Newton's Second Law

*f*lexboo**k**
next generation textbooks

CHAPTER **1**   # Newton's Second Law

Lesson Objectives

- State Newton's second law of motion.
- Identify the relationship between acceleration and weight.

Lesson Vocabulary

- Newton's second law of motion

Introduction

A car's gas pedal, like the one in **Figure** 1.1, is sometimes called the accelerator. That's because it controls the acceleration of the car. Pressing down on the gas pedal gives the car more gas and causes the car to speed up. Letting up on the gas pedal gives the car less gas and causes the car to slow down. Whenever an object speeds up, slows down, or changes direction, it accelerates. Acceleration is a measure of the change in velocity of a moving object. Acceleration occurs whenever an object is acted upon by an unbalanced force.

FIGURE 1.1

The car pedal on the right controls the amount of gas the engine gets. How does this affect the car's acceleration?

Acceleration, Force, and Mass

Newton determined that two factors affect the acceleration of an object: the net force acting on the object and the object's mass. The relationships between these two factors and motion make up **Newton's second law of motion**. This law states that the acceleration of an object equals the net force acting on the object divided by the object's mass. This can be represented by the equation:

$$\text{Acceleration} = \frac{\text{Net force}}{\text{Mass}}, \text{ or}$$

$$a = \frac{F}{m}$$

You can watch a video about how Newton's second law of motion applies to football at this URL: http://science36 0.gov/obj/video/58e62534-e38d-430b-bfb1-c505e628a2d4 .

Direct and Inverse Relationships

Newton's second law shows that there is a direct relationship between force and acceleration. The greater the force that is applied to an object of a given mass, the more the object will accelerate. For example, doubling the force on the object doubles its acceleration. The relationship between mass and acceleration, on the other hand, is an inverse relationship. The greater the mass of an object, the less it will accelerate when a given force is applied. For example, doubling the mass of an object results in only half as much acceleration for the same amount of force.

Consider the example of a batter, like the boy in **Figure** 1.2. The harder he hits the ball, the greater will be its acceleration. It will travel faster and farther if he hits it with more force. What if the batter hits a baseball and a softball with the same amount of force? The softball will accelerate less than the baseball because the softball has greater mass. As a result, it won't travel as fast or as far as the baseball.

FIGURE 1.2

Hitting a baseball with greater force gives it greater acceleration. Hitting a softball with the same amount of force results in less acceleration. Can you explain why?

Calculating Acceleration

The equation for acceleration given above can be used to calculate the acceleration of an object that is acted on by an unbalanced force. For example, assume you are pushing a large wooden trunk, like the one shown in **Figure** 1.3. The trunk has a mass of 10 kilograms, and you are pushing it with a force of 20 newtons. To calculate the acceleration of the trunk, substitute these values in the equation for acceleration:

$$a = \frac{F}{m} = \frac{20 \text{ N}}{10 \text{ kg}} = \frac{2 \text{ N}}{\text{kg}}$$

Recall that one newton (1 N) is the force needed to cause a 1-kilogram mass to accelerate at 1 m/s^2. Therefore, force can also be expressed in the unit kg·m/s^2. This way of expressing force can be substituted for newtons in the solution to the problem:

$$a = \frac{2 \text{ N}}{\text{kg}} = \frac{2 \text{ kg} \cdot \text{m/s}^2}{\text{kg}} = 2 \text{ m/s}^2$$

Why are there no kilograms in the final answer to this problem? The kilogram units in the numerator and denominator of the fraction cancel out. As a result, the answer is expressed in the correct units for acceleration: m/s^2.
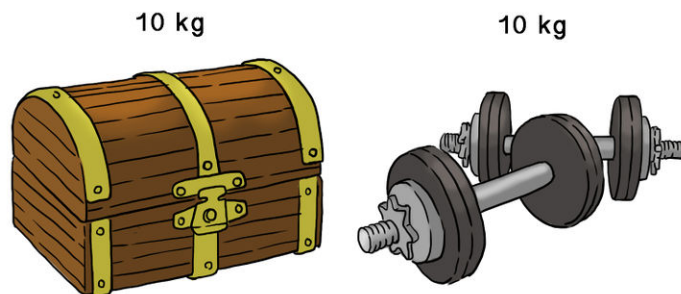

10 kg   **10 kg**

FIGURE 1.3

This empty trunk has a mass of 10 kilograms. The weights also have a mass of 10 kilograms. If the weights are placed in the trunk, what will be its mass? How will this affect its acceleration?

You Try It!

Problem: Assume that you add the weights to the trunk in **Figure** 1.3. If you push the trunk and weights with a force of 20 N, what will be the trunk's acceleration?

Need more practice? You can find additional problems at this URL: http://www.auburnschools.org/ajhs/lmcrowe/Week%2014/WorksheetPracticeProblemsforNewtons2law.pdf .

Acceleration and Weight

Newton's second law of motion explains the weight of objects. Weight is a measure of the force of gravity pulling on an object of a given mass. It's the force (F) in the acceleration equation that was introduced above:

$$a = \frac{F}{m}$$

This equation can also be written as:

$$F = m \times a$$

The acceleration due to gravity of an object equals 9.8 m/s^2, so if you know the mass of an object, you can calculate its weight as:

$$F = m \times 9.8 \text{ m/s}^2$$

As this equation shows, weight is directly related to mass. As an object's mass increases, so does its weight. For example, if mass doubles, weight doubles as well. You can learn more about weight and acceleration at this URL: http://www.nasa.gov/mov/192448main_018_force_equals_mass_time.mov .

Problem Solving

Problem: Daisy has a mass of 35 kilograms. How much does she weigh?

Solution: Use the formula: $F = m \times 9.8 \text{ m/s}^2$.

$F = 35 \text{ kg} \times 9.8 \text{ m/s}^2 = 343.0 \text{ kg} \cdot \text{m/s}^2 = 343.0 \text{ N}$

You Try It!

Problem: Daisy's dad has a mass is 70 kg, which is twice Daisy's mass. Predict how much Daisy's dad weighs. Then calculate his weight to see if your prediction is correct.

Helpful Hints

The equation for calculating weight ($F = m \times a$) works only when the correct units of measurement are used.

- Mass must be in kilograms (kg).
- Acceleration must be in m/s^2.
- Weight (F) is expressed in kg·m/s^2 or in newtons (N).

Lesson Summary

- Newton's second law of motion states that the acceleration of an object equals the net force acting on the object divided by the object's mass.
- Weight is a measure of the force of gravity pulling on an object of a given mass. It equals the mass of the object (in kilograms) times the acceleration due to gravity (9.8 m/s^2).

Lesson Review Questions

Recall

1. State Newton's second law of motion.
2. Describe how the net force acting on an object is related to its acceleration.
3. If the mass of an object increases, how is its acceleration affected, assuming the net force acting on the object remains the same?
4. What is weight?

Apply Concepts

5. Tori applies a force of 20 newtons to move a bookcase with a mass of 40 kg. What is the acceleration of the bookcase?

6. Ollie has a mass of 45 kilograms. What is his weight in newtons?

Think Critically

7. If you know your weight in newtons, how could you calculate your mass in kilograms? What formula would you use?

Points to Consider

Assume that a 5-kilogram skateboard and a 50-kilogram go-cart start rolling down a hill. Both are moving at the same speed. You and a friend want to stop before they plunge into a pond at the bottom of the hill.

- Which will be harder to stop: the skateboard or the go-cart?
- Can you explain why?

References

1. Ray Sawhill. http://www.flickr.com/photos/raysawhill/8306059830/ . CC BY 2.0
2. Flickr:Ron B. http://www.flickr.com/photos/clamcake/4528602078/ .
3. Laura Guerin. CK-12 Foundation . CC BY-NC 3.0