MEEN 357 - 501
Authors: Jacob Hargreaves, David Guess, Ian Wilhite

6.1 Coding

Question 1: We had you define the acceleration due to gravity as a field in a structure that you had to pass as an input argument to several functions. Instead, we could have had you type the value for the constant, 3.72 m/s2 , directly in those functions. Do you believe there is an advantage to how we had you do it? Explain. Would you have done it differently? Explain why or why not.

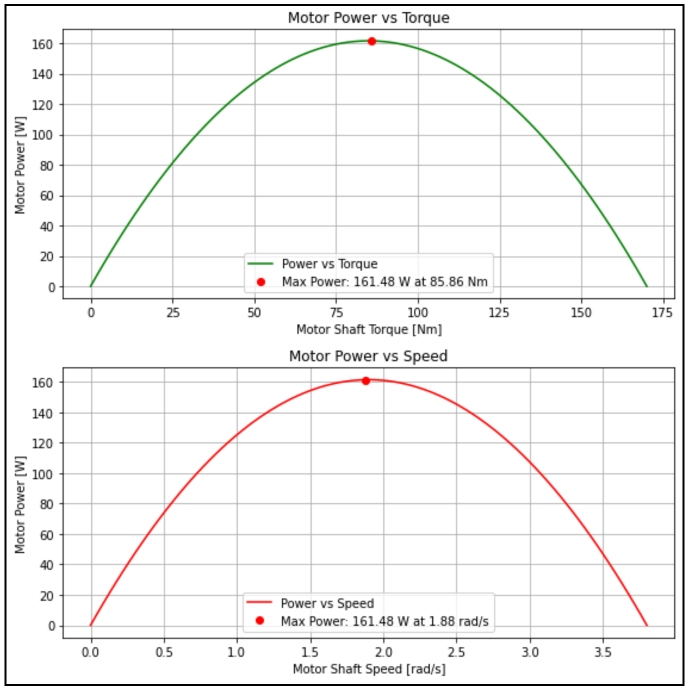
We believe that there are advantages to the way we define acceleration in this project. Because we did not code the gravity constant to simply be the value on Mars, we can update the gravity constant easily if we want to analyze the rover on other planets or moons. If we wanted to change the gravity constant, we could simply alter its structure in one place rather than having to change its value in every single function. It is for these reasons that we would not have done anything differently regarding the acceleration due to gravity.

Question 2: What happens if you try to call F_gravity using a terrain slope of 110 degrees? Is this desirable behavior? Explain why you think this.

When we try to call F_gravity using a terrain slope above 90 degrees, such as a slope of 110 degrees, F_gravity returns a force greater than the force of gravity in free fall. This is because the equation used in this function is $F_{gravity} = - m_{rover} * g * sin(\alpha)$ and when α (the angle of inclination) is above 90 degrees, the sin() value is greater than 1. This is not desirable behavior because the rover would never feel a force of gravity greater than the free fall force.

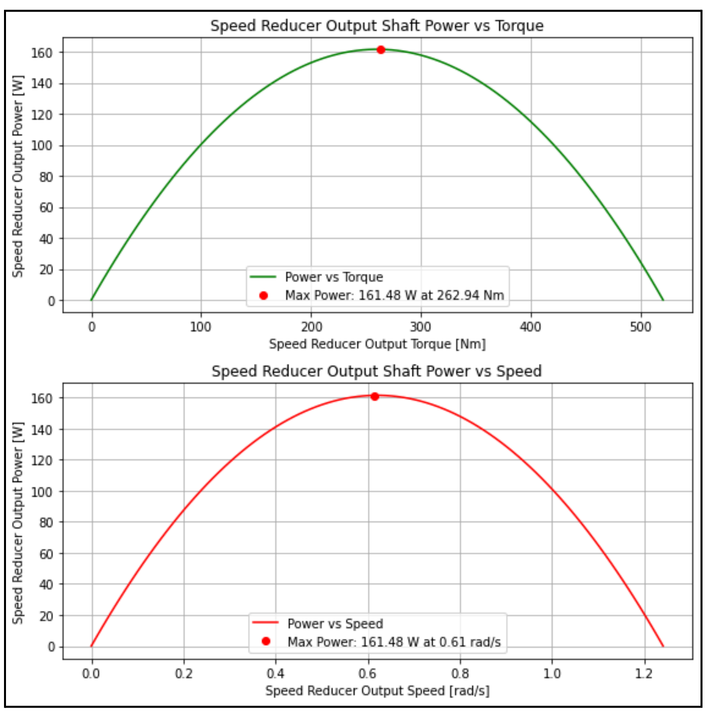
6.2 Motor and Speed Reducer Behavior

Question 3: What is the maximum power output by a single rover motor? At what motor shaft speed does this occur? Provide graphs or other data to support your answer.



As shown in the graph above, the maximum power output by a single rover motor is about 161.48 Watts and occurs at a motor shaft speed of 1.88 rad/s.

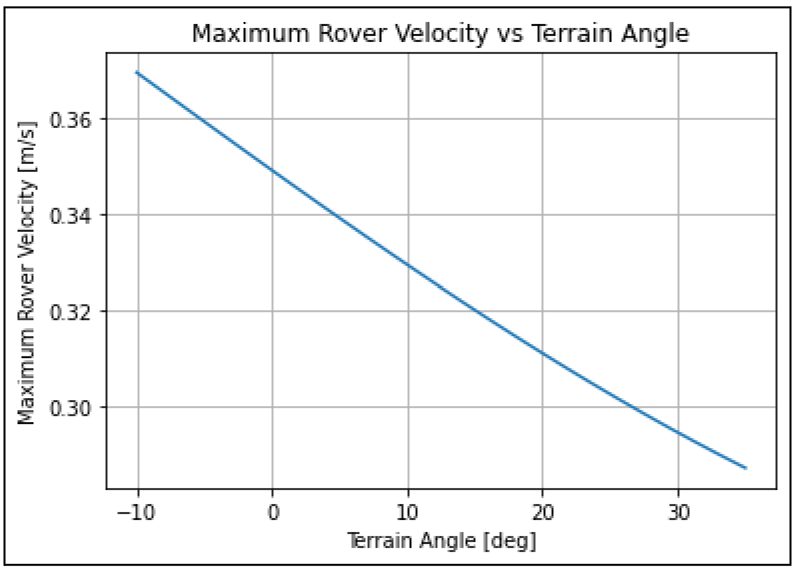
Question 4: What impact does the speed reducer have on the power output of the drive system? Again, provide any graphs or supporting data.



The speed reducer causes the maximum power output of the drive system to occur at a much lower motor shaft speed of 0.61 rad/s, as seen above. The speed reducer does this in order to help the rover overcome resistance such as rough terrain. The rover can better overcome this resistance as it has more torque at a lower speed. The speed reducer allows for more torque overall as compared to the figures in question #3.

6.3 Rover Behavior

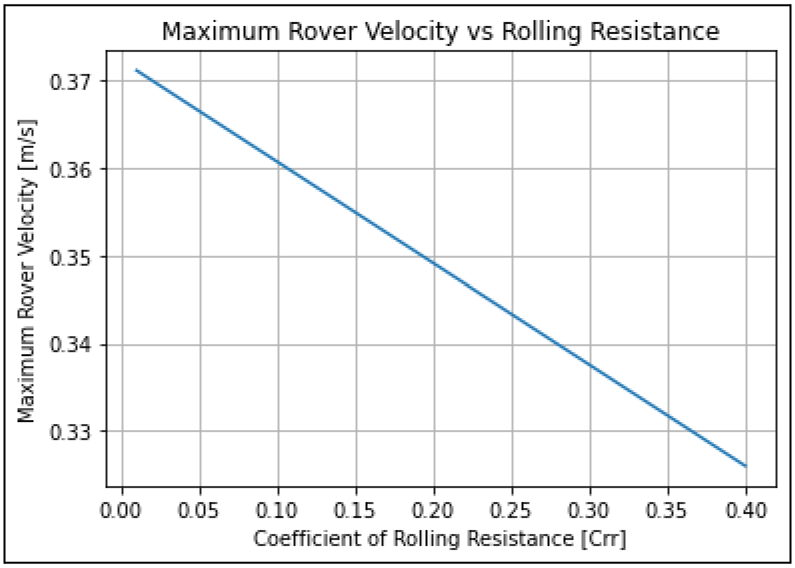
Question 5: Examine the graph you generated using analysis_terrain_slope.py. (Provide the graph in your response for reference.) Explain the trend you observe. Does it make sense physically? Why or why not? Please be precise. For example, if the graph appears linear or non-linear, can you explain why it should be the way you observed? Refer back to the rover model and how slope impacts rover behavior.



This trend from the graph above makes perfect sense. On downhill motion (Negative Terrain Angle) the rover experiences additional acceleration from gravity. Therefore, a higher maximum velocity is obtained. On flat and uphill motion (Positive Terrain Angle), the maximum velocity of the rover steadily decreases. This is because the rover has to overcome both gravity and rolling resistance pulling it backward.

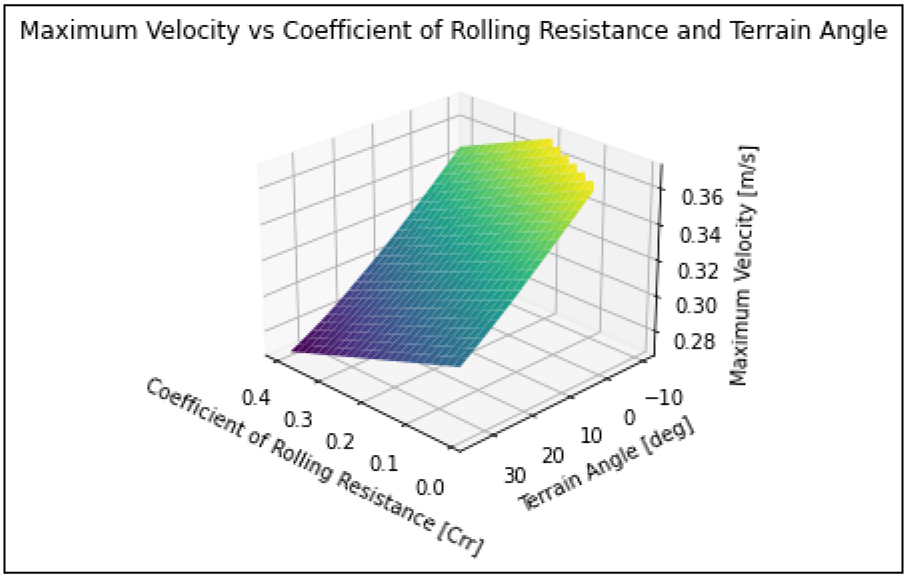
Additionally, the graph appears approximately linear, which suggests that the impact of slope on the rover's speed is proportional, which aligns with the rover model where gravitational forces and resistive forces change linearly with increasing slope.

Question 6: Examine the graph you generated using analysis_rolling_resistance.py. (Provide the graph in your response for reference.) Explain the trend you observe. Does it make sense physically? Why or why not? Please be precise. For example, if the graph appears linear or non-linear, can you explain why it should be the way you observed? Refer back to the rover model and how the coefficient of rolling resistance impacts rover behavior.



This graph shows a linear decrease in maximum rover velocity as the coefficient of rolling resistance (Crr) increases. This makes sense because rolling resistance is a force that opposes the rover’s motion. As Crr increases, the motor has to exert more energy to overcome this resistance. Since the rolling resistance is directly proportional to Crr, the decrease in velocity follows a linear trend. This means that as Crr rises, the rover's maximum achievable speed steadily decreases. This is also consistent with the energy required to counteract the increasing resistance.

Question 7: Examine the surface plot you generated using analysis_combined_terrain.py. (Provide the graph in your response for reference.) What does this graph tell you about the physical conditions under which it is appropriate to operate the rover? Based on what you observe, which factor, terrain slope or coefficient of rolling resistance, is the dominant consideration in how fast the rover can travel? Please explain your reasoning.



The 3D-surface plot shows that both the terrain slope and the coefficient of rolling resistance (Crr) have a significant impact on the maximum velocity of the rover. As the terrain slope increases, the rover's maximum velocity decreases, and as the Crr increases, the velocity also decreases. However, the graph shows that terrain slope has a more noticeable effect on the rover's speed compared to the rolling resistance. This is evident from the steep gradient along the terrain angle axis, meaning that changes in slope result in larger variations in speed. Therefore, terrain angle is the dominant factor. This is because steeper angles significantly reduce the rover's maximum velocity while rolling resistance primarily adds resistance.