Physics 3AB - Year 12

Waves, Particles and Quanta
Unit Test
2015

Name: Solutions

Mark: / 52

= %

Time Allowed: 50.0 Minutes

Notes to Students:

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

Question 1 **(3 marks)**

A helium-neon laser puts out a beam of red light containing a very narrow range of frequencies centred at 4.74 x 10^{14} Hz. Calculate the energy of each photon at that frequency in eV.

$E = hf$ (0.5)

$= (6.63\times10^{-34})(4.74\times10^{14})$ (0.5)

$= 3.14\times10^{-19}\,J$ (0.5)

$\frac{3.14\times10^{-19}}{1.6\times10^{-19}} = 1.96\,eV$ (0.5) (1)

Question 2 **(4 marks)**

Volume for volume, carbon dioxide gas is heavier than air. If the air inside an organ pipe is replaced with carbon dioxide, state what will happen to the value of the fundamental frequency of the organ pipe. Explain your reasoning.

- Carbon dioxide gas is heavier, the particles will have more inertia and not move as quickly. The speed of sound in carbon dioxde will be lower than the speed of sound in air.
- The length of the pipe is unchanged and hence the wavelength of the fundamental harmonic will not be changed.
- As v=fλ, if v decreases but the wavelength does not
- Then the frequency of the fundamental harmonic must also decrease.

Question 3 **(4 marks)**

A group of aliens on a spaceship travel past a laboratory on Earth at a speed of 0.70c. The humans in the laboratory are performing an experiment to measure the period of a mass oscillating on a spring. The humans measure the period of oscillation to be 2.00 s.

(a) Will the period measured by the aliens be? Circle your chosen response.

(1 mark)

(i) Greater than 2.00 s

(ii) Equal to 2.00 s

(iii) Less than 2.00s

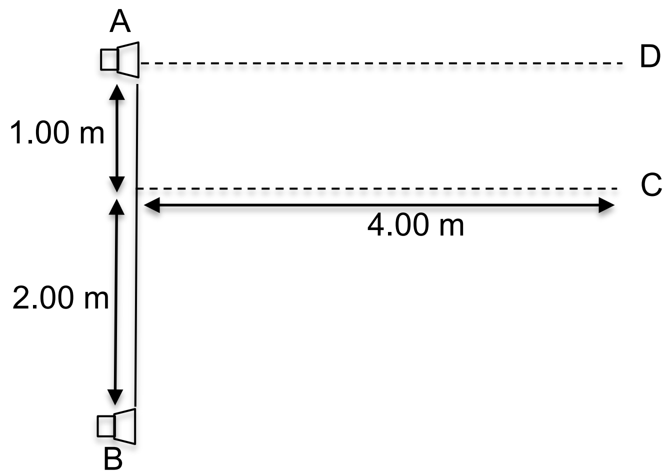
(b) Explain the reasoning behind your choice in (a).

(3 marks)

- There is relative motion between the humans and the aliens, so the distance measured for the oscillation of the spring increases.
- As the speed of light is a constant value (c) the ratio of distance to time must stay constant.
- As the distance increases, the time must dilate as well to maintain the ratio, hence the period of oscillation will increase.

Question 4 **(6 marks)**

Two small speakers, A and B, are connected to the same oscillator and emit waves of the same frequency in phase. The speakers are arranged as shown in the diagram below. The speed of sound in air is 340 ms^{-1}.



(a) Calculate the path difference for an observer standing at C.

(3 marks)

$$Path\ Difference = |AC - BC|$$

$$AC = \sqrt{4^2 + 1^2} = 4.12\ m$$ (1)

$$BC = \sqrt{4^2 + 2^2} = 4.47\ m$$ (1)

$$4.47 - 4.12 = 0.350\ m$$ (1)

(b) If the observer at C hears a 'loud' sound, calculate the lowest possible frequency of the sound.

(3 marks)

Lowest frequency = 1st soft spot

PD = $\lambda/2$

$$\frac{\lambda}{2} = 0.350\ m$$

$$v = f\lambda$$ (1)

$$340 = (f)(2 \times 0.35)$$ (1)

$$f = 486\ Hz$$ (1)

Question 5 **(2 marks)**

State one similarity and one difference between quarks and leptons.

Similarity

- Each come in a family of six particles (and associated antiparticles)
- Or both appear to be fundamental particles (i.e not made up of any smaller particles).
- Both experience the weak force
- Both experience the gravitational force
  (not electromagnetic – not all leptons are charged)

Difference

- Leptons can exist as individual particles, quarks can only exist together in groups of two or three.
- Or Quarks join together to make other particles, leptons do not.
- All quarks are charged, not all leptons have charge
- Leptons do not feel the strong force, quarks do

Question 6 **(3 marks)**

A tuning fork in air, where the speed of sound is 343 ms^{-1} produces a tone with a wavelength of 0.780 m. If the tuning fork is now placed in acetone, calculate the length of the wave created in the liquid when the tuning fork is struck. Sound waves travel at 1200 ms^{-1} in acetone.

$$v = f\lambda$$ (1)

$$\frac{v_{air}}{\lambda_{air}} = \frac{v_{acetone}}{\lambda_{acetone}}$$

$$\frac{343}{0.78} = \frac{1200}{\lambda_{acetone}}$$ (1) Or other suitable working

$$\lambda_{acetone} = 2.73\,m$$ (1)

Question 7 **(4 marks)**

The B-string from a guitar is fixed at both ends under tension with a vibrating length of 33.0 cm. Its third overtone oscillates at a frequency 984 Hz. Calculate the wave speed and wavelength of the standing wave that is setup.

$$f_n = \frac{nv}{2L} \quad n = 4$$ (0.5)

$$984 = \frac{4v}{(2)(0.330)}$$ (0.5)

$$v = 162\ ms^{-1}$$ (1)

$$v = f\lambda$$ (0.5)

$$162 = (984)(\lambda)$$ (0.5)

$$\lambda = 0.165\ m$$ (1)

Question 8 **(8 marks)**

A cathode ray tube is a vacuum tube through which electrons are accelerated.

(a) Calculate the smallest (minimum) wavelength of X-ray that can be produced by an electron as it crashes into the metal mask of a cathode ray tube operating with an accelerating voltage of 20.0 kilovolts.

(4 marks)

$$E = Vq$$ (0.5)

$$= (20.0\times10^{3})(1.60\times10^{-19})$$ (0.5)

$$= 3.20\times10^{-15}\ J$$ (1)

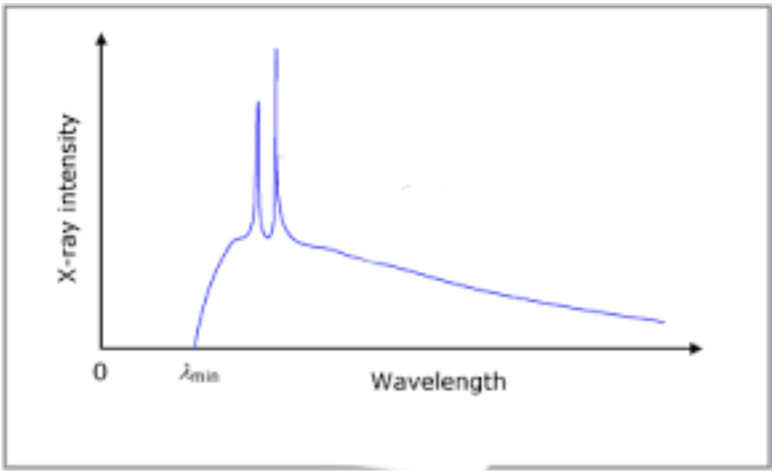
$$E = \frac{hc}{\lambda}$$ (0.5)

$$3.20\times10^{-15} = \frac{(6.63\times10^{-34})(3\times10^{8})}{\lambda}$$ (0.5)

$$\lambda = 6.22\times10^{-11}\ m$$ (1)

(b) The diagram below shows the X-ray spectra for this particular metal. If the accelerating voltage across the cathode tube were increased, state if the cut-off wavelength will change. Explain your reasoning.

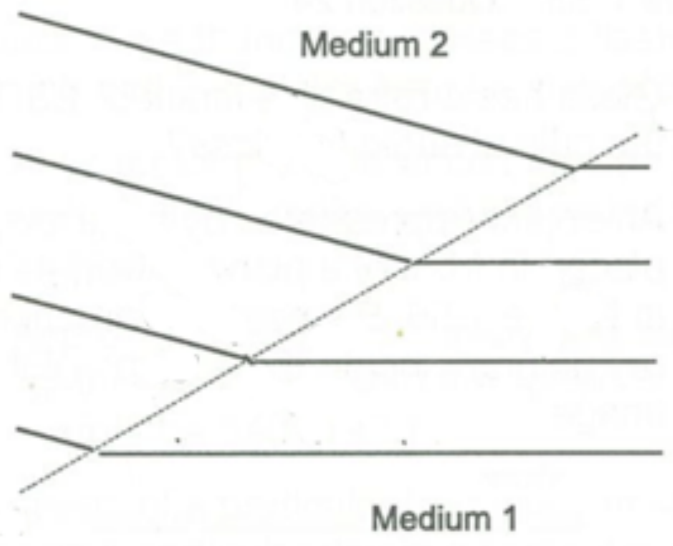
(4 marks)



- $\lambda_{minimum}$ would decrease (move to the left) as the accelerated electrons have a greater amount of kinetic energy.
- If the electron transfers all its energy into a photon in one collision, the photon produced will have the greatest amount of energy possible and hence the smallest wavelength as $E=hc/\lambda$.
- The intensity of photons of all wavelengths will increase.

Question 9 **(4 marks)**

The diagram below shows sound waves refracting from medium 1 into medium 2. One medium is air and the other is water.



(a) State which of the two media is air.

(1 mark)

- medium 1

(b) Explain your reasoning.

(3 marks)

- Sound waves travel faster in water than in air
- The wavelength of the waves in medium 2 is larger than for medium 1.
- As the frequency of the waves stays the same

Question 10 **(14 marks)**

The energy of the ground state of an atom is known to be -5.00 eV. A gas of this atom is illuminated with 'white light' (400 – 700 nm). A spectrometer, which is sensitive to the 400 – 700 nm range is used to measure the radiation absorbed and emitted.

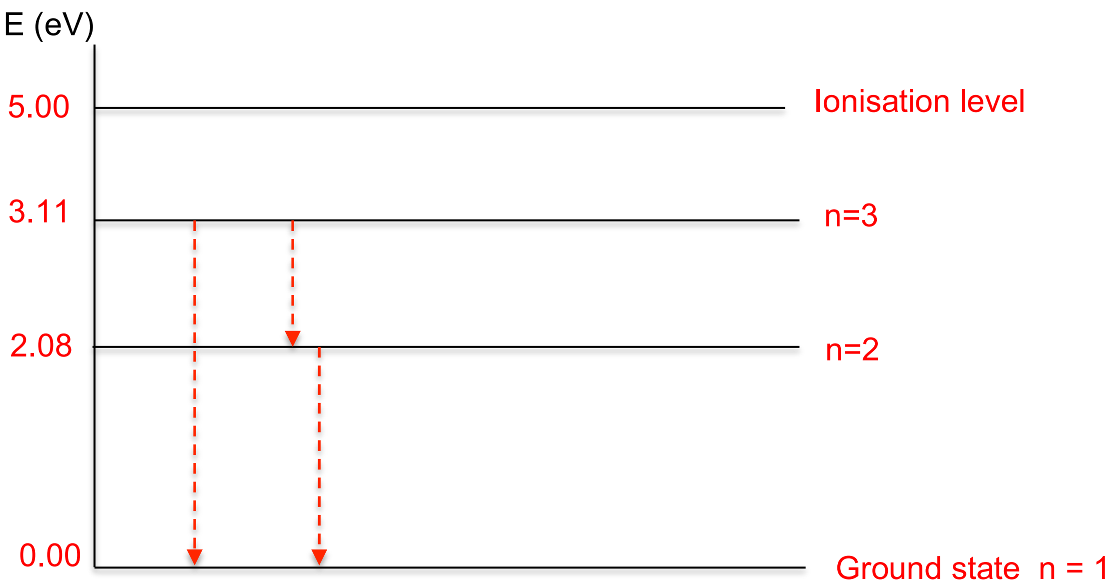
The sample is observed to absorb light at only 400 nm. After the 'white light' is turned off, the sample emits visible radiation of 400 nm and 600 nm wavelengths.

(a) On the diagram below, indicate the location and energy of;

1. The ground state
2. The ionisation level
3. The energy level to which the atom was first excited and
4. One other energy level that the experiment suggests might exist.

Space is given below for you to show your working.

(8 marks)



(or -5.00 eV, -2.92 eV, -1.89 eV, 0.00 eV)

Correct labels (RHS) – 0.5 mark each
Correct energy levels (LHS) – 1 mark each (0.00 and 5.00)
2 marks each (3.11 and 2.08) part marks can be given for incorrect values if working is shown.

$$E = \frac{hc}{\lambda}$$
$$= \frac{(6.63\times10^{-34})(3\times10^{8})}{400\times10^{-9}}$$
$$= 4.97\times10^{-19}\,J$$
$$\frac{4.97\times10^{-19}}{1.6\times10^{-19}}$$
$$= 3.11\,eV$$

$$E = \frac{hc}{\lambda}$$
$$= \frac{(6.63\times10^{-34})(3\times10^{8})}{600\times10^{-9}}$$
$$= 3.32\times10^{-19}\,J$$
$$\frac{3.32\times10^{-19}}{1.6\times10^{-19}}$$
$$= 2.08\,eV$$

(b) On the diagram drawn in (a), sketch the possible decay pathways and state and/or calculate the wavelengths for the three transitions.

(4 marks)

n = 3 to n = 1: 400 nm (1)

n = 2 to n = 1: 600 nm (1)

$$E = \frac{hc}{\lambda}$$

n = 3 to n = 2: $(3.11 - 2.08)(1.6 \times 10^{-19}) = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{\lambda}$ (1)

$$\lambda = 1.21 \times 10^{-6}\ m \quad (1210\ nm)$$

(1)

(c) Explain why only two of these photons were detected by the spectrometer.

(2 marks)

- The n = 3 to n = 2 transition is in the infra-red.
- It cannot be detected by the spectroscope which can only detect visible light.

END OF TEST