Name: _____

Lab #4: Circular Motion
Preparation for the lab

1. Read the app instructions found at the end of this lab report. Depending on which type of phone you have (android or iOS), follow the appropriate set of instructions to install the app, configure it, and verify it functions properly. You will need to use the files called "AppData_StudentTemplate.xlsx" and "AppData_Sample.csv". Completion will result in a graph and the display of some average values. Print out your graph and submit with this pre-lab.

2. John stands in a rectangular field at various positions and points, arm outstretched, towards the crosshairs at the center of the field. For each position, draw two arrows indicating the direction that he is pointing. The **first arrow** emanates from the black dot where he is located, and the **second arrow** is a translation of this arrow to the origin, i.e. an arrow emanating from the central crosshairs. The length of the arrow is not important.
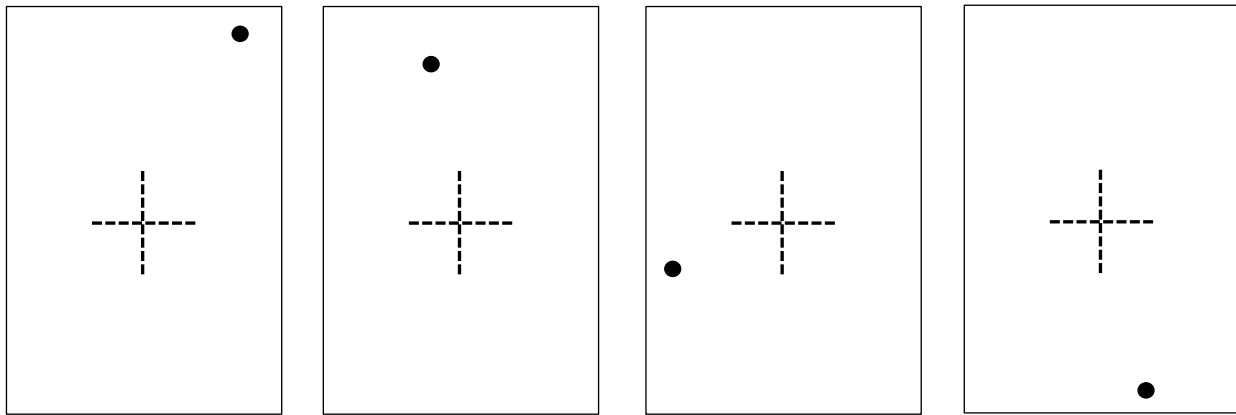
3. John does the same pointing game, only now we only have the resulting arrow indicating the direction. The only information we have about his position is that he was walking somewhere on the field. **For each scenario,** draw 2 dots per diagram, indicating 2 positions at which John could have been standing, for which the arrow would be <u>exactly</u> in the direction shown.
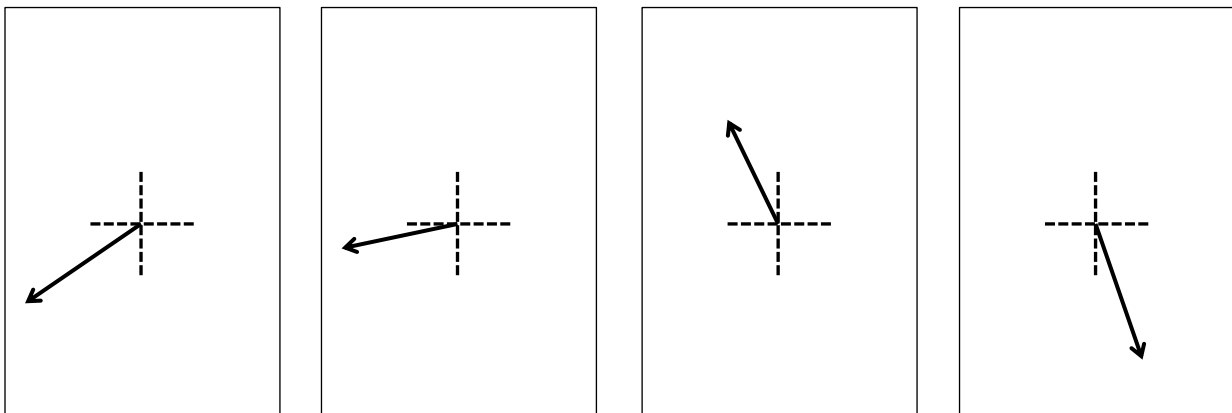
4. A cell phone is rotating on a circular table. Its accelerometer sensor points in the direction of the centripetal acceleration due to uniform circular motion. We don't know where the accelerometer is located within the phone, but we have three candidate positions indicated. Draw **three** arrows emanating from the crosshairs indicating the direction of the acceleration for each of these positions.

Indicate which sensor position(s) would result in an acceleration vector:

   a. whose y-component is zero
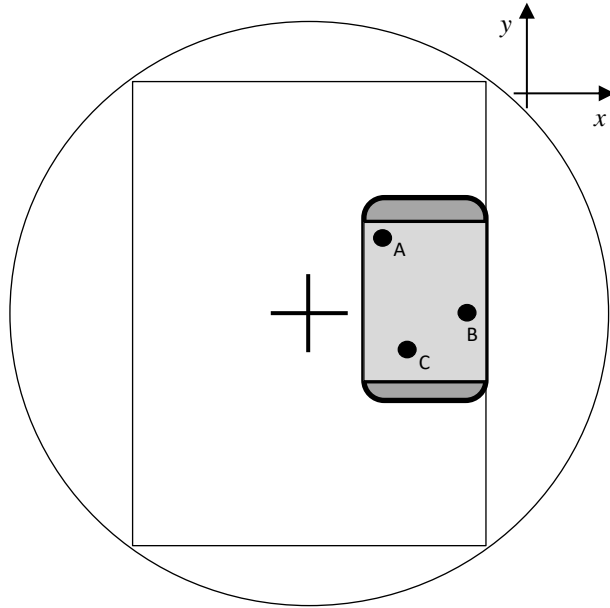
   [A]   [B]   [C]

   b. whose y-component is negative
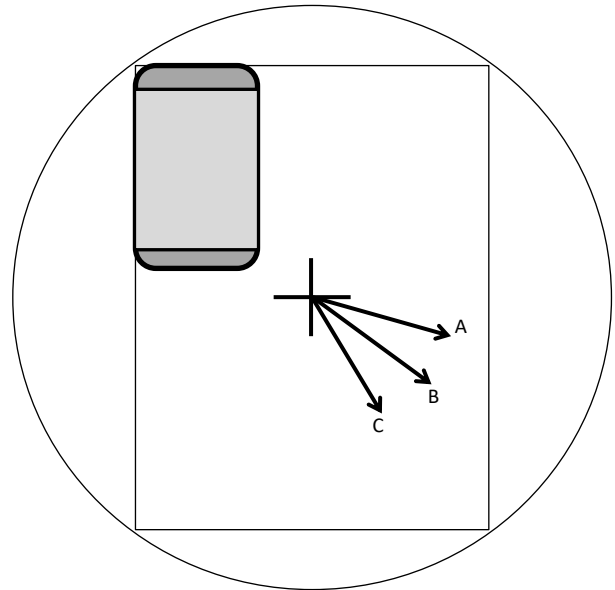
   [A]   [B]   [C]

   c. whose x-component is negative

   [A]   [B]   [C]

5. For **each** acceleration vector shown, draw 2 dots indicating possible accelerometer positions within the phone.

Lab 4: Circular Motion

Report presented by:

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Introduction

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Objectives

In this lab, we are going to be using the principles of circular motion to determine the location of the accelerometer in your smartphone.

Part 1: Experimental Set-Up

1. Your phone: Make and Model (be specific!): _____
2. You will be using the '**SpinFrame**', shown below, which is simply a rigid rectangular frame secured and centered to a circular disk that can rotate on top of a standard record player.
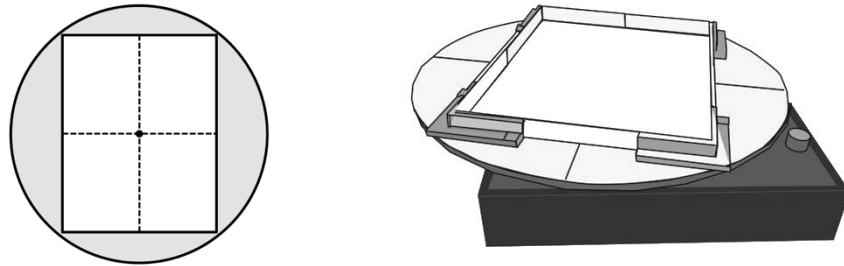

left: top view showing frame on disk; right: disk mounted on record player (the **SpinTable**)

3. Smart Phones have their own internal coordinate system. In order to properly interpret the data from the acceleration app, you need to know the coordinate system for your particular phone. Consult the following figure when interpreting the signs of the acceleration reported by the app.
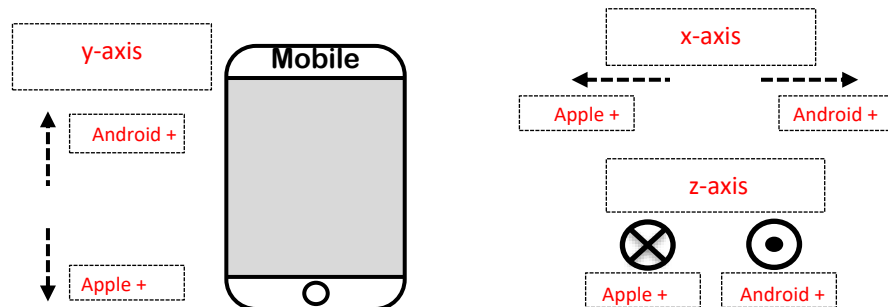

4. You may want to configure the app so that only the x- and y-axes are displayed. Since we are only considering the motion in a horizontal plane, we can ignore the z-axis.
5. On the record player:
   o Leave the needle arm attached in its resting bracket to avoid damage.
   o Set the 3-position speed switch to "78". The units are revolutions per minute (rpm).
   o Set the power dial fully counter-clockwise to the **OFF** position.

- Set the on-off switch to **OFF**.
- The record player will begin to turn by switching the power dial from **OFF** to **ON**. Try it once to make sure it works. (Rotating the dial further does **NOT** change the speed of the turntable)

6. Ensure the SpinTable is sitting flat on top of the record player. The pin in the middle of the record player should be in the center hole underneath the SpinTable.
7. Prepare a "frame sheet":
   - Draw a coordinate system on a piece of paper that will be placed inside the frame, as shown on the figure below. (Use a ruler and the frame itself so that it will be properly aligned!)
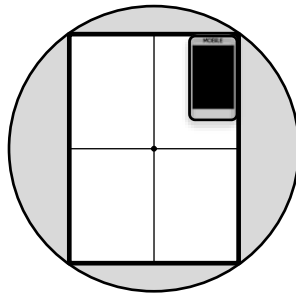

   - Label the axes with the coordinate system that matches your phone, if the phone is placed as shown in the above image.
   - Place the paper back in the frame.

8. Prepare an outline of your phone:
   - Trace an outline of your phone. The trace should have straight lines so it will fit snuggly into the corner of the frame.
   - If your phone has many buttons that make this difficult, use a straight edge to mark the corners and connect them after your phone has been removed (see diagram below).
   - Cut out the trace and mark one side as "ear"
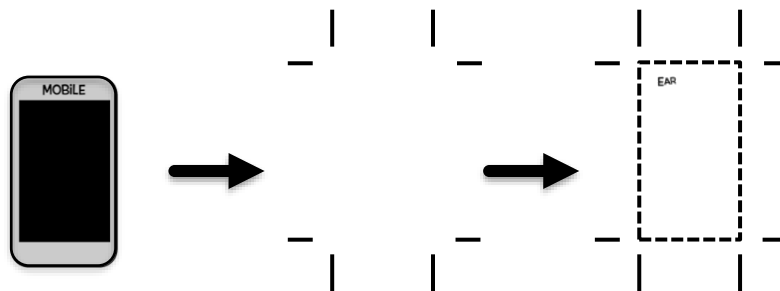
### Part 2: Acceleration vector and the radial line

Make a rough trace of your phone on your paper, and label the 'ear-side' of your phone in the location shown in the figure. Place the phone in the corner of the frame, making sure it is snug and aligned with the two edges of the frame.
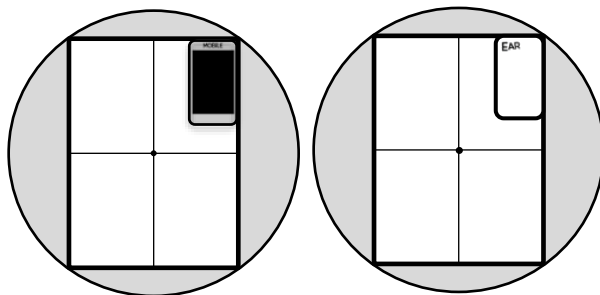
1. Start the accelerometer app to begin recording data.

2. Set the turntable into motion. Once it has reached full speed, leave it for about 3 seconds and then turn the power dial to **OFF**.

3. Once the table comes to a stop, stop recording in the app. Remove the phone from the table.

4. Copy the data file to your computer (consult the *App Instructions* section at the back of this document) and using the **AppData_StudentTemplate.xlsx** file, determine the average acceleration value along the x- and y-axes during the constant-velocity portion of the motion. Record those values in Table 1 for phone position 1. (Hint: Change the "Range begin" and "Range end" values to select the relevant data to include in your average.)

5. Print a copy of the graph.

6. Use the components of acceleration from step (4.) and produce a *radial line* on your frame sheet:

   o Using a scale of 1 cm = 1m/s^2, carefully draw the x- and y-components of the phone-measured acceleration vector, using as the origin the center of your paper [Fig **A.**].

   o Add a vector to represent the resultant of these components [Fig **B.**]. This vector indicates the magnitude and direction of the total acceleration experienced by your **phone's sensor**.

   o Trace the vector backwards producing a radial line [Fig **C.**]. This shows which areas of the phone could be potential locations of the accelerometer sensor.

7. Place your outline on top of your frame sheet and re-trace your radial line onto your phone outline.
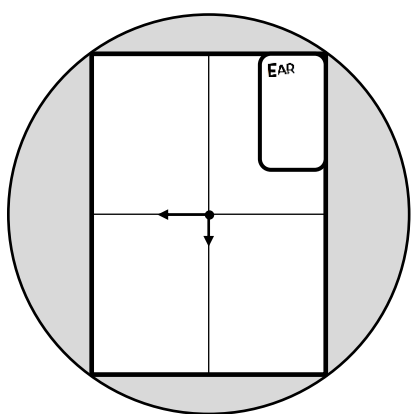
A.
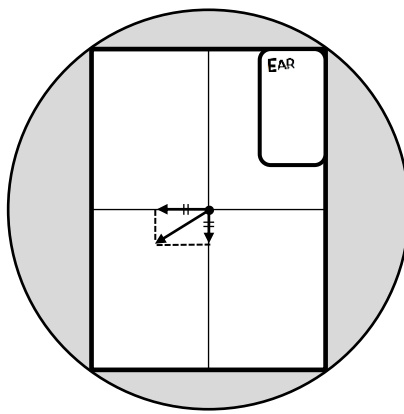
B.
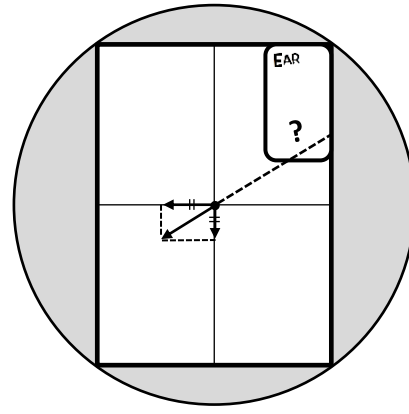
C.

Table 1

Phone Position	a_x (g)	a_x (m/s^2)	a_y (g)	a_y (m/s^2)
1				
2				
3				
4				

Part 3: Radial line from 2nd quadrant

1. Place your phone in the upper-*left* corner of the SpinTable frame and repeat steps from ***Part 2***.
2. Your last step will be to place your outline in the upper-left corner and re-trace your new radial line onto the outline. Your outline will now have two lines on it.
3. **The place of intersection of the two lines is your initial guess for the position of your phone's accelerometer!**

Part 4: Radial lines from 3rd and 4th quadrants

1. Repeat ***Part 2*** for the remaining two corners, always keeping the phone with the same 'ear' orientation.

2. Your outline will now have 4 lines on it, allowing you to validate the accuracy of your estimated accelerometer sensor position. Keep in mind that the sensor itself is not an ideal point object but an electronic component extending a few millimeters along both x- and y-directions.

3. On your phone cut out, report your position as a vector with respect to the phone's local coordinate system, in which the bottom-left corner of the outline is used as the reference origin position.

4. If possible, compare your position against a known position from a manufacturer's diagram. (You can google it! Not for marks, since it isn't possible to find for every phone model.)
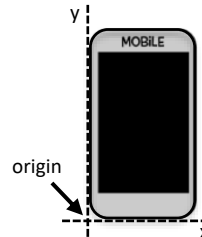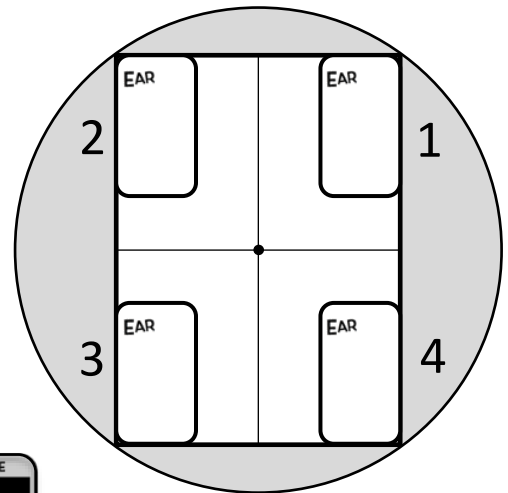
TO DO: Print out four graphs of acceleration, one for each position of your phone. Staple them to this document and submit with your lab. You must also submit your frame sheet and the cut out of your phone.

Part 5: Finding the centripetal acceleration and angular speed

Question 1:   You have found the components of the acceleration vector for four phone positions. Use these components to find the magnitude of the centripetal acceleration for position 1 for your phone.

Question 2:   Would you expect the centripetal acceleration to be the same or different for the other positions for your phone? Explain briefly. Check your explanation by calculating the centripetal acceleration for another position for your phone (position 3).

Question 3: Use either value of the centripetal acceleration you just found to calculate the angular speed of the turntable.

Question 4: Given that the turntable rotates at 78 RPM, find the percent difference between the value of angular speed you found and the theoretical value.

Part 6: Forces in circular motion

Question 5: Now for something different. Place a coin on the spin frame at the location of the accelerometer of your phone. Explore what happens when you operate the turntable at the three different speed settings. Record your observations here.

Question 6: For a single location, and at a speed where the coin does NOT slip, find the magnitude of the force of static friction. Show all of your work.

Question 7: Can you use the above information to solve exactly for the coefficient of static friction? Explain how you would do this, or explain why it isn't possible.
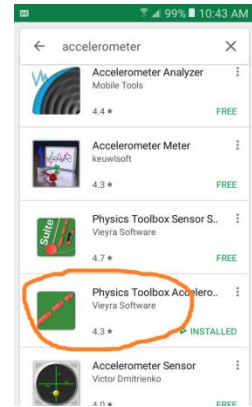
Sources of uncertainty

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Conclusion

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App Instructions

Instructions for the Android Accelerometer App

1. Download and install the app called "Physics Toolbox Accelerometer".
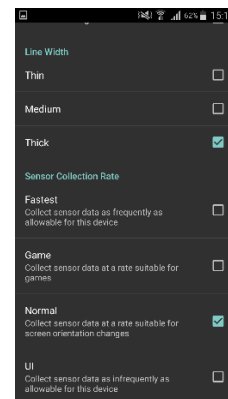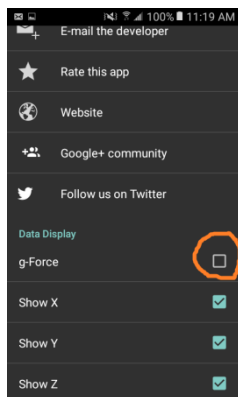
2. Tweak display settings

   a. Click on the settings icon.

   b. Uncheck "display g-force" (See figure below left)

   c. You can optionally choose which axes to display, depending on which experiment you are performing (below left).

   d. Scroll down to choose "thick line" (See figure above right).

   e. Choose "normal" for the sample rate (above right).

f. Switch between landscape and portrait mode, depending whether you prefer viewing the time axis (landscape) or the acceleration-values axis (portrait mode) stretched out more. (Both modes present 20 seconds of data at a time).
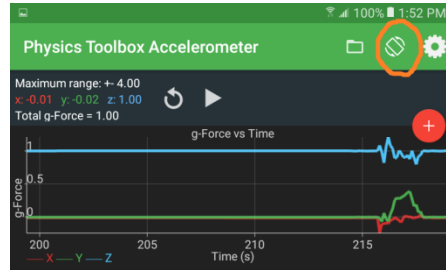

3. Live display of numerical values.

The instantaneous values of acceleration for each axis are displayed in the upper left-hand corner. For static positions of your smartphone you can read off these values directly. For any other situations, use the record-to-file and analysis instructions that follow.

4. Control buttons and recording data.

The pause-play button only controls the on-screen display. The circular arrow button clears the screen. In order to start collecting data, click the orange "+" button. If you clear the display just before initiating the data recording, then the display will be representing the data that is being recorded.
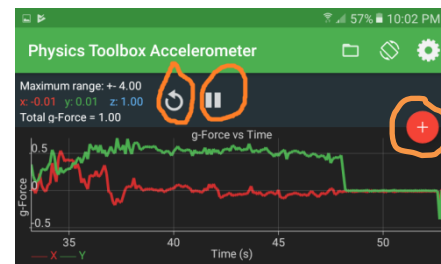

5. Sharing data.

Once you end the recording, you can save the data to your phone's hard disk. For further analysis, send yourself the file via your favorite sharing mechanism. (If the file doesn't automatically attach when you try to share it, you might have to click on the folder icon to select the file first).
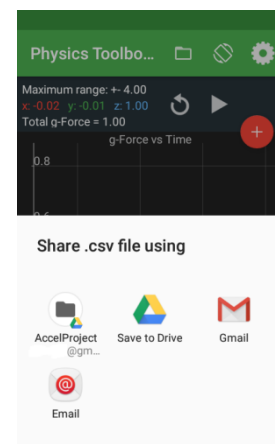
Instructions for the iOS Accelerometer App

1. Download and install the app called "Accelerometer" by DreamArc.
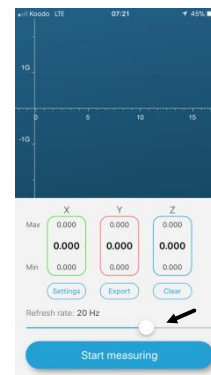
2. Tweak the settings
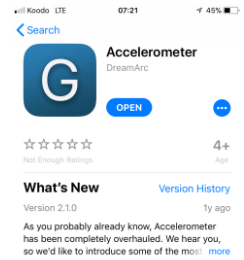
    a. Click on the settings icon.

    b. Make sure '**Remove gravity**' is not selected. (IT SHOULD **NOT** SHOW GREEN!)

    c. The sample rate can be modified by moving the slider. For our purpose, select a sample rate of 3 Hz.

3. Live display of numerical values.

    The instantaneous values of acceleration for each axis are displayed underneath the graph area. For static positions of your smartphone you can read off these values directly. For any other situations, use the record-to-file and data analysis instructions that follow.
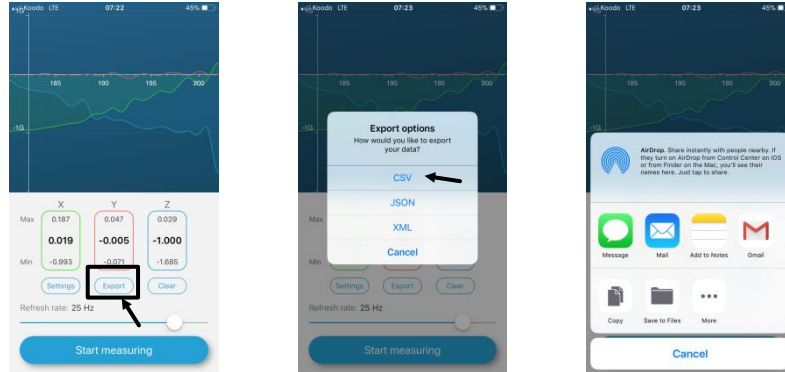
4. Control buttons and recording data.

    Select '**Start measuring**' to begin recording data. To stop data collection, click '**Stop measuring**'.
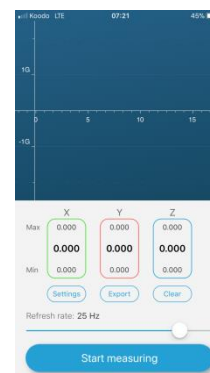
5. Sharing Data.

Once you end the recording, you can export the data (select **CSV** – comma separated values) for further analysis. Send yourself the file via your favorite sharing mechanism.

Data Analysis (Instructions for any operating system)

1. Initial data validation

   a. Place your phone flat on a horizontal table top.

   b. Record for 1 or 2 seconds and then stop the recording.

   c. Export the file to your PC. (See specific instructions for your operating system.)

   d. Open the file by double-clicking on it. This should launch Excel.

   e. The data should appear under 4 columns like as shown. <u>If this not the case</u>, follow the special instructions found on the next page.

   f. Notice that *x* and *y* values are close to zero, and z values are close to +1 (for android) or -1 (apple devices).

2. Using the "Student Template" file: Shortcut for plotting and finding average values.

   a. Open the file AppData_StudentTemplate.xlsx.

   b. Copy the data under the "x" and "y" columns of your CSV file and paste them into columns B and C of AppData_StudentTemplate.xlsx. The data will automatically be graphed.

   c. Determine the average values of a_x and a_y for the data when it plateaus. To do so, set the begin and end portions of the range for averaging (cells I2 and I3). The average values for that range will be displayed.

3. Notes:

   a. The apps use units of "*g*": An acceleration value of 1.0 means 9.8 m/s^2 : Multiply all values found by 9.8 to get acceleration values in SI units.

   b. The first column is usually not time, but just an integer index. You may divide these values by the sampling rate to get the actual time in seconds

Troubleshooting file viewing in Excel

1. If you used an email transfer, and the data appeared in the body of the message instead of as an attachment:
   - Select all the data, copy-paste into an empty text document (via eg. Notepad), and then follow directions as described in (2.) below.

2. In case of issues properly opening the CSV file in Excel (more likely with files recorded from iOS phones):

a. Open Excel and go to a new empty spreadsheet (do not open the .csv or .txt file directly).

b. Click on the tab **Data**, and choose 'From Text' in the banner.

c. Select your file 'filename.csv' and click **Import**.

d. Choose <u>Delimited</u>, then click **Next**.

e. Under the Delimeters heading, check the box Se<u>m</u>icolon and <u>C</u>omma, then click **Next**.

f. Under the Column data format, choose <u>G</u>eneral. Click **Finish**.
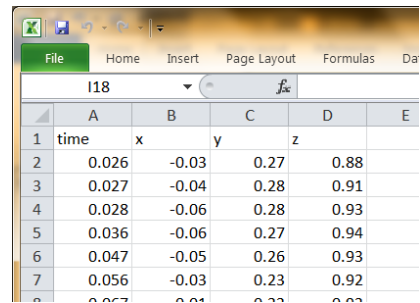
3. If your phone is configured for French number format, but your PC uses English formats:

   a. Open File—> Options -->Advanced ; look under "editing options"

   b. Deselect "Use system separators".

   c. Change decimal separator to a comma, and thousands separator to *.

   d. File should now open correctly