s^3 + 2s^2 + 4s^3 + 8s^2 + 8S + K = 0$$

$s^4 + 6s^3 + 10s^2 + 8S + K = 0 \longrightarrow$ (2 mark)

S^4	1	10	K
S^3	6	8	0
S^2	8.667	$\frac{6K}{6}$	0
S^1	$\frac{89.336-6K}{8.667}$	0	
S^0	K		

Array $\longrightarrow$ (2 mark)

for System to be stable there should not be sign change in first column.

$K > 0$ from S^0 $\longrightarrow$ (1 mark)

& $\frac{69.336-6K}{8.667} > 0$ from S^1

$$69.336 - 6K > 0$$

$$69.336 > 6K$$

$$\frac{69.336}{6} > K$$

$11.556 > K \longrightarrow$ (2 mark)

Range of K is $0 < K < 11.556 \longrightarrow$ (1 mark)

c) Name the continuous and composite modes of control actions. Compare P, I and D control actions with respect to,

i) Mathematical expression
ii) Response to the error
iii) Offset
iv) Stability

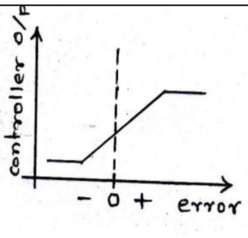
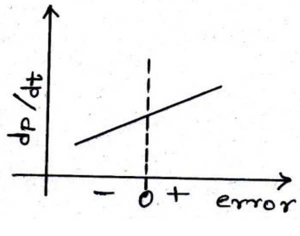
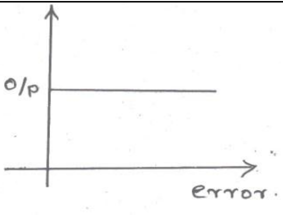
Ans: - {**For names - 2 mark, Comparison – 6 mark (1.5 mark each point)**}

Continuous mode of control actions: -

- Proportional control mode.
- Integral control mode.
- Derivative control mode.

Composite mode of control actions: -

- Proportional Integral control (PI)
- Proportional Derivative control (PD)
- Three mode controller (PID) or proportional Integral Derivative control.

Sr. No.	Parameter	P	I	D
1.	Mathematical Expression	$P = K_P e_P + P_0$ Where K_P - proportional gain P_0 - controller o/p with no error.	$P(t) = K_I \int_0^t e_P \, dt + P(0)$ Where K_I – Integral gain P(0) = controller o/p when integral action starts	$P(t) = K_D \, d e_P / dt$ Where K_D = gain
2	Response to the error			
3.	Offset	Due to change in load, offset is present.	No offset or it eliminates offset error.	It cannot eliminates offset.

4.	Stability	Stability is less due to steady state error.	It is Stable.	Unstable.