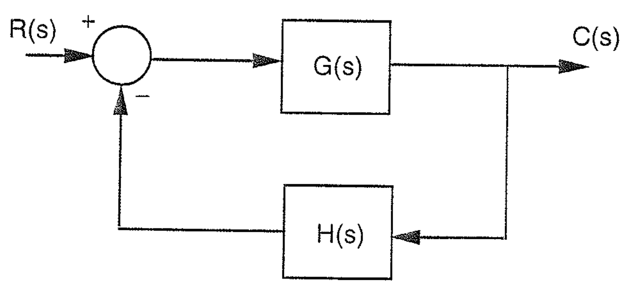
AC-1
August 2009 QE

Answer all six questions.
Use the Table at the end of the exam for some of your calculations.

(I) Multiple Choice Questions. [**2 points each; 20 points total**]

For this question, you are advised to write down your answer on the question sheets and then transfer your answer to your answer book.

Consider the feedback control system shown below.



______ (1) The roots of the characteristic equation $1 + G(s)H(s) = 0$ are
(A) the open-loop zeros of the system
(B) the open-loop poles of the system
(C) the closed-loop zeros of the system
(D) the closed-loop poles of the system
(E) None of the above.

______ (2) The poles of the characteristic equation $1 + G(s)H(s) = 0$ are
(A) the open-loop zeros of the system
(B) the open-loop poles of the system
(C) the closed-loop zeros of the system
(D) the closed-loop poles of the system
(E) None of the above.

______ (3) The zeros of the characteristic equation $1 + G(s)H(s) = 0$ are
(A) the open-loop zeros of the system
(B) the open-loop poles of the system
(C) the closed-loop zeros of the system
(D) the closed-loop poles of the system
(E) None of the above.

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________ (4) Root locus is a graphical plot of the < A or B > of $1+G(s)H(s)=0$ as an unknown parameter K changes from zero to infinity.

(A) poles

(B) zeros

________ (5) If a phase-lag compensator is added to the above system, then the performance of the compensated system will improve in

(A) Transient response
(B) Steady-state error
(C) Bandwidth
(D) All (A), (B) and (C)
(E) Both (A) and (B)
(F) Both (B) and (C)
(G) Both (A) and (C)
(H) None of the above.

________ (6) If a phase-lead compensator is added to the above system, then the performance of the compensated system will improve in

(A) Transient response
(B) Steady-state error
(C) Bandwidth
(D) All (A), (B) and (C)
(E) Both (A) and (B)
(F) Both (B) and (C)
(G) Both (A) and (C)
(H) None of the above.

________ (7) A phase-lag compensator compensates the uncompensated system primarily by

(A) cutting the gain around the mid- to high frequencies

(B) increasing the gain around the mid- to high frequencies

(C) providing necessary negative phase angle to the uncompensated system at ω_m

(D) providing necessary positive phase angle to the uncompensated system at ω_m

(E) None of the above.

________ (8) A phase-lead compensator compensates the uncompensated system primarily by

(A) cutting the gain around the mid- to high frequencies

(B) increasing the gain around the mid- to high frequencies

(C) providing necessary negative phase angle to the uncompensated system at ω_m

(D) providing necessary positive phase angle to the uncompensated system at ω_m

(E) None of the above.

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______ (9) The open-loop transfer function of the system is

(A) $G(s)$ (B) $G(s)H(s)$ (C) $\dfrac{G(s)}{1+G(s)}$

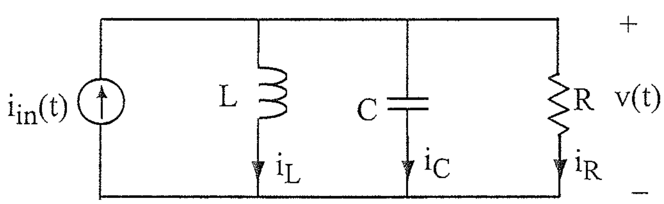
(D) $\dfrac{G(s)}{1+G(s)H(s)}$ (E) $\dfrac{1}{1+G(s)H(s)}$ (F) None of the above.

______ (10) The feedforward transfer function of the system is

(A) $G(s)$ (B) $G(s)H(s)$ (C) $\dfrac{G(s)}{1+G(s)}$

(D) $\dfrac{G(s)}{1+G(s)H(s)}$ (E) $\dfrac{1}{1+G(s)H(s)}$ (F) None of the above.

(II) Given the RLC circuit shown below. [**10 points total**]



(A) Draw a block diagram of the system with $I_{in}(s)$ as input and $I_R(s)$ as output. Do not simplify or reduce your block diagram, and each electrical component should be represented by a single block. [**8 points**]

(B) Find the overall transfer function $\dfrac{I_R(s)}{I_{in}(s)}$ from your block diagram. Express the transfer function in terms of R, L, C components. [**2 points**]

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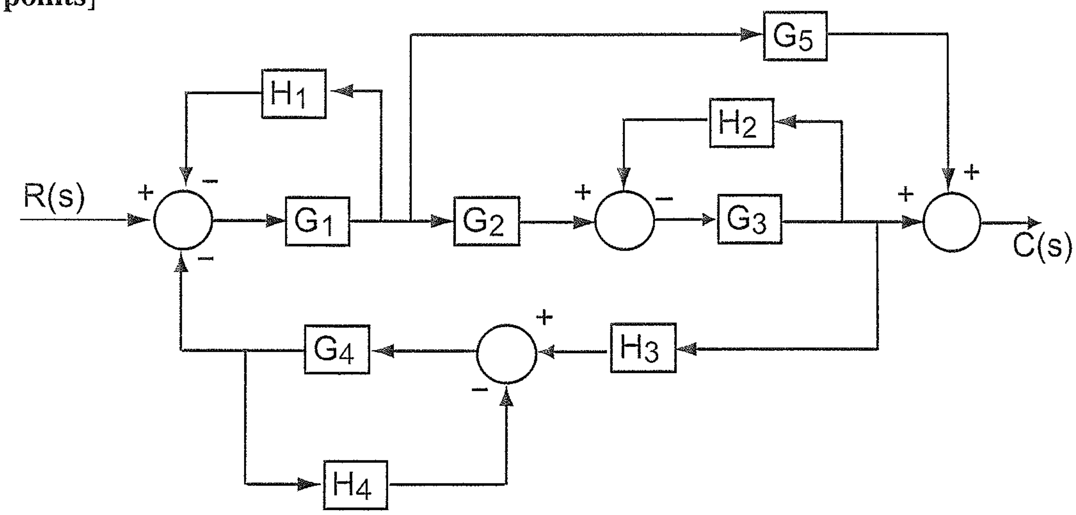
(III) Determine the transfer function $\frac{C(s)}{R(s)}$ for the block diagram shown below using the Mason gain formula. (No block diagram reduction before applying the Mason Gain Formula). [**10 points**]



(IV) For a negative unity feedback control system with [**25 points total**]

$$G(s) = \frac{5(K+s)}{s^2(s+4)},$$

(A) Location of open-loop poles (if none, state none) ____________________

Location of open-loop zeros (if none, state none) ____________________

Draw the root locus for $K > 0$. [**10 points**]

(B) Determine any breakaway and/or breakin points, if any. (If none, state none!) [**5 points**]

(C) Determine the angle of departure/arrival, if any. (If none, state none!) Some trigonometric function values are given at the end of the exam question. [**5 points**]

(D) Determine the value of K and the frequency at which the loci cross the $j\omega$-axis, if any. (If none, state none!) [**5 points**]

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(V) Given a negative unity feedback control system with $G(s)$ as

$$G(s) = \frac{K}{s(s+2)(s+3)}$$

The input $r(t) = [1+3t]u(t)$ is applied to the system, where $u(t)$ is a unit step function. Determine the minimum steady-state error that the system can achieve. **[10 points]**

(VI) Given a negative unity feedback control system with **[25 points total]**

$$G(s) = \frac{K(s+1)^2}{s^3}$$

(A) Sketch the *complete* Nyquist plot. In your plot, indicate where are $\omega = 0^+$, $\omega = 0^-$, $\omega = +\infty$, and $\omega = -\infty$. **[15 points]**

(B) What is the gain margin when $K = 1$ (expressed as a number)? **[10 points]**

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Some Calculated Values

Trigonometric Function Values	Other Function Values
$\tan^{-1}(\frac{1}{4}) = 14.04°$	$\sqrt{2} = 1.41$
$\tan^{-1}(\frac{1}{3}) = 18.43°$	$\sqrt{3} = 1.73$
$\tan^{-1}(\frac{1}{2}) = 26.57°$	$\sqrt{5} = 2.24$
$\tan^{-1}(\frac{2}{3}) = 33.69°$	$\sqrt{6} = 2.45$
$\tan^{-1}(\frac{3}{4}) = 36.87°$	$\sqrt{7} = 2.65$
$\tan^{-1}(1) = 45°$	$\sqrt{8} = 2.83$
$\tan^{-1}(2) = 63.43°$	$\sqrt{10} = 3.16$
$\tan^{-1}(3) = 71.57°$	$\sqrt{11} = 3.32$
$\tan^{-1}(4) = 75.96°$	$\sqrt{12} = 3.46$
$\tan^{-1}(5) = 78.69°$	$\sqrt{13} = 3.61$
$\tan^{-1}(6) = 80.54°$	$\sqrt{14} = 3.74$
$\tan^{-1}(7) = 81.87°$	$\frac{1}{6} = 0.167$
$\tan^{-1}(8) = 82.87°$	$\frac{1}{7} = 0.143$
$\tan^{-1}(9) = 83.66°$	$\frac{1}{8} = 0.125$
$\tan^{-1}(10) = 84.29°$	$\frac{1}{9} = 0.111$
$\tan^{-1}(15) = 86.19°$	$\frac{1}{12} = 0.0833$
$\tan^{-1}(20) = 87.14°$	$\frac{1}{13} = 0.0769$
$\tan^{-1}(30) = 88.09°$	$\frac{1}{14} = 0.0714$