Code: AE11 **JUNE 2011** **Subject: CONTROL ENGINEERING**
Time: 3 Hours **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.**
- **The answer sheet for the Q.1 will be collected by the invigilator after 45 Minutes of the commencement of the examination.**
- **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 second-order system $s^2 + 3s + 20 = 0$, with a damping ζ of 0.336, the value of damped natural frequency (rad/s) is:

(A) 4.21 **(B)** 8.42
(C) $\sqrt{20}$ **(D)** $3\sqrt{20}$

b. Constant-M circle has infinite radius with centre at infinity on the real axis, i.e. a straight line parallel to the imaginary axis of the G(s)-plane for:

(A) M < 1 **(B)** M = 0
(C) M = 1 **(D)** M > 1

c. The steady-state error e_{ss} for a unit-ramp input is constant (as in Fig.1) for a system of Type:

(A) 2 **(B)** 1
(C) 0 **(D)** 3

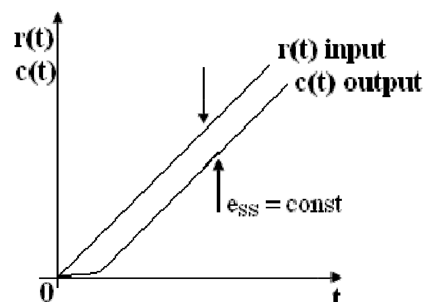

Fig.1

d. The overall transfer function of Fig.2 is:

(A) RCs
(B) $\frac{1}{RCs}$
(C) 1+RCs
(D) $\frac{1}{1+RCs}$

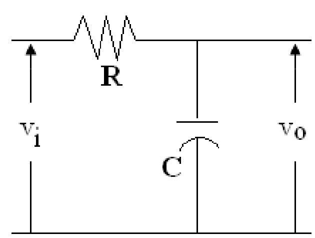

Fig.2

e. The Bode asymptote plot of Fig.3 refers to the system with G(s) equal to:

(A) 1+0.1s
(B) 1+10s
(C) 0.01+10s
(D) 0.1+0.01s

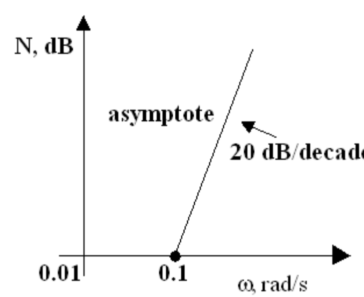

Fig. 3

f. The root-locus of the system $G(s) = \frac{k}{s(s+4)}$ shown in Fig.4 gives a value of k at point s_1 equal to:

(A) 4 **(B)** 16
(C) 25 **(D)** 29

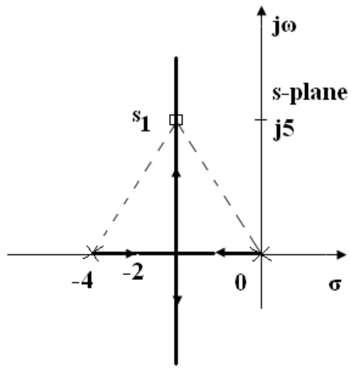

Fig.4

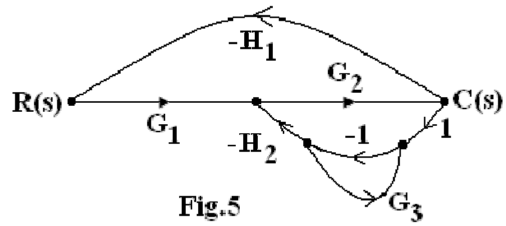

Fig.5

g. A system with characteristic equation $4s^3 + 2s^2 + 100s + k = 0$ is stable by Routh-Hurwitz criterion if:

(A) $0 < k < 50$ **(B)** $0 < k < 100$

(C) $50 < k < 100$ **(D)** $0 < k < 200$

h. In the signal-flow graph of Fig.5, the number of pairs of non-touching loops is:

(A) 2 **(B)** 1

(C) 0 **(D)** 3

i. The Nyquist plot for $G(s) = \dfrac{5}{s(s-1)}$ shown in Fig.6 is:

(A) unstable

(B) stable

(C) marginally stable

(D) conditionally stable

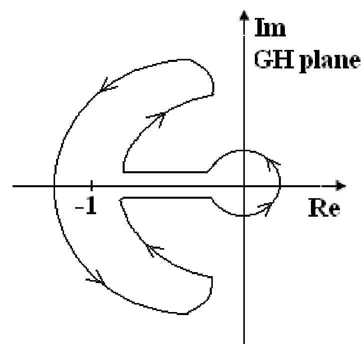

Fig.6

j. A mass M initially at rest acted upon by a force F(t) as in Fig.7 is described by:

(A) $F(t) = M\dfrac{dv}{dt} + K\int x\,dt$

(B) $F(t) = M\dfrac{d^2v}{dt^2} + K\int v\,dt$

(C) $F(t) = M\dfrac{d^2x}{dt^2} + Kv$

(D) $F(t) = M\dfrac{d^2x}{dt^2} + Kx$

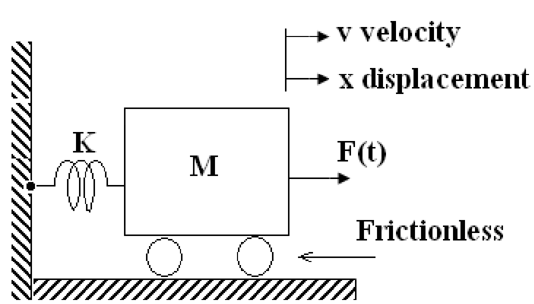

Fig.7

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

Q.2 a. Obtain the transfer function $G(s) = \dfrac{\theta(s)}{T(s)}$ for the inertia-spring-damper system of Fig.8. Show that it represents a second-order system. **(4)**

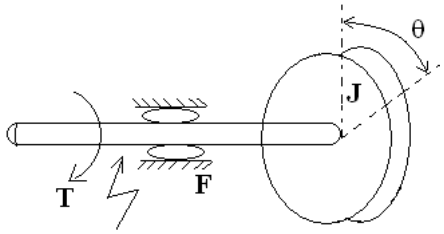

Fig.8

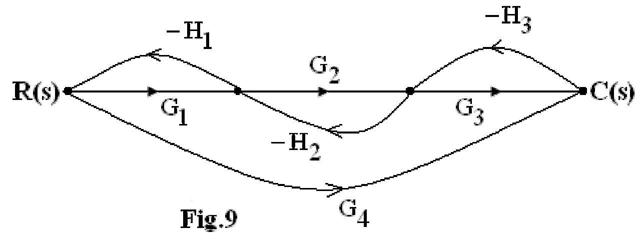

Fig.9

b. Draw the block-diagram of the basic feedback control system, identifying all signals at the input and output of G(s) and H(s). Derive the system characteristic equation. **(4)**

c. Consider the system with $G(s) = \frac{Y(s)}{R(s)} = \frac{1}{s^2 + 3s + 2}$ to which a standard test input signal r(t) = 5t u(t) is applied. Find the constant, ramp and exponential components of the dynamic response y(t). What will be the steady state response $y_{ss}(t)$? **(8)**

Q.3 a. State Mason's gain rule for determining the overall system gain from a signal flow graph. Obtain the overall transfer function of Fig.9 using Mason's gain rule. **(4+4)**

b. Draw appropriate block-diagrams to represent:
(i) combining two blocks in cascade.
(ii) moving a summing point that is after a block.
(iii) moving a take-off point that is before a block.
(iv) eliminating a feedback loop. **(2×4)**

Q.4 a. Consider the basic controller block-diagram of Fig.10. Write the expressions for G(s) and obtain the time-response y(t) for various types of controls:
(i) integral (ii) PI
(iii) PD (iv) PID **(2×4)**

b. Explain briefly the following terms used in characterising a feedback control system:
(i) stability (ii) disturbance rejection
(iii) steady-state accuracy (iv) robustness **(2×4)**

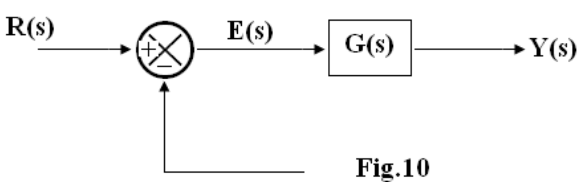

Fig.10

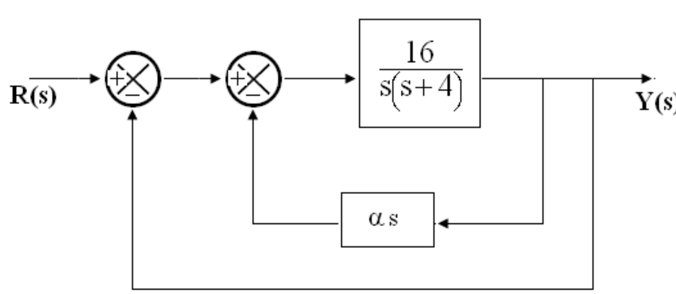

Fig.11

Q.5 a. Using Routh stability criterion, find whether the system with characteristic equation $\Delta(s) = s^5 + s^4 + 4s^3 + 24s^2 + 3s + 63 = 0$ is stable or not. **(8)**

b. For the system of Fig.11, determine the peak overshoot when $\alpha = 0$ and input is a unit-step function. Determine the rate-feedback constant α that will decrease the peak overshoot to 1.5%. **(4+4)**

Q.6 a. Consider a closed-loop system with $G(s) = \frac{k}{s}, H(s) = e^{-\tau_D s} \approx \frac{2-s}{2+s}$. Write the characteristic equation{sketch the root-locus on a graph sheet}. Given that the root-locus is a circle. Find the value of k corresponding to the intersection of the locus with the $j\omega$-axis. **(8)**

b. A bridged-T network of Fig.12 is used as a compensator. Derive its transfer function and show that the numerator is of the form $s^2 + 2\zeta\omega_0 s + \omega_0^2$ where $\omega_0 = \frac{1}{C\sqrt{R_1 R_2}}$ and $\zeta = \sqrt{\frac{R_1}{R_2}}$. **(8)**

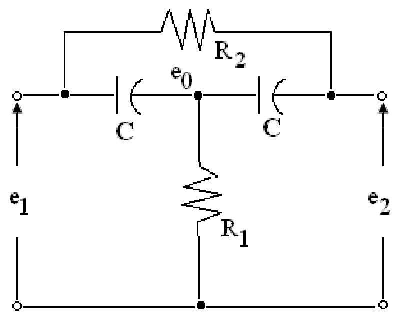

Fig.12

Q.7 a. Sketch the Nyquist plot for $G(s)H(s) = \frac{1}{s(s+1)}$ and determine the stability of the system. **(8)**

b. Draw on a graph sheet the frequency response plot in Nichols coordinate system using the following data:

Frequency, ω, rad/s $\Rightarrow$	0.2	0.5	0.78	1.25	2.2	3.0
Gain, dB $\Rightarrow$	15	5	0	-7	-15	-21
Phase, deg $\Rightarrow$	-110	-120	-140	-160	-180	-190

Determine the gain-crossover frequencies, phase-crossover frequencies, phase-margin and gain-margin. **(8)**

Q.8 a. Draw the circuit of a lead compensator using opamp satisfying $D(s) = \frac{16(s+1)}{(s+6)}$. Calculate the values of the circuit elements. **(6)**

b. Explain how the use of digital control (i.e. use of digital computer as a compensator device) overcomes limitations of analog control. **(6)**

c. What is robust control system? **(4)**

Q.9 a. Draw Bode plot on a semilog graph sheet for the system $G(s) = \frac{9.7}{s(0.046s+1)}$ with $\omega_{ref} = 1\,\text{rad/s}$. Find the phase-margin. **(8)**

b. Discuss the effects and limitations of phase lead compensation **(8)**