5 Applying Newton's Laws

5.1 Equilibrium

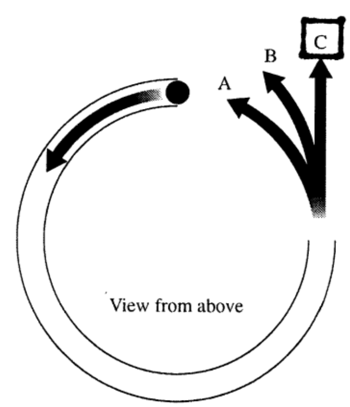
1. If an object is at rest, can you conclude that there are no forces acting on it? Explain.

No. You can only conclude that there is no net force on the object if it remains at rest.

2. If a force is exerted on an object, is it possible for that object to be moving with constant velocity? Explain.

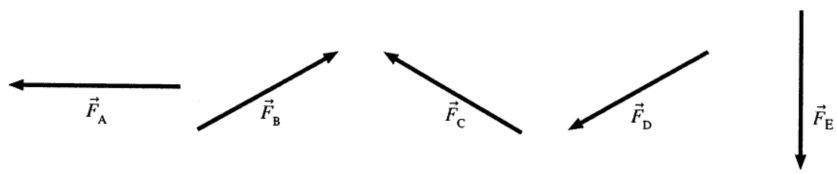
If one nonzero force acts on an object, then it must accelerate (It cannot move at constant velocity). If multiple forces act on the object, it can move at constant velocity if those forces sum to zero net force.

3. A hollow tube forms three-quarters of a circle. It is lying flat on a table. A ball is shot through the tube at high speed. As the ball emerges from the other end, does it follow path A, path B, or path C? Explain your reasoning.



The ball will follow path C. After leaving the tube, the ball no longer is in contact with the wall of the tube and, with no net force, will continue in a straight line.

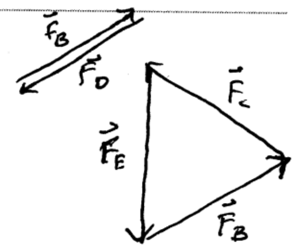
4. The vectors below show five forces that can be applied individually or in combinations to an object. Which forces or combinations of forces will cause the object to be in equilibrium?



$\vec{F}_B + \vec{F}_D$

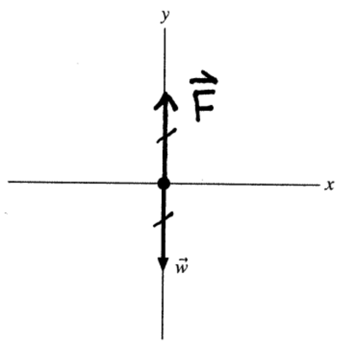
OR

$\vec{F}_B + \vec{F}_C + \vec{F}_E$

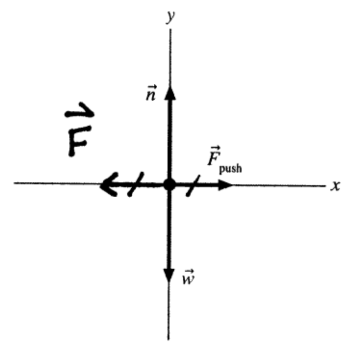


5. The free-body diagrams show a force or forces acting on an object. Draw and label one more force (one that is appropriate to the situation) that will cause the object to be in equilibrium.

a.

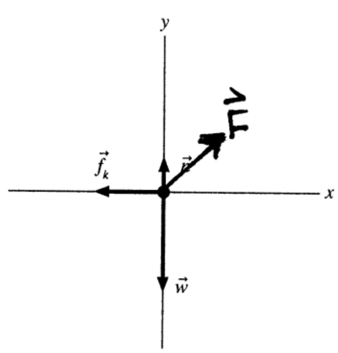


b.

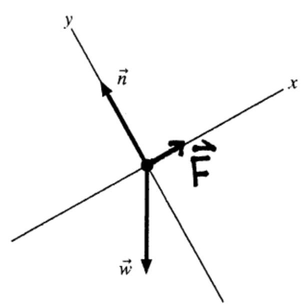


6. The free-body diagrams show a force or forces acting on an object. Draw and label one more force (one that is appropriate to the situation) that will cause the object to be in equilibrium.

a.



b.



5.2 Dynamics and Newton's Second Law

7. a. An elevator travels *upward* at a constant speed. The elevator hangs by a single cable. Friction and air resistance are negligible. Is the tension in the cable greater than, less than, or equal to the weight of the elevator? Explain. Your explanation should include both a free-body diagram and reference to appropriate laws of physics.

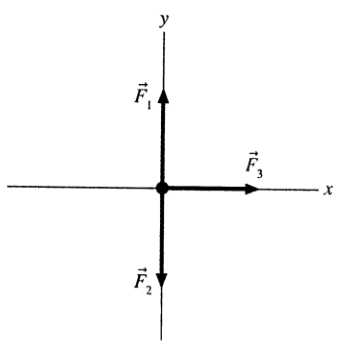
Because the elevator is not accelerating, the net force on it must be zero. Therefore, the tension and weight must be equal in magnitude and opposite in direction.

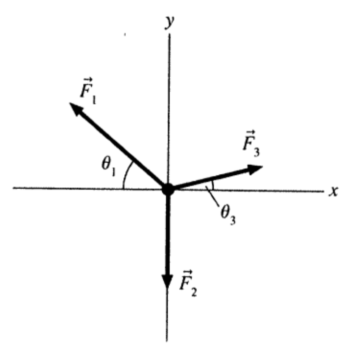
b. The elevator travels *downward* and is slowing down. Is the tension in the cable greater than, less than, or equal to the weight of the elevator? Explain.

Because the elevator is slowing down, its acceleration is in the opposite direction from its motion. Therefore, the net force on the elevator is upward and the tension is greater than the weight.

Exercises 8–9: The figures show free-body diagrams for an object of mass m. Write the x- and y-components of Newton's second law. Write your equations in terms of the *magnitudes* of the forces $F_1, F_2, \ldots$ and any *angles* defined in the diagram. One equation is shown in each question to illustrate the procedure.

8.





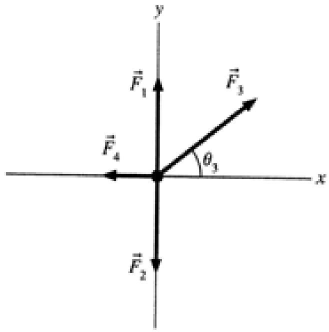
$ma_x = F_3$

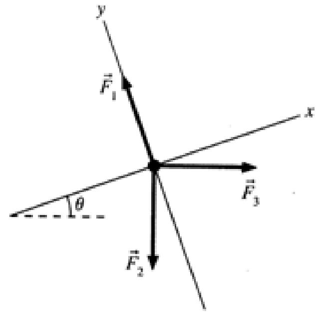
$ma_y = F_1 - F_2$

$ma_x = F_3 \cos\theta_3 - F_1 \cos\theta_1$

$ma_y = F_1 \sin\theta_1 + F_3 \sin\theta_3 - F_2$

9.





$ma_x = F_3 \cos\theta_3 - F_4$

$ma_y = F_1 + F_3 \sin\theta_3 - F_2$

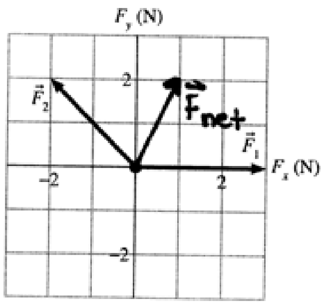
$ma_x = F_3 \cos\theta - F_2 \sin\theta$

$ma_y = F_1 - F_2 \cos\theta - F_3 \sin\theta$

Exercises 10–12: Two or more forces, shown on a free-body diagram, are exerted on a 2 kg object. The units of the grid are newtons. For each:

- Draw a vector arrow *on the grid,* starting at the origin, to show the net force $\vec{F}_{net}$.
- In the space to the right, determine the numerical values of the components a_x and a_y.

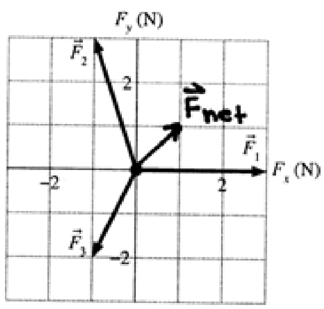
10.



$a_x = \frac{1}{2kg}(3N - 2N) = \frac{1}{2}\frac{m}{s^2}$

$a_y = \frac{1}{2kg}(2N) = 1\frac{m}{s^2}$

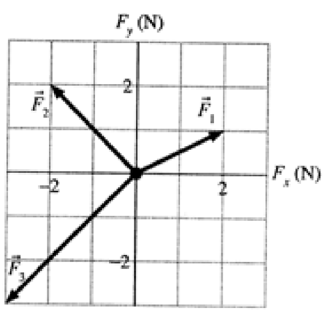
11.



$a_x = \frac{1}{2kg}(3N - 1N - 1N) = 0.5\frac{m}{s^2}$

$a_y = \frac{1}{2kg}(3N - 2N) = 0.5\frac{m}{s^2}$

12.

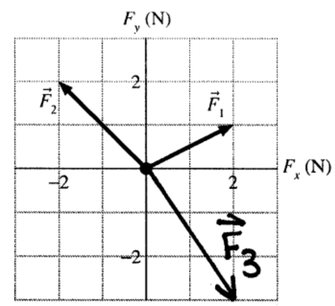


$a_x = \frac{1}{2kg}(2N - 2N - 3N) = 1.5\frac{m}{s^2}$

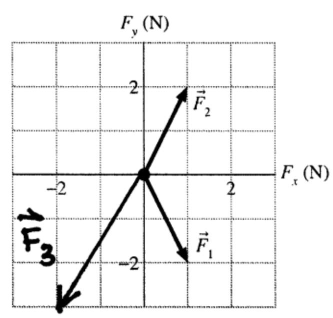
$a_y = \frac{1}{2kg}(1N + 2N - 3N) = 0\frac{m}{s^2}$

Exercises 13–15: Three forces $\vec{F}_1$, $\vec{F}_2$, and $\vec{F}_3$ cause a 1 kg object to accelerate with the acceleration given. Two of the forces are shown on the free-body diagrams below, but the third is missing. For each, draw and label *on the grid* the missing third force vector.

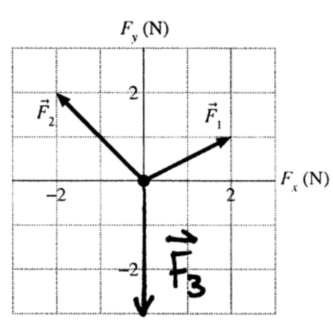
13. $a_x = 2\ \text{m/s}^2$
 $a_y = 0\ \text{m/s}^2$



14. $a_x = 0\ \text{m/s}^2$
 $a_y = -3\ \text{m/s}^2$



15. The object moves with constant velocity.

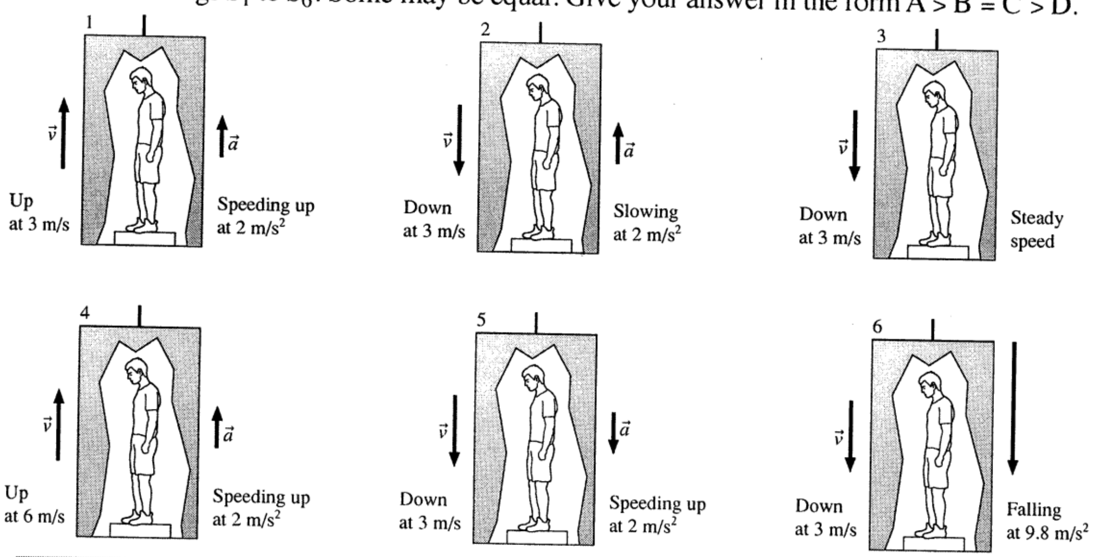


18. An astronaut orbiting the earth is handed two balls that are identical in outward appearance. However, one is hollow while the other is filled with lead. How might the astronaut determine which is which? Cutting them open is not allowed.

The force required to accelerate an object is proportional to its mass. ($\vec{F}=m\vec{a}$). Thus, the astronaut can determine which ball is hollow and which is filled with lead by shaking each or causing each to accelerate with a given force. The force required to accelerate the hollow ball is less due to its lower mass.

5.4 Normal Forces

19. Suppose you stand on a spring scale in six identical elevators. Each elevator moves as shown below. Let the reading of the scale in elevator n be S_n. Rank in order, from largest to smallest, the six scale readings S_1 to S_6. Some may be equal. Give your answer in the form A > B = C > D.



Order: $S_1 = S_2 = S_4 > S_3 > S_5 > S_6$

Explanation: The scale reading reads your apparent weight, which depends upon the magnitude and direction of your acceleration only, not your speed. Cases 1, 2 and 4 all involve equal upward accelerations. Case 3 has no acceleration so the scale reads your true weight. Case 5 reads less than your true weight because your acceleration is downward. For case 6, the scale reading S_6 will be zero.