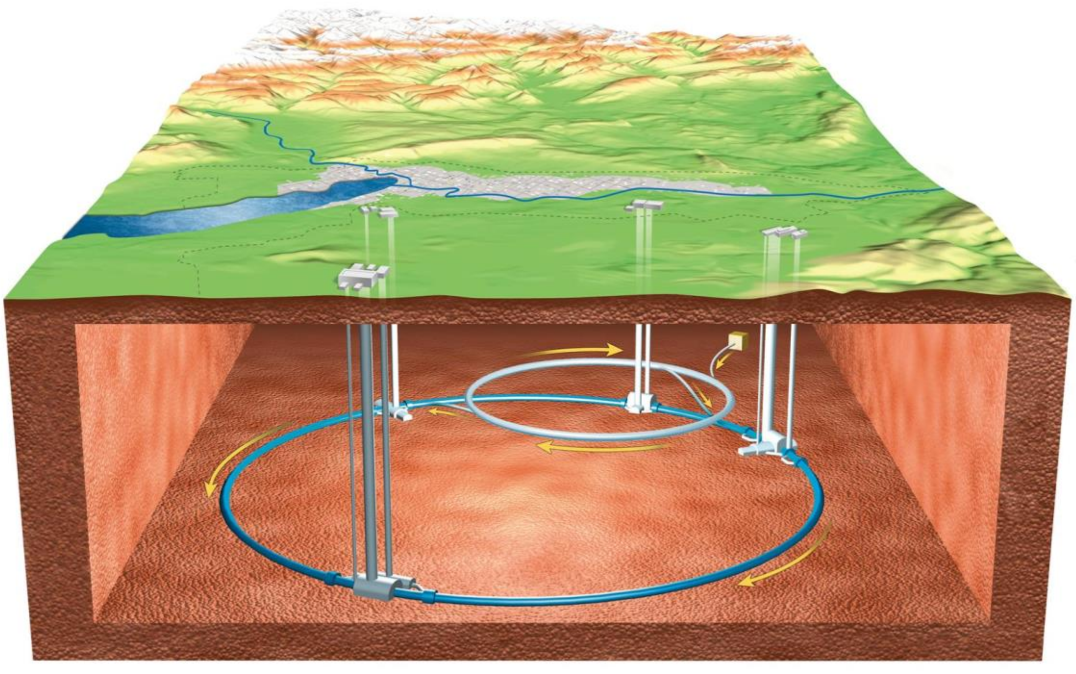
Wallace Hall Academy

CfE Higher Physics

Particles and Waves



Exam Questions Part 1

Cover image: cutaway diagram of CERN, CERN

Contents

DATA SHEET

COMMON PHYSICAL QUANTITIES

Quantity	*Symbol*	*Value*	*Quantity*	*Symbol*	*Value*
Speed of light in vacuum	c	$3{\cdot}00 \times 10^{8}\,m\,s^{-1}$	Planck's constant	h	$6{\cdot}63 \times 10^{-34}\,J\,s$
Magnitude of the charge on an electron	e	$1{\cdot}60 \times 10^{-19}\,C$	Mass of electron	m_e	$9{\cdot}11 \times 10^{-31}\,kg$
Universal Constant of Gravitation	G	$6{\cdot}67 \times 10^{-11}\,m^{3}\,kg^{-1}\,s^{-2}$	Mass of neutron	m_n	$1{\cdot}675 \times 10^{-27}\,kg$
Gravitational acceleration on Earth	g	$9{\cdot}8\,m\,s^{-2}$	Mass of proton	m_p	$1{\cdot}673 \times 10^{-27}\,kg$
Hubble's constant	H_0	$2{\cdot}3 \times 10^{-18}\,s^{-1}$			

REFRACTIVE INDICES

The refractive indices refer to sodium light of wavelength 589 nm and to substances at a temperature of 273 K.

Substance	*Refractive index*	*Substance*	*Refractive index*
Diamond	2·42	Water	1·33
Crown glass	1·50	Air	1·00

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550, 10590	Infrared
Helium-neon	633	Red

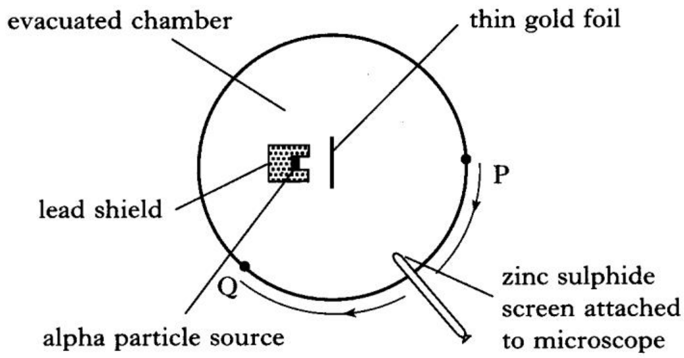
PROPERTIES OF SELECTED MATERIALS

Substance	*Density*/kg m^{-3}	*Melting Point*/K	*Boiling Point*/K
Aluminium	$2{\cdot}70 \times 10^{3}$	933	2623
Copper	$8{\cdot}96 \times 10^{3}$	1357	2853
Ice	$9{\cdot}20 \times 10^{2}$	273	....
Sea Water	$1{\cdot}02 \times 10^{3}$	264	377
Water	$1{\cdot}00 \times 10^{3}$	273	373
Air	1·29	....	....
Hydrogen	$9{\cdot}0 \times 10^{-2}$	14	20

The gas densities refer to a temperature of 273 K and a pressure of $1{\cdot}01 \times 10^{5}$ Pa.

Section 1: The Standard Model

1. The diagram shows the apparatus used by Rutherford to investigate the scattering of alpha particles by a gold foil.



From the observations made as the microscope and screen were moved from P to Q, Rutherford deduced that an atom has a nucleus which is:

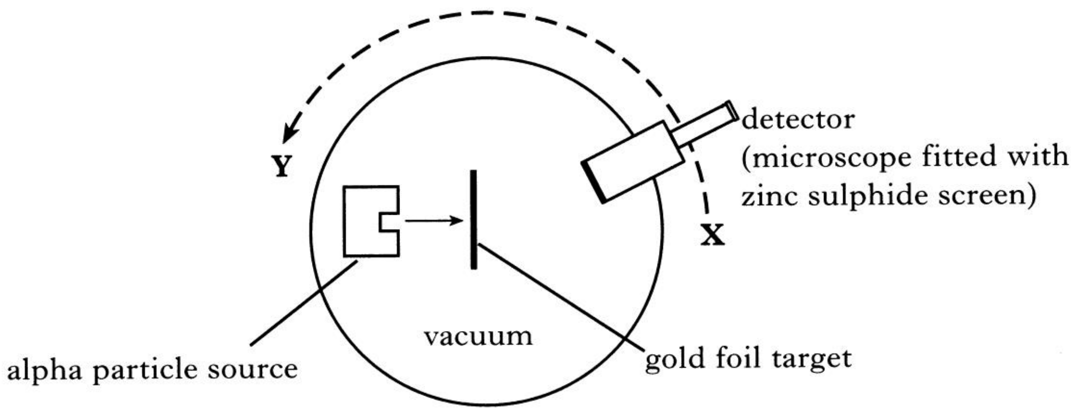
(a) positively charged;
(b) massive;
(c) much smaller than the volume of the atom.

Explain how the observations from the scattering experiment led to these three deductions. 3

(3)

2. About one hundred years ago Rutherford designed an experiment to investigate the structure of the atom. He used a radioactive source to fire alpha particles at a thin gold foil target.

His two assistants, Geiger and Marsden, spent many hours taking readings from the detector as it was moved to different positions between X and Y.



(a) How did the number of alpha particles detected at **X** compare with the number detected at **Y**? 1

(b) State **three** conclusions Rutherford deduced from the results. 3

(4)

3. Information on the properties of three elementary particles together with two types of quarks and their corresponding antiquarks is shown in the tables below.

Properties of elementary particles			
Particle	Number of quarks	Charge	Baryon number
Proton	3	+e	1
Antiproton	3	−e	−1
Pi-meson	2	−e	0

Properties of quarks and antiquarks		
Particle	Charge	Baryon number
Up quark	$+\frac{2}{3}e$	$+\frac{1}{3}$
Down quark	$-\frac{1}{3}e$	$+\frac{1}{3}$
Anti-up quark	$-\frac{2}{3}e$	$-\frac{1}{3}$
Anti-down quark	$+\frac{1}{3}e$	$-\frac{1}{3}$

(a) Using information from the tables above, show that a proton consists of two up quarks and one down quark. 1

(b) State the combination of quarks that forms a pi-meson. 1

(2)

4. The following strong interaction has been observed.

$$K^- + p \rightarrow n + X$$

The K^- is a strange meson of quark composition $\bar{u}\,s$.

The u quark has a charge of +2/3.

The d quark has a charge of −1/3.

(a) Determine the charge of the strange quark. 1

(b) Use the appropriate conservation law to determine whether particle X is positive, negative or neutral. 1

(c) State whether particle X is a baryon or a meson. Justify your answer. 2

(4)

5. (a) The equation for a β^- decay can be written as:

$$n \rightarrow p + \beta^- + \bar{\nu}$$

(i) For each of these four particles, state its name, and where appropriate, its quark composition. 3

(ii) Write a similar equation for a β^+ decay. 1

(iii) State the interaction associated with β decay. 1

(b) In 1995 scientists at CERN created atoms of antihydrogen.

(i) Name the particles that make up an atom of antihydrogen. 1

(ii) State the charge of an atom of antihydrogen. 1

(iii) Explain why it is not possible to store atoms of antihydrogen. 1

(8)

6. In February 2000 scientists at CERN announced that they had made some "quark-gluon plasma" (QGP), the extremely dense energetic matter that was present throughout the universe about 1 μs after the Big Bang. This was done by colliding lead ions in a particle accelerator.

(a) (i) A particular isotope of lead has 82 protons and 124 neutrons in its nucleus. Write the symbol for this isotope of lead in the form

$$^{x}_{y}\mathrm{Z}$$

2

(ii) State the other particle present in an atom of this isotope of lead. 1

(b) When QGP existed in the early universe, all the particles in the table below were present.

Quarks			Leptons		
Name	Symbol	Charge	Name	Symbol	Charge
up down	u d	+2/3 –1/3	electron electron-neutrino	e^- ν_e	–1 0
charm strange	c s	+2/3 –1/3	muon muon-neutrino	μ ν_μ	–1 0
top bottom	t b	+2/3 –1/3	tau tau-neutrino	τ^- ν_τ	–1 0

(i) Protons and neutrons are made entirely of up and down quarks. Show how an appropriate number of quarks can combine to give the correct charge for a proton. 1

(ii) Describe briefly the circumstances required for the remaining quarks in the table to be created. 1

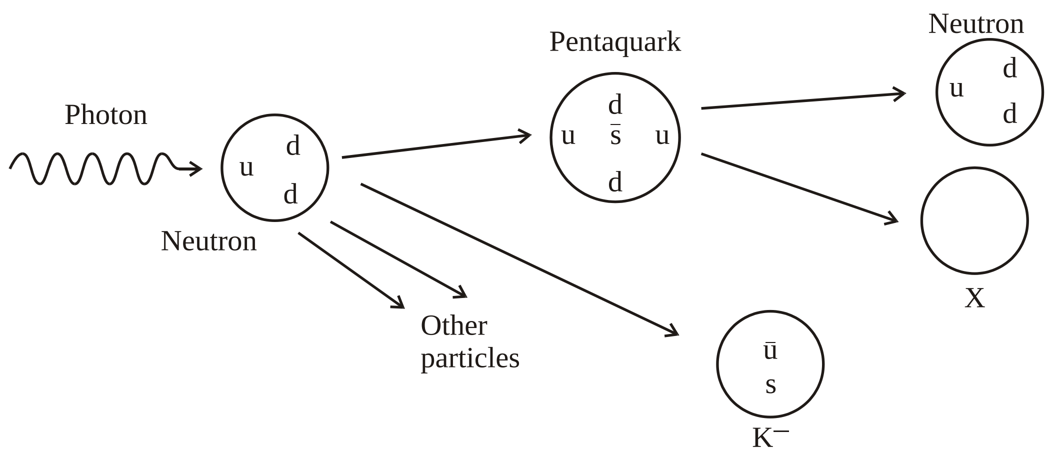
(iii) The early universe also contains positrons. Describe how the positron compares to the electron. 1

(6)

7. In July 2003 scientists at the SPring-8 synchrotron in Japan announced the discovery of a pentaquark – a particle made up of 5 quarks.

(a) Previously, quarks had been known to occur in two types of combinations called hadrons. Name these two types and describe the quark combination of each. 4

(b) The pentaquark was produced by firing gamma photons at a target. It decayed very rapidly into other products. The diagram shows some of the particles involved in the production and decay of the pentaquark, including the quark composition for several of them.



(i) Name **one** quantity conserved during the decay of the pentaquark. 2

(ii) The table below shows the charges of the six types of quarks as a fraction of the charge of a proton.

Quark type			Charge
up	charm	top	2/3 *e*
down	strange	bottom	–1/3 *e*

Determine the charge of the pentaquark. Express your answer as a fraction of the charge of a proton. 1

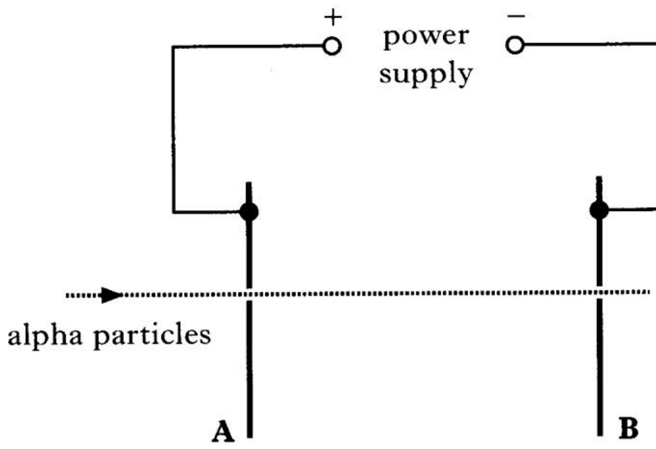
(iii) Determine the charge of particle X. 1

(iv) Suggest a possible quark composition for particle X. Justify your answer. 2

(10)

Section 2: Forces on Charged Particles

1. The apparatus shown in the diagram is designed to accelerate alpha particles.



An alpha particle travelling at a speed of $2{\cdot}60 \times 10^{6}$ m s^{-1} passes through a hole in plate A. The mass of an alpha particle is $6{\cdot}64 \times 10^{-27}$ kg and its charge is $3{\cdot}20 \times 10^{-19}$ C.

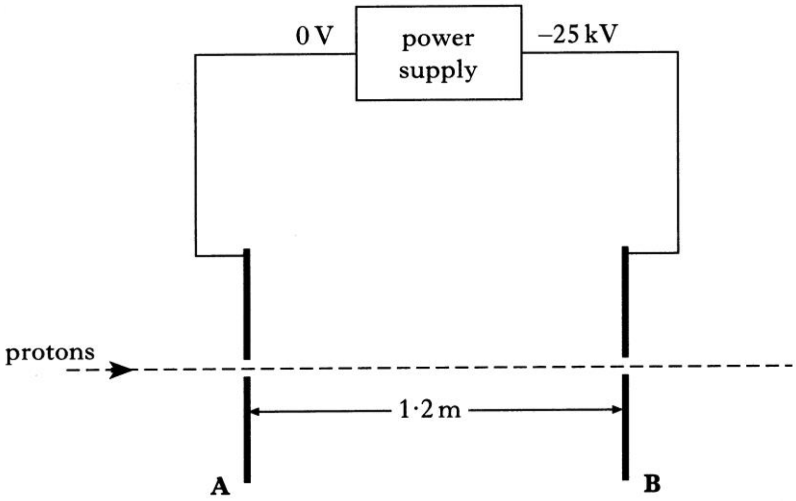
(a) When the alpha particle reaches plate B, its kinetic energy has increased to $3{\cdot}05 \times 10^{-14}$ J.
Show that the work done on the alpha particle as it moves from plate A to plate B is $8{\cdot}1 \times 10^{-15}$ J, 2

(b) Calculate the potential difference between plates A and B. 2

(c) The apparatus is now adapted to accelerate **electrons** from A to B through the same potential difference.
How does the increase in kinetic energy of an electron compare with the increase in kinetic energy of the alpha particle in part (a)? Justify your answer. 2

(6)

2. A particle accelerator increases the speed of protons by accelerating them between a pair of metal plates, **A** and **B**, connected to a power supply as shown below.



The potential difference between **A** and **B** is 25 kV.

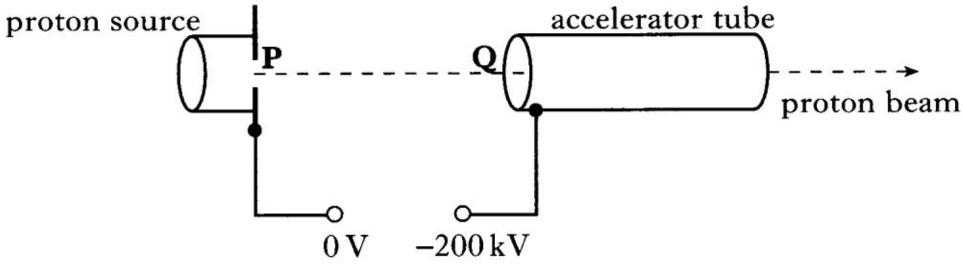
(a) Show that the kinetic energy gained by a proton between plates A and B is $4{\cdot}0 \times 10^{-15}$ J. 2

(b) The kinetic energy of a proton at plate **A** is $1{\cdot}3 \times 10^{-16}$ J.
Calculate the velocity of the proton on reaching plate **B**. 3

(c) The plates are separated by a distance of 1·2 m.
Calculate the force produced by the particle accelerator on a proton as it travels between plates **A** and **B**. 2

(7)

3. The diagram below shows the basic features of a proton accelerator. It is enclosed in an evacuated container.



Protons released from the proton source start from rest at **P**.
A potential difference of 200 kV is maintained between **P** and **Q**.

(a) What is meant by the term *potential difference of 200 kV*? 1

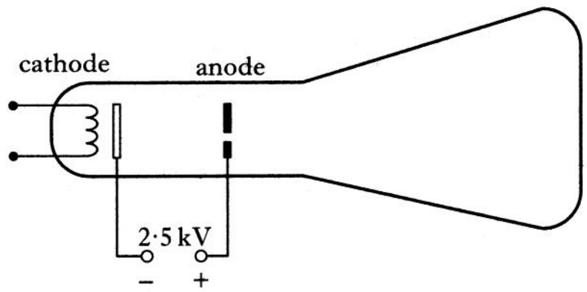
(b) Explain why protons released at **P** are accelerated towards **Q**. 1

(c) Calculate:
(i) the work done on a proton as it accelerates from **P** and **Q**; 2
(ii) the speed of a proton as it reaches **Q**. 2

(d) The distance between **P** and **Q** is now halved.
What effect, if any, does this change have on the speed of a proton as it reaches **Q**? Justify your answer. 2

(8)

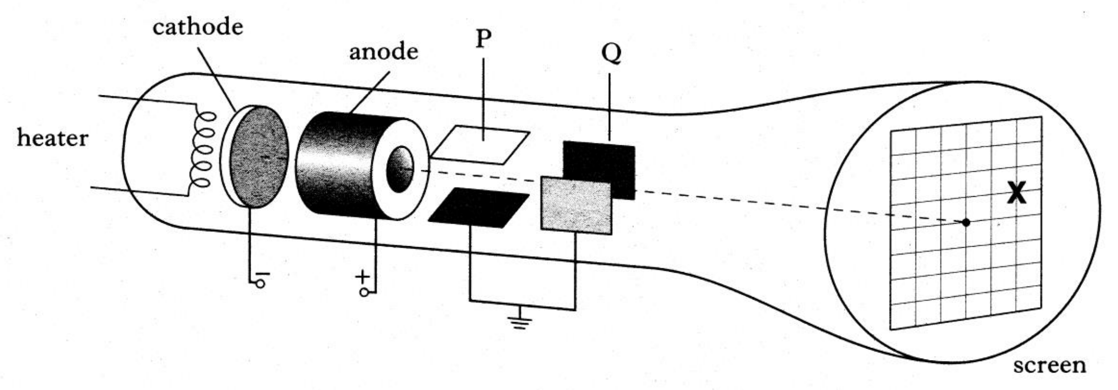
4. The diagram shows an arrangement which is used to accelerate electrons.
The potential difference between the cathode and the anode is 2·5 kV.



Assuming that the electrons start from rest at the cathode, calculate the speed of an electron just as it reaches the anode. 3

(3)

5. The diagram below shows a cathode ray tube used in an oscilloscope.



The electrons which are emitted from the cathode start from rest and reach the anode with a speed of $4{\cdot}2 \times 10^{7}$ m s^{-1}.

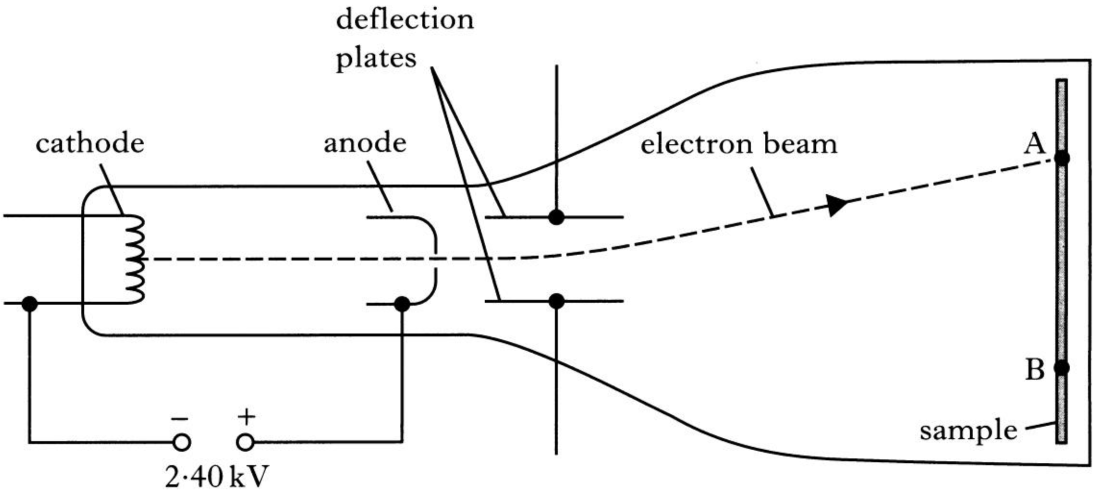
(a) (i) Calculate the kinetic energy in joules of each electron just before it reaches the anode. 2

(ii) Calculate the p.d. between the anode and the cathode. 2

(b) Describe how the spot at the centre of the screen produced by the electron beam can be moved to position **X**.
Your answer must make reference in the relative sizes and polarity (signs) of the voltages applied to plates P and Q. 2

(6)

6. Identification of elements in a semiconductor sample can be carried out using an electron scanner to release atoms from the surface of the sample for analysis. Electrons are accelerated from rest between a cathode and anode by a potential difference of 2·40 kV.
A variable voltage supply connected to the deflection plates enables the beam to scan the sample between points A and B shown in the figure below.



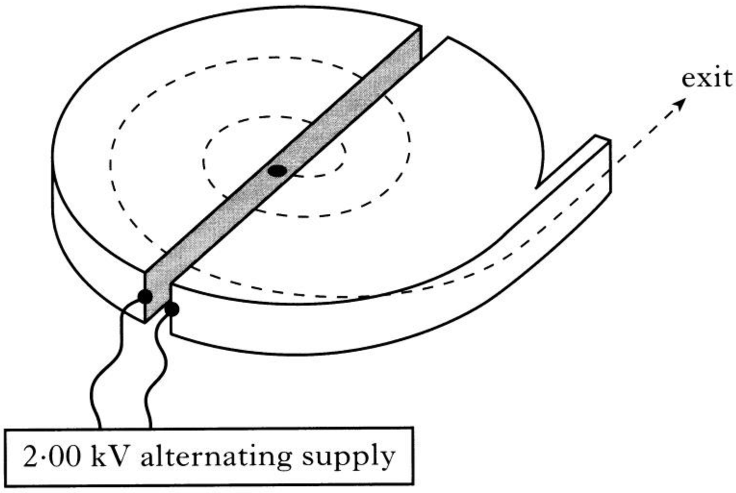
(a) Calculate the speed of the electrons as they pass through the anode. 2

(b) Explain why the electron beam follows:
  (i) a curved path between the plates; 1
  (ii) a straight path beyond the plates. 1

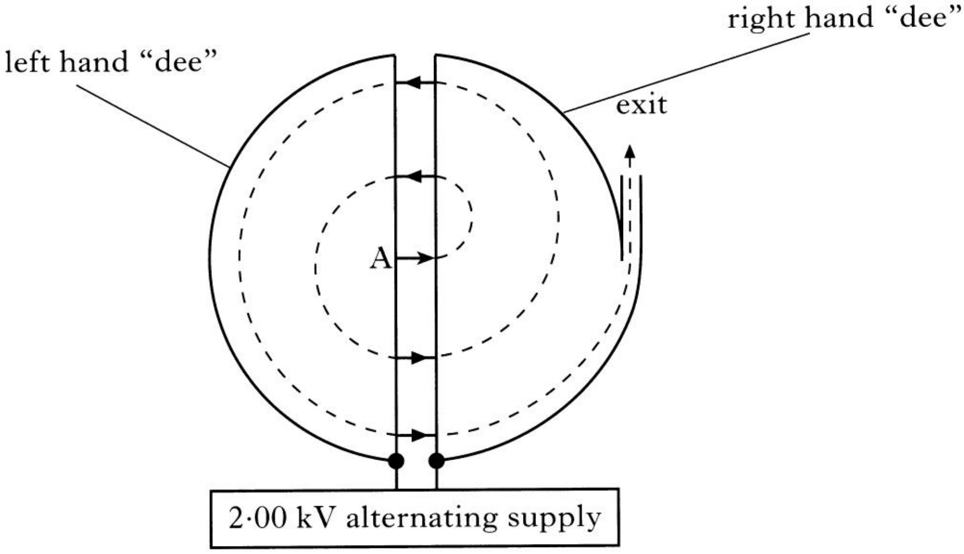
(c) The anode voltage is now increased. State what happens to the length of the sample scanned by the electron beam. You must justify your answer. 2

(6)

7. A cyclotron is a particle accelerator which consists of two D-shaped hollow structures, called “dees”, placed in a vacuum.



The diagram below shows the cyclotron viewed from above.



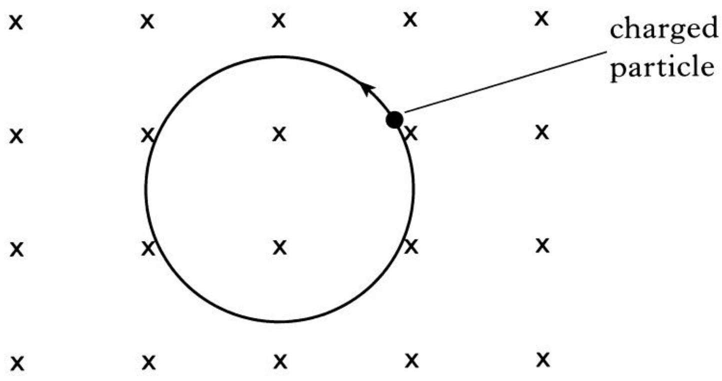
(a) Protons are released from rest at point A and accelerated across the gap between the “dees” by a voltage of 2·00 kV.
Show that the speed of the protons as they **first** reach the right hand “dee” is $6{\cdot}19 \times 10^5$ m s^{-1}. 2

(b) Inside the “dees” the electric field strength is zero but there is a uniform magnetic field. This forces the protons to move in semi-circular paths when inside the “dees”.
State the direction of the magnetic field in the “dees”. 1

(c) While the protons are inside the “dee”, the polarity of the applied voltage is reversed so that the protons are again accelerated when they cross to the left hand “dee”.
Calculate the speed of the protons as they **first** enter the left hand “dee”. 2

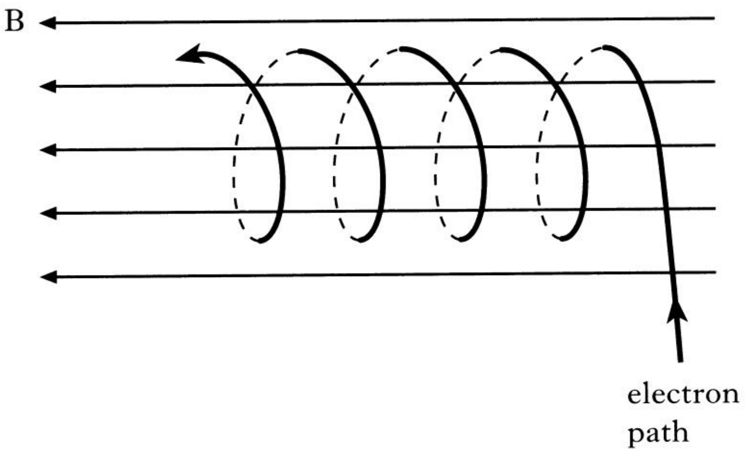
(5)

8. (a) A charged particle moves with a speed of $2{\cdot}0 \times 10^6$ m s^{-1} in a circular orbit in a uniform magnetic field directed into the page as shown below.



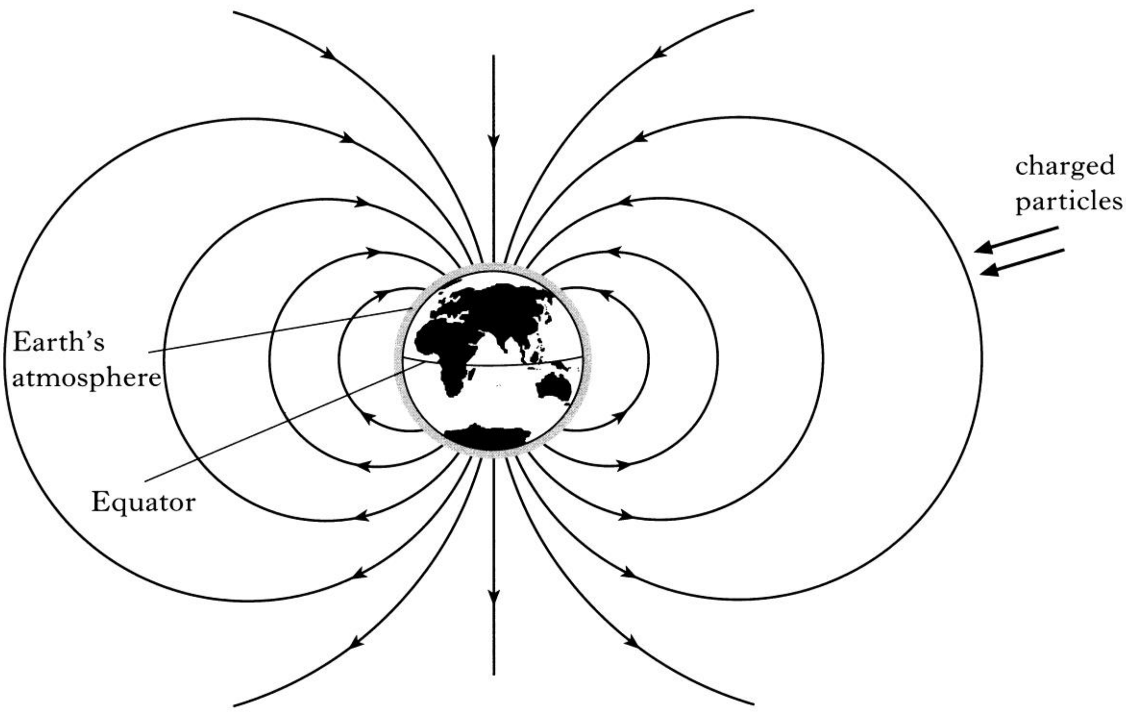
State whether the charge on the particle is positive or negative. 1

(b) An electron enters a uniform magnetic field at an angle to the magnetic field lines as shown below.



Explain the shape of the electron path in the magnetic field. 2

(c) Charged particles which enter the Earth’s atmosphere near the North pole collide with air molecules. The light emitted in this process is called the Aurora Borealis.
In the figure below, the Earth’s magnetic field is indicated by continuous lines which show the magnetic field direction in the region surrounding the Earth. The extent of the Earth’s atmosphere is also shown.



Charged particles approach the Earth in the direction shown in the diagram. Explain why these particles do not cause an aurora above the Equator. 2

(5)

Section 3: Nuclear Reactions

1. A smoke alarm contains a very small sample of the radioactive isotope Americium-241, represented by the symbol

$$^{241}_{95}\mathrm{Am}$$

(a) How many neutrons are there in a nucleus of this isotope? 1

(b) This isotope decays by emitting alpha particles as shown in the following statement.

$$^{241}_{95}\mathrm{Am} \longrightarrow \, ^{s}_{r}\boldsymbol{T} + \alpha$$

(i) Determine the numbers represented by the letters ***r*** and ***s***. 1

(ii) Use the data booklet to identify the element ***T***. 1

(3)

2. Some power stations use nuclear fission reactions to provide energy for generating electricity. The following statement represents a fission reaction.

$$^{235}_{92}\mathrm{U} \quad + \quad ^{1}_{0}\mathrm{n} \quad \rightarrow \quad ^{139}_{57}\mathrm{La} \quad + \quad ^{\boldsymbol{r}}_{42}\mathrm{Mo} \quad + \quad 2\,^{1}_{0}\mathrm{n} \quad + \quad \boldsymbol{s}\,^{0}_{-1}\mathrm{e}$$

(a) Determine the numbers represented by the letters ***r*** and ***s*** in the above statement. 1

(b) Explain why a nuclear fission reaction releases energy. 1

(c) The masses of the particles involved in the reaction are shown in the table.

Particle	*Mass*/kg
$^{235}_{92}\mathrm{U}$	$390{\cdot}173 \times 10^{-27}$
$^{139}_{57}\mathrm{La}$	$230{\cdot}584 \times 10^{-27}$
$^{\boldsymbol{r}}_{42}\mathrm{Mo}$	$157{\cdot}544 \times 10^{-27}$
$^{1}_{0}\mathrm{n}$	$1{\cdot}675 \times 10^{-27}$
$^{0}_{-1}\mathrm{e}$	negligible

Calculate the energy released in this reaction. 3

(5)

3. A nuclear fission reaction is represented by the following statement.

$$^{235}_{92}\text{U} \quad + \quad ^{1}_{0}\text{n} \rightarrow \; ^{137}_{\boldsymbol{r}}\text{Cs} \quad + \quad ^{\boldsymbol{s}}_{37}\boldsymbol{T} \quad + \quad 4\,^{1}_{0}\text{n}$$

(a) Is this a spontaneous or induced reaction? You must justify your answer. 1

(b) Determine the numbers represented by the letters ***r*** and ***s*** in the above reaction. 1

(c) Use the data booklet to identify the element represented by ***T***. 1

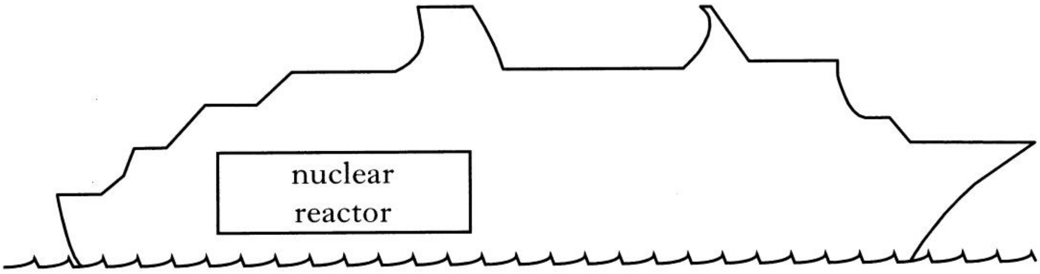
(d) The masses of the nuclei and particles in the reaction are given below.

	Mass/kg
$^{235}_{92}\text{U}$	$390{\cdot}219 \times 10^{-27}$
$^{137}_{\boldsymbol{r}}\text{Cs}$	$227{\cdot}292 \times 10^{-27}$
$^{\boldsymbol{s}}_{37}\boldsymbol{T}$	$157{\cdot}562 \times 10^{-27}$
$^{1}_{0}\text{n}$	$1{\cdot}675 \times 10^{-27}$

Calculate the energy released in the reaction. 3

(6)

4. A ship is powered by a nuclear reactor.



One reaction that takes place in the core of the nuclear reactor is represented by the statement below.

$$^{235}_{92}\mathrm{U} + ^{1}_{0}\mathrm{n} \rightarrow ^{140}_{58}\mathrm{Ce} + ^{94}_{40}\mathrm{Zr} + 2^{1}_{0}\mathrm{n} + 6^{0}_{-1}\mathrm{e}$$

(a) The symbol for the Uranium nucleus is $^{235}_{92}\mathrm{U}$.

What information about the nucleus is provided by the following numbers?

(i) 92 1

(ii) 235 1

(b) Describe how neutrons produced during the reaction can cause further nuclear reactions. 1

(c) The masses of the particles involved in the reaction are shown in the table.

Particles	*Mass*/kg
$^{235}_{92}\mathrm{U}$	$390{\cdot}173 \times 10^{-27}$
$^{140}_{58}\mathrm{Ce}$	$232{\cdot}242 \times 10^{-27}$
$^{94}_{40}\mathrm{Zr}$	$155{\cdot}884 \times 10^{-27}$
$^{1}_{0}\mathrm{n}$	$1{\cdot}675 \times 10^{-27}$
$^{0}_{-1}\mathrm{e}$	negligible

Calculate the energy released in the reaction. 3

(6)

5. Radium (Ra) decays to Radon (Rn) by the emission of an alpha particle. Some energy is also released by this decay. The decay is represented by the statement shown below.

$$^{226}_{88}\text{Ra} \longrightarrow {}^{x}_{y}\text{Rn} + {}^{4}_{2}\text{He}$$

The masses of the nuclides involved are as follows.

$$\text{Mass of } {}^{226}_{88}\text{Ra} = 3{\cdot}75428 \times 10^{-25}\ \text{kg}$$

$$\text{Mass of } {}^{x}_{y}\text{Rn} = 3{\cdot}68771 \times 10^{-25}\ \text{kg}$$

$$\text{Mass of } {}^{4}_{2}\text{He} = 6{\cdot}64832 \times 10^{-27}\ \text{kg}$$

(a) What are the values of x and y for the nuclide ${}^{x}_{y}$Rn? 1

(b) Why is energy released by this decay? 1

(c) Calculate the energy released by one decay of this type. 3

(5)

6. Energy is released from stars as a result of nuclear reactions. One of these reactions is represented by the statement given below.

$$^{14}_{7}\text{N} + {}^{4}_{2}\text{He} \longrightarrow {}^{18}_{9}\text{F} + \text{gamma radiation}$$

(a) What type of nuclear reaction is described by this statement? 1

(b) Explain why this reaction results in the release of energy. You should make reference to an equation in your explanation. 2

(3)

7. The following statement represents a nuclear reaction which may form the basis of a nuclear power station of the future.

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + ^{1}_{0}\mathrm{n}$$

(a) State the name given to the above type of nuclear reaction. 1

(b) Explain, using $E = mc^2$, how this nuclear reaction results in the production of energy. 2

(c) Using the information given below, and any other data required from the Data Sheet, calculate the energy released in the above nuclear reaction.

$$\text{mass of } ^{3}_{1}\mathrm{H} = 5\cdot00890 \times 10^{-27}\,\mathrm{kg}$$
$$\text{mass of } ^{2}_{1}\mathrm{H} = 3\cdot34441 \times 10^{-27}\,\mathrm{kg}$$
$$\text{mass of } ^{4}_{2}\mathrm{He} = 6\cdot64632 \times 10^{-27}\,\mathrm{kg}$$
$$\text{mass of } ^{1}_{0}\mathrm{n} = 1\cdot67490 \times 10^{-27}\,\mathrm{kg}$$

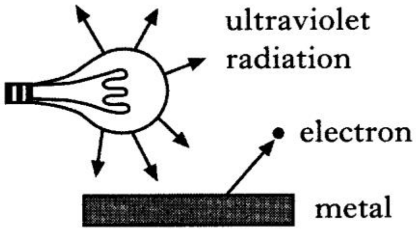
3

(d) Calculate how many of the reactions of the type represented above would occur each second to produce a power of 25 MW. 2

(8)

Section 4: Wave-particle Duality

1. 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; 1

(ii) the maximum speed of an emitted electron. 2

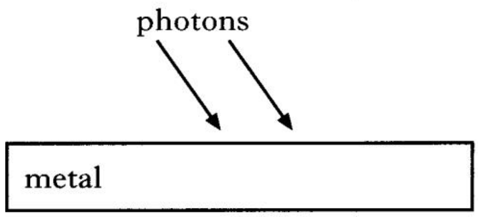
(b) The source of ultraviolet radiation is now moved further away from the surface of the metal.
State the effect, if any, this has on the maximum speed of an emitted electron. Justify your answer. 2

(5)

2. To explain the photoelectric effect, light can be considered as consisting of tiny bundles of energy. These bundles of energy are called photons.

(a) Sketch a graph to show the relationship between photon energy and frequency. 1

(b) Photons of frequency $6{\cdot}1 \times 10^{14}$ Hz are incident on the surface of a metal.



This releases photoelectrons from the surface of the metal.

The maximum kinetic energy of any of these photoelectrons is $6{\cdot}0 \times 10^{-20}$ J.

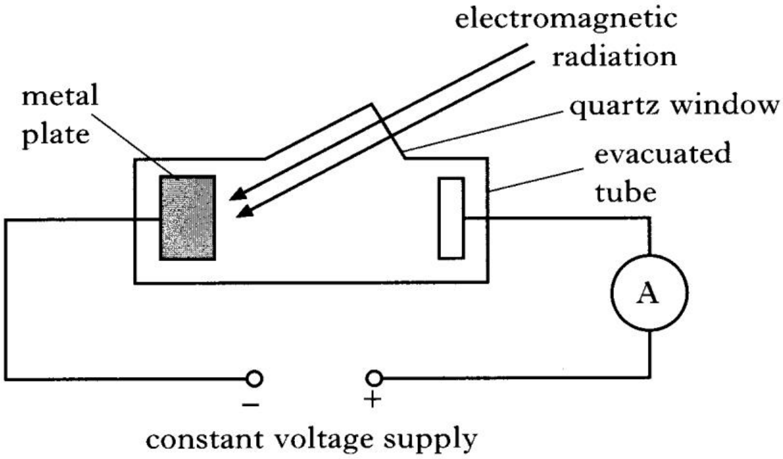
Calculate the work function of the metal. 3

(c) The irradiance due to these photons on the surface of the metal is now reduced.

Explain why the maximum kinetic energy of each photoelectron is unchanged. 1

(5)

3. 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. 2

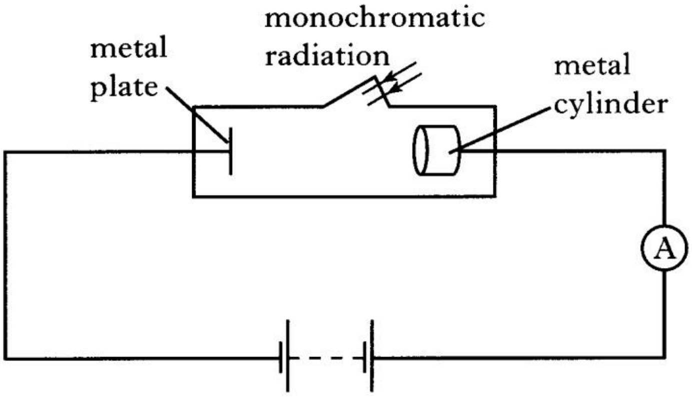
(b) The wavelength of the incident radiation is now altered. Photons of energy $5{\cdot}12 \times 10^{-19}$ J are incident on the metal plate.

(i) Calculate the maximum kinetic energy of the electrons just as they leave the metal plate. 1

(ii) The irradiance of this radiation on the metal plate is now decreased. State the effect this has on the ammeter reading. Justify your answer. 2

(5)

4. 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.
Monochromatic radiation is directed onto the plate.
Photoelectrons produced at the plate are collected by the cylinder.
The frequency and the irradiance can be altered independently.
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. 1

(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.

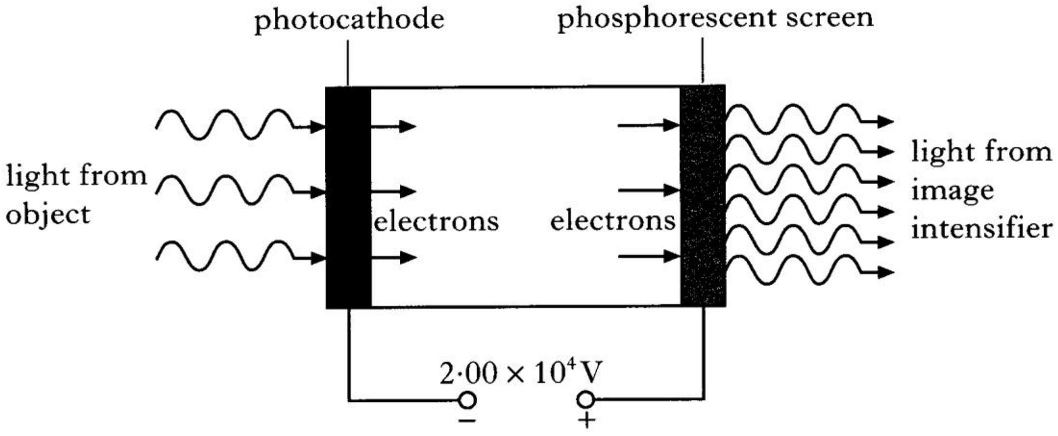
(i) Calculate the maximum kinetic energy of a photoelectron. 3

(ii) The battery connections are now reversed.
Explain why there could still be a reading on the ammeter. 1

(5)

5. An image intensifier is used to improve night vision. It does this by amplifying the light from an object.

Light incident on a photocathode causes the emission of photoelectrons. These electrons are accelerated by an electric field and strike a phosphorescent screen causing it to emit light. This emitted light is of a greater intensity than the light that was incident on the photocathode.



The voltage between the photocathode and the phosphorescent screen is $2{\cdot}00 \times 10^4$ V.

The minimum frequency of the incident light that allows photoemission to take place is $3{\cdot}33 \times 10^{14}$ Hz.

(a) What name is given to the minimum frequency of the light required for photoemission to take place? 1

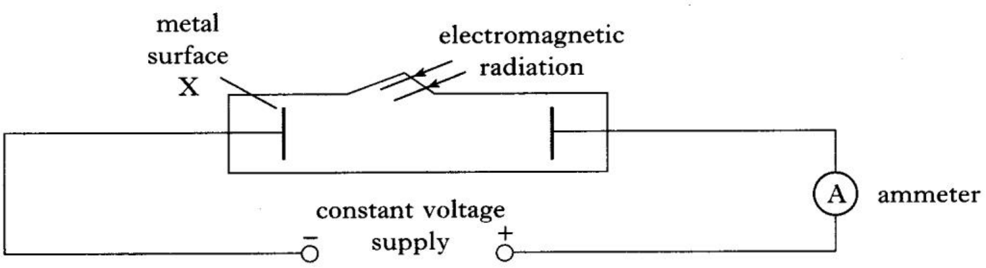
(b) (i) Show that the wok function of the photocathode material is $2{\cdot}21 \times 10^{-19}$ J. 2

(ii) Light of frequency $5{\cdot}66 \times 10^{14}$ Hz is incident on the photocathode. Calculate the maximum kinetic energy of an electron emitted from the photocathode. 2

(iii) Calculate the kinetic energy gained by an electron as it is accelerated from the photocathode to the phosphorescent screen. 2

(7)

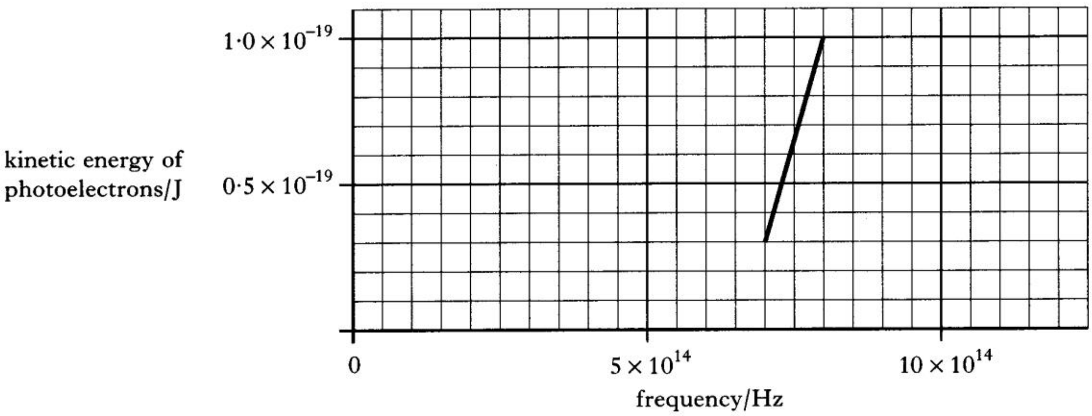
6. (a) The apparatus shown below is used to investigate photoelectric emission from the metal surface X when the electromagnetic radiation is shone on the surface.
The frequency of the electromagnetic radiation can be varied.



(i) When radiation of a certain frequency is shone on the metal surface X, a reading is obtained on the ammeter.
Sketch a graph to show how the current in the circuit varies with the irradiance of the radiation. 2

(ii) Explain why there is no reading on the ammeter when the frequency of the radiation is decreased below a particular value. 1

(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 X. 1

(ii) The table below gives the work function of different metals.

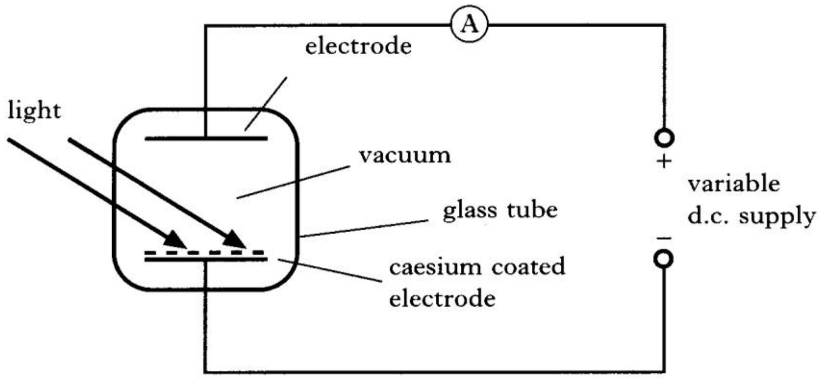
Metal	*Work function*/J
Potassium	$3{\cdot}2 \times 10^{-19}$
Calcium	$4{\cdot}3 \times 10^{-19}$
Zinc	$6{\cdot}9 \times 10^{-19}$
Gold	$7{\cdot}8 \times 10^{-19}$

Which one of these metals was used in the investigation?
You must justify your answer using the information given in the table. 3

(7)

7. (a) It is quoted in a text book that
"the work function of caesium is $3{\cdot}04 \times 10^{-19}$ J".
Explain what is meant by the above statement. 1

(b) In an experiment to investigate the photoelectric effect, a glass vacuum tube is arranged as shown below.



The tube has two electrodes, one of which is coated with caesium.
Light of frequency $6{\cdot}1 \times 10^{14}$ Hz is shone on to the caesium coated electrode.

(i) Calculate the maximum kinetic energy of a photoelectron leaving the caesium coated electrode. 3

(ii) An electron leaves the caesium coated electrode with this maximum kinetic energy.
Calculate its kinetic energy as it reaches the upper electrode when the p.d. across the electrode is 0·80 V. 3

(c) The polarity of the supply voltage is now reversed.
Calculate the minimum voltage which should be supplied across the electrodes to stop photoelectrons from reaching the upper electrode. 2

(9)

ELECTRON ARRANGEMENTS OF ELEMENTS

Key

Atomic number Symbol Electron arrangement Name

TRANSITION ELEMENTS

Group 1 (1)	Group 2 (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	Group 3 (13)	Group 4 (14)	Group 5 (15)	Group 6 (16)	Group 7 (17)	Group 0 (18)
1 H 1 Hydrogen																	2 He 2 Helium
3 Li 2,1 Lithium	4 Be 2,2 Beryllium											5 B 2,3 Boron	6 C 2,4 Carbon	7 N 2,5 Nitrogen	8 O 2,6 Oxygen	9 F 2,7 Fluorine	10 Ne 2,8 Neon
11 Na 2,8,1 Sodium	12 Mg 2,8,2 Magnesium											13 Al 2,8,3 Aluminium	14 Si 2,8,4 Silicon	15 P 2,8,5 Phosphorus	16 S 2,8,6 Sulphur	17 Cl 2,8,7 Chlorine	18 Ar 2,8,8 Argon
19 K 2,8,8,1 Potassium	20 Ca 2,8,8,2 Calcium	21 Sc 2,8,9,2 Scandium	22 Ti 2,8,10,2 Titanium	23 V 2,8,11,2 Vanadium	24 Cr 2,8,13,1 Chromium	25 Mn 2,8,13,2 Manganese	26 Fe 2,8,14,2 Iron	27 Co 2,8,15,2 Cobalt	28 Ni 2,8,16,2 Nickel	29 Cu 2,8,18,1 Copper	30 Zn 2,8,18,2 Zinc	31 Ga 2,8,18,3 Gallium	32 Ge 2,8,18,4 Germanium	33 As 2,8,18,5 Arsenic	34 Se 2,8,18,6 Selenium	35 Br 2,8,18,7 Bromine	36 Kr 2,8,18,8 Krypton
37 Rb 2,8,18,8,1 Rubidium	38 Sr 2,8,18,8,2 Strontium	39 Y 2,8,18,9,2 Yttrium	40 Zr 2,8,18,10,2 Zirconium	41 Nb 2,8,18,12,1 Niobium	42 Mo 2,8,18,13,1 Molybdenum	43 Tc 2,8,18,13,2 Technetium	44 Ru 2,8,18,15,1 Ruthenium	45 Rh 2,8,18,16,1 Rhodium	46 Pd 2,8,18,18,0 Palladium	47 Ag 2,8,18,18 1 Silver	48 Cd 2,8,18,18,2 Cadmium	49 In 2,8,18,18,3 Indium	50 Sn 2,8,18,18,4 Tin	51 Sb 2,8,18,18,5 Antimony	52 Te 2,8,18,18,6 Tellurium	53 I 2,8,18,18,7 Iodine	54 Xe 2,8,18,18,8 Xenon
55 Cs 2,8,18,18,8,1 Caesium	56 Ba 2,8,18,18,8,2 Barium	57 La 2,8,18,18,9,2 Lanthanum	72 Hf 2,8,18,32,10,2 Hafnium	73 Ta 2,8,18,32,11,2 Tantalum	74 W 2,8,18,32,12,2 Tungsten	75 Re 2,8,18,32,13,2 Rhenium	76 Os 2,8,18,32,14,2 Osmium	77 Ir 2,8,18,32,15,2 Iridium	78 Pt 2,8,18,32,17,1 Platinum	79 Au 2,8,18,32,18,1 Gold	80 Hg 2,8,18,32,18,2 Mercury	81 Tl 2,8,18,32,18,3 Thallium	82 Pb 2,8,18,32,18,4 Lead	83 Bi 2,8,18,32,18,5 Bismuth	84 Po 2,8,18,32,18,6 Polonium	85 At 2,8,18,32,18,7 Astatine	86 Rn 2,8,18,32,18,8 Radon
87 Fr 2,8,18,32,18,8,1 Francium	88 Ra 2,8,18,32,18,8,2 Radium	89 Ac 2,8,18,32,18,9,2 Actinium	104 Rf 2,8,18,32,32,10,2 Rutherfordium	105 Db 2,8,18,32,32,11,2 Dubnium	106 Sg 2,8,18,32,32,12,2 Seaborgium	107 Bh 2,8,18,32,32,13,2 Bohrium	108 Hs 2,8,18,32,32,14,2 Hassium	109 Mt 2,8,18,32,32,15,2 Meitnerium									

LANTHANIDES	57 La 2,8,18,18,9,2 Lanthanum	58 Ce 2,8,18,20,8,2 Cerium	59 Pr 2,8,18,21,8,2 Praseodymium	60 Nd 2,8,18,22,8,2 Neodymium	61 Pm 2,8,18,23,8,2 Promethium	62 Sm 2,8,18,24,8,2 Samarium	63 Eu 2,8,18,25,8,2 Europium	64 Gd 2,8,18,25,9,2 Gadolinium	65 Tb 2,8,18,27,8,2 Terbium	66 Dy 2,8,18,28,8,2 Dysprosium	67 Ho 2,8,18,29,8,2 Holmium	68 Er 2,8,18,30,8,2 Erbium	69 Tm 2,8,18,31,8,2 Thulium	70 Yb 2,8,18,32,8,2 Ytterbium	71 Lu 2,8,18,32,9,2 Lutetium
ACTINIDES	89 Ac 2,8,18,32,18,9,2 Actinium	90 Th 2,8,18,32,18,10,2 Thorium	91 Pa 2,8,18,32,20,9,2 Protactinium	92 U 2,8,18,32,21,9,2 Uranium	93 Np 2,8,18,32,22,9,2 Neptunium	94 Pu 2,8,18,32,24,8,2 Plutonium	95 Am 2,8,18,32,25,8,2 Americium	96 Cm 2,8,18,32,25,9,2 Curium	97 Bk 2,8,18,32,27,8,2 Berkelium	98 Cf 2,8,18,32,28,8,2 Californium	99 Es 2,8,18,32,29,8,2 Einsteinium	100 Fm 2,8,18,32,30,8,2 Fermium	101 Md 2,8,18,32,31,8,2 Mendelevium	102 No 2,8,18,32,32,8,2 Nobelium	103 Lr 2,8,18,32,32,9,2 Lawrencium