SECTION B

7. Read through the following article carefully.

Cool Physics for Smart Phones
by Justino Luis Moreno

Paragraph

Some meters can be expensive to buy but if you've got a smart phone it's surprising just how many
meters it can be employed as, if you get hold of the right apps. Right now on my iphone I've got a 1
seismometer, magnetometer, accelerometer, tiltometer, protractor, light meter, ruler, decibel meter,
oscilloscope and frequency meter. In the hands of a physicist your smart phone is transformed into
a whole lot of experimental fun.

Experiment 1 - Measuring the speed of sound
All you need is a hollow cardboard tube of length between 1 and 3 metres. You'll
also need a frequency meter app (mine's part of a free guitar tuner) and somebody
who can make didgeridoo noises into the cardboard tube. Anyone can make these
noises after a bit of practice and you should even be able to play the two lowest
notes. The cardboard tube didgeridoo can be classed as a pipe that is closed at 2
one end. There is a node of air displacement at the closed end, and an antinode
at the open end. The second lowest note is called the third harmonic because it
has a frequency of 3 times the lowest (or 'fundamental' or 'first harmonic'). When
carrying out this experiment with a hollow tube of length 1.800 m, the fundamental
note had a frequency of 47 Hz. This gave a value of the speed of sound of around
340 m s^{-1} which is not bad with a piece of throw-away cardboard and a free guitar
tuning app.

Figure 1

Experiment 2 - Investigating polarisation of light
Unfortunately, light meter software tends to use a unit called 'lux,' but as long as we don't change 3
light source mid-experiment the lux is proportional to the intensity. We shall concentrate on an
experiment to do with polarisation - the variation of transmitted intensity through a polaroid with
angle of the polaroid relative to the polarised light. The set-up is shown below.

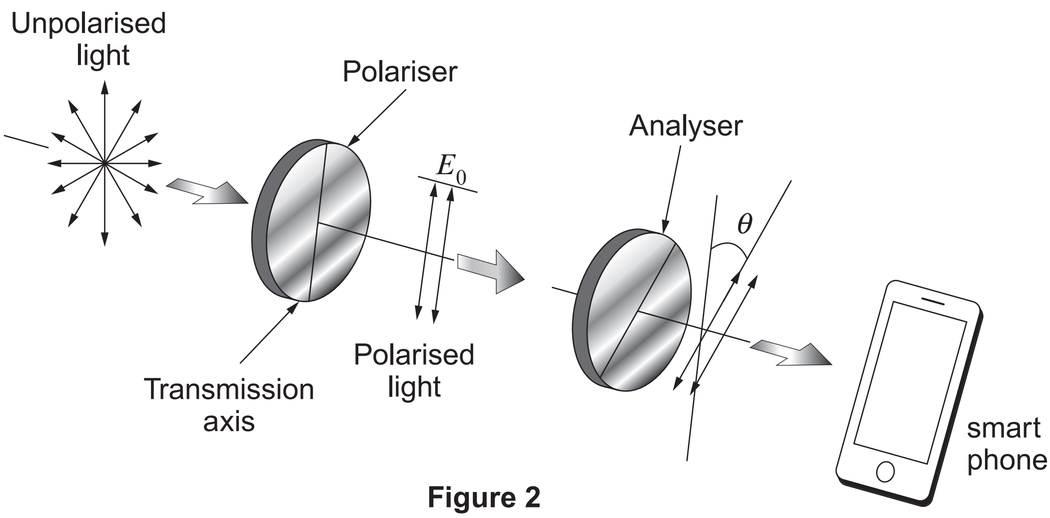

Figure 2

The polariser provides the polarised light, the analyser is rotated in steps through 180° and the
intensity of light is recorded using the smart phone. You can measure the angle (θ) with a plastic
protractor but there is a smarter way. You can tape the analyser over the smart phone camera and 4
have 2 apps running simultaneously – a light meter to measure the light intensity and a tiltometer to
measure the angle of the analyser.

Paragraph

These were the results obtained: 5

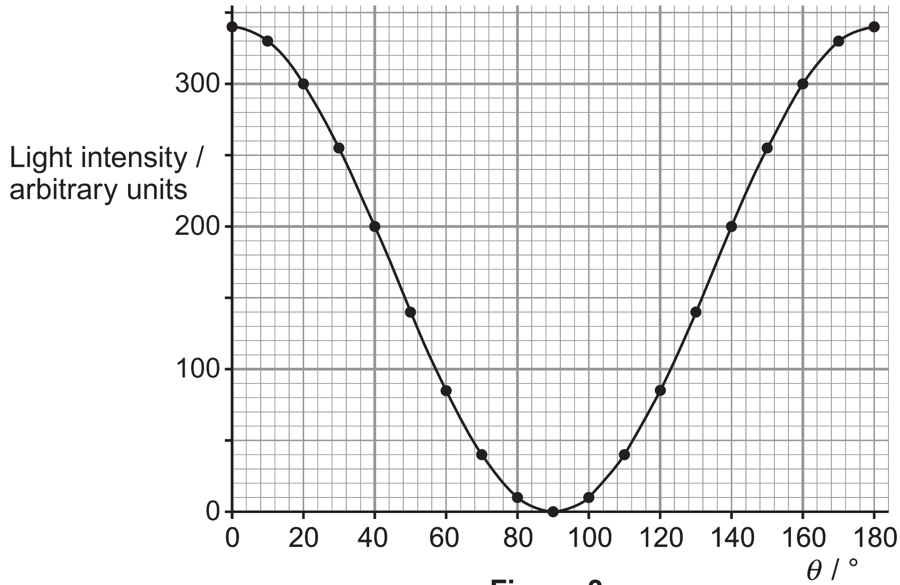

Figure 3

These results are in excellent agreement with Malus's Law – that the intensity, I, of light is given by:

$$I = I_0 \cos^2 \theta$$

where θ is the angle of the analyser relative to the polariser.

Experiment 3 - Measuring the coefficient of friction
There is a simple rule of friction that states: 6

$$F = \mu R$$

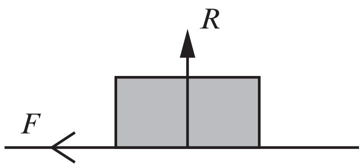

Figure 4

where F is the maximum frictional force, R is the normal contact force and μ is the coefficient of friction. Basically, μ is a dimensionless constant that tells you how slippery the contact is between two smooth surfaces. The greater the value of μ the greater the frictional force (for a given value of R).

One of the easiest methods of obtaining values of the coefficient of friction is to place a block on a slope and tilt the slope until the block slips. When the block slips it's easy to show that the coefficient 7 of friction is given by: $\mu = \tan\theta$

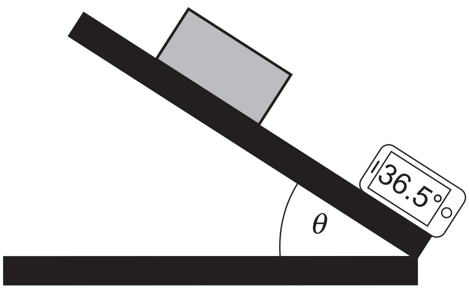

Figure 5

Paragraph

The angle can be measured easily with an uncertainty of less than 1° using a smart phone with a 8
tiltometer placed on the slope. Here are some results obtained for rubber on tarmac.

Surface	Mean slide angle (degrees)	Mean coefficient of friction
smooth rubber on tarmac	44.4	0.98
rubber with treads on tarmac	40.4	0.85

Table 1

Experiment 4 - Investigating magnetic field strengths

The phone was used as a magnetometer to take readings of the magnetic field strength, B, at two 9
distances, r, from the centre of a small bar magnet (with the magnet end-on to the magnetometer). The results are shown in Table 2.

r / cm	B / mT
8.0	9.8
12.0	2.9

Table 2

These results suggest that B depends on r according to an inverse cube law, that is a law of the form: 10

$$B = \frac{K}{r^3}$$

where K is a constant.

Experiment 5 - Investigating the acceleration of a car

All sorts of investigations can be done with a mobile phone used as an accelerometer. Oscillations
particularly lend themselves to this method. As an even simpler case, though, here is a (tidied up) 11
acceleration-time graph, based on accelerometer readings for a car **starting from rest** at time t = 0 and going along a straight road.

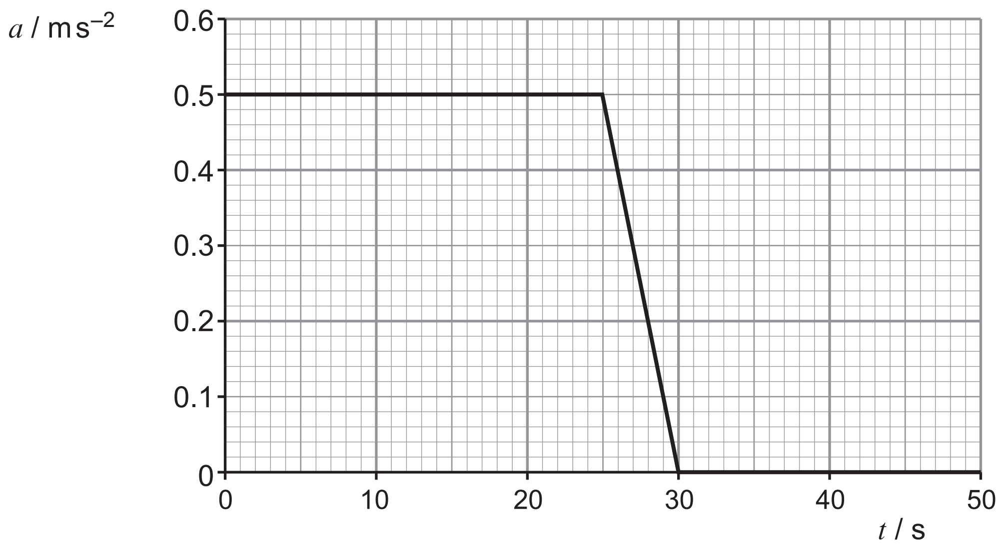

Figure 6