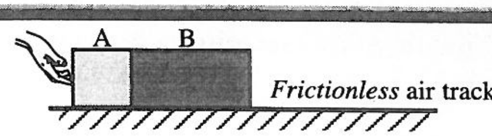
1. Two gliders of unequal mass ($m_A < m_B$) are placed on a *frictionless* air track.



Glider A is pushed horizontally as shown so that the gliders move faster and faster.

a. In the space provided below, draw a separate free-body diagram for each glider while it is speeding up. Recall that your diagram should include:

- a description of each force,
- the name of the object *on which* each force is exerted, and
- the name of the object *exerting* each force.

Free-body diagram for glider A	Free-body diagram for glider B

b. Rank the magnitudes of all the *horizontal* forces (if any) in order from largest to smallest. If two forces are equal in magnitude, indicate that explicitly. Explain.

c. At right, draw arrows to indicate the directions of the *net forces* on gliders A and B. If the net force on either glider is zero, indicate that explicitly. Explain.

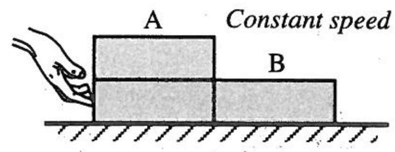
Direction of net force on glider A	Direction of net force on glider B

Is the magnitude of the *net force* on glider A *greater than, less than,* or *equal to* the magnitude of the *net force* on glider B? Explain.

I. Applying Newton's laws to interacting objects: constant speed

Three identical bricks are pushed across a table at *constant speed* as shown. The hand pushes horizontally. (*Note:* There is friction between the bricks and the table.)

Call the stack of two bricks system A and the single brick system B.



A. Compare the *net force* (magnitude and direction) on system A to that on system B. Explain how you arrived at your comparison.

B. Draw separate free-body diagrams for system A and system B. Label each of the forces in your diagrams by identifying: the type of force, the object on which the force is exerted, and the object exerting the force.

Free-body diagram for system A	Free-body diagram for system B

C. Is the magnitude of the force exerted on system A by system B *greater than, less than,* or *equal to* the magnitude of the force exerted on system B by system A? Explain.

Would your answer change if the hand were pushing system B to the left instead of pushing system A to the right? If so, how? If not, why not?

D. Identify all the *Newton's third law (action-reaction)* force pairs in your diagrams by placing one or more small "×" symbols through each member of the pair *(i.e.,* mark each member of the first pair as —×→, each member of the second pair as —××→, *etc.).*

What criteria did you use to identify the force pair(s)?

Is your answer to part C consistent with your identification of Newton's third law (or action-reaction) force pairs? If so, explain how it is consistent. If not, resolve the inconsistency.

E. Rank the magnitudes of all the *horizontal* forces that you identified on your free-body diagrams in part B. (*Hint:* Recall that the bricks are pushed so that they move at constant speed.)

Did you apply Newton's second law in comparing the magnitudes of the horizontal forces? If so, how?

Did you apply Newton's third law in comparing the magnitudes of the horizontal forces? If so, how?

What information besides Newton's laws did you need to apply in comparing the magnitudes of the horizontal forces?

F. Suppose the mass of each brick is 2.5 kg, the coefficient of kinetic friction between the bricks and the table is 0.2, and the bricks are moving at a constant speed of 0.50 m/s.

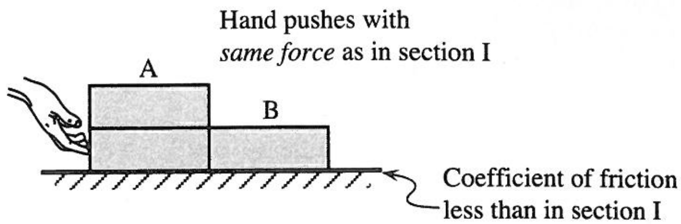
Determine the magnitude of each of the forces that you drew on your free-body diagrams in part B. (Use the approximation $g = 10\ \text{m/s}^2$.)

Would your answers change if the bricks were moving half as fast? If so, how? If not, why not?

➪ Discuss your answers to section I with a tutorial instructor before continuing.

II. Applying Newton's laws to interacting objects: varying speed

Suppose the bricks were pushed by the hand with the same force as in section I; however, the coefficient of kinetic friction between the bricks and the table is *less than* that in section I.



A. Describe the motions of systems A and B. How does the motion compare to that in part I?

B. Compare the *net force* (magnitude and direction) on system A to that on system B. Explain.

C. Draw and label separate free-body diagrams for systems A and B.

Free-body diagram for system A	Free-body diagram for system B

D. Consider the following discussion between two students.

Student 1: *"System A and system B are pushed by the same force as before, so they will have the same motion as in section I."*

Student 2: *"I disagree. I think that they are speeding up since friction is less. So now system A is pushing on system B with a greater force than system B is pushing on system A."*

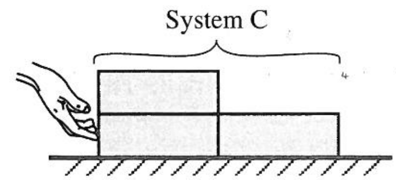
With which student, if either, do you agree? Explain your reasoning.

E. Rank the magnitudes of all the *horizontal* forces that appear on your free-body diagrams in part C. Explain your reasoning. (Describe explicitly how you used Newton's second and third laws to compare the magnitudes of the forces.)

Is it possible to *completely* rank the horizontal forces in this case?

III. Applying Newton's laws to a system of interacting objects

Let C represent the system consisting of all three bricks. The motion of the bricks is the same as in section II.



A. Compare the magnitude of the *net force* on system C to the magnitudes of the *net forces* on systems A and B. Explain.

B. Draw and label a free-body diagram for system C.

Free-body diagram for system C

Compare the forces that appear on your free-body diagram for system C to those that appear on your diagrams for systems A and B in section II.

For each of the forces that appear on your diagram for system C, list the corresponding force (or forces) on your diagrams for systems A and B.

Are there any forces on your diagrams for systems A and B that you did not list? If so, what characteristic do these forces have in common that none of the others share?

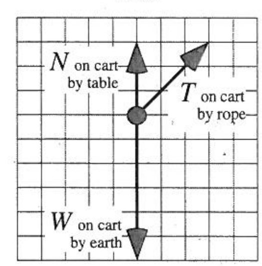
Why is it not necessary to consider these forces in determining the motion of system C?

Note that such forces are sometimes called *internal forces,* to be distinguished from *external forces*.

IV. Interpreting free-body diagrams

At right is a free-body diagram for a cart. All forces have been drawn to scale.

Free-body diagram for cart



In the space below, sketch the cart, rope, *etc.*, as they would appear in the laboratory.

What can you say about the motion of the cart based on the free-body diagram? For example, could the cart be: moving to the left? moving to the right? stationary? Explain whether each case is possible and, if so, describe the motion of the cart.