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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL

(A constituent institution of MAHE, Manipal)

IV SEMESTER B.TECH. (MECHATRONICS ENGINEERING)

END SEMESTER EXAMINATIONS, APRIL 2018

SUBJECT: LINEAR CONTROL THEORY [MTE 2203]

(25/04/2018)

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Data not provided may be suitably assumed and justified.

1A A D.C. motor develops 55 N-m of torque at a speed of 600 rad/s when 12 volts are applied. It stalls out at this voltage with 100 N-m of torque and, when the load is not connected, it rotates at a speed of 1300 rad/s. The inertia and damping of the armature are 7 kg-m^2 and 3 N-m-s/rad, respectively. The motor drives an inertia load of 180 kg-m^2 through a gear train as shown in figure 1A. **04**

(i) Find $G(s) = \theta_L(s) / e_a(s)$ for the system

(ii) Define the parameters: No load speed and Stall torque.

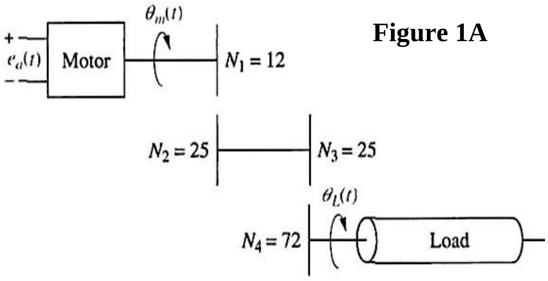


Figure 1A

1B Consider a satellite attitude control system shown in figure 1B-(i). The output of this system exhibits continued oscillations and is not desirable. **03**

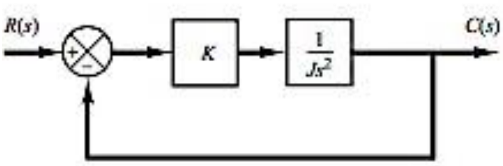


Figure 1B-(i)

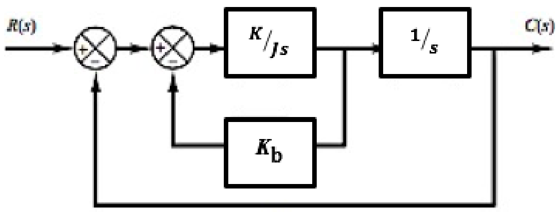


Figure 1B-(ii)

(i) Specify the reason for the oscillatory response of the system.
(ii) The system can be stabilized by use of tachometer as shown in figure 1B-(ii). If $K/J = 4$, what value of K_b will yield the damping ratio to be 0.6?

1C The block diagram shown in figure 1C represents a heat-treating oven. The set point (desired temperature) is 1000°C. Calculate the temperature at steady state condition. **03**

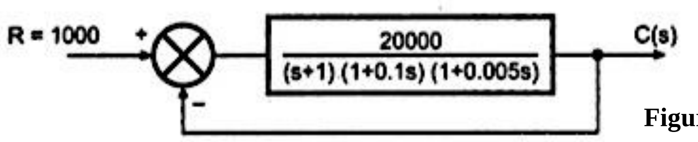


Figure 1C

2A Figure 2A-(i) shows a mechanical vibratory system. When a 2N force is applied to the system, the mass oscillates as shown in figure 2A-(ii). If the mass in 160kg, determine b and k of the system from the response curve provided. The displacement ‘x’ is measured from the equilibrium/steady state position. **04**

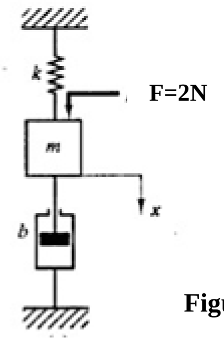


Figure 2A-(i)

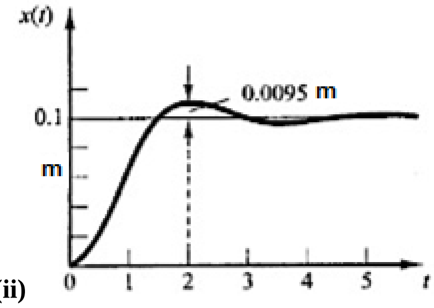


Figure 2A-(ii)

2B Using block diagram reduction techniques reduce the block diagram shown in figure 2B to a single transfer function. **04**

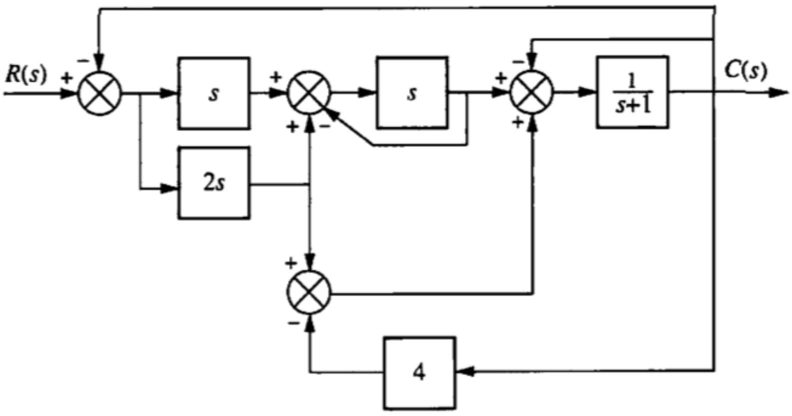


Figure 2B

2C Differentiate between Open loop control systems and Closed loop control systems in terms of Accuracy, Stability, Cost and Maintenance, Construction. **02**

3A The OLTF of a system is represented as follows: **04**

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

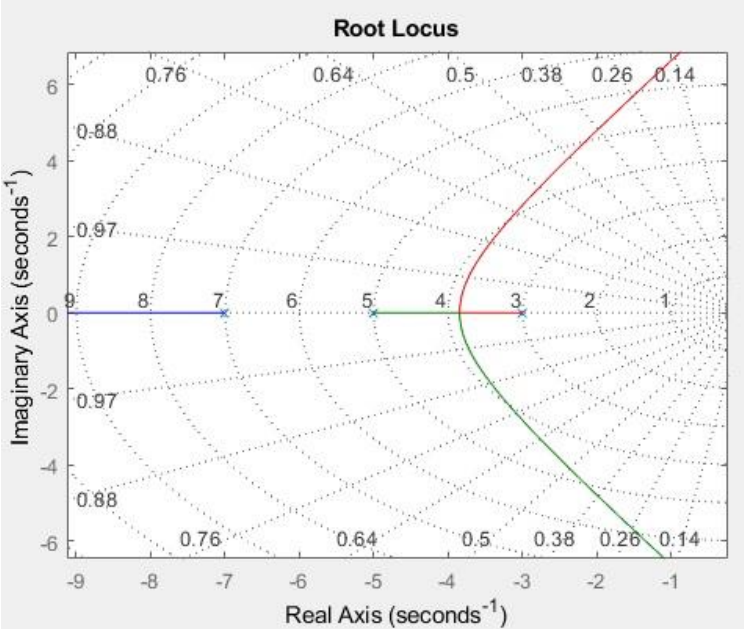
Using the Routh Hurwitz Criterion, for the unity feedback system, do the following:

(i) Comment on the stability of system.

(ii) Find the range of gain that keeps the system stable.

(ii) Calculate the value of gain that makes the system oscillate and also frequency of oscillation at this gain value.

3B A unity feedback system with $G(s) = 1/[(s+5)\,(s+3)\,(s+7)]$ is operating at 7.5% overshoot. Root locus of the uncompensated system is shown in figure 3B. **06**



ζ	Pole location
0.26	-1.5±5.6i
0.38	-2±4.8i
0.50	-2.6±3.5i
0.64	-2.7±3.4i

Figure 3B

(i) Design a compensator such that the appropriate static error is reduced by a factor of 2 without appreciably changing the dominant poles of the uncompensated system. Verify the design.

(ii) How differently do active compensators and passive compensators work when it comes to changing the steady state performance of the system?

4A Define the term degree of freedom. Write, but do not solve the equations of motion for the translational mechanical system show in figure 4A below (Free body diagrams not necessary). **04**

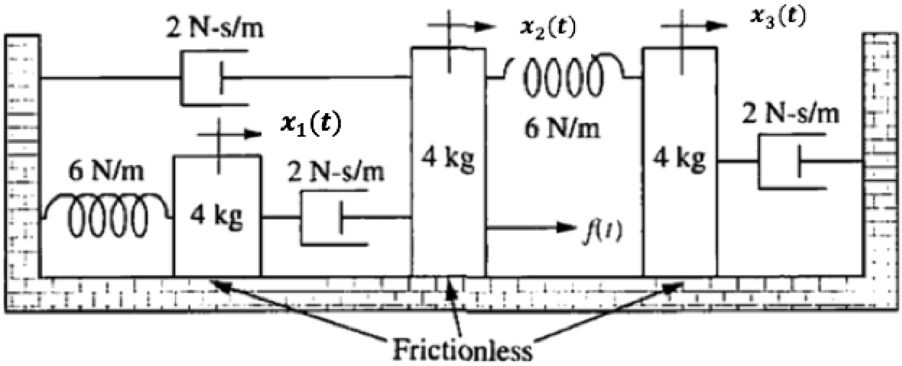


Figure 4A

4B For the signal flow graph shown in figure 4B, apply Mason's Gain Formula to compute the transfer function $C(s)/R(s)$. **03**

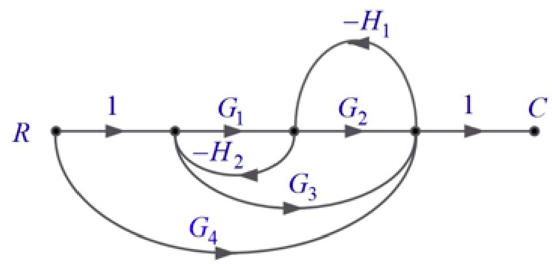


Figure 4B

4C For a unity feedback system shown below, find the value of 'K' such that a ramp input of slope 40 will yield an error of 0.006 in the steady state when compared to the output. **03**

$$G(s) = \frac{K(s+2)}{s(s+2)(s+13)}$$

5A Sketch the root locus for the unity feedback system represented by following open loop transfer function: **06**

$$G(s) = \frac{K(s+1)}{s^2(s+10)}$$

5B For each of the root loci shown below [5B-(i), 5B-(ii)], specify whether or not the sketch can be a root locus. If the sketch cannot be a root locus, elucidate the reason for the same. **02**

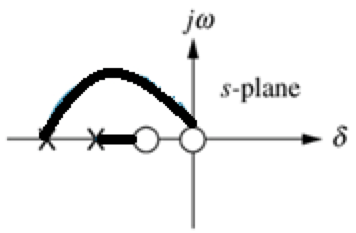


Figure 5B-(i)

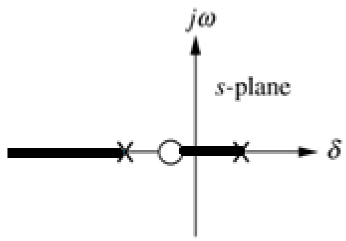


Figure 5B-(ii)

5C State the different compensation techniques used to improve the transient performance of a system with suitable transfer functions and pole zero locations. **02**