KATHMANDU UNIVERSITY
End Semester Examination
May/June, 2022

Marks Scored:

Level : B.E.
Year : III

Course : COEG 301
Semester : II

Exam Roll No: Time: 30 mins. F. M. : 10

Registration No.: Date :

SECTION "A"

[20Q × 0.5 = 10 marks]

Encircle the most appropriate option among the given choices.

1. The signal, X(s), in Fig. 1 is:
   a. Actuating Signal
   b. Feedback Signal
   c. Error Signal
   d. Feed-forward Signal

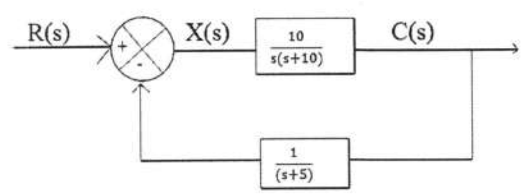

Fig. 1

2. Which of the following indicates an impulse test waveform in Fig. 2?

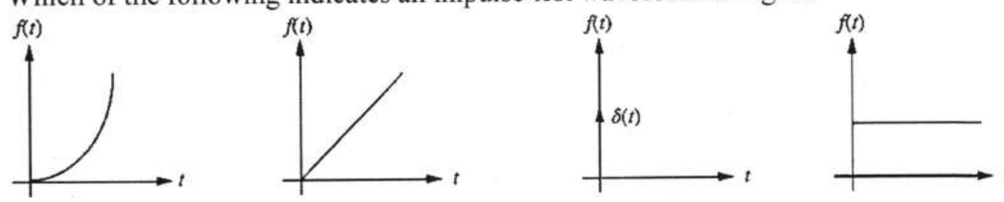

Fig. 2

a. b. c. d.

3. Find $\frac{\theta_o}{\theta_i}$, for the gear train shown in Fig. 3, where N_x represents the number of teeth.

   a. $\frac{N_1 N_4 N_5}{N_2 N_3 N_6}$ b. $\frac{N_1 N_3 N_5}{N_2 N_4 N_6}$

   c. $\frac{N_2 N_4 N_6}{N_1 N_3 N_5}$ d. $\frac{N_2 N_3 N_6}{N_1 N_4 N_5}$

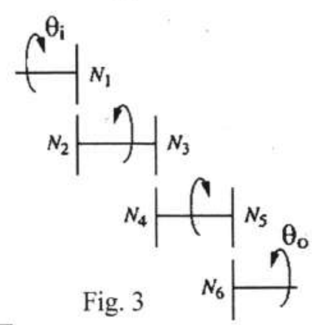

Fig. 3

4. The operational-amplifier in Fig. 4 represents:
   a. Non-inverting amplifier
   b. Inverting amplifier
   c. Differentiator
   d. Integrator

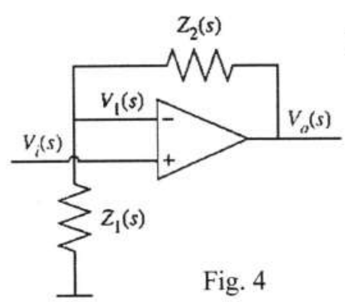

Fig. 4

5. Hydraulic capacitance in a liquid level system is given by (where V is the accumulated volume, h is the head height and t is the time),

   a. $\frac{\Delta V}{\Delta t}$ b. $\frac{\Delta V}{\Delta h}$ c. $\frac{\Delta h}{\Delta V}$ d. $\frac{\Delta h}{\Delta t}$

6. For a generalized state space representation, $\dot{x}(t) = A\,x(t) + B\,u(t)$ and $y(t) = C\,x(t) + D\,u(t)$, which of the following matrix operation yields transfer function, $\frac{Y(s)}{U(s)}$?

a. $C(sI-A)^{-1}B+D$ b. $C(sI-A)^{-1}D+B$ c. $A(sI-C)^{-1}B+D$ d. $C(sI-D)^{-1}B+A$

7. The transfer function, Y(s)/X(s), of the block diagram in Fig. 5 is:

a. $\frac{K_p+K_is+K_ds^2}{s}$ b. $K_pK_iK_d$

c. $\frac{K_ps+K_i+K_ds^2}{s}$ d. $\frac{K_ps^2+K_i+K_ds}{s}$

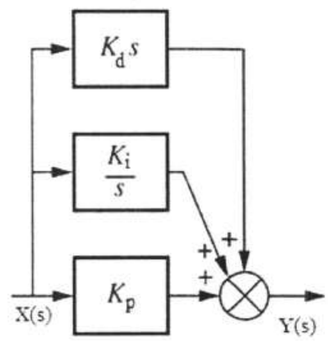

Fig. 5

8. If the unit step response of a first-order system $\left(\frac{1}{sT+1}\right)$ is given by, $(1 - e^{t/T})$, what will be the steady-state error?

a. ∞ b. 0 c. 1 d. $e^{-t/T}$

9. The damping ratio of the second-order system with the characteristic polynomial, (s^2+2s+4), is:

a. 2 b. 1 c. 0.5 d. 0.25

10. If the two poles of a second-order system are purely negative real and equal, the response of the system would be:

a. Overdamped b. Underdamped c. Undamped d. Critically damped

11. 'Type 2' systems yield a finite steady-state error (other than zero) when subjected to

a. Step input b. Ramp input c. Impulse input d. Parabolic input

12. The number of loops in the signal flow graph shown in Fig. 6 is:

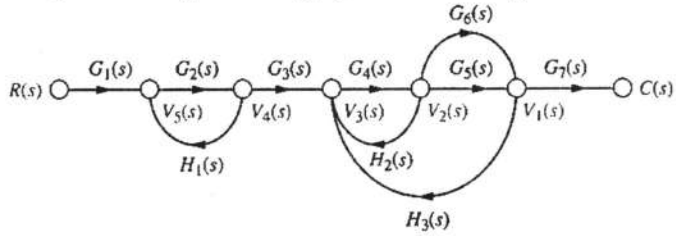

Fig. 6

a. One b. Two c. Three d. Four

13. If a system oscillates with a constant frequency and amplitude, the system is said to be

a. Unstable b. Stable

c. Conditionally stable d. Marginally stable

14. If the characteristic equation of a system is, $s^5 + 4s^4 + 3s^2 + 2s + 1 = 0$, the system will be:

a. Unstable b. Stable

c. Marginally stable d. Conditionally stable

15. For G(s) H(s) = $\frac{K}{s\,(s+1)\,(s+2)}$, which of the following ranges in the real axis consist root loci?

a. $(0, +\infty)$ and $(-1, 0)$
b. $(-1, 0)$ and $(-\infty, -2)$
c. $(-2, -1)$ and $(-1, 0)$
d. $(-2, -1)$

16. The number of asymptotes in the root locus shown in Fig. 7 is:

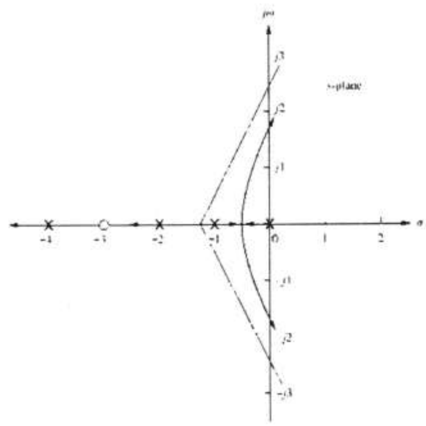

Fig. 7

a. Four b. Three c. Two d. Five

17. If the number of poles of G(s)H(s) in the right half s-plane is zero, upon analyzing the Nyquist plot in Fig. 8, how many closed-loop poles are there in the right half s-plane?

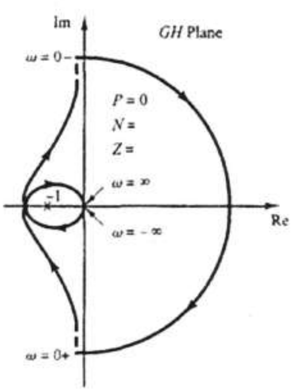

Fig. 8

a. Zero b. One c. Two d. Four

18. Fig. 9 is the bode plot of:

a. Lead compensator
b. Lag compensator
c. Lead-lag compensator
d. Integrator

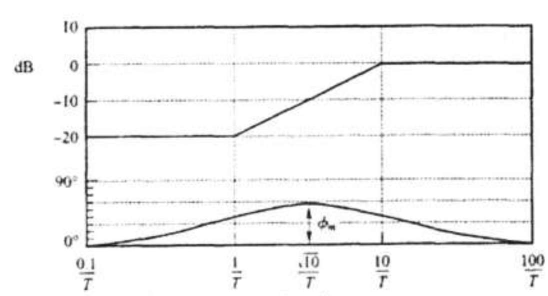

Fig. 9

19. Which of the following refers to the log-magnitude curve of a 'Type 0' system in Fig. 10?

a. b. c. d.

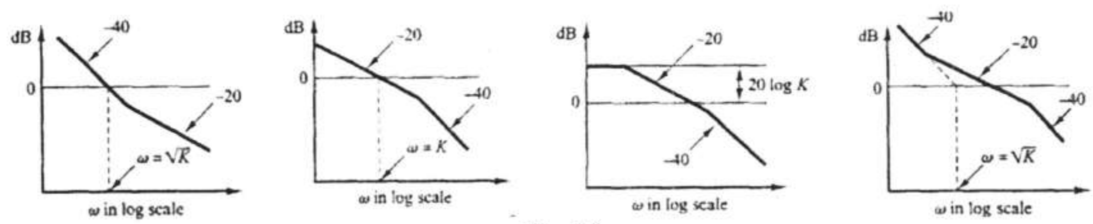

Fig. 10

20. A system with the Nichols chart as shown in Fig. 11 has .... gain margin.

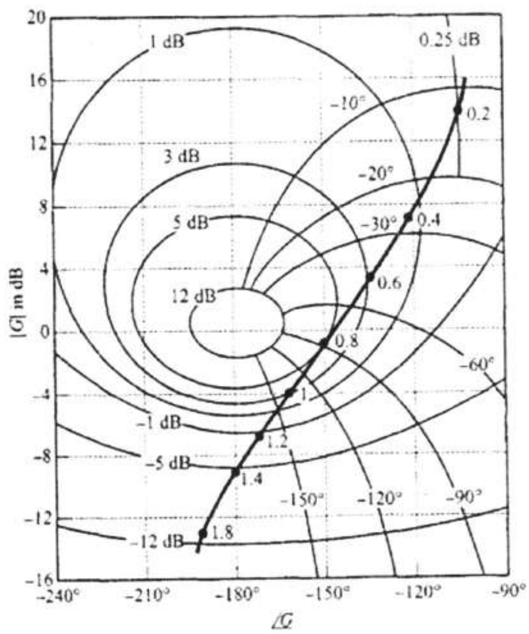

Fig. 11

a. Positive b. Negative c. Zero d. Infinite

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SECTION "B"
[5Q × 8 = 40 marks]

Attempt *ANY FIVE* questions. Assume necessary data if required.

1. The schematic diagram of the antenna azimuth angle control system is shown in Fig. 1. The desired azimuth angle is given from the n-turn input potentiometer. The closed-loop control system has an output potentiometer, the same number of turns as in the input potentiometer, coupled with a gear with N_3 teeth. The input and the output potentiometer convert the angular displacement into a voltage signal, V_i (t) and V_o (t) respectively. An error signal, $V_e(t) = V_i(t) - V_o(t)$, is processed through a differential pre-amplifier with the proportional gain, K. The pre-amplified signal, $V_p(t) = K\, V_e(t)$, is amplified with a power amplifier to operate the actuator of the system, a DC motor (fixed field). The motor drives the antenna to have the azimuth angle output of the antenna, θ_o (t), following the input angle of the potentiometer, θ_i (t).

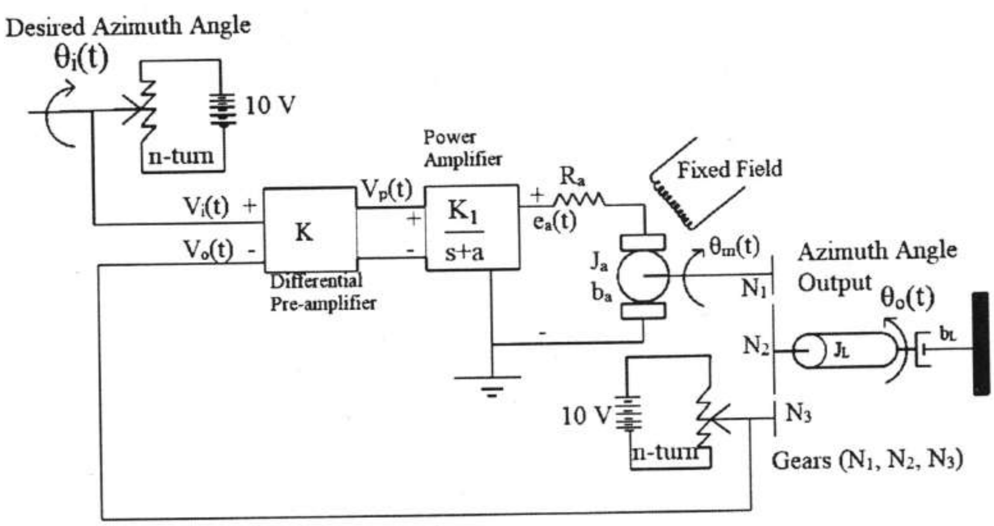

Fig. 1

The system parameters are as follows:
Number of turns in the potentiometers (n) = 5 turns (n turns = 10 V = $2\pi n$ radians)
Power Amplifier (K_1 = 100, a=100); Gears (N_1 = 25, N_2 = 250, N_3 = 250)
Motor ($R_a = 8\Omega$, J_a = 0.02 kg-m^2, b_a = 0.01 N-m-s/rad); Back emf constant (k_b) = 0.5 V-s/rad; Torque Constant (k_t) = 0.5 N-m/A; Load (J_L = 1 kg-m^2, b_L = 1 N-m-s/rad)

(a) Find the transfer functions, $\frac{V_i(s)}{\theta_i(s)}, \frac{E_a(s)}{V_p(s)}, \frac{\theta_m(s)}{E_a(s)}$ [3]

(b) Show the motor-load state-space representation in the matrix form. [5]
(State variables: θ_m (t), ω_m (t); Input variable: e_a (t); Output variable: θ_o (t))

2. A liquid level control system has the following state equations:

$$\frac{dh(t)}{dt} = 0.02\,\theta_m(t) - h(t); \qquad \frac{d\theta_m(t)}{dt} = \omega_m(t);$$
$$\frac{d\omega_m(t)}{dt} = 8333.33\,r(t) - 8333.33\,h(t) - 11.77\,\omega_m(t)$$

a. Draw the block diagram of the system, and by using block diagram reduction technique, find the transfer function, $\frac{H(s)}{R(s)}$. [4]

b. Draw the signal flow graph and find the transfer function, $\frac{H(s)}{R(s)}$, by using Mason's Gain Formula. [4]

3.

a. A second-order system, $T(s) = \frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$, subjected to a unit step input had a maximum overshoot of 16.3% at 0.605 seconds. Find the damping ratio, the natural frequency, the rise time (0 to 100%), and the settling time (within 2%) of the system. [3]

b. A servomechanism shown in Fig. 2 is designed to keep a radar antenna pointed at a flying aeroplane. The aeroplane is flying with a velocity of 600 km/hr, at a range of 2 km. Determine the required velocity error coefficient, K_v, if the maximum tracking error is to be within 0.1°. [5]

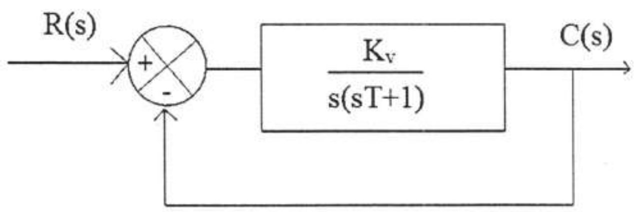

Fig. 2

4. A system with the plant transfer function, G(s), is indicated in Fig. 3.

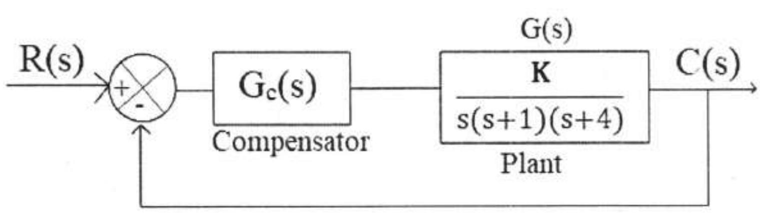

Fig. 3

a. Plot the root locus of the uncompensated network with $G_c(s) = 1$, and find the value of K when the damping ratio, $\zeta = 0.5$. [4]

b. Design a lag compensator, $G_c(s) = \frac{\frac{1}{aT}+s}{\frac{1}{T}+s}$ which would meet $\zeta = 0.5$. Also, the compensated network should have the velocity error constant, $K_v \geq 5$. [4]

5. The open-loop transfer function of a unity feedback system is,

$$G(s)\,H(s) = \frac{K}{s\,(1+0.1s)\,(1+0.001s)}$$

a. Find the value of K which will meet the velocity error constant, $K_v = 1000$. For that value of K, check the system's stability by using a bode plot. [4]

b. Design a lead compensator, $G_c(s) = \frac{1}{a}\left(\frac{1+aTs}{1+Ts}\right)$, which would meet the phase margin, $P.M \geq 45°$, and $K_v=1000$. [4]

6.

a. A unity-feedback system has the following feed-forward transfer function,

$$G(s) = \frac{K}{s\,(s+1)\,(s+5)}$$

Sketch the polar plot and determine the range of K for which the system would be stable. [5]

b. Check the stability of a unity-feedback system with $G(s)H(s) = \frac{1}{s\,(s+1)\,(0.5s+1)}$ by using Nichols chart. Specify the phase margin and the gain margin. [3]