Name	Date started	Target end date

GCE AS / A LEVEL — PHOTONS QUESTION PACK

Legacy PH2 · New spec Unit 2 Topic 7 · AS unit, 20% of A-level

REVISE
.wales

PHYSICS — UNIT 2 · PHOTONS

PH2.7 Photons — photoelectric effect, E = hf & work function

Photon energy E = hf = hc/λ, the photoelectric effect threshold frequency, calculation of work function and maximum kinetic energy of emitted photoelectrons, and the wave-particle duality evidence.

NEW 2015 SPEC · UNIT 2 TOPIC 7

Estimated time for entire question pack: ~3 h 15 min

Derived from the legacy PH2 paper's pace of 80 marks in 1¼ hours.

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC PH2 papers (2008 modular spec) that maps onto new-spec Unit 2 Topic 7 (2.7).

Questions are ordered chronologically within each section.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

The number of marks is given in brackets at the end of each question or part-question. A calculator is required. The Data Booklet is allowed.

For Examiner's use only

Q	Source	Max	Mark
1	PH2 Jun 09 Q4	12	
2	PH2 Jan 10 Q4	11	
3	PH2 Jun 10 Q4	11	
4	PH2 Jan 11 Q5	12	
5	PH2 Jun 11 Q3	13	
6	PH2 Jan 12 Q4	10	
7	PH2 Jun 12 Q6	11	
8	PH2 Jan 13 Q4	11	
9	PH2 Jun 13 Q5	12	
10	PH2 Jan 14 Q5	9	
11	PH2 Jun 14 Q5	8	
12	PH2 Jun 15 Q5	10	
13	PH2 Jun 16 Q4	9	
	Total	139	

Photons — what the new spec asks

WJEC GCE AS / A Level Physics (from 2015) · Unit 2: Electricity & Light · Topic 2.7.

Photons A

- Photon energy $E = hf = hc/\lambda$.
- Photon as a quantum of EM radiation.
- Calculate photon energy and rate of emission from a source's power.

Photoelectric effect A

- Threshold frequency f_0 below which no electrons are emitted.
- Work function $\phi = hf_0$.
- Max KE: $KE_{max} = hf - \phi$.

Wave vs particle evidence A

- Why classical wave theory fails to explain the photoelectric threshold.
- Use intensity vs frequency dependence to argue for photons.

Stopping potential A

- Define stopping potential V_s; $eV_s = KE_{max}$.
- Plot V_s against f; gradient = h/e, intercept gives ϕ.

Photons in one page

Quick-reference notes — revisit before each section.

Photon energy

$h = 6.63 \times 10^{-34}$ J s.

Visible photon: $E \sim 3 \times 10^{-19}$ J ≈ 2 eV.

1 eV = 1.60×10^{-19} J.

Photoelectric effect

If $f < f_0$: no electrons ejected, however bright.

If $f \geq f_0$: ejection is instant, even at low intensity.

Work function

Minimum energy to free an electron from the metal surface.

Different for each metal.

Einstein equation

Plot KE_{max} vs f: gradient = h, x-intercept = f_0.

y-intercept (at f = 0) = $-\phi$.

Stopping potential

$eV_s = KE_{max}$.

Plot V_s against f: gradient = h/e.

Wave-particle duality

Wave model fails to predict threshold or instantaneity.

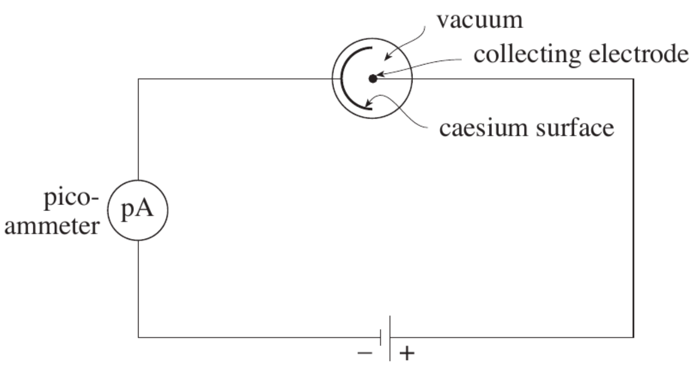
Photon model explains both.

Yet diffraction & interference are wave phenomena.

Section index

Use this index to jump straight to the section you need.

4. The circuit shown below is set up in a darkened room with the blinds drawn.



(a) (i) When the blinds are opened a little, so that sunlight falls on the caesium surface, the ammeter registers a continuous current. Explain, in terms of photons and electrons, why this happens. [3]

....

....

....

....

(ii) What difference, if any, would be observed if the blinds were adjusted so that a greater intensity of light fell on the caesium surface? Give your reasoning. [2]

....

....

....

(b) (i) State two ways in which the apparatus would need to be modified in order to measure the maximum kinetic energy of the emitted electrons. [2]

....

....

....

only

(ii) The work function of caesium is $3{\cdot}1 \times 10^{-19}$ J. The highest frequency of electromagnetic radiation in the sunlight passing through the window may be assumed to be $8{\cdot}6 \times 10^{14}$ Hz. Use Einstein's photoelectric equation to calculate the maximum kinetic energy of the electrons emitted from the caesium surface. [2]

(iii) Show that this corresponds to a maximum speed of $7{\cdot}5 \times 10^{5}$ ms^{-1} for electrons leaving the caesium surface. [2]

(iv) According to Einstein's equation the maximum kinetic energy of the emitted electrons does not depend on the intensity of the light (for a given frequency). Explain in terms of photons, why this non-dependence is to be expected. [1]

4. *(a)* Einstein's *photoelectric equation* may be written

$$E_{\text{k max}} = hf - \phi .$$

(i) What quantity of energy does hf represent? [1]

....

(ii) A student mistakenly thinks that the 'minus' sign should be a 'plus' sign. Explain, in terms of electrons and photons, why the equation must be correct as written above. [3]

....

....

....

....

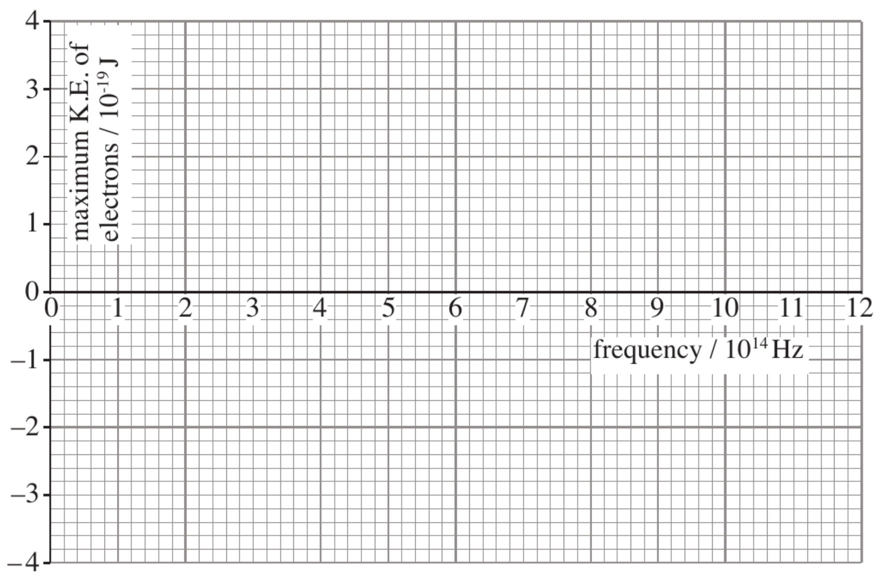
....

....

(b) In an experiment in which a sodium surface is exposed to electromagnetic radiation, these results are obtained.

f / 10^{14} Hz	6.9	9.6	11.8
$E_{\text{k max}}$ / 10^{-19} J	0.79	2.58	4.04

(i) Plot these data points on the grid, and hence draw the graph line. [2]



(ii) Use the data, or your graph, to determine values for

(I) the *work function* of sodium, [1]

....

....

....

(II) the *Planck constant*. Show your working. [2]

....

....

....

....

....

(iii) Draw on the grid a line, labelled (iii), which might be obtained if a metal with a **lower** work function were used in the experiment. [2]

4. *(a)* (i) What is the *photoelectric effect?* [2]

(ii) Give an account of the photoelectric effect in terms of photons, electrons and energy, explaining how it leads to *Einstein's photoelectric equation.* [4]

(b) (i) A zinc surface of work function 4.97×10^{-19} J is irradiated with two frequencies of electromagnetic radiation in turn. For each frequency, show whether or not electrons are emitted from the surface, and if they are emitted, calculate their maximum kinetic energy.

(I) 7.99×10^{14} Hz [2]

(II) 6.74×10^{14} Hz [1]

(ii) What would be the maximum kinetic energy of the electrons emitted if the surface were irradiated with both frequencies at once? Explain your reasoning. [2]

5. *(a)* Define the *work function* of a metal surface. [1]

....

....

(b) The work function of sodium is 3.8×10^{-19} J. Use Einstein's photoelectric equation to find

(i) the lowest frequency of light which will eject electrons from a sodium surface, [2]

....

....

....

....

(ii) the maximum kinetic energy of electrons emitted from a sodium surface when light of frequency 7.0×10^{14} Hz is shone on to the surface. [2]

....

....

....

(c) (i) The answer to *(b)*(ii) is unaffected if the *intensity* of light is increased. Explain, in terms of *photons*, why this should be the case. [2]

....

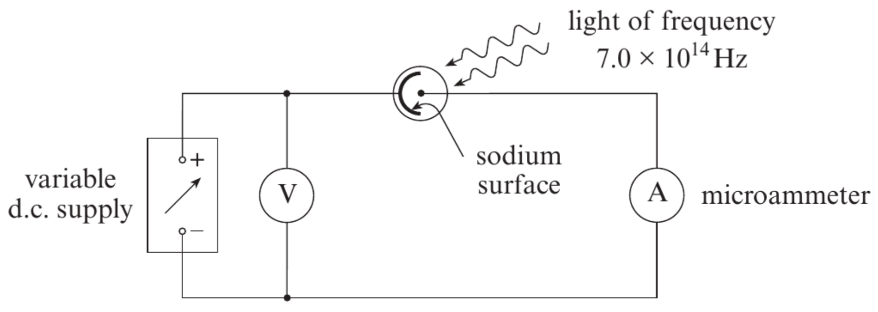
....

....

(ii) What aspect of photo-electric emission *is* affected by the light intensity? [1]

....

(d) The diagram shows apparatus set up to check experimentally the answer to *(b)*(ii). Describe how you would make this check. [4]



....

....

....

....

3. *(a)* When ultraviolet radiation of high enough frequency falls on a tin plate (held by an insulating support) the plate acquires a charge. Explain, in terms of electrons and photons, why this happens, and whether the charge is positive or negative. [3]

....

....

....

....

....

....

(b) The *work function* of tin is 7.1×10^{-19} J.

(i) What is meant by the work function of a metal? [1]

....

....

(ii) Calculate the minimum frequency of ultraviolet radiation needed for photoelectric emission from tin. [2]

....

....

....

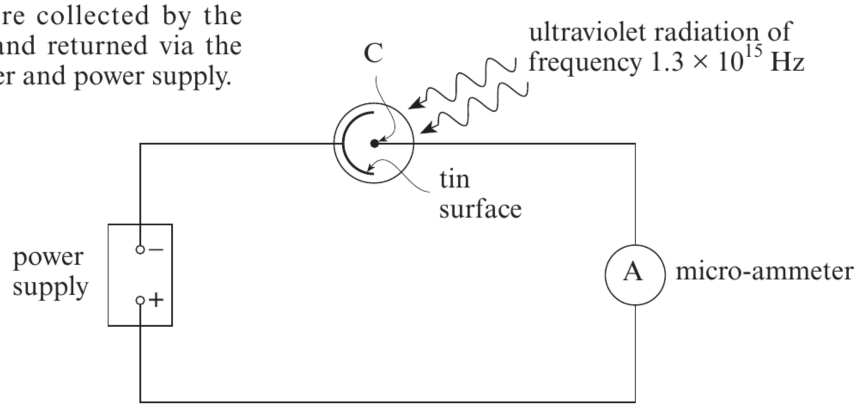
(iii) Calculate the **frequency** of ultraviolet radiation needed for the emitted electrons to have a maximum kinetic energy of 1.5×10^{-19} J. [2]

....

....

....

(c) In the set-up shown, assume that all the electrons emitted from the tin surface are collected by the electrode C, and returned via the micro-ammeter and power supply.



(i) The micro-ammeter reads 0.64 μA (0.64×10^{-6} coulombs per second). Show that 4.0×10^{12} electrons are emitted per second. [1]

....

....

(ii) Only 1 in 1200 of the incident photons causes emission of an electron. By considering the energy of an individual photon, calculate the ultraviolet energy per second falling on the tin surface. [4]

....

....

....

....

....

....

1322 010007

4. *(a)* The *work function* of caesium is 3.4×10^{-19} J.

Calculate the lowest *frequency* of light that will cause photo-electric emission from a caesium surface. [2]

....

....

....

(b) Light of frequency 7.4×10^{14} Hz is shone on to a caesium surface.

(i) Calculate the maximum kinetic energy, KE_{max}, of the emitted electrons for this frequency of light. [2]

....

....

....

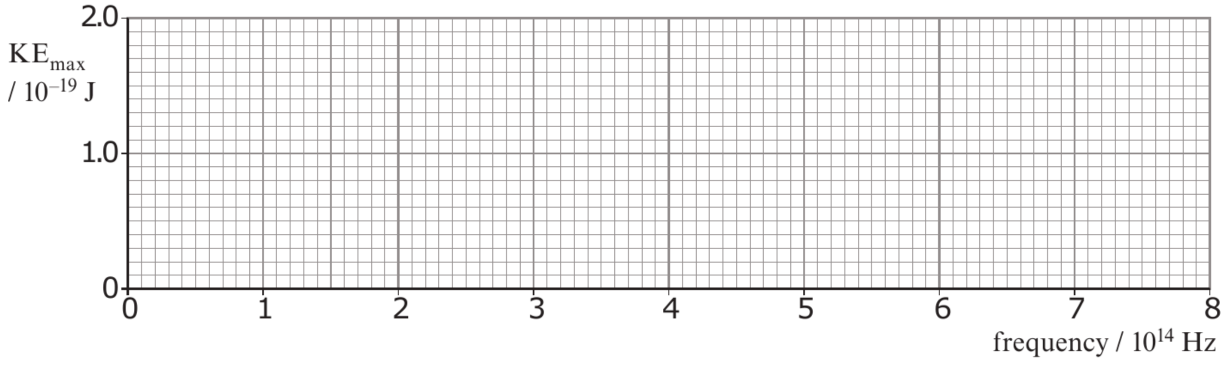
(ii) Explain **in physical terms** why KE_{max} is less than the energy of an incident photon. [2]

....

....

....

(c) (i) Making use of your answers to *(a)* and *(b)*(i), draw a graph, on the axes provided, to show how KE_{max} would depend on the frequency of incident light. [2]



(ii) What does the gradient of this graph represent? [1]

....

(iii) On the same axes sketch a graph that could be obtained for a metal with a greater work function than caesium. **Label this graph '(iii)'.** [1]

6. *(a)* State, **in terms of energy**, the meaning of each term in Einstein's photoelectric equation

$$E_{k\max} = hf - \phi.$$

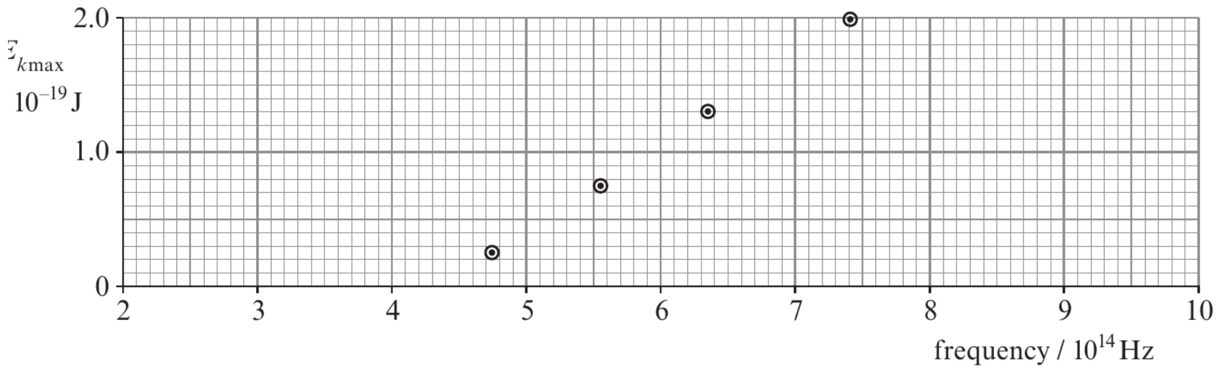
(i) $E_{k\max}$ .... [1]

(ii) hf .... [1]

(iii) ϕ ....

.... [1]

(b) Monochromatic light of frequency 7.40×10^{14} Hz is shone on to a caesium surface, and $E_{k\max}$ is measured. The procedure is repeated for three other frequencies, enabling four points to be plotted on the grid below.



(i) Showing your working, determine from the grid above

(I) a value for the Planck constant, [2]

....

....

....

(II) the work function of caesium. [2]

....

....

....

....

(ii) When a lithium surface is used instead of a caesium surface, $E_{k\max}$ is found to be 0.40×10^{-19} J for light of frequency 7.40×10^{14} Hz.

(I) Draw the expected line of $E_{k\max}$ against frequency on the same grid. [2]

(II) This line cannot be checked satisfactorily by experiment using visible light. Name the region of the electromagnetic spectrum which is required. [1]

....

(III) What is different about lithium, as compared to caesium, which makes it necessary to use this region of the electromagnetic spectrum? [1]

....

4. *(a)* Here is a summary of a theory (now considered incorrect) to account for the photoelectric effect:

> "The electrons in a surface gradually gain energy from light waves falling on the surface. After a time they will have gained enough energy to escape. The greater the intensity of the light waves the greater the maximum kinetic energy of the emitted electrons."

State some ways in which Einstein's explanation (in terms of photons) of the photoelectric effect differs from the theory above. [4]

.....

.....

.....

.....

.....

.....

.....

.....

(b) The work function of sodium is 3.8×10^{-19} J.

(i) Calculate the maximum kinetic energy of electrons emitted from a sodium surface irradiated with ultraviolet radiation of frequency 8.7×10^{14} Hz. [2]

.....

.....

.....

.....

(ii) Discuss whether or not this maximum kinetic energy would change if the surface were also irradiated **at the same time** with radiation of frequency 8.5×10^{14} Hz. [2]

.....

.....

.....

.....

Examiner only

(iii) Determine whether or not visible light can cause the emission of electrons from a sodium surface, giving your reasoning and conclusion. Take the range of visible wavelengths to be 400 nm to 700 nm. [3]

....

....

....

....

....

....

5. *(a)* (i) The threshold frequency for electrons to be emitted in the photoelectric effect is $f_o = \frac{\phi}{h}$. Explain, in terms of energy, why this is so. [3]

....

....

....

....

....

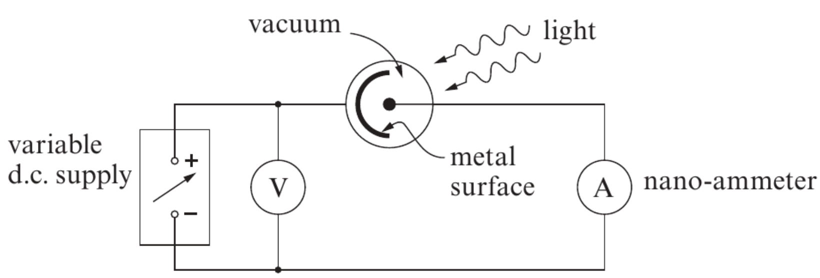
(ii) Explain why increasing the *intensity* of light will not increase the maximum kinetic energy, $E_{k\,max}$, of the emitted electrons. [2]

....

....

....

(b) Monochromatic light is shone on to a metal surface in a photocell connected as shown. Describe how you would find the maximum kinetic energy of the emitted electrons. [3]



....

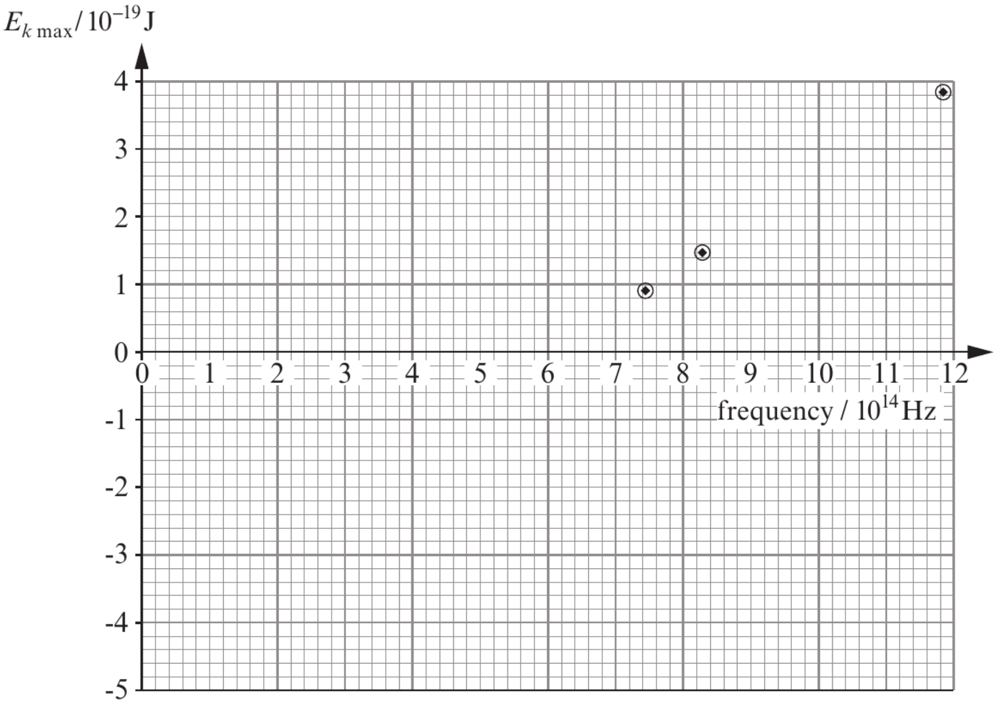
....

....

....

....

(c) The experiment is carried out, using three known frequencies of light in succession, giving the points plotted on the grid.



(i) Calculate the gradient of the graph and check whether or not it has the expected value, giving your working and conclusion clearly. [2]

....

....

....

....

(ii) The metal with the exposed surface in the photocell is known to be one of the five metals whose work functions are listed.

metal	caesium	potassium	sodium	barium	calcium
ϕ / 10^{-19} J	3.12	3.68	3.78	4.03	4.59

Use the graph to determine which of these metals is in the photocell, giving your reasoning. [2]

....

....

Examiner only

5. The work function of calcium is 4.60×10^{-19} J.

(a) (i) State what is meant by the work function of a metal. [1]

(ii) Calculate the lowest frequency of radiation for which Einstein's photoelectric equation applies to a calcium surface. [1]

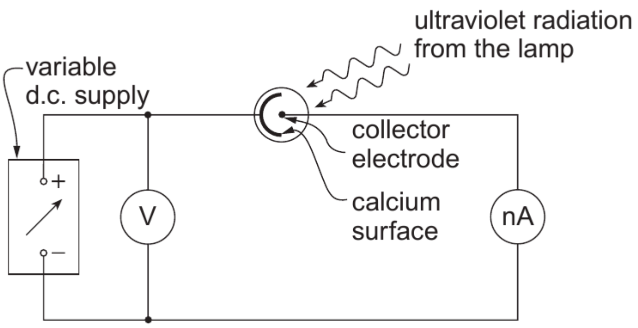
(iii) Explain, in physical terms, why the equation does not apply for frequencies lower than this. [2]

(b) Calculate the frequency of radiation needed to eject electrons of maximum kinetic energy 2.30×10^{-19} J from the calcium surface. [2]

(c) A mercury vapour lamp emits ultraviolet radiation of frequencies 8.2×10^{14} Hz and 11.8×10^{14} Hz.

(i) Calculate the **maximum** kinetic energy of electrons ejected from a calcium surface when the lamp is placed near the surface. Explain your reasoning. [2]

(ii) Calculate the potential difference needed to stop electrons reaching the collector electrode in the circuit shown. [1]



....

....

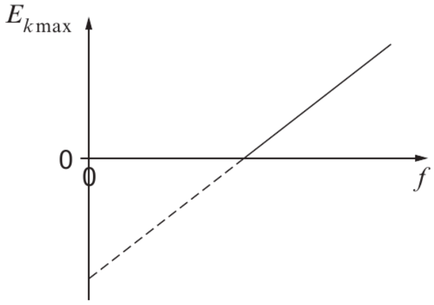
....

5. *(a)* Magnesium has a *work function* of 5.9×10^{-19} J. What does this statement mean? [1]

(b) Calculate the maximum kinetic energy of electrons ejected from a magnesium surface by ultraviolet radiation of frequency 1.16×10^{15} Hz. [2]

(c) Explain in physical terms why electrons are not emitted when radiation of frequency 8.21×10^{14} Hz (instead of the original frequency) falls on a magnesium surface. Support your answer with a calculation. [2]

(d) The graph shows how the maximum kinetic energy, $E_{k\max}$ of electrons ejected from a magnesium surface varies with the frequency, f, of ultraviolet radiation falling on the surface.



State the physical quantities represented by:

(i) the gradient; [1]

(ii) the intercept on the $E_{k\max}$ axis; [1]

(iii) the intercept on the f axis. [1]

Examiner only

5. *(a)* Einstein's photoelectric equation is $E_{k\,\max} = hf - \phi$

State, in terms of *energy,* the meaning of each term in the equation.

(i) $E_{k\,\max}$ .... [1]

(ii) hf .... [1]

(iii) ϕ ....

.... [1]

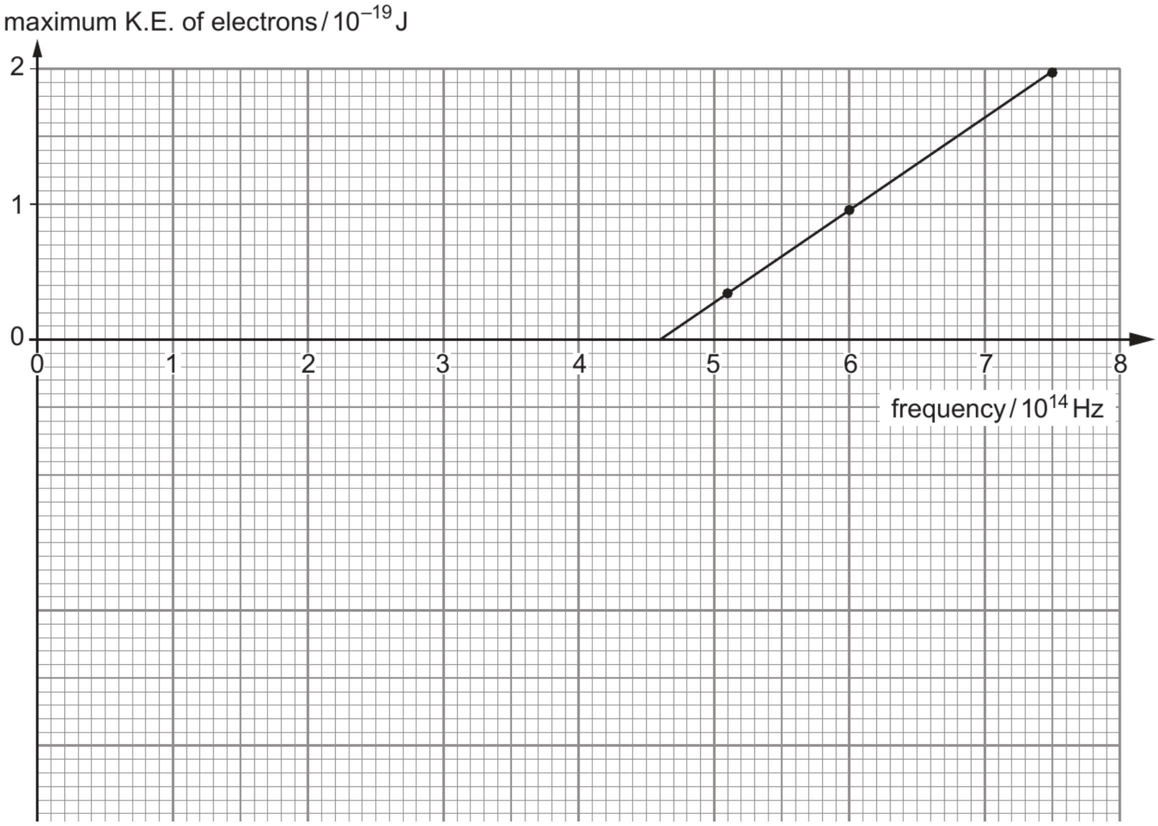
(b) The minimum frequency of radiation which will eject electrons from a surface is f_0. Determine, as a multiple of f_0, the frequency of radiation which will eject electrons with maximum kinetic energy 2ϕ from the same surface. [2]

....

....

....

(c) A student determines the maximum kinetic energy of electrons ejected from a caesium surface by incident light of three frequencies, and plots the straight line graph shown.



(i) Determine from the graph values for:

(I) the Planck constant; [2]

....

....

....

(II) the work function of caesium. [1]

....

(ii) The student starts to repeat the process for a sodium surface, but runs out of time after obtaining data for one graph point:

$$f = 6.0 \times 10^{14}\,\text{Hz}, \quad E_{k\,\max} = 0.32 \times 10^{-19}\,\text{J}$$

Obtain a value for the work function of sodium, showing your reasoning. [2]

....

....

....

....

4. *(a)* Einstein's photoelectric equation may be written:

$$E_{k\,\max} = hf - \phi$$

In terms of *energy*, state the meanings of:

(i) hf .... [1]

(ii) ϕ ....

.... [1]

(b) The *work function* of sodium is 3.65×10^{-19} J. Light of various frequencies (see below) is shone on to a sodium surface. In each case calculate the **maximum** kinetic energy of the emitted electrons, or explain in terms of photons, with an appropriate calculation, why there is no emission.

(i) violet light of frequency 7.40×10^{14} Hz [2]

....

....

....

(ii) a mixture of violet light of frequency 7.40×10^{14} Hz and blue light of 6.82×10^{14} Hz [1]

....

....

....

(iii) yellow light of frequency 5.22×10^{14} Hz [2]

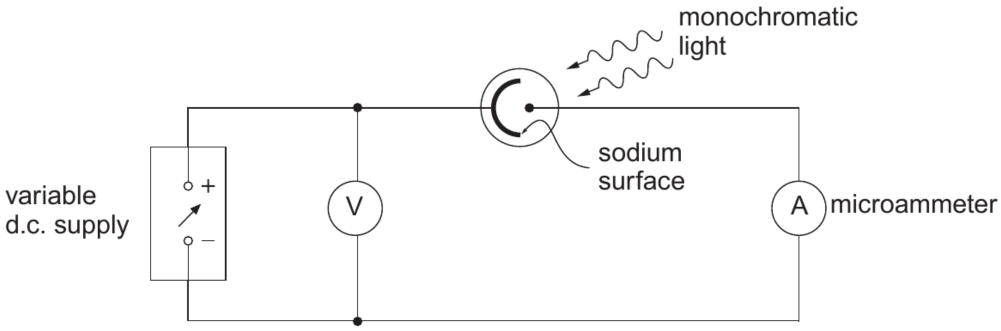
....

....

....

Examiner only

(c) The diagram shows a circuit set up to determine the maximum kinetic energy, $E_{k\,\mathrm{max}}$, of electrons ejected from a sodium surface by light of a certain frequency.



Describe how you would use the apparatus to determine $E_{k\,\mathrm{max}}$. [2]

....

....

....

END OF QUESTION PACK

13 questions · 139 marks · ~3 h 15 min

Source: WJEC PH2 (2008 modular spec)

Curated for WJEC Physics 2015 spec AS Unit 2 — Topic 7 (2.7)