

Chapter 5 – Newton's Laws of Motion



Sir Isaac Newton (1642 – 1727)

- Developed a picture of the universe as a subtle, elaborate clockwork slowly unwinding according to well-defined rules.
- The book “Philosophiæ Naturalis Principia Mathematica” contains all his laws of motion and theories of tides and gravitation.
- He also wrote another book, "Opticks", which was published in 1704 and describes the Calculus and other mathematics. It also describes his theory of light.

Newton's System – Basic Definitions:

1. Quantity of matter: *mass*
 2. Quantity of motion: *momentum*
 3. Property of mass: *inertia*
 4. Action that changes the state of motion: *force*
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- I. First law of motion: *The Law of Inertia*
 - II. Second law of motion: *The Law of Acceleration*
 - III. Third law of motion: *The Law of Action and Reaction*
The Law of Universal Gravitation

5.1 Fundamental Particles; 5.2 The Fundamental Forces of Nature



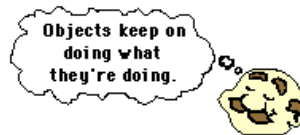
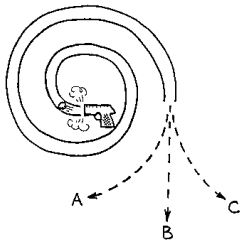
Please read these two sections on your own from the textbook.

5.3 Newton's First Law of Motion and a Qualitative Conception of Force

Mass as a measure of inertia. Mechanical equilibrium

Newton's first law of motion

WHEN THE PELLET FIRED INTO THE SPIRAL TUBE EMERGES, WHICH PATH WILL IT FOLLOW?
(NEGLECT GRAVITY)



“Any system in mechanical equilibrium remains in mechanical equilibrium unless compelled to change that state by nonzero total force acting on the system.”

“Every system continues in its state of rest or of uniform speed in a straight line unless acted on by a nonzero net force.”

5.4 The Concept of Force and Its Measurement

Quantifying force. Force is a vector quantity

5.5 Newton's Second Law of Motion

Nonzero net force

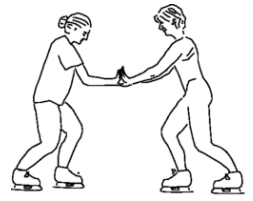


Please Read: Strategic Example 5.2 (page 178)

Practice Problem: Force to stop a car. What force is required to bring a 1500-kg car to rest from a speed of 100 km/h during a time of 4 seconds?

5.6 Newton's Third Law of Motion

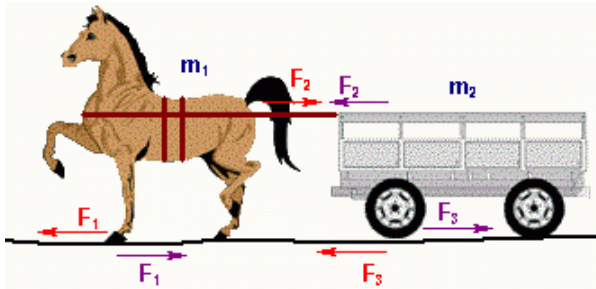
Third law force pairs (interaction pairs). Internal vs. external forces



Conceptual Example: What makes a car go forward?

Conceptual Example: How does a rocket accelerate?

Horse: For me to pull the cart will be a futile effort; the cart will pull back on me with an equal force. Why bother?



5.7 Limitations to Applying Newton's Laws of Motion

5.9 Second Law and Third Law Force Diagrams (Free-Body Diagrams)

Problem – Solving Strategy

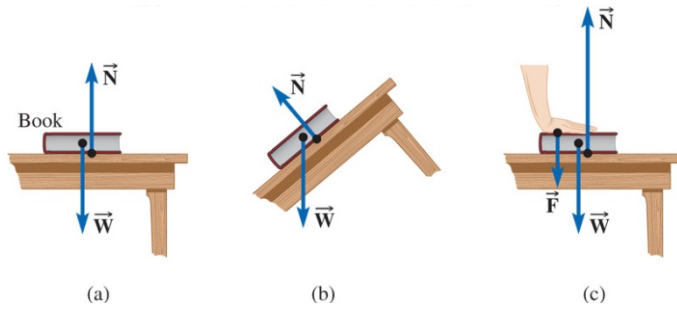
- *Make a simple drawing that captures the information given in the problem.*
- *Consider only **one object at a time** and draw a **free-body diagram** for that body showing all forces acting **on** that body, **including any unknown forces** that you have to solve for.*
- *Label each force.*
- *Choose a convenient xy coordinate system and resolve the forces into components.*
- *Apply Newton's second law for each body, separately for the x and y components.*
- *Solve the equations for the unknowns.*

Practice Problem: A truck driving on a level highway is acted upon by the following forces: a downward gravitational force of 52 kN, an upward contact force due to the road of 52 kN, another contact force due to the road of 7 kN, directed east, and a drag force due to air resistance of 5 kN, directed west. (a) What is the net force acting on the truck? (b) What is the acceleration of the truck? (c) What should be the air drag such that the truck is in equilibrium?

5.10 Weight and the Normal Force on a Surface

Weight

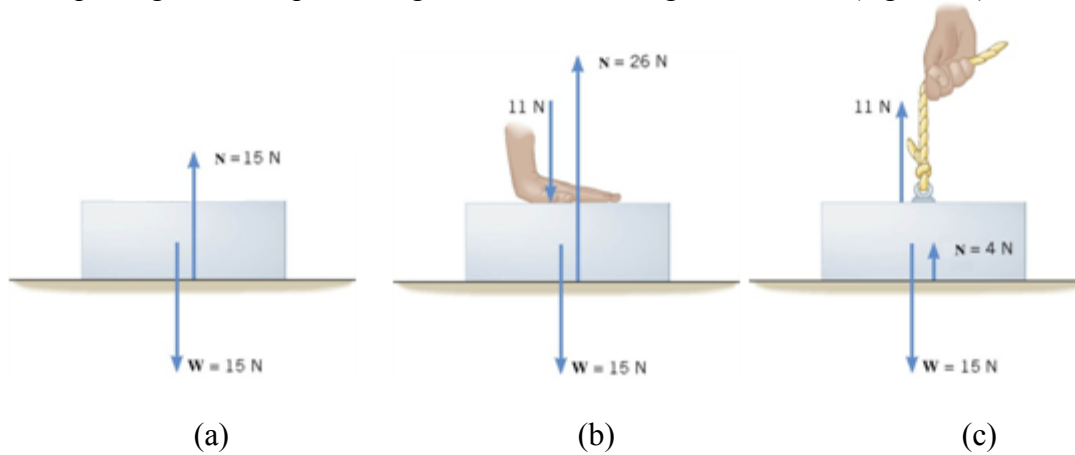
The normal force and Newton's third law



Please Read: Strategic Example 5.5 (page 186)

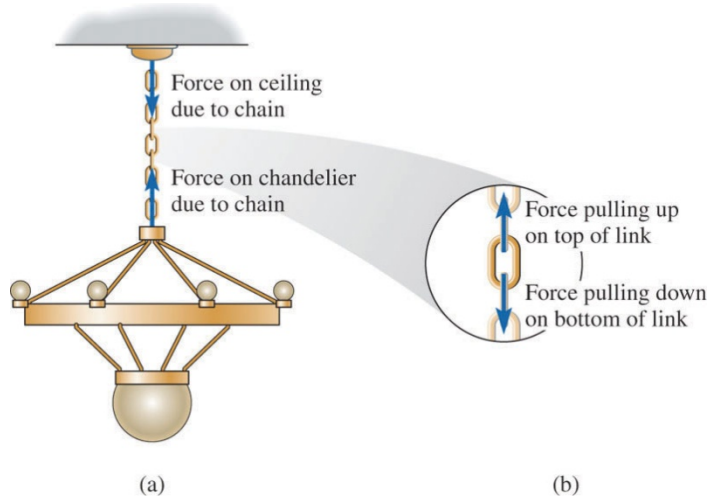
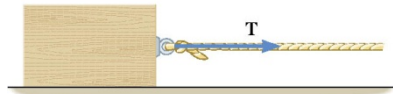


Practice Problem: A 1.53-kg box is resting on the smooth horizontal surface of a table. (a) Determine the weight of the box and the normal force acting on it. (b) The box is now pushed down with a force of 11.0 N. Again, determine the normal force acting on the box. (c) The box is now pulled upward with a force of 11.0 N. What is the normal force on the box now? (d) What happens if the force pulling the box upward has a magnitude of 15 N? (e) What happens if the force pulling the box upward is greater than the weight of the box (e.g. 17 N)?



5.11 Tensions in Ropes, Strings, and Cables

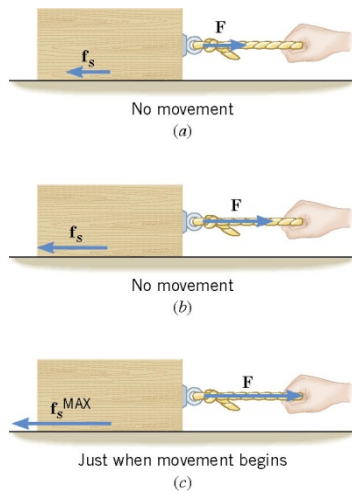
Ideal string. Ideal pulley



Please Read: Strategic Examples 5.8 (page 192) and 5.9 (page 194)



5.12 Static Friction

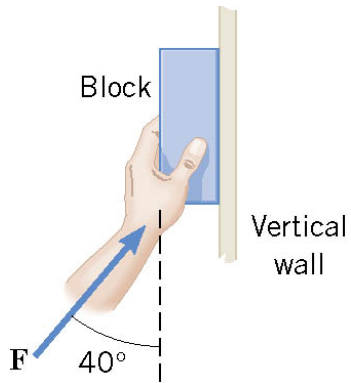


Example: A book is placed on an incline that makes a 30° angle with the horizontal. What is the minimum value of the coefficient of static friction between the book and the incline that will prevent the book from sliding?



Please Read: Strategic Examples 5.11 (page 199) and 5.12 (page 201)

Example: The weight of the block in the drawing is 88.9 N. The coefficient of static friction between the block and the vertical wall is 0.560. (a) What minimum force \mathbf{F} , directed as in the figure, is required to prevent the block from sliding down the wall? (b) What minimum force is required to start the block moving up the wall?



5.13 Kinetic Friction at Low Speeds

Check Your Understanding: To make an object start moving on a surface with friction requires

- (a) less force than to keep it moving on the surface.
- (b) the same force as to keep it moving on the surface
- (c) more force than to keep it moving on the surface.
- (d) a force equal to the weight of the object.

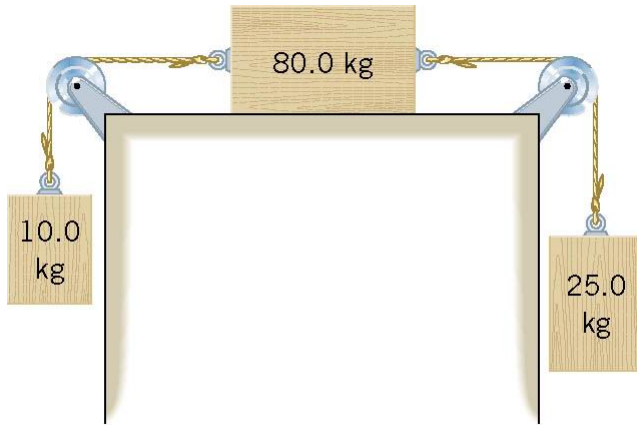


Please Read: *Strategic Example 5.16 (page 206)*

Practice Problem: A 10-kg box rests on a horizontal floor. The coefficient of static friction is $\mu_s = 0.40$ and the coefficient of kinetic friction is $\mu_k = 0.30$. Determine the force of friction acting on the box if a horizontal external applied force \mathbf{F} is exerted on it of magnitude: (a) 0, (b) 10 N, (c) 20 N, (d) 38 N, and (e) 40 N.

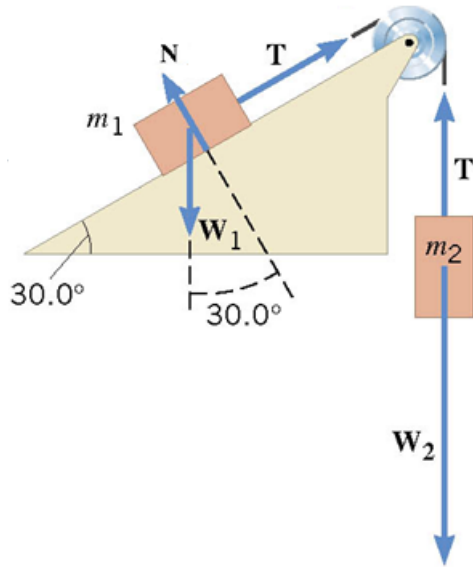
Example: Find the acceleration of a crate sliding down an incline that makes an angle θ with the horizontal. The coefficient of kinetic friction between the box and the incline is μ_k .

Practice Problem: Three objects are connected by strings that pass over massless and friction-free pulleys. The objects move and the coefficient of kinetic friction between the middle object and the table surface is 0.100. (a) What is the acceleration of the three objects? (b) Find the tension in each of the two strings.



Example: Accelerating Blocks. A block of mass $m_1 = 8.00$ kg, on a 30.0° incline, is connected to a second block of mass $m_2 = 22.0$ kg by an ideal cord that passes over a massless and frictionless pulley as in the drawing.

i) What is the minimum value of the coefficient of static friction μ_s , between block 1 and the incline, required to prevent the block from sliding up the incline?



- ii) Find the acceleration of each block and the tension in the cord in the following situations:
 (a) the kinetic coefficient of friction between block 1 and the incline is $\mu_k = 0.150$; (b) the incline is frictionless, and (c) when the cord is cut.

