Question 1

(vibrating) tuning fork (3)

column of air (3)

means of changing length of column / metre stick and callipers (3)

(–1 if no label)

Describe how the first position of resonance was found.

hold (vibrating) fork over column (3)

increase length of column (from zero) *(accept "change length of column")* (3)

until (loudest) sound is heard (from column) (3)

Using the recorded data, calculate the speed of sound in air.

$v = 4f(l + 0.3d)$ (3)

$v = 4f(0.16545)$ (3)

$v = 338.8\ m\ s^{-1}$ *(–1 for omission of or incorrect units)* (3)

Why was it necessary to measure the diameter of the air column?

because wave exists partially above the top of the tube (6)

(accept "end correction", "error in length" etc. for 3 marks)

Another student carried out the experiment by measuring the length of the column of air for each of the first two positions of resonance but did not measure the diameter of the air column.
Explain how this second student would find the speed of sound in air.

find distance between first two positions of resonance / $l_2 - l_1$ (3)

double this distance for wavelength / $\lambda = 2(l_2 - l_1)$ (2)

multiply wavelength by frequency (for speed) / $(v =)\ f\lambda$ (2)

Question 2

What is the Doppler effect?

the (apparent) change in the frequency (of a wave) **(3)**
due to the relative motion between the source (of the wave) and the observer **(3)**

Explain, with the aid of labelled diagrams, how the Doppler effect occurs.

source, concentric circles labelled as waves **(3)**
source moving towards/away from observer, non-concentric circles **(3)**
wavelength shorter moving towards the observer (or equivalent) **(3)**
therefore frequency greater (or equivalent) **(3)**

An ambulance siren emits a sound of frequency 750 Hz. When the ambulance is travelling towards an observer, the frequency detected by the observer is 820 Hz.

What is the speed of the ambulance?

Doppler formula **(3)**
correct substitution **(3)**
correct rearrangement for u **(3)**
29 m s^{-1} *(–1 for omission of or incorrect units)* **(3)**

State two other practical applications of the Doppler effect.

e.g. police "speed guns" / measuring velocities of stars / ultrasound (scan) / landing aircraft / weather forecasting *(any two)* **(2 × 2)**

The resistance of the conductor in a strain gauge increases when a force is applied to it. Strain gauges can act as the resistors in a Wheatstone bridge, and any change in their resistance can then be detected.

How would an observer know that a Wheatstone bridge is balanced?

zero reading on / no deflection of / no current flowing through **(2)**
galvanometer **(2)**

The Wheatstone bridge in the diagram is balanced.

What is the resistance of the unknown resistor?

$R_1 \div R_2 = R_3 \div R_4$ **(3)**
17.36 Ω *(–1 for omission of or incorrect units)* **(3)**

Write an expression for the resistance of a wire in terms of its resistivity, length and diameter.

$R = \rho l/A$ **(3)**
$R = 4\rho l/\pi d^2$ **(3)**

The radius of a wire is doubled. What is the effect of this on the resistance of the wire?

resistance decreases **(3)**
by a factor of 4 **(3)**

Question 3

7. **What is meant by the term resonance?**

transfer of energy between two systems *(stated or implied)* 3
of similar natural frequencies 3

How would resonance be demonstrated in the laboratory?

apparatus (e.g. Barton's pendulums // column of air and tuning fork) 3
procedure (e.g. set one pendulum oscillating // hold vibrating fork over column of air etc.) 3
observation 3

A set of wind chimes, as shown in the diagram, is made from different lengths of hollow metal tubing that are open at both ends. When the wind blows, the wind chimes are struck by a clapper and emit sounds.

The sound from one of the tubes was analysed. The following frequencies were identified in the sound: 550 Hz, 1100 Hz and 1651 Hz.

What name is given to this set of frequencies?

overtones / harmonics 5

Draw labelled diagrams to show how the tube produces each of these frequencies.

550 Hz (f): antinodes (A) at both ends 3
linked correctly to one node (N) (in the centre) 3

1100 Hz ($2f$): antinodes at both ends 3
linked correctly to two nodes 3

1651 Hz ($3f$): antinodes at both ends linked correctly to three nodes 3
(–1 if no correct label)

The length of the metal tube is 30 cm. Use any of the above frequencies to calculate a value for the speed of sound in air.

$c = f\lambda$ 3
$\lambda = 0.60$ m 3
$c \approx 550 \times 0.60 = 330$ m s^{-1} *(–1 for omission of or incorrect units)* 3

A sample of wire, of length 12 m and mass 48 g, was being tested for use as a guitar string. A 64 cm length of the wire was fixed at both ends and plucked. The fundamental frequency of the sound produced was found to be 173 Hz. Calculate the tension in the wire.

$\mu = 0.048 \div 12 = 0.004$ kg m^{-1} 3
$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ 3
$T = 4(lf)^2\mu$ 3
T $[= 4 \times (0.64 \times 173)^2 \times 0.004] = 196$ N *(–1 for omission of or incorrect units)* 3

Question 4

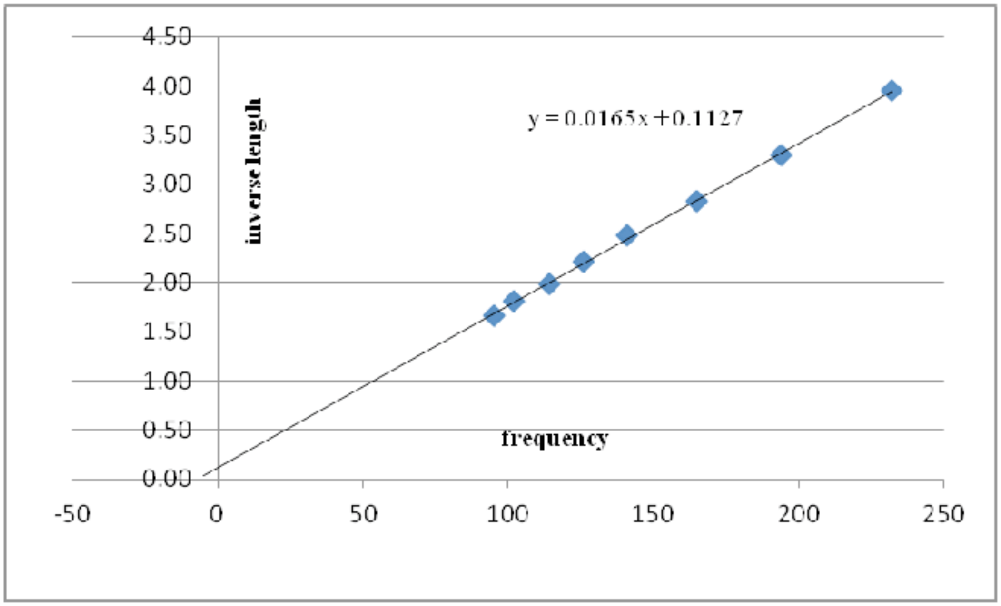
How were the data obtained?

arrangement showing string, means of changing l , pulley and pan / newton balance / fixed at both ends		3
vibrating fork placed on bridge	**(−1 per item omitted)**	3
adjust length until standing wave formed / resonance occurs /rider falls		3
measure length (between nodes / bridges)		3
repeat with forks of different frequencies --- stated/implied		3

Using the data, draw a suitable graph on graph paper to show the relationship between the fundamental frequency of the stretched string and its length.

inverse l values		3
plot points	**(−1 per each incorrect point)**	2×3
straight line (through origin)		3

l	0.603	0.553	0.503	0.453	0.403	0.353	0.303	0.253
f	95	102	114	126	141	165	194	232
1/*l*	1.66	1.81	1.99	2.21	2.48	2.83	3.30	3.95



The fundamental frequency of a stretched string depends on factors other than its length. Name one of these factors and give its relationship with the fundamental frequency.

tension (in string) / mass per unit length (of string)	3
valid relationship ➔ $f \propto \sqrt{T}$ / $\sqrt{\frac{1}{\mu}}$	3

If you were doing an experiment to establish the relationship between the fundamental frequency of a stretched string and this other factor, how would you obtain the relevant data?

For tension factor:	find resonance for a fork f_1 by changing tension	3
	method for changing/measuring tension // keep l fixed	3
	repeat for forks of different frequencies	1

Question 5

(*a*) **Destructive interference can occur when waves from coherent sources meet. Explain the underlined term.**

same frequency/wavelength 3

in phase / constant phase difference 3

Give two other conditions necessary for total destructive interference to occur.

same amplitude 4

out of phase by: $\frac{1}{2}\lambda$ / $\frac{1}{2}$*cycle* / 180° / π / when crest meets trough 4

The diagram shows a standing wave in a pipe closed at one end. The length of the pipe is 90 cm.

(i) **Name the points on the wave labelled P and Q.**

P: node Q: antinode 3+3

(ii) **Calculate the frequency of the standing wave.**

$1\frac{1}{4}\lambda = 0.90\,\text{m}$ // $\lambda = 0.720\,\text{m}$ (state/imply) 3

$v = f\lambda$ 3

$f = \frac{340}{0.720}$ / $f = 472.2$ Hz **(–1 for omission of or incorrect unit)** 3

(iii) **What is the fundamental frequency of the pipe?**

$\frac{\lambda}{4} = 0.90$ / $\lambda = 3.60\,\text{m}$ 3

$f_o = \frac{340}{3.60}$ / $f_o = 94.44\,\text{Hz}$ **(–1 for omission of or incorrect unit)** 3

The clarinet is a wind instrument based on a pipe that is closed at one end.
What type of harmonics is produced by a clarinet?

odd (multiples of the fundamental) 3

(*b*) **An audio speaker at a concert emits sound uniformly in all directions at a rate of 100 W.**
Calculate the sound intensity experienced by a listener at a distance of 8 m from the speaker.

$$\text{SI} = \frac{\text{Power}}{\text{Area}}$$ 3

$$\text{SI} = \frac{100}{4\pi(8)^2} \;/\; 0.124\ \text{W m}^{-2}$$ **(–1 for omission of or incorrect unit)** 3

The listener moves back from the speaker to protect her hearing. At what distance from the speaker is the sound intensity level reduced by 3 dB? (speed of sound in air = 340 m s^{-1})

SIL decreased by 3 dB → SI halved (state/imply) 3

$\text{SI}\ \alpha\ \frac{1}{R^2}$ // $0.062 = \frac{100}{4\pi R^2}$ 3

$\frac{I_1}{I_2} = \frac{R_2^2}{R_1^2}$ // $2 = \frac{R_2^2}{64}$ // $R^2 = \frac{100}{4\pi(0.062)}$ / 128.35 3

$R_2 = 11.32\,\text{m}$ // $R = 11.33\,\text{m}$ **(–1 for omission of or incorrect unit)** 3

Question 6

(b)

The following reaction occurs in a nuclear reactor:

$$^{235}U + {}^{1}_{0}n \rightarrow {}^{141}Ba + X + 3{}^{1}_{0}n + 202.5\ \text{MeV}$$

(i) Identify the element X.

Kr / krypton 6

6

(ii) Calculate the mass difference between the reactants and the products in the reaction.

$E = mc^2$ 3

$m = \frac{(202.5\times10^{6})(1.6\times10^{-19})}{(3\times10^{8})^{2}}$ 3

$m = 3.6\times10^{-28}\,\text{kg}$ 3

(–1 for omission of or incorrect units) 9

(iii) What is a chain reaction?

self-sustaining reaction / reaction where fission neutrons produce further fission (giving more neutrons) etc./ clear diagrammatic representation 6

Give one condition necessary for a chain reaction to occur.

mass of fuel present exceeds the critical mass / at least one of the neutrons released must cause fission of another nucleus 3

9

(iv) Give one environmental impact associated with a nuclear reactor.

toxic /radioactive waste, exposure to radiation, etc. 4

Question 7

(*d*) The sound intensity level at a concert increases from 85 dB to 94 dB when the concert begins. By what factor has the sound intensity increased?

if sound intensity doubles → intensity level increases by 3 dB 4

(a factor of) 8 / 2^3 3

Question 8

(*c*) What is the relationship between the frequency of a vibrating stretched string and its length?

(they are) inversely / indirectly // $f \propto$ 4

proportional // $\frac{1}{l}$ 3

Question 9

(*b*) The pitch of a musical note depends on its frequency. On what does (i) the quality, (ii) the loudness, of a musical note depend?

(i) (number or relative strengths of) overtones /harmonics // wave form 3
(ii) amplitude / frequency/ λ / intensity / rate at which (acoustic) energy enters ear 3

What is the Doppler effect?

(apparent) change in frequency 3
due to *relative motion* (stated or implied) between source and observer 3

A rally car travelling at 55 m s^{-1} approaches a stationary observer. As the car passes, its engine is emitting a note with a pitch of 1520 Hz. What is the change in pitch observed as the car moves away?

$$f' = \frac{f v_a}{v_a \pm v} \text{ (accept + or − format)}$$ 3

$f' = \frac{1520(340)}{340+55}$	$f'_{in} = \frac{340 \times 1520}{340-55} = 1813.33\text{ Hz}$	3
$f' = 1308.35$	$f'_{out} = 1308.35\text{ Hz}$	3
$\Delta f = 211.65\text{ Hz}$	$\Delta f = 504.98 \approx 505\text{ Hz}$ **(-1 for omission of or incorrect units)**	3

Give an application of the Doppler effect.

calculate speeds of stars or galaxies / reference to red (or blue) shift / radar / speed traps / etc. 4

Question 10

(*b*) Define sound intensity.

energy per sec / power / watt // ***P /A*** 3
per unit area / m^{-2} // correct notation 3

A loudspeaker has a power rating of 25 mW. What is the sound intensity at a distance of 3 m from the loudspeaker?

surface area of sphere = $4\pi r^2$	surface area of hemisphere = $2\pi r^2$	3
S.I at 3 m = $(25 \times 10^{-3}) \div 4\pi(3)^2$	S.I at 3 m = $(25 \times 10^{-3}) \div 2\pi(3)^2$	3
S.I = 2.21×10^{-4} W m^{-2}	S.I = 4.42×10^{-4} W m^{-2} **(-1 for omission of or incorrect units)**	3

(accept either answer)

The loudspeaker is replaced by a speaker with a power rating of 50 mW.
What is the change:

(i) in the sound intensity?

increased by: 2.21×10^{-4} W m^{-2} ‖ 4.42×10^{-4} W m^{-2} 6

(accept either answer: -1 if the new increased S.I value is given rather than the *change*)

('it is doubled' 3 marks)

(ii) in the sound intensity level?

increased by: 0.30 B or 3 dB 3

The human ear is more sensitive to certain frequencies of sound. How is this taken into account when measuring sound intensity levels?

dBA / decibel adapted / a frequency weighted scale is used
// sound level meter (modified so that it) responds more to sounds between 2kHz and 4 kHz / just like the ear
any one 4

Question 11

Question 3

A cylindrical column of air closed at one end and three different tuning forks were used in an experiment to measure the speed of sound in air. A tuning fork of frequency *f* was set vibrating and held over the column of air.
The length of the column of air was adjusted until it was vibrating at its first harmonic and its length *l* was then measured. This procedure was repeated for each tuning fork.
Finally, the diameter of the column of air was measured.

The following data was recorded.

f/Hz	512	480	426
l/cm	16.0	17.2	19.4
Diameter of column of air = 2.05 cm			

Describe

(i) how the length of the column of air was adjusted;
(ii) how the frequency of the column of air was measured;
(iii) how the diameter of the column of air was measured. (16)

length: (open) pipe raised /lowered while immersed in water // piston moved inside (open) pipe 3

frequency: read frequency (*f*) from (tuning) fork // refer to 'fork of known frequency'
// *f* of air column = *f* of tuning fork 6

diameter: (internal) pipe diameter measured // use a vernier (or digital) calipers
(-1 for omission of 'vernier' or use of metre rule) 7

How was it known that the air column was vibrating at its first harmonic? (9)

(first time) resonance / loud sound is observed 3 x 3

Using all of the data, calculate the speed of sound in air. (15)

$v = f\lambda$ 3

$\lambda = 4(l + 0.3\,d)$ 3

$v_1 = 340(.3)$ m s^{-1} ; $v_2 = 342(.0)$ m s^{-1} ; $v_3 = 341(.1)$ m s^{-1} 2 x 3
(3 marks only for *one* or *two* correct values for *v*)

$v_{ave} = 341(.13)$ m s^{-1} 3
(-1 for omission of or incorrect unit)

[If 'end correction' not used, award 4 x 3 max. In this case, values calculated are:
$v_1 = 327.7$ m s^{-1} ; $v_2 = 330.24$ m s^{-1} ; $v_3 = 330.58$ m s^{-1} ; ➔ $v_{ave} = 329.5$ m s^{-1}]

Question 12

(d) **A sound wave is diffracted as it passes through a doorway but a light wave is not. Explain why. (7)**
wavelength of light (much) less than wavelength of sound 7

Question 13

(e) **What is the Doppler effect?** (7)
(apparent) change in frequency (of a wave) 4
any reference to motion (of S or O or both) 3

Question 14

Question 11
Read the following passage and answer the accompanying questions.

The growth of rock music in the 1960s was accompanied by a switch from acoustic guitars to electric guitars. The operation of each of these guitars is radically different.
The frequency of oscillation of the strings in both guitars can be adjusted by changing their tension. In the acoustic guitar the sound depends on the resonance produced in the hollow body of the instrument by the vibrations of the string. The electric guitar is a solid instrument and resonance does not occur.
Small bar magnets are placed under the steel strings of an electric guitar, as shown. Each magnet is placed inside a coil and it magnetises the steel guitar string immediately above it. When the string vibrates the magnetic flux cutting the coil changes, an emf is induced causing a varying current to flow in the coil. The signal is amplified and sent to a set of speakers.
Jimi Hendrix refined the electric guitar as an electronic instrument. He showed that further control over the music could be achieved by having coils of different turns.

(Adapted from Europhysics News (2001) Vol. 32 No. 4)

(a) **How does resonance occur in an acoustic guitar?** (7)
energy is transferred from strings to <u>hollow body</u> / <u>sound box</u> /<u>air within</u> 4
both vibrate at the same frequency 3

(b) **What is the relationship between frequency and tension for a stretched string?** (7)
frequency proportional to / $f \ \alpha$ 4

square root of tension / $\sqrt{T}$ 3

(c) **A stretched string of length 80 cm has a fundamental frequency of vibration of 400 Hz. What is the speed of the sound wave in the stretched string?** (7)
$v = f\lambda$ 4
$v = 400(1.6)$ / 640 m s^{-1} **(-1 for omission of or incorrect units)** 3

(d) **Why must the strings in the electric guitar be made of steel?** (7)
any reference to *magnetism* 7

(e) **Define magnetic flux.** (7)
$(\Phi =)\ BA$ 4
give notation 3

(f) **Why does the current produced in a coil of the electric guitar vary?** (7)
(induced) <u>emf</u> / <u>flux</u> varies (due to amplitude of vibrating string) 7

(g) **What is the effect on the sound produced when the number of turns in a coil is increased?** (7)
louder sound / greater (sound) intensity) / greater amplitude 7

(h) **A coil has 5000 turns. What is the emf induced in the coil when the magnetic flux cutting the coil changes by 8×10^{-4} Wb in 0.1 s?** (7)

$E = (-)N\Delta\phi / \Delta t$ **(-1 if *N* omitted)** 4

$E = 5000(8 \times 10^{-4} / 0.1)$ / 40 V 3
(-1 for omission of or incorrect units)

Question 15

Question 12 (c)

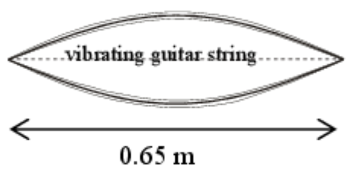
The frequency of a stretched string depends on its length.
Give two other factors that affect the frequency of a stretched string. (6)

tension 3

mass per unit length / mass per metre / linear density 3

The diagram shows a guitar string stretched between supports 0.65 m apart. The string is vibrating at its first harmonic.

The speed of sound in the string is 500 m s^{-1}. What is the frequency of vibration of the string? (9)



$\lambda = 2 \times 0.65$ or 1.3 m 3

$v = f\lambda$ 3

[$f = v/\lambda = 500 / 1.3$] ➔ $f = 384.6$ Hz 3

(-1 for omission of or incorrect unit)

Draw a diagram of the string when it vibrates at its second harmonic. (7)

h/m 7

What is the frequency of the second harmonic? (6)

$f_{2nd} = 2 f_{1st}$ 3

= 769.2 Hz **(-1 for omission of or incorrect unit…. penalise *once* only for hertz unit)** 3

Question 16

Question 7
A student used a laser, as shown, to demonstrate that light is a wave motion.

(i) Name the two phenomena that occur when light passes through the pair of narrow slits. (6)

diffraction 3
interference 3

(ii) A pattern is formed on the screen. Explain how the pattern is formed. (12)

slits act as coherent sources 3

waves overlap / meet / path difference between waves (or shown on diagram) 3

constructive interference gives brightness / bright lines / bright fringes 3

destructive interference gives darkness / dark lines / dark fringes 3

(iii) What is the effect on the pattern when

(a) the wavelength of the light is increased. (4)

distance between fringes / lines / spots increases // pattern more spread out 4

(b) the distance between the slits is increased. (4)

distance between fringes / lines / spots decreases // pattern less spread out 4

Describe an experiment to demonstrate that sound is also a wave motion. (12)

two loudspeakers connected to signal generator // rotate vibrating (tuning) fork 3

walk in front of and parallel to speakers // near ear 3

observation: (e.g. sound loud and low / waxes and wanes) 3

conclusion: interference occurs showing that sound is a wave motion 3

Sound travels as longitudinal waves while light travels as transverse waves. Explain the difference between longitudinal and transverse waves. (9)

longitudinal waves: the direction of the vibrations (of medium) 3

is parallel to the direction of (propagation) of the wave 3

transverse wave: the direction (of the vibrations) is perpendicular to the (direction of the) wave 3

Describe an experiment to demonstrate that light waves are transverse waves. (9)

light source and two pieces of polaroid 3

rotate one polaroid relative to the other and light (intensity)decreases (to zero) 3

polarization indicates transverse waves 3