Wheeled Mobility Assignment
16-665: Robot Mobility on Air, Land, and Sea

Assignment Parameters
This is an individual assignment. Conceptual collaboration is encouraged but students may not exchange work or code nor copy information from another source. Cite all references. This assignment is worth 12% of the total grade for this class. Please type or neatly write your solutions. Submission will be in .pdf form. Points will be given for correct work and correct solutions.

Learning Objectives
1. Practice understanding of models of wheeled vehicle-terrain interaction
2. Use analytic techniques to make informed parametric comparisons
3. Evaluate tradeoffs of various drive, steering, and suspension configurations

Submission Instructions
- Create a single .pdf _le with your solutions for all the sections named andrewid_assignment4.pdf.
- Ensure that your .pdf contains all work, explanations, images, and code.
- Submit to Canvas using the proper assignment link.

Topic #1. Wheeled Vehicle Performance on Soil

1.1 Terramechanics [4 points] Consider that you are evaluating the merits of a 4-wheeled vehicle against a 6-wheeled vehicle that is expected to operate in soft terrain whose cohesion is c and angle of internal friction is φ. For the given soil, the pressure-sinkage parameters are k_c and k_φ, and the exponent of sinkage is n. There is only one wheel type available: A rigid tire of diameter d and width b. Assume that gross vehicle weight is W_G in both cases and that the weight is evenly distributed among the wheels.

1.1.1 Compaction (1 point)
What is the ratio of the total compaction resistance of the 4-wheeled concept over the 6-wheeled concept? Given this, which concept is better to minimize compaction resistance; the one with 4 or the one with 6 wheels? Justify your answer through your work. Let n=0.5.

1.1.2 Thrust (1 point)
Assume that the contact area of each tire and the soil for the 4-wheeled vehicle is 20% larger than the 6-wheeled vehicle. What is the ratio of total thrust of the 4-wheeled concept over the 6-wheeled concept? Given this ratio, which concept is better to maximize soil thrust assuming no slip? Justify your answer through your work.

1.1.3 Drawbar Pull (1 point)
Derive an analytical equation for the drawbar pull of that can be generated by a single wheel of the 6-wheeled vehicle. Use the variables above. Assume that the only significant form of motion resistance is compaction.

1.1.4 Soil Parameters (1 point)
How would the maximum thrust change if the vehicle is operating in packed clay versus loose sand (not ideal case)? Ensure that your answer is complete in describing the change as the vehicle weight and contact area change.

1.2 Wheeled Mobility Metrics, MMP [3 points] The Mean Maximum Pressure (MMP) is a semi-empirical metric of wheeled mobility. The MMP of a wheeled vehicle is computed given by the following equation (also refer to slide #24 of lecture #3).

$$MMP = \frac{6.895 W_G}{nab^{0.8} d^{0.8} \delta^{0.4}}$$

1.2.1 Value of MMP (1 point)
If you were to decide between two vehicle designs one of which had an MMP=40 and the other an MMP=100, which one would you choose?

1.2.2 Parametric Analysis (2 points) Using a computer program to generate a 3D parametric plot of MMP as a function of d and b. Assume that W_G= 100kN, a= 2, n= 2, and δ= 0.1m. What observations can you make on the effect of d and b on MMP? What happens if δ= 0.2m (show the new 3D plot and discuss)?

Topic #2. Wheeled Vehicle Maneuverability and Adaptation to Terrain

2.1 Maneuverability and the Mechanics of Steering [4 points]

2.1.1 Steering Kinematic Configurations (1 point)
For the list of steering configurations listed below, draw an example vehicle, using arrows to show what portions of the vehicle (if any) can move.
(a) Skid (also called differential), (b) Ackermann, (c) Articulated, and (d) Explicit (Independent) Wheel Articulation.

2.1.2 Evaluating Steering Configurations (1 point)
For the same list of four configurations, list one distinct positive attribute and one negative attribute of that steering system.

2.1.3 Forces during Skid Steering (2 points)
Using slide #10 of lecture #4 as a reference, explain the meaning of forces F_x, F_y, and R_r. What does each one of these forces represent? How will you estimate R_r and F_y?

2.2 Terrain Adaptation and Suspension Configuration [1 point]

Discuss three reasons why you would want to utilize a semi-active suspension over a passive suspension on a high-speed, all-terrain wheeled vehicle. Discuss one reason why an active suspension may be more suitable over a semi-active suspension in this case.