

**UNIVERSITY OF BOLTON**

**SCHOOL OF BUILT ENVIRONMENT &  
ENGINEERING**

**RAK CAMPUS**

**BENG (HONS) MECHANICAL ENGINEERING**

**SEMESTER 2 EXAMINATIONS 2009/2010**

**ENGINEERING SYSTEMS 2**

**MODULE NO: DMT2027**

Date: Tuesday, 1 June 2010

Time: 17.00 – 19.00

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**INSTRUCTIONS TO CANDIDATES:**

There are SIX questions

Answer ANY FOUR questions

All questions carry equal marks

**CANDIDATES REQUIRE :**

Thermodynamic properties of fluids provided

Take density of water = 1000 kg/m<sup>3</sup>

Formula sheet provided

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- Q1 a) Oil of density  $860 \text{ kg/m}^3$  flows up a vertical pipe section of diameter 225mm. A manometer filled with fluid of density  $1075 \text{ kg/m}^3$  is used to measure the pressure drop across an orifice plate with a throat diameter of 75mm, as shown in Fig. Q1a.

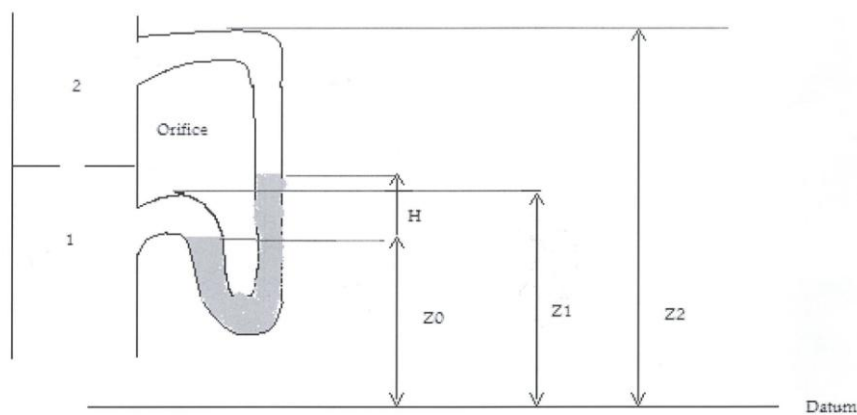


Fig. Q1a

Determine the flow rate of oil if the deflection of the manometer fluid is 0.5m of oil. Assume a discharge coefficient of 0.659 for the orifice.

(10 marks)

- b) Describe, with the aid of a diagram :
- The arrangement of a venturi meter and explain its mode of action. (8 marks)
  - The construction and operation of a pitot static tube. (7 marks)

**Total 25 marks**

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- Q2 a) A pipeline is 15cm in diameter and is at an elevation of 100m at section A. At section B it is at an elevation of 107m and has a diameter of 30cm. When a discharge of 50  $\ell/s$  of water is passed through this pipe the pressure at Section A is observed to be 30 kPa and the energy loss in the pipe is 2m of water. Draw the system diagram and calculate the pressure at B when the flow is from A to B. (13 marks)
- b) A pipe bend has a cross-sectional area of  $0.01\text{m}^2$  at inlet and  $0.0025\text{m}^2$  at outlet. It bends  $90^\circ$  from its direction. The velocity of flow of water is 4m/s at inlet with a pressure of 100 kPa gauge. Draw the diagram and calculate the force acting parallel and perpendicular to the initial direction.

Take density of water =  $998 \text{ kg/m}^3$  (12 marks)

**Total 25 marks**

- Q3 a) A piston-cylinder arrangement initially contains water at pressure 2MPa and temperature  $300^\circ\text{C}$ . During the piston movement, there is heat transfer to the water in such a way that the pressure in the cylinder remains constant.
- (i) Sketch the process on a p-v diagram indicating the relative position of the saturation curve. (2 marks)
- (ii) Find the work done per kilogram of water during the expansion. (5 marks)
- (iii) Find the heat transfer per kilogram of water during the expansion. (5 marks)
- b) The resistance to motion R for a sphere of diameter D moving at constant velocity V through a compressible fluid is dependent upon the density  $\rho$  and the bulk modulus K. The resistance is primarily due to the compression of the fluid in front of the sphere. Use the dimensional analysis Buckingham's pi theory to find the dimensionless relationship between these quantities. (13 marks)

**Total 25 marks**

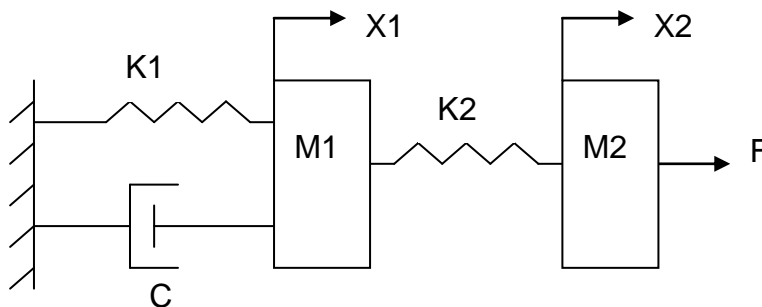
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Q4 Figure Q4 shows a simplified industrial robotic system, where  
 $M1 = 8 \text{ Kg}$ ,  $K1 = 16 \text{ N/m}$ ,  $C = 3 \text{ Ns/m}$   
 $M2 = 2 \text{ Kg}$ ,  $K2 = 50 \text{ N/m}$

- (a) Develop the differential equations for the robotic system. (8 marks)
- (b) Use the Laplace transform to transfer the differential equations obtained from Q4(a) above. Assume that the system is subject to a unit step input and the initial conditions of the system are zeros (i.e. at time = 0,  $x$ ,  $\dot{x}$ ,  $\ddot{x}$  are all zeros). (4 marks)
- (c) Determine the transfer function  $G(s) = X1(s)/F(s)$  (13 marks)

**Total 25 marks**



**Figure Q4** A Simplified Industrial Robotic System

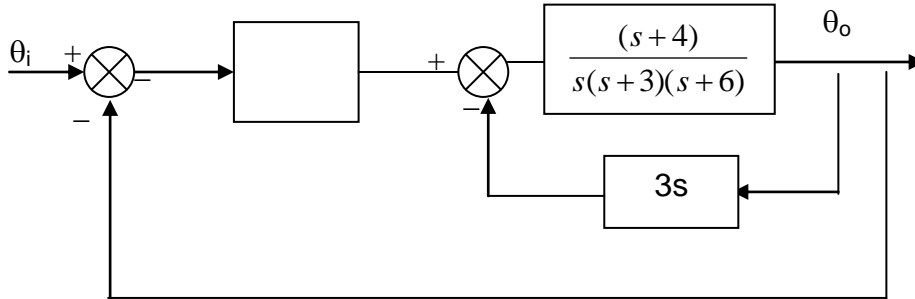
Q5

- (a) Explain the term “Steady-State Error” and define the term “System Stability” with respect to a control system. (6 marks)
- (b) Steady-state error and stability are important design considerations when CNC machining. Figure Q5 gives a block diagram of a control system for CNC machining.
  - (i) find the value of  $K$  so that there is 2% error in the steady state when a unit ramp input ( $\theta_i = 1/s^2$ ) is applied to the system. (7 marks)
  - (ii) use the Routh-Hurwitz stability criterion to check the system’s stability. (12 marks)

**Total 25 marks**

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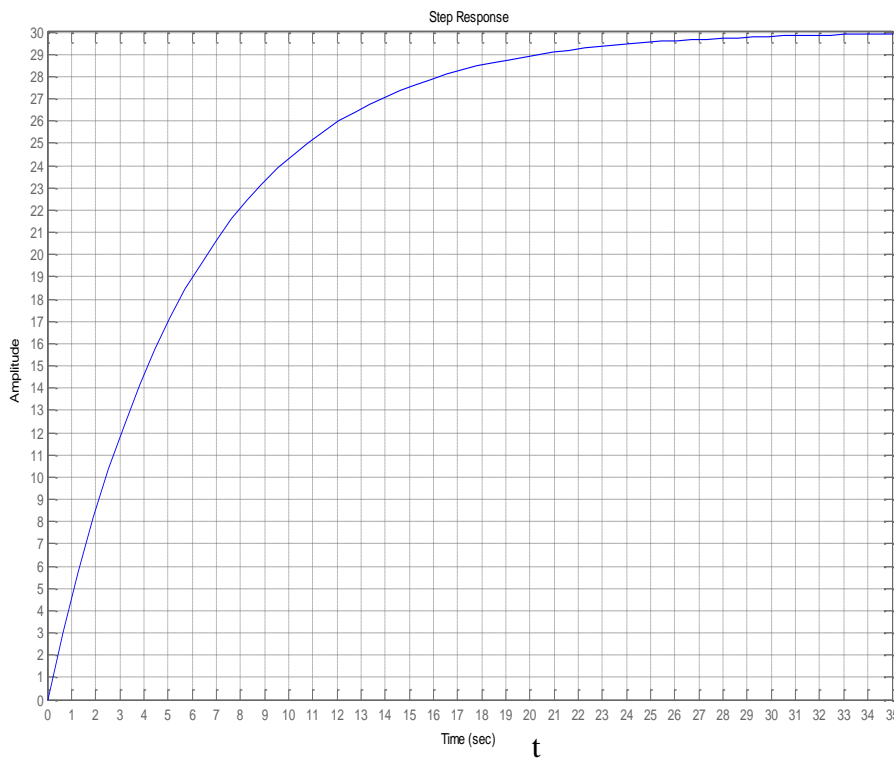
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**Figure Q5** A Control System for a Typical CNC Machine

Q6

- (a) Figure Q6(a) shows the output of a thermal system which is subjected to a step input.



**Figure Q6(a)** The output of a thermal system

- (i) Specify the system performance by determining the time constant  $\tau$  and the final steady value  $G_{ss}$ . (3 marks)
- (ii) Determine the system's transfer function. (2 marks)

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(iii) Using the transfer function obtained (ii) above, if the step input is 50, what will be the time  $t$  taken for the output of the thermal system to reach 90% of its final value? (5 marks)

(b) Figure Q6(b) is a block diagram for a motorbike's suspension system.

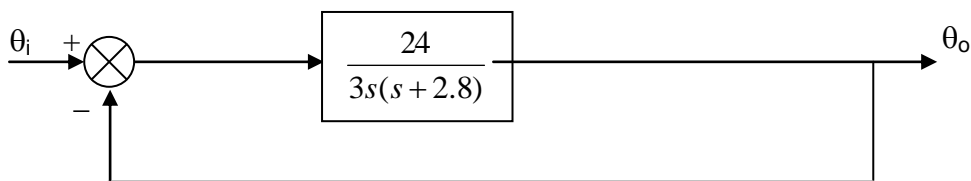


Figure Q6(b) A Motorbike's Suspension System.

- (i) What is the suspension system's transfer function  $G(s) = \theta_o/\theta_i$ ? (3 marks)
- (ii) If a unit step input is applied into the suspension system, determine the system's percentage overshoot, rise time, settling time, peak time, natural frequency, damped frequency, and damping ratio. (12 marks)

**Total 25 marks**

**END OF QUESTIONS**

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## THERMOFLUIDS

### Formulae Sheet

$$P = F/A$$

$$\rho = m/v$$

$$\dot{m} = \rho AV$$

$$P = P_g + P_{\text{atm}}$$

$$P = \rho gh$$

$$\text{Bulk Modulus } \beta = - \frac{dP}{dv/v}$$

$$\tau = \mu du/dy$$

$$h = \frac{4\sigma}{\rho g s d}$$

$$Z_1 + \frac{P_1}{\rho g} + \frac{V_1^2}{2g} = Z_2 + \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$V_1 = \sqrt{\frac{2gh \left( \frac{\rho_L}{\rho} - 1 \right)}{\left( \frac{a_1}{a_2} \right)^2 - 1}}$$

$$Q - W = \Delta U + \Delta PE + \Delta KE$$

$$W = \int PdV$$

$$P V^n = C$$

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$$W = \frac{P_1 V_1 - P_2 V_2}{n - 1}$$

$$W = P (v_2 - v_1)$$

$$W = PV \ln \left( \frac{V_2}{V_1} \right)$$

$$Q = C_d A \sqrt{2gh}$$

$$V_1 = C \sqrt{2g h_2 \left( \frac{\rho g_m}{\rho g} - 1 \right)}$$

$$\sum F = \frac{\Delta M}{\Delta t} = \Delta M$$

$$F = \rho QV$$

$$Re = VL \rho / \mu$$

$$dQ = du + dw$$

$$du = cu dT$$

$$dw = pdv$$

$$pv = mRT$$

$$h = h_f + xh_g$$

$$s = s_f + xsf_g$$

$$v = x Vg$$

$$\dot{Q} - \dot{w} = \sum \dot{m} h$$