SSABSA
SENIOR SECONDARY ASSESSMENT BOARD OF SOUTH AUSTRALIA
EXTERNAL EXAMINATION 2006

# 2006 PHYSICS

ATTACH SACE REGISTRATION NUMBER LABEL TO THIS BOX

QUESTION BOOKLET
**1**
20 pages, 11 questions

**Tuesday 7 November: 9 a.m.**

Time: 3 hours

## Section A

### Part 1

Examination material: Question Booklet 1 (20 pages)
Question Booklet 2 (15 pages)
Question Booklet 3 (12 pages)
one SACE registration number label

*Approved dictionaries and calculators may be used.*

**Instructions to Students**

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 two sections: Section A is divided between Question Booklet 1 and Question Booklet 2; Section B is in Question Booklet 3.

   **Section A** (Questions 1 to 21)
   This section consists of short-answer and extended questions.

   Answer Part 1 of Section A (Questions 1 to 11) in the spaces provided in Question Booklet 1. Write on page 20 of Question Booklet 1 if you need more space to finish your answers.

   Answer Part 2 of Section A (Questions 12 to 21) in the spaces provided in Question Booklet 2. Write on page 15 of Question Booklet 2 if you need more space to finish your answers.

   **Section B** (Questions 22 to 24)
   This section consists of one experimental skills question and two extended-response questions.

   Write your answers in the spaces provided in Question Booklet 3. Write on pages 11 and 12 of Question Booklet 3 if you need more space to finish your answers.
3. The allocation of marks and the suggested allotment of time are:

| | | |
|---|---|---|
| Section A | | |
| Part 1 | 75 marks | 65 minutes |
| Part 2 | 75 marks | 65 minutes |
| Section B | 50 marks | 50 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 this question booklet.

**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;
- receive zero marks for the examination;
- be liable to such further penalty, whether by exclusion from future examinations or otherwise, as SSABSA determines.

*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 | $f$ | work done | $W$ | | |

### Physical Constants

| | | | |
|---|---|---|---|
| Acceleration of gravity at the Earth's surface | $g = 9.8\ \text{m s}^{-2}$ | Charge of the electron | $e = 1.60 \times 10^{-19}\ \text{C}$ |
| Constant of universal gravitation | $G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$ | Mass of the electron | $m_e = 9.11 \times 10^{-31}\ \text{kg}$ |
| Speed of light in a vacuum | $c = 3.00 \times 10^8\ \text{m s}^{-1}$ | Mass of the proton | $m_p = 1.673 \times 10^{-27}\ \text{kg}$ |
| Coulomb's law constant | $\frac{1}{4\pi\varepsilon_0} = 9.00 \times 10^9\ \text{N m}^2\ \text{C}^{-2}$ | Mass of the neutron | $m_n = 1.675 \times 10^{-27}\ \text{kg}$ |
| Planck's constant | $h = 6.63 \times 10^{-34}\ \text{J s}$ | Mass of the $\alpha$ particle | $m_\alpha = 6.645 \times 10^{-27}\ \text{kg}$ |

### 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

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

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

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

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

$W = F s\cos\theta$ — $\theta$ = angle between force $\mathbf{F}$ and displacement $\mathbf{s}$

**Section 2: Electricity and Magnetism**

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

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

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

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

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

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

$W = q\Delta V$

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

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

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

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

**Section 3: Light and Matter**

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

$E = hf$

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

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

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

$L$ = slit-to-screen distance

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

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

**Section 4: Atoms and Nuclei**

$E_n - E_m = hf$

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

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

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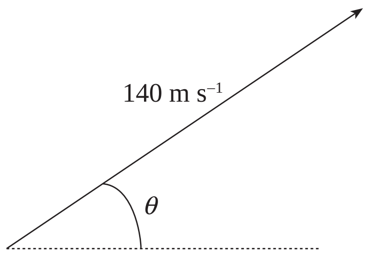
# SECTION A

## Part 1 (Questions 1 to 11)

(75 marks)

*Answer **all** questions in this part in the spaces provided.*

1. A projectile is launched from the ground with an initial velocity of 140 m $s^{-1}$ at an angle $\theta$ above the horizontal, as shown in the diagram below. *Assume air resistance is negligible and the ground is level*.




(a) On the diagram above, show clearly how the horizontal component of velocity $\boldsymbol{v}_H$ is added to the vertical component of velocity $\boldsymbol{v}_V$ to give the initial velocity vector.

(3 marks)

(b) The time of flight of the projectile is measured as 18.7 s and its range as $1.98 \times 10^3$ m.

Show that the launch angle $\theta$ that results in this range is approximately 41°.

(4 marks)

(c) (i) State the other launch angle that would result in the same range for this projectile.

(1 mark)

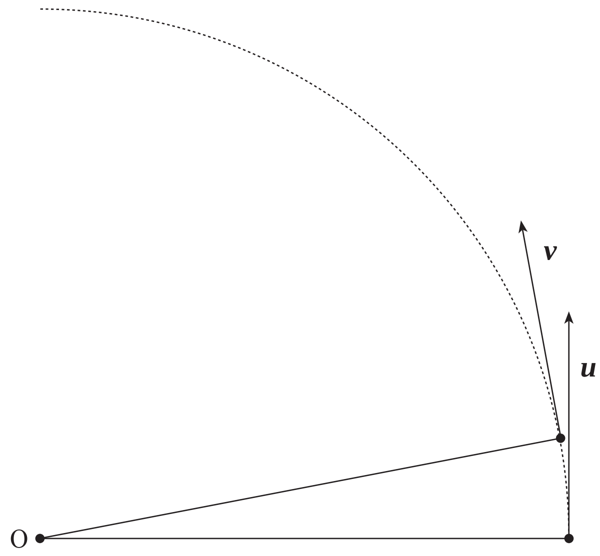
(ii) State and explain the effect of this different launch angle on the time of flight of the projectile.

(3 marks)



PLEASE TURN OVER

2. The velocity of a particle moving with uniform circular motion about O is shown at two positions in the diagram below:




(a) (i) On the diagram above, use the velocity vectors ***u*** and ***v*** to draw a labelled vector diagram showing the change in velocity $\Delta \boldsymbol{v}$ of the particle. (2 marks)

(ii) Comment on the direction of the change in velocity $\Delta \boldsymbol{v}$.

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______________________________________________________ (1 mark)

(b) Hence state and explain the direction of the acceleration of the particle.

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______________________________________________________ (3 marks)

3. Some satellites have geostationary orbits and some satellites have polar orbits.

(a) State *two* differences between geostationary orbits and polar orbits.

(2 marks)

(b) (i) Using the relationships $v = \sqrt{\frac{GM}{r}}$ and $v = \frac{2\pi r}{T}$, show that the radius of a satellite orbiting the Earth can be given by the equation $r = \sqrt[3]{\frac{GMT^2}{4\pi^2}}$, where $M$ is the mass of the Earth, $T$ is the period of the satellite, and $r$ is the radius of the orbit.

(3 marks)

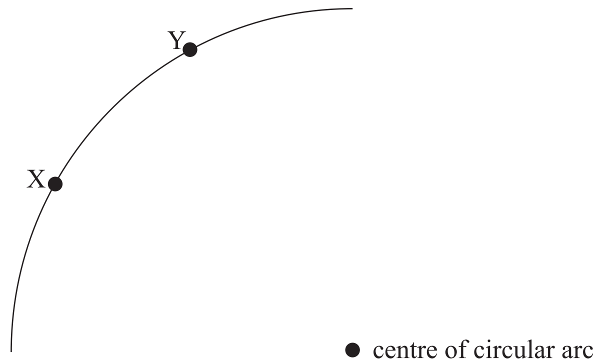
(ii) Hence determine the altitude of a satellite in a geostationary orbit around the Earth. The mass of the Earth is $M = 5.97 \times 10^{24}$ kg and its radius is $R = 6.4 \times 10^{6}$ m.

(4 marks)



PLEASE TURN OVER

4. A rocket moves along a circular arc by ejecting gas in short-duration thrusts. Two positions X and Y on this circular arc are shown in the diagram below. *Assume the rocket is in a region of space where gravity is negligible*.




(a) On the diagram above, draw arrows at X and Y, to show the direction in which the gas is ejected in order for the rocket to travel along this circular arc with constant speed.

(2 marks)

(b) Hence, *using the law of conservation of momentum*, state and explain the direction in which the force acts on the rocket in order to change its direction along this circular arc.

(4 marks)

5. (a) On the diagram below, draw vectors to show the magnitude and direction of the electric forces acting between an alpha particle and an electron.


[*This diagram is not drawn to scale.*] (2 marks)

(b) Hence state and explain which of the two particles will experience greater acceleration, due to these electric forces.

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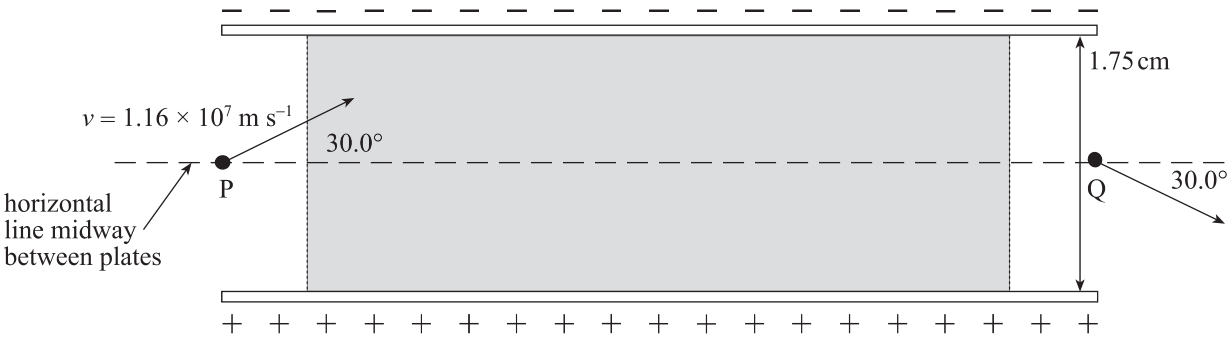
______________________________________________ (3 marks)

6. A uniform electric field is set up in a vacuum between two horizontal, parallel conducting plates with equal and opposite charges per unit area. The electric field has a magnitude of $1.40 \times 10^4$ V m$^{-1}$. The charged plates are a distance of 1.75 cm apart and the lower plate is positively charged, as shown in the diagram below.

An electron enters at P, midway between the plates, with a speed of $v = 1.16 \times 10^7$ m s$^{-1}$ and at an angle of 30.0º above the horizontal. The electron exits at Q, midway between the plates, with the same speed but at an angle of 30.0º below the horizontal.

*Assume the effect of gravity on the electron is negligible.*




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

(a) On the diagram above, sketch the electric field in the shaded region. (2 marks)

(b) Show that the magnitude of the initial vertical component of velocity of the electron is $5.80 \times 10^6$ m s$^{-1}$.

______________________________________________ (1 mark)

(c) Explain why the horizontal component of velocity of the electron remains constant between the plates.

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______________________________________________ (2 marks)

(d) (i) Show that the magnitude of the acceleration of the electron between the plates is $2.46 \times 10^{15}$ m s$^{-2}$.

(2 marks)

(ii) State the direction of the acceleration of the electron between the plates.

(1 mark)

(e) Show, using calculations, that the electron does *not* hit the upper plate.

(4 marks)

(f) (i) On the diagram opposite, sketch the path of the electron between the plates. (2 marks)

(ii) On the path you have sketched, indicate clearly with the symbol $v_{min}$ the position at which the speed of the electron is a minimum. (1 mark)

7. An electric current flows in a straight conductor. The current is directed perpendicularly into the page, as shown in the diagram below:

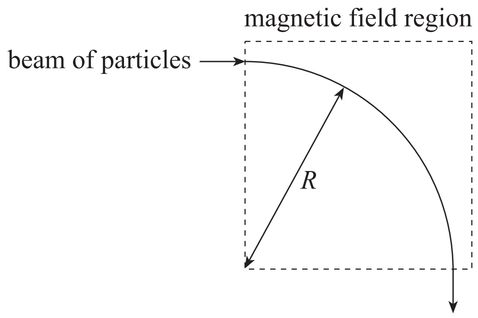
On the diagram, sketch *three* magnetic field lines produced by this current. (3 marks)

8. The magnetic force on a straight current-carrying wire in a uniform magnetic field is 50% of its maximum possible value.

Calculate the angle between the wire and the magnetic field.

(3 marks)

9. A region where a uniform magnetic field is used to direct a beam of positive particles is shown in the diagram below. The particles have a charge of $+1.60 \times 10^{-19}$ C and are moving with a speed of $1.00 \times 10^{7}$ m s$^{-1}$. The beam of particles enters at right angles to the magnetic field and follows a circular path of radius $R$.




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

(a) State the direction of the magnetic field in the region shown.

______________________________________________________________________ (1 mark)

(b) Explain why the beam of particles follows a circular path within the region shown.

______________________________________________________________________ (3 marks)

(c) The magnetic field in the region is 0.330 T.

Calculate the ratio of the radius of the path $R$ to the mass of the particles $M$ in the beam $\frac{R}{M}$. State the units of this ratio.

(4 marks)

10. (a) Show that the kinetic energy $K$ of the ions that emerge at radius $r$ from a cyclotron is given by $K = \dfrac{q^2 B^2 r^2}{2m}$.

(4 marks)

(b) Calculate the kinetic energy of an alpha particle that emerges at a radius of 0.12 m from a cyclotron with a magnetic field of 0.80 T.

(2 marks)

11. A receiving antenna has a vertical orientation. It receives an electromagnetic wave produced by a radio station transmitting at a frequency of $1.071 \times 10^8$ Hz.

(a) State the direction of the plane of polarisation of the electromagnetic wave.

(1 mark)

(b) Calculate the wavelength of the electromagnetic wave.

(2 marks)

*You may write on this page if you need more space to finish your answers to Part 1 of Section A. Make sure to label each answer carefully (e.g. 6(d)(i) continued).*

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EXTERNAL EXAMINATION 2006

# 2006 PHYSICS

| SACE REGISTRATION NUMBER | | | |
|---|---|---|---|
| SEQ | FIGURES | CHECK LETTER | BIN |
| | | | |

PHYSICS

**QUESTION BOOKLET**

**2**

15 pages, 10 questions

**Tuesday 7 November: 9 a.m.**

## Section A

## Part 2

*Write your answers to Part 2 of Section A in this question booklet.*

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# SECTION A

## Part 2 (Questions 12 to 21)

(75 marks)

*Answer **all** questions in this part in the spaces provided.*

12. A laser airborne depth sounder (LADS) emits a vertically directed laser pulse. Reflections from the surface and the bottom of a lake are detected after a delay of 2.61 $\mu$s and 2.89 $\mu$s respectively, where 1 $\mu$s = 1 × $10^{-6}$ s. The speed of the light in fresh water is 2.25 × $10^{8}$ m $s^{-1}$.

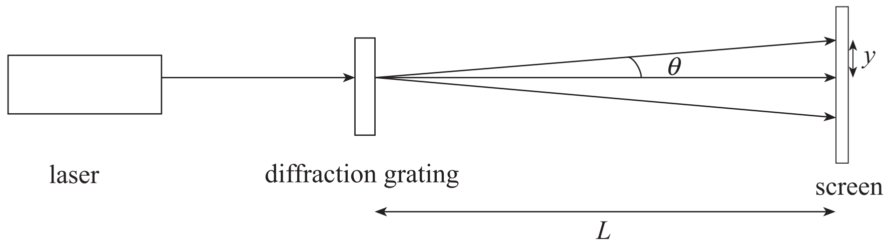
    Calculate the depth of the lake.

    (4 marks)



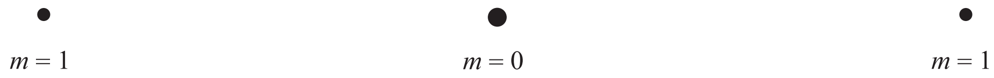
PLEASE TURN OVER

13. A laser beam is incident on a diffraction grating, as shown in the diagram below.
The distance $L$ between the diffraction grating and the screen is 0.29 m. The distance between the zero and first-order maxima on the screen is $y$. The diffraction grating has 300 lines per millimetre.




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

The zero and two first-order maxima observed on the screen are shown in the diagram below:




[*This diagram is drawn to scale.*]

(a) State *one* safety precaution you should take when using a laser.

______________________________________________________________________

______________________________________________________________________ (1 mark)

(b) (i) Using the diagram above, calculate the average distance $y$ between the zero and first-order maxima. Clearly show your working.

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______________________________________________________________________

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______________________________________________________________________ (2 marks)

(ii) Hence calculate the diffraction angle $\theta$ of the first-order maxima, using the average distance $y$ that you calculated in part (i).

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______________________________________________________________________ (2 marks)

(c) The wavelength of the laser light used in this experiment is $6.34 \times 10^{-7}$ m.

Show that the expected diffraction angle $\theta$ of the first-order maxima is 11º.

(3 marks)

(d) A teacher measures $y$ and calculates the diffraction angle $\theta$ of the first-order maxima as 13º.

State and explain which measurement, the teacher's or the one you calculated in part (b)(ii), is more accurate.

(2 marks)

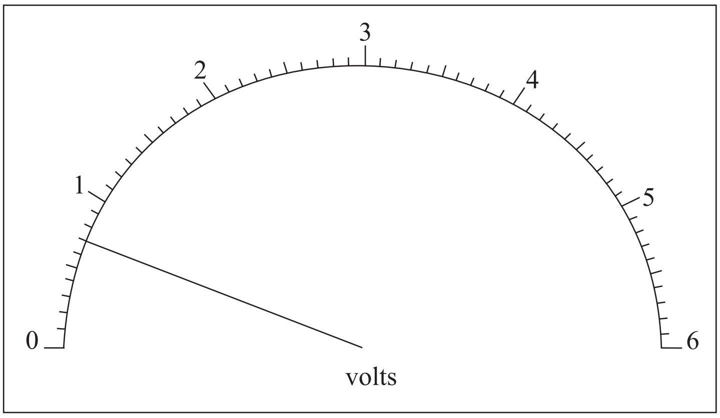
14. A photoelectric experiment is conducted using three monochromatic light sources, A, B, and C, of different wavelengths. These light sources are incident on metal M and then on metal N. The results obtained are shown in the table below:

| Light source | Wavelength ($\times 10^{-7}$ m) | Metal M | Metal N |
|---|---|---|---|
| A | 3.0 | electrons emitted | electrons emitted |
| B | 6.0 | electrons emitted | no electrons emitted |
| C | 7.0 | no electrons emitted | no electrons emitted |

(a) Explain why, for light source B, electrons are emitted from metal M but not from metal N.

(3 marks)

(b) The stopping voltage for light source B and metal M is measured with the voltmeter shown below:




(i) State the stopping voltage shown on the voltmeter.

(1 mark)

(ii) Explain why the stopping voltage can be used to determine the maximum kinetic energy $K_{max}$ of the photoelectrons.

(3 marks)

(iii) Calculate the work function of metal M.

(4 marks)

15. Neutrons with a speed of 790 m $s^{-1}$, when fired at a crystal surface, are diffracted.

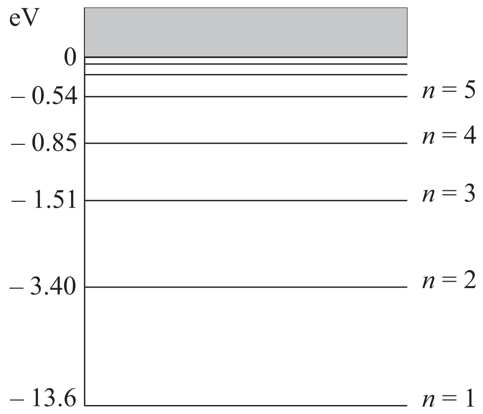
(a) Show that a neutron with this speed has a wavelength of $5.0 \times 10^{-10}$ m.

(2 marks)

(b) Explain why a crystal surface acts as a suitable diffraction grating for these neutrons.

(2 marks)

16. Some of the energy levels of hydrogen are shown in the diagram below:




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

(a) (i) Show that the energy of the photon released when an electron makes a transition from the $n = 3$ to the $n = 2$ level is $3.02 \times 10^{-19}$ J.

(2 marks)

(ii) Calculate the wavelength of the photon.

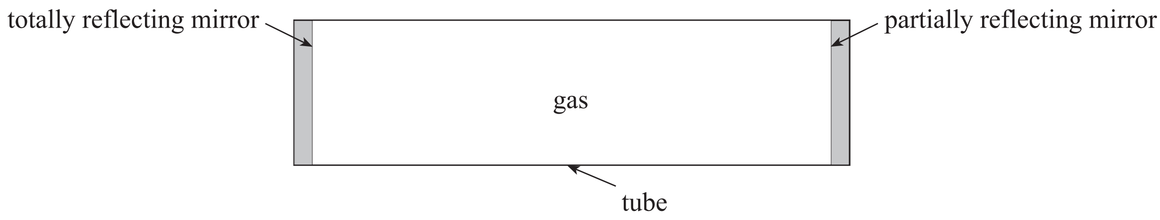
(3 marks)

(b) (i) On the diagram above, draw an arrow to represent the transition corresponding to the lowest energy absorption line if the hydrogen gas is at room temperature. (1 mark)

(ii) State the region of the electromagnetic spectrum in which this absorption line occurs.

(1 mark)

17. A helium–neon gas laser has a totally reflecting mirror at one end of a tube and a partially reflecting mirror at the other end, as shown in the diagram below. The tube contains a mixture of helium and neon gas. An electrical discharge supplies energy to the gas.




(a) Describe how the process of stimulated emission differs from the process of ordinary (or spontaneous) emission.

(3 marks)

(b) Explain the purpose of *each* of the mirrors.

(4 marks)

18. Polonium–214 changes into lead–210 by alpha decay, as shown in the equation below:

$$^{214}_{84}\text{Po} \longrightarrow ^{210}_{82}\text{Pb} + ^{4}_{2}\alpha$$

(a) Calculate the difference in the masses of the products and the reactant if 5.44 MeV is released in each decay.

(3 marks)

(b) (i) Using the law of conservation of momentum, show that the ratio of the speed of the alpha nuclei $v_\alpha$ to that of the lead nuclei $v_{Pb}$ is approximately 52.5. Assume that the polonium nuclei start at rest.

(4 marks)

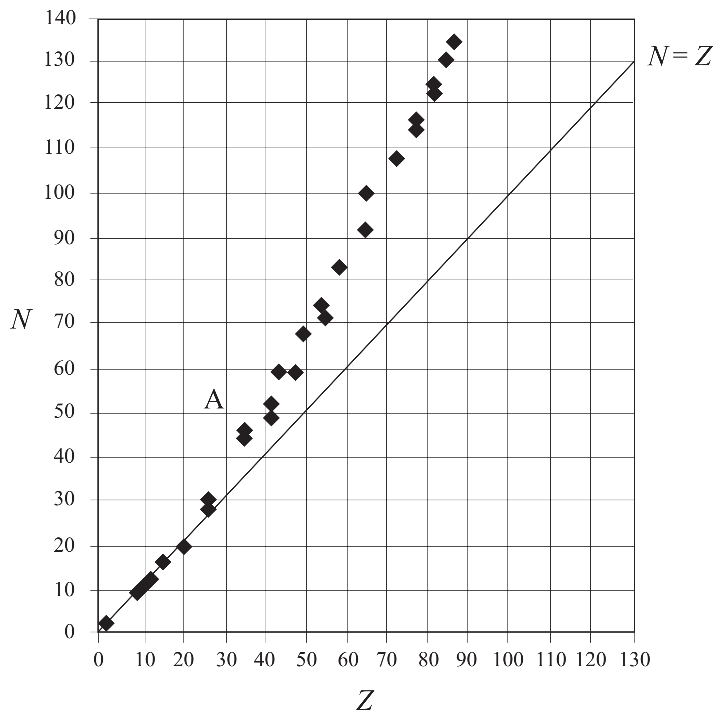
(ii) Hence explain why the alpha particle acquires most of the kinetic energy released in this reaction.

(3 marks)



PLEASE TURN OVER

19. The trend in the number of neutrons $N$ versus atomic number $Z$ for some stable isotopes is shown in the graph below:




(a) State and explain the type of radioactive decay you would expect an isotope at position A to undergo.

(3 marks)

(b) (i) Complete the nuclear equation for the conversion of a proton into a neutron.

$$^{1}_{1}p \longrightarrow {}^{1}_{0}n + \_\_\_\_\_\_ + \_\_\_\_\_\_$$

(2 marks)

(ii) Using conservation laws that apply to nuclear reactions, justify the production of each of the particles, including the neutron, in the decay above.

(3 marks)

20. The half-life of a particular radioactive source is 27 minutes. A 10 g sample of this source is observed to have an activity of 72 Bq.

(a) Calculate the time it will take for the activity of this sample to decrease to 9.0 Bq.

(3 marks)

(b) State how the half-life would be affected if the radioactive source were cooled to a low temperature. Give one reason for your answer.

(2 marks)

21. (a) (i) Describe the function of the moderator in a nuclear reactor.

(2 marks)

(ii) State *two* properties that a moderator should have.

(2 marks)

(b) (i) Describe what is meant by a chain reaction in nuclear fission.

(2 marks)

(ii) Explain how the enrichment of the uranium fuel helps to achieve a chain reaction.

(3 marks)

*You may write on this page if you need more space to finish your answers to Part 2 of Section A. Make sure to label each answer carefully (e.g. 19(b)(ii) continued).*

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EXTERNAL EXAMINATION 2006

# 2006 PHYSICS

SACE REGISTRATION NUMBER

SEQ | FIGURES | CHECK LETTER | BIN

PHYSICS

QUESTION BOOKLET

**3**

12 pages, 3 questions

**Tuesday 7 November: 9 a.m.**

## Section B

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

## SECTION B (Questions 22 to 24)

(50 marks)

*Answer **all** questions in this section in the spaces provided.*

22. (a) An experiment to investigate the drag force acting on an object at different speeds is carried out in a wind tunnel. The results are shown in the table below:

| Speed $v$ (m $s^{-1}$) | Drag force $D$ (N) | Speed squared $v^2$ ($m^2$ $s^{-2}$) |
|---|---|---|
| 4.04 | 169 | |
| 6.12 | 340 | |
| 7.99 | 512 | |
| 10.1 | 820 | |
| 11.9 | 1080 | |

(i) Complete the table above by calculating each of the values of speed squared $v^2$ to the appropriate number of significant figures. (3 marks)

(ii) On the page opposite, plot (*in pencil*) a graph of drag force $D$ against speed squared $v^2$ and draw a line of best fit. (4 marks)

(iii) State and explain whether your graph is consistent with the hypothesis that the drag force is directly proportional to the speed squared ($D \propto v^2$).

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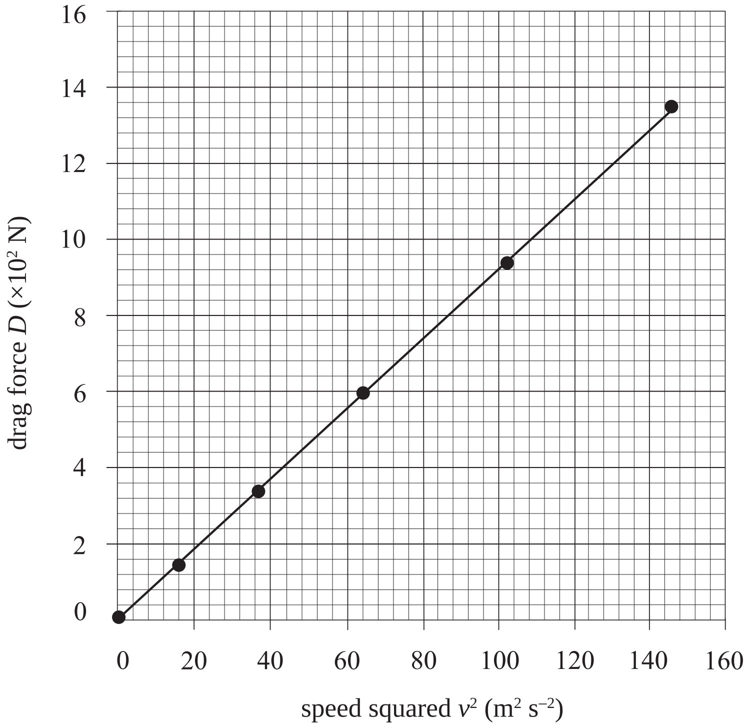
_______________________________________________ (3 marks) drag force $D$ (N)

speed squared $v^2$ ($m^2\ s^{-2}$)

(b) The experiment is repeated, using a different-shaped object. The graph obtained from the results of this second experiment is shown below:




(i) Using the graph above, determine the drag force that would be produced if $v^2 = 155\ m^2\ s^{-2}$. Clearly indicate on your graph how you arrived at your answer.

(2 marks)

(ii) Calculate the gradient of the line of best fit for this graph, clearly labelling on the graph the points you have used. State the units of the gradient.

(3 marks)

(iii) The relationship between the drag force and the speed of the object is given by

$$D = \frac{1}{2}\rho v^2 A C$$

where $\rho$ is the density of the surrounding fluid, $A$ is the cross-sectional area of the object, and $C$ is the drag coefficient of the object (it has no units).

Using this relationship and the gradient you calculated in part (b)(ii), find the value of the drag coefficient $C$ for this experiment if $\rho$ = 1.23 kg $m^{-3}$ and $A$ = 0.25 $m^2$.

(3 marks)

(c) State and explain the type of error in your graph in part (a), given the relationship described in part (b)(iii).

(2 marks)

(d) Identify *two* factors that should be held constant during an experiment to investigate the drag force acting on an object at different speeds.

(2 marks)

*Questions 23 and 24 are extended-response questions. Answer* ***both*** *questions.*

*Write your answers in this question booklet:*

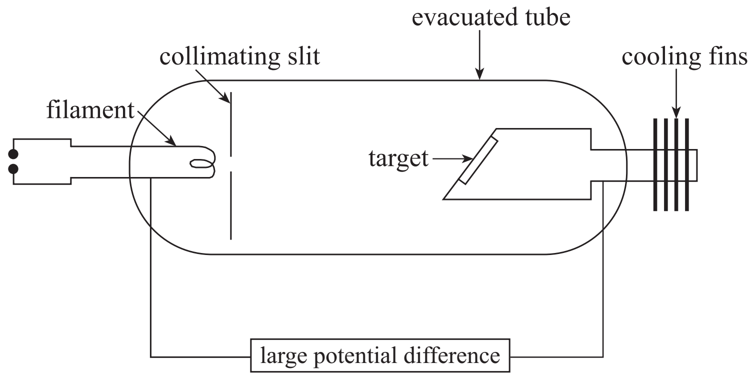
- *Question 23, on pages 7 and 8, is worth 16 marks.*
- *Question 24, on pages 9 and 10, is worth 12 marks.*

In answering these questions, you should:

- communicate your knowledge clearly and concisely;
- use physics terms correctly;
- present information in an organised and logical sequence;
- include only information that is related to the question.

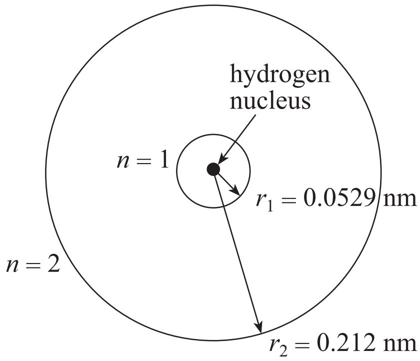
You may use clearly labelled diagrams that are related to your answer.

23. An X-ray tube, as shown in the diagram below, is used to produce X-ray photons:




- Using the diagram above, state where electrons are produced and explain how they are accelerated in the X-ray tube.
- Explain the continuous range of frequencies and the maximum frequency in the spectrum of the X-rays. (16 marks)

24. Electrons can orbit the nucleus of an atom at various radii in discrete energy levels. There is an electrostatic force of attraction between the positive nucleus and the negative electron. The lowest two energy levels of hydrogen, $n = 1$ and $n = 2$, have radii $r_1 = 0.0529$ nm and $r_2 = 0.212$ nm respectively, as shown in the diagram below:




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

Using proportionality:

- discuss the factors that affect the magnitude of the electrostatic force of attraction;
- compare the magnitude of the electrostatic forces acting on the electron in the $n = 1$ and the $n = 2$ energy levels. (12 marks)

*You may write on this page and page 12 if you need more space to finish your answers to Questions 22, 23, and 24. Make sure to label your answers carefully (e.g. 22(b)(ii) continued).*



PLEASE TURN OVER