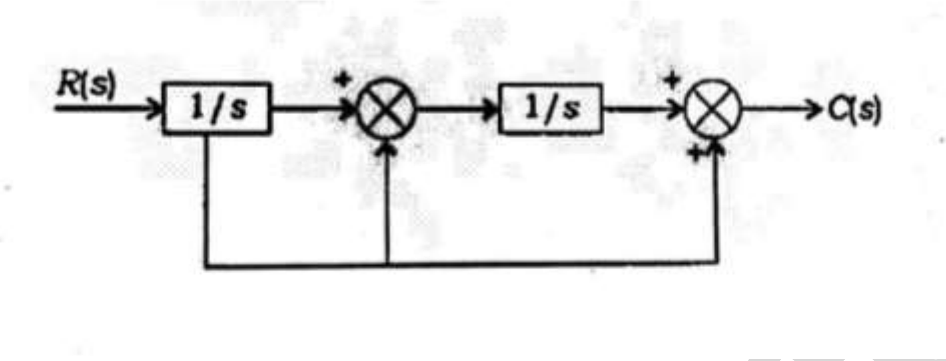
Electrical Engineering - Optional For IAS (UPSC)

Control Systems - 2015-2021

UPSC – ELECTRICAL Engineering optional – 2015 Questions

1. For the block diagram shown in the figure given below, obtain $\frac{C(s)}{R(s)}$ using block diagram reduction technique: **[10M]**



2. A system input (x)- output (y) is described by the relation

$$\frac{d^2y}{dt^2} + 8\frac{dy}{dy} + ky = 50x(t)$$

Evaluate the response $y(t)$ and its maximum value for an input $x(t) = 2.5u(t)$, $u(t)$ is a unit step function. Given $k = 25$. **[10M]**

3. State the Nyquist stability criterion. Draw the complete Nyquist plot and there from check the stability of the closed-loop system whose open-loop transfer function is

$$\mathrm{G(s)H(s)} = \frac{\mathrm{K(s+4)}}{\mathrm{s^2(s+1)}}.$$ **[20M]**

4. The transfer function of a control system is given by

$$\frac{Y(s)}{U(s)} = \frac{s^2 + 3s + 4}{s^3 + 2s^2 + 3s + 2}$$

Derive the state model of the system in controllable phase variable form. Comment on the observability. What is the value of the smallest time constant of the system? **[20M]**

5. The open-loop transfer function of a unity feedback control system is given by

$$G(s) = \frac{K}{S(1 + 0.2s)(1 + 0.05s)}$$

Determine the value of K so that the gain margin is 20 db. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2016 Questions

1. The open loop transfer function of a unity negative feedback control system is given by

$$G(s) = \frac{K}{(s+2)(s+4)(s^2+6s+25)}.$$

For what value of K, will the system work as an oscillator in its closed loop form? **[5M]**

2.

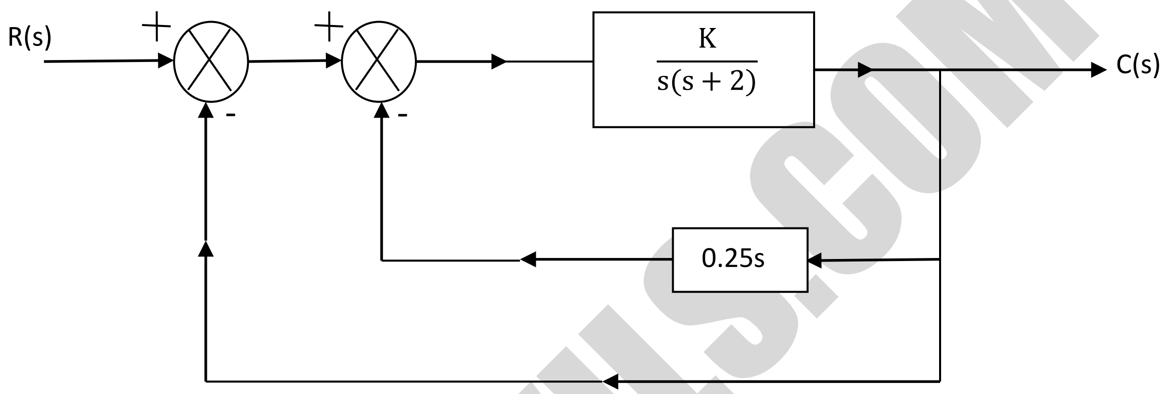


Figure (a)

(i) Figure (a) shows the block diagram of a control system. Find its characteristic equation.

(ii) Calculate its damping factor and undamped natural frequency for K=10.

(iii) What should be the value of K for critical damping ?

(iv) For $K = 10$, find the expression for $c(t)$ and obtain the time at which the first overshoot occurs. Also calculate the peak overshoot occurs magnitude. **[20M]**

3. Consider a control system with characteristic equation

$$s(s+4)(s^2+2s+2) + K(s+1) = 0.$$

Draw complete root loci labeling all important values. Find the angles of asymptotes and the intercept of asymptotes. **[10M]**

4. (i) Explain with proper transfer function a standard PID controller. Explain why derivative term is not employed alone.

(ii) The open loop transfer function of a system is given by $G(s) = \frac{5}{s(s+2)}$. It is desired to locate the poles of this transfer function at -8 and $-3 \pm 4j$ by using a suitable PID controller. Find the suitable gains needed by the PID controller to achieve this task. **[10M]**

5. State and explain Nyquist criterion. **[05M]**

6. (i) Explain the following terms in reference to performance indices in a control system:

1. Rise time
2. Integral square error
3. Integral of time multiplied square error
4. Integral absolute error
5. Integral of time multiplied absolute error **[10M]**

(ii) Consider system describe by

$$\begin{vmatrix} \dot{x}_1 \\ \dot{x}_2 \end{vmatrix} = \begin{bmatrix} -4 & -1 \\ 3 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u,$$

$$y = [1, \quad 0] \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}.$$

Obtain the transfer function of the system. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2017 Questions

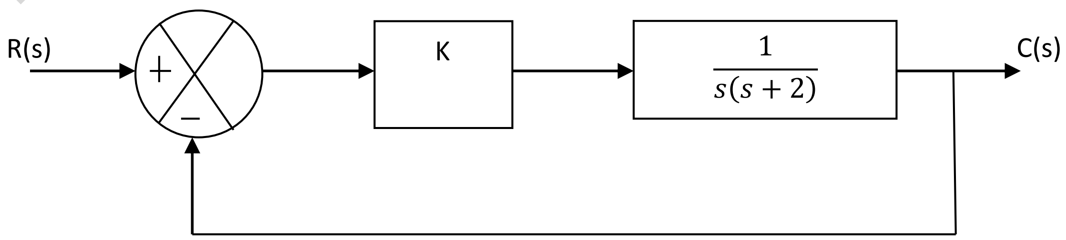
1. For the open-loop transfer function $G(s)H(s) = \frac{K(s-3)(s-5)}{(s+1)(s+2)}$

Find out the break-away and break-in points, if any, for the root locus. Also specify whether the gain is maximum or minimum at these point **[10M]**

2. For a given unstable open-loop system whose transfer function is $G(s)H(s) = \frac{s+3}{s(s-1)}$ sketch the Nyquist Contour and Nyquist Plot. Comment on the stability of the closed-loop system. **[20M]**

3. Consider a unity feedback system having transfer function $\frac{C(s)}{R(s)} = \frac{a}{s^2+bs+a}$. Determine the open-loop transfer function and steady state error coefficients. **[15M]**

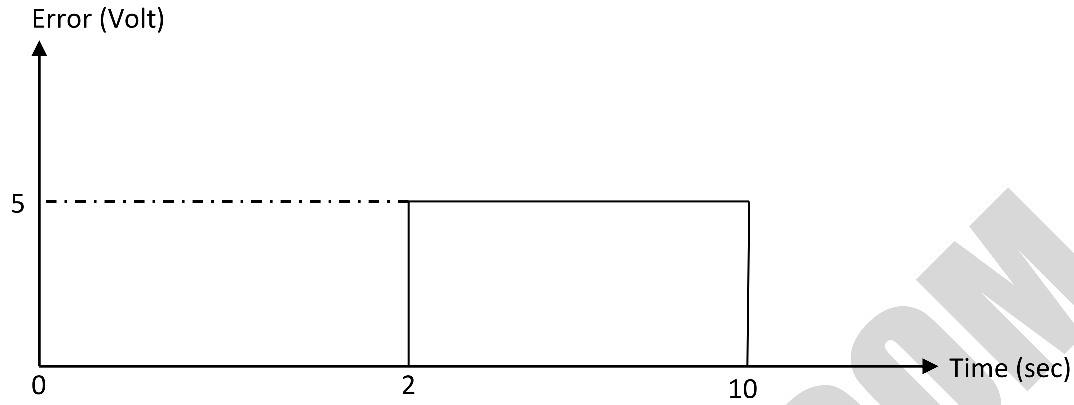
4.



For $\gamma(t) = 0.9t$, it is required that the steady state error should be less than 0.05. Determine the value of gain (K) of proportional controller for the system shown above.

[10M]

5.



The error signal as shown above is given to the controller. The initial controller output is zero. Draw the output of the controller if it is a

(i) P controller with proportional gain $(K_P) = 10$

(ii) I controller with integral gain $(K_I) = 2$ **[15M]**

6. A continuous system has transfer function $\frac{C(s)}{R(s)} = \frac{3}{(s-2)(s+3)(s+4)}$

Find out the state model of the system. Find out the state feedback gain $K = [K_1\ K_2\ K_3]$ such that the closed loop poles will be at $-4, -3\ and - 2$. **[20M]**

UPSC – ELECTRICAL Engineering optional – 2018 Questions

1. For the open-loop transfer function $\mathrm{G(s)\ H(s)} = \frac{\mathrm{K}}{\mathrm{s(s+4)(s+5)}}$, determine the following:

(i) Point of intersection of asymptotes with real axis

(ii) Point of intersection of root locus with imaginary axis and the value of K at this point

[10M]

2. For the system, whose open-loop transfer function is $\mathrm{G(s)H(s)} = \frac{\mathrm{K}}{(\mathrm{s}+2)^2(\mathrm{s}+3)}$,

determine K which satisfies the following specifications :

(i) Position error constant $K_p \geq 2$

(ii) Gain margin≥ 3 **[20M]**

3. Consider a unity feedback control system whose forward path transfer function is given by $G(s) = \frac{9}{s(s+1)}$. Determine-

(i) percentage overshoot resulting from application of unit step input;

(ii) steady-state error resulting from application of unit step and unit ramp input. **[20M]**

4. The characteristic equation of a system is given by

$$s^4 + 3s^3 + 10s^2 + 20s + 100 = 0$$

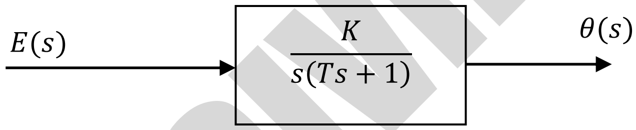
By Routh-Hurwiz criterion, determine the number of poles of the system with positive real parts. **[10M]**

5. For the open-loop transfer function

$$G(s)H(s) = \frac{1}{(s+p_1)(s+p_2)}; \quad p_1, p_2 > 0.$$

sketch Nyquist plot. Comment on the stability of the closed-loop system. **[20M]**

6. (i) Consider the block diagram of a system shown below :



Write the differential equations relating θ to e and hence write the state model of the system choosing state variables as $\theta(t)$ and $\dot{\theta}(t)$.

(ii) Sketch Bode plot of a lead compensator. **[20M]**

UPSC – ELECTRICAL Engineering optional – 2019 Questions

1. Explain the gain margin and phase margin of a control system for Nyquist stability criterion. Derive expressions for the centre and radius of a constant magnitude loci (M-circles) of a unity feedback control system and draw circles for $M = 0.5, 1.0, 1.2, 1.6, 2.0$ and 3.0 on the graph paper with suitable scales and explanations. **[10M]**

2. Sketch the root locus form the open-loop transfer function

$\mathrm{G(s)H(s)} = \frac{\mathrm{K}}{\mathrm{s(s+6)(s^2+4s+13)}}$ and determine the following:

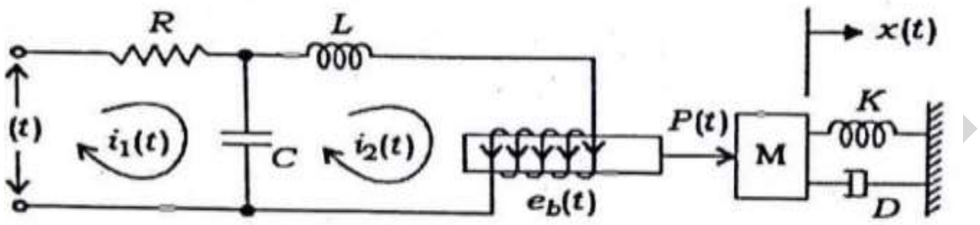
(i) The angles of departure from complex poles

(ii) The break-away points

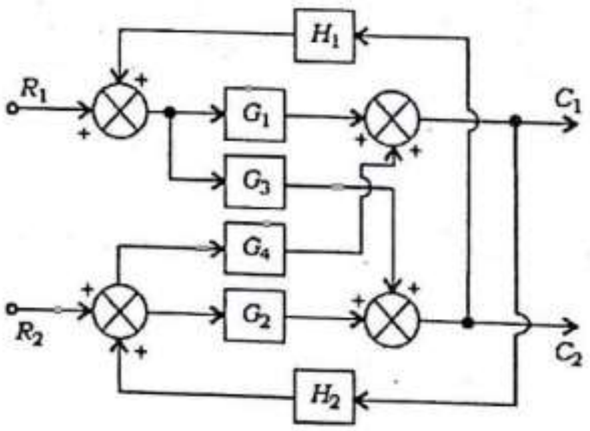
(iii) The intersection with imaginary axis

(iv) The stability conditions **[20M]**

3. Find the transfer function $X(s)/E(s)$ for the electromechanical system shown in the following figure. Consider (1) the force acting on mass $P(t) = K_2 i_2(t)$ and (2) the back e.m.f. of coil $e_b(t) = K_1 \frac{dx(t)}{dt}$, where K_1 and K_2 are constants. **[10M]**



4. The block diagram representation of a control system is shown below: **[10M]**



Find $\frac{C_2}{R_1}$ transfer function using the following:

(1) Block diagram reduction method

(2) Mason's gain formula

5. A unity feedback control system is characterized by the open-loop transfer function

$$G(s) = \frac{K(s+13)}{s(s+3)(s+7)}$$

(i) Using the R-H criterion, calculate the range of values of K for the system to be stable.

(ii) Check whether for $K = 1$, all these roots of the characteristic equation of the above system have damping factor greater than 0.5. **[10M]**

6. The overall transfer function of a control system is given by

$$\frac{C(s)}{R(s)} = \frac{16}{(s^2 + 1.6s + 16)}$$

It is desired that the damping ratio be 0.8 .Determine the derivative rate of feedback constant K_d, and compare rise time, peak time, maximum overshoot and steady-state error for unit ramp input without and with derivative feedback control. **[20M]**

7. Explain the gain margin and phase margin of a control system for asymptotic Bode plot. The open-loop transfer function of a system is given by

$$G(s)H(s) = \frac{30}{s(0.5s+1)(0.08s+1)}$$

Draw the Bode plot and determine the following:

(1) The gain margin

(2) The phase margin

(3) The stability **[10M]**

8. Sketch the Bode plot and determine the values of gain K for the open-loop transfer function $G(s)H(s) = \frac{K}{s(s+1)(0.1s+1)}$

So that−

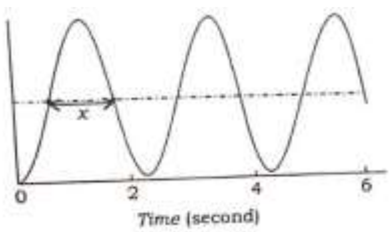
(1) the gain margin is 15 dB;

(2) the phase margin is 60°. **[10M]**

UPSC – ELECTRICAL Engineering optional – 2020 Questions

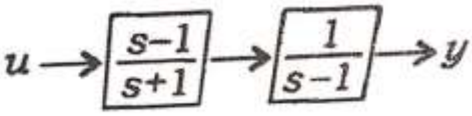
1. The open-loop transfer function of a feedback system is given by $G(s)H(s) = \frac{K(s+3)}{(s-1)(s-2)}$. Determine the gain K at the break-in point of the root locus of the system. **[10M]**

2. The unit step response of a unity feedback system exhibits sustained oscillations as shown in the figure below. The open-loop transfer function of the system is $G(s) = \frac{K}{(s+1)(s+4)(s+a)}$. The time x in the figure is 1.0471 second. Determine the values of K and a. **[20M]**

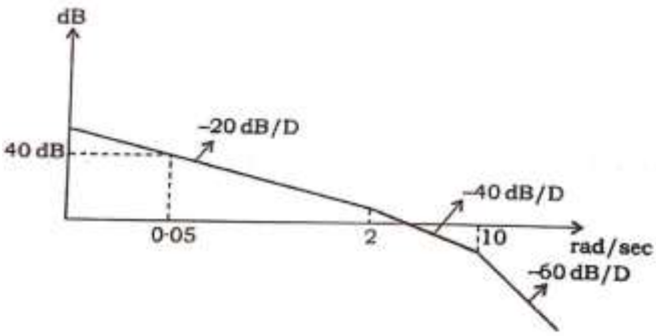


3. The unit impulse response of a linear system is given by $c(t) = e^{t}u(t) + e^{-t}u(t)$. When the same system is subjected to an input of $e^{-3t}u(t)$, determine the output of the system. Assume that the system is initially relaxed. **[10M]**

4. Two first-order systems are connected in cascade as shown in the figure below. Obtain the state-space representation of the system. Also check the controllability and observability of the system. u is the input to the system and y is the output. **[20M]**



5. The open-loop transfer function of a unity feedback system is given by $G(s)H(s) = e^{-Ts}G_1(s)$, where $G_1(s)$ is a minimum phase system. The approximate Bode magnitude plot of the open-loop transfer function, which is shown in the figure below, crosses the 0 dB line at $\omega = 2.8\ rad/sec$. If the phase margin of the system is $-12.17°$, determine the transportation lag T. **[20M]**



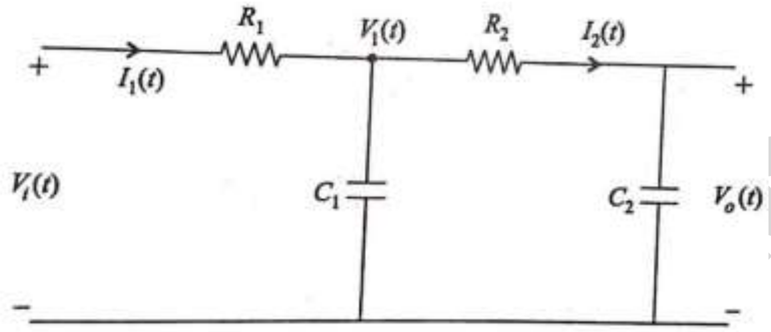
UPSC – ELECTRICAL Engineering optional – 2021 Questions

1. A system is described by the following state equations: **[10M]**

$$\dot{x}_1 = x_1 + x_2 + 3x_3$$
$$\dot{x}_2 = 2x_1 + 3x_2 + u_1$$
$$\dot{x}_3 = 2x_2 + x_3 + u_2$$

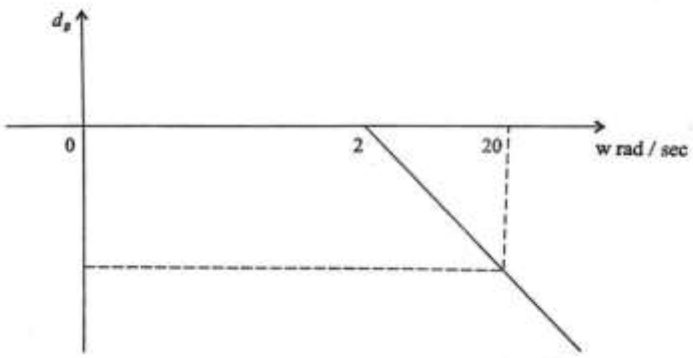
Check the controllability of the system.

2. For the network shown if figure, draw a block diagram representing each circuit element by a block. Use block diagram reduction technique to obtain the transfer function of the network. The voltage $V_i(t)$ is the applied input and the voltage across the capacitor $V_o(t)$ is the output. **[20M]**



3. A convolutional code is described by $g_1 = [1\ 1\ 0]$, $g_2 = [1\ 0\ 1]$, $g_3 = [1\ 1\ 1]$ Find the transfer function and the free distance for this code. Also verify whether or not this code is catastrophic. **[10M]**

4. The approximate magnitude plot, obtained experimentally, of a non-minimum phase system is shown in figure. Calculate the phase in degrees at $\mathrm{w} = 3$ rad/sec. **[10M]**



5. The two top rows of a Routh table of a characteristic polynomial is given in the table. Determine the roots of the characteristic equation which lie in the left half s-plane. Complete the remaining rows of the table. **[10M]**

s^4	1	10	24
s^3	5	20	

6. State Nyquist stability criterion. Is the feedback system shown in figure in open loop stable? Determine the closed loop stability of the system using Nyquist stability criterion. Show all the required plots clearly. **[20M]**