Wave Particle Quantum Test 2017

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Wave Particle Quantum Test 2017

ALL SAINTS' COLLEGE

Year 12 Physics – ATAR
Wave-Particle Quantum Physics
July 2017

Time allowed: 50 minutes
Total marks available: 50
Show calculation answers to 3 significant figures

Student Name:__________________________

1. Light can travel through the vacuum of space but sound cannot.

a) Explain why sound cannot transmit through a vacuum. (2)

Sound is a mechanical wave that requires an elastic medium to transmit energy ✓
Vacuum has no particles ✓

b) Explain why light can transmit through a vacuum (2)

Light is an electromagnetic wave that can self propogate through a vacuum. ✓
Electric field and magnetic field regenerate each other (transverse wave oscillate perpendicular to each other). ✓

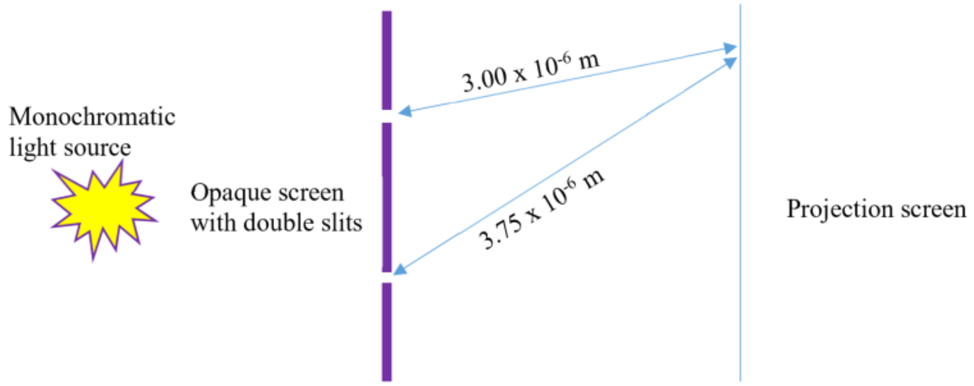
2. Calculate the mass of a particle with a De Broglie wavelength of 1.617×10^{-11} m travelling at 15% the speed of light. (Note: momentum p = mass x velocity) (3)

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$$m = \frac{h}{\lambda v} = \frac{6.63 \times 10^{-34}}{1.617 \times 10^{-11} \times 3 \times 10^{8} \times 0.15}$$ ✓

$$m = 9.11 \times 10^{-31} \text{ kg}$$ ✓

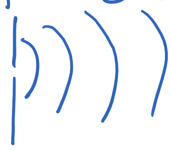
3. Light has passed through 2 slits in a Young's double slit experiment



a) Explain how light from slit 1 can meet light from slit 2 at the location shown rather than just 2 separate points of light being observed on the projection screen directly in front of the slits?

(2)

Light waves difract through the Slits and form circular wavefronts that transfer across 2 dimensions.



b) The light has a wavelength of 500 nm. Path length 1 is 3.75×10^{-6} m, path length 2 is 3.00×10^{-6} m. Consider the location where the 2 waves meet on the screen. Will this be a bright spot or a dark spot? Explain your response and support with calculations.

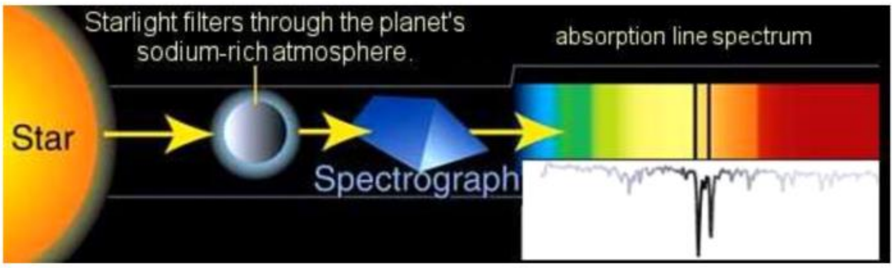
(4)

path difference $= 3.75 \times 10^{-6} - 3.00 \times 10^{-6}$
$= 0.75 \times 10^{-6}$ m

waves in path difference $= \frac{0.75 \times 10^{-6}}{500 \times 10^{-9}} = 1\frac{1}{2}$

path difference of $(n + \frac{1}{2})\lambda$ means 2 waves arrive out of phase.
Destructive interference = dark spot

4. The diagram shows light from a star passing through the atmosphere of its orbiting planet before being passed through a prism to produce a spectrograph of the light spectrum. The atmosphere of the planet is found to be rich in sodium vapour.



a) Explain why there are dark lines missing from the continuous spectrum when viewed on the spectrograph. (3)

Continuous spectrum contains all possible photon wavelengths.
Those photons that have energy value that matches energy level difference in sodium atom are absorbed for excitation.
Because they have been subtracted they appear as black lines.

b) Explain why scientists can state with confidence that the atmosphere of the orbiting planet contains sodium vapour. (2)

Energy level values for Sodium are unique to sodium so it is an easily identifiable pattern when viewed as a line spectrum.

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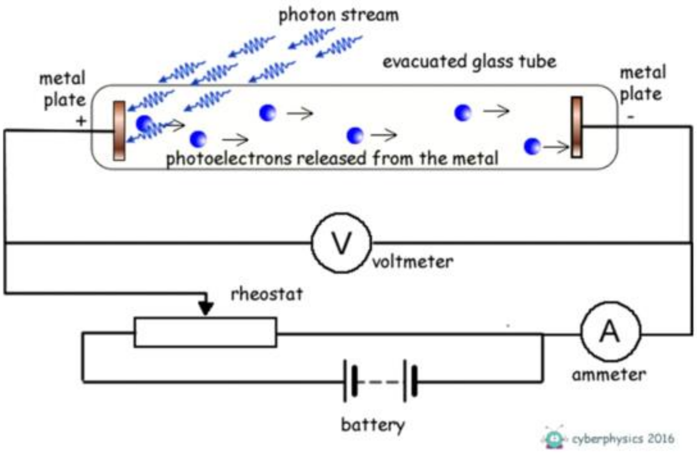
5. The photoelectric effect is when a beam of light above a certain threshold frequency causes electrons to be ejected from a clean metal surface. This is detailed in the diagram below. The rheostat can be adjusted to set the stopping voltage.

The target metal plate is Zinc which has a work function of 4.31 eV. The stopping voltage is -5.50 V



a) Explain what stopping voltage is in this context. (2)

The voltage that allows electric field to do work on moving electrons to transform all kinetic energy out of them and make them come to rest. ✓ ($W = q_e V_0 = \Delta KE$) ✓

b) Explain why light below the threshold frequency will not eject electrons from the Zinc plate. (2)

There is a minimum amount of energy required to transfer to metallic electrons as PE and allow them to escape metal surface. ✓ ✓ $E_{photon} = hf$ so if f below threshold E is insufficient

c) Calculate the threshold frequency for Zinc. (2)

$W = 4.31\ eV = 4.31 \times 1.60 \times 10^{-19}$ J

$W = h.f \quad f = \frac{W}{h} = \frac{4.31 \times 1.60 \times 10^{-19}}{6.63 \times 10^{-34}}$ ✓

$f = 1.04 \times 10^{15}$ Hz ✓

d) Calculate the frequency of the EM radiation on the Zinc plate when the stopping voltage is -5.50 V (4)

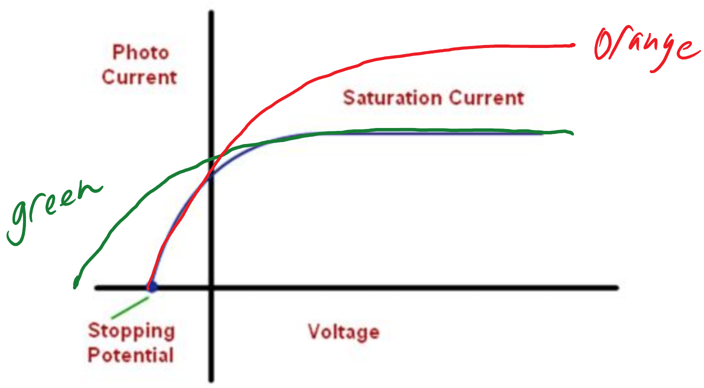
$q \cdot V_0 = hf - W$

$(-1.60 \times 10^{-19} \times -5.50) = (6.63 \times 10^{-34} \times f) - (4.31 \times 1.60 \times 10^{-19})$

$1.60 \times 10^{-19} \times 9.81 = 6.63 \times 10^{-34} \times f$

$f = \frac{1.60 \times 10^{-19} \times 9.81}{6.63 \times 10^{-34}} = 2.37 \times 10^{15}\ Hz$

The metal plate is now swapped to Caesium and the following plot was found for Current vs Voltage when orange light was shone onto the Caesium plate.



e) Sketch the approximate curve for green light of the same intensity and label it "green" (1)

greater negative V_0, same saturation current

f) Sketch the curve for orange light of the double the intensity and label it "orange double intensity" (1)

Same V_0, greater saturation current.

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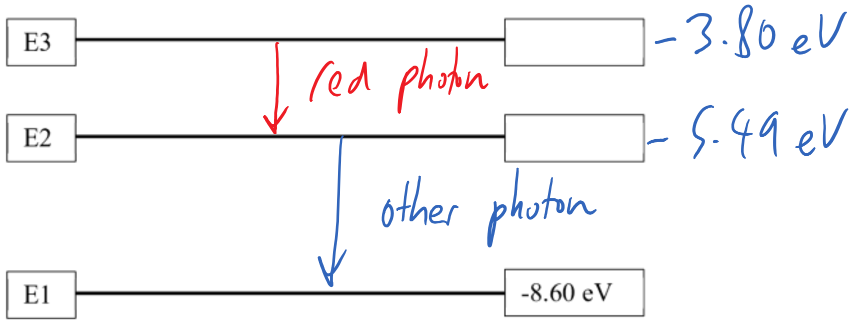
6. When a solution of green chlorophyll is illuminated with UV light it starts to glow red with a wavelength of 735 nm. This is because of the process of fluorescence. One of the atoms in chlorophyll has a ground state energy level value of -8.60 eV. It is excited to Energy Level 3 (E3) by a UV photon of wavelength 259 nm. The red photon is emitted in a de-excitation from E3 to E2. A second photon is emitted when the atomic electron makes a transition from E2 to E1.

a) On the diagram below show and label the atomic electron transitions that result in the two possible photon emissions.

(2)



b) Calculate the value of Energy Levels 2 and 3 (eV) and show them on the diagram. Show your working in the space below.

(4)

$$|E_3 - E_1| = hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{259 \times 10^{-9}}$$

$$|E_3 - E_1| = 7.6795 \times 10^{-19}\ J$$

$$|E_3 - E_1| = \frac{7.6795 \times 10^{-19}}{1.60 \times 10^{-19}} = 4.80\ eV$$

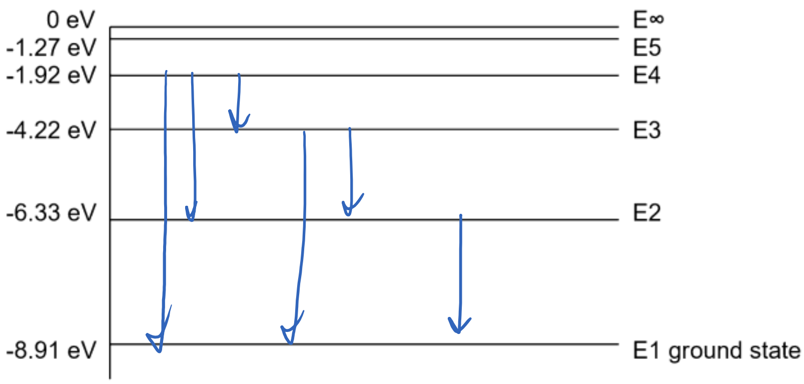
$$E_3 = E_1 + |E_3 - E_1| = -8.60 + 4.80 = -3.80\ eV$$

$$|E_3 - E_2| = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{735 \times 10^{-9}}$$

$$|E_3 - E_2| = 2.7061 \times 10^{-19}\ J = 1.691\ eV$$

$$E = E_3 - |E_3 - E_2| = -3.80 - 1.691 = -5.49\ eV$$

7. The diagram below details some of the energy levels for a simple atom.



a) Consider the atom in its ground state. Is it possible for the atom to absorb a 2.14 eV photon? Explain briefly. (2)

$-8.91 + 2.14 = -6.77$ eV ✓

Does not correspond to an energy level so, No. ✓

b) An atom in its ground state is bombarded by an external electron with a kinetic energy of 24.0 eV. In the collision 75% of the kinetic energy is transformed into the ground state atomic electron. Explain what will happen to the ground state electron after the collision and explain how energy is conserved. (3)

75% x 24 = 18.0 eV transferred to atomic electron.

8.91 eV required for ionisation ✓

18.0 - 8.91 = 9.09 eV of KE of ionised electron ✓

bombarding electron retains 24-18 = 6.00 eV of kinetic energy after collision ✓

c) An atomic electron is at E4. How many lines in the emission spectrum would be possible for the energy levels considered above if it returns to the ground state? Indicate them on the diagram. (2)

On diagram ✓

Number of lines = 6 ✓

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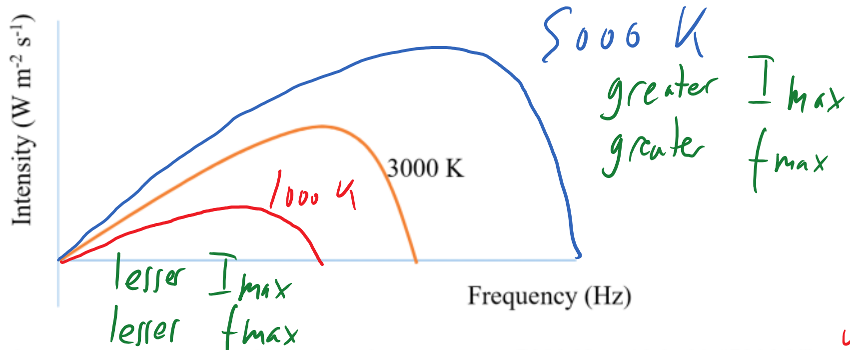
8. A photon has a momentum of 1.18×10^{-27} kg m s^{-1}. Calculate the wavelength of this photon. (2)

De Broglie $\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{1.18 \times 10^{-27}}$ ✓

$\lambda = 5.62 \times 10^{-7}$ m ✓

9. A black body spectrum for a star of temperature 3000 K is shown on the graph below. The graph shows a plot of intensity versus frequency.



a) Sketch the approximate curve for a star of temperature 5000 K and label it "5000 K" ✓
Sketch the approximate curve for a star of temperature 1000 K and label it "1000 K" ✓

(2)

b) Explain why a continuous range of wavelengths are emitted from a black body rather than easily distinguishable line emission that would be emitted from a low pressure monatomic gas. (3)

When particles are densely packed ✓ then electron transitions can occur within and between atoms. ✓ (particle model)

OR

any accelerated charged particle emits emr radiation. Within a black body a vast range of decelerations possible as many particles collide (upper + dominant frequencies are proportional to temp.) (wave model)

∴ a continuous range of photon emissions possible up to a max frequency set ✓ by temperature (temp ∝ KE ∝ collision intensity) (or similar)

End of test