Question 18 (5 marks)

The energy level diagram for a hydrogen atom is shown in Figure 19.

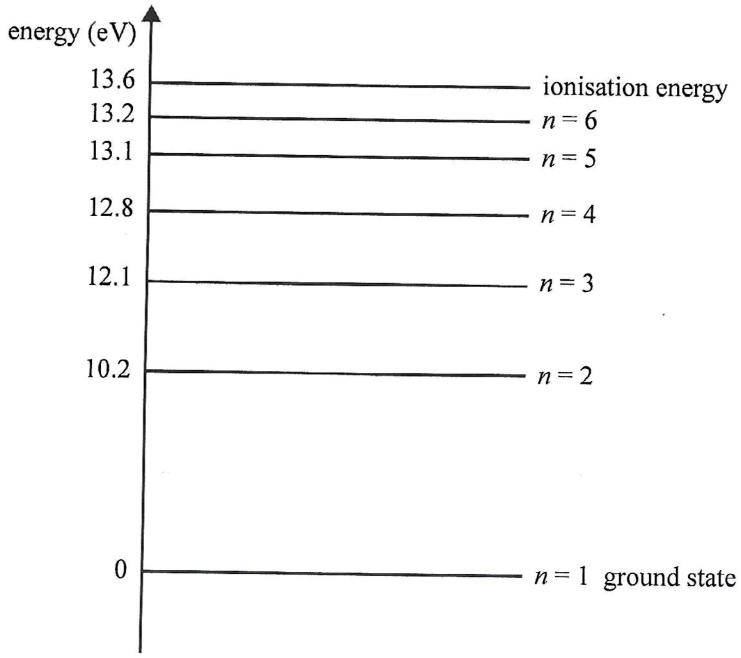


Figure 19

a. A hydrogen atom in the ground state is excited to the $n = 4$ state.

Explain how the hydrogen atom could be excited to the $n = 4$ state in one step. 2 marks

By absorbing 12.8 eV of energy from incident photon

b. List the possible photon energies that could be emitted as the atom goes from the $n = 4$ state to the $n = 2$ state. 3 marks

2.6 eV, 1.9 eV, 0.7 eV

61%

Question 18 68%

Quantised energy levels within atoms can best be explained by

A. electrons behaving as individual particles with different energies.

B. electrons behaving as waves, with each energy level representing a diffraction pattern.

C. protons behaving as waves, with only standing waves at particular wavelengths allowed.

D. electrons behaving as waves, with only standing waves at particular wavelengths allowed.

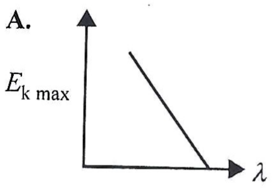
Question 20 36%

When photons with energy E strike a metal surface, electrons may be emitted.

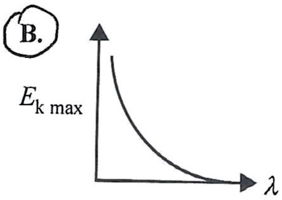
The maximum kinetic energy, $E_{k\,max}$, of the emitted electrons is given by $E_{k\,max} = E - W$, where W is the work function of the metal.

Which one of the following graphs best shows the relationship between the maximum kinetic energy of these electrons, $E_{k\,max}$, and the wavelength of the photons, λ?

A.

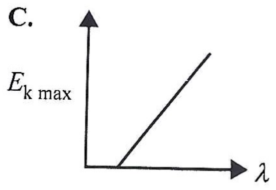


B.

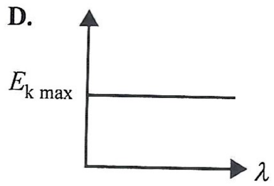


$$E_{k\,max} = \frac{hc}{\lambda} - W$$

C.



D.



END OF SECTION A

Question 11 (4 marks) See solution in Relativity revision

An astronaut has left Earth and is travelling on a spaceship at $0.800c$ ($\gamma = 1.67$) directly towards the star known as Sirius, which is located 8.61 light-years away from Earth, as measured by observers on Earth.

a. How long will the trip take according to a clock that the astronaut is carrying on his spaceship? Show your working. 2 marks

____

____

____

years

b. Is the trip time measured by the astronaut in **part a.** a proper time? Explain your reasoning. 2 marks

____

____

____

Question 12 (5 marks)

In a Young's double-slit interference experiment, laser light is incident on two slits, S_1 and S_2, that are 4.0×10^{-4} m apart, as shown in Figure 11a.

Rays from the slits meet on a screen 2.00 m from the slits to produce an interference pattern. Point C is at the centre of the pattern. Figure 11b shows the pattern obtained on the screen.

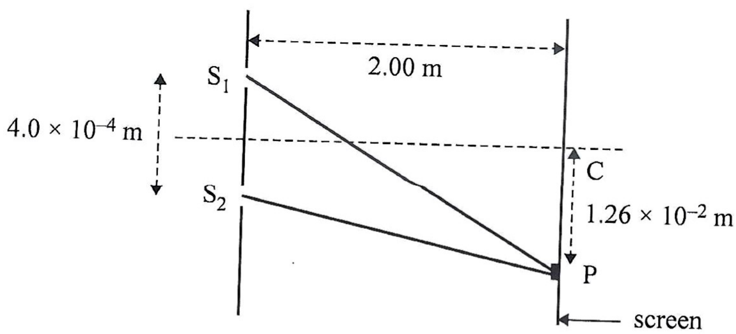


Figure 11a

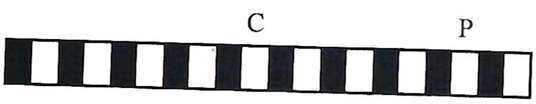


Figure 11b

a. There is a bright fringe at point P on the screen.

Explain how this bright fringe is formed. 2 marks

~~[illegible]~~ P is a 4th bright fringe, so 10%
path difference = 4λ so constructive interference
is occuring.

b. The distance from the central bright fringe at point C to the bright fringe at point P is 1.26×10^{-2} m.

Calculate the wavelength of the laser light. Show your working. 3 marks

$\Delta x = \frac{\lambda L}{d}$ $\Delta x = \frac{1.26 \times 10^{-2}}{4} = 3.15 \times 10^{-3}$ 28%

$\lambda = \frac{\Delta x d}{L} = \frac{3.15 \times 10^{-3} \times 4 \times 10^{-4}}{2} = 6.3 \times 10^{-7}$ m

630 nm

Question 14 (3 marks) 45 %

Figure 13 shows a representation of an electromagnetic wave.

Correctly label Figure 13 using the following symbols.

E – electric field *B* – magnetic field *c* – speed of light *λ* – wavelength

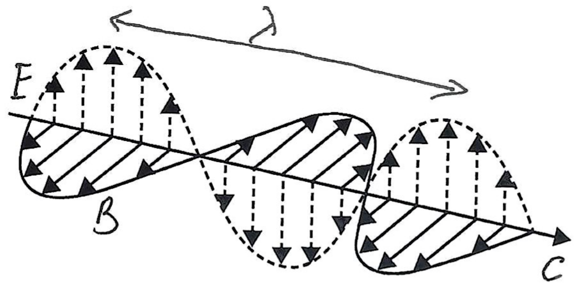


Figure 13

Question 15 (4 marks)

The metal surface in a photoelectric cell is exposed to light of a single frequency and intensity in the apparatus shown in Figure 14.

The voltage of the battery can be varied in value and reversed in direction.

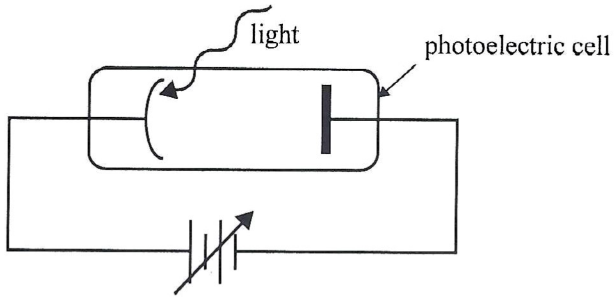


Figure 14

a. A graph of photocurrent versus voltage for one particular experiment is shown in Figure 15.

On Figure 15, draw the trace that would result for another experiment using light of the same frequency but with triple the intensity. 2 marks

52 %

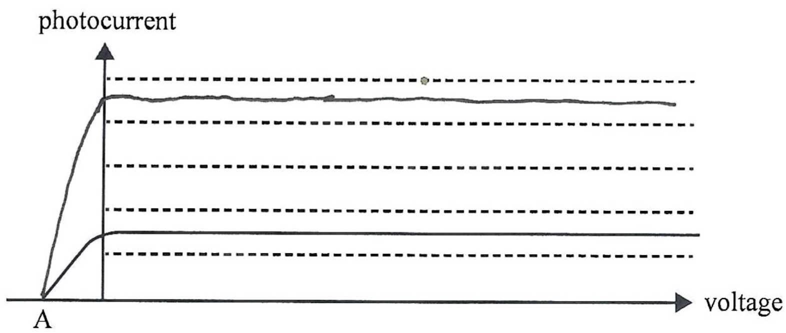


Figure 15

b. What is a name given to the point labelled A on Figure 15? 1 mark

stopping voltage

c. Why does the photocurrent fall to zero at the point labelled A on Figure 15? 1 mark

32 %

Stopping voltage is enough to stop even the most energetic electrons.

Question 16 (5 marks)

A beam of electrons travelling at 1.72×10^5 m s^{-1} illuminates a crystal, producing a diffraction pattern as shown in Figure 16. Take the mass of an electron to be 9.1×10^{-31} kg. Ignore relativistic effects.

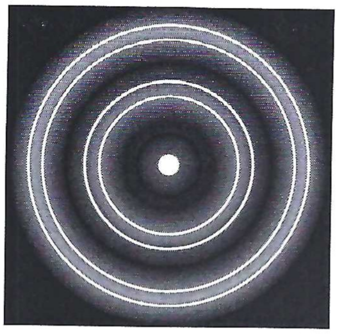


Figure 16

a. Calculate the kinetic energy of one of the electrons. Show your working. 2 marks

$E_K = \frac{mv^2}{2} = \frac{9.1\times10^{-31}\times(1.72\times10^5)^2}{2} = 1.35\times10^{-20}$ J 51%

$\frac{1.35\times10^{-20}}{1.6\times10^{-19}} = 0.08$

0.08 eV

b. The electron beam is now replaced by an X-ray beam. The resulting diffraction pattern has the same spacing as that produced by the electron beam.

Calculate the energy of one X-ray photon. Show your working. 3 marks

$p_{el} = p_{ph}$ $p_{el} = mv = 9.1\times10^{-31}\times1.72\times10^5$ 32%

$= 1.57\times10^{-25}$ kg m s^{-1}

$E_{ph} = pc = 1.57\times10^{-25}\times3\times10^8 = 4.71\times10^{-17}$ J

$4.71\times10^{-17} \div 1.6\times10^{-19} = 2.94\times10^2$

294 eV

Question 17 (5 marks)

Figure 17 shows the emission spectrum for helium gas.

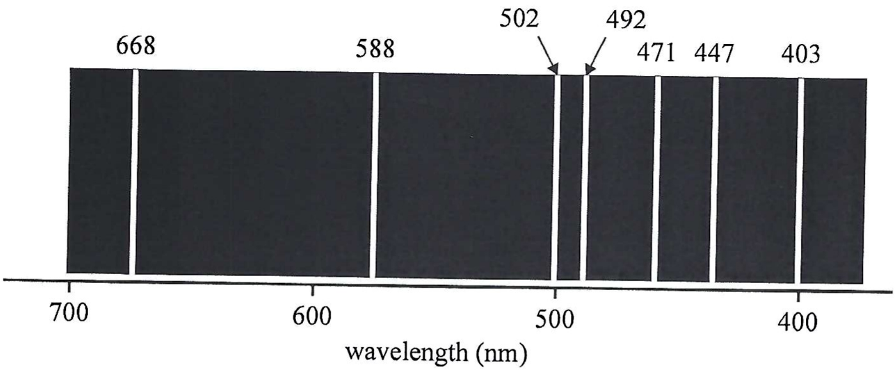


Figure 17

a. Which spectral line indicates the photon with the lowest energy? 1 mark

60 %

668 nm Longest wavelength – lowest energy

b. Calculate the frequency of the photon emitted at the 588 nm line. Show your working. 2 marks

59 %

$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{5.88 \times 10^{-7}} = 5.1 \times 10^{14}$

5.1×10^{14} Hz

c. Explain why only certain wavelengths and, therefore, certain energies are present in the helium spectrum.

2 marks

17%

Electrons can exist in helium atom only in discrete energy levels. When electrons transition between those levels only discrete amounts of energy can be emitted.

Question 11 (4 marks)

A transverse wave is travelling through a medium, as shown in Figure 14. The frequency of the source producing the wave is 40 Hz and the wave travels at a speed of 35 m s^{-1}. The amplitude of the wave is 0.50 m.

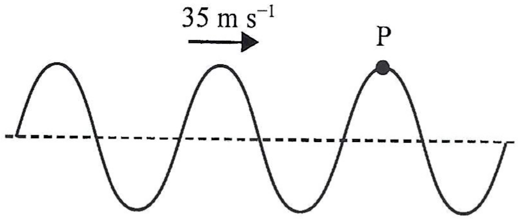


Figure 14

a. What is the period of oscillation for point P in Figure 14? 1 mark

$T = \frac{1}{f} = \frac{1}{40} = 0.025$ s

25 ms

b. On the axes below, sketch the displacement versus time graph for the point P of this transverse wave, showing at least **two** complete cycles. Include scales and units on each axis. 3 marks