# Lesson Outline for Teaching

## Lesson 1: Gravity and Friction

**A.** Types of Forces

**1.** A push or a pull is called a(n) force.

**2.** A(n) contact force is a push or a pull on an object by another object that is touching it.

**3.** A force that one object can apply to another object without touching it is a(n) noncontact force.

**4.** Gravity, magnetism, and electric forces are examples of noncontact forces.

**5.** Forces have strength and direction.

**6.** An arrow can be used to show a force; the length shows the strength of the force, and the direction of the arrow shows the direction of the force.

**7.** Forces are measured in units called newtons.

**B.** What is gravity?

**1.** Mass is the amount of matter in an object.

**2.** Gravity is an attractive force that exists between all objects that have mass.

**3.** Mass is often measured in kilograms.

**4.** According to the law of universal gravitation, all objects are attracted to one another with a gravitational force that is proportional to the mass of the objects and the distance between them.

**a.** When the mass of one or both objects increases, the gravitational force between the objects increases.

**b.** When the distance between two objects increases, the attraction between the objects decreases.

**5.** Weight is the gravitational force exerted on an object.

**a.** Near Earth's surface, an object's weight is the gravitational force exerted on the object by Earth.

**b.** The weight of an object on Earth decreases significantly only when the object moves a great distance away from Earth.

**C.** Friction

**1.** Friction is a force that resists the motion of two surfaces that are touching.

**2.** Static friction prevents surfaces from sliding past each other.

**3.** Up to a limit, the strength of static friction changes to match the applied force.

## Lesson Outline continued

4. Sliding friction opposes the motion of surfaces sliding past each other.
   a. When an object is sliding, the force of sliding friction does not change; for this reason, increasing the applied force makes a sliding object move faster.
   b. If you stop pushing a sliding object, the object will eventually stop due to sliding friction.
5. Fluid friction is friction between a surface and a fluid, such as air or water.
   a. Fluid friction between an object and air is called air resistance.
   b. Decreasing an object's surface area by changing its shape decreases the object's air resistance.
6. One reason for friction between surfaces is the microscopic roughness, or the dips and bumps of one surface that catch on those of the other surface.
7. One reason for friction between surfaces is that atoms and molecules with opposite charges attract each other.
8. Lubricants decrease friction by causing a slight separation between solid surfaces, so they don't contact each other.

## Discussion Question

Describe different situations in which you have experienced gravity, static friction, and sliding friction.

Related to gravity, students might describe a variety of situations with things falling, what happens to thrown objects, and what happens to objects in space. Related to static friction, students might describe trying to slide heavy objects; they might describe why objects remain in place when they are pushed or pulled and why objects on wheels need a certain amount of force to start moving. Related to sliding friction, students might describe why sliding objects, such as skates, pucks, and game pieces, slow down over time and why objects on wheels slow down over time.

# Lesson Outline for Teaching

## Lesson 2: Newton's First Law

**A.** Identifying Forces

**1.** To understand the motion of an object, you need to understand the forces acting on it.

**2.** When two or more forces act on an object, the forces combine.

**a.** The combination of all the forces that act on an object is the net force.

**b.** When the forces applied to an object act in the same direction, the net force is the sum of the individual forces.

**c.** Because forces have direction as well as strength, when you combine forces, you also have to specify a(n) reference direction.

**d.** When you combine forces in two opposite directions, one force is positive and the other force is negative.

**e.** When the forces applied to an object act in exact opposite directions, the net force is the sum of the individual positive and negative forces.

**3.** Forces that combine and form a net force of zero are balanced forces.

**a.** Balanced forces have no effect on the motion of an object.

**b.** Forces that combine and form a net force that is not zero are unbalanced forces.

**B.** Newton's First Law of Motion

**1.** According to Newton's first law of motion, if the net force on an object is zero, the motion of the object does not change.

**2.** When balanced forces act on an object, the object's velocity does not change.

**3.** If unbalanced forces act on an object at rest, the object will start moving.

**4.** If unbalanced forces act on a moving object, the object will change its velocity.

**5.** The tendency of an object to resist a change in its motion is called inertia.

**C.** Why do objects stop moving?

**1.** A book sitting on a table stays in place because of inertia.

**2.** If you want to make the book move, you have to push the book hard enough to overcome the static friction between the book and the table.

**3.** On Earth, friction can be reduced, but it never goes away completely.

**4.** On Earth, to keep an object in motion, a(n) force that balances friction must be applied continuously to it.

## Discussion Question

What can you say about the net force with balanced forces? With unbalanced forces?

With balanced forces, the net force is always zero. With unbalanced forces, the net force is never zero.

# Lesson Outline for Teaching

## Lesson 3: Newton's Second Law

**A.** How do forces change motion?

**1.** Forces change an object's motion by changing its speed, its direction, or both.

**2.** Only unbalanced forces can change the velocity of an object.

**3.** You know unbalanced forces are acting on an object that is at rest when the object starts moving.

**4.** Unbalanced forces change the velocity of a moving object.

**a.** If a net force acts on a moving object in the direction that the object is moving, the object will speed up.

**b.** If a net force acts on a moving object in the direction that is opposite to the direction that the object moves, the object slows down.

**c.** Another way unbalanced forces can change the velocity of a moving object is to change the direction of the object's motion.

**5.** The force of gravity acts on a ball that is thrown by changing the direction of the ball, pulling it downward.

**6.** Another name for change in velocity over time is acceleration.

**7.** Unbalanced forces can make an object accelerate by changing the object's speed, direction, or both.

**B.** Newton's Second Law of Motion

**1.** According to Newton's second law of motion, the acceleration of an object is equal to the net force acting on the object divided by the object's mass.

**2.** The direction of acceleration is the same as the direction of the net force.

**3.** The units for Newton's second law are SI units—force is measured in newtons; mass is measured in kilograms; acceleration is measured in meters per second squared.

**4.** One newton is the same as one $kg \cdot m/s^2$.

**C.** Circular Motion

**1.** Circular motion is any motion in which an object is moving in a curved path.

**2.** Inertia causes objects to tend to move along a straight path.

**3.** In circular motion, a force that acts perpendicular to the direction of motion toward the center of the curve is called a(n) centripetal force.

**4.** An object that is moving in a circle accelerates in the direction of the centripetal force.

## Lesson Outline continued

5. Any object that circles a larger object is called a(n) satellite.
   a. Satellites move in a circle because a(n) centripetal force acts on them.
   b. Gravity is the centripetal force that acts on satellites by continuously changing their direction of motion; this results in circular motion.
6. Earth's gravitational pull keeps the Moon in orbit around Earth.
7. The planets remain in orbit because the Sun's gravity pulls on them.

## Discussion Question

Make up a story problem that uses Newton's second law of motion.

Problems should require solving for force, mass, or acceleration using the equation $a = \frac{F}{m}$.

Two of the three variables should be given or calculable from the story; units should be from the SI system (newtons, kilograms, and meters per second).

# Lesson Outline for Teaching

## Lesson 4: Newton's Third Law

**A.** Opposite Forces

**1.** When an object applies a force on another object, the second object applies a force of the same strength on the first object.

**2.** When an object exerts a force on another object, the second object exerts a force on the first object in the opposite direction.

**B.** Newton's Third Law of Motion

**1.** According to Newton's third law of motion, when one object applies a force on a second object, the second object applies an equal force in the opposite direction on the first object.

**2.** Any time a person pushes against a stationary object, the object exerts an equal and opposite force on the person.

**3.** A(n) force pair is the forces that two objects apply to each other.

**a.** The forces in a force pair are equal in strength and act in opposite directions. They do not cancel each other out because each acts on a different object.

**b.** For every action force, there is a reaction force that is equal in strength but opposite in direction of the action force.

**C.** Using Newton's Third Law of Motion

**1.** When you push against an object, the force you apply is called the action force.

**2.** Newton's third law establishes that the object you push on applies an equal and opposite reaction force against you.

**3.** According to Newton's second law of motion, when the reaction force results in an unbalanced force, there is a(n) net force, and the object accelerates.

**D.** Momentum

**1.** Momentum is a measure of how hard it is to stop a moving object.

**2.** Momentum is the product of an object's mass and its velocity.

**3.** According to Newton's second law of motion, the force on an object is equal to the mass of the object multiplied by the acceleration, or the change in the object's velocity.

**4.** Because momentum is the product of mass and velocity, the force on an object equals its change in momentum.

**E.** Conservation of Momentum

**1.** In any collision, one object transfers momentum to another object.

**2.** According to the law of conservation of momentum, the total momentum of a group of objects remains the same unless outside forces act on the objects.

## Lesson Outline continued

3. One outside force is friction, which decreases the velocities of billiard balls and most other moving objects, and they lose momentum.
4. In a(n) elastic collision, the colliding objects bounce off each other.
5. In a(n) inelastic collision, the colliding objects stick together.
6. In elastic and inelastic collisions, the total momentum of all the objects is always the same before and after any collision.

## Discussion Question

An in-line skater uses two hands to push against a wall in front of her. Explain why she rolls backward.

The skater exerts an action force on the wall; the wall exerts a reaction force of equal size but in the opposite direction on the skater. The reaction force is greater than the force of static friction on the skater, so the skater rolls backward, away from the wall.