

INSTRUCTIONS TO CANDIDATES

Answer Instructions:	There are three (3) questions. Attempt all questions.
Materials Provided:	Nil
Pass Level:	50%

Note:

In order to ensure that the examiner is aware of your entire examination returns, please ensure that:

- *Your student I.D. number is entered clearly and legibly on all examination answer booklets that you use.*
- *You indicate which questions are answered in each booklet.*
- *All answer booklets are sequentially numbered in the box provided on the front page of each booklet.*
- *The total number of booklets that you use is also indicated in the box provided on the front page of each booklet.*

QUESTION 1

a) Find poles and zeros of the following transfer functions and mark poles with \times and zeros with small circles \odot in the s-plane.

i) $H(s) = \frac{3s + 5}{(2s^2 + 3s + 9)(3s^2 + 5s + 13)}$

ii) $G(s) = \frac{s^2 + 3s + 7}{s(s^2 + 5s + 19)}$

[4 Marks]

b) A dynamic system is represented by the following differential equation:

$$a\ddot{y} + b\dot{y} + cy = du$$

where y and u are the output and input, respectively, a , b and c are the system parameters.

i) Assuming that all initial conditions are zeros, write the transfer function for the system and find all poles and zeros of the transfer function. Use these numerical values: $a = 3$, $b = 7$, $c = 4$ and $d = 2$.

[5 Marks]

ii) If the input u is a unit step function find the system response y in time domain.

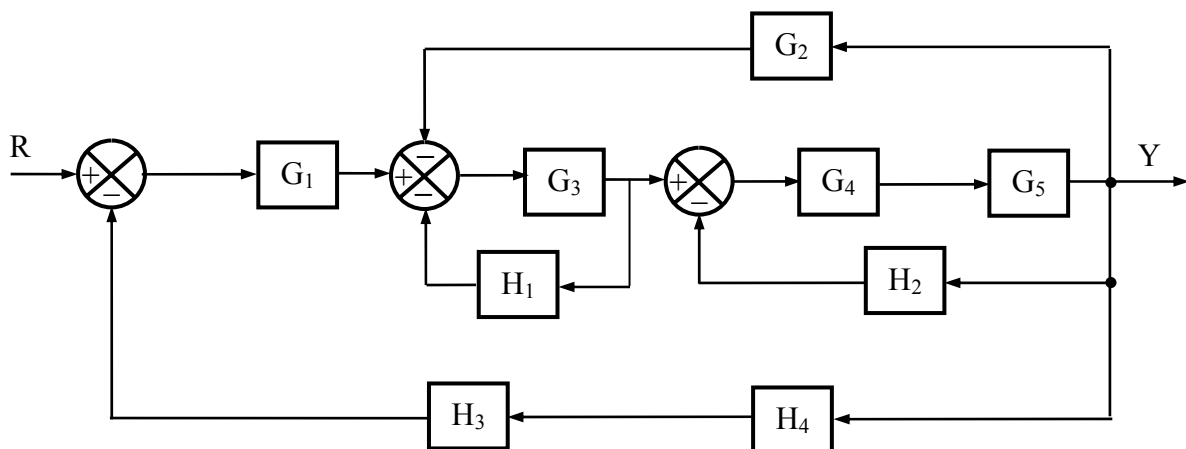
[4 Marks]

iii) Find the damping ratio, natural frequency and static sensitivity if y is the output displacement in m and u the input force in N.

[3 Marks]

QUESTION 2

Reduce the following block diagram:



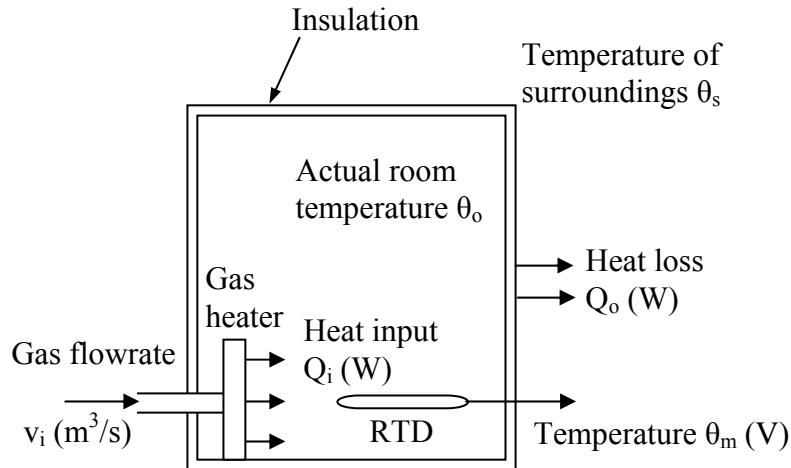
[6 Marks]

QUESTION 3

Do one of the following problems:

3.1 Thermal System:

In order to design a temperature control system for a room, a gas heater and RTD are arranged as shown in the following figure. It is assumed that the heat flow generated by the gas heater is proportional to the gas flowrate, i.e. $Q_i(s) = K_h V(s)$ where K_h is the heater constant (Ws/m^3) and the measured temperature of the RTD is proportional to the actual room temperature, i.e. $\theta_m = H\theta_o$ where H is the static sensitivity of the RTD ($V/^\circ C$).



Variables and numerical values:

- $v_i(t)$ = gas flowrate (m^3/s)
- $\theta_o(t)$ = actual temperature of the room ($^\circ C$)
- $\theta_m(t)$ = measured temperature (V)
- $\theta_s(t)$ = temperature of surroundings ($^\circ C$) = $0^\circ C$
- R_T = the thermal resistance of the walls ($^\circ Cs/J$) = $0.1 \text{ } ^\circ Cs/J$
- C_T = the thermal capacitance of the air in the room ($J/^\circ C$) = $90 \text{ } J/^\circ C$
- H = static sensitivity of the RTD ($V/^\circ C$) = $1 \text{ } V/^\circ C$
- K_h = $5 \text{ } Ws/m^3$

i) The RTD has an error of $\pm 0.5\%$ and is connected to a signal conditioning circuit that consists of an amplifier with an error of $\pm 0.55\%$, a voltage-to-current converter with an error $\pm 0.35\%$ and an indicator with an error of $\pm 0.65\%$, calculate the maximum possible error and probable error.

[2 Marks]

ii) Write a transfer function for the relationship between the room temperature $\theta_m(t)$ and the gas flowrate $v_i(t)$, i.e. $\Theta_m(s)/V_i(s)$ and find its poles and zeros.

[6 Marks]

iii) Find the time constant and sensitivity of the room system.

[2 Marks]

3.2 Fluid System:

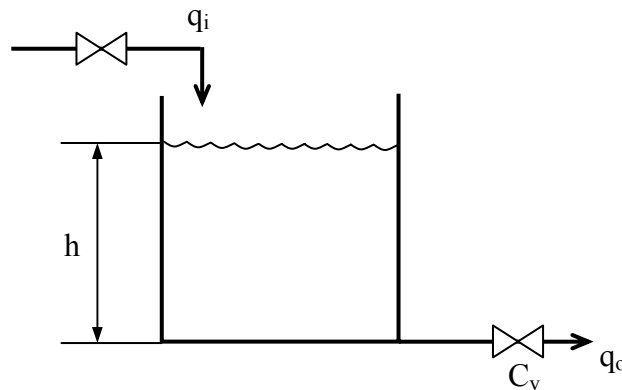
A simple surge tank with a fixed valve on the outflow line is illustrated in the following figure. The tank has the diameter of 1 m. If the outflow rate q_o is proportional to the liquid height, i.e. $q_o = C_v h$ ($C_v = 2 \text{ l/min/m}$), and the liquid density is constant ($\rho = 1000 \text{ kg/m}^3$) write a differential equation for the relationship between the output level h (m) and inflow rate q_i (600 l/min) with the assumption that the process is initially empty.

i) Write the transfer function $G(s) = H(s)/Q_i(s)$ and find its poles and zeros.

[6 Marks]

ii) Find the time constant and static sensitivity of the system.

[2 Marks]



iii) If the liquid level is measured by a level transducer that consists of a level sensor (resistance type) with $K_1 = 1 \text{ mV/cm}$, an amplifier with $K_2 = 100 \text{ V/V}$ and a voltage-to-current converter with $K_3 = 2 \text{ mA/V}$, calculate the overall sensitivity. If the transducer reading is 10 mA, what is the liquid level?

[2 Marks]