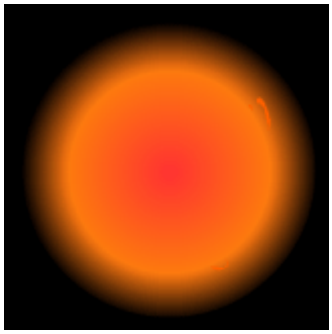
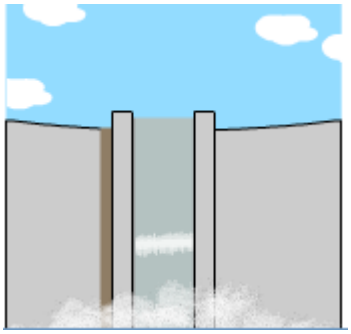
WORK, POWER AND ENERGY

All of us use words like work, power and energy. In this unit we will define their meaning in the context of physics; we will evaluate the need for such exactitude in order to tackle many facts of daily life; and investigate new applications; we will verify how the calculation of work (W), of the power (P) produced by a machine or the measurement of energy (E) consumed or stored, are very useful for maintaining and developing the society in which we live.

Let's have a look at the ideas we already have about work, power and energy.


The sun is an inexhaustible source of **energy**. Without it, life on earth could not exist.

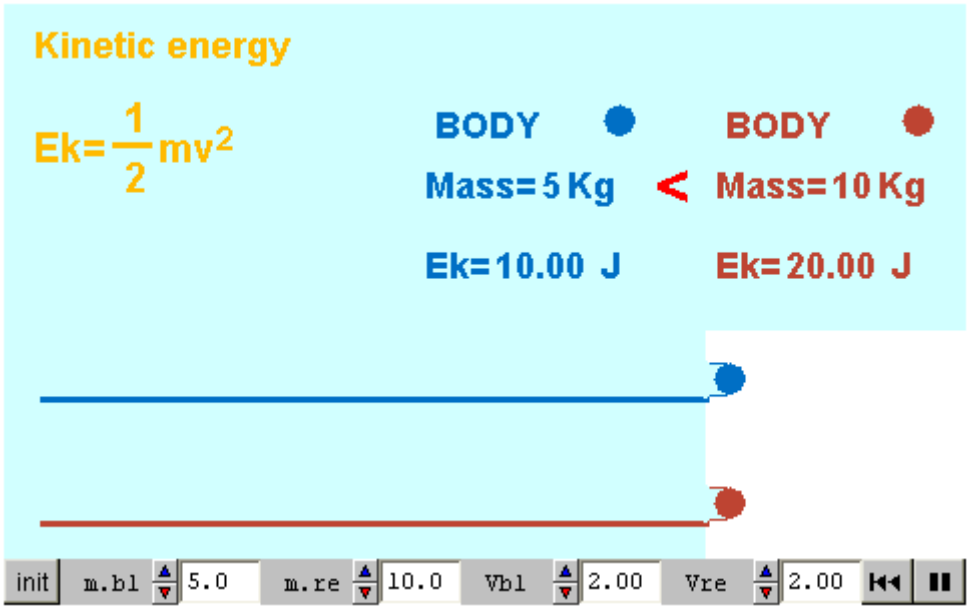
The source of part of the electric **energy** we consume comes from the ***energy*** stored in the reservoirs

A ***powerful*** hoist needs ***energy*** (fuel) to keep on ***working***.

ENERGY: KINETIC ENERGY

Energy is the capacity of an object to transform the world which surrounds it. Its **unit** is the **joule**.

By moving, bodies have the capacity to transform their environment. Think how by moving we are able to transport objects, bump into them, break them...
Carry out the following simulation:



INSTRUCTIONS

- This is a representation of the movement of two objects and their collision with a pile of snow.
- With the controls "m.bl" and "m.re" you can choose the mass of each object.
- With the controls "vbl" y "vre" you can choose the speed at which they move.
- By clicking on "play" you can observe the visual in motion.
- Always click on "init" before each new observation.

EXERCISES

THE EFFECTS OF KINETIC ENERGY AND THE FACTORS THAT IT DEPENDS ON

1- Calculate the kinetic energy of a body with the following characteristics:

- Mass = 5 Kg and velocity = 2 m/s.
- Mass = 10 Kg and velocity = 5 m/s.

(VERIFY YOUR RESULTS WITH THE VISUAL)

2- OBSERVE and compare the effects produced by the collision of the two bodies with the pile of snow in the following cases:

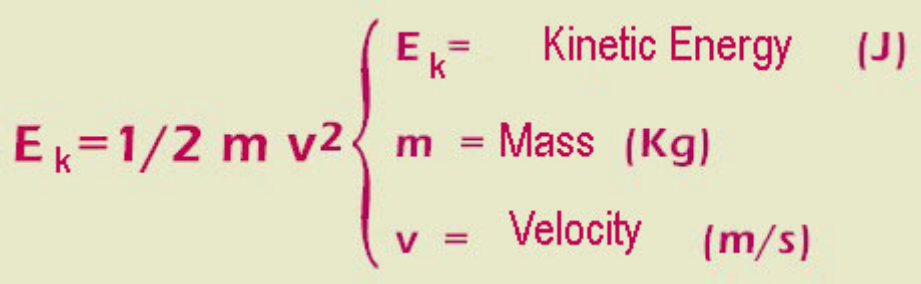
BLUE object: mass = 5 Kg, velocity = 2 m/s RED object: mass = 5 Kg, velocity = 4 m/s.

BLUE object: mass = 10 Kg, velocity = 3 m/s RED object: mass = 5 Kg, velocity = 3 m/s.

3- How does the mass influence the distance covered during the deceleration?

4- How does the velocity influence the distance covered during the deceleration?

LEARN :we call the energy a body possesses because it moves, kinetic energy. The kinetic energy of a body depends on its mass and its velocity according to the expression:

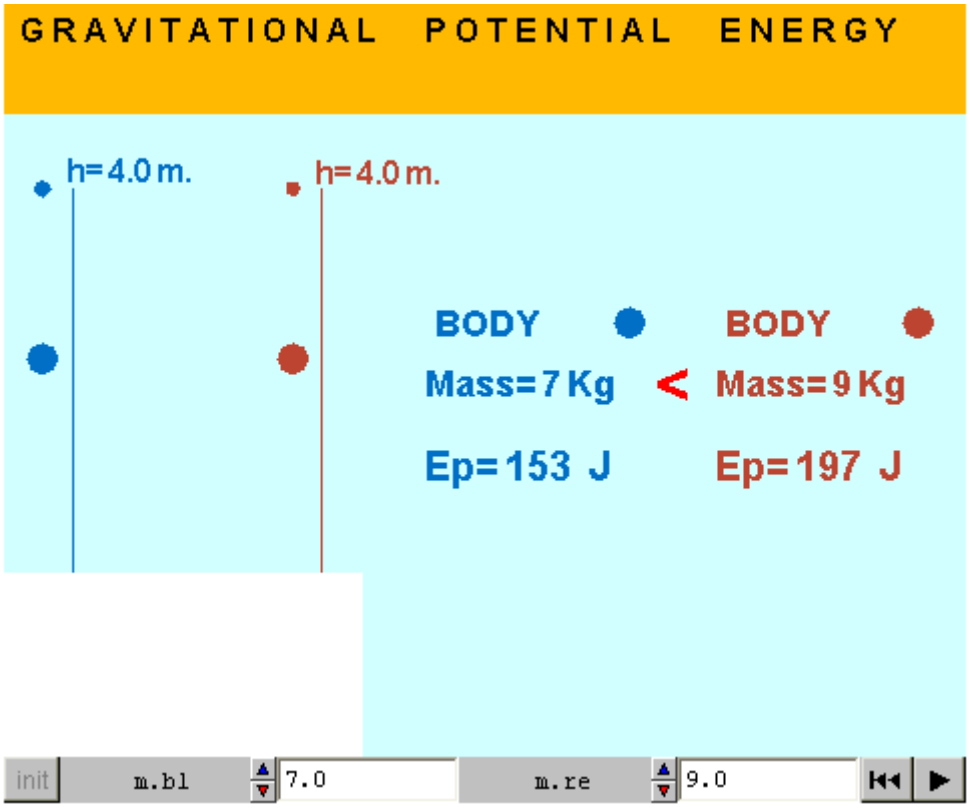


LEARN::the velocity of a body gives it the capacity to transform its environment. This capacity is its kinetic energy and it depends on the square of its velocity and its mass.

ENERGY: POTENTIAL ENERGY

The fact that they are under the influence of the gravitational field gives objects the capacity to fall. Remember the exploitation of waterfalls to generate electric energy.

In the following visual we will discover gravitational potential energy and the way to calculate it:



INSTRUCTIONS

- This visual represents two freely falling objects from the height indicated by the letter h.
- With the "m.bl" and "m.re" controls you can select the mass of each object.
- By clicking on "play" you can observe the fall.
- Always press "init" before the next observation.

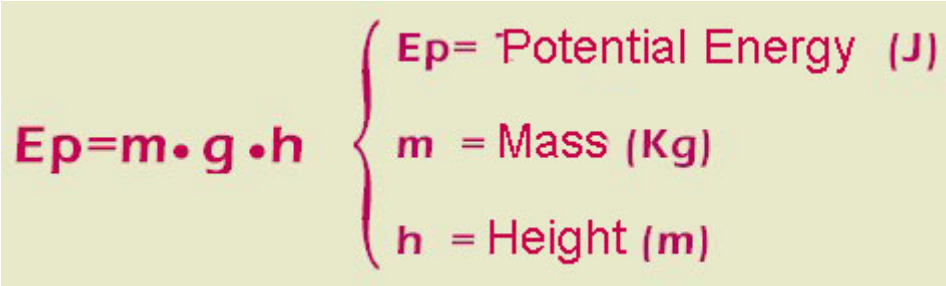
EXERCISES

1. Calculate the potential energy of the blue object with a mass of 7 Kg from the following heights:

BLUE object: h = 4.5 m; BLUE object: h = 2.0 m; BLUE object: h = 1.0 m.

2. Observe the variation of the potential energy when the bodies are dropped ("play").
3. Find out how the potential energy changes with the body's mass.

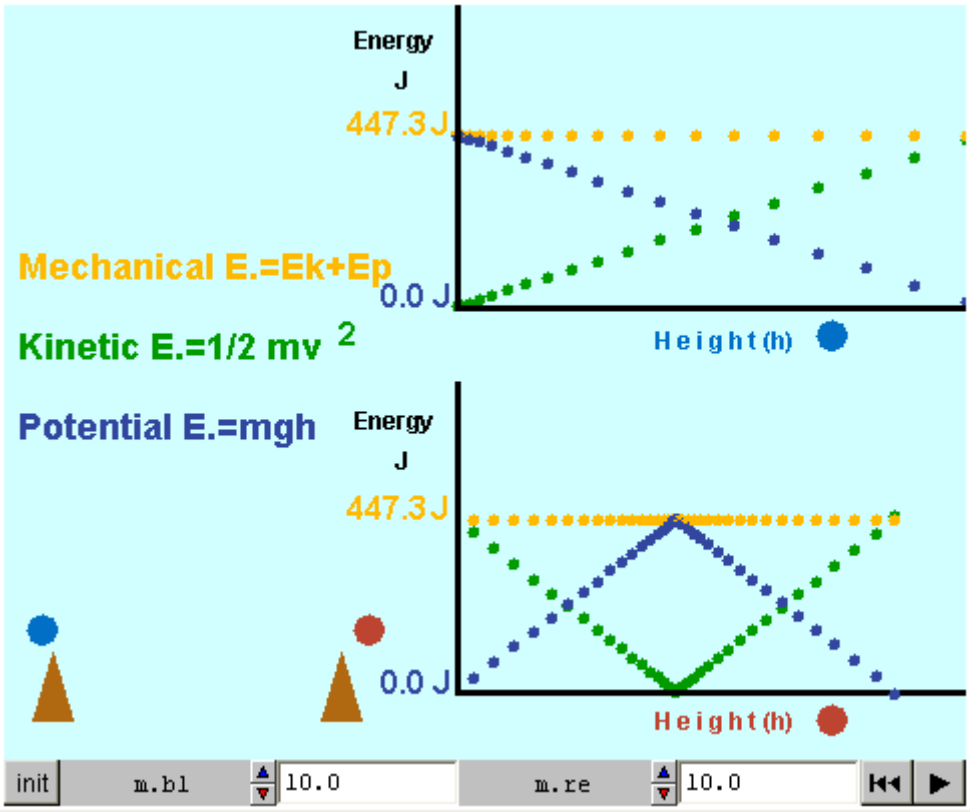
LEARN: Gravitational potential energy is due to the capacity of objects to fall. Its source is the existence of the earth's gravitational field. Its magnitude is directly proportional to the height at which the object is found, with respect to a determined reference point which we situate on the surface of the earth, and the mass of the object. Its mathematical expression is:



MECHANICAL ENERGY: THE PRINCIPLE OF CONSERVATION

We already know about two types of energy: potential energy and kinetic energy. There are many more types of energy: chemical, nuclear, electric.... However, the two which we have talked about are part of everyday phenomena. Historically they are the ones which have been used since antiquity.

We are going to study a situation where objects only possess two types of energy: free fall.



INSTRUCTIONS

- This visual represents the movement of a body that falls onto a lever and makes another body move.
- With the "m.bl" and "m.re" controls you can select the mass of each object.
- By clicking on "play" you can observe the fall.
- Click on "pause" to be able to observe the object more easily.
- Always press "init" before the next observation.

EXERCISES

THE CONSERVATION OF MECHANICAL ENERGY IN A BODY

1- "Play" and observe how the objects' kinetic energy and potential energy change in the graph. USE THE PAUSE TO FOLLOW THE EVOLUTION OF THE VALUES

2- Change the mass of the objects and observe the kinetic and potential energies again.

BLUE object: mass = 14 Kg, RED object: mass = 14 Kg.

BLUE object: mass = 7 Kg, RED object: mass = 14 Kg.
BLUE object: mass = 7 Kg, RED object: mass = 7 Kg.
3- How does the mass of the BLUE object affect the response of the RED object?
4- Can you find a relation between the kinetic and potential energies by looking at the graph?

LEARN:

The sum of the kinetic and potential energy of an object is called **Mechanical Energy.**

$$Em = E_k + Ep \begin{cases} Em = \text{Mechanical Energy} & (J) \\ E_k = \text{Kinetic Energy} & (J) \\ Ep = \text{Potential Energy} & (J) \end{cases}$$

LEARN:

THE PRINCIPLE OF THE CONSERVATION OF MECHANICAL ENERGY

The sum of the kinetic and potential energy of a freely falling object *remains constant* at any instant.-

TRANSFORMATION OF ENERGY

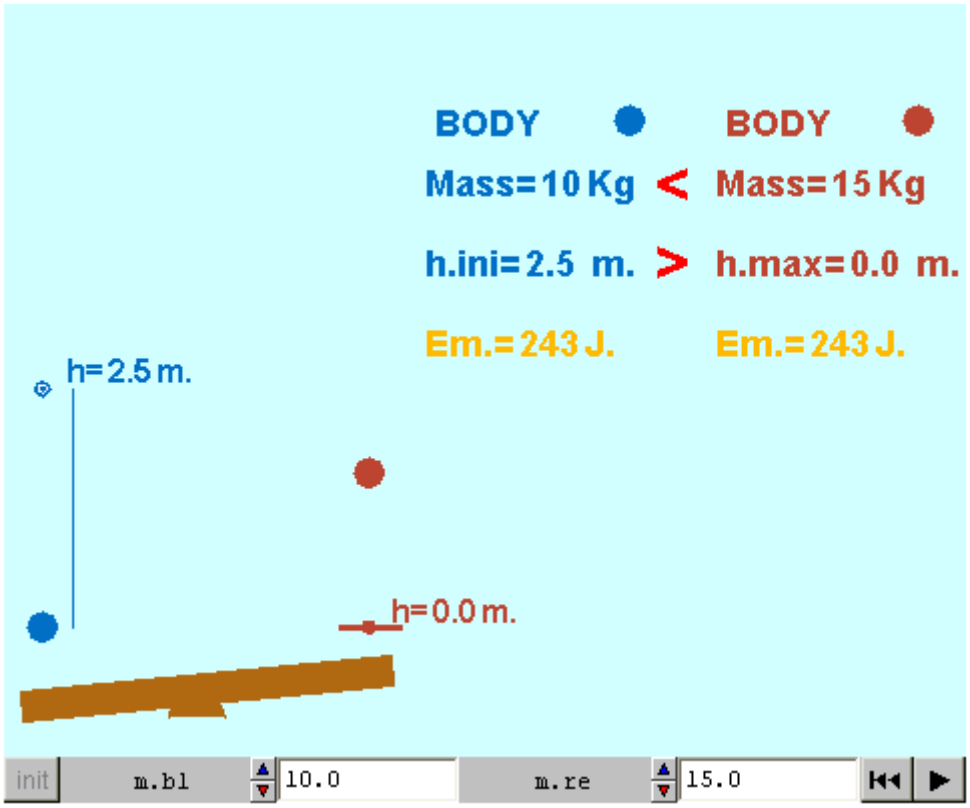
What does it mean when we say that a physical magnitude, in this case **Mechanical Energy**, is conserved?
Throughout these pages we have emphasized that there are many types of energy. We have concentrated on potential gravitational energy and kinetic energy. Both are characteristics of a freely falling body. We have seen that the sum of its values remains constant. What exactly does this mean? It means that a physical magnitude like energy has the property of being able to

transform itself from one form into another, so that the decrease in one means an increase in another or others.

Man has managed to take advantage of this property of energy. We have developed ways to transform some forms of energy into other more exploitable forms: potential gravitational energy into electric energy, electric energy into lighting, chemical energy into heating...
In the case of the free fall phenomenon only kinetic and potential energy are involved and so the decrease/increase in one means an increase/decrease in the other.

The transformation from one form of energy to another is a phenomenon which in certain cases is easily produced.

The following simulation presents a very everyday fact: an object bounces on a seesaw and transmits its energy to the other side. This is one more example of the conservation of mechanical energy.



INSTRUCTIONS

- We are representing the fall of an object onto a lever that causes the movement of another object.
- With the "m.bl" and "m.re" controls you can select the mass of each object.
- The initial height of the blue object can be selected by clicking on it and dragging it to the right position.
- You can also select the height reached by the red object the same way.
- The mechanical energy data describe the system except when the objects are still on the lever.
- Always press "init" before an observation.

EXERCISES

CONSERVATION OF MECHANICAL ENERGY

1- Drag the BLUE object to the following heights and observe the height reached by the RED object.

BLUE object: h=5.5 m. mass=7 Kg RED object : mass= 7 Kg.
BLUE object: h=3.5 m. mass=7 Kg RED object: mass= 7 Kg.
BLUE object: h=2.5 m. mass=7 Kg RED object: mass= 7 Kg.

What height does the RED object reach?
What is the mechanical energy of the RED object?

2- With the help of the visual, find the height from which a 9 kg. BLUE object must fall to make a 3 kg. RED object reach a height of h=6 m

LEARN:

The energy a body possesses in one form can be transformed into other forms and in total will always have the same value...Does this mean it can always be used by man?

ENERGY AND WORK

Is there any relationship between work and energy?

We presented energy as the capacity of a body to modify its environment. The word "modify" includes many things: illuminate, heat, ... move. The work developed by a force is in the end produced by some type of energy. This energy is transformed into work and thus they share the same unit of measure the joule (J).

Let's think about the Principle of Conservation of Mechanical Energy. Does it only apply to free fall?

If we were able to take into account all the energy transformations both into other forms of energy (heat, light, kinetic ...) and in work, which take place in a process, we could generalize the Principle of the Conservation of Energy.

Basically all or some of the following types of energy intervene in a movement:

- Kinetic Energy
- Potential Energy
- Work carried out by forces other than weight
- Work carried out by friction

POWER

In the majority of processes in which there is an energy exchange and/or work is done an important factor is the time taken in the process.

If we think about appliances like a refrigerator, a dryer, a light bulb which consume electric energy and transform it in order to cool, heat, illuminate..., the

physical magnitude which relates the electric energy consumed in a unit of time is called power.

Power applies to any process of energy transfer. So, for example, we can also talk of the power of a crane to lift a load, and the work performed by a hoist in the time unit.

$$P = E/t \quad \begin{cases} P = \text{Power} & (w) \\ E = \text{Energy} & (J) \\ t = \text{Time} & (s) \end{cases}$$

$$P = W/t \quad \begin{cases} P = \text{Power} & (w) \\ W = \text{Work} & (J) \\ t = \text{Time} & (s) \end{cases}$$

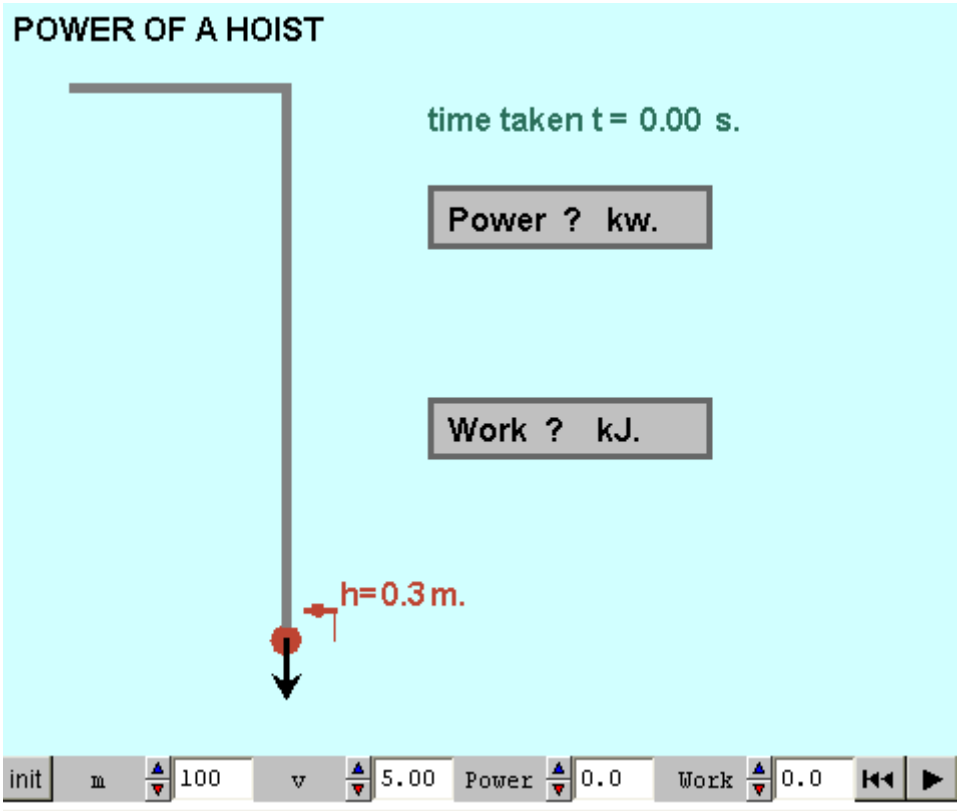
$$P = W/t = F \cdot d/t = F \cdot v$$

$$\begin{cases} P = \text{Power (w)} \\ F = \text{Force (N)} \\ v = \text{Velocity (m/s)} \end{cases}$$

The hoist

We know that the minimal force necessary to move an object is that which counteracts the forces which exist against the direction of the movement. This is equal to finding a force which cancels out the resultant force acting on the object.

A very frequent situation found in building projects is the use of cranes. It is essential to know the magnitude of the load we are going to lift in order to choose the crane. Power is an important question.



INSTRUCTIONS

- This is a representation of a hoist.
- You can control the following variables:

CONTROLS	MEANING	UNIT
m	The mass lifted	Kg
v	The speed of elevation	m/s
h	The height reached	m
power	The power of the hoist	Kw
work	The work done by the hoist to lift the weight	kJ

- The work and power selected will be evaluated by the visual and it will tell you if they are consistent with the other parameters.
- Always press "init" before each trial.

EXERCISES

1- Calculate the minimum work necessary to lift the following weights: mass lifted = 10, 100 and 200 Kg. Test your results with the visual.

2- What is the minimum power necessary for the hoist to lift a 100 Kg object to the height of 2.5 m. at the following speeds: 5 m/s, 10 m/s, 15 m/s?

EVALUATION

1.Mark the actions in which work is being done

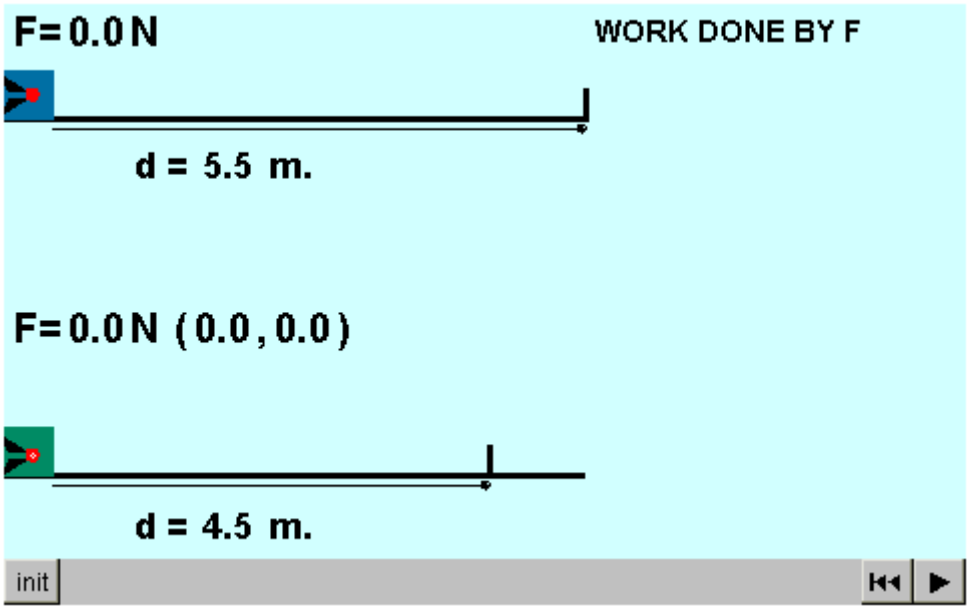
- Carrying a rucksack to school
- a vehicle warming up its motor
- a computer running a program

2.Choose the statement that lists all the magnitudes that the work done by a force depends on

- The force and the speed
- The displacement and the direction of the force
- The trajectory, the displacement and the time taken
- The magnitude and direction of the force, and the displacement

3. The work done to move an object 5.1 m with a 1.4 N force in the direction of the movement is: (you may wish to use the visual)

- approximately 2 J
- approximately 7 J.
- approximately 7 N.



INSTRUCTIONS

- To apply a force, drag the red dot to a new position with your mouse.
- The force on the green object can also change its direction.
- The distance covered is indicated by the letter d.
- The work done by the forces is expressed with the letter W.
- By clicking on "play", you can see the effect of the forces.
- Always press "init" before every new observation.

EXERCISES

1- Apply the following forces:

BLUE object: F = 10 N, GREEN object: F = 10 N, angle = 0°.
BLUE object: F = 10 N, GREEN object: F = 10 N, angle = 30°.
BLUE object: F = 10 N, GREEN object: F = 10 N, angle = 45°.
BLUE object: F = 10 N, GREEN object: F = 10 N, angle = 90°.

How does the work change in relation to the direction of F?

2- Find the force that must be applied to the BLUE object in order to get the same amount of work as the work done by a force of 8 Newtons with an angle of 30° on the Green object.

4. The kinetic and potential energies of a 6 Kg object freely falling at 5 m/s from a height of 2 m is:

- Potential energy: 75 J, Kinetic energ: 100 J
- Kinetic energy: 75 J, Potential energy: 75 J.
- Kinetic energy:75 J, Potential energy: 117.6 J.

5. If we drop a 7.5 Kg object from a height of 3 m onto a lever in such a way that it launches a 5.5 kg. object on the other side upwards, would this object be able to reach a height of 4m? You might want to use the visual **CONSERVATION OF MECHANICAL ENERGY**.
The second object will reach the height because it is lighter than the first one

- It won´t reach the height
- It will reach the height because its potential energy at the height of 4m will be produced by the kinetic energy of the first object in its collision with the lever.
- It won´t reach the height because the mechanical energy of the second object will never be equal to the energy transmitted by the first object when it collides with the lever.

6. In a movement, some or all of the following types of energy and work are involved:

- Mechanical and kinetic energies
- potential energy and the work done by the force that moves the body
- Kinetic energy, potential energy, work done by forces excluding the body´s weight and work lost through fricition
- Kinetic energy, potential energy and work done by the body´s weight.

7. The power of a hoist is defined as:

- The work done in a unit of time. The SI unit for power is the Watt.
- It is the potential energy given to the object that is being lifted. Its SI unit is the Joule.
- The speed at which it lifts objects. Its SI unit is m/s.

8. The mechanical energy of a freely falling object is the difference between its potential energy and its kinetic energy.

- True
- False

9. To lift an object of 100 kg. at a speed of 6 m/s to a height of 4 m, the power of the machine must be at least 5.9 Kw and the work done by the crane is 3.9 kJ.

- True
- False

10. Energy is a physical magnitude that describes the capacity of an object to do work.

- True
- False