Code: A-11 **Subject: CONTROL ENGINEERING**

Time: 3 Hours **Max. Marks: 100**

NOTE: There are 11 Questions in all.

- **Question 1 is compulsory and carries 16 marks. Answer to Q. 1. must be written in the space provided for it in the answer book supplied and nowhere else.**
- **Answer any THREE Questions each from Part I and Part II. Each of these questions carries 14 marks.**
- **Any required data not explicitly given, may be suitably assumed and stated.**

Q.1 Choose the correct or best alternative in the following: (2x8)

a. Closed-loop transfer function of a unity-feedback system is given by $\frac{Y(s)}{R(s)}=\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$. Steady-state error to unit-ramp input is

(A) ∞ **(B)** $2\zeta/\omega_n$

(C) 1 **(D)** $4/\zeta\omega_n$

b. Effect of back emf in an armature-controlled dc servomotor is

(A) to increase effective motor friction, thereby reducing motor time-constant.

(B) to increase effective motor friction, thereby increasing motor time-constant.

(C) to increase motor inertia, thereby increasing motor time-constant.

(D) to increase motor inertia, thereby reducing motor time-constant.

c. Feedback control systems are

(A) Insensitive to both forward-and feedback-path parameter changes.

(B) Less sensitive to feedback-path parameter changes than to forward-path parameter changes.

(C) Less sensitive to forward-path parameter changes than to feedback-path parameter changes.

(D) Equally sensitive to forward-and feedback-path parameter changes.

d. The characteristic equation of a feedback control system is given by $2s^4+s^3+2s^2+5s+10=0$. The number of roots in the right-half of s-plane are

(A) zero. **(B)** 1.

(C) 2. **(D)** 3.

e. A unity feedback system has open-loop transfer function $G(s)=25/[s(s+6)]$. The peak overshoot in the step-input response of the system is approximately equal to

(A) 5%. **(B)** 10%.

(C) 15%. **(D)** 20%.

f. A unity feedback system with forward-path transfer function $G(s)=1/\left[s^2(s+1)\right]$ is subjected to an input $r(t)=k_1+k_2t+\frac{1}{2}t^2$. The steady-state error of the system is

(A) infinity. **(B)** 1.

(C) zero. (D) None of answers in (A), (B) & (C) is correct.

g. A type-1 plant is changed to type-2 feedback system by the following cascade control action.

(A) PD (B) PI

(C) Either PD or PI. (D) Neither PD nor PI.

h. A unity feedback system has open-loop transfer function $G(s) = K/[s(1+s\tau)]$. The gain margin of the feedback system is

(A) ∞. (B) 0.

(C) 1. (D) None of answers in (A), (B) & (C) is correct.

PART I

Answer any THREE Questions. Each question carries 14 marks.

Q.2 a. The parameters of the mechanical system of Fig.1 are M = 1,000 Kg; B = 10,000 N / (m / sec); K = 100,000 N / m . A step force of 1000 Newton is applied to the mass at t=0. The initial conditions are $y(0) = \dot{y}(0) = 0$. From the physical parameters of the system, obtain the following parameters: damping ratio, undamped natural frequency, and damped natural frequency which describe the dynamical behavior of the system. **(9)**

b. Obtain the step response of the system of Fig.1. **(5)**

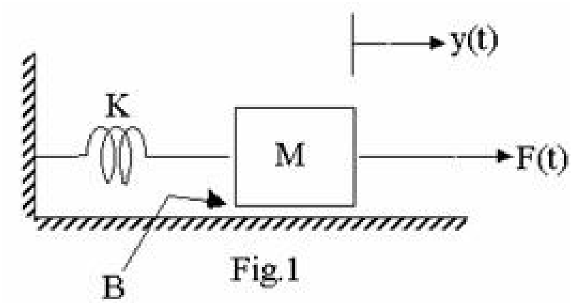

Fig.1

Q.3 Consider the system shown in Fig.2 with $R_a = 10\Omega$, $L_a = 0.1H$, $K_b = 1\,\text{volt}/(\text{rad/sec})$, $\dot{\theta}_L/\dot{\theta}_M = 1/2$, $K_t = 0.8\,\text{volt}/(\text{rad/sec})$, $K_p = 1.5\,\text{volt/rad}$.

Moment of inertia of load, $J_L = 2N-m/(\text{rad/sec}^2)$

Moment of inertia of motor shaft, $J_M = 0.1N-m/(\text{rad/sec}^2)$

Coefficient of viscous friction of load, $B_L = 0.02N-m/(\text{rad/sec})$

Coefficient of viscous friction of motor shaft, $B_M = 0.01N-m/(\text{rad/sec})$

(i) Find the transfer function $\theta_M(s)/E_a(s)$ **(9)**

(ii) A multi-loop (Consisting of speed-feedback loop, and a position feedback loop) feedback control system built around the system of Fig.2 with suitable additional hardware, drives the load to the commanded position θ_R inspite of load torque disturbances. Make a sketch of the feedback control system showing how the hardware is to be connected. **(5)**

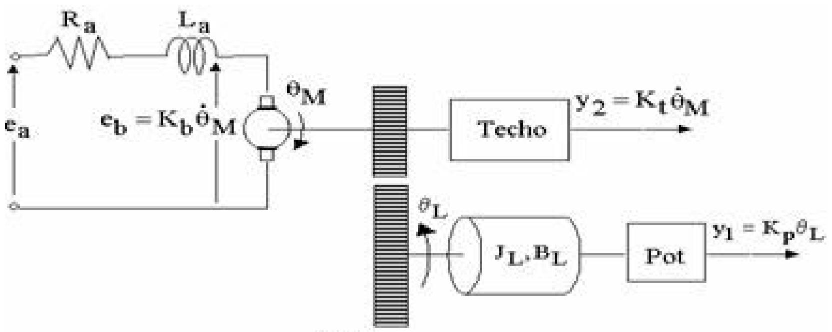

Fig.2

Q.4 a. Show that a high loop gain in feedback systems results in
- (i) good steady-state tracking accuracy;
- (ii) good disturbance signal rejection;
- (iii) low sensitivity to process parameter variations; and
- (iv) good relative stability, i.e., rate of decay of transients.

(8)

b. What are the factors that limit the gain? **(6)**

Q.5 a. Show that rise time, peak time, and settling time measures of performance of a standard second-order system are mutually dependent and therefore must be specified in a consistent manner. **(5)**

b. A unity feedback system has the plant $G(s) = \dfrac{K}{s(\tau s + 1)}$ with a cascade controller $D(s) = K_c(1 + T_D s)$. Describe the effects of K_c and T_D on steady-state error, settling time and peak overshoot of system response. **(9)**

Q.6 a. Compare the power of Routh stability criterion with root locus analysis for investigation of closed-loop stability. **(4)**

b. Find the range of gain K (K>0), for which the system shown in Fig.3 is stable. **(10)**

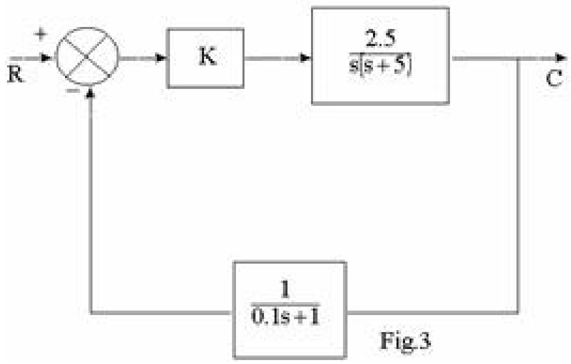

Fig.3

PART II

Answer any THREE Questions. Each question carries 14 marks.

Q.7 a. Consider a unity-feedback system with a forward path transfer function $G(s)=\frac{K(s+3)}{s(s+2)}; K \geq 0$. Show that a part of the root locus is a circle. **(9)**

b. Construct the root locus for the G (s) in part (a) and determine the damping ratio for maximum oscillatory response. What is the value of K for this damping ratio? **(5)**

Q.8 a. Explain the terms 'gain margin' and 'phase margin', with reference to Nyquist plots. **(4)**

b. Using Bode plots, determine gain crossover frequency, phase crossover frequency, gain margin and phase margin of a feedback system with the open-loop transfer function $G(s)=\frac{10}{s(0.1s+1)^2}$. **(10)**

Q.9 a. Define the terms 'resonance peak' and 'bandwidth' as applied to a closed-loop control system. **(4)**

b. The experimental frequency response data of a system presented on Bode plot and asymptotically approximated is shown in Fig.4. Find the transfer function of the system (the system is known to have minimum-phase characteristics). **(10)**

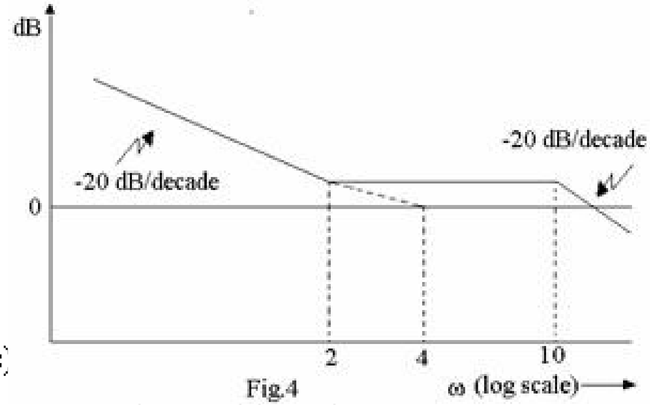

Fig.4

Q.10 transfer function of a control system is

G(s

(i) Determine approximate values of gain margin and phase margin.

(ii) If a lag compensator with transfer function

$$D(s) = \frac{K_c(1+3s)}{1+5s}$$

is inserted in the forward path, find the value of K_c to keep the gain margin unchanged. **(6+8)**

Q.11 Fig.5 shows a minor-loop feedback compensation scheme. It is required to realize the control action by a digital controller with a uniform sampling interval of T sec. Give a digital control algorithm using the trapezoidal rule for integration. Also give a block diagram of the digital control system. **(14)**

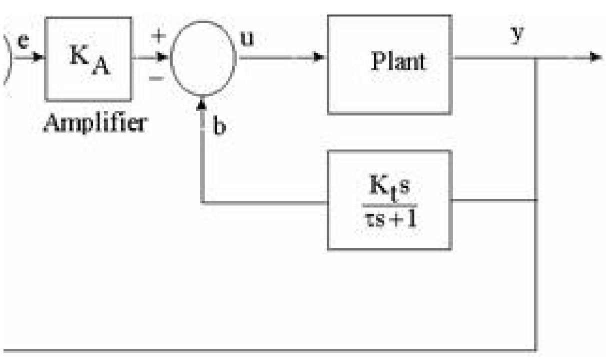

Fig.5