ME 2450 Algorithms Integrated in Design 02
Propulsion System Analysis

Name: ______________________

Due: February 28, 2019

Collaborators: ______________________

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I declare that the assignment here submitted is original except for source material explicitly acknowledged.

I also acknowledge that I am aware of University policy and regulations on honesty in academic work, and of the disciplinary guidelines and procedures applicable to breaches of such policy and regulations, as contained in the University website.

Name	Date
Signature	Student ID

Score

Presentation:	/2
Technical Content:	/8
Total:	/10

Introduction

For this assignment, you will develop an analysis of a train being driven by a turbine or a piston powered by a constant-pressure source. Report your results in a memo and turn it in on Gradescope before midnight on February 28.

Algorithm Integration for Design

Modeling the Propulsion Force

(2 pts.) Suppose that you have chosen to propel your train using a piston (Figure 1) with a radius $r_p = 10.0$ cm. The piston is attached to one of the train's axles by a rack-and-pinion system with a gear of radius $r_g = 1.0$ cm. The axle is attached to a train wheel with a radius $r_w = 2.5$ cm. Assume that the pressure $P_0 = 50.0$ psig provided by your compressed air tank will be constant over the entire race. Determine the force that will be imparted to the train wheels by the piston.

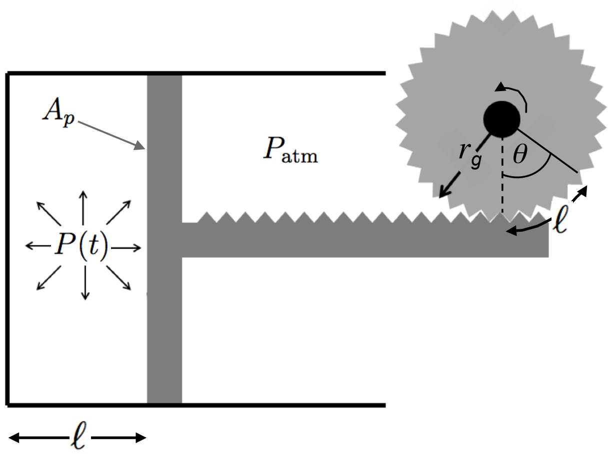

Figure 1: Schematic of a Simplified Piston Propulsion System. The air is assumed to be constant at pressure P_0. This pressure provides a constant force against the piston head of area A_P, which is connected to the train's axle by a rack-and-pinion, with a pinion gear of radius r_g.

Modeling the Train Motion

(4 pts.) Include the other forces that will affect your train's motion as illustrated in the free-body diagram in Figure 1. As you determined in AID 01, the basic equation of motion of the train may be written as given in (1) as follows:

$$m\frac{dx^2}{dt^2} = F_t - F_d - F_r \tag{1}$$

In order to predict the trains velocity and position, the forces on the right hand side of (1) must be modeled. In this assignment, you will model them as follows:

$$m\frac{dx^2}{dt^2} = F_t - \frac{1}{2}\rho A C_d V_{\text{tr}}^2 - C_r m g \tag{2}$$

Here, C_r is a rolling resistance coefficient (about 0.03) and C_d is the aerodynamic drag coefficient and V_{tr} is the velocity of the train. This mathematical model can be formulated as a root-finding problem to find the steady-state velocity of the train. (You may have to look up the definition of steady-state in an engineering textbook or using a search engine.) Estimate this steady-state velocity using three of the different root-finding methods that we have covered in class: (1) Bisection Method, (2) Modified Secant Method, and (3) Muller's Method. You must submit a copy of your computer code and evidence of code verification through testing. Note, that you do not need to rewrite code that you have previously written for homework or lab.

Figure 2: Free-body diagram of the forces acting on the train during the race.

To obtain a value for the velocity, you may make reasonable assumptions related to the acceleration of gravity and the density of air. Also, you will probably have to estimate the following parameters based on information you can find in existing literature or from your best estimate of your plans for your train:

- Mass of the train (assume the tank is schedule 40 PVC)
- Rolling resistance coefficient, C_r
- Drag coefficient, C_D
- Frontal area of the train, A (may be related to tank size)

In your write-up, comment on the effect each of these methods has on:

- The number of iterations required to find the velocity estimate.
- The relative error of each velocity estimate in comparison with the true value.

Your calculations for this section must be performed with a computer program that should be included with pdf file you submit. Also include any code output or codes written for verification tests.

Propulsion System Design

(2 pts.) Investigate the effect of several different parameters on the force imparted to the train by the propulsion system. Select at least five different combinations of the following variables:

- Tank pressure, P_0
- Train mass, m
- Piston radius, r_p

- Pinion gear radius, r_g

Now, select one of the root-finding methods that you have coded up and use it to find the steady-state velocity under each of these conditions. Please submit a labeled table with each of the parameters that you selected and the resulting velocities.

Conclusion

One of the most important skills of an engineer is to be able to break a large, daunting problem into parts and then to successively solve those smaller individual problems. In this assignment, you have estimated the force that the pressurized tank imparts to your train and you have used that information in a mathematical model of the steady-state train velocity. Although no answer is required in your memo, consider the following question: What would you need to change about your model to generate a more accurate train velocity estimate?