**THE HONG KONG POLYTECHNIC UNIVERSITY**

**DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING**

| | | | | | |
|---|---|---|---|---|---|
| **Subject Code** | : | EE3005/EE3005A/EE3005B | | | |
| **Subject Title** | : | Systems and Control | | | |
| **Session** | : | Semester 1, 2023/24 | **Venue** | : | SH2 |
| **Date** | : | 15 December 2023 | **Time** | : | 08:45 – 11:45 |
| **Time Allowed** | : | 3 Hours | **Subject Examiner(s)** | : | Dr N.C. Cheung |

**This question paper has a total of 8 pages (attachments included).**

**Instructions to Candidates**: Answer ALL Questions

**Physical Constants**: Nil

**Other Attachments**: Reference Formulae
Lin-Log Graph Paper (2 pages)

**Available from Invigilator**: Lin-Log Graph Paper

**DO NOT TURN OVER THE PAGE UNTIL YOU ARE TOLD TO DO SO.**

**Question 1 – Laplace Transform (10 marks)**

For the equation listed below, expand *Y(s)* into a partial fraction expression, hence find its *y(t)*, by using Laplace inverse transform.

$$Y(s) = \frac{s^2 + 9s + 19}{(s+1)(s+2)(s+4)}$$

**Question 2 – System Block Diagrams (10 marks)**

For the system block diagram shown in Fig. Q2(a), convert it into the form shown in Fig. Q2(b), and find the expressions of *X(s)* and *Y(s)*.

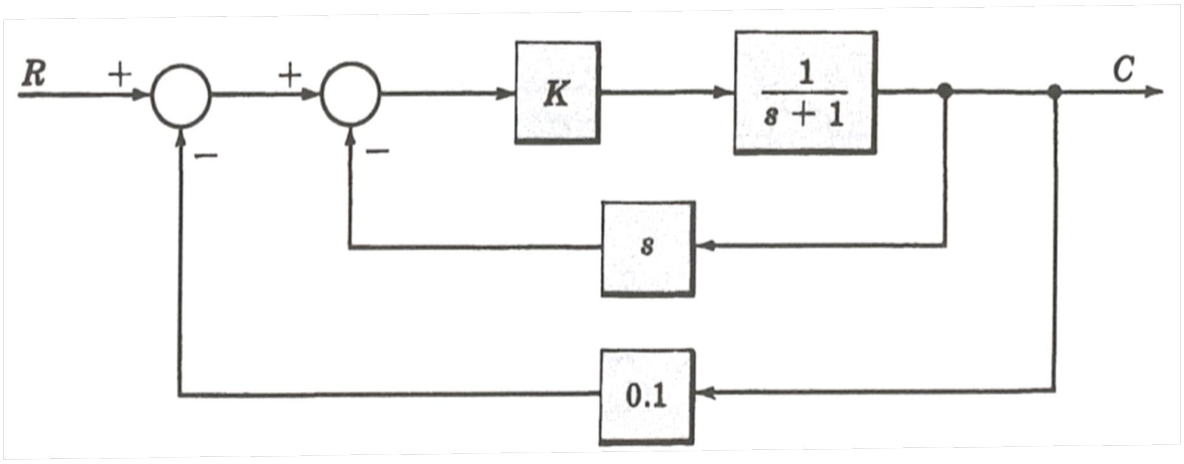


Fig. Q2(a)

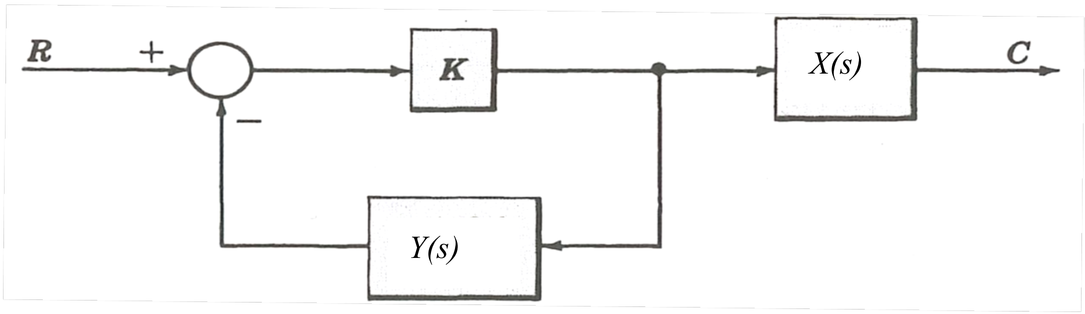


Fig. Q2(b)

**Question 3 – Signal Flow Graphs (10 marks)**

Determine the transfer function of the signal flow graph shown in Fig. Q3, by using the General Gain Formula.

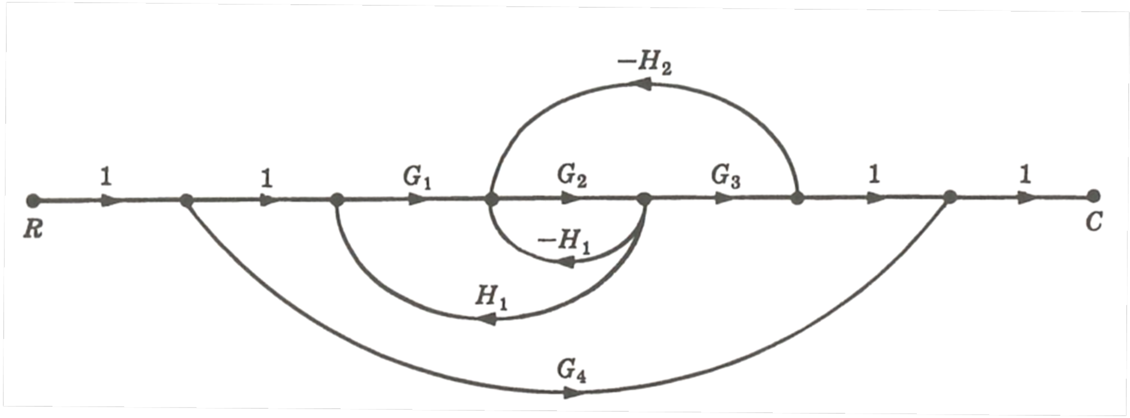


Fig. Q3

**Question 4 – Analogue Simulation (10 marks)**

Implement the control block diagram shown in Fig. Q4, into an analogue simulation circuit. Your answer should include values of all electronic components.

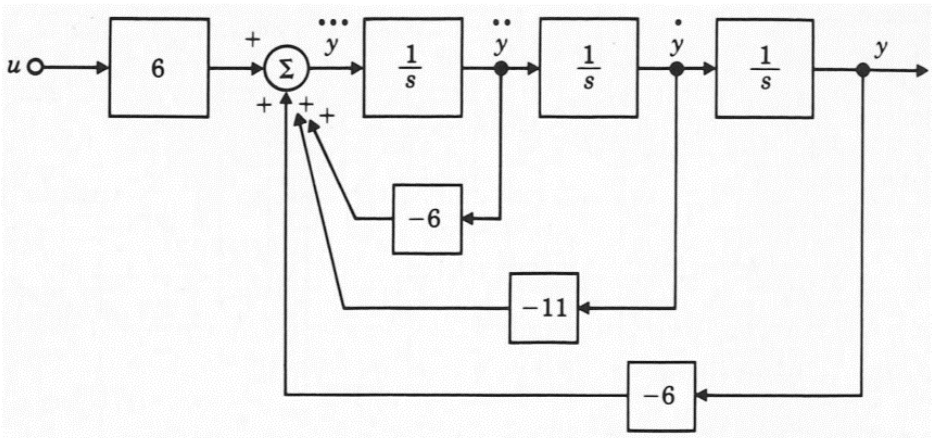


Fig. Q4

**Question 5 – Modelling (10 marks)**

Fig. Q5 shows the diagrams of a mechanical system and an electrical system. By comparing the system force/voltage equations of these two systems, explain how these two systems are analogous to each other.

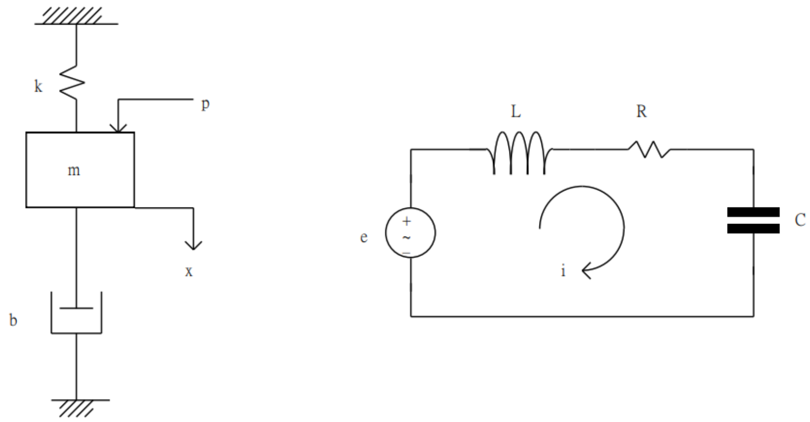


Fig. Q5

**Question 6 – Transient and Steady State Analysis (10 marks)**

A second-order system is subject to a unit step input. Regarding the output of this response, explain the following terms:

i. Delay time
ii. Rise time
iii. Peak time
iv. Maximum overshoot
v. Settling time

Use a graph to support your explanation.

**Question 7 – PID Control (10 marks)**

List out the step-to-step procedure of obtaining the tuning values of the PID controller, by using the Ziegler-Nichols Transient Response Method.

**Question 8 – Bode Plot (10 marks)**

By using the lin-log graph paper, plot the magnitude and phase Bode plots for the following function:

$$GH(s) = \frac{10(1 + j\omega)}{(j\omega)^2\left(1 + \frac{j\omega}{4}\right)}$$

**Question 9 – Bode Design (10 marks)**

By using two sets of gain/phase plots, explain the differences between the gain and phase margins of a stable system and an unstable system.

**Question 10 – State Space Analysis (10 marks)**

Use a flow diagram to explain the differences between the first (observable) canonical form and the second (controllable) canonical form, and the relationships between them.

**- End of Questions -**

| Time function $f(t)$ | | Laplace transform $L[f(t)]=F(s)$ |
|---|---|---|
| 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 | $e^{-at}\cos \omega t$ | $\frac{s+a}{(s+a)^2+\omega^2}$ |

Derivatives: The Laplace transform of a time derivative is

$$\frac{d^n}{dt^n}f(t) = s^nF(s) - f(0)s^{n-1} - f'(0)s^{n-2} - \cdots$$

Where $f(0)$, $f'(0)$ are the initial conditions, or the values of $f(t)$, d/d$t$ $f(t)$ etc. at $t = 0$

Definite integral $L[\int_{0-}^{t} f(t) \cdot dt] = \frac{F(s)}{s}$

Time delay $L[f(t-T)] = e^{-sT}F(s)$

Linearity $L[f_1(t) \pm f_2(t)] = F_1(s) \pm F_2(s)$

Constant multiplication $L[af(t)] = aF(s)$

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

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

For a system with transfer function $\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$ and accepting a unit step input:

the approximate 5% settling time is $3/(\zeta\omega_n)$ if $\zeta$ is small,

the first peak time is $\frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$ if $\zeta<1$,

the maximum percentage overshoot is $e^{-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}} \times 100\%$

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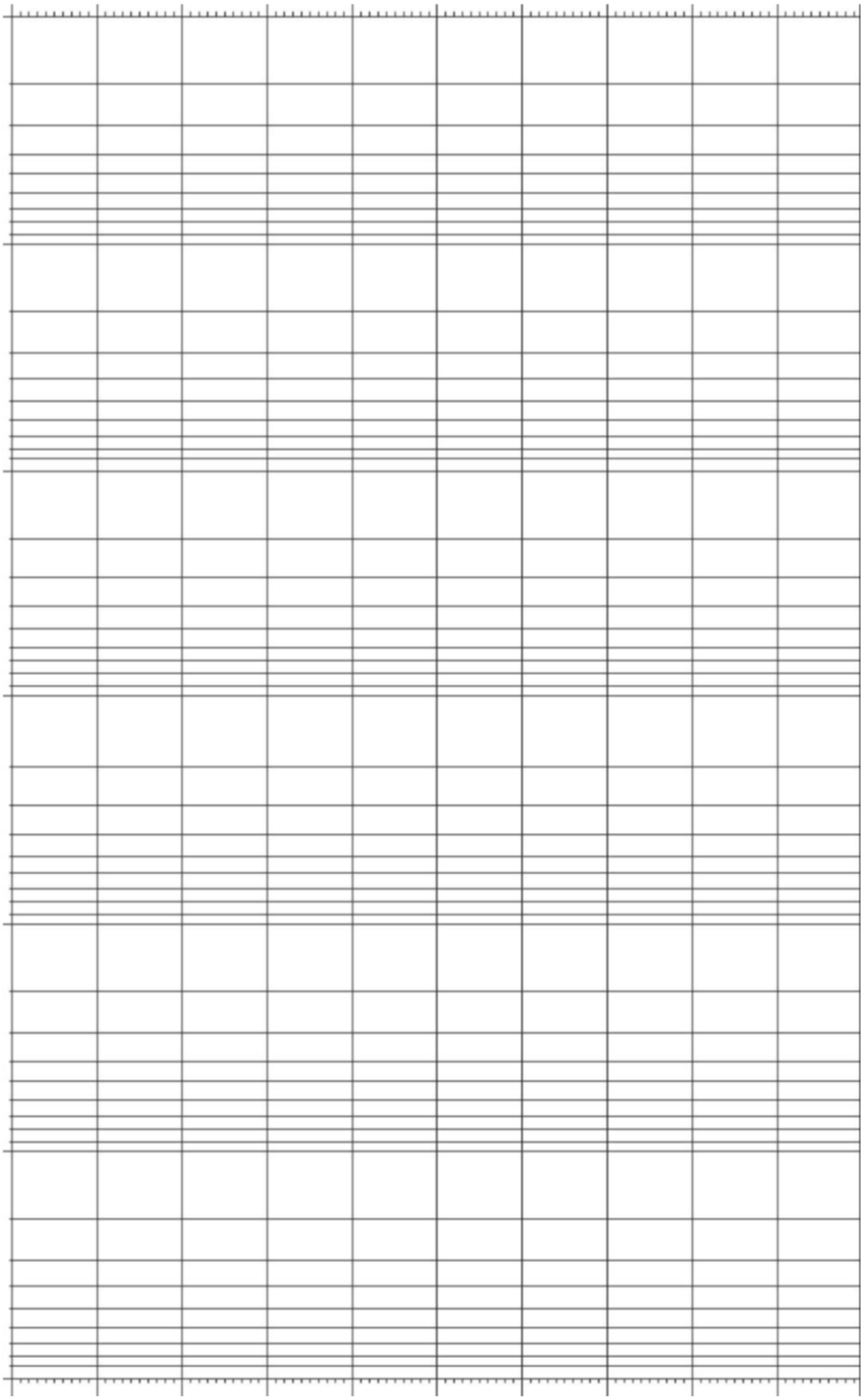

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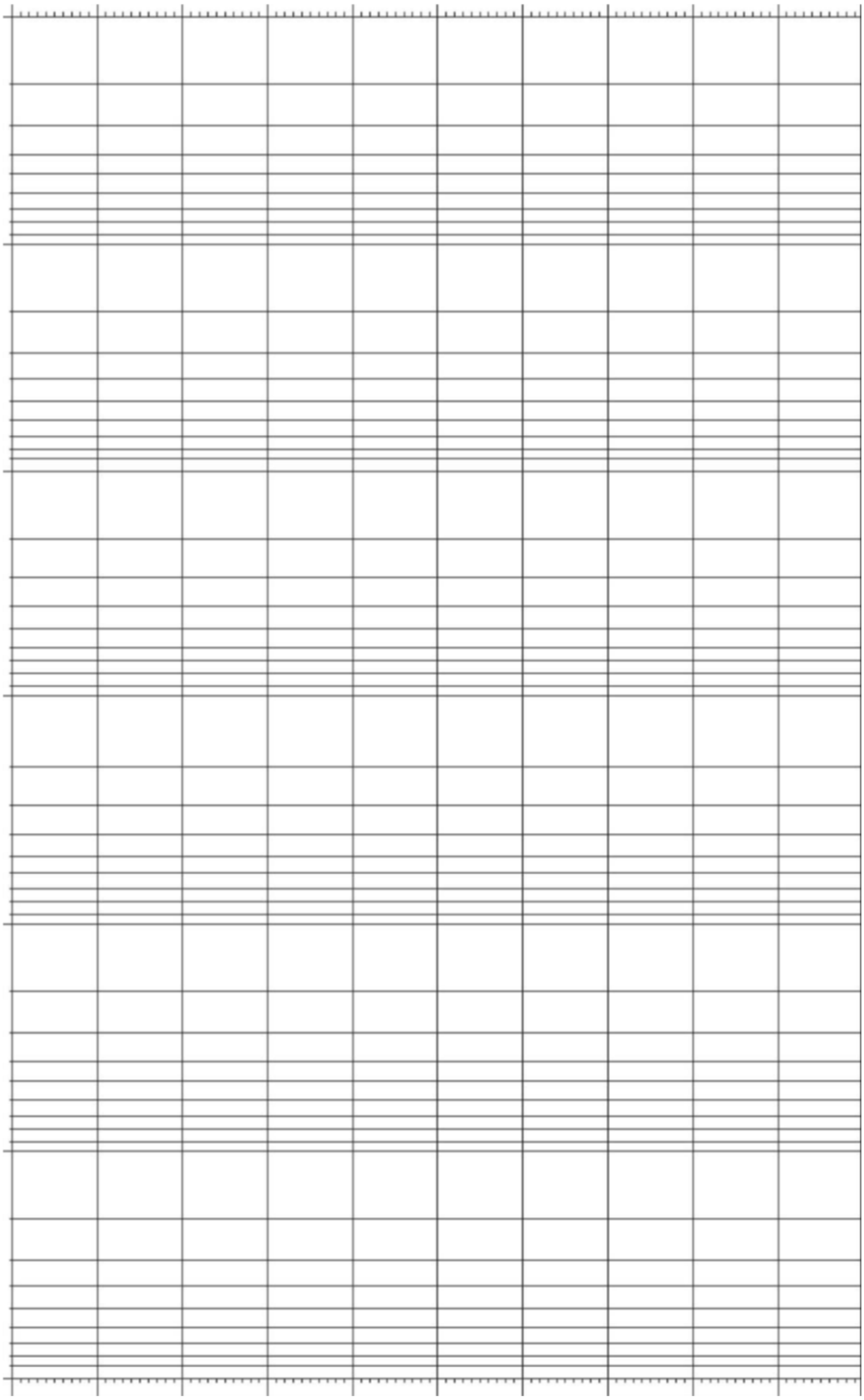

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