Forces
Learning Goals for Students and Teachers

Student and Teacher Learning Goals	Additional Teacher Learning
1. A *force* is a push or a pull that cause a change in the speed or direction of an object's motion. (Lesson 1) a. All forces are *interactions* between two objects. (Lesson 1) b. In most cases, *direct* contact between two objects is required to exert a force that causes a change in the motion of one or more objects. One exception is gravity, which exerts a force without requiring two objects to touch. Gravity pulls an object toward the ground without any direct contact or interaction between the ground and the object. (Lesson 1)	1Ta. If two or more forces act on an object, the result is called a *net force*. Forces acting on an object in the same direction increase the net force. Forces acting on an object in opposite directions can result in a net force of zero. 1Tb. A net force in the direction of an object's motion increases the speed of the object. A net force in the *opposite* direction of an object's motion decreases the speed of the object. 1Tc. An object with a zero net force acting on it will maintain a constant speed and direction (in a straight line). 1Td. The *mass* of an object affects the rate at which its speed changes when a net force acts on it. For example, a net force would change the speed and direction of a soccer ball much more than it would change the speed and direction of a bowling ball because the mass of a bowling ball is greater than the mass of a soccer ball. 1Te. *Acceleration* is a change in the velocity of an object in a moment of time. 1Tf. An object accelerates when a net force is acting on it. The direction of the acceleration is the same as the direction of the net force. The acceleration of an object is proportional to the net force and inversely proportional to the mass of the object. This law is represented as follows: $a = F_{net}/m$ 1Tg. The law $a = F_{net}/m$ applies instantaneously to the individual object experiencing a force. If F changes (in direction of magnitude), so does *a*. 1Th. The strength of a force is measured in units called *Newtons* (N) or *pounds* (lbs).
2. Forces have both a strength and direction. (Lesson 2) a. Arrows are used to represent the strength and direction of a force. (Lesson 2) b. The direction of an arrow represents the direction of the force. (Lesson 2) c. The length of an arrow represents the strength of the force. (Lesson 2)	2Ta. The *weight* of an object is the force of gravity pulling it toward Earth's center. The unit of weight (force) represented as pounds can be converted to Newtons. 2Tb. The force of gravity (weight) is exerted in any interaction between two objects with mass, but the gravitational pull of Earth dominates this effect entirely. 2Tc. Gravity always exerts a pulling force on an object, never a pushing force. The gravitational pull on an object occurs invisibly across empty space, and no

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	contact or air is necessary between the object and Earth. (The action of gravity on an object takes place at a distance.) 2Td. No gravitational forces act on objects that are far from Earth (or any other planet, body, or star).
3. When two forces push or pull an object at the same time, the effect they cause is due to the sum of the forces. (Introduced in lesson 2 and reinforced in lessons 5 and 6) a. Forces that push or pull an object in the same direction are added together, and forces acting in opposite directions are subtracted from each other. (Lessons 2 and 5) b. When the total strength of all the forces acting in the same direction is larger than the total strength of all the forces acting in the opposite direction, a change in speed will occur because the forces are unequal. (Lesson 6) c. Even when an object is at rest, forces are acting on it equally in opposite directions. This results in a total force of zero, which means that the object will stay at rest. No change in motion will occur. (This is always the case on Earth.) (Lesson 5)	3Ta. If two or more forces act on an object, the net result is called the *net force.* 3Tb. Forces acting on an object in the same direction increase the net force. Forces acting on an object equally in opposite directions produce a net force of zero.
4. *Friction* is a force that acts in the opposite direction of an object's motion. (Lessons 3 and 4) a. Friction is created when tiny bumps on the surface of one object (such as the ground) push against tiny bumps on the surface of another object. b. The rougher the surface of an object (i.e., more bumps or larger bumps), the greater the forces acting in the opposite direction of the other object's motion.	4Ta. Friction occurs when the surfaces of two objects rub, roll, or slide across each other. *Static friction* occurs when a force is applied to an object, but the object doesn't move. *Fluid friction*, also known as *draft force*, occurs when the molecules of a fluid interact with each other or when a fluid interacts with other matter, such as air. 4Tb. *Air resistance* is a form of fluid friction created when an object in motion makes contact with air molecules. 4Tc. The greater the mass of an object in motion, the more friction will be generated to oppose or resist that motion.
5. Understanding the forces acting on an object allows you to predict and explain future motion. (Lesson 6)	