

Assignment 8: Matlab Scripts and Plots

Date Due: March 29, 2024

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Problem 1

An engineer would like to solve the system of linear equations:

$$23x_1 + 45x_2 + 67x_3 + 56x_4 + 22x_5 = 120$$

$$13x_1 + 35x_2 + 37x_3 + 26x_4 + 20x_5 = 130$$

$$18x_1 + 14x_2 + 45x_3 + 29x_4 + 16x_5 = 200$$

$$20x_1 + 14x_2 + 15x_3 + 19x_4 + 19x_5 = 210$$

$$17x_1 + 14x_2 + 45x_3 + 29x_4 + 16x_5 = 312$$

- Create a script in Matlab to solve the system of equations. You can read the data from a text file or just enter the information in the script. Display the results for each value of x into the Command Window with a nice format. For example : $x_1 = 35$ and so on.
- Add code to the script to find the values of x that are positive. Display those in the Command Window.
- Find the Eigenvalues of the right-hand side matrix containing the coefficients of each x using the “eig” command in Matlab.

Problem 2

A train engineer finds that the basic train resistance of a high-speed train (see Figure 1) to be:

$$R = A + BV + CV^2$$

$$P_r = 1000 * R * V$$

Where:

R is the basic train resistance in kiloNewtons

P_r is the power required to move the train in Watts

V is the train speed in meters/second

A, B, C are empirical constants derived from wind tunnel test. The values of A, B, C are 8.1, 0.11, and 0.012, respectively.

- Create a Matlab script** to estimate the value of the basic train resistance (R) and the power required (P) as a function of train speed (V). For this analysis create a vector of speeds between 0 and 80 meters/second at intervals of 1 m/s and estimate resistance and power.
- Plot the train resistance (in Newtons) and the power required in Watts. Use a subplot to plot both graphs in a 2 by 1 matrix configuration.
- Convert the power required to horsepower in the script and plot horsepower (in y-axis) as a function of train speed (in the x-axis).



Figure 1. High-speed Train (Shinkansen 300 series). Source: Wikipedia.

Problem 3

A simple formula used in highway engineering to estimate the horizontal radius of a road is:

$$R = \frac{v^2}{g(e + f)}$$

where:

R is the road horizontal radius (in meters)

v is the road design speed (m/s)

g is the gravitational constant (9.81 m/s²)

e is the superelevation rate of the road (%/100). For example, a road with a superelevation rate of 0.06 implies the road of inclined at a lateral slope of 0.06 meters for each one meter in horizontal distance (see . Typical values of e vary from 0 (no superelevation) to 0.10 (high superelevation).

f is the lateral friction force coefficient developed between the vehicle tires and the pavement (see Figure 2).

The lateral friction force coefficient varies according to the table below. This means, at higher speeds, the car has less grip on the road to execute a turn.

Road Design Speed (m/s)	Lateral Friction Coefficient f (dim)
5.0	0.18
8.3	0.17

Road Design Speed (m/s)	Lateral Friction Coefficient f (dim)
12.5	0.16
16.7	0.15
25.0	0.12
28.0	0.11
33.4	0.09
35.0	0.083

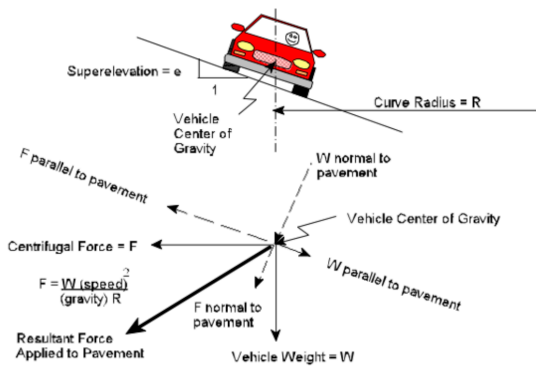


Figure 2. Road Superelevation Diagram. NYDOT.

- A) Plot the road design speed versus the lateral friction coefficient in Matlab (see values in Table 1). Use the **Basic fitting method** demonstrated in class to find the best **second-order polynomial** of the data.

The objective is to find the value of lateral friction coefficient (f) for any speed required. The estimation of f can be performed using the linear regression approximation of f versus speed (v). The regression equation is of the form:

$$f = A + Bv + Cv^2$$

where:

A , B , C are the regression coefficients to be found using the Matlab Basic fitting method.

v is the road design speed (m/s).

Show me the plot and the equation of the second order polynomial found using Matlab.

- B) Create a Matlab script to estimate the radius of the horizontal curve (in meters) according to the equation provided as a function of design speed. Find the solutions for speed values ranging from 10 to 35 m/s (steps 05 m/s). Use a constant value of superelevation rate 0.04.
- C) Plot the radius of the curve for the speed values and label accordingly.
- D) Repeat the process for superelevation rate of 0.08.
- E) Comment on the effect of superelevation in the radius of the curve. How could superelevation help the civil engineer?

Problem 4

Figure 3 shows a beam supported on both ends with a single load applied at a distance “a” and “b” from both ends.

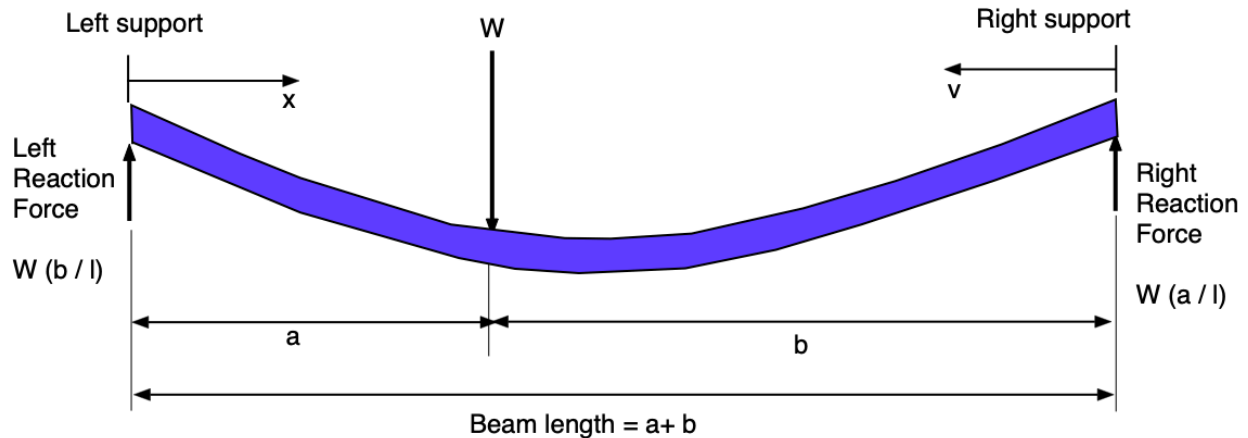


Figure 3. A simple beam supported at both ends with a load W at some known location. Adapted from: http://www.engineersedge.com/beam_bending/beam_bending3.htm. The nomenclature for beam deflection equations are shown below.

W = load (N)

E = Modulus of elasticity (N/m²)

I = Moment of inertia (m⁴)

x = Beam station (or distance) from left side of the beam to the loading point (m)

v = Beam station (or distance) from right hand side beam end point to the loading point (m)

l = beam length (m)

a, b = distances from each beam end point towards the loading point (m)

Let:

$$y_a = \frac{-Wbx}{6EI}(l^2 - x^2 - b^2)$$

$$y_b = \frac{-Wav}{6EI}(l^2 - v^2 - a^2)$$

where:

y_a = deflection of the beam from left support point (section a) in meters

y_b = deflection of the beam from right hand side support point (section b) in meters

Task 1

Create a **Matlab script** to estimate the deflections of the beam (y_a and y_b). Inputs to the script are the parameters W, E, I, a, b and vectors x and v . The output of the Matlab script are two vectors with values of deflection (y_a) and (y_b) for the given stations x and v . Your function should be able to handle vector operations.

Task 2

Test your Matlab script with the values shown below. Clearly state the values of the deflections at the values of the beam stations (x and v) shown below.

$$W = 3900 \text{ N}$$

$$E = 205e9 \text{ N/m}^2$$

$$I = 0.0008 \text{ m}^4$$

$$b = 3.75 \text{ meters}$$

$$a = 3.00 \text{ meters}$$

Find the deflection of the beam (y_a) for values of x ranging from 0 to "a" with step size 0.01 meters. Also, find the deflections of the beam at stations v from 0 to "b" with step size 0.01 meters.

In the calculations for Task 2 define x and v as a vector to produce two output vectors of deflections (y_a) and (y_b).

Task 3

Make a subplot of the beam deflection (y_a) as a function of beam station (x). Make a subplot of the beam deflection (y_b) as a function of beam station (v). Arrange the subplots in a single figure with deflections y_a in the top plot.

Task 4

Add code to the script created in tasks 1-3 to estimate two reaction forces and to measure the CPU it takes to do the calculations in your computer. Display in the Command Window the reaction forces and the CPU time to do the calculations.