BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

AEH507

Department of Engineering and Physics Bachelor of Science (Honours) Degree in Agricultural Engineering Part III

Control Systems

Time: 3 HOURS (100 Marks)

INSTRUCTIONS

Answer any **FOUR** questions. Each question carries **25 marks**

---

1 (a) With the aid of a block diagram describe elements that make up an automatic control system. **[8]**

(b) Describe five advantages of closed loop control system over open loop control system. **[5]**

(c) State five characteristics of an ideal control system. **[5]**

(d) Discuss the effect of positive feedback on stability of control systems. **[2]**

2 (a) A unity feedback control system is characterised by the following open loop transfer function $G(s) = \frac{0.4s+1}{s(s+0.6)}$.

Determine:

i) The transient response for unit step input and sketch the response. **[10]**

ii) The maximum overshoot, **[5]**

iii) The corresponding peak time. **[5]**

(b) Find the Laplace Transform of the following differential equation. **[5]**

$$\frac{d^2x_0}{dt^2} + 3\frac{dx_0}{dt} + 2x_0 = 0$$

Initial conditions $x_0 = 4$, $\frac{dx_0}{dt} = 3$

3 (a) The graph below (Figure Q3) shows Time Response specifications in symbol form. Define any four specifications shown. **[6]**

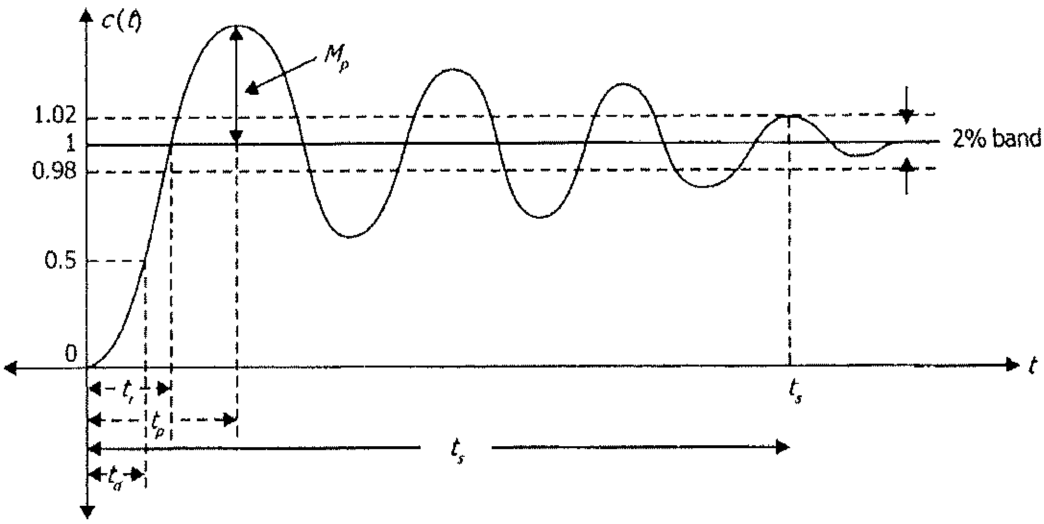

Figure Q3: Time Response

(b) A mass - spring - system has the following parameters: Stiffness K = 800 N/m, Mass M = 3 kg, and Damping Coefficient k_d = 20 Ns/m.

i) Calculate the time constant, critical damping coefficient and the damping ratio. [3]

ii) Derive the equation for the force required when the piston is accelerating. [3]

iii) Use the equation to evaluate the static deflection when F = 12 N. [3]

iv) Use the equation to evaluate the force needed to make the mass accelerate at 4 m/s^2 at the moment when the velocity is 0.5 m/s. [3]

4 (a) Use the graph below (Figure Q4) the answer the following questions:

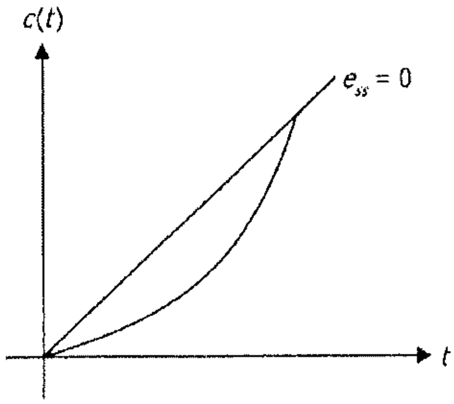

Figure Q4

(i) State the type of input. [1]

(ii) State type of system [2]

(ii) Show that, $K_V = \infty$ and e_{ss} = 0 for ramp input type 2 and higher-order systems. [4]

(b) For the closed loop control system shown below, shown that

$|M(j\omega)| = \left|\frac{G(j\omega)}{1+G(j\omega)H(j\omega)}\right|$

and $\angle M(j\omega) = \angle G(j\omega) - \angle[G(j\omega)H(j\omega)]$ [8]

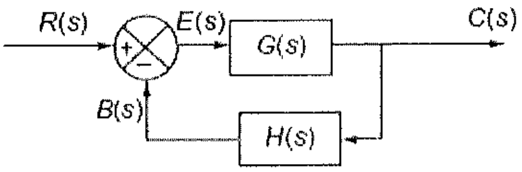

Figure 4 (b): Closed Loop Control System

(c) The characteristic equation of a system is given here. Identify the poles of the system. [5]

$$10s^2 + 4s + 15 = 0$$

(d) Prove the following rule for eliminating feedback. [5]

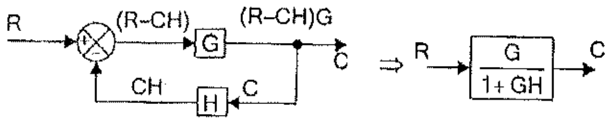

Figure 5

5 Using Mason's gain formula determine the following from the given signal flow diagram:

(a) Identify the number of forward paths and their gain, [4]

(b) Combination of non-touching loops, [5]

(c) The value of determinant, [4]

(d) Value of Δ_k, and [6]

(e) Using Mason's gain formula [6]

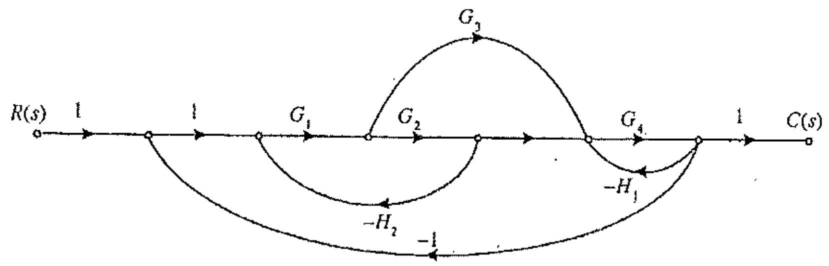

Figure 6

6 (a) A hydraulic cylinder has a bore of 60 mm and is controlled with a valve of constant $k_v = 0.06\ m^2/s$. Determine:

i) The time constant given that x_i and x_o are zero when t = 0. [5]

ii) The velocity of the piston and [5]

ii) The output position after 0.3 seconds when the input is changed to 5 mm. [3]

(b) A simple thermal heating system has a transfer function $\frac{\theta_o}{\theta_i} = \frac{1}{(Ts+1)}$

The temperature of the system at any given time is θ_o and is at 30 °C when the set temperature θ_i is changed from 30 °C to 100°C. The time constant T = 7 seconds. Deduce the formulae for how the system temperature changes with time and sketch the graph. [12]