ENGLISH
EDITION

BUILDING PHYSICS THROUGH SOCCER

BASED ON: ISTAGE3 - FOOTBALL IN SCIENCE TEACHING

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Prologue

Building physics through soccer shows a successful application, carried out in a classroom of 4th of Secondary, a sequence of activities through gamification, using football as a motivating element. In this book the dynamics to be followed are provided and the necessary resources are specified so that it can be replicated in the classroom.

Usually, the subject of Physics is considered by students to be one of the most difficult in high school. However, this subject is of great importance, being able to affirm that many of the concepts of other disciplines are born from physics, as it helps us to understand many situations of our daily life.

If physics is an experimental science, why is it not implemented in the same way in the classroom? Why do not we adopt constructivist teaching visions centered on the student? Would not it be easier to work these concepts from a vision that helps students relate to situations from their own experience?

In many cases these good practices are not taken to the classroom, alluding to the lack of availability of a well-equipped laboratory or the disinterest of the students. This makes it difficult for them to carry out experimental activities on the one hand and to raise them from a constructivist point of view, which would give the students the necessary tools to solve problems through procedures established by them, since this is an active, participatory and interactive students' process.

To compensate for these weaknesses, it is proposed to find a point of motivation in the students through educational gamification activities: through the elements of a game and, as such, with established rules (time limits, scores, improvement of challenges, etc.), trying students to get involved in order to improve their learning from the transformation of their attitude in the classroom and towards the subject.

That said, you must differentiate gamification game. The latter is a tool for learning that shapes a sequence of activities that is supported by the conceptions of the game. Some of the characteristics that must be taken into account in the gamification are: to mark some bases for the game, to stipulate the mechanics to follow, to be clear about the objective to be achieved (problem solving), to find a connection between the player and the game, promote learning and find a motivating element.

The gamification favors the cooperative experiences inside the classroom, promoting the participation of all the individuals in the group, motivated by the same objective: the resolution of the problem and, indirectly, their learning.

From a design of experiences that allow us to experiment with affordable materials (chalk, meter, ball ...), taking advantage of available technologies (such as the use of the mobile device) and tools and applications that help us in the process, the present book, **Building physics through soccer** is born.

María Diez Ojeda

Introduction

In this book we present a series of gamification activities about football. We want to integrate in the contents of the 4th Secondary Physics and Chemistry curriculum of Castilla y León some activities of the proposal: **iSTAGE3 - Football in Sciences Teaching,** developed by Science on Stage, https://www.science-on-stage.eu/.

Based on this proposal, we have completed and adapted maintaining a constructivist problem-solving methodology. It is not that the student has to apply the contents and formulas that he has previously learned. In this unit we are going to discover what the equations of both uniform rectilinear motion and uniformly accelerated rectilinear motion are, in the same way that Galileo Galilei worked: experimenting, observing, and deducing the relation that exists between the variables of motion.

The development of these contents has been done in 8 sessions. It has tried to adjust the content of each session to about 50 minutes, which is the usual duration of a class.

This project, developed at Jesús-María de Burgos School and in which Master Teacher students participated, was selected to participate in the European STEM League on October 20-21, 2017 at the German Football Museum in Dortmund.

In this final, the 11 selected projects were gathered, among teachers from all over Europe, who had implemented Football activities in the Teaching of Sciences in the classroom.

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SCIENCE ON STAGE GERMANY

THE EUROPEAN NETWORK FOR SCIENCE TEACHERS

From left to right: Miguel Ángel Queiruga, Pablo Olmedillo, Daniel Rebolleda, Íñigo Santesteban and Noelia Velasco, in the final of the European STEM League held in Dortmund.

Our presentation videos:
https://youtu.be/-GtupQh0B3U // https://youtu.be/qtveKA3nwow

Presentation

Welcome to **Building physics through soccer!**

The contents of this publication have been divided into 8 sessions, in which suggestions are given on how to apply gamification and constructivism to the study of some physics content. They are open proposals that everyone can modify to their liking depending on their group of students.

In Session 1, the student's prior knowledge is detected, which will help the teacher to determine which aspects to emphasize, define new activities or establish an adequate implementation rhythm. Between Session 2 and Session 7, the contents of physics are worked on. Each session has an explanation of how to carry it out in the classroom and, in general, refers to a file, which can be photocopied directly and delivered to students for the development of the activity, allowing in many cases that students are the ones to solve the problematic situation by trying different approaches.

It is important to insert a recapitulation session, in this case Session 4, which allows, through review and dialogue, to establish if the student is adequately assuming the contents, if the activities are being carried out properly and if the students are adequately fulfilling the assigned role. At the same time, this session can be used by some lagging team to catch up.

In the last session, it is suggested that the students answer a test that allows the gathering of opinions and suggestions (a model is included, Sheet 8).

We hope that these contents are interesting for you and we hope your opinions and even proposals for change or expansion of the contents.

Session 1

In the first session, students solve the initial questionnaire (Sheet 1.1: initial test, in order to determine the previous knowledge of the student). After this, the teacher presents the topic on which to work and explains how to do it, giving the student the document "General instructions" (Sheet 1.2): methodology, team making, general materials needed to carry out the activities, criteria of Evaluation, general characteristics of the reports (see document "model of daily report", Sheet 1.3), etc.

Emphasis is placed on the need to use the mobile not only as a stopwatch and calculator, but as an element to obtain photographs and video, which will later serve to illustrate the reports and to obtain the necessary data to complete the activities. In cooperative work, it is mandatory that the teams indicate before starting the activity, how the role-sharing has been done; and it is also mandatory to make these roles change in each session.

In this first session, students also work on Sheet 2, which deals with concepts of kinematics studied in previous courses: trajectory, displacement and speed.

SHEET 1.1

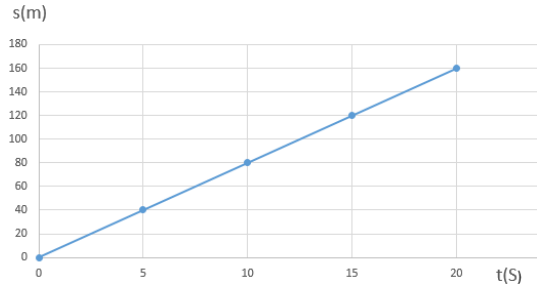
INITIAL TEST. NAME:

1. Define briefly and clearly: position, trajectory, displacement, space traveled.

2. Define acceleration.

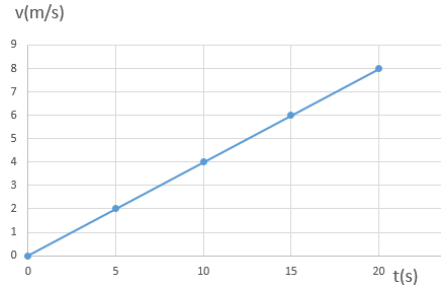
3. Draw a footballer who is running slower and slower to the right. Represent the velocity and acceleration vectors.

4. The graph of the figure below corresponds to a:



a) RUM
b) CAM
c) UARM

5. The graph of the figure below corresponds to a:



a) RUM
b) CAM
c) UARM

6. Define briefly what the kinetic energy and the potential energy are.

7. What does the kinetic theory of gases say?

8. If I drop both an inflated soccer ball and another deflated one from the window:

a) The ball that is inflated will reach the ground first.
b) The ball that is deflated will reach the ground first.
c) None of the above answers are correct.

SHEET 1.2
GENERAL INSTRUCTIONS

You will do some activities based on the information provided by the teacher. Some will be done at school, others at home, but it is important that you do the work the same day so that you do not accumulate. Most activities will be of cooperative work, but some will have to be resolved individually.

To do the activities, we will form teams of 4 students.

In addition to the specific material that may be required for each specific activity, we will need some general materials:

- *Notebook, pens, pencils, ruler, etc.*
- *Smartphone (to use the calculator, taking photos, videos, etc.), convenient: two per team.*
- *Measuring tape*
- *Chalk*
- *Activity sheets.*

The roles we will assign are as follows (each day the roles will be changed):

Coordinator	*He takes care of each partner fulfilling his role. Organize the team so that the activities are carried out on time.*
Secretary	*He takes note of the activities. He will share them with each student in the group.*
Reporter	*He takes pictures and video recordings.*
In charge of material	*He requests the material to the teacher or is responsible for obtaining it so that it is ready at the beginning of the activity.*

Once the activity is finished, the coordinator will write the section of the sheet corresponding to observations and difficulties that have arisen.

Each member of the team must have in their notebook reflected and resolved activities.

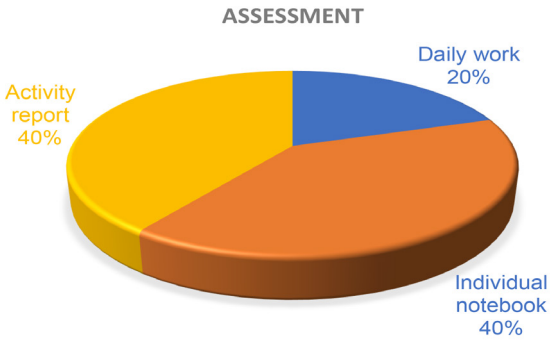
At the end of the activity series:

- Each student will deliver their notebook, for evaluation, at the teacher's request.

- A report in digital format will be delivered (daily) by each team, containing the developed activities duly resolved.

Assessment of activity:

20 %	**Daily work:** Each student fulfills their role, works properly, collaborates with the group, etc.
40 %	**Individual notebook**
40%	**Activity report**



Example weighting used in the evaluation of activities

SHEET 1.3

DAILY REPORT TEMPLATE:

Coordinator	*Student's name:* .....
Secretary	*Student's name:* .....
Reporter	*Student's name:* .....
In charge of material	*Student's name:* .....

You must make a report that contains the following sections:

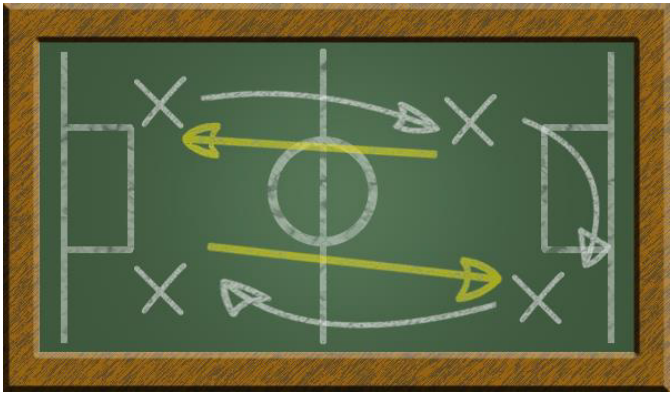
- *Activities:*
- *Problem formulation:*
- *Explanation:*
- *Resolution:*
- *Conclusions:*
- *Images and explanatory photographs:*
- *Difficulties found and how they have been solved:*

SHEET 2

Review of some concepts worked on previous courses.

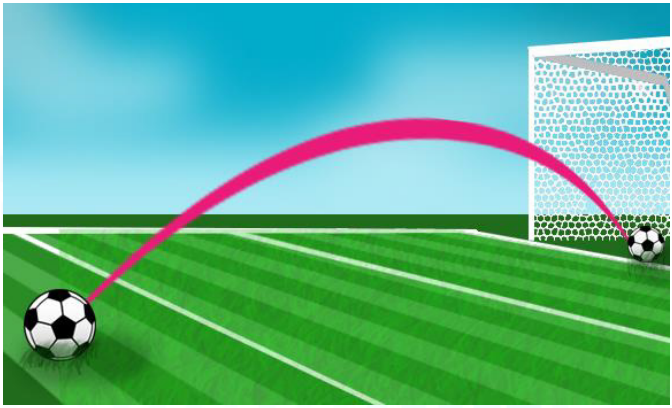
You will need: general materials.

1. Trajectory and displacement. In the following strategy diagram, imagine that the white arrows represent the movement of the players, and the yellow ones are straight lines that join the initial and final point. Could you tell what the trajectory is and what the displacement is?



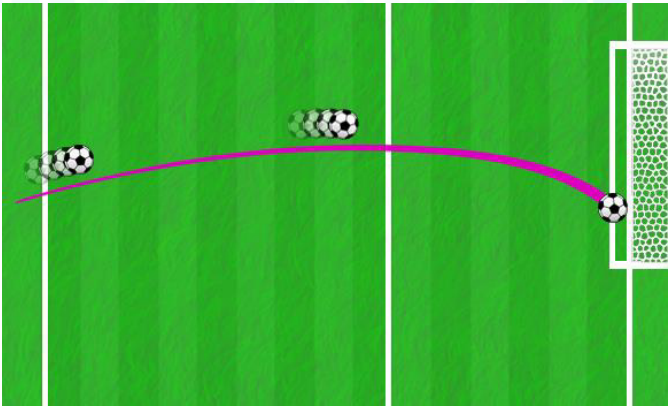
Strategy diagram

2. In the next image, a player shoots the ball and scores goal. What trajectory has the ball followed? What has the displacement been?



Shooting at goal

3. Solve the same issues using the following image:



Shooting at goal

4. In the school football field, you take as coordinate origin the point that you want. Represent it with chalk (afterwards you must represent it in your notebook). Tell a partner to stand somewhere on the field. Take the coordinates of your partner. Represent the position vector. Tell him to move to another point and reshape the vector position of your partner. What would the displacement vector be?

VELOCITY

5. Adapted from: BBC. ¿Cómo se explica la magia de los tiros libres? https://goo.gl/rbSg7Q

The faster you kick the ball, the less time the goalkeeper has to react, as shown by Nottingham Forest's Stuart Pearce shot in the 1991 final, which his team lost 2-1 to Tottenham Hotspur.
The ball moved the 21 meters that separated it from the goal arc in just seven tenths of a second.

- What was the average speed of the ball? Write it in meters per second and in kilometers per hour.

- Now, you must divide the field every 5 m. A partner must run (always at the same pace) through the field from end to end. Other partners will take the time he needs to go through the marked points. Represent the position / time graph. Determine the equation for the graph. What has the speed been?

- In the previous images, represent in different points of the trajectory, the velocity vector of the ball.

Session 2

The results obtained in the previous session are briefly discussed. Students are given the Sheet 3. It is necessary to tell students the importance of doing a comprehensive reading of the text before beginning the activity. It also highlights the importance of rigorous data collection.

In this activity, many physics contents come into play. After reading the text in sheet 3, the teacher can review some aspects the students have doubts about, leaving others to resolve later session.

Some issues may seem unnecessary, but they are intended for students to work on concepts from different perspectives and to understand the connection between different physical magnitudes (e.g., movement and energy).

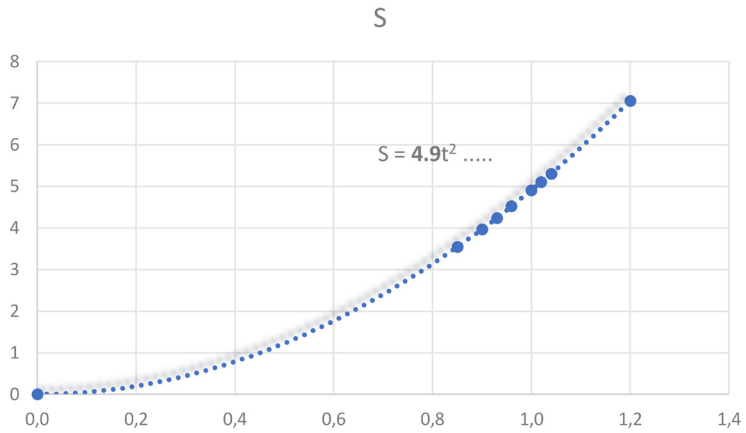
To find the equation of the movement of a free fall, the student must take some good data. From the representation and analysis, he must intuit the parabolic form of the graph obtained. By solving mathematically the system of equations obtained from the substitution of points, he can obtain the parameters of the parabola, and from there, taking into account that we have previously talked about the acceleration with which the bodies fall, the student can generalize the results.

Another way of approaching the problem is to represent the data in Excel, obtaining the graph and from it, the corresponding parabola

Ideally, the data that a student might take could be as shown in the following table:

t (s)	S (m)
0.000	0.000
0.850	3.540
0.900	3.969
0.930	4.238
0.960	4.516
1.000	4.900
1.020	5.098
1.040	5.300
1.200	7.056

The representation of the data would result in a graph like the following one:



With such good data, the student could be advised to appreciate that the main coefficient of the parabola is half the acceleration of gravity.

It can be combined with an analysis of motion videos using the Tracker software (https://physlets.org/tracker/).

SHEET 3

1. Drop the ball from the window.

Although we know that all bodies fall with the acceleration of gravity, let's check it out. You must measure the height from the window to the playground. Drop the ball. Time how long it took the ball to reach the ground.

a) Assuming the energy is conserved you can calculate the speed at which it reaches the ground.

b) Determine the acceleration from the definition of this magnitude.

c) How do you think the speed vs. time graph would be, assuming it has increased uniformly? Represent it. Calculate the area that forms this graph with the time axis.

d) Represent the graph distance traveled vs. elapsed time (for this you will need to record the
action). What kind of graph did you get?

e) Find the equation of motion from the previous graph (note: to obtain the equation of motion you must think about what type of curve is the one that is obtained and how many parameters you need to determine it). Is there any relation between the parameters of the equation obtained and any magnitude you have previously calculated?

f) Sharing and conclusions.

2. ***Relativity of the movement.***

A student moves evenly in a straight line while throwing a ball vertically upwards. A partner moves parallel to him recording a video. Another partner records a video of the scene while they are standing still at a distance. Compare what you see in the videos and draw conclusions about the trajectories.

Session 3

In this session 3, the activity proposed in Sheet 5, where the reaction time and the circular movement are worked, will be carried out. The previous day, the student has been given a copy of Sheet 4 to do individually at home. The aim is to try to promote not only cooperative work but individual study and reflection.

This individual activity is an example of a problem that does not have a unique solution (possible solution shown below). The student should look for data on the internet and obtain a conclusion from them, not just numerical. It is important for them to resolve this activity before working on Sheet 5 so that it connects between the results found.

Example of resolved Activity:

The arc of the goal is 7.32 meters. The penalty point is located 11 meters away from the goal. The average speed of a shoot is between 87.4 km / h and 95.76 km / h (24.3 m / s and 26.6 m / s), so it would take the ball to get to the goal between 0.44 seconds... If the goalkeeper were in the middle of the goal, he should have to travel 3.66 meters to reach one end. If the speed of a person can be 30 km / h (8.33 m / s), in the time it would take the ball to reach the goal, he would travel 3.66 meters, the same as half the width of the goall Why is it so difficult to stop the ball?

References:

As. Missiles at 103 km/hora. https://goo.gl/GarWSU

Wikipedia. Kilometres per hour. https://en.wikipedia.org/wiki/Kilometres_per_hour

In Sheet 5 we find two small independent activities. The first of them, obtaining the reaction time of each of the students. They continue to work in cooperative teams, but are organized (in pairs, for example) to carry out this activity.

In the second activity of this Sheet 5, it is introduced the circular movement and its relation with the linear movement.

SHEET 4

ACTIVITY TO SOLVE EACH STUDENT AT HOME:

Stopping the penalty

Use the internet to find the data you need.

Goal arc measures: .....

Distance from goal to the penalty spot: .....

Calculate the maximum distance to the goal (see image): .....

Speed of an athlete running: .....

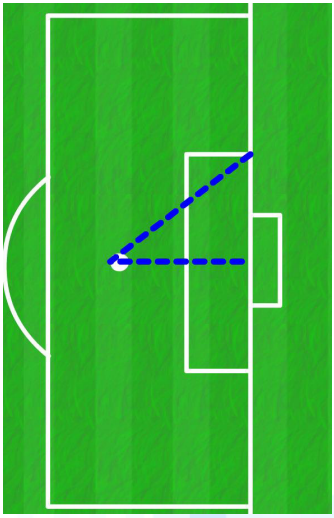
The goalkeeper is usually in the middle, what is the maximum distance he will travel trying to stop the ball? .....

Average speed of the ball after a shoot: .....

When the player hits the ball, how long does the ball take to reach the goal? .....

During that time, how far will the goalkeeper go? .....

Analyze the results and answer: why is it so difficult to stop the ball?



SHEET 5

REACTION TIME (IN PAIRS)

To avoid touching the ball, a player with his hands in a natural position must react to the actions of the other players on the ball and the ball trajectory. This reaction will depend on many parameters, such as the distance between the player and the ball, the speed of the ball and the reaction time of the player. The reaction time of the player can be calculated with a very simple experiment. Students only have to measure the distance a falling ruler travels.

$$s = \frac{1}{2} g \cdot t^2$$

$$t = \sqrt{\left(\frac{(2 \cdot h)}{g}\right)}$$

t: reaction time [s]
h: distance covered [m]
g: gravitational acceleration; $g = 9.81 \frac{m}{s^2}$

Screenshot from iStage3-Football in Science Teaching.
Science on Stage Deutschland e. V., Berlin, 2016 (English version).

What is needed?

- Ruler (30 cm) and chronometer.

The class must be divided in pairs. One of the students of the pair holds the ruler, the other one places the centers of his fingers next to 0 mark. The first student drops the rule, the second student tries to catch it as quickly as possible. Read the distance the rule has fallen.

CIRCULAR MOVEMENT

Rolling with the ball.

- Take the soccer ball. Calculate its radius, calculate the length of its circumference. Explain how you have done it.

- Make it roll on the floor. When it has rotated 2π radians (360°), how long has it traveled on the ground? And when it has rotated half (π radians)? And when it has rotated the fourth part (π/2 radians)? Make the graph rotated angle (radians) / space traveled. Find a relationship between the rotated angle and what the ball travels horizontally.

- Strike the ball strongly until it reaches the other end of the field. Take a distance as a reference and measure the time it takes to go through it. When it has reached the other end, what angle has the ball turned? How many meters has it covered in a second? What angle has it traveled every second? Do you find any relation between these two magnitudes?

Session 4

It is advisable to include a session to share results. For example, students may be working on computers with the PC:

- Reviewing reports.

- Clarifying concepts between them.

- Asking questions to other teams and to the teacher.

The teacher can take advantage of this moment to interact with each team, by guiding them in how they have developed the activities and based on the analysis of the reports delivered by the students so far.

Example of dynamics

The teacher reviews everything that has been done up to this moment. Let's think that, although in an almost playful way, many physics concepts have been worked on. The teacher can summarize the contents that have been worked on in the previous sessions, connecting one session with the next and giving a global vision. In addition, you can comment and put in common, the mistakes that have been made: what the teacher has observed during the development of the sessions and what you have seen in the reports.

Subsequently, the work teams meet and, with the teacher's observations, improve their reports while asking any questions they may have.

Session 5

In this session, the contents are introduced:

- *Kinetic theory of gases.*

- *Pressure of a gas.*

- *Coefficient of restitution.*

A part of the activity must be done previously at home by the student: a review of concepts on the kinetic theory of gases.

In addition to the general materials, the student needs to have an air pump with a pressure gauge (or a compressor).

Students will work with Sheet 6. Attention, there is a previous task to do at home!

SHEET 6
UNDER PRESSURE

First part (to prepare the day before at home).

Introduction: Do you remember the kinetic theory of matter applied to gases?

Use the application:
http://www.lamanzanadenewton.com/materiales/aplicaciones/ltc/La_Teoria_Cinetica.html

Read the following points:

- *Kinetic theory / Postulates of kinetic theory*

- *Applications of kinetic theory / What is the pressure of a gas?*

Make a synthesis of the ideas in your notebook.

Answer the following questions:

- *What is the pressure of a gas called?*

- *What factors influence the pressure of a gas?*

- *If you inflate a soccer ball, is there any particular point where the particles collide more and therefore there is more pressure?*

- *A gas is a fluid and so is water. Look for differences and similarities in terms of pressure, gases and liquids..*

Part 1: Mass of air vs. pressure

- How can you find the mass of air inside the balloon?

- How would you calculate the volume of the ball?

- Measure the masses of the balloon at different pressures and draw the Mass vs Pressure graph assuming the volume of the balloon.

- If you dip the ball in a bucket of water to the bottom, would you be able to calculate the mass of water it "supports"? Do it.

Part 2: Bounce height vs pressure

- Release the ball from a height, always the same. Observe, depending on the pressure of the ball, how it affects the height.

- For each determined pressure (P), calculate, taking into account the heights and the equations of free fall, the speed before reaching the ground and after reaching the ground. Obtain the coefficient of restitution (e= speed after/speed before). Draw the graph e / P.

The ball-floor coefficient of restitution depends on the pressure of the ball.

Session 6

To finish this set of activities about football, a fun and simple activity that allows the student to analyze the movements he makes when walking, running and jumping.

The concept of power is introduced as energy put into play per unit of time.

As an extension activity, it is proposed to use a Smartphone application that allows to obtain the acceleration *(Accelerometer Analyzer or the accelerometer of Physics Toolbox Suite).*

SHEET 7
HANDLING THE BALL

To move faster and jump higher you have to use your hands. This is because the pendulum movement of the arms reduces the movement of the hips and the amplitude of movement of the shoulders and reduces the angular acceleration of the body resulting from the movement of the legs. Conversely, when a person runs with arms straight by his sides or behind his back, the linear velocity is smaller.

Activity:

Represent in the football field the distance of 20 m. You will run that distance three times and calculate the average speed. Complete the following table:

	Normal movement Time (seconds)	Arms by your sides Time (seconds)	Arms behind your back Time (seconds)
Student 1			
Student 2			

If the movement of the arms when running is important, it is also important when jumping. In the following experience, you will need to make video captures to represent the trajectory of some partners when they make a normal jump and when they make a similar jump, but with arms straight by their sides.

- *Represent the trajectory.*

- *Calculate the increase of potential energy (mgh) in each case.*

- *Calculate the power developed in each case: Power = energy put into play / time.*

- *Extension activity: In each case, you can calculate the acceleration with the application for smartphone* ***Accelerometer Analyzer.***

Session 7

Review session. The teacher analyzes the most frequent errors that have been made, looking for the causes that may have originated them, together with the students.

Session 8

The students do the final test (the same questions as in the initial test). This way, the teacher can see the students learning degree.

After this, the students answer a questionnaire to collect information about their opinion about the activity, as well as the difficulties that have arisen and suggestions.

SHEET 8
QUESTIONNAIRE

1: absolutely disagree, 2: disagree, 3: agree, 4 fully agree

ITEM	1	2	3	4
I think I've learned a lot				
The classes have been interesting to me				
The way of working has seemed appropriate for the subject				
I would like to work with this methodology more contents				
I would like to work with this methodology all the contents				
The explanations of the sheets were adequate				
Cooperative work has been effective				
I had difficulties to get organized				
I did the activities without distracting myself				

What difficulties have I had in the development of the activities? How did I solve them?

What I have learned, will I be able to apply it to my life in the future? If yes, how?

Final reflection and suggestions.

NOTES

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NOTES

THE END

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