Lee and Chris are constructing their own pipe organ. It consists of a number of plastic pipes, each of which has been cut to a specific length. Their design is such that each pipe can be considered to be an air column **closed at one end**. The organ is to have a range of 4 octaves, where the highest note has a fundamental resonance of approximately 2000 Hz.

The speed of sound may be taken as 320 ms^{-1}.

Question 6

One particular pipe is designed to resonate at a fundamental frequency of 160 Hz.

Which of the choices below is the best estimate of the length of this pipe?

A. 0.25 m
B. 0.5 m
C. 1.0 m
D. 2.0 m

$\lambda = 4L$ $\quad L = \frac{\lambda}{4} = 0.5\ m$

$\lambda = \frac{v}{f} = \frac{320}{160} = 2\ m$

2 marks

73 %

Question 7

List two other frequencies below 1000 Hz at which this pipe could resonate.

$160 \times 3 = 480$ $\quad 160 \times 5 = 800$

480 Hz	800 Hz

2 marks

14%

Sarah is planning to buy some plastic pipe from a hardware store. To measure the length of the pipe, she intends to blow across one end of the pipe and measure the frequency of the resonance produced.

The shop owner questions this method, but in the end agrees to let her perform the measurements. Sarah takes a section of pipe **open at both ends**, and performs the measurements. A clear resonance of 200 Hz can be heard.

Question 7

Use this information to determine the length of the pipe. Show your working/reasoning.

(speed of sound 340 m s^{-1})

$\lambda = \frac{v}{f} = \frac{340}{200} = 1.7$ m

$L = \frac{\lambda}{2} = \frac{1.7}{2} = 0.85$

0.85 m

3 marks

34%

Question 8

At which **one or more** of the following frequencies could the pipe also resonate?

A. 300 Hz

B. 400 Hz

C. 500 Hz

D. 600 Hz

$200 \times 2 = 400$

$200 \times 3 = 600$

B, D

2 marks

73%

Question 9

Briefly explain resonance in terms of the behaviour of the sound waves in a tube open at both ends.

When frequency of sound is equal to natural frequency of the pipe resonanse (increase in the amplitude) occur. It happen as a result of standing wave formation when sound waves travel in opposite direction along the pipe and reflecting from the open ends and if wavelength match pipe length interference will produce standing wave.

3 marks

9%

Use the following information to answer Questions 2 and 3.

A concert flute, as shown in Figure 2, can be modelled as a tube of length 0.67 m that is open at both ends. Take the speed of sound as 335 m s^{-1}. Assume all the flute holes are closed.

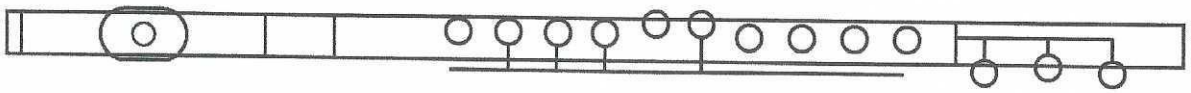

Figure 2

Question 2 82 %

The wavelength of the fundamental frequency played by this flute is closest to

A. 2.68 m
B. 1.34 m
C. 0.34 m
D. 0.17 m

$\lambda = 2L = 2 \times 0.67$

Question 3 72 %

The next harmonic above the fundamental will have a frequency closest to

A. 500 Hz
B. 375 Hz
C. 250 Hz
D. 125 Hz

$\lambda_2 = L = 0.67\,m$

$f = \frac{v}{\lambda} = \frac{335}{0.67} = 500$

Question 11 50 %.

A teacher asks a student to identify a gas contained in a tube by measuring the speed of sound.

The student connects a signal generator to a loudspeaker and a microphone is moved away from the speaker (to the right of the page) until a minimum (node) is displayed on the oscilloscope.

At a frequency of 500 Hz, the student finds the distance between two adjacent nodes to be 0.96 m.

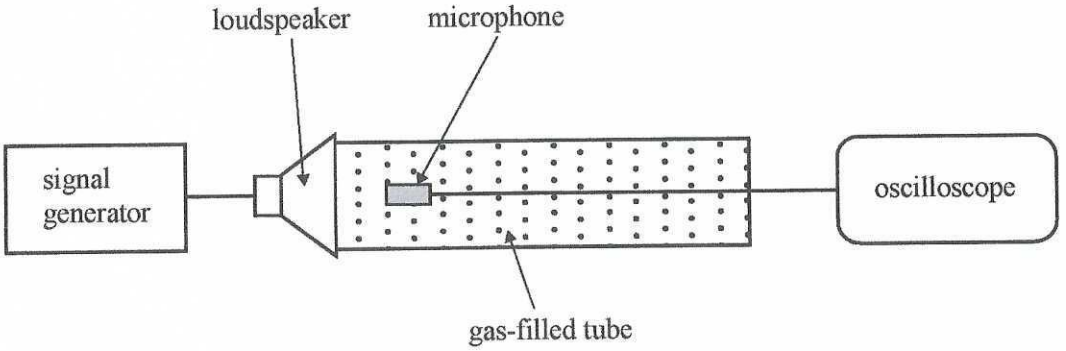

Figure 8

Which one of the following is the most likely speed of sound in the gas?

A. 480 m s^{-1}

B. 500 m s^{-1}

C. 960 m s^{-1}

D. 1000 m s^{-1}

Distance between adjacent nodes $= \frac{\lambda}{2}$

$\lambda = 2 \times 0.96 = 1.92$

$V = f\lambda = 500 \times 1.92 = 960$

Use the following information to answer Questions 5–8.

Students are conducting an experiment to observe sound standing waves in an air column in a hollow tube, as shown in Figure 4. The length of the tube is 1.7 m and it is open at both ends. A sine wave signal generator drives a loudspeaker mounted at the end of the tube. A frequency meter measures the frequency. Take the speed of sound in air to be 340 m s^{-1}.

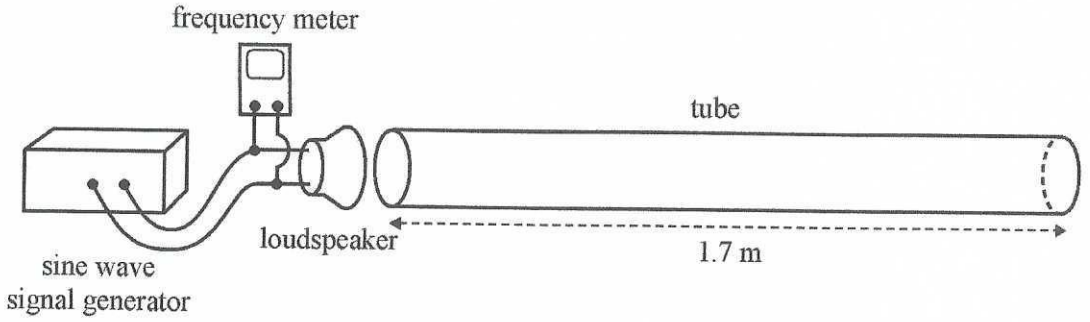

Figure 4

The students increase the frequency from zero until they detect the first resonance (first harmonic).

Question 5 67%.

Which physical observation will best enable the students to identify when the first resonance occurs?

A. a decrease in the current through the loudspeaker
B. a sudden increase in the frequency
C. a sudden decrease in the sound intensity
D. a sudden increase in the sound intensity

Question 6 83%

Which one of the following best describes the frequency at which the students will observe this first resonance?

A. 17 Hz
B. 50 Hz
C. 100 Hz
D. 170 Hz

$\lambda = 2L = 3.4\,m$

$f = \frac{v}{\lambda} = \frac{340}{3.4}$

Question 7 67%

The students place a cap on the end of the tube furthest from the loudspeaker so that it is now closed at one end and open at the other. They increase the frequency until they observe the first resonance, then they increase it again until they observe the next resonance.

Which one of the following best describes the frequency at which the students will observe the second resonance?

A. 170 Hz
B. 150 Hz
C. 100 Hz
D. 50 Hz

$\lambda_0 = 4L = 6.8\,m$

$f_0 = \frac{v}{\lambda} = \frac{340}{6.8} = 50\,Hz \qquad f_3 = 3f_0$

Question 8 30 %

The students now investigate the variation of pressure in a sound standing wave in another tube. A standing wave is set up at 80 Hz.

One student has a pressure sensor that measures the pressure above atmospheric pressure (a positive reading) or below atmospheric pressure (a negative reading).

The apparatus is shown in Figure 5. The sensor is placed at a pressure node.

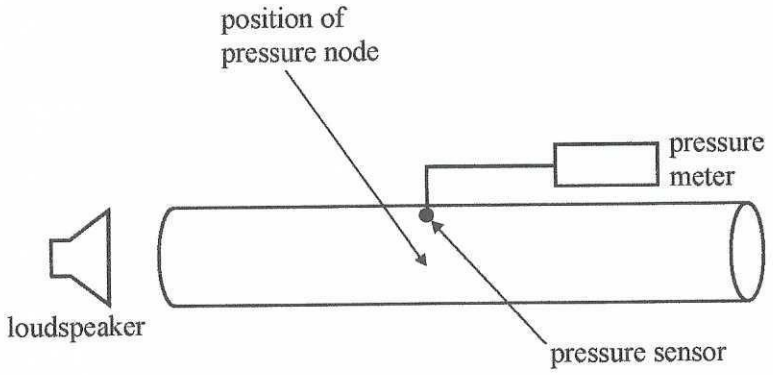

Figure 5

Which one of the following best describes the pressure the student will measure?

A. The reading will remain at a constant and positive value.

B. The reading will go from zero to a positive value 80 times per second.

C. The reading will go from a negative to a positive value 80 times per second.

(D.) The reading will be a constant zero.

At the node there is no variation in pressure

Use the following information to answer Questions 5 and 6.

Students conduct an experiment to observe standing waves in air columns. They use a hollow tube immersed in water, so the length of the air column in the tube can be varied, as shown in Figure 2.

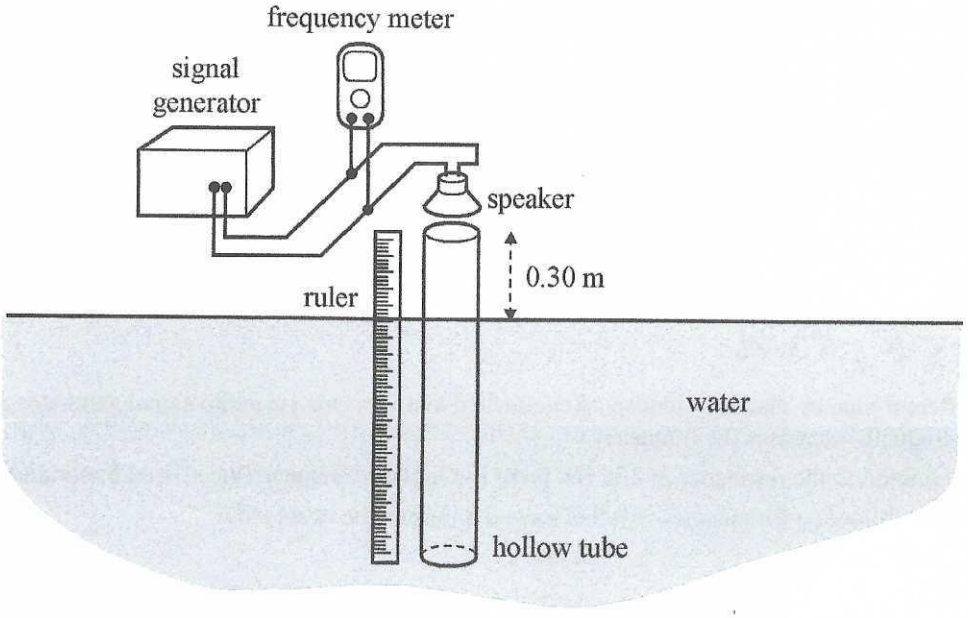

Figure 2

The speed of sound in air under the conditions during their experiment is 320 m s^{-1}. The end of the tube nearest the speaker acts as an open end and the end of the tube away from the speaker acts as a closed end.

The students set the signal generator to 200 Hz. They begin with the tube at a length of 0.30 m and then raise the tube until they hear the first resonance.

Question 5 69%

Which one of the following is the best estimate of the length of the air column at which they hear the first resonance?

(A.) 0.40 m
B. 0.80 m
C. 1.6 m
D. 3.2 m

$\lambda = \frac{v}{f} = \frac{320}{200} = 1.6\ m \qquad L = \frac{\lambda}{4} = 0.4$

Question 6 66%

Which one of the following is the best estimate of the length of the air column at which they hear the next resonance?

A. 0.40 m
B. 0.60 m
(C.) 1.2 m
D. 1.6 m

$\lambda = \frac{4L}{3} \qquad L = \frac{3}{4}\lambda$

Use the following information to answer Questions 8 and 9.

Roger is an instrument-maker who is constructing and testing pipes for a pipe organ.
The pipes can be considered to be uniform tubes open at one end and closed at the other.
He needs to design a pipe to give a wavelength of 0.325 m.

Question 8 68 %

Which one of the following is closest to the length Roger should make the pipe?

A. 0.081 m
B. 0.325 m
C. 0.650 m
D. 1.35 m

$L = \frac{\lambda}{4} = \frac{0.325}{4}$

Question 9 35 %, 53 %

Roger tests a different pipe by placing a loudspeaker attached to a very precise audio signal generator at the open end of the pipe and gradually increases the frequency.
He finds that in addition to the resonance at 256 Hz, there is a higher resonance (the second harmonic).
At which one of the following frequencies will this second harmonic be observed?

A. 128 Hz
B. 512 Hz
C. 768 Hz
D. 1024 Hz

$f = 3f_0 = 768$

B was accepted due to the wrong wording of the question as next harmonic is actually third and termin second harmonic means $2f_0$.