

MOVEMENT I

OBJECTIVES

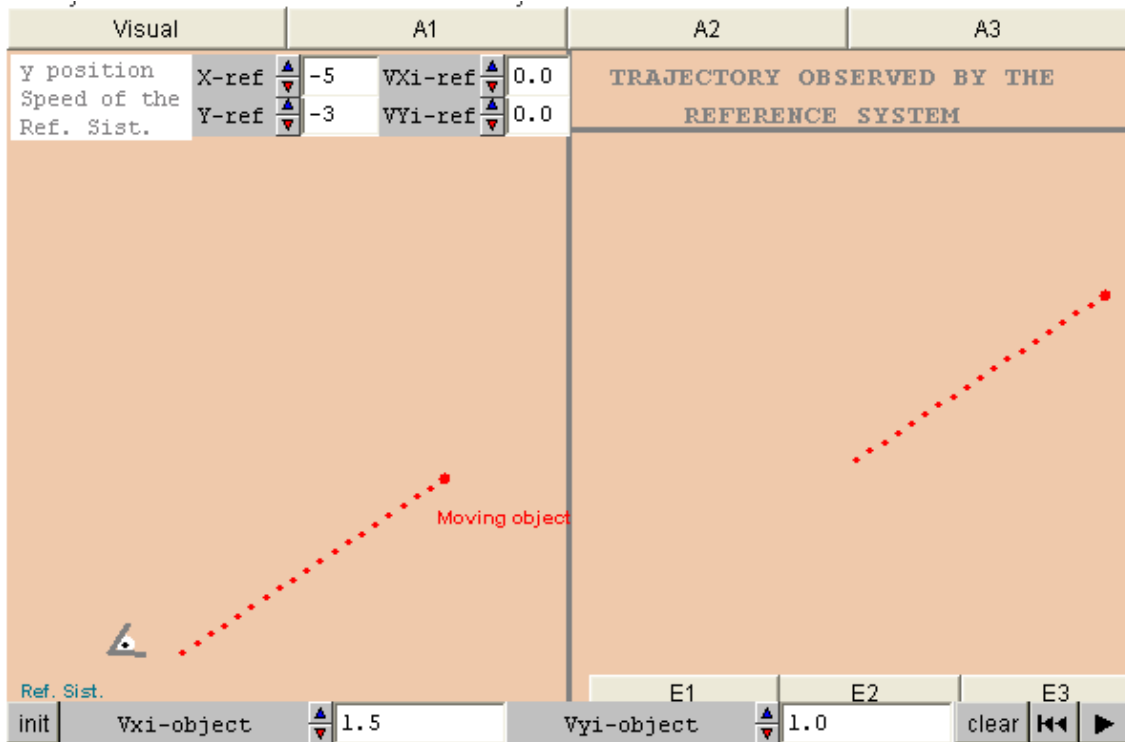
This teaching unit aims at introducing vectors into the study of movement.

- There is a revision of the concepts of :
Reference system, position and displacement vectors, presented in the 4th year of secondary education (Trajectory)
- There is a return to fundamental concepts like UM, AUM, UCM presented in previous courses: 2nd year of secondary education: [Kinematics](#); 4th year of secondary education: [Rectilinear Movt.](#) and [Uniform Circular Movement](#).
- Concepts like average and instantaneous velocity are defined, and there is a simulation of the average velocity vector when time tends towards zero.

1.1 What is a Reference system?

The place from which the position of a moving object is observed is a Reference system.

The eye of the observer is a reference system.



VISUAL: This visual represents the movement of a point, a reference system (an eye) and how the eye sees the movement. The position of the eye can be changed (with VX_{i-ref} and VY_{i-ref}). The velocity of the moving object can be changed with the bottom controls ($VX_{i-object}$ and $VY_{i-object}$)

A1: Change the position of the eye. Move it to different places. Click on play and observe how the eye sees the movement of the red object.

A2: Change the speed of the eye. Place it somewhere and change its VX and VY . Click on play and watch how the eye sees the movement of the red object (right-hand window).

A3: Change the speed of the red object. Click on play and watch how the reference system sees the movement.

E1: In your notebook, describe what happens when: a) the object moves at the same speed as the R.S., and b) they are moving in opposite directions with the same velocity.

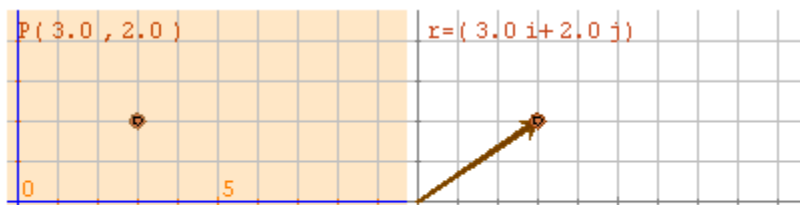
E2: In your notebook, describe what happens when: a) the object is moving at twice the speed of the R.S., b) the object and the R.S. are moving in opposite directions and the velocity of the R.S. is twice that of the object.

E3: In your notebook, describe what happens when the object is moving at the same velocity as the R.S., but they are moving in perpendicular directions. Repeat the descriptions changing the directions mentioned above to their opposites.

1.2 Coordinate axes are a reference system

Here you have two systems of Cartesian coordinate axes. They are usually used to situate the Reference system at its origin.

You can imagine that the eye in the previous visual is situated at the point (0,0)



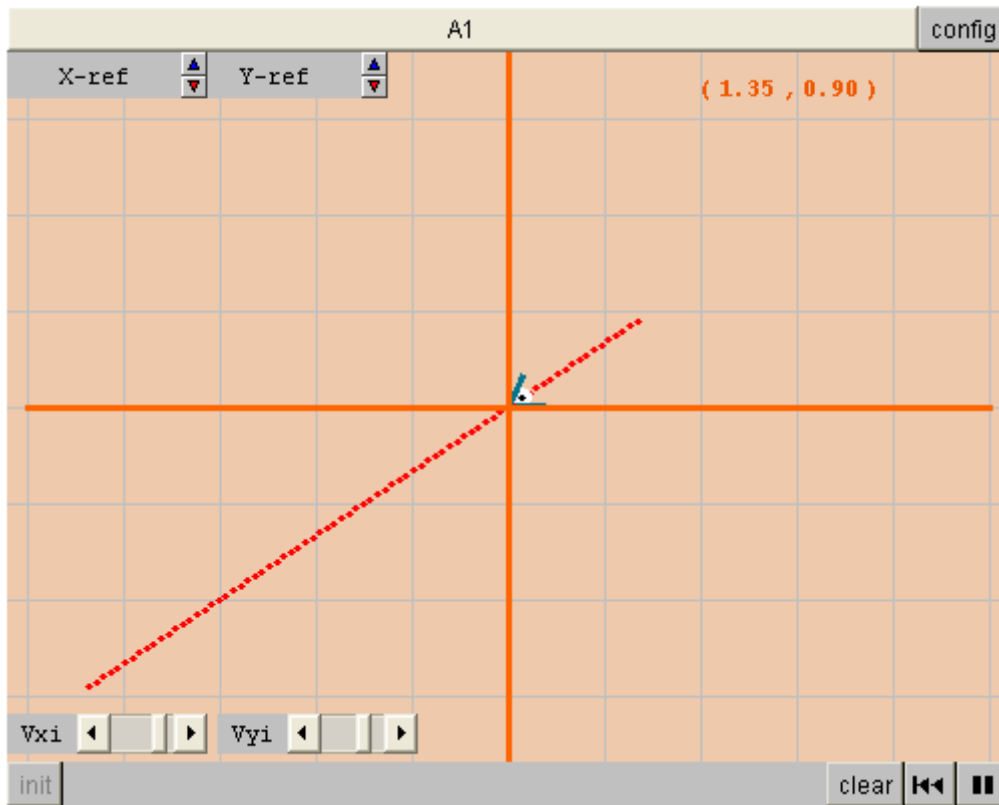
Two coordinates at a point on a plane

Move the brown circles and observe how the position of a point and of a vector are determined.

The reference systems do not have to be at the bottom of the page. Foll. page

Two coordinates or components: a vector on the plane

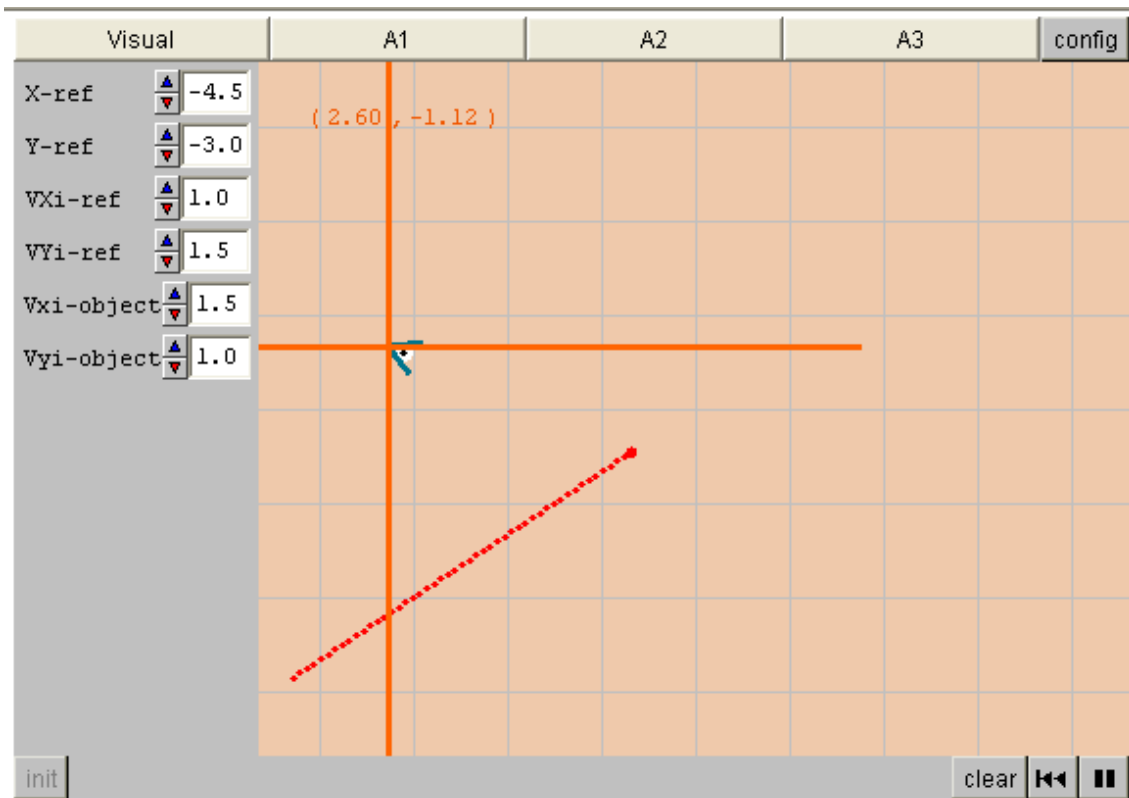
Reference systems are usually drawn in the centre or in the bottom left-hand corner of the page. This is just a convention. In the visual you can place the axes at different points and also change the velocity of the moving object. Try.



A1: Try to make the object move parallel to each of the axes

1.3 Reference systems may be moving

Everything in the universe is moving. So any reference system which we choose will also be moving. To simplify the problem at times we assume that the very distant stars are at rest.



VISUAL: This visual represents a reference system on two coordinate axes that you can place at different points. The reference system may be moving or still. There is a moving object whose position will depend on the position of the reference system and its velocity. If the movement is occurring where you cannot see it, you can drag the space.

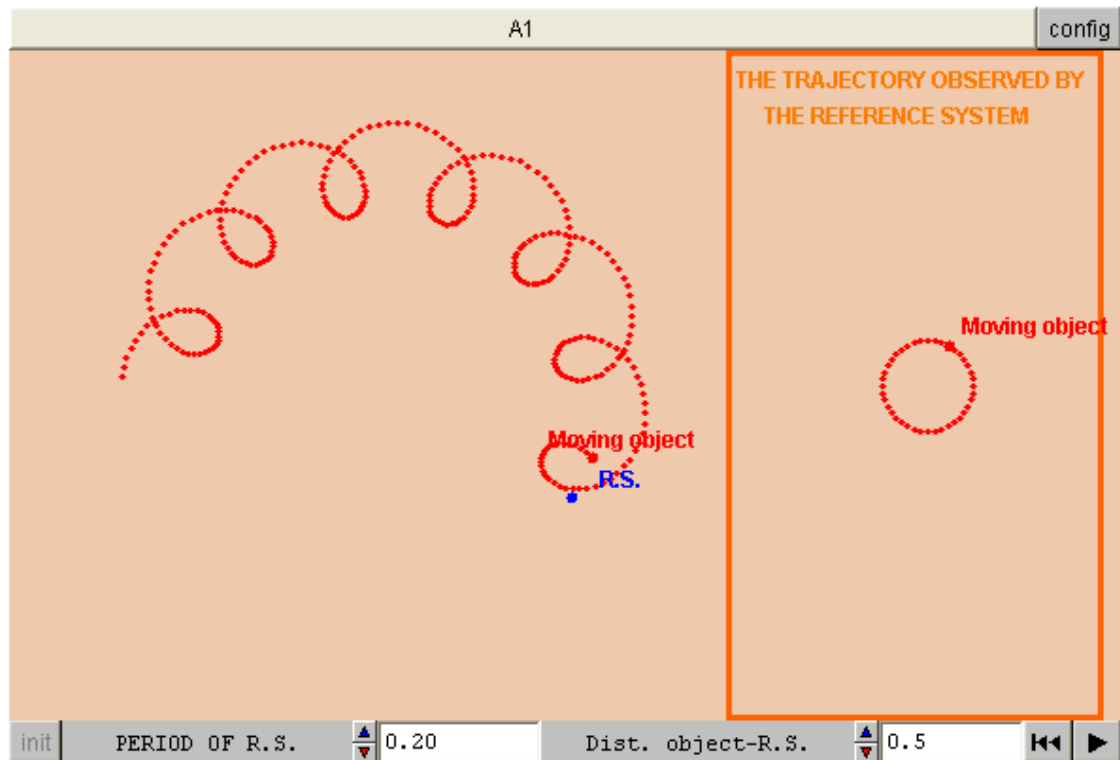
A1: Keep the reference system still. Modify its position and observe the change in the relative position of the moving object.

A2: Keeping the reference system still, choose different positions for it and change the speed of the object. Try different velocities. What happens when you change $V_{xi-object}$ and $V_{yi-object}$?

A3: Set the position of the reference system and modify the speeds of the object and the reference system. Pay special attention to the following situations: a) The reference system and the objects have equal speeds. b) The ratio of the speeds is 2, 0.5, etc.

1.4 The movement of the moon is very different according to the reference system used

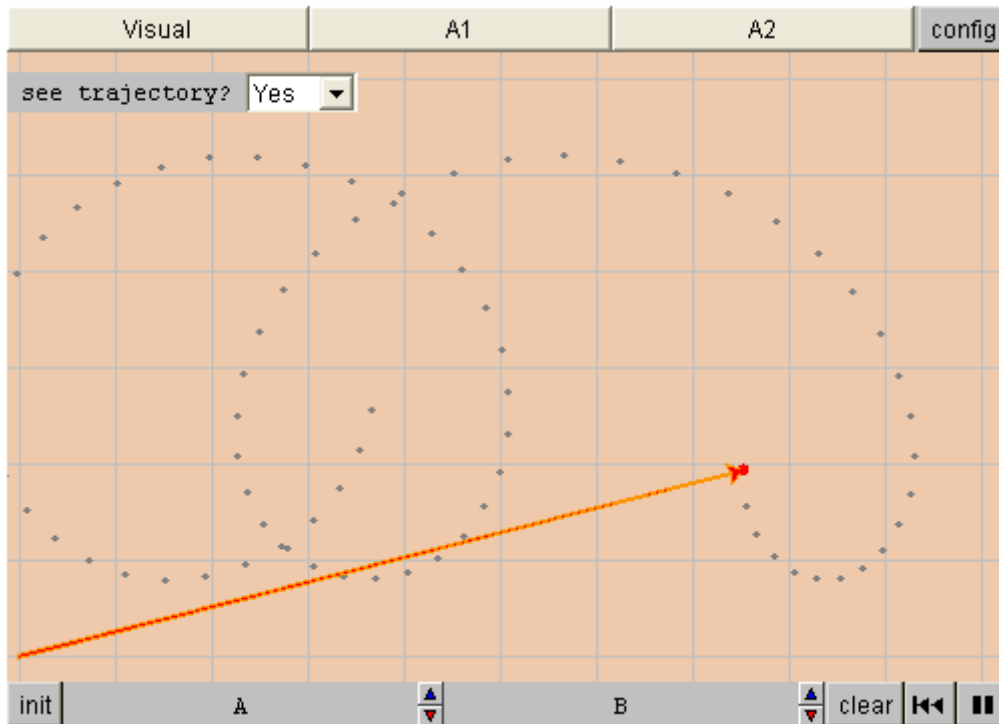
The movement of the moon around the earth is very different according to whether it is seen from the earth or the sun.



A1: Change the values of the controls and watch the movement as it is observed from the sun and from the earth.

2.1 Position and trajectory

The location of a point tells us about its movement. The trajectory tells us what path it has followed; however, these are not sufficient to completely describe a movement.



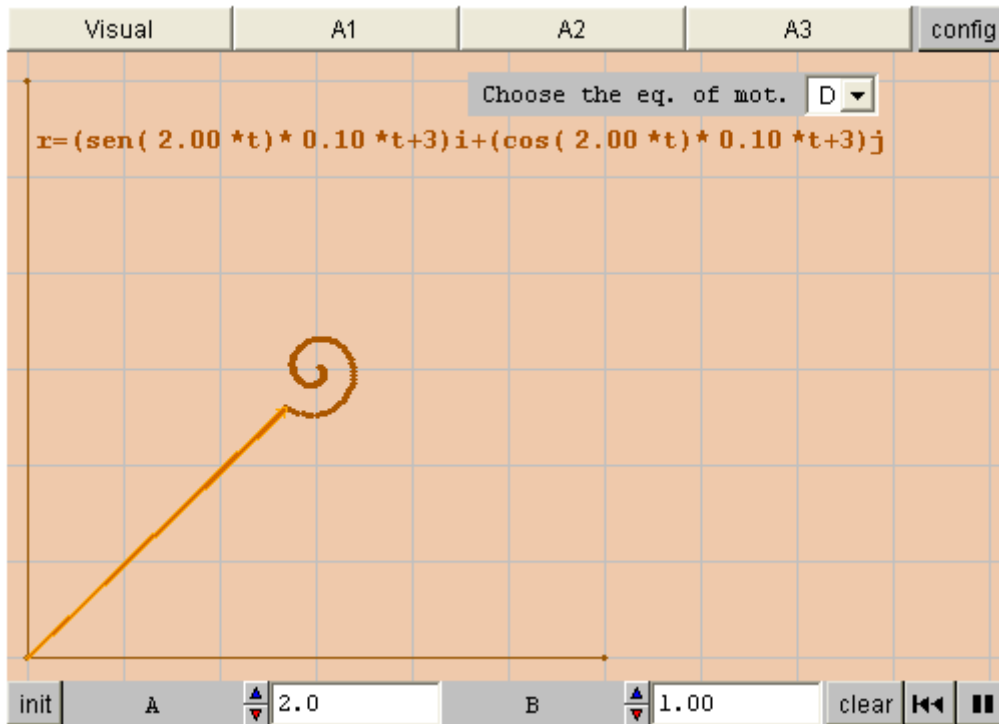
VISUAL: This visual represents the position vector of a moving object. You can choose whether or not to see its trajectory. You can also modify some of the parameters of the movement (A and B).

A1: Change the values of A (one of the controls at the bottom of the visual) and watch the changes in the movement. What is the effect of this control on the movement?

A2: Change the values of B (one of the controls at the bottom of the visual) and watch the changes in the movement. What is the effect of this control on the movement?

2.2 The equation of motion

The equation of motion of a body contains all the information about its movement: where it will be at any moment.



VISUAL: This visual lets you choose seven different equations of motion. You just have to choose one and click on play. The reference system is indicated by the coordinate axes. Use the clear button before you choose the next equation.

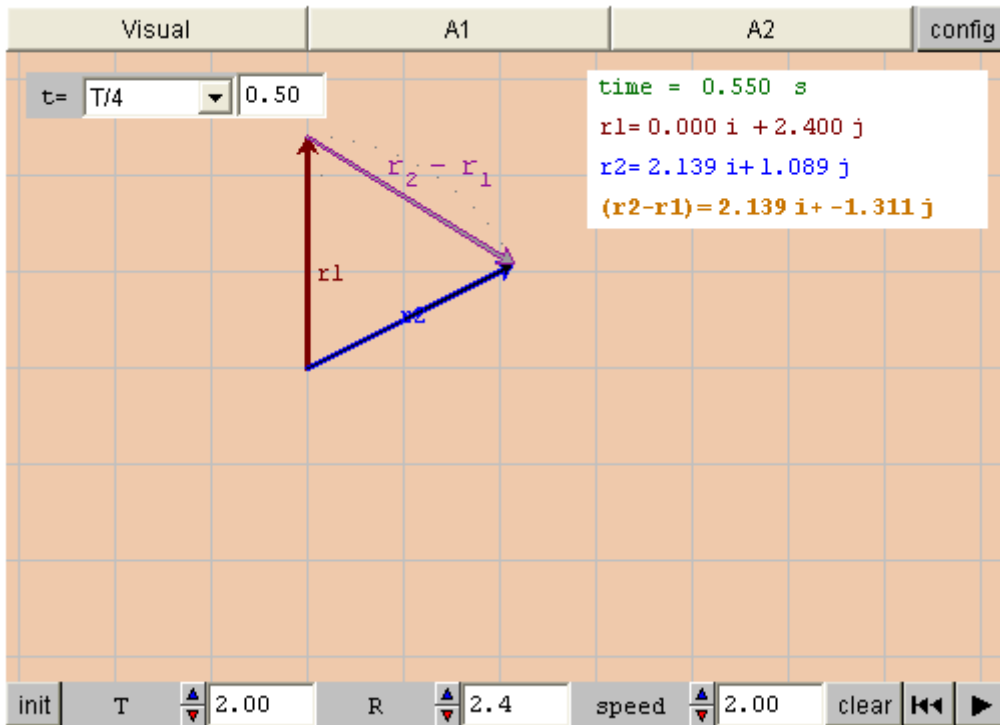
A1: When no equation of motion has been selected, you can see a simple one: a Uniform Rectilinear Movement. Identify the equation of motion. Change the value of the B control and watch what happens.

A2: Choose equation A. Watch this movement. Note that the origin of coordinates is at the point (0,0). Modify the parameters at the bottom of the visual and watch what happens.

A3: Observe the form of the equations for each movement. Modify the parameters with the controls at the bottom of the visual and watch what happens.

2.3 Displacement

The displacement vector between two instants is a vector which joins the initial position of the vector with its final one. The direction goes from the initial to the final one.



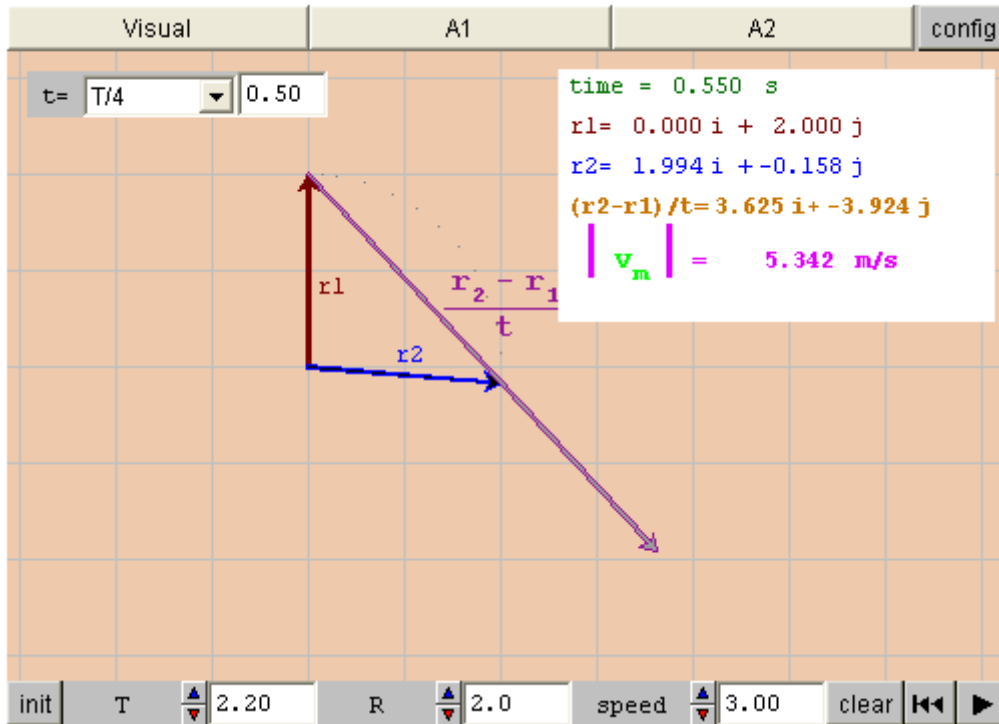
VISUAL: This visual represents a circular movement. You can select the duration of the movement (T , at the bottom of the visual). Then select T on the top menu. You can also select submultiples of T .

A1: Choose the duration of the movement. Then observe the displacement vector when $T/32$, $T/16$, $T/8$, $T/4$ and $T/2$ are selected.

A2: You can modify the radius of the circumference and the speed of the moving object. Observe the values of the displacement vector each time.

3.1 Average velocity

The average velocity vector between two points is the quotient of the displacement vector and the time elapsed.



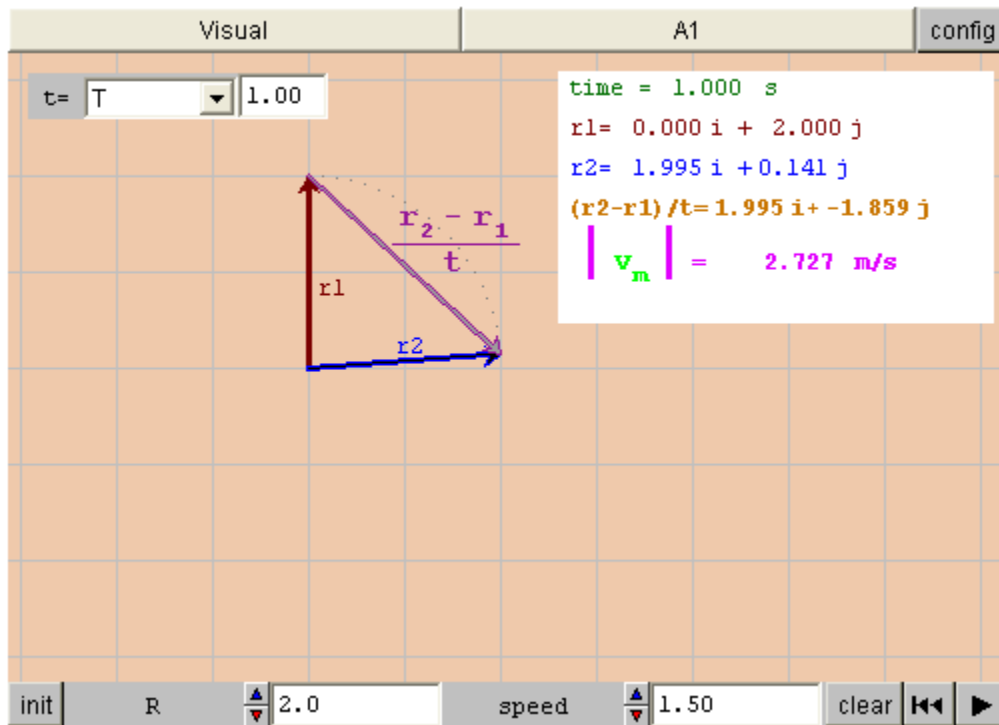
VISUAL: This visual represents a Uniform Circular Movement. You can compare the values of the displacement vector and the average velocity. First select a value of T on the control at the bottom of the visual and then select it on the drop-down menu.

A1: Having selected a value of T, choose different submultiples of T and observe the variation of the average velocity vector as time goes by.

A2: Why doesn't the average velocity vector reach r2?

3.2 Instantaneous velocity

Instantaneous velocity approaches the average velocity between two points which are very close together. In mathematical terms instantaneous velocity is said to be the limit of the quotient of the displacement vector and time, when time tends towards zero. It can also be said that instantaneous velocity is the derivative of the displacement vector with respect to time.

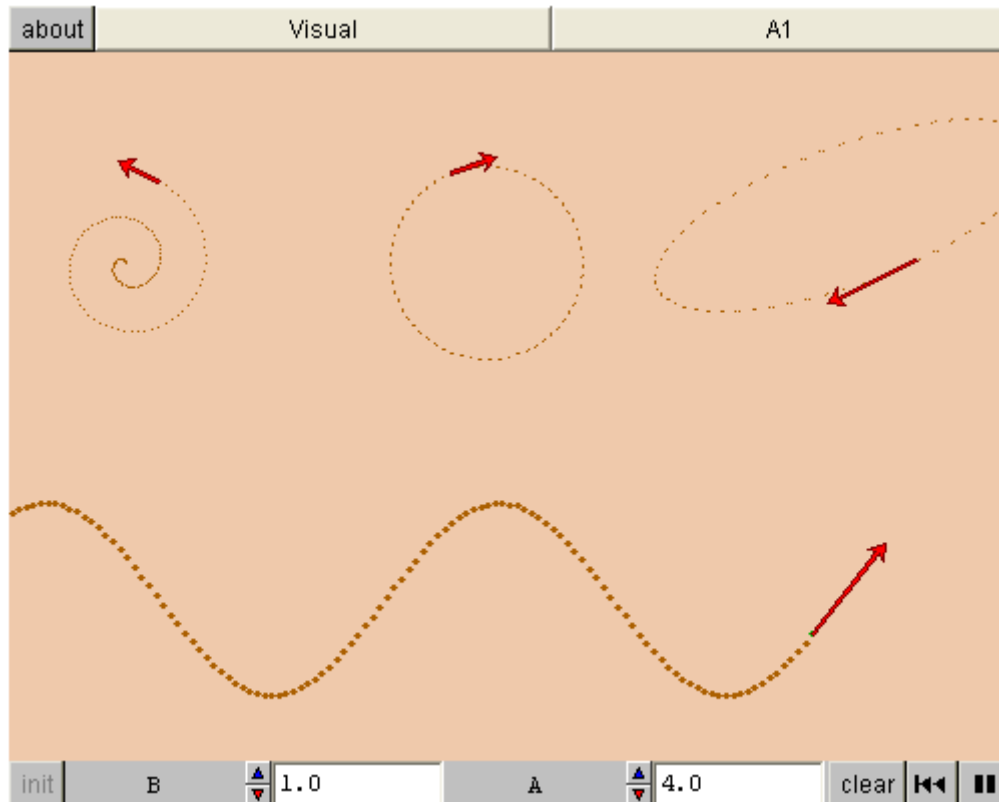


VISUAL: This visual represents the circular movement of an object that covers approximately one quarter of the circumference. You can change the speed and the radius of the movement.

A1: Choose a value for T and click on play. Then choose T/2, T/4, T/8 T/16 and T/32. Note that as time decreases, the value of the average velocity tends to remain constant and its direction tends towards a vector tangential to the trajectory.

3.2 Instantaneous velocity is a vector tangential to the trajectory

The instantaneous velocity vector can be easily calculated by working out the derivative of the displacement vector with regard to time. The result is a vector tangential to the trajectory in the direction of the movement.



VISUAL: This visual represents four different movements, each of them with its instantaneous velocity vector.

A1: Modify the values of controls A and B and you will change some of the parameters of the movements. Note that the velocity vector is tangent to the trajectory at each point.

Evaluation

Do you understand all the terms?:

Reference system, components of a vector, position vector and displacement vector?

Do you know the meaning of: the equations of motion, average velocity and instant velocity, and what displacement is?

Can you describe movements in vectorial terms?

Do you understand the concepts of average and instantaneous velocity and can you follow the "step at the limit of the visual where instantaneous velocity is defined"?

You can find out in the [Evaluation](#) >>>

Choose the right answer to each question

Movement (I)

Multiple choice test

1 When the A control is modified in [this visual](#)

- You can see the trajectory.
- the radius of the movement changes.
- the speed changes

2 In [this visual](#), when the object is moving in the same direction as the R.S. at twice the speed:

- The object moves slower in relation to the R.S. than if the R.S. were at rest.
- The object moves closer to the R.S. as time goes by.
- The object moves faster in relation to the R.S. than if the R.S. were at rest.
- The object moves more and more slowly in relation to the R.S. as time goes by.

3 In [this visual](#), you can place a point and a vector in two cartesian coordinate spaces. Which of these statements is FALSE?

- A point is determined by two coordinates that might be positive or negative.
- The unit vector along the y axis is called j and the unit vector along the x axis is called i.
- The unit vector along the y axis is called i and the unit vector along the x axis is called j.
- The position vector is determined by two components, each of them

has a numerical value. There is a unit vector along each axis.

4 When the time interval is very small,

- the average velocity in the interval is very small.
- The average velocity in the interval is approximately equal to the instantaneous velocity.
- The average velocity in the interval is very large.

5 In [this visual](#), it is possible to make the object travel along the y axis as fast as possible with the reference system at rest

- When x-ref: -4.4 y-ref: 0; vx-ref: 0, vy-ref:0; vx-object:0 and vy-object:2
- When x-ref: -4.4 y-ref: 0; vx-ref: 0, vy-ref:0; vx-object:2 and vy-object:0
- When x-ref: -4.4 y-ref: 0; vx-ref: 0, vy-ref:0; vx-object:2 and vy-object:2
- When x-ref: -4.4 y-ref: 2; vx-ref: 0, vy-ref:2; vx-object:0 and vy-object:2

6 In [this visual](#)

- The moving object represents the sun
- The moving object represents the earth
- The moving object represents the moon

7 In [this visual](#), it is possible to make the object travel along the x axis as fast as possible with the reference system at rest

- when x-ref: -4.4 y-ref: 2; vx-ref: 0, vy-ref:2; vx-object:0 and vy-object:2
- when x-ref: -4.4 y-ref: 0; vx-ref: 0, vy-ref:0; vx-object:0 and vy-object:2
- When x-ref: -4.4 y-ref: 0; vx-ref: 0, vy-ref:0; vx-object:2 and vy-object:2
- when x-ref: -4.4 y-ref: 0; vx-ref: 0, vy-ref:0; vx-object:2 and vy-object:0

8 In [this visual](#), when the R.S. and the object are moving at the same velocity: (there is more than one correct answer)

- The R.S. does not move in relation to the object
- The object does not move in relation to the R.S.
- The R.S. moves in relation to the object
- The object moves in relation to the R.S.

9 The $r = 3ti + 2j$ equation of movement in [this visual](#)

- represents the Uniform Movement of an object that moves along a curve.
- represents the Uniformly Accelerated Movement of an object that is travelling parallel to the x axis
- represents the Uniform Movement of an object that moves along an ellipse
- represents the Uniform Movement of an object that travels parallel to the x axis

10 In [this visual](#), when the R.S. and the object are moving in opposite directions: (there is more than one correct answer)

- The R.S. moves faster in relation to the object than if it were at rest.
- The object moves slower in relation to the R.S. than if the R.S. were at rest.
- The R.S. moves slower in relation to the object than if it were at rest.
- the object moves faster in relation to the R.S. than if the R.S. were at rest.

11 As the time interval in [this visual](#) decreases

- The displacement vector decreases.
- The displacement vector remains constant.
- The displacement vector tends to be perpendicular to the trajectory.
- the displacement vector becomes larger.

12 In [this visual](#), the object does not move parallel to the coordinate axes in only one case:

$v_x \neq 0$ y $v_y = 0$

$v_x = 0$ y $v_y \neq 0$

$v_x \neq 0$ y $v_y \neq 0$

13 To determine the movement of an object completely

it is enough to know its velocity.

it is enough to know its equation of motion.

It is enough to know the trajectory.

it is enough to know the value of the displacement vector at each moment.

14 The displacement vector between two points of a trajectory

can point from the second point to the first point or the other way round depending on the shape of the trajectory.

always points from the second point to the first point.

always points from the first point to the second point.

15 In [this visual](#), when the object is moving at the same speed as the R.S. but their directions are perpendicular,

the R.S. sees the object move away in the same direction.

the R.S. sees the object come towards it or move away in a different direction.

the R.S. sees the object move away in a different direction.

the R.S. sees the object come towards it or move away in the same direction.