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香港理工大學



AP-Sensor User Manual

DEPARTMENT OF APPLIED PHYSICS



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Supported by:



AP-Sensor User Manual

DEPARTMENT OF APPLIED PHYSICS

1. Overview

AP-Sensor is a mobile app that makes use of built-in physical detectors in mobile devices (e.g. smartphones, tablets) to take measurements of a couple of physical parameters in laboratory and daily life. The app is dedicatedly developed by Department of Applied Physics, the Hong Kong Polytechnic University (Learn more: <http://www.polyu.edu.hk/ap>). With the popularization of mobile devices, our vision is to make physics laboratory mobile and easily accessible. Apart from conducting experiments in school, you are also encouraged to use the app to make observations to your daily environment.

2. App Installation

1. To start using the application, download the file “AP-Sensor_v2.3.apk” as provided.
2. Open the “AP-Sensor_v2.3.apk” file and click “INSTALL” (in Fig 2.1) to start install the app (Fig 2.2).
3. Open the app after successful installation (Fig 2.3).
4. Recognize the app icon. Tab the icon to open the app in the app menu of your device.

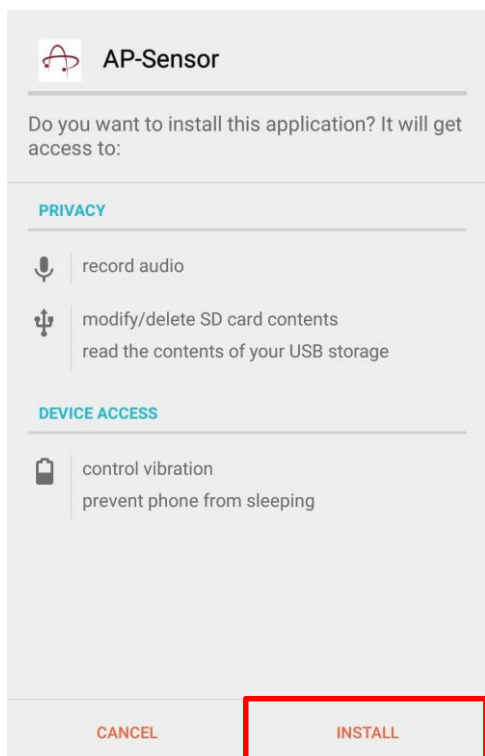


Fig 2.1

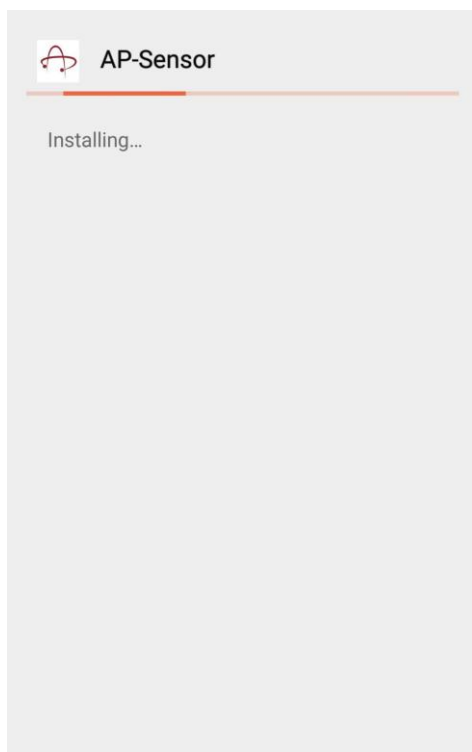


Fig 2.2

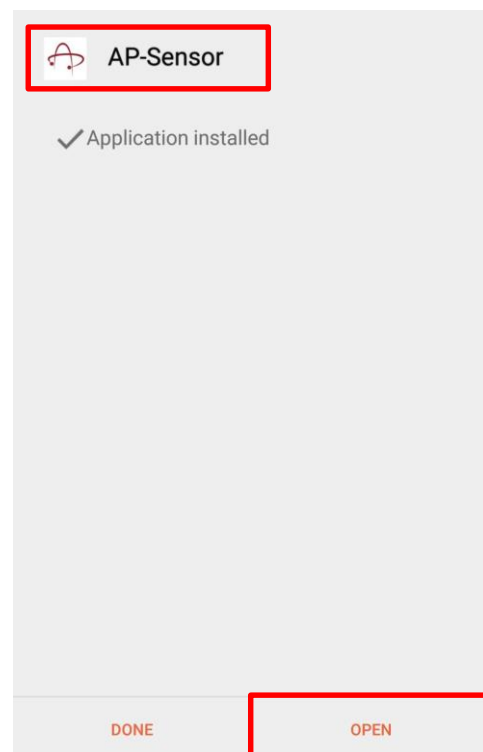


Fig 2.3

3. Background Information of the App

Main Menu

There are two tabs of which you can choose on the top – “Basic Functions” and “Experiment”. When the app is first opened, the page will be the “Basic Functions” (Fig 3.1).

In the “Basic Functions” tab

- There are 7 activities – a **Sound Generator** and **6 detectors** (Accelerometer, Magnetometer, Light Sensor, Gyroscope, Sound Level Meter and Sound Analyzer) making use of **5 different sensors**.
- Note that some of the sensors, however, are absent in some mobile devices depending on its functionality. In that case such kinds of measurements cannot be made by the devices.

In the “Experiment” tab

- There are **6 experiment presets** (Velocity in One Axis, Apparent Weight in Lift, B-Field versus Distance, Radial Speed of a Magnet, Light Intensity versus Distance and Find Revolutions and Distance).
- The presets utilize certain sensors to allow measurements in experiments.

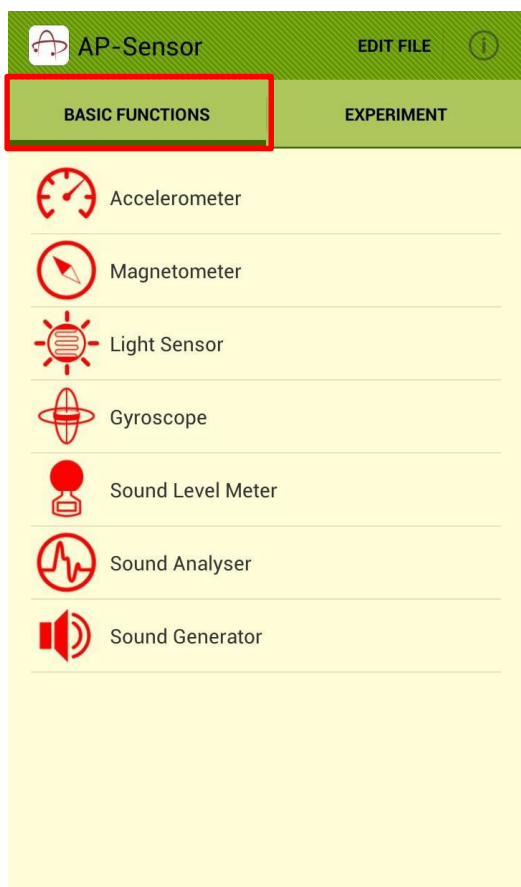


Fig 3.1

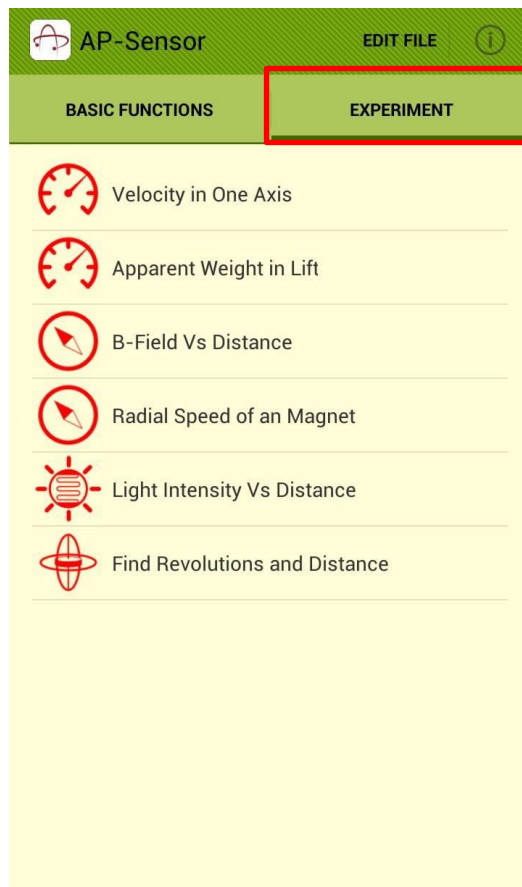


Fig 3.2

Axes and Units of Sensors (Accelerometer, Magnetometer and Gyroscope)

The Axes employed in Accelerometer and Magnetometer are specified in Fig 3.3.

- Depending on different phone manufacturers, direction of sign of y-axis and z-axis may be inverted.
- The unit taken in Accelerometer is ms^{-2} (meter per square second).
- The unit taken in Magnetometer is μT (10^{-6} Tesla).

The Axes employed in Gyroscope are specified in Fig 3.4.

- Depending on different phone manufacturers, direction of sign of axes may be inverted.
- The unit taken is rad s^{-1} (radian per second).

***Task: You can investigate the axes applied on your device before starting any experiment.



Fig 3.3

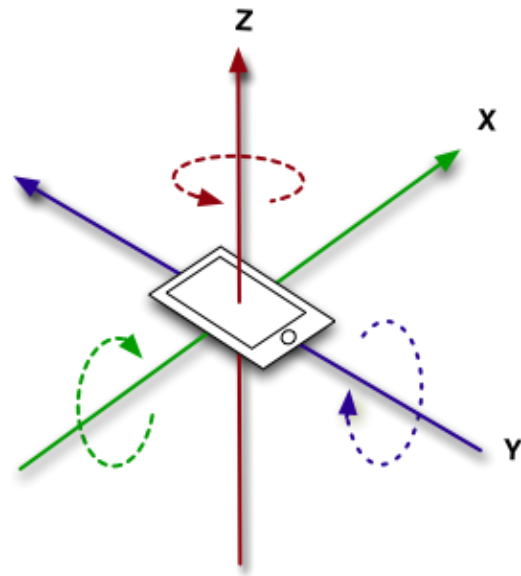


Fig 3.4

Light Sensor

Many advanced mobile devices are equipped with “Adaptive Brightness” function which enhances display efficiency and user experience. Provided that the function is enabled, your screen will automatically increase brightness when you are in a bright environment, on the other hand decrease brightness when you move to a dark environment.

- The working principle is to make use of a light-sensitive device, namely a photo diode, which can turn the received light into electric current (See more: Photoelectric Effect).
- The higher the light intensity, the higher is the electric current.
- The illuminance in the SI unit lx you read is converted from the current induced by the light.
- In free space, the illuminance obeys inverse square law – inversely proportional to the square

of distance of the detector from the light source along the line joining the detector and the source.

You can check its availability in Setting → Display (Fig 3.5). Note that this function is not available in some models of mobile devices, in that case the Light Sensor is not functional and the illuminance reading will stay at 40lx regardless of any change in light intensity.

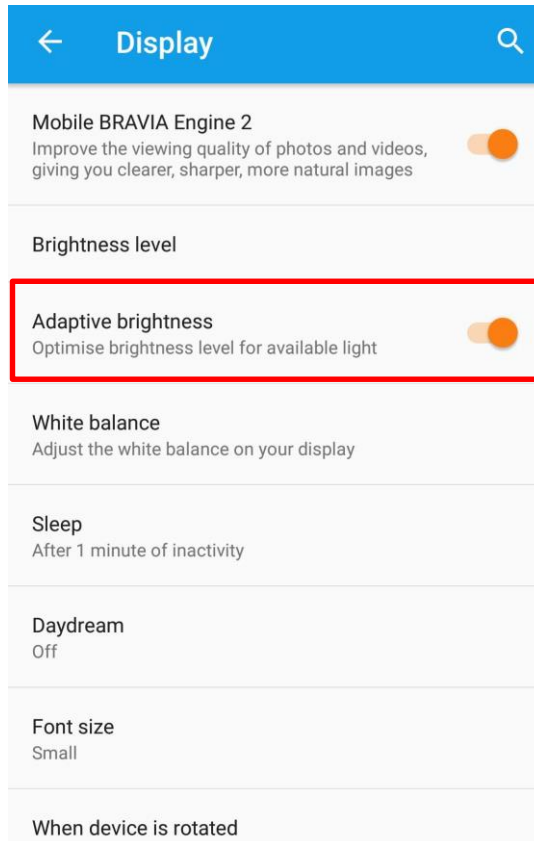


Fig 3.5

Sound Generator, Sound Analyzer and Sound Level Meter

Sound Generator generates sound with desired frequency through built-in speaker of the device.

Sound Analyzer and Sound Level Meter receive sound through built-in microphone of the device.

- Loudness of speaker bases on user profile, which can be adjusted by pressing “+volume” and “–volume” on the edge of the phone, or in Settings → Sound & notification.
- Sound Analyzer breaks down the composition of frequencies of one source. (Learn More: Fourier Transformation.
- In this app, microphone takes 8192Hz sampling rate, using 16-bit audio bit depth, and data received from the microphone is relative power, P/P_r .
- 16-bit depth can receive maximum $2^{16} = 66536$ levels, in range -32768 to $+32767$.

***Task: By equation $I(\text{dB}) = 20\log\left|P/P_r\right|$, calculate the maximum sound level that can be measured by the app. (Ans: 90.3dB)

Edit Files

After taking readings with the app, the data collected can be saved as comma separated values (.csv) file. The files can be found, deleted or sent to a designated email address.

1. Press the “Edit File” button on the top of the main menu (Fig 3.6).
2. Select the file(s) to be deleted or sent (Fig 3.7).
3. For sending files, input the designated email address and subject then “Send” (Fig 3.8).
4. For deleting files, press “Delete” and confirm after 5 seconds.

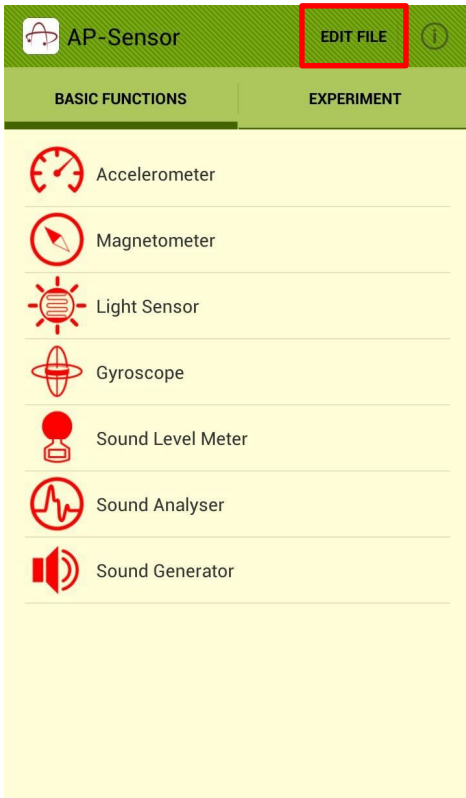


Fig 3.6

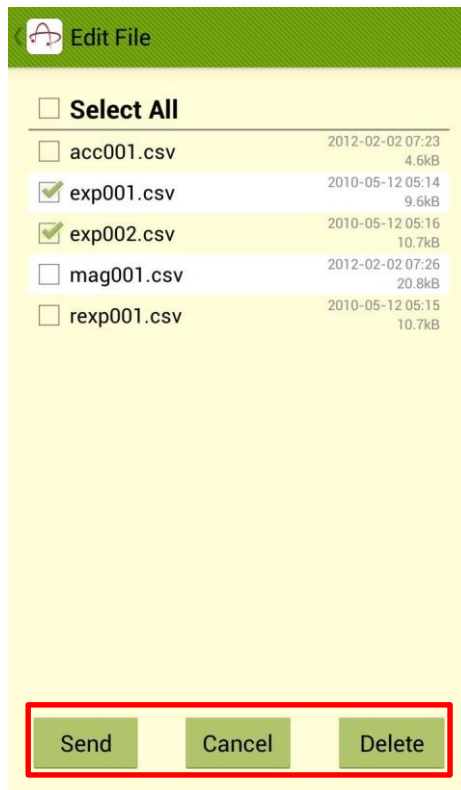


Fig 3.7

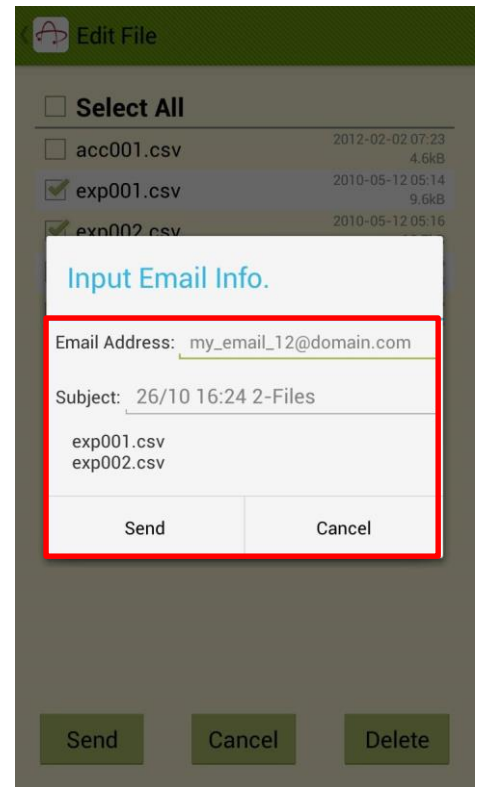
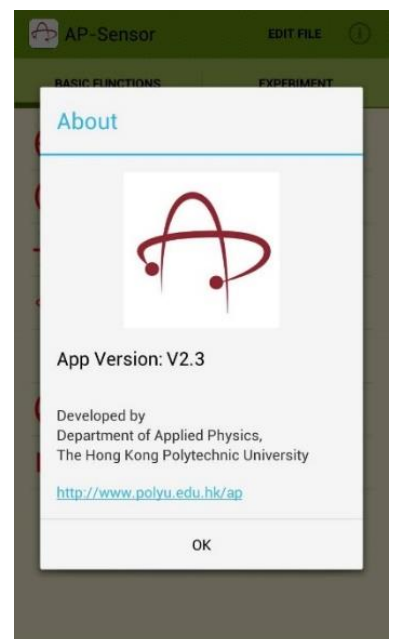


Fig 3.8

About AP-Sensor

The app information can be checked by pressing the info logo at the top right hand corner of the main menu (Fig 3.9 & 3.10).

Fig 3.9 & 3.10



4. Basic Functions

Use of Accelerometer, Magnetometer, Light Sensor and Gyroscope

The functionality of Accelerometer, Magnetometer, Light Sensor and Gyroscope share the common features except that they measure different parameters with different sensors. In this part, Accelerometer is taken as an example to interpret how to manipulate the interface. You can work out the same things in Magnetometer, Light Sensor and Gyroscope.

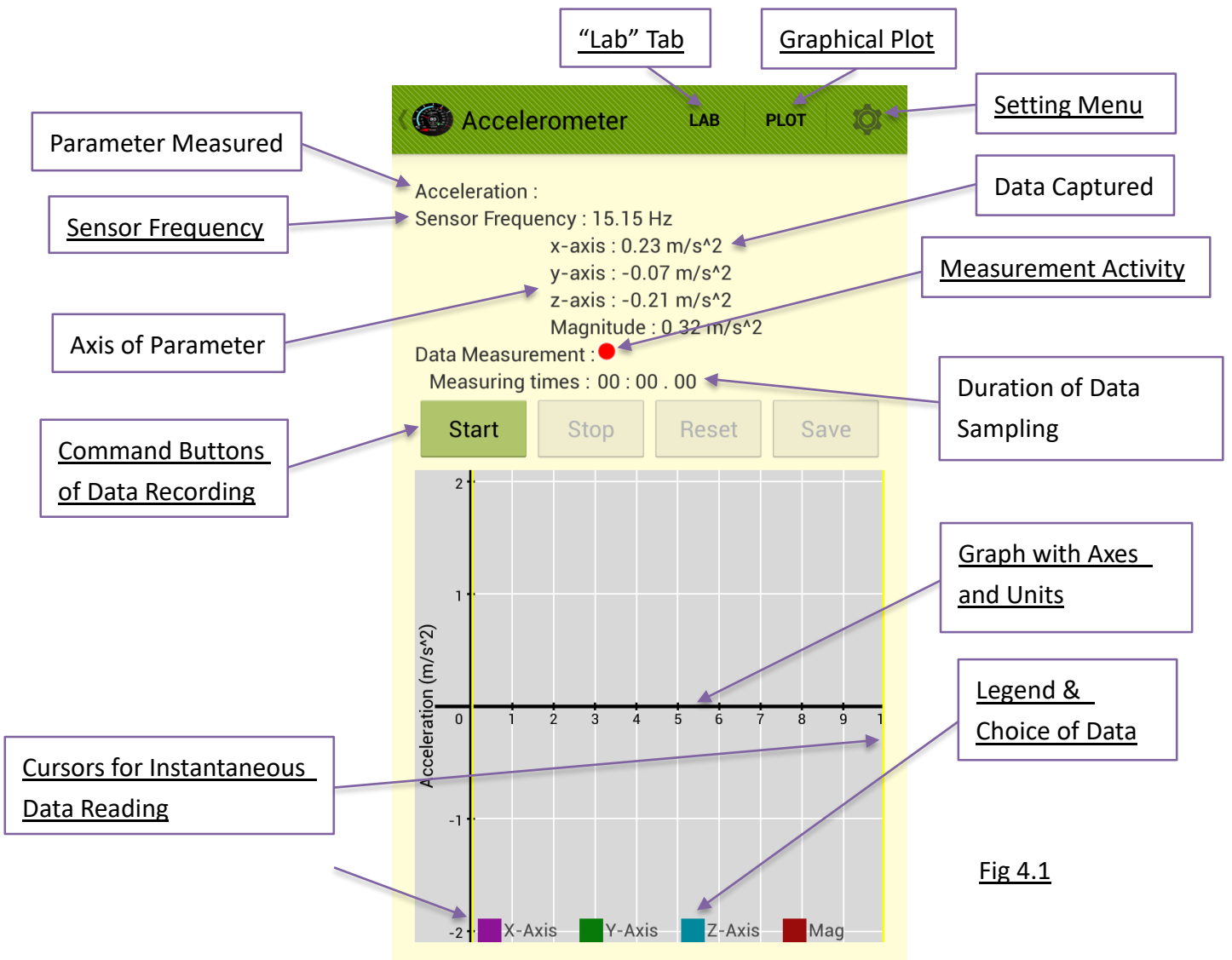


Fig 4.1

Details of Functionality

Familiarize with the readings before carrying out experiments.

Sensor Frequency: Sampling rate (SR) of sensor. It can be set in “Setting Menu”.

Measurement Activity: Green light while recording; Red light while not recording.

Graphical Plot (Fig 4.2): Full screen graph plotting data points over time. The recording cannot be paused or saved.



Fig 4.2

“Lab” Tab (Fig 4.3): Directory to the experiment presets that are conducted by the sensors.



Fig 4.3

Setting Menu (Fig 4.4): 3 options pop up – 1. Info; 2. Orientation; 3. Setting.

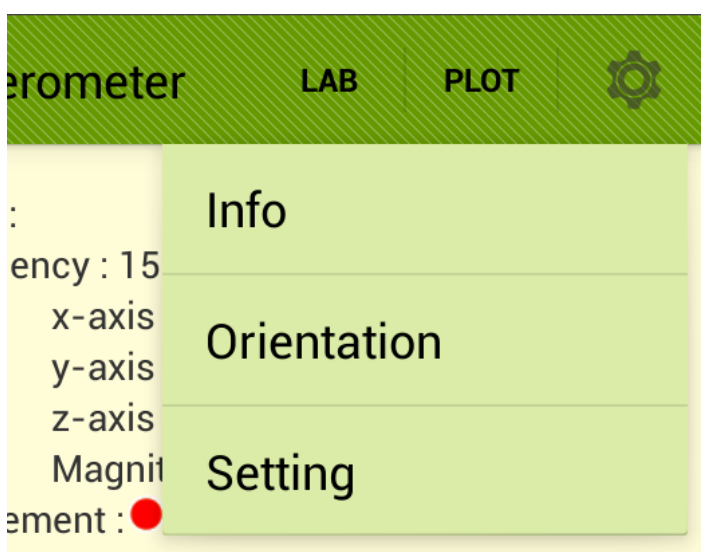


Fig 4.4

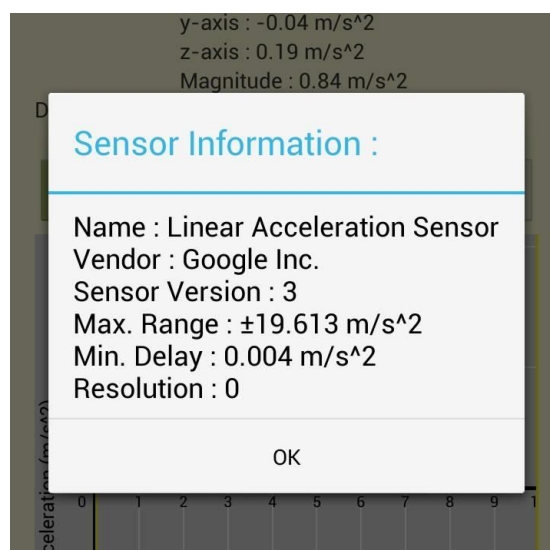


Fig 4.5

1. Info → Sensor Info (Fig 4.5): The name, vendor, version, range, delay and resolution of the sensor are displayed.
2. Orientation (Fig 4.6): Shows angles of phone to ground
Graphical representation of horizontal and vertical angles (Fig 4.7) can be found by pressing the info button.

Calibrate: Set current horizontal and vertical angle to be zero

Reset: Cancel calibration

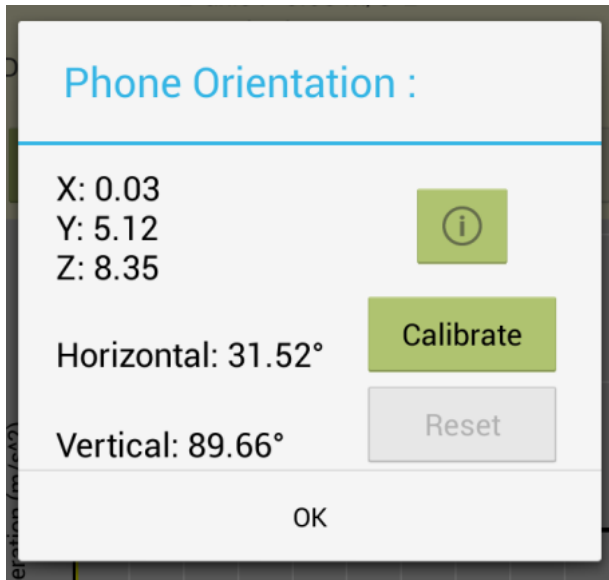


Fig 4.6

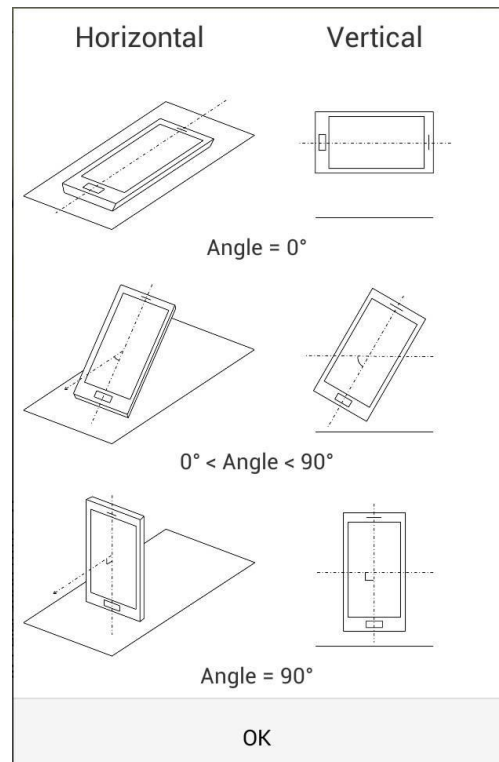


Fig 4.7

3. Setting: There are two parameters to be set (Fig 4.8).
 - i. Rate Type: Sampling rate (SR) of **sensor** listed in descending order FASTEST>GAME>UI>NORMAL. The default sampling rate is UI, which is usually 15Hz.
 - ii. Sampling Rate: Sampling rate of the **app**. The app will capture data base on this SR, defaulted as 20Hz.

Precautions:

- Please select appropriate *Sampling Rate* bases upon the *Rate Type* employed. For example, if Sampling Rate of 100Hz is selected whereas Rate Type is UI (15Hz), duplicated data will save into file.

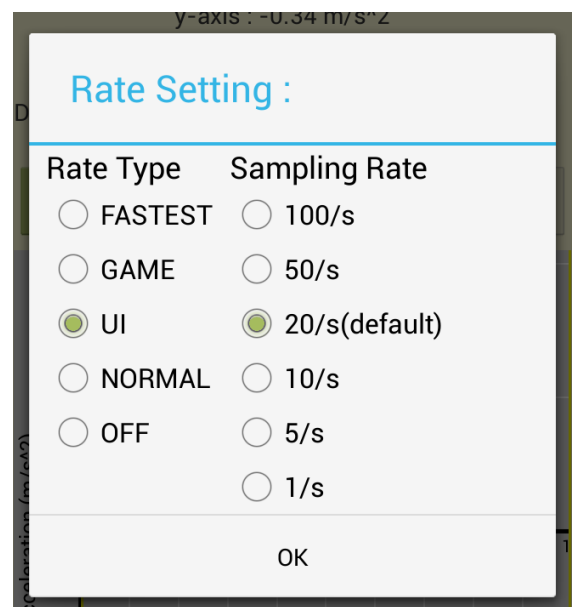


Fig 4.8

- Some old phone may not able to endure 100Hz Sampling Rate. Test the ability of the device before selection. Pick the best settings before starting any experiment.
- Sampling rate of sensor is different from sampling rate of activity.

Command Buttons of Data Recording: 4 buttons to manipulate the data logging.

- Start Button: Start recording
- Stop Button: Pause recording, can be resumed by pressing “Start Button” again
- Reset Button: Clear the graph and ready for restarting recording
- Save Button: Active after one Start-Stop cycle, see “Data Saving” below

Data Saving

- In “Save Data” activity (Fig 4.9), you can preview the data log by scrolling the table. You can name the file and save the data into a .csv file.
- Press “Save” to save data. If file with same name is found on storage, there are options to let user change file name or cover old file.
- Press “Cancel” to go back.
- Press “Plot” to view and use the features of the graph. Utilities of graph functions will be introduced next.
- To view the files, choose “Edit File” in the main menu as introduced in Section 3.

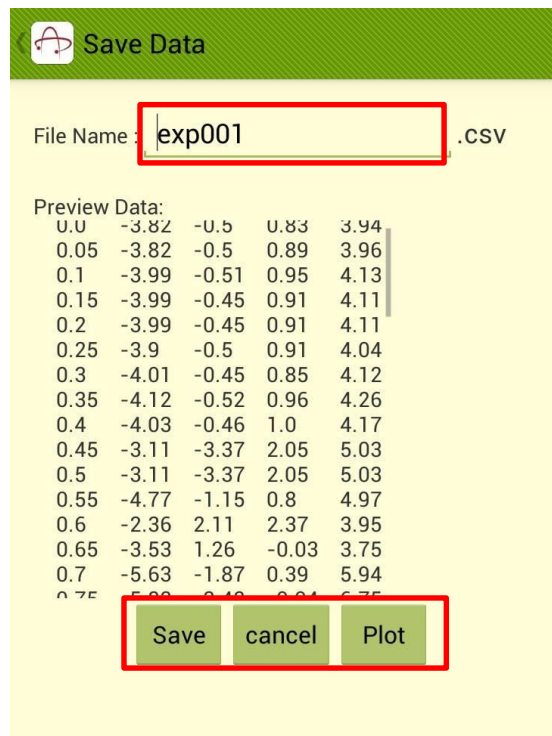


Fig 4.9

Graph with Axes and Units: Shows captured data of sensor in graph.

- After the data is captured, you can use featured functions to observe data when it is paused.
- A powerful function of the graph is that you can zoom in and out the graph in x- and y-axis by sweeping with two fingers. Fig 4.10 is a zoom-out of the plot, Fig 4.11 is a zoom-in of the plot.

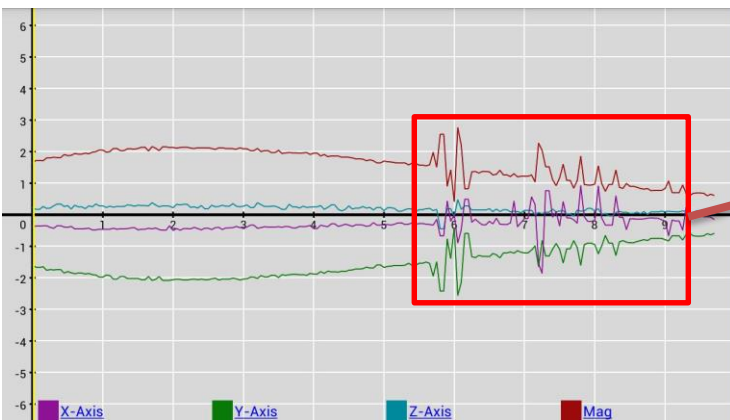


Fig 4.10

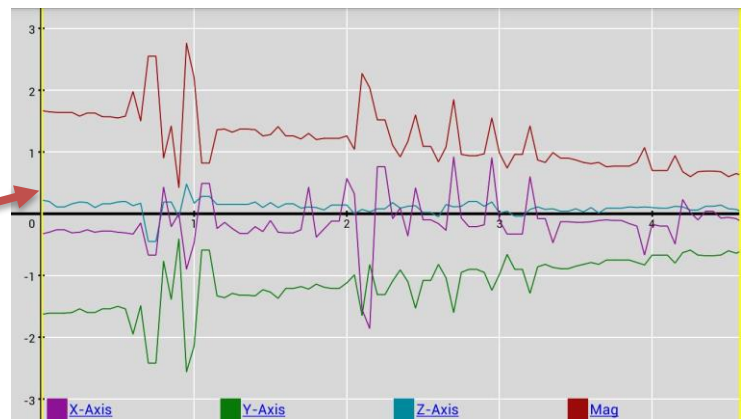


Fig 4.11

Legend & Choice of Data

The red boxes in Fig 4.12 and 4.13 show the legend of the graphs, i.e. the colours of plot corresponding to data of different axes.

- Press the desired data set to dim out other sets and show only the desired data set.
- Press another desired set to show that set only. Press the same button to return to full plot.
- Only ONE data set can be chosen at the same time.
- You can still zoom the graph in and out when using this feature.

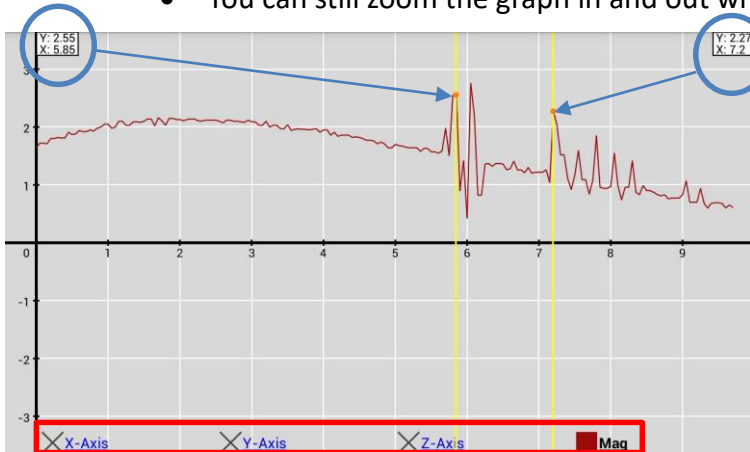


Fig 4.12



Fig 4.13

Cursors for Instantaneous Data Reading

Another powerful function of the app is that you can check the numerical values of every single data point on the graph easily.

- The blue arrows in Fig 4.12 and 4.13 indicate the cursor, in form of yellow lines, which you can drag it across the graph. The orange spots represent the data points as indicated by the cursors.
- In the white boxes on the top left and right corner, annotated by the blue circles, the readings of x- and y- axes are shown.
- Example: In Fig 4.12, the left cursor points the magnitude of acceleration is 2.55ms^{-2} at $t=5.85\text{s}$. The right cursor points the magnitude of acceleration is 2.27ms^{-2} at $t=7.2\text{s}$. In Fig 4.13, the left cursor points the acceleration in x-axis is -1.86ms^{-2} at $t=7.25\text{s}$. The right cursor points the acceleration in x-axis is 0.91ms^{-2} at $t=8.05\text{s}$.
- The readings will only be shown when ONE data set is chosen.
- You can move the cursor to any point in the graph, but left cursor must be on left side of right cursor, and vice versa, they cannot be swapped.
- You can still zoom the graph in and out when using this feature.

Sound Level Meter

- The Sound Level Meter receives sound by built-in microphone of the device. The unit of measurement is in decibel (dB).
- There is a digital display of the sound level detected, showing 3 decimal places.
- The simulated Permanent Magnet Moving Coil (PMMC) meter shows an “analog” display of the sound level at a frequency of 4Hz, showing 1 decimal place.

- The “± button” allows manual adjustment of the offset of the meter at a maximum of ±20dB (-20dB offset is demonstrated in Fig 4.14, the sound level is 32.383dB in digital display and it is 12.4dB in PMMC analog display). It can be used to normalize the background noise.
- The graph plots the variation of values detected in previous 10 seconds.
- The maximum sound level that can be shown is 90.3dB.
- The meter cannot be paused. “File Saving” and “Plot” functions are not enabled in this mode.

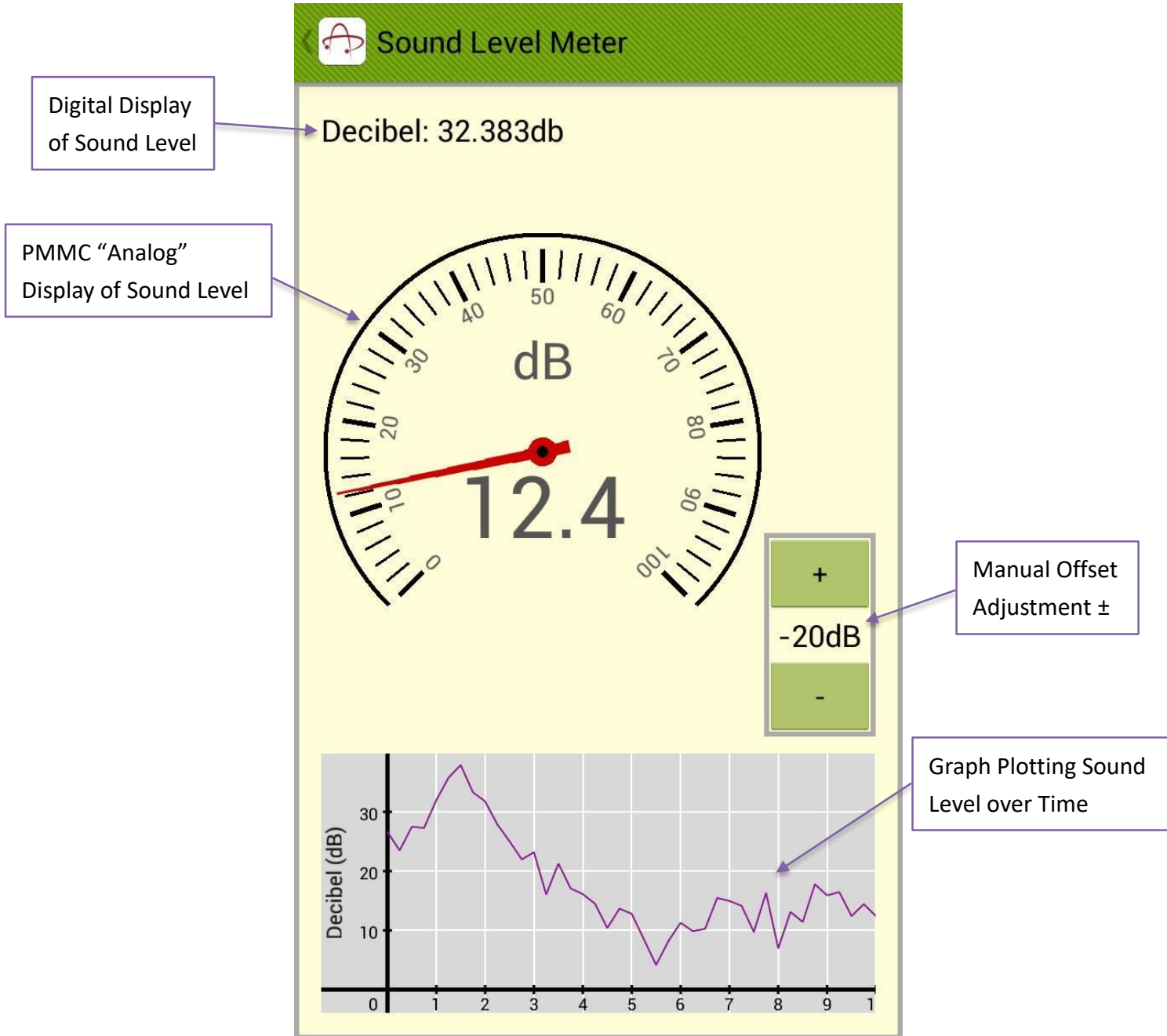


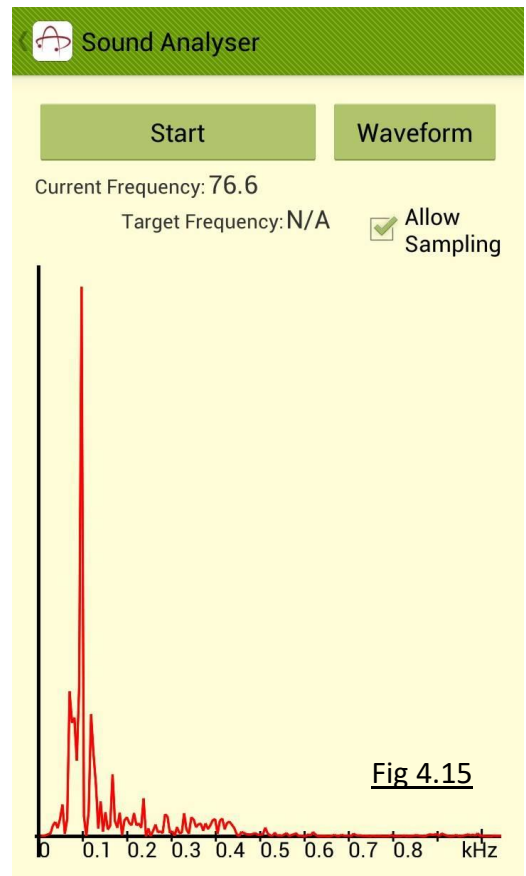
Fig 4.14

Sound Analyzer

There are 3 modes in the Sound Analyzer which provides different functions, namely “Spectrum”, “Waveform” and “Tuner”.

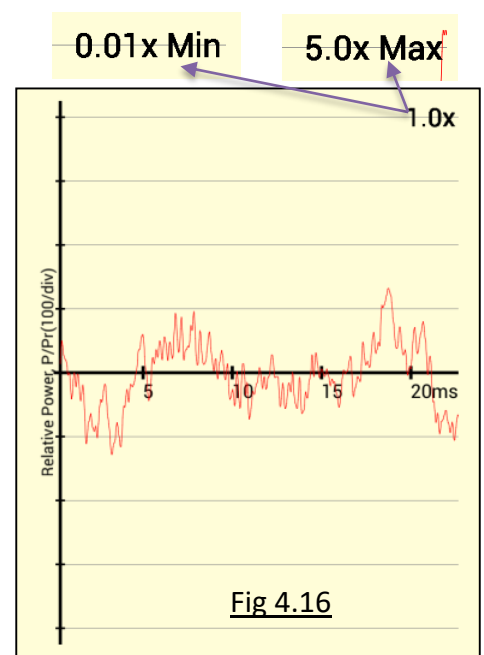
Spectrum Mode

- By Fourier Transformation, the Sound Analyzer receives sound from microphone and breaks down the sound into a composition of different frequencies, displayed in a spectrum.
- The “Current Frequency” indicates the peak frequency at that instant in Hz (76.6Hz in Fig 4.15). While the default mode is “Spectrum”, you can also observe other different frequencies composing the sound.
- “Target Frequency” is not enabled before getting into “Tuner” mode. It will be discussed in “Tuner” mode.
- When the “Allow Sampling” Checkbox is enabled, all the peak frequencies over 2 seconds will be sampled and the peak frequency will be shown. It is recommended to disable the checkbox at low frequencies.
- The Sound Analyzer starts taking measurement once you enter, press “Stop” to stop the measurement. The data at that instant will be shown. The graph can be zoomed in and out by sweeping the plot with two fingers when measurement is stopped. It displays amplitude of frequencies ranged from 0 to 3kHz.
- Press the “Waveform” button on the top right corner to switch into “Waveform” mode. The button is used to switch modes in order “Spectrum” → “Waveform” → “Tuner”.



Waveform Mode

- The waveform of current detected sound is shown.
 - The graph can be zoomed in and out by sweeping the plot with two fingers when measurement is stopped for the ease of observation. The x-axis shows the time in ms ($10^{-3}s$), defaulted as 22ms, zooming in to at most 3ms and out to at most 45ms. The y-axis shows the relative power of the sound, defaulted as 100unit/div, zooming in to at most 20/div and out to at most 10k/div.
- ***Task: You can observe the wavelength here and compare the value observed in the “Spectrum” mode.



Tuner Mode

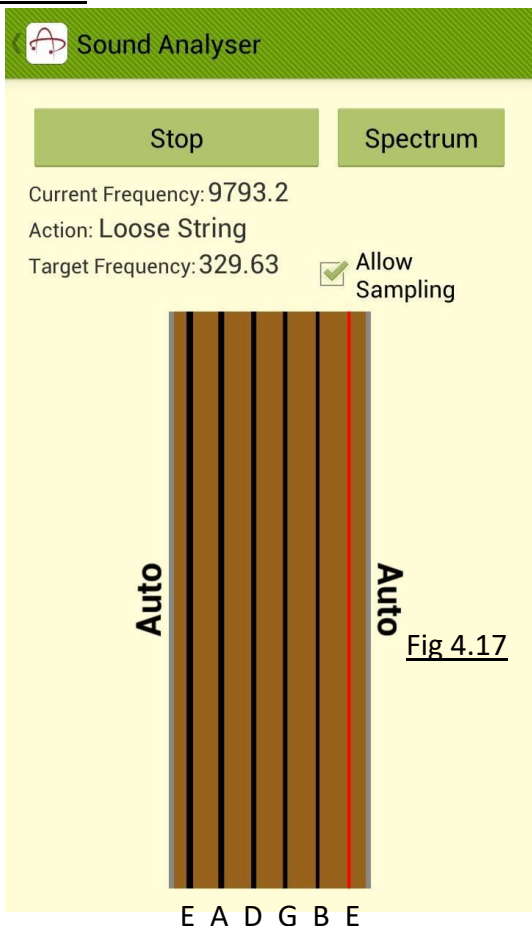


Fig 4.17

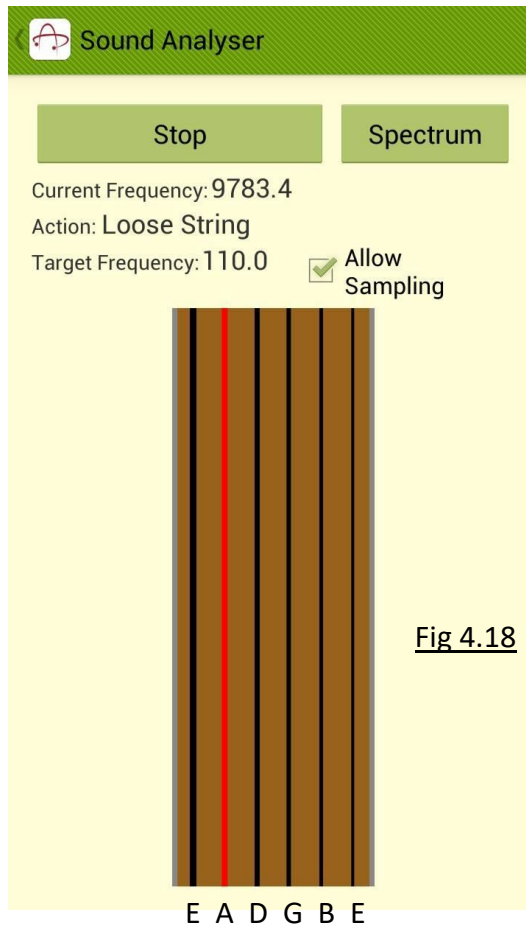


Fig 4.18

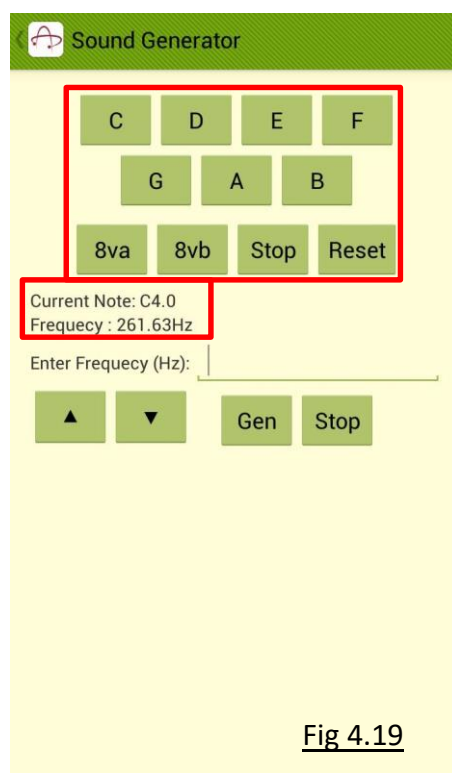
If you are a guitar lover, the “Tuner” mode serves a practical function for you.

- The corresponding pitches for different strings of an acoustic guitar are shown above.
- By default (Fig 4.17), the Sound Analyzer receives the sound and automatically match with the guitar string of the closest frequency, shown as red. The target frequency of that string will be shown. The words “Auto” appear at both sides of the strings animation.
- The “Action” is an instruction for user to adjust the string to the target frequency. There are several Actions instructing user to tune the guitar:
 - Tighten String
 - Close | Tighten String
 - Acceptable | Tighten String
 - Perfect
 - Acceptable | Loose String
 - Close | Loose String
 - Loose String
- Press on a desired string to fix the target frequency. (String of pitch A is chosen in Fig 4.18.) The words “Auto” will disappear. The Sound Analyzer will stop matching with the guitar string of the closest frequency. Press another desired string to fix another target frequency. Press the same string to return to automatic frequency targeting.

- For a string of length L and mass m , its linear density $\mu = \frac{m}{L}$. The velocity of wave traveling in the string under tension T is given by $v = \sqrt{\frac{T}{\mu}}$, and thus its frequency in fundamental harmonic is given by $f = \frac{1}{2L} \sqrt{\frac{T}{\mu}}$.

Sound Generator

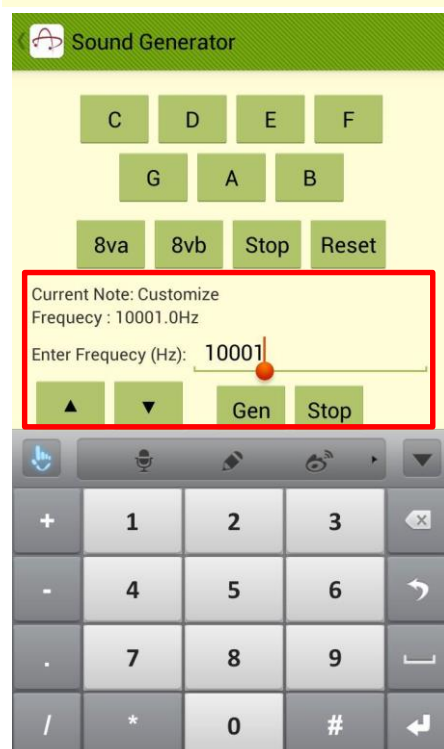
- The Sound Generator generates sinusoidal sound wave with a desired frequency.
- Sound frequency can be set with 2 methods.
 1. Using preset music notes (Fig 4.19)
 - Press the buttons C, D, E, F, G, A, B to change to the defined pitches of the music notes.
 - Press the buttons 8va to increase one octave and 8vb to decrease one octave. Defaulted at the 4th octave, down to the 1st octave and up to the 8th octave. The pitch can be changed anytime.
 - Currently playing note and its corresponding frequency will be automatically shown in “Current Note” and “Frequency”.
 - Press “Stop” button to stop generating sound wave.
 - Press “Reset” button to reset note to “C4” (Note C of 4th octave).



2. Manually entering desired frequency (Fig 4.20)
 - Desired frequency in Hz can be entered in the field “Enter Frequency (Hz)”.
 - The “Current Note” will become “Customize”.
 - Press “Gen” button to start generating sound wave.
 - Press the “Up/Down arrow” to adjust desired frequency by 1Hz. Long press the button to adjust frequency continuously, user can hear the frequency change when the button is long-pressing.
 - Press “Stop” button to stop the sound wave.

- Note: If you do not press the “Stop” button, the sound will still keep being generated even if the app interface is closed.

Fig 4.20



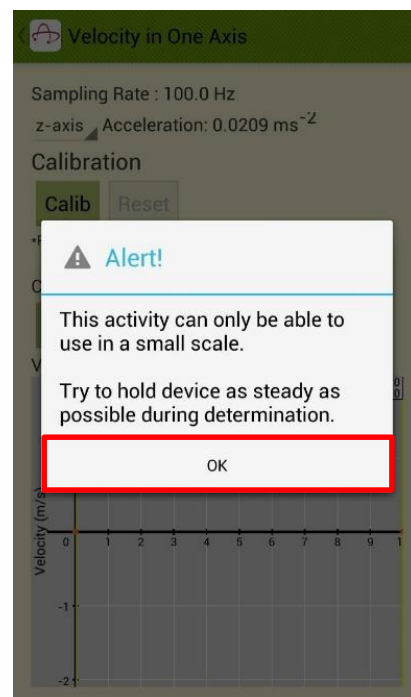
5. Experiments

The app contains 6 experiments using different sensors in the device. The experiments include “Velocity in One Axis” and “Apparent Weight in Lift” (using Accelerometer), “B-Field Vs Distance” and “Radial Speed of a Magnet” (using Magnetometer), “Light Intensity Vs Distance” (using Light Sensor), “Find Revolutions and Distance” (using Gyroscope). In the experiments, you will get an idea of how the sensors of your mobile device can be utilized for physical measurements, and how they can be applied in daily life. Many other experiments can also be carried out with the application even though they are not in the provided experiment presets.

Velocity in One Axis

This experiment allows measurement of velocity of the phone in a specified axis (x-, y-, z-axis). The measurement, however, can only be used over small distance without significant shock because of the limitation of the Operating System. When you first enter this experiment, a precaution message will show up (Fig 5.1). Press “OK” to proceed.

Fig 5.1



- The Sampling Rate is fixed at 100.0Hz.
- Press the “Axis Selection” tab on the left of the instantaneous Acceleration reading (up to 4 decimal places) to choose a desired axis (Fig 5.2). x-axis is chosen as an example. Fig 3.3 and 3.4 give reference for the axes but they may vary in different devices. You are advised to test the axes of your device in advance.
- Place the phone on a flat surface and press “Calib”. Wait for 5 seconds to calibrate the error in the axis (Fig 5.3). The measurement cannot be started before calibration.
- The value of error will be shown after calibration. Press “Start” to begin measurement. The velocity against time will be plotted and the value of instantaneous velocity up to 4 decimal places is shown above the graph (Fig 5.4).
- The “zoom” function and the cursors for instantaneous readings are available on the graph when the measurement is stopped (Fig 5.5). The “save” function is also enabled. Refer to Part 4 for more details.

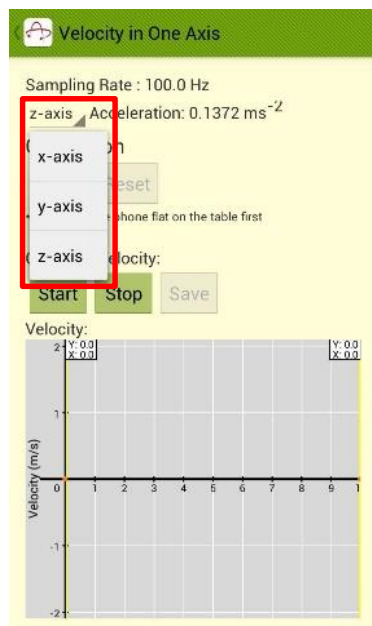


Fig 5.2

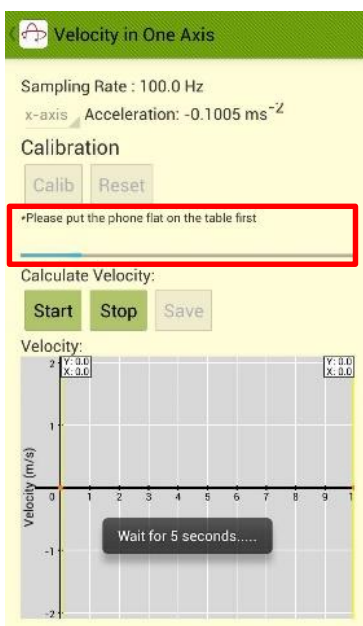


Fig 5.3

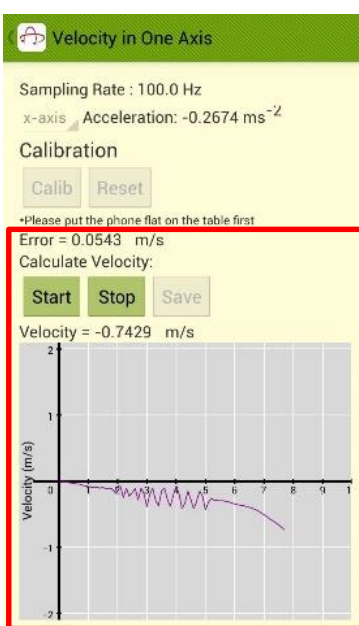


Fig 5.4

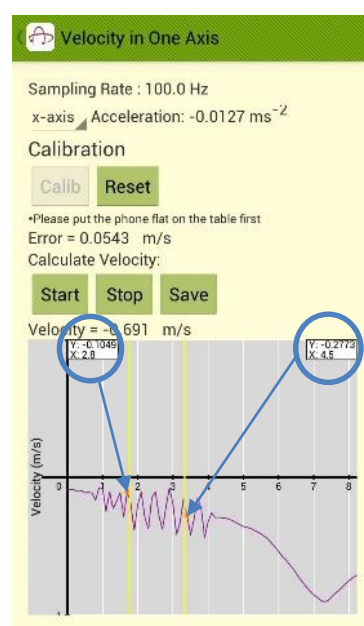


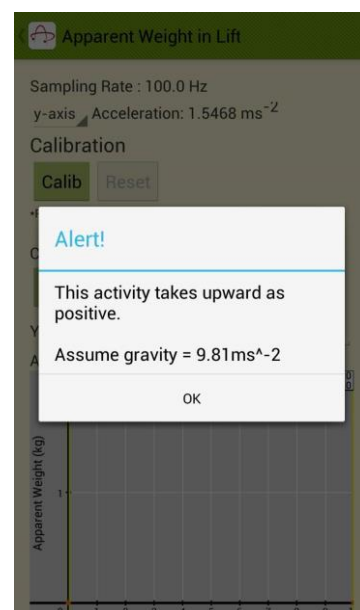
Fig 5.5

Apparent Weight in Lift

By measuring the acceleration in a chosen axis, this experiment will show you the acceleration and your apparent weight in lift when it accelerates/decelerates. A message will pop up noticing that the experiment is taking upward acceleration as positive with gravity assumed to equal 9.81ms^{-2} (Fig 5.6). Press “OK” to proceed.

Fig 5.6

- The Sampling Rate is fixed at 100.0Hz.
- Press the “Axis Selection” tab on the left of the instantaneous Acceleration reading (up to 4 decimal places) to choose a desired axis (Fig 5.7). In this case, z-axis is chosen and the display of the device should face to the top. Fig 3.3 and 3.4 give reference for the axes but they may vary in different devices. You are advised to test the axes of your device in advance.
- Place the device on a flat surface and press “Calib”. Wait for 5 seconds to calibrate the error in the axis (Fig 5.8). The measurement cannot be started before calibration.
- The value of error will be shown after calibration. Input your weight (in kg) in the field provided (Fig 5.9).
- Press “Start” to begin measurement. The apparent weight and acceleration against time will be plotted in two graphs simultaneously. The value of instantaneous apparent weight up to 4 decimal places is shown above the graph. The “zoom” function and the cursors for instantaneous readings are available on both graphs when the measurement is stopped (Fig 5.10). The “save” function is also enabled. Refer to Part 4 for more details.



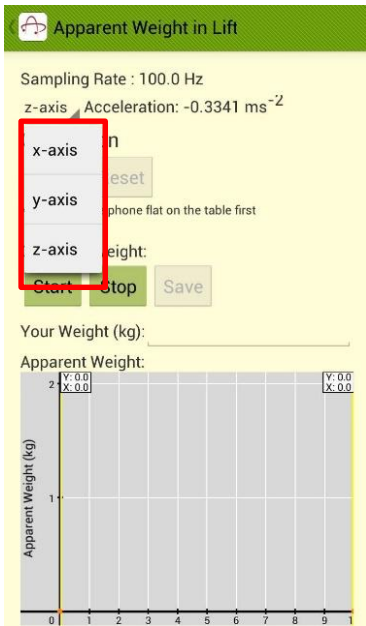


Fig 5.7

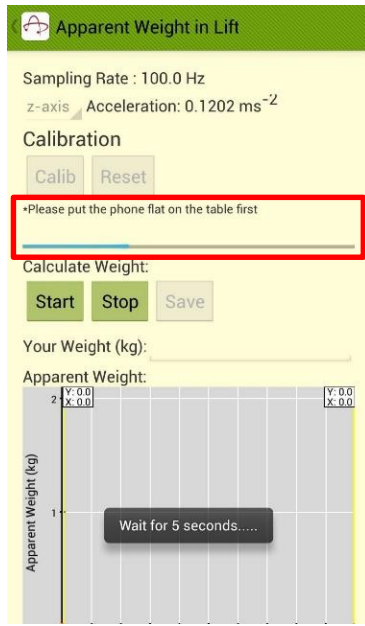


Fig 5.8

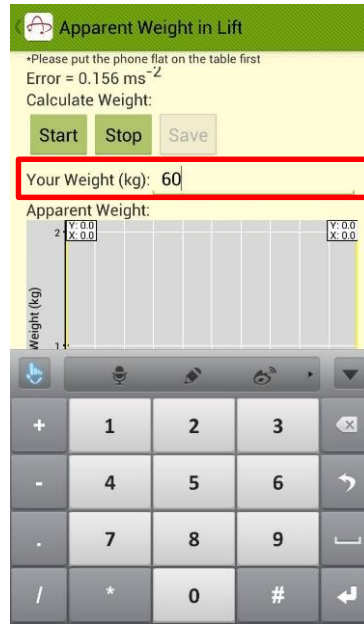


Fig 5.9

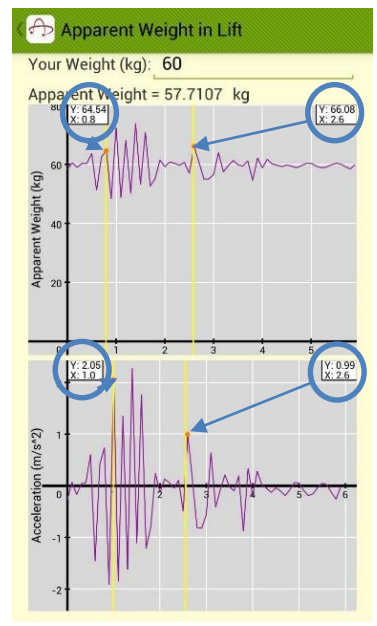


Fig 5.10

B-Field Vs Distance

Using the built-in Magnetometer of the device, the app can determine magnetic field strength acting on the phone. You can manually count the magnetic field strength in μT (10^{-6}T) at different distance from a point. In Fig 5.11, the instantaneous magnetic field strength detected is shown. By default, the starting point is set at 5.0mm, the distance per step from the starting point is 5.0mm.

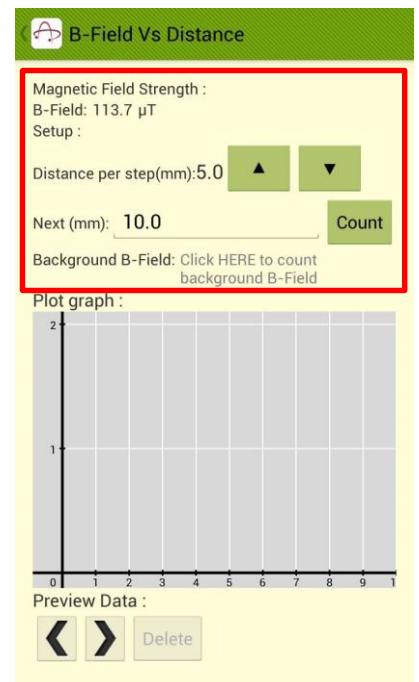


Fig 5.11

- Press the space next to “Background B-Field” to count the background magnetic field. The background field strength will be shown in the space (Fig 5.12). The magnetic field reading will show a normalized value after eliminating the background field, so that you can detect the magnetic field strength of a single object more accurately. Press again to reset the background value if necessary.
- Press the “Up/Down Arrow” to increase/decrease the “Distance per step” by 0.1mm. The example below is set to 7.2mm. Given that the starting point at 5.0mm, the next data point will be 12.2mm (Fig 5.13).
- When you move the device to the desired distance, press “Count” to record the data and plot the point on the graph. The app will automatically be ready for counting the next data point. You can check the data recorded in the table at the bottom of the interface (Fig 5.14).
- If you are not taking measurements at every fixed distance, or if you are taking measurement at large distance, you can type the desired distance directly in the field “Next” (Fig 5.15), and press “Count” to record data at that distance. In the example below, 500.0mm is recorded after 26.6mm.

- Under the “Preview Data”, you can press the “Left/Right Arrow” to pick the desired data point, shown as red. Undesired data point can be deleted by pressing “Delete” button. Note that the “Delete” action is irreversible. In Fig 5.16, the 2nd data point from Fig 5.14 is deleted.

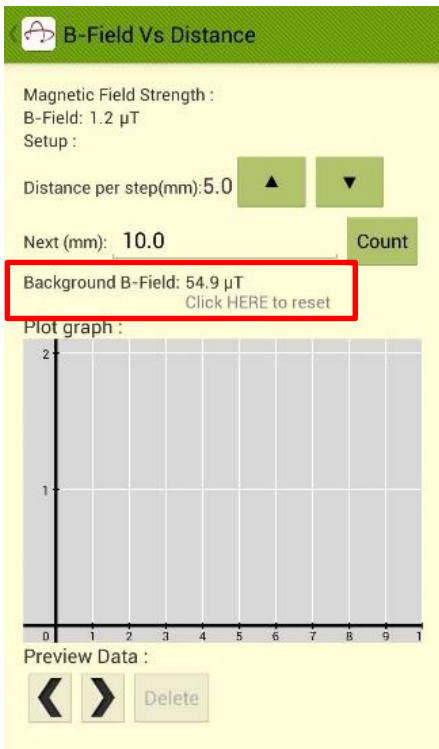


Fig 5.12

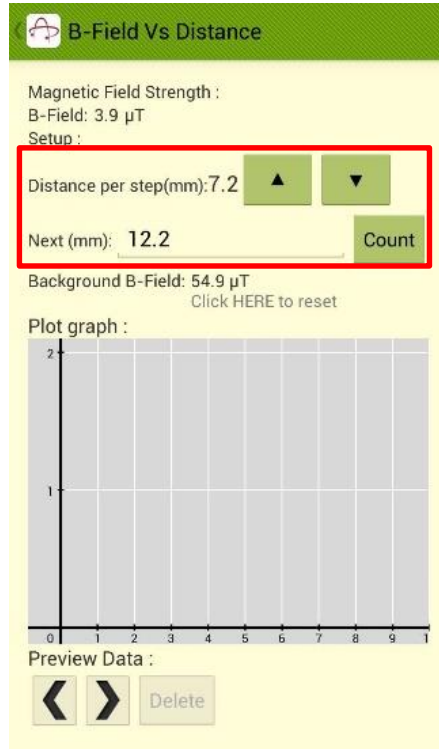


Fig 5.13

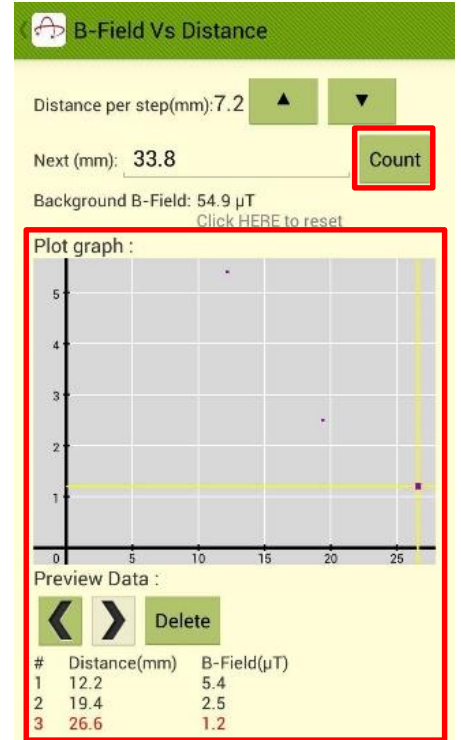


Fig 5.14

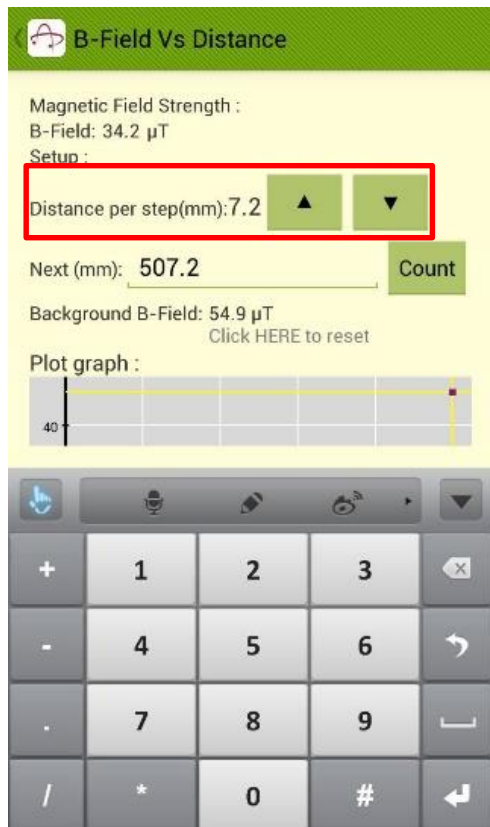


Fig 5.15

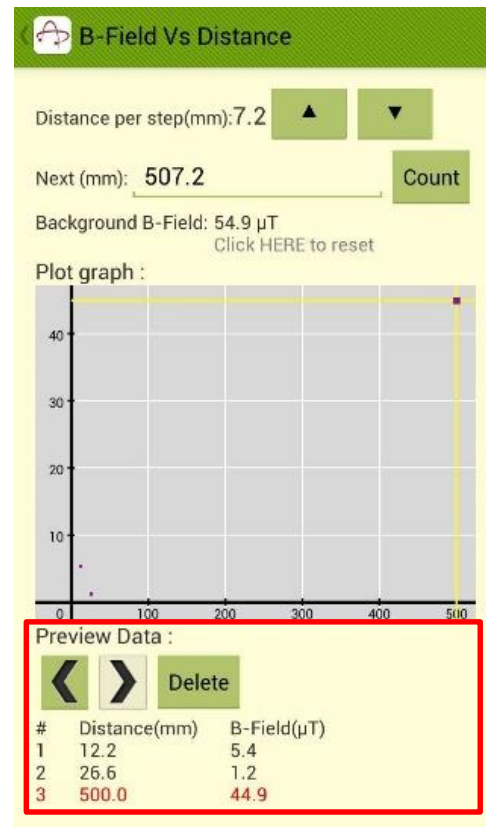


Fig 5.16

Radial Speed of a Magnet

With Magnetometer measuring magnetic field in different axes, the app is able to detect rotation of a magnetized object, such as a magnet, by the variation of magnetic field it induces during rotation.

- The Sampling Rate is 15.15Hz by default.
- The separate readings of magnetic field in x-, y-, z-axis and the magnitude are shown. The unit is in μT (10^{-6}T). The radial speed of rotation of the object is shown below (Fig 5.17). In this example, however, the radial speed is not recorded due to limitation of mobile device.
- Press “Start” to begin recording data in the graph Magnetic Field Strength in 3 axes and magnitude against time, thus there are 4 lines in the graph. In the meantime, the graph of radial speed against time is also plotted (Fig 5.18).
- When the measurement is stopped, you can utilize the “Legend Choice”, “Zoom” and “Cursor” functions in both graphs to obtain precise readings (Fig 5.19).
- The “Save” and “Plot” functions are enabled in this experiment. Refer to Part 4 for more details. The data and graphs will be cleared after pressing “Reset” button. Note that the Reset process is irreversible.

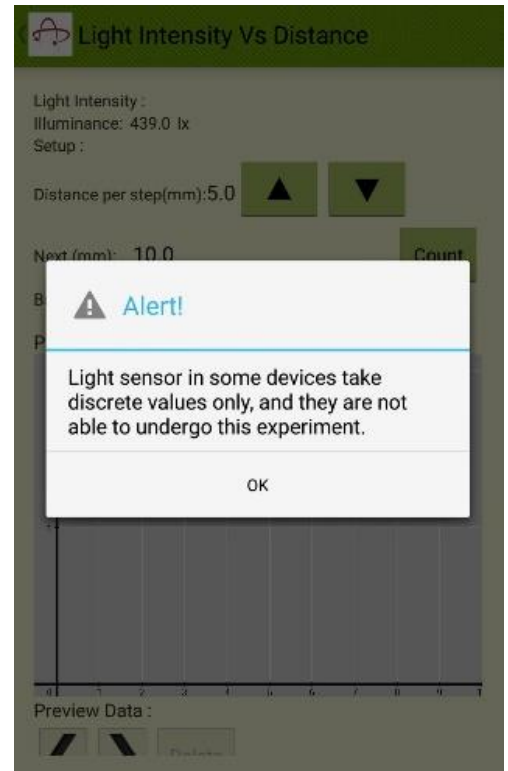


Fig 5.20

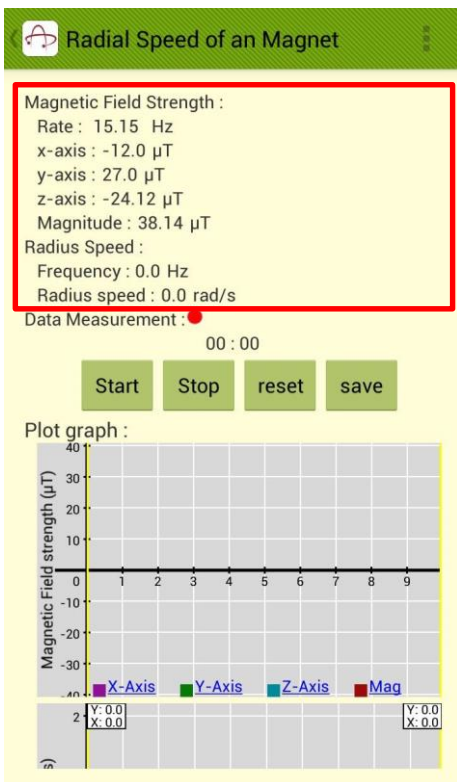


Fig 5.17

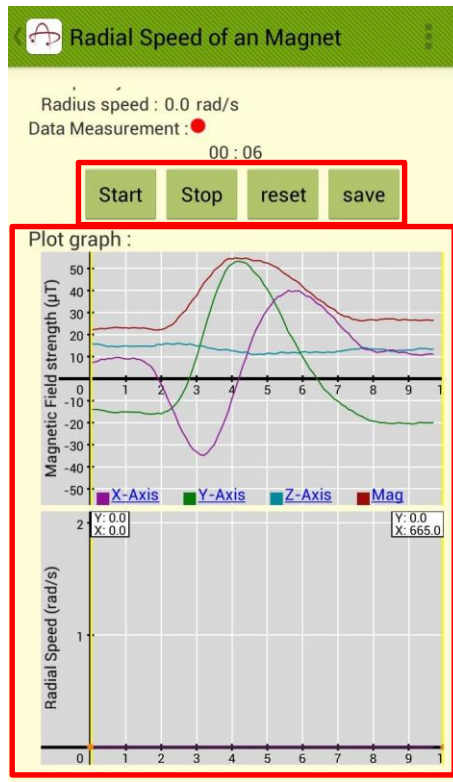


Fig 5.18



Fig 5.19

Light Intensity Vs Distance

Similar to the “B-field Vs Distance” experiment, the app also possesses the ability to record light intensity at manually determined distance and plot a graph of light intensity vs. distance. The function, nonetheless, is only applicable on mobile devices that are equipped with light-sensitive photo diode (i.e. that offers “adaptive brightness” function). On some devices, the illuminance are quantized into discrete level by the Operating System. In that case, the experiment cannot be conducted accurately. A warning signal regarding this will show up when you enter this experiment (Fig 5.20). Press “OK” to proceed.

- Press the space next to “Background illuminance” to count the background light intensity. The background light intensity will be shown in the space (Fig 5.21). The illuminance reading will show a normalized value after eliminating the background light, so that you can detect the illuminance of a single object more accurately. Press again to reset the background value if necessary.
- Press the “Up/Down Arrow” to increase/decrease the “Distance per step” by 0.1mm. The example below is set to 3.0mm. Given that the starting point at 5.0mm, the next data point will be 8.0mm (Fig 5.21).
- When you move the device to the desired distance, press “Count” to record the data and plot the point on the graph. The app will automatically be ready for counting the next data point.
- If you are not taking measurements at every fixed distance, or if you are taking measurement at large distance, you can type the desired distance directly in the field “Next” (Fig 5.22), and press “Count” to record data at that distance. In the example below, 300.0mm is recorded after 20.0mm.
- You can check the data recorded in the table at the bottom of the interface (Fig 5.23).
- Under the “Preview Data”, you can press the “Left/Right Arrow” to pick the desired data point, shown as red. Undesired data point can be deleted by pressing “Delete” button. Note that the “Delete” action is irreversible. In Fig 5.24, the 3rd and the 4th data point from Fig 5.23 are deleted.

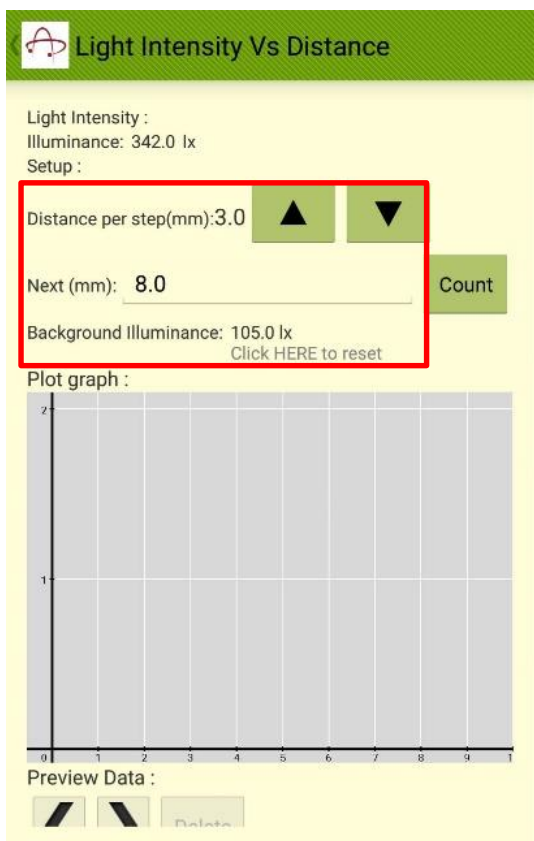


Fig 5.21

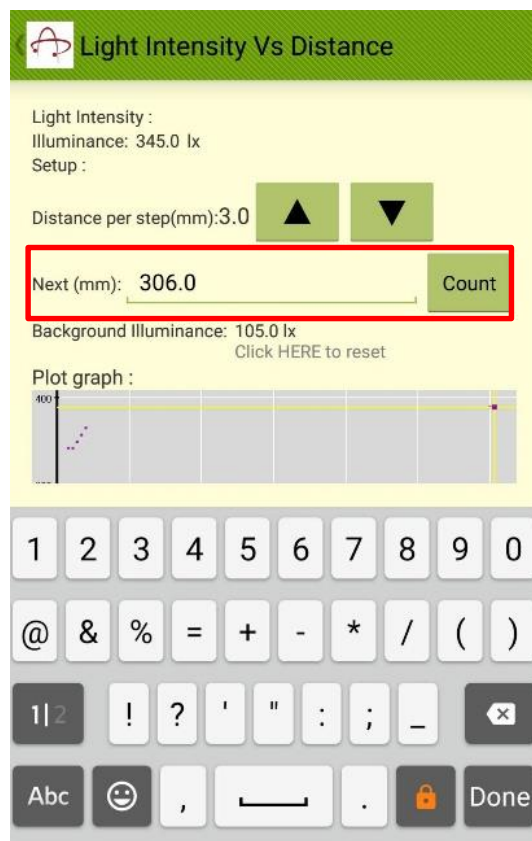


Fig 5.22

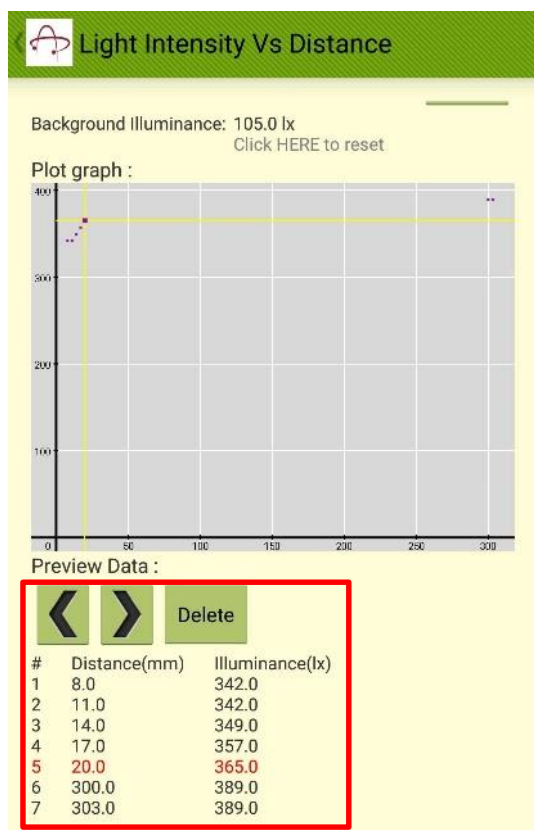


Fig 5.23

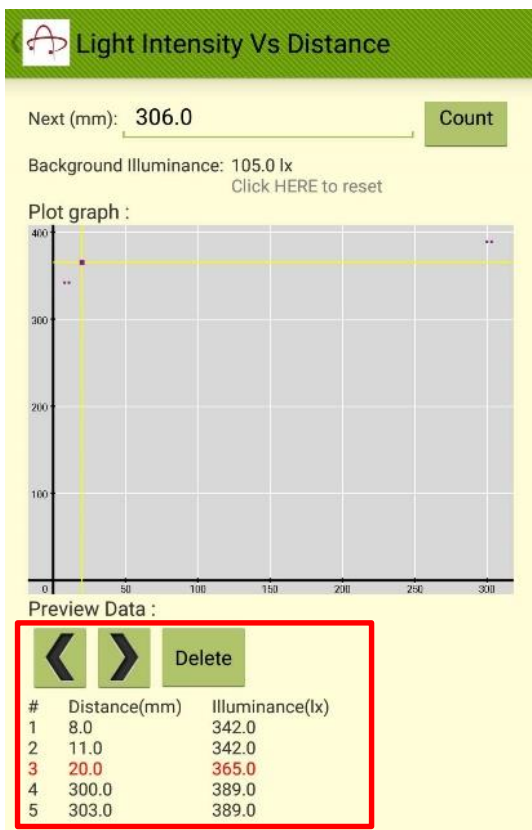
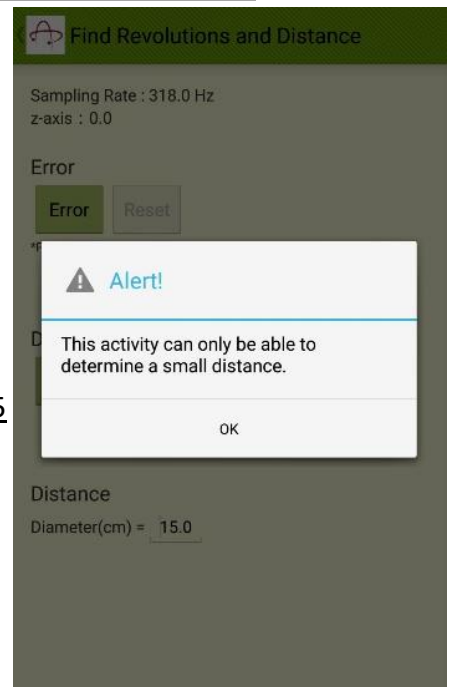


Fig 5.24

Find Revolutions and Distance

Using the Gyroscope in the mobile device, we can find revolutions of an object about z-axis of the gyroscope (the mobile device). For an object at a distance a from the device, i.e. the diameter of spin (in cm) is $2a$, the distance traveled by the object will also be calculated. A warning signal noting that the experiment can only be conducted over a small distance will pop up when you enter the experiment (Fig 5.25).

Fig 5.25



- The Sampling Rate is fixed at about 50.0Hz.
- Place the device on a flat surface and press the “Error” button. Wait for 5 seconds to calibrate the error in the axis (Fig 5.26). The measurement cannot be started before calibration. Unlike the previous experiments, z-axis is the only possible axis of measurement.
- If you wish to measure the distance traveled by an object at a certain diameter from the device, input the diameter (NOT radius) in cm in the field “Diameter”. The value defaulted is 15.0cm. The value input in this example is 10.5cm (Fig 5.27).
- Start the measurement by pressing the “Start” button. In Fig 5.28, the device is rotated about z-axis by one turn. You can observe the displacement in radian, number of turn and the distance traveled for an object 5.25cm away from the phone. Try to verify the experimental result with your theoretical value.

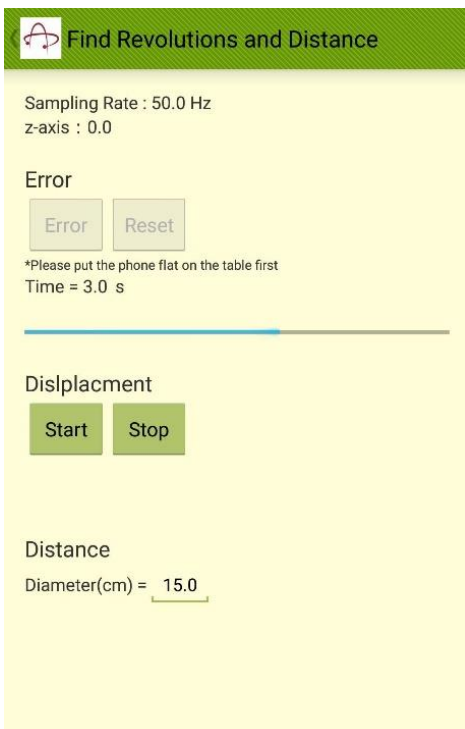


Fig 5.26



Fig 5.27

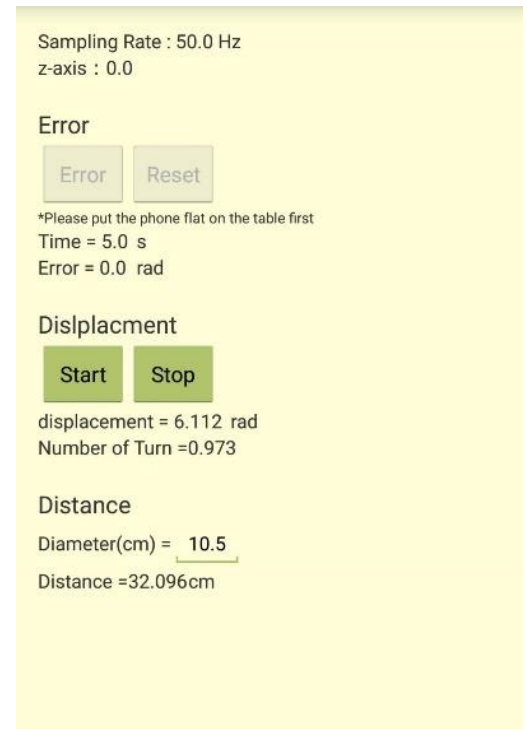


Fig 5.28

- End of Manual -

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