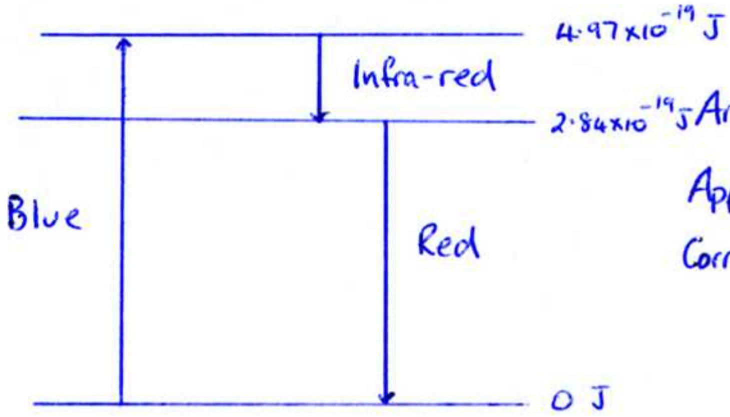
YEAR 12 PHYSICS
ASS. 6 - WAVES + ATOMIC PHYSICS

NAME: SOLUTIONS **TOTAL:** $\overline{}$ 79

1. 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.



Arrows correct - 1 mark
Appropriate spacing - 1 mark
Correct energies - 1 mark

(3)

(b) Calculate the energy in joules of a photon of blue light and a photon of red light. Blue light has wavelength of 4.00 x 10^2 nm and red light 7.00 x 10^2 nm. Use the energy values to label the transitions in the diagram you drew in part (a).

$$E(\text{red}) = \frac{hc}{\lambda}$$

$$= \frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{(7.00 \times 10^{-7})} \quad (1)$$

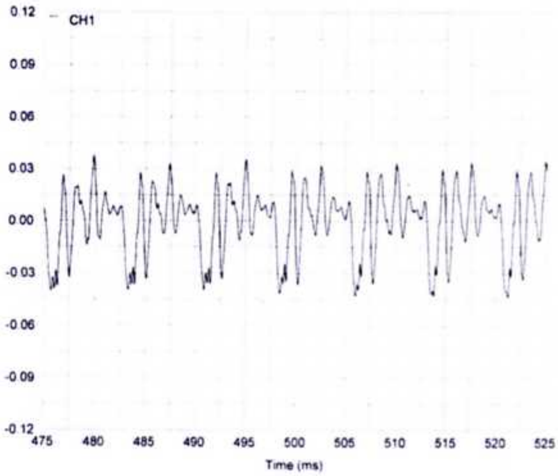
$$= \underline{2.84 \times 10^{-19}\ \text{J}} \quad (1)$$

$$E(\text{blue}) = \frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{(4.00 \times 10^{-7})}$$

$$= \underline{4.97 \times 10^{-19}\ \text{J}} \quad (1)$$

(3)

2. 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.

• Musical note. (1)

• The waveform has a repeating pattern. (1)

(2)

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

(i) Effect on the shape of the trace.

• No change in shape. (1)

(ii) Effect on the amplitude of the trace

• Larger amplitude. (1)

(2)

3. Two identical tuning forks vibrate at a frequency of 256 Hz. One of them has a drop of wax placed on it. This lowers its frequency. When the two tuning forks are sounded, 6.0 beats per second are heard. What is the frequency of the tuning fork with the wax on it? Show your working.

$f_{beat} = |f_2 - f_1|$ (1)

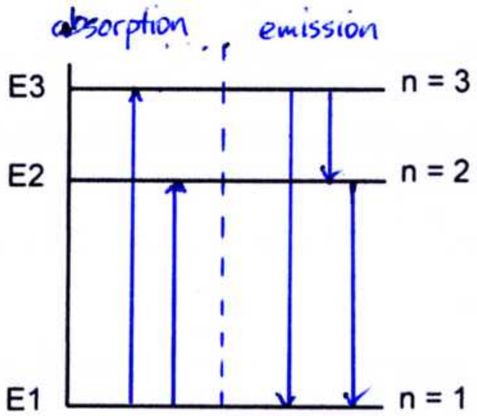
$= 256 - 6$ (1)

$= 250$ Hz (1)

Must show working.

(3)

4. The energy level diagram for a hypothetical atom is shown below. On this diagram draw arrows to show the transitions that would produce emission and absorption spectra for this atom. Indicate which transitions are responsible for the absorption spectrum and which for the emission spectrum.



Correct absorption/emission labels - 1 mark

1 mark off for every missing transition.

(3)

5. A 1.00 mW light source emits a narrow beam that shines on a screen. The wavelength of the light is 633 nm.

(a) Calculate how many photons strike the screen per second.

$E_{light} = 1{\cdot}00 \times 10^{-3}$ J per second.

$E_{photons} = \frac{hc}{\lambda}$

$= \frac{(6{\cdot}63\times10^{-34})(3{\cdot}00\times10^{8})}{(633\times10^{-9})}$ (1)

$= 3{\cdot}14\times10^{-19}$ J (1)

$\#\text{photons} = \frac{1{\cdot}00\times10^{-3}}{3{\cdot}14\times10^{-19}}$

$= 3{\cdot}18\times10^{15}$ (1)

(3)

(b) If the power of the beam is ***doubled***, which of the following statements is ***true***? Circle your answer.

A. The photons travel faster.

B. Each photon has more energy.

C. More photons hit the screen every second. (1)

D. The frequency of the light is doubled.

(1)

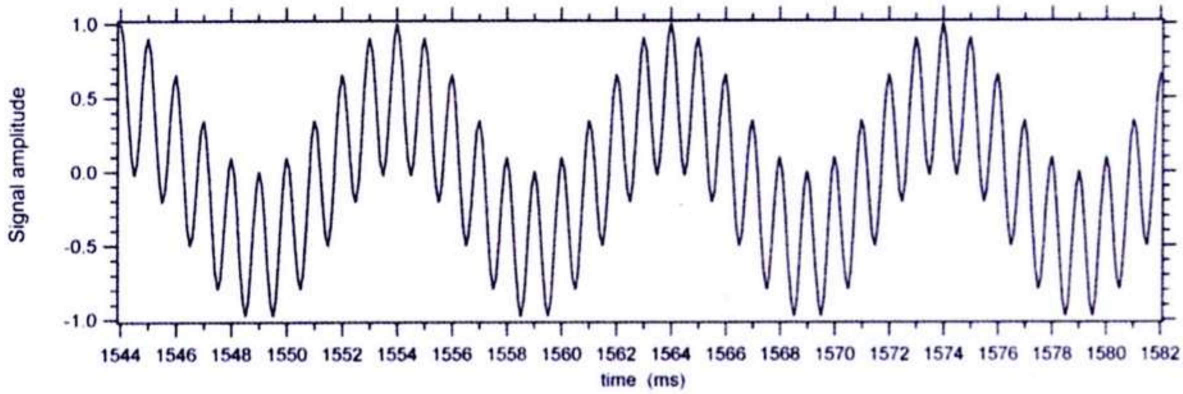
6. For the three properties of a sound wave; frequency, wavelength and speed complete the table below stating whether the property is changed or unchanged when undergoing reflection, refraction and diffraction. One property for diffraction has been completed for you.

Property	**Reflection**	**Refraction**	**Diffraction**
frequency	unchanged	unchanged	unchanged
wavelength	unchanged	changed	unchanged
speed	unchanged	changed	unchanged.

(4)

($\frac{1}{2}$ mark each).

7. The following oscilloscope trace shows the superposition of two waves. The horizontal axis is in milliseconds.



Calculate the frequency of each wave.

Wave with large time period gives the "general shape".

$T = 1559 - 1549$

$= 10\ \text{ms}.$ (1)

$f = \frac{1}{T}$

$= \frac{1}{10 \times 10^{-3}}$

$= 1{\cdot}00 \times 10^{2}\ \text{Hz}$ (1)

Wave with smaller time period has 10 oscillations in 10 ms.

$\therefore T = 1{\cdot}0\ \text{ms}.$ (1)

$f = \frac{1}{T}$

$= \frac{1}{1{\cdot}0 \times 10^{-3}}$

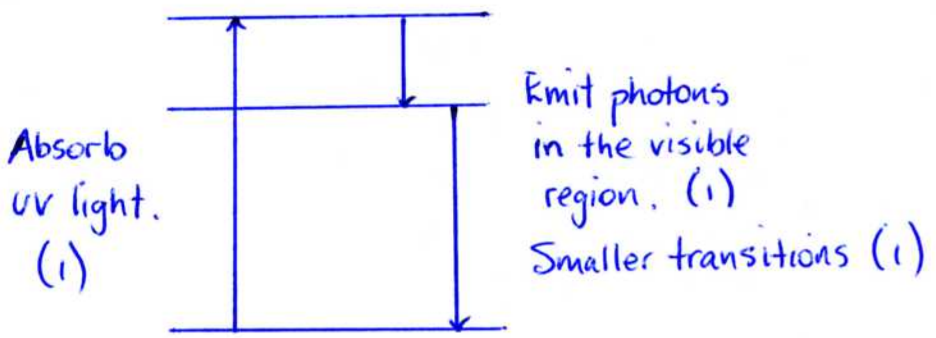
$= 1.00 \times 10^{3}\ \text{Hz}.$ (1)

(4)

8. Some materials emit visible light when illuminated by ultraviolet light.

(a) What is this phenomenon called? Fluorescence or phosphorescence. (1) (1)

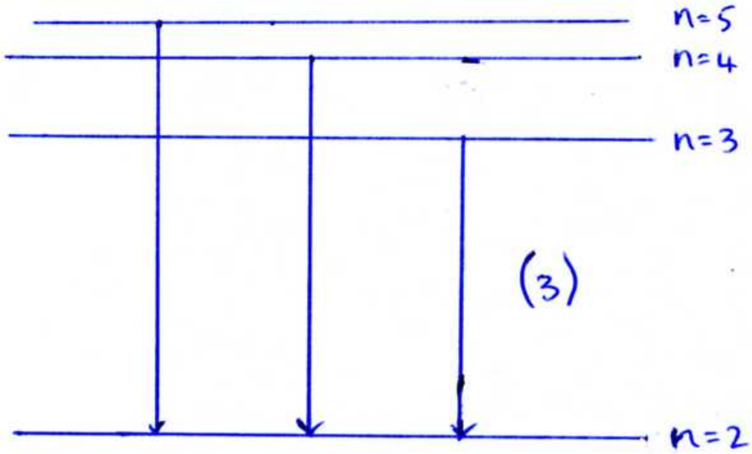
(b) Explain how this phenomenon occurs. You may wish to draw a diagram to aid your explanation.



(3)

9. 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.



Smaller spacings - 1 mark.

(4)

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

- 4.40×10^{-7} m (1)
- $E = \frac{hc}{\lambda}$ ⇒ Smallest λ has highest energy. (1)

(2)

(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.

$$E(\text{photon}) = \frac{hc}{\lambda}$$
$$= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(4.90\times10^{-7})} \quad (1)$$
$$= 4.06\times10^{-19}\ \text{J}$$
$$= 2.54\ \text{eV}. \quad (1)$$

$$E(\text{photon}) = E_4 - E_2$$
$$\Rightarrow E_4 = 2.54 - 3.4$$
$$= \underline{-0.9\ \text{eV}} \quad (1)$$

(3)

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 wavelength 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.

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

$$\Rightarrow \quad \lambda_{observed} = (z+1)\lambda_{earth} \qquad (1)$$

$$= (4.25+1)(4.90\times10^{-7})$$

$$= 2.55\times10^{-6}\ \text{m}. \qquad (1)$$

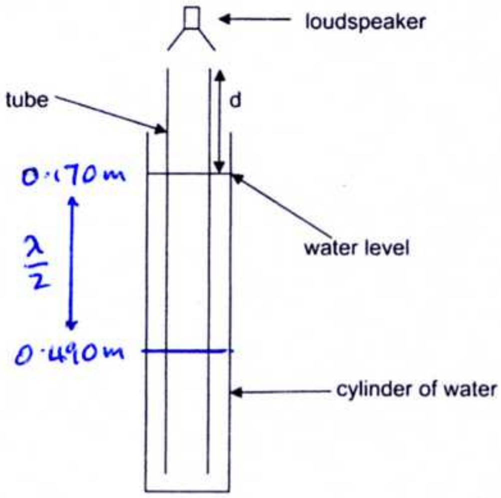
(2)

10. (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.

- Suitable example (1)
  e.g. Ringing wine glass, Tacoma Bridge, rattle in a car, etc.
- Explanation should mention: natural frequency. (1)
  driving frequency equals the natural frequency. (1).

(3)

A loudspeaker emitting a single frequency is held over a tube that 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.

$$\frac{\lambda}{2} = 0{\cdot}490 - 0{\cdot}170 \quad (1)$$

$$\Rightarrow \lambda = 0{\cdot}640 \text{ m} \quad (1)$$

(2)

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

$$v = f\lambda$$

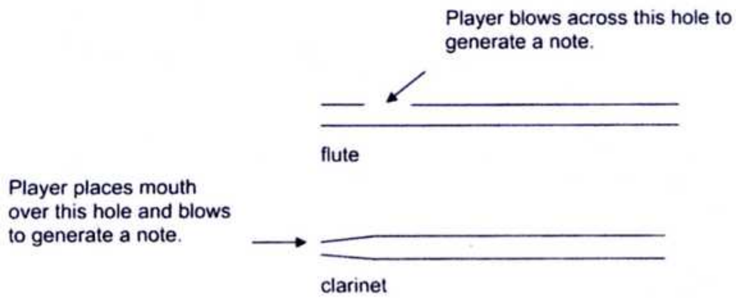
$$\Rightarrow f = \frac{v}{\lambda}$$

$$= \frac{346}{0{\cdot}640} \quad (1)$$

$$= \underline{5{\cdot}41 \times 10^{2} \text{ Hz}} \quad (1)$$

(2)

(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 : 3 : 5 (1)

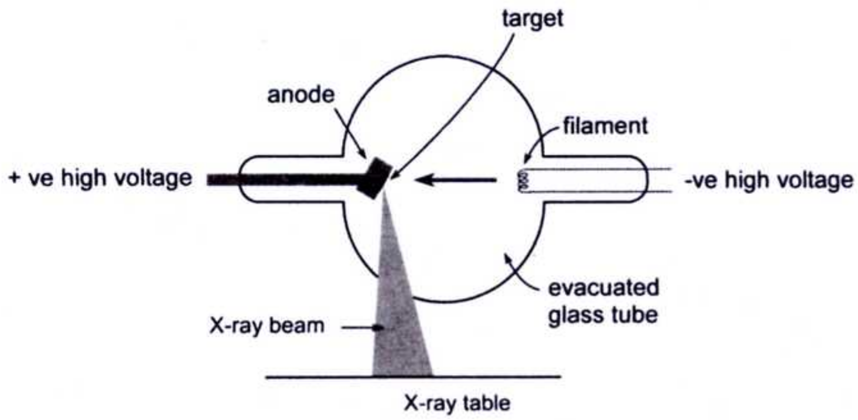
(1)

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

- Flute is an open pipe. (1)
- Clarinet is a closed pipe. (1)
- Closed pipes only have odd harmonics. (1)

(3)

11. The diagram below shows the basic components of a stationary anode X-ray tube.



(a) Describe how X-rays are produced in the tube.

- Heated filament produces electrons. (1)
- High potential difference accelerates the electrons towards the target. (1)
- Electrons decelerate rapidly in the target. (1)
- Kinetic energy is converted to X-rays and heat energy. (1)

(4)

(b) An X-ray tube with a tungsten anode is operating at a peak voltage of 100 kilovolts. Determine the upper limit in electron volts for the energy of an X-ray photon emitted from the tungsten target.

- Max E_k = 100 keV (1)

$\therefore$ Max. energy of X-ray = 100 keV. (1)

(2)

(c) Exposure to X-rays is potentially more harmful than exposure to ultraviolet light.

(i) Explain why X-rays are so harmful compared with ultraviolet light.

- X-rays have a much shorter λ, which gives them much deeper penetration. (1)
- X-rays have much more energy since $E_{photon} = \frac{hc}{\lambda}$. (1)

(2)

(ii) Describe and justify two precautions that an X-ray operator must take to reduce their risk of exposure.

One: Stay behind shield. (1)
Shield absorbs X-rays. (1).

Two: Spend less time in the area. (1)
Radiation effects accumulate. (1).

Wear lead clothing. (1)
Lead absorbs X-rays. (1)

Stay at a distance from the machine. (1)
Radiation intensity decreases with distance. (1).

[Any 2 acceptable precautions]

(4)

12. Two pipes open at both ends are 0.840 m and 0.850 m long. They are sounded together at their fundamental frequencies and produce beats at the rate of 46 every 20.0 s.

(a) Calculate the beat frequency produced by the pipes.

$f_{beat} = \frac{46}{20.0}$ (1)

$= 2.30\text{ Hz}$ (1)

(2)

(b) (i) Show that for two such pipes the beat frequency is equal to

$$f_{beat} = \frac{v}{2}\left|\frac{1}{L_2} - \frac{1}{L_1}\right|$$

where: v = speed of sound
L_1 = length of pipe 1
L_2 = length of pipe 2

For fundamental: $f_1 = \frac{v}{2L_1}$ and $f_2 = \frac{v}{2L_2}$. (1)

$$f_{beat} = |f_2 - f_1|$$
$$= \left|\frac{v}{2L_2} - \frac{v}{2L_1}\right| \quad (1)$$
$$= \frac{v}{2}\left|\frac{1}{L_2} - \frac{1}{L_1}\right| \quad (1).$$

(3)

(ii) Calculate the speed of sound for the situation described above.

$$f_{beat} = \frac{v}{2}\left|\frac{1}{L_2} - \frac{1}{L_1}\right|$$

$$\Rightarrow v = \frac{2 f_{beat}}{\left|\frac{1}{L_2} - \frac{1}{L_1}\right|} \quad (1)$$

$$= \frac{2(2.30)}{\left|\frac{1}{0.84} - \frac{1}{0.85}\right|} \quad (1)$$

$$= \underline{3.28 \times 10^2 \text{ ms}^{-1}}. \quad (1)$$

(3)

(c) Calculate the fundamental frequency of the 0.840 m long pipe.

$$f = \frac{nv}{2L}$$

$$= \frac{(1)(328)}{2(0.840)} \quad (1)$$

$$= \underline{1.95 \times 10^{2} \text{ Hz}} \quad (1)$$

(2)

(d) If the gas in the 0.840 m pipe was replaced with carbon dioxide at 25°C and 101.3 kPa, would the fundamental frequency increase, decrease or remain the same? Explain your answer.

- Decrease. (1)
- Speed of sound in CO_2 is lower at this temperature and pressure. (1)
- $f \propto v \Rightarrow f$ is less. (1)

(3)