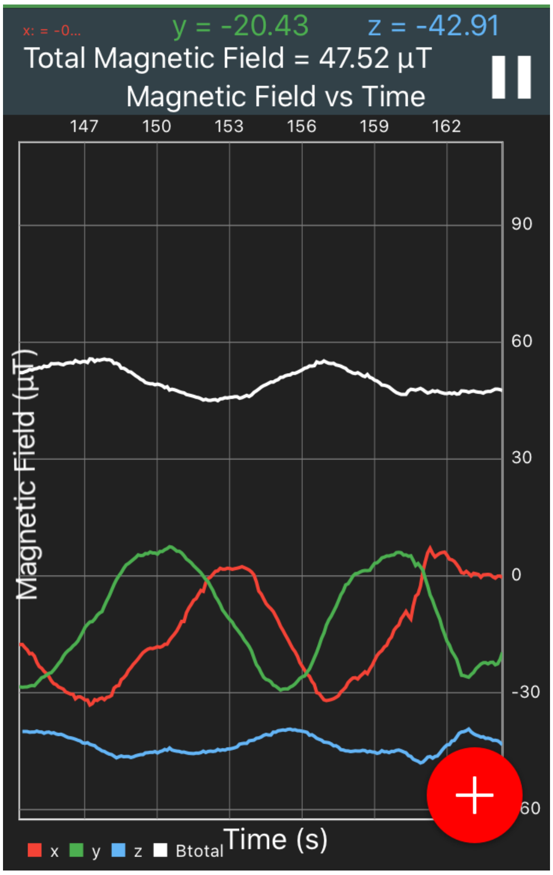
Introduction to smartphone magnetometry - teacher notes

- This exercise is designed to get students thinking about the magnetic sensor as an actual physical object with a physical location inside the phone and understand some of its limitations.
- This information will help students to design and conduct surveys using this instrument.
- Measuring the ambient field and calculate its inclination also forces the transition from thinking of the magnetic field as a 3D vector rather than a 2D one.

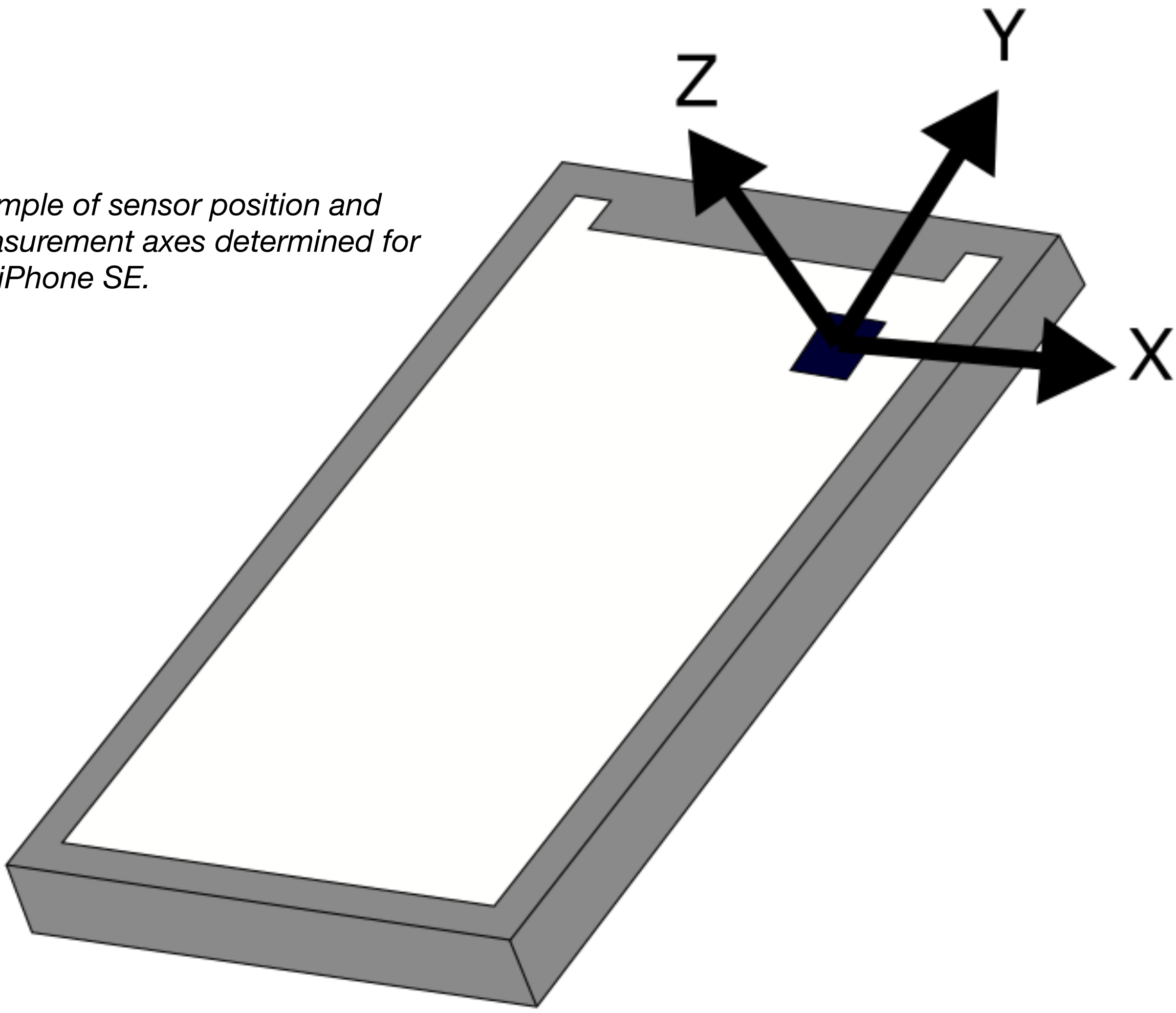
1/2: Sensor location and axes

- Although the location of the sensor will likely differ between different phones, since modern smartphones are mostly battery it is most likely located close to one of the edges.
- I have got good results with a bottle cap and an earbud. The sensor only reliably picks these items up if they are directly underneath the sensor and within a 1-2 cm. The students should realise from this that the smartphone sensor has a relatively low sensitivity.
- Small fridge magnets also work, but use with caution: if strong magnets get too close it will saturate the sensor and temporarily cause it to stop working.
- Rotating the phone generates varying sinusoidal signals on the two sensor axes that are measuring the horizontal components of the field, whilst the axis measuring the vertical component of the field stays relatively stable. In the first rotation (bottom horizontal) the stable axis is perpendicular to the phone surface; in the second rotation (bottom vertical) it is the axis running up/down the phone surface.



Example: in this case, the rotation shows that x and y (large, sinusoidal variations) are currently measuring horizontal components of the field and z (much less variation) is measuring the vertical

Example of sensor position and measurement axes determined for the iPhone SE.



Measurement procedure

Disadvantages of screenshot method:

- susceptible to noise (single snapshot differs from actual average value);
- action of pressing buttons disrupts sensor readings and orientation,
- for a survey, numbers need to be transcribed from multiple screenshots.

However, the data recording procedure is a little fiddly and dependent on phone OS and accessibility of a computer for pulling up the saved file (although the data analysis can also be done using Google Docs on the phone). Polling the students as to the specific set-ups and providing tailored support/instructions may be required.

3/4/5: Example of ambient geomagnetic field measurements and inclination from Kent Ohio:

- The Physics Toolbox app uses units of μT (x10-6 T): expected values for the geomagnetic field should be in the tens of μT range.
- In the saved data files, measurement timestamps show one reading every 0.1 seconds.

RECORD LENGTH: 11 seconds

	Average Value	**Max Value**	**Min Value**
Bx	13.37 μT	14.05 μT	12.73 μT
By	-15.23 μT	-14.84 μT	-15.52 μT
Bz	-46.53 μT	-45.75 μT	-47.19 μT
Btotal	50.75 μT	51.30 μT	50.10 μT

During 10-20 second measurement periods, the measured value typically varies by ±0.25 to ±0.75 μT. This sets limits in the magnitude of local anomaly that can be distinguished from noise.

Calculated field values:

Horizontal B_H: $=\sqrt{x^2+y^2}$ = 20.27 μT

Vertical B_V = 46.53 μT

(note: needs to be some discussion of the down=positive convention in geophysics, which is not followed by the sensor in the phone used)

Inclination: $=\tan^{-1}\left(\frac{B_V}{B_H}\right)$ = 66.5°

Predicted field values (WMM for day or survey):

Horizontal B_H = 19.89 μT

Vertical B_V = 48.72 mT

Inclination: 67.8 °

This measurement is quite close to the expected value: a more advanced treatment might include propagating errors (which includes estimates of error in the vertical orientation of the phone) to see if the predicted inclination is within error.

A similar measurement inside the house 2 minutes later produced a measurably lower horizontal magnetisation (15.43 μT) and a correspondingly steeper inclination (70.7°), indicating that something inside the house (and/or the house itself) was modifying the local magnetic field. The closest obvious source of local magnetism in this case was the kitchen oven.

Pooling and Discussion of Results

To conclude this exercise, a group discussion is recommended, that would involve pooling individual results to:

- compare the performance of difference smartphone sensors and the possible reasons for any differences (case materials, sensor position, local environment are all possible factors).
- see if there are variations in inclination values due to geography (if the group is spread across a wide range of latitudes), local geology or other local factors (e.g. urban vs rural).
- compare the deviations observed when inside (house construction, or proximity to strong magnetic sources such as kitchen appliances).