Circular motion using the SpinFrame

and

smartphone accelerometers

INTRODUCTION: *Where, exactly, is your smarphone's accelerometer located?*

Smart phones detect motion using tiny accelerometer sensors. The exact location of that sensor, however, is NOT at the center of the phone. It is different for each model of phone and depends on the layout of the electronics on its circuit board. You will determine what this location is for your phone by examining the data produced by your phone's accelerometer while it is spinning on a turntable.

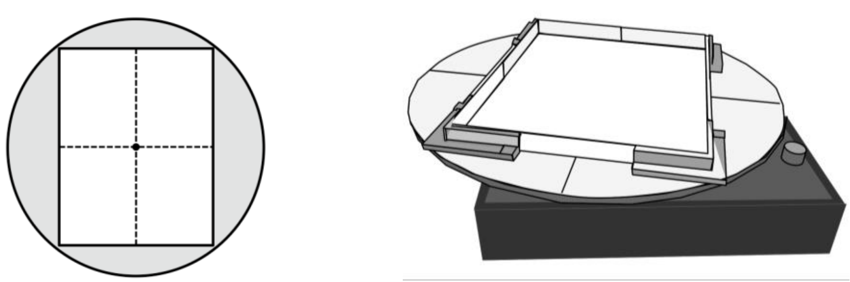
DOCUMENTS:

- To do BEFORE the lab period
    - *"App installation instructions"* (Peform all instruction steps, not just "basic usage"). Submit to your teacher the printed graph that you produce as you enter the lab.
    - *"Pre-lab exercises: Centrally-pointing vectors".* Submit to your teacher as you enter the lab.
    - READ: "*Understanding accelerometers"* (Parts 1 and 2 only)
    - REVIEW: *"Discovering your smartphone's coordinate system"*

APPARATUS:

-Your phone: Make and Model (be specific!): ____

-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**)

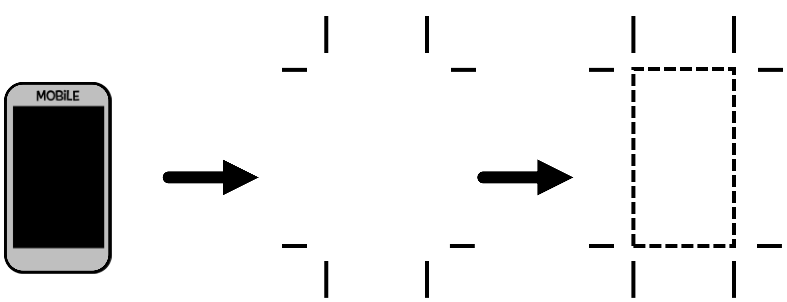
PROCEDURE:

PART 0: Determine your phone's local coordinate system

Confirm that you know the axes of your phone. Have your teacher verify those results before continuing with the procedure here.

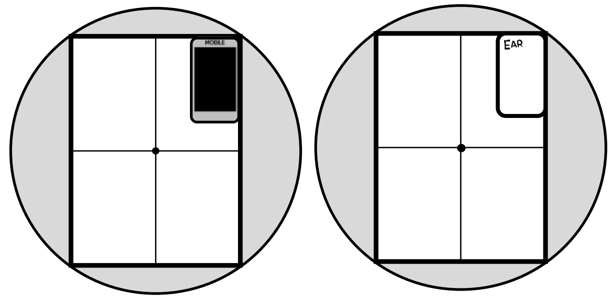
PART 1: Set-up

1. Configure the app so that only the x- and y-axes are displayed.
   Since we are only considering motions in a horizontal plane, we can ignore the third z-axis as well as the effects on accelerometers due to gravity.
2. On the record player: (treat it with care, it is delicate!)
   - Leave the needle arm attached in its resting bracket to avoid damage.
   - Set the 3-position speed switch to "78". The units are revolutions per minute (rpm).
   - 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 **<u>NOT</u>** change the speed of the turntable)
3. 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.
4. Prepare a "frame sheet":
   - Place a piece of paper in the frame. Make little tick marks on the paper at the halfway positions along each edge. There are small lines on the frame for this purpose.
   - Remove the piece of paper from the frame. Use a ruler to connect the tick marks across the middle of the paper along each axis, forming two perpendicular lines. Place the paper back in the frame.
5. Prepare an outline:
   - Place your phone on a new piece of paper.
   - Use the vertical edge of a block to carefully mark the four edges of your phone as shown below. Connect the lines to produce a rectangular trace of your phone



   - Cut out the phone outline by following these lines. Mark one side as 'ear'.

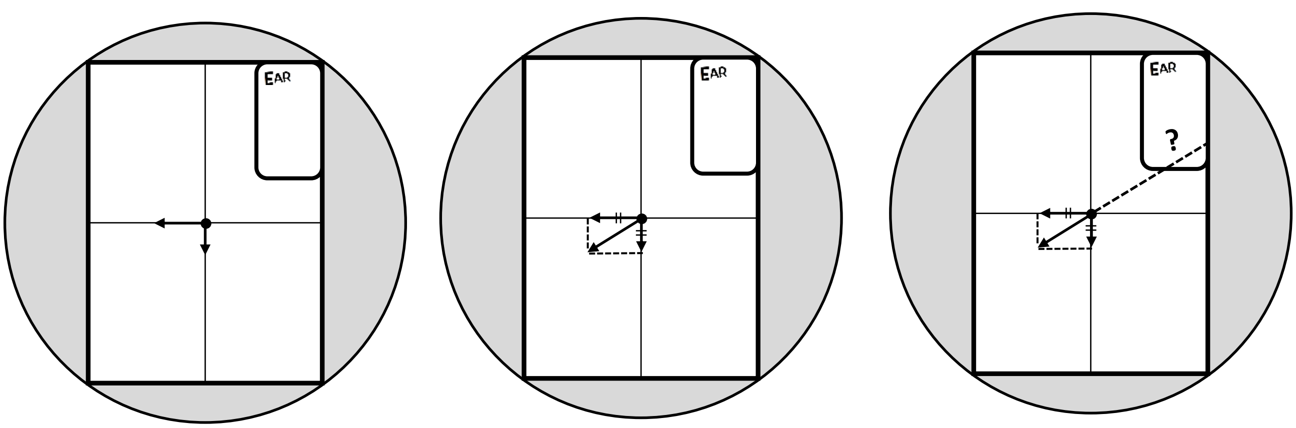
PART 2: Acceleration vector and radial line



Place your phone in the upper-right corner of the SpinTable frame as shown. Make a rough trace of your phone on your paper, and indicate which end is the 'ear-side' of your phone. Place the phone back in the corner of the frame, making sure it is aligned and fully in contact with the two edges of the frame.

1. Start the accelerometer app to begin recording data. (Apple users: make a note of the sample rate or refresh rate.)
2. Set the turntable into motion. Once it has reached full speed, leave it for 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 (see *AppInstructions.doc*) and using the **AppData_StudentTemplate.xlsx** file provided by your instructor, 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.
5. Print a copy of this graph, ensuring that the horizontal axis properly shows the time in reasonable units of time. (Refer to *AppInstructions.doc* document if you need hints.)
6. You will now take the acceleration data reported in **STEP 4** and produce a *radial line* on your frame sheet:
   - 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.**].
   - 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 **<u>phone's sensor</u>**.
   - 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.

     Convince yourself (... and your partner) that the location should ideally lie somewhere along this line.
7. Place your outline on top of your frame sheet and re-trace your radial line onto your outline.



A. B. C.

Table 1: Raw data output from phone app. Make and model of your phone: ___________________________________

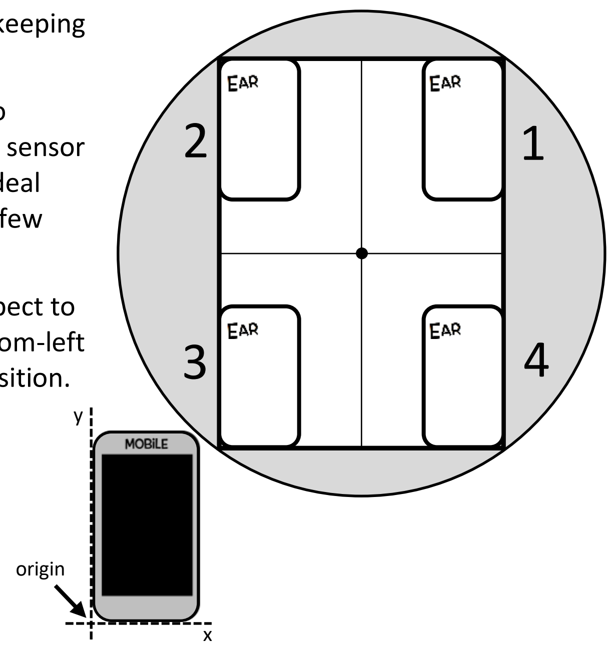
PHONE POSITION	a_x (g)	a_x (m/s^2)	a_y (g)	a_y (m/s^2)
1				
2				
3				
4				

PART 3: Radial line from 2nd quadrant

1. Place your phone in the upper-*left* corner of the SpinTable frame and repeat **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. Using a ruler, 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!)



TO DO: Print out four graphs of acceleration, one for each position of your phone. Staple to this document and submit with your lab.

Questions:

1. Measure the radial distance of the accelerometer for each phone position with a ruler. Enter values into Table 2 below.
2. What is the angular velocity for each position? What is the tangential velocity? Enter values into the table. Do your results make sense? Explain briefly.
3. For position 1 and position 3, use your measured values of r and v to calculate the value of the radial acceleration. (You can do the other two if you have time at the end). What equation do you need to use? Enter values of a_r into Table 2 (second last column).
4. For each quadrant position, you have created an acceleration vector (see Table 1). Calculate the magnitude of the acceleration vectors for phone positions 1 and 3. Enter values into the LAST column of Table 2.
5. Compare the values of the acceleration found in Questions 3 and 4. Do your results make sense?
6. Find the percent difference between the values of acceleration found in questions 3 and 4.

Table 2

				From Question 3	From Question 4
PHONE POSITION	r (m)	ω (rad/s)	v (m/s)	Calculated: a_r (m/s^2)	Magnitude of a (from components)
1					
2					
3					
4					