Homework 4: Wave-Particle Duality

1. To demonstrate the photoelectric effect, radiation is directed onto the surface of a clean charged zinc plate.
Identify which of the following conditions is required to produce the emission of photoelectrons from the zinc plate.

	Charge on zinc plate	*Frequency of radiation*
A	Positive	Above a certain value
B	Negative	Above a certain value
C	Positive	Any value
D	Negative	Any value
E	Negative	Below a certain value

2. Photons of energy $7{\cdot}0 \times 10^{-19}$ J are incident on a clean metal surface. The work function for the metal is $9{\cdot}0 \times 10^{-19}$ J.
Identify which of the following statements is correct.

A No electrons are emitted from the metal surface.
B Electrons with a maximum kinetic energy of $2{\cdot}0 \times 10^{-19}$ J are emitted from the metal surface.
C Electrons with a maximum kinetic energy of $7{\cdot}0 \times 10^{-19}$ J are emitted from the metal surface.
D Electrons with a maximum kinetic energy of $9{\cdot}0 \times 10^{-19}$ J are emitted from the metal surface.
E Electrons with a maximum kinetic energy of $16{\cdot}0 \times 10^{-19}$ J are emitted from the metal surface.

3. Ultraviolet radiation is incident on a zinc plate.
Photoelectrons with a certain maximum kinetic energy are released from the zinc. The irradiance of the ultraviolet radiation is now increased.
Identify the row in the table which correctly describes what happens to the maximum kinetic energy of the photoelectrons and the rate at which they are released.

	Maximum kinetic energy of photoelectrons	*Rate at which photoelectrons are released*
A	remains the same	remains the same
B	decreases	increases
C	increases	remains the same
D	increases	increases
E	remains the same	increases

4. A student makes note of the following statements after a lesson about photoelectric emission.

I Photoelectric emission from a metal occurs only if the frequency of the incident radiation is greater than the threshold frequency.
II The threshold frequency depends on the metal from which photoemission takes place.
III If the frequency of the incident radiation is less than the threshold frequency, increasing its irradiance will cause photoemission.

Identify which of the statements is/are correct.

A I only
B II only
C I and II only
D II and III only
E I, II and III

5. The photon energies for three different radiations are as follows.

Radiation 1: $2{\cdot}78 \times 10^{-19}$ J
Radiation 2: $4{\cdot}97 \times 10^{-19}$ J
Radiation 3: $6{\cdot}35 \times 10^{-19}$ J

Identify which of the following statements is correct.

A The wavelength of radiation 1 is longer than that of radiation 2.
B The wavelength of radiation 3 is longer than that of radiation 2.
C The frequency of radiation 1 is higher than that of radiation 2.
D The frequency of radiation 1 is higher than that of radiation 3.
E The frequency of radiation 2 is higher than that of radiation 3.

6. A light emitting diode produces light of wavelength λ.
Identify the relationship which could be used to calculate the energy of a photon of light emitted by this diode.

A $h\lambda$
B $\frac{h}{\lambda}$
C $\frac{h\lambda}{c}$
D $\frac{hc}{\lambda}$
E $hc\lambda$

7. The minimum energy required to eject an electron from a certain metal is $3{\cdot}0 \times 10^{-19}$ J.
Light of frequency $4{\cdot}8 \times 10^{14}$ Hz is incident on the metal.
Identify which of the following statements is correct.

A Electrons will not be ejected from the metal
B Electrons will be ejected with 0 J of kinetic energy.
C Electrons will be ejected with $1{\cdot}8 \times 10^{-20}$ J of kinetic energy.
D Electrons will be ejected with $3{\cdot}2 \times 10^{-20}$ J of kinetic energy.
E Electrons will be ejected with $6{\cdot}2 \times 10^{-20}$ J of kinetic energy.

8. When light of frequency f is shone on to a certain metal, photoelectrons are ejected with a maximum velocity v and kinetic energy E_k.

Light of the same frequency but twice the irradiance is shone onto the same surface.

A student makes the following statements about the new light.

I Twice as many electrons are ejected per second.
II The speed of the fastest electrons is now $2\,v$.
III The kinetic energy of the fastest electrons is now $2\,E_k$.

Identify which of the statements is/are correct.

A I only
B II only
C III only
D I and II only
E II and III only

9. Ultraviolet radiation is incident on a clean zinc plate and photoelectrons are ejected.
The clean zinc plate is replaced by a different metal which has a lower work function. The same irradiance of ultraviolet radiation is incident on this metal.

A student makes the following statements when comparing the new metal to the zinc plate.

I The maximum speed of the photoelectrons is greater.
II The maximum kinetic energy of the photoelectrons is greater.
III There are more photoelectrons ejected per second.

Identify which of the statements is/are correct.

A I only
B II only
C III only
D I and II only
E I, II and III

10. Electromagnetic radiation of frequency $9{\cdot}0 \times 10^{14}$ Hz is incident on a clean metal surface.
The work function of the metal is $5{\cdot}0 \times 10^{-19}$ J.

Calculate the maximum kinetic energy of a photoelectron released from the metal surface.

A $9{\cdot}0 \times 10^{-19}$ J
B $6{\cdot}0 \times 10^{-19}$ J
C $5{\cdot}0 \times 10^{-19}$ J
D $4{\cdot}0 \times 10^{-19}$ J
E $1{\cdot}0 \times 10^{-19}$ J

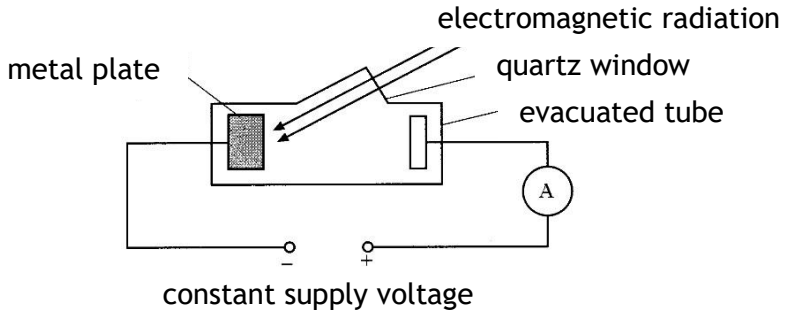
11. Ultraviolet radiation from a lamp is incident on the surface of a metal. This causes the release of electrons from the surface of the metal.

The energy of each photon of ultraviolet radiation is $5{\cdot}23 \times 10^{-19}$ J.
The work function of the metal is $2{\cdot}56 \times 10^{-19}$ J.

(a) Calculate:
(i) the maximum kinetic energy of an electron released from this metal by this radiation;
(ii) the maximum speed of an emitted electron.

(b) The source of ultraviolet radiation is now moved further away from the surface of the metal.
State the effect, if any, this has on the maximum speed of an emitted electron.
You must justify your answer.

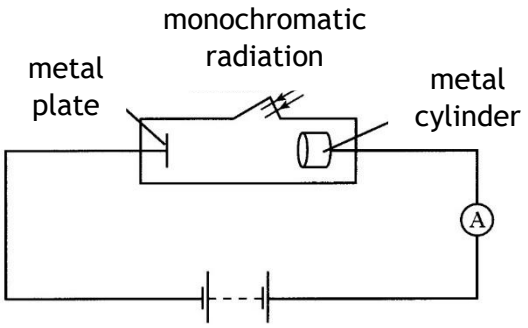
12. A metal plate emits electrons when certain wavelengths of electromagnetic radiation are incident on it.



When light of wavelength 605 nm is incident on the metal plate, electrons are released with zero kinetic energy.

(a) Show that the work function of this metal is $3{\cdot}29 \times 10^{-19}$ J.
(b) The wavelength of the incident radiation is now altered.
Photons of energy $5{\cdot}12 \times 10^{-19}$ J are incident on the metal plate.
Calculate the maximum kinetic energy of the electrons just as they leave the metal plate.

13. In 1902, P. Lenard set up an experiment similar to the one shown below.



There is a constant potential difference between the metal plate and the metal cylinder.
Photoelectrons produced at the plate are collected by the cylinder.
The frequency of the radiation is set at a value above the threshold frequency.

(a) The irradiance of the radiation is slowly increased.
Sketch a graph of the current against irradiance of radiation.

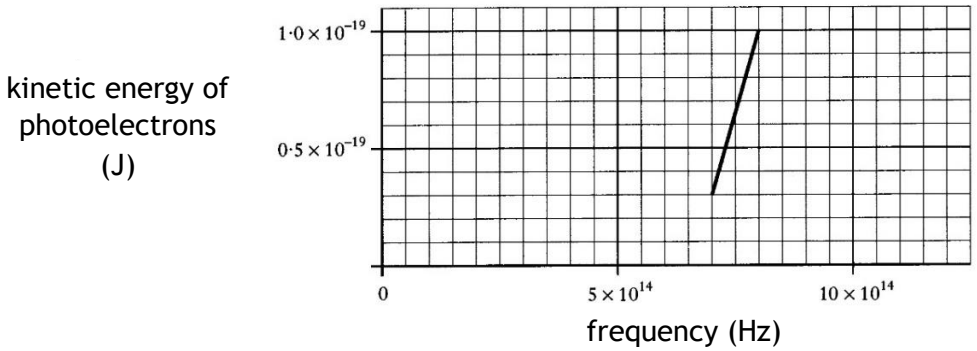
(b) The metal of the plate has a work function of $3{\cdot}11 \times 10^{-19}$ J. The wavelength of the radiation is 400 nm.
Calculate the maximum kinetic energy of a photoelectron.

(c) The battery connections are now reversed.
Explain why there could still be a reading on the ammeter.

14. A circuit is set up, as in Question 13, to investigate photoelectric emission from a metal plate when electromagnetic radiation is shone on the surface. The frequency of the electromagnetic radiation can be varied.
When radiation of a certain frequency is shone on the metal plate, a reading is obtained on the ammeter.

(a) Explain why there is no reading on the ammeter when the frequency of the radiation is decreased below a particular value.

(b) The maximum kinetic energy of the photoelectrons emitted from X is measured for a number of different frequencies of the radiation.
The graph shows how this kinetic energy varies with frequency.



(i) Use the graph to find the threshold frequency for metal.
The table below gives the work function of different metals.

Metal	*Work function / J*
Potassium	$3{\cdot}2 \times 10^{-19}$
Calcium	$4{\cdot}3 \times 10^{-19}$
Zinc	$6{\cdot}9 \times 10^{-19}$
Gold	$7{\cdot}8 \times 10^{-19}$

(ii) Which one of these metals was used in the investigation?
You must justify your answer using the information given in the table.