Tutorial: Name ____________________________ Section _____

Thinking about forces for objects and systems

I. Thoughts about free-body diagrams and system schemas

Physics courses, including this one, make a big deal of teaching you to draw diagrams for forces (including free-body diagrams and system schemas). Two students are arguing about the value of these diagrams:

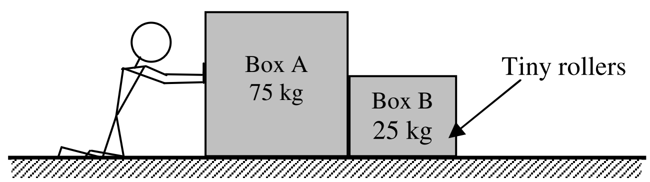
Velma: System schemas are more useful, because they show all the forces in the entire system, not just the forces on one object.

Daphne: Free-body diagrams are more useful, because they show the magnitude and direction of each force, which system schemas don't.

In a few sentences, describe to what extent you agree and/or disagree with each student.

II. Boxes on rollers

We'll now start thinking about "multi-body" force problems.



A student pushes two boxes, one in front of the other, as shown in the diagram. Box A has mass 75 kg, while box B has mass 25 kg. Fortunately for the student, the boxes are mounted on tiny rollers and slide with negligible friction. The student exerts a 200 N horizontal force on box A.

A. (*Work together*) Here are some questions about the blocks' accelerations.

1. Without doing any calculations, state whether the acceleration of block A is greater than, less than, or equal to that of block B. How do you know?

2. Using any method you want, find the acceleration of the blocks. (*Hint:* It's possible to do this quickly.)

3. There are two approaches to multi-body problems: (i) Lumping together the various objects and thinking of them as a single big mass, or (ii) Thinking separately about each object. Which approach did you just use to find the acceleration?

4. In this particular problem (finding the acceleration of the blocks), was it helpful or would it have been helpful to draw a free-body diagram? What about a system schema? Briefly explain why or why not.

B. (*Work together*) Box B contains kitchen stuff, including some poorly packed glassware that might break if the force pushing on the side of the box approaches 200 newtons. Recall that the student pushes on box A with a force of 200 newtons. Is that force "transmitted" to box B? In other words, is the glassware in the box in danger of breaking? Don't do any calculations; answer intuitively, and explain your thinking.

C. (*Work together*) We'll now lead you through an intuitive, calculation-free way of figuring out whether box B feels a 200 newton force.

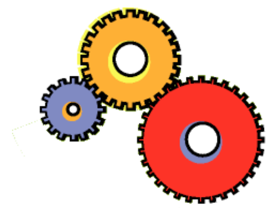
1. First, draw a system schema for this system.

2. Next, draw two separate free-body diagrams, one showing the forces acting on box A, the other showing the forces acting on box B.

Forces acting on ***Box A*** *Forces acting on* ***Box B***

☆ *Consult an instructor before you proceed.*

3. Using those diagrams, we can play the *implications* game. Specifically, we will tentatively *assume* that the force exerted by box A on the side of box B equals 200 newtons, and see where that assumption leads.



   i. **If it's true that** $F_{\text{A on B}}$ = 200 newtons, **then** how strong is $F_{\text{B on A}}$?

   ii. So, **If it's true that** $F_{\text{A on B}}$ = 200 newtons, **then** what is the net force on box A?

   iii. Based on the implication you just identified, should we accept or reject the assumption that $F_{\text{A on B}}$ = 200 newtons? In other words, should we accept or reject the assumption that the 200-newton force the student exerts on box A gets "transmitted" to box B?

D. (*Work together*) In *this particular problem (*figuring out whether box B feels a 200 newton force), did drawing a free-body diagram help your reasoning, or was the diagram primarily a way for the TA to see if you knew which forces were present? Did the system schema help? Briefly explain.

E. (*Work together*) Find a way to calculate $F_{\text{A on B}}$ exactly, and do it. (*Hint:* Way back in part A, you found the acceleration of both blocks.)

☆ *Consult an instructor before you proceed.*

F. (*Work together*) In part E, which approach to multi-body problems did you use: (i) Lumping the boxes together and thinking of them as a single big mass, or (ii) Thinking separately about box A and box B? Or did you use some of each approach?

G. (*Work together*) Try to come up with an intuitive way of understanding why $F_{\text{A on B}}$ is less than 200 newtons, not equal to 200 newtons – a way that makes sense to you personally. Record it here.

H. Reviewing their work on the two-box problem, a group of students is discussing whether to label the force on block B as $F_{\text{A on B}}$ or $F_{\text{student on B}}$. One of the students in the group states,

> "The rule says that you're supposed to label it $F_{\text{A on B}}$. But this is one of those rules that's an arbitrary choice, like the rule that red means stop and green means go. Breaking this rule wouldn't actually mislead you when you're solving a problem."

Do you agree that the rule is an arbitrary choice, or do you think there is some kind of deeper reason behind it? Explain.

III. Horse and wagon

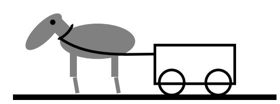
Here's a classic problem from the Halliday & Resnick textbook series. Something like it often shows up on physics exams:

> *A horse is urged to pull a wagon. The horse refuses to try, citing Newton's third law as a defense: The pull of the horse on the wagon is equal but opposite to the pull of the wagon on the horse. "If I can never exert a greater force on the wagon than it exerts on me, how can I ever start the wagon moving?" asks the horse.*

A. (*Work together*) How would you respond to the horse? In other words, how could you convince him that Newton's third law doesn't prevent him from pulling the wagon? This is hard—do the best you can, and move on if you get completely stuck. In part B we'll give some major help.

B. (*Work together*) We'll now lead you through a way of thinking about this problem.

1. Start by drawing a system schema and two separate free-body diagrams, one showing the forces acting on the horse, the other showing the forces acting on the wagon. To keep things simpler, you can draw just the horizontal forces. **Assume the horse pulls the wagon leftward.** Hint: When you start walking, what force propels you forward?



System schema

Forces acting on ***horse***

Forces acting on ***wagon***

☆ *Consult an instructor before you proceed.*

2. The horse seems to imply that he can't move the wagon for the following reason: The backward force exerted by the wagon on the horse equals—and therefore cancels—the forward force exerted by the horse on the wagon. Based on the diagrams you just drew, do those two forces cancel each other? Explain.

3. Based on the diagrams you just drew, is it possible for the horse to feel a net forward force even though the wagon pulls back on him just as strongly as he pulls forward on the wagon? Explain.

4. At this point, how would you respond to the horse?

C. In *this particular problem,* did drawing a free-body diagram and/or system schema help your reasoning, or were the diagrams primarily a way for the TA to see if you knew which forces were present? Briefly explain.