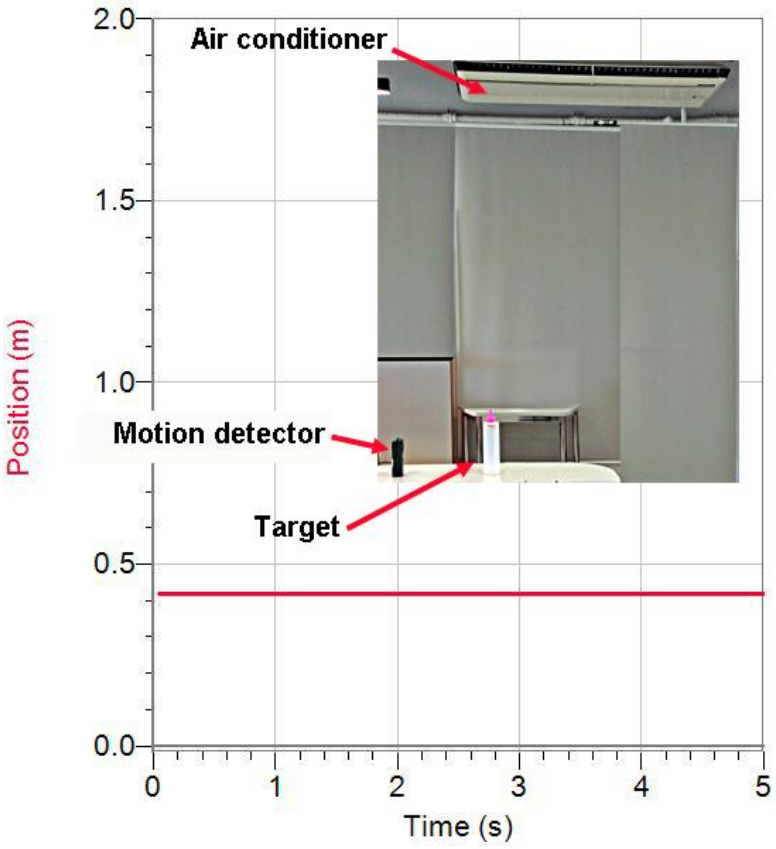
Digital errors

A Vernier motion detector emits 40 000 Hz ultrasound pulses. The echo return time from the nearest object is recorded and a calculation is performed in Logger pro to plot distance against time. Air is a nondispersive medium for sound. The speed of ultrasound is the same as the speed of the longer wavelengths of speech etc.

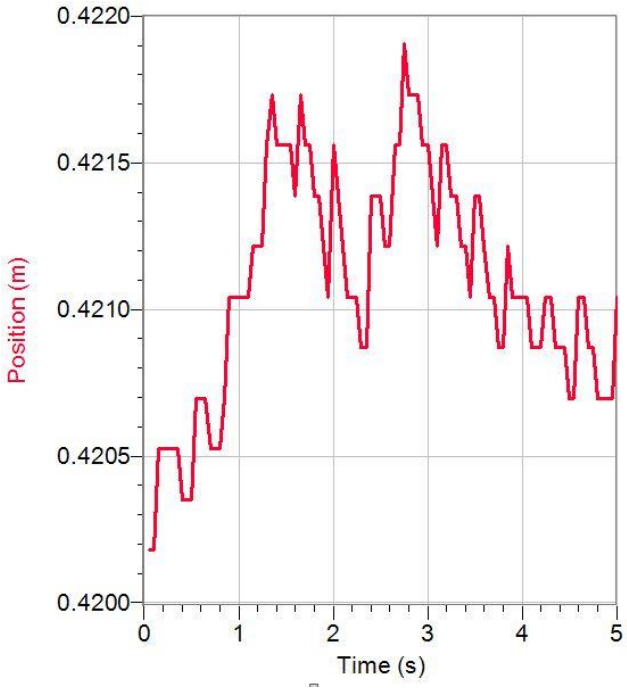


Graph 1 - the target is a little more than 0.4 metres from the motion detector.

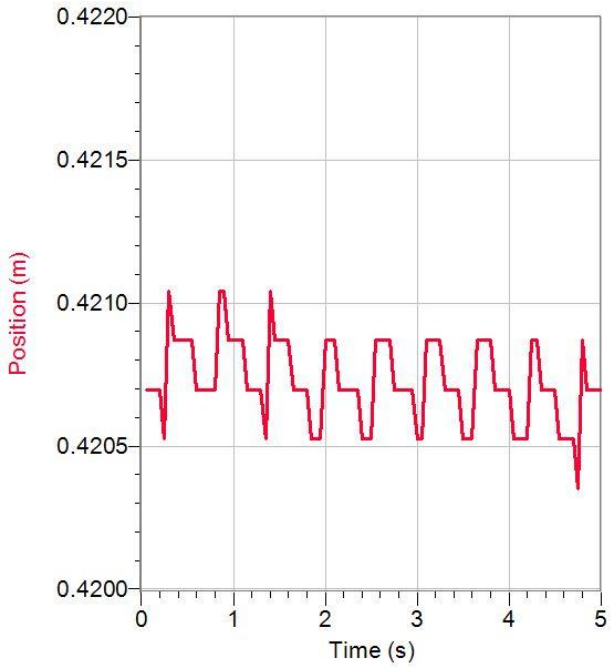
The inset in figure 1 shows a plastic bottle and a motion detector on the bench below an air conditioner. Changing the scale on the position axis shows the errors involved in the distance measurement.

Graph 2 below shows that the target is on average about 42 cm from the detector but there are errors of as much as ±1 mm in the distance measurement. Turning the air conditioner off reduces errors in distance measurement to ± 0.2 mm. (figure 3).

The distance measurement in Graph 2 includes a small ± 0.2 mm random error and a slower drift either way of as much as ± 1 mm. Why?



Graph 2 – distance measurement from the motion detector to the target with the air conditioner on.

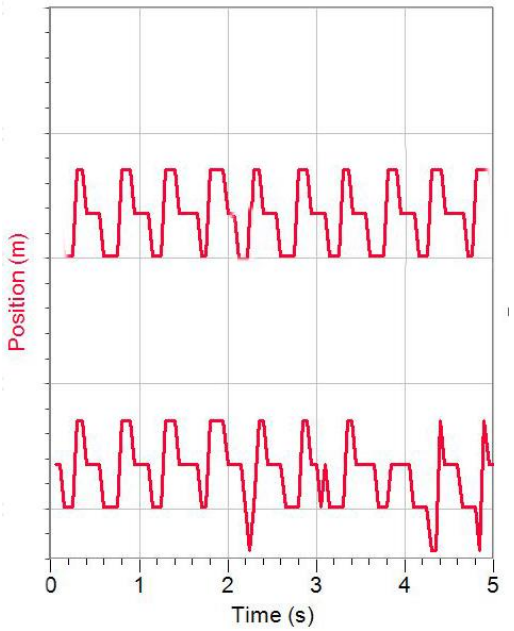


Graph 3 – distance measurement from the motion detector to the target with the air conditioner off.

Following suggestions from students the target was replaced by a larger plastic container to eliminate any wobble due to wind currents and the measurements were repeated with and without noise in the room. Both modifications made no difference. In a noisy room with the air conditioners turned off only a small random error of ± 0.2 mm was seen and with the air conditioners on, the drift of up to ± 1 mm returned when using the larger target.

Fig 1 – the motion detector with larger target

With the air conditioners off, making wind currents on the reflection path by waving a large sheet of cardboard introduced small additional errors.



Graph 4 – relative errors with a larger target in still air (above), and with wind currents made by waving a cardboard sheet (below).

The speed of sound dependents on air temperature. Since cold air currents are present when the air conditioners are on, and since cooler air falls and the air in a room becomes layered at different temperatures this effect could be responsible for the drift in distance measurements seen in figure 2 and the smaller variations seen in the lower trace in figure 5. To test his idea a hair drier was waved near the reflection path to introduce warm air currents between the motion detector and the target.

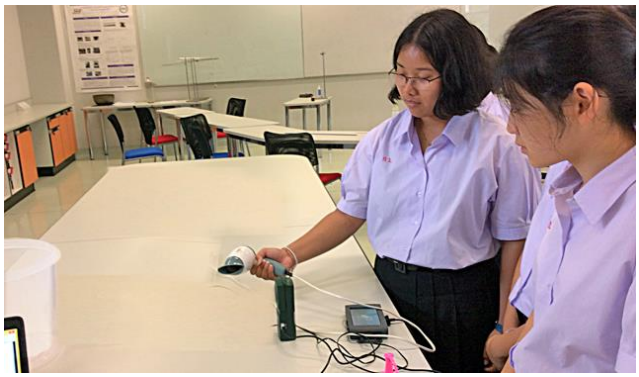
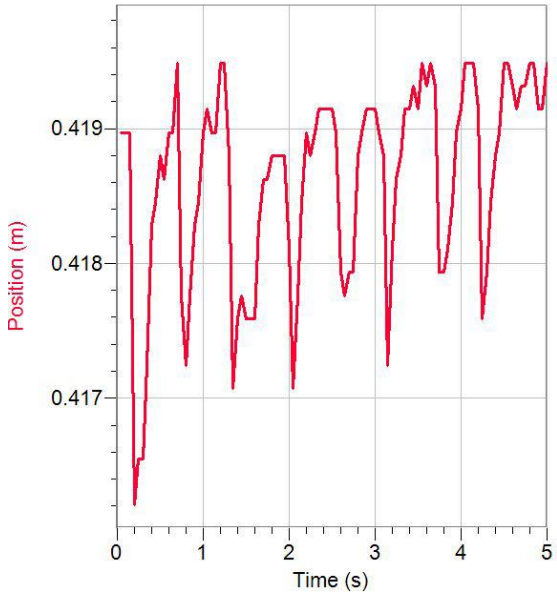


Fig 2 – M4 with a hair drier.



Graph 5 – the variations in distance measurements when using the hair drier.

The variations seen in Graph 5 when using the hair drier are more rapid than with air conditioner generated cold air currents, but the size of the errors is similar. The drifts in distance values of ±1 mm seen in figure 2 are due to similar random variations in temperature along the reflection path.