Important Instructions to examiners:

1. The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2. The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3. The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills).
4. While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5. Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6. In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7. For programming language papers, credit may be given to any other program based on equivalent concept.

Q.1 a) Attempt any three of the following: **12M**

i) What do you mean by stability? Define critical stable system.

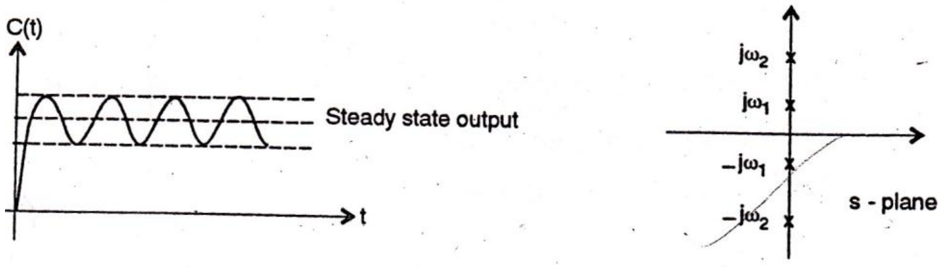
Ans: Stability: **1M**

A linear tyme invariant system is said to be stable if following conditions are satisfied:

1. When the system is excited by a bounded input, output is also bounded and controllable.
2. In the absence of the input, output must tend to zero irrespective of the initial conditions.

Critically stable: **3M**

A linear time invariant system is said to be critically or marginally stable if for a bounded input its output oscillates with constant frequency and amplitude, such oscillations of output are called as undamped oscillations. When one or more pairs of non-repeated roots are located on imaginary axis, The system is said to be critically stable.



(a) (b) Location of poles

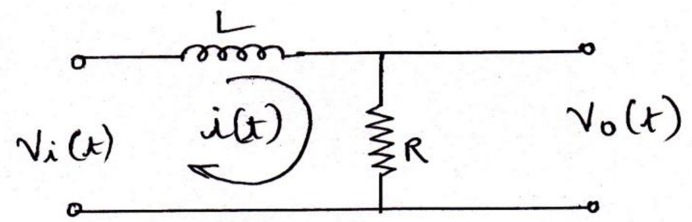
ii) Give the classification of robotics.

Ans: (four types – 4 marks)

Robotics are classified into six categories:

- Geometry: Rectangular, Cylindrical, Spherical
- Degree of freedom: arm, wrist
- Power sources: Eledric, Pneumatic, Hydraulic
- Type of motion: Slew motion, joint-interpolation, straight-line interpolation, circular interpolation.
- Path control: Limited sequence, point-to-point, continuous path, controlled path.
- Intelligence level: Low-technology (non-servo), high-technology (servo).

iii) Derive the transfer function for the given circuit refer fig. No.1



Ans: Applying KVL to loop,

4M

Vi(t) = Ri(t) + L di(t)/dt

Taking Laplace transform,

Vi(s) = RI(s) + Ls I(s)

Output voltage across R is,

Vo(t) = Ri(t)

Taking Laplace Transform,

Vo(s) = R I(s)

∴ Transfer function is, Vo(s)/Vi(s) = RI(s)/[RI(s) + L s I(s)]

Vo(s)/Vi(s) = R/(R+L s)

iv) Find the poles and zeros of given transfer function

G(s) = 20 / (s+1)(s+4)

Ans: solution

G(s) = 20 / (s+1)(s+4)

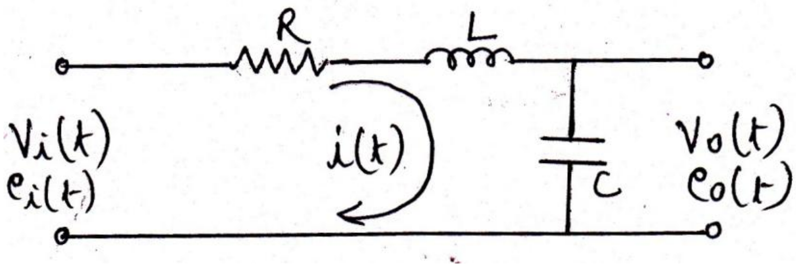
Zeros = Nil
2M

Poles = s = -1, s = -4
2M

i.e. no. of poles = 2

b) Attempt any One of the following:
6M

i) Find out the Transfer function of given system refer fig No. 2



Ans: Solution:

6M

Solution : Apply KVL to loop.

$$V_i (t) = R_i (t) + L\frac{di (t)}{dt} + \frac{1}{c}\int i (t)\, dt \quad \dots (1)$$

Taking L.T.

$$V_i (s) = R\, I (s) + Ls\, I (s) + \frac{1}{sc}\, I (s)$$

$$= \left(R + Ls + \frac{1}{sc}\right) I (s) \quad \dots (2)$$

Output voltage is across capacitor is,

$$V_o(t) = \frac{1}{c}\int i(t)\,dt \qquad \ldots (3)$$

Taking L.T.

$$V_o(s) = \frac{1}{sc}\, I(s) \qquad \ldots (4)$$

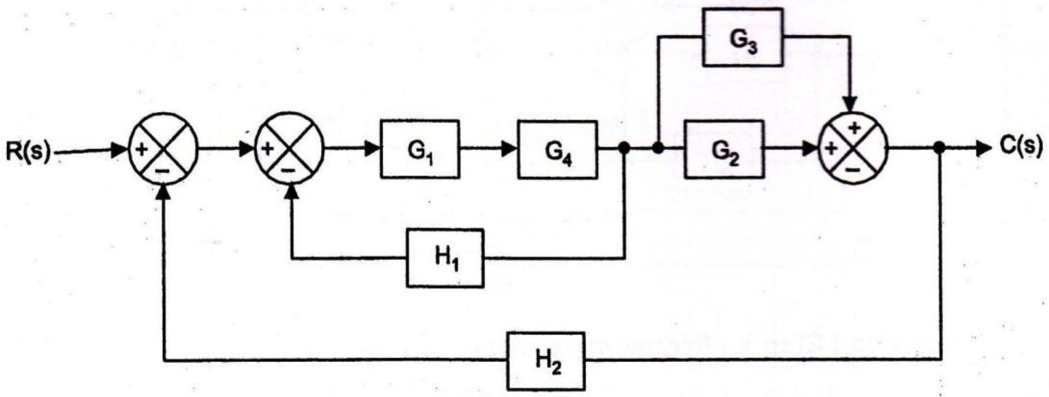
Take the ratio of equation (2) and (4),

∴ Transfer function is,

$$G(s) = \frac{V_o(s)}{V_i(s)} = \frac{1}{sc\left(R + Ls + \frac{1}{sc}\right)}$$

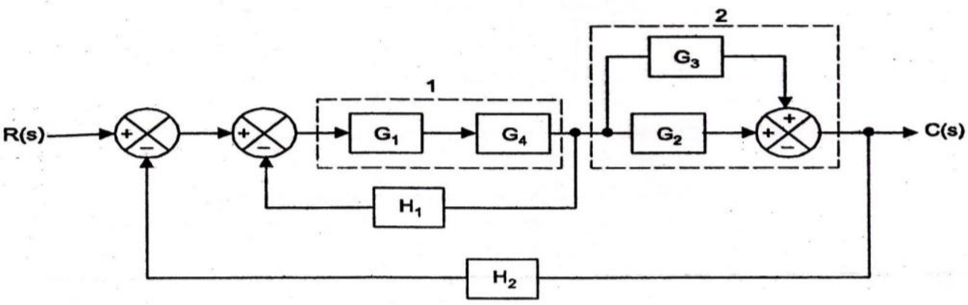
$$= \frac{1}{s^2LC + sRC + 1}$$

ii) Describe the transfer function of system using block reduction technique.



Ans: Solution: **6M**

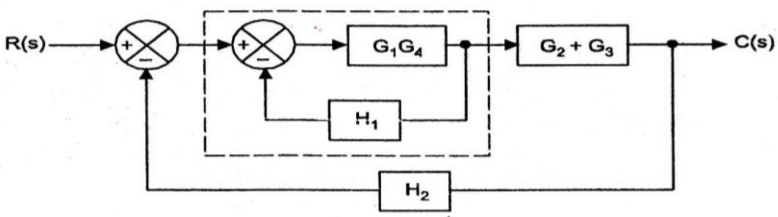
Solution : Step 1 : Redraw the given block diagram.



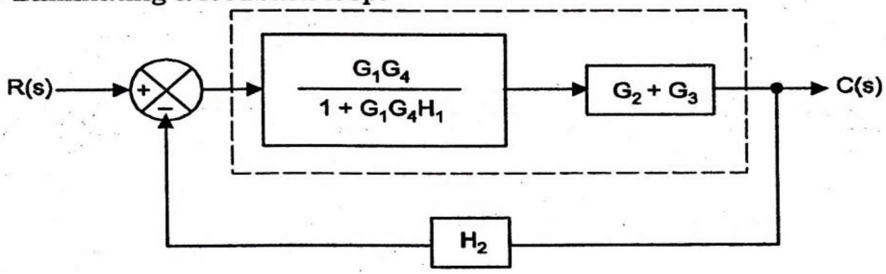
Step 2 :

Rule – For 1 – Combining blocks in cascade.

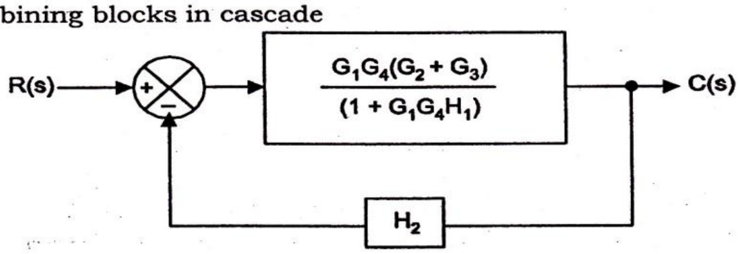
For 2 – Blocks in parallel



Step 3 :
Rule – Eliminating a feedback loop.



Step 4 :
Rule – Combining blocks in cascade



Step 5 :
Finding transfer function by eliminating feedback loop.

$$\text{T.F.} = \frac{C(s)}{R(s)} = \frac{\dfrac{G_1 G_4 (G_2 + G_3)}{(1 + G_1 G_4 H_1)}}{1 + \dfrac{G_1 G_4 (G_2 + G_3)}{1 + G_1 G_4 H_1} H_2}$$

$$\boxed{\text{T.F.} = \frac{C(s)}{R(s)} = \frac{G_1 G_4 (G_2 + G_3)}{(1 + G_1 G_4 H_1) + G_1 G_4 (G_2 + G_3) H_2}}$$

Thus, Reduced block diagram is,

$$R(s) \longrightarrow \boxed{\frac{G_1 G_4 (G_2 + G_3)}{(1 + G_1 G_4 H_1) + G_1 G_4 (G_2 + G_3) H_2}} \longrightarrow C(s)$$

Q.2 Attempt any two of the following: 16M

a) Determine the stability of the system whose characteristics equation is given as. $S^4 + 8S^3 + 24S^2 + 32S + 16 = 0$, using Routh criterion.

Ans: Solution: **8M**

$S^4 + 8S^3 + 24S^2 + 32S + 16 = 0$

S^4	1	24	16
S^3	8	32	0
S^2	20	16	
S^1	25.6	0	
S^0	16		

As there are no sign changes in column 1 system is stable.

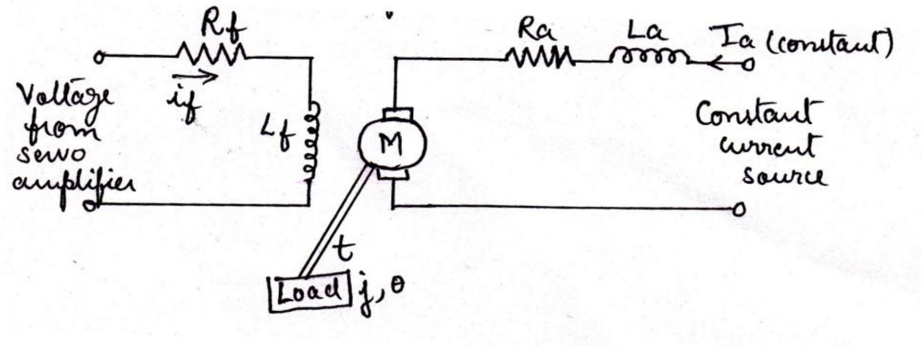
b) Explain with neat sketches types of DC Servomotor.

Ans: Types of DC servomotor are:

1) Field controlled DC servomotor
2) Armature controlled DC servomotor

1) Field controlled DC servomotor: (Explanation 2M and diagram 2M)

In this motor, controlled signal is applied to the field winding and armature current is kept constant.



The controlled signal obtained from servo amplifier is applied to field winding with the help of constant current source, armature current Ia is kept constant.

f = Viscous friction coefficient between motor and load

Tm = Torque developed by motor

θ = angular displacement of motor

J = moment of inertia of motor

i_f = field current

i_a = armature current

DC motor are used in linear range of magnetization curve (torque speed characteristics) Therefore air gap flux ϕ is proportional to field current.

i.e. $\phi \propto i_f$ or $\phi = k_f\, i_f$ -------------------(1)

Reaction of flux ϕ with armature current Ia produces torque Tm that forces the armature to rotate

$\therefore$ $Tm \propto \phi \cdot Ia$ or $Tm = k_1\, \phi\, Ia$ ------------------ (2)

Substituting (1) in (2)

$Tm = k_f\, k_1\, i_f\, Ia$

$Tm = k_T .\, i_f$

Torque equation in terms of J, f, and θ

$Jd^2\theta/dt^2 + f\, d\theta/dt = Tm = k_T\, i_f$

$(Js^2 + f\, s)\, \theta(s) = Tm(s) = k_T\, I_f\,(s)$

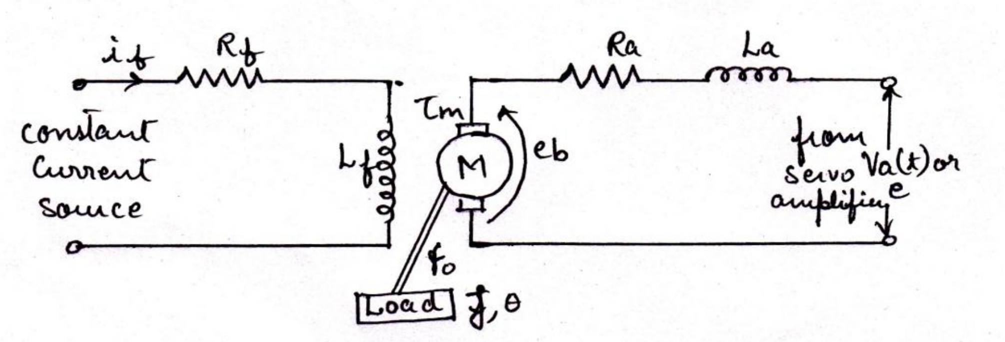
$\theta(s) = k_T\, I_f\,(s) / Js^2 + f\, s$

Transfer function = output / input = $[k_T I_f(s) / Js^2 + f s] / [(R_f + L_f s) I_f(s)]$

$$= k_T / [(Js^2 + f s)(R_f + L_f s)]$$

Field controlled DC motor has large L_f/R_f ratio time constant is high. It is used for small size motor.

2) Armature controlled DC servomotor: (Explanation 2M and diagram 2M)



Here error voltage from the servo amplifier is given to the armature of DC motor. Field is connected to a constant current source. Therefore field current I_f is constant.

Tm = Torque developed by motor

θ = angular displacement of motor.

Va(t) or e = applied armature voltage.

f_o = coefficient of viscous friction between motor and load.

eb = back emf

DC motor are used in linear range of magnetization curve therefore air gap flux is proportional to field current.

$\phi \propto I_f$ or $\phi = k_f i_f$ --------------------- (1)

Reaction of flux ϕ with armature current Ia produces Torque Tm that forces the armature to rotate.

$\therefore$ $Tm \propto \phi . Ia$ or $Tm = k_1 \phi Ia$ --------------------- (2)

Substituting (1) in (2) we get

$Tm = K_1 K_f I_f . Ia$

Since I_f is constant.

$Tm = K_T Ia$

Back emf is induces into the armature winding which is proportional to the speed of motor.

$\therefore$ $eb \propto d\theta/dt$ or $eb = Kb\, d\theta/dt$ ------------------- (3)

The differential equation of armature circuit is,

$E = La\, dIa/dt + Ra\, Ia + eb$ ------------------- (4)

Taking Laplace of (3) and (4) we get,

$Eb(s) = Kb\, s.\, \theta(s)$

$E(s) = La\ s\ Ia(s) + Ra\ Ia(s) + Eb(s)$

$= La\ s\ Ia(s) + Ra\ Ia(s) + Kb\ s\ \theta(s)$

Armature input voltage controls the motor shaft output. It is used for large size motor.

c) A system has G(s) H(s) = $s(s^2+s+1)(s+4)+k = 0$

where k is positive. Determine the range of 'k' for the system to be stable.

Ans: Solution:

8M

$s(s^2+s+1)(s+4)+k = 0$

$s^4 + 5s^3 + 5s^2 + 4s + k = 0$

The Routh array for this equation is,

s^4	1	5	k
s^3	5	4	
s^2	21/5	k	
s^1	16.8-5k/4.2	0	
s^0	k		

For stable system, all signs of elements in first column are positive.

Thus, condition of system stability requires

$K > 0$

And

$(16.8 – 5k) > 0$, $16.8 > 5k$, $3.36 > k$

Therefore, for stability, k should be in the range

$3.36 > k > 0$

Q3. Attemp any four of following: **16M**

a) A system is represented by differential equation

$$\frac{d^2 c(t)}{dt^2} + \frac{5d\,c(t)}{dt} + 8\,c(t) = \frac{2dr(t)}{dt} + r(t)$$

Where c(t) is input and y is output. Derive the transfer function of the system.

Ans: (N*ote: students can solve any one of the below options.*) **4M**

i) c(t) = output and r(t) = input

Taking Laplace transform of the above equation and considering zero initial conditions, we get —[2M]

$$S^2C(S) + 5SC(S) + 8(C(S)) = 2SR(S) + R(S)$$

$$C(S)\left[S^2+5S+8\right] = R(S)\left[2S+1\right]$$

∴ Transfer function

$$\frac{C(S)}{R(S)} = \frac{2S+1}{S^2+5S+8}$$ — [2M]

OR

ii) c(t) is input and r(t) is output.

Taking laplace transform of the given equation. We get,

$$S^2C(S) + 5SC(S) + 8(C(S)) = 2SR(S) + R(S)$$

$$C(S)\left[S^2+5S+8\right] = R(S)\left[2S+1\right]$$

$$\frac{R(S)}{C(S)} = \frac{S^2+5S+8}{2S+1}$$

b) Explain the following terms with respect to robotics.

i) DOF **ii) End effector**

Ans:- DOF: **2M**

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: **2M**

End effector is the device at the end of a robotic arm designed to interact with the environment.

End effector originates from robotic manipulators (robotic arm) It is the last link of the robot.

c) State the principle of ON-OFF control action with Mathematical expression and its characteristics.

Ans: (Principle 2 marks, mathematical expression 1 mark and characteristics 1 mark)

Principle of on-off controller:

This is the most elementary controller mode which has only two fixed position, ie. ON and OFF position. It is the simplest and cheapest mode of action, hence commonly used in industrial and domestic controls. In this mode, when the error signal e(t) is greater than the set point r(t) i.e reference point, the output u(t) of the controller is zero(OFF) and when the error signal is less than the set point the output maximum(ON).

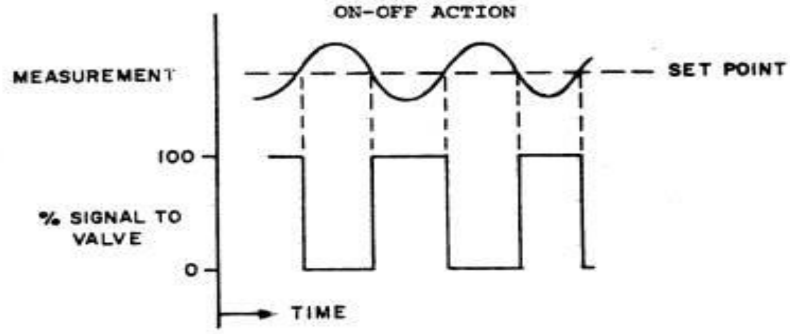
Mathematical expression:

u(t)= 0% (OFF) for e(t) > 0

u(t)=100% (ON) for e(t) < 0

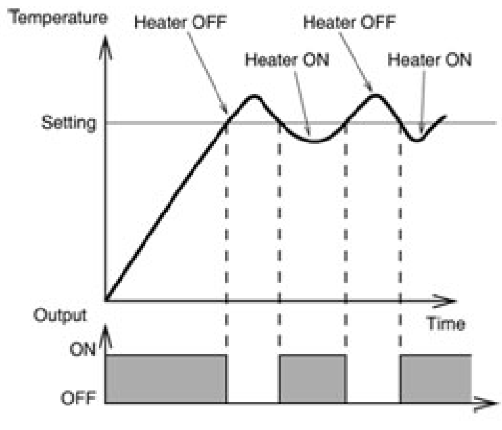
FIGURE 5

ON-OFF ACTION



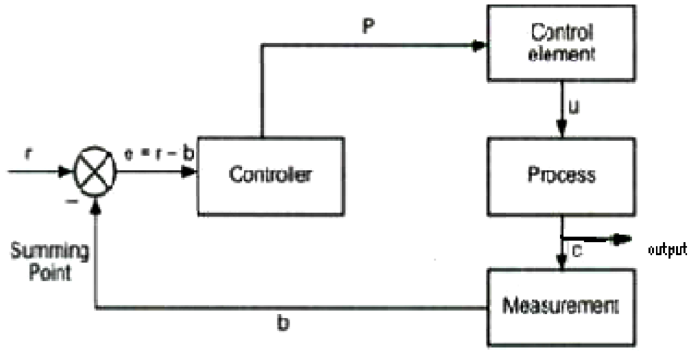
OR

ON/OFF Control



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

Ans:-(Diagram 2 marks, explanation 2 marks)



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/Summing point: 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.

e) Derive steady state error expression in terms of open loop transfer function G(s) having unity f/b system. Obtain ess for unit step input.

Ans: (derivation of ess = 3 marks, ess for unit step input= 1 mark)

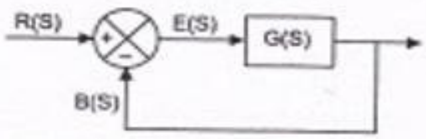


Fig. : Unit Feedback System

From Fig. the transfer function of negative feedback is,

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)} \qquad [\because H(s) = 1]$$

and $\quad C(s) = E(s)\,G(s) \qquad$ [Output = gain × input]

Equation becomes,

$$\frac{E(s)\,G(s)}{R(s)} = \frac{G(s)}{1+G(s)}$$

$$\therefore \quad E(s) = \frac{1}{1+G(s)}\,R(s)$$

The steady state error e_{ss}, may be found by final value theorem as,

$$\therefore \quad e_{ss} = \lim_{t\to\infty} e(t)$$

$$= \lim_{s\to 0} s \cdot E(s)$$

$$= \lim_{s\to 0} s \cdot \frac{R(s)}{1+G(s)} \qquad \left[\because E_s = \frac{R(s)}{1+G(s)}\right]$$

For unity feedback, i.e. $H(s) = 1$

$$\therefore \quad e_{ss} = \lim_{s\to 0} \frac{s\cdot R(s)}{1+G(s)}$$

or when feedback element is present.

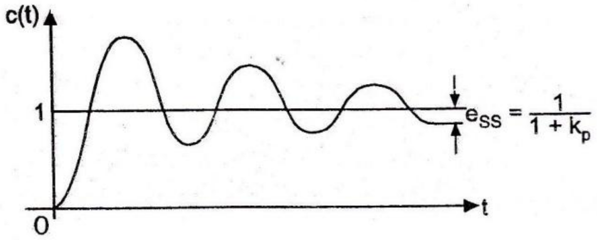
$$e_{ss} = \lim_{s\to 0} \frac{s\cdot R(s)}{1+G(s)\,H(s)}$$

Unit Step Input

Input, $r(t) = u(t)$

and $R(s) = \frac{1}{s}$

$$e_{ss} = \lim_{s \to 0} s \cdot \frac{R(s)}{1 + G(s)}$$
$$= \lim_{s \to 0} s \cdot \frac{1/s}{1 + G(s)}$$
$$= \lim_{s \to 0} \frac{1}{1 + G(s)}$$
$$= \frac{1}{1 + G(0)} = \frac{1}{1 + k_p}$$



Where $k_p = G(0)$ is defined as the position error constant.

Q4. a) Attempt any three of the following: 12 M

i) For given transfer function.

$$T\,F = \frac{K(s+6)}{s(s+2)(s+5)(s^2+7s+12)}$$

Find out

1) Poles

2) Zeros

3) Characteristic equation

4) Locate poles and zeros on S – plane

Ans:- (Each carries 01M)

i) Poles are the roots of the equation obtained by equating denominator to zero i.e. roots of

$$s(s+2)(s+5)(s^2+7s+12) = 0$$

i.e. $s(s+2)(s+5)(s+3)(s+4) = 0$

So there are 5 poles located at

$s = 0, -2, -5, -3$ and -4

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

$$K(s+6) = 0$$

i.e. $s = -6$

There is only one zero.

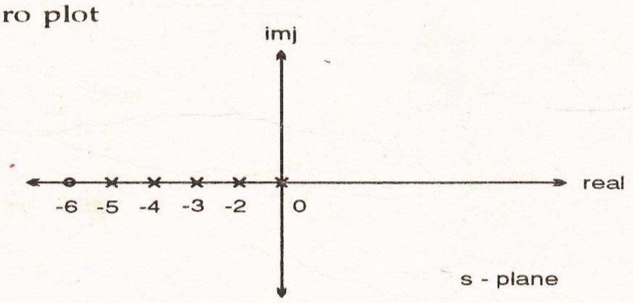
iii) Characteristic equation is one, whose roots are the poles of the transfer function. so it is

$$s(s+2)(s+5)(s^2+7s+12) = 0$$

i.e. $s(s^2+7s+10)(s^2+7s+12) = 0$

i.e $s^5 + 14s^4 + 71s^3 + 154s^2 + 120s = 0$

iv) Pole-zero plot



ii) For a system having closed loop transfer function for unit step i/p. determine

1) Natural frequency (wn)

2) Damping ratio (ξ)

3) Damping Frequency (wd)

4) Peak over shoot (% MP)

$$\frac{C(s)}{R(s)} = \frac{25}{s^2+6s+25}$$

Ans:- **(Each carries 01M)**

Comparing the T.F. with the standard form $\frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}$

$\omega_n^2 = 25$ and $2\xi\omega_n = 6$

$\omega_n = 5$ rad/sec $\therefore$ $\xi = 0.6$

$$\theta = \tan^{-1}\left[\frac{\sqrt{1-\xi^2}}{\xi}\right] = 0.9272 \text{ radians}$$

$$\omega_d = \omega_n\sqrt{1-\xi^2} = 5\sqrt{1-(0.6)^2} = 4 \text{ rad/sec}$$

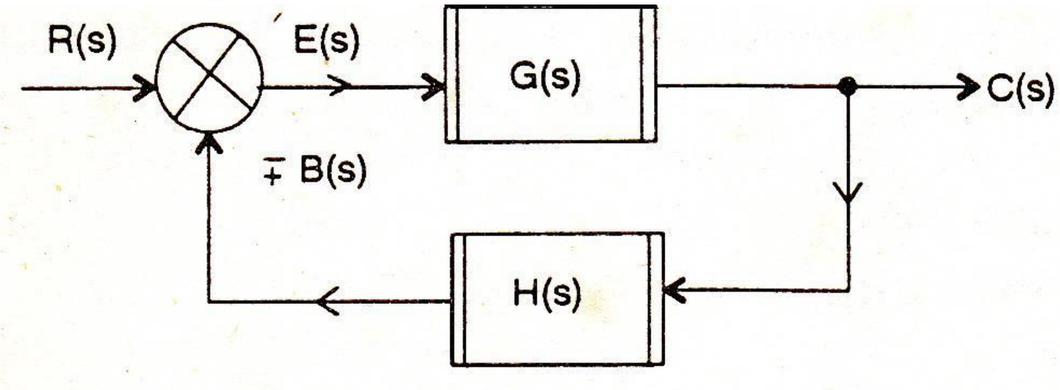
$$\% M_p = e^{-\pi\xi/\sqrt{1-\xi^2}} \times 100 = 9.48\ \%$$

iii) Define transfer function and derive the transfer function for a general closed loop control system

Ans : (**Definition 01 M, derivation 03 M**)

Transfer function of a linear time-invarient system is define as the ratio of the laplace transform of the output variable to the Laplace transform of the input variable assuming that all initial conditions are zero

The transfer function for a general closed loop control



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

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

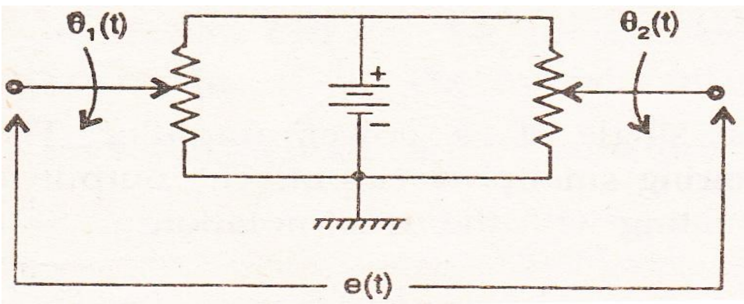
iv) Describe potentiometer as error detector.

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.

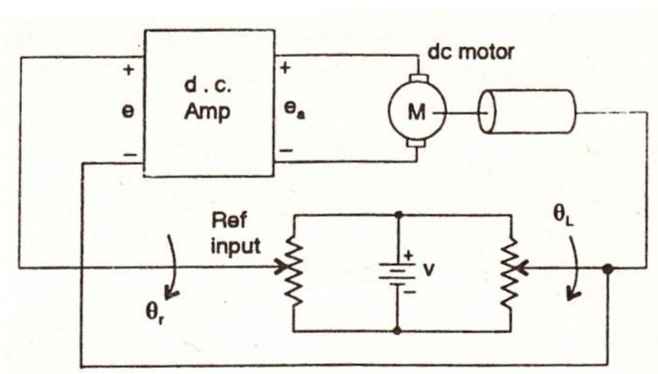
$E(t) \alpha Qc (t).$

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 $e(t) = Ks [Q_1(t) – Q_2 (t)]$



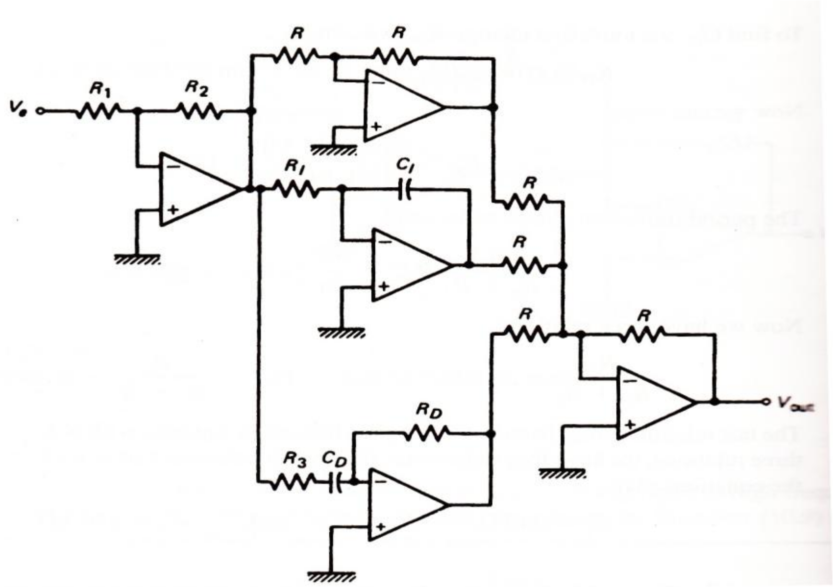
One potentiometer displacement is to be considered as reference i/p the other is variable. The difference between these two error which is amplified and given to DC motor so that it positions the load properly.

Thus potentiometer can be used as an error detector.

b) Attempt any one of the following: 6M

i) Draw electronic PID controller. State its equation and explain it.

Ans:- (Diagram-2M, Equation-2M, Explanation-2M)



Equation of PID controller

$$-V_{out} = \frac{R_2}{R_1} V_e + \frac{R_2}{R_1}\frac{1}{R_1 C_1}\int V_e\,dt + \frac{R_2}{R_1} R_D C_D \frac{dV_e}{dt} + V_0$$

Explanation

Derivative action leads the proportional mode and integral action lags the proportional mode. PID controller is the most powerful and complex mode. It produces output depending upon magnitude duration and rate of change of error signal. It eliminates offset, has fast response. But turning of parameters (K_p, K_i, K_D)is difficult. It is a major disadvantage.

ii) Explain with diagram variable reluctance type of stepper motor and state its application

Ans:- (Diagram -2M, Explanation-2M, Application-2M)

Fig (a)

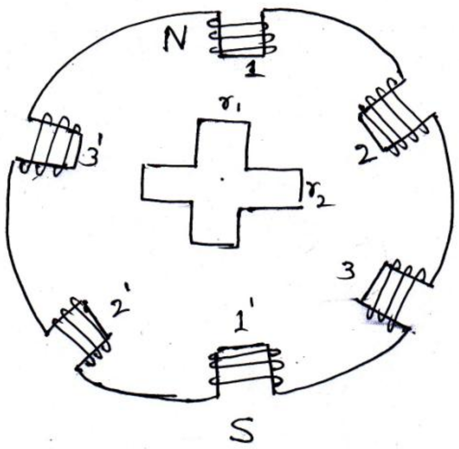
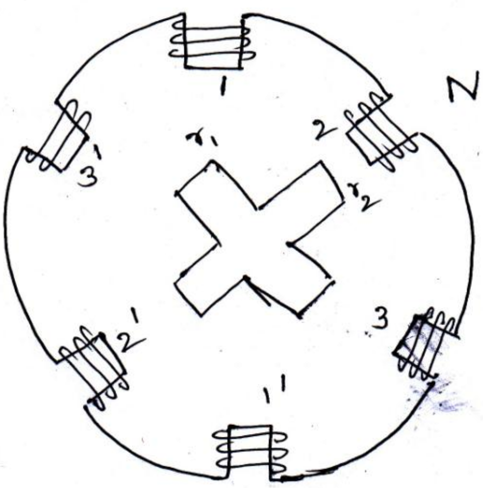


Fig (b)



3 stator phases (6poles) and 4 rotor poles.

variable reluctance type of stepper motor

Here rotor is made of magnetic material with a certain number of teeth. The rotor is derives by a phased arrangement of stator coils with different no of poles so that the rotor can never be in perfect alignment with stator. As the no of stator & rotor poles can be increased, the step angle can be reduced here. Therefore it is used applications where small step angles are needed such as micropositioning tables.

Consider a VRSM with 3 stator phases (6 poles) and 4 rotor poles. Here, consider no.1 staor pole as excited, making it North & '1' as South. Rotor pole r_1, r_2 are South poles. In fig (a) r_1 is aligned with no.1 stator pole. In fig 2, no.2 stator poles are excited. Rotor pole r_2 is nearest to the position of alignment rotor moved to align r_2 with no.2 stator pole. It causes a rotation of rotor by 30^o anticlockwise.

Relationship to find step angler in VRSM = 360/(no of rotor teeth * no of stator phases).

Therefore here, 360/(4*3) = 30^o

Application of stepper motor: ***(Note: Any Two Applications)***

- Computer-controlled stepper motors are one of the most versatile forms of positioning systems. They are typically digitally controlled as part of an open loop system, and are simpler and more rugged than closed loop servo systems.
- Industrial application are in high speed pick and place equipment and multi-axis machine CNC machines often directly driving lead screws or ballscrews
- In the field of laser and optics they are frequently used in precision positioning equipment such as linear actuators, linear stages, rotation stages, goniometers and mirror mounts. Other uses are in packaging machinery, and positioning of valve pilot stages for fluid control systems.
- Stepper motors are used in floppy disk drives, flatbed scanners, computer printers, plotter and many more devices
- In robotics when the movement is controlled by Stepper motors.

Q5 Attempt any four of the following: 16M

a) Define the following Time response specification

i) Peak overshoot(M_p): **1M**

It is the largest error between reference input and output during the transient period.

OR

It also can be defined as the amount by which output overshoots its reference steady state value during the first overshoot.

$$\%M_p = e^{-\pi\xi}\sqrt{1-\xi^2} * 100$$

[Note: any one defination]

ii) Settling time (T_s): **1M**

This is defined as the time required for the response to decrease and stay specified percentage of its final value.

$T_s = \frac{4}{\xi w_n}$

iii) Rise time (T_r): **1M**

It is the time required for the response to rise from 10% to 90% of the final valve for over damped systems and 0 to 100% of the final value for under damped system.

$T_r = \frac{\pi - \theta}{w_r}$

Where θ must be radians

iv) Delay time (T_d): **1M**

It is the time required for the response to reach 50% of the final value in first attempt.

$$T_d = \frac{1 + 0.7\xi}{w_n}$$

b) Define and write mathematical expression for a step and ramp signal with their laplace transform.

Ans:-

Step input signal (Position function) :- **2M**

Definition:- It is the sudden application of input at a specified time.

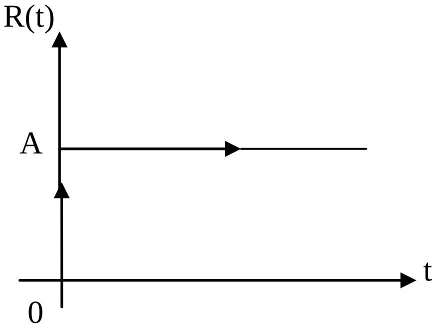
Mathematically it can be described

$R(t) = A$ for $t \geq 0$

$= 0$ for $t < 0$

If A = 1, then it is called as unit step function and denoted by u (t).

Laplase transform of such input is A/S.



Ramp input signal :- **2M**

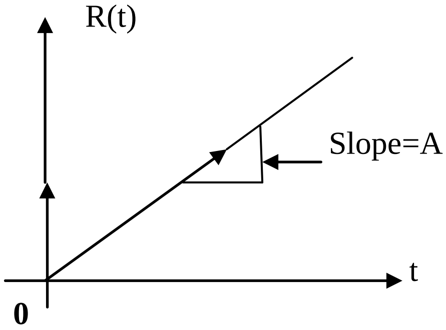
Definition:-

It is constant rate of change in input i.e. gradual application of input.
Magnitude of Ramp input is nothing but its slop.
Mathematically it is defined as

$$R(t) = A\,t \qquad t \geq 0$$

$$= 0 \qquad t < 0$$

If A = 1, it is called as unit ramp i/p. Its laplace transform = A/S^2.



c) Differentiate between armature controlled and field control D.C. servomotor

Ans: **(Any four point carries 04 Marks)**

Sr. No	Armature controlled DC motor	Field controlled DC motor
1.	Field current is constant	Armature current is constant
2.	Control voltage is applied to armature	Control voltage is applied to field
3.	Close loop system	Open loop system
4.	Small time constant	Large time constant
5.	High power requirement	Low power requirement
6.	Less expensive	More expensive
7.	Better efficiency	Poor efficiency
8.	Permanent magnets can be used instead of field coil	Field coil is must.
9.	Suitable for large rated motor	Suitable for small rated motor

d) Draw the block diagram of Robot and explain its working.

Ans: B**lock diagram of Robot:** **2M**

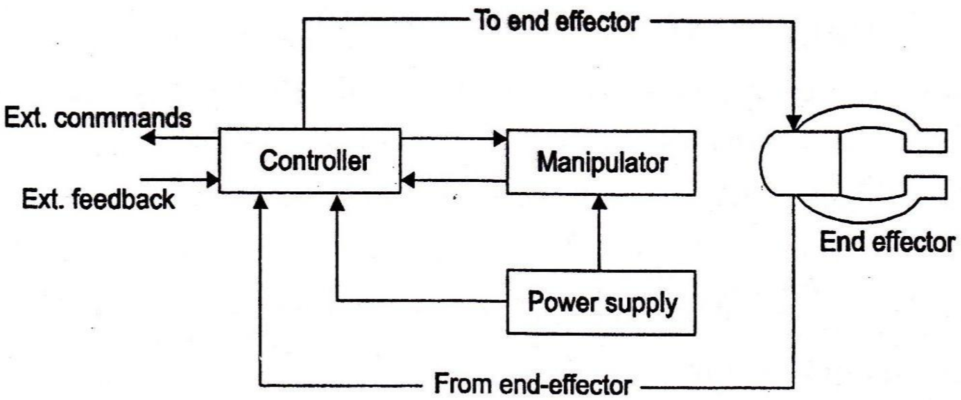


Fig.: Functional Diagram of Robotics

Explanation – **2M**

- 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, pragmatic 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.

e) Compare open loop and closed loop control system (any 4 points).

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

(Note: Other relevant 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.

f) Explain PI controller

Ans: **4M**

Proportional controller: The controller output is directly proportional to the error or The change in controller output from set point is proportional to error.

$P_{OUT} - P_O \ \alpha \ Ep$

$P_{OUT} - P_O = K_P E_P$

$P_{OUT} = K_P E_P + P_O$ where Kp is proportional constant

Main drawback of proportional controller is OFFSET which is permanent residual error

Integral controller : It eliminates OFFSET error of Prop controller because controller output depends upon the history of errors form t=0

Rate of change of controller output α error

$$\frac{dP_{out}}{dt} \quad \alpha \quad Ep$$

$$\frac{dP_{out}}{dt} = Ki\ Ep$$

Pout=Ki∫Epdt+Po

The drawback of Integral controller is the action is very slow, it decreases the stability.

PI controller: Integral controller is rarely used alone because of its slow response to disturbances. When it is combined with prop controller, its slow response and offset of proportional mode can be eliminated.

$$P_{out} = K_p\, E_p + K_p\, K_i \int_0^t E_p \quad (t)\, dt + \ P_o$$

PI mode ensures that when a deviation takes place, proportional mode reacts immediately to change the controller output since there is not a time integral of deviation. Offset error occurs with a load change but mode provides a new controller output which in turn changes the error to be zero after a load change.

Q6. Attempt any four of the following. 16M

a) What is offset and how it is eliminated?

Ans: (Offset 2 marks and elimination of offset 2 marks)

The proportional controller produces a permanent residual error in the controlled variable, when a change in load occurs. This is referred to as offset.

Offset can be minimized

i) by having larger value of error constant k_p , which also reduces the proportional band.

ii) by automatic resetting .

b) List two application and advantages of ON-OFF controller

Ans: (**Applications 2 marks and advantages 2 marks)**

Applications of ON-OFF controller:

i. It is widely used for large-scale systems with relatively slow process rate.

ii. It is used in domestic appliances such as room heater, air-conditioner, refrigerator, air-cooler,etc.

Advantages of ON-OFF controller:

(i) Simple in construction

(ii) economical and cheapest

c) Derive k_p, k_v for type "I" control system

Ans: The open loop transfer function of a unity feed back system can be written as in time constant form

$$G(s)\,H(s) = \frac{K(1+T_1 s)(1+T_2 s)\ldots}{s^j(1+T_a s)(1+T_b s)\ldots\ldots}$$

where K = Resultant system gain

and j = TYPE of the system

TYPE' of the system means number of poles at origin of open loop T.F. G(s) H(s) of the system.

So $j = 1$ is TYPE one system

Where k = Resultant system gain.

And j = TYPE of the system.

j = 1 is TYPE one system

Position Error coefficient:- **2M**

TYPE 1 :

i.e. $$G(s)\,H(s) = \frac{K(1+T_1 s)(1+T_2 s)\ldots\ldots}{s(1+T_a s)(1+T_b s)\ldots\ldots}$$

As input is step ,

$$K_p = \lim_{s \to 0} G(s)\,H(s) = \infty$$

Velocity Error coefficient :- **2M**

$$G(s)\,H(s) = \frac{K(1+T_1 s)(1+T_2 s)\ldots\ldots}{s(1+T_a s)(1+T_b s)\ldots\ldots}$$

$$K_v = \lim_{s \to 0} s\,G(s)\,H(s) = K \text{ Constant}$$

d) Explain the effect of damping.

Ans: (4 points = 4 marks)

The effect of damping is as follows: ζ is the damping ratio

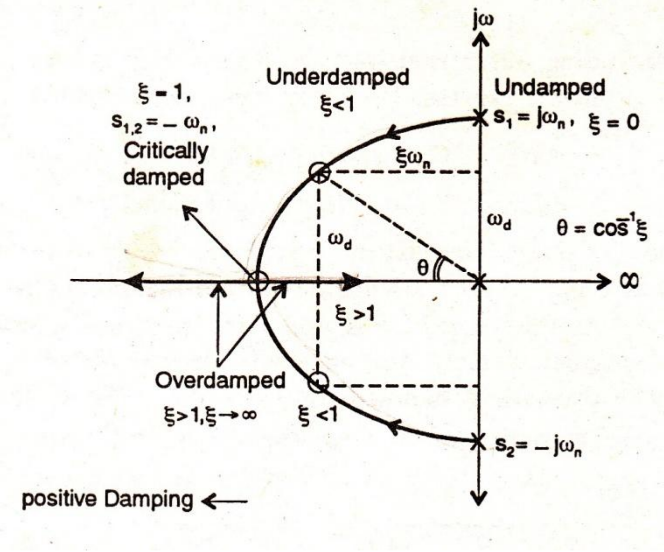
For $0<\zeta<1$ i.e under-damped

For $\zeta > 1$ i.e over-damped

For $\zeta = 1$ i.e critically damped

For $\zeta = 0$ i.e undamped

OR



[Note: Diagram is optional]

e) Explain Rotary encoder with neat diagram.

Ans: (Diagram 2 marks and explanation 2 marks)

Explanation:

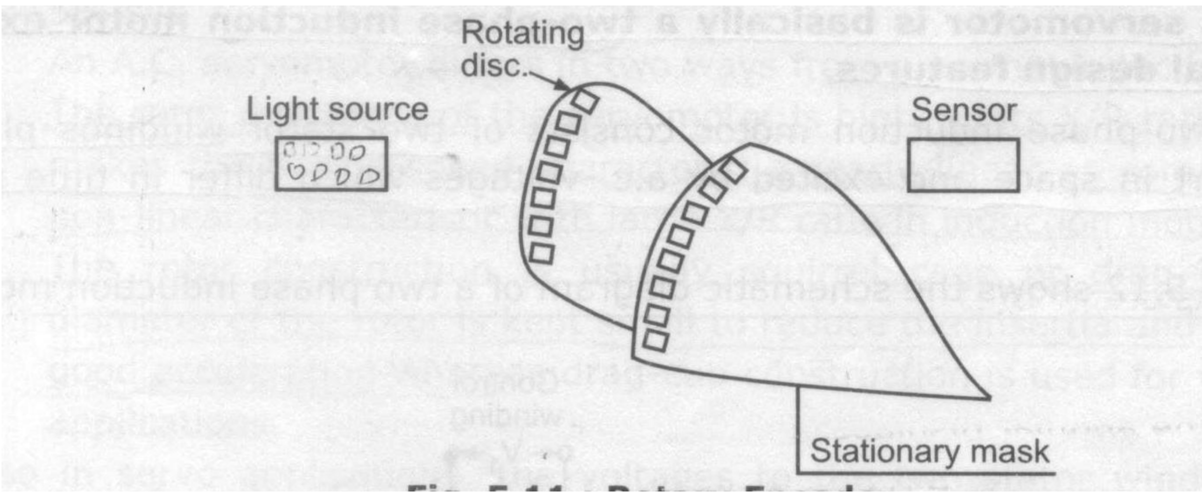
The electromechanical device used to convert the angular position of a shaft or axle to an analog or digital code is called a rotary encoder**.**They can be as absolute or rotary encoders

The rotary encoder consists of four elements : rotary disc, a light source, a stationary mask and a sensor.

Light source falls through alternate opaque and transparent parts and results in angular displacement in terms of 1’s and 0’s.

It is used in robotics, measurement of angular position, industrial controls, computer input devices, track motion, etc.

Diagram of rotary encoder



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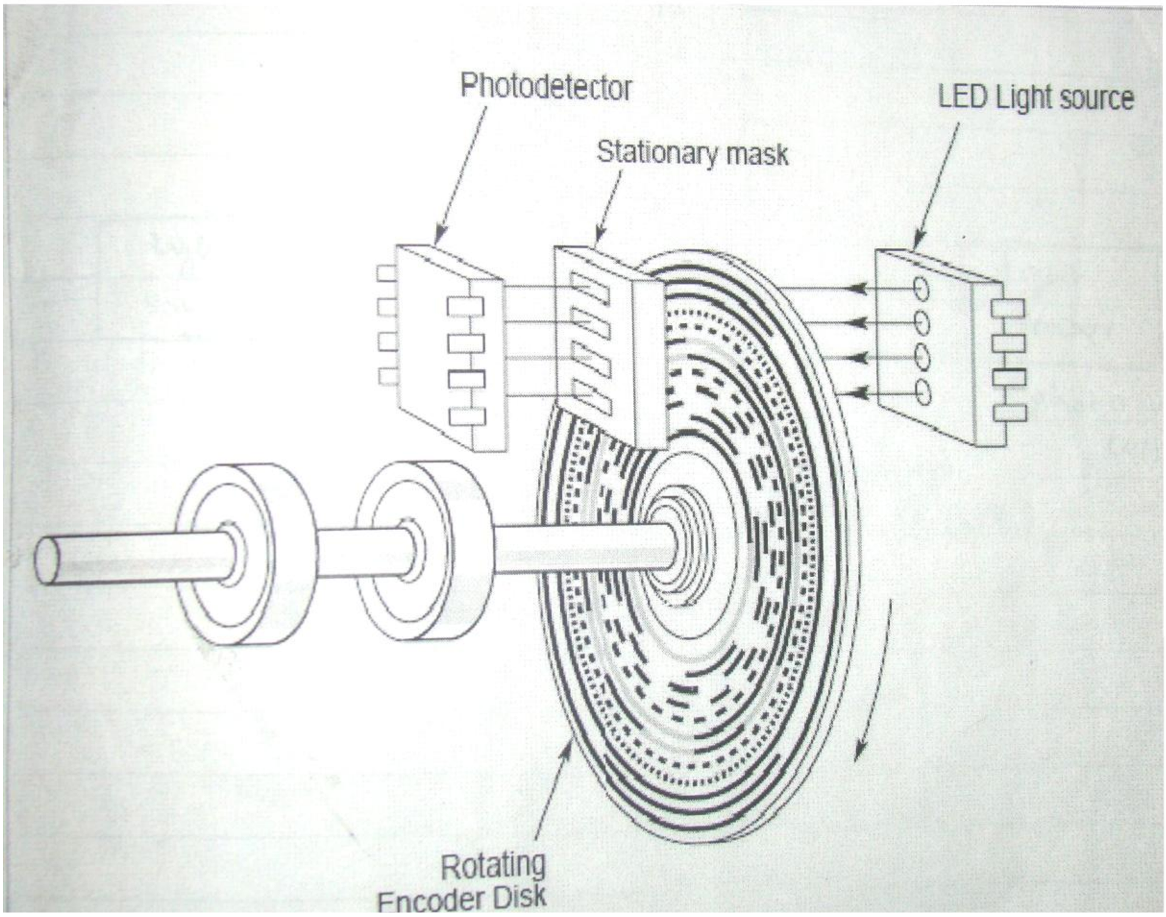
Photodetector
LED Light source
Stationary mask
Rotating
Encoder Disk