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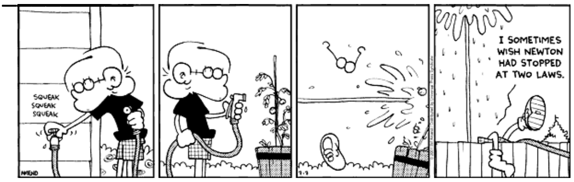


Honors Physics

Lesson 7: Newton's Third Law and Passive Forces

7.1 Experiment: Newton's 3rd Law Forces of Interaction

(a) Team up with a partner to hook two spring scales together to perform the next experiment:
Use your spring scale to pull gently on your partner's spring scale.
What force did your spring scale exert on your partner's? Write your answer in the blank below:

Force of my spring scale on my partner's = ______________ Newtons

What force did your partner's exert on yours? Write your answer in the blank below:

Force of my partner's spring scale on mine = ______________ Newtons

(b) This time, **have your partner gently pull on *your* spring scale** and observe the force this time. What force did your spring scale exert on your partner's?
Write your answer in the blank below:

Force of my spring scale on my partner's = ______________ Newtons

What force did your partner's exert on yours? Write your answer in the blank below:

Force of my partner's spring scale on mine = ______________ Newtons

(c) Now **both pull gently on each other's spring scales**. What were both forces this time? Fill in the blanks below:
Force of my spring scale on my partner's = ______________ Newtons

Force of my partner's spring scale on mine = ______________ Newtons

(d) How are the two forces related in each case? Describe the resulting forces you exert on each other in terms of size and direction. (Who pulls harder? Are they the same or opposite directions?)

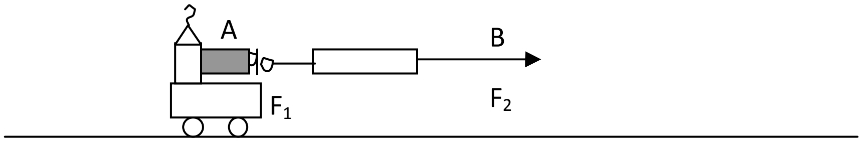
(e) Try stretching a rubber band between your thumb and forefinger.
Can you stretch it out without using your thumb to pull back on it? Explain.

(f) Suppose object A pushes (or pulls) on object B. Must object B push (or pull) back on object A?

What can you conclude about the forces each object exerts on the other? Which one, if any, is larger?

7.2 Experiment: Dynamic Pull

(a) Attach a force probe to a lab cart with a kilogram of mass loaded onto it. Use the spring scale to pull on the force probe attached to the cart and get the cart moving. Observe both forces (from force probe A and spring scale B) as you do this.



Which one pulls harder?

(b) How hard did the spring scale pull on the cart in this case?

(c) What does this pull do to the motion of the cart?

(d) What direction does the cart pull (as measured by the force probe attached to it)?

(e) How hard did the cart pull back on the spring scale (as measured by the force probe attached)?

(f) What effect does that pull (the cart's pull on the spring scale) have on the motion of <u>the cart itself</u>?

What object's motion might it influence? (What does this force have an effect on?)

(g) If spring scale A pulls forward on the cart, the cart pulls back against it. There are forces from <u>both</u> spring scales acting <u>in both directions</u>. Explain, then, how the cart gets moving when you give it a pull. (Note: it's not because one force pulls harder!)

*Newton's Third Law can be stated as follows: "If one object exerts a force on a second object, then the second object exerts a force back on the first object which is equal in magnitude and opposite in direction to that exerted on it by the first object."

7.3 <u>Experiment: Normal Forces</u>

(a) Place a mass on top of a cushion.
When the cushion has a force applied to it, does it push back?

How do you know?

(b) What happens to the cushion's surface when it is pushed?

(c) Does the cushion push up more or less than the force of the mass pushing down?

How can you tell?

(d) Now place the same mass on top of a stiffer surface.
Does this surface bend more or less than the cushion does when the same force is applied?

(e) Does the stiffer surface push more or less than the force of the mass pushing down?

How can you tell?

(f) Compare your answers to part (c) and (e).
Did the cushion's surface push more or less than the stiffer surface?

(g) Based on your observations with the stiffer surface, what would happen to the amount the surface bends if it was a much stiffer surface like a tabletop that holds up the mass?

Do solid objects bend, microscopically?

(h) Does a table or wall bend noticeably if an active force is applied to it?

Suggest a possible explanation describing how walls and tables can push back against something that pushes against them (i.e. exert normal forces). (In other words, try to explain it in this context. How do they do it?)

7.4 Experiment: Friction Forces

(a) **PREDICT**: What do you think friction depends on? (Common ideas are surface area, speed they slide across, surface types, weight, mass, etc. What do *you* think?)

Friction actually only depends on two things, how "rough" or "sticky" the surfaces are between each other and how hard they're pressed together. The roughness factor is called the "coefficient of friction" (μ) and the squeezing force is the "normal force" (F_N). There are 2 types of friction related as follows:

If surfaces are not sliding: $\mathbf{F_{static\ fric} \leq \mu_s F_N}$ If surfaces are sliding: $\mathbf{F_{kinetic\ fric} = \mu_k F_N}$

Notice that the static friction force can have a range of values from zero up to its maximum possible value of $\mu_s F_N$.

In this experiment, we will make use of these relations to calculate the coefficient of static friction between two surfaces.

(b) Slowly push forward on your table until it slides.
Is it harder to break the table loose from rest or to keep it sliding? (Put the table back when you're done ☺)

(c) Now use a spring scale to do the same to a friction block. Place the block on a wooden surface. For added friction, place a kilogram on the block. Now apply a horizontal force to the block, slowly increasing from 0 up until the block breaks loose, then continue to slide the block along the surface.
How much force was required to break it loose? This is the maximum static friction force in this case.

Force to "break loose" the block = ____________________ Newtons

How much force was required to keep the block sliding? This is the kinetic friction force in this case.

Force to keep block sliding = ______________________ Newtons

(d) You should see that it takes more force to break something loose than it takes to keep it sliding. This is why the coefficient of static friction is usually higher than the coefficient of kinetic friction.
Draw a graph of force vs time of your experiment in (c). You don't have to label specific times on the x-axis. We want the *shape*.

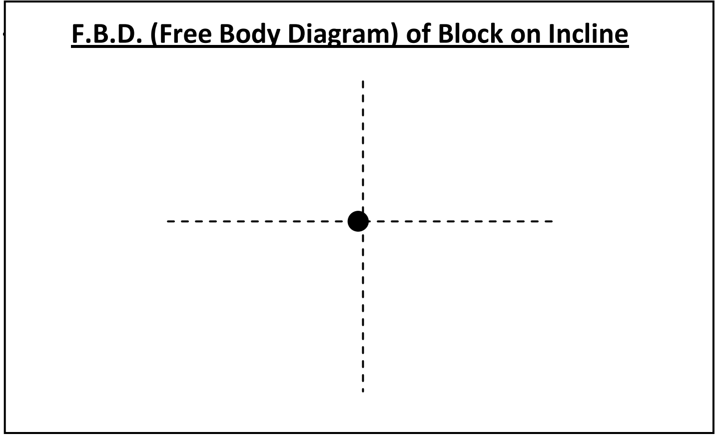
7.5 Experiment: Finding the Coefficient of Static Friction and Force Diagrams

(a) Place a friction block on top of a wooden surface then slowly lift one end of the wooden surfaced to tilt the surface at an angle. Increase the angle slowly until the block just begins to slide off, then record the angle the surface makes with the table here.

$\theta_{surface}$= ____________ °

We'll use this angle to determine the "stickiness" (coefficient of friction) between the block and surface. To begin, we'll **make a Free Body Diagram (or F.B.D. = a diagram of forces) by drawing each force as an arrow coming off of a dot** that represents the block.
Following steps (b) through (g) put in the forces tail-to-tail on the drawing of your block below (the dot) using the following prompts to help you along.

F.B.D. (Free Body Diagram) of Block on Incline



(b) What touches the block? (We'll ignore the small effects of the air in this experiment)

(c) The wooden surface supports the block.
What direction does this support force push?

In the box above, draw this force on the dot in the proper direction and label it F_N for Normal Force.

(d) The wooden surface also keeps it from sliding down (or attempts to).
What direction does this force push?

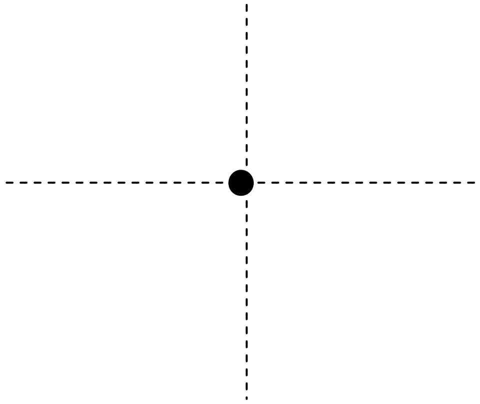
In the box above, draw this force on the dot in the proper direction and label it $F_{s,max}$ for Maximum Static Friction Force. (It's maximum because at that steep an angle, friction's working at its limit!)

(e) What pulls down on the block?

Draw in that force in the proper direction and label it F_g for Gravitational Force (or *mg* in terms of its mass and acceleration constant, just as we used it in Lesson 6).

(f) By now, your diagram should be shaped roughly like a lopsided "Y" with arrowheads at the endpoints.
To minimize the angles, we're going to perform a handy trick:
Look at the page with your FBD on it. Now *literally rotate your page* until it looks more like an "L" with a dangly diagonal at the bottom. Make it so that F_N points upward.
This is called "tilting your axes" ("axes" = plural for "axis"). Specifically, you "tilted your axes along the Normal Force line." **Redraw the FBD tilted-style below**. It should look more like an "L" here with a dangly thing than a "Y".

F.B.D. (Free Body Diagram) of Block on Incline
[Axes tilted along the incline]



(g) In the box above, label the angle the gravitational force makes with the axis (as shown in class).

(h) What is the acceleration of the block just before it begins to slip down the surface?

Are the forces balanced?

(i) Write out the equation relating the forces acting on the y-axis and solve for F_N.

(j) Write out the equation relating the forces acting on the x-axis and solve for Fs,max.

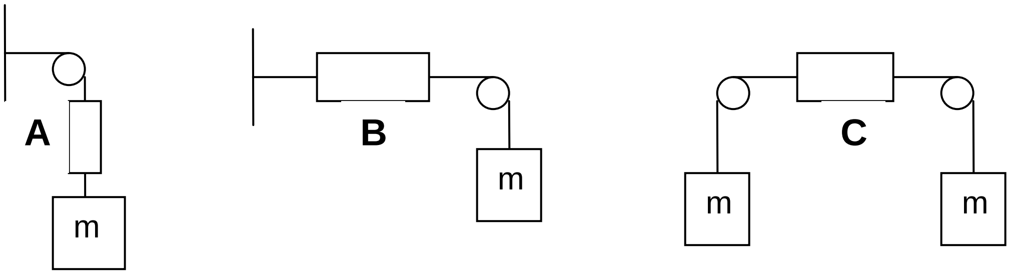
(k) Replace Fs, max with $\mu_s F_N$ and plug in your equation from (i) for F_N.

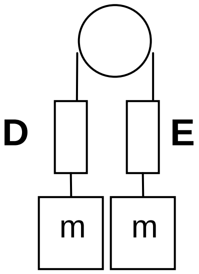
(l) Solve for μ_s: μ_s = ___________ (Note that μ_s has no units)

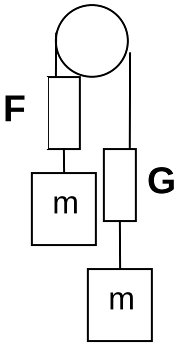
7.6 Experiment: Tension Forces

When your dog pulls you with a leash, the force is transmitted down the leash to you. If your dog pulls hard enough, you may begin to slide. **Tension is the name given to forces transmitted this way by stretching things like strings, ropes, rubber bands, springs, wires, chains, and cables**.

(a) Suppose you were to hang equal masses in the various configurations shown below.







Each mass: m=100g=0.100kg
F_g = mg = (0.100kg)(9.8m/s^2) = 0.98N ≈ 1N

PREDICT the reading in Newtons on each of the spring scales shown in the pictures. Remember that these readings indicate the forces that are transmitted by the tensions at various places along the string.

F_A = _________ N F_B = _________ N F_C = _________ N F_D = _________ N
F_E = _________ N F_F = _________ N F_G = _________ N

(b) Now measure all of the forces and record their values.

F_A = _________ N F_B = _________ N F_C = _________ N F_D = _________ N
F_E = _________ N F_F = _________ N F_G = _________ N

7.7 Experiment: Tension Forces when a String Changes Direction

(a) Bend paper clips into double hooks (if needed). Use these to attach rubber bands to the top and bottom of a string. Hang a mass from the bottom and hang the whole thing from a spring scale at the top.
While you are doing this, predict the amount of stretch of both rubber bands.
PREDICT: Which rubber band will stretch more, the top one or the bottom one?

(b) Which rubber band is actually stretched more, the one at the top or the bottom?

What does this say about the tension in the top and bottom of a stretched string?

(c) How would the results change if it was a very massive string, like a heavy chain? Which would stretch more in that case?

What would make the results change in this way? (Explain why that would happen.)

7.8 Exercise: Tension in a Stretched String

(a) Sketch this below:
A muscleman (left) pulls on a rope attached to one arm of a monkey. The monkey's other arm is holding a string attached to one side of a spring scale. The other side of the spring scale is tied to a tree (right).

(b) The muscleman pulls to the left with a force of F = -150N.
What is the magnitude and direction of the force that the rope is exerting on the man?

(c) What is the magnitude and direction of the force that the left-hand rope is exerting on the monkey's arm (the one closest to the man)?

(d) What is the magnitude and direction of the force that the spring scale is exerting on its monkey-end?

(e) What is the magnitude and direction of the force that the spring scale is exerting on it's tree-end?

(f) What is the magnitude and direction of the force that the rope is exerting on the tree?

(g) What is the magnitude and direction of the force that the tree is exerting on the rope?

(h) Summarize what your observations reveal about the nature of tension forces everywhere along a string.

7.9 Experiment: Can a String Support a Lateral Force?

(a) Do you think a string can exert a force which is strictly perpendicular to the direction of the string? Attach two 2.5N-range spring scales to a string, one on each end, and support a 200 g (0.2 kg) mass with the angle with the horizontal initially at 90° (both pointing straight up). What is the force from each spring scale?

(b) Now increase the angle to approximately 60°. What is the spring scale reading now?

(c) What happens to the force of tension the spring scale reads as the string straightens out, making the angle smaller and smaller?

(d) How big a force of tension would be needed to straighten the string out completely?

Is this possible?

(e) While the 0.2kg mass is ***<u>at rest</u>***, what is the net force acting on it?

(f) We know gravity pulls straight down on it. What magnitude and direction of a force would be needed to balance it out?

(g) What is the magnitude and direction of the vector sum of the two spring forces for any angle? (In other words, if you add the two force vectors together, what would they add up to. Consider your answer to the previous question.)