INDIAN INSTITUTE OF TECHNOLOGY

Date: 15 September 2016 AN/FN **Time:** 2 Hrs **Full Marks:** 30 **No. of Students:** 182

Semester: *Autumn* **Department:** *Mechanical Engineering* **Sub. Name:** *Systems and Control*

Instructions: *Answer all questions. Marks are indicated in the right hand margin.*

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1. Draw bond graph model of the electrical system shown in Fig. 1. There is no need to causal the model. **(5 Marks)**

2. Draw augmented bond graph model of the mechanical system shown in Fig. 2. Find its degrees of freedom from causality assignment. Assume that the square block and the cylinder can only have horizontal translation. The disk can rotate about the revolute joint shown in the figure. Both ends of the spring are revolute joints, i.e., the spring is a two-force member. **(10 Marks)**

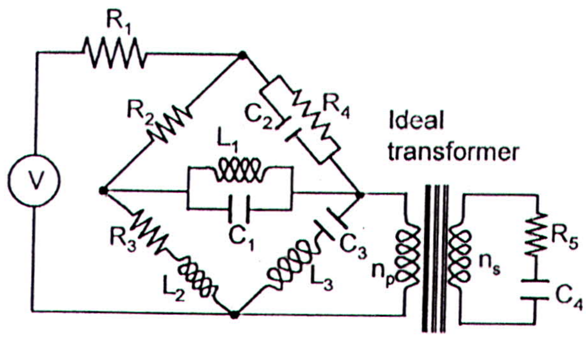

Fig. 1.

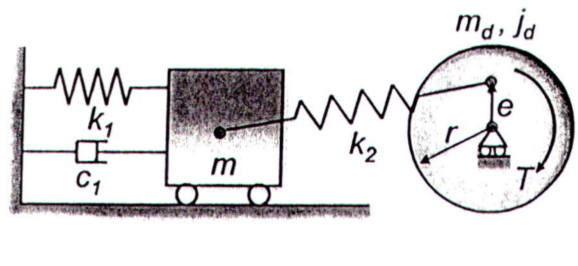

Fig. 2.

3. Using bond graph transformer and gyrator equivalence, derive the equivalent circuit of the real transformer shown in Fig. 3 with the magnetic domain referred to the secondary side. The input and load resistances are R_E and R_L, respectively; the primary and secondary side winding inductances are L_p and L_s, respectively; and the number of turns in the primary and secondary sides are n_p and n_s, respectively. The mean core length is L, the average core cross-section is A and the magnetic permeability of the core is μ. Assume that flux is continuous across the core and losses, such as fringe flux, leakage flux, and core loss, etc. can be approximated by a single resistance R_c in the magnetic domain.

(5 marks)

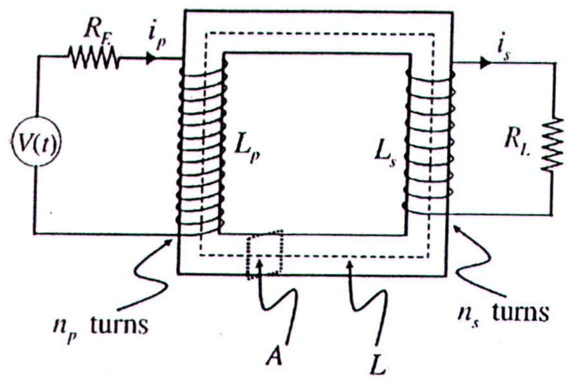

Fig. 3.

4. Derive the state-space equations of the system shown in Fig. 4. Assume viscous friction at the contact between spool and the rolling surface at a radius of r_o. The rope of negligible mass is wound around the spool of radius r_i. The mass and rotary inertia of the disk are M and J, respectively. Include gravity g in the model.

(10 Marks)

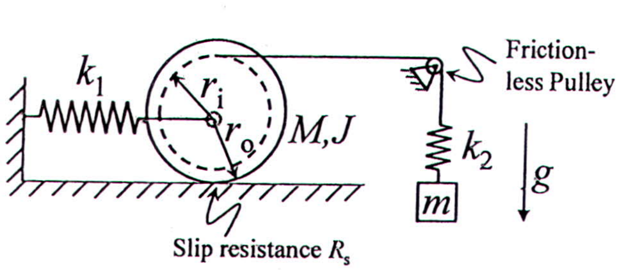

Fig. 4.