Unit 2. Motion and forces

1. Does the car move?

Look at the picture below, where you can see several cars and a motorcycle stopped at a traffic light in red. If you are inside one of them, how do you know if your car starts moving or if it is still stopped?

2. Changing the state of movement of a body

Now you are going to propose situations with objects whose motion you want to change: making a quiet mobile move, stopping one that is moving, making it go faster or slower or in other direction… What do you have to do in all cases to get it?

3. The deforming effect of forces (INVESTIGATION-LABORATORY)

You are going to stretch and compress some objects that are easily deformed by the action of a force. Besides producing changes on the motion of the bodies, forces can also produce deformation of the objects (strings, rubbers, balloons, plasticine…). Observe if the deforming effect causes different consequences in the strings and the plasticine.

4. Space flights

In the picture, you can see the takeoff of a spacecraft from Canaveral cape. Do you know what are the two main forces acting on it when it is taking off?

5. Throwing a ping-pong ball (INVESTIGATION-LABORATORY)

Being still without advancing or retreating, throw a ping-pong ball vertically upwards.

a) Explain what you see, and what your colleagues see as external observers. Draw the respective trajectories (the line that joins all the positions occupied by the ball during the motion). Keep in mind what you see and what you have observed in the train simulation.

b) Describe the difference between trajectory and space travelled.

c) Repeat the same process but walking at the same time that you throw the ball. Do your colleagues and you see the same now?

6. What the speedometer shows

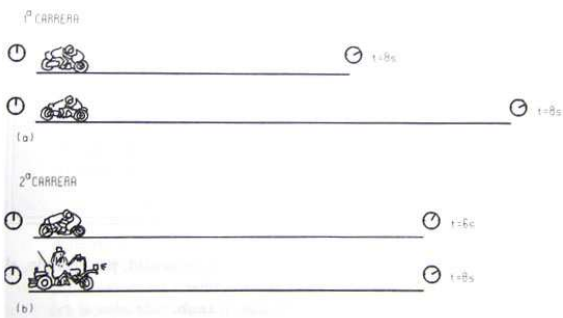
You drive a car at a speed of 100 kilometres per hour (the speedometer shows 100 km/h). What does this value mean?

7. Calculating the speed of a car

You travel in a car that moves at a constant speed on a national road. When you go through the kilometric point 130 you start the stopwatch and you go through the point 135 just 3 minutes later. What does the speedometer show?

8. Motorcycle races

In the picture, you can see the starting and ending points of two motorcycles and the times they have taken to move from one point to the other in two different races. Justify which motorcycle has moved faster in each case if they have moved at a constant speed.



9. Overtaken by a motorcycle

If when you are travelling in a car at a speed of 100 km/h a motorcycle driving at 120 km/h overtakes you, at which speed does it go away from you? At what distance is it from you half an hour later if the speeds don´t change?

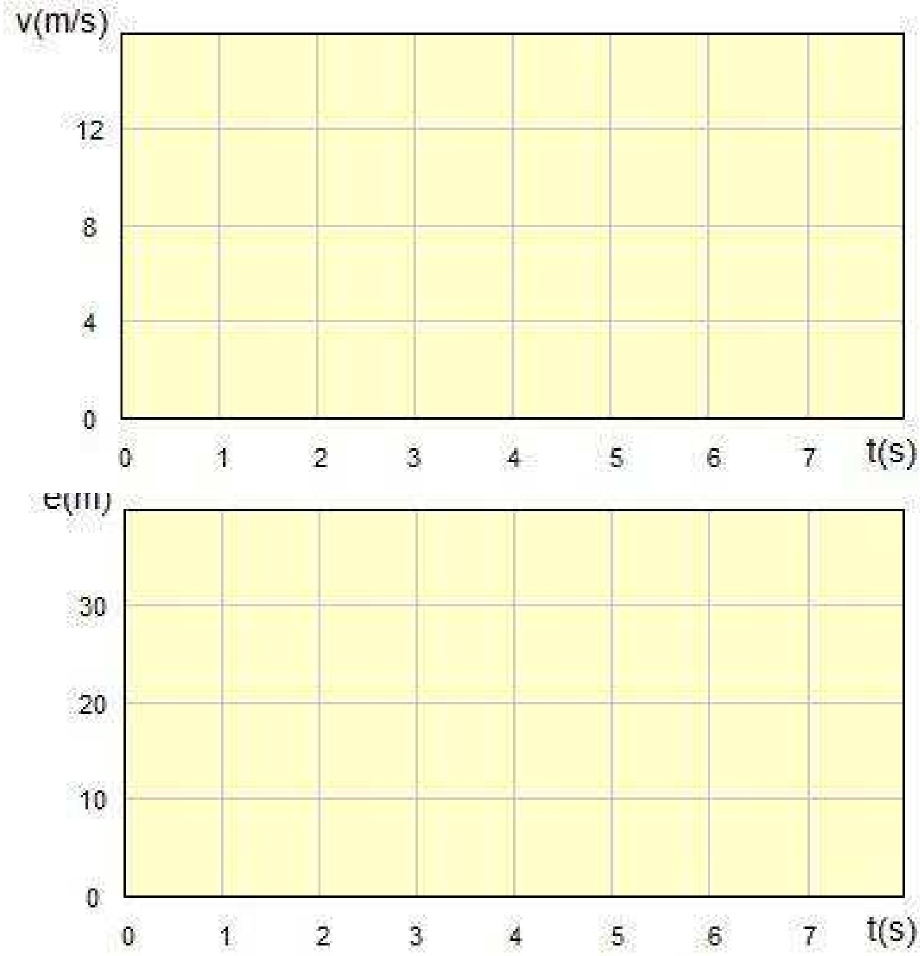
10. What is its speed?

Look at the picture. Driving on a road at 108 km/h, there is a car in front of you moving also at a constant speed. When it is 150 meters before your car, you start measuring the time it takes you to overtake it, which is one minute. Calculate the approximate speed of the car you have just overtaken.

11. Graphics of movement (INVESTIGATION-LABORATORY)

You are going to work with two simulators of the simplest case of rectilinear motion (the trajectory is a straight line) and uniform (the speed is constant). In both of them, you can choose the speed of the motorcycle, and in the first one, you will see the graphic that represents the speed depending on the time, while in the second there is a representation of the space travelled by this motorcycle depending on the time.

Simulate the motion at speeds of 2,5 and 10 m/s. Choose these speed values and press the starting button of the simulation. Observe how the motorcycle moves and the shape of the graphic. You can stop at any time during the movement. If you look at the values of position and time, how can you relate them?



12. From Jaca to Zaragoza

Is the speed of a car constant during a long trip? From Jaca to Zaragoza there is a distance of 150 km/h. If a car takes one hour and a half to travel this distance, what is its average speed? Does the result mean that it always goes at the same speed?

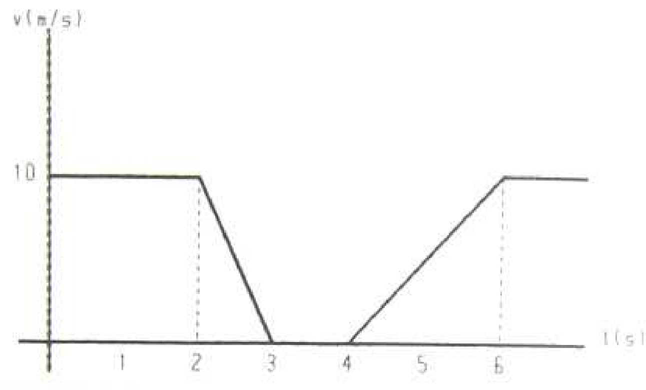
13. The speed of a swimmer

The male world record of 50 meters freestyle is 20,01 s. In the table, you have the times taken by an amateur swimmer to complete this distance. Is the speed of the swimmer constant? Order the intervals depending on the speed. Calculate the average speed during the race and the average speed required to beat the world record.

Posición (m)	Tiempo (s)
0	0,00
10	10,43
20	22,12
30	33,72
40	42,14
50	53,45

14. Graphic of the speed during a motion

Observe the next graph. Describe the motion in the next intervals of time: 0 to 2 s, 2 to 3 s, 3 to 4 s, 4 to 6 s and from 6 s. In which intervals is the speed constant? In which of them varies? Does it increase or decrease?



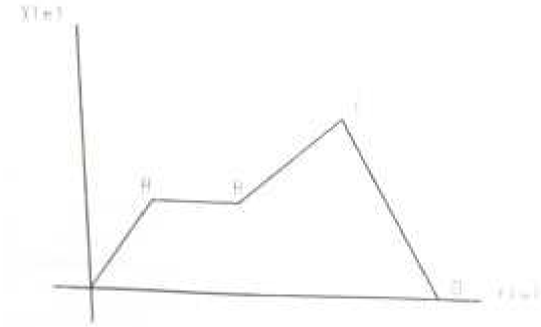
15. Comparing cars

Adverts to sell cars always tell us the time needed to go from 0 to 100 km/h. Look at the next data and order the cars depending on their ability of acceleration. Notice that a Formula 1 car goes from 0 to 100 km/h in less than 3 seconds!

Car A: 9 s
Car B: 11 s
Car C: 10 s
Car D: 8 s

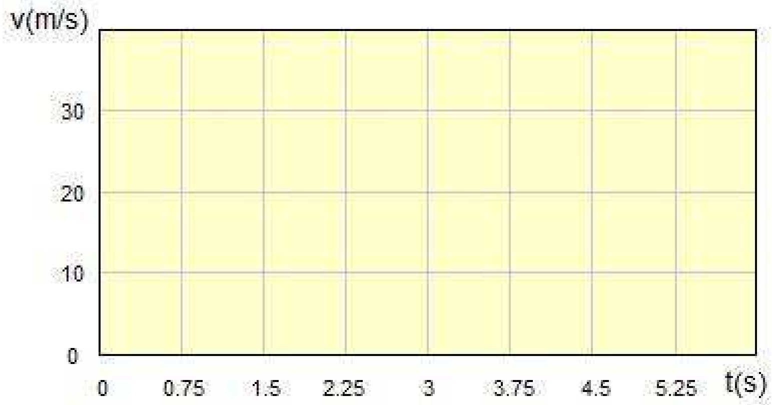
16. Position-time graph

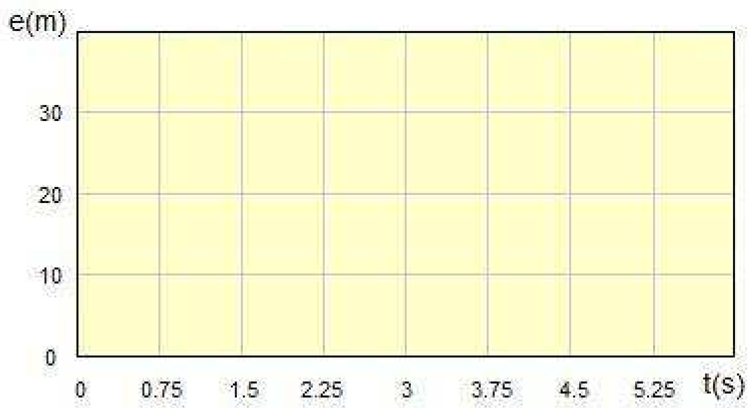
In the picture, it is represented the position occupied by a mobile depending on the time. Describe the motion between 0 and A, between A and B, between B and C and between C and D.



17. Motions with acceleration (INVESTIGATION-LABORATORY)

Observe the next simulators, where the motorcycle starts from rest with the acceleration that you set. Do the experience with accelerations from 1 to 5 IS units. How does the speed vary in each case? And the space travelled? What does it happen to the graph of the speed when you increase the acceleration?



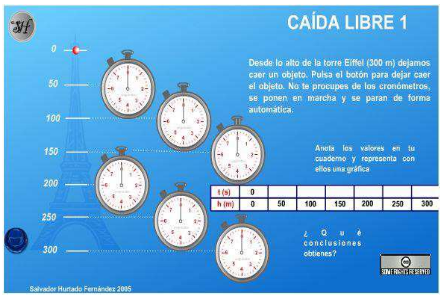


18. Throwing a ping-pong ball (INVESTIGATION-LABORATORY)

A kind of motion that you already know is vertical motion free fall and vertical shoot. Throw a ping pong ball vertically and describe the movement until it comes back to your hand (constant speed? Acceleration?)

19. The Eiffel Tower (INVESTIGATION-LABORATORY)

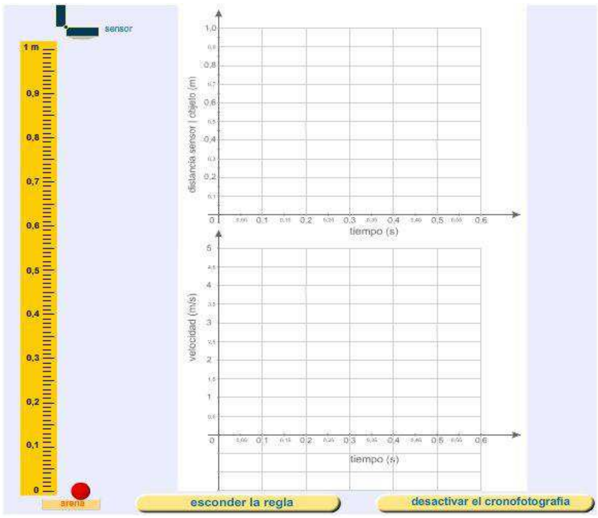
Now you are going to use a freefall simulator: start it and write down the results in a table, making the graphic representation. Does the ball fall at a constant speed? Calculate the average speed in each 50 meters interval. What are your conclusions?



20. Chronophotography (INVESTIGATION-LABORATORY)

With this other freefall simulator, you will be able to measure the time of freefall from one meter to the floor and even from lower heights. You just have to take the ball to the height that you want (the centre of the ball) and release it. In the graphs, you will see the evolution of the distance travelled and the speed of the ball. Do the experiment with heights of 0,25 m, 0,50 m, 0,75 m y 1,0 m and answer the next questions:

a) It takes twice the time to travel twice the distance.
b) The speed increases regularly.
c) When it has travelled twice the distance, the speed is double too.



21. Impact speed

When a body freefalls from a height of 20 meters, it takes 2,0 s to impact against the floor. Calculate its speed at that moment measured in km/h, considering that g has a value of 10 m/s^2

22. What are rpm?

Look at the specifications of a drill and a shaker. What do the rpm data mean (revolutions per minute)?

a) Drill at 400 or 1500 rpm (1st and 2nd speed).

b) Shaker at 1800 rpm at high speed.

23. The Earth rotates

As you know, the Earth turns around itself. What is its rotating speed? Would its value in rpm be higher or lower?

24. The ferris wheel

Observe the ferris wheel that rotates. Using a stopwatch, determine its period and frequency of rotation.

25. The "soga-tira" game

Is a traditional Aragonese game, although it is one of the most universal ones, as its origins come back to the year 2500 a.C in Egypt, and it is played in a lot of countries. In Spain, it belongs to the traditional games or sports of several provinces.

In this game, two teams fight to be able to move the other time a determined distance pulling the same rope (as you can see in the picture). Try to find another way to describe it using the word "force".

26. No battery

In the picture, you can see a group of people pushing a car that has run out of battery. Do you think the number of people pushing is important to move the car? Use in your answer the word "force".

27. Riding a bike

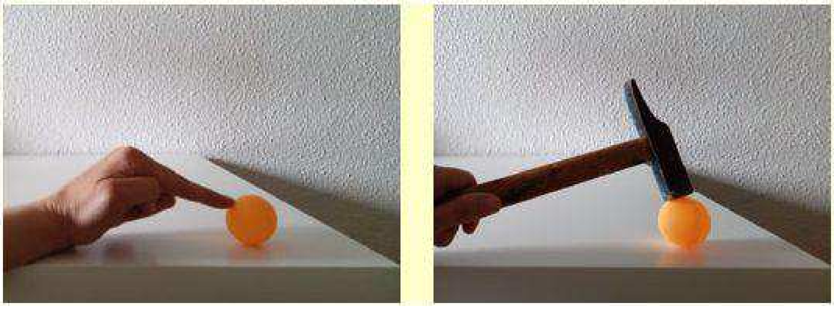
The woman riding a bike comes across a family, parents and children, riding bikes too, in a straight section of the road. Do you think all of them go in the same direction?

28. The force on the ball

A ping-pong ball is in the edge of the table. Observe the different ways that it is touched (in every case we are applying a force). Would the effects be the same? How would you represent the forces in each case? Represent them with an arrow that indicates the direction and sense.

29. With the hand and the hammer

Now the ball is hit softly with the hand and then hardly with a hammer, as you can see in the pictures. Would the effects be the same? How would you represent each situation?



30. Where do I apply the force?

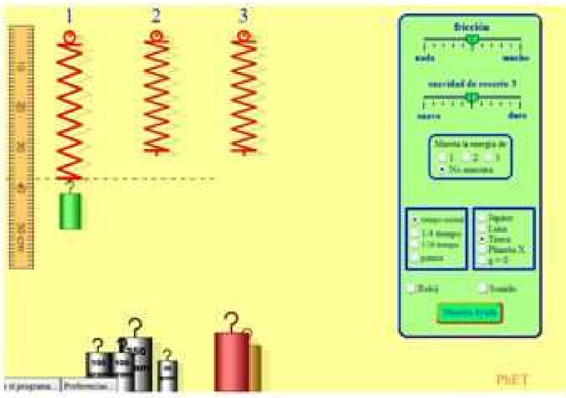
Is it the same to apply the force on one side or in the middle?

31. Dynamometers (INVESTIGATION-LABORATORY)

To know the intensity of a force you just have to read what the dynamometer shows when the spring is stretched. Try with several dynamometers to see how much force you have to apply to reach 1 N, 2 N… If you have a dynamometer that shows tens of Newton you will see that it is difficult to stretch it.

Hang a dynamometer of 2N on a mass of 50 g and observe what it shows. Writing the mass in kg, deduce the experimental relationship between mass and weight. Try with other masses to confirm your conclusion.

32. Calibrating a spring



You are going to use the next simulation to calibrate the spring of a dynamometer. You have a ruler, three spring and three different masses. You already know the relationship between the mass and the force it applies: 50 g apply a force of 0,5 N.

a) Are the three spring equal?

b) Use the dotted line and the ruler, that you can move as you want, to answer the next questions:

How long has the spring 1 been stretched when a force of 0,5 N is applied? And if the force is 1 N? And if it is 2,5 N? Can you deduce the value of the three masses?

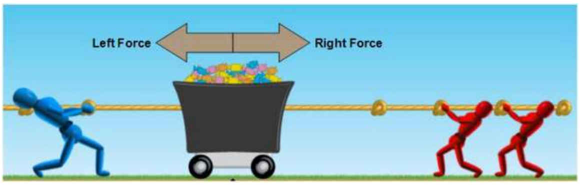
c) On the left you can change the spring softness. Do it and try with different masses. Write down what you observe.

33. The resultant of several forces (INVESTIGATION-LABORATORY)

In this simulation, two teams (blue and red) play a game similar to "soga-tira" but with a carriage full of candy. Depending on the size of the participants they can pull with more or less force. The biggest ones pull with a force of 100 N, the medium with 100 N and the smallest with 50 N.

If you set the option "values" and "sum forces" you will see the total force applied by each team and the resultant or net force of the action of both teams.

Try four different situations (balanced and unbalanced teams) and describe what happens to the carriage depending on the participants in each case. Try to explain it using the correct words. Write also the values of the forces applied by each team.



34. The jumping cube (INVESTIGATION-LABORATORY)

You are going to observe different facts related to forces. You need a skate, an object that makes the skate stop and a small object (the Rubik cube of the picture, for example). If you put the object on the skate and push it against the pad, what happens to the object? How do you explain it?

35. Inertia in space (INVESTIGATION-LABORATORY)

You have already observed the inertia in the Surface of the Earth but, what would happen in the space? The video you are going to see next was recorded in the International Space Station, where the effects of gravity can´t be appreciated. What differences do you observe?

36. What does inertia depend on?

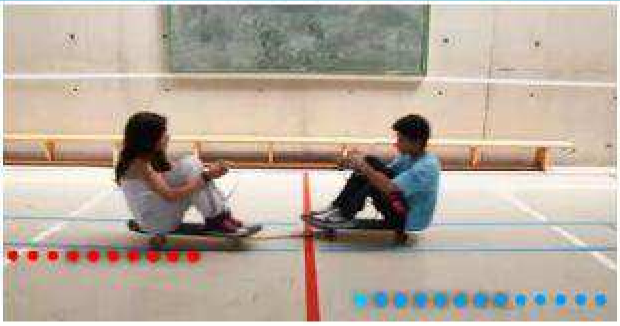
Observe the pictures of the car and the bus. Which one of the two mobiles is easier to start moving? Why? Now, look at the bicycle and the lorry. If both move at the same speed, which one is easier to stop? Why?

37. Blowing balls

You are going to observe what happens when you blow two similar balls but with different masses over a table (made of wood, metal or glass for example). What does it happen to the balls? Why?

38. With two…skates

Look at the video. You can observe that when the girl pushes the boy or pulls from it, both move but not at the same speed. Explain these experimental facts using the Newton laws.



39. Friction blocks (INVESTIGATION-LABORATORY)

Take a wooden or metallic block hung to a dynamometer and slide it on different surfaces, as it is shown in the picture. You must notice:

You always have to pull horizontally.

- Once it starts moving, try to keep a constant speed.
- Once it is moving, write down the value in the dynamometer. Is it always the same value? Why?

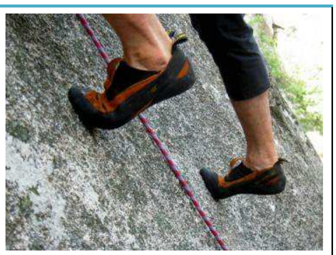
40. Intensity of frictional force

Observe how the same body slides on different surfaces with different frictions, from a hypothetical one with no friction to another one with a lot of friction.

Describe what you observe and represent a diagram for each case where the frictional force appears. Relate it to the intensity of the frictional force.

41. Climbing almost vertical walls

Why do you think that climbers don´t use normal trainers and use cat foot? What do you think that may happen when they are dirty or wet?

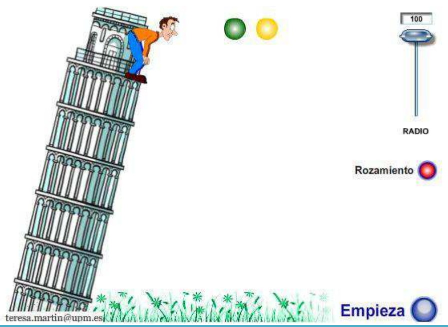


42. The Galileo experience (INVESTIGATION-LABORATORY)

You are going to use the next animation where two balls fall from the top of Pisa tower, reproducing one of the most famous experiments of physics done by Galileo Galilei, one of the fathers of modern science, in the XVI century.

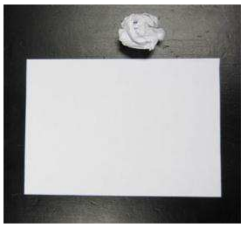
a) You will start letting the two identical (except for the colour) balls fall from the top of the tower without considering frictional force (friction button in red). Now reduce the size of the yellow ball and throw them again. Does something different happen?

b) Repeat the experiment considering frictional force (you have to click on the friction button, that will become green). What do you observe? What does it happen to the yellow ball? And if you make it smaller?



43. Losing the papers (INVESTIGATION-LABORATORY)

Take two identical paper sheets (with the same mass) and let one of while you wrinkle it. What do you observe? Does the speed of falling depend on the mass? Explain the reason of what you observe in the experiment.



44. El Pequeño País

After everything you have learned. Can you do a physical analysis of what happens in the comic?

45. Walking on Pluto

The video you are going to see next is taken from a documental serial of BBC called "Space Odyssey: Voyage to the Planets" where there is a recreation of a manned trip through the Solar System. Notice that the images you are going to see are just a simulation of what a trip to Pluto could be. What do you observe about the motion of the astronaut? Why do you think this happens?

46. Is the weight constant?

Observe the next animation, where the mass of a sack of coffee is determined and where you can also measure its weight in the Earth and in the Moon with a dynamometer. Are both values the same? Which one is higher?

47. Construction of a housemade dynamometer (INVESTIGATION-LABORATORY)

In this experience, you are going to determine the approximate mass of an unknown object using a dynamometer that you are going to build and calibrate.

Necessary materials: a plastic tube (can be a transparent hose tube), a perforated plug (it may be a rubber protector for the chairs), elastic rubber, a piece of wire, a permanent marker pen and a holder with calibrated weights.

You have to pass the rubber through the hole in the cap and hold it. For this, conveniently, you should make a small knot at the end of it as a stop. On the other end of the rope you will place a hook made with wire. You must make another knot in the rubber to fix the hook.

Finally, you must put the plug in the plastic tube so that the rubber and the hook hang inside it so that the hook protrudes slightly.

Once you have finished, think about how to calibrate it with the known masses and how to determine the weight of the object of unknown mass. What do you think about this way of determining the weight?

48. Calculating weights

Calculate the weight in the Earth of objects with a mass of 20g, 5 kg and 50 kg. Express the result in Newtons and consider g as 9,8 N/kg.

49. The first female astronaut.

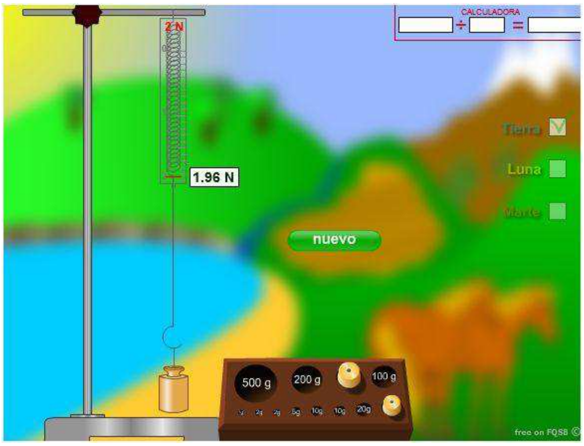
On 16th June of 1963, being 26 years old, Valentina Tereshkova became the first woman that travelled to space. Born in Russia, after finishing her engineering career, he joined the female cosmonaut's body. Select the right statement for Valentina in the Surface of the Earth:

a) Her weight was 60 kg.
b) Her mass was 60 kg.
c) She weighted 60 N.

50. Weight in the Earth and the Moon

An astronaut that travels to the Moon has a mass of 70 kg. What would be his weight in the Earth? And in the Moon? (remember that g = 9,8 N/kg on the surface of the Earth and g=1,6 N/kg on the surface of the Moon).

51. Weight in space (INVESTIGATION-LABORATORY)



If you calculate the weight of an object in another planet or on the Moon you have to use the same expression but a different value of g. For example, in the Moon, g has a value of 1,6 N/kg, so the weight would be lower than in the Earth, one-sixth, while the mass would be the same.

The next animation allows us to measure the force experimented by a dynamometer when we put masses of different weight on it in the Earth, in the Moon and in Mars. You just have to select the option that you want in the boxes on the right. To put the masses in the dynamometer you have to pick them with the mouse and if you want to do a new measurement you have to select the green box with the word “nuevo”.

a) Calculate the weight for the masses of 50 g, 100 g y 200 g in the Earth and check it measuring with the dynamometer (remember that g=9,8 N/kg in the Earth).

b) Use the animation to know the weight of these masses in the Moon. After measuring with the dynamometer, justify the results comparing to the results in the Earth (remember that g=1,6 N/kg in the Moon).

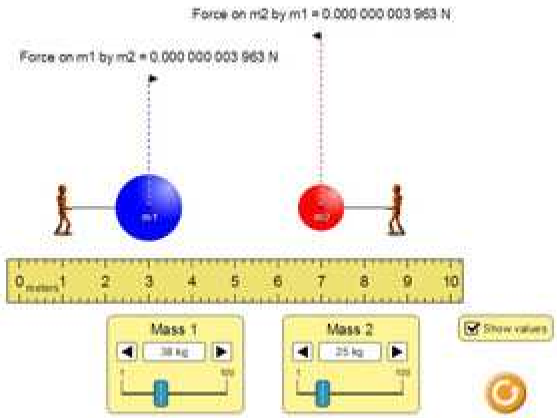
c) Measuring with the dynamometer the weight of the masses, calculate the value of gravity in Mars.

52. Universal gravitation law (INVESTIGATION-LABORATORY)

Here you have an animation to experiment how the force of attraction between two bodies changes depending on their mass and the distance between them.

It has been observed experimentally that the bigger the masses and the shortest the distance, the higher the force between two bodies. The universal gravitation law establishes a numerical relationship between the force, the mass and the distance.

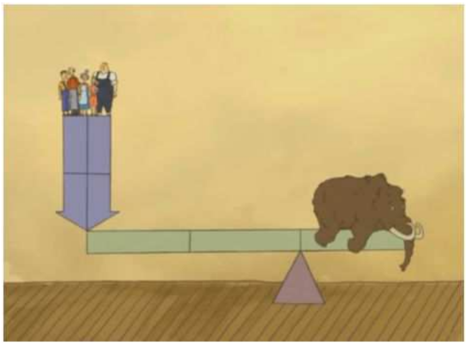
Using this simulator, design an experience to determine the relationship between these magnitudes. For example, how does the force vary when we duplicate one of the masses?



53. Cracking nuts

To break the nutshell you need a force of 100 N: If you use a nutcracker in a way that the distance from the hand to the fulcrum (axis of rotation, F) is 20 cm and de nut is 5 centimetres to that point, what is the force needed to crack the nut?

54. How do things work



There is a book and a cartoon series with that title that explain how things work in a funny way. Look at the picture where there is a lever used to rise a mammoth.

The mammoth is a species of mammals extinct 4000 years ago, at the end of the last glaciation. It is estimated that the biggest specimens reached heights of 4 meters and weights of 10 tons, although normally they were 3 meters tall and weighed 6 tons. Calculate how many people of 75 kg on average are needed to rise a normal mammoth, of 6 tons, with a lever like the one in the picture.

55. Balancing seesaws (INVESTIGATION-LABORATORY)

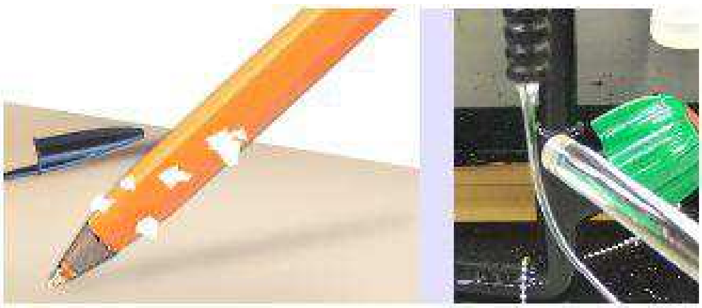
In the next application, you can play with the lever law to balance a seesaw with different weights.

The operation is very simple. Click the "intro" option to learn how the simulator works, putting different weights and checking if the seesaw balances. At the end, you have a game with four levels.

56. Electrification by friction (INVESTIGATION-LABORATORY)

Rub a plastic ruler or a pen with a piece of wool. Approach the object to some little pieces of paper (confeti) that you have left previously on the table. Observe what happens.

When you are at home, open the kitchen sink. Rub a plastic ruler or a piece of wool and approach it to the trickle of water Observe what happens.



57. The dust rug

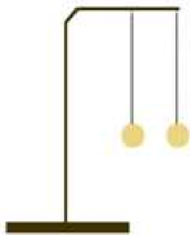
The makers say that dusters and cloths don´t drag the dust but hold it. What is the reason why dust sticks to them so easily?

58. The electric pendulum (INVESTIGATION-LABORATORY)

Build an electric pendulum with a ball of "poliexpan" (expanded polystyrene foam) attached to a thin thread about 15 cm long. Attach the thread to a support as indicated in the figure.

Rub a plastic rod or a pen with a wool cloth, approach it to the ball of the pendulum and watch what happens.

Repeat the experience with a glass rod rubbed with a silk cloth.



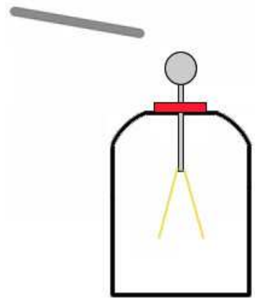
Now you are going to work with a double pendulum-like the one in the image. Hang two polystyrene balls (lined with aluminium foil) from a stand as in the electric pendulum, in a way that they are separated by 1 cm.

Rub the plastic rod with the wool cloth, touch the two balls together and remove the rod. Touch the balls with your hand and repeat the experience with the glass rod. Finally, bring the plastic rod (rubbed) to one of the balls and the glass rod (rubbed) to the other.

59. Electrification by induction (INVESTIGATION-LABORATORY)

You are going to use an electroscope, which is a glass recipient closed with a cork crossed by a metallic rod. Two thin metallic sheets are hanging from the lower end and the top ends with a metallic sphere

After touching the ball with your finger, approach the electrified plastic bar to the top of the electroscope, without touching it. Separate the plastic rod and repeat the experience with the glass rod. Touch the ball with your finger. Finally, approach the electrified glass rod to the top of the electroscope without putting them in contact.



60. The Van der Graaf generator (INVESTIGATION-LABORATORY)

To simplify the charging process and not having to rub continuously we use the Van der Graaf generator. An engine moves a rubber band that rubs with a metal grid when it turns, charging the sphere in contact with it. Some devices do a similar function like the one called an electrostatic magic wand, that produces spectacular effects although it has less capacity to generate a charge.

You are going to see in the laboratory the experiences in the video and some other similar ones, that you will have to explain using what you have learnt about electrification.

61. Charging the pen

Imagine that when you rub a pen with the sleeve of your sweater 106 electrons move to the pen. How is the sleeve charged after that?

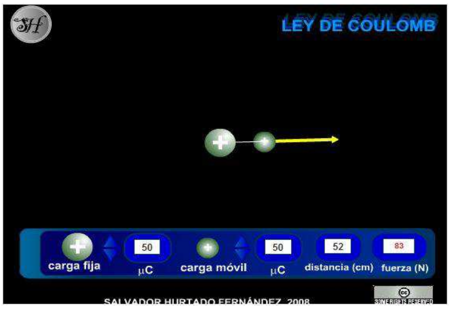
62. Charging balloons (INVESTIGATION-LABORATORY)

In the simulation, move the balloon on the sweater and observe what happens (electrification by rubbing). Once the balloon is charged, approach it to the wall and observe what happens (electrification by induction). Choose the “two balloons” option and charge both balloons. Look what happens when you try to approach them to each other and to the sweater.

63. ¡Chis chas!

When you take off a synthetic fibre sweater in the darkness, small clicks are produced. Explain why this happens.

64. Forces between charges (INVESTIGATION-LABORATORY)



Look at the next simulation. You are going to change the magnitude of the two charges and the distance between them and observe how the interaction force between them changes. Notice that if the distance is the same, the position doesn´t matter (there is spherical symmetry).

a) Assign to the fixed and mobile charges a value of 40 units and set a distance of 30 cm. Write down the value of the force.

b) Move the mobile charge around the central one keeping the distance. How is the value of the force between the charges?

c) Change the value of the fixed charge to 80 units. What is the value of the force?

d)? And if you duplicate the value of the mobile charge?

e) Now try duplicating the distance between charges.

Justify how the value of the force changes depending on the value of the charges and the distance between them.

65. The box of charges (INVESTIGATION-LABORATORY)

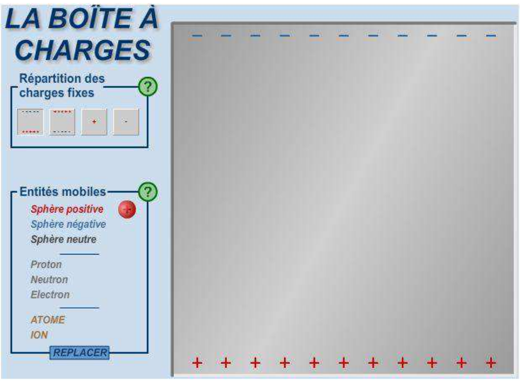
Look at the next simulator. Put the four possible distributions of charges in the working area and after that all the mobile particles that you can select.

a) Justify what you observe for each case.

b) Proton, neutron and electron are the fundamental particles of matter atomic structure. What charges do they have??

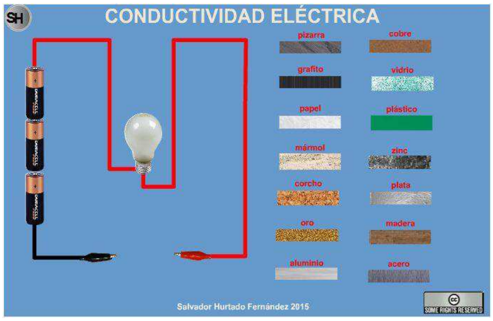
c) And the atoms?

d) Do ions have a charge?



66. Conductors and isolators (INVESTIGATION-LABORATORY)

With the next simulator, you are going to classify some materials depending on if they are conductor or isolators. You just have to approach them to one of the circuit terminals and observe if the lightbulb turns on or not. What do all the conductor materials have in common?



67. Electric current

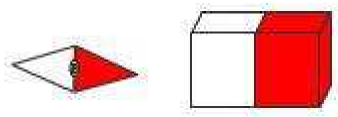
Why doesn´t electric current circulate until we close the switch?

68. Magnetic forces (INVESTIGATION-LABORATORY)

Everybody knows that magnets attract nails and pincers, that are objects made of iron. Now you are going to do the experience to check how the interaction between the magnets and these objects is produced. Put a neodymium magnet on the table and a nail close to it. Get them closer and observe what happens. Repeat the experience with the pincer. In the video you have both experiences filmed.

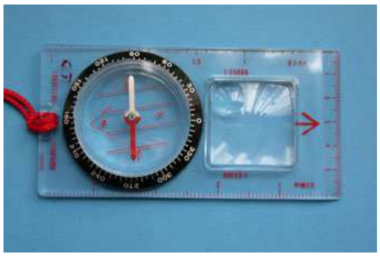
69. Experiences with magnets (INVESTIGATION-LABORATORY)

You are going to do three experiences with magnets, following the instructions in the video: attraction and repulsion between two magnets, deviation effect of the trajectory of a metallic ball because of the action of a magnet and effect of a magnet on a compass (magnetized needle).



70. Identifying the poles of a magnet (INVESTIGATION-LABORATORY)

Design a method to know which one is the positive pole and the negative pole of a magnet. You only have a compass to do that. Practice it with a magnet.



71. Generation of electric current with magnets (INVESTIGATION-LABORATORY)

The easiest way to produce electric current is moving a magnet close to a boil (copper thread rolled forming turns). Look at the picture to see how a led lamp turns on when we let the magnet fall through the tube or when we approach it and then take it out from the turn in the simulator.

You are going to investigate the factors influencing the intensity of the electric current produced, which is indicated by the luminosity of the lightbulb. Follow your teacher´s instructions to determine the factors (number of magnets, number of turns in the coil…). In the next unit, you will study the applications of this technique in power plants for the production of electric current.