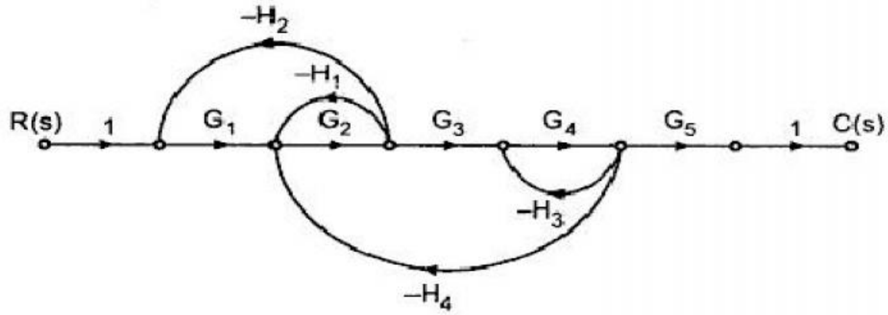
# EC8391 CONTROL SYSTEM ENGINEERING
# TUTORIAL PROBLEMS
# UNIT - I

1.Find C(s)/R(s)

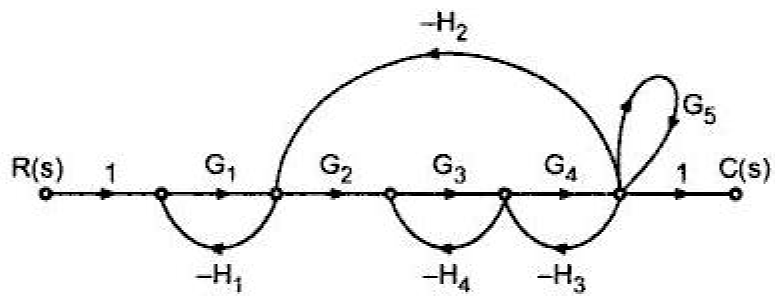



$$T_1 = G_1 G_2 G_3 G_4 G_5$$

$$\Delta = 1-[L_1 + L_2 + L_3 + L_4] + [L_1 L_3 + L_2 L_3]$$

$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3 G_4 G_5}{1 + G_2 H_1 + G_1 G_2 H_2 + G_4 H_3 + G_2 G_3 G_4 H_4 + G_2 G_4 H_1 H_3 + G_1 G_2 G_4 H_2 H_3}$$

2.

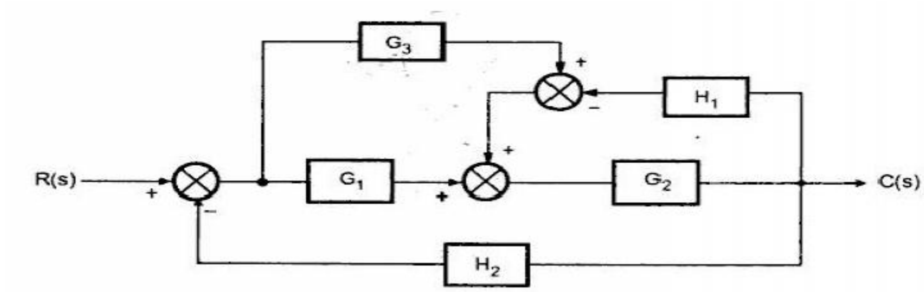



$$T_1 = G_1 G_2 G_3 G_4$$

$$\Delta = 1-[L_1 + L_2 + L_3 + L_4 + L_5] + [L_1 L_2 + L_1 L_3 + L_1 L_5 + L_2 L_5] - [L_1 L_2 L_5]$$

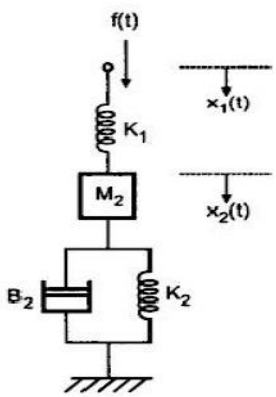
$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 G_3 G_4}{1 + G_1 H_1 + G_3 H_4 + G_4 H_3 + G_2 G_3 G_4 H_2 + G_5 + G_1 G_3 H_1 H_4 + G_1 G_4 H_1 H_3 - G_1 H_1 G_5 - G_3 G_5 H_4 - G_1 G_3 G_5 H_1 H_4}$$

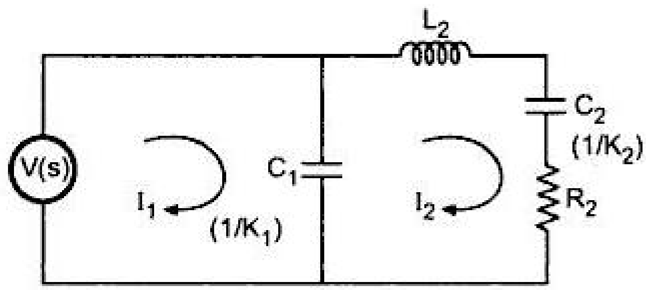
3. Find C(s)/R(s)



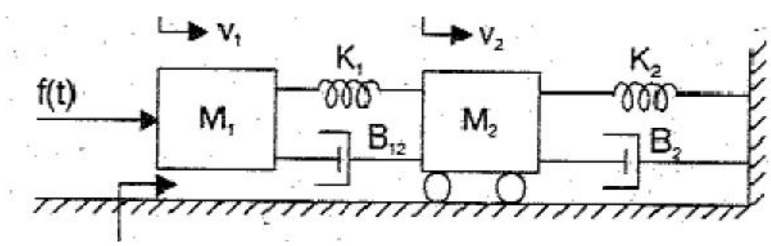

$$\frac{C(s)}{R(s)} = \frac{G_1 G_2 + G_2 G_3}{1 + G_1 G_2 H_2 + G_2 G_3 H_2 + G_2 H_1}$$

4. Draw the F-V and F-I for the given mechanical system.

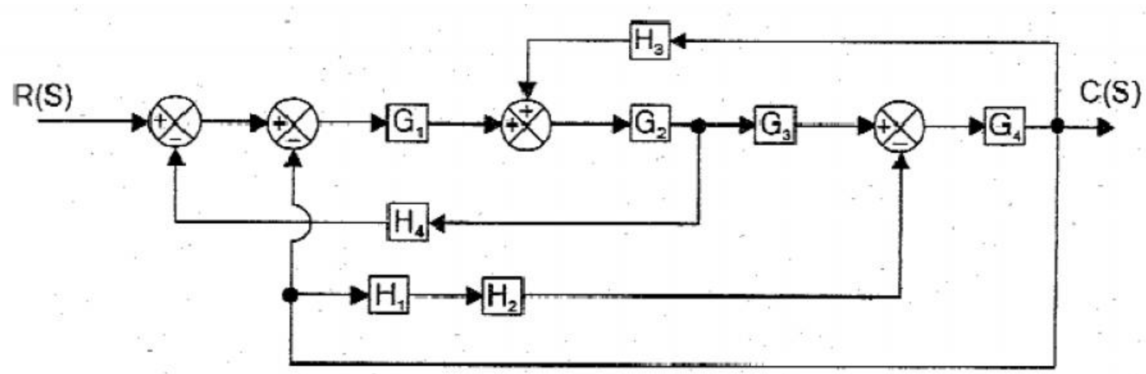



5. Draw the force to voltage and force to current




6. Find C(s)/R(s)




## UNIT –II

**1.**

A closed loop servo is represented by the differential equation $\frac{d^2c}{dt^2}+8\frac{dc}{dt}=64\,e$

Where c is the displacement of the output shaft, r is the displacement of the input shaft and e = r – c. Determine undamped natural frequency, damping ratio and percentage maximum overshoot for unit step input.

Undamped natural frequency of oscillation, $\omega_n$ = 8 rad/sec

Damping ratio, $\zeta$ = 0.5

Percentage peak overshoot, $\%M_p$ = 16.3%

**2.**

For a unity feedback control system the open loop transfer function, $G(s)=\frac{10(s+2)}{s^2(s+1)}$. Find

a) the position, velocity and acceleration error constants,

b) the steady state error when the input is R(s), where $R(s)=\frac{3}{s}-\frac{2}{s^2}+\frac{1}{3s^3}$

(a) Position error constant, $K_p=\infty$

Velocity error constant, $K_v=\infty$

Acceleration error constant, $K_a=20$

(b) When, $R(s)=\frac{3}{s}-\frac{2}{s^2}+\frac{1}{3s^3}$, Steady state error, $e_{ss}=\frac{1}{60}$

**3.**

The open loop transfer function of a servo system with unity feedback is G(s) = 10/s(0.1s+1). Evaluate the static error constants of the system. Obtain the steady state error of the system, when subjected to an input given by the polynominal,

$r(t) = a_0 + a_1t + \frac{a_2}{2}t^2$,

(a) Position error constant, $K_p = \infty$

(b) Velocity error constant, $K_v = 10$

(c) Acceleration error constant, $K_a = 0$

(d) When input, $r(t) = a_o + a_1t + \frac{a_2t^2}{2}$, Steady state error, $e_{ss} = \infty$

## UNIT-III

**1.**

Sketch the bode plot for the following transfer function and determine phase margin and gain margin.

$$G(s) = \frac{75\,(1+0.2s)}{s\,(s^2+16s+100)}$$

The phase plot crosses $-180°$ only at infinity. The $|G(j\omega)|$ at infinity is $-\infty$ db.

Hence gain margin is $+\infty$.

**2.**

Given, $G(s) = \frac{K\,e^{-0.2s}}{s\,(s+2)\,(s+8)}$. Find K so that the system is stable with,

(a) gain margin equal to 2db, (b) phase margin equal to 45°.

$\therefore 20 \log K = 24$ ; $K = 10^{24/20}$ ; $K = 15.84$

**3.**

For the function, $G(s) = \frac{5(1+2s)}{(1+4s)\,(1+0.25s)}$, draw the bode plot.

The phase angle of $G(j\omega)$, $\phi = \tan^{-1}(2\omega) - \tan^{-1}(4\omega) - \tan^{-1}(0.25\omega)$

## UNIT-IV

**1.**

Consider a unity feedback system having an open loop transfer function $G(s) = \frac{K(1+10s)}{s^2(1+s)(1+2s)}$. Sketch the Nichols plot and determine the value of K so that (i) Gain margin is 10db, (ii) Phase margin is 10°.

(a) When K = 1,

Gain margin = −19.5 db

Phase margin = −45°

(b) For a gain margin of 10db, $K = K_1$ = 0.0335

(c) For a phase margin of 10°, $K = K_2$ = 0.07

**2.**

The open loop transfer function of unity feedback system is, $G(s) = Ke^{-0.2s}/s(1+0.25s)(1+0.1s)$. Using Nichols chart, determine the following.

(a) The value of K so that the gain margin of the system is 4 db.

(b) The value of K so that the phase margin of the system is 40°

(c) The value of K so that resonant peak $M_r$ of the system is 1 db. What are the corresponding values of $\omega_r$ and $\omega_b$?

(d) The value of K so that the bandwidth $\omega_b$ of the system is 1.5 rad/sec.

**3.**

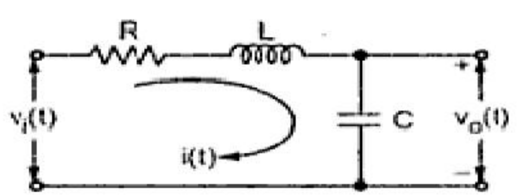
Construct Routh array and determine the stability of the system whose characterisitc equation is $s^6+2s^5+8s^4+12s^3+20s^2+16s+16=0$. Also determine the number of roots lying on right half of s-plane, left half of s-plane and on imaginary axis.

$$s^6+2s^5+8s^4+12s^3+20s^2+16s+16=0.$$

## UNIT-V

**1.**

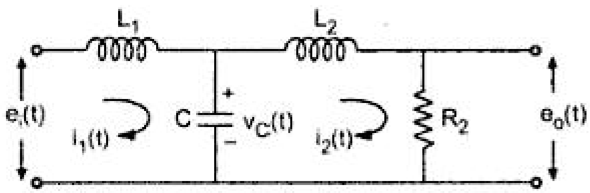
*Obtain the state model of the given electrical system.*



$$Y(t) = [0 \;\; 1] \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + [0]\, U(t)$$

$$Y(t) = C\, X(t) \quad \text{and} \quad D = [0]$$

**2.** *Obtain the state model of the given electrical network*




**3.** *Construct the state model using phase variables*