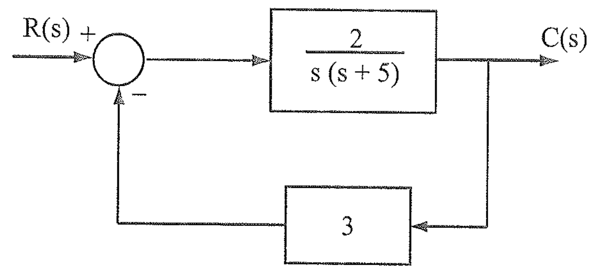
AC-1
August 2011 QE

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

(I) Consider the feedback control system shown below, where $R(s)$ is the input and $C(s)$ is the output of the system. [**10 points total**]



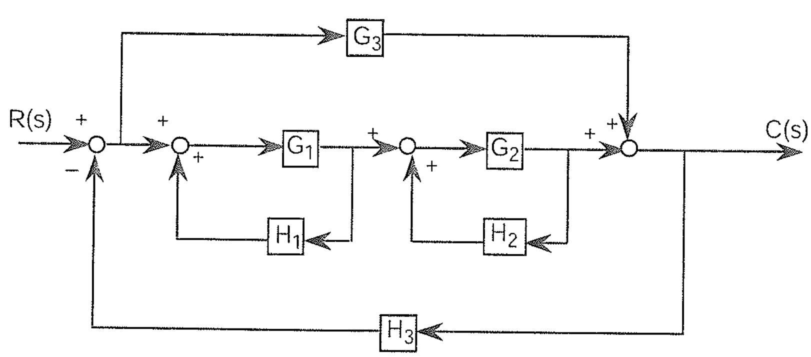
(A) The open-loop transfer function is ______________________

(B) The feedforward transfer function is ______________________

(C) The closed-loop transfer function is ______________________

(D) Find the differential equation relating $c(t)$ and $r(t)$. [**5 points**]

(II) Using the Mason's gain formula, determine the overall transfer function $\frac{C(s)}{R(s)}$ of the system shown below. (No block diagram reduction before applying the Mason's gain formula.) [**15 points**]



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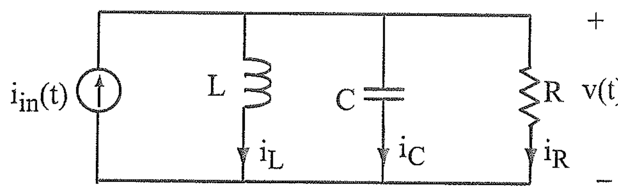
(III) Given a negative unity feedback control system with

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

An input $r(t) = (4+2t)u(t)$ is applied to the system, where $u(t)$ is a unit step function. It is desired that the steady-state error be equal to or less than 0.1 for the given input $r(t)$. Determine the minimum value that K must have to satisfy this requirement. [**15 points**]

(IV) Given an RLC circuit as shown below with $i_{in}(t)$ as input and $v(t)$ as output.



(A) Draw a block diagram of the system with $I_{in}(s)$ as input and $V(s)$ as output. Do not simplify or reduce your block diagram, and *each electrical component should be represented by a single block.* [**10 points**]

(B) Find the overall transfer function $\frac{V(s)}{I_{in}(s)}$ from your block diagram in (A). Express the transfer function in terms of R, L, C components. [**5 points**]

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

$$G(s) = \frac{K}{s(s^2+6s+10)}$$

(A) Sketch the root locus for $K > 0$. [**10 points**]

(B) Determine the 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**]

(VI) Given a negative unity feedback control system with

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

(A) Sketch the *complete* Nyquist plot. In your plot, indicate where are $\omega = 0^+$, $\omega = 0^-$, $\omega = +\infty$, and $\omega = -\infty$.[**10 points**]

(B) Determine the range of K for which the system is stable, using ONLY the concept from the Nyquist Stability Criterion (i.e., from the crossing of the negative real-axis of the $G(j\omega)$-plane). [**10 points**]

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Some Calculated Values

Trigonometric Function Values	Other Function Values
$\tan^{-1}(\frac{1}{4}) = 14.04°$	$\sqrt{2} = 1.41$
$\tan^{-1}(\frac{1}{3}) = 18.43°$	$\sqrt{3} = 1.73$
$\tan^{-1}(\frac{1}{2}) = 26.57°$	$\sqrt{5} = 2.24$
$\tan^{-1}(\frac{2}{3}) = 33.69°$	$\sqrt{6} = 2.45$
$\tan^{-1}(\frac{3}{4}) = 36.87°$	$\sqrt{7} = 2.65$
$\tan^{-1}(1) = 45°$	$\sqrt{8} = 2.83$
$\tan^{-1}(2) = 63.43°$	$\sqrt{10} = 3.16$
$\tan^{-1}(3) = 71.57°$	$\sqrt{11} = 3.32$
$\tan^{-1}(4) = 75.96°$	$\sqrt{12} = 3.46$
$\tan^{-1}(5) = 78.69°$	$\sqrt{13} = 3.61$
$\tan^{-1}(6) = 80.54°$	$\sqrt{14} = 3.74$
$\tan^{-1}(7) = 81.87°$	$\frac{1}{6} = 0.167$
$\tan^{-1}(8) = 82.87°$	$\frac{1}{7} = 0.143$
$\tan^{-1}(9) = 83.66°$	$\frac{1}{8} = 0.125$
$\tan^{-1}(10) = 84.29°$	$\frac{1}{9} = 0.111$
$\tan^{-1}(15) = 86.19°$	$\frac{1}{12} = 0.0833$
$\tan^{-1}(20) = 87.14°$	$\frac{1}{13} = 0.0769$
$\tan^{-1}(30) = 88.09°$	$\frac{1}{14} = 0.0714$
$\tan(10) = 0.1763$	$\tan(15) = 0.2679$
$\tan(20) = 0.3640$	$\tan(25) = 0.4663$
$\tan(30) = 0.5774$	$\tan(35) = 0.7002$
$\tan(40) = 0.8391$	$\tan(45) = 1.0000$
$\tan(50) = 1.1918$	$\tan(55) = 1.4281$
$\tan(60) = 1.7321$	$\tan(65) = 2.1445$
$\tan(70) = 2.7475$	$\tan(75) = 3.73205$
$\tan(80) = 5.6713$	$\tan(85) = 11.4300$