Christ Church Grammar School

Science Department
Year 12 2021

ATAR PHYSICS
UNIT 4: WAVE PARTICLE AND QUANTA
TOPIC TEST 2021

Teacher: JRM CJO PCW
(Please circle)

Time allowed for this paper **NAME:** ______________________

Working time for paper: 50 minutes.

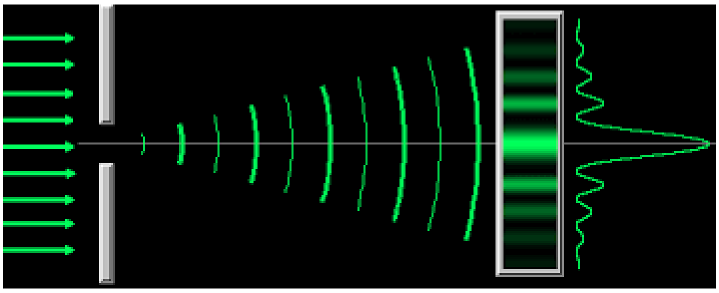
Instructions to candidates:

- You must include **all** working to be awarded full marks for a question. Answers should be expressed to 3 significant figures unless otherwise indicated.
- Marks may be deducted if diagrams are not drawn neatly with a ruler and to scale (if specified).
- Marks will be deducted for incorrect or absent units.
- **No** graphics calculators are permitted – scientific calculators only.

Mark:	/ 51
=	%

Question 1 **(10 marks)**

An interference diffraction pattern can be observed when light or electrons are fired through a single slit, as pictured below.

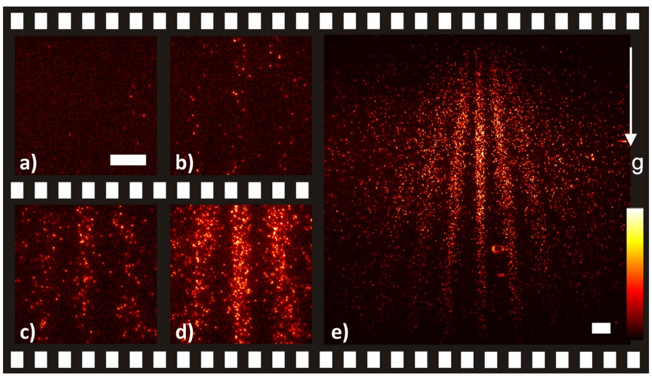


(a) Explain how the electron diffraction experiment supports either (Choose 1):

- Wave particle duality of matter; or
- Quantum mechanics.

(3 marks)

In 2012 researchers successfully performed a quantum interference experiment with much larger and more massive molecules than ever before. They fired molecules composed of over 100 atoms at a barrier with openings designed to minimise molecular interactions, and observed the build-up of an interference pattern, pictured below:



The molecules used in this experiment have an atomic mass of 1298 amu (2.15×10^{-24} kg). In order to detect the very small wavelength, the molecules needed to be travelling very slow. The molecules were found to have an approximate wavelength of 5.20 pm.

(b) Calculate the speed that the molecules were fired.

(3 marks)

(c) Calculate the energy of a photon with an equivalent wavelength (expressed in eV) and classify this type of photon on the electromagnetic spectrum.

(4 marks)

Question 2 **(8 marks)**

The standard model can be used to classify all known elementary particles.

(a) State two questions that could be asked about the properties of any fundamental particle that would allow it to be classified as either a Hadron, Lepton or Boson.

(2 marks)

(b) State two limitations of the standard model.

(2 marks)

(c) Explain how an unstable nucleon can emit a Z boson during its decay, when the mass of the Z boson emitted may exceed the known mass of the nucleon?

(2 marks)

Particle accelerators have been used to make significant discoveries that have helped to develop and support the standard model.

(d) Explain why particle accelerators cannot accelerate neutrons.

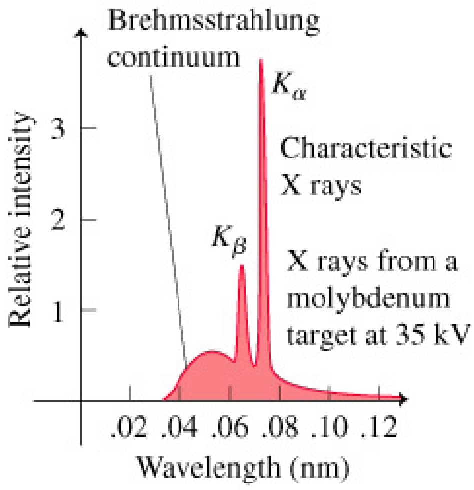
(2 marks)

Question 3 **(10 marks)**

The figure alongside shows the spectrum of X-rays that would be obtained from a 35.0 kV X-ray tube with a molybdenum target.

(a) Explain how Bremsstrahlung X-ray photons are produced.

(2 marks)



Classical mechanics suggest that the bombarding electrons can reach extremely high speeds. In reality, relativistic effects reduce this speed to lower than would have been predicted classically.

(b) Show, using concepts of classical physics (ignoring effects of relativity) that the maximum speed of the bombarding electrons is greater than 10% c and hence relativistic effects must be considered.

(4 marks)

(d) **Calculate** the minimum wavelength of the emitted photons (do not attempt to interpolate from the graph).

(4 marks)

Question 4 **(4 marks)**

In the search to describe the nature of light, Niels Bohr rejected the plum pudding model of the atom and instead adapted the Rutherford planetary model of the atom that accurately described Hydrogen.

(a) State one difference between the Bohr model of the atom and the planetary model.

(1 mark)

(b) Using this model, state which observation was Bohr able to successfully explain.

(1 mark)

(c) In an atom of Hydrogen the electrons surround the nucleus. Explain what it means when it is said that these levels are quantised.

(2 marks)

Question 5 **(12 marks)**

Geoff is an interstellar space traveler who can cruise at a speed of 2.51×10^{8} m s^{-1} relative to Earth. In 2022 his boss Fred decides that Geoff should travel to a nearby star, Wolf 359, to investigate its atomic spectra. Wolf 359 is 7.90 light years away from Earth.

(a) Calculate the time it would take for Geoff to reach Wolf 359 as measured by an observer on Earth.

(3 marks)

(b) Calculate the time the journey would take from Geoff's perspective. (If you could not complete part (a) use 9.56 years)

(3 marks)

On his journey, Geoff passes his friend Barry. As they pass each other, Geoff measures Barry's velocity to be 0.557c in the opposite direction.

(c) Calculate the velocity of Barry relative to an observer on Earth.

(3 marks)

When Barry left Earth, his space craft was 14.2 m long (measured from Barry's frame of reference).

(d) Calculate the length of Barry's space craft as measured by Geoff when they pass each other.

(3 marks)

Question 6 **(7 marks)**

IKAROS was the first interplanetary space craft to use solar sails. In December of 2010, the 315 kg craft flew past Venus. In order to reach Venus in such a short time, engineers calculated that it needed a change in momentum of 1.12 g m s^{-1} each second. The main type of electromagnetic radiation that was to be used for this solar sail had a wavelength of 1.00 nm.

(a) Calculate the number of photons needed to collide with the solar sail each second to achieve the specified change in momentum. Assume each photon loses 100% of its momentum during the collision.

(4 marks)

(b) IKAROS received sufficient momentum such that its velocity was relativistic. State and explain how length contraction would affect the observations of the sail's cross-sectional area from Earth. Assume that IKAROS was traveling directly away from Earth.

(3 marks)

END OF TEST