**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.

By calling gravity from another function, it allows flexibility for changing the value in the future. This is particularly helpful if the rover was to be tested on different planets. When driving in Earth’s gravitational field instead of Mars’s, then the acceleration due to gravity would only need to be changed in one place: “define\_rover.py”.

The alternative solution would be changing each reference to gravity from 3.72 to 9.81. Not only is this more time consuming but it is a method that is prone to error if even one value is not changed.

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.

If the user inputs a magnitude of a terrain-angle above 75 degrees into the F\_gravity function, an error message informs the user of this. This is desired since the rover may not be able to climb or descend a slope that is too steep. After an unknown degree, the rover would either slip or tilt due to extreme angles. Hence, it is logical to only permit angles magnitudes that are below 75 degrees.

**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.

Chart

Description automatically generated

For a single motor, the max power output is approximately 26.842 Watts at 1.8 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

Chart, diagram

Description automatically generated

The speed reducer makes the power of a single more output 26.842 Watts (161.053 Watts for entire drive system), which is the same value given by the motor without a speed reducer. The max output speed from the speed reducer is about 0.588 rad/s. The maximum torque for the drive system is 274.013 Nm. The maximum torque delivered by the speed reducer system is larger than that of the motors on their own.

**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.

Chart, line chart

Description automatically generated

As the terrain angle increases, the maximum rover speed decreases since more energy is converted into gravitational potential energy rather than kinetic energy (velocity). Gravitational potential energy is linear but kinetic energy is parabolic and since energy is always conserved, this explains why the graph is curved. The velocity of the rover as a function of change in height will not be linear.

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.

Chart, line chart

Description automatically generated

The relationship between the rolling resistance coefficient and the maximum rover speed appears linear. This means that the maximum rover speed is directly proportionally to the coefficient of rolling resistance. Assuming that the rover is in equilibrium, the increase of the dynamic frictional force will not accelerate the rover—only decrease its terminal velocity. This is because when summing the forces in the direction of motion, the frictional forces eventually equal the drivetrain-output forces and hence, there cannot be any acceleration.

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.

Chart, surface chart

Description automatically generated

The graph shows how terrain angle and the coefficient of rolling resistance impact the maximum rover speed. As both variables decrease, the maximum possible speed of the rover increases. However, the model does not allow the rover to drive when there is no friction on a downhill slope. The maximum rover speed changes more dramatically with an increment of terrain angle change compared to the impact of the coefficient of rolling resistance. This can be seen on the graph by comparing the slope of the speed vs. angle curve to the speed vs. CRR curve.