# CSS Model Answer W2014

Subject Code: **12270** Page No: ____/ N

**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 judgement 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.

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**Q. 1 a) Attempt any THREE of the following: (12marks)**

**i) Define the following terms.**

**1) Stable system**

**2) Unstable system**

**3) Critically stable system**

**4) Conditionally stable system**

ANS **: (1 M each)**

**i) Stable system :-**

If the poles are located on the left half of the s-plane system is said to be stable.

Or

When the system is excited by a bounded input, the output is also bounded and controllable.

**ii) Unstable system :-**

If the poles are located on the right half of the s-plane system is said to be unstable.

Or

When the system is excited by a bounded input, the output is unbounded.

**iii) Critical stable system :-**

If the poles (non repeated) are located purely on imaginary axis of s-plane, system is said to be critically stable.

**iv) Conditionally stable system:-**

If the Stability of system depends on condition of parameter of the system, such a system is called conditionally stable system.

**ii) Define steady state response and transient response of a system and write the expression for steady state error.**

ANS**: (Definition 11/2 M each, Expression 1M)**

**Transient response:** response of the system till it reaches the final steady state. It shows how the system settles down to the final value .

**OR**

That part of time response that goes to zero as time becomes very large

**Steady state response:** response of the system after the transients dies out.

- Give appropriate marks if it is marked in the graph instead of definition.

**Expression:**

$$\text{Steady state error } e_{ss} = \lim_{S \to 0} S*E(s)$$

$$= \lim_{S \to 0} S*R(S)/(1+G(S)H(S))$$

**OR**

$$ess = \mathrm{Lt}_{t \to \infty} [ ( r(t) - c(t)]$$

**iii) Draw block diagram of closed loop control system. Give practical example for the same.**

ANS**: (Diagram 2 M, Example 2M)**

**Diagram:**

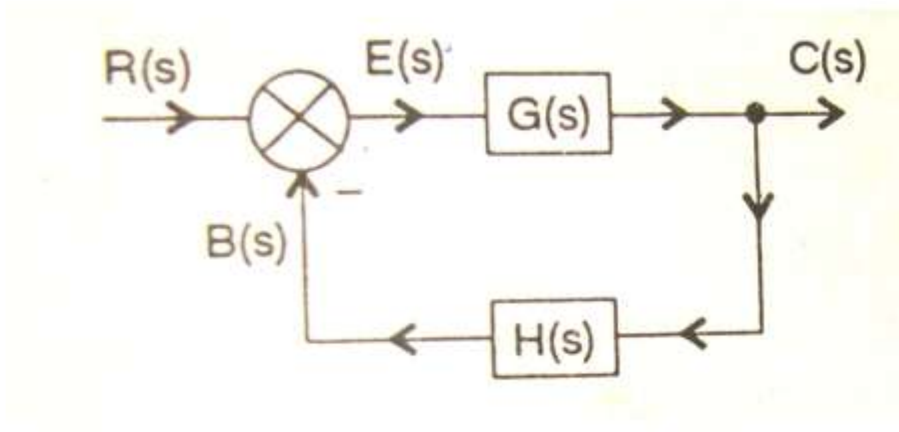



**Fig: Closed loop system.**

**Example : <u>(Any 2, 2 M)</u>**

Temperature control system, level control system, human beings, automobiles driven by a drive, Voltage stabilizer, missile launching, air traffic control ,,satellite tracking

**(iv) Draw the block diagram of Robot and state any two applications of Robot**

ANS**: ( Diagram 2 M, Applications 2 M)**

**<u>Major components of robots:</u>**

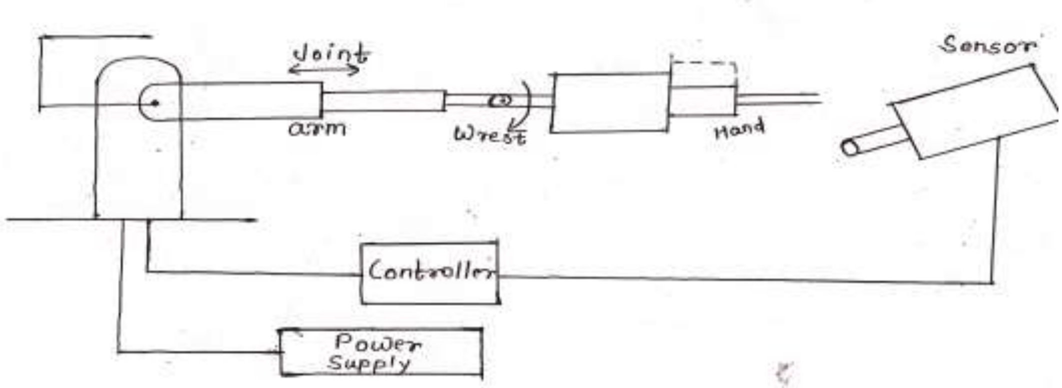



**Fig: Block diagram of Ro**

**Applications:( any two )**

1. Jobs which are monotonous like assembling, stamping, packaging etc. can be done by robots in industry.
2. Can be used in nuclear research, military applications , underwater applications etc. by replacing the human being.
3. To increase the productivity , robots are used in the manufacturing industry

**b. Attempt any ONE of the following. (6marks)**

**i) Derive the expression for output response of a first order system for unit step input. Draw its output response with labeling.**

ANS**: Transfer function of first order RC network:**

Transfer function of first order system t= C(S)/R(S)=$V_{out}$(S) /$V_{in}$(S) **01 mark**
=1/(RCS+1 ) or 1/1+sT

For unit step input, R(S)= $V_{in}$(S) = 1/S

Therefore, C(S) = 1/(RCS+1)*S

Applying partial fraction, $C(S) = \dfrac{1}{S(RCS+1)} = \dfrac{A}{S} + \dfrac{B}{1+RCS}$ **02 mark**

A=1, B= -RC,

Therefore, $C(S) = \dfrac{1}{S(RCS+1)} = \dfrac{1}{S} + \dfrac{-RC}{1+RCS} == \dfrac{1}{S} - \dfrac{1}{(1/RC)+S}$

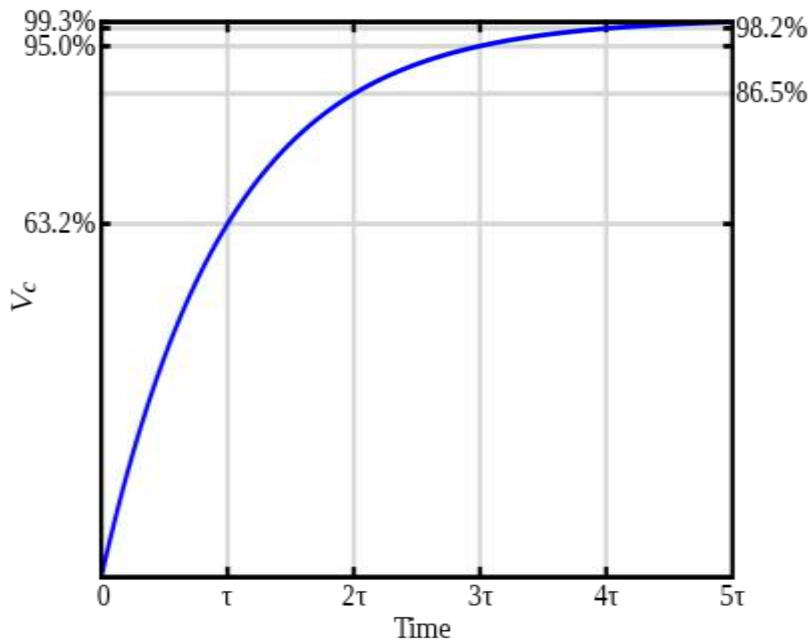
Taking Laplace inverse**,** **01 mark**

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

RC is the time constant $\tau$

**Output response:** **02 mark**

**C(t)**




**t**

**ii) Derive the transfer function of the given block diagram as shown in Figure No. 1. Using block reduction technique.**

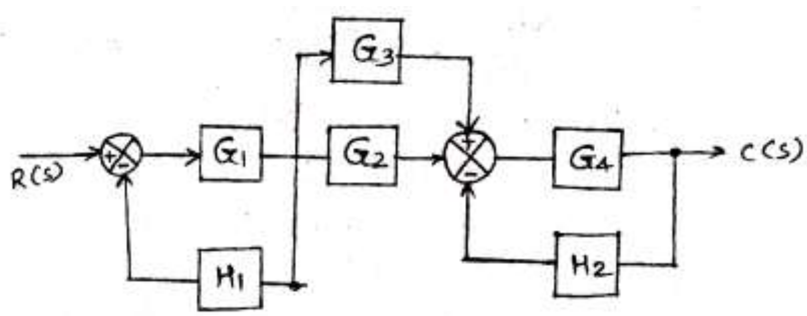
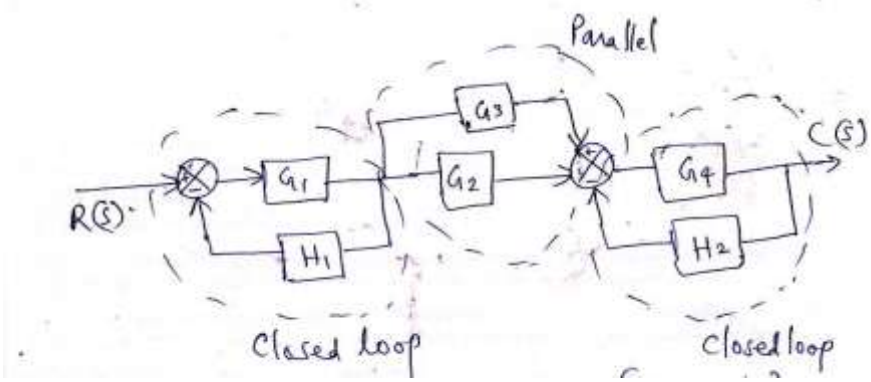
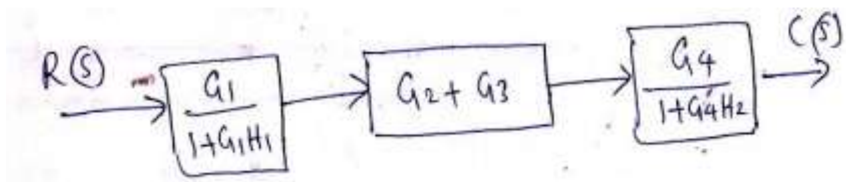



**Fig.no.1**

ANS **:**

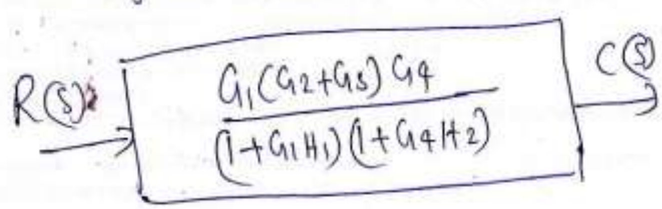
**03marks**




**$1\frac{1}{2}$ marks**

taking the blocks in series,




$$\therefore Tf = \frac{C(s)}{R(s)} = \frac{G_1(G_2+G_3)G_4}{(1+G_1H_1)(1+G_4H_2)}$$

**$1\frac{1}{2}$ marks**

**Q. 2 Attempt any TWO of the following: (16marks)**

**a) Determine stability of the system whose characteristic equation is given as is $S^5+S^4+3S^3+9S^2+16S+10=0$ .**

**NOTE: (Apply Routh's criteria for above characteristic equation)**

**ANS: (8 M)**

( Initial Rouths Array – 6 mark, Conclusion – 2 marks)

| | | | |
|---|---|---|---|
| $S^5$ | 1 | 3 | 16 |
| $S^4$ | 1 | 9 | 10 |
| $S^3$ | -6 | 6 | 0 |
| $S^2$ | 10 | 10 | 0 |
| S | 12 | 0 | 0 |
| $S^0$ | 10 | 0 | 0 |

Routh's stability criteria states that the elements of 1st column of Routh's array should not have any sign change for the system to be stable. The number of sign changes in the 1st column indicates the number of Poles on RHS which makes the system unstable. Here, 2 sign changes in the 1st column indicate 2 RHS poles. Therefore system is **unstable**.

**b) (i) Derive transfer function of an armature controlled DC Servomotor.**

**ANS:** **( 4 M)**

**NOTE:-** (CHECK THE BASIC EQUATIONS & GIVE THE MARKS ACCORDINGLY).

Here error voltage from the servo amplifier is given to the armature of DC motor .field is connected to

A constant current source.: field current $I_f$ is constant.

$T_m$ –Torque developed by motor

Ɵ-Angular displacement of motor

$V_a$( f) or e =Applied armature voltage

J =Moment of inertia

$f_0$ = Coefficient of viscous friction between motor and load.

$e_b$ = Back emf.

Dc motors are used in linear range of magnification curve C torque-speed characteristics .

$\therefore$ , air gap flux

$\phi$ is proportional to field current

$\phi \propto I_f \quad \phi = K_f \; I_f$ ______________________________ 1)

Reaction of flux $\phi$ with armature current $I_a$ produces torque $T_m$ that forces the armature to rotate

$\therefore \; T_m \propto \phi . I_a$ or $T_m = K_i \phi \; I_a$ ______________________2)

Substituting 1) in 2) $T_m = K_i K_f I_f I_a$

Since $I_f$ is const., $T_m = K_T \; I_a$

Back emf $e_b$ = as armature location in mag. Field ,a voltage is $180^0$ out of phase with applied armature

Voltage . $\therefore$ $I_f$ is called back emf $e_b$. $I_f$ is proportional to the speed of motion.

$\therefore \; e_b \propto \frac{d\theta}{dt}$ or $e_b = K_b \frac{d\theta}{dt}$ ______________________3)

The differential equation of armature ckt is

$e = L_a \frac{dIa}{dt} = R_a I_a + e_b$ ______________________ 4)

Taking laplace of 3) & 4),

$E_b(S) = K_b\ S\theta\ (S)$

$E(S) = L_a\ S\ I_a(S) + R_a\ I_a\ (S) + E_b(S)$

$= L_a\ S\ I_a(S) + R_a\ I_a\ (S) + K_b\ S\theta\ (S)$____________5)

Torque equation is

$$J\ \frac{d^2\theta}{dt^2} + f_0\ \frac{d\theta}{dt} = T_m = K_T\ I_a$$

Taking laplace

$JS^2\ \theta\ (S) + f_0\ S\theta\ (S) = K_T\ I_a(S)$

Or $\theta\ (S) = K_T\ I_a(S)/\ JS^2\ + f_0\ S$__________________-6)

Substituting 6) in 5)

$E(S) = L_a\ S\ I_a(S) + R_a\ I_a\ (S) + (K_b\ \ K_T\ I_a(S)\ /\ JS^2\ + f_0\ )$

$TF = \theta\ (S)\ /\ E(S) = K_T\ /\ [\ (JS^2\ + f_0\ S)\ (\ L_a\ S\ + R_a\ ) + S\ K_b\ \ K_T\ ]$

**(ii) Draw diagram of armature controlled DC servomotor with neat labelling.**

ANS**: ( Diagram 4 M)**

**Diagram:**

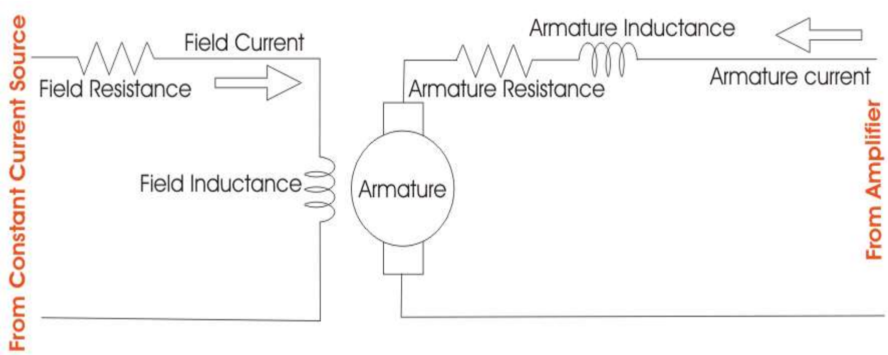



**Fig.: Armature controlled DC servomotor**

**'OR'**

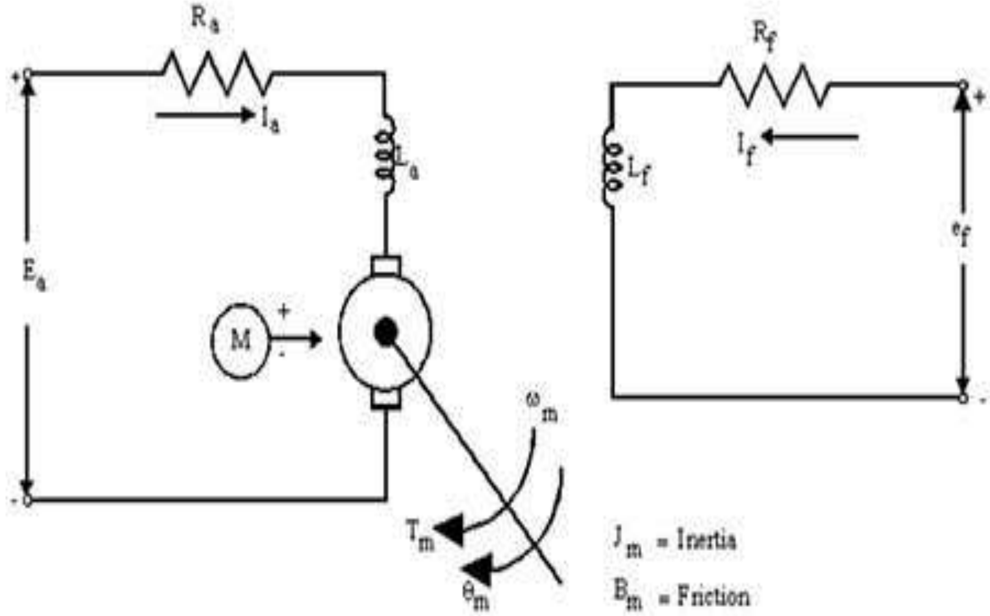



**Fig.: Armature controlled DC servomotor**

**c) Open loop transfer function G(S) of certain unity feedback system is given below, Determine the range of 'k' for which the system is stable.**

**G(S)=K(S+13) / [S(S+3)(S+7)]**

ANS**: (characteristic equation 2M, Routh's Array 3M, Range of 'K' 3M)**

G(S)= K(S+13) / [S(S+3)(S+7)]

H(S)= 1

G(S)H(S)= K(S+13)/[S(S+3)(S+7)]

Characteristic equation is,

1+G(S)H(S)= 0

1+{K(S+13)/[S(S+3)(S+7)]}= 0

{S(S+3)(S+7)+K(S+13)}/[S(S+3))S+7)]= 0

$S^3+10S^2+ (21+K)S+13K= 0$

**Routh's Array**:

| | | |
|---|---|---|
| $S^3$ | 1 | 21+K |
| $S^2$ | 10 | 13K |
| $S^1$ | $\frac{10(21+K)-13K}{10}$ | 0 |
| $S^0$ | 13K | |

To satisfy stability by Routh's criterion, first column elements of routh's array should be Positive.

Therefore for the upper range of K:

For the row $S^1$ $\frac{10(21+K)-13K}{10} > 0$

$10(21+K)-13K > 0$

$210+10K-13K > 0$

$210-3K > 0$

$210 > 3K$

$70 > K$

Lower range of K:

For the row $S^0$ $13K > 0$

$K > 0$

The range of K value is **$0 < K < 70$**

**Q.3. Attempt any FOUR of the following:** **16marks**

**a) Compare open loop and closed loop control system.**

ANS: **- (Any 4 points – 4 marks)**

| SR. NO. | OPEN LOOP | CLOSED LOOP |
|---|---|---|
| 1. | No Feedback element | Feedback element is present |
| 2. | Error detector is absent | Error detector is present |
| 3. | Inaccurate | Accurate |
| 4. | Small bandwidth | large bandwidth |
| 5. | More stable | less stable |
| 6. | Simple construction | Complex construction |
| 7. | Less costly | more costly |
| 9. | Sensitive to disturbance | not sensitive to disturbance |

**b) List any FOUR advantages of robotics.**

ANS**:-(<u>1 mark for each point)</u>**

**Advantages of robotics:**

1. Can work in hazardous and dangerous areas
2. Jobs which are monotonous like assembling, stamping, packaging etc. can be done by robots in industry.
3. Can be used in nuclear research, military applications, underwater applications etc. by replacing the human being.
4. To increase the productivity, robots are used in the manufacturing industry.

**c)Explain neutral zone with neat sketch in reference to ON-OFF control action.**

ANS: **- (Explanation – 2 marks, neat sketch- 2 marks)**

ON-OFF controller is a two position discontinuous controlling mode.
The mathematical equation of ON-OFF Controller is shown below:

$P = 0\ \%\ ,\quad e_p < 0$

$\ \ = 100\ \%\quad e_p > 0$

**Neutral Zone**:

In virtually any practical implementation of the two – position controller, there is an overlap as $e_p$ increases through zero or decreases through zero, in this span, no change in controller output occurs.

Fig shows p versus $e_p$ for ON-OFF Controller. Until an increasing error changes by $\Delta e_p$ above zero, the controller output will not change state. In decreasing it must fall $\Delta e_p$ below zero before the controller changes to the 0% rating.

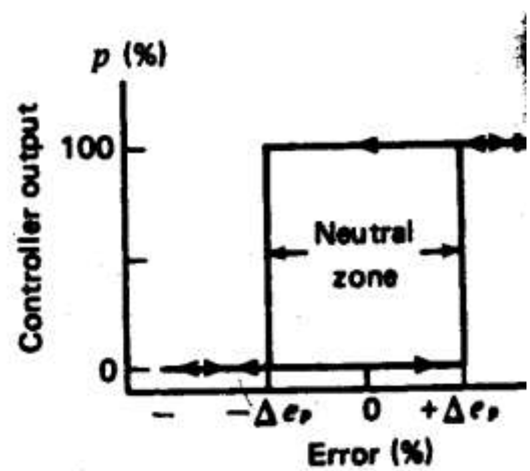
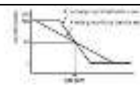
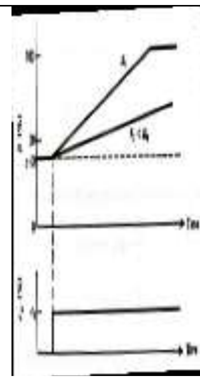
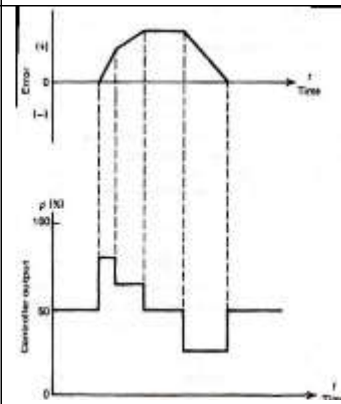



**Fig. Neutral zone**

**d) Compare P, I and D control actions on the basis of**
**i) Mathematical expression ii) Response of error**
**iii) Offset iv) Stability**

ANS- **(each point- 1 mark)**

| Sr No | Parameter | P | I | D |
|---|---|---|---|---|
| **1** | **mathematical expression** | $K_p e_p$ | $u(t) = K_i \int_0^t e(\tau)\,d\tau + p(o)$ | $u(t) = K_d \frac{d}{dt} e(t)$ |
| **2** | **Response of error** <br> **For zero error o/p is constant** |  |  <br> **For zero error o/p is not zero** |  <br> **For zero error o/p is zero** |
| **3** | **Offset** | **Causes offset** | **It eliminates the effect of offset** | **It causes offset** |
| **4** | **Stability** | **More stable** | **Less stable** | **unstable** |

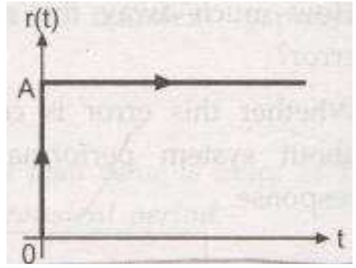
**e) State the standard test signals used in time domain analysis with their Laplace transform**

**ANS:.(Each test signal 1M)**

**NOTE**:- ( Give 2 marks for listing the names of 4 standard test signals & 2 marks for writing their Laplace Transform.)

**1. <u>Step input signal</u> :**

**<u>Definition</u>:-**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).
Laplace transform of such input is A/S.

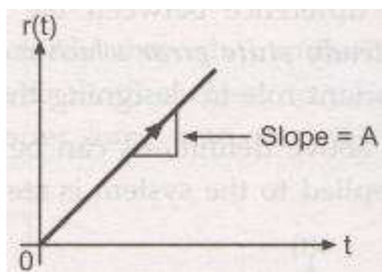



**2. Ramp input signal:**

**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 $t \geq 0$
= 0 $t < 0$

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

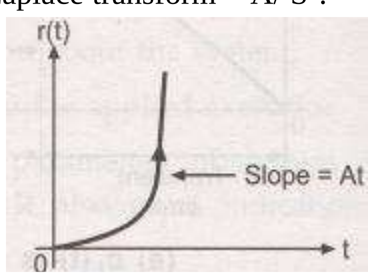



**3.Parabolic input signal:**

**Definition:-**

It is constant rate of change ramp input.
Mathematically it is defined as
R (t) = A $t^2$ /2, $t \geq 0$
= 0 $t < 0$

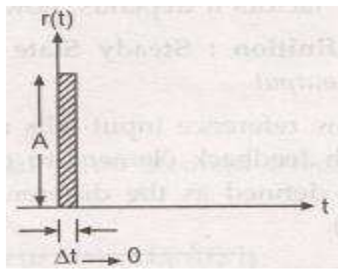
If A = 1, it is called as unit ramp i/p. Its Laplace transform = A/ $S^3$.



**4.Impulse input signal:**

**Definition:-**

It is an input that has zero value everywhere except at t=0.
R (t) = $\delta$(t) = 1 for t = 0
= 0, t ≠ 0




Laplace transform is 1.

**Q.4 a) Attempt any THREE of the following:** **12marks**

**i)What is frequency response?**
**Define: Bandwidth, Gain margin Phase margin with respect to frequency response.**

ANS**: (Each definition: 1 mark)**

- **Frequency Response**: The magnitude and phase relationship between sinusoidal input and steady state output is known as frequency response. The term frequency response means the steady state response of a system to a sinusoidal input.
- **Bandwidth:** The range of frequencies over which the magnitude M is equal to or greater than 0.707 of its zero frequency value
- **Gain Margin**: The gain margin is defined as the additional gain that should be added at the phase cross over frequency to bring the system to the verge of instability.
- **GM is the negative of the magnitude of G(jw)H(jw) in dB at the phase cross over frequency.**
- **Phase Margin**: The amount of additional phase lag which can be introduced in the system till system reaches on the verge of instability
  **** Give appropriate marks for marking in graph.**

**ii) Write the meaning of poles and zeros with suitable example**.

ANS: **(Poles: Definition 1mark, Zeros: Definition 1 mark and example: 2 marks)**

**Poles**: The value of s for which the transfer function becomes infinite.

**Zeros:** The value of s for which the transfer function becomes zero.

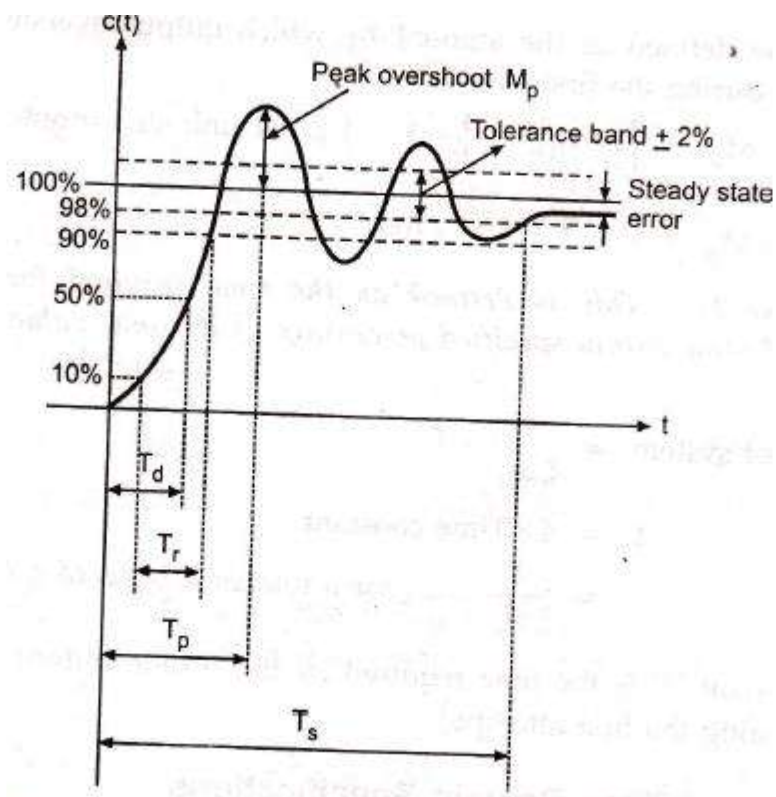
**Example**: ( consider any example)

Consider the transfer function: G(s) =( s+2)/ (s(s+1)(s+4))

Poles are obtained by making denominator of the transfer function =0
There are three poles at s = 0, s = -1 and s = - 4
ii) Zeros are obtained by making numerator of the transfer function = 0
There is one zero at s = -2

**iii)Draw time response of second order underdamped system with neat labeling:**

ANS**: Diagram with neat labeling: 4 marks**



**iv)How AC servomotor differs from two phase induction motor? Draw its torque speed characteristics.**

ANS**: <u>Any 2 points: 2 marks, characteristics: 2 marks</u>**

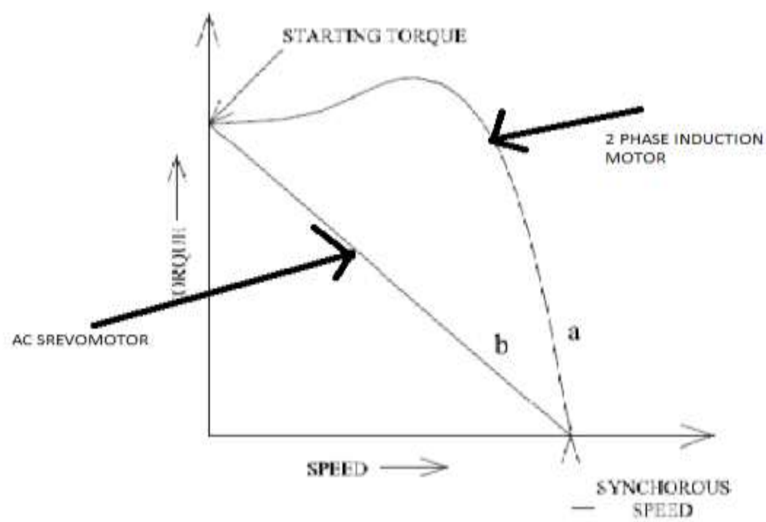


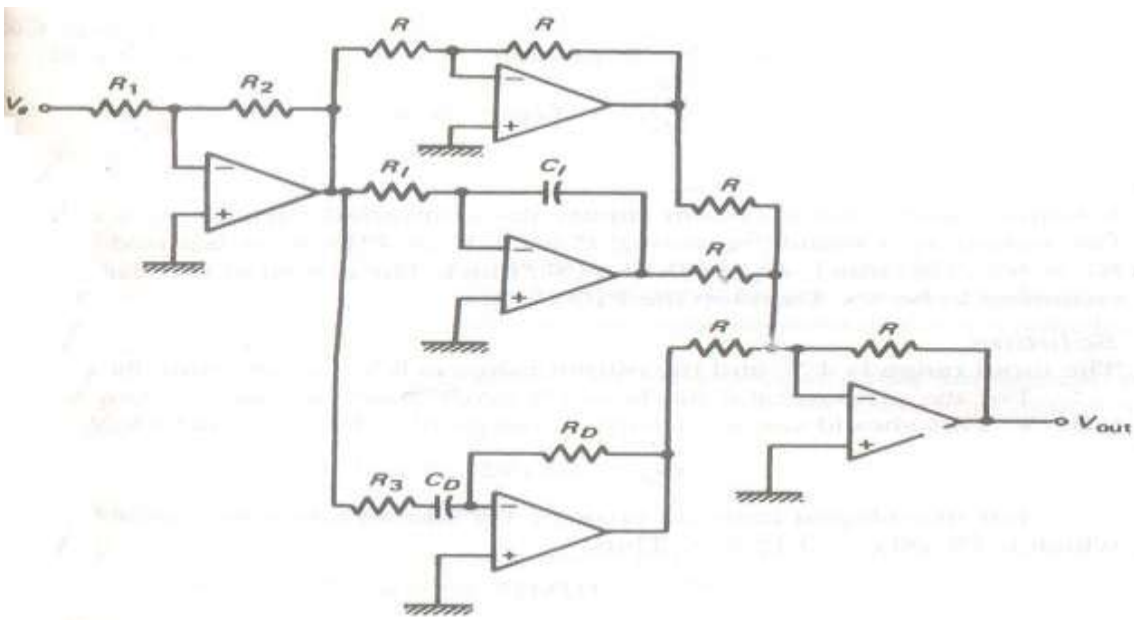

**Fig. Torque speed characteristics**

| S.NO | Two Phase Induction Motor | AC Servomotor |
|---|---|---|
| **2.** | **More inertia** | **Less inertia** |
| **3.** | These motor are widely used in high power industrial drives. | Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing |
| **4.** | Diameter of rotor is large | Diameter of rotor is small |
| **5.** | Torque producing capacity is high & torque speed characteristic. is non linear | Torque speed characteristic is Linear. |
| **6..** | X/R ratio is more | X/R ratio is less |

**b) Attempt any ONE of the following:** **6marks**

**i)Draw electronic PID controller and write its mathematical equation. State two advantages of PID controller.**

ANS**: ( Diagram: 3marks, Equation 1marks,Two advantages: 2 marks)**




$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{d}{dt} e(t)$$

**OR**

$V_{out}$ = R2/R1 Ve + R2/R1 * 1/RICI ∫ Ve dt + R2/R1 *RD CD d/dt Ve

**Two advantages**:

Advantages of electronic PID controller:

1) It is the most powerful mode of controllers
2) It eliminates offset
3) Fast response
4) Can be used for virtually any process control

**(ii) How synchro works as an error detector, draw suitable diagram. Define electrical zero position of synchro transmitter.**

ANS:

**(Diagram: 2 marks, synchro as an error detector: 2 marks, Definition of electrical zero: 2 marks)**

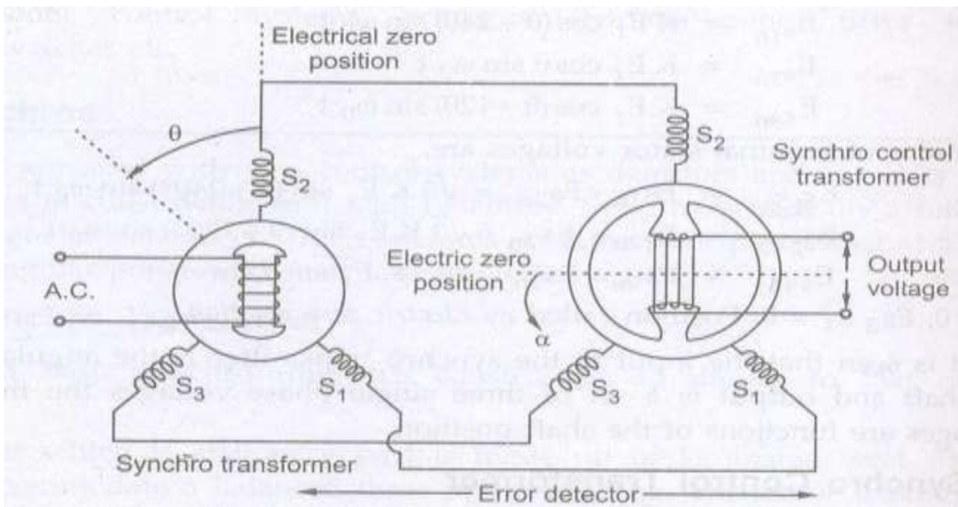



**Fig.Synchro as an error detector**

**Explanation:**

Synchro transmitter along with synchro control transformer is used as error detector. The control transformer is similar in construction to that of synchro transmitter except that its rotor is cylindrical in shape. Therefore, the flux is uniformly distributed in the air gap. The output of the synchro transmitter is given to the stator windings of the control transformer as shown. The voltage induced in the stator coils and corresponding currents of the transmitter are given to the control transformer stator coils Circulating currents of same phase but different magnitude will flow through both set of stator coils. This establishes an identical flux pattern in the air gap of control transformer. The flux pattern in the air gap of control transformer will have the same orientation as that of transmitter rotor. The voltage induced in the transformer rotor will be proportional to the cosine of angle between the two rotors.

The output equation is given by:

$e(t)=Ks\phi(t)$

Where: input voltage to the transmitter rotor and $\phi$ is the angular difference between both rotors.

When $\phi=90$ both rotors are perpendicular to each other and the output voltage is zero. This position is called electrical zero and is used as reference position

The error voltage is proportional to the angular difference between the transmitter and control transformer shaft positions.

**Q.5 Attempt any FOUR of the following.** **16marks**

**a) State Routh's stability criterion and explain with a suitable example.**

ANS: **(Statement 2M,any 1 example 2M)**

**Routh's stability criterion:**

The necessary and sufficient conditions for system to be stable is "All the terms in the first column of the Routh's array must have same sign. They should not be any sign change in the first column of Routh's array.

If they are any sign changes existing then,

a) System is unstable
b) The number of sign changes equal the number of the roots lying in the right half of the S-plane.

Consider the general characteristic equation as,

$$F(s) = a_0 s^n + a_1 s^{n-1} + a_2 s^{n-2} + \ldots\ldots + a_n = 0$$

**Method of forming an array :**

$$\begin{array}{c|ccccc}
s^n & a_0 & a_2 & a_4 & a_6 & \ldots\ldots \\
s^{n-1} & a_1 & a_3 & a_5 & a_7 & \\
s^{n-2} & b_1 & b_2 & b_3 & & \\
s^{n-3} & c_1 & c_2 & c_3 & & \\
\vdots & \vdots & \vdots & \vdots & & \\
s^0 & a_n & & & &
\end{array}$$

Coefficients for first two rows are written directly from characteristic equation.

From these two rows next rows can be obtained as follows.

$$b_1 = \frac{a_1 a_2 - a_0 a_3}{a_1}, \qquad b_2 = \frac{a_1 a_4 - a_0 a_5}{a_1}, \qquad b_3 = \frac{a_1 a_6 - a_0 a_7}{a_1}$$

From 2nd and 3rd row, 4th row can be obtained as

$$c_1 = \frac{b_1 a_3 - a_1 b_2}{b_1}, \qquad c_2 = \frac{b_1 a_5 - a_1 b_3}{b_1}$$

This process is to be continued till the coefficient for $s^0$ is obtained which will be $a_n$. From this array stability of system can be predicted.

**Example: (any example)**

$$s^3 + 4s^2 + s + 16 = 0$$

**Solution :** $a_0 = 1, \quad a_1 = 4, \; a_2 = 1, \quad a_3 = 16$

$$\begin{array}{c|cc} s^3 & 1 & 1 \\ s^2 & +4 & 16 \\ s^1 & \frac{4-16}{4} = -3 & 0 \\ s^0 & +16 & \end{array}$$

As there are two sign changes, **system is unstable.**

Number of roots located in the right half of s-plane = Number of sign changes = 2.

**OR**

**Example:-**

$$s^3 + 6s^2 + 11s + 6 = 0$$

**Solution :** $a_0 = 1, \quad a_1 = 6, \quad a_2 = 11, \quad a_3 = 6, \; n = 3$

$$\begin{array}{c|cc} s^3 & 1 & 11 \\ s^2 & 6 & 6 \\ s^1 & \frac{11 \times 6 - 6}{6} = 10 & 0 \\ s^0 & 6 & \end{array}$$

As there is no sign change in first column, **system is stable.**

**b)What is proportional controller? Write it's mathematical expression. Draw it's controller output Vs error characteristics.**

ANS: **(2M definition, 1M equation, 1M characteristics)**

**Proportional controller:**

A smooth, linear relationship exist between controller output and the error. Thus over some range of errors about the set point, each value of error has unique value of controller output in one to one correspondence . The range of error to cover the 0% to 100% controller output is called proportional band , because one to one correspondence exist only for the errors in this range.

Mathematical expression of is proportional controller:

$$P=K_pe_p+p_o$$

Where $K_p$=proportional gain between error and controller output

$p_o$= controller output with no error

**Controller output Vs error characteristics**

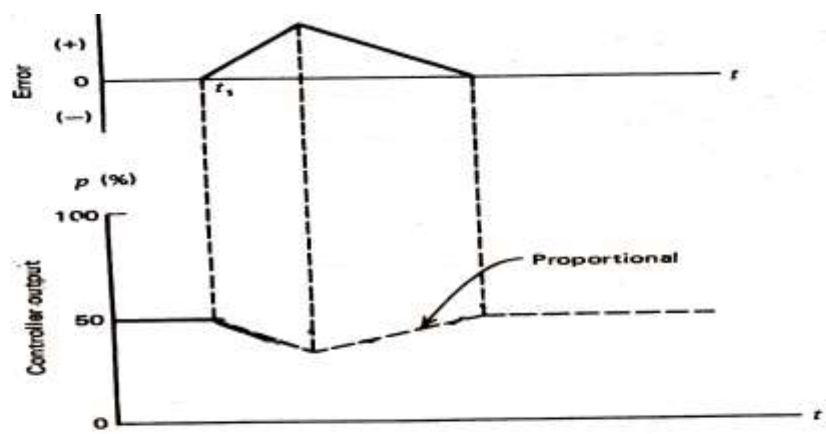



**Fig. Controller output Vs Error characteristics**

**c) Derive the transfer function of following electrical RC circuit. (Refer fig no. 2)**

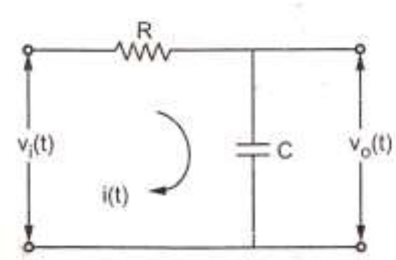
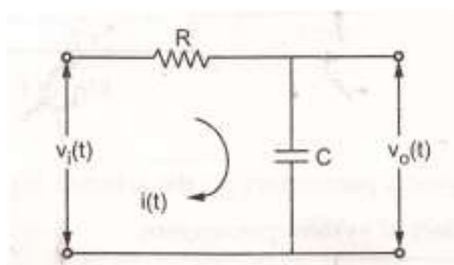



Fig no.2

ANS**: (KVL equation 1M, Laplace transform 2M Transfer function 1M)**




Transfer function of following electrical RC circuit

$Vi\ (t) = R*i(t) + \int i(t)\ dt/C$
$Vo\ (t) = \int i(t)\ dt/C$
Laplace of above two equations :
$Vi\ (s) = R\ I(s) + I(s)/s\ C$
$Vo\ (s) = I(s)/Sc$
Transfer function= output/input=$Vo(S)/Vi(S)$
$= I(s)/Sc/\{R\ I(s) + (I(s)/s\ C)\}$
$=1/(RCs+1\ )$

**d)Explain the following terms :**

i) Degree of freedom(DOF)

ii) End effector

**ANS<u>: (Each explanation 2M)</u>**

1. **<u>Degree of freedom (DOF):</u>**
   It roughly indicate the capability of a robot. Every joint axis defines a degree of freedom. DOF in mechanics is defined as the no. of independent movements that an object can perform in 3-D space. DOF is equal to the no. of joints i.e for each DOF a joint is required . Six degrees of freedom is needed for maximum flexibility.

Three degrees of the freedom located in the arm of robotic system.

i) The rotational reverse : For left and right moment of the robots arm
ii) The radial reverse : For in and out of motion of arm relative to the base
iii) The vertical traverse: Provides up and down motion of the arm

Three degrees of freedom are located in the wrist:

i)Pitch:Up and down movement of the wrist
ii) Yaw: right and left movement of the wrist
iii)Roll: It is the rotation of the hand.

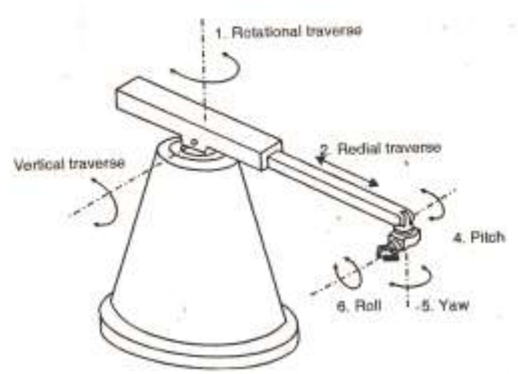



**Fig. Degree of freedom**

**ii) <u>End effector: -</u>**

It is a device at the end of robotic arm , designated to interact with the work environment. It is a last link of the robot. It is similar to human hand with or without finger . It incorporates various sensors

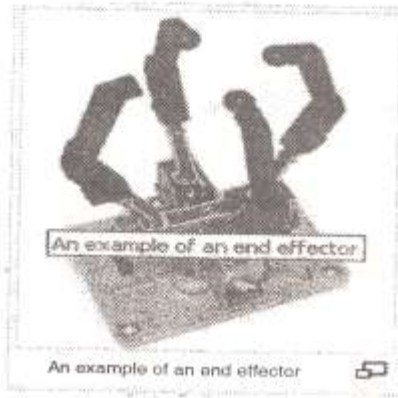



**Fig. End effector**

**d) Compare armature controlled and field control DC servo motor.**

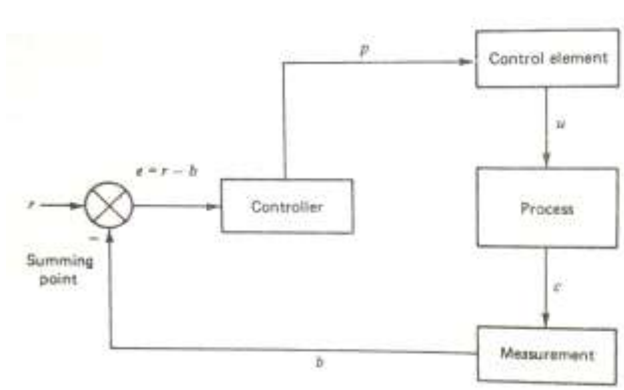
ANS: **( Any four comparison 1M each)**

| 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 | More expensive | Less expensive |
| 7 | Better efficiency | Poor efficiency |

**f) Draw the block diagram of process control system and state the role of controllers in process industry.**

ANS: **(Diagram 2M,Role of controllers 2M)**

**Block diagram of process control system:**



The role of controllers in process industry is being continuously reshaped following trends. We can clearly observe two types of roles.

**1. Traditional role :**

i) Economical : operating conditions must be controlled by controllers to minimize the operating costs and maximize profits.

ii) Production specification: The plant should maintain the production specifications for delivery final products with consistant quality.

iii) Safety: Safety is primary requirement which is done by controllers or control system.

iv) Environmental regulations: Many countries have laws mandating that air, water and ground emmitions from chemical plants must confirm to specified limits in chemical composition and flow rate.

**2. Expanded role:**

i) An industrial plant is complex combination of various unit operations to produce desire products . So controllers keep continuous control on the production.

ii) Controllers reduce man power so that increases productivity.

iii) This days controllers such as PLC,DCS,SCADA are used for controlling the plant so that plant has become fully automated.

**Q.6 Attempt any FOUR of the following: 16marks**

**a) A second order system has,**

$$\frac{C(s)}{R(s)} = \frac{16}{s^2+5s+16}$$

**For unit step input determine,**

**(i) Natural frequency (Wn) and damped frequency (Wd) of oscillations.**

**(ii) Rise time (Tr)**

**(iii)Peak overshoot (%Mp)**

**(iv)Delay time(Td)**

ANS: (**1M for each calculation)**

$$\frac{C(s)}{R(s)} = \frac{16}{s^2+5s+16}$$

Comparing the T.F with standard form,

$$\frac{\omega_n^2}{s^2+2\xi\omega_n s+\omega_n^2}$$

1] $\omega_n^2 = 16$

$\omega_n = 4$ rad/s

2] $2\xi\omega_n = 5$

$$\xi = \frac{5}{2\times4} = \frac{5}{8} = 0.625$$

3] $\omega_d = \omega_n\sqrt{1-\xi^2}$

$= 4\sqrt{1-(0.625)^2}$

$= 3.122$ rad/sec

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

$$= \tan^{-1}\left[\frac{\sqrt{1-(0.625)^2}}{\xi}\right]$$

$= \tan^{-1}[1.248]$

$= 0.8956$

4] $T_r = \frac{\pi-\theta}{\omega_d} = \frac{\pi-0.8956}{3.122} = 0.719$ sec.

5] $T_d = \frac{1+0.7\xi}{\omega_n} = 0.3593$

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

$$= e^{-\pi(0.625)/\sqrt{1-(0.625)^2}}$$

$$= e^{-2.51}$$

$= 0.081$

$\% M_p = 8.1\%$

**b) A unity feedback system has,**

$$G(s) = \frac{40\,(s+2)}{s\,(s+1)\,(s+4)}$$

**Determine,**

**i)Type of system**

**ii)Position error constant($K_p$)**

**iii)Velocity error constant($K_v$)**

**iv)Acceleration error constant($K_a$)**

ANS: **(Type of system -1M, $K_p$- 1M, $K_v$ -1M, $K_a$ -1M)**

To determine type of system arrange G(s)H(s) in time constant form.

$$G(s)H(s) = \frac{40(s+2)}{s(s+1)(s+4)} = \frac{40(2)\,(1+0.5s)}{s(1+s)\,(4)\,(1+0.25s)}$$

$$= \frac{20\,(1+0.5s)}{s(1+s)\,(1+0.25\,s)}$$

Comparing this with standard form,

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

where $j$ = Type of system

∴ $j$ = 1 so given system is type 1 system.

**Error coefficients :**

1) $$K_p = \lim_{s\to 0} G(s)H(s) = \lim_{s\to 0} \frac{20\,(1+0.5s)}{s(1+s)\,(1+0.25s)} = \infty$$

2) $$K_v = \lim_{s\to 0} s\,G(s)H(s) = \lim_{s\to 0} \frac{20(1+0.5s)}{(1+s)\,(1+0.25\,s)} = \mathbf{20}$$

3) $$K_a = \lim_{s\to 0} s^2\,G(s)H(s) = \lim_{s\to 0} \frac{s(1+0.5s)\cdot 20}{(1+s)\,(1+0.25s)} = \mathbf{0}$$

**c) Define transfer function. Derive the expression of T.F of closed loop system?**

ANS: (**Definition 01M, Derivation of T.F 03M**)

**Transfer function**: It is defined as the ratio of Laplace transform of output of the system to the Laplace transform of input, under the assumption that all initial conditions are zero.

$$T(s) = \frac{Laplace\ transform\ of\ output}{Laplace\ transform\ of\ input} = \frac{C(s)}{R(s)}$$

Consider a simple closed loop system using negative feedback as shown

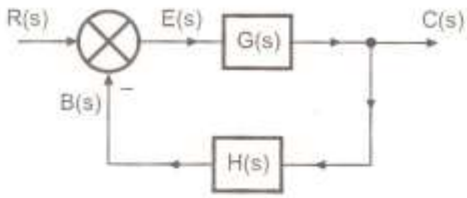



**Fig. 7.6**

where E(s) = Error signal, and B(s) = Feedback signal

Now, E(s) = R(s) − B(s)

But B(s) = C(s)H(s)

$$E(s) = R(s) - B(s) \quad \text{— (1)}$$

$$B(s) = C(s)\,H(s) \quad \text{— (2)}$$

$$C(s) = E(s)\,G(s) \quad \text{— (3)}$$

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

$$E(s) = \frac{C(s)}{G(s)}$$

$$\frac{C(s)}{G(s)} = R(s) - C(s)H(s)$$

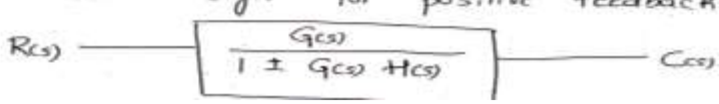
$$C(s) = R(s)G(s) - C(s)H(s)G(s)$$

$$C(s)\left[1 + G(s)H(s)\right] = R(s)\,G(s)$$

$$\therefore \frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}$$

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 \pm G(s)H(s)}$$

Use + sign for negative feedback.
nd Use − sign for positive feedback.



**d) State the meaning of the following terms with respect to controllers**.

**i) Control action**
**ii)Offset**
**iii)Proportional band**
**iv) Deviation or error signal**

ANS: **(each term 1M)**
**NOTE:- (**give marks if writing about control modes, ie continuous, discontinuous etc )

i) **Control action:**

The controller plays an essential role in the control system. Of the four basic functions of a control system, (measurement, comparison, computation, and correction) comparison and computation are solely achieved by the controller. The correction is materialized by the final control element, but this is done according to the controller's calculation.

The control mechanism in the controller may be considered as consisting of two sections

- The Comparator
- The Controller

The purpose of the first is to compare the measured and the desired values of the controlled variable and then compute the difference between them as the error. If there is no error, i.e. the controlled variable is at the setpoint, then no action is taken.

If an error is detected, the second section of the controller operates to alter the setting of the final control element in such a way as to minimize the error in the least possible time with the minimum disturbance to the system. To achieve this objective, different actions could be taken by the controller and hence different signals are sent to the final control element.

**ii)Offset**:

It is a permanent residual error in proportional controller which is inherent in nature; it is due to one to one correspondence existing between the controller output and error.

**iii)Proportional Band**:

It is defined as percentage of error which results in 100% change in proportional controller output.

**OR**

the range of error to cover 0% to 100% controller o/p.

$$PB = 100/K_p$$

Where, $K_p$ is proportional gain between error and controller output.

iv) **Deviation or error signal:**

It is given by,

$$e = r - b$$

Where, e = error

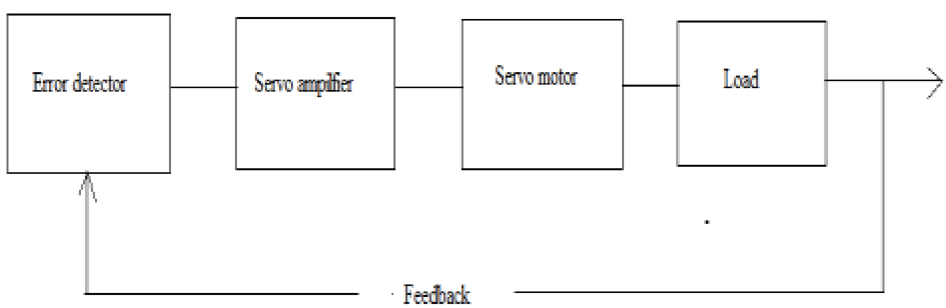
b= measured indication of variable

r= setpoint of variable

**e)Draw and explain block diagram of servo system.**

ANS**: (Block diagram 2M, Explanation 2M)**

**NOTE**:- (Give marks for drawing and explaining AC or DC Servo system also.)




**Block diagram of servo system:**

**Explanation:**

Servosystems are automatic feedback control system which work on error signals with output is the form of mechanical position, velocity or accelerations.

The components of servosystems are:

1) Error detector
2) Servo amplifier
3) Servo motor