HARMONIC MOTION

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STEMJAM Teaching Guide

Developing make spaces to promote creativity
around STEM in schools
Acronym: STEMJAM
Project no. 2016-1-ES01-KA201-025470

www.stemjam.eu

Co-funded by the
Erasmus+ Programme
of the European Union

HARMONIC MOTION

ABSTRACT

The ultrasonic position sensor is exploited to measure the period of the harmonic motion for a spring-mass system. If the spring constant is known the system can be used for mass measurement, if the mass is known the spring constant can be characterized.

DIDACTIC OBJECTIVES

While playing the activity you will:

- Physics: explore Harmonic Motion, identify its main parameters and equations.
- Physics: Hooke's Law.
- Physics: understand the importance of Harmonic Motion as a simple model for many more complex related phenomena.
- Maths: Working with formulas, equations and unknowns.
- Engineering: Design of structures. Choice of the most suitable structure for the assembly of the chosen components and Sensors.

While implementing the code:

- Mathematics: the concept of local minimum of a function.
- Computer Science: Computational thinking, algorithm development.

STEM Subject: Science☒ Technology ☐ Engineering☐ Mathematics☒

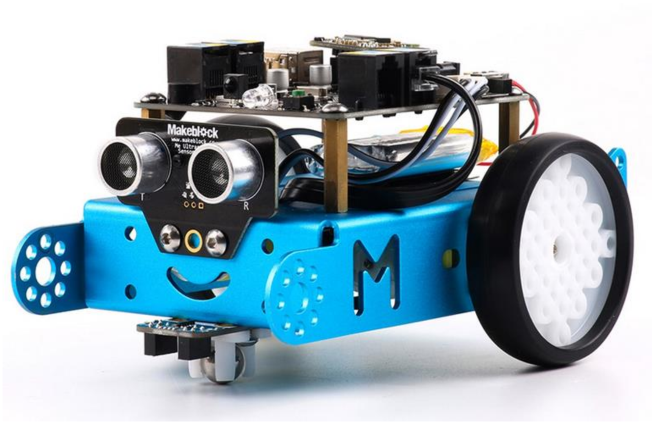
Education Level: 12-14 years☒ 14-16 years☒

PROBLEM STATEMENT

Use position measurements from the ultrasonic sensor to determine the oscillation period of a mass hung from a spring.

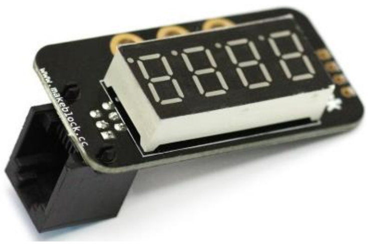
BOM (Bill of Materials Needed)

- mBot => Ref. 90054

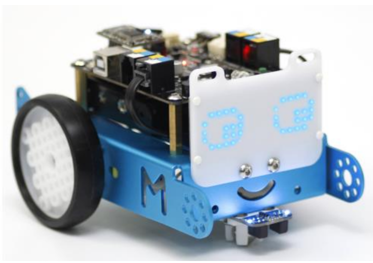


- Me **Ultrasonic Sensor**:

- Me **7-Segment Serial Display - Red**:



- Me **LED Matrix 8 × 16**:

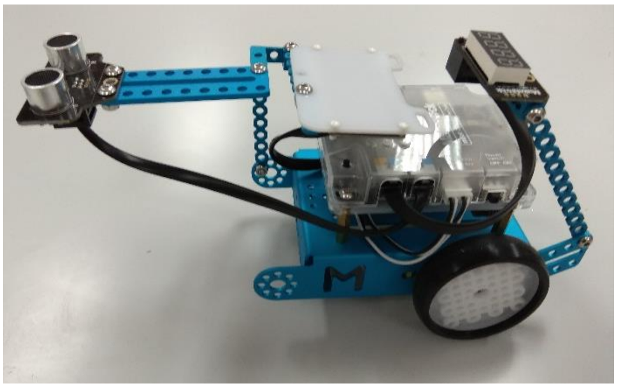
❖ Different beams and structures:

❖ 3 Cables RJ25.

❖ Springs, masses, mounting support.

ELEMENT	ID	CABLE	AMOUNT	PORT 1			PORT 2			PORT 3				PORT 4				P.MOT1	P.MOT2
				Y	B	W	Y	B	W	Y	B	W	Bl	Y	B	W	Bl	W*	W*
Mbot Robot 2´4G																			
Motor 1	W*																	W*	
Motor 2	W*		1																W*
Me 7-Segment serial display	B		1					B											
Me Led Matrix 8x16	B		1								B								
Me Ultrasonic sensor	Y		1	Y															
RJ25 cables			3																
Structures and beams																			
Laptops			1																
Attrezzo (not essential)																			

1. First experiments



2. Optimal structure

ACTIVITY DESCRIPTION

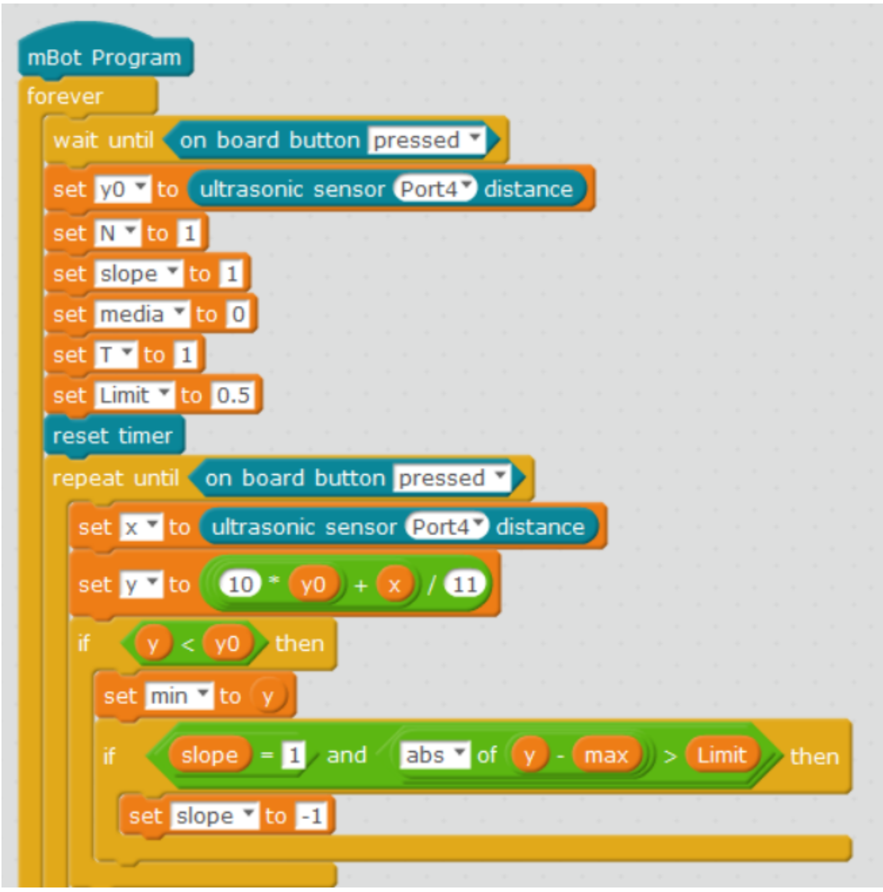
In the following, first we list the simple steps need to play the activity in its basic form. You may arrange the equipment and decide which measurements your students will have to perform, i.e. build your own "Learning scenario" suitable to your students age and background.

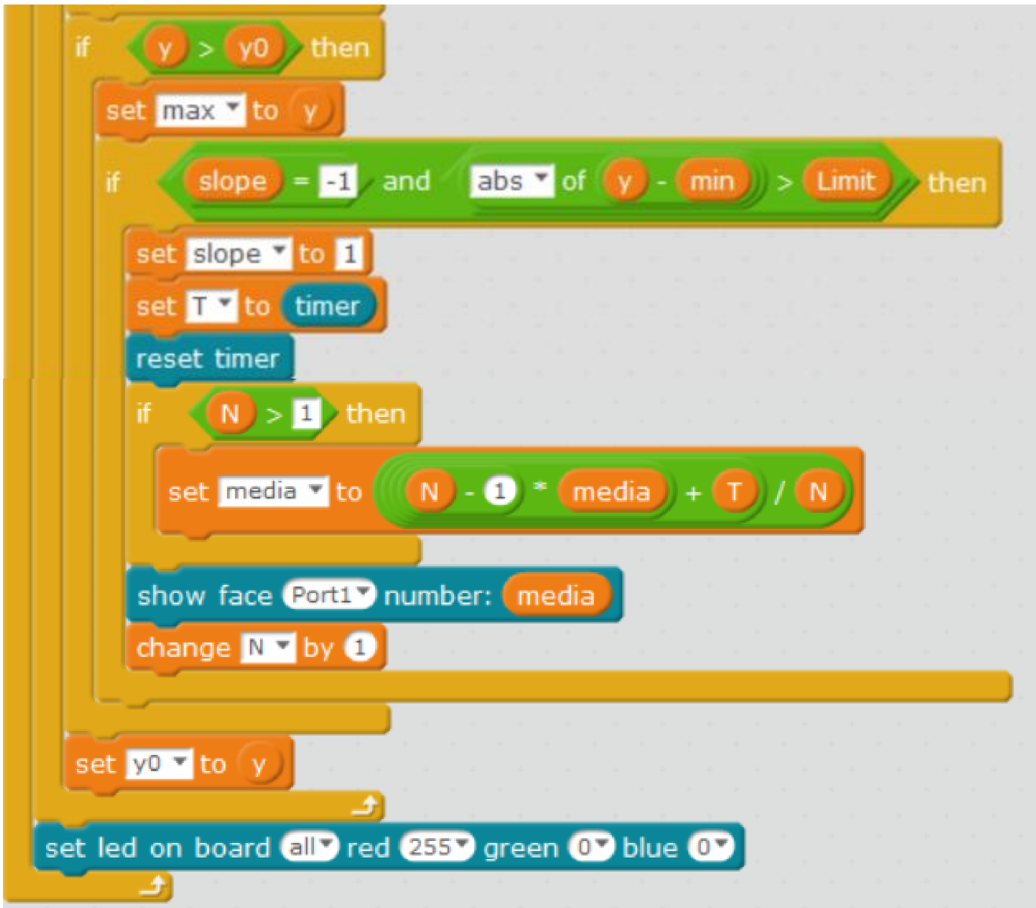
Later we suggest a more complete scenario, suitable for 14 to 14-years old students and shows the results.

1. Hang a spring over a proper support and attach a mass to it. Start an oscillatory motion.
2. Place the mBot ultrasonic sensor below the spring in upward vertical position, so that the ultrasonic sensor see the mass (eventually enlarge the mass surface by a cardboard).
3. Press the on board button to start measurements. The oscillation period is shown on the led display and the spring constant can be evaluated
4. Discuss the importance of such a relatively simple phenomenon through the dedicated supporting material (see attached presentation).

<u>Basic Code for period measurements</u>

The following algorithm reads from the ultrasonic sensor the distance/height z(t) of the mass attached to the spring and evaluates where this function increases and decreases, in order to locate minima and maxima. Each critical point is used to trigger timer start and stop, allowing to measure the period of the harmonic motion. A threshold value is used to distinguish real change in the function from noise. The algorithm do not uses derivatives, but directly compare the function values. It is therefore not very robust, but it can be easily understood by students without any background in calculus.





Photos from the activity

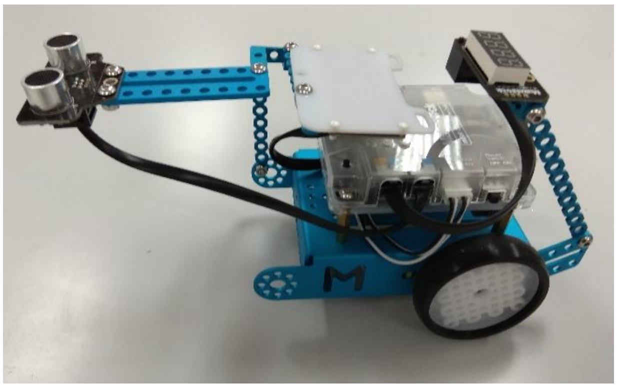
A typical laboratory session on springs include both static (Hooke's law) and dynamic measurements (period of the harmonic motion) , according to student's age and background.
To develop a complete experiment, with younger students (12-13 years old) we set up additional code for static measurements, while with elder students (14-16 years old) we performed the dynamical measurements explained before.

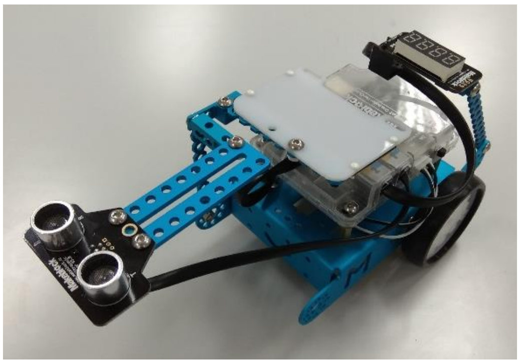
<u>Static experiment: Hooke's law</u>

According to Hooke's law, elastic forces are proportional to the spring elongation through a coefficient called the *elastic constant* ***k***. For a vertical spring-mass system in equilibrium conditions, the mass itself then results proportional to the elongation and to the constant. Therefore by hanging known masses to the spring and measuring the elongation it is easy to evaluate the spring constant.

The idea for the experiment was to measure the spring elongation for three different masses and estimate the spring constant as an average from the three measures.
In order to complete this activity the students had to

- <u>Build up THE STRUCTURE</u>, where all the mechanical and electronics elements were set and arranged in the best configuration.





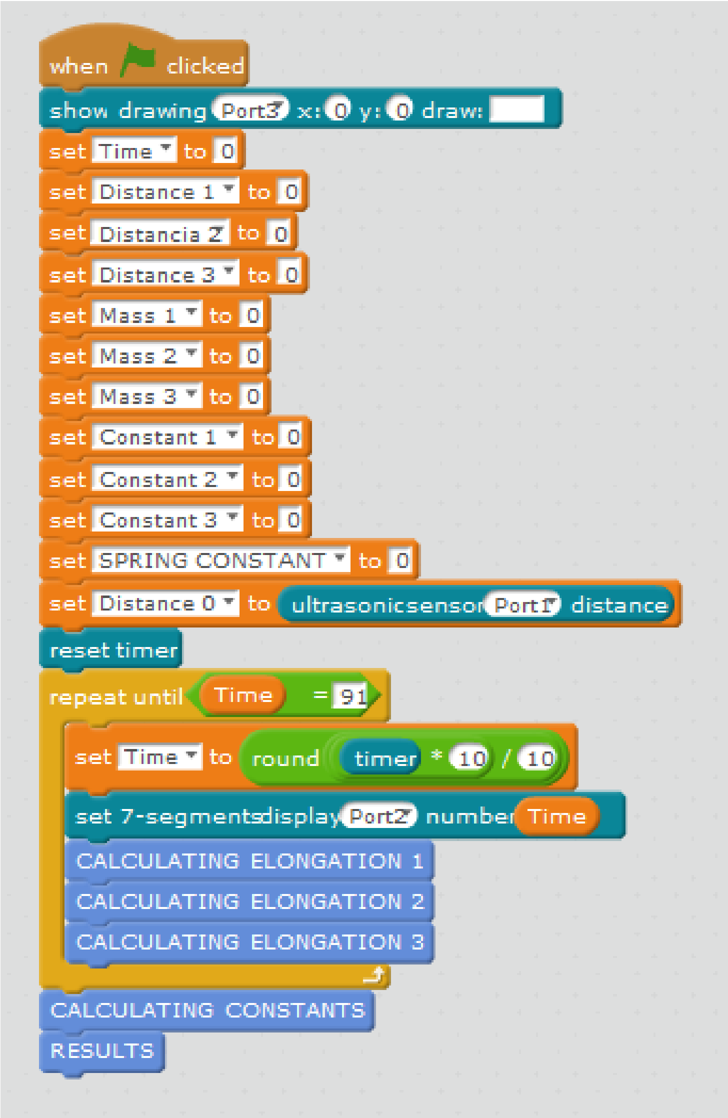
- Develop the flow-chart and the code for data collection and automatic evaluation of the spring constant. In addition, they will have to program different sounds and light effects for the activity. For all the programming, we will use MBlock software. We can download it at MBlock´s page: http://www.mblock.cc/download/ . Once the software is installed, it will be paired with MBot by using the 2.4G Wireless Serial Port.

- Arrange the experimental setup.

Code for the static (Hooke's Law) experiment

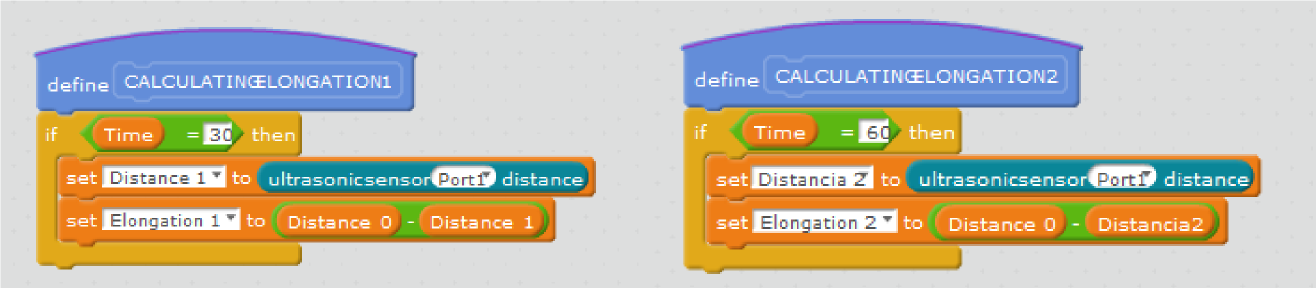
1. Introduction part of the program:

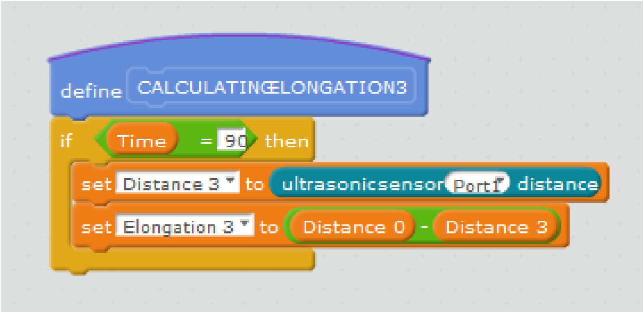
Right at the beginning, we will reset all the variables and the led matrix.



2. Evaluating Elongations Routines:

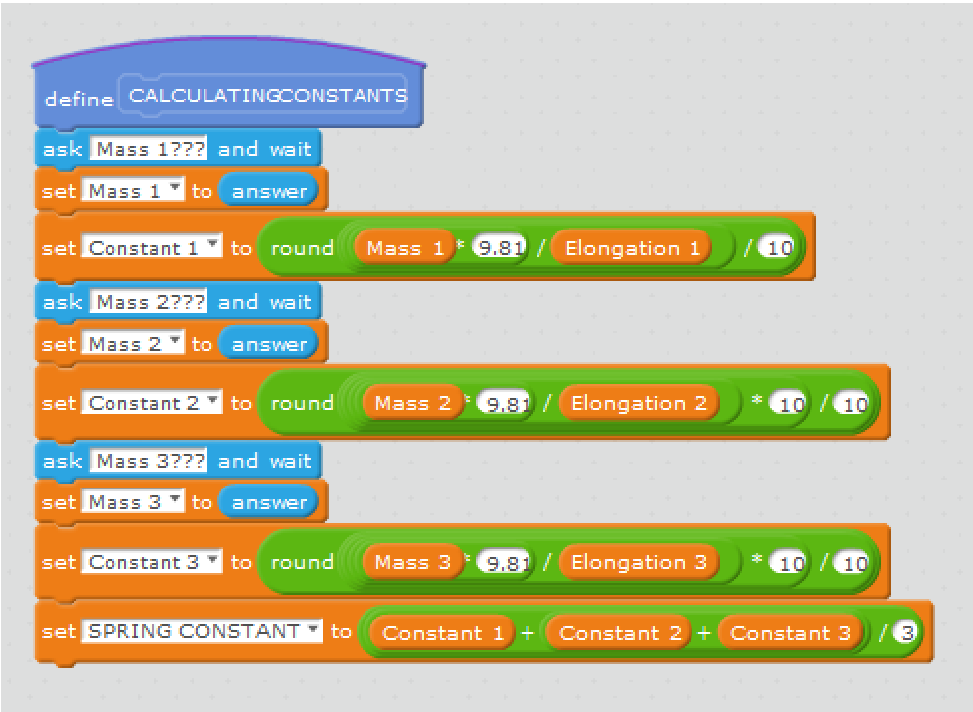
We are going to calculate the spring constant as an average of three constants. We obtaine these data (the 3 constants), by doing the same experiment three times, but changing the mass each time. Therefore, the routine is the same; it just changes the time when the ultrasonic sensor measures the distance towards the hung mass.





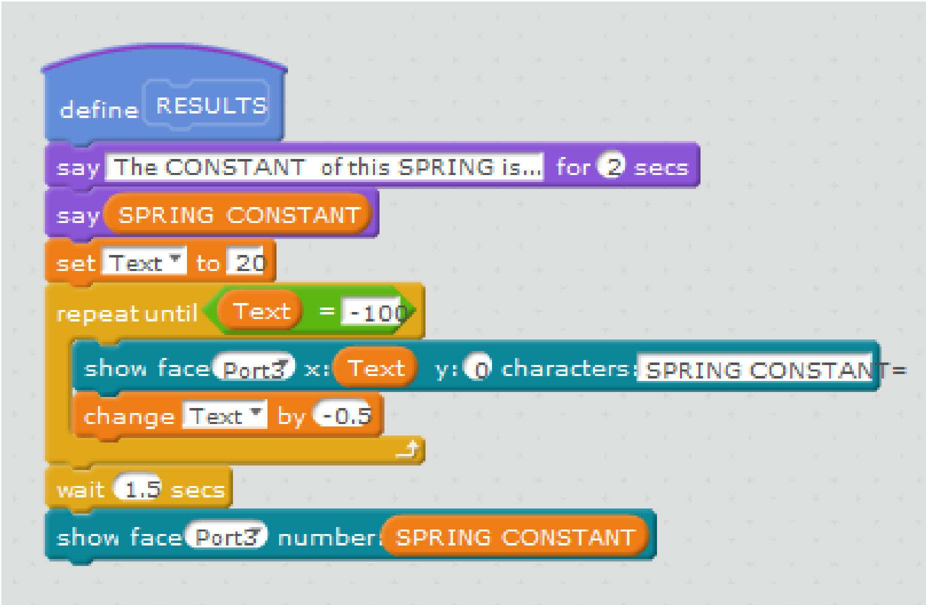
3. Calculating Constants Routine:

In this routine, the program asks for the masses we hung in each experiment. Then it calculates the constant of the spring, for each experiment (C1, C2, C3). Finally, the spring constant is calculated as an average of the previous ones.



4. Results Routine:

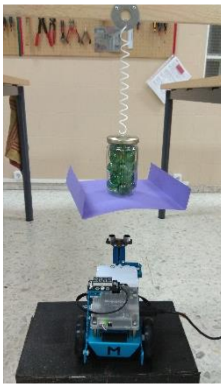
This routine is designed for showing the results, the value of the spring constant.

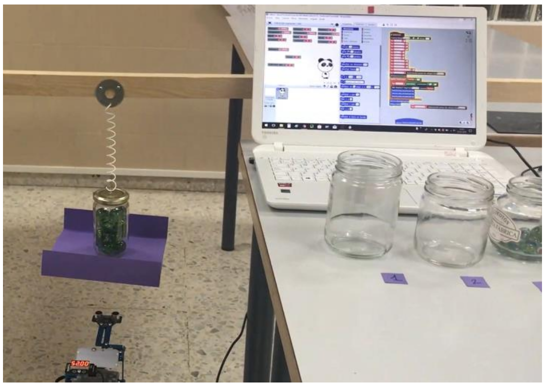
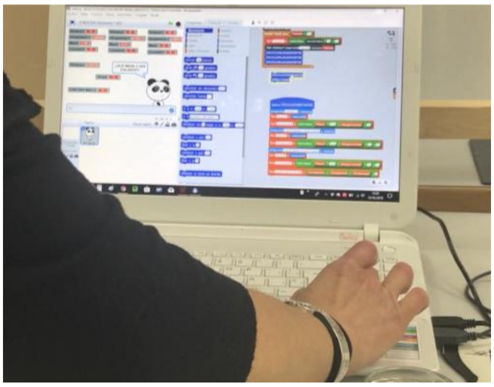
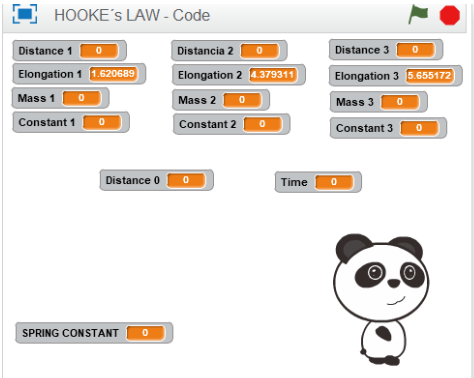


<u>Experimental setup</u>

Once the programming was finished we realized the experimental setup. If, like in our case, you are lacking commercial laboratory masses, you can use standard jam bottles with an hook as mass holders and put glass balls inside in order to freely adjust the mass value.





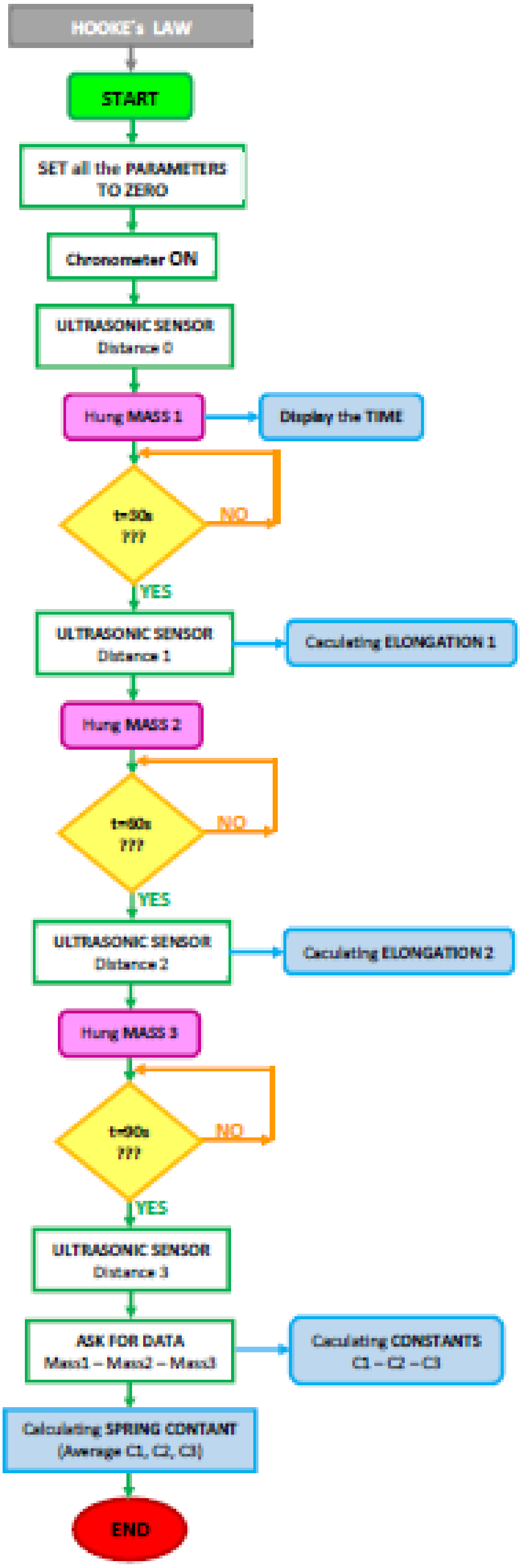



HOOKE´s LAW - Code
Distance 1 0
Elongation 1 1.620689
Mass 1 0
Constant 1 0
Distancia 2 0
Elongation 2 4.379311
Mass 2 0
Constant 2 0
Distance 3 0
Elongation 3 5.655172
Mass 3 0
Constant 3 0
Distance 0 0
Time 0
SPRING CONSTANT 0

6.000

12.00

0.33
12.00

FLOW CHART


HOOKE's LAW
START
SET all the PARAMETERS TO ZERO
Chronometer ON
ULTRASONIC SENSOR Distance 0
Hung MASS 1
Display the TIME
t=30s ???
NO
YES
ULTRASONIC SENSOR Distance 1
Caculating ELONGATION 1
Hung MASS 2
t=60s ???
NO
YES
ULTRASONIC SENSOR Distance 2
Caculating ELONGATION 2
Hung MASS 3
t=90s ???
NO
YES
ULTRASONIC SENSOR Distance 3
ASK FOR DATA Mass1 – Mass2 – Mass3
Caculating CONSTANTS C1 – C2 – C3
Calculating SPRING CONTANT (Average C1, C2, C3)
END

STUDENT'S EVALUATION

To report on this activity and give marks to your students you may use the Evaluation guide designed for the project. Useful indicators specific for this activity include:

- Physics: She/He performs laboratory measurements with care and accuracy.
- Physics: She/He properly applies the relationships among the different parameters in simple exercises about springs.
- Physics: She/He recognizes the physics and maths of harmonic oscillations in other context beside mechanics.
- Computer Science: She/He properly uses iterations, counters, logical operators, IF statement.

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"Jugando con MBlock". Makeblock España.

"Divirtiéndome con MBot". Susana Oubiña.

Comunidad de Makeblock en español. (http://www.makeblock.es/foro/).

"Curso de Scratch + Arduino". J. Javier Esquiva Mira.

https://www.youtube.com/watch?v=4pV2hMkKWV8&list=PL5tA44GpyFntFHtHd6Zxb2xQZpxwOfeu3

SCALABILITY

The activity is suitable for students aged 12 or higher.

With older students (14-15) increasing mathematical details can be included.

MORE INFORMATION

DIFFICULTIES:

- ULTRASONIC SENSOR: to get a more accurate measurement we have put a cardboard glued to the bottom of the container for the mass.