NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING

DEPARTMENT OF INDUSTRIAL AND MANUFACTURING ENGINEERING

Bachelor of Engineering Honours Degree Industrial and Manufacturing Engineering

INDUSTRIAL INSTRUMENTATION AND CONTROL II

TIE3214

Second Semester Special Supplementary Examination Paper

August 2024

This examination paper consists of 6 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Semi-log paper & graph paper

Examiner's Name: Eng G Kanyemba

INSTRUCTIONS AND INFORMATION TO CANDIDATE

1. This question paper contains six (6) questions
2. Answer any four (4) questions.
3. Each question carries 25 marks.
4. Use of calculators is permissible.

Question 1

(a) Figure Q1.1 shows an RCL circuit with a resistor with resistance R, inductor with inductance L and capacitor with capacitance C. Formulate the differential equation relating the potential differences $v_1(t)$ and $v_2(t)$. [15]

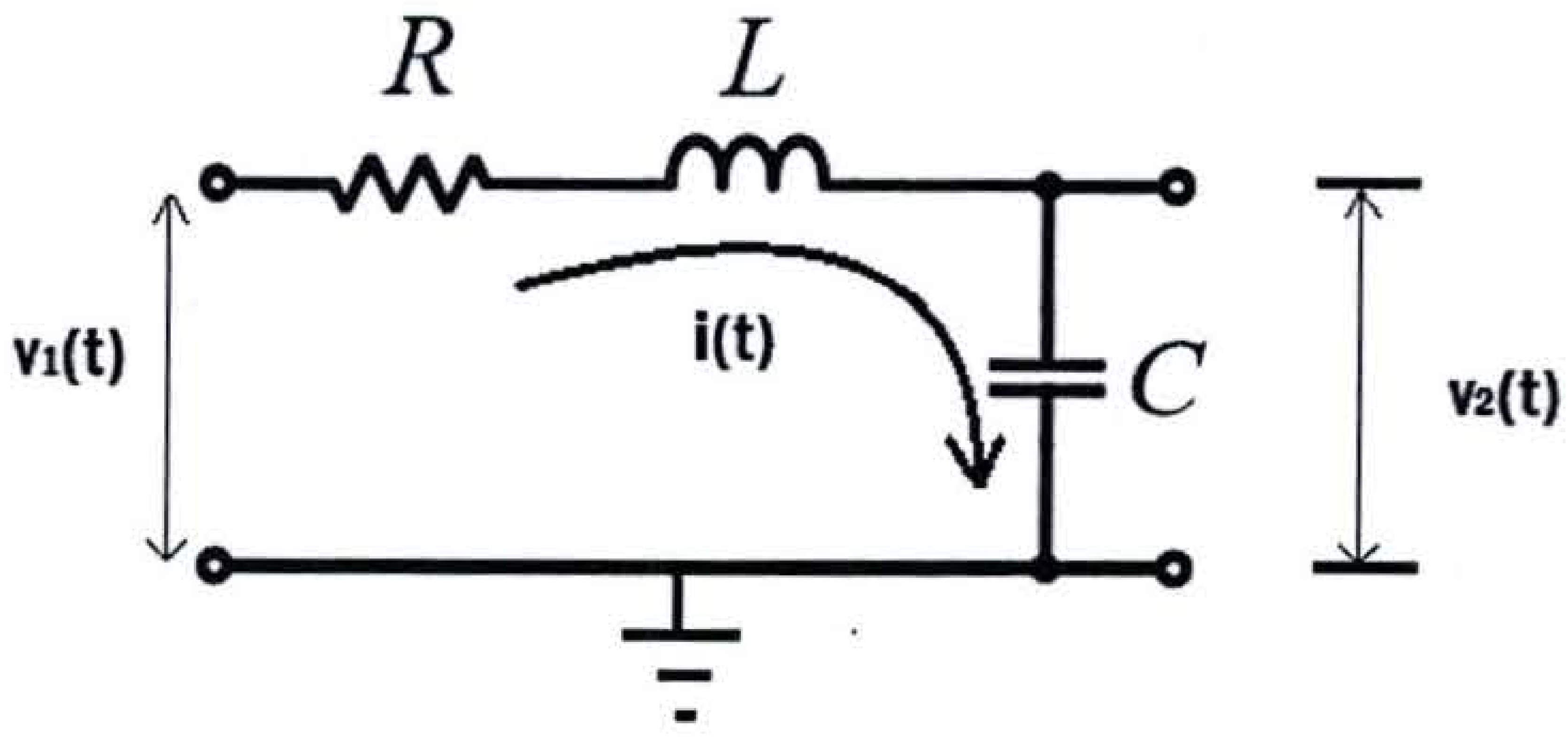

Figure Q1.1 RLC Circuit

(b) State the following theorems:-

(i) Initial Value Theorem. [2]

(ii) Final Value Theorem. [2]

(c) Given the system in Figure Q1.2, where R(s) is the input signal, E(s) is the error signal and Y(s) is the output signal.

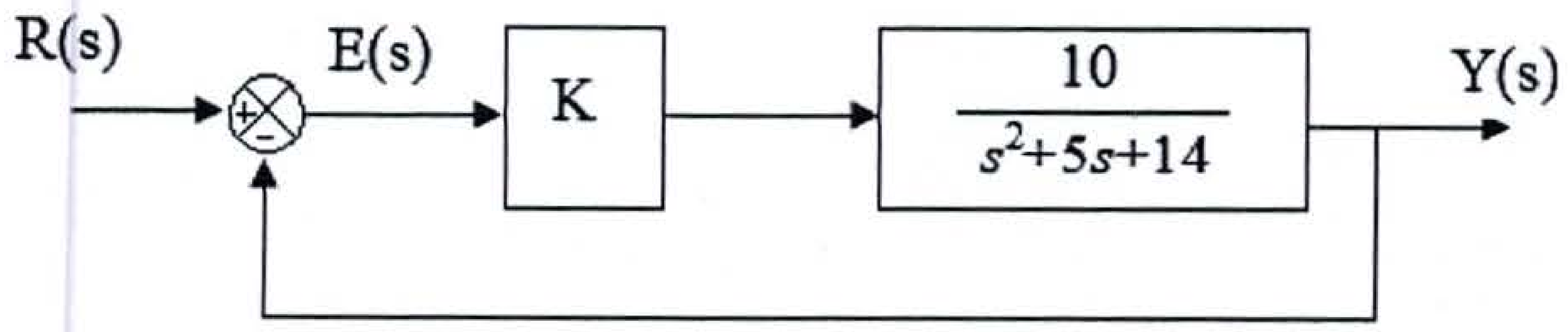

Figure Q1.2 Control System

(i) What is the closed-loop transfer function of the system? [4]

(ii) Calculate the value of the controller gain K required to achieve a steady error of $e_{ss} \leq 0.2$ to a unit step input? [2]

Question 2

(a) Compute the initial and final values of the transfer function X(s) below

$$X(s) = \frac{808}{s(s^2+2s+101)}$$ [8]

(b) With the aid of a clearly labelled diagram explain a transient error and a steady state error. [7]

(c) Calibration of industrial instruments is of great importance as far as quality control is concerned. Discuss. [10]

Question 3

(a) State any two challenges associated with thermostatic control. [2]
(b) Compute the transfer function of the system shown in Figure Q3 by reduction. [15]

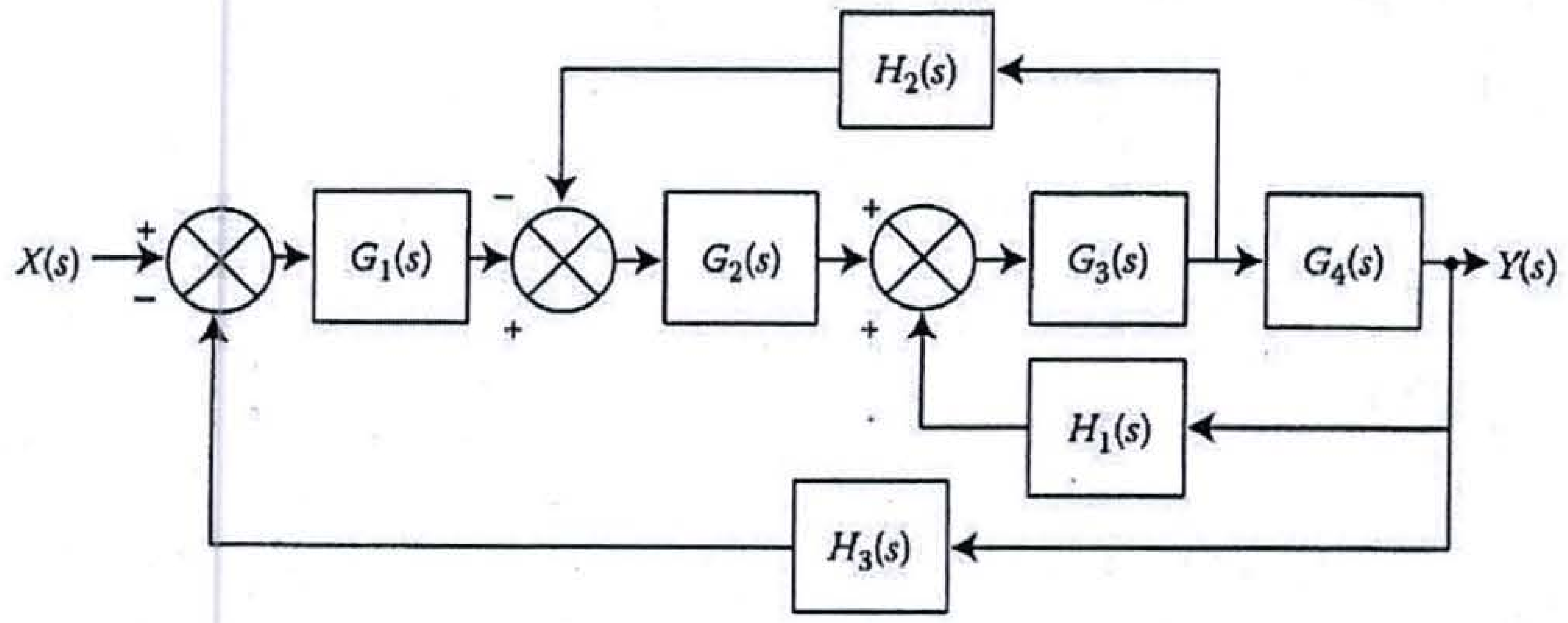

Figure Q3: System with interconnected loops

(c) Find the inverse Laplace function corresponding to the following transform

$$F(s) = \frac{32}{(s^2+12s+32)}$$ [8]

Question 4

(a) The root locus method is a very powerful tool that is used when designing a compensator for a control system. Explain the root locus method. [5]

(b) Given that that $G(s) = \frac{(s+3)}{(s+1)(s+2)(S+4)}$, sketch the root locus diagram for the system.[20]

Question 5

The transfer function of a system, G(s), is given as

$$G(s) = \frac{2s + 1}{(s + 1)(s + 4)(s + 6)}$$

(a) Determine the poles and zeros of the system. [5]
(b) Use the Routh-Hurwitz stability to determine the stability of the system. [20]

Question 6

(a) Draw the bode plot for the system whose transfer function G(s) is given as

$$G(s) = \frac{20000}{(s+3)(s+20)(s+70)}$$

[15]

(b) On the plot show clearly

(i) The gain crossover frequency [2]

(ii) The gain margin [2]

(iii) The phase crossover frequency [2]

(iv) The phase margin [2]

(v) Determine from the plot if the system is stable [2]

End of examination paper.

APPENDICES

Appendix A: Common Laplace transform pairs

	Time function $f(t)$	*Laplace transform* $\mathscr{L}[f(t)] = F(s)$
1	unit impulse $\delta(t)$	1
2	unit step 1	$1/s$
3	unit ramp t	$1/s^2$
4	t^n	$\frac{n!}{s^{n+1}}$
5	e^{-at}	$\frac{1}{(s+a)}$
6	$1 - e^{-at}$	$\frac{a}{s(s+a)}$
7	$\sin \omega t$	$\frac{\omega}{s^2 + \omega^2}$
8	$\cos \omega t$	$\frac{s}{s^2 + \omega^2}$
9	$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2 + \omega^2}$
10	$e^{-at}(\cos \omega t - \frac{a}{\omega} \sin \omega t)$	$\frac{s}{(s+a)^2 + \omega^2}$

(c) Constant multiplication

$$\mathscr{L}[af(t)] = aF(s)$$

(d) Real shift theorem

$$\mathscr{L}[f(t-T)] = e^{-Ts}F(s) \quad \text{for} \quad T \geq 0$$

(e) Convolution integral

$$\int_0^t f_1(\tau)f_2(t-\tau)d\tau = F_1(s)F_2(s)$$

(f) Initial value theorem

$$f(0) = \lim_{t \to 0} [f(t)] = \lim_{s \to \infty} [sF(s)]$$

(g) Final value theorem

$$f(\infty) = \lim_{t \to \infty} [f(t)] = \lim_{s \to 0} [sF(s)]$$

Appendix B: Common partial fraction expressions

(i) Factored roots

$$\frac{K}{s(s+a)}=\frac{A}{s}+\frac{B}{(s+a)}$$

(ii) Repeated roots

$$\frac{K}{s^2(s+a)}=\frac{A}{s}+\frac{B}{s^2}+\frac{C}{(s+a)}$$

(iii) Second-order real roots ($b^2 > 4ac$)

$$\frac{K}{s(as^2+bs+c)}=\frac{K}{s(s+d)(s+e)}=\frac{A}{s}+\frac{B}{(s+d)}+\frac{C}{(s+\mathrm{e})}$$

(iv) Second-order complex roots ($b^2 < 4ac$)

$$\frac{K}{s(as^2+bs+c)}=\frac{A}{s}+\frac{Bs+C}{as^2+bs+c}$$

Completing the square gives

$$\frac{A}{s}+\frac{Bs+C}{(s+\alpha)^2+\omega^2}$$

Note: In (iii) and (iv) the coefficient a is usually factored to a unity value.

Semi-log paper

1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1

Semi-log paper

1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 1