HW #3
Assigned April 24, 2019. Due May 1, 2019 at 6:00 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. (60 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: 
\[ k_1 = 100000 \text{N/m}, \quad b_2 = 10000 \text{N-s/m} \]

mass 3: car chassis: 
\[ m_3 = 1000 \text{kg} \]

elements 4, 5: seat suspension: 
\[ k_4 = 20000 \text{N/m}, \quad b_5 = 2000 \text{N-s/m} \]

mass 6: mass of seat and person: 
\[ m_6 = 60 \text{kg} \]

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

\[ F_6(t) \ldots \text{force Bernice applies to ceiling} \]

**Initial condition:** 
\[ x_1 = -0.104 \text{m}, \quad v_3 = 0 \text{m/s}, \quad x_4 = -0.0294 \text{m} \text{ and } v_6 = 0 \text{ m/s} \]

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 \( F_6(t) \) 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 \( F_6(t) = 0 \) and the specified velocity of the road (derived from \( X_{\text{road}}(t) \)) and plot \( v_6(t) \) and \( x_6(t) - x_6(t=0) \). This is the motion and position of Bernice trying to read the EA3 material before class in the car.
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?
3. (20 points)

A baseball player is running to a base in a baseball game (Figure 1a). He studied EA3 before (with a grade B+) and thinks he can touch the base faster by sliding into the base (Figure 1b). Assume the height of the player is 1.8m, the center of mass of the player is always 0.9m from his toe when he runs, stands or slides, and the player runs at a speed of 7m/s. We will ignore the influence on center of mass due to the movement of his arms and assume his center of mass is on the ground when he slides. His initial sliding speed (when he suddenly drops into a slide) is assumed to be same as his running speed. The acceleration due to gravity is 9.81m/s², and the coefficient of friction between his body and the dirt is 0.8 when he slides.

3a)  

3b)  

3-1. Before the game the base runner used above numbers and did a careful calculation on how far away from the base he should be when he suddenly drops to a slide. His plan is to have his toe just touch the base when he stops sliding.

- What is the distance he calculates?

3-2. A student from our EA3 watched the game and did not think that the player saved time by doing his way.

- Will the player save time by sliding into the base as planned in part 1? [ ] Yes. [ ] No.

- How many seconds does he save or lose compared to running all the way to base?