Section 3.2: Newton's First Law of Motion

Tutorial 1 Practice, page 126

1. When a bus or train suddenly accelerates forward from rest, there is no force applied to your body. According to Newton's first law, your body will continue to remain at rest. Relative to the motion of the bus or train, your body might be thrown backward. If you are not holding onto something in the bus or subway train, you might hit something or fall, and get injured.

2. When the frictionless tablecloth is pulled on quickly, no friction or other forces are applied to the bottom of the plates. According to Newton's first law, the plates will remain at rest on top of the table.

3. When the driver pushes on the brakes, the wheels of the car experience no external force from the frictionless black ice surface. As a result, the car will continue to move at a constant velocity according to Newton's first law of motion.

4. According to Newton's first law, an applied external force can move the snow that is at rest off the shovel. To do this, you can hammer the shovel on the ground to shake off the snow.

5. (a) Given: three forces of 13 000 N [up], 1250 N [left], and 1400 N [left]

Required: $\vec{F}_1$; $\vec{F}_g$

Analysis: $\vec{F}_{net} = 0$ N. Choose up and right as positive. So, down and left are negative. Define right and left forces as being along the x-axis. So, up and down forces are along the y-axis.

Solution:
The net force on the x-axis is 0 N.
$$\left(F_{net}\right)_x = F_1 + (-1250 \text{ N}) + (-1400 \text{ N})$$
$$0 = F_1 - 2650 \text{ N}$$
$$F_1 = +2650 \text{ N}$$
$$\vec{F}_1 = 2650 \text{ N [right]}$$

The net force on the y-axis is 0 N.
$$\left(F_{net}\right)_y = +13\,000 \text{ N} + F_g$$
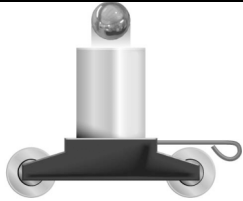$$0 = +13\,000 \text{ N} + F_g$$
$$F_g = -13\,000 \text{ N}$$
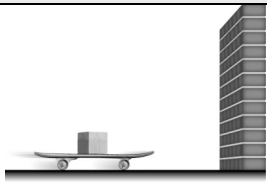$$\vec{F}_g = 13\,000 \text{ N [down]}$$

Statement: $\vec{F}_1$ is 2650 N [right] and $\vec{F}_g$ is 13 000 N [down].

(b) The answers will not change because the change in the velocity of the car does not change the net forces along the y-axis and along the x-axis, which are still zero.

Mini Investigation: Testing Newton's First Law, page 127

1. Predictions may vary. Sample answers given.

Situation	Sketch of situation	Prediction/ explanation	Observation	Explanation
A. A coin is on top of a playing card on the left fist. Hit the card.		The coin will flip up into the air, travel in an arc, and land on the ground.	The coin flips up into the air and travels in an arc before landing on the ground.	The coin resting on the card responds to the force of the card moving upward and pushing the coin with it.
B. A moving ballistics cart fires a ball by exerting a force straight up.		The ball will move straight up in the air, slow down, and then fall to the ground.	The ball moves straight up in the air, slows, and then falls to the ground.	A force by the ballistics cart results in the ball moving upward.

Situation	Sketch of situation	Prediction/explanation	Observation	Explanation
C. A moving skateboard with an object on top hits a wall.		The skateboard will bounce back at the same time the object continues to move forward.	The skateboard bounces back at the same time the object continues to move forward.	The object continues to move forward even though the skateboard bounces back because the object is not subjected to the same force imposed on the skateboard by the wall.
D. A thread supports an object. Another thread is underneath. Pull slowly on the bottom thread.		The object will not move.	The object does not move.	The object continues to remain stationary when there is no net force to cause it to change.
E. A thread supports an object. Another thread is underneath. Pull quickly on the bottom thread.		The object will move.	The object moves.	The object begins moving when there is a net force to cause its position to change. Even if the quick pulling action does not cause the thread to break, the object will tend to vibrate as a result of the quick motion.

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1. Answers may vary. Sample answer:
The use of equipment such as air tables, where little friction is present, can help demonstrate Galileo's thought experiments. With frictionless surfaces available, the result of Galileo's thought experiment, **Figure 2 (a)**, should show that a ball rolling down an incline, onto a horizontal surface, and up another incline could roll up to the same height as its starting position.

2. The inertia of an object depends on the mass of the object. An object with more mass has more inertia, whereas an object with less mass has less inertia. Therefore, the truck, with the greatest mass, has the most inertia and the feather, with the least mass, has the least inertia.

3. The three skaters are either at rest or moving at constant velocity. According to Newton's first law, the net force on each skater is zero.

4. (a) When the pickup truck accelerates forward, your body will be pushed quickly backward due to inertia. If you are sitting in the back of the truck, you may collide with the truck cab and get injured.

(b) To keep the car moving at a constant velocity, the net force on the car in the direction of motion must be zero. The large applied force by the engine of the car has to be cancelled by the friction of the road surface to maintain a constant velocity. Slippery ice surface gives almost no friction so it is hard to get the car moving on ice.

(c) When the car suddenly accelerates forward, the object on the ledge of the car between the rear windshield and the rear seat will be bounced back toward the rear windshield due to inertia. Sharp and heavy objects may crack the windshield.

(d) During liftoff when the spacecraft accelerates upward by a large force, the astronauts will experience a downward push due to inertia. If they stay in a vertical position, this force will compress them from head to toe. It is easier on the body when the astronauts are placed horizontally in the capsule.

5. (a) No, only seat belts significantly improve safety when the car suddenly slows down. In this situation, your body will be pushed quickly forward due to inertia. If there is no seat belt, you could slam into the steering wheel or hit the

windshield with your head. Since you are moving forward, you do not use the headrest.

(b) No, only headrests significantly improve safety when the car suddenly speeds up. In this situation, your body will accelerate forward because the seat exerts a force on it. If there is no headrest, your head will snap backward due to inertia, possibly resulting in a neck injury. Since you are moving forward and your head is moving backward, and the seatbelt is not holding your head, you do not use the seatbelt.

6. When the car suddenly speeds up or slows down, the cup and the coffee that are at rest continue to stay at rest according to Newton's first law. This means they will move in the opposite direction as the acceleration of the car. A lid prevents the coffee from splashing out of the cup and the cup holder prevents the cup from falling.

7. Answers may vary. Sample answer:
The tension in the string is a force pulling the puck toward the spike. If the string is suddenly cut, according to Newton's first law, the puck will resist this change of motion by moving out of the circular path in a direction away from the spike.

8. For an object resting on a horizontal surface, the net force on the object is zero. The forces acting on the object are the normal force and the force gravity. Therefore, the normal force must be equal in magnitude to the force of gravity so that they can cancel each other to give a net force of zero on the object.

9. Answers may vary. Sample answer:
As the car turns, according to Newton's first law, you body continues to go straight. As a result, you will lean toward the door.

10. Answers may vary. Sample answer:
Since an icy highway is slippery with almost no friction, a fast-moving car will not slow down even when you push on the brakes because there is no force acting on the wheels that will stop the motion. When you go around a curve on an icy highway at a fast speed, according to Newton's first law, the car tends to remain in its high-speed straight motion. As a result, it will fly off the curve, causing a skid. So, you should always slow down when driving around a curve on an icy road.

11. (a) When the ring is suddenly pulled horizontally, the chalk will remain in its rest motion under gravity. So, it will fall straight down into the container.

(b) As the chalk falls to the bottom of the container due to gravity and hits it, it will be bounced back upward and break. The water in the container

provides a frictional force on the chalk, slowing it down. The water keeps the chalk from breaking into pieces.

12. Answers may vary. Sample answer:
(a) When the bus moves at a constant velocity, there is no force acting on the apple or the bus. When the apple is thrown upward, the vertical velocity of the apple is changed but not its horizontal velocity. According to Newton's first law, both the apple and the bus will continue at the same velocity as your hand and the bus. So, the apple will land back in your hand.

(b) When the bus slows down, the bus is travelling slower than the apple, which continues to move forward at constant velocity. The apple will land farther in front of you.

13. (a) Given: two forces of 32 N [down] and 17 N [right]

Required: $\vec{F}_1$; $\vec{F}_2$

Analysis: $\vec{F}_{net} = 0$. Choose up and right as positive. So, down and left are negative. Define right and left forces as being along the x-axis. So, up and down forces are along the y-axis.

Solution:
The net force on the x-axis is 0 N.

$$\left(F_{net}\right)_x = F_1 + 17 \text{ N}$$
$$0 = F_1 + 17 \text{ N}$$
$$F_1 = -17 \text{ N}$$
$$\vec{F}_1 = 17 \text{ N [left]}$$

The net force on the y-axis is 0 N.

$$\left(F_{net}\right)_y = F_2 + (-32 \text{ N})$$
$$0 = F_2 - 32 \text{ N}$$
$$F_2 = +32 \text{ N}$$
$$\vec{F}_2 = 32 \text{ N [up]}$$

Statement: $\vec{F}_1$ is 17 N [left] and $\vec{F}_2$ is 32 N [up].

(b) Given: three forces of 54 N [up], 60 N [right], and 86 N [left]

Required: $\vec{F}_1$; $\vec{F}_2$

Analysis: $\vec{F}_{net} = 0$. Choose up and right as positive. So, down and left are negative. Define right and left forces as being along the x-axis. So, up and down forces are along the y-axis.

Solution:
The net force on the x-axis is 0 N.

$$\left(F_{net}\right)_x = F_1 + 60 \text{ N} + (-86 \text{ N})$$
$$0 = F_1 - 26 \text{ N}$$
$$F_1 = +26 \text{ N}$$
$$\vec{F}_1 = 26 \text{ N [right]}$$

The net force on the y-axis is 0 N.

$$\left(F_{net}\right)_y = +54 \text{ N} + F_2$$
$$0 = +54 \text{ N} + F_2$$
$$F_2 = -54 \text{ N}$$
$$\vec{F}_2 = 54 \text{ N [down]}$$

Statement: $\vec{F}_1$ is 26 N [right] and $\vec{F}_2$ is 54 N [down].

14. Answers may vary. Sample answer:
(a) Use the edge of a thin ruler to apply a very quick horizontal force to the quarter at the bottom. In doing this, the stack of quarters above will remain pulled on by gravity and move straight down onto the top of the desk, still as a stack. This procedure will allow you to take the stack apart one quarter at a time.
(b) This works because of Newton's first law, which states that an object remains in its motion if there is no force acting on it. So the stack of quarters will not be affected by the force from the ruler, but they will continue to be affected by gravity.
15. Answers may vary. Students' pamphlets should show proper headrest use and use Newton's first law of motion to show how it prevents injury during a car crash. Pamphlets should include statistics with references and could include diagrams such as Figure 6 on page 125.