How to determine the location of the accelerometer in a smartphone thanks a record player

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Pedagogical issues :

Notions, contents and Required skills : *Set up an experiment to analyse a motion with a smartphone*

Introduction

The idea is to use an inquiry method to find the position of the accelerometer in the smartphone without open it (of course !). This work is for a K12 pupil (or student, they are so tall…)

To do so, the students will use the properties of uniform circular motion. More specifically, they will determine the radius of the circle covered by the accelerometer when the smartphone is in two different positions on a rotating disk. The intersection of the two circles will give them the position of the accelerometer in the smartphone.

The uniform circular motion is created by the rotation of a record player (33rpm).
They can use the documents for help and set up the procedure to locate the accelerometer in the smartphone. Locate it. Compare the results with the manufacturer's specifications.

Documents

Document 1 : The axes of the accelerometers in a smartphone

The accelerometer measures accelerations according to three axes. It's an electronic component a few millimeters in size, located inside the phone. It measures all the accelerations the smartphone undergoes, among which gravity. The accelerometer is generally not at the center of the smartphone.

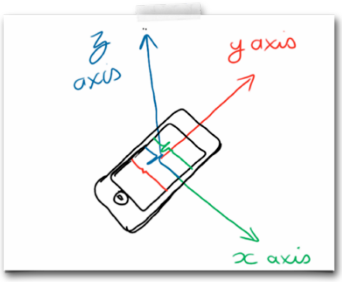


Fig 1: The 3 axis of the accelerometers.

Document 2 : how to use the Sensor Kinetics app

Sensor Kinetics records the data collected by the smartphone's captors.

Fig 2: In the main window, select set rate: 12Hz.
Go to Accelerometer Sensor

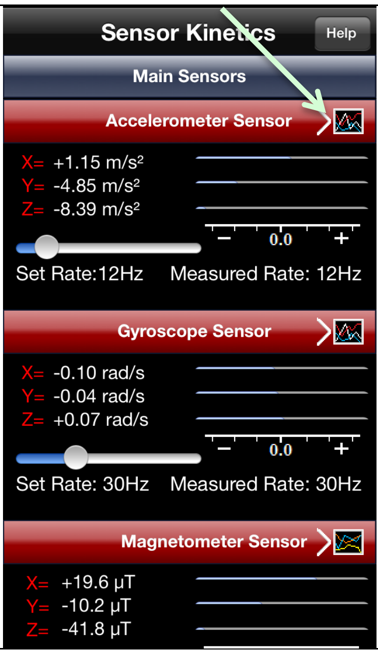


Fig 3: In the Accelerometer window, use the start/stop switch for data collection.

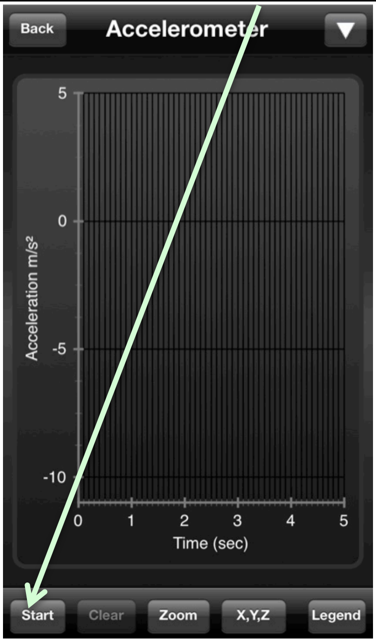
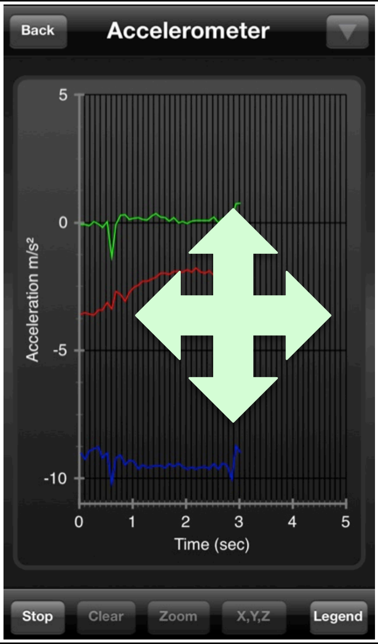


Fig 4: To measure the data once they're collected, touch the screen to zoom in on the graph.



Document 3 : uniform circular motion.

Expression of the acceleration vector :

$\vec{a} = \frac{s^2}{R}\vec{N}$ v is the speed (m.s^{-1}) and R is the radius of the circle (m)

$v = \frac{circumference}{period}$; $v = \frac{2 \cdot \pi \cdot R}{T}$ $ou\ v = 2 \cdot \pi \cdot R \cdot f$ These two equations account for the link between acceleration, the radius of the circle and the rotating frequency : $a = (2\pi f)^2 \cdot R$

f is the frequency in Hz.

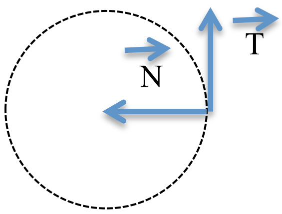


fig 5: Frenet unit vectors

Document 4 :

Value of the sum of accelerations $\vec{a_x}$ et $\vec{a_y}$: $a_{xy} = \sqrt{{a_x}^2 + {a_y}^2}$

Tips to set up the procedure:

To carry out the measure, you have to determine the distance R between the accelerator and the center of the record player.
Use the formulas from document 3 to calculate the distance. You will need to know the acceleration due to the rotation and speed of rotation.

The acceleration is measured thanks to the accelerometer. The speed is measured from the 33rpm of the record player.
The experiment will have to be carried out twice, with the smartphone in 2 different positions. Find 2 circles (radius R_1 et R_2). The intersection of the two circles will give you the location of the accelerometer.

Procedure :

1) Place the phone on the deck of the record player (the x axis towards the center). Mark the position of the phone by placing it on a sheet of paper. Cut out a cross to mark the axis of the record player and circle the phone.

Fig 6 first position of the smartphone

2) Start collecting data with « Sensor Kinetics », start the record player, wait while it spins a few times, turn off the record player, stop collecting data.

3) Zoom in on the graph in « Sensor Kinetics » to determine ax and ay. (Here a_x=0,82m.s^{-2} ; a_y=0,61m.s^{-2}) . Measure the accelerations by zooming in on the graph. If the platform of the record player is not horizontal, then there is an oscillation, in which case you will need the average between the minimum and maximum values of the acceleration.

4) Use the equation from document 4 to determine the acceleration due to the rotation a_{xy} (in this case: $a_{xy} = \sqrt{0{,}82^2 + 0{,}61^2}$; a_{xy}=1,0m.s^{-2})

5) Use the equation from document 3, determine the radius of the circle covered by the accelerometer. $a = (2\pi f)^2 \cdot R$; $R = \frac{a}{(2.\pi.F)^2}$; here $R = \frac{1{,}0}{(2.\pi.0{,}55)^2}$;R=0,084m

6) On the paper, draw the circle, radius R, center : the axis of the record player deck.

7) Turn the phone and the paper 90° on the record player deck. Cut out another cross to mark the axis of the record player. Go through steps 2, 3, 5 and 6 again. (see fig 7).

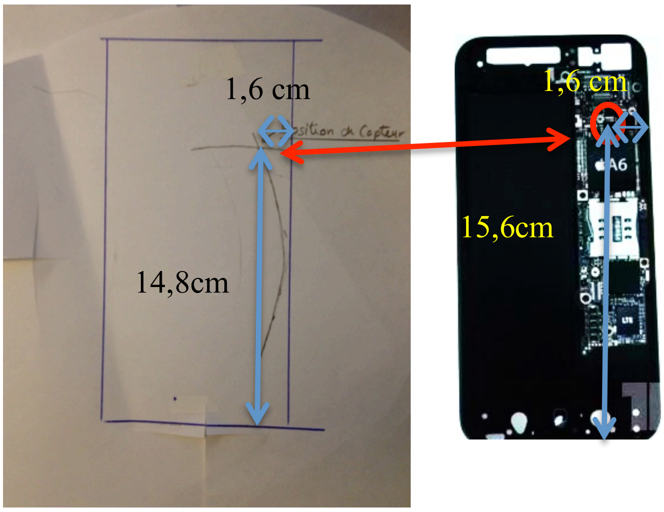
Fig 7: Second position of the smartphone

In this second case : a_x=0,17m.s^{-2} ; a_y=1,14m.s^{-2}

$a_{xy} = \sqrt{0{,}17^2 + 1{,}14^2}$; a_{xy}=1,14m.s^{-2}

$R = \frac{1{,}14}{(2.\pi.0{,}55)^2}$; R=9,5cm

8) The intersection of the two circles indicates the location of the accelerometer in the smartphone. This is confirmed by the picture of an open smartphone (here an iPhone 5C) : the results match the location of the captor in the smartphone. The accelerometer is right above the A6 chip.



Note: for the iPhone 4 (see the matching results on the pictures opposite)

$a_x=0{,}26 m.s^{-2}$; $a_y=-0{,}70 m.s^{-2}$

$a_{xy} = \sqrt{0{,}26^2 + 0{,}70^2}$; $a_{xy}=0{,}75 m.s^{-2}$

$R = \frac{0{,}75}{(2.\pi.0{,}55)^2}$; R=6,3cm

If you turn the smartphone 90° :

$a_x=-0{,}65 m.s^{-2}$; $a_y=0 m.s^{-2}$

$a_{xy}=0{,}65 m.s^{-2}$

you will find : $R = \frac{0{,}65}{(2.\pi.0{,}55)^2}$ R=5,5cm