AMIETE – ET (OLD SCHEME)

Code: AE11 **Subject: CONTROL ENGINEERING**
Time: 3 Hours **JUNE 2010** **Max. Marks: 100**

NOTE: There are 9 Questions in all.

- **Question 1 is compulsory and carries 20 marks. Answer to Q.1 must be written in the space provided for it in the answer book supplied and nowhere else.**
- **Out of the remaining EIGHT Questions, answer any FIVE Questions. Each question carries 16 marks.**
- **Any required data not explicitly given, may be suitably assumed and stated.**

Q.1 Choose the correct or the best alternative in the following: (2×10)

a. For the system $GH(s) = \frac{5}{s(s-1)}$, letting $s = j\omega$ as $\omega \to 0$, $\angle GH(j\omega) \to$

(A) $-90^\circ +$ a small angle **(B)** $-270^\circ +$ a small angle

(C) $-180^\circ +$ a small angle **(D)** $0^\circ +$ a small angle

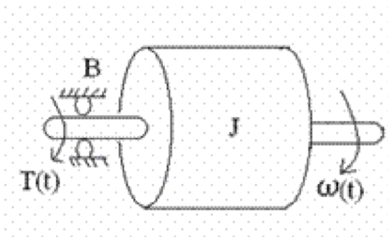

Fig. 1

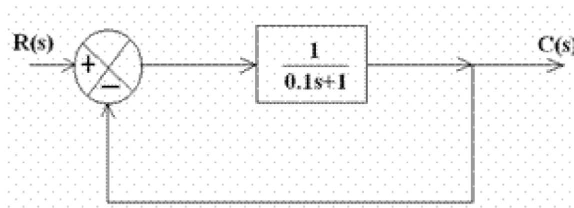

Fig. 2

b. For the inertia-damper rotational system with a rigid shaft shown in Fig. 1 the torque equation is:

(A) 0.2s $T(t) = J\frac{d\omega(t)}{dt}$ **(B)** $T(t) = J\frac{d\omega(t)}{dt} - B\omega(t)$

(C) $T(s) = Js\omega(s) + B\omega(s)$ **(D)** $T(s) - B\omega(s) = J\omega(s)$

c. The output c(t) for an impulse input r(t)= $\delta(t)$ for the system of Fig. 2 is:

(A) $10e^{20t}$ **(B)** $10e^{-20t}$

(C) $10e^{t}$ **(D)** $10e^{-t}$

d. The time constant of the second order-system $G(s) = \frac{12}{s(s+0.2)}, H(s) = 1,$ is:

(A) 0.2s **(B)** 12s

(C) 60s **(D)** 10s

e. The origin for the frequency response plot is (0 dB gain, -180° phase) in:

(A) Root-locus **(B)** Nichols chart

(C) Nyquist plot **(D)** None of these

f. The type of the system and the velocity error constant K_v for the system with $G(s) = \frac{5(3s+1)}{(s^2+2s)(4s^2+s+1)}, H(s) = 1$ are given by:

(A) 1 and $\frac{15}{4}$ (B) 1 and $\frac{5}{4}$

(C) 1 and $\frac{15}{2}$ (D) 1 and $\frac{5}{2}$

g. The point of intersection of the asymptotes (centroid) for the root-locus of the system $G(s) = \frac{K(s+5)}{s(s+2)(s+3)}, H(s) = 1$, is:

(A) 0 (B) 2

(C) 3 (D) 5

h. Application of Routh-Hurwitz criterion to the system of Fig. 3 shows that it will be unstable for:

(A) $K \geq 1$ (B)

(C) $K \geq 4$ (D

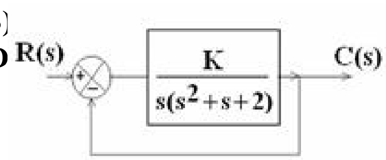

Fig. 3

i. The basic circuit of Fig. 4 represents a:

(A) lag compensator
(B) lead compensator
(C) lag-lead compensator
(D) lead-lag compensator

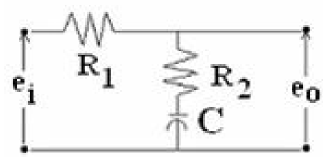

Fig. 4

j. While using digital implementation of analog compensators, the integral approximation procedure shown in Fig. 5 is called:

(A) forward rectangular rule
(B) forward difference approximator
(C) trapezoidal rule
(D) backward rectangular rule

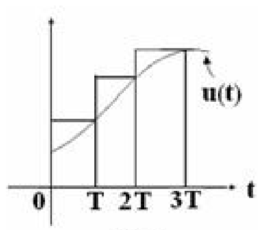

Fig. 5

Answer any FIVE Questions out of EIGHT Questions.
Each question carries 16 marks.

Q.2 a. Consider an external force F(t) applied to mass M_1 as in Fig. 6. Write the free- body diagram and the differential equations. Draw the electrical equivalent network using force-current analogy. **(8)**

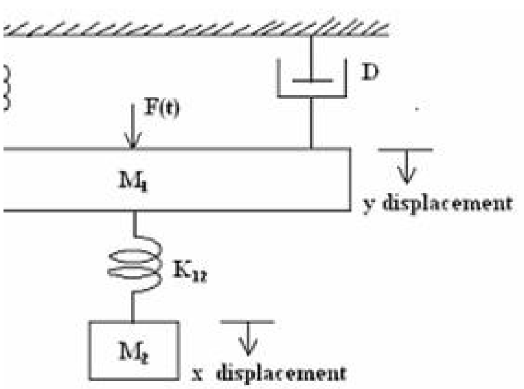

Fig. 6

b. With a neat diagram, explain the function of an ac tacho-generator and obtain its transfer function. **(8)**

Q.3 a. Using block-diagram reduction technique, find the closed-loop transfer function of Fig 7. **(8)**

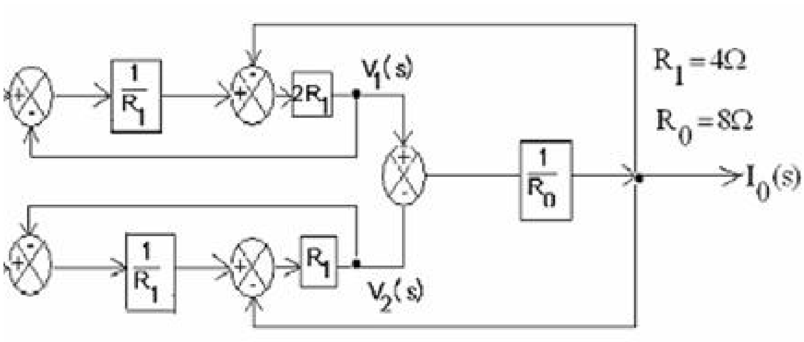

Fig. 7

b. Obtain the overall transfer function of the system whose signal-flow graph is shown in Fig. 8, using Mason's gain formula. **(8)**

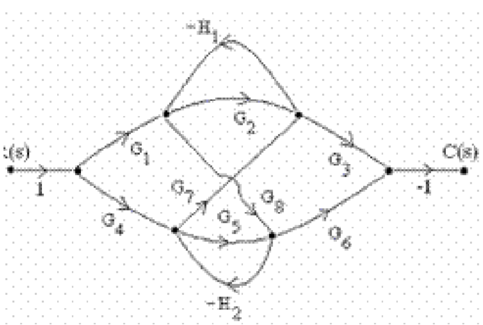

Fig. 8

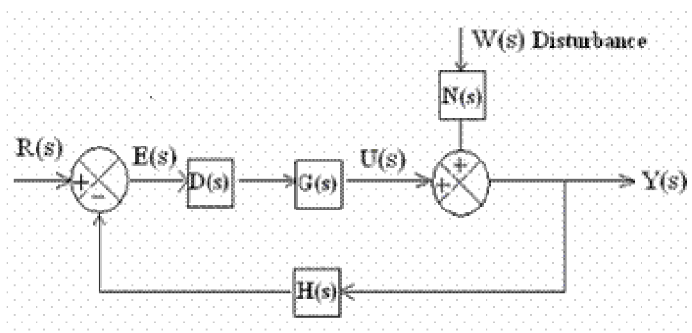

Fig. 9

Q.4 a. Consider the feedback control system of Fig. 9 with a disturbance input W(s). Show that feedback reduces the effect of disturbance on the controlled output. Obtain the sensitivity function $S(j\omega)$ of the system and the disturbance transfer function $\frac{Y(S)}{W(S)}$. How is disturbance rejection accomplished? **(8)**

b. Determine the damping ratio ς and the values of 'a' and 'b' if the first overshoot is 16% and time-constant is 0.1 sec for the system forward path transfer function $G(S)= 10/S^2$ and feed back $H(S)= (as+b)$. **(8)**

Q.5 a. Use Routh stability criterion to check the stability of systems with characteristic equation: (i) $s^3 + 4s + 80 = 0$, and show (ii) $s^3 + 7s^2 + 25s + 39 = 0$ has all roots with real parts more negative than –1. **(8)**

b. For the unity feedback system: $G(s) = \frac{5(4s+1)}{(s^2+2s)(4s^2+8s+16)}$, state the type of the system and identify its poles and zeros. Determine the steady state errors for a unit step input, a unit ramp input and an acceleration input, $t^2/2$. If this system is required to follow a parabolic input signal, will it perform satisfactorily? **(8)**

Q.6 a. Draw a typical passive electrical network and the pole-zero plot, and write the transfer function for each type of compensator: lead, lag and lag-lead. Explain the need for compensation networks in control systems. **(8)**

b. Sketch the root-locus for a unity feedback system having forward path transfer function as $G(s) = \frac{K}{S}\left(\frac{2-S}{2+S}\right)$ and find the value of K when the root-locus cuts the $j\omega$-axis. **(8)**

Q.7 a. For a standard second order system $G(s) = \frac{\omega_n^2}{s(s+2\varsigma\omega_n)}, H(s) = 1$, show that the phase-margin is given by $\phi_m = \tan^{-1}\left(\frac{2\varsigma}{\sqrt{\sqrt{4\varsigma^4+1} - 2\varsigma^2}}\right)$. Calculate ϕ_m for $\varsigma = 0.5$ and $\frac{1}{\sqrt{2}}$. What will be the approximation for ϕ_m for low values of damping ratio ς? **(8)**

b. Sketch the Nyquist plot and determine the stability of the system $G(s)H(s) = \frac{5}{s(s+1)(s-2)}$. **(8)**

Q.8 a. The transfer function of a lead compensator is given by $G_c(s) = \frac{\tau s + 1}{\alpha\tau s + 1}$, where $\alpha < 1, \tau > 0.$ Find the magnitude of $G_c(j\omega)$ at the frequency ω_m of maximum phase lead ϕ_m and express $\sin\phi_m$ in terms of α. If $\tau = 0.36$ and $\alpha\tau = 0.06$, find $|G_c(j\omega_m)|$ **(8)**

b. Obtain the open-loop transfer function of the system whose Bode magnitude plot is shown in Fig. 10. **(8)**

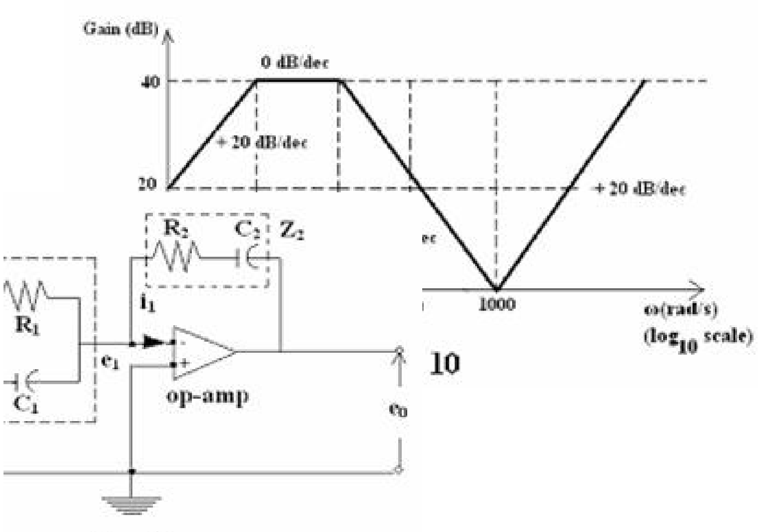

Fig. 11

Q.9 a. Consider the circuit of Fig. 11 with an ideal op-amp. Derive the transfer function in terms of: (i) $Z_1(s)$ and $Z_2(s)$, (ii) circuit elements. Show that the circuit process the input signal by “proportional + integral + derivative” action.

(8)

b. What is a robust control system? List the model uncertainty factors that should be considered to make the system design robust. **(8)**