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Reasoning with Newton's Laws

Purpose and Expected Outcome

In this activity, you will deepen your understanding of Newton's laws and how they relate to physical situations.

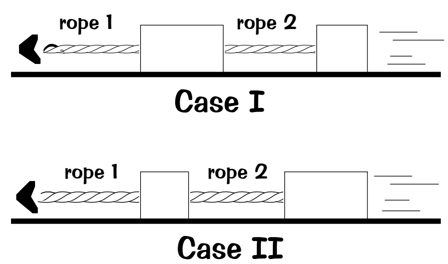
Prior Experience / Knowledge Needed

You should be familiar with Newton's laws of motion. Also, you should be able to draw and label free-body diagrams, and you should be able to determine the components of vectors.

Explanation of Activity and Example

In this activity, you are given a variety of physical situations, and you are asked to make comparisons of different physical quantities such as acceleration and force. Answer each question and explain the reasoning you used. The main emphasis is on the explanation, rather than the comparison. You might guess the right answer, but the explanation will show whether or not you have understood the situation.

Example. Two blocks are pulled to the left at constant speed as shown. The mass of each block is proportional to its size. All coefficients of friction are the same. Both cases are the same except that the blocks are reversed in case II. In which case is the normal force on the lefthand block larger? Explain.



Answer: *Case I. The blocks are not accelerating, so by Newton's 2nd law, the net force on each block must be zero. Therefore, the tension force due to rope 1 balances the tension force due to rope 2 and the force of friction, and the normal force balances the weight of the block. Because the lefthand block in case I has the larger weight, case I has the larger normal force.*

SITUATION A

Two blocks are pulled to the left at constant speed as shown in the example above. The mass of each block is proportional to its size. All coefficients of friction are the same. Both cases are the same except that the positions of the blocks are reversed in case II.

A1. In which case is the tension in rope 1 larger? Explain.

A2. In which case is the tension in rope 2 larger? Explain.

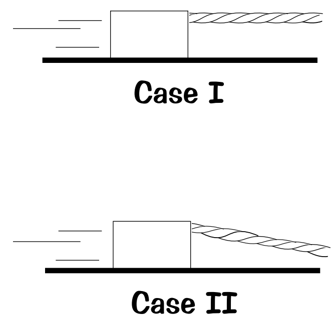
Suppose now that the speed of the blocks in case I is twice the speed of the blocks in case II. (That is, $v_I = 2v_{II}$.)

A3. In which case is the tension in rope 1 larger? Explain.

A4. In which case is the difference between the tensions in the ropes larger? Explain.

SITUATION B

Consider the two cases shown to the right. The blocks are identical, both surfaces are frictionless, and the tensions in the two ropes are the same.



B1. In which case does the block have the larger acceleration? Explain.

B2. In which case does the surface exert the larger normal force? Explain.

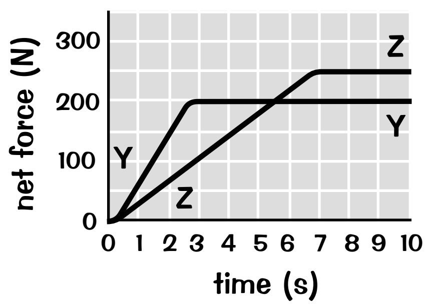
Now assume that there is friction between the block and the surface in each case. Assume also that the coefficients of friction are the same and that the blocks are each being pulled at constant speed.

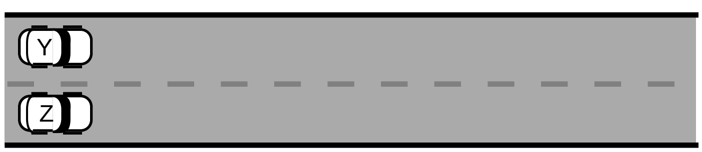
B3. Are the tension forces in the two cases still equal to each other? Explain.

B4. In which case is the tension in the rope larger? Explain.

SITUATION C

Two cars, Y and Z, are traveling side-by-side down a long, straight highway. The net force acting on each car as a function of time is shown to the right. The cars are identical. At $t = 0$, both cars are at rest, and they are located next to each other, as shown below.





C1. Is there ever a time when the two cars have the same acceleration? If so, when does this occur? Explain.

C2. Which car has the larger velocity at t = 4s? Explain.

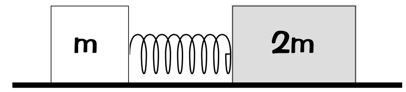
Now assume that car Y has twice the mass of car Z. That is, $m_Y = 2m_Z$.

C3. Is there ever a time when the two cars have the same acceleration? If so, when does this occur? Explain.

C4. Which car has the larger velocity at t = 10s? Explain.

SITUATION D

A spring is compressed between two blocks as shown. The surface is horizontal and frictionless. The blocks are released from rest at the same instant.

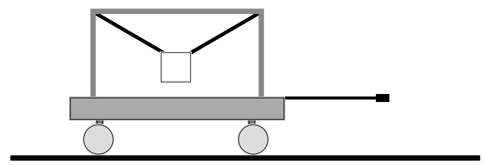


D1. Which block has the larger net force exerted on it just after they are released? Explain.

D2. Which block has the larger acceleration just after they are released? Explain.

SITUATION E

A block is suspended inside a wooden crate, which is placed on a child's wagon as shown. Someone pulls on the wagon, causing the whole system to accelerate to the right.



E1. Which string exerts the larger tension force on the block? Explain.

E2. Now someone pulls just hard enough to keep the system moving at constant speed. Which string applies the larger tension force in this case? Explain.

Reflection

R1. In how many of the situations did you use a free-body diagram to help you answer the questions? In what ways did they help you? In those cases that you did not use a free-body diagram, did you struggle with the questions? Comment on the usefulness of free-body diagrams.

R2. Consider each of the situations in this activity. What was helpful for answering the questions? For instance, which of Newton's laws did you use (if any)? What techniques did you use (such as finding the slope of a graph or drawing a free-body diagram)? What ideas did you need to understand (such as position or velocity)? Examine each situation separately, and list what you used to answer the questions.

R3. Combine all the items listed in R2 into a single list showing the relative importance of each. Start with the most important and end with the least.