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OLLSCOIL NA hEIREANN
The National University of Ireland

National University of Ireland, Galway

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Third Year Mechanical and Biomedical Engineering Examination

ANALYSIS OF VIBRATIONS & CONTROL SYSTEMS

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Attempt *Five* Questions, including at least two questions from each section.
Use separate answer books for each section.
Time Allowed: 3 Hrs.

The following are available : Laplace tables and semi-log graph paper

Section A

1(a) Determine the equivalent stiffness and mass of the system shown in Figure 1 with reference to the rotation θ at the pivot point P. The beam APB is rigid with negligible mass and a torsional spring is attached at P. ***(15)***

(b) Determine the natural frequency of the system. ***(5)***

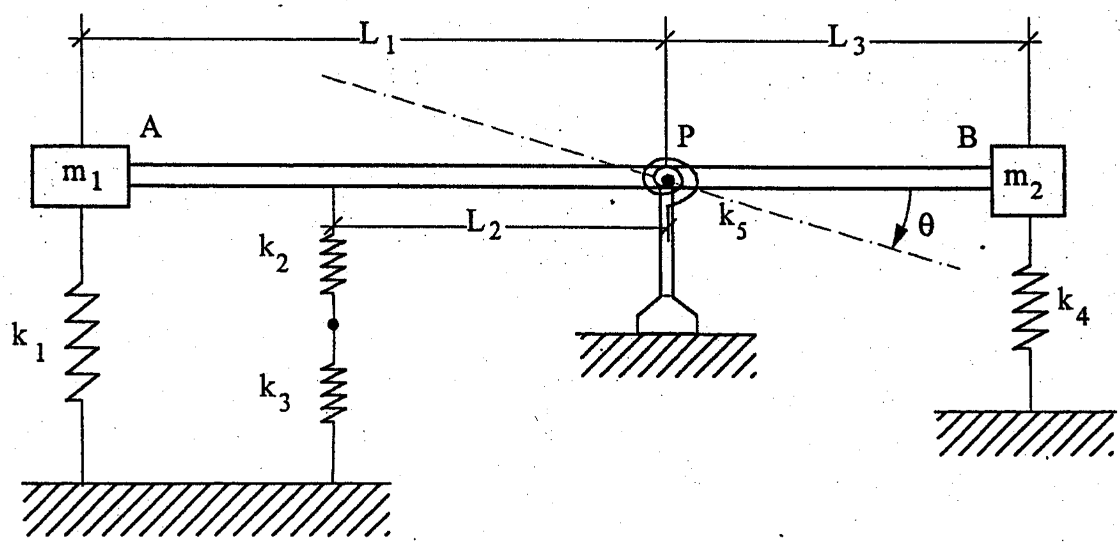


Figure 1.

2. A swing door has a width of 1m and a total mass of 50kg; it is hung about a vertical edge where a torsional spring and a viscous damper are mounted. The spring constant is given as 15Nm/rad.

(a) Find the damping constant necessary to provide 50% of critical damping in the return swing of the door. *(12)*

(b) Calculate the reduction in the angular displacement of the door over one complete cycle from an open position through a closed position and back to the open position. *(8)*

3. A reciprocating pump of mass 200kg is driven through a belt by an electric motor operating at 3000rpm. The pump is mounted on rubber isolator blocks giving a total stiffness of 5 MN/m and a damping constant of 3.125 kNs/m.

(a) Determine the amplitude of steady-state vibrations at the operating speed due to an imbalance in the pump equivalent to a harmonic force excitation of 1kN. *(10)*

(b) Determine the amplitude of the force transmitted through the isolator blocks to the pump foundations. *(10)*

4. The layout of an overhead crane and associated physical quantities are shown in Figure 4. The cabin is located at midspan and the mass of the beam and cables may be neglected.

(a) Develop the equations of motion for the crane as an equivalent two degree of freedom system with respect to vertical vibrations of masses M_1 and M_2. ***(8)***

(b) Determine the natural frequencies of the crane. ***(12)***

Note: The deflection δ at midspan of a simple supported beam under a central load P is $\delta = PL^3/48EI$ where L is the span.

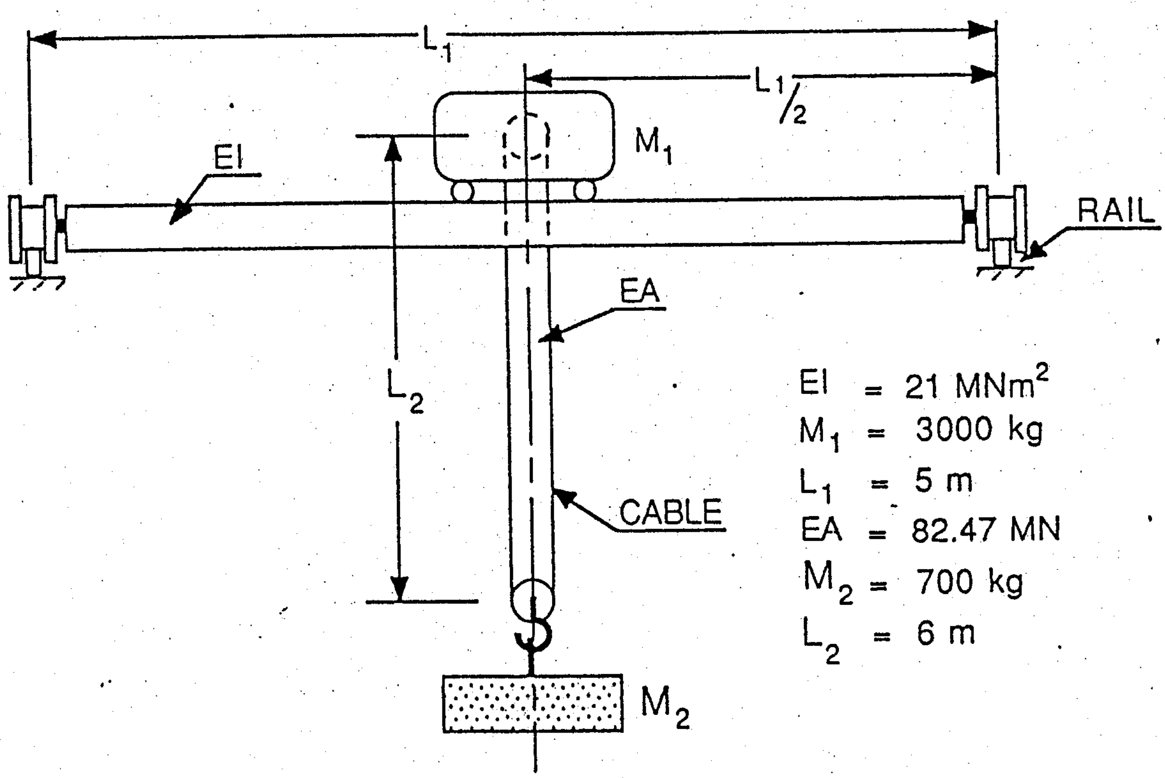


Figure 4.

Section B

5(a) The schematic shown represents a hydraulic actuator. Determine the transfer function relating main piston displacement (y) to lever position (e). Oil compressibility effects may be neglected. *(10)*

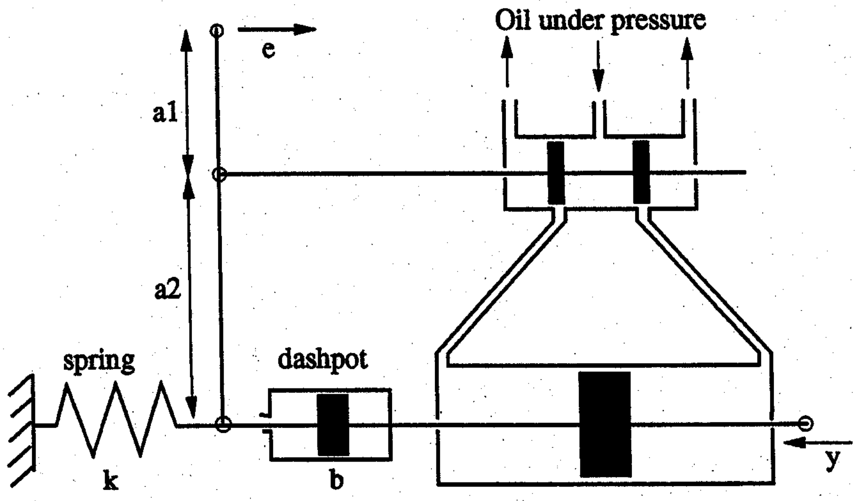


Figure 5(a)

(b) State the Ziegler-Nicholas rules for tuning a PI (proportional + intergral or two term controller) and apply the rules to tune a PI controller for the system with open loop transfer function: *(10)*

$$\frac{K}{s(s+1)(s+2)(s+3)}$$

6(a) Very briefly discuss the role of Root Locus in the analysis/synthesis of control systems. Explain the main geometric properties (construction rules) including:

(i) number of locii
(ii) real axis locus
(iii) start and end points
(iv) high gain asymptotes, and
(v) breakaway/breakin points

(10)

(b) Sketch the Root Locus for the system with the block diagram shown in Figure 6(b). *(10)*

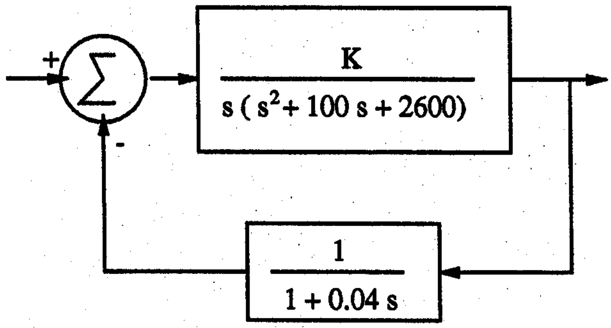
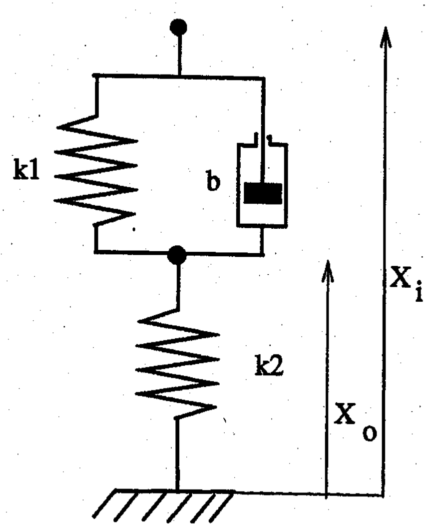


Figure 6(b)

7(a) The schematic diagram for the mechanical system comprising springs and a dashpot shown in Figure 7 is an important compensating network in control systems. Derive the transfer function and sketch the Bode frequency response. Using the frequency response sketched, explain the effect of including such a network in the feedforward path of a control system. *(10)*



(b) The open-loop frequency response of a control system is tabulated for a range of ω (rads/sec) in Table 7(b). Estimate the phase margin and derive the settings for a phase lag controller which would yield a phase margin of 40^0. *(10)*

ω_i	$db[\omega_i]$	$Ph[\omega_i]$
0.126	44.003	-92.711
0.158	41.993	-93.411
0.2	39.978	-94.292
0.251	37.953	-95.399
0.316	35.913	-96.792
0.398	33.852	-98.542
0.501	31.756	-100.739
0.631	29.609	-103.49
0.794	27.384	-106.929
1	25.051	-111.206
1.259	22.571	-116.495
1.585	19.904	-122.975
1.995	17.021	-130.81
2.512	13.909	-140.128
3.162	10.58	-150.988
3.981	7.064	-163.388
5.012	3.399	-177.314
6.31	-0.375	-192.83
7.943	-4.226	-210.177
10	-8.129	-229.835
12.589	-12.067	-252.556
15.849	-16.027	-279.366
19.953	-20.002	-311.587
25.119	-23.986	-350.878
31.623	-27.976	-399.302
39.811	-31.97	-459.42
50.119	-35.966	-534.425
63.096	-39.963	-628.309
79.433	-43.962	-746.068
100	-47.961	-893.972

Table 7(b)

8(a) The schematic shown in Figure 8(a) depicts a so-called seismic instrument which can be used to measure either displacement (vibrometer) or acceleration (accelerometer).

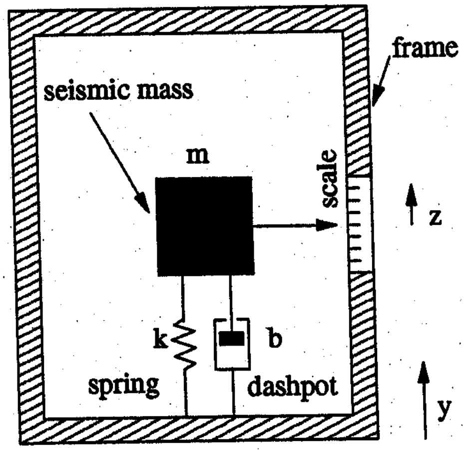


Figure 8(a)

Derive the transfer functions relating displacement of seismic mass to:

(i) frame displacement, and

(ii) frame acceleration

(10)