LEARNING SET 1 INTRODUCTION

Learning Set 1

What Makes Things Move?

◀ *6 class periods**

Students use spring scales and masses to explore how balanced and unbalanced forces affect the motion of an object. Using a model for the challenge, students determine how much force they will need to lift a mass (the crate) and how much force a thread (the rope) can bear.

Overview

Students are introduced to the question, *What makes things move?* They define force and investigate balanced and unbalanced forces to determine that unbalanced forces are required in order to change an object's speed and/or direction. Students define gravity and friction so they are able to apply these ideas when they build their machines in subsequent sections. Students add their learning and evidence to the *Project Board*. Finally, students explore a model of the force needed to lift the crate to the top of the cliff. Using a spring scale and thread, students measure the force needed to lift the crate and determine the amount of force a thread can handle before it breaks. In later sections, students will use this information to solve the challenge that they have been using.

*A class period is considered to be one 40 to 50 minute class.

Targeted Concepts, Skills, and Nature of Science	Section
Scientists often work together and then share their findings. Sharing findings makes new information available and helps scientists refine their ideas and build on others' ideas. When another person's or group's idea is used, credit needs to be given.	1.1, 1.3, BBQ
Criteria and constraints are important in design.	BBQ
Scientists must keep clear, accurate, and descriptive records of what they do so they can share their work with others and consider what they did, why they did it, and what they want to do next.	1.1, 1.3
Graphs and tables are an effective way to communicate results of scientific investigation.	1.3

Targeted Concepts, Skills, and Nature of Science	Section
Identifying factors that lead to variation is an important part of scientific investigation.	1.3
Scientific investigations and measurements are considered reliable if the results are repeatable by other scientists using the same procedures	Unit Intro, 1.3
Scientists make claims (conclusions) based on evidence obtained (trends in data) from reliable investigations.	1.3
Explanations are claims supported by evidence, accepted ideas, and facts.	1.3
Scientists use models to simulate processes that happen too fast, too slow, on a scale that cannot be observed directly (either too small or too large), or that are too dangerous.	BBQ
When the forces exerted on an object are unbalanced, the speed and/or direction of the object will change, otherwise there is no change in motion.	1.1, 1.2,1.3, 1.4, BBQ
Earth's gravity pulls things toward Earth.	1.2, 1.3, 1.4
Friction is a resistive contact force arising between two surfaces sliding over each other. Friction always opposes the relative motion or tendency toward motion.	1.4

Students' Initial Conceptions and Capabilities

- **Students often associate force as a property of the object rather than the interaction between objects. (Driver, 1994; Dykstra, et al., 1992; Jung et al., 1981; Osborne, 1985.) For example, after a skateboard is pushed by someone's hand, it begins to move. Many students may think that the push from the hand stays with the skateboard while it is moving.**
- **Students often think that any object moving at a constant speed must have force acting on it in the direction of its motion. (Driver, 1994; Gunstone & Watts, 1985.) For example, students may believe that when you push a cart across the floor with a constant speed, there is an overall force in the direction of the cart. Because the speed and direction of the cart are not changing, there is no unbalanced force on the cart. The forces acting on the cart add up to zero.**

Students' Initial Conceptions and Capabilities

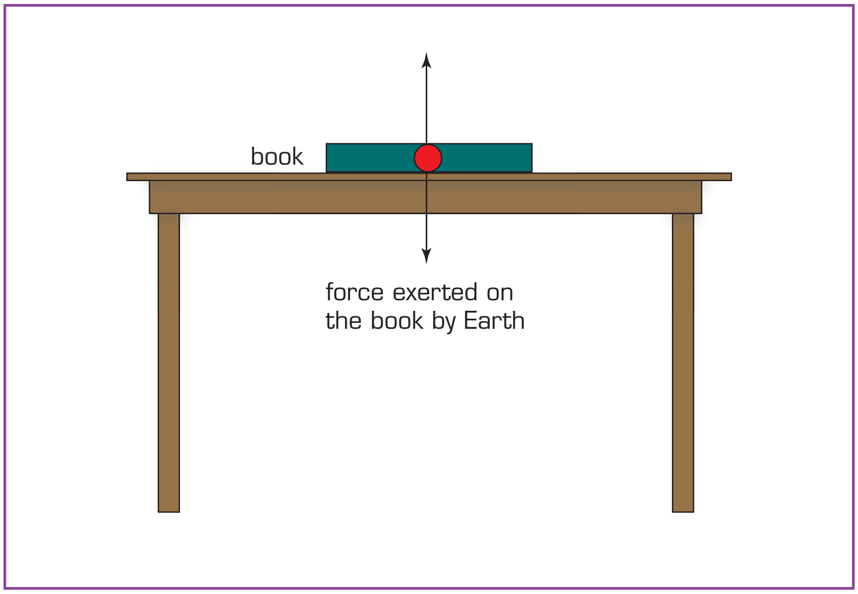
- Students may confuse inertia and friction, thinking that all objects resist moving from a state of rest because of friction. (Driver, 1994; Jung et al., 1981; Brown & Clement, 1992.) This is something not clarified in the student text because it is beyond the scope of this Unit's content. However, students may ask about why a small force applied to an object on a table does not get the object moving. This is due to a frictional force known as static friction that opposes the tendency of motion.
- Students may think of friction as a directionless force and some don't recognize that friction is a force. (Driver, 1994; Brown & Clement, 1989.)
- Some students think of forces only as getting things to move from rest. (Driver, 1994; Gunstone & Watts, 1985, Minstrell, 1989.)

Understanding for Teachers

Forces and Force Diagrams

Many students have misconceptions of forces. It is impossible for us not to try to make sense of the world around us, but sometimes how we make sense leads us to incorrect ideas because of limited observations. In *Moving Big Things,* the focus is on simple machines rather than forces. Forces are introduced, but it is not expected for students to truly understand Newton's Laws or have a deep understanding of forces. This is the focus of another Unit. The main goal of this Unit is for students to understand that we use machines all the time and that they are able to increase or decrease and/or redirect the pushes and pulls we apply to the machine. Nonetheless, it is important for you to have an understanding of forces for deeper questions the students may ask, and to address students' misconceptions that you can identify.

A force is a push or a pull and arises because of an interaction between two objects. Forces never occur for a single object. There must be an interaction between two objects for a force to exist. When we consider forces and how they affect the motion or state of equilibrium of an object, it is useful to draw the forces only acting on that object. For example, if we were to build a book support and did not want the book to fall, then we would want the book to be at rest on the book support and not change its motion. If we were to draw a force diagram of this, we would draw all the forces acting on the book, because the book is the object we are interested in.



If an object is at rest, or if the object is moving with constant velocity (no change in speed or direction), then that object has no acting net force. This is known as Newton's First Law, also called the Law of Inertia. Inertia is the resistance to changing motion. Most students will apply this for an object at rest, but many do not understand that it applies also to a moving object with constant velocity. For the book support example above, the forces are balanced so the overall force acting on the book is zero, resulting in no change of its motion. Many students will have difficulty understanding that if the object is moving, but not changing its motion, then there is no overall force acting on the object. This is addressed in a different Unit. It is a difficult concept for students to grasp because of our everyday life experiences with the ever present force of friction. If this issue arises in this Unit, try to explain that a moving object's motion does not change unless an overall force acts on it, such as friction. Have students consider an object such as a toy car moving over a table and have the students think about what happens when friction is reduced, eventually going to zero (as in outer space). This will help students construct the idea that objects really do continue their motion, undisturbed unless an overall force acts on the object.

If an object changes its motion by either changing its direction or its speed, a net force is acting on the object. This is Newton's Second Law which further tells us how the object is changing its speed or direction by relating the force with the object's acceleration.

Force is a push or a pull and only exists between pairs of objects that are interacting. There is no force if there is no interaction. If you push on the wall, the wall pushes back on you. If a book rests on the table, its surface is interacting with the surface of the table. This force is commonly known as the normal force and is a type of compression force. This can be summed up by Newton's Third Law: For every action there is an equal and opposite reaction. Or, in more scientific terms: Forces result when objects interact, and they always arise in pairs. Whenever object A exerts a force on object B, then object B simultaneously exerts an equal but opposite force on object A. For the example of the book support, there is a force exerted on Earth by the book, and a normal force (a type of compression force) exerted by the book on the book support.

Friction

Friction is ever present and is a force that resists the intended change in motion. There are different types of friction, but all arise from interactions between surfaces of objects in contact with each other. In our everyday experiences, objects slow down because of the force of friction and/or drag acting on them. Based on these observations, students usually conclude that a force is needed to keep something in motion. This is not the case. A good way to increase student understanding is to have them observe the motion of an object for a fixed push with decreasing friction between the surfaces. Students then have less difficulty imagining what it would be like for a frictionless surface.

Static friction is the force of friction acting on an object that is not in motion relative to the surface it is touching. When there is a big bucket of bricks and you try to push it with one finger across the table, static friction opposes your push. The force of static friction is dependent on how smooth the surfaces in contact are and the compression force between the two objects (how strongly the objects are pushed together). It is a force that opposes pushes or pulls acting on the object until finally it is overcome and the object begins to move. Once the object begins moving another force of friction acts on it, known as kinetic friction.

Kinetic friction also arises from how smooth the surfaces are and the compression force between the objects. Kinetic friction occurs when the surfaces of the objects are moving relative to each other. The maximum strength of kinetic friction is usually less than the maximum strength of static friction. This is often the reason why it is harder to get something in motion than keep it in motion.

Rolling friction is another type of friction that is more complex. Rolling friction is what actually pushes a car forward, although sometimes describing a car moving forward is approximated with static friction since the tire of the car does not move relative to the road's surface. Kinetic friction would be applied if the wheels of the car locked and the car was skidding across the road.

It is important to note that friction is still not well understood and is currently being researched by scientists. Often friction is described as being caused by two bumpy surfaces moving over each other. Certainly if we looked at a table top under a microscope it would look bumpy. Even smooth ice is bumpy on the microscopic level. As our technology increases and we are able to observe the microscopic world better, we are beginning to question more how friction works on the atomic scale.