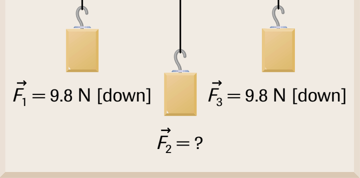

The above diagram shows a possible setup for a vertical force board. (You may prefer to modify the setup, however, using a force table instead of a force board, as suggested for this activity.) In this vertical force board, there are three different forces, each acting on a different string. If two of the forces are known, the third force can be determined. Describe how you would determine the unknown force $\vec{F}_2$.

Practice

Understanding Concepts

1. Assume the 8-passenger Learjet shown in **Figure 10** has a force of gravity of 6.6×10^4 N [down] acting on it as it travels at a constant velocity of 6.4×10^2 km/h [W]. If the forward thrust provided by the engines is 1.3×10^4 N [W], determine

(a) the upward lift force on the plane

(b) the force due to air resistance on the plane

2. Choose which of the objects in *italics* are not examples of Newton's first law, giving a reason in each case:

(a) A cat-food *can* moves at a constant velocity on a conveyor belt in a factory.

(b) A *skydiver* falls vertically at terminal speed.

(c) A rubber *stopper* is tied to the end of a string and swings back and forth as a pendulum.

(d) A *shopper* stands on an escalator, halfway between floors in a department store, and rises at a constant speed.

(e) A *ball* travels with projectile motion after leaving a pitcher's hand.

3. A child is trying to push a large desk across a wooden floor. The child is exerting a horizontal force of magnitude 38 N, but the desk is not moving. What is the magnitude of the force of friction acting on the desk?

4. A snowboarder is travelling at a high speed down a smooth snow-covered hill. The board suddenly reaches a rough patch, encountering significant friction. Use Newton's first law to describe and explain what is likely to happen to the snowboarder.

5. You are sitting on a bus that is travelling at a constant velocity of 55 km/h [N]. You toss a tennis ball straight upward and it reaches a height just above the level of your eyes. Will the ball collide with you? Explain your answer.

6. The following sets of forces are acting on a common point. Determine the additional force needed to maintain static equilibrium.
   (a) 265 N [E]; 122 N [W]
   (b) 32 N [N]; 44 N [E]
   (c) 6.5 N [25° E of N]; 4.5 N [W]; 3.9 N [15° N of E]

7. A single clothesline is attached to two poles 10.0 m apart. A pulley holding a mass $\left(|\vec{F}_g| = 294\text{ N}\right)$ rolls to the middle of the line and comes to rest there. The middle of the line is 0.40 m below each end. Determine the magnitude of the tension in the clothesline.

Applying Inquiry Skills

8. (a) Describe how you could use a piece of paper, a coin, and your desk to demonstrate the law of inertia for an object initially at rest.
   (b) Describe how you could safely demonstrate, using objects of your choosing, the law of inertia for an object initially in motion.

Making Connections

9. Explain the danger of stowing heavy objects in the rear window space of a car.

Answers

6. (a) 143 N [W]
   (b) 54 N [36° S of W]
   (c) 7.2 N [16° W of S]
7. 1.8×10^3 N

Figure 10
The Bombardier Learjet® 45, built by the Canadian firm Bombardier Inc., is one of the first executive jets designed entirely on computer.

Practice

Understanding Concepts

10. A horizontal force is applied to a hockey puck of mass 0.16 kg initially at rest on the ice. The resulting acceleration of the puck has a magnitude of 32 m/s^2. What is the magnitude of the force? Neglect friction.

11. A fire truck with a mass of 2.95×10^4 kg experiences a net force of 2.42×10^4 N [fwd]. Determine the acceleration of the truck.

12. Derive an equation for the constant net force acting on an object in terms of the object's mass, its initial velocity, its final velocity, and the time interval during which the net force is applied.

13. A 7.27-kg bowling ball, travelling at 5.78 m/s [W], strikes a lone pin straight on. The collision lasts for 1.2 ms and causes the ball's velocity to become 4.61 m/s [W] just after the collision. Determine the net force (assumed to be constant) on the ball during the collision.

Applying Inquiry Skills

14. Describe how you would use an elastic band, three small carts with low-friction wheels, and a smooth horizontal surface to safely demonstrate Newton's second law. (Your demonstration need not involve taking numerical data.) Obtain teacher approval if you wish to try your demonstration.

Making Connections

15. Mining operations in outer space will require unique innovations if they are carried out where there is a very low force of gravity, such as on asteroids or the moons of various planets. One plan is to develop a device that will push particles with the same constant force, separating them according to the accelerations they achieve. Research "mining methods in zero-*g*" to learn more about this application of Newton's second law. Describe what you discover.

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Answers

10. 5.1 N

11. 0.820 m/s^2 [fwd]

13. 7.1×10^3 N [E]

Answers

16. (a) 24 N
    (b) 1.3×10^7 N
    (c) 2.45×10^{-2} N
    (d) 1.77×10^{-8} N
17. (a) 1.56×10^{-1} kg
    (b) 1.18×10^5 kg
18. 2.8×10^2 N [down]

Practice

Understanding Concepts

16. Determine, from the indicated masses, the magnitude of the weight (in newtons) for each of the following stationary objects on Earth's surface:
   (a) a horseshoe (2.4 kg)
   (b) an open-pit coal-mining machine (1.3 Gg)
   (c) a table tennis ball (2.50 g) (Assume $|\vec{g}| = 9.80$ N/kg.)
   (d) a speck of dust (1.81 μg) (Assume $|\vec{g}| = 9.80$ N/kg.)
   (e) you

17. Determine the mass of each of the following objects, assuming that the object is stationary in a gravitational field of 9.80 N/kg [down]:
   (a) a field hockey ball with a weight of 1.53 N [down]
   (b) cargo attaining the 1.16 MN [down] weight limit of a C-5 Galaxy cargo plane

18. What is the weight of a 76-kg astronaut on a planet where the gravitational field strength is 3.7 N/kg [down]?

Applying Inquiry Skills

19. Show that the units N/kg and m/s^2 are equivalent.

Newton's Third Law of Motion

When a balloon is inflated and released, air rushing from the open nozzle causes the balloon to fly off in the opposite direction (**Figure 12(a)**). Evidently, when the balloon exerts a force on the air in one direction, the air exerts a force on the balloon in the opposite direction. This is illustrated in **Figure 12(b)** where vertical forces are not shown because they are so small.

Practice

Understanding Concepts

20. Explain the motion of each of the following objects in *italics* using the third law of motion. Describe the action and reaction forces, and their directions.
  (a) A *rocket* being used to put a communications satellite into orbit has just left the launch pad.
  (b) A rescue *helicopter* hovers above a stranded victim on a rooftop beside a flooded river.
  (c) An inflated *balloon* is released from your hand and travels eastward for a brief time interval.

21. You are holding a pencil horizontally in your hand.
  (a) Draw a system diagram of this situation, showing all the action-reaction pairs of forces associated with the pencil.
  (b) Explain, with the help of an FBD, why the pencil is not accelerating.

Applying Inquiry Skills

22. Describe how you would safely demonstrate Newton's third law to students in elementary school using toys.

SUMMARY Newton's Laws of Motion

- Dynamics is the study of forces and the effects the forces have on the velocities of objects.
- The three laws of motion and the SI unit of force are named after Sir Isaac Newton.
- Newton's first law of motion (also called the law of inertia) states: If the net force acting on an object is zero, the object maintains its state of rest or constant velocity.
- Inertia is the property of matter that tends to keep an object at rest or in motion.
- An object is in equilibrium if the net force acting on it is zero, which means the object is either at rest or is moving at a constant velocity.
- Newton's second law of motion states: If the external net force on an object is not zero, the object accelerates in the direction of the net force. The acceleration is directly proportional to the net force and inversely proportional to the object's mass. The second law can be written in equation form as $\vec{a} = \frac{\Sigma \vec{F}}{m}$ (equivalently, $\Sigma \vec{F} = m\vec{a}$).
- Both the first and second laws deal with a single object; the third law deals with two objects.
- The SI unit of force is the newton (N): $1\ \text{N} = 1\ \text{kg}\cdot\text{m/s}^2$.
- The weight of an object is the force of gravity acting on it in Earth's gravitational field. The magnitude of the gravitational field at Earth's surface is 9.8 N/kg, which is equivalent to $9.8\ \text{m/s}^2$.
- Newton's third law of motion (also called the action-reaction law) states: For every action force, there is a simultaneous force equal in magnitude, but opposite in direction.

Section 2.2 Questions

Understanding Concepts

1. A mallard duck of mass 2.3 kg is flying at a constant velocity of 29 m/s [15° below the horizontal]. What is the net force acting on the duck?

2. A 1.9-kg carton of juice is resting on a refrigerator shelf. Determine the normal force acting on the carton.

3. An electrical utility worker with a mass of 67 kg, standing in a cherry picker, is lowered at a constant velocity of 85 cm/s [down]. Determine the normal force exerted by the cherry picker on the worker.

4. Magnetic forces act on the electron beams in television tubes. If a magnetic force of magnitude 3.20×10^{-15} N is exerted on an electron ($m_e = 9.11 \times 10^{-31}$ kg), determine the magnitude of the resulting acceleration. (The mass of an electron is so low that gravitational forces are negligible.)

5. A karate expert shatters a brick with a bare hand. The expert has a mass of 65 kg, of which 0.65 kg is the mass of the hand. The velocity of the hand changes from 13 m/s [down] to zero in a time interval of 3.0 ms. The acceleration of the hand is constant.

(a) Determine the acceleration of the hand

(b) Determine the net force acting on the hand. What object exerts this force on the hand?

(c) Determine the ratio of the magnitude of the net force acting on the hand to the magnitude of the expert's weight.

6. In target archery, the magnitude of the maximum draw force applied by a particular bow is 1.24×10^2 N. If this force gives the arrow an acceleration of magnitude 4.43×10^3 m/s^2, what is the mass, in grams, of the arrow?

7. The magnitude of the gravitational field strength on Venus is 8.9 N/kg.

(a) Calculate the magnitude of your weight on the surface of Venus.

(b) By what percentage would the magnitude of your weight change if you moved to Venus?

8. One force is given for each of the following situations. Identify the other force in the action-reaction pair, and indicate the name of the force, its direction, the object that exerts it, and the object on which it is exerted:

(a) A chef exerts a force on a baking pan to pull it out of an oven.

(b) The Sun exerts a gravitational force on Saturn.

(c) A swimmer's hands exert a backward force on the water.

(d) Earth exerts a gravitational force on a watermelon.

(e) An upward force of air resistance is exerted on a falling hailstone.

9. Two identical bags of gumballs, each of mass 0.200 kg, are suspended as shown in **Figure 14**. Determine the reading on the spring scale.

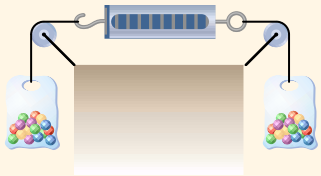

Figure 14

Applying Inquiry Skills

10. (a) Hold a calculator in your hand and estimate its mass in grams. Convert your estimate to kilograms.

(b) Determine the weight of the calculator from your mass estimate.

(c) Determine the weight of the calculator from its mass as measured on a balance.

(d) Determine the percent error in your estimate in (b).

Making Connections

11. An astronaut in the International Space Station obtains a measurement of personal body mass from an "inertial device," capable of exerting a measured force. The display on the device shows that a net force of 87 N [fwd] gives the astronaut an acceleration of 1.5 m/s^2 [fwd] from rest for 1.2 s.

(a) Why is the astronaut unable to measure personal body mass on an ordinary scale, such as a bathroom scale?

(b) What is the mass of the astronaut?

(c) How far did the astronaut move during the 1.2-s time interval?

(d) Research how an inertial device works. Write a brief description of what you discover.

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12. Research the career of Isaac Newton. Report on some of his major accomplishments as well as his eccentricities.