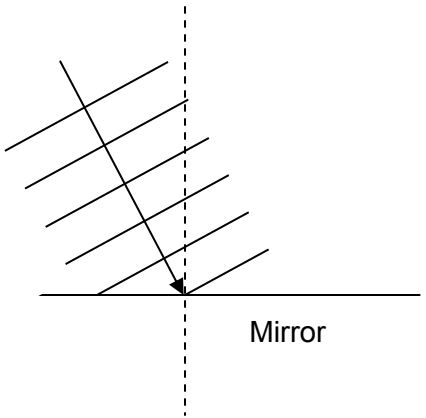
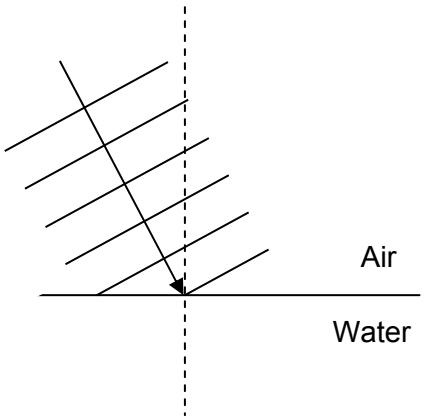
Question 1 **(4 marks)**

The diagrams below show wavefronts of light incident on two different surfaces. In diagram (a) the wavefronts are incident on a mirror. In diagram (b) the wavefronts are incident on an air-water interface. In both diagrams a dotted line at 90° to the surface has been drawn. Complete the diagrams showing how the wavefronts behave as they interact with the surface. In both cases you should draw four wavefronts. The direction of travel of the wavefronts is included.

(a)



(b)



Question 3 **(3 marks)**

Particles called *quarks* are the 'building blocks' of other sub-atomic particles. Table 1 lists the names of some quarks and two of their quantum numbers; charge q and strangeness S.

Table 1: Some properties of quarks

Quark	Charge, q	Strangeness, S
up	$+{}^{2}/_{3}$	0
down	$-{}^{1}/_{3}$	0
charm	$+{}^{2}/_{3}$	0
strange	$-{}^{1}/_{3}$	-1
top	$+{}^{2}/_{3}$	0
bottom	$-{}^{1}/_{3}$	0

When quarks combine their individual quantum numbers 'add'. For example, a fictitious particle, the Joton, made of two charm quarks and one top quark would have a charge of $+{}^{2}/_{3} + {}^{2}/_{3} + {}^{2}/_{3} = {}^{6}/_{3} = 2$ and a strangeness of 0+0+0 = 0.

Use Table 1 to determine the values of the charge and strangeness quantum numbers for the particles in Table 2.

Table 2: Properties of some sub-atomic particles

Particle	Quark composition	Charge, q	Strangeness, S
Lambda	up, down, strange		
Xi	up, strange, strange		
Sigma minus	down, down strange		

Question 4 **(5 marks)**

In April 2009 *New Scientist* magazine reported the discovery of several species of fish that emit red light as a means of communication. This was surprising because these fish swim at depths where wavelengths corresponding to red light do not penetrate but blue light does. The fish might produce red light using a fluorescent protein that absorbs blue light and then emits red.

(a) Draw an energy level diagram showing possible electron transitions taking place in the atoms of the fluorescent protein that could give rise to the observed phenomenon. (2 marks)

(b) Calculate the energy in joules of a photon of blue light and a photon of red light. Blue light has wavelength of 400 nm and red light 700 nm. Use the energy values to label the transitions in the diagram you drew in part (a). (3 marks)

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Question 6 **(4 marks)**

Until about 50 years ago, astronomers used visible light to observe the Universe. They now use a variety of types of electromagnetic radiation to make their observations. With reference to the properties of electromagnetic radiation, explain the potential advantages to an astronomer of studying the Universe using:

(a) radio waves

(b) X-rays

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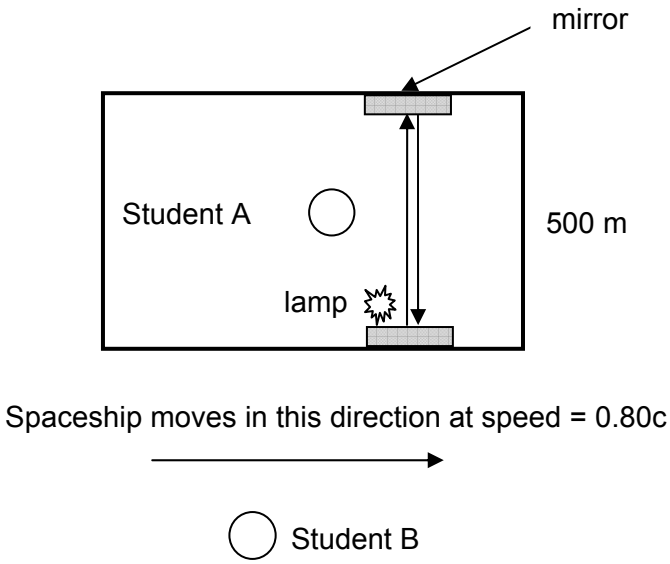
Question 9 **(4 marks)**

Many hundreds of years in the future, two students are measuring the time it takes for a pulse of light to travel between a lamp and a mirror placed on opposite sides of a spaceship. The spaceship is 500 m wide and can travel at a speed equal to 0.80c (0.80 $\times$ the speed of light).

Top down view



Student A is in the spaceship moving at 0.80c. Student B is stationary outside the spaceship.

The students start stopwatches when a light pulse leaves a lamp closest to Student B and stops them when it returns reflected off the second mirror furthest from B.
Student A measures the time for the pulse of light to travel to the mirror and back to be 3.30 μs.
Student B measures the time for the pulse of light to travel to the mirror and back to be 5.50 μs.
Both students have recorded their times correctly.

Explain why Student B measures a longer time than Student A, using a labelled diagram to aid your explanation. Calculations are not required.

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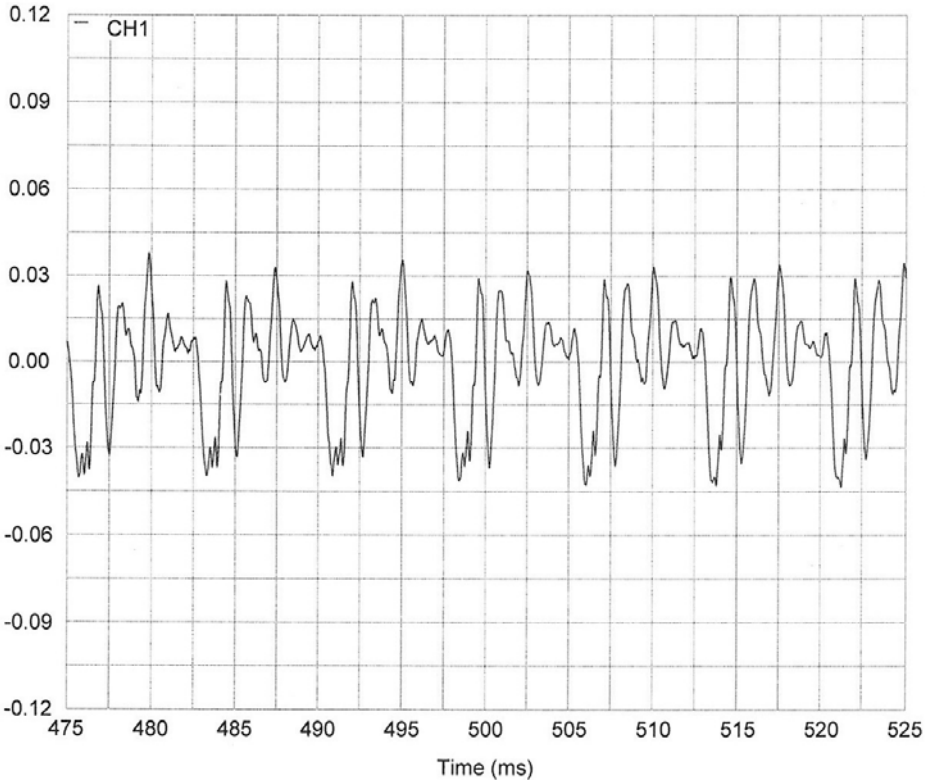
Question 12 **(4 marks)**

The graph below shows the trace of a sound displayed on a cathode ray oscilloscope (CRO). The horizontal (x) axis is time and the vertical (y) axis is amplitude.



(a) Is the above trace noise or a musical note? Explain your reasoning. (2 marks)

(b) Describe the effect on the trace if the sound wave was **louder.** (2 marks)

(i) Effect on the shape of the trace: _____

(ii) Effect on the amplitude of the trace: _____

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Question 14 **(11 marks)**

There are three lines in the emission spectrum of hydrogen that occur in the visible part of the electromagnetic spectrum. These involve transitions to the n = 2 energy level.

The three lines have the wavelengths 6.60×10^{-7} m, 4.90×10^{-7} m and 4.40×10^{-7} m.

(a) Draw an energy level diagram to illustrate the transitions from the n = 3, 4, 5 levels to the n = 2 level. Label the levels n = 2, 3, 4, 5. (4 marks)

(b) Which value of wavelength from the list above corresponds to the transition with the largest energy difference? Explain your answer. (2 marks)

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(c) The n = 2 level has an energy of -3.4 eV. The photon with wavelength 4.9×10^{-7} m corresponds to the transition between the n = 4 and n = 2 energy levels. Calculate the energy of the n = 4 energy level in eV. (3 marks)

The following passage describes how the redshift of a star or galaxy can be measured:

'To determine the redshift, the absorption or emission spectra of the astronomical object are looked for. These can be compared with known spectra of various elements and compounds existing on Earth. If the same pattern of lines is seen in a spectrum from a distant source but occurring at shifted wavelengths, it can be identified as originating from the same element or compound. If the same spectral line is identified in both spectra but at different wavelengths then the redshift can be calculated.'

Redshift is expressed in terms of a parameter z.

$$z = \frac{\lambda_{observed}}{\lambda_{earth}} - 1$$

The redshift of the galaxy 8C is z = 4.25.

(d) Calculate the wavelength of the n = 4 to n = 2 transition in hydrogen that would be observed by an astronomer studying the galaxy 8C. (2 marks)

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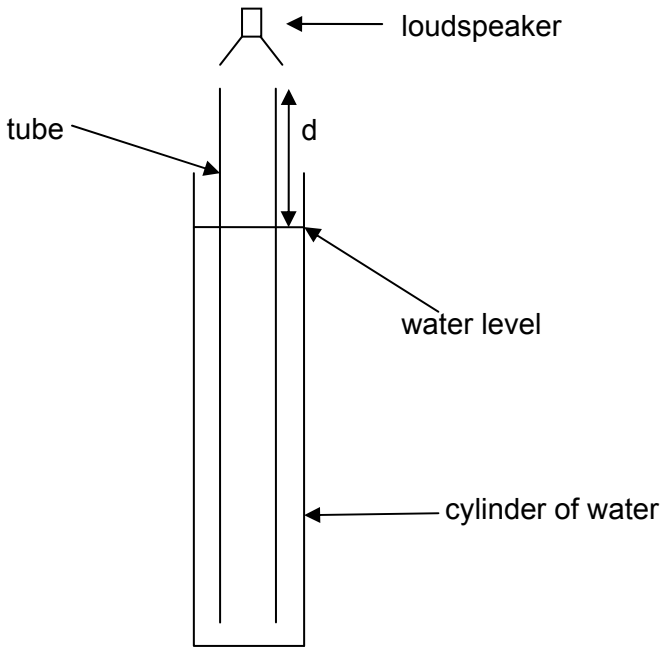
Question 20 **(11 marks)**

(a) Apart from the phenomenon of vibrating air columns, provide one example in which resonance may be observed. Explain how resonance occurs in the example that you have chosen. (3 marks)

A loudspeaker emitting a single frequency is held over a tube which has one end placed in a cylinder of water at 25°C. As the length of tube in the water is changed, the sound heard also changes. The equipment is illustrated in the diagram below.



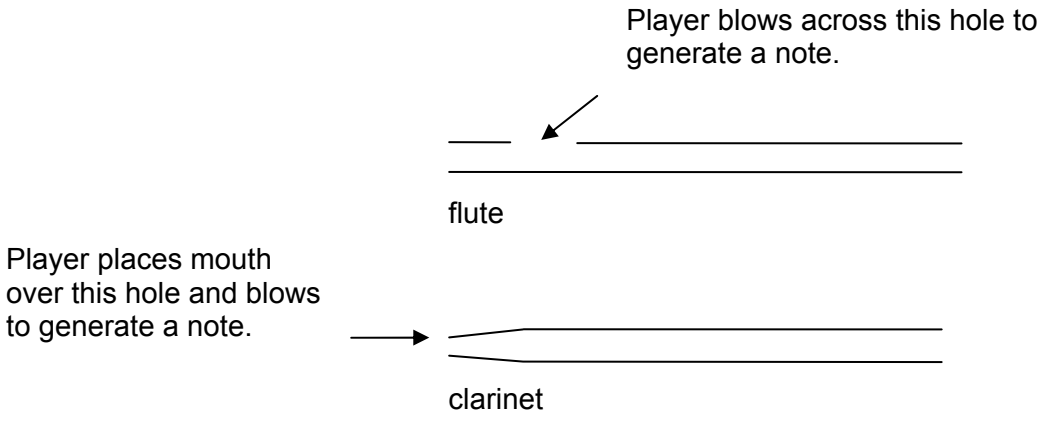
The first resonance is heard when the length of the air column above the water (labelled **d** in the diagram) is 17.0 cm and a second is heard when the length of the air column is 49.0 cm.

(b) Calculate the wavelength of sound in the cylinder. (2 marks)

See next page

(c) Calculate the frequency being emitted by the loudspeaker. (2 marks)

(d) The diagrams below show very simple versions of a flute and a clarinet.



(i) The ratio of the first three frequencies heard in the flute $f_1:f_2:f_3$ is 1:2:3. Determine the ratio of the first three frequencies heard in the clarinet. (1 mark)

(ii) Using your knowledge of vibrations in air columns, explain the differences between the frequencies heard in the flute and those in the clarinet. (3 marks)

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