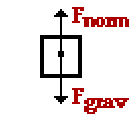
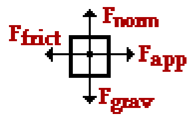
Drawing and Interpreting Free-Body Diagrams

A free-body diagrams is given for the following physical situations at the instant in time for which they are described. As is always done in free-body diagrams, the forces are labeled according to type and arrows are drawn such that their length reflects the magnitude of the force.

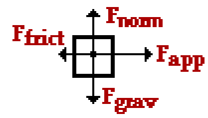
a. A book is at rest on top of a table.



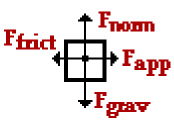
b. A book is being pushed to the right across a table surface with a constant velocity. (Neglect F_{air}.)



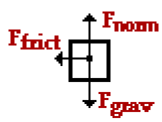
c. A book is being pushed to the right across a table surface and accelerating in the direction of the push. (Neglect F_{air}.)



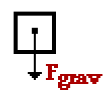
d. A student is pushing lightly upon a large box in an attempt to push it to the right across the floor, but the box fails to move.



e. A rightward-moving box (which was previously set into rightward motion across the floor) gradually slows to a stop.

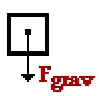


f. An air track glider is gliding to the right at constant velocity.

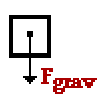


(or replace the F_{norm} with F_{air})

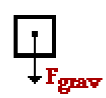
g. A ball is dropped from rest from the top of a building. (Neglect F_{air}.)



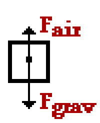
h. Several seconds after being thrown, a football is moving upwards and rightwards towards the peak of its trajectory. (Neglect F_{air}.)



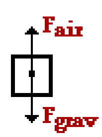
i. Several seconds after being thrown, a football reaches the precise peak of its trajectory. (Neglect F_{air}.)



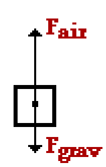
j. A falling skydiver is speeding up.



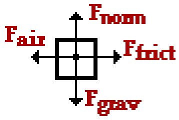
k. A falling skydiver has reached a terminal velocity.



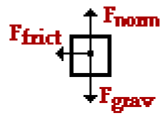
l. After reaching a terminal velocity, a falling skydiver has opened her parachute.



m. A car is moving to the right at a high speed across a level roadway surface; the driver's foot remains on the gas pedal.

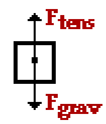


n. A car is skidding to a stop (with wheels locked) while traveling to the right across a level roadway surface.

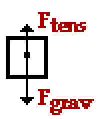


(F_{air} could be added to F_{frict})

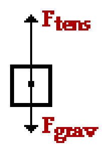
o. An elevator (held by a cable) is moving upwards at a constant velocity. (Neglect F_{air}.)



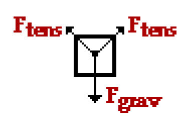
p. An upward moving elevator (held by a cable) slows down. (Neglect F_{air}.)



q. A downward moving elevator (held by a cable) slows down. (Neglect F_{air}.)



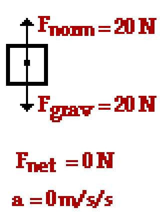
r. A picture hangs symmetrically by two wires oriented at angles to the vertical.



Force-Mass-Acceleration Relationships

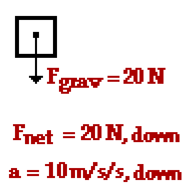
Construct free-body diagrams for the following objects; label the forces according to type. Use the approximation that **$g=10\ m/s^2$**
to determine the magnitude of all forces and the net force and acceleration of the object.

1. A 2-kg box is at rest on a table.



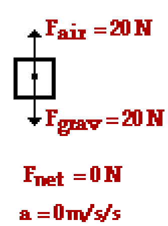
("At rest" would indicate a balance of forces and an acceleration of 0 m/s/s.)

2. A 2-kg box is free-falling from the table to the ground.



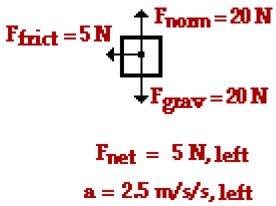
("Free-falling" indicates that the only force that influences the motion is the force of gravity.)

3. A 2-kg box equipped with a parachute is falling at a terminal velocity after being dropped from a plane.



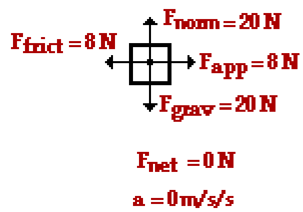
(A "terminal velocity" indicates a constant velocity and a balance of forces.)

4. A 2-kg box is sliding to the right across a table. The force of friction upon the box is 5 N.



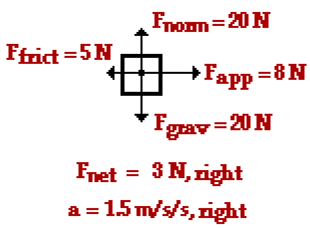
(Friction is directed opposite the motion and causes a leftward acceleration; no rightward force is spoken of, only a rightward motion.)

5. An 8-N force is applied to a 2-kg box to move it to the right across the table at a constant velocity of 1.5 m/s.



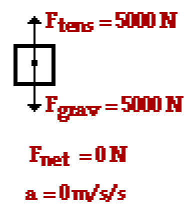
(A "constant velocity" indicates an acceleration of 0 m/s/s and a balance of forces.)

6. An 8-N force is applied to a 2-kg box to accelerate it to the right across a table. The box encounters a force of friction of 5 N.



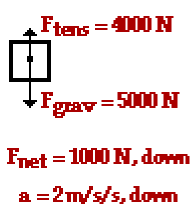
(The horizontal forces can be summed as vectors; divide by the mass to obtain the acceleration value.)

7. A 500-kg freight elevator is descending down through the shaft at a constant velocity of 0.50 m/s.



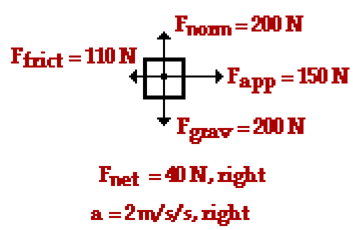
(A "constant velocity" indicates an acceleration of 0 m/s/s and a balance of forces.)

8. A 500-kg freight elevator is moving upwards towards its destination. Near the end of the ascent, the upward moving elevator encounters a downward acceleration of 2.0 m/s/s.



(Begin by multiplying m•a to find the net force - 1000 N, down. The downward gravity force must be 1000 N more than the upward tension force.)

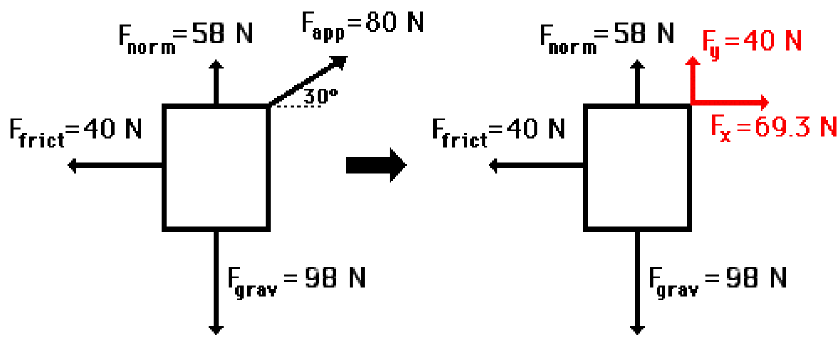
9. A 150-N rightward force is applied to a 20-kg box to accelerate it to the right across a rough surface at a rate of 2.0 m/s/s.



(Begin by multiplying m•a to determine the net force - 40 N, right. The rightward applied force must be 40 N more than the leftward friction force.)

Determining the Acceleration of a Box Moving at an Angle

Consider the situation below in which a force is directed at an angle to the horizontal. In such a situation, the applied force could be resolved into two components. These two components can be considered to replace the applied force at an angle. By doing so, the situation simplifies into a familiar situation in which all the forces are directed horizontally and vertically.



A force directed at an angle to the horizontal can be resolved into two components. Together, these two components are a replacement for the single force.

Once the situation has been simplified, the problem can be solved like any other problem. The task of determining the acceleration involves first determining the net force by adding up all the forces as vectors and then dividing the net force by the mass to determine the acceleration. In the above situation, the vertical forces are balanced (i.e., F_{grav}, F_y, and F_{norm} add up to 0 N), and the horizontal forces add up to 29.3 N, right (i.e., 69.3 N, right + 40 N, left = 29.3 N, right). The net force is 29.3 N, right and the mass is 10 kg ($m = F_{grav}/g$); therefore, the acceleration is 2.93 m/s/s, right.

Your Turn to Practice

To test your understanding, analyze the two situations below to determine the net force and the acceleration.