

STATICS

What will we learn in this teaching unit?

- In the first place we will learn that forces are physical magnitudes which permit us to analyse the interactions among objects. These are what cause the world around us to appear as it does.
- Secondly we will master the methodology necessary to operate with many forces acting on an object at the same time.
- Thirdly we will learn to analyse how objects can be made to remain in equilibrium.

WHAT DO WE UNDERSTAND BY INTERACTION?

Interaction is the mutual action between two or more objects.



Observe the interactions in the illustration. Indicate, in each situation, which bodies are interacting and what the interaction consists of.

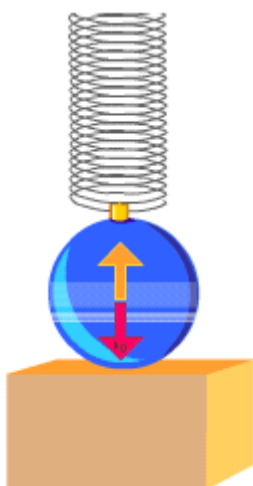
Force is a physical magnitude which serves to explain the interaction among bodies.

The effects of the interactions are many. Initially we are going to concentrate on the capacity of forces to cause deformation...

FORCES (F)

Force is a physical magnitude which helps us to understand the appearance of our world. Everything which surrounds us is subject to interactions with other bodies (FORCES) and due to their balance or lack of balance the world has the appearance that we experience.

The basis of most scientific progress, critical for the development of our society, like the construction of bridges, aeroplanes..., is based on the mastery and use of forces.



Push the block from under the spring. Do it several times and carefully observe the movement of the spring.

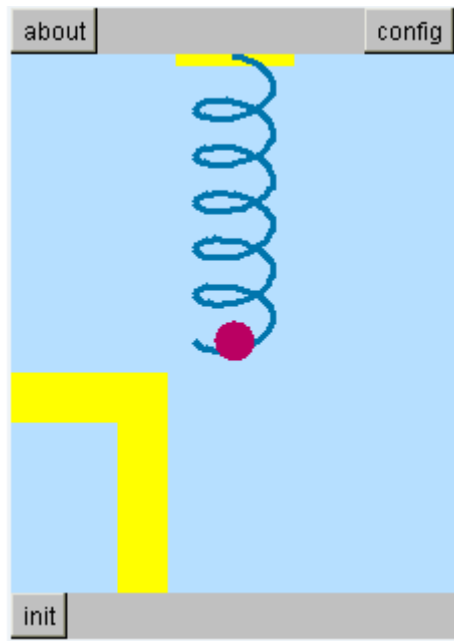
You will find that:

The tendency to contract (orange arrow) is smaller the less the spring is stretched. The more the string is stretched, the greater the tendency (orange arrow) to recover its position of equilibrium.

Why does the spring stretch? Has the weight of the suspended body (red arrow) anything to do with it? When does the spring stop stretching?

We will answer these questions and many others in this unit.

SOME EFFECTS OF THE FORCES



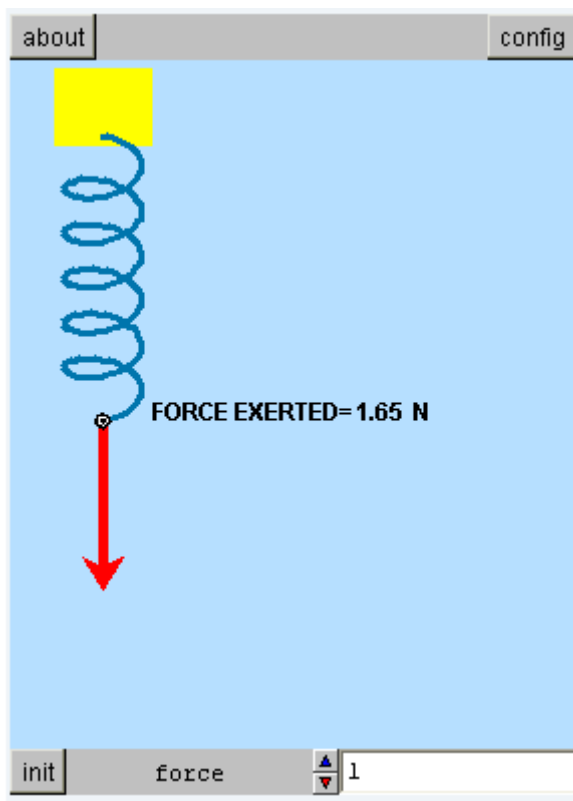
Place the cursor over the red object and slide it downwards several times.

What should we observe as we stretch it more? ...that we also have to exert a greater force.

Explanation

A body (you) is interacting with another body (the spring) and the effect is to stretch it.

MODULE OR INTENSITY OF A FORCE



Click the cursor on the spring and pull it down. Observe and answer:

- Does the force you exert increase or decrease as the spring stretches?

Click on the Force control and stretch the spring again. Observe carefully and answer:

- What do you think the arrow tries to symbolize?
- What relationship exists between the size of the arrow and the force exerted on the spring?

Definition

The module of a force is a number which indicates its intensity. Its unit in the Système International d'Unités is the Newton (N)

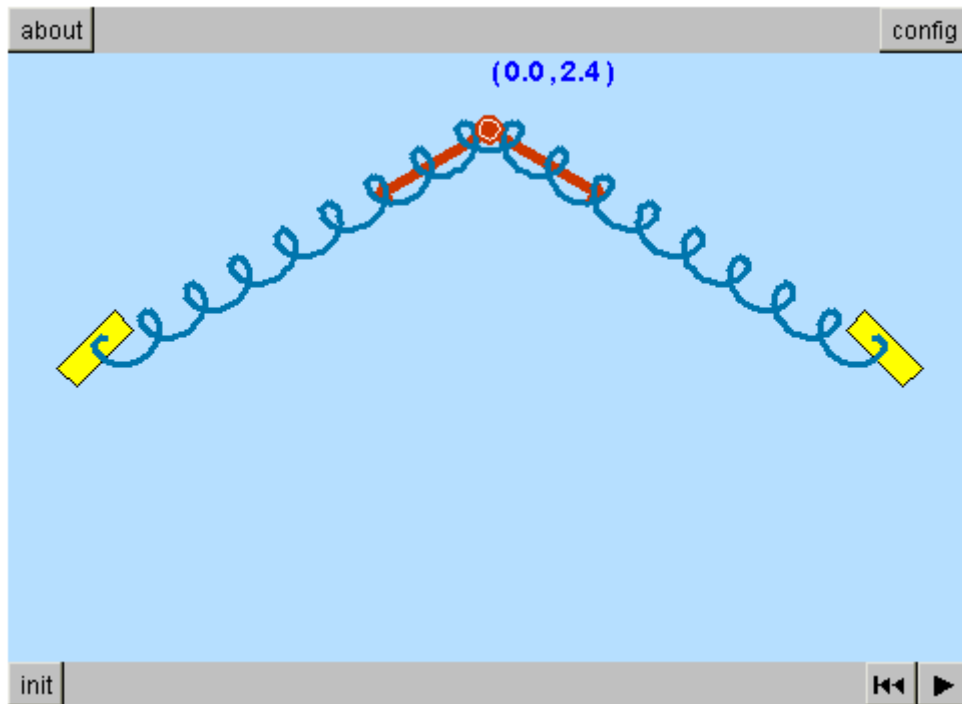
Forces are symbolized with arrows. Its size is directly proportional to the module of the force it represents.

THE ORIENTATION AND DIRECTION OF A FORCE

The use of arrows as illustrations to represent forces gives us the possibility of representing more than just their module.

An object on a horizontal board is subject to the action of two springs. (See simulation)

- 1- Click on the object and place it on the point $(0.0, 2.4)$. To fix its position you can use the arrow keys on the keyboard. Click on "play" (release the object).
- 2- Click on "Init", place the red object on the point $(1.0, 2.4)$. Observe.
- 3- Click on "Init" again. Work with the visual changing the initial positions of the object and try to analyse the effect this produces.



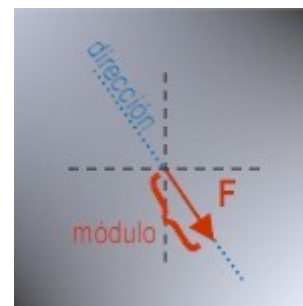
Consider

1. What do you think determines the different responses you have observed in the objects?
2. What do the lines that appear in the visual symbolize?
3. Start the visual and place the object in any position. Before clicking on "play" give a qualitative indication of the direction in which the object will move.
4. Find some situation in the visual where the object will stay at rest (velocity=zero).

Learn

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.



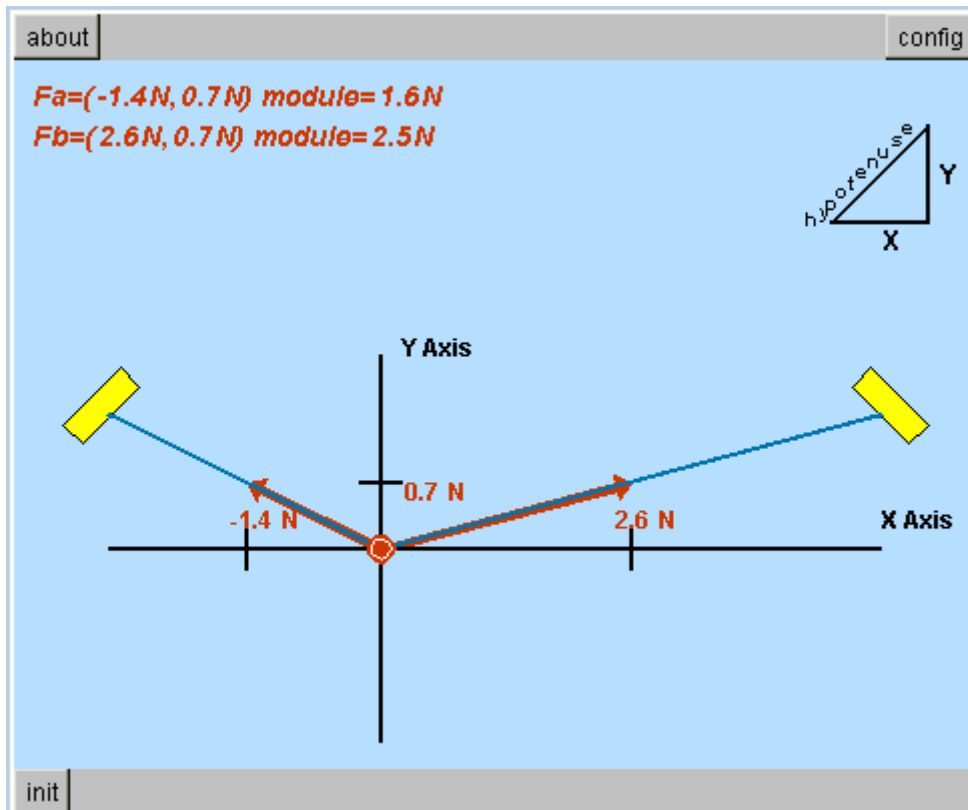
The orientation with which the force is applied is the straight line which contains the arrow and the direction is indicated with its point.

COMPONENTS OF A FORCE

Representing the forces which act on an object consists of knowing and drawing the position of the arrow which symbolizes them. To draw an arrow on an object it is enough if we know the initial (origin) and final points. **The point of application (origin) will always be the centre of the body on which it acts.**

An object is subject to the action of two ropes. Observe the elements which make up the visual and follow the instructions:

- a. Some Cartesian coordinates are drawn over the object
- b. Click the cursor on the object and move it
- c. Observe that the end of the forces (arrows) is determined by a point. You can see its value at the top of each axis. Click the cursor on the object and move it around the visual. Notice how the value of this point changes and make your own predictions and check them.



Learn

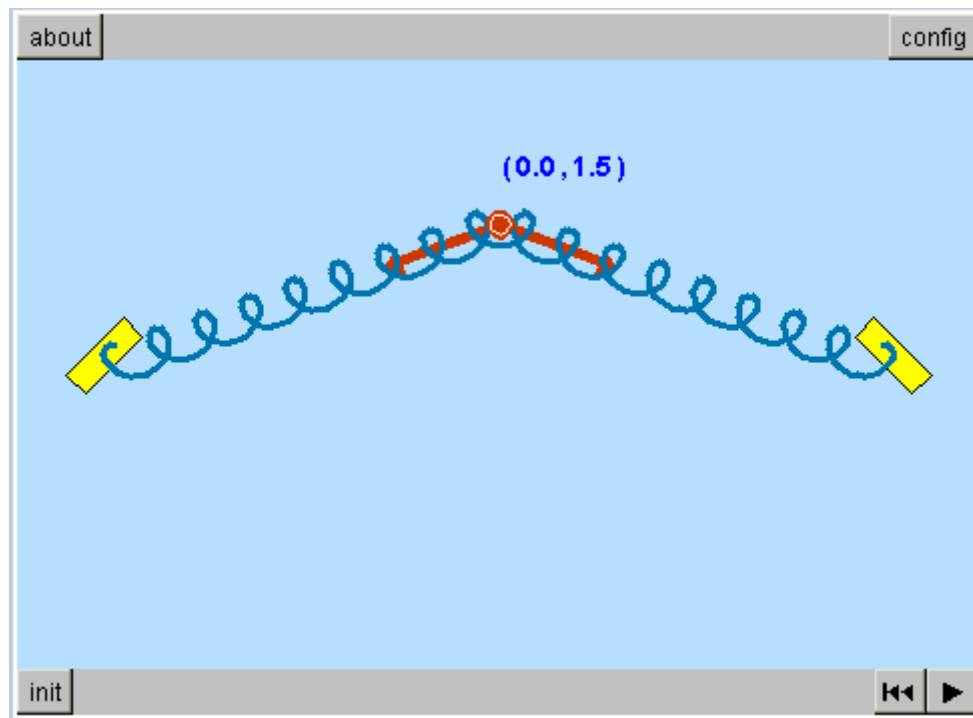
We call the value of the X coordinate of the point that determines the end of the force vector X component of the force

We call the value of the Y coordinate of the point that determines the end of the force vector Y component of the force

The three force components are represented within parentheses $F=(F_x, F_y)$

THE COMBINED EFFECT OF VARIOUS FORCES: THE COMPOSITION OF FORCES

The great variety of situations which life presents, suggests that bodies interact with more than one object at the same time. This means that the number of forces acting on it are not normally limited to one.



We hold an object on a table using the action of two springs.

1- Observe the visual as it first appears and try to describe the forces acting on the object. What will happen if we release the object from the action of the springs? You can find out by releasing the object with the "play" control in the visual.

2- Click on home and move the object to the point on the plane $(0, 1.5)$. Observe the forces that act in this new situation.

Learn

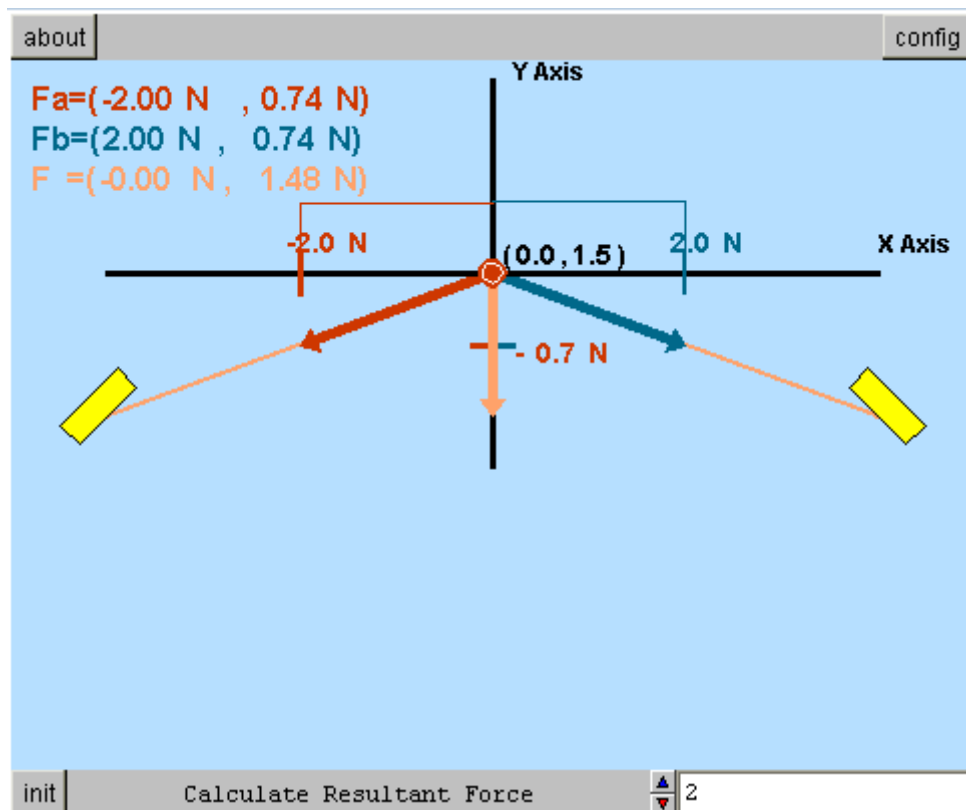
The action of more than one force on an object produces just one effect. In the case above it produces one single movement.

Question

Do you think that by using just one spring in the visual above we could produce the same effect as that due to the combined action of the two forces?

THE RESULTANT FORCE

We have seen on the previous page that several forces acting on the same object produce a single effect. Would it be possible to substitute all these forces with one single force which produces the same effect as the combined action of all of them?



We have represented a red object held by two elastic cords.

1-Describe the forces acting on the object.

2-Click on the "calculate resultant force" control. Observe and describe what happens in the visual.

3- Looking at the visual, note down the components of the elastic forces and that of the resultant which act on the object placed in the following positions: (-1,0); (1,0); (-2,1); (1, 1.5).

Learn

We call the force which has the same effect on the object as that achieved by more than one force, the resultant force.

The X component is calculated by adding up all the X components of the forces acting on the object.

The Y component is calculated adding up all the Y components of the acting forces.

Question

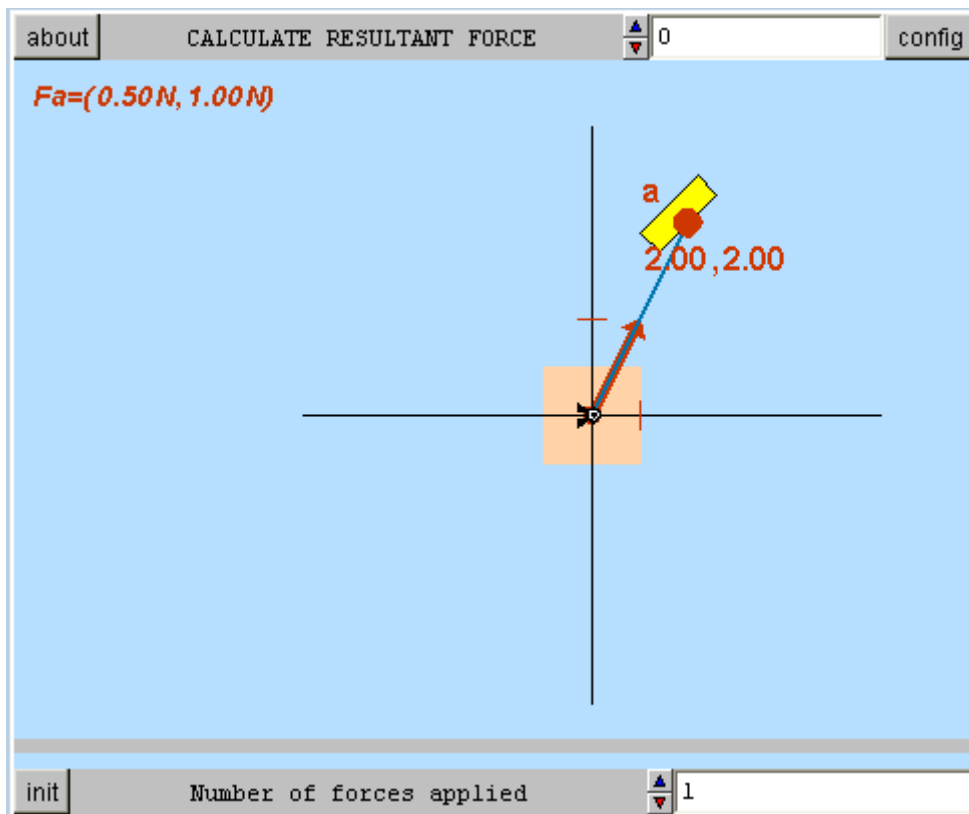
Calculate in your notebook the resultant of the elastic forces acting on the object in the positions indicated in the exercise in the visual and check your answer with the one given in the visual.

THE COUNTERBALANCE

In some of the previous visuals we were "holding" an object which was subject to the action of elastic forces, with the aim of keeping it at rest. When it was released ("play" control) the body lost its equilibrium and accelerated.

Instructions

- 1- Place the elastic cord in position (2,2)
- 2- Draw the force which you think would balance the previous one. Use the arrow keys on the keyboard. Find out if your answer is correct clicking on "play".
- 3- Click on home and choose two forces with the control. Put them where you like and calculate the resultant force.
- 4- Click on home and do the same but with three forces acting on the object.



You have just calculated the resultant force of up to three forces. The process for the case where there are more forces follows the same logic.

Learn:

The force capable of countering the effect produced by the resultant force is called the counterbalance. It is a force with the same module, the same orientation but the opposite direction compared with the resultant. The components of the counterbalance are therefore equal to those of the resultant but with the opposite sign, $(-F_x, -F_y)$.

An object is in translational equilibrium when it has a constant velocity. (velocity = 0 m/s, that is stopped, which is a constant velocity!)

Work with the visual above

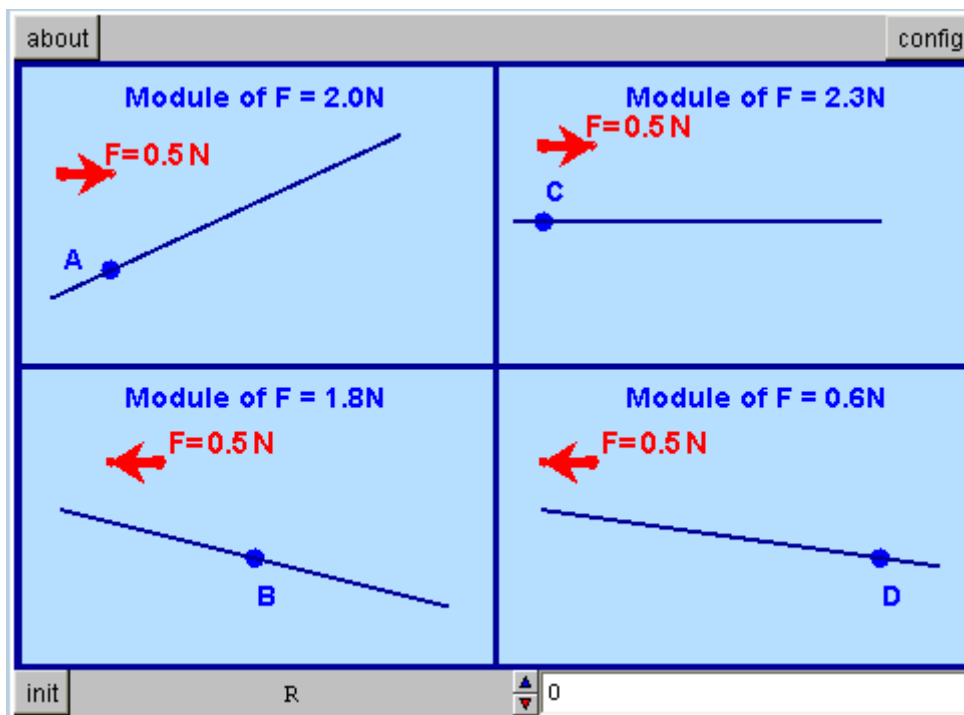
1. Draw two elastic forces: $F_a = (-1.00 \text{ N}, 1.00 \text{ N})$ and $F_b = (1.15 \text{ N}, 0.45 \text{ N})$
2. Calculate the resultant in your notebook. Check it with the visual

3. Calculate the force which balances F_a and F_b . Check it with the visual
- 4.. Draw three elastic forces: $F_a=(-1.75 \text{ N}, 0.60 \text{ N})$, $F_b=(1.45 \text{ N}, 0.00 \text{ N})$, $F_c=(-1.50 \text{ N}, -1.00 \text{ N})$
5. Calculate the resultant and the counterbalance in your notebook.
Check it with the visual

QUESTIONS ABOUT THE MODULE, ORIENTATION AND DIRECTION OF A FORCE

1. Why is the module of a force not sufficient to understand its effects?
How can we completely determine a force?

Work with the following visual: it consists of four independent areas.



Click on the arrow in the first box and place it **with the correct module** on the point of application and with the orientation indicated.

Click on the R control and you will get the correct answer.

Continue with the boxes b, c, d and click R each time to get the correct answer.

3. Can only one force act on an object?

EVALUATION

1. A force acting on an object is represented by an arrow with its origin on the object:

- True
- False

2. An object can only interact with another object

- True
- False

3. The action of a set of forces on the same object produces the same effect as a single force that is usually known as resultant force.

- True
- False

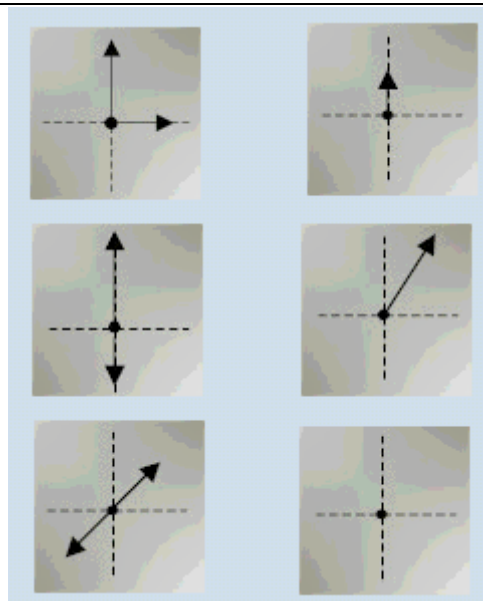
4. The resultant force of two forces of components $(2,0)$ y $(-3,1)$ acting on an object is $(3,0)$

- True
- False

5. Forces have four components

- True
- False

6. The diagrams on the left represent forces acting on an object. The diagrams on the right represent resultant forces. Drag the diagrams on the left onto their corresponding resultant force.



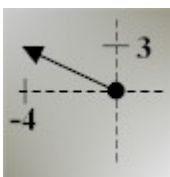
7. If we hang a bag full of tennis balls that weighs 200N from a spring, the elastic force that the spring must exert to hold up the bag must be at least 200N in the opposite direction.

- True
- False

8. Forces, like mass or time, only need a number to be completely defined

- True
- False

9. Choose the correct answer for the components and module of the force represented in the diagram.



- components (3,-4); module 5 N;
- components (-4,3); module 25 N
- components (-4,3); module 5 N
- components (3,4); module 5 N.

10. The correct unit of force is:

- Jules (J)
- Newtons (Nw)
- Newtons (N)