5.2 WHAT IS A FORCE?

5.2.1 Forces and Newton's Third Law of Motion

Two bodies interact and influence each other's motion through a force between them. Intuitively, a force is a push or a pull a body exerts on another body. When you push on a wall, you are aware of the fact that you are applying a force on the wall. What is not obvious is that in generating the force, you have helped create a force by wall also.

Fundamentally, every force requires two participating objects. When the force acts on one of the bodies, it has one direction, and when it acts on the other body, it has the opposite direction, as codified in the statement of the third law in Philosophiae naturalis principia mathematica, also known as Principia by Sir Isaac Newton published in 1686.

"To every action there is always opposed an equal reaction; or the mutual actions of two bodies upon each other are always equal, and directed to the contrary parts."

In Principia Newton further elaborated the meaning of the **third law**, "Whatever draws or presses another is as much drawn or pressed by that other. If you press a stone with your finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse (if I may so say) will be equally drawn back towards the stone: for the distended rope, by the same endeavor to relax or unbend itself, will draw the horse as much towards the stone, as it does the stone towards the horse, and will obstruct the progress of the one as much as it advances that of the other."

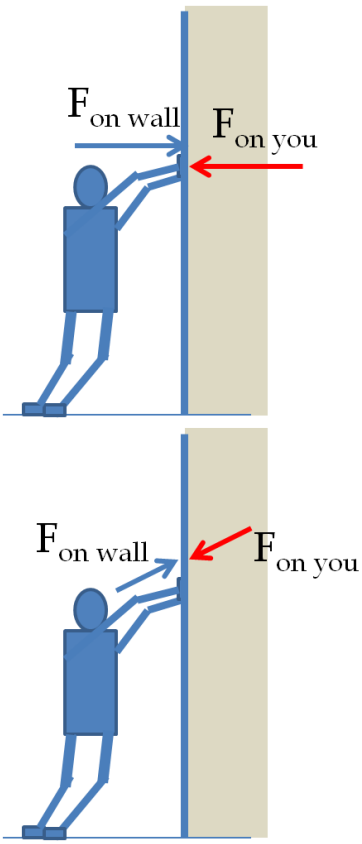

Figure 5.3: Forces pairs. You push on the wall, the wall pushes you back!

Example 5.2.1. A plough pulled by horses. In Fig. 5.4, two horses pull on a plough and a man is also pushing on the plough. Focusing on the forces between the horses and the plough, we note that there is a force between the horses and the plough since the they are linked by a belt under tension. When this force acts on the horses, we call the force $\vec{F}_{\text{on horses}}$, and when it acts on the plough, we call the force $\vec{F}_{\text{on plough}}$. Note the language here: the force is between the horses and the plough, but we do not have a force vector until we ask the question - on which object the force is acting? The same force generates two different forces, one on each object of the link.

Since, the two forces, $\vec{F}_{\text{on horses}}$ and $\vec{F}_{\text{on plough}}$, are not acting on the same object, they are not used simultaneously in any one problem concerning either the motion of the horse or that of the plough. When

Figure 5.4: Forces act between two objects connected by a visible or an invisible link. The pictures here show the force between the horses and the plough that act through the linking belt which is under tension. The force between the horses and the plough can act on the horses or the plough. When the force acts on the horses, it generates $\vec{F}_{\text{on horses}}$, and when it acts on the plough, it generates $\vec{F}_{\text{on plough}}$. The force $\vec{F}_{\text{on horses}}$ influences the motion of horses only and does not affect the motion of plough, and the force $\vec{F}_{\text{on plough}}$ influences the motion of the plough and not that of the horses.

we study the motion of the horses, the force of use is the force on the horses and not the force on the plough, although it is there. On the other hand, when we study the motion of the plough, the force on the plough is used.

Example 5.2.2. The forces between train cars. The cars of a train are pulled by forces between cars that act along the links between the cars as illustrated in Fig. 5.5. A shown in the figure, there is a force between car A and car B that acts through the link between them, and there is force between car B and car C that acts through the link between B and C. These two forces create two forces on car B as shown in the figure. Can you find how the force between A and B acts on A? Can you find how the force between B and C acts on C?

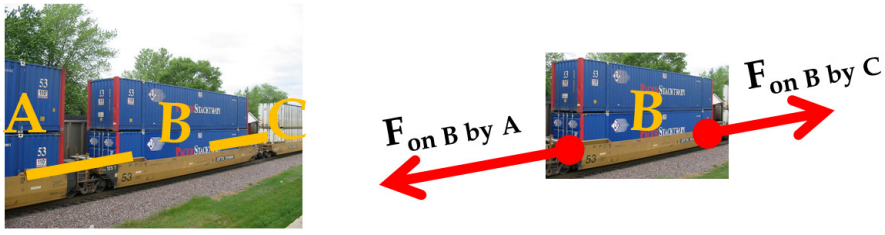

Figure 5.5: The forces between cars A, B and C of a train take place due to bolts and hooks linking A and B, and those linking B and C. The force between A and B and that between B and C acting on B generate two forces on B shown in the figure. The motion of B is governed by the combined effect of these two forces on B.

Example 5.2.3. Forces between Earth and Moon. The previous two examples show forces that act through a visible link between

objects - the belt in the horses/plough and the bolts/hooks between the cars. Fig. 5.6 shows a different type of force - the force between the Earth and the Moon that appear to act without a visible link between them. Such forces are also called action-at-a-distance forces.

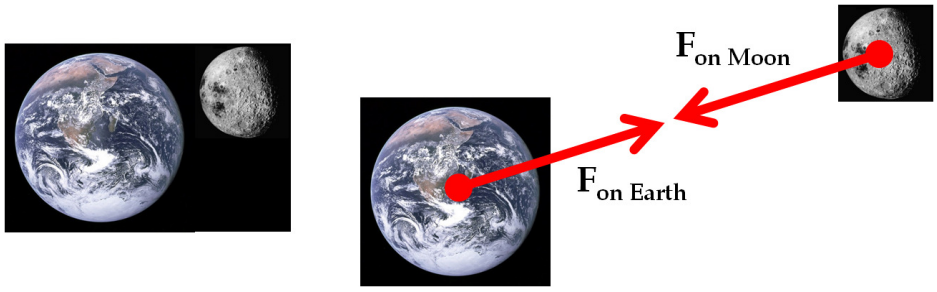

Figure 5.6: The gravitational force between the Earth and the Moon act through an invisible gravitational link between them, called the gravitational field. The gravitational force between Earth and Moon can act on the Earth or the Moon, generating a force on Earth and one on Moon. To study the motion of the Moon, you need the force on Moon and not the force on Earth.

The action-at-a-distance force between the Earth and the Moon is called gravitational force and the invisible force field linking the two objects is called the gravitational field. The force of gravitation acts between all objects in nature. The force between the Earth and the Moon can act on either the Earth or the Moon: when it acts on the Earth, it pointed towards the Moon, and when it acts on the Moon, it is pointed towards Earth. The force on Moon affects the motion of the Moon and the force on Earth affects the motion of the Earth.

Example 5.2.4. Electric force between electric charges. Figure 5.7 shows another action-at-distance force, the electric force between a positively charged object, such a proton, and a negatively charged object, such as an electron. The invisible force field linking the two objects is called the electric field. The electric force between the charges generates a force on the positive charge and one on the negative charge. To study the motion of the negative charge you need the force on the negative charge and not the one on the positive charge. Similarly for the motion of the positive charge, you will need only the force on the positive charge.

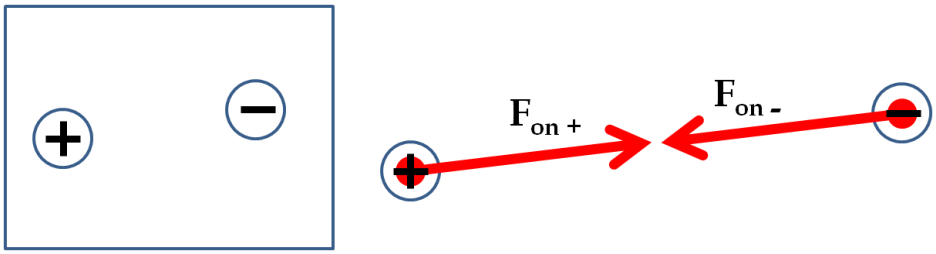

Figure 5.7: The electric forces between charges act through an invisible link between the charges, called the electric field. The electric force between a positive charge and a negative charge is shown. The electric force between the charges generates a force on the positive charge and one on the negative charge. To study the motion of the negative charge you need the force on the negative charge and not the one on the positive charge. Similarly for the motion of the positive charge, you will need only the force on the positive charge.