Name 1: _____

Name 2: _____

Date: _____

Challenge #2: How Far?

Overview

Up to **two** students can work on this challenge. Remember each team member must contribute to at least one the completion of one of the physics components for one challenge and the completion of one of the engineering components for another challenge. This challenge is about **forces**. You will be asked to do the following:

1. Determine coefficient of friction between your rover material and challenge-specific materials
2. Answer questions about friction

Your Rover Material

You generally have three options regarding the material construction of your rover, laser-cut MDF wood, laser-cut cardboard, or 3D-printed PLA. Your rover's exterior, may however, be made of another material; regardless, please note the exterior material of your rover that will be making contact with the interior of the tunnel.

Rover Shell Material: _____

Coefficient of Friction Review

Please remember that, to determine the coefficient of friction, you need to use the following equation:

$$F_f = \mu F_N$$

If you are doing your experiment on a flat surface, then the gravitational force of the material on top (F_g=mg, where g=9.81 m/s^2) is equal to the normal force (F_N). You can also push one surface against the other, as we did in lab 3, to make sure that the net force experienced is equal to the force of friction, such that:

$$F_{net}=ma_{net}=F_f$$

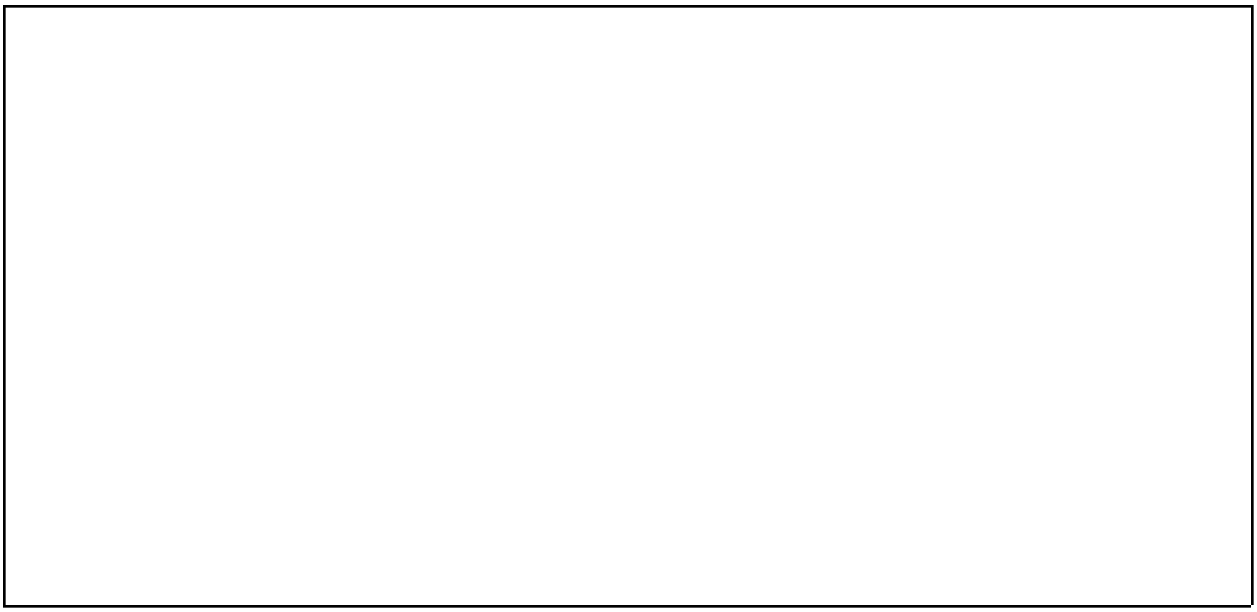
In the equation above, m is the mass of the surface on top and the acceleration is determined either using a kinematic equation or Vernier Video Analysis (the latter of which is more ideal). You should then be able to determine your coefficient of friction with:

$$\mu = \frac{F_f}{F_N}$$

Coefficient of Friction Between Your Rover Material & Interior Material 1

After you have determined your rover shell material, it is time to determine the coefficient of friction between it and the first interior material for the tunnel. The first layer of the tunnel is made of **cardboard**.

In the space below, please draw a force diagram (or free body diagram) of your experimental set-up to determine the coefficient of friction.



Use Vernier Video Analysis or a kinematic equation to determine your net acceleration and write it below:

Acceleration (a_{net}): _____

Then, determine the mass (in kg) of the surface on top and subsequently your force of friction:

Mass (m): _____

Force of Friction (F_f): _____

Using the equation for gravitational force (F_g=mg, where g=9.81 m/s^2), determine your normal force:

Normal Force (F_N): _____

Using the equation for the force of friction ($F_f=\mu F_N$), determine your coefficient of friction between these two surfaces.

Coefficient of Friction (μ): _____

Coefficient of Friction Between Your Rover Material & Interior Material 2

You should now attempt to determine the coefficient of friction between your rover shell material and the second interior material for the tunnel. The second layer of the tunnel is made of **sandpaper**.

In the space below, please draw a force diagram (or free body diagram) of your experimental set-up to determine the coefficient of friction.

Use Vernier Video Analysis or a kinematic equation to determine your net acceleration and write it below:

Acceleration (a_{net}): _____

Then, determine the mass (in kg) of the surface on top and subsequently your force of friction:

Mass (m): _____

Force of Friction (F_f): _____

Using the equation for gravitational force (F_g=mg, where g=9.81 m/s^2), determine your normal force:

Normal Force (F_N): _____

Using the equation for the force of friction ($F_f=\mu F_N$), determine your coefficient of friction between these two surfaces.

Coefficient of Friction (μ): _____

Coefficient of Friction Between Your Rover Material & Interior Material 3

You should now attempt to determine the coefficient of friction between your rover shell material and the third interior material for the tunnel. The third layer of the tunnel is made of **walnut plywood**.

Exceeding Proficiency*: If you determine the coefficient of friction on your own for this section, and it is correct or reasonable, you will receive exceeding proficiency.*

In the space below, please draw a force diagram (or free body diagram) of your experimental set-up to determine the coefficient of friction.

Use Vernier Video Analysis or a kinematic equation to determine your net acceleration and write it below:

Acceleration (a_{net}): _____

Then, determine the mass (in kg) of the surface on top and subsequently your force of friction:

Mass (m): _____

Force of Friction (F_f): _____

Using the equation for gravitational force (F_g=mg, where g=9.81 m/s^2), determine your normal force:

Normal Force (F_N): _____

Using the equation for the force of friction (F_f=μF_N), determine your coefficient of friction between these two surfaces.

Coefficient of Friction (μ): _____

Questions About Friction

There are two types of coefficients of friction, which are they?

Which type of coefficient of friction did you calculate?

Do you expect the coefficient of static friction or the coefficient of kinetic friction to be higher?

Why did you answer the way you did to the previous question?

Point System (TEACHER ONLY - CIRCLE ONE)

Not Yet (0pts) (50%)	**Approaching Proficiency (10pts) (60%)**	**Somewhat Proficient (20pts) (70%)**	**Proficient (30pts) (85%)**	**Exceeding Proficiency (40pts) (100%)**
You have not correctly completed any of the elements of this challenge component.	You have correctly completed at least one element of this challenge component.	You have correctly completed half of the elements of this challenge component.	You have correctly completed all of the elements of this challenge component.	You have additionally and correctly completed the independent element of this challenge component.
Comments:				