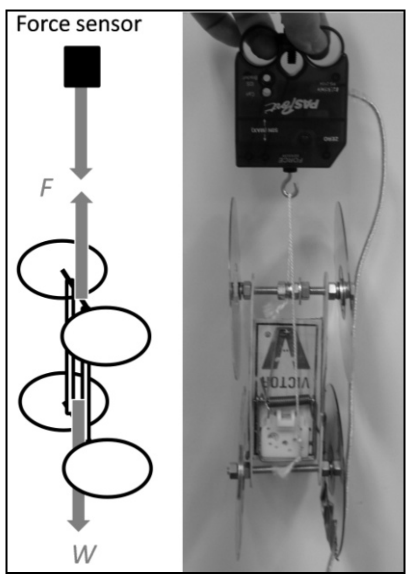
Drexel-SDP GK-12 LESSON

Lesson: Forces, Forces Everywhere

Subject Area(s) Measurement, Number & Operations, Physical Science, Science & Technology

Associated Unit Forget the Chedda!

Lesson Title Forces, Forces Everywhere



Weight is caused by gravitational acceleration.

Grade Level 7 (6-12)

Lesson # 3 of 5

Lesson Dependency
Construct A Car, Quantify It, Convert It

Time Required 20 minutes

Summary
This is an introductory lesson on forces that intends to introduce and explain Newton's laws. The laws of motion theorized by Newton, specifically the dependency between motion, force, and acceleration, can be directly examined using a mousetrap-powered car. These concepts are reinforced with the associated activity, Dragged Racers, in order to analyze frictional force on the mousetrap cars.

Engineering Connection
Forces and the motion they create are fundamental concepts in the fields of Civil, Materials, and Mechanical Engineering. Civil and architectural engineers account for forces when designing roadways and buildings, since the structures must support the weight of the building materials, the loads they are intended to support, and environmental forces (vibrations and wind drag). Materials Engineers develop new materials for specific purposes. When used in structural applications, the materials need to be mechanically tested, such as tensile (stretch) or compression tests. In these mechanical tests, forces are monitored as the sample materials are deformed. When optimizing the design of a mechanical system, Mechanical Engineers must account for forces that are acting on that system. Automobile and Aerospace Engineers (a subset of Mechanical Engineers) are continuously challenged to design efficient vehicles that would minimize drag and friction while maximizing torque.

Keywords
Measure, car, distance, position, force, gravity, friction, normal force, coefficient of friction

Educational Standards
- PA Science:
  - 3.1.7 – Unifying themes
- PA Math:
  - 2.1.8.D – Apply ratio and proportion to mathematical problem situations involving distance, rate, time, and similar triangles
  - 2.3.5.D – Convert linear measurements within the same system
  - 2.3.8.A – Develop formulas and procedures for determining measurements
  - 2.4.5.B – Use models, number facts, properties, and relationships to check and verify predictions and explain reasoning

Pre-Requisite Knowledge
Students must have been introduced to units.

Learning Objectives
After this lesson, students should be able to:
- Identify conditions in which an object will move (unbalanced forces)
- Describe what quantities constitute a force
- Compute forces arising from gravity and friction

- Compare the effects of different forces on an object

Introduction / Motivation

Today we're going to discuss and experiment with forces. For better or worse, we deal with forces every day. Forces are associated with motion – they allow us to move and stop moving. Isaac Newton studied forces and motion in the 17th century and developed what we know as Newton's Laws of Motion. There are three laws: the first law states that a motionless object will remain motionless unless an unbalanced force acts upon it. This is what you'd expect by observation, right? If you put your mousetrap car on the floor, it remains where it is. But if you give it a push, it will move.

Newton's second law relates forces to an object's motion. If we give that mousetrap car a push when it is on the floor, it starts to move and its velocity changes. This change in velocity is known as acceleration. According to the 2nd law, not only are forces responsible for acceleration of objects, but acceleration can also be responsible for forces. Take the concept of *weight*, for example. If you go to the moon, will you have the same weight that you have on Earth? (No). The reason for that is *gravity*. Gravitational accelerations act on your body's *mass* and cause weight (show how this relates to the $F=m*a$ formula).

[Optional details] The Universal Theory of Gravitation can be used to find a planet's gravitational field – there is a universal constant of gravitation that can be used along with a planet's mass and radius to find the value of gravity. You might not have known it but the Universal Theory of Gravitation has been used in a "Yo' Momma" joke: "Yo momma … she has her own gravitational pull." In our case, Earth's gravity takes a value close to 9.8 m/s^2.

Forces can be described by the direction in which the acceleration acts – gravity acts downward (toward the ground), so we describe the direction of our weight as downward. The reason we're not moving right now due to the gravity is because the floor is supporting us. The force that the floor supports us with is known as *Normal Force*. This principle corresponds to Newton's third law: for every action (force), there is an equal and opposite reaction.

We use Normal Force that occurs between an object and its supporting surface to find the friction on an object. Friction is a force that occurs between two surfaces. Friction has its benefits – we need friction to keep our feet on the ground so we can walk, but friction and its cousin *drag* (force of moving gas or liquid against solid surface) act against our best intentions of energy-efficient car design. There are two kinds of friction: static and kinetic. Each are proportional to the normal force, but by different amounts. We call this constant of proportionality the "coefficient of friction" and represent it by the greek lowercase letter mu: μ.

Who has slipped and fallen on a patch of ice? (Show of hands). Then you've experienced both static and kinetic friction. When you were walking and had traction, your foot was not moving on the ice, so you were experiencing *static friction*. However, if you used too much force when pushing off the ice, your foot moved relative to the ice and slipped: you experienced *kinetic friction*.

Vocabulary / Definitions

Word	Definition
Static	Condition where forces are balanced on an object and it does not move
Dynamic	Condition where unbalanced forces on an object cause it to move
Mass	Property attributed to the density and volume of an object
Gravity	Acceleration imposed by the earth's mass, 9.98 m/s^2 or 32.2 ft/s^2

Velocity	Speed *and* direction of an object
Acceleration	The *rate of change* of velocity
Displacement	Distance by which an object moves
Friction	Force that occurs between two surfaces in contact
Mechanics	Study of how objects or materials deform or move in response to applied forces.
Weight	Also known as 'body force,' the inherent force an object has due to its mass responding to a gravitational field. The reason we *weigh* less on the moon is not because our mass changes; the moon's gravitational field is not as strong as the Earth's.
Normal Force	Amount of force exerted by a surface on an object. Flat surfaces exert a *Normal Force* equal to the *Weight* of an object.
Drag	The force exerted by a fluid (gas or liquid) on a solid object. We experience *drag* on our bodies when the wind blows against us.

Lesson Background & Concepts for Teachers

There are three fundamental laws governing the relation between forces and motion of objects, namely

1. An object at rest or in motion at constant speed remains at rest or at that speed until a net force acts on it
2. An object acted upon by a net force will accelerate in the direction of this force
3. Forces act in equal and opposite pairs

These principles are the foundation for the study of mechanics, or the forces associated with the motion of objects. There are two distinct cases of mechanics that stem from the net forces acting on an object: static equilibrium, the case in which forces are balanced and there is no motion of an object; and dynamics, the study of motion of objects that results from unbalanced forces.

Force and acceleration are related proportionally by the equation F=m*a, where F is the force, m is mass, and a is acceleration. This equation implies that applying an unbalanced net force F will result in an acceleration, a. Likewise, acceleration will result in motion (dynamic) or an applied force (static) on an object.

Example:

Say you have a mousetrap car on the floor. It is not moving (at rest), so any forces acting on it are balanced. The car is acted upon by a gravitational acceleration, but the floor provides a force (acting on the mousetrap car's wheels) that is equal and opposite to the force generated by the gravitational acceleration, so the car doesn't move. This is an example of static equilibrium.

However, if you push the car from the side and it moves, the motion can be described by a positive acceleration immediately after being pushed, followed by a negative acceleration (deceleration) due to frictional forces, which make it slow down to a stop. The motion of the car after being pushed is an example of dynamic motion.

Gravity is an acceleration that effects all objects on Earth and is the cause of the force we call weight. In engineering terms, weight is known as *body force*. In the example with the car, the body force of the car is balanced by an equal and opposite force exerted by the floor. The force the floor exerts on the car's wheels is called *normal force*. The term "normal force" is used because it applies to the amount of force that is *perpendicular* to the surface on which the object is supported.

Friction is a force we encounter every day – it is the force generated by two surfaces in contact. We're talking about friction when we consider the traction of your shoes or tires on the ground. There are two types of friction: static and kinetic. Static friction applies to objects at rest, such as a car parked on a hill. Kinetic friction applies to objects in motion, such as a car skidding on the road. Frictional force always acts parallel to the surface on which the object is supported and is a factor of the normal force. This factor is the *coefficient of friction*, represented symbolically by the lowercase Greek letter mu. Subscripts indicate which frictional coefficient is used: μ_s represents the coefficient of static friction and μ_k denotes the coefficient of kinetic friction.

Friction is explored in "Dragged Racers," where students will examine frictional forces by gauging the force needed to pull a car on the floor. By the end of "Dragged Racers," students should have compared the forces needed to start and maintain the motion of the mug and calculated frictional coefficients for each surface pairing. Each group will use their calculated values to optimize the design of their mousetrap vehicle.

Associated Activities
Dragged Racers

Lesson Closure
Segue into associated activity based on DataStudio workbook: Dragged Racers.

Assessment
Check end result in "Dragged Racers" activity: has the friction force been calculated?

Additional Multimedia Support
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Owner
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