Name: ______________________ Class: ____________ Date Due: __________

Systems of Objects

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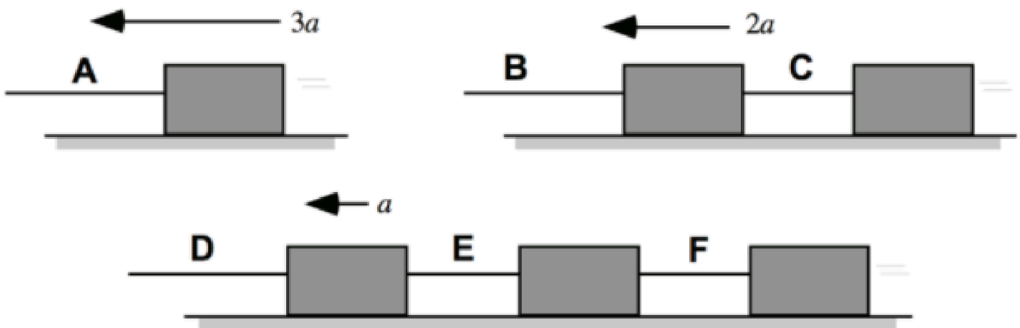
B3-RT27: Ropes Pulling Identical Boxes—Rope Tension

Boxes are pulled by ropes along frictionless surfaces, accelerating toward the left. All of the boxes are identical, and the accelerations of the boxes are indicated.

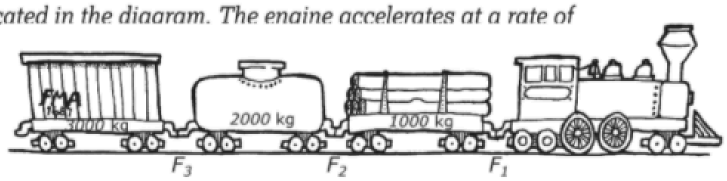


Rank the tension in these ropes.

						OR	☐	☐	☐
1 Greatest	2	3	4	5	6 Least		All the same	All zero	Cannot determine

Explain your reasoning.

A train engine pulls a train with three cars. Each car has the mass shown. Suppose that the cars are connected by metal bars with the tensions indicated in the diagram. The engine accelerates at a rate of $2\ \text{m/s}^2$. *Assume that the cars travel on bearings with negligible friction.*



Using Representations

PART A: The dots below represent the three train cars. Draw free-body diagrams showing and labeling the forces (not components) exerted on each car. Draw the relative lengths of all vectors to reflect the relative magnitudes of all the forces. Each force must be represented by a distinct arrow starting on and pointing away from the dot. For each diagram, write an equation that relates the horizontal forces in the diagram to acceleration.

Forces on the 3,000 kg car

________ = ________

Forces on the 2,000 kg car

________ = ________

Forces on the 1,000 kg car

________ = ________

PART B: The dots below represent three different systems. Draw free-body diagrams showing and labeling the forces (not components) exerted on each *system*. Draw the relative lengths of all the vectors to reflect the relative magnitudes of all the forces. Each force must be represented by a distinct arrow starting on and pointing away from the dot. For each diagram, write an equation that relates the forces in the diagram to acceleration.

Forces on the system of the 2,000 kg and 3,000 kg cars

________ = ________

Forces on the system of the 2,000 kg and 1,000 kg cars

________ = ________

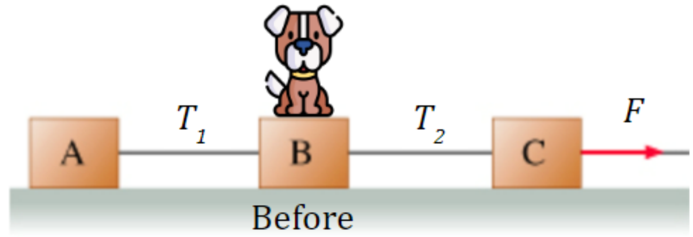
Forces on system of the 3,000 kg, 2,000 kg, and 1,000 kg cars

________ = ________

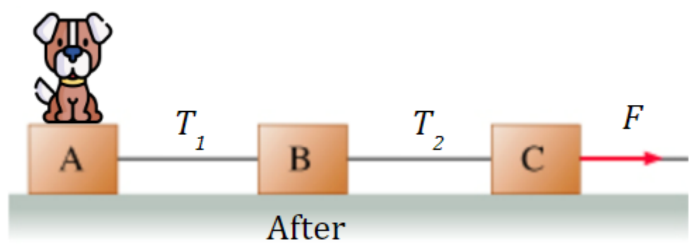
Determine values for F_1, F_2, and F_3. Explain why F_1 is the greatest even though F_3 is connected to the greatest mass.

Puppy Riding Boxes: Three blocks each with mass 25 kg sit on a horizontal frictionless floor. A puppy that also has mass 25 kg sits on block B. The blocks are connected by light strings as shown, and block C is pulled by a constant force *F* which causes a constant acceleration of 2 m/s/s.

a. Determine the tensions T_1 and T_2 in the Before picture by choosing objects and/or systems of objects to draw free body diagrams of and writing Newton's 2nd Law for them.



b. Determine the tensions T_1 and T_2 in the After picture by choosing objects and/or systems of objects to draw free body diagrams of and writing Newton's 2nd Law for them.

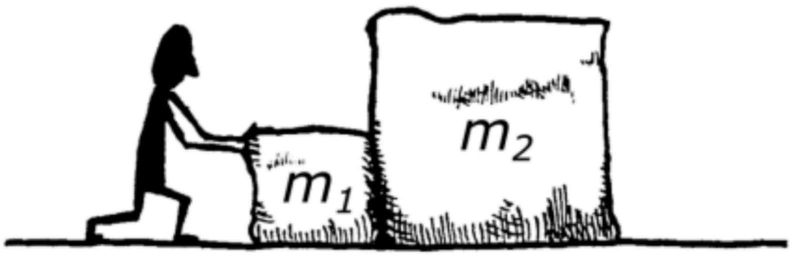


c. Explain any changes (or lack thereof) that you find in the tension of the rope connecting box A and box B.

d. Explain any changes (or lack thereof) that you find in the tension of the rope connecting box B and box C.

Pushing Two Blocks

Two blocks with masses m_1 = 4 kg and m_2 = 16 kg are pushed to the right on a frictionless surface.
The person applies a force F = 100 N.



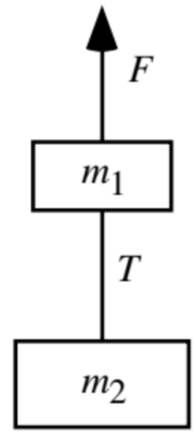
a. Determine the acceleration of the two block system.

b. Draw and label a free body diagram for each block separately, and determine the values of all the forces on the diagram. Label the internal forces as either F_{12} (force of the smaller mass pushing on the larger mass) or F_{21} (force of the larger mass pushing on the smaller mass)

c. How does the force of the smaller mass pushing on the larger mass (F_{12}) compare to F? Explain how you know.

d. How does the force of the smaller mass pushing on the larger mass (F_{12}) compare to the force of the larger mass pushing on the smaller mass (F_{21})? Explain your answer.

Two blocks with masses m_1 = 4 kg and m_2 = 16 kg are accelerated upwards (on Earth) with a force F = 800 N.



a. Draw a free body diagram for each block.

b. Determine the acceleration of the two-block system and the tension in the string.

c. If the two masses were switched, what would happen to the acceleration of the two-block system? Explain your answer. You may use diagrams and equations, but they cannot be your complete answer.

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d. If the two masses were switched, what would happen to the tension in the string? Explain your answer. You may use diagrams and equations, but they cannot be your complete answer.

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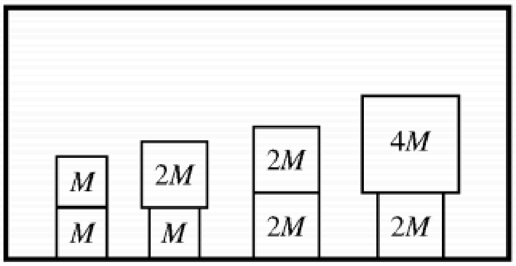
Questions 40-42 refer to the following material.

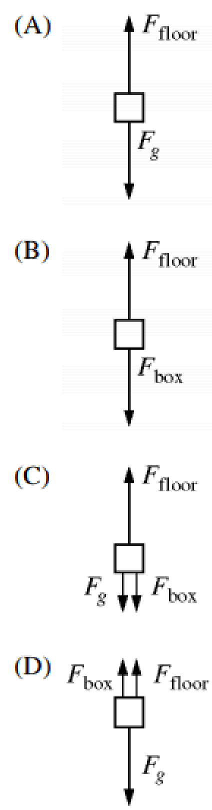


The stacks of boxes shown in the figure above are inside an elevator that is moving upward. The masses of the boxes are given in terms of the mass M of the lightest box.

40. How does the magnitude of the force exerted by the top box on the bottom box compare with the magnitude of the force exerted by the bottom box on the top box for each of the stacks?

(A) The two magnitudes are always equal in each of the stacks.
(B) The two magnitudes are always different in each of the stacks.
(C) The two magnitudes are equal when the boxes have equal mass and different when the boxes have different masses.
(D) The two magnitudes are equal when the elevator is moving at constant speed and different when it is accelerating.

41. Assume the elevator is moving at constant speed, and consider the bottom box in the stack that has two boxes of mass $2M$. Let F_{floor} be the force exerted by the floor on the box, F_g be the force exerted by gravity on the box, and F_{box} be the force exerted by the top box on the bottom box. Which of the following best represents the forces exerted on the bottom box?

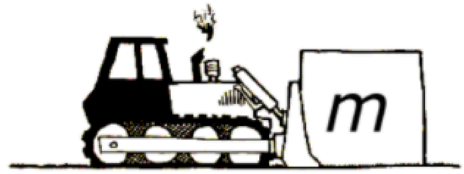


42. Assume the elevator has upward acceleration a, and consider the stack that has two boxes of mass M. What is the magnitude of the force exerted on the top box by the bottom box?

(A) Mg
(B) Ma
(C) $M(a-g)$
(D) $M(a+g)$

Scenario

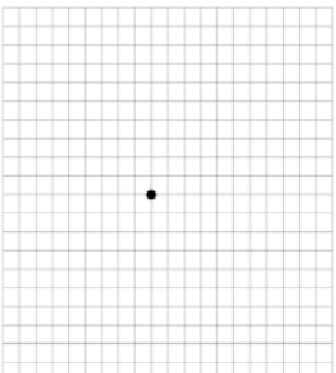
A bulldozer of mass M pushes a cube of cement of mass m across rough ground. The bulldozer and cube are speeding up.



Using Representations

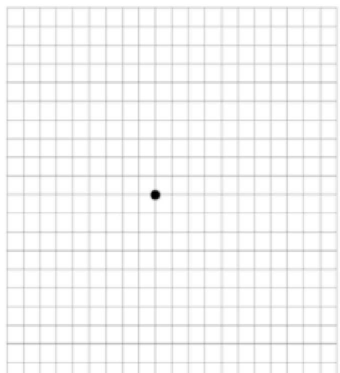
PART A: The dots below represent the bulldozer, cube, and bulldozer-cube system. Draw free-body diagrams showing and labeling the forces (not components) exerted on each system. Draw the relative lengths of all vectors to reflect the relative magnitudes of all the forces. For the bulldozer/cube system, draw an "external force" diagram.

Forces on Bulldozer



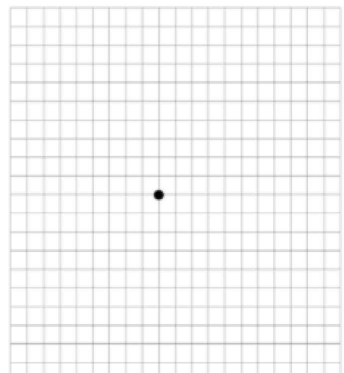
__________ = __________

Forces on Cube



__________ = __________

External Forces on Bulldozer/Cube System

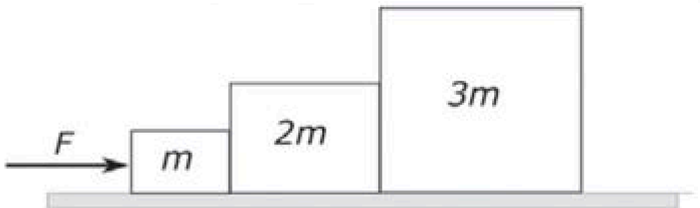


__________ = __________

Quantitative Analysis

PART B: In the blanks above, write an equation stating Newton's second law in the horizontal direction for the bulldozer, the cube, and the bulldozer-cube system.

Pushing Three Blocks



Three blocks of mass m, $2m$ and $3m$ sit next to each other on a horizontal surface where friction between the blocks and the surface can be neglected. A constant force F is applied to the right.

A. Determine an expression for the acceleration of each block.
B. Draw a free body diagram for each block.
C. Determine the magnitude in terms of F and rank the following forces:
    a. F_{23}: the force of the block of mass $2m$ on the block of mass $3m$.
    b. F_{32}: the force of the block of mass $3m$ on the block of mass $2m$.
    c. F_{12}: the force of the block of mass m on the block of mass $2m$.
    d. F_{21}: the force of the block of mass $2m$ on the block of mass m.
D. If the order were reversed, would the box of mass $2m$ push on the box of mass m with a greater, lesser, or the same force as was calculated above for F_{21}? Justify your answer.