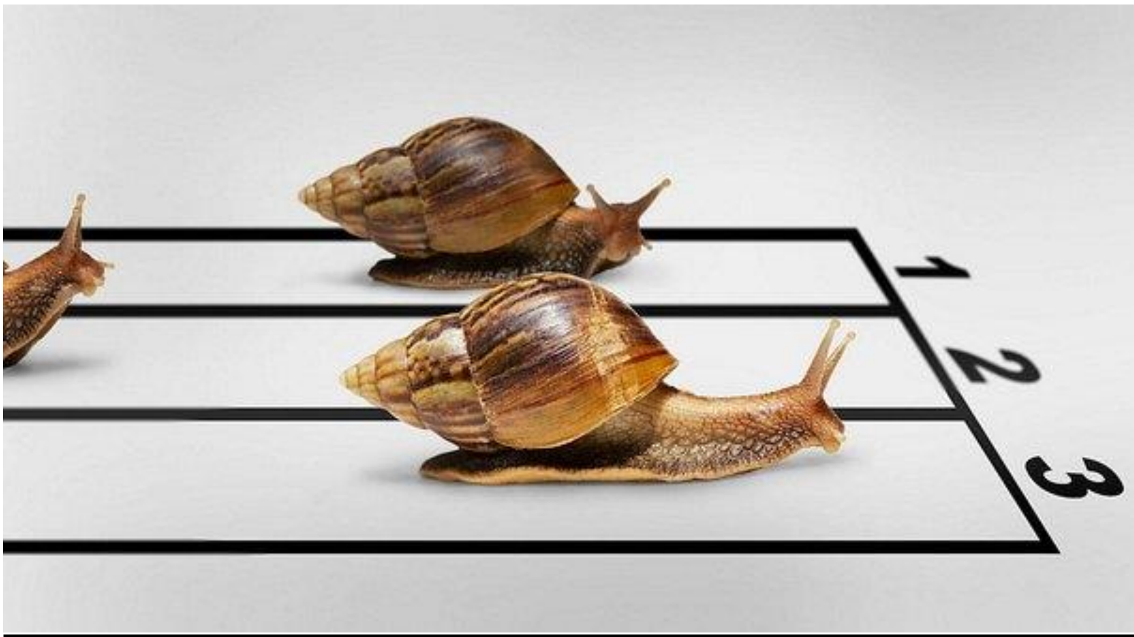
MOTION

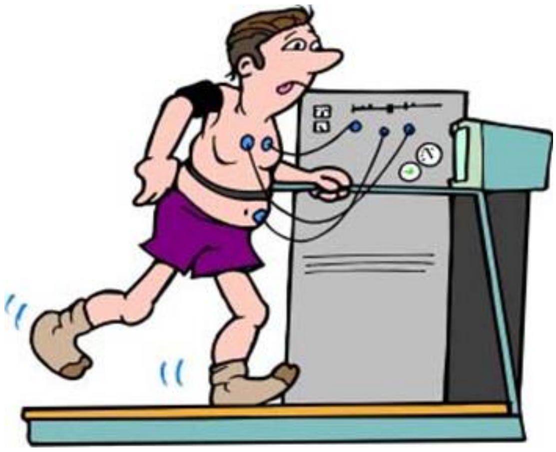


1. WHAT IS MOTION?

It seems a silly question because everyone knows if something moves or not, but in the History of Physics it has taken centuries to establish a right criterion to know if something moves or not. Someone as intelligent as the Greek philosopher Aristotle thought that the Earth was completely at rest. However, today we know that it moves at a velocity of about 30 km/s around the Sun; and the whole Earth-Sun moves around the center of our galaxy, the Milky Way, at an incredible velocity: 220 km/s. All of us are now travelling to these enormous velocities!

Pay attention: Why don't we perceive this velocity?

A.1. Write down the meaning of «motion» for you.



A.2. A person is running on a treadmill. Do you think he is moving?

A.3. Is our class moving now? Think about the question carefully before answering.

A.4. Look at the picture above and answer the following questions:

a) Do people move relative to themselves?

b) Do they move relative to the ground?

c) In summary, do they move or not?

To know if a body is moving or not, you always have to set a reference (we call this reference system, RS). We say that a body moves if it changes its position on this reference system. We say that a body is at rest if it does not change its position on this reference system. Without a reference system we can not know if something moves or not.

A.5. Have you ever been on a train (or bus) with other trains (or buses) on both sides and believe that you move when in fact you don't? Why can this curious phenomenon happen? What conclusion can you give?

A.6. In this incredible video you can see 164 parachutists beating the world record in free fall formation (in 2015).

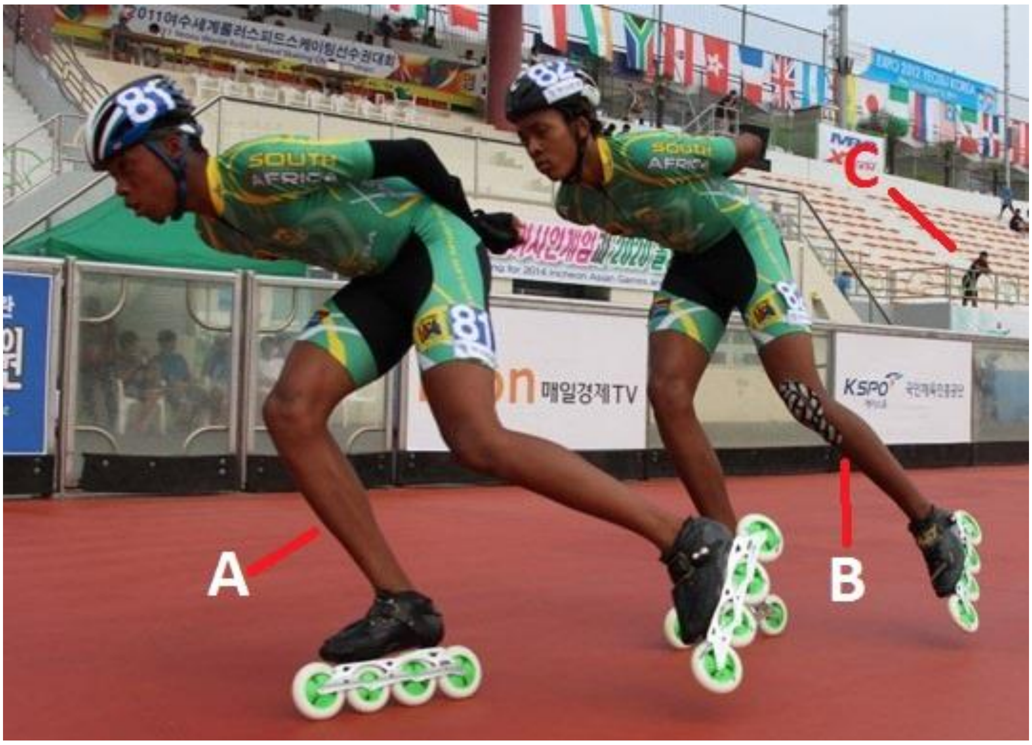
a) At specific time of the video they seem at rest despite being falling at high velocity. Why?

b) In other moment the plane seems to be moving from the point of view of parachutist. Why is that?

A.7. In this video you can see a skier coming down from the top of a mountain.

a) Why are the trees the ones that move?

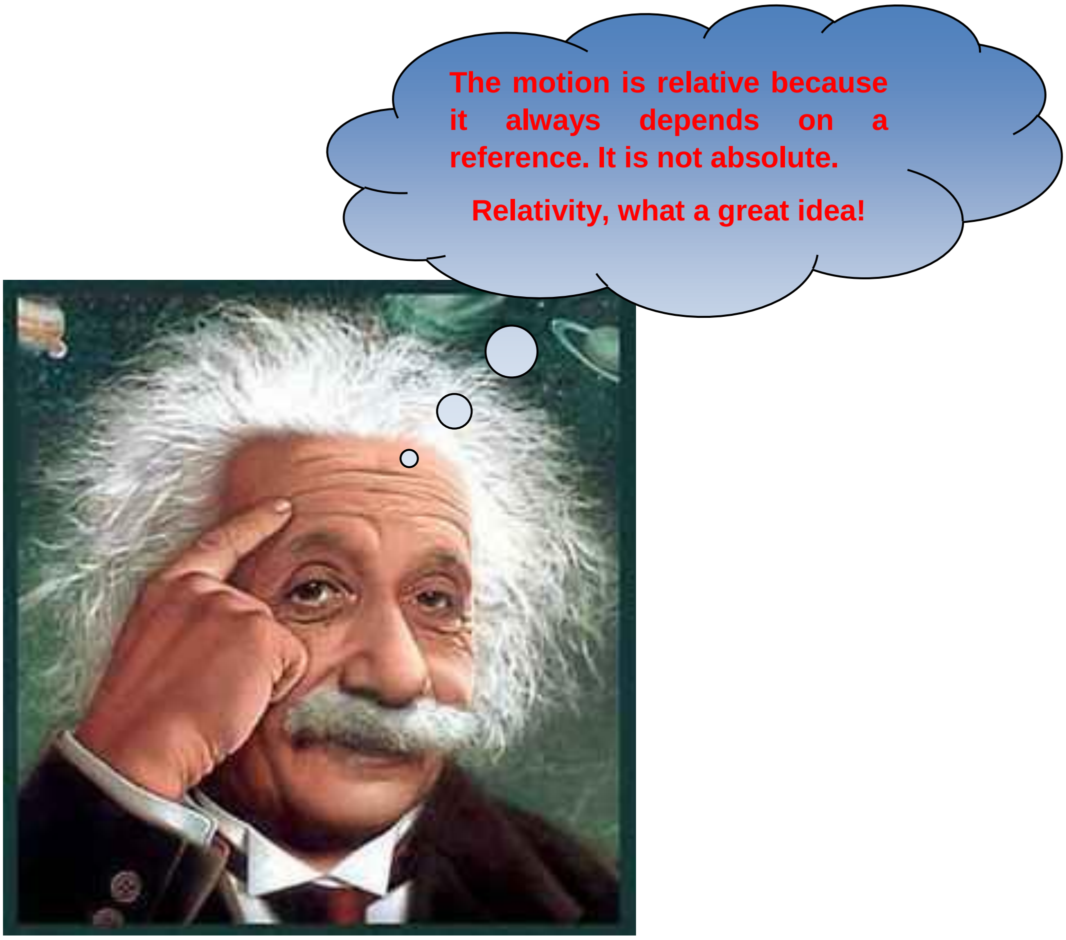
b) At the end of the video it is the sky the one that moves. Why is that?



A.8. In the picture above you have two skaters, **A** and **B**, which are maintained at the same distance walking track; there is also an observer **C** looking at what happens in the race. Complete the following table of statemens about this situation indicating if they are **true** or **false**.

Clue: Imagine yourself in the position of the reference system and see what happens from there.

	T	F
1. The observer C moves relative to harrow.		
2. The A skater is at rest relative to the skater B.		
3. The observer C moves relative to the Sun.		
4. The Sun is at rest relative to the skater B.		
5. The A skater moves relative to the floor of the track.		
6. The track moves relative to the observer C.		
7. The track moves relative to the skater A.		
8. The track is at rest relative to the skater B.		
9. The skater B moves relative to the harrow .		
10. The observer C moves relative to the skater A.		



2. TRAJECTORY

We define the trajectory of a body as the line connecting all positions occupied by mobile.

A.9. The trajectories can be regular (circular, elliptical, parabolic, straight, etc.) or irregular. Make a draw and classify the following trajectories:

a) A fly during a day.

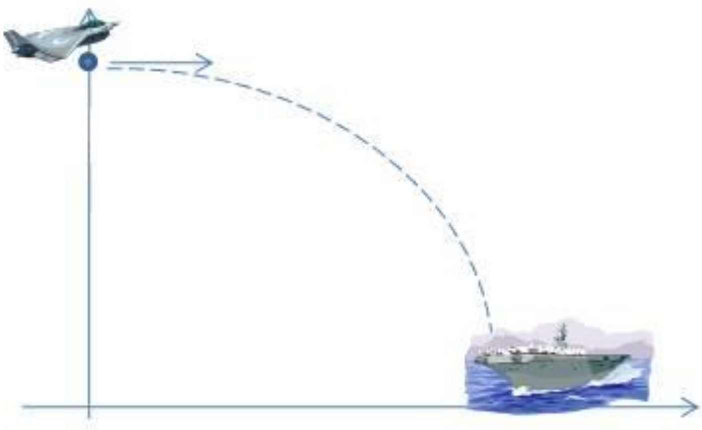
b) A cab of the wheel in the port of Málaga.

c) A ball in a triple in a basketball game.

d) An athlete in a 100-meter race.

e) The Earth revolving around the Sun.

A.10. Do you think the trajectory is an absolute or relative concept? Explain your answer.



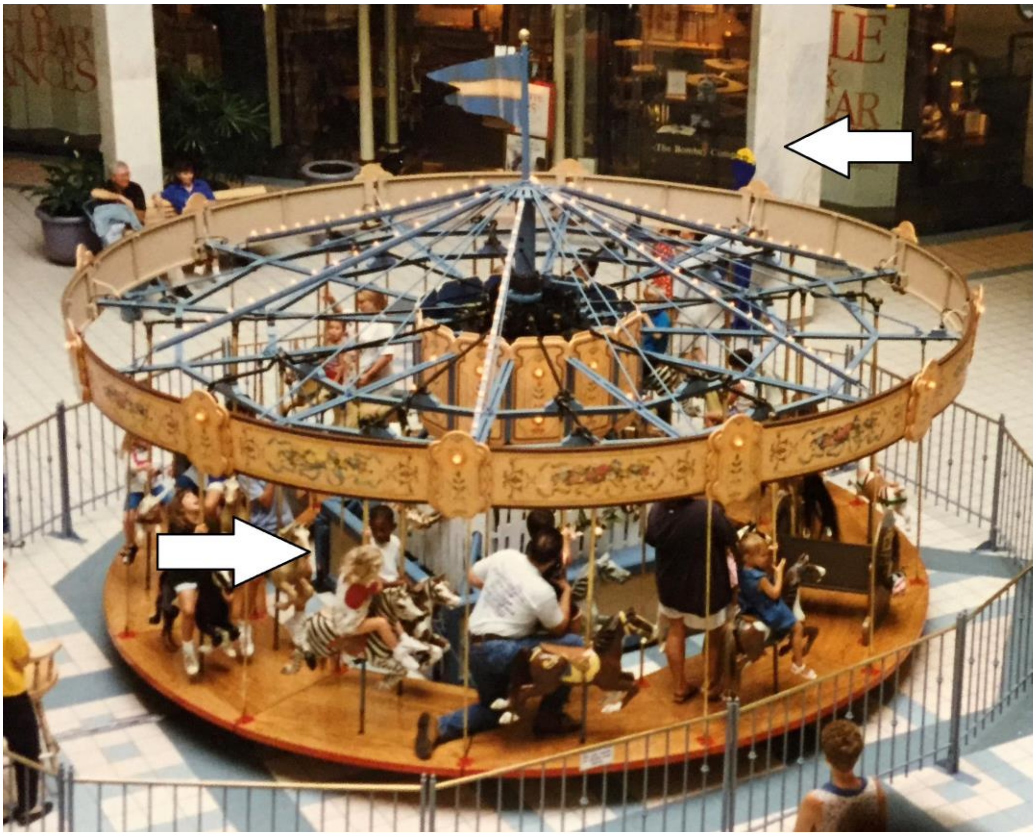
A.11. How is the trajectory of a bomb dropped from a plane to an aircraft carrier?

a) From a **RS** placed in the plane.

b) From a **RS** located on the aircraft carrier.

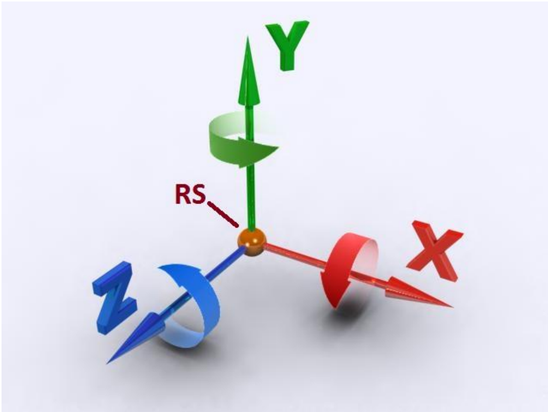
You can check your answer in the following link.

Challenge for the most curious students: **A person goes from the center to a carousel until a horse in the end, while the carousel rotates. How can you see the trajectory from a RS located in the center of the carousel? How can you see it from a RS located on the top floor, outside the carousel?**



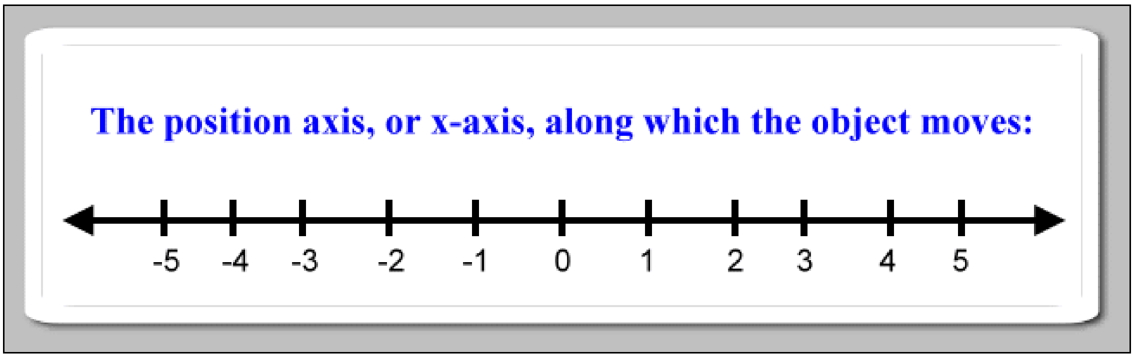
3. POSITION AND DISTANCE TRAVELLED

A.12. Imagine a street or road where you have a car accident. Phone the crane and you must give your position. How do you do it? In general, what needs to be done to determine a position in a line (one dimension), in a plane (two dimensions) and in space (three dimensions)?

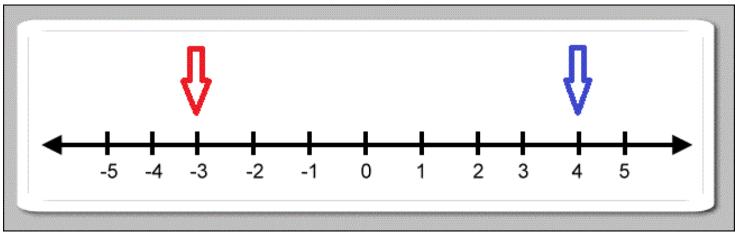


To determine a position on a line is enough to establish a RS and give a coordinate from it (e.g. X). For a plane need an RS and two coordinates (e.g. X and Y). And for space an RS and three coordinates (e.g. X, Y, Z).

To facilitate the study of motion, only we work on one line. The position of a mobile will be the X coordinate at which you are located. For the position we use the symbol e.



A.13. In the draw below indicates the positions of the red and blue arrows.

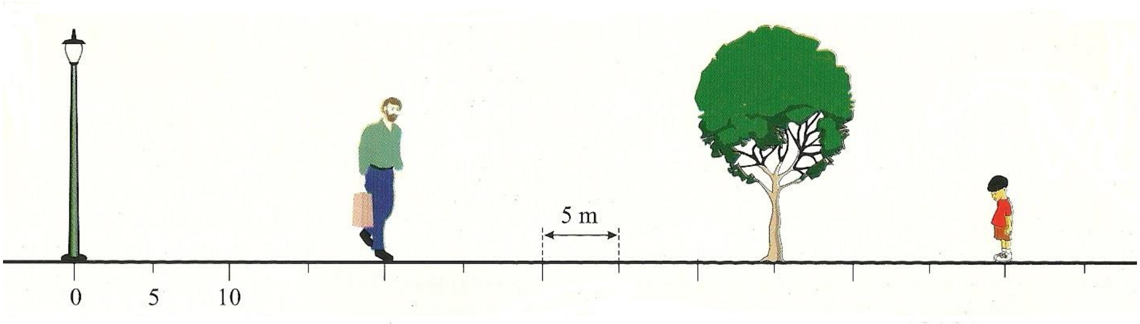


A.14. Calculate the distance if we move from the red postion to the blue one (coordinates are in meters). Perform the same calculation for the reverse displacement (from the blue position to the red one).

In general, we calculate the distance, d, with the following formula:

d = ef - ei

By applying the formula, a positive distance means that the displacement was made to the right and a negative result means that we have moved to the left.



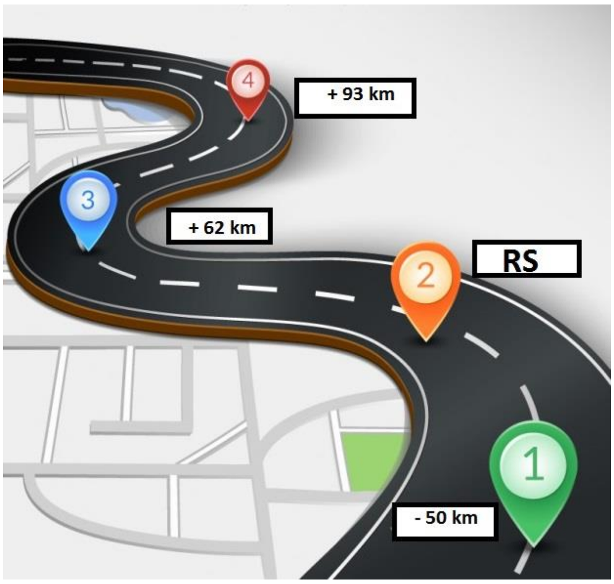
A.15. In the picture above:

a) What object is the **RS**?

b) Indicate the position of the person, the tree and the child relative to the **RS**.

c) What distance does the person travel to the tree?

d) What distance does the child travel to the tree?



A.16. Considering the picture above answers the following questions:

a) What does it mean that a vehicle is at kilometer 93 of the A-92 highway?

b) Can you know the distance travelled with only that data?

c) What distance does a car travel from position **4** to **1**?

d) What about from position **3** to **4**?

4. VELOCITY

Everyone has an intuitive idea of velocity. Another thing is that we know how to explain and to express it as mathematical formula to operate in situations that happen in everyday life. Our first goal is to establish the mathematical notion of velocity.

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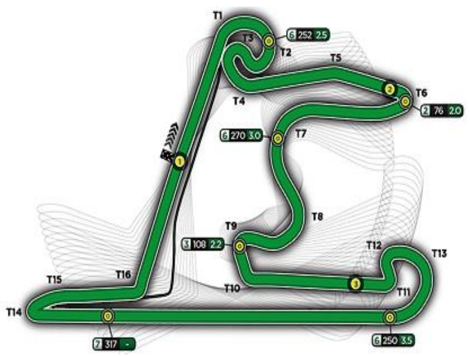
The Jerez Circuit

The Shanghai Circuit



A.17. Look for information on the Internet about the length of the circuit of Jerez (Spain) and Shanghai (China) and answer the following questions:

a) Two Formula 1 cars take exactly the same time on both circuits. Which one is faster?

b) If the time taken is the same, what is the general relationship between velocity and distance?

c) Two Formula 1 cars travel the Jerez circuit and one takes more time than the other. Which one is faster?

d) If the distance is the same, what is the general relationship between velocity and the time invested?

In general, we calculate the velocity using the following formula (which summarizes the above conclusions):

$$v = \frac{distance\ traveled}{time\ spent}$$

By using this formula we can see that the unit in which we measure the velocity in the International System of Units is m/s. Although, in daily life, normally we use the unit km/h.

A.18. a) What does mean a velocity of 1 m/s?

b) What does mean a velocity of 10 m/s?

c) What does mean a velocity of 1 km/h?

d) What does mean a velocity of 7 km/h?

e) Can you convert 1 m/s into km/h?

f) Convert 120 km/h into m/s. At this velocity you have a cluelessness that lasts 1 s; how many meters do you travel without seeing where you're going?

g) The velocity of sound is 340 m/s. When an aircraft exceeds this velocity a crash occurs. Expressed in km/h the velocity at which this occurs (aircraft pilots call this velocity **Mach 1**).

h) A military aircraft in 2013 reached **Mach 5** velocity. If the pilot of that plane has a cluelessness that lasts 1 s; how many meters does he travel without seeing where he's going?

A.19. The peregrine falcon is the fastest air animal; sailfish in water; and the cheetah in land. Knowing that the peregrine falcon in horizontal flight reaches the 145 km/h; the sailfish is able to move in the water at 30 m/s; and that the cheetah can run 100 meters in 3,23 s, order these amazing and beautiful animals from the highest to the lowest velocity.

A.20. The car **A** leaves Málaga at an average velocity of 80 km/h to Granada. The car **B** leaves Casabermeja half an hour later at a velocity of 120 km/h to the same destination. Calculate what car will arrive first (the distance Málaga-Granada is 126 km and Malaga-Casabermeja is 22 km).

Does the fastest car always arrive first? What other factors may influence this situation?

A.21. In the above situation we talked about average velocity. Do you think both cars always go at the same velocity? What difference can we find between average and instantaneous velocity?

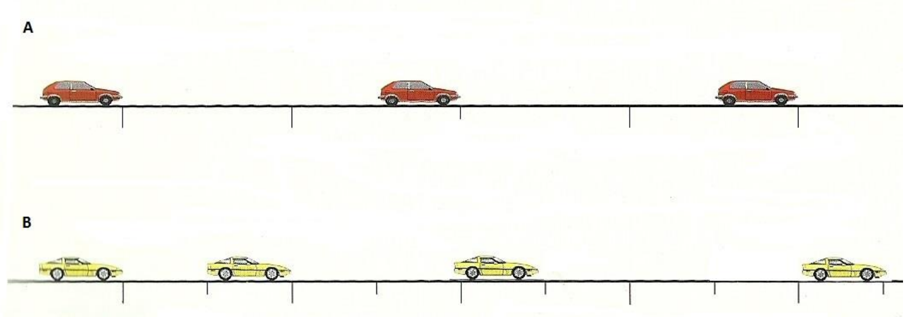
A.22. In the next chart you can find the position data versus time of two cars, **A** and **B**, moving along the same road. Calculate the average velocity of both in each part of the course and answer the following questions:

a) How does the velocity change in each case? What is the main difference?

b) Do you think you have the same kind of motion? Why?

c) What happens to the distances travelled in equal times in both motions?

Position of car A (m)	0	2	4	6	8	10
Position of car B (m)	0	0,5	1,5	3	5	7,5
Time (s)	0	1	2	3	4	5



5. ACCELERATION

In uniform motions velocity remains constant and therefore equal distances are covered in equal times. However in accelerated motions velocity can change (increase or decrease), so the distances travelled also can change.

To describe and calculate accelerated motions we will introduce a new concept: acceleration.

A.23. To accelerate from 0 to 100 km/h the car **A** spends less time than other car **B**. Which one accelerates more? While the car **C** goes from 0 to 100 km/h at a given time, the car **D** reaches a higher velocity at the same time. Which one accelerates more? What general conclusions can you reach about acceleration? What factors influence on acceleration?

In general, we calculate the acceleration with the following formula (which summarizes the above conclusions):

$$a = \frac{change\ of\ velocity}{time\ spent}$$

Where the velocity change can be calculated as $\Delta v = v_f - v_i$, and the time spent in that change can also be expressed as $\Delta t = tf - ti$, if we know the velocities in two times given.

Using that formula the unit in which we measure the acceleration in the International System of Units is m/s^2.

A.24. a) What does an acceleration of 1 m/s^2 mean?

b) What does an acceleration of – 1 m/s^2 mean?

c) What does an acceleration of 5 m/s^2 mean?

d) What does an acceleration of – 5 m/s^2 mean?

e) The acceleration of free fall is 10 m/s^2. According to this information you can complete a table with the velocity that a parachutist reaches, who is pulled from a plane in the first 10 s of free fall (we assume that the air does not influence).

f) Which system do you think is more accelerated, the AVE that goes from 0 to 270 km/h in 10 minutes or a cyclist who goes from 0 to 30 km/h in 10 s?

g) Can a person accelerate more than the AVE? And achieve more velocity? Can a person keep the acceleration more time than the train?

A.25. A research published in the scientific journal Nature, reports that the cheetah reaches accelerations of 13 m/s^2 (this high acceleration, according to this research, is the best weapon for survival in this animal). Given that a Formula 1 car can reach the speed of 200 km/h in a time of 5,5 s, calculate if it accelerates more or less than the cheetah.

6. GRAPHIC REPRESENTATION OF THE MOTION

A.26. In the following chart you can find the position data versus time of three cars, **A**, **B** and **C**, moving along the same road. Represent the data of the three motions in a graph position (Y) versus time (X) and answer the following questions:

a) What kind of movement do the three cars have? Is there any car with acceleration?

b) What is the difference between the motions of the cars **A** and **C**? What is the meaning of the cutoff point of the graph with the axis position (Y)?

c) What is the difference between the motions of the cars **A** and **B**? What does the slope of the graph position/time mean?

d) What happens at time t = 2 s between cars **B** and **C**?

e) Do you think that if any of these cars accelerate the shape of the graph position/time would remain?

Position of car A (m)	0	2	4	6	8	10
Position of car B (m)	0	3	6	9	12	15
Position of car C (m)	2	4	6	8	10	12
Time (s)	0	1	2	3	4	5

A.27. In the next chart you can find the position data versus time of a car that falls down freely along a sloping street. Represent the data in a graphical position/time. What conclusions can you reach about the kind of motion that has the mobile?

Position of the car (m)	0	0,5	2	4,5	8	12,5
Time (s)	0	1	2	3	4	5

Uniform motion presents a graphical position/time as a straight line. This is because in this kind of motion always equal distances are covered in equal times. The point of intersection with the Y axis of the graph means the initial position of the mobile. The slope of the graph reports about mobile velocity.

The accelerated motion (let's assume that the acceleration is always the same) presents a graphical position/time as a parabolic curve. This is because in this type of motion the distance increases more and more as time goes by.

A.28. The following graph shows the motion of two cars **A** and **B**. Answer the following questions:

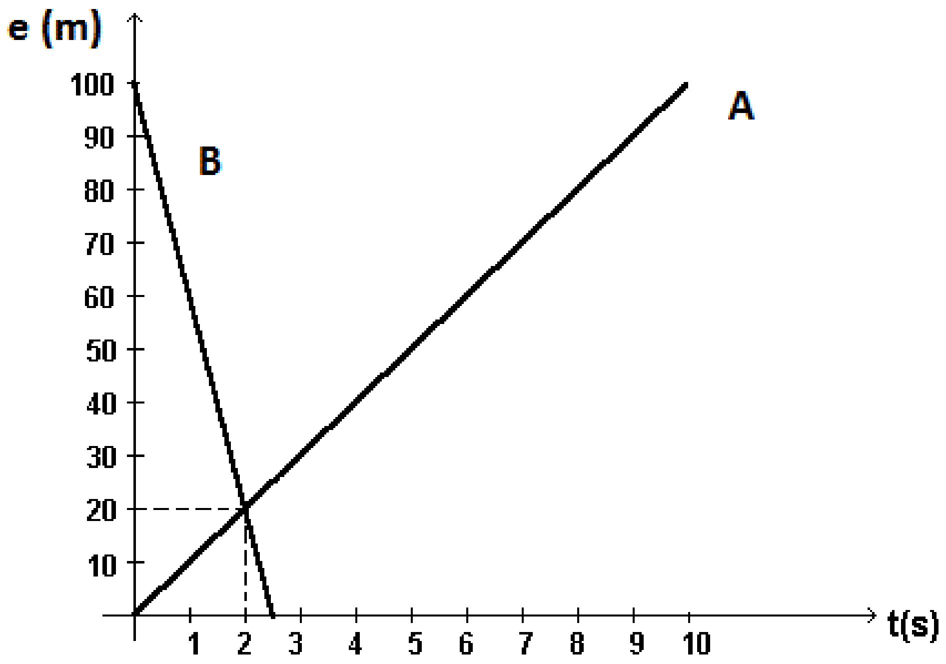
a) What is the kind of motion in both? Why?

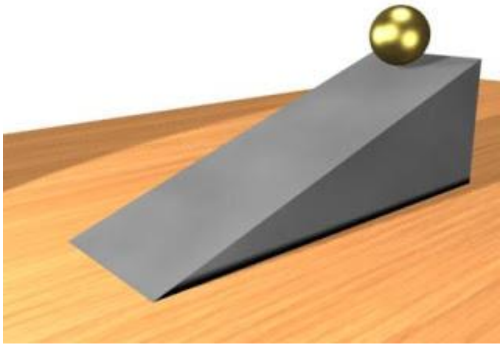
b) What are the differences between the motion of both?

c) What car has more velocity? Answer this question without making calculations.

d) Calculate the velocity of both.

e) What happens at time t = 2 s?





A.29. The above figure represents the fall of a marble on an inclined plane. Let's do a **little research** on this system working in group. Perform with your teammates the following activities:

a) Make a hypothesis about the kind of movement that you think will have the marble.

b) Design an experiment to check if your hypothesis is correct.

c) Perform the experiment and present data in a table and also in a graph.

d) Give a conclusion about your hypothesis.

e) Communicate your results using an experimental investigation report.

7. SUMMARY

A.30. Try to make a mind map that summarizes the previous unit.

8. EDUCATIONAL RESOURCES ON THE INTERNET

- Motion simulator giving starting position, velocity and acceleration, for two different cars.
- Video with simulated motions and their graphic representation.
- Graph with questions about accelerated motions.

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APPENDIX 1: GENERAL VOCABULARY OF THE UNIT

APPENDIX 2: SPECIFIC VOCABULARY OF THE UNIT