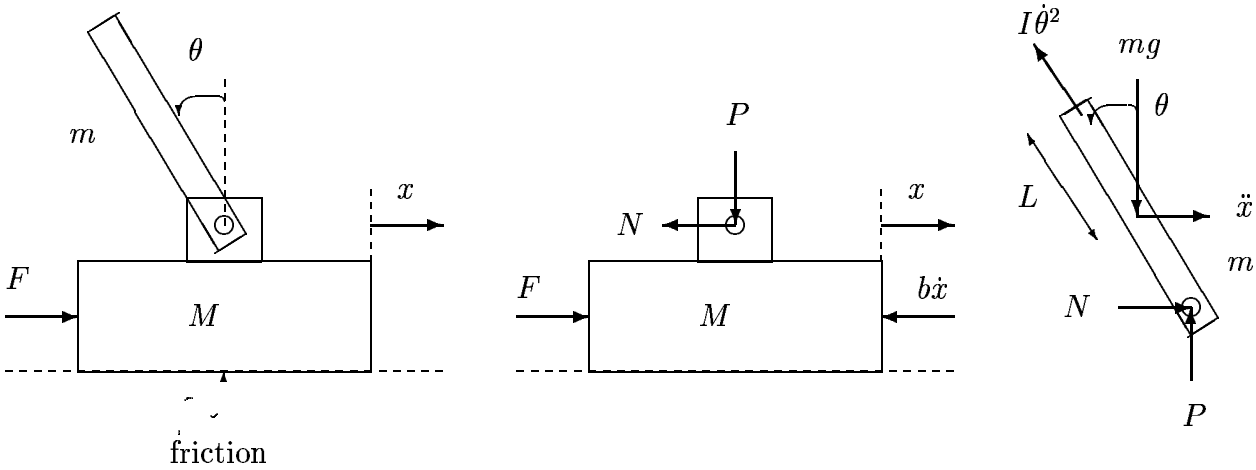
EEE 101 AY2001-2002 : First Exam Sample Problems

1. Name three advantages and two disadvantages of a closed loop system as opposed to an open loop system.

2. Inverted pendulum. Determine the transfer function of the cart and inverted pendulum system shown below where

M : mass of the cart	m : mass of the pendulum
l : length to pendulum center of mass	I : inertia of the pendulum about the cetroid
b : coefficient of friction	F : force applied to the cart
x : cart position	θ : pendulum angle from the vertical



a. Sum forces in the FBD (free body diagram) of the cart along the horizontal axis. Sum forces in the FBD of the pendulum along the horizontal. Combine the two equations to arrive at the first equation of motion. Neither N nor P should appear in the first equation of motion.

b. Determine the second equation of motion. Hint. Sum forces in the FBD of the pendulum along the perpendicular and sum moments around the centroid of the pendulum. Simplify.

c. The two equations of motion required above are nonlinear. Linearizing the two equations about $\theta_0 = 0$ gives the following two equations where ϕ represents the perturbation about θ_0 and r the new input.

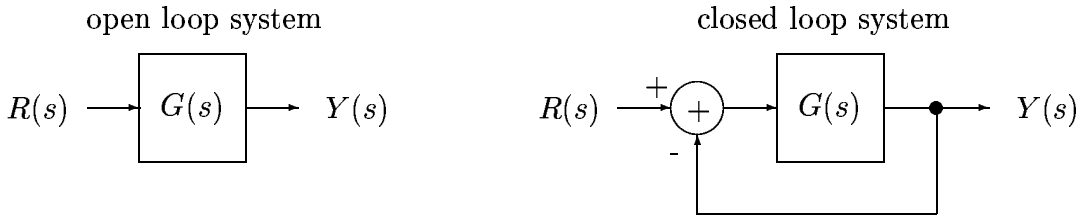
$$(M + m)\ddot{x} + b\dot{x} - ml\ddot{\phi} = r$$
$$(I + ml^2)\ddot{\phi} - mgl\phi = ml\ddot{x}$$

Determine the state space representation of the above equations using the state variables $y_1 = x$, $y_2 = \dot{x}$, $y_3 = \phi$ and $y_4 = \dot{\phi}$.

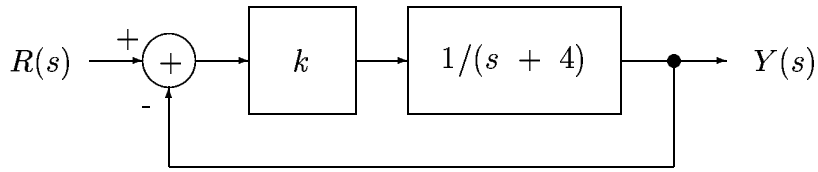
d. Determine the transfer function $\Phi(s)/R(s)$. Express in the following form where $a_n = ml$.

$$\frac{\Phi(s)}{R(s)} = \frac{a_n s^n + \ldots + a_1 s + a_0}{b_m s^m + \ldots + b_1 s + b_0}$$

3. Define $e(t) = r(t) - y(t)$. Given an open loop system and a closed loop system as follows.



a. Determine steady-state error e_{ss} in response to a unit step input for the open loop and closed loop systems in terms of G(0).
b. Sketch $|e_{ss}|$ vs. different values of $G(0)$, $-\infty < G(0) < \infty$ for the open loop and closed loop systems. Label all relevant points of the graphs.
c. For $G(0) > 0$, determine what range of $G(0)$ will give $|e_{ss}^{closed\ loop}| < |e_{ss}^{open\ loop}|$ for a step input.
d. A unit step input is applied to the following system. What value of k will give $|e_{ss}| = 0.1$.



4. A EEE 101 student is checking out his/her MATLAB skills.

a. The student issued the following command :
`[ns,ds] = series([1 1],[1 2 1],[1 0],[1 5 2])`.
The student claims that the resulting `[ns,ds]` corresponds to the transfer function

$$G(s) = \frac{s^2 + s}{s^4 + 7s^3 + 13s^2 + 9s + 3}$$

Is the student accurate? Justify.
b. The student issues another command :
`[nf,df] = feedback([1 1],[1 2 1],[1],[1],-1)`.
The student claims that the resulting `[nf,df]` corresponds to the transfer function

$$G(s) = \frac{s + 1}{s^2 + 3s + 1}$$

Is the student accurate? Justify.