Summer 2020

Physics A level

Summer Work

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This Summer Work includes…

- Background Reading and questions on the photoelectric effect

- Revision of GCSE maths skills including significant figures, standard form and rearranging equations.

Please make sure that..

- ALL questions have been completed on paper, clearly showing all your working
- Notes have been made as evidence of your background reading

Task 1

Read through the following slides. They give you some information on a quantum phenomenon called the photoelectric effect. Read and make notes on the information, you will need to some extra research as directed on the slides.

Light as a wave or particle?

Light exhibits behaviours that are characteristic of a wave which would be difficult to explain if light was thought of as purely a particle. Light reflects, refracts, diffracts and interferes in the same manner that any wave would.

(Draw a diagram to show each behaviour).

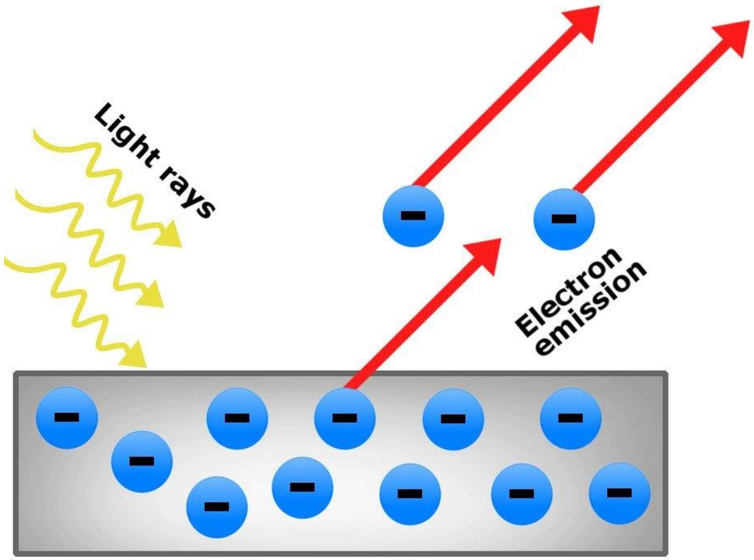
There are however, phenomenon which can’t be explained using the idea that light is wave. The photoelectric effect is one of these phenomenon.

The discovery of the photoelectric effect

- Research who discovered the photoelectric effect and how the discovery was made

The photoelectric effect

A metal contains conduction electrons, which move about freely inside the metal. Electrons can be emitted from the surface of the metal when electromagnetic radiation above a certain frequency is directed at the metal and the electron can absorb enough energy to break free from the bonds holding it.



The photoelectric effect

The observations made during the discovery of the photoelectric effect could not be explained with the wave theory of light. During studies of the photoelectric effect, it was expected that the number of electrons ejected from the metal would increase with the intensity or brightness of the light directed towards the metal. However, this was not the case and it was found that it was actually the wavelength of the light that affected the number of electrons ejected. It was also found that increasing the intensity of light increased the number of electrons ejected but not their speed.

The photoelectric effect

- Photoelectric emission of electrons from a metal surface does not take place if the frequency of the incident radiation is below a certain value – **threshold frequency**. This minimum frequency needed depends on the type of metal. $f_{min}(Hz) = \frac{\phi\ (J)}{h\ (Js)}$ where ϕ is the work function and h is the Planck constant. You will come across these on the next few slides.
- The number of electrons emitted per second is proportional to the intensity of the incident radiation, provided the frequency is greater than the threshold frequency. However, if the frequency of the incident radiation is less than the threshold frequency, no photoelectric emission from the metal surface can take place, no matter how intense the incident radiation is.
- Photoelectric emission occurs without delay as soon as the incident radiation is directed at the surface, provided the frequency of the radiation exceeds the threshold frequency, and regardless of intensity.
- The wave theory of light cannot explain the need for a threshold frequency or why photoelectric emission occurs without delay.
- According to wave theory, each electron at the surface should gain some energy from the incoming wave regardless of how many waves arrive per second. So emission would occur but may be delayed.

Einstein's explanation

The photon theory of light was put forward by Einstein in 1905 to explain the photoelectric effect. Einstein assumed light composed of wavepackets or photons with energy equal to:

$$E = h\,f$$

(J) (Js) (Hz)

Where h is the Planck constant 6.63×10^{-34} Js, f is the frequency of light.

f is also equal to: $f = \frac{hc}{\lambda}$ so the energy equation can also be written as:

$$E = \frac{hc}{\lambda}$$

Where c is the speed of EM waves $3 \times 10^{8}\,ms^{-1}$ and λ is the wavelength of light in metres.

The photoelectric effect

To explain the photoelectric effect, Einstein said that:

- When light is incident on a metal surface, an electron at the surface absorbs a single photon from the incident light and therefore gains energy equal to hf, where hf is the energy of a photon
- An electron can leave the metal surface if the energy gained from a single photon exceeds the **work function ϕ** of the metal. This is the minimum energy needed by an electron to escape from the metal surface. Excess energy gained by the photoelectron becomes kinetic energy.

The maximum kinetic energy of an emitted electron is:

$$E_{Kmax} = hf - \phi \qquad E_{kmax} = \frac{1}{2} m v^2$$

The photoelectric effect

Electrons that escape from the metal place can be attracted back to it by giving the plate a sufficient positive charge. The minimum potential difference need to stop photoelectric emission is called the stopping potential, V_s. At this potential, the maximum kinetic energy of the emitted electron is reduced to zero because each emitted electron must do extra work to leave the metal surface.

$$E_{kmax} = e\ V_s$$

Where e is the charge on an electron 1.60×10^{-19}C and V_s is the stopping potential.

The photoelectric effect

Use the following websites to research:

- The use of a photocell to demonstrate the photoelectric effect, include a circuit diagram in your notes.
- Photoelectric effect graph – include a sketch and label the parts of the graph and what you can calculate from it

http://www.studyphysics.ca/2007/30/07_emr/34_photo_graphs.pdf

https://physics.info/photoelectric/

Recall questions

1. Explain what the photoelectric effect is
2. What is meant by the threshold frequency?
3. What is meant by the work function of a metal?
4. How is the maximum kinetic energy of a photoelectron related to the work function?
5. Explain what is meant by the stopping potential.

Task 2

Apply what you have learnt to these A-level questions

1 (a) Describe what occurs in the photoelectric effect.

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(2)

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

Deduce whether light of this wavelength can cause the photoelectric effect when incident on the potassium surface.

work function of potassium = 2.3 eV

Hint: This will need converting to joules! 1eV = 1.6×10^{-19} J

(c) The photoelectric effect provides evidence for light possessing particle properties.

State and explain **one** piece of evidence that suggests that light also possesses wave properties.

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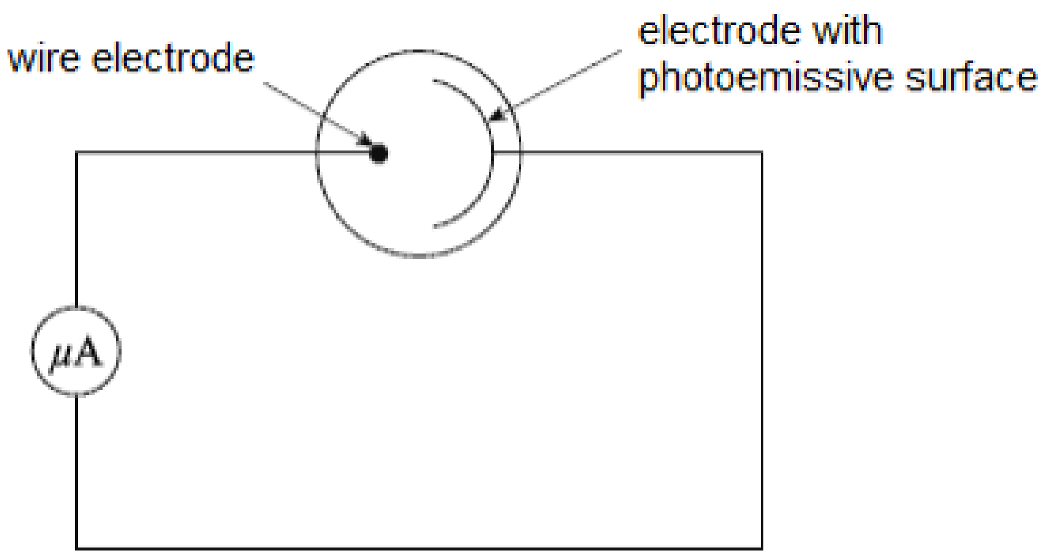
2 **Figure 1** shows a photocell which uses the photoelectric effect to provide a current in an external circuit.

Figure 1



(a) Electromagnetic radiation is incident on the photoemissive surface.

Explain why there is a current only if the frequency of the electromagnetic radiation is above a certain value.

(b) State and explain the effect on the current when the intensity of the electromagnetic radiation is increased.

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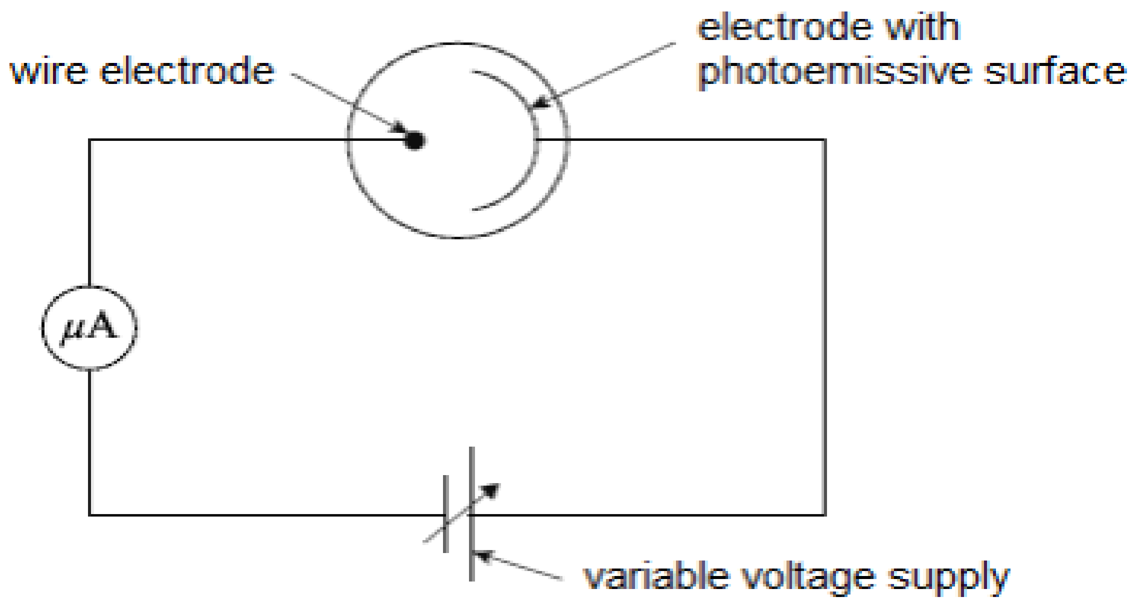
(c) A student investigates the properties of the photocell. The student uses a source of electromagnetic radiation of fixed frequency and observes that there is a current in the external circuit.
The student then connects a variable voltage supply so the positive terminal is connected to the electrode with a photoemissive surface and the negative terminal is connected to the wire electrode. As the student increases the supply voltage, the current decreases and eventually becomes zero. The minimum voltage at which this happens is called the stopping potential. The student's new circuit is shown in **Figure 2**.

Figure 2



The photoemissive surface has a work function of 2.1 eV. The frequency of the electromagnetic radiation the student uses is 7.23×10^{14} Hz.

Calculate the maximum kinetic energy, in J, of the electrons emitted from the photoemissive surface.

(d) Use your answer from **part (c)** to calculate the stopping potential for the photoemissive surface.

stopping potential = ____________________ V

(1)

(e) The student increases the frequency of the electromagnetic radiation.

Explain the effect this has on the stopping potential.

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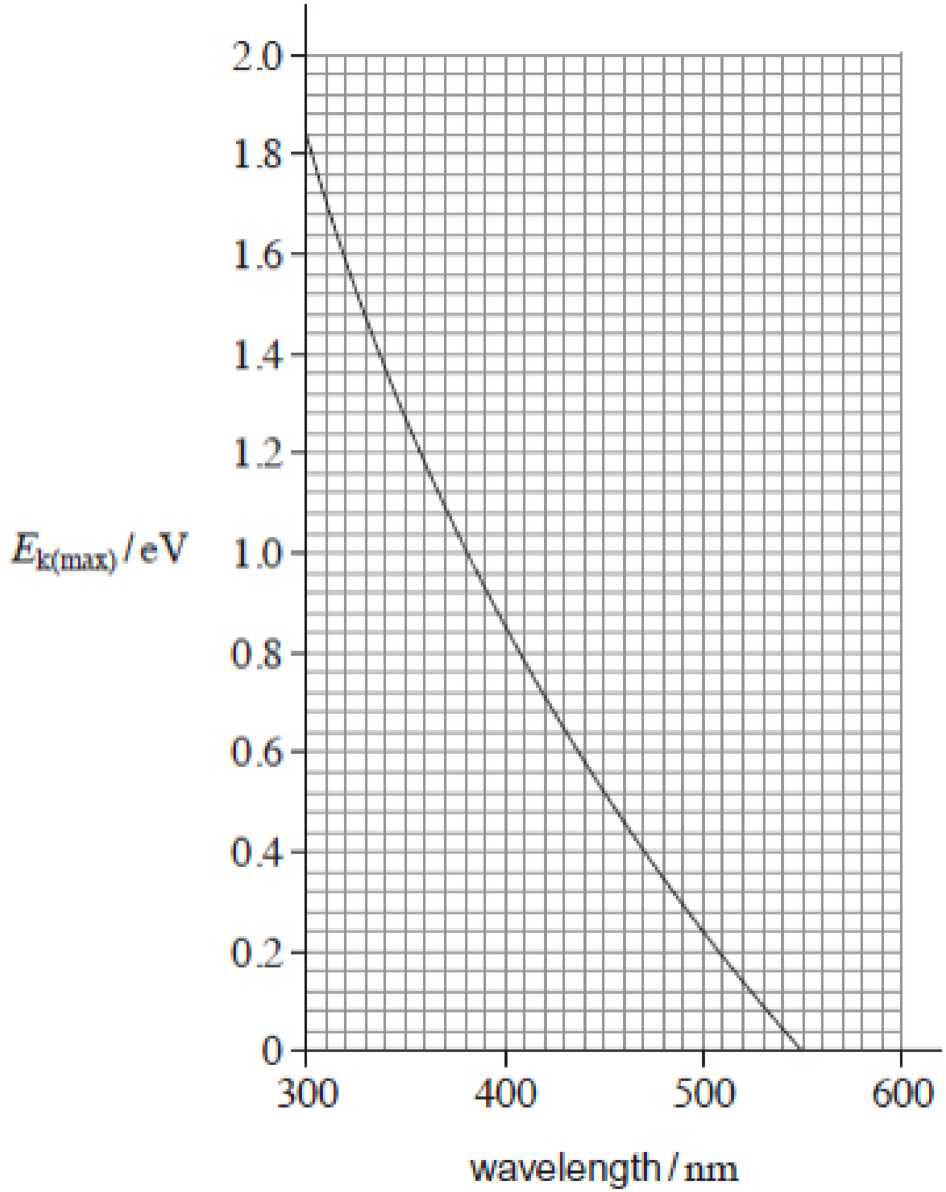
3 The maximum kinetic energy, $E_{k(max)}$, of photoelectrons varies with the wavelength of electromagnetic radiation incident on a metal surface.
This variation is shown in the graph.



(a) (i) Define the term work function.

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(2)

(ii) Show that the work function of the metal is approximately 4×10^{-19} J.

Use data from the graph in your calculation.

(3)

(b) Monochromatic radiation is incident on the metal surface.
Photoelectrons are ejected with a maximum speed of 4.6×10^{5} m s^{-1}.

Determine the wavelength of the incident radiation.

wavelength ____________________ m

(3)

(Total 8 marks)

Task 3: Essential maths skills for A-level physics

Use your GCSE notes from Science/Maths or online resources to help answer the following questions.

Significant figures

1. How many significant figures are each of these given to?

   a) 154654 b) 14 010 c) 24.300 d) 0.000450

2. What is 1572.86^{o}C to:

   a) 2 sig. figs b) 3 sig. figs c) 4 sig. figs

3. A car travels 522m in 37 seconds. Calculate the car's average speed, giving your answer to an appropriate number of significant figures.

Standard form

1. A current is measured as 0.00064A. Rewrite this in standard form
2. The half-life of an isotope is 1.34×10^5s. Rewrite this in decimal form.
3. The North star is approximately 4.12×10^{18}m from Earth. Light travels 9.5×10^{15}m in a year. How many years does it take light from the North star to reach the Earth?

Converting units

- To add the prefix to a number divide by the scaling factor
- To remove the prefix from a number multiply by the scaling factor

Complete the following table

Prefix	Symbol	Scaling factor
Tera		$1x10^{12}$
Giga		
Mega		
Kilo		
		1
Milli		
Micro		
Nano		
Pico		
Femto		

Converting units

1. The diameter of an atom is estimated to be 100pm. What is this in metres?
2. The diameter of a fluorine nucleus is estimated to be 7.5fm. What is this in nanometres?
3. The mass of the Moon is 7.3×10^{16}Gg. What is this in kg?

Using and rearranging equations

The first question will need this equation: v= u + at, where v is final velocity (ms^{-1}), u is the initial velocity (ms^{-1}), a is acceleration (ms^{-2}) and t is time (s).

1. A car is travelling at $15ms^{-1}$. Calculate how long it would take to reach a velocity of $22ms^{-1}$ if it accelerated at $0.80ms^{-2.}$
2. The relationship between the force, F, on a spring and the extension, ΔL, is F $= k\ \Delta L$ where k is the spring constant. A spring has an extension of 0.025m when a force of 16N is applied to it. The force on the spring is removed and a new force of 28N is applied. Calculate the new extension of the spring.
3. The electric force between two charged particles is given by the equation $\mathrm{F} = \frac{1}{4\pi\varepsilon_0}\frac{Q_1 Q_2}{r^2}$ where Q_1 and Q_2 are the charges on the two particles measured in coulombs, r is the distance between them measured in metres and E_o is the constant $8.85\text{x}10^{-12}Fm^{-1}$. If the force between two electrons (each with a charge of $-1.6\text{x}10^{-19}$) is $2.6\text{x}10^{-11}$N, what is the distance between them?