DU 9. FORCES IN ACTION

DU 9 FORCES IN ACTION

1. WHAT IS A FORCE?

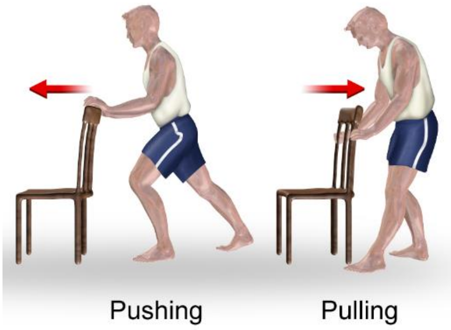


Figure 9.1

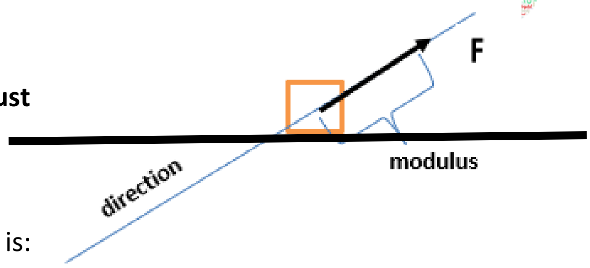
"FORCES ARE INVOLVED WHENEVER OBJECTS INTERACT"

- **A force is just a push or pull that one object exerts on another object. Examples:**
  - an object's weight
  - friction
  - tension in a rope
  - attraction between an electron and proton
- Bodies do not have to be in contact to exert forces on each other, e.g., gravity.
- The SI unit of force is the Newton (N).

THE EFFECT OF A FORCE: Force is an action or agency that causes a body of mass m a **<u>deformation</u>, a <u>rotation</u>, an <u>acceleration</u>, or an increase in pressure on the body.**

- They are **<u>vector quantities</u>,** so they are drawn as vector arrows.

- FORCES are caused by the **<u>interaction</u>** of two objects.
- **A free-body diagram shows all the forces acting on just one object.**



Forces are represented by arrows. The information they provide is:

- The size of the arrow is proportional to the **module**, so that the greater the force, the longer the arrow.
- The **orientation** with which the force is applied is the straight line which contains the arrow, and the **direction** is indicated by its pointer.

2. <u>FUNDAMENTAL FORCES OF NATURE</u>

One of the most basic and important tasks in physics is to classify the forces of nature. There are different types of forces such as friction, magnetism, gravitational forces, and so on. All forces in the Universe can be classified in 4 types, the fundamental Forces of Nature

- **GRAVITATIONAL:** All objects with mass attract each other with a gravitational force. WEIGHT= m x g
- **ELECTROMAGNETIC FORCE:** They use attraction and repulsion between positive and negative charges → Atomic structure.

NUCLEAR FORCES:

- **WEAK NUCLEAR FORCE:** These are the forces involved in the radioactive activity of atoms.
- **STRONG NUCLEAR FORCE**: Positive protons in the nucleus are held together by the strong nuclear force.

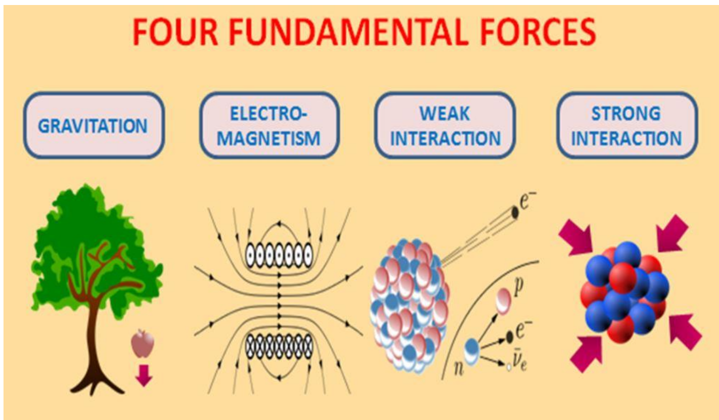


Figure 9.2

3. STRETCHING A SPRING. HOOKE´S LAW

- **Elasticity** is the property of an object or material which causes it to be restored to its original shape after distortion.

- **A spring** is an example of an elastic object- when stretched, it exerts a restoring force which tends to bring it back to its original length.

- **Hooke's Law:** the restoring force is generally proportional to the amount of stretch.

- **Measuring forces: Spring balance**

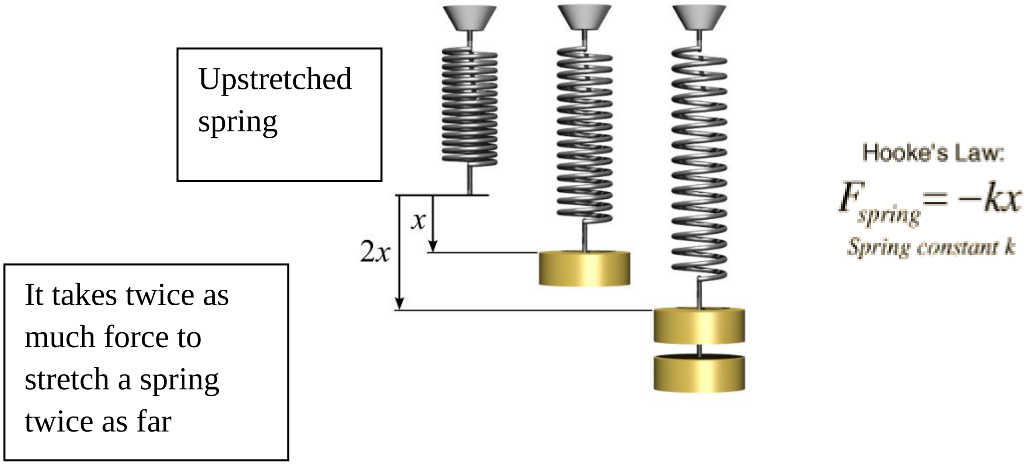


Figure 9.3

The negative sign indicates that the spring force is a restoring force

Hookes´s Law

The extension or compresion (deformation) of an elastic body is directly proportional to the force applied to it.

Hooke's Law:

$$F_{spring} = -kx$$

Spring constant k

There is a negative sign on the right-hand side of the equation because the restoring force always acts in the opposite direction to the displacement (for example, when a spring is stretched to the left, it pulls back to the right).

When Hooke's Law holds, the behaviour is linear; if shown on a graph, the line depicting force as a function of displacement should show a direct variation.

FORCE-EXTENSION GRAPH

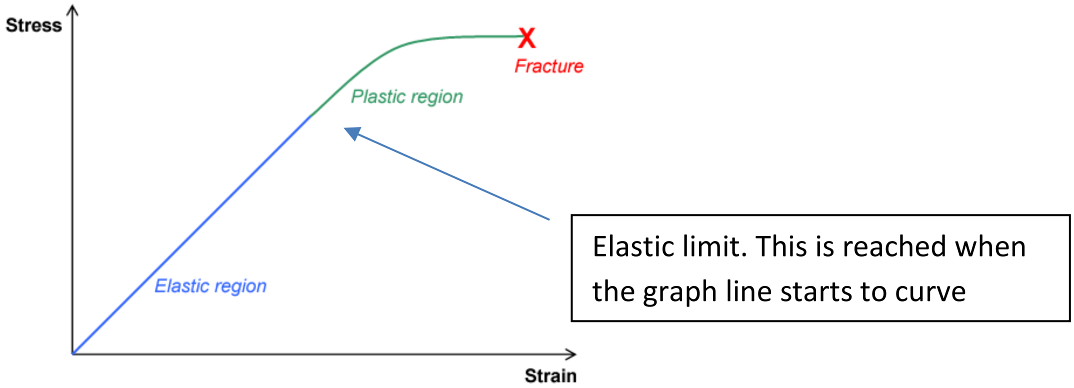


Figure 9.4

- **Hooke's Law states: -**
  - the extension is proportional to the force
  - the spring will go back to its original length when the force is removed so long as we do not exceed the **elastic limit**.

- The **elastic limit** is where the graph departs from a straight line. If we go past it, the spring will not go back to its original length. When we remove the force, we are left with a permanent extension.
- **Below the elastic limit**, we say that the spring is showing "elastic behaviour": the extension is proportional to the force, and it will go back to its original length when we remove the force.
- **Beyond the elastic limit**, we say that it shows "plastic behaviour". This means that when a force is applied to deform the shape, it stays deformed when the force is removed.
- We use Hooke's Law in **spring balances**, **kitchen scales** and other devices where we measure using a spring.
- Small forces can be measured on a **spring balance** or force meter in units called **Newtons (N).**

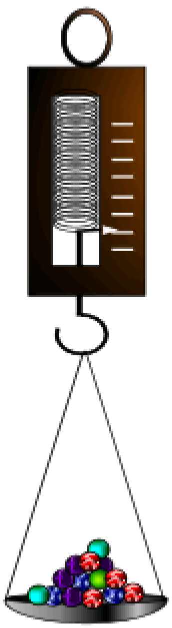


Figure 9.5

4. ADDITION OF FORCES

A variety of mathematical operations can be performed with and upon vectors.

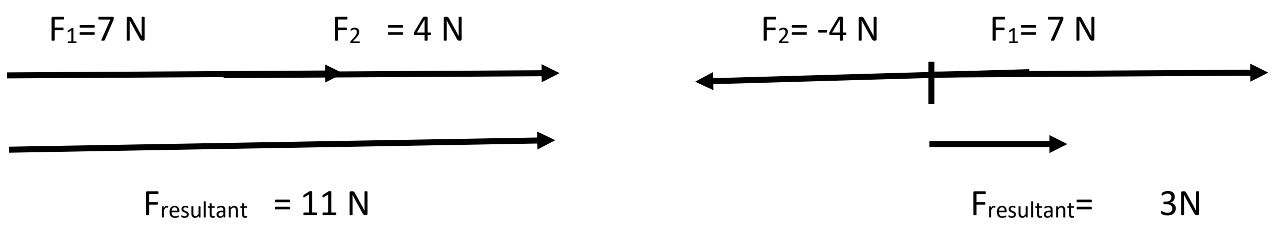
One such operation is the **addition of vectors**. Two vectors can be added together to determine the result (or **resultant)**.

The **net force** experienced by an object was determined by computing the vector sum of all the individual forces acting upon that object. That is the net force was the result (or resultant) of adding up all the force vectors. During that unit, the rules for summing vectors (such as force vectors) were kept relatively simple. Observe the following summations of two force vectors:

ADDITION OF FORCES IN 1 DIMENSION

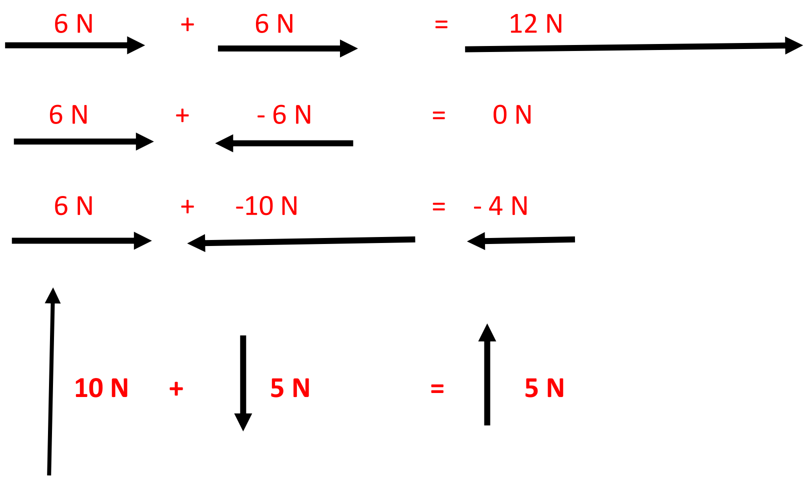
The magnitude of the resultant force is the algebraic sum of the forces

- Adding forces in the same direction and along the same line
- Adding forces in the opposite directions and along the same line.



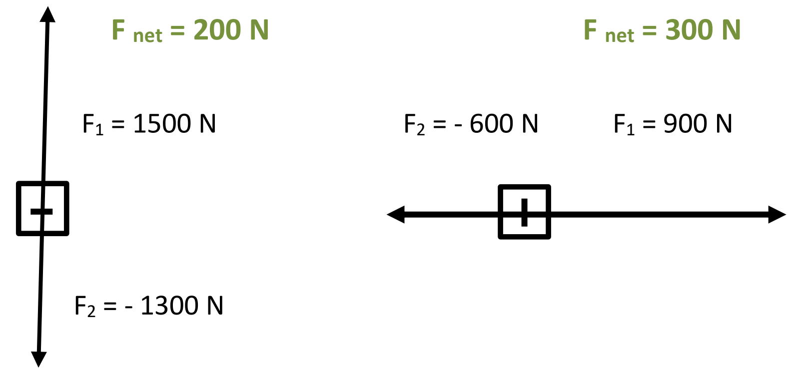
direction is the same as the forces

direction is the same as the larger force



These rules for summing up vectors are applied to free-body diagrams in order to determine the net force (i.e., the vector sum of all the individual forces). Sample applications are shown in the diagram below.

The **resultant** is the vector sum of two or more vectors. It is the result of adding two or more vectors together.



5. FORCES AND MOVEMENT

Motion happens when an object changes position.

The word ***force*** is much more difficult to understand because it has meanings in English (and Galician) that are different from its meanings in science. In the movie, Star Wars, the phrase "may the force be with you" is used often. This Star Wars phrase represents just one of the many definitions for the word force in English; however, scientists think about forces in a different way.

A **force** (in science) is often defined as a push or pull on an object that can produce motion.

Another way to think about a force is as an interaction between two objects involving a push or a pull.

These definitions indicate that in order to have a force, two objects must be present—one object being pushed and another object doing the pushing.

The unit of force is a **Newton**, named after Sir Isaac Newton, who spent much of his life dedicated to analysing force and motion.

A Newton (N) is the force that causes a body with a mass of 1 kg to accelerate by one metre per second squared (1m/s²).

Force is an action or agency that causes a body of mass m:

- **a deformation**
- **a rotation**
- **an acceleration,** or
- **an increase in pressure on the body.**

Figure 9.6
Sir Isaac Newton

When we apply a <u>force</u> on a non-malleable or rigid solid, it gains <u>acceleration</u>.

- **Acceleration is directly proportional to the net force acting on an object. (Second Newton´s Law of Motion)**
- The **equation** that expresses this is: $\mathbf{F = m \times a}$

  F = net force

  m= mass of the object

  a = acceleration of the object

- If **no force** is applied to an object at rest, it will continue to be **at rest**.
- If **no force** is applied to an object in movement, it will continue moving at the same velocity, with **uniform linear motion** (no acceleration).
- If a **net force** is applied to a stationary body, the body will **accelerate**.
- If a **force** acts on a body in motion, or if the sum of the forces acting on it is not zero, it will change its motion, it will experience **acceleration**.

INERTIA: It is **the reluctance to change the velocity**. It is a property of matter by which it continues in its existing state of rest or uniform motion in a straight line unless that state is changed by an external force.

- Inertia depends on its mass: a bigger mass needs a bigger force to overcome its inertia and change its motion.
- If you are driving at 65 km/h and have an accident, the car may come to a sudden stop, but your body is still travelling at 65 km/h. Without a seatbelt, your inertia would throw you through the windscreen.

MISCONCEPTIONS

- If an object is moving, there must be some force making it move. **Wrong! It could be moving without accelerating.**
- If v = 0, then F_{net} must be zero. **Wrong! Think of a projectile shot straight upwards and at its peak.**
- An object must move in the direction of the net force. **Wrong! It must accelerate that way but not necessarily move that way.**
- **Heavy objects must fall faster than light ones. Wrong! The rate is the same in a vacuum.**
- If an object accelerates, its speed must change. **Wrong! It could be turning at constant speed.**

FORCES AND KINEMATICS

To solve motion problems involving forces:

1. *Find net force (by combining vectors).*
2. *Calculate acceleration (using 2nd law).*
3. *Use kinematics equations:*

$$v = v_0 + at$$

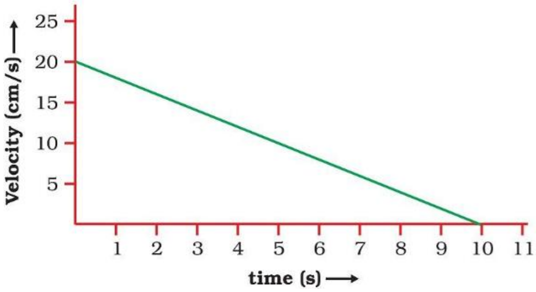
$$x = x_0 + v_0 \cdot t + \tfrac{1}{2} \cdot a \cdot t^2$$

Examples.

A car is moving at 6 m/s. Let's assume that the wheels of a 5-kg car apply 10 N of net force. What is the acceleration if friction and drag are negligible?

DATA	EQUATION	
net force=10 N	$F = m \times a$	**10 N= 5 kg × a**
mass= 5 kg		$a = \frac{10\ N}{5\ kg} = \mathbf{2\ m/s^2}$
acceleration?		$\boxed{a = 2\ m/s^2}$

This is the velocity-time graph of a 1500 kg car moving along a straight line. What is the net force acting on the car?



DATA

mass= 1500 kg

net force=?

acceleration?

EQUATION

F = m × a

from the graph, we note that

at time= 0 s	at time= 10 s
initial velocity = 20 cm/s	final velocity= 0 m/s

a = $\frac{\boldsymbol{final\ velocity - initial\ velocity}}{\boldsymbol{time\ taken}}$

a= $\frac{0 cm/s - 20\ cm/s}{10\ s - 0\ s}$ = -2 cm/s^2

a= -0,02 m/s^2 (SIU)

F = m × a

F = 1500 kg × **(-0,02) m/s^2** =

$\boxed{\textbf{F= 30 N}}$

6. FORCES AROUND US

There are lots of examples of forces all round us. However, there are 2 forces, weight and friction, which are always present in our daily lives.

✓ WEIGHT

Figure 9.7

Weight $W = m \cdot g$

- Weight is the force of gravity on a body.
- We call a body´s weight the force with which the Earth attracts the body.
- **Weight = mass × acceleration due to gravity.** $\boldsymbol{W = m \cdot g}$
- This follows directly from F = *m a*.
- Near the surface of the Earth $g = 9.8\ m/s^2$.
- The acceleration due to gravity on the Moon is much lower than that on the Earth's surface ($a = 1{,}6\ m/s^2$), so, body weight on the Moon is less than that on the Earth´s surface.

✓ FRICTION

Friction is the force bodies can impart on each other when they come into contact.

The friction forces are parallel to the contact surface and occur when…

- One body slides over another, or…
- They cling together despite an external force.

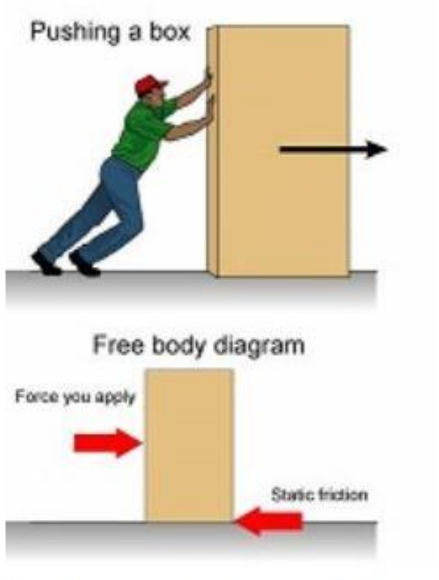


Figure 9.8

It is a force that opposes the surfaces sliding. Friction is a force that resists the motion of one object against another. **Friction opposes the movement of objects.**

Friction plays an important part in many everyday processes. For instance, when two objects rub together, friction causes some of **the energy of motion to be converted into heat.** This is why rubbing two sticks together will eventually produce a fire.

Friction can be a useful force because it **prevents our shoes slipping on the pavement when we walk and stops car tyres skidding on the road**. When you walk, friction is caused between the tread on your shoes and the ground. This friction acts to grip the ground and prevent sliding.

- Friction is not so useful everywhere. In some cases, friction is not required to execute the action. If you want to save energy and increase an engine's efficiency, friction is not useful.

  When a spacecraft returns to the Earth, **it is highly affected by atmospheric friction.** It requires much force, and energy is lost in the form of heat. **The spacecraft must be fitted with a heat shield to bear this heat.**

7. FORCES AND EQUILIBRIUM

Not only are we surrounded by objects in movement, but also by objects that do not move: the table on the floor, the lamp hanging from the ceiling or the book on the table.

We say the objects are in equilibrium because they are stationary.

The Earth´s force of attraction (weight) is acting on all the objects, but, if they continue at rest, it means that the resultant force acting on each other must be 0. There must be some other forces acting on each object.

A body is in equilibrium when the sum of the resultant forces acting on it is zero.

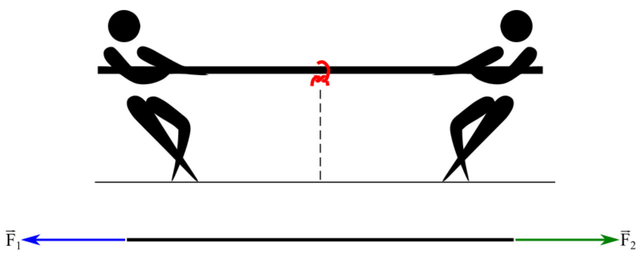


Figure 9.9

If 2 children pull on the rope with exactly the same force at each end, the sum of all the forces is zero. We can say that the rope and the handkerchief will not move. We say that **it is in equilibrium.**