HW #3

Assigned April 14, 2017. Due April 21, 2017 at 5:00 pm CST on Canvas.

Name: ____________________________  Section Number: _____

Please refer to the homework guidelines on the web regarding late HW policy and TA help. This HW requires Matlab programming. Start early.

1.

(80 points) In this homework we will apply the tools learned in EA3 for mechanical systems to a realistic problem.

This problem uses Matlab. Turn in your program and graph(s), as well as discussion of the solution. Be neat!

This system represents a person riding in a car. In particular, m3 represents the mass of the car chassis and m6 represents the seat and person. The driving velocity from the road is applied at the bottom and is given below along with the other system parameters.

Bernice is a student in EA3. Every day she gets a ride to class from her boyfriend, Fred, who owns a 1980 Volvo. To make sure she is ready for the class, Bernice reviews the day's material during the ride to class. Because Fred's car is suffering from seriously weak shock absorbers, car vibrations make it difficult on Bernice to read the text. She then decides that if she exerts a proper force with her hand pushing on the ceiling of the car she can maintain the absolute distance between her and the street as constant. Follow the steps below to determine how Bernice can achieve her goal.
**elements 1, 2:** shock absorption from tires/shocks:
k1 = 100,000 N/m, \( b_2 = 10,000 \text{N} \cdot \text{s/m} \)

**mass 3:** car chassis:
m3 = 1,000 kg

**elements 4, 5:** seat suspension:
k4 = 20,000 N/m, \( b_5 = 2000 \text{N} \cdot \text{s/m} \)

**mass 6:** mass of seat and person: m6 = 60 kg

\( X_{\text{road}}(t) = 0.01 \sin(10t) \) ...
effective bumpiness of road transmitted to car; **Hint:** use \( X_{\text{road}}(t) \) to find the velocity applied by the road

F6(t)... force Bernice applies to ceiling

**Initial condition:** x1 = -0.104 m, v3 = 0 m/s, x4 = -0.0294 m and v6 = 0 m/s

1-1. For the system shown, identify a minimal complete set of state variables and find the state equations. All elements are linear, ideal, etc. Note that the state equations for the system should account for the force of gravity acting on the masses (i.e. consider an additional gravitational force on each mass which is not explicitly shown in the figure above), the driving velocity \( V_{\text{road}}(t) \) at the base and a force F6(t) on mass 6.

1-2. Write a Matlab code to solve this system of equations using the forward Euler method. Note: Be sure to add the applied force/velocity terms to the state equation in your code.

1-3. Run your Matlab code with F6(t) = 0 and the specified velocity of the road (derived from \( X_{\text{road}}(t) \)) and plot v6(t) and x6(t) - x6(t=0). This is the motion
and position of Bernice trying to read the EA3 material before class in the car.

1-4. Now derive the expression to find $F_6(t)$ such that Bernice remains stationary (i.e. $x_6(t)=$constant which implies $v_6(t) = 0$ and $v_6'(t) = 0$). Implement this condition in your Matlab code to find the necessary $F_6(t)$. Plot $F_6(t)$ and $v_3(t)$ at least up to a time of 2 seconds. Notice the sign of the result. Can Bernice apply this force by simply pressing on the ceiling with her hand, or does she need a handle mounted in the ceiling to hold onto?

1-5. Instead of pushing on the ceiling, is it possible to place an active damping system in the seat suspension, so that $b_5$ is a function of time: $b_5(t)$ to achieve the same result? Discuss how you would obtain the needed $b_5(t)$ (with $F_6(t)=0$; do not try to program this) and comment whether this is physically possible.

2. (20 points)

Someone left a big refrigerator on an adjustable ramp. The angle of the ramp can be increased in order to then deliver the refrigerator to a loading dock above. Consider the mass of the refrigerator to be $m$.

2-1. Draw a free body diagram of the refrigerator: to do this, redraw the refrigerator, separated from the ramp and carefully label all forces acting on the refrigerator.

2-2. Obtain equations for the normal force, $N$, and the friction force, $f$, if the refrigerator is stationary. It is helpful to use a coordinate system aligned with the ramp.
2-3. Let the coefficient of friction \( \mu = 0.4 \). Determine when the block will slip down the incline, as the angle, \( \alpha \), is slowly increased.

2-4. If the angle, \( \alpha \), is 25 degrees, will the block slip? If it does slip, what will be its acceleration down the ramp?