21

INDIAN INSTITUTE OF TECHNOLOGY

Mid-semester Examination

Date: 16 September 2015 **Time:** 2 Hrs **Full Marks:** 30 **No. of Students:** 175

Semester: *Autumn* **Department:** *Mechanical Engineering*

Sub. Name: *Systems and Control* **Sub. No.:** *ME40601*

Instructions: *Answer **any four** questions. Make suitable assumptions if required with justifications. The nomenclature and representations used are as discussed in the class. No further clarification will be provided.*

---

1. Draw a bond graph model of the electrical system shown in Figure 1. The numbers of turns in the primary and secondary sides of the ideal transformer are N_p and N_S, respectively. Use suitable grounds.

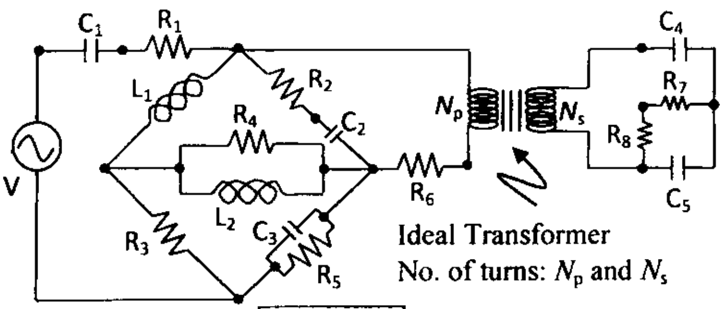

Figure 1

2. Derive an equivalent purely electrical system of the multi-energy domain (electrical, magnetic and mechanical) system shown in Figure 2. The magnetic domain can be referred to the primary or secondary side of the electrical domain of an ideal transformer. The magnetic core of the transformer has cross-section A, effective length or mean core length L, and magnetic permeability μ. R_c is the resistance that represents total magnetic core losses. The DC motor characteristic constant is μ_m. The numbers of turns in the primary and secondary sides of the transformer are N_p and N_s, respectively. The rotor shaft is rigid and J_d is the rotary inertia of the disc including that of the rotor of the motor. R_1 and R_2 are two resistances and R_d is a variable resistance of the diode. Mention the parameters of the equivalent system in terms of the original system parameters.

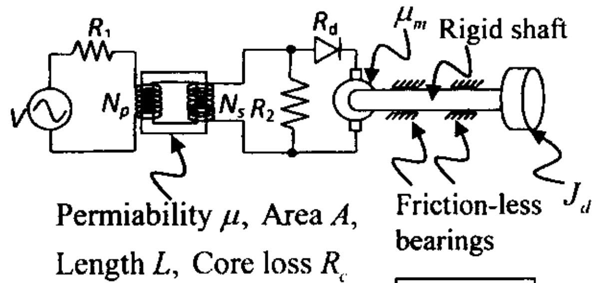

Figure 2

3. Using bond graph approach, find the degrees of freedom of the system shown in Figure 3. The spool mass and rotary inertia are M and J, respectively. The outer rim of the spool (radius r_o) is in contact with the ground, the rope is wound around the inner core (radius r_i) and there is no slip between the ground and the spool (pure rolling). If the system is initially in static equilibrium and a small disturbance is given then find its natural frequency of oscillation. Note that the system is linear and hence, gravity can be neglected while determining the natural frequency.

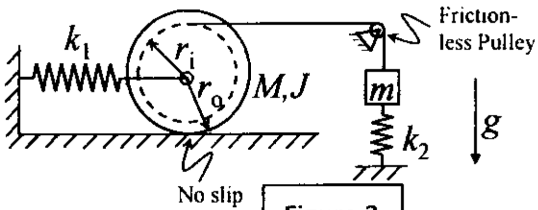

Figure 3

4. Draw a block diagram model of the system shown in Figure 4. The block of mass M can slide up and down without friction. The pendulum rod can extend or shorten axially. A friction-less revolute joint is used to suspend the pendulum. There can be large motions and the system is non-linear. Assume that the pendulum rod is massless and the bob is a point mass. Gravity must be included in the model.

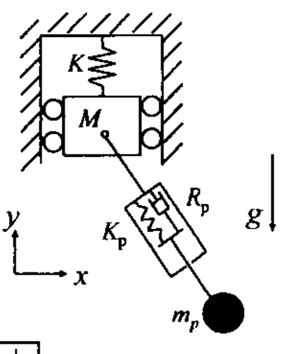

Figure 4

5. Derive the state-space equations of the pitch-plane model of the vehicle system shown in Figure 5. Consider only vertical motion and pitch in the model.

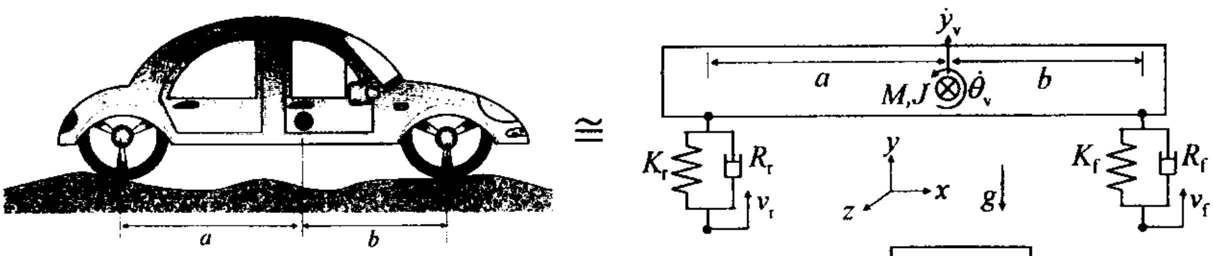

Figure 5