Physics 3AB

Particles, Waves and Quanta Test 2014

Name: Solutions	Mark: / 54 = %

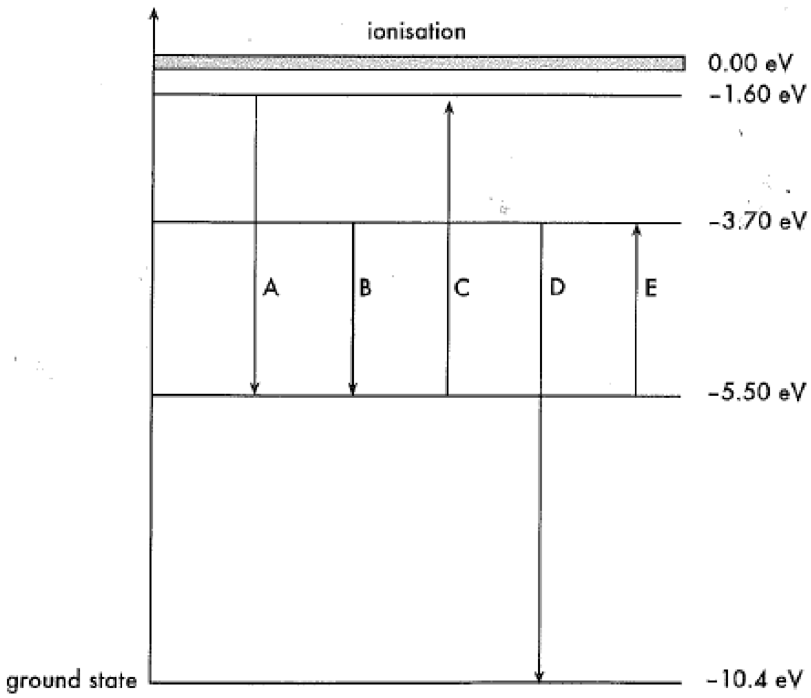
Time Allowed: **50 minutes**

Notes to Students:

- You must include **all** working to be awarded full marks for a question.
- Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
- **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(7 marks)**

The diagram below shows the atomic energy levels for mercury.



atomic energy levels of mercury

(a) State which transition (A, B, C, D, or E) on the energy level diagram demonstrates the change in atomic energy levels for the emission of a photon of energy 2.88 x 10^{-19} J. Include appropriate working to justify your answer.

(3 marks)

Transition B

(1) $\frac{2.88\times10^{-19}}{1.6\times10^{-19}} = 1.80\ eV$

(1) $-3.70-(-5.50) = 1.80\ eV$

(b) Calculate the shortest wavelength of photon that can be produced when the atom is bombarded with 7.00 eV electrons.

(4 marks)

$7.00 eV photon \rightarrow excitation to n = 3$

$shortest \lambda = l \arg est energy : n = 3 \rightarrow n = 1$

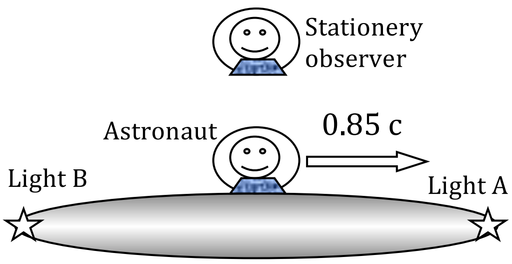
$E = \frac{hc}{\lambda}$ (1)

(1) $(-3.7-(-10.4)(1.6\times10^{-19})) = \frac{(6.63\times10^{-34})(3\times10^{8})}{\lambda}$ (1)

$\lambda = 1.86\times10^{-7} m$ (1)

Question 2 **(6 marks)**

An astronaut flies past a stationary observer at a constant 85% of the speed of light. His spacecraft has two lights, A at the front and B at the rear. The stationary observer sees the two lights A and B turn on simultaneously.



(a) The astronaut is positioned in the middle of his spaceship and is able to observe both lights at the same time. State the order in which the astronaut sees the lights turn on and explain your reasoning.

(3 marks)

- He will see A turn on before B
- The speed of light is always the same, the astronaut is moving towards A and so the light has a decreasing distance to travel and reaches him before
- The light from B which has an increasing distance to travel.

(b) A chemical reaction that takes 60.0 s in the laboratory on Earth has been taken on the spacecraft. The astronaut carries out the same experiment, while the spacecraft is moving, and times its duration. Will the duration of the experiment be; Circle your chosen response

(i) greater than 60 seconds

(ii) equal to 60 seconds

(iii) less than 60 seconds

(1 mark)

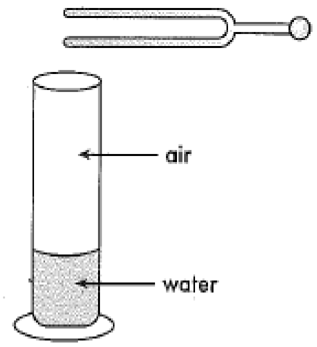
(c) Explain your reasoning for your choice in (b).

(2 marks)

- The astronaut is not moving relative to the experiment.
- So he measures the proper time for the experiment – i.e 60 seconds.

Question 3 **(2 marks)**

A student holds a vibrating 256 Hz tuning fork above a measuring cylinder full of water. He then lowers the water height, creating an air column, as shown in the diagram below.



He observes that the sound produced becomes quite loud for the first time when the length of the air column is 32.0 cm. The student then selects a tuning fork of a higher frequency and vibrates it above the 32.0 cm air column. It also produces quite a loud sound.

What is a possible frequency for the second tuning fork?

Any odd integer multiple of the fundamental

e.g. 3 x 256 = 768 Hz

Question 4 **(4 marks)**

A microwave oven has a power output of 700 W at a frequency of 2450 MHz. Assuming the microwave oven is 100% efficient, calculate the number of photons released in the 2.00 minutes taken to heat a cup of coffee.

$E = hf$ (0.5)

$= (6.63\times10^{-34})(2450\times10^{6})$

$= 1.62\times10^{-24}\ J$ (0.5)

$P = \frac{E}{t}$ (0.5)

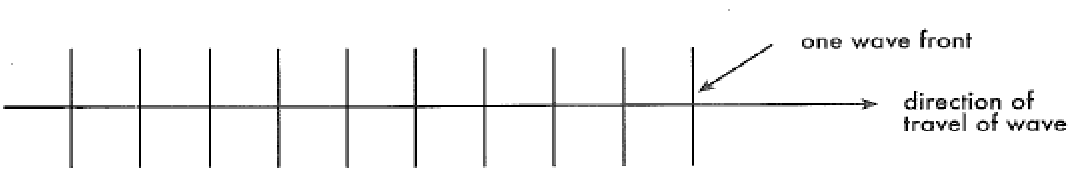
$700 = \frac{E}{(2\times60)}$ (0.5)

$E = 84000\ J$ (0.5)

(0.5) $\frac{84000}{1.62\times10^{-24}} = 5.19\times10^{28}\ photons$ (1)

Question 5 **(3 marks)**

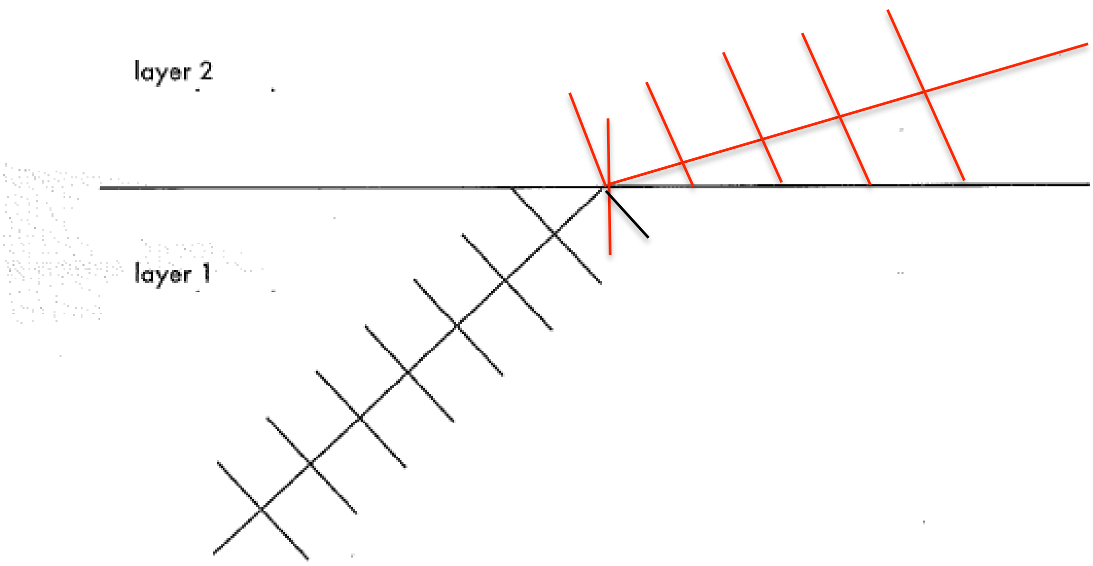
A sound wave can be represented by wavefronts at a particular instant of time. The direction of wave travel is shown by a line drawn perpendicular to each wave front. The diagram below shows a sound wave travelling to the right at a certain instant of time.



Under certain atmospheric conditions the air can form layers in which the sound has different speeds. In a particular case, sound travels from one layer (layer 1) to another (layer 2) where the temperature is approximately 25.0% greater. The diagram below only shows the sound in layer 1.

On the diagram below, sketch the wavefronts in layer 2.

1 mark – correct direction
1 mark – wavelength increased (-0.5 if not in rough ratio)
1 mark – wavelengths are equally spaced



Question 6 **(8 marks)**

Light from different lamps is passed through a spectrometer. For each of the following cases;

1. State the type of spectrum that would be observed

2. Describe the spectrum that would be observed

(a) Light from an incandescent globe – e.g. a tungsten filament light globe.
(2 marks)

- Continuous Spectrum
- All colours of the visible spectrum

(b) Light from an incandescent globe that has passed through a coloured solution.
(3 marks)

- Band Absorption Spectrum
- Black bands on a
- Continuous spectrum

(c) Light from a mercury vapour discharge lamp.
(3 marks)

- Line Emission Spectrum
- Coloured lines on a
- Black background

Question 7 **(3 marks)**

(a) What is the name given to a particle that is made up of quarks?
(1 mark)

Hadron

(b) All quarks all have an associated particle called an antiquark. State;

(i) One property a quark and its antiquark have in common.
(1 mark)

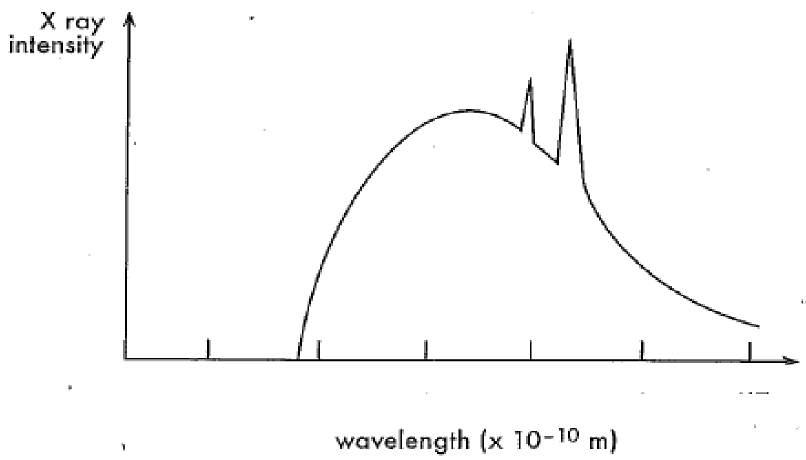
mass

(ii) One property that is different for a quark and its antiquark.
(1 mark)

charge

Question 8 **(8 marks)**

The graph below shows the spectrum obtained when a molybdenum anode in an X-ray tube is bombarded with electrons accelerated across a potential difference of 34.0 kV.



(a) Calculate the lowest (cutoff) wavelength of X-ray that can be produced by this X-ray tube.
(4 marks)

$E = qV$ (0.5)

$= (1.6\times10^{-19})(34.0\times10^{3})$ (0.5)

$= 5.44\times10^{-15}\ J$ (1)

$E = \frac{hc}{\lambda}$ (0.5)

$5.44\times10^{-15} = \frac{(6.63\times10^{-34})(3\times10^{8})}{\lambda}$ (0.5)

$\lambda = 3.66\times10^{-11}\ m$ (1)

(b) Explain the formation of the Bremsstrahlung radiation (the continuous background radiation).

(3 marks)

- When an electron strikes the anode (metal plate) it will decelerate.
- The amount of deceleration is continuous – in some collisions it may be large, in others small.
- An accelerating charged particle emits electromagnetic radiation, as the amount of deceleration is continuous, so are the wavelengths of the radiation emitted.

(c) Explain why there is a cutoff wavelength of X-ray that can be produced.

(2 marks)

- The electron decelerates to zero velocity, so the photon emitted has the maximum energy.
- Maximum energy is the highest possible frequency of photon emitted and hence shortest wavelength ($c=f\lambda$)

Question 9 **(12 marks)**

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 46.0 every 20.0 seconds.

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

(2 marks)

(1) $\frac{46}{20} = 2.30\ Hz$ (1)

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

(2 marks)

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

Where: v = speed of sound in air
L_1 = length of pipe 1
L_2 = length of pipe 2

$$f_n = \frac{nv}{2L}$$ (0.5)

$$f_{1pipe1} = \frac{v}{2L_1} \qquad f_{1pipe2} = \frac{v}{2L_2}$$

$$f_{beat} = |f_1 - f_2|$$ (0.5)

$$= \left|\frac{v}{2L_1} - \frac{v}{2L_2}\right|$$ (0.5)

$$= \frac{v}{2}\left|\frac{1}{L_1} - \frac{1}{L_2}\right|$$ (0.5)

(c) Calculate the speed of sound in air for the pipes.

(2 marks)

$$2.3 = \frac{v}{2}\left|\frac{1}{0.840} - \frac{1}{0.850}\right|$$ (1)

$$v = 328\ ms^{-1}$$ (1)

(d) Calculate the 3rd overtone of the 0.84 m long pipe.

(3 marks)

$$f_n = \frac{nv}{2L}$$ (1)

$$3rd\ overtone = 4th\ harmonic$$

$$f_4 = \frac{(4)(328)}{(2)(0.84)}$$ (1)

$$= 781\ Hz$$ (1)

(e) If the gas in the pipe was replaced with carbon dioxide gas at the same temperature, how would the fundamental frequency of the pipes change? Explain your reasoning.
[speed of sound in carbon dioxide is 269 ms^{-1}]

(3 marks)

- The length of the pipe does not change and hence the wavelength of the fundamental frequency does not change.
- As the velocity of the speed of sound decreases, the frequency of the fundamental mode of vibration
- must decrease to maintain the ratio of $\lambda = v/f$.

End of Test