# Topic 4 – Guidance for Practical 1

## *Experimental determination of the speed of sound using stationary waves*

### Safety

Although great care has been taken in checking the accuracy of the information provided in this guidance, Cambridge University Press shall not be responsible for any errors, omissions or inaccuracies.

Teachers and technicians should always follow their school and departmental safety policies. You must ensure that you consult your employer’s model risk assessments and modify them as appropriate to meet local circumstances before starting any practical work. Risk assessments will depend on your own skills and experience, the skills and experience of your students, and the facilities available to you. Everyone has a responsibility for his or her own safety and for the safety of others. The notes below should not be regarded as a risk assessment.

You should carry out the practical yourself before presenting it to students. Make sure you are comfortable with the procedures, and can anticipate any difficulties your students may encounter.

### Guidance

Students will practice recording measurements in appropriate tables, processing data to linearise graphs and using graphical method to determine experimental values.

If possible, the groups should be well apart to make it easier for the students to hear when resonance takes place.

### Apparatus and materials

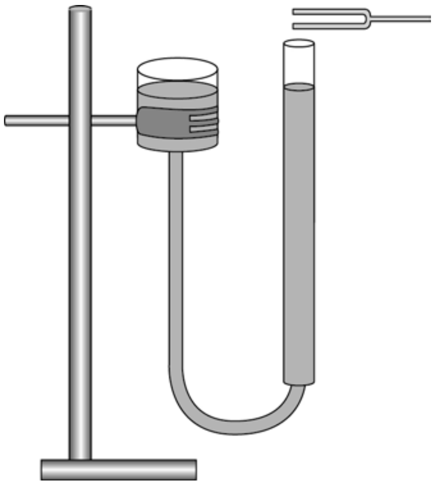
Each group will need:

- deep cylindrical container (e.g. $1\,dm^3$ measuring cylinder)
- glass resonance tube (diameter smaller than cylindrical container)
- stand and clamp
- set of tuning forks and rubber bung
- metre rule
- water
- thermometer

### Setting up the practical

An alternative layout for this experiment is the resonance tube apparatus (see below).



### Answers to questions

**1** Students should use their measurements of $L_1$ and $L_2$ and the formula $e = \frac{L_2 - 3L_1}{2}$ to determine the value of the end correction $e$.

**2** Temperature is a measure of the average kinetic energy of the molecules. At higher temperatures molecules can vibrate faster and sound waves can travel quicker. For dry air at 0 °C the speed of sound is $331\,\text{m}\,\text{s}^{-1}$ and at room temperature (25 °C) around $245\,\text{m}\,\text{s}^{-1}$.

# Topic 4 – Guidance for Practical 2

## *Experimental determination of refractive index*

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### Guidance

Students will practice measuring angles, recording measurements in appropriate tables and using graphical methods to determine experimental values.

As an extension, students could determine the critical angle (question **2**), calculate its theoretical value (using $\theta_2 = 90°$) and compare the two values.

### Apparatus and materials

Each group will need:

- semicircular Perspex block
- ray box
- power supply
- protractor
- sheet of paper
- ruler
- set square

### Answers to questions

**1** When the incident angle becomes equal or larger to the value of the critical angle, total internal reflection takes place and there is no refracted ray.

**2** When light travels in a medium and meets a boundary with a medium that is less dense than the one it is travelling into, then there is a critical angle for which total internal reflection occurs. In this case the angle of refraction can be considered to be equal to 90°.
Students should gradually increase the incidence angle until there is no refracted beam; this angle of incidence is the critical angle.

**3** The refractive index depends on the wavelength. This is called dispersion and generally the smaller the wavelength the higher the refracted index, i.e. for the same incident angle the blue ray would be refracted at a larger angle than the red ray.

# Topic 4 – Guidance for Practical 3

## *Experimental determination of the acceleration of free fall using a simple pendulum*

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You should carry out the practical yourself before presenting it to students. Make sure you are comfortable with the procedures, and can anticipate any difficulties your students may encounter.

### Guidance

Students will practice time measurements and the theory of SHM will be reinforced through this practical example. They will gain experience in transforming equations in their linear forms.

Some teachers prefer to do this practical at the beginning of the course, showcasing another way of measuring the gravitational acceleration and not during the oscillations topic. In this case most students need a lot of support with data handling, uncertainties and linearising graphs. This is the reason that the procedure is so detailed.

### Apparatus and materials

Each student/group will need:

- stand and clamp
- cotton thread (~ 1.1 m)
- rubber stopper with hole to fit the thread
- small brass or lead pendulum bob
- stopwatch
- metre rule
- protractor
- fiducial mark

### Setting up the practical

To determine the period of the SHM, a digital sensor could be used instead of a stopwatch.

If a motion sensor is used, the pendulum bob has to be large enough to be detected by the sensor. The students will measure the time between two minima of the distance of the bob from the sensor. Be aware that most motion sensors have a minimum distance below which they cannot measure.

In this type of circular motion the tension of the thread is maximum when the pendulum is perpendicular, i.e. at the equilibrium position. To measure the time of one period the students should measure the time between three maxima of the force.

 

## Supporting the practical

When using a stopwatch, the period of the SHM should be measured against a fixed point on the bench, preferably the equilibrium position.

The students could measure the time for ten full oscillations, but a larger number reduces the effects of random errors in the measurement and increases accuracy.

## Answers to questions

**1** Rearranging the initial equation as $T = \left(\frac{2\pi}{\sqrt{g}}\right)\sqrt{L}$, so that the gradient of a $T$ vs $\sqrt{L}$ graph is equal to $\frac{2\pi}{\sqrt{g}}$.

**2** On the Moon the gravitational field strength $g$ is smaller therefore for the same pendulum length the period would be larger. The gradient of the $T^2$ vs $L$ graph would be smaller.

# Topic 4 – Guidance for Practical 4

## *Relationship between mass suspended by a spring and the period of oscillation of the spring–mass system*

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You should carry out the practical yourself before presenting it to students. Make sure you are comfortable with the procedures, and can anticipate any difficulties your students may encounter.

### Guidance

Students will practice time measurements and the theory of SHM will be reinforced through this practical example. The will gain experience in transforming equations in their linear forms and using graphical methods to calculate values.

Students can practice a way of reducing the uncertainty of their measurements using a fiducial mark. They can discuss the value of estimated uncertainty with and without a fiducial mark.

It would be useful to find the limit of proportionality for the springs you are using so that students do not exceed this limit. If they do, it can lead to a nice discussion about the behaviour of materials and the stress–strain curve.

### Apparatus and materials

Each student/group will need:

- stand and two clamps
- steel spring (of known spring constant)
- ruler
- plumb line
- mass hanger (100 g) and slot masses (100 g)
- fiducial mark (long pin)
- adhesive putty
- stopwatch

### Setting up the practical

To determine the period of the SHM, a digital sensor could be used instead of a stopwatch.

If a motion sensor is used, the mass has to be large enough to be detected by the sensor. The students will measure the time between two minima of the distance of the mass from the sensor. Be aware that most motion sensors have a minimum distance below which they cannot measure.

### Supporting the practical

The students could measure the time for ten full oscillations, but a larger number reduces the effects of random errors in the measurement and increases accuracy.

 

### Answers to questions

**1** Rearranging the initial equation as $T = \left(\frac{2\pi}{\sqrt{k}}\right)\sqrt{m}$ means that a $T$ vs $\sqrt{m}$ graph will be linear.

**2** In a $T$ vs $\sqrt{m}$ graph, gradient = $\left(\frac{2\pi}{\sqrt{k}}\right)$, therefore $k = \left(\frac{2\pi}{\text{gradient}}\right)^2$.