Activity worksheet: free fall and projectile motion

Name	Group	Date

What you will learn

With the free fall and projectile motion simulation you will drop and throw objects on Earth, with and without air, and on the Moon. You will find out whether heavy objects fall faster than light ones, what happens to the velocity and the acceleration at the highest point and why a ball launched horizontally and another one dropped at the same time reach the ground together.

How to work. Each activity has three steps:

1. **Predict.** Before looking at the simulation, write down what you think will happen and why.
2. **Observe.** Set up the simulation, watch what happens and note down the data.
3. **Explain.** Compare what happened with your prediction and explain why.

If your prediction turns out to be wrong, don't rub it out: getting it wrong and understanding why is the best way to learn.

Each activity has a link that opens the simulation already set up. If you have the worksheet on paper, go to **simulaciencia.es/en/simulations/caida-libre** and set it up as described under “Set up the simulation”.

How to read the data. Press “Launch” to start. The object leaves a trail of dots, one every 0.2 s: if the dots get further apart, it is going faster and faster. The blue arrow is the velocity and the orange one, the acceleration. The “Motion data” drop-down gives the time, position and velocity and, at the end, the launch results. With “×0.25” everything goes four times slower, and with the − and + buttons under “Instant” you can move forwards or backwards one dot at a time.

Before you start

What do you think now? Write T (true) or F (false). You will come back to this table at the end.

Statement	T or F
a) If there were no air, a steel ball would reach the ground before a feather.	
b) When you throw a ball upwards, its acceleration at the highest point is zero.	
c) A ball thrown upwards comes back to your hand with the same speed it left with (without air).	
d) A ball launched horizontally takes longer to reach the ground than another one dropped at the same time from the same height.	
e) In projectile motion, the velocity at the highest point is zero.	

Activity 1. Do heavier things fall first?

Set up the simulation: Vertical mode, a feather and a steel ball from 45 m, **with air**. Open the simulation ready to use

Predict. Which one will reach the ground first? And if we take the air away?

My prediction

Observe. Press “Launch”. Then untick “With air” and launch again. Finally, without air, change the place to the **Moon**.

Case	Time for the steel ball (s)	Time for the feather (s)
Earth, with air		
Earth, without air		
Moon		

Explain. What makes the feather fall more slowly in the classroom? Does the time of fall depend on the mass when there is no air?

My explanation

Activity 2. Does it always fall at the same speed?

Set up the simulation: Vertical mode, steel ball from 45 m, without air, one dot every 0.2 s. Open the simulation ready to use

Predict. How do you think the trail dots will be spaced: evenly, closer and closer together or further and further apart?

My prediction

Observe. Launch and note down the final data under “Launch results”. Use the − and + buttons to read the velocity at a few instants.

Time (s)	0	1.0	2.0	3.0
Velocity (m/s)				

Time of fall (s)	Velocity on landing (m/s)

Explain. How much does the velocity increase every second? Check the time of fall with $h = ½ \cdot g \cdot t^2$ and the velocity with $v = g \cdot t$ ($g = 9.8$ m/s²).

My explanation and calculations

Activity 3. Up and back down again

Set up the simulation: Vertical mode, from the ground at 20 m/s upwards, with **Pause at maximum height**. Open the simulation ready to use

Predict. At the highest point, what are the velocity and the acceleration? At what speed will it come back to the ground?

My prediction

Observe. Launch. When it stops at the top, look at the arrows and the data. Then press “Resume”.

Question	What I observe
Maximum height (m) and time to get there (s)	
Velocity at the highest point	
Direction of the acceleration at the top	
Direction of the velocity and of the acceleration while it goes up	
Time of flight (s) and velocity on reaching the ground (m/s)	

Explain. Why does the ball slow down while it goes up? Check the maximum height with $h = v_0^2 / (2 \cdot g)$.

My explanation

Activity 4. The graphs of the throw

Set up the simulation: the same throw, with the **Graphs**. Open the simulation ready to use

Predict. Sketch what you think the velocity–time graph will look like, from the moment it leaves until it is back on the ground.

My prediction

Observe. Launch and look at the two graphs.

Question	What I observe
Shape of the position–time graph	
Shape of the velocity–time graph	
Instant when the velocity is zero (s)	
Does the slope of the line change going up and coming down?	

Explain. Work out the slope of the velocity–time graph. Which quantity is it?

My explanation

Activity 5. Launched and dropped at the same time

Set up the simulation: Projectile mode, horizontal launch from 20 m at 10 m/s, with **Drop another ball at the same time** and the **Projections**. Open the simulation ready to use

Predict. One ball leaves horizontally and the other is dropped at the same instant. Which one will reach the ground first?

My prediction

Observe. Launch at "×0.25" and watch the two "shadows" of the launched ball, one on the ground and one on the vertical axis.

Question	What I observe
Time for the launched ball and for the dropped one (s)	
How are the dots of the shadow on the ground spaced?	
How are the dots of the shadow on the vertical axis spaced?	

Question	What I observe
Distance at which the launched ball lands (m)	

Explain. What kind of motion does the ball have horizontally? And vertically? Does one affect the other?

My explanation

Activity 6. The highest point of an angled launch

Set up the simulation: Projectile mode, from the ground at 20 m/s and 45°, with **Pause at maximum height**. Open the simulation ready to use

Predict. What will the velocity be at the highest point?

My prediction

Observe. Launch. At the pause, look at the arrows and the data. Then resume and note down the results.

v_x at the top (m/s)	v_y at the top (m/s)	Maximum height (m)	Time of flight (s)	Range (m)

Explain. Why is the velocity zero at the top of a vertical throw but not here? Has v_x changed during the flight?

My explanation

Activity 7. Which angle goes furthest?

Set up the simulation: Projectile mode, from the ground at 20 m/s, with **Keep previous trajectories**. Open the simulation ready to use

Predict. Which angle will go furthest? Will there be two different angles that land at the same place?

My prediction

Observe. Launch at the angles in the table. Then tick “With air”, choose the tennis ball and repeat at 35°, 40° and 45°.

Angle	15°	30°	45°	60°	75°
Range without air (m)					

Angle	35°	40°	45°
Range with air, tennis ball (m)			

Explain. What do the angles that give the same range have in common? What does the air change?

My explanation

Challenges

In **Challenge** mode the simulation gives you a problem with random data. Work it out in your exercise book, type your result and press “Check”. If you miss, you will see where it landed and you can ask for a hint.

- Up to the balcony and How long does it take? (Year 11)
- Hit the target and Two angles (Year 12)

Challenge	Data	My calculation	Did I get it?

Apply what you have learnt

Solve these without the simulation (g = 9.8 m/s², no air). Write the formula, the working with units and the result. Afterwards you can check it in the simulation.

1. A stone is dropped from an 80 m bridge. How long does it take to reach the water and at what speed does it hit it?
2. You throw a ball upwards at 15 m/s. How high does it go and how long is it in the air?
3. An astronaut drops a hammer from 45 m on the Moon (g = 1.6 m/s²). How long does it take to fall? Compare with Earth.
4. (Year 12) A ball rolls off a table 1.25 m high and lands 6 m from the table. At what speed did it leave the table?
5. (Year 12) A ball is kicked from the ground at 25 m/s at an angle of 37° (take sin 37° = 0.60 and cos 37° = 0.80). Work out the components of the initial velocity, the maximum height, the time of flight and the range.

Problem	Working and result
1	
2	
3	
4	
5	

Review your ideas

Go back to the “Before you start” table. Would you change any answer? Write which one and explain why with something you have seen in the simulation.

What has changed in my ideas

Going further (Year 12)

Launch from a 20 m rooftop at 15 m/s and 30°, with the results hidden. Open the simulation ready to use

1. Write the equations x(t) and y(t) of the motion. Compare them with those under “Equations of motion”.
2. Work out the time of flight, the range and the maximum height. Launch, untick “Hide results” and check.
3. Work out the velocity on reaching the ground with its two components. Check that it matches the one given by conservation of mechanical energy.
4. Now launch at 45°. Does it go further than at 30°? Why is 45° no longer the best angle?

My answers

Self-assessment

Put a cross to show how you feel at the end.

I can...	Yes	Nearly	Not yet
Explain why, without air, all objects fall the same way			
Work out the time of fall and the velocity of a dropped object			
Explain what happens to the velocity and the acceleration at the highest point			
Interpret the position–time and velocity–time graphs of a throw			
Explain projectile motion as uniform motion horizontally and uniformly accelerated motion vertically			
Use a prediction and an observation to change an idea I had			

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