

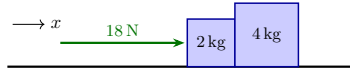
PHY 121 — Newton's Laws Group Practice

Use $g = 9.8 \text{ m/s}^2$. Strings and pulleys are ideal (massless strings, massless frictionless pulleys). All surfaces are frictionless.

Problem 1

Warm-up: two blocks in contact

Two blocks are pushed along a horizontal frictionless surface by an 18 N force directed horizontally to the right.

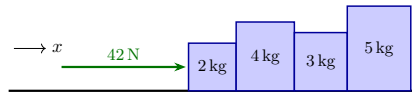


- (a) Draw a free-body diagram for each block (show only the horizontal forces). What is the acceleration of each block?
- (b) What is the *magnitude* of the contact force between the two blocks?
- (c) What is the net force on the 2 kg block? Is it larger or smaller than the 18 N applied force, and why?
- (d) How does the force of the 2 kg block on the 4 kg block compare with the force of the 4 kg block on the 2 kg block? Which of Newton's laws tells you this?

Problem 2

Contact forces

Now four blocks are pushed along a horizontal frictionless surface by a 42 N force directed horizontally to the right.

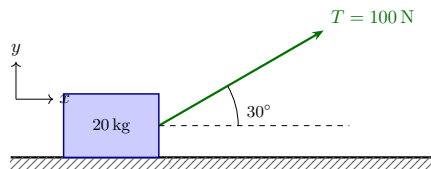


- (a) What is the acceleration of each block?
- (b) What is the *magnitude* of the contact force between the 3 kg and 4 kg blocks?
- (c) What is the net force on the 5 kg block?
- (d) **New situation:** the 42 N force is now applied to the *right-hand* side of the 5 kg block, pushing the stack to the *left*. Without recalculating from scratch, predict: is the contact force between the 3 kg and 4 kg blocks larger, smaller, or the same as in (b)? Then compute it.

Problem 3

Force components and the normal force

A 20 kg block is pulled by a rope with tension $T = 100\text{ N}$ directed 30° above the horizontal. The floor is frictionless.

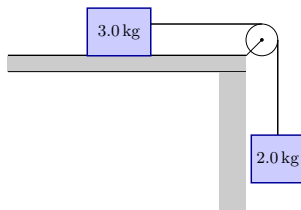


- (a) What are the x and y components of the tension force $\vec{T}$?
- (b) What are the other two forces acting on the block? Express them as vectors.
- (c) Use Newton's second law to find:
 - (i) the acceleration of the block in the x -direction;
 - (ii) the size of the normal force exerted by the floor on the block.
- (d) Is the normal force larger or smaller than mg ? Explain physically in one sentence. Then find the tension T (at the same 30°) at which the block just begins to lift off the floor.

Problem 4

Two objects connected by a string

A 3.0 kg block rests on a frictionless table and is connected by a string over a pulley at the table's edge to a hanging 2.0 kg block. The system is released from rest.

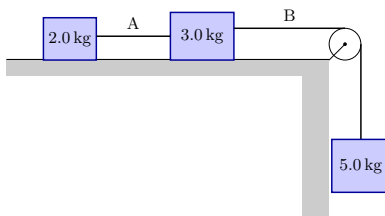


- (a) **Predict first, discuss, and agree as a group:** is the tension in the string *greater than*, *less than*, or *equal to* the weight of the hanging block? Justify your answer using the motion of the hanging block.
- (b) Draw a separate FBD for each block. Compare the magnitudes of the acceleration of the two blocks, and compare the tension at the two ends of the string. Explain why each comparison holds.
- (c) Find the acceleration of the blocks and the tension in the string.
- (d) Without recalculating, how do a and T behave in each limit? Explain what you expect physically, then check with your formulas.
 - (i) The hanging mass m_2 becomes very large compared with m_1 .
 - (ii) The table mass m_1 becomes very large compared with m_2 .

Problem 5

Challenge (optional): three blocks, two strings

Two blocks on a frictionless table are connected by string A. A second string B connects the 3.0 kg block over a pulley to a hanging 5.0 kg block. The system is released from rest.

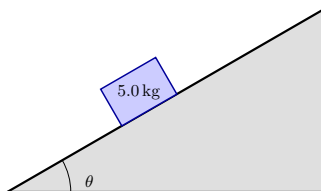


- (a) Without calculating, *rank* the following from largest to smallest and explain your ranking: the weight of the hanging block, the tension in string B, and the tension in string A.
- (b) Find the acceleration of the system and the tension in each string. (Hint: how can you choose a “system” to get the acceleration quickly?)
- (c) A classmate says: “The tension in string B is just the weight of the hanging block, 49 N.” Write a short, polite response explaining the error.
- (d) String A is cut. What is the acceleration of the 2.0 kg block immediately afterward? What are the new acceleration of the other two blocks and the new tension in string B?

Problem 6

Inclined planes: choosing axes

A 5.0 kg block slides on a frictionless incline that makes an angle $\theta = 30^\circ$ with the horizontal.

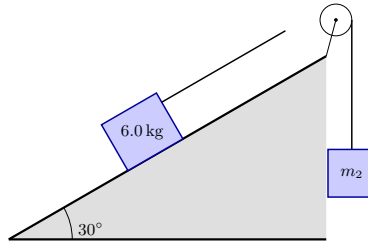


- (a) Draw an FBD for the block. Choose axes with the x -axis *along* the incline (down-slope positive) and the y -axis *perpendicular* to the incline. Show on your diagram the angle between the weight vector and the y -axis.
- (b) Write the components of the weight in your axes, then apply Newton’s second law along each axis.
- (c) Find the acceleration of the block and the size of the normal force.
- (d) Does the acceleration depend on the mass of the block? What do your results give for $\theta = 0^\circ$ and $\theta = 90^\circ$? Do these make sense?

Problem 7

Combining ideas: incline + pulley

A 6.0 kg block is on a frictionless 30° incline and is connected by a string over an ideal pulley at the top of the incline to a hanging block of mass m_2 .



- (a) Suppose $m_2 = 4.0$ kg. Before calculating, predict the direction in which the 6.0 kg block will move (up or down the incline), and give your reasoning in terms of forces.
- (b) Draw FBDs for both blocks and find the acceleration of the system and the tension in the string.
- (c) What value of m_2 would keep the system at rest (in equilibrium)? What is the tension then?
- (d) Now $m_2 = 2.0$ kg. Find the acceleration and tension. What does the sign of your answer tell you about which way the system actually moves, and how does the tension compare with $m_2 g$?
- (e)* *Extension:* The string is cut when $m_2 = 4.0$ kg and the blocks are moving at 1.0 m/s. Describe the subsequent motion of each block (acceleration and direction).