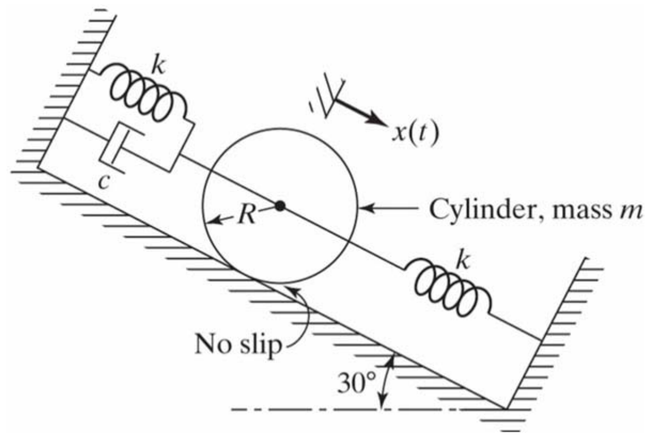
ME497: Acoustics and Vibrations in Design, Final Exam, April 19, 2011
Department of Mechanical Engineering, University of Saskatchewan
Time: 2:00-5:00 pm **Instructor: Reza Fotouhi** **Student Name/ID ………..……………………**

Close-book exam, two letter size double-sided formula sheets are allowed. No other materials or computer are allowed in the exam. One Calculator is permitted. Please **answer questions 1, 2, 3, and one of (4 or 5)**. Question 5 will not be marked if both 4 and 5 are answered. All questions have equal mark. Begin each problem on a new page in your answer book. Show your work. **Return the question sheet** inside the exam booklet when you hand back your exam.

Q1 – For the system shown,

a. Derive the translational equation of motion in terms of $m, c, k, R,$ and x, and show that it can be written as $m_{eq}\ddot{x} + c_{eq}\dot{x} + k_{eq}x = 0$, identify m_{eq}, c_{eq}, k_{eq}.
b. For $m_{eq} = 10kg, c_{eq} = 150N \cdot s/m, k_{eq} = 1000N/m$ obtain damping ratio ζ, and damped frequency ω_d
c. Using part (b) data and $x(0) = 0.1m, \dot{x}(0) = 10m/s$, obtain natural response of the system.

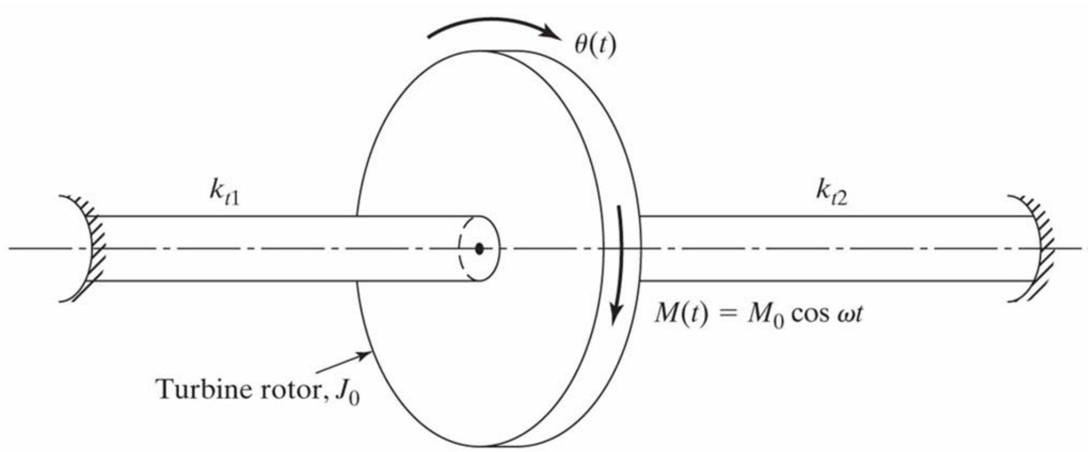
For a cylinder with radius *R* and mass *m*, the mass moment of inertia is $J = mR^2/2$



Q2 – A turbine rotor is mounted on a stepped shaft that is fixed at both ends as shown. The rotational stiffness of the two segments of the shaft are k_{t1} and k_{t2}. The turbine generates a harmonic torque given by $M(t) = M_0 \cos(\omega t)$ about the shaft axis. The mass moment of inertia of the rotor about the shaft axis is J_o, and equivalent torsional damping constant of the system is c_t.

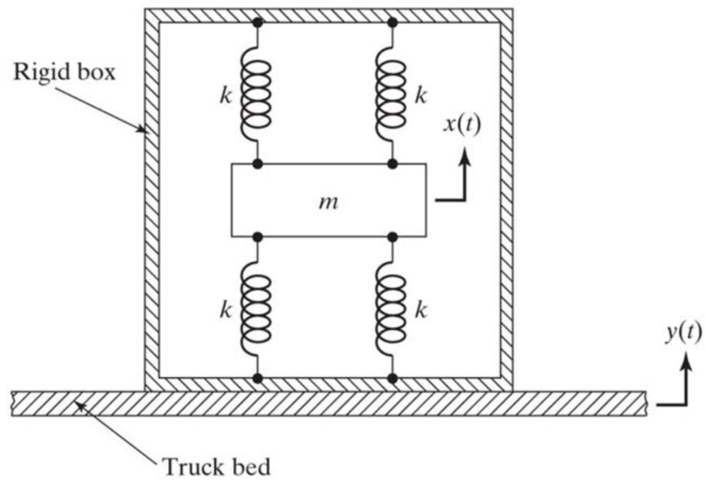
a. Find the rotor rotational equation of motion in terms of parameters $J_o, c_t, k_{t1}, k_{t2}, M_o, \omega, and\ \theta$. You may use Euler (Newton) equation.
b. Obtain the steady-state response (force response) of the rotor θ, and draw torque balance diagram for the turbine (similar to what was done in the class), using the following data:

$$k_{t1} = 3000N \cdot m/rad\ ,\ k_{t2} = 4000N \cdot m/rad$$
$$M_o = 200N \cdot m,\ \omega = 500rad/s,\ J_o = 0.05kg \cdot m^2$$
$$c_t = 2.5N \cdot m \cdot s/rad$$



Q3 – (Design of isolator) A delicate instrument weighing 200 N is suspended by four identical springs, each with stiffness 50,000 N/m, in a rigid box as shown. The box is transported by a truck. If the truck is subjected to a vertical harmonic motion given by $y(t) = 0.02\, sin(10t)\, m$,

a. Find the maximum displacement, velocity, and acceleration experienced by the instrument.
b. Can you make the maximum displacement of the instrument (X) to be 50% of maximum vertical motion of the truck bed (Y) by adding a viscous damper to the rigid box? Justify your response.
c. Propose a design (give values of spring coefficient, k and damping coefficient, c) such that ratio X/Y is less than 50%. If you are using a viscous damper c, justify its use.



Q4 – A canteen of dimensions 8m × 4m × 3.5 m (long× wide× high) contains an extractor fan situated at ceiling height half way along one of the long walls. The sound power level of the fan is 72 dB in the 125 Hz octave band. The reverberation time of canteen has been measured and is 0.8 seconds in this octave band.

a. Obtain the total sound pressure level in this frequency band at a point 3 m from the fan.
b. Obtain the direct and reverberant portions of the sound pressure level at this point (in part a)
c. As an engineer you are asked to convert the canteen to a room suitable for meeting. How much extra absorbent material you need to make this canteen an ideal meeting room? What will be the average absorption coefficient of this meeting room?

Q5 – A theater of dimensions 30m × 35m × 10 m (long× wide× high) has a seating capacity of 1000 persons on wooden chairs. Area of 90 percent of the total floor consists of timber boards on joists. The remaining 10 per cent of the total floor is stage. The walls and ceiling are concrete. The entire ceiling, rear wall and side walls are to be treated with the same absorbent material.

a. What values of absorption coefficient are required for this material to achieve a reverberation time of 1 sec, at 125 Hz and 2kHz frequencies, in the theatre with a full capacity audience?
b. As an engineer you are asked to make this theater suitable for orchestra. How much extra absorbent material you need to make this theater ideal for orchestra? What will be the average absorption coefficient of this new theater?

	Absorption coefficients		
Material	125 Hz	500 Hz	2 kHz
Timber boards on joists	0·15	0·1	0·1
Concrete	0·02	0·02	0·05
Stage	0·4	Nil	Nil
	Absorption units (m^2)		
Audience/person	0·15	0·4	0·45