MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Mechanical Engineering

2.004 Dynamics and Control II
Fall 2007

Problem Set #1

Posted: Friday, Sept. 7, '07 **Due: Friday, Sept. 14, '07**

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1. For each one of the following systems, argue if in your opinion it is open–loop or closed–loop. In your argument, include your definitions of the system's inputs and outputs. Briefly describe how feedback is effected in the systems which you decide are closed–loop.

a) Washing machine.

b) T Green line subway car.

c) Audio speaker.

d) Air conditioner.

e) Manual gear train in an automobile.

f) Automatic gear train in an automobile.

2. Rework the solution to the motor–shaft system of Lecture 2 with viscous friction to include non–zero initial conditions $\omega(0) = \omega_0 \neq 0$. Express your result analytically in terms of ω_0; then plot substituting numerical values identical to those in Lecture 2 and

a) $\omega_0 = 0.5\,\text{rad/sec}$;

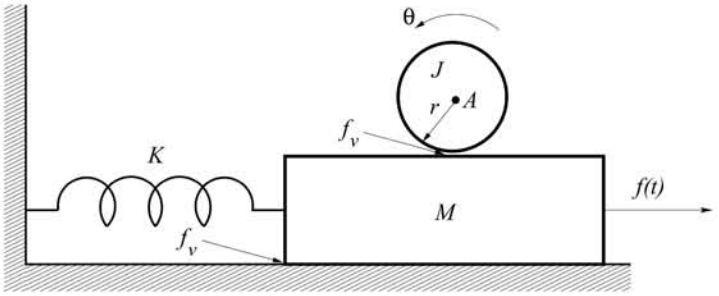
b) $\omega_0 = 2.0\,\text{rad/sec}$.

What do you observe?

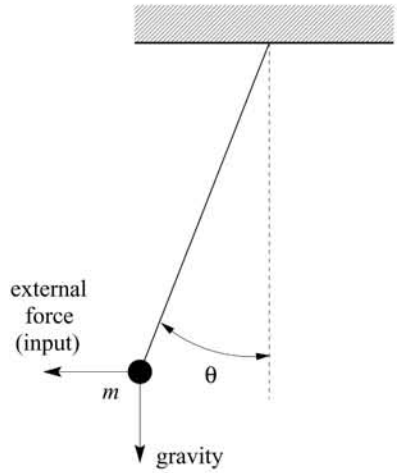
3. Rewrite the shaft equation of motion from Lecture 2 to include drag friction and modify the MATLAB file `shaftcv_kernel` to solve the resulting equation of motion numerically. Plot the velocity $\omega(t)$ for $0 \leq t \leq 10\,\text{sec}$, drag coefficient $f_d = 0.2\,\text{kg}$ and all other numerical values as in Lecture 2.

4. Write (but don't solve) the equations of motion for the following mechanical systems, and state if the systems are linear or nonlinear.

a) An inertia J of radius r attached to a fixed axis of rotation A as shown below. The inertia is in contact with a mass M attached via a spring of stiffness K to a fixed wall. The inertia–mass contact is subject to viscous friction of coefficient f_v. The motion of the mass with respect to the horizontal floor is subject to the same viscous friction coefficient f_v. The system input is a horizontal force $f(t)$ on the mass M and the output is the rotation $\theta(t)$ of the inertia.



b) A pendulum consisting of a mass m attached to a rigid mass–less rod as shown below. The system input is a horizontal external force and the output is the angle θ.



5. Given below are the equations of motion for several systems. $f(t)$ denotes the external force (*i.e.*, input). Which of these systems are linear? Include a brief justification based on the definition of linear systems from Lecture 1.

a) $7\ddot{x} + 0.5\dot{x} + 5\sin\left(\frac{2\pi}{10}t\right)x = f(t)$.

b) $7\ddot{x} + 0.5\dot{x} + 5(1 + 0.1x)x = f(t)$.

c) $\frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{1}{2}m\dot{x}^2 + \frac{1}{2}kx^2\right) = 0$.