2.1 Forces in Nature

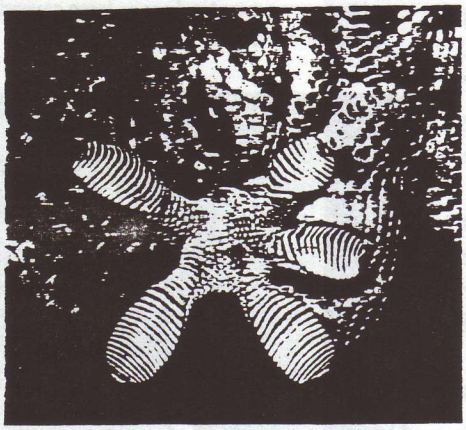

Figure 1
Scientists study examples of force in nature, such as this gecko's ability to cling to surfaces, in the hope of finding yet unknown applications.

Forces are everywhere. If there were no forces in our universe, our Earth would not be trapped in its orbit around the Sun; the uses of electricity would never have been discovered; we would not be able to operate automobiles or even walk — in fact, we would not exist, because objects need forces to keep their shape. Figure 1 shows the underside of the foot of an animal called a gecko. Geckos have the ability to climb up a glass wall and hang from one toe. Each gecko foot has about half a million setae, or hairs, each split into hundreds of ends. These setae exert a force of adhesion on materials such as glass, but they let go if they are tipped at an angle of 30° or more from the surface. Researchers estimate that this small creature could lift 40 kg of mass if all the setae operated together.

In simple terms, a **force** is a push or a pull. Forces act on almost anything. They speed things up, slow them down, push them around corners and up hills. Forces can also distort matter by compressing, stretching, or twisting.

Force is a vector quantity. Like other vector quantities, its direction can be stated in various ways, such as forward, up, down, east, northeast, and so on.

force: a push or a pull

fundamental forces: forces are classified into four categories—gravitational, electromagnetic, strong nuclear, and weak nuclear

VERY INTERESTING

Practice

Understanding Concepts

1. State an everyday life example in which a force causes an object to (a) decrease its speed; (b) become compressed; (c) become stretched.
2. You are facing eastward, standing in front of a gate that can swing. In what direction is your force if you pull on the gate? push on the gate?

Applying Inquiry Skills

3. Assume you are given an empty matchbox, a magnet, a metal paperclip, an elastic, and a balloon. Make a list of ways you could make the matchbox move with or without touching the matchbox with the given materials. (*Hint:* You may place items in the box.)

DID YOU KNOW?

Combining Fundamental Forces

Researchers have discovered that two of the fundamental forces, the electromagnetic force and the weak nuclear force, have a common origin. The combined force is called the *electroweak* force. Its effects can be verified in experiments performed using high-energy collisions in particle accelerators. As these accelerators become stronger, researchers are hoping to observe evidence of even more unification of forces, to verify the Grand Unified Theory (GUT) and, eventually, the Theory of Everything (TOE). This will help scientists understand more about what occurred shortly after the "big bang" start of the universe. At first, an unimaginably huge force existed and particles were indistinguishable (TOE: all four forces were unified). Then, the force of gravity separated from the other three forces (GUT). Much later, as the universe expanded and cooled, the forces all separated, leaving matter as we know it.

The Four Fundamental Forces

There may seem to be many different types of forces around us, but physicists have found that they are able to understand how objects interact with one another by classifying forces into only four categories. The four **fundamental forces** of nature are the gravitational force, the electromagnetic force, the strong nuclear force, and the weak nuclear force. A comparison of these forces is shown in Table 1.

* * *

Table 1 Comparing the Fundamental Forces

Force	Relative strength (approx.)	Range	Effect
gravitational	1	∞	attraction only
electromagnetic	10^{36}	∞	attraction and repulsion
weak nuclear	10^{25}	less than 10^{-18} m	attraction and repulsion
strong nuclear	10^{38}	less than 10^{-15} m	attraction and repulsion

* copy this chart in your notes. Answer questions 1, 2.

The **gravitational force**, or the **force of gravity**, is the force of attraction between all objects in the universe. It is important for large objects such as stars, planets, and moons. It holds them together and controls their motions in the same way that it controls the motion of falling objects here on Earth. You can see in Table 1 that the gravitational force is tiny compared to the other fundamental forces. However, it has an important role in the universe because it exerts attraction only. The gravitational force is an example of an "action-at-a-distance" force, in other words, a force that acts even if the objects involved are not touching. The force of gravity between two objects is noticed only if at least one of the objects has a large mass.

gravitational force or **force of gravity**: force of attraction between all objects

The **electromagnetic force** is the force caused by electric charges. It includes both electric forces (such as static electricity) and magnetic forces (such as the force that affects a magnetic compass). The electromagnetic force can exert either an attraction or a repulsion (Figure 2), so on average, the forces tend to cancel each other out. If this were not the case, then electromagnetic forces would completely overwhelm the force of gravity. It is the electromagnetic force that holds atoms and molecules together, making diamonds hard and cotton weak. It tenses muscles and explodes sticks of dynamite. In fact, most common forces that we experience are electromagnetic in origin. Sometimes it is convenient to treat electric and magnetic forces separately, even though they are both caused by electric charges.

electromagnetic force: force caused by electric charges

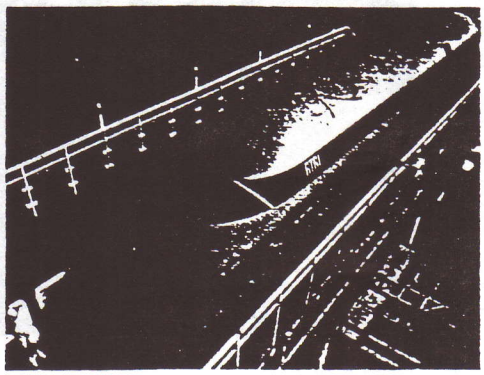

Figure 2
The magnetic force of repulsion keeps this magnetic levitation train separated from the track. With a maximum speed of 450 km/h, the train runs smoothly and quietly.

There are strong and weak nuclear forces acting between the particles within the nucleus of an atom. The nucleus contains positively charged particles and neutral particles called protons and neutrons, respectively. The **strong nuclear force** holds the protons and neutrons together, even though the protons are influenced by the electric force of repulsion. This nuclear force is a short-range force but is much stronger than the electromagnetic force. It is significant only when the particles are close together.

strong nuclear force: force that holds protons and neutrons together in the nucleus of an atom

Besides the proton and the neutron, there are many more "elementary" particles. The electron is but one of the others. Many of these particles, including the neutron, are unstable and break up. The **weak nuclear force** is responsible for the interactions involved. This type of force is noticed only at extremely small distances.

weak nuclear force: force responsible for interactions involving elementary particles such as protons and neutrons

Practice

Understanding Concepts

4. List the fundamental forces in order from the strongest to the weakest.
5. In what way is gravitational force unique among the fundamental forces?
6. Which of the fundamental forces do you notice most often in your everyday activities? Give some examples to illustrate your answer.

Forces We Experience Daily

We experience several types of forces daily. The most obvious one is the force of gravity between Earth and objects at or near it its surface. The direction of this force is toward Earth's centre, a direction referred to as vertically downward (Figure 3).

DO QUESTIONS

4, 5, 6

* HIGHLIGHT IMPORTANT PARTS.

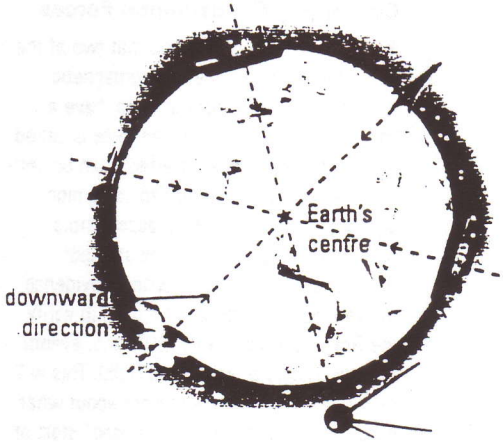

Figure 3
The force of gravity between Earth and objects at or near its surface is directed in a line to Earth's centre. This direction defines what we mean by vertical at any location on Earth.