LONDON SCIENCE COLLEGE

Name:

Date:

QUANTUM PHYSICS
TEST 2

AS-Level

Mark

Grade

PHYSICS

For this paper you must have:

- Ruler
- Pencil and Rubber
- Scientific calculator, which you are expected to use when appropriate

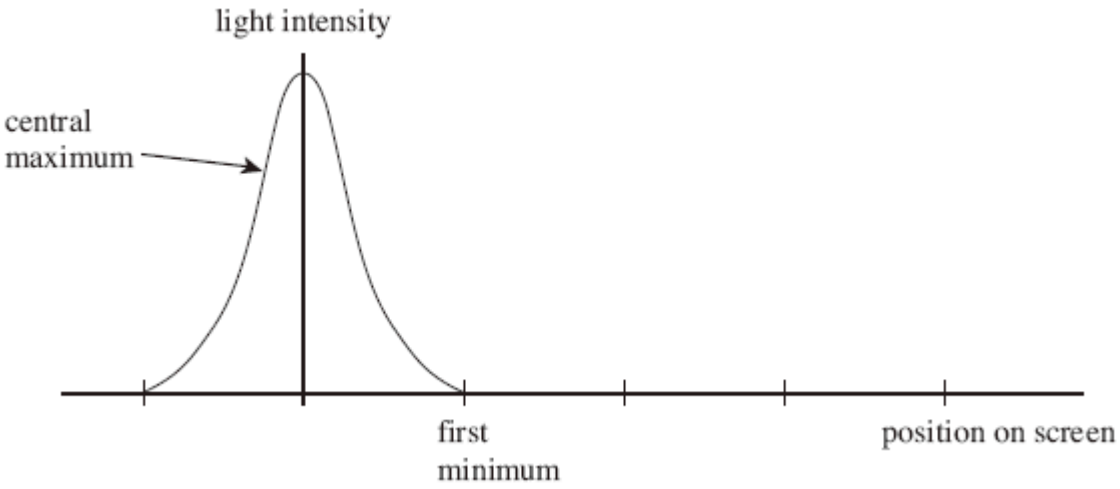
Instructions

- Answer all questions
- Answer questions in the space provided
- All working must be shown

Information

- The marks for the questions are shown in brackets

1 A single slit diffraction pattern is produced on a screen using a laser. The intensity of the central maximum is plotted on the axes in the figure below.



(a) On the figure above, sketch how the intensity varies across the screen to the right of the central maximum.

(2)

(b) A laser is a source of *monochromatic*, *coherent* light. State what is meant by

monochromatic light _____

_____

coherent light _____

_____

(2)

(c) Describe how the pattern would change if light of a longer wavelength was used.

_____

_____

(1)

(d) State **two** ways in which the appearance of the fringes would change if the slit was made narrower.

_____

_____

(2)

(e) The laser is replaced with a lamp that produces a narrow beam of white light. Sketch and label the appearance of the fringes as you would see them on a screen.

(3)

(Total 10 marks)

2 An electron has a speed of 8.4×10^5 m s^{-1}.

Calculate the de Broglie wavelength of this electron.

_____

_____

_____

_____

_____

de Broglie wavelength _____ m

(Total 2 marks)

3 (a) State what is meant by the *photoelectric effect*.

_____

_____

_____

_____

(1)

(b) Violet light of wavelength 380 nm is incident on a potassium surface.

(i) Calculate the energy of a photon of this light.

photon energy _____ J

(3)

(ii) Show that this photon can cause the photoelectric effect when incident on the potassium surface.

work function of potassium = 2.3 eV

(2)

(c) The potassium surface is now given a positive charge.
Explain why no photoelectric effect is observed.

(2)

(Total 8 marks)

4 When a clean metal surface in a vacuum is irradiated with ultraviolet radiation of a certain frequency, electrons are emitted from the metal.

(a) (i) Explain why the kinetic energy of the emitted electrons has a maximum value.

(2)

(ii) Explain with reference to the work function why, if the frequency of the radiation is below a certain value, electrons are not emitted.

_____

_____

_____

_____

(2)

(iii) State a unit for work function.

_____

(1)

(b) Light energy is incident on each square millimetre of the surface at a rate of 3.0×10^{-10} J s^{-1}. The frequency of the light is 1.5×10^{15} Hz.

(i) Calculate the energy of an incident photon.

answer = _____ J

(2)

(ii) Calculate the number of photons incident per second on each square millimetre of the metal surface.

answer = _____

(2)

(c) In the wave theory model of light, electrons on the surface of a metal absorb energy from a small area of the surface.

(i) The light striking the surface delivers energy to this small area at a rate of 3.0×10^{-22} J s^{-1}.

The minimum energy required to liberate the electron is 6.8×10^{-19} J.

Calculate the minimum time it would take an electron to absorb this amount of energy.

answer = _____ s

(1)

(ii) In practice the time delay calculated in part c (i) does not occur. Explain how this experimental evidence was used to develop the particle model for the behaviour of light.

_____

_____

_____

_____

(2)

(Total 12 marks)

5 Electrons exhibit *wave properties*.

(a) What phenomenon can be used to demonstrate the wave properties of electrons? Details of any apparatus used are not required.

_____

_____

(1)

(b) Calculate the de Broglie wavelength of electrons travelling at a speed of 4.50×10^5 m s^{-1}.

answer = _____ m

(2)

(c) The muon has a mass equal to 207 times the mass of an electron.
Calculate the speed of muons with the same de Broglie wavelength as the electrons in part (b).

answer = _____ m s^{-1}

(3)

(Total 6 marks)

6 (a) A fluorescent tube is filled with mercury vapour at low pressure. In order to emit electromagnetic radiation the mercury atoms must first be *excited*.

(i) What is meant by an excited atom?

_____

_____

(1)

(ii) Describe the process by which mercury atoms become excited in a fluorescent tube.

_____

_____

_____

_____

_____

_____

(3)

(iii) What is the purpose of the coating on the inside surface of the glass in a fluorescent tube?

_____

_____

_____

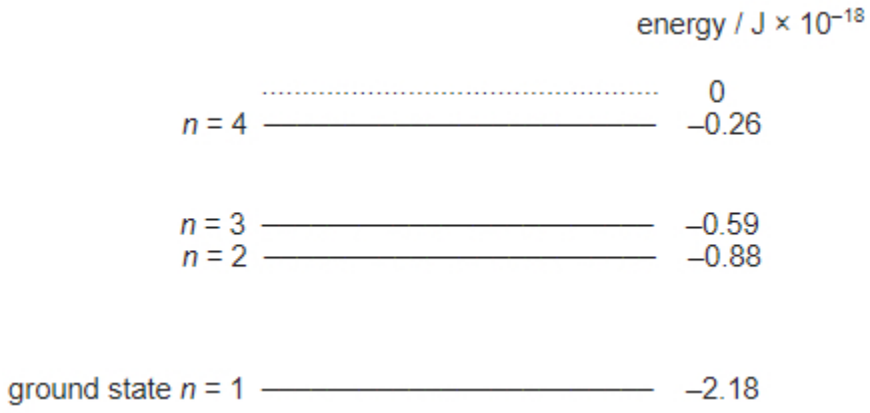
_____

_____

_____

(3)

(b) The lowest energy levels of a mercury atom are shown in the diagram below. The diagram is **not** to scale.



(i) Calculate the frequency of an emitted photon due to the transition level $n = 4$ to level $n = 3$.

answer = _____ Hz

(3)

(ii) Draw an arrow on the diagram above to show a transition which emits a photon of a longer wavelength than that emitted in the transition from level $n = 4$ to level $n = 3$.

(2)

(Total 12 marks)

7 (a) When illuminated with electromagnetic waves, a metal surface can exhibit the photoelectric effect. The maximum wavelength that causes the emission of photoelectrons with zero kinetic energy is 6.8×10^{-7} m.

(i) Show that the threshold frequency for the surface is approximately 4.4×10^{14} Hz.

(2)

(ii) Show that the work function for the surface is approximately 2.9×10^{-19} J.

(2)

(iii) Calculate the maximum kinetic energy of electrons emitted from the surface when it is illuminated with ultraviolet radiation of frequency 7.8×10^{14} Hz.

maximum kinetic energy _____ J

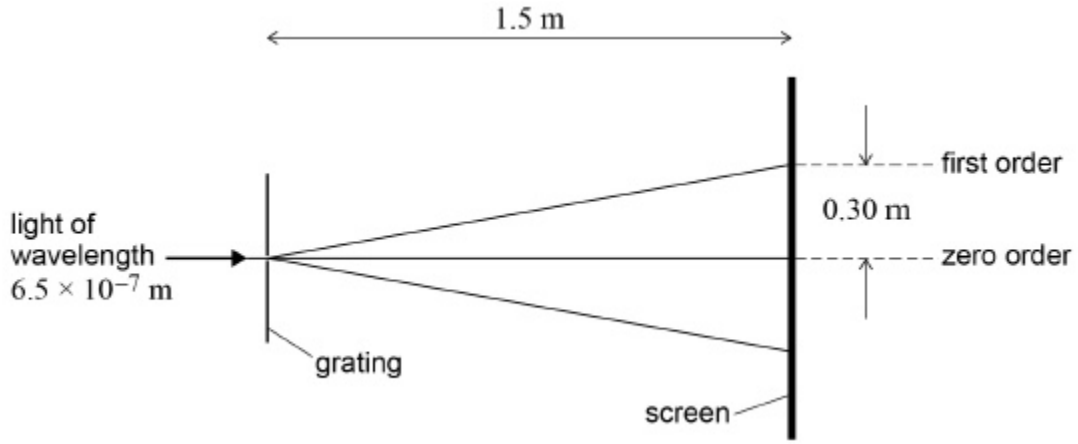
(2)

(b) Explain why the photoelectric effect cannot be explained by the wave theory of light.

(2)

(Total 8 marks)

8 A diffraction grating is illuminated normally with light of wavelength 6.5×10^{-7} m
When a screen is 1.5 m from the grating, the distance between the zero and first-order maxima on the screen is 0.30 m



What is the number of lines per mm of the diffraction grating?

A 3.3×10^{-6} ⬭

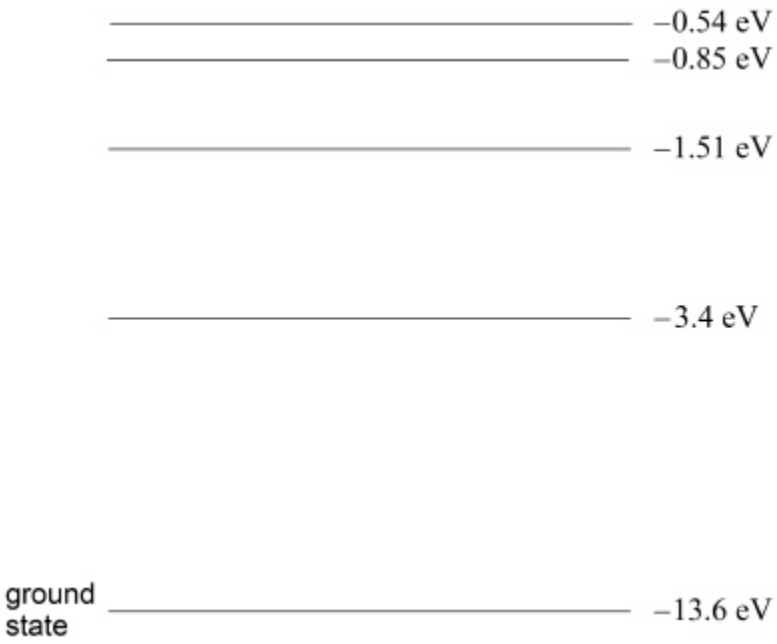
B 3.3×10^{-3} ⬭

C 3.0×10^{2} ⬭

D 3.0×10^{5} ⬭

(Total 1 mark)

9 The diagram shows an energy-level diagram for a hydrogen atom.



Electrons, each having a kinetic energy of 2.0×10^{-18} J, collide with atoms of hydrogen in their ground state. Photons are emitted when the atoms de-excite.

How many different wavelengths can be observed with incident electrons of this energy?

A 1 ⬭

B 3 ⬭

C 6 ⬭

D 7 ⬭

(Total 1 mark)

10 Which statement suggests that electrons have wave properties?
Tick (✓) the correct answer.

Electrons are emitted in photoelectric effect experiments. ☐

Electrons are released when atoms are ionised. ☐

Electrons produce dark rings in diffraction experiments. ☐

Electron transitions in atoms produce line spectra. ☐

(Total 1 mark)

11 When light of a certain frequency greater than the threshold frequency of a metal is directed at the metal, photoelectrons are emitted from the surface.
The power of the light incident on the metal surface is doubled.

Which row shows the effect on the maximum kinetic energy and the number of photoelectrons emitted per second?

	Maximum kinetic energy	**Number of photoelectrons emitted per second**	
A	remains unchanged	remains unchanged	⬭
B	doubles	remains unchanged	⬭
C	remains unchanged	doubles	⬭
D	doubles	doubles	⬭

(Total 1 mark)