ME 355 – System Modeling and Numerical Methods
Fall 2021

Project 3

Due Monday, October 18 by 11:59 pm
Preliminary functions are due Wednesday, October 13 by 11:59 pm
This project must be turned in on Blackboard.

You are the lone mechanical engineer at Mountain Bikes Unlimited. As you are working on a bicycle design, your project lead comes to your cubicle with an urgent request.

"I know this is odd, but our client is concerned that when they pedal, they are going to be so strong that the pedal bracketing system will deflect. They are saying that they are worried this deflection will strain their ankles. Can you look into this for me?"

You sigh and begin sketching out the system. You sketch the mountain bike you are working on in Figure 1a, and a free-body diagram of the pedal bracketing system in Figure1b. For the entire pedal bracketing system, you assume the entire system is static and no dynamic forces will impact the energy of the system. You then decide to look up the material properties and parameters for the pedal bracketing system. These are listed in Table 1.

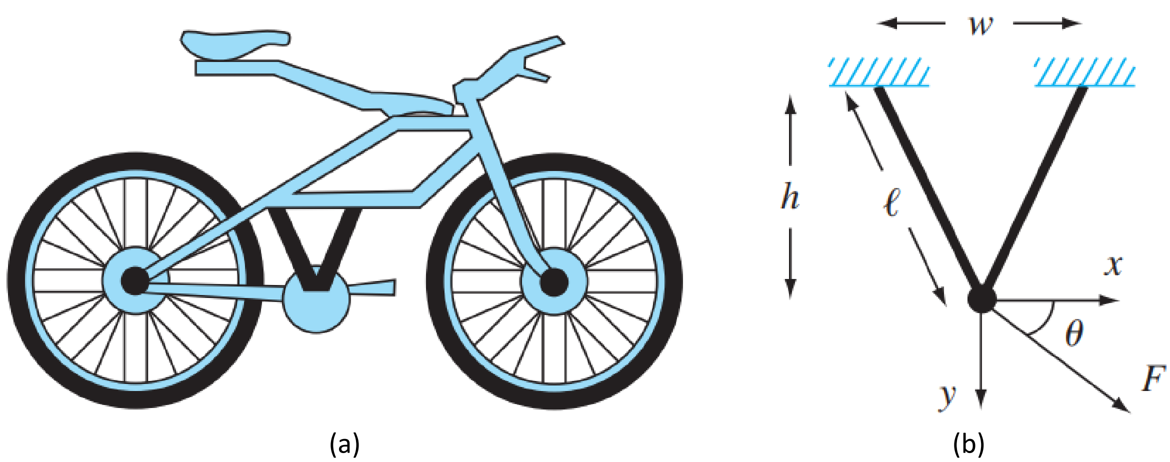

Figure 1. (a) A sketch of the mountain bikes produced at Mountain Bikes Unlimited, and (b) a diagram of the model used to examine the pedal bracketing system.

Table 1. Material and geometric parameters for the mountain bike.

Parameter	**Symbol**	**Value**	**Units**
Young's Modulus	E	2×10^{11}	Pa
Cross-sectional Area	A	0.0001	m^2
width	w	0.44	m
length	l	0.56	m
height	h	0.5	m

Your job is to analyze the deflection of the pedals when a given force is applied to the system. During your analysis, **assume the force (F) is 10,000 N and θ can only range from 0 (straight right) to $\pi/2$ (straight down)**. You plan to accomplish this analysis by:

1) Developing the model equation for potential energy based on the variables E, A, w, l, h, θ, and F.
2) Examining the deflection under different conditions.

You plan on modeling the beams using two different methods.

1) *Truss Method*
   In this method, the two rods will be modeled as truss elements. The truss elements can be modeled as springs with stiffness EA/l. Like the in-class example, you will need to develop the potential energy equation using this method.

2) *Beam Method*
   In this method, the two rods will be modeled as beam elements. The equation for the potential energy of the rods modeled as beam elements includes potential energy from the linear movement and the bending movement of the rods. It can be modeled as

$$\mathrm{PE}(x, y) = \frac{EA}{l}\left(\frac{w}{2l}\right)^2 x^2 + \frac{EA}{l}\left(\frac{h}{l}\right)^2 y^2 - Fx\cos\theta - Fx\sin\theta.$$

Functions

To complete this task, you will need to develop **2** MATLAB functions. Preliminary versions of these functions are due on the date specified above. To get full credit for the preliminary functions you must have made a legitimate attempt. You may make changes to the functions after the preliminary function due date and prior to the final due date.

1. **PETruss.m**
   PE = PETruss(x, y, theta, F, E, A, w, l, h)
   This function calculates the potential energy of the pedal bracketing system by modeling the rods as truss elements.

2. **PEBeam.m**
   PE = PEBeam(x, y, theta, F, E, A, w, l, h)
   This function calculates the potential energy of the pedal bracketing system by modeling the rods as beam elements.

Analysis Documentation

For your project, you want to provide documentation to show your project lead your analysis. To complete your documentation, your report should include the following sections.

1. Title Page
2. Truss Method
   Explanation of the model using the truss method. This should include:
   a. Figure of the pedal bracketing system using spring elements. This can be hand drawn on unlined paper and scanned into your report.
   b. Clear instructions on how you derived your model equation for potential energy for the truss method.
   c. Your model equation for potential energy for the truss method.
3. Analysis
   This section only needs to include the following labeled figures. You should make these figures in a file called **project3.m**. To calculate the x and y displacement for a given set of parameters you will need to use the fminsearch function. For examples, see the example code from class. Note: plots are in the form of y-axis versus x-axis variable.
   a. Truss Method
      i. Plot of x displacement versus theta
      ii. Plot of y displacement versus theta
      iii. Plot of total displacement versus theta
   b. Beam Method
      i. Plot of x displacement versus theta
      ii. Plot of y displacement versus theta
      iii. Plot of total displacement versus theta
4. Discussion
   This section should contain the following:
   a. Brief discussion of the displacement plots for the truss method.
   b. Brief discussion of the displacement plots for the beam method.
   c. Descriptive comparison between the truss and beam methods for the:
      i. X displacement
      ii. Y displacement
      iii. Total displacement
   d. Discussion on why there are disparities between the truss and beam methods.
   e. Discussion on which method you believe to be more accurate and why.

Deliverables

Be sure to submit all 4 files!

1. PETruss.m
2. PEBeam.m
3. Project3.m
4. Analysis Documentation PDF

Rubric (Total 100 Points)

Function 1 – **15 Points**
Function 2 – **5 Points**
Turned in preliminary functions on time **– 10 points**

Modeling Documentation – **70 Points**
  Professional Format – **10 Points**
  Title Page – **5 Points**
  Truss Method – **15 Points**
  Analysis – **25 Points**
  Discussion – **15 Points**

Notes for Report

For any equations, please use the equation editor.
For Figures and Tables, please follow the guidelines outlined in the example report on Blackboard.
Include a title page.

Notes for Functions

These notes do not apply to the **project3.m** file.
All functions must be named EXACTLY as listed above. This includes capitalization.
Functional inputs and outputs must be EXACTLY as defined in the Functions section.

Test Data

If you run the following code below in the MATLAB command window, you should get the following output. Do note, this does NOT guarantee your code is correct.

PETruss(1,1,1,1,1,1,1,1,1) = -0.4965

PEBeam(1,1,1,1,1,1,1,1,1) = -0.1318