UNIVERSITY OF GRONINGEN WMBE024-05

SEMESTER 1 ASSESSMENT PAPER 2023/2024

CONTROL ENGINEERING

DURATION – 2 hours

This paper contains four questions.

All answers must be in separate answer books.

Answer **ALL** questions**.**

An outline marking scheme is shown in brackets to the right of each question.

Linear-Logarithmic Graph Paper is provided with this examination paper.

A table of Laplace Transforms is given at the end of this examination paper.

Only University approved calculators may be used.

Q1.

Consider a two-degree-of-freedom mechanical system shown in Figure Q1.

(a) Write the dynamic equations for the mechanical system.

[8]

(b) Show that the transfer function between the input $f(t)$ and the output $x_2(t)$ using Laplace transform is $\frac{k}{s(mc\,s^2+mk\,s+kc)}$ when initial conditions are zero.

[8]

(c) Find the time response $x_2(t)$ to a unit impulse input $f(t) = \delta(t)$ using inverse Laplace transform with zero initial conditions when $m = 1\text{kg}$, $c = 1Ns/\text{m}$ and $k = 4\text{N/m}$.

[9]

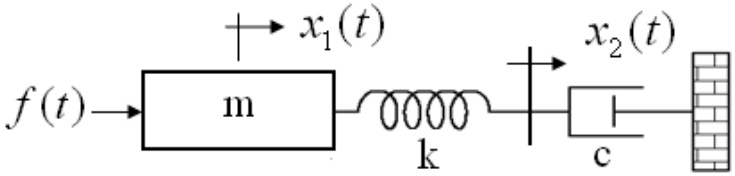


Figure Q1

[Total: 25 marks]

Q2.

Consider the block diagram shown in Figure Q2.

(a) Simplify the block diagram and obtain the closed-loop transfer function $\frac{Y(s)}{R(s)}$.

[6]

(b) Use the Routh-Hurwitz criterion to find the range of K for which the closed-loop system is stable.

[5]

(c) Calculate the natural frequency and the peak time $t_p = \frac{\pi}{\omega_d}$ when $K = 8$.

[5]

(d) Sketch the root locus for the open-loop transfer function $\frac{K}{(s+5)(s+10)}$ when K varies from zero to infinity.

[9]

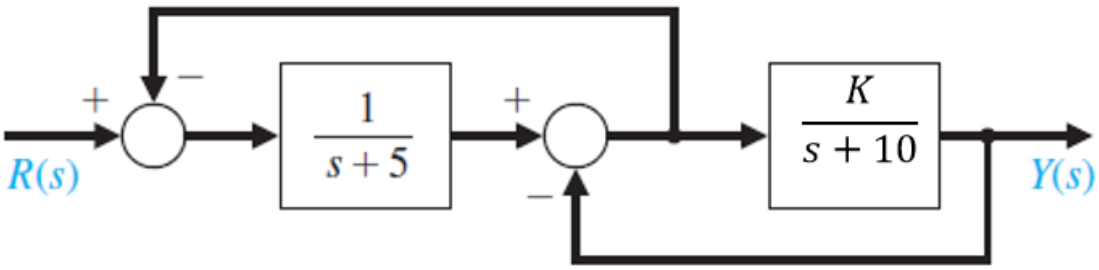


Figure Q2

[Total: 25 marks]

Q3.

Consider the unity feedback system shown in Figure Q3. The transfer function for the plant is $G(s)=\dfrac{(s+2)}{s(s+1)(s+10)}$.

(a) Determine the value of gain K such that the steady state error to a unit ramp input is equal to 0.01.

[5]

(b) Find the value of K such that one of the closed-loop pole is at $s=-5$.

[4]

(c) Draw the magnitude and phase of the Bode plot for the open-loop transfer function $KG(s)$ when $K=1$.

[16]

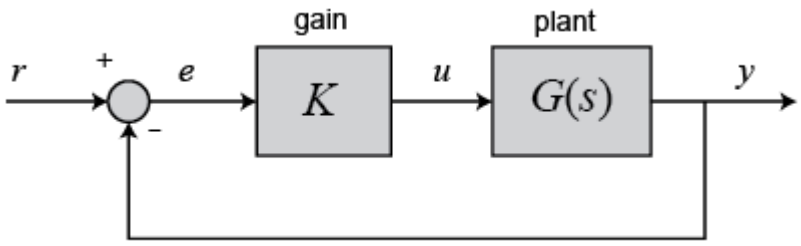


Figure Q3

[Total: 25 marks]

Q4.

Consider an electrical system shown in Figure Q4.

(a) Write the equations of motion for the system and plot the block diagram for the differential equations.

[10]

(b) Write the equations of motion in the state-space form using the state vector $\begin{bmatrix} q_1 \\ q_2 \\ \dot{q}_1 \\ \dot{q}_2 \end{bmatrix}$ where the charge is $q(t) = \frac{di(t)}{dt}$, and $i(t)$ is the current.

[10]

(c) Write the equation for the output voltage across the resistor $V_O(s)$ in the state space form using the state vector as above.

[5]

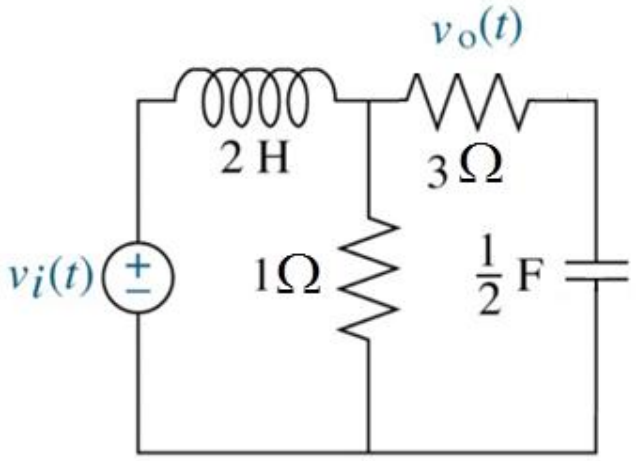
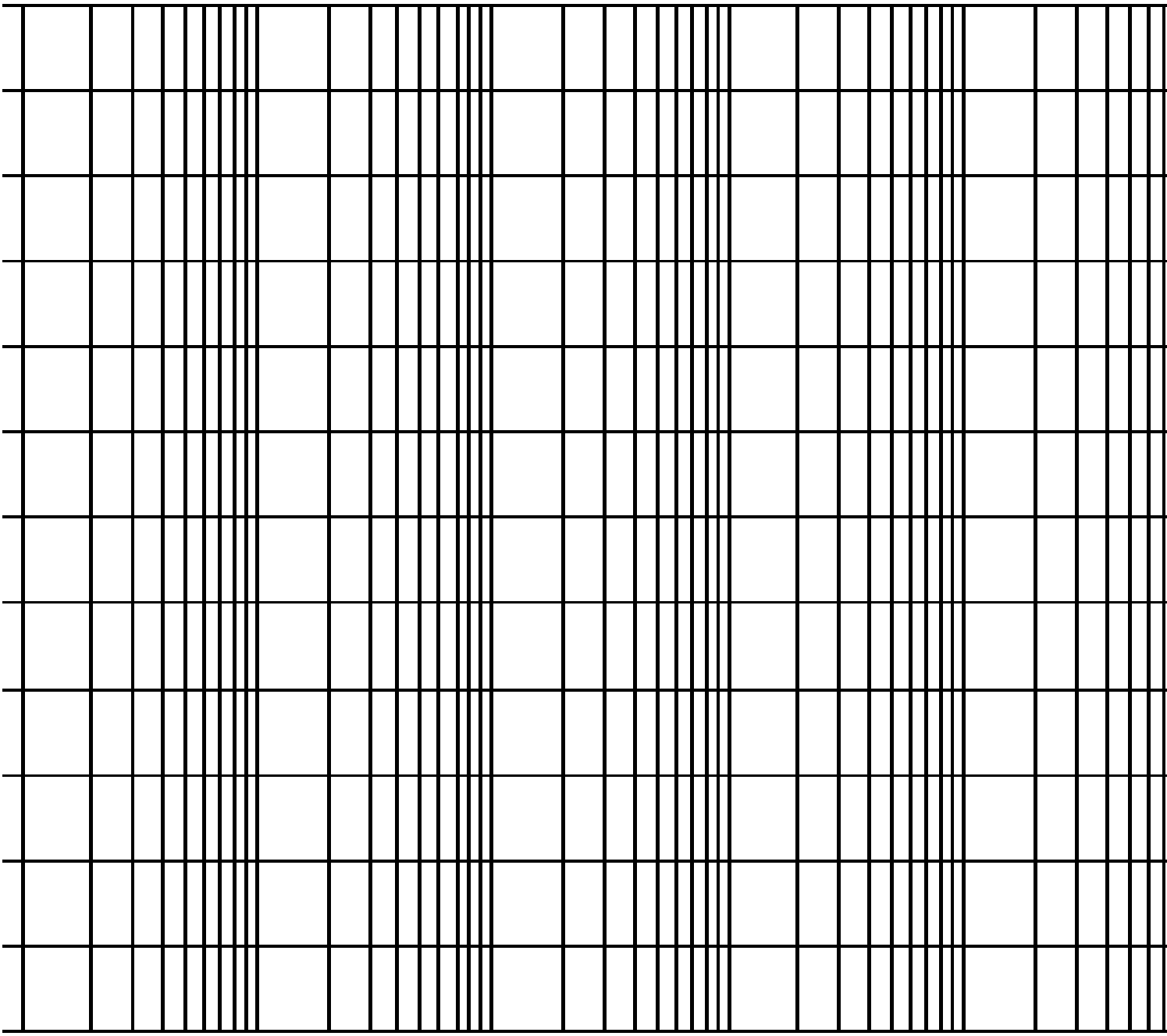


Figure Q4

[Total: 25 marks]

Laplace Transforms:

$x(t)$	$X(s)$
Unit impulse $\delta(t)$	1
Unit step $u(t)$	$\frac{1}{s}$
$t^n, \quad n=1,2,...$	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$t^n e^{-at}, \quad n=1,2,...$	$\frac{n!}{(s+a)^{n+1}}$



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