BENGAL ENGINEERING AND SCIENCE UNIVERSITY, SHIBPUR

M.E. 1st. Semester Examination, 2011 (held in December, 2011)

Sub. : **Hydraulic Control System I**

Branch : Engineering Mechanics | Code No : **AM 912**

Time : 3 hrs. | Full marks : 70

(i) Answer any **five** questions

(ii) All questions carry equal marks.

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1. With the help of a neat sketch, explain the working principle of a liquid-level control system in a single reservoir with proportional type controller. Draw the block diagram of the system and obtain its time response against a unit step input. Also determine steady state error, if there is any. What will happen to the system performance if the proportional controller is replaced by an integral controller?

2a) State and explain Nyquist Stability criteria. The open loop transfer function of a closed loop system is given by,

$$G(s)H(s) = \frac{K}{s(s+1)(s+2)}$$

Using Nyquist criteria determine the critical value of the gain, K, so that the closed loop system becomes stable.

b) Using Routh's criteria, find the values of 'K' for which the systems with following characteristic equations will be stable:

(i) $s^3 + 20s^2 + 64s + 64K = 0$ (ii) $s^4 + 3s^3 + 3s^2 + 2s + K = 0$

3a) Describe, with a neat sketch, the working principle of a 'Hydraulic PI-Controller'. Hence, deduce its Transfer Function. Also, discuss its effect on steady-state error in a second order system.

b) Find the damping ratio, natural frequency, rise time and settling time of a second order system working against a unit step input such that the maximum overshoot does not exceed 0.2 and the peak time is 6ms.

4 State and explain 'Gain Margin' and 'Phase Margin' of a linear time-invariant closed loop system working against sinusoidal input. Hence, show that the 'constant magnitude loci' of closed loop frequency response of unity feedback system are circles (for $M \neq 1$). Also sketch the loci for different values of 'Gain', M.

A unity feedback closed loop control system has an open loop transfer function as,

$$G(s) = \frac{as+1}{s^2}$$

Determine the value of 'a' so that the 'phase margin' is 45°.

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5. What is the functional difference between a 'gear pump' and a 'vane pump'? Describe, with a neat sketch, the working principle of a 'flat vane pump'. Also deduce an approximate expression for capacity of a 'flat vane pump'.

   3 numbers of electrodes of an electric arc furnace, each driven by a hydraulic cylinder of area ratio 1:2 and 100 mm bore, are to be operated simultaneously at 100 mm/sec by 2 identical vane pumps. All the cylinders are to be operated by a single 4-way 3-position tandem centre DC valve which causes a pressure drop of 2 bar in each of pressure line and return line. The total load required to operate the electrodes is 75 ton. Find the relief valve set pressure and capacity of each pump.

6. The pump of a hydraulic drive system having a fixed capacity of 82 ml/rev, volumetric efficiency of 90% and mechanical efficiency of 84% is running at 1500 r.p.m. The variable delivery motor has a maximum capacity of 66 ml/rev and its volumetric efficiency and mechanical efficiency are same as those of the pump. The relief valve is set at 135 bar. If the motor is subjected to a constant load of 34 Nm, determine (i) the motor speed and pressure drop across the motor at this speed, (ii) the maximum motor speed and associated motor capacity and (iii) the theoretical maximum power that can be transmitted and speed range associated with it.

7. Describe with a neat sketch the working principle of a 'pressure relief valve'.

   An asymmetric actuator of area ratio 1:2 has to transmit a load of 100 kN during forward stroke. The cylinder bore is 100 mm. The direction of motion of the actuator is controlled by a 4-way 3-position tandem centre DC valve having a pressure drop of 2 bar in each of pressure and return line. The relief valve has a sleeve of 10 mm diameter and rectangular drain port of 10 mm width extended over full length of the circumference of the sleeve.

   Draw the hydraulic circuit and determine the stiffness of the mechanical spring of the relief valve, if the maximum pressure override is not to exceed 5%. Also estimate the maximum discharge through the relief valve, Assume specific gravity of the working fluid to be 0.8.

8. With the help of neat sketch/standard symbol, write short notes on **any three** of the following:

   (i) Pressure Compensated Flow Control Valve, (ii) Pressure Reducing Valve, (iii) Meter-In and Meter-Out Circuits, (iv) Counter Balance Circuit, (v) Axial Piston Motor