INDIAN INSTITUTE OF TECHNOLOGY

Date: ___ September 2011 AN/FN **Time:** 2 Hrs **Full Marks:** 30 **No. of Students:** 110
Semester: *Autumn* **Department:** *Mechanical Engineering*
Sub. Name: *Systems and Control*
Instructions: *Answer all questions. Each question carries 10 marks. Neglect gravity unless stated.*

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1. Draw augmented (power directed and causalled) bond graph models of the two systems shown in Figure 1.

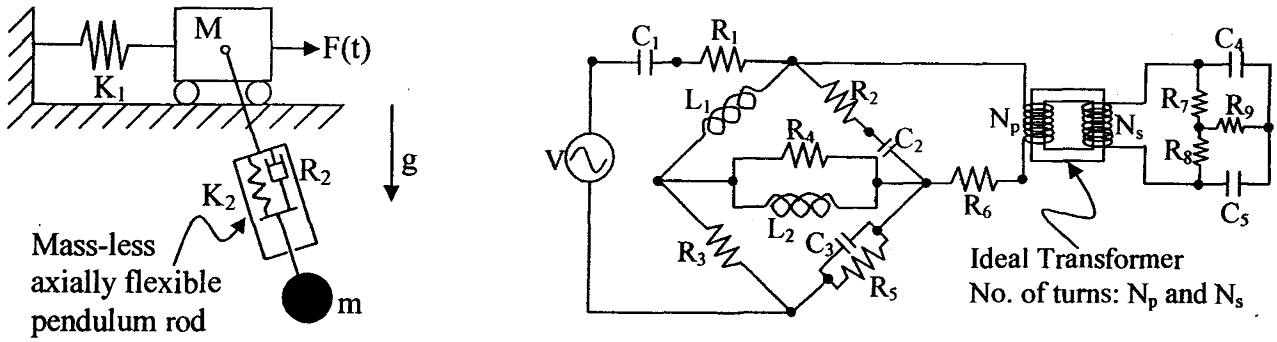

Figure 1

2. In the system shown in Figure 2, the center of the pulley can move along a vertical slot. There is no resistance to pulley's vertical translation and rotational motions. The mass, rotary inertia and radius of the pulley are M, J and r, respectively. There is no slip between the pulley and the rope. Gravity can be neglected.

Draw an augmented (power directed and causalled) bond graph model of the system. Determine the number of integrally causalled and differentially causalled inertia elements and find the degrees-of-freedom of the system.

Use transformer equivalence to reduce the model to that of a single oscillator (one spring - one mass system) at common velocity port $\dot{X}_1$. What is the equivalent mass m_{eqv} and stiffness k_{eqv} at the common velocity port (1-junction) $\dot{X}_1$? What is the natural frequency of vibration of the system $\omega_n = \sqrt{k_{eqv}/m_{eqv}}$ if $m = 1$ kg, $M = 8$ kg, $J = 0.04$ kg.m^2, $k_1 = 200$ N/m, $k_2 = 800$ N/m and $r = 0.1$ m.

Hint: use kinematic constraints $\dot{X}_2 = -r\dot{\theta}$ and $\dot{X}_1 = \dot{X}_2 - r\dot{\theta}$.

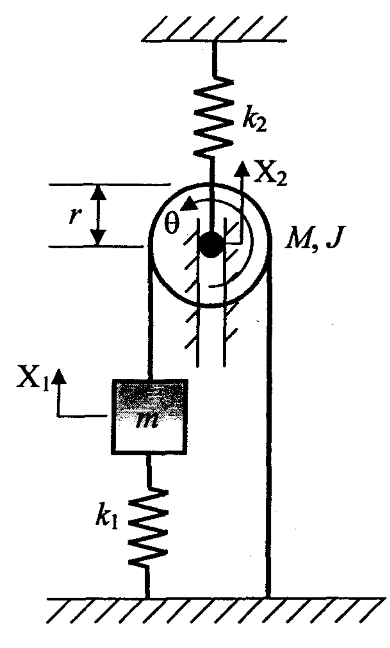

Figure 2

3. Derive the equivalent system of the system shown in Figure 3 by referring the magnetic domain to the primary side of the electrical domain of the transformer. Derive the state-space equations of the equivalent system from its bond graph model. The magnetic core has cross-section A, effective length L and magnetic permeability μ. R_c is the damping that represents magnetic core losses. The number of turns in primary and secondary sides of the transformer are N_p and N_s, respectively. The DC motor constant is μ_m. The transmission shaft is torsionally rigid and J_d is the rotary inertia of the disc including the rotary inertia of the rotor of the motor. R_1 and R_2 are two electrical resistances.

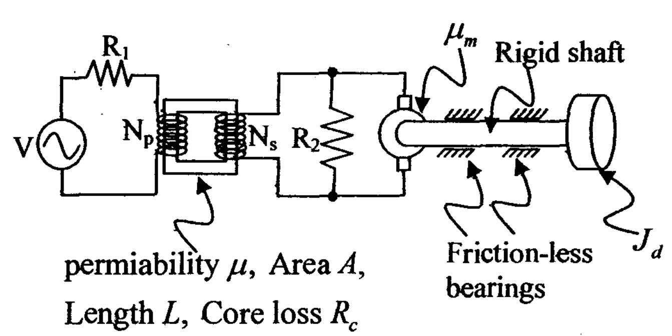

Figure 3