7 Newton's Third Law

7.1 Interacting Objects

7.2 Analyzing Interacting Objects

Exercises 1–7: Follow steps 1–3 of Tactics Box 7.1 to draw interaction diagrams describing the following situations. Your diagrams should be similar to Figures 7.5 and 7.9.

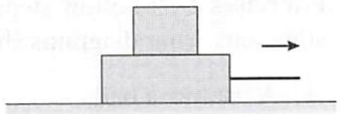
1. A bat hits a ball.

2. A massless string pulls a box across the floor. Friction is not negligible.

3. A boy pulls a wagon by a rope attached to the front of the wagon. The rope is not massless, and rolling friction is not negligible.

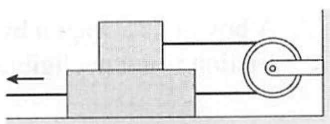
4. A skateboarder is pushing on the ground to speed up. Treat the person and the skateboard as separate objects.

5. The bottom block is pulled by a massless string. Friction is not negligible. Treat the two blocks as separate objects.



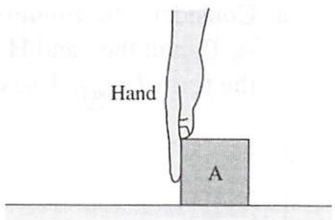
6. A crate in the back of a truck does not slip as the truck accelerates forward. Treat the crate and the truck as separate objects.

7. The bottom block is pulled by a massless string. Friction is not negligible. Treat the pulley as a separate object.



7.3 Newton's Third Law

8. Block A is pushed across a horizontal surface at a *constant* speed by a hand that exerts force $\vec{F}_{\text{H on A}}$. The surface has friction.



a. Draw two free-body diagrams, one for the hand and the other for the block. On these diagrams:

- Show only the *horizontal* forces, such as was done in Figure 7.13 of the text.
- Label force vectors, using the form $\vec{F}_{\text{C on D}}$.
- Connect action/reaction pairs with dotted lines.
- On the hand diagram show both $\vec{F}_{\text{A on H}}$ and $\vec{F}_{\text{arm on H}}$.
- Make sure vector lengths correctly portray the relative magnitudes of the forces.

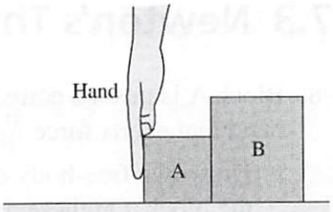
b. Rank in order, from largest to smallest, the magnitudes of *all* of the horizontal forces you showed in part a. For example, if $F_{\text{C on D}}$ is the largest of three forces while $F_{\text{D on C}}$ and $F_{\text{D on E}}$ are smaller but equal, you can record this as $F_{\text{C on D}} > F_{\text{D on C}} = F_{\text{D on E}}$.

Order:

Explanation:

c. Repeat both part a and part b for the case that the block is *speeding up*.

9. A second block B is placed in front of Block A of question 8. B is more massive than A: $m_B > m_A$. The blocks are speeding up.



a. Consider a *frictionless* surface. Draw *separate* free-body diagrams for A, B, and the hand H. Show only the horizontal forces. Label forces in the form $\vec{F}_{C \text{ on } D}$. Use dashed lines to connect action/reaction pairs.

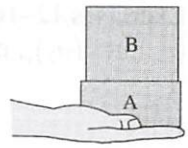
b. By applying the second law to each block and the third law to each action/reaction pair, rank in order *all* of the horizontal forces, from largest to smallest.

Order:

Explanation:

c. Repeat parts a and b if the surface has friction. Assume that A and B have the same coefficient of kinetic friction.

10. Blocks A and B are held on the palm of your outstretched hand as you lift them straight up at *constant speed*. Assume $m_B > m_A$ and that $m_{hand} = 0$.



a. Draw *separate* free-body diagrams for A, B, and your hand H.

- Show *all* vertical forces, including the gravitational forces on the blocks. Also include the force $\vec{F}_{\text{arm on H}}$.
- Make sure vector lengths indicate the relative sizes of the forces.
- Label forces in the form $\vec{F}_{\text{C on D}}$.
- Connect action/reaction pairs with dashed lines.

b. Rank in order, from largest to smallest, all of the vertical forces. Explain your reasoning.

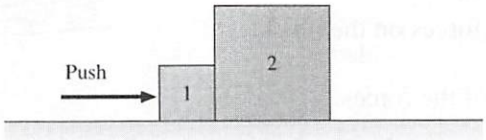
11. A mosquito collides head-on with a car traveling 60 mph.

a. How do you think the size of the force that the car exerts on the mosquito compares to the size of the force that the mosquito exerts on the car?

b. Draw *separate* free-body diagrams of the car and the mosquito at the moment of collision, showing only the horizontal forces. Label forces in the form $\vec{F}_{\text{C on D}}$. Connect action/reaction pairs with dotted lines.

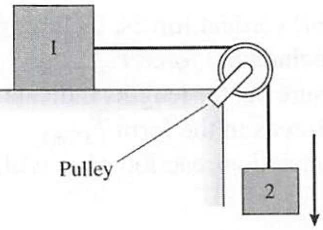
Exercises 12–16: Write the acceleration constraint in terms of *components*. For example, write $(a_1)_x = (a_2)_y$, if that is the appropriate answer, rather than $\vec{a}_1 = \vec{a}_2$.

12.



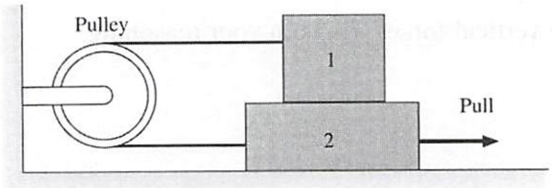
Constraint: ____________

13.



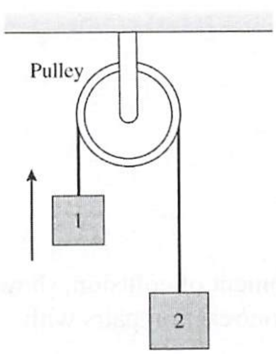
Constraint: ____________

14.



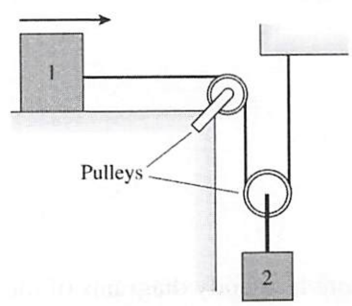
Constraint: ____________

15.



Constraint: ____________

16.



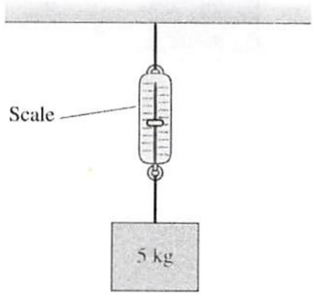
Constraint: ____________

7.4 Ropes and Pulleys

Exercises 17–22: Determine the reading of the spring scale.

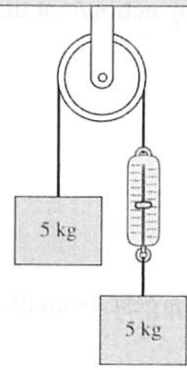
- All the masses are at rest.
- The strings and pulleys are massless, and the pulleys are frictionless.
- The spring scale reads in kg.

17.



Scale = ____________________

18.



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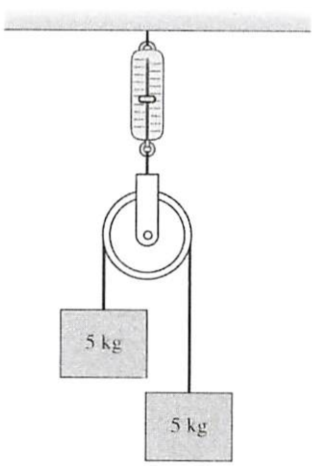
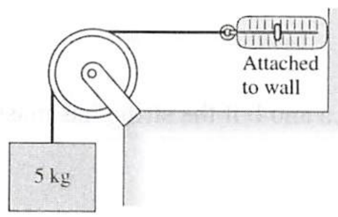
19.



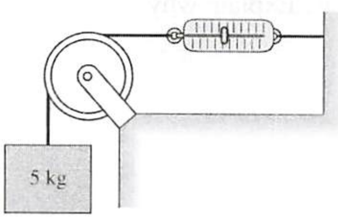
Scale = ____________________

20.



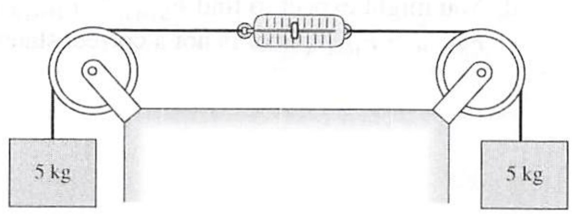
Scale = ____________________

21.



Scale = ____________________

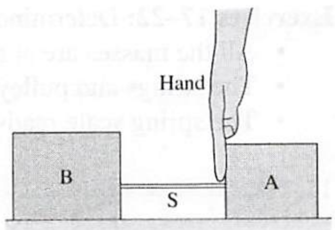
22.



Scale = ____________________

7.5 Examples of Interacting-Objects Problems

23. Blocks A and B, with $m_B > m_A$, are connected by a string. A hand pushing on the back of A accelerates them along a frictionless surface. The string (S) is massless.



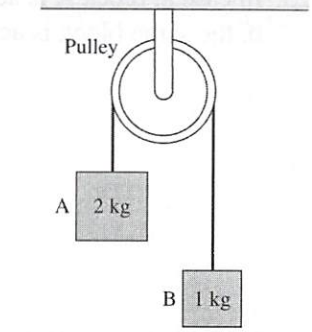
a. Draw separate free-body diagrams for A, S, and B, showing only horizontal forces. Be sure vector lengths indicate the relative size of the force. Connect any action/reaction pairs with dotted lines.

b. Rank in order, from largest to smallest, all of the horizontal forces. Explain.

c. Repeat parts a and b if the string has mass.

d. You might expect to find $F_{S\text{ on }B} > F_{H\text{ on }A}$ because $m_B > m_A$. Did you? Explain why $F_{S\text{ on }B} > F_{H\text{ on }A}$ is or is not a correct statement.

24. Blocks A and B are connected by a massless string over a massless, frictionless pulley. The blocks have just this instant been released from rest.



a. Will the blocks accelerate? If so, in which directions?

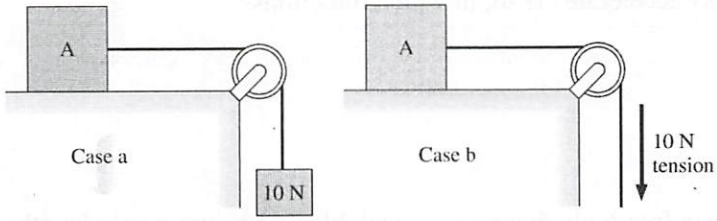
b. Draw a separate free-body diagram for each block. Be sure vector lengths indicate the relative size of the force. Connect any action/reaction pairs or "as if" pairs with dashed lines.

c. Rank in order, from largest to smallest, all of the vertical forces. Explain.

d. Compare the magnitude of the *net* force on A with the *net* force on B. Are they equal, or is one larger than the other? Explain.

e. Consider the block that falls. Is the magnitude of its acceleration less than, greater than, or equal to g? Explain.

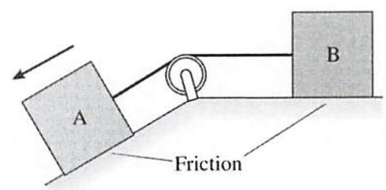
25. In case a, block A is accelerated across a frictionless table by a hanging 10 N weight (1.02 kg). In case b, the same block is accelerated by a steady 10 N tension in the string.



Is block A's acceleration in case b greater than, less than, or equal to its acceleration in case a? Explain.

Exercises 26–27: Draw separate free-body diagrams for blocks A and B. Connect any action/reaction pairs (or forces that act *as if* they are action/reaction pairs) together with dashed lines.

26.



27.