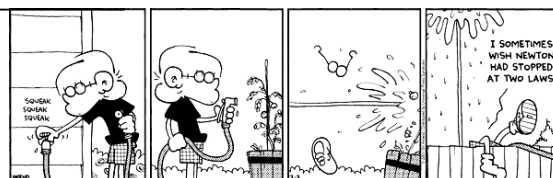


Name _____
Period _____

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?)

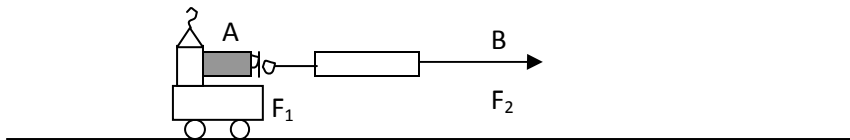
- (e) Try stretching a rubber band between your thumb and forefinger.
Can you stretch it out without using your thumb to pull back on it? Explain.

- (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 the cart itself?

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 both spring scales acting in both directions. 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 Experiment: Normal Forces

- (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: $F_{\text{static fric}} \leq \mu_s F_N$

If surfaces are sliding: $F_{\text{kinetic fric}} = \mu_k F_N$

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 Friction and Force Diagrams

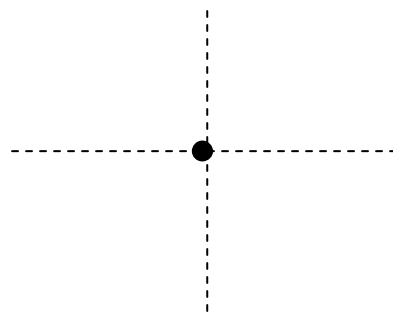
- (a) Place a friction block with a kilogram on top onto a horizontal wooden surface and use a spring scale to pull the block, but hold the spring scale at an angle. Pull so that the block moves at a constant speed and record the angle the spring scale makes with the table and the size of the force here. Hang it for its mass.

$\theta_{\text{SpringScale}} =$ _____ $^{\circ}$ Force = _____ N mass of block = _____ kg

We'll use this angle and force to determine the "stickiness" (coefficient of friction) between the block and surface and a few other things. 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 (f) 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 in step (a), draw this force coming from the dot in the proper direction and label it F_N for Normal Force.

(d) The wooden surface also keeps it from sliding forward as fast as it would on a more slippery surface.
What direction does this force push?

In the box in step (a), draw this force coming from the dot in the proper direction and label it F_k for Kinetic Friction Force. (It's kinetic because the surfaces are sliding against each other.)

(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) There's one more force pulling it along. What is the last force that moves the block?

Draw in that force in the proper direction and label it F_A for Applied Force. Be sure it points in the same direction on the diagram as it was applied. (Label any angles carefully.)

In the box in step (a), label the angle the diagonal force makes with the x axis.

(g) What is the acceleration of the block as it slips across the surface?

Are the forces balanced?

- (h) Does the entire diagonally applied force go into pulling the block forward along the x axis? Does any of it go into lifting the block at all? How do we find out how much lifts (y axis) and how much pulls forward (x axis)?
- (i) Solve for both components of the applied force by drawing the vector triangle for the applied force here.

x component of force (F_{Ax}) = _____ N y component of force (F_{Ay}) = _____ N

- (j) Write out the equation relating the forces acting on the y-axis (there are 3 forces) and solve for F_N .

- (k) Write out the equation relating the forces acting on the x-axis (there are 2 forces) and solve for F_k .

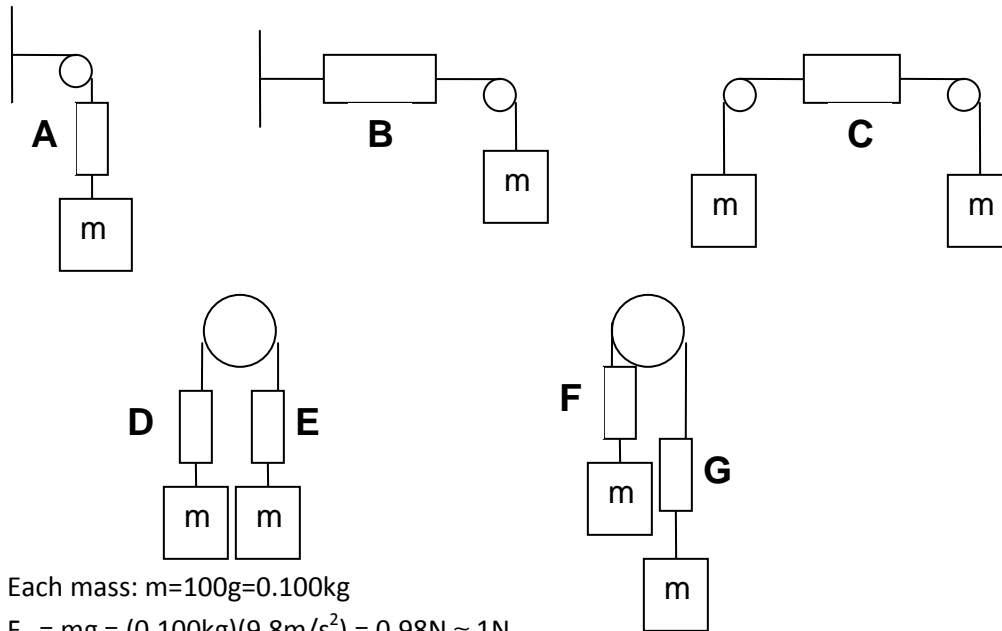
- (l) Replace F_k with $\mu_k F_N$ and plug in your equation from (i) for F_N .

- (m) Solve for μ_k : $\mu_k = \underline{\hspace{2cm}}$ (Note that μ_k 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.



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.

$F_A = \underline{\hspace{2cm}} \text{ N}$ $F_B = \underline{\hspace{2cm}} \text{ N}$ $F_C = \underline{\hspace{2cm}} \text{ N}$ $F_D = \underline{\hspace{2cm}} \text{ N}$
 $F_E = \underline{\hspace{2cm}} \text{ N}$ $F_F = \underline{\hspace{2cm}} \text{ N}$ $F_G = \underline{\hspace{2cm}} \text{ N}$

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

$F_A = \underline{\hspace{2cm}} \text{ N}$ $F_B = \underline{\hspace{2cm}} \text{ N}$ $F_C = \underline{\hspace{2cm}} \text{ N}$ $F_D = \underline{\hspace{2cm}} \text{ N}$
 $F_E = \underline{\hspace{2cm}} \text{ N}$ $F_F = \underline{\hspace{2cm}} \text{ N}$ $F_G = \underline{\hspace{2cm}} \text{ N}$

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 $F = -150\text{N}$.

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 its 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 at rest, 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.)