SPH4U: Friction!

Recorder: ________
Manager: ________
Speaker: ________
0 1 2 3 4 5

We normally think of friction as the force that stops things from moving. This is in many respects still true, but we must also realize that friction is the force that is usually responsible for starting things moving too!

A: Rubbing the Wrong Way?

Find a convenient, hand-sized object.Place the objecton the flat palm of your hand. Keep your hand completely horizontal and cause the object to move horizontally and speed up **with** your hand (no slipping).

1. **Reason.** Why does the object accelerate?

The object remains on the hand because the force of friction is keeping it there. This means that the force of friction causes the object to accelerate.

2. **Reason.** Marie says, "At first I thought a *horizontal* applied force causes it to accelerate. But then I remembered that an applied force is really just a normal force. It doesn't make sense to have a horizontal normal force here." Do you agree with Marie? Explain.

We agree with Marie. There is a vertical normal force, but not a horizontal normal force. There isn't an applied force in the horizontal direction.

3. **Reason.** Emmy says, "In this situation a friction force must act in the forwards direction." Albert responds, "That's not right. Friction always opposes an object's motion. It should point in the backwards direction." Who do you agree with? Explain.

In this situation, the force of friction must act in the forwards direction since it is the only horizontal force and we know that the object is accelerating.

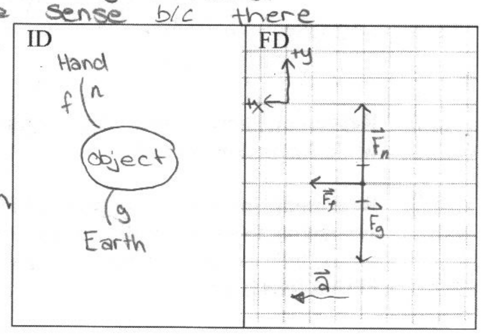
4. **Predict.** What would happen to your objectif there was *no friction at all* between it and your hand? Explain.

If there was no friction at all, the object will simply fall from your hand onto the table, while your hand continued to accelerate. This would make sense b/c there would be no force acting on the object in the horizontal

5. **Test.**Try this out with the equipment at the front of the class.Record your observations.Do they support your prediction? Is there a force that keeps the cart in place while you move the track underneath?

The object remains at rest when we move the track underneath. They support our prediction. There is no force that keeps the cart in place while we move the track.

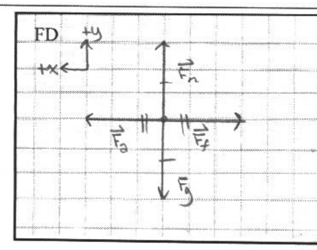
6. **Represent.** Draw an ID and FD for the object while it is speeding up.



Friction is a contact force that tries to prevent two surfaces from sliding relative to one another. If there is no slipping of the two surfaces, *static friction* **may** be present. If the two surfaces are slipping, *kinetic friction* is present.

B: Two Kinds of Friction

1. **Represent.** Place your object on the table. Exert a force on the object using a 5N spring scale such that it slides at a constant velocity. Draw a FD for it while sliding.



2. **Explain.** Why does the spring scale reading equal to the force of *kinetic friction?*

The spring scale reading corresponds to the applied force, which must equal the force of kinetic friction, in order for the net force to be zero. The net force is 0 b/c the object moves with constant velocity.

3. **Explain.** You might have noticed thatreading on the spring scale jerked lower as soon as the box began to slide. (If you didn't notice this, apply a small and gradually increasing force or find a heavier object.) What does that higher initial reading tell us about the friction between your object and the table? (Hint: Remember there is *another* type of friction!)

The higher initial reading tells us that there is static friction, which is the max. force required to get an object to start moving.

The force of friction depends on the characteristics of the surfaces involved (as represented by the coefficient of friction, μ), and how hard the surfaces are pressed together (the normal force, F_n). The two forces of friction can be found from the two expressions, $F_{fk} = \mu_k Fn$ and $0 < F_{fs} \leq F_{fsmax}$, where $F_{fsmax} = \mu_s F_n$.

4. **Calculate.** Make measurements anddetermine the coefficient of kinetic friction for your object.

$\vec{F}_n = 2.8N$

$\vec{F}_{fk} = 1.2N$

$F_{fk} = \mu_k F_n$

$\mu_k = \frac{F_{fk}}{F_n}$

$\mu_k = \frac{1.2N}{2.8N}$

$= 0.429$

∴ the coefficient of kinetic friction is 0.429

5. **Reason.** Imagine you repeat this experiment in an elevator accelerating upwards. Emmy says, "I bet the value for μ will get smaller since μ depends on F_n". Albert says, "The equation written as $\mu = F_f / F_n$ makes it look like μ depends on F_n, but is actually doesn't." Who do you agree with?Explain.

As we increase the normal force, the force of friction will also increase. This means that μ doesn't depend on F_n, so we agree with Albert.

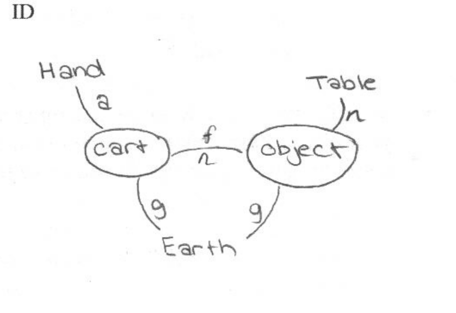
C: Friction Causing Motion

Place yourobject in the middle of a dynamics cart (make sure your object doesn't touch the front or back of the cart). Use the spring scale to pull **on the cart** and cause both the cart and object to move together.

1. **Observe and Explain.** Exert a small, gentle force on the cart, causing both the cart and object to accelerate together. Describe the motion of the object. What force was responsible for the **object's** motion? Be specific.

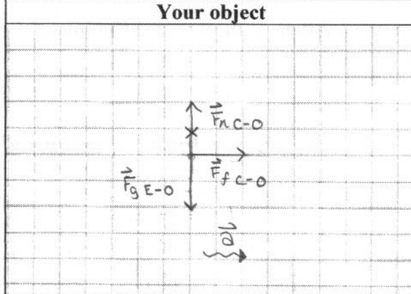
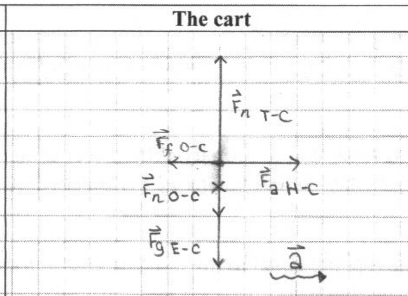
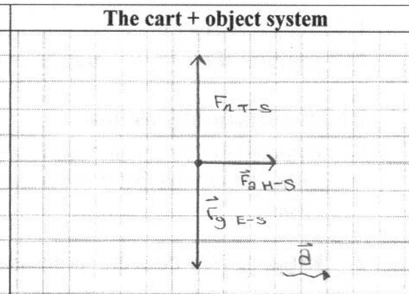
The object accelerated with the cart. Friction was responsible for the object's motion because it caused the object to accelerate

ID



2. **Represent.** Draw an interaction diagram for the cart and object while you pull on the cart.

3. **Represent.**Now we will draw three FDs while the cart and object are moving together (no slipping). Use the 3rd law notation for the forces. Indicate any 3[rd] law force pairs that appear.Hint: The cart FD has five(!) forces.

Your object	The cart	The cart + object system
		

4. **Explain.** Write an expression for the net force experienced by your object. Why can this net force take on a range of values? Is there any limit to these values? What does this imply about the possible values of the acceleration?

$F_{net\,y} = ma_y$ $F_{net\,x} = ma_x$

$F_n - F_g = 0$ $F_f = ma_x$

This net force can take on a range of values because it is static friction. The static friction must be greater than 0 and less than the max. static friction. This implies that there can be many possible values for acceleration.

5. **Reason.** If wepull too hard on the cart, the object will begin to slip. We want to determine the largest force of tension that we can exert **on the cart**without any slipping of your object. Which FD is easiest for finding the acceleration? Measure the mass of your object and cart.

The third force diagram is easiest for finding the acceleration.

The mass of our object and cart is 1.5kg

6. (*Homework*) **Solve.** Determine the largest force that we can exert on the cart before the object starts to slip. (Hint: Use your reasoning from the two previous questions. Assume$\mu_s = 0.6$)

$F_{net\,y} = ma_y$

$F_{n\,T\text{-}S} - F_{g\,E\text{-}S} = 0$

$F_{n\,T\text{-}S} = F_{g\,E\text{-}S}$

$= mg$

$= 1.5kg(9.8N/kg)$

$= 14.7N$

$F_s = \mu F_n$

$= 0.6(14.7N)$

$= 8.82N$

∴ the largest force we can exert on the cart before the object starts to slip is 8.82N

D: Friction and the Ramp

You need a track**(no retort stand!).**

1. **Observeand Calculate.** Determine the coefficient of static for your object on the **horizontal**track surface. Draw an ID and FD for this situation. There is a lot of error in this measurement, so record a high and low possible value for your measurement and calculate a high and low possible value for the coefficient. Show your work.

$F_n = 2.8N$

$F_s = 0.8N$ (low)

$= 1.0N$ (high)

High value

$F_s = \mu F_n$

$\mu = \frac{F_s}{F_n}$

$= \frac{1.0N}{2.8N}$

$= 0.357$

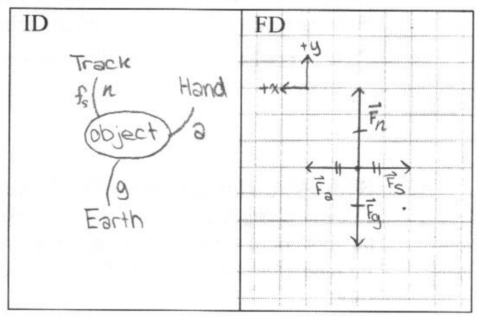
low value

$F_s = \mu F_n$

$\mu = \frac{F_s}{F_n}$

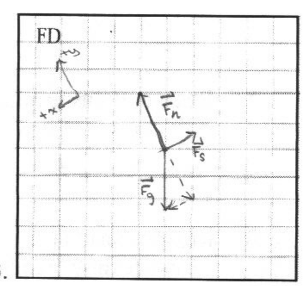
$= \frac{0.8N}{2.8N}$

$= 0.286$



2. **Reason.** Now draw a FD for the box at rest on an **incline**. Let the *x*-axis be parallel to the incline. How will each force change when the angle of the incline increases? Explain.

F_{gx} F_{gx} will increase b/c F_g doesn't change when the incline is increased.	F_{gy} F_{gy} will decrease b/c F_g doesn't change when the incline is increased
F_n F_n will decrease b/c F_{gy} has decreased	$F_{fs\,max}$ $F_{fs\,max}$ will increase b/c F_{gx} has increased,



3.

Predict. Analyze the situation using Newton's 2nd law. What angle do you predict the box would start moving at? (Find a high and low value.)Do all your work algebraically and you will get a *very* simple expression.

$F_{net\,y} = ma_y$

$F_n - F_{gy} = 0$

$F_n - F_g\cos\theta = 0$

$F_n = F_g\cos\theta$

$\cos\theta = \frac{F_n}{F_g}$

$F_{net\,x} = ma_x$

$F_{gx} - F_{fs\,max} = 0$

$F_g\sin\theta - F_{fs\,max} = 0$

$F_g\sin\theta = \mu_s F_n$

$F_n = \frac{F_g\sin\theta}{\mu_s}$

$\cos\theta = \frac{F_g\sin\theta}{F_g\mu}$

$\cos\theta = \frac{\sin\theta}{\mu}$

$\cos\theta\,\mu_s = \sin\theta$

$\mu_s = \frac{\sin\theta}{\cos\theta}$

$\mu_s = \tan\theta$

$\theta = \tan^{-1}(\mu_s)$

High value

$\theta = \tan^{-1}(0.357)$

$= 19.6°$

low value

$\theta = \tan^{-1}(0.286)$

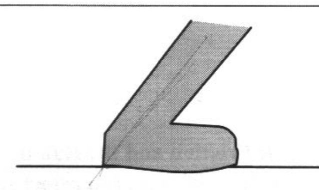
$= 16.0°$

4. **Test.**Call your teacher over to test your prediction. Record the angle at which it begins to slide. Do your observations confirm your prediction? Note that there are large sources of error in this investigation!

The object began to slide when the angle of the incline was 18°. This confirms our prediction b/c it falls within the range of our prediction.

E: Friction and You

What is the cause of our motion when we walk, drive, or ride a bike?



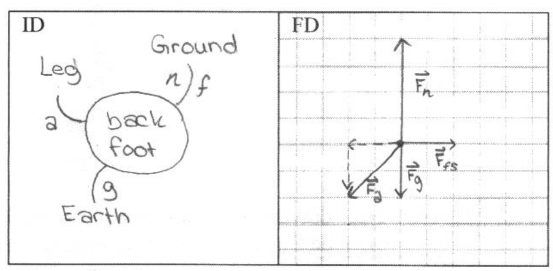
1. **Observe.** Have one group member walk slowly. Watch carefully: does their back foot slide against the ground?

Their back foot does not slide against the ground.

2. **Reason.** Consider the system of the back foot while walking.Have that person freeze in place as their back foot is pushing against the ground. What is the back foot interacting with?

The back foot is interacting with the ground. and the Earth

3. **Represent.** This is a very difficult situation to model with a FD, but being fearless, we will try! Draw an ID and a FD for the system of the back foot at the moment pictured above. Include a force at an angle for the effect of the leg on the foot.



4. **Explain.** What force is pushing forward on the foot? Ultimately, this is the external force responsible for making the system of your body accelerate forward.

The force of friction pushes forward on the foot.

5. **Reason.** If this forward force disappeared, what would happen as we try to walk?

If this forward force disappeared, we wouldn't be able to walk, we would just slip back.

6. **Reason.** Isaac says, "According to my third law, there is an equal size friction force of the foot on the earth. Why don't we notice this?" Explain to Isaac why we don't notice the effect of this force.

We don't notice the effect of this force b/c the magnitude of the force is so small compared to the mass of the Earth, that the acceleration experienced by the Earth is pretty much negligiable.