Exam Number: ___________

Department of Mechanical Engineering
Michigan State University

Ph.D. Qualifying Examination
August 2009
Dynamic Systems and Control

Open Book
Answer All Questions
All Questions Weighted Equally

Exam Prepared by

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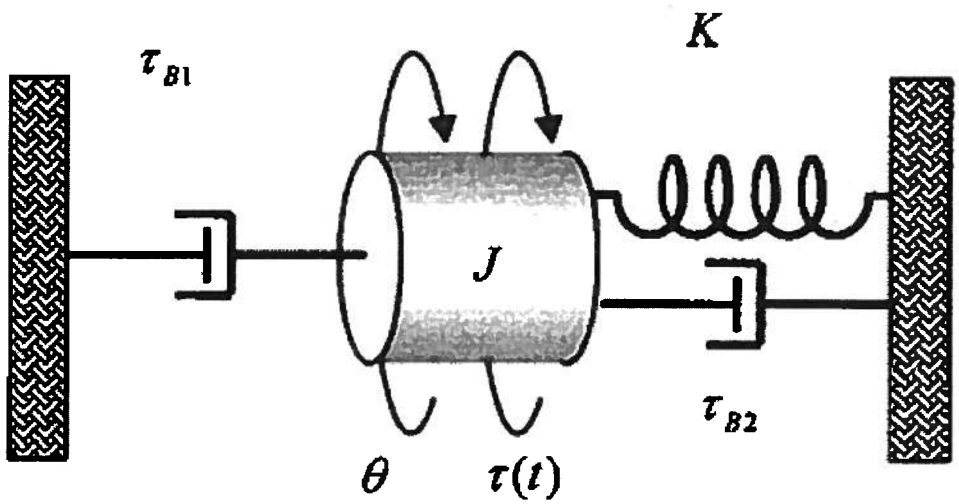
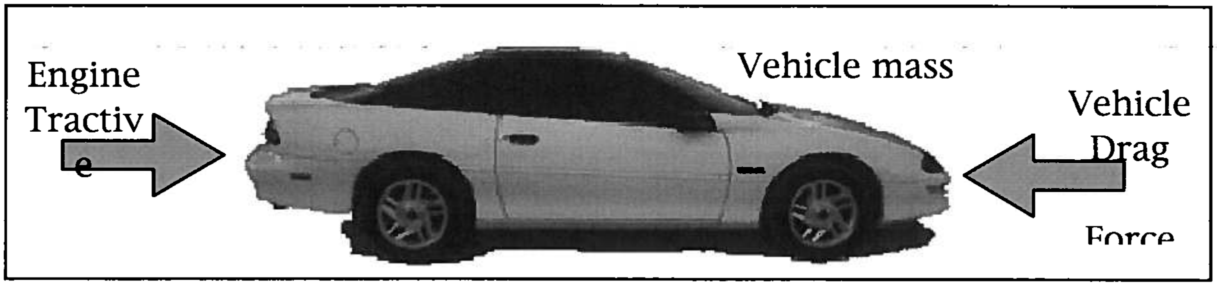
1) Consider the following mechanical system where $\tau(t)$ is the applied input torque; $\tau_{B1}(t) = 10\dot{\theta}(t)$ and $\tau_{B2}(t) = -15\dot{\theta}(t)$ are damping forces; and K=20 and J=2 are the spring stiffness and inertia, respectively.



a) Draw the free body diagram of the system.
b) Derive the equations of motion
c) Determine the transfer function from the input $\tau(t)$ to the output $\theta(t)$, i.e, $\frac{\Theta(s)}{T(s)}$
d) Determine the system stability from the transfer function.



2) The nonlinear dynamics of a 1995 Camaro are governed by the ordinary differential equation

$$100\dot{v} + 46.87 - 1.558v + 0.02267v^2 = e[229.2 - 0.560v]$$

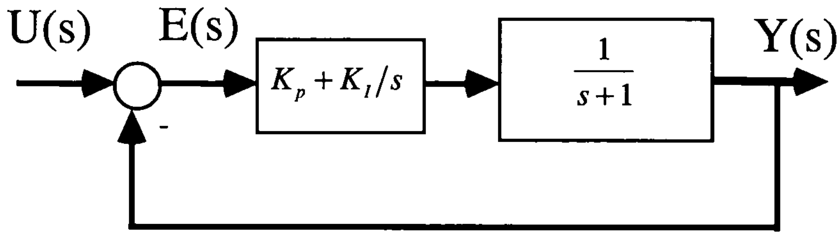
where the vehicle model variables are velocity, $v = v(t)$ in ft/sec and engine throttle, $e = e(t)$ in percent.

a) Determine the linearized differential equation relating $\square$ to $e(t)$ for the equilibrium operating point at $v_0 = 88\, ft/\sec$. Hint: the linearized equations are written using deviation varaiables such as $\bar{v} = (v - v_o)$ and $\bar{e} = (e - e_o)$. (Attach calculations)

b) Determine the <u>steady state</u> response $\bar{v}_{SS}$ (ft/sec) of the linearized system found above to the excitation $\bar{e}_{SS} = 5\%$

$\bar{v}_{SS} =$	ft/sec

3) You are to design a Proportional + Integral (PI) controller for the system shown below.



a) Find gains K_p and K_I that render the system stable and have a maximum system time constants of $\tau_{max} = 0.5\,\text{sec}$ (All others are smaller) and has a closed loop error of less than 1%.

$K_P =$
$K_I =$

b) At the gains you supplied in part b), what is the steady state error for a unit step input to this system?

4) Sketch bode diagrams for the following transfer functions:

a) $G(s)=-10$
b) $G(s)=1/s^2$
c) $G(s)=1/(s+1)$