AUSTRALIAN MARITIME COLLEGE

DIVISION OF
ACADEMIC AND RESEARCH

EXAMINATION

COURSE:	Bachelor of Engineering (Ocean Engineering) Bachelor of Engineering (Marine and Offshore Systems)
SUBJECT:	Instrumentation and Process Control
CODE:	E07 267
DURATION:	3 Hours
YEAR:	2006
SEMESTER:	2
EXAMINER/S:	Hung Nguyen

MOBILE PHONES AND ELECTRONIC DICTIONARIES ARE STRICTLY PROHIBITED IN THE EXAMINATION VENUE
STUDENTS ARE PERMITTED TO BRING THE FOLLOWING ITEMS INTO THIS EXAMINATION:
Formulae Sheet for Instrumentation and Process Control
Formulae Sheet for Mathematics
Non-programmable Calculator

INSTRUCTIONS TO CANDIDATES

Answer Instructions:	There are six (6) questions. Attempt all questions. You should read the questions very carefully before answering in order to avoid misunderstanding. There are a total of 96 marks available in this examination. Marks follow each question.
Materials Provided by Lecturer:	Nil
Pass Level:	You are required to achieve over 50% of the possible marks for this examination.

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

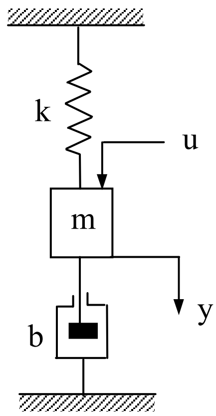
(a) Describe the general structure of a closed-loop control system using a block diagram. State the functions of each component.

[8 Marks]

(b) A spring mass damper system shown in the following figure is at rest (i.e. $y(0) = 0$ and $\dot{y}(0) = 0$) before excitation force $u(t)$ is given.

(i) Write a differential equation for the relationship between the output displacement $y(t)$ (m) and the input force $u(t)$ (N). Find the transfer function and its poles and zeros. Use these values: $m = 2$ kg, $b = 200$ Ns/m, $k = 250$ N/m and $u(t)$ is a step function.

[4 Marks]

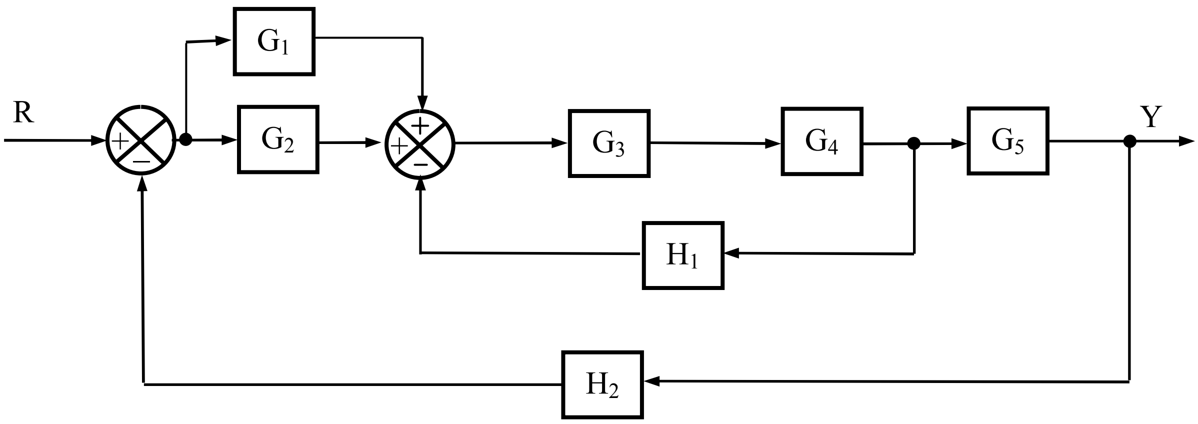


(ii) Write a state space representation for the system.

[2 Marks]

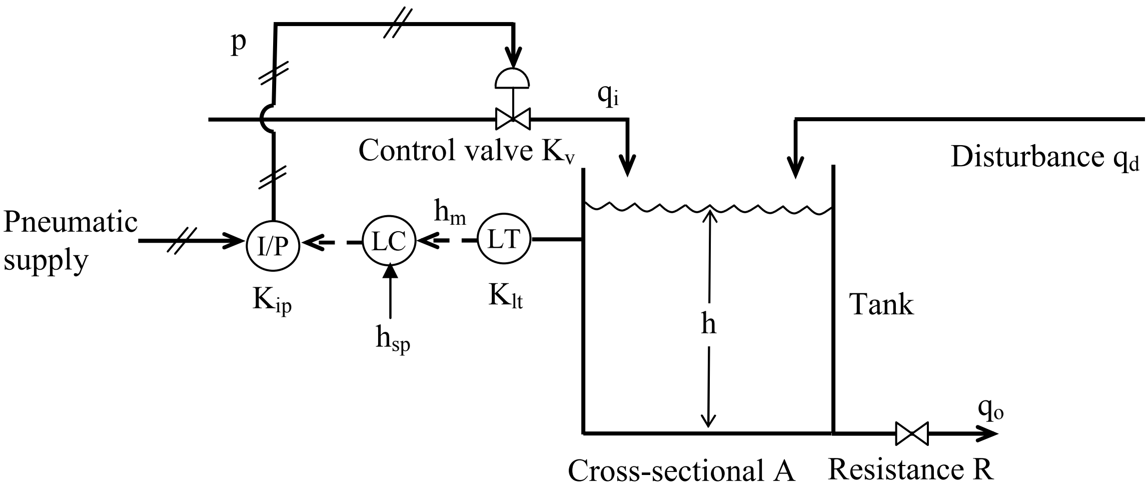
QUESTION 2

(a) What is a block diagram? The following is a block diagram for a closed-loop control system. Write the total feedback (closed-loop) transfer function:



[8 Marks]

(b) The following schematic diagram shows a feedback liquid level control system. The relationship between the liquid level h (m) and input flow rate q_i (m^3/s) is represented by the transfer function of $G(s) = \frac{H(s)}{Q_i(s)} = \frac{K}{Ts+1}$. The PID controller has control gains of K_P, K_I and K_D. Draw a block diagram for the system and write the total feedback transfer function.



[8 Marks]

QUESTION 3

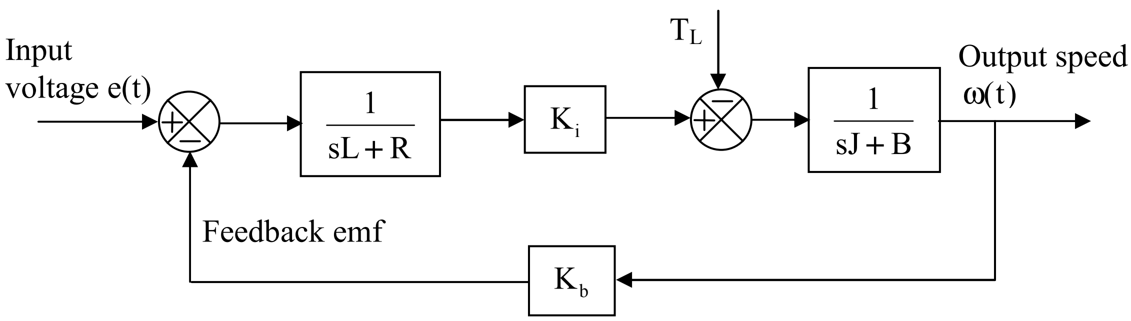
(a) Define the transfer function of a continuous-time system, its poles and zeros. Find poles and zeros of the following transfer functions:

(i) $G(s) = \dfrac{2s+1}{s^2+3s+5}$

(ii) $H(s) = \dfrac{s^2+2s+2}{s(s^2+3s+7)(s^2+7s+5)}$

[6 Marks]

(b) A simplified version of the DC motor model is shown below. The input is voltage e(t) in V and the output is rotational speed, $\omega(t)$, in rad/sec.



where L is the armature inductance (Henry)
R is the armature resistance (Ω)
K_i is the torque constant (Nm/A)
J is the moment of inertia of the rotor (kgm^2)
K_b is the back emf constant (V/rad/s)
T_L is the load torque (Nm), assuming that $T_L = 0$.

(i) Write the transfer function (Ω/E) of the motor system.

[2 Marks]

(ii) The motor is used for a position control system with a PID controller, an amplifier and a displacement transducer. Assuming that the PID controller has control gains of K_P, K_I and K_D, the amplifier has a gain of K_a and the displacement transducer has a sensitivity of K_t (rad/V), draw a block diagram and write the total feedback transfer function for the whole control system. Note that $\theta(t) = \int \omega(t)dt$.

[4 Marks]

QUESTION 4

(a) What is the steady state error of a dynamic system? State the procedures to determine the steady state error. You may use formulae and simple sketches to illustrate your answers.

[6 Marks]

(b) Determine steady state errors of the following systems if the test signal is a step function.

(i) $H(s) = \dfrac{2}{4s+1}$

(ii) $G(s) = \dfrac{1}{s^2+5s+2}$

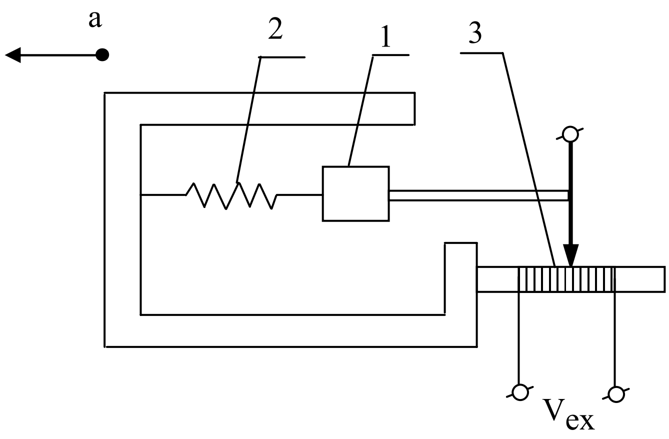
[6 Marks]

QUESTION 5

(a) Describe a pressure transducer (principle, structure, features and applications)

[8 Marks]

(b) A potentiometer-typed accelerometer is shown in the following figure (1 = seismic mass, 2 = spring, and 3 = potentiometer).



The accelerometer parameters are as follows: m = 0.05 kg, spring stiffness $k = 2\times 10^3$ N/m, the maximum displacement = +/- 0.05 m, $R_T = 100\ \Omega$ and excitation voltage V_{ex} = DC 12 V. Calculate

(i) the maximum acceleration that can be measured

(ii) the natural frequency

(iii) the output voltage if the acceleration is 500 m/s^2 and there is no load resistor?

[6 Marks]

QUESTION 6

(a) Describe a final control element (including operating principle, simple structure, features and/or characteristics and applications).

[8 Marks]

(b) A pressure measuring system consists of a piezoelectric transducer with sensitivity K_1 of 50 pC/bar, a charge amplifier with sensitivity K_2 of 5 mV/pC and an oscilloscope with sensitivity K_3 of 1 cm/V. If the pressure to be measured is 30 bars, what is the trace deflection on the oscilloscope? The piezoelectric transducer, charge amplifier and oscilloscope have percentage errors $\pm 0.5\%$, $\pm 0.75\%$ and $\pm 1.25\%$, respectively. Calculate the maximum possible error and the probable error.

[4 Marks]

AUSTRALIAN MARITIME COLLEGE

DIVISION OF ACADEMIC AND RESEARCH

SUPPLEMENTARY EXAMINATION

COURSE:	Bachelor of Engineering (Ocean Engineering) Bachelor of Engineering (Marine and Offshore Systems)
SUBJECT:	Instrumentation and Process Control
CODE:	E07 267
DURATION:	3 Hours
YEAR:	2006
SEMESTER:	2
EXAMINER/S:	Hung Nguyen

MOBILE PHONES AND ELECTRONIC DICTIONARIES ARE STRICTLY PROHIBITED IN THE EXAMINATION VENUE
STUDENTS ARE PERMITTED TO BRING THE FOLLOWING ITEMS INTO THIS EXAMINATION:
Formulae Sheet for Instrumentation and Process Control
Formulae Sheet for Mathematics
Non-programmable Calculator

INSTRUCTIONS TO CANDIDATES

Answer Instructions:	*There are six (6) questions. Attempt all questions. You should read the questions very carefully before answering in order to avoid misunderstanding. There are a total of 72 marks available in this supplementary examination. Marks follow each question.*
Materials Provided by Lecturer:	Nil
Pass Level:	*You are required to achieve over 50% of the possible marks for this supplementary examination.*

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) State the following terms: a continuous-time transfer function representing a dynamic system, its pole/s and zero/s. You may use formulae and examples to illustrate your answers. A dynamic system is represented by the following differential equation:

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

where y and u are output and input, respectively, and a, b, c and d are system parameters. Write the transfer function for the system with all zero conditions. Find poles and zeros using a = 1, b = 3, c = 10 and d = 2.

[6 marks]

(b) Find poles and zeros of the following transfer functions and plot them in the s-plane.

(i) $G(s) = \dfrac{s+1}{s^2+2s+5}$

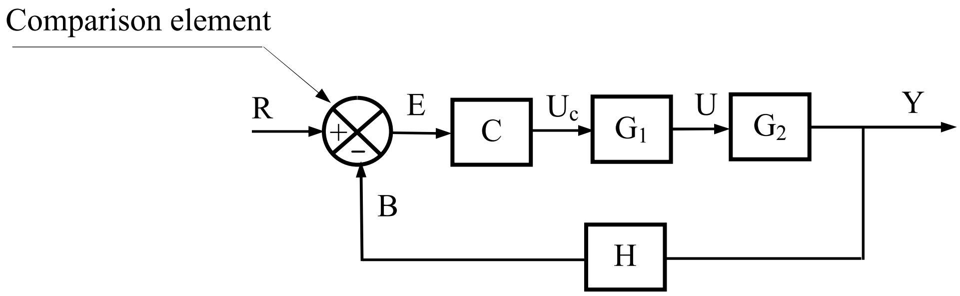
(ii) $\dfrac{2s+1}{s^2\left(s^2+s+3\right)}$

(iii) $\dfrac{K}{s^2+2\zeta\omega s+\omega_n^2}$ (where K = constant, natural frequency $\omega = 10$ Hz, and damping ratio $\zeta = 0.25\ s^{-1}$)

[6 marks]

QUESTION 2

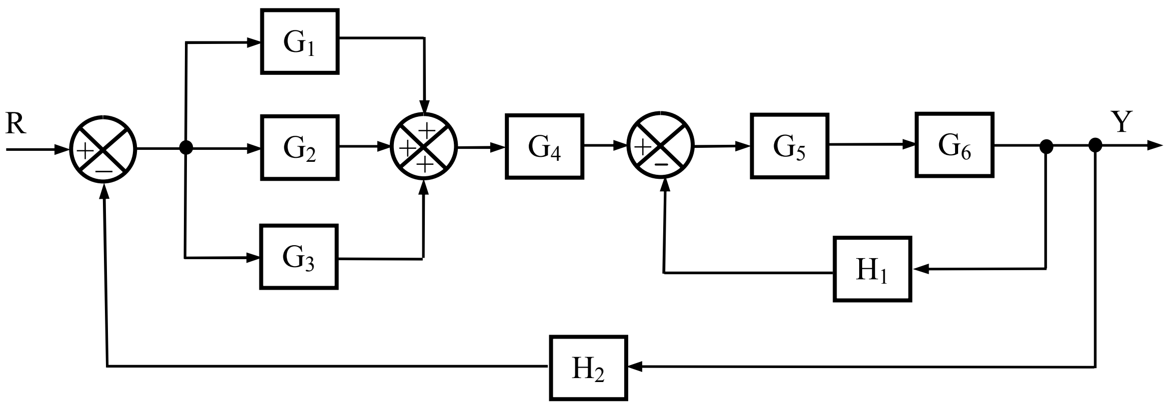
(a) Using the following block diagram for a closed-loop control system



where G_2 = plant (dynamic system) to be controlled, H = measurement element, C = controller and G_1 = final control element, state the functions of each block and of the comparison element. Write down the following transfer functions: forward-path transfer function, open-loop transfer function and closed-loop (feedback) transfer function.

[6 Marks]

(b) Reduce the following block diagram



[4 Marks]

QUESTION 3

(a) What is the steady-state error of a dynamic system? State procedures to determine the steady state error of a given forward-path transfer function when a test signal (step, ramp or parabolic function) applies (using the final value theorem of Laplace transform). You may use formulae and/or simple sketches to illustrate your answers.

[6 Marks]

(b) Determine steady-state errors of the following forward-path transfer functions when a unit step input is applied:

(i) $H(s) = \frac{3}{5s+1}$

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

[6 Marks]

QUESTION 4

(a) Describe a differential pressure transmitter (operating principle, simple structure, features and applications in control).

[8 marks]

(b) A car has a uniformly accelerated motion of 5 m/s^2. Find the speed required and distance traveled in 4 seconds from rest.

[2 Marks]

(c) A ship has a single-element transducer Doppler speed log with the ultrasonic beam at an angle of 60^o to the horizontal. The ultrasonic has frequency of 400 kHz, and velocity of propagation of 1,500 m/s in seawater. The ship speed is at 15 knots (1 NM = 1852 m). Calculate the Doppler shift.

[2 Marks]

QUESTION 5

(a) Describe a control valve as a final control element in the closed-loop control system (including operating principle, simple structure, features and applications).

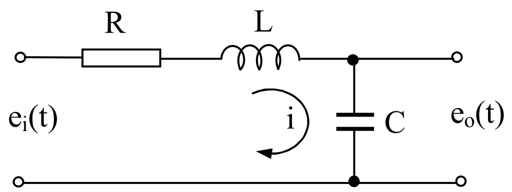
[8 Marks]

(b) A U-tube manometer is used to measure the difference in pressure across an orifice plate in a pipe carrying water. Determine the pressure difference when the manometer indicates a head of 0.5 m of mercury. The specific density of water is 1, the specific density of mercury is 13.6 and g = 9.81 m/s^2.

[2 Marks]

QUESTION 6

The following figure shows an RLC network:

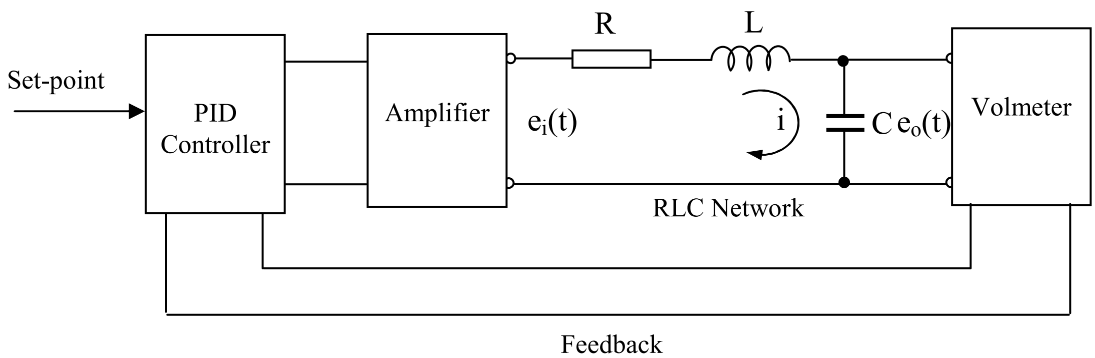


where R = resistance (Ω), L = inductance (H) and C = capacitance (F), $e_i(t)$ and $e_o(t)$ are input voltage (V) and output voltage (V), respectively.

(a) Write a differential equation relating $e_i(t)$ and $e_o(t)$. Assuming that all initial conditions are zero, write down the transfer function for the network and find its poles and zeros if R = 50 Ω, L = 0.1 H and C = 1000 μF.

[8 Marks]

(b) Assuming that in order to control the output voltage as desired the above RLC network is connected to an amplifier with gain of K_a and a PID controller with control gains K_p, K_i and K_d, and $e_o(t)$ is fed back to the PID controller through a voltmeter with a sensitivity of K_m (V/V) as illustrated in the following figure:



draw a block diagram for the closed-loop control system and write down the total feedback transfer function.

[8 Marks]