L6th

A level Physics

Easter Vacation Work

<u>Spectra and Photoelectric Effect</u>

<u>How much work should you be doing over the 3 weeks that you have off?</u>

- 2 hours of file tidying – get them perfectly ordered
- 1 hour for each teacher of consolidating notes – are you missing any flashcards etc?
- *2 -3 hours answering these questions*

<u>What we are expecting to check when you return:</u>

✔ These questions have been marked

✔ You have calculated your percentage and grade

✔ Written down the areas where you are still struggling. We will collate these and swiftly address these in clinic during the first few weeks of term.

Total: /57 marks	**Grade (circle):**
Topics that you are still struggling with and why:	**A* = 75%**
	A = 70%
	B = 65 %
	C = 60 %

Happy Easter!

Q1. The intensity of a monochromatic light source is increased. Which of the following is correct?

	Energy of an emitted photon	Number of photons emitted per second	
A	increases	increases	
B	increases	unchanged	
C	unchanged	increases	
D	unchanged	unchanged	

(Total 1 mark)

Q2. An electron has a kinetic energy E and a de Broglie wavelength λ. The kinetic energy is increased to $4E$. What is the new de Broglie wavelength?

A $\frac{\lambda}{4}$

B $\frac{\lambda}{2}$

C λ

D 4λ

(Total 1 mark)

Q3. In a photoelectric experiment, light is incident on the metal surface of a photocell. Increasing the intensity of the illumination at the surface leads to an increase in the

A work function

B minimum frequency at which electrons are emitted

C current through the photocell

D speed of the electrons

(Total 1 mark)

Q4.

$E = 0$	ionisation level
$E_2 = -2.42 \times 10^{-19}$ J	level 2
$E_1 = -5.48 \times 10^{-19}$ J	level 1
$E_0 = -2.18 \times 10^{-18}$ J	ground state

The diagram represents some of the energy levels of an isolated atom. An electron with a kinetic energy of 2.0×10^{-18} J makes an inelastic collision with an atom in the ground state.

(a) Calculate the speed of the electron just before the collision.

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(2)

(b) (i) Show that the electron can excite the atom to level 2.

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(ii) Calculate the wavelength of the radiation that will result when an atom in level 2 falls to level 1 and state the region of the spectrum to which this radiation belongs.

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(6)

(c) Calculate the minimum potential difference through which an electron must be accelerated from rest in order to be able to ionise an atom in its ground state with the above energy level structure.

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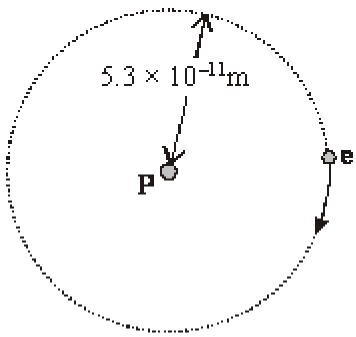
(2)
(Total 10 marks)

Q5. The Bohr model of a hydrogen atom assumes that an electron **e** is in a circular orbit around a proton **P**. The model is shown schematically in **Figure 1**.

Figure 1



In the ground state the orbit has a radius of 5.3×10^{-11} m. At this separation the electron is attracted to the proton by a force of 8.1×10^{-8} N.

(a) State what is meant by <u>the ground state</u>.

....

....

(1)

(b) (i) Show that the speed of the electron in this orbit is about 2.2×10^{6} m s^{-1}.

mass of an electron = 9.1×10^{-31} k g

(ii) Calculate the de Broglie wavelength of an electron travelling at this speed.

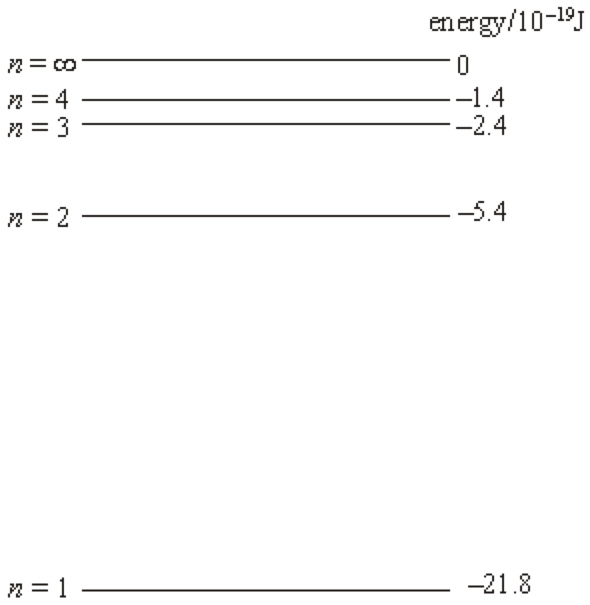
Planck constant = 6.6×10^{-34} J s

(iii) How many waves of this wavelength fit the circumference of the electron orbit? Show your reasoning.

(7)

(c) The quantum theory suggests that the electron in a hydrogen atom can only exist in certain well-defined energy states. Some of these are shown in **Figure 2**.

Figure 2



An electron **E** of energy 2.5×10^{-18} J collides with a hydrogen atom that is in its ground state and excites the electron in the hydrogen atom to the *n* = 3 level.

Calculate

(i) the energy that is needed to excite an electron in the hydrogen atom from the ground state to the *n* = 3 level,

(ii) the kinetic energy of the incident electron **E** after the collision,

(iii) the wavelength of the lowest energy photon that could be emitted as the excited electron returns to the ground state.

speed of electromagnetic radiation = 3.0×10^{8} m s^{-1}

(5)

(Total 13 marks)

Q6. (a) A particular photocell is designed to emit electrons when visible light is incident on its cathode. When yellow light of wavelength 570 nm is incident on the cathode the electrons are emitted with almost zero kinetic energy.

speed of electromagnetic radiation in a vacuum	=	3.0×10^{8} m s^{-1}
the Planck constant	=	6.6×10^{-34} J s
charge on electron	=	-1.6×10^{-19} C

(i) Show that the threshold frequency of the cathode material is about 5×10^{14} Hz.

(2)

(ii) Calculate the work function of the cathode material.

(2)

(b) Ultra-violet radiation of photon energy 4.7×10^{-19} J and of the same intensity as the visible light in part (a) is now incident on the cathode.

(i) Calculate the maximum velocity of the emitted electrons.

mass of electron = 9.1×10^{-31} kg.

(4)

(ii) State and explain the effect on the number of electrons emitted per second resulting from this change in the photon energy of the incident radiation.

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(2)
(Total 10 marks)

Q7.(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.

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(2)

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

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(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.

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maximum kinetic energy .... J

(2)

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

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(2)
(Total 8 marks)

Q8. When light of a certain frequency is shone on a particular metal surface, electrons are emitted with a range of kinetic energies.

(a) Explain

- in terms of photons why electrons are released from the metal surface, and
- why the kinetic energy of the emitted electrons varies upto a maximum value.

The quality of your written communication will be assessed in this question.

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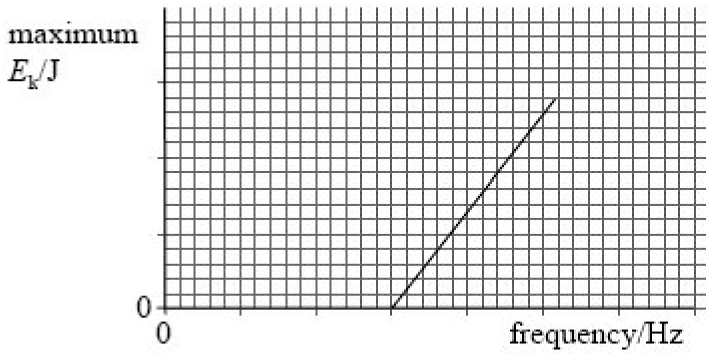
(6)

(b) The graph below shows how the maximum kinetic energy of the electrons varies with the frequency of the light shining on the metal surface.



(i) On the graph mark the *threshold frequency* and label it f_0.

(1)

(ii) On the graph draw a line for a metal which has a higher threshold frequency.

(2)

(iii) State what is represented by the gradient of the graph.

....

(1)

(c) The threshold frequency of a particular metal surface is 5.6×10^{14} Hz. Calculate the maximum kinetic energy of emitted electrons if the frequency of the light striking the metal surface is double the threshold frequency.

answer = ... J

(3)
(Total 13 marks)

M1.C

[1]

M2.B

[1]

M3.C

[1]

M4.(a) $v \left(\sqrt{\frac{2E}{m}}\right) = \sqrt{\frac{2 \times 2.0 \times 10^{-18}}{9.1 \times 10^{-31}}}$ **(1)**

$= 2.1 \times 10^{6}$ m s^{-1} **(1)**

2

(b) (i) difference between E_2 and E_0 = 1.94×10^{-18} J **(1)**
which is less than the electron kinetic energy **(1)**

(ii) $(E_2 - E_1) = 3.06 \times 10^{-19}$ **(1)** $\left(= \frac{hc}{\lambda}\right)$

$\lambda = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{3.06 \times 10^{-19}}$ **(1)** $= 6.5 \times 10^{-7}$ m **(1)**

in visible [or red] region **(1)**

6

(c) for ionisation, p.d. = $\frac{21.8 \times 10^{-19}}{1.6 \times 10^{-19}}$ **(1)** =13.6 V **(1)**

2

[10]

M5. (a) lowest energy state/level that the electron can occupy

or state in which electron needs most energy to be released

B1 1

or the level of an unexcited electron (not lowest orbit)

(b) (i) force = mv^2/r or $mr\omega^2$ and $v = r\omega$

B1

$8.1 \times 10^{-8} = 9.1 \times 10^{-31} \times v^2/5.3 \times 10^{-11}$
or (v^2 =) 4.72×10^{12} seen

B1

2.17 × 106 (m s^{-1})

B1

(ii) $\lambda = h/mv$ or $6.6 \times 10^{-34}/9.1 \times 10^{-31} \times 2.2 \times 10^6$

C1 7

3.3×10^{-10} m

A1

(iii) circumference = $2\pi 5.3 \times 10^{-11} = 3.3 \times 10^{-10}$ m

M1

1 (allow e.c.f. from (ii))

A1

(c) (i) $1.9(4) \times 10^{-18}$ J

B1

(ii) 5.6×10^{-19} J (e.c.f. 2.5×10^{-18} − their (i))

B1

(iii) energy difference $E = 3 \times 10^{-19}$ J

(condone any difference)

C1

E = hc/λ *or* E = hf *and* c=fλ

or their E = 6.6 × 10^{-34} × 3.0 × 108/λ

C1

6.6 or 6.7 × 10^{-7} m

A1

5

[13]

M6. (a) (i) $f = c/\lambda$ or correct substitution irrespective of powers

C1

5.26 × 10^{14} (Hz) **not** 5.2 × 10^{14}

A1

2

(ii) $\Phi = hf$ or substitution irrespective of powers

C1

3.3 – 3.5 × 10^{-19} J

A1

2

(b) (i) statement or clear use of photoelectric equation

C1

max ke = 1.2 – 1.4 × 10^{-19} (J)

C1

½ mv^2 or substituted values ecf for max ke

C1

5.1 – 5.6 × 10^5 ms^{-1} **(cao)**

A1

4

(ii) same intensity and shorter wavelength =>less photons incident per

B1

second
fewer electrons emitted per second

B1

condone *argument* for unchanged numbers of electrons (based on 1 to 1 correspondence between photons and electrons)

2

[10]

M7.(a) (i) $f = c/\lambda$ seen in this form

C1

4.41×10^{14} seen

A1

2

(ii) $\Phi = hf$

C1

2.917×10^{-19} to 2.93×10^{-19} seen

A1

2

(iii) $h(7.8 \times 10^{14})$ – their (ii)

C1

2.2×10^{-19} (J) to 2.3×10^{-19} (J)

A1

2

(b) no photoemission below threshold frequency (even with bright light)

B1

wave theory would allow gradual accumulation of energy to cause emission

B1

2

[8]

M8. (a)

QWC	descriptor	mark range
good-excellent	The candidate provides a comprehensive and logical explanation which recognises that light consists of photons of energy *hf* and that an electron at or near the metal surface can only gain the energy of a single photon when it interacts with a photon. In addition, the candidate should recognise the significance of the work function (of the metal) in this context in relation to the maximum kinetic energy that an emitted electron can have. The candidate should also provide some indication of why the kinetic energy of an emitted electron may be less than the maximum kinetic energy. Although the term 'work function' might not be defined or used, the candidate's explanation should clearly state that each electron needs a minimum amount of energy to escape from the metal.	**5-6**
modest-adequate	The candidate provides a logical and coherent explanation which includes the key ideas including recognition that light consists of photons of energy *hf* and that an electron at or near the metal surface can only gain the energy of a single photon when it interacts with a photon. In addition, the candidate should be aware that each electron needs a minimum amount of energy to escape from the metal. They should appreciate that the kinetic energy of an emitted electron is equal to the difference between the energy it gains from a photon and the energy it needs (or uses) to escape from the metal. However, the explanation may lack a key element such as why the kinetic energy of the emitted electrons varies.	**3-4**

The explanations expected in a good answer should include most of the following physics ideas

energy is needed to remove an electron from the surface

work function φ (of the metal) is the minimum energy needed by an electron to escape from the surface

light consists of photons , each of energy $E = hf$

one photon is absorbed by one electron

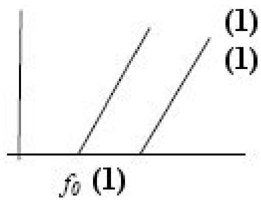
an electron can escape (from the surface) if $hf > \varphi$

kinetic energy of an emitted electron cannot be greater than $hf - \varphi$

an electron below the surface needs to do work/uses energy to reach the surface

kinetic energy of such an electron will be less than $hf - \varphi$

(b) (i)



(ii) parallel line, higher threshold frequency **(1)(1)**

(iii) Planck's constant **(1)**

4

(c) (use of $hf_0 = \phi$)

$hf = 6.63 \times 10^{-34} \times 2 \times 5.6 \times 10^{14}$ **(1)**

$\phi = 3.7(1) \times 10^{-19}$ J **(1)**

$E_k = 2 \times 3.7 \times 10^{-19} - 3.7 \times 10^{-19} = 3.7 \times 10^{-19}$ J **(1)**

3

[13]p