Physics 3AB

Waves, Particles and Quanta Unit Test 2012

Name: Solutions

Mark: / 56

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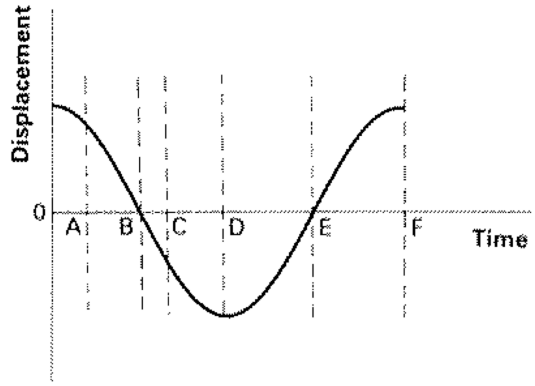
Notes to Students:

- 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 **(4 marks)**

The diagram below shows the displacement-time graph of an oscillator.



(a) How does the velocity at time B compare with that at time E?

(1 mark)

- Same magnitude, opposite directions

(b) How does the velocity at time D compare with that at time F?

(1 mark)

- Both have zero velocity (neither are moving)

(c) State two points that are 90° out of phase.

(1 mark)

- BD; DE; EF; BF etc

(d) If the wave is moving to the left, in which direction is point C moving?

(1 mark)

- downwards

Question 2 **(1 mark)**

What is the electric charge of an antiproton?

- -1e (-1/2 mark if no 'e')

Question 3 **(8 marks)**

A laser used to weld detached retinas emits light with a wavelength of 652 nm in pulses that are 20.0 ms in duration. The average power during each pulse is 0.600 W.

(a) How much energy is in each pulse?

(3 marks)

$$P = \frac{E}{t} \quad (1)$$

$$0.6 = \frac{E}{20 \times 10^{-3}} \quad (1)$$

$$E = 1.20 \times 10^{-2}\ J \quad (1)$$

(b) What is the energy of one photon?

(3 marks)

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

$$= \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{652 \times 10^{-9}} \quad (1)$$

$$= 3.05 \times 10^{-19}\ J \quad (1)$$

(c) How many photons are there in each pulse?

(2 marks)

$$\# = \frac{1.20 \times 10^{-2}}{3.05 \times 10^{-19}} \quad (1)$$

$$= 3.93 \times 10^{16} \quad (1)$$

Question 4 **(3 marks)**

If we see someone's clock running slow due to relative motion, how will they see our clocks running? Explain your reasoning.

- They will also see our clocks running slow.
- Both observers must agree on the speed of light, to the others it will appear as if we are moving away from them.
- Therefore the distance between us will still increase and time dilate accordingly to maintain the ratio of 'c'.

Question 5 **(3 marks)**

If a bell is ringing inside a bell jar, we can no longer hear it when the air is pumped out, but we can still see it. What differences in the properties of propagation of sound and light waves does this indicate?

- Sound requires a medium to travel through but light waves do not.
- Light is a self-propagating wave, due to the changing electric field due to an accelerating charged particle inducing a changing magnetic field and vice versa.
- Sound waves are a longitudinal, mechanical wave and require the intermolecular forces between particles in a medium to move a disturbance back to the equilibrium position.

Question 6 **(6 marks)**

Two speakers of a stereo system are separated by 6.00 m. They are connected to a single frequency generator and are set up so that they are facing each other. Assume the speed of sound in air is 344 ms^{-1}.

(a) If a person stands in the exact middle of the two speakers, what would they hear? Explain your reasoning.

(3 marks)

- Loud spot.
- The distance the person is from is speaker is the same, therefore the distance the waves travel is the same.
- The waves arrive in phase giving constructive interference.

(b) If the person now stands 2.00 m closer to the left hand speaker and the frequency from the generator is 43.0 Hz, what will they hear?

(4 marks)

$v = f\lambda$

$344 = (43)(\lambda)$

$\lambda = 8.00\ m$ (1)

$PD_1 = 1$

$PD_2 = 5$

$5 - 1 = 4m$ (1)

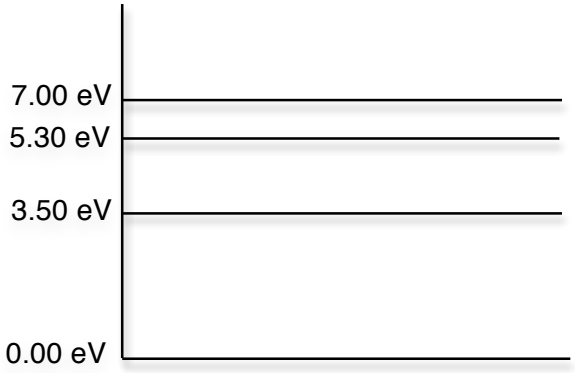
$\frac{4}{8} = 0.5$ (1)

$waves\ arrive\ 180^\circ\ out\ of\ phase$

$\therefore soft\ spot$ (1)

Question 7 **(10 marks)**

Consider the four energy levels shown in the diagram below.



(a) How many spectral lines will result from all possible decay transitions among these levels?

(1 mark)

6

(b) State which transition (i.e n = ? to n = ?) corresponds to the highest frequency light emitted and calculate the frequency of this photon.

(4 marks)

$n = 4 \; to \; n = 1$ (1)

$E = hf$ (1)

$(7)(1.6 \times 10^{-19}) = (6.63 \times 10^{-34})(f)$ (1)

$f = 1.69 \times 10^{15} \; Hz$ (1)

(c) State which transition corresponds to the longest wavelength light emitted and calculate the wavelength of this photon.

(4 marks)

$n = 4 \; to \; n = 3$ (1)

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

$(7 - 5.3)(1.6 \times 10^{-19}) = \dfrac{(6.63 \times 10^{-34})(3 \times 10^{8})}{\lambda}$ (1)

$\lambda = 7.31 \times 10^{-7} \; m$ (1)

(d) How many absorption lines would be present if white light were shone through the cold atoms?

(1 mark)

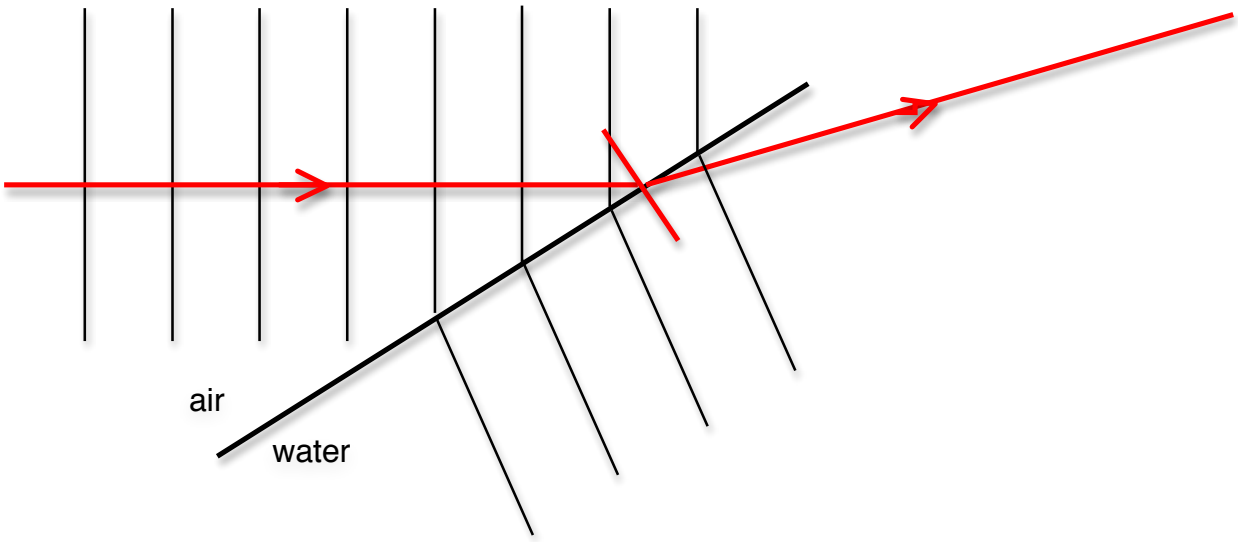
- 3 lines

Question 8 **(5 marks)**

A sound wave travels from air to water as shown in the diagram below. The speed of the wave in air is 346 ms^{-1} and its frequency is 500 Hz.

(a) Complete the diagram to show how the wave moves after entering the water.

(2 marks)



1 – correct direction 1 – clear increase in wavelength

(b) If the speed of sound in water is 1480 ms^{-1}, calculate the wavelength of the sound wave in water.

(3 marks)

$v = f\lambda$ (1)

$1480 = (500)(\lambda)$ (1)

$= 2.96\,m$ (1)

Question 9 **(3 marks)**

Describe the spectra that would be produced by each of these sources, when viewed through a spectroscope;

(a) A tungsten filament lamp.

(1 mark)

- Continuous spectrum with all the colours of white light (rainbow).

(b) A discharge tube filled with one type of gas

(1 mark)

- Coloured lines on a black background.

(c) White light is shone through a solution of a molecular substance

(1 mark)

- Continuous background with black bands missing.

Question 10 **(3 marks)**

Sometimes a tone from an instrument or an audio device will cause another object in the room to begin vibrating loudly. Name this phenomenon and explain its occurrence.

- The phenomenon is resonance.
- When an object is made to vibrate by an outside source with a frequency at or near to one of its natural frequencies,
- There will be an increase in the amplitude of the oscillations.

Question 11 **(8 marks)**

Blowing across the open mouth of an empty test tube produces the fundamental resonant mode of the air column inside the test tube.

(a) If the length of the air column in the test tube is 14.0 cm, what is the frequency of the standing wave?

(3 marks)

$$f = \frac{v}{4L} \quad (1)$$

$$= \frac{346}{(4)(0.14)} \quad (1)$$

$$= 618\ Hz \quad (1)$$

(b) What will be the frequencies of the 2nd and 3rd overtones of the air column inside the test tube?

(2 marks)

$f_3 = 3090$ Hz; $f_5 = 4330$ Hz

(c) What will happen to the frequency of the fundamental resonant mode as the test tube is filled with water? Explain your reasoning.

(3 marks)

- As the test tube is filled with water the length of air in which a standing wave can form is reduced.
- As the wavelength of the fundamental standing wave is four times the length of the air column, if the length of the air column is reduced, so will be the wavelength of the fundamental standing wave.
- As the speed of sound in the air will be constant, if the wavelength decreases, the frequency of the fundamental will increase.

Question 12 **(2 marks)**

State the differences between hadrons and leptons

- Leptons are fundamental particles (no smaller structure), hadrons are made up of quarks.
- Hadrons 'feel' the strong force, leptons do not.