# 2004 PHYSICS

ATTACH SACE REGISTRATION NUMBER LABEL TO THIS BOX

QUESTION BOOKLET
**1**
16 pages, 1 question

**Tuesday 2 November: 9 a.m.**

Time: 3 hours

## Question Booklet 1

Examination material: Question Booklet 1 (16 pages)
Question Booklet 2 (8 pages)
Question Booklet 3 (21 pages)
SACE registration number label

*Approved dictionaries and calculators may be used.*

**Instructions to Candidates**

1. You will have 10 minutes to read the paper. You must not write in your question booklets or use a calculator during this reading time but you may make notes on the scribbling paper provided.
2. This paper is in three sections. Section A is in Question Booklet 1, Section B is in Question Booklet 2, and Section C is in Question Booklet 3.

   **Question Booklet 1**
   **Section A** (Question 1)
   Answer ***all parts*** of this short-answer question in the spaces provided in this booklet.
   You may write on page 16 if you need more space to finish your answers to Section A.

   **Question Booklet 2**
   **Section B** (Questions 2 and 3)
   This section consists of essay questions. Answer ***either*** Question 2 ***or*** Question 3 on the pages provided in Question Booklet 2.

   **Question Booklet 3**
   **Section C** (Questions 4 to 8)
   This section consists of extended questions. Answer ***all*** questions in this section.
   Write your answers in the spaces provided in Question Booklet 3.
   You may write on page 21 if you need more space to finish your answers to Section C.
3. The allocation of marks and the suggested allotment of time are:

| | | |
|---|---|---|
| Section A | 70 marks | 50 minutes |
| Section B | 30 marks | 30 minutes |
| Section C | 100 marks | 100 minutes |
| TOTAL | 200 marks | 180 minutes |

4. The equation sheet is on pages 3 and 4, which you may remove from this booklet.
5. Vector quantities in this paper are represented by symbols in bold type.
6. Marks may be deducted if you do not clearly show all steps in the solution of problems or if you do not define additional symbols. You should use diagrams where appropriate in your answers.
7. Use only black or blue pens for all work other than graphs and diagrams, for which you may use a sharp dark pencil.
8. Attach your SACE registration number label to the box at the top of this page. Copy the information from your SACE registration number label into the boxes on the front covers of Question Booklet 2 and Question Booklet 3.
9. At the end of the examination, place Question Booklet 2 and Question Booklet 3 inside the back cover of Question Booklet 1.

**STUDENT'S DECLARATION ON THE USE OF CALCULATORS**

By signing the examination attendance roll I declare that:

- my calculators have been cleared of all memory;
- no external storage media are in use on these calculators.

I understand that if I do not comply with the above conditions for the use of calculators I will be in breach of the rules and liable to a penalty of receiving zero marks for the examination.

*You may remove this page from the booklet by tearing along the perforations so that you will have the information in front of you for easy reference.*

## EQUATION SHEET

The following tables show the symbols of common quantities and physical constants used in the equations.
Other symbols used are shown next to the equations. Vectors are shown in bold type. If only the magnitude of a vector quantity is used, the symbol is not shown in bold type.

### Symbols of Common Quantities

| | | | | | |
|---|---|---|---|---|---|
| acceleration | $\mathbf{a}$ | wavelength | $\lambda$ | momentum | $\mathbf{p}$ |
| time | $t$ | force | $\mathbf{F}$ | electric field | $\mathbf{E}$ |
| displacement | $\mathbf{s}$ | charge | $q$ | kinetic energy | $K$ |
| velocity | $\mathbf{v}$ | mass | $m$ | magnetic field | $\mathbf{B}$ |
| period | $T$ | potential difference | $\Delta V$ | electric current | $I$ |
| frequency | $f$ | | | | |

### Physical Constants

| | | | |
|---|---|---|---|
| Constant of universal gravitation | $G = 6.67 \times 10^{-11}$ N m$^2$ kg$^{-2}$ | Mass of the electron | $m_e = 9.11 \times 10^{-31}$ kg |
| Speed of light in a vacuum | $c = 3.00 \times 10^8$ m s$^{-1}$ | Mass of the proton | $m_p = 1.673 \times 10^{-27}$ kg |
| Coulomb's law constant | $\frac{1}{4\pi\varepsilon_0} = 9.00 \times 10^9$ N m$^2$ C$^{-2}$ | Mass of the neutron | $m_n = 1.675 \times 10^{-27}$ kg |
| Planck's constant | $h = 6.63 \times 10^{-34}$ J s | Mass of the $\alpha$ particle | $m_\alpha = 6.645 \times 10^{-27}$ kg |
| Charge of the electron | $e = 1.60 \times 10^{-19}$ C | | |

### Section 1: Motion in Two Dimensions

$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$ — $\mathbf{v}$ = velocity at time $t$; $\mathbf{v}_0$ = velocity at $t = 0$

$v^2 = v_0^2 + 2as$

$\mathbf{s} = \mathbf{v}_0 t + \frac{1}{2}\mathbf{a}t^2$

$\Delta\mathbf{v} = \mathbf{v}_f - \mathbf{v}_i$ — $\mathbf{v}_f$ = final velocity; $\mathbf{v}_i$ = initial velocity

$\bar{\mathbf{a}} = \frac{\Delta\mathbf{v}}{\Delta t}$ — $\bar{\mathbf{a}}$ = average acceleration

$a = \frac{v^2}{r}$ — $r$ = radius of circle

$v_H = v\cos\theta$

$v_V = v\sin\theta$

$v = \frac{2\pi r}{T}$

$\tan\theta = \frac{v^2}{rg}$

$F = G\frac{m_1 m_2}{r^2}$ — $r$ = distance between masses $m_1$ and $m_2$

$v = \sqrt{\frac{GM}{r}}$ — $M$ = mass of object orbited by satellite; $r$ = radius of orbit

$\mathbf{F} = m\mathbf{a}$

$\mathbf{p} = m\mathbf{v}$

$\mathbf{F} = \frac{\Delta\mathbf{p}}{\Delta t}$

$K = \frac{1}{2}mv^2$

**Section 2: Electricity and Magnetism**

$F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q_1 q_2}{r^2}$ $r$ = distance between charges $q_1$ and $q_2$

$\boldsymbol{E} = \dfrac{\boldsymbol{F}}{q}$

$E = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r^2}$

$W = q\Delta V$ $W$ = work done on the charge

$E = \dfrac{\Delta V}{d}$ $d$ = distance between plates

$\boldsymbol{a} = \dfrac{q\boldsymbol{E}}{m}$

$F = I\Delta l B \sin\theta$ $\theta$ = angle between field $\boldsymbol{B}$ and current element $I\Delta\boldsymbol{l}$

$F = qvB\sin\theta$ $\theta$ = angle between field $\boldsymbol{B}$ and velocity $\boldsymbol{v}$

$r = \dfrac{mv}{qB}$

$T = \dfrac{2\pi m}{qB}$

$K = \dfrac{q^2B^2r^2}{2m}$

**Section 3: Light and Matter**

$c = f\lambda$ $c$ = speed of light

$d\sin\theta = m\lambda$ $d$ = distance between slits
$m$ = integer (0, 1, 2, . . . )

$\Delta y = \dfrac{\lambda L}{d}$ $\Delta y$ = distance between adjacent minima or maxima

$L$ = slit-to-screen distance

$E = hf$

$K_{max} = hf - W$ $W$ = work function of the metal

$f_{max} = \dfrac{e\Delta V}{h}$ $\Delta V$ = tube potential difference

$p = \dfrac{h}{\lambda}$

**Section 4: Atoms and Nuclei**

$E_n - E_m = hf$

$A = Z + N$ $A$ = mass number of nucleus
$Z$ = atomic number of nucleus
$N$ = number of neutrons

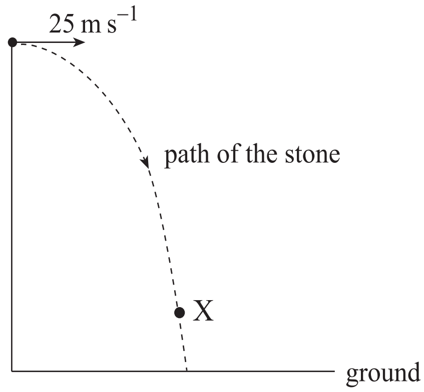
$E_b = \Delta mc^2$ $E_b$ = binding energy
$\Delta m$ = mass defect

## SECTION A (Question 1)

(70 marks)

*Answer ALL parts of this question in the spaces provided.*

1. (a) A stone is thrown from a position near the surface of the Earth with an initial horizontal velocity of 25 m $s^{-1}$, as shown in the diagram below. The vertical component of the velocity of the stone at point X is 36 m $s^{-1}$. *Assume air resistance is negligible*.




(i) Draw and label a vector diagram to show the addition of the horizontal and vertical components of the velocity of the stone at the instant it reaches point X.
(The diagram does not need to be drawn to scale.)

(2 marks)

(ii) Calculate the magnitude and direction of the velocity of the stone at point X.

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(b) Describe and explain the effect that increasing the launch height of a shot-put has on the maximum range. *Assume air resistance is negligible.*

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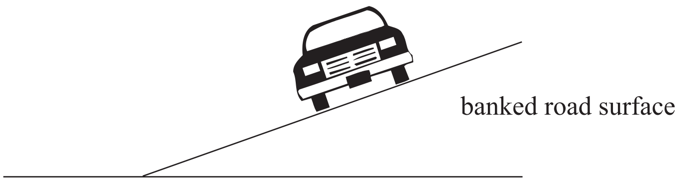
______________________________________________________________ (3 marks)

(c) A car travelling with uniform circular motion round a banked curve on a road is shown in the diagram below:




(i) On the diagram above, draw and label vectors to represent the normal force and the gravitational force acting on the car. (2 marks)

(ii) Using the diagram above, explain the *cause* of the centripetal acceleration that enables the car to travel round the banked curve without moving up or down the slope of the road surface.

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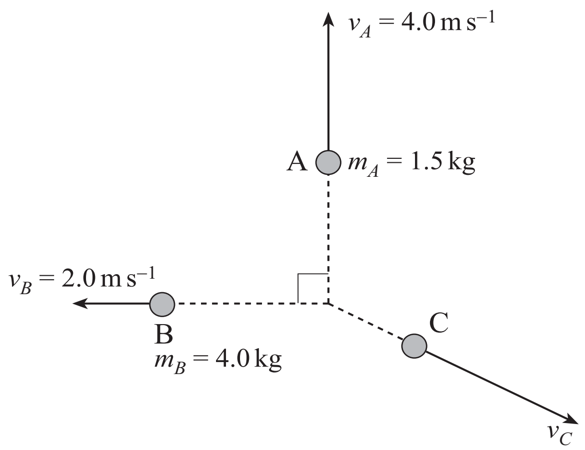
______________________________________________________________ (3 marks)

(d) A mass of 8.0 kg that is initially at rest explodes into three fragments, A, B, and C.

After the explosion:

- fragment A has a mass $m_A$ = 1.5 kg and a speed $v_A$ = 4.0 m s$^{-1}$;
- fragment B has a mass $m_B$ = 4.0 kg and a speed $v_B$ = 2.0 m s$^{-1}$.

Fragment A and fragment B move at 90° to each other, as shown in the diagram below. *Assume the system is isolated.*




(i) Using vector addition, determine the magnitude of the *sum* of the momenta of fragment A and fragment B after the explosion.

(4 marks)

(ii) State the magnitude of the momentum of fragment C.

(1 mark)

(e) State why it is important to increase the number of measurements made in an experiment.

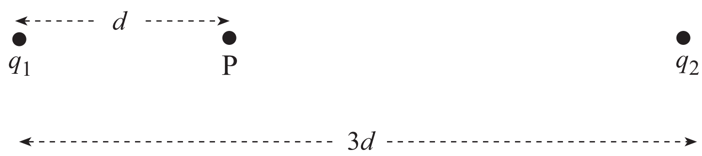
(1 mark)

(f) A student conducts an experiment to investigate the relationship between the magnetic force and the current flowing in a wire when it is suspended in a magnetic field. The student measures and records values of the magnetic force as the current in the wire is varied.

State one factor that the student would need to hold constant during the experiment.

______________________________________________ (1 mark)

(g) Two point charges, $q_1$ and $q_2$, are separated by a distance $3d$ in a vacuum, as shown in the diagram below. Point P is situated on a line between $q_1$ and $q_2$, at a distance $d$ from $q_1$.




(i) Write an expression in terms of $q_1$ and $d$ for the electric field at point P due to point charge $q_1$.

______________________________________________ (1 mark)

(ii) The strength of the electric field at point P is zero.

Calculate the ratio $q_1 : q_2$ of the point charges.

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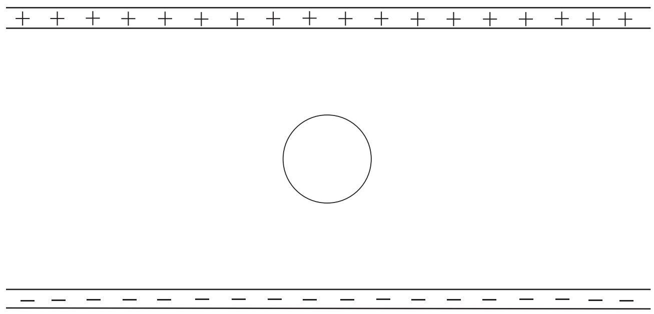
______________________________________________ (3 marks)

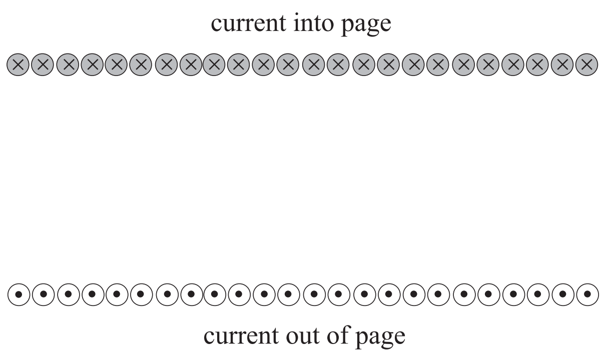
(h) The diagram below shows an uncharged metal sphere between a section of two equally and oppositely charged and *infinitely* long parallel conducting plates in a vacuum.

On the diagram below, sketch the resultant electric field.



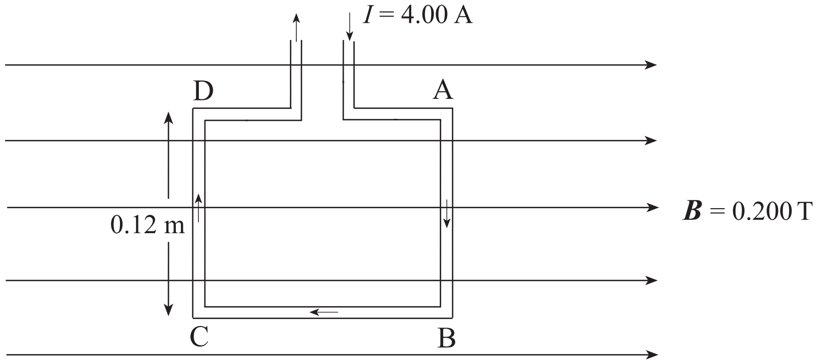
(3 marks)

(i) On the diagram below, sketch the magnetic field of a current-carrying solenoid that consists of many tightly wound coils of wire. The direction of the current is indicated on the diagram.




(3 marks)

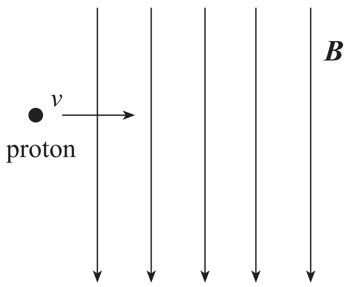
(j) A square loop of wire, ABCD, with sides of length 0.12 m, is shown in the diagram below. A current $I$ of 4.00 A flows in a clockwise direction through the loop of wire. The wire is suspended in a uniform magnetic field $\boldsymbol{B}$ = 0.200 T directed to the right.




Calculate the magnitude and state the direction of the magnetic force acting on side AB of the loop of wire.

(3 marks)

(k) A proton enters a uniform magnetic field in an evacuated chamber. The initial velocity $v$ of the proton is perpendicular to the magnetic field, as shown in the diagram below:




(i) Explain why the kinetic energy of the proton remains constant. (*Ignore gravity.*)

(4 marks)

(ii) Describe and explain the path of a neutron that enters the magnetic field at the same position and velocity as the proton.

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______________________________________________________________________ (4 marks)

(l) Explain why a cyclotron must be evacuated.

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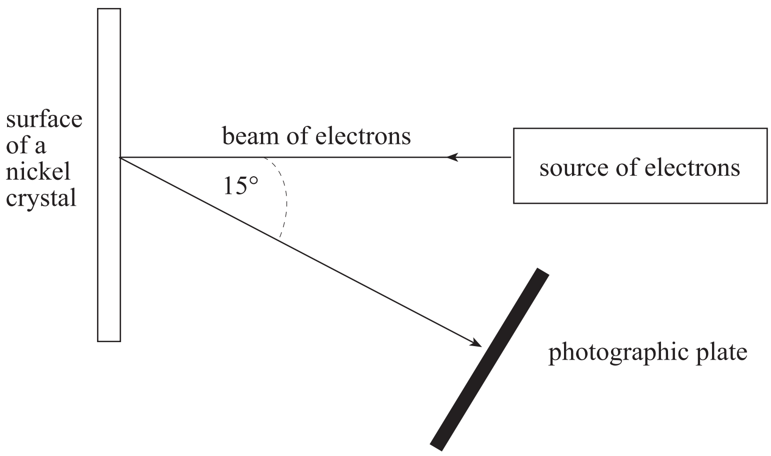
______________________________________________________________________ (3 marks)

(m) A beam of electrons is directed onto the surface of a nickel crystal. A photographic plate is used to detect the scattered electrons, as shown in the diagram below:




(i) The speed of an electron in the beam is $8.5 \times 10^6$ m s$^{-1}$.

Show that the wavelength of the electron is approximately $8.6 \times 10^{-11}$ m.

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______________________________________________________________________ (2 marks)

(ii) The first-order beam of the diffracted electrons is measured at an angle of 15° to the incident beam, as shown in the diagram on page 11.

Calculate the interatomic spacing of the nickel crystal.

(2 marks)

(n) The potential difference across an X-ray tube is increased.

Explain the effect this will have on the hardness of the X-rays produced by the X-ray tube.

(2 marks)

(o) A transmission diffraction grating has 4300 lines per centimetre.

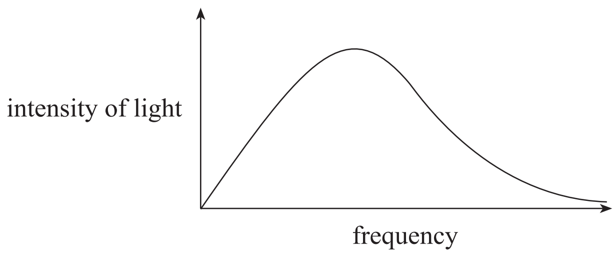
Calculate the maximum possible order that could be observed if the incident light had a wavelength $\lambda = 5.1 \times 10^{-7}$ m.

(3 marks)

(p) Explain why transmissions from some country television channels are polarised at right angles to those of city channels.

(2 marks)

(q) The diagram below represents the frequency distribution of the intensity of the light produced by a heated filament wire at low temperature:




On the diagram above, draw the frequency distribution of light that would be produced if the temperature of the filament wire were increased.

(2 marks)

(r) A 16.0 g sample of carbon is obtained from the thigh bone of a human skeleton. Investigators believe the skeleton is 17 193 years old.

A 1.00 g sample of carbon from the thigh bone of a living human being has a carbon-14 decay rate of 15 decays per minute. Carbon-14 has a half-life of 5730 years.

Calculate the activity that you would expect of the sample obtained from the skeleton.

(3 marks)

(s) The fusion of two isotopes of hydrogen is shown in the equation below:

$$^{1}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He$$

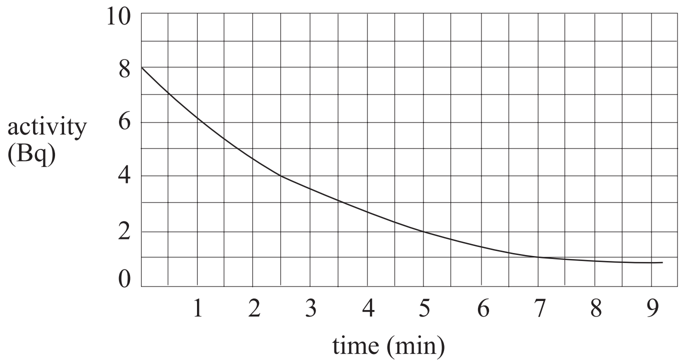
The masses of the particles in the equation above are:

$$^{1}_{1}H = 1.673292 \times 10^{-27} \text{ kg}$$
$$^{2}_{1}H = 3.344014 \times 10^{-27} \text{ kg}$$
$$^{3}_{2}He = 5.007946 \times 10^{-27} \text{ kg.}$$

Calculate, in MeV, the amount of energy that would be released in the reaction.

________________________________________ (4 marks)

(t) The activity of a radioactive sample against time is shown in the graph below:




(i) Using the graph above, state the activity of the sample at 3 minutes.

________________________________________ (1 mark)

(ii) (1) On the graph above, show how you would determine the half-life of the sample. (1 mark)

(2) State the value of the half-life. ____________________ (1 mark)

(u) Describe how the conditions in the interior of the Sun allow nuclear fusion to take place.

(3 marks)

*You may write on this page if you need more space to finish your answers to Section A. Make sure to label each answer carefully (e.g. 1(d)(i) continued).*

# 2004 PHYSICS, Question Booklet 1

## Erratum

page 14

(s) Delete ‘atomic’ from line 3.

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PUBLIC EXAMINATION 2004

# 2004 PHYSICS

SACE REGISTRATION NUMBER

SEQ | FIGURES | CHECK LETTER | BIN

PHYSICS

QUESTION BOOKLET
2
8 pages, 2 questions

## Question Booklet 2

**Tuesday 2 November: 9 a.m.**

*Write your answer to Section B in this question booklet.*

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**SECTION B** (Questions 2 and 3)

(30 marks)

*Answer EITHER Question 2 OR Question 3.*

*Write your essay on pages 5 to 8.*

*In answering the essay question, you should communicate your knowledge and understanding of physics concisely, precisely, and logically.*

*Include only information that is related to the question.*

*Use clearly labelled diagrams that are related to your answer.*

2. Write an essay in which you discuss an experiment that involves the use of a transmission diffraction grating of known slit separation to calculate the wavelength of a monochromatic light source.

Your essay should include:

- a description of the experimental arrangement, including a labelled diagram of the apparatus;
- a description of the pattern observed;
- a description of the experimental procedure used, including a statement of all measurements required;
- an explanation of how you would reduce the effect of errors in your measurements;
- an explanation of how you would calculate the wavelength of the monochromatic light source.

(30 marks)

3. Write an essay in which you discuss the nature and properties of the particle emissions from radioactive nuclei, and the effects of these emissions on living matter.

Your essay should include:

- a comparison of the penetration through matter of alpha, beta, and gamma radiations, and an explanation of why alpha is the least penetrating radiation;
- an explanation of why emitted alpha particles have a small number of discrete energies, and why they are often accompanied by the emission of gamma rays;
- a justification for the emission of an antineutrino in beta minus decay;
- a description of how ionising radiation can damage living matter, with two examples of how radiation dosages from a radioactive source can be minimised.

(30 marks)

*Write your Section B essay on the following pages (5 to 8).*

Question number answered

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PUBLIC EXAMINATION 2004

# 2004 PHYSICS

SACE REGISTRATION NUMBER

SEQ | FIGURES | CHECK LETTER | BIN

PHYSICS

QUESTION BOOKLET
3
21 pages, 5 questions

## Question Booklet 3

**Tuesday 2 November: 9 a.m.**

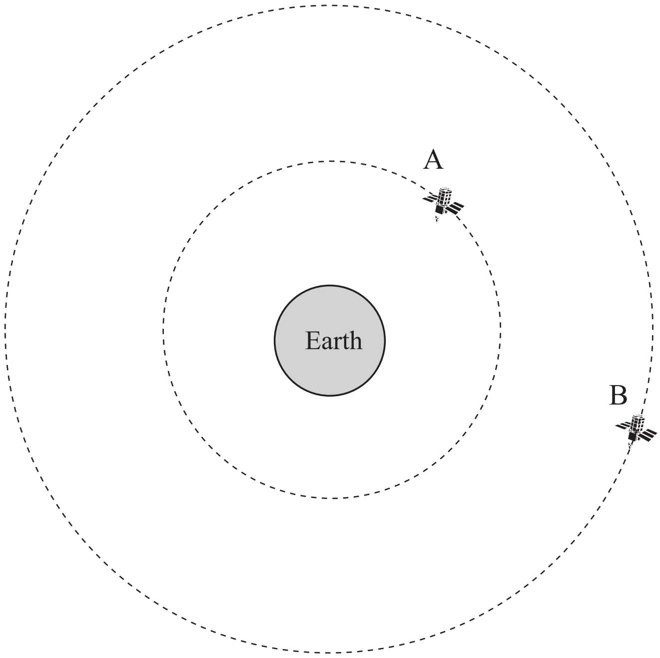
*Write your answers to Section C in this question booklet.*

## SECTION C (Questions 4 to 8)

(100 marks)

*Answer ALL questions in this section. Write your answers in the spaces provided.*

4. Two satellites, A and B, orbit the Earth, as shown in the diagram below. Both satellites are in circular orbits. The radius of satellite B is greater than the radius of satellite A.




[*This diagram is not drawn to scale.*]

(a) On the diagram above, draw and label vectors to represent the acceleration of satellite A and satellite B.

(2 marks)

(b) Satellite A orbits at a radius of $2.112 \times 10^7$ m. Satellite B orbits at a radius of $4.224 \times 10^7$ m and at a speed of 3072 m $s^{-1}$.

(i) Show that the speed $v$ of a satellite of mass $m_s$, moving in an orbit of radius $r$ round a planet of mass $M$, is given by $v = \sqrt{\frac{GM}{r}}$, where $G$ is the constant of universal gravitation.

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______________________________________________ (2 marks)

(ii) Hence show that the mass of the Earth is approximately $5.98 \times 10^{24}$ kg.

(2 marks)

(iii) Calculate the orbital speed of satellite A.

(2 marks)

(iv) Calculate the orbital period of satellite B.

(2 marks)

(c) Geostationary satellites move in an equatorial orbit in the same direction as the Earth's rotation.

Explain why geostationary satellites have orbits of relatively large radius.

(2 marks)

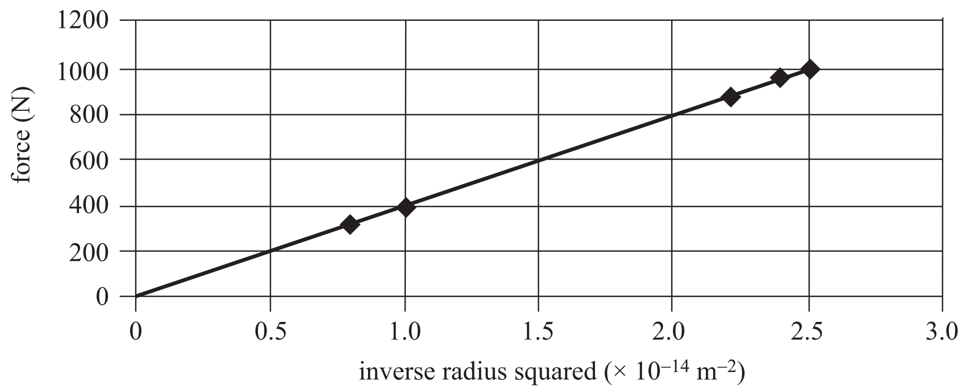
(d) Two satellites of equal mass orbit the Earth. One satellite has a radius of $r_1$ and the other has a radius of $r_2$. Radius $r_1$ is twice the value of radius $r_2$.

Calculate the ratio $F_1 : F_2$ of the gravitational forces acting on the satellites.

(3 marks)

(e) An object is placed at different radii $r$, measured from the centre of the Earth. The force $F$ acting on the object is measured at each position.

The graph of the force versus the inverse radius squared ($^1/r^2$) is shown below:




(i) Using the graph above, determine the distance $r$ between the Earth and the object when the force is 600 N.

(2 marks)

(ii) Show without calculation that the gradient of the line of best fit on the graph opposite should be equal to *GMm*, where *G* is the constant of universal gravitation, *M* is the mass of the Earth, and *m* is the mass of the object.

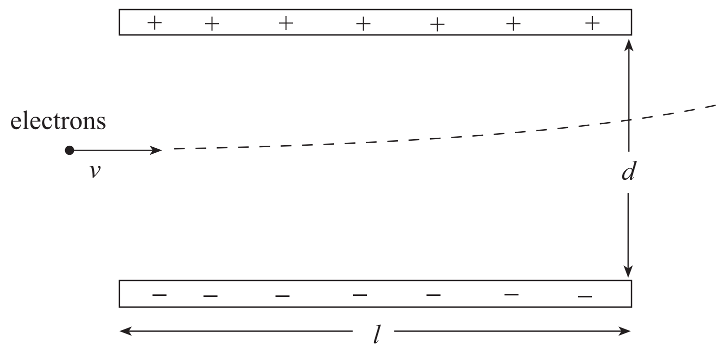
(3 marks)

5. Electrons in a vacuum tube are accelerated from rest by a potential difference of 8000 V. (*Ignore the gravitational force acting on the electrons*.)

(a) Show that the speed $v$ of an electron in this vacuum tube after acceleration is approximately $5.30 \times 10^7$ m s$^{-1}$.

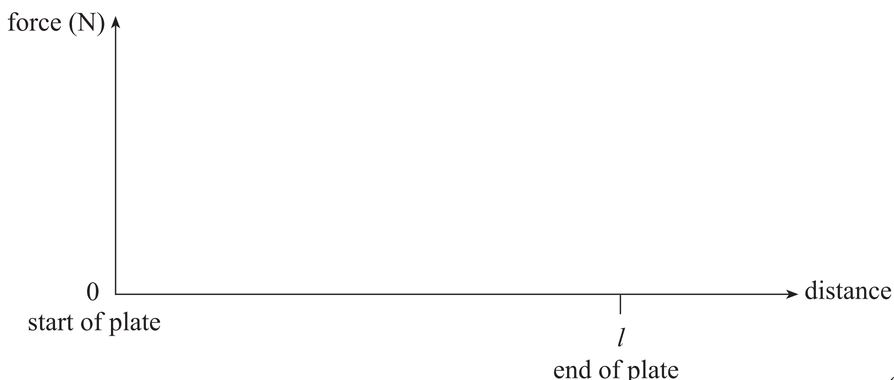
(3 marks)

(b) The electrons then pass between two equally and oppositely charged metal plates of length $l$ that are separated by a distance $d$. The potential difference between the plates is $\Delta V$. (*Assume the electric field is uniform between the plates.*)




[*This diagram is not drawn to scale.*]

On the axes below, sketch a graph of the force $\boldsymbol{F}$ acting on an electron against the distance travelled parallel to the plates. (*Calculations are not required.*)




(2 marks)

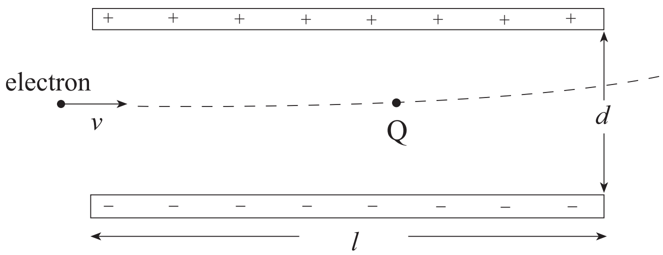
(c) Show that the magnitude of the acceleration of an electron in the uniform electric field is given by

$$a = \frac{q\Delta V}{md}.$$

(2 marks)

(d) The plates are separated by a distance $d = 8.0 \times 10^{-3}$ m. The potential difference $\Delta V$ between the plates is 240 V.

The electron, moving at an initial speed $v = 5.30 \times 10^{7}$ m s$^{-1}$, enters midway between the plates. The motion of the electron is in the plane of the page and perpendicular to the electric field, as shown in the diagram below:




[*This diagram is not drawn to scale*.]

(i) State the magnitude of the component of the velocity of the electron that is *perpendicular* to the electric field at point Q.

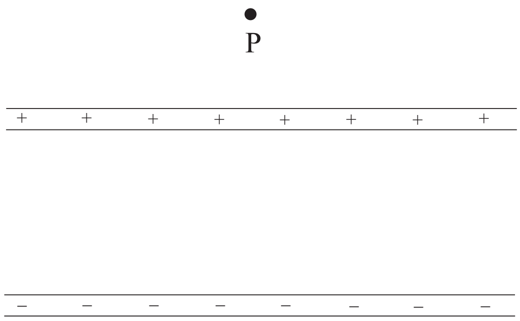
(1 mark)

(ii) Calculate the magnitude of the velocity of the electron at point Q on the diagram $9.0 \times 10^{-10}$ s after it enters the electric field.

*space for optional vector diagram*

(5 marks)

(e) The diagram below shows a section of two equally and oppositely charged and *infinitely* long conducting plates and a point P outside the plates:




[*This diagram is not drawn to scale.*]

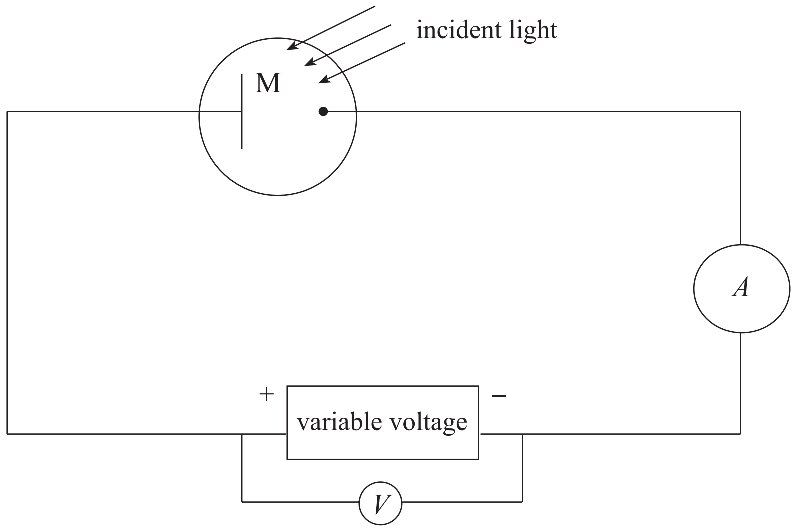
Explain why there would be no electric field at point P.

(4 marks)

(f) Describe how ions can be accelerated to high energies in a cyclotron.

(3 marks)

6. Light is incident on a metal plate M, which is enclosed in an evacuated glass envelope, as shown in the diagram below. The current flow as a result of electrons ejected by the light is shown on the ammeter *A*. The current flow is reduced to zero by the use of a variable voltage supply. The stopping voltage is measured on the voltmeter *V*.




(a) In the experiment shown above, the frequency of the incident light is $6.0 \times 10^{14}$ Hz.

(i) Calculate, in eV, the energy of the incident photons used in this experiment.

(3 marks)

(ii) Calculate the work function *W* of the metal plate if the stopping voltage is recorded as 1.49 V.

(4 marks)

(b) The variable voltage is adjusted to a value lower than that of the stopping voltage so that a measurable current is shown on ammeter $A$. The intensity of the light is then increased, but its frequency remains the same.

(i) State and explain the effect this change would have on the current.

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______________________________ (2 marks)

(ii) The stopping voltage is measured using this higher intensity light.

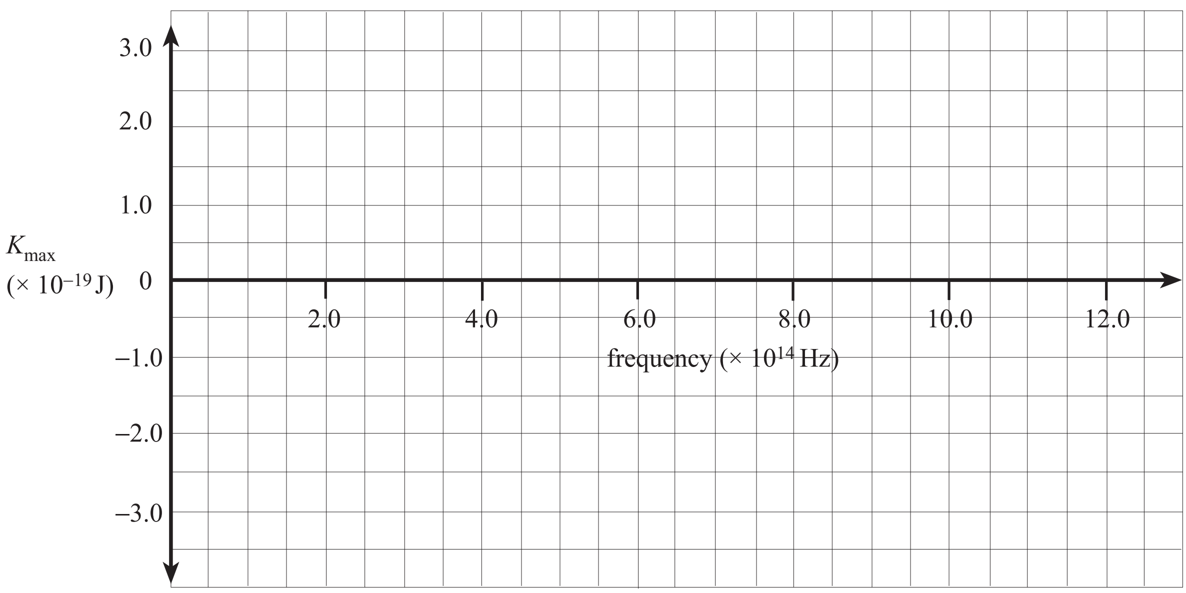
State whether the change in intensity of light would affect the previously measured stopping voltage.

______________________________ (1 mark)

(c) A similar experiment is conducted using a second metal plate P. The maximum kinetic energy of the electrons $K_{max}$ is determined for a number of different incident frequencies, as summarised in the table below:

| Incident frequency ($\times 10^{14}$ Hz) | $K_{max}$ ($\times 10^{-19}$ J) |
|---|---|
| 11.8 | 2.60 |
| 9.90 | 1.81 |
| 8.20 | 1.10 |
| 6.90 | 0.57 |

(i) On the grid below, plot these results on a graph of $K_{max}$ versus incident frequency and draw the line of best fit.




(3 marks)

(ii) Using the line of best fit that you have drawn on the graph in part (c)(i):

(1) state the value of the threshold frequency $f_0$ of the metal plate P.

(1 mark)

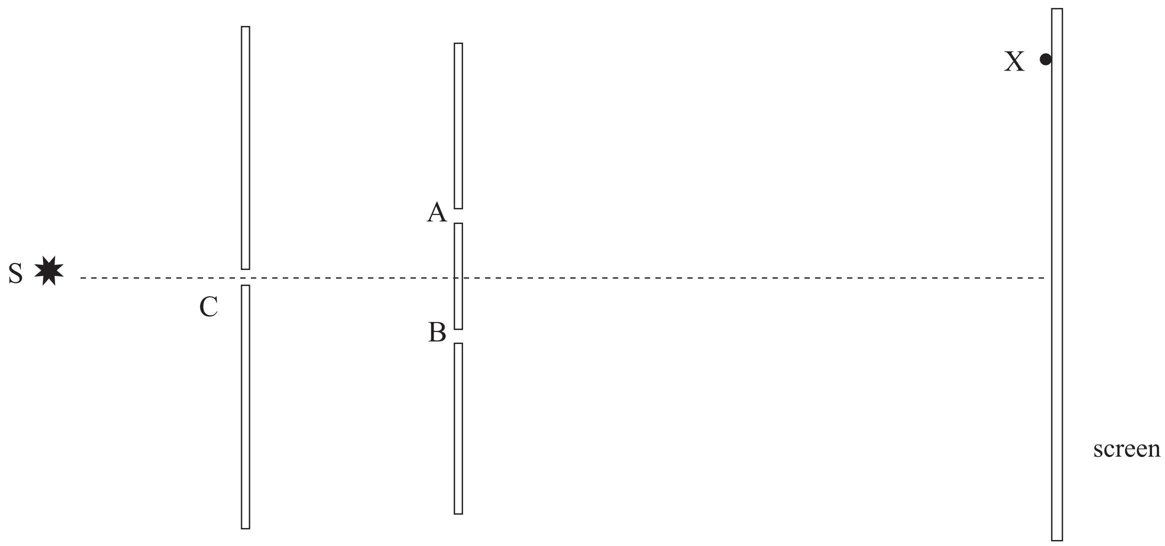
(2) clearly mark the position of $f_0$ on the graph. (1 mark)

(3) state the value of the work function $W$ of the metal plate.

(1 mark)

(4) clearly mark the position of $W$ on the graph. (1 mark)

(d) Monochromatic incoherent light produced by source S illuminates a narrow slit C. The light, after passing through C, then illuminates the two narrow slits A and B. An interference pattern is observed on the screen. The two-slit arrangement is shown in the diagram below:




[*This diagram is not drawn to scale.*]

(i) Consider point X on the screen.

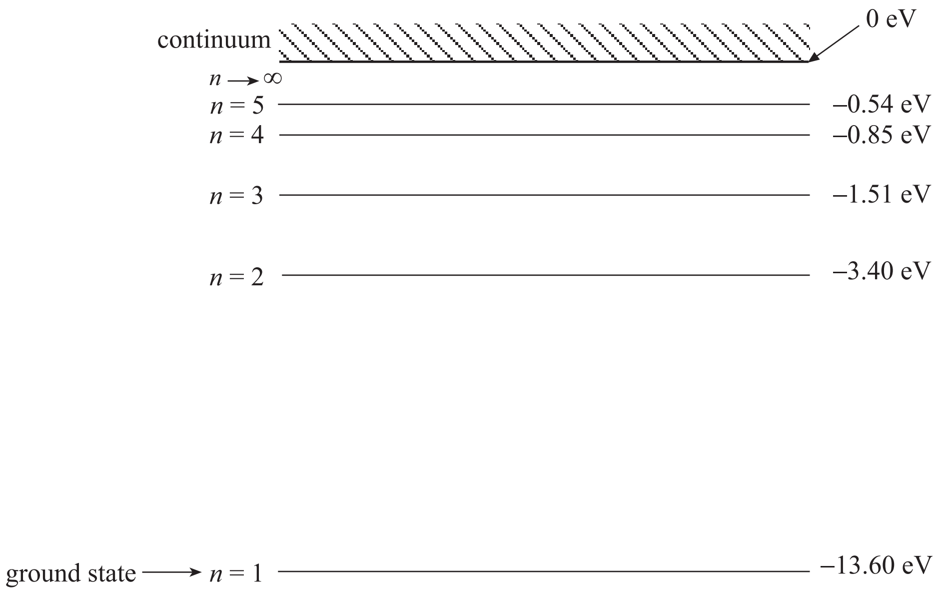
Explain what is meant by the statement: 'The waves radiated by slits A and B arrive out of phase at point X.'

(2 marks)

(ii) State the purpose of using the single slit C for observable interference in this arrangement.

(1 mark)

7. Some of the energy levels for a hydrogen atom are shown in the diagram below:




[*This diagram is not drawn to scale.*]

(a) (i) On the diagram above, draw a line representing the transition from the $n = 3$ level to the $n = 2$ level.

(1 mark)

(ii) Calculate the wavelength of the photon emitted when an electron undergoes a transition from the $n = 3$ level to the $n = 2$ level.

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______________________________ (4 marks)

(b) Explain what is meant by the ionisation energy of an atom.

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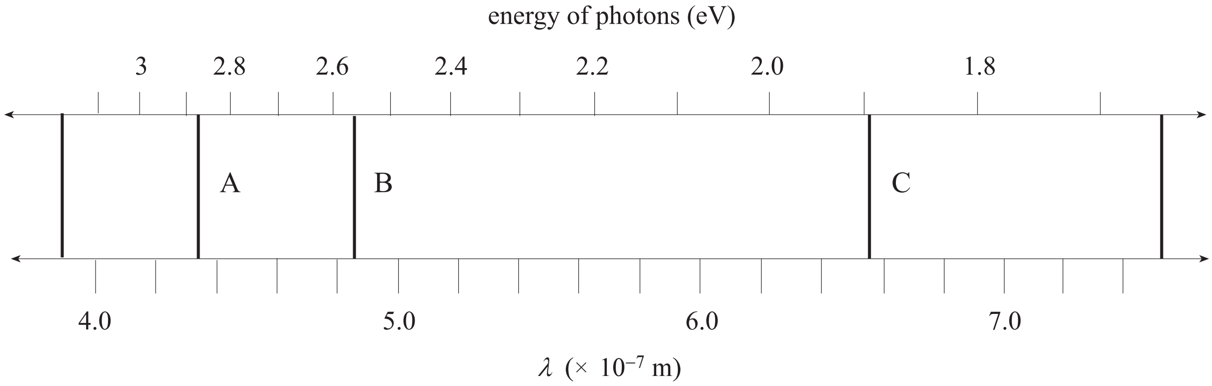
______________________________ (2 marks)

(c) A student used a spectroscope to view the emission spectrum of atomic hydrogen. The student observed three distinct lines, A, B, and C, as shown in the diagram below. The wavelength $\lambda$ and the energy of the photon corresponding to the wavelength can be estimated from the scales shown.




(i) Estimate the wavelength of the line marked B on the diagram.

________________________________________ (1 mark)

(ii) State which one of lines A, B, and C represents the transition from the $n = 3$ level to the $n = 2$ level.

________________________________________ (1 mark)

(iii) An emission line with a wavelength of $4.10 \times 10^{-7}$ m can also be produced by atomic hydrogen but was not observed.

Using the diagram, estimate the energy of the photons that produce this line.

________________________________________

________________________________________ (1 mark)

(d) Explain what is meant by the process of fluorescence.

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________________________________________ (3 marks)

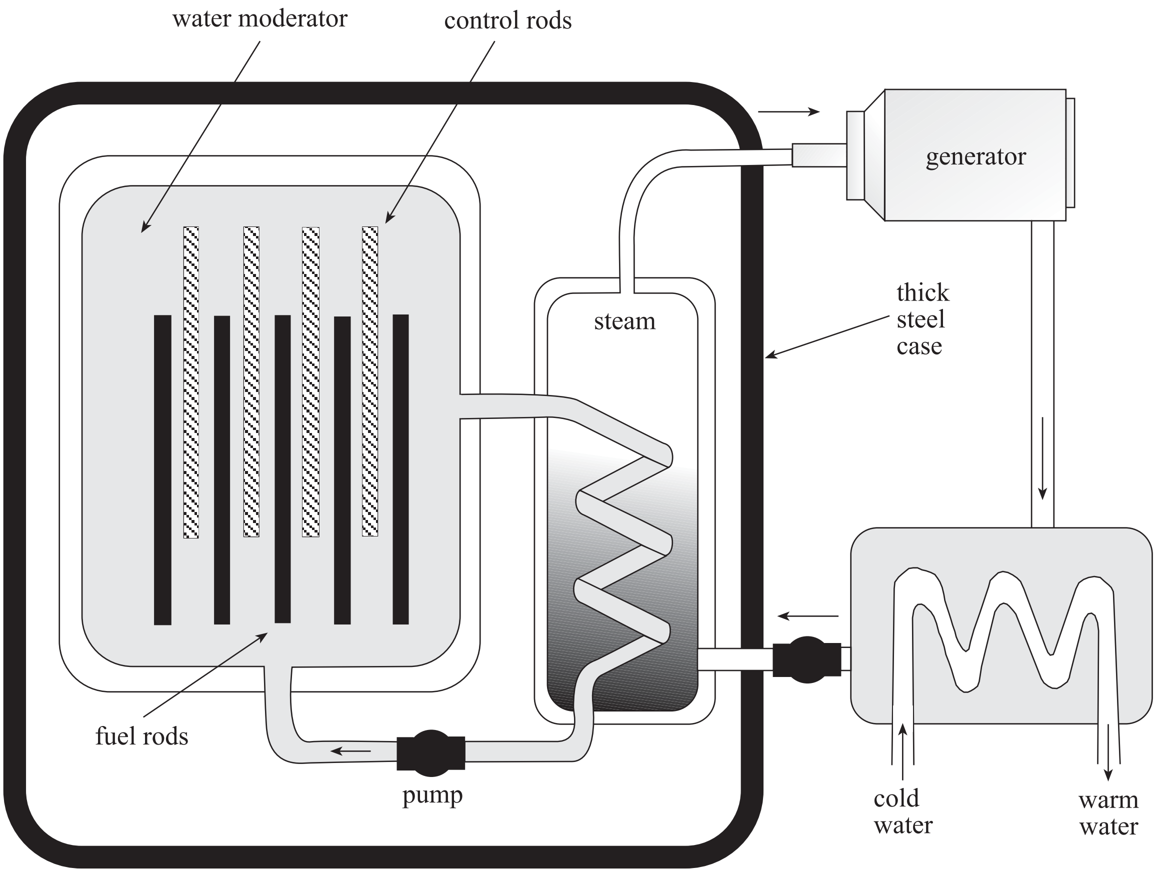
(e) When $^{235}_{92}U$ interacts with a neutron $^{1}_{0}n$, it may produce $^{140}_{54}Xe$ and $^{94}_{38}Sr$ as fission decay fragments, as well as a number ($k$) of neutrons, as shown in the equation below:

$$^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + k\,^{1}_{0}n.$$

Calculate the value of $k$.

______________________________________________ (1 mark)

(f) A simplified diagram of a water-moderated fission power station is shown below. (Safety rods have been omitted from the diagram.)




(i) Briefly explain the function of the control rods.

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______________________________________________ (2 marks)

(ii) Briefly explain the function of the water moderator.

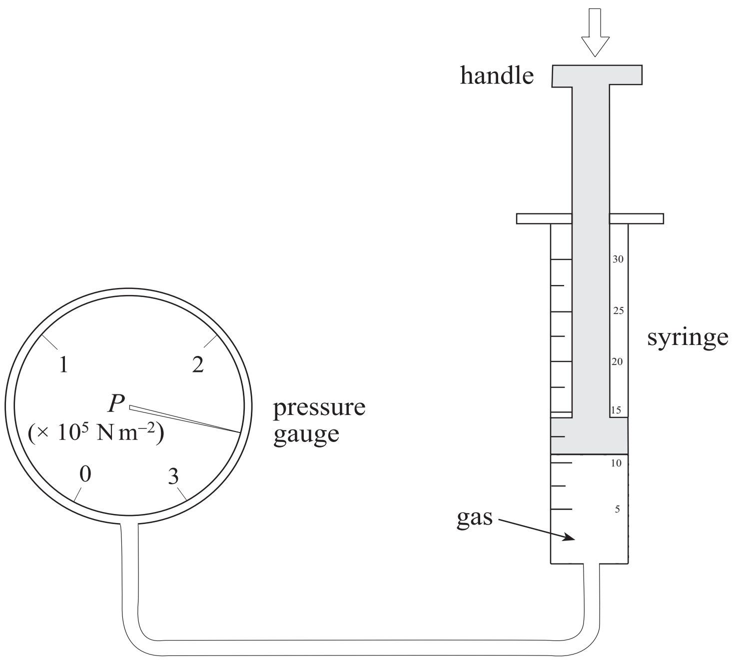
(2 marks)

(iii) Explain why naturally occurring uranium must be enriched for use in fuel rods.

(2 marks)

8. A student undertakes an experiment to investigate the relationship between pressure $P$ and total volume $V$ of a gas. The student changes the volume of the gas trapped in the syringe by exerting a force on the handle, as shown in the diagram below. The volume of gas is determined by using the scale marked on the syringe. The pressure is measured in units of $N\ m^{-2}$, using the pressure gauge.

After changing the volume of gas trapped in the syringe, the student records the pressure at a constant temperature.




(a) Complete the following table by calculating the values for $1/V$.

| $V$ ($m^3$) | $1/V$ | $P$ ($N\ m^{-2}$) |
|---|---|---|
| $1.0 \times 10^{-5}$ | | $2.57 \times 10^5$ |
| $1.5 \times 10^{-5}$ | | $1.90 \times 10^5$ |
| $2.0 \times 10^{-5}$ | | $1.55 \times 10^5$ |
| $2.5 \times 10^{-5}$ | | $1.34 \times 10^5$ |
| $3.0 \times 10^{-5}$ | | $1.20 \times 10^5$ |

(2 marks)

(b) (i) State the independent variable in this experiment.

(1 mark)

(ii) State the reason for your answer to part (b)(i).

(1 mark)

(c) On page 17, plot a graph of $P$ on the vertical axis against $1/V$ on the horizontal axis, and draw a line of best fit.

(6 marks)

(d) (i) The relationship between $P$ and $V$ can be represented by $P = \frac{bT}{V}$, where $b$ is a constant and $T$ is the constant temperature.

Explain why your graph suggests that there is a systematic error in the data.

(3 marks)

(ii) Calculate the gradient of your line of best fit. Include the units of the gradient.

(3 marks)

(iii) Using information from your graph, write the equation of your line of best fit in terms of $P$ and $1/V$.

(2 marks)

(iv) The constant temperature $T$ is measured in units of kelvin (symbol K). The value of $b$ is known to be $6.71 \times 10^{-3}$ J K$^{-1}$.

Using the gradient you calculated in part (d)(ii), determine the value of the temperature of the gas.

(2 marks)

*You may write on this page if you need more space to finish your answers to Section C. Make sure to label each answer carefully (e.g. 5(a) continued).*