1

Government of South Australia

SACE Board of SA | South Australian Certificate of Education

Physics
2017

Question Booklet 1

- **Part 1 of Section A** (Questions 1 to 12) 75 marks
- Answer ***all*** questions in Part 1
- Write your answers in this question booklet
- You may write on page 20 if you need more space
- Allow approximately 75 minutes

Examination information

Materials
- Question Booklet 1 (Part 1 of Section A)
- Question Booklet 2 (Part 2 of Section A)
- Question Booklet 3 (Section B)
- SACE registration number label

Reading time
- 10 minutes
- You may make notes on scribbling paper

Writing time
- 3 hours
- Clear, well-expressed answers are required
- Use black or blue pen
- You may use a sharp dark pencil for diagrams
- Approved calculators may be used

Total marks 180

Attach your SACE registration number label here

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Supervisor check	Re-marked

You may remove this page from the booklet by tearing along the perforations.

EQUATION SHEET

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

Symbols of Common Quantities

acceleration	$\vec{a}$	wavelength	λ	momentum	$\vec{p}$
time	t	force	$\vec{F}$	electric field	$\vec{E}$
displacement	$\vec{s}$	charge	q	kinetic energy	K
velocity	$\vec{v}$	mass	m	magnetic field	$\vec{B}$
period	T	potential difference	ΔV	electric current	I
frequency	f	work done	W		

Magnitude of Physical Constants

Acceleration due to 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 α particle	$m_\alpha = 6.645 \times 10^{-27}\ \text{kg}$

Section 1: Motion in Two Dimensions

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

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

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

$v_H = v\cos\theta$ — θ = angle to horizontal

$v_v = v\sin\theta$

$v = \frac{2\pi r}{T}$ — r = radius of circle

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

$\vec{a}_{ave} = \frac{\Delta\vec{v}}{\Delta t}$ — $\vec{a}_{ave}$ = average acceleration

$a = \frac{v^2}{r}$

$\tan\theta = \frac{v^2}{rg}$ — θ = banking angle

$F = G\frac{m_1 m_2}{r^2}$ — 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

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

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

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

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

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

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

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

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

$W = q\Delta V$

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

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

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

$r = \frac{mv}{qB}$ r = radius of circle

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

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

Section 3: Light and Matter

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

$d\sin\theta = m\lambda$ d = distance between slits
θ = angular position of mth maximum
m = integer $(0, 1, 2, \ldots)$

$\Delta y = \frac{\lambda L}{d}$ Δy = distance between adjacent minima or maxima
L = slit-to-screen distance

$d = \frac{1}{N}$ N = number of slits per metre of grating

$E = hf$ E = energy of photon

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

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

$W = hf_0$ f_0 = threshold frequency

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

Section 4: Atoms and Nuclei

$E_n - E_m = hf$ $E_n - E_m$ = energy difference

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

$E = mc^2$ E = energy

TABLE OF PREFIXES

Refer to the following table when answering questions that involve the conversion of units:

Prefix	Symbol	Value
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

SECTION A

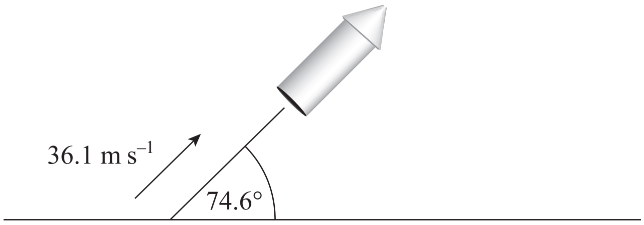
Part 1 (Questions 1 to 12)

(75 marks)

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

1. A firework is launched from ground height with an initial velocity of $36.1\ \mathrm{m\,s^{-1}}$, at an angle of $74.6°$ above the horizontal, as shown in the diagram below.

   Ignore air resistance in all parts of this question.



[This diagram is not drawn to scale.]

(a) Show that the vertical component of the initial velocity of the firework is $34.8\ \mathrm{m\,s^{-1}}$.

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____ (1 mark)

(b) Show that the maximum height of the firework is $62\ \mathrm{m}$.

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____ (2 marks)

(c) The firework explodes 1.15 seconds after it is launched.

Calculate the horizontal distance travelled by the firework from its launch position to the position at which it explodes.

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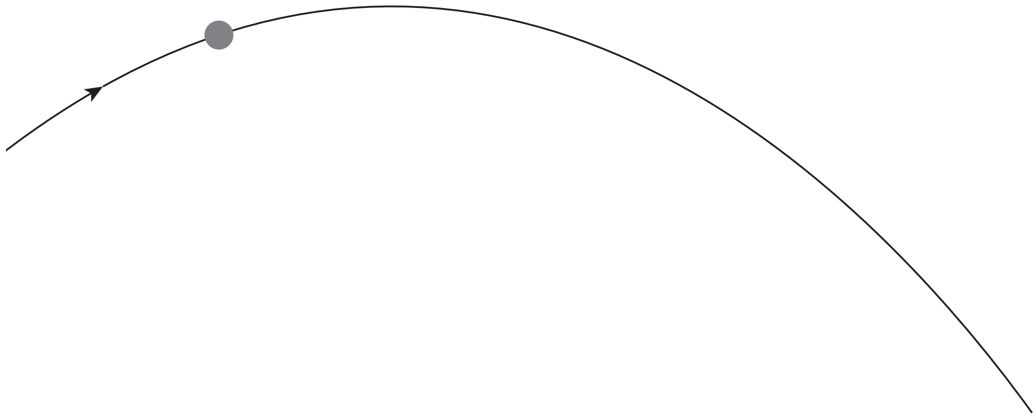
____ (3 marks)

2. A ball that is launched in the absence of air follows the path shown in the diagram below.



When the ball is launched in air, it experiences air resistance throughout its flight.

(a) Explain why air resistance decreases the horizontal component of the velocity of the ball.

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____ (2 marks)

(b) *On the diagram above*, draw the path of the ball when it is launched in the presence of air with the same velocity and from the same height as when it is launched in the absence of air. (2 marks)

(c) Explain the effect that air resistance has on the maximum height of the ball.

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____ (2 marks)

3. A satellite used in meteorology orbits Earth in a circular path of radius 7.08×10^3 km. The mass of Earth is 5.97×10^{24} kg.

Source: IBCAO Data: Google, SIO, NOAA, U.S. Navy, NGA, GEBCO Landsat/Copernicus

(a) Show that the speed of the satellite is 7.50×10^3 m s^{-1}.

(2 marks)

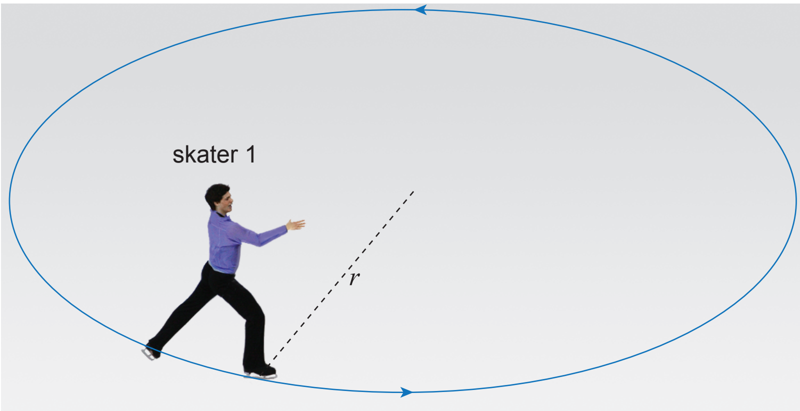
(b) Calculate the number of orbits completed by the satellite in 24 hours.

(3 marks)

(c) Explain *one* advantage of using a low-altitude orbit for a satellite in meteorology.

(2 marks)

4. In a solo ice-skating routine, skater 1, of mass $75.5\ \mathrm{kg}$, moves alone in a circular path with a radius r of $5.15\ \mathrm{m}$ and at a constant speed of $4.21\ \mathrm{m\,s^{-1}}$, as shown in the diagram below.



[This diagram is not drawn to scale.]

Source: Adapted from © Valeria Cantone | Dreamstime.com

(a) *On the diagram above*, draw an arrow to show the acceleration of skater 1.

(1 mark)

(b) Show that the magnitude of the net force acting on skater 1 is $260\ \mathrm{N}$.

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____ (2 marks)

(c) In a pair ice-skating routine, skater 1 carries skater 2, who is of mass $57.6\ \mathrm{kg}$. The two skaters move in a circular path at the same speed as skater 1 alone, but with a different radius from that of skater 1 alone. The magnitude of the net force acting on the two skaters is the same as that acting on skater 1 alone ($260\ \mathrm{N}$).

Source: Adapted from © Valeria Cantone | Dreamstime.com

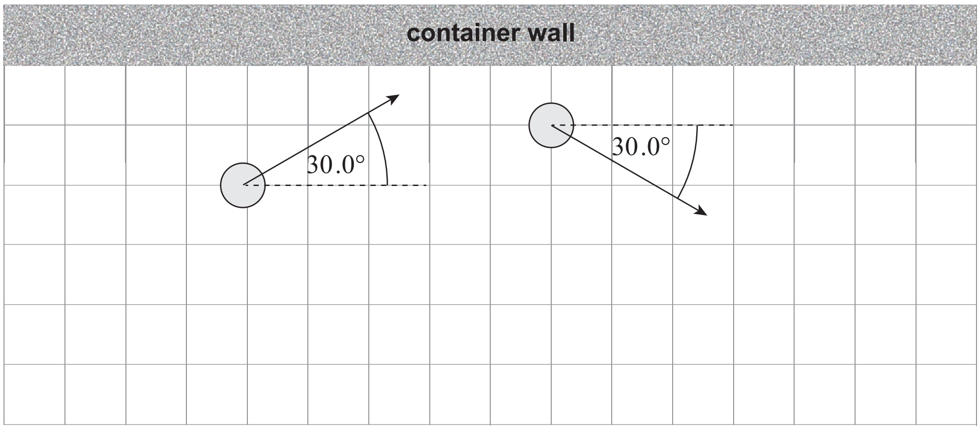
(i) Show that the magnitude of the centripetal acceleration of the two skaters is $1.95\ \mathrm{m\,s^{-2}}$.

____ (2 marks)

(ii) Calculate the radius of the circular path of the two skaters.

____ (3 marks)

5. The motion of a helium atom is shown in the diagram below. The helium atom of mass 6.65×10^{-27} kg, moving at a velocity of 1.35×10^{3} m s^{-1} at 30.0° above the horizontal, collides with the wall of its container. After the collision, the helium atom moves with the same speed at 30.0° below the horizontal.



(a) Calculate the magnitude of the initial momentum of the helium atom.

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____ (2 marks)

(b) *On the grid above*, draw and label a vector diagram to show the change in momentum $\Delta\vec{p}$ of the helium atom as a result of the collision. (2 marks)

(c) The helium atom is in contact with the wall for 2.14×10^{-4} s.

Calculate the magnitude of the average force applied to the helium atom by the wall.

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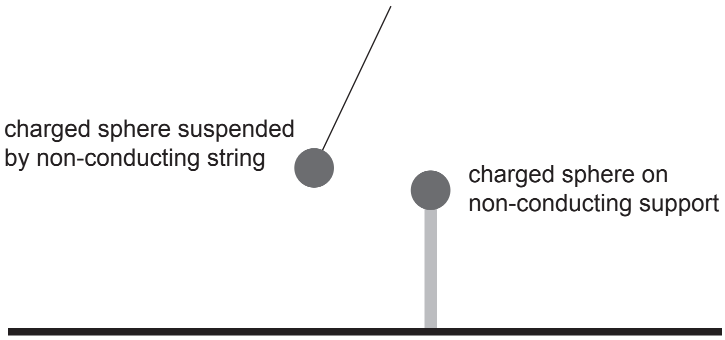
____ (4 marks)

6. The diagram below shows apparatus used to investigate Coulomb's law. Two charged spheres remain stationary due to the electric force between them.



The two spheres each have a charge of $+3.4 \times 10^{-9}$ C, and the distance between each of their centres is 3.2 cm.

Calculate the magnitude of the electric force that each sphere exerts on the other.

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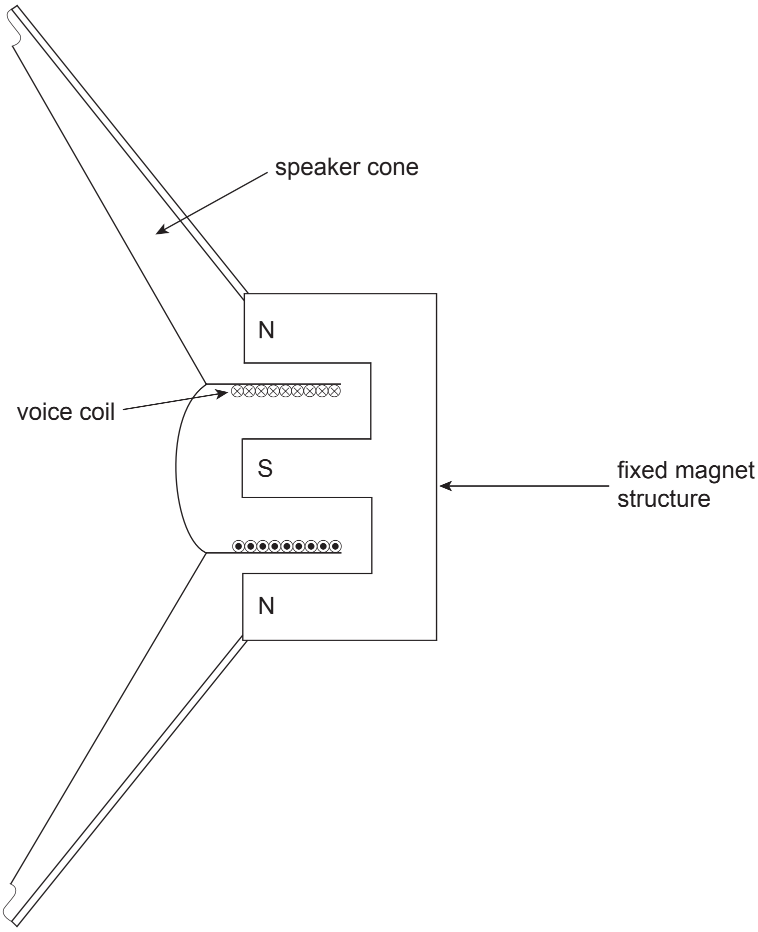
____ (3 marks)

7. A loudspeaker is used to convert an electric current into sound waves.

(a) A moving-coil loudspeaker, as shown in the diagram below, uses a fixed magnet structure and a current-carrying voice coil.



(i) *On the diagram above*, draw an arrow to show the direction of the magnetic field between the poles of the magnet. (1 mark)

(ii) Explain how a continually reversing electric current in the voice coil causes the speaker cone to vibrate.

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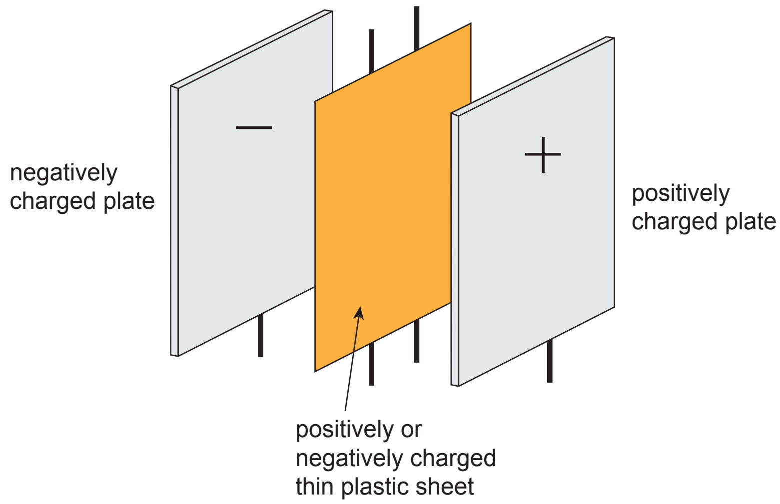
____ (2 marks)

(b) An electrostatic loudspeaker contains a charged thin plastic sheet placed between two oppositely charged parallel plates, as shown in the diagram below. The plastic sheet vibrates when the sign of the charge on it is continually reversing.



Source: Adapted from http://electronics.howstuffworks.com/question713.htm 26/2/2017

(i) *On the diagram above*, draw an arrow to show the direction of the electric field between the charged plates. (1 mark)

(ii) Explain how the continually varying sign of the charge on the plastic sheet causes the sheet to vibrate.

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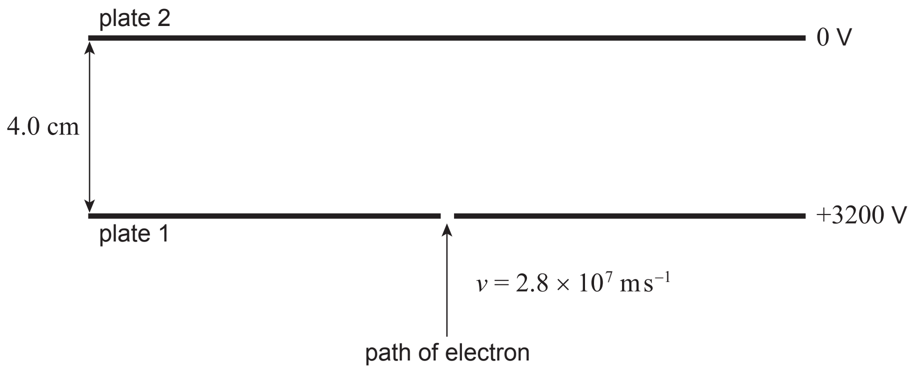
___ (2 marks)

8. An electron enters a uniform electric field in the region between two oppositely charged parallel conducting plates, as shown in the diagram below.

The electron enters the field through a small opening in the positively charged plate (plate 1), perpendicular to the plate, and with a speed of $2.8 \times 10^7\ \mathrm{m\,s^{-1}}$. The parallel plates are separated by a distance of $4.0\ \mathrm{cm}$, and there is a potential difference of 3200 V between them.

Assume the conducting plates are located in a vacuum, and ignore the effect of gravity.



[This diagram is not drawn to scale.]

(a) Show that the magnitude of the acceleration of the electron in the region between the parallel plates is $1.4 \times 10^{16}\ \mathrm{m\,s^{-2}}$.

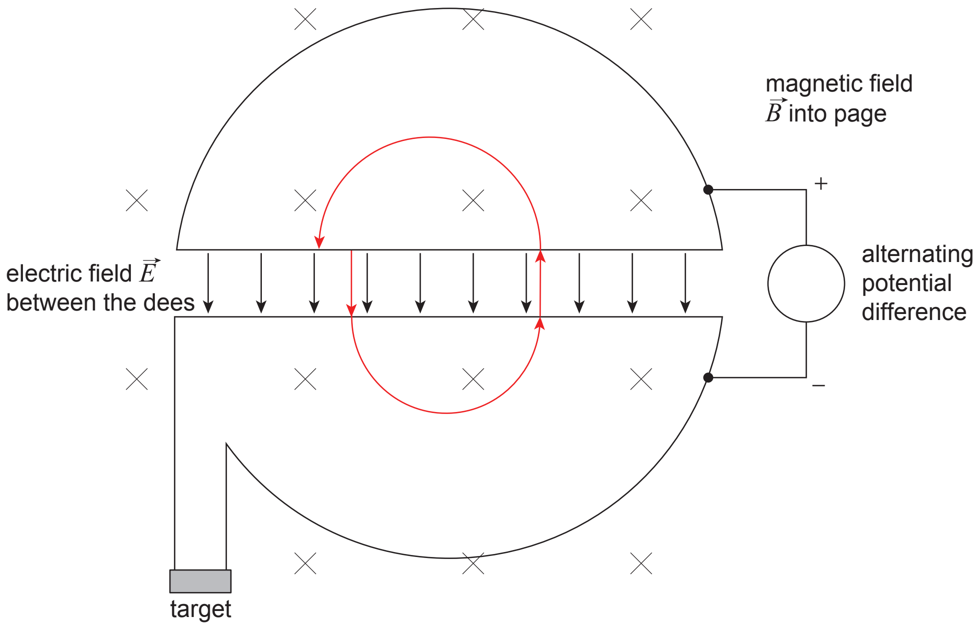
____ (3 marks)

(b) The electron does not reach plate 2. It changes direction and returns along its original path.

Determine the minimum distance of the electron from plate 2.

____ (4 marks)

9. The diagram below shows a cyclotron of radius 76 cm. An alternating electric field between the dees and a constant magnetic field are used to accelerate protons. The maximum potential difference across the gap between the dees is 240 V, and the magnetic field strength is 1.4 T.



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

(a) Explain why the magnitude of the magnetic field in the cyclotron affects the maximum kinetic energy of the protons, but the magnitude of the electric field across the gap between the dees does not.

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___ (3 marks)

(b) Calculate the kinetic energy of the protons that emerge from the cyclotron.

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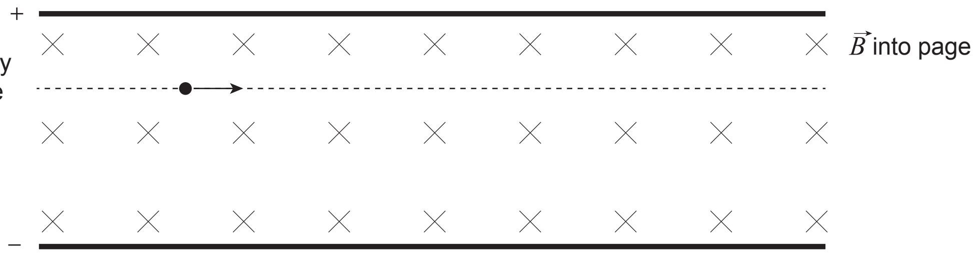
___ (3 marks)

10. A uniform electric field $\vec{E}$ between two oppositely charged parallel plates is perpendicular to a uniform magnetic field $\vec{B}$, as shown in the diagram below.

Ignore the effect of gravity in this question.



The diagram shows the path of a positively charged particle that has entered the fields at speed v, perpendicular to each field. The particle passes through the fields without being deflected.

(a) *On the diagram above*, draw and label vectors to show the forces acting on the positively charged particle. (2 marks)

(b) Hence show that the speed required for the particle to pass through the fields without being deflected is given by $v = \frac{E}{B}$.

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____ (3 marks)

11. (a) A television antenna transmits an electromagnetic wave of frequency 219.5 MHz.

Calculate the wavelength of the electromagnetic wave.

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____ (3 marks)

(b) The map below shows television antenna **X** in a small city, television antenna **Y** in a country town, and a location, **P**.

Antenna **X** transmits a horizontally polarised electromagnetic wave. Antenna **Y** transmits a vertically polarised electromagnetic wave. The waves from **X** and **Y** are transmitted at the same time and have the same wavelength.

[This map is drawn to scale.]

(i) State which wave (the wave transmitted from **X** or the wave transmitted from **Y**) reaches **P** first.

____ (1 mark)

(ii) Explain why the wave transmitted from **Y** is polarised at right angles to the wave transmitted from **X**.

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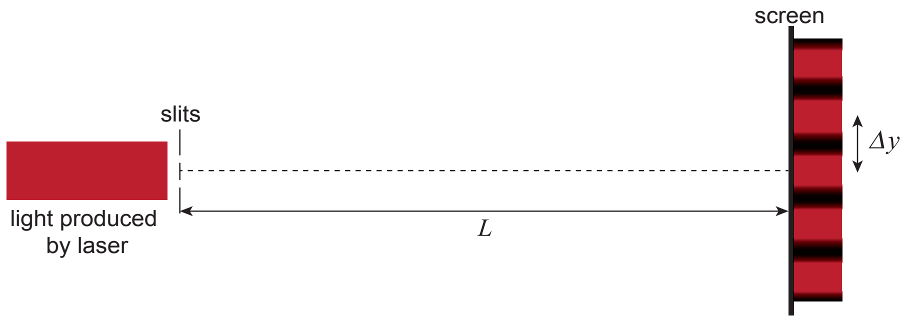
____ (2 marks)

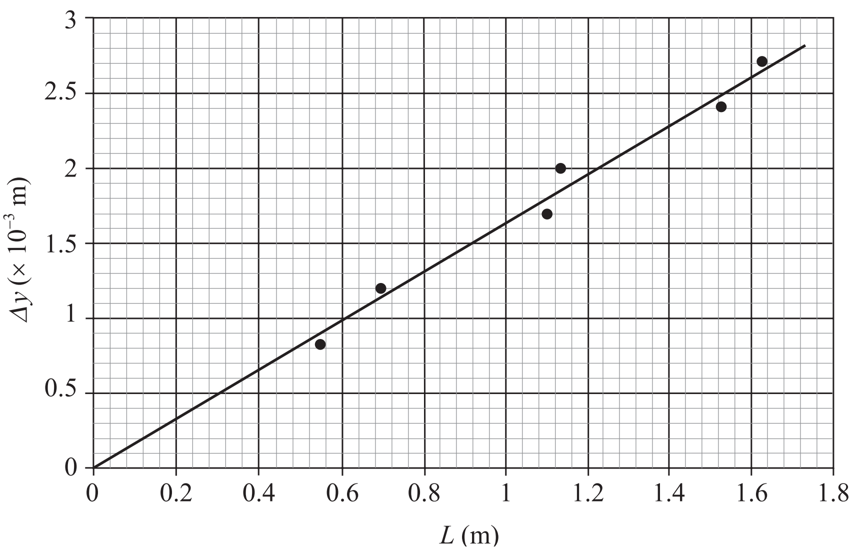
12. A group of students conducted a two-slit experiment to determine the wavelength of the light produced by a laser. The diagram below shows the light produced by a laser incident on two slits a distance $d = 4.00 \times 10^{-4}$ m apart. A pattern was produced on a screen.



[This diagram is not drawn to scale.]

The students measured the slit-to-screen distance L and took one measurement of the distance between adjacent maxima Δy on the screen. They then changed L five times, and measured Δy once for each value of L.

The data obtained are shown on the graph below.



(a) The slope of the line of best fit is 1.63×10^{-3}.

Using the slope, calculate the wavelength of the light produced by the laser.

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____ (3 marks)

(b) Describe *one* way to improve the precision of the students' data.

(2 marks)

(c) The students then doubled the distance between the slits for one value of L.

Describe the change in the pattern on the screen. Justify your answer.

(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. 11(b)(ii) continued).

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Physics
2017

Question Booklet 2

2

- **Part 2 of Section A** (Questions 13 to 21) 75 marks
- Answer ***all*** questions in Part 2
- Write your answers in this question booklet
- You may write on page 18 if you need more space
- Allow approximately 75 minutes

Copy the information from your SACE label here

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SECTION A

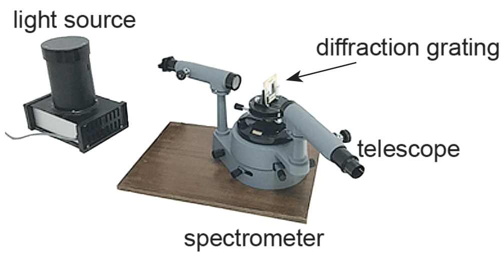
Part 2 (Questions 13 to 21)

(75 marks)

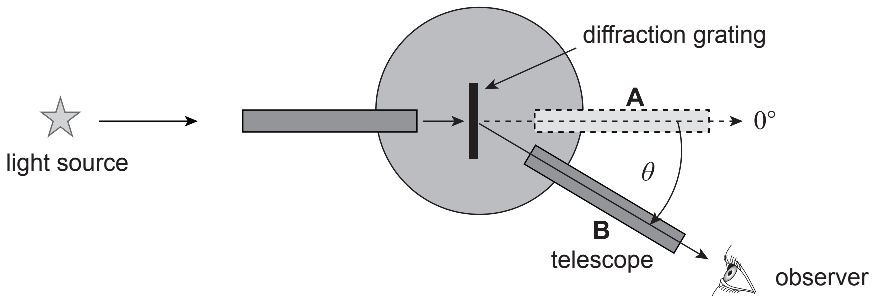
*Answer **all** questions in this part in the spaces provided.*

13. The photograph shows a spectrometer with a diffraction grating and a monochromatic light source. The diffraction grating has 450 lines per millimetre.

    In an experiment, a student uses this equipment to produce and view a line emission spectrum. The telescope is moved to view various lines and the student then measures the positions of the lines.



The student observes the zero-order maximum of the spectrum when the telescope is at **A**, at an angle of $0°$. The student then moves the telescope from **A** until the first-order maximum is observed, when the telescope is at **B**, at an angle θ of $15.4°$, as shown in the diagram below.



(a) Calculate the wavelength of the monochromatic light.

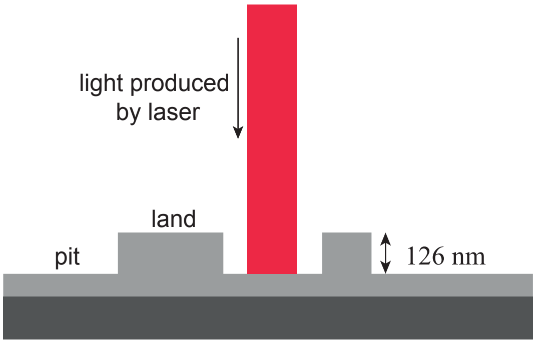
____ (3 marks)

(b) The student then replaces the monochromatic light with white light.

Describe the first-order maximum of the spectrum that is now observed.

____ (2 marks)

14. Information stored on a compact disc is read by reflecting light produced by a laser of wavelength $504\ \text{nm}$ from the lands and the pits of the compact disc, as shown in the diagram below.
The difference in height between a pit and a land is $126\ \text{nm}$.



(a) Light that is reflected from a pit travels further than light that is reflected from a land.

Show that the extra distance travelled by light reflected from a pit is $252\ \text{nm}$.

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____ (1 mark)

(b) (i) Determine the ratio $\dfrac{\text{extra distance travelled}}{\text{wavelength of light}}$.

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____ (1 mark)

(ii) Hence explain how the interference of light can be used to read information stored on a compact disc.

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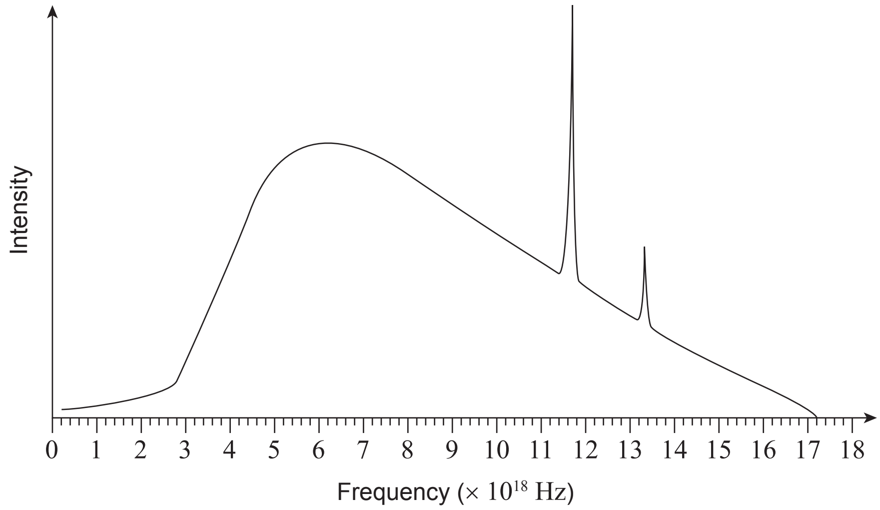
____ (3 marks)

15. The graph below shows a typical spectrum produced by an X-ray tube.



(a) *Using the graph above*, state the maximum frequency of the X-rays emitted.

____ (1 mark)

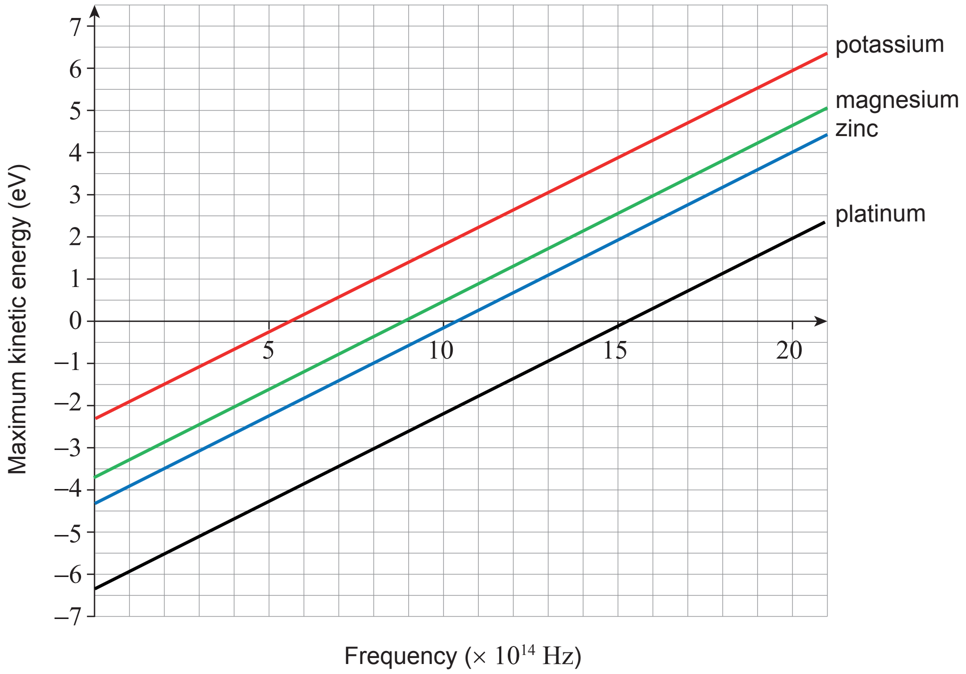
(b) Show that the maximum frequency of the X-rays produced in this X-ray tube is given by $f_{\max} = \dfrac{e\Delta V}{h}$, where ΔV is the potential difference across the X-ray tube.

____ (3 marks)

(c) Calculate the potential difference ΔV that produces X-rays of the maximum frequency shown on the graph above.

____ (3 marks)

16. An experiment was performed in which light of different frequencies was incident on a photocell with a potassium surface, and the maximum kinetic energy of the photoelectrons was determined. This experiment was repeated for three other photocells with surfaces made of different metals. The graph below shows the results for the experiment.



(a) *Using the graph above*, identify the metal surface with the largest work function.

____ (1 mark)

(b) Using the concept of photons and the conservation of energy, explain why each metal represented on the graph above has a different threshold frequency.

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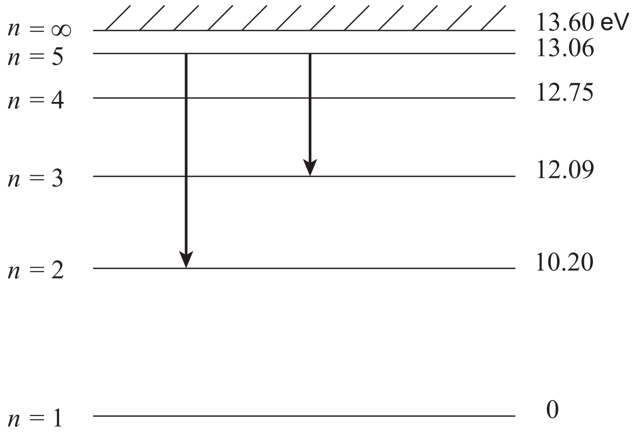
____ (4 marks)

17. The diagram below shows some of the energy levels of hydrogen. Each arrow represents a transition between energy levels.



(a) (i) Explain why the light produced in the transition $n = 5$ to $n = 3$ has a longer wavelength than the light produced in the transition $n = 5$ to $n = 2$.

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______________________________________ (2 marks)

(ii) (1) Calculate the wavelength of the photon emitted when a hydrogen atom undergoes the transition $n = 5$ to $n = 3$.

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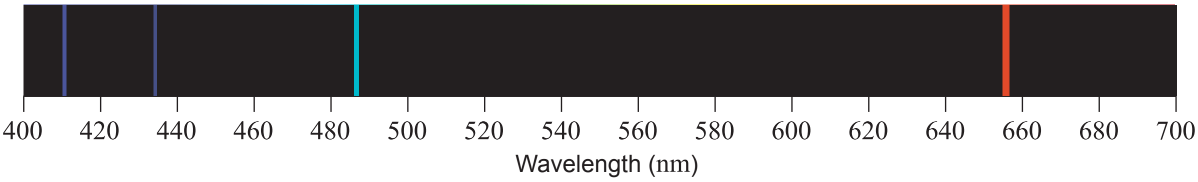
______________________________________ (3 marks)

(2) State the region (visible, infrared, or ultraviolet) in the electromagnetic spectrum of this photon.

______________________________________ (1 mark)

(b) The visible line emission spectrum of atomic hydrogen (shown below) consists of discrete wavelengths of light.



Explain how the presence of these discrete wavelengths of light provides evidence for the existence of states with discrete energies in hydrogen atoms.

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____ (3 marks)

18. Fission of uranium-235 produces a range of products. One product is caesium-137.

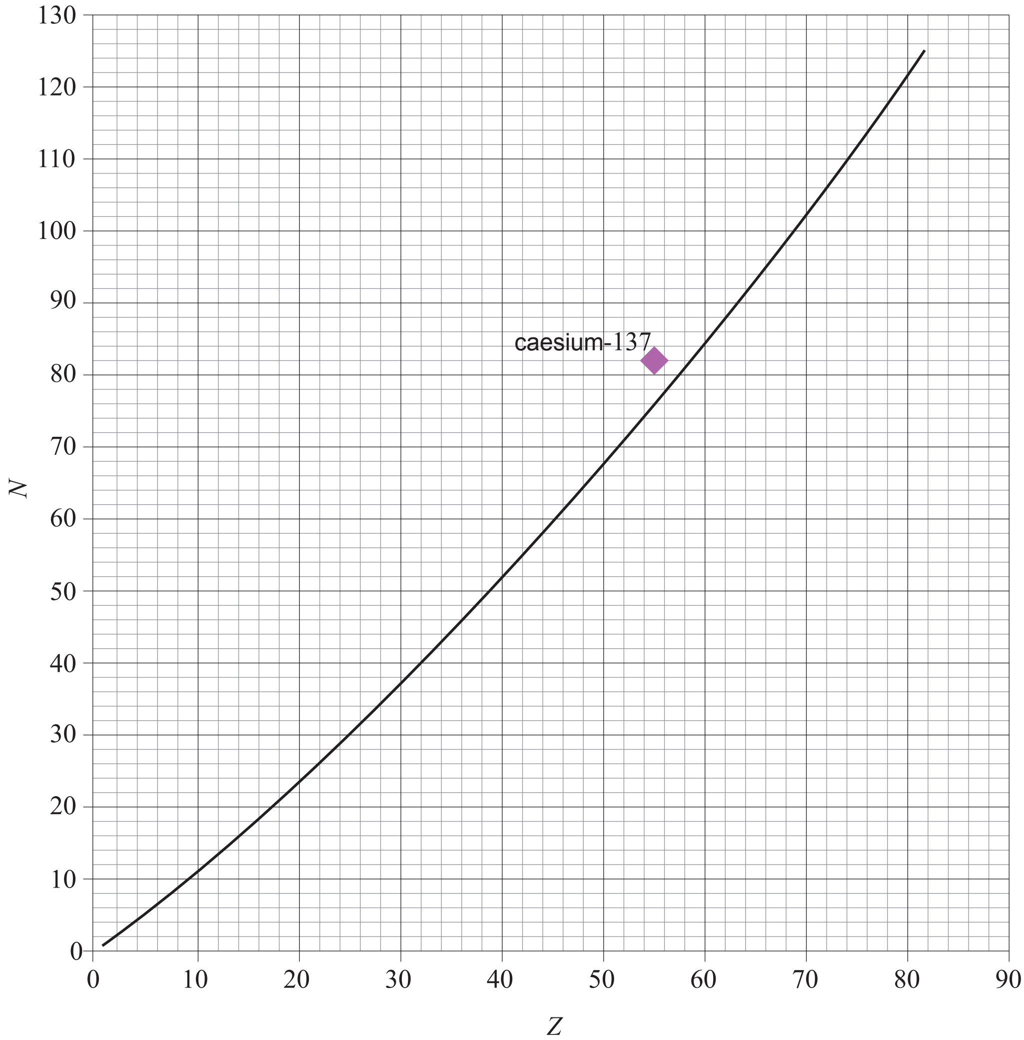
(a) Determine the value of A and the value of Z for Br in the nuclear equation below:

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \longrightarrow ^{137}_{55}\text{Cs} + ^{A}_{Z}\text{Br} + 3^{1}_{0}\text{n}$$

$A =$ ____________________

$Z =$ ____________________ (2 marks)

(b) The graph below shows N versus Z for some stable nuclei. The position of caesium-137 is also plotted. Caesium-137 is radioactive.



Predict the type of decay that caesium-137 undergoes. Justify your answer.

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____ (2 marks)

(c) Ionising radiation, released when caesium-137 decays, is used by radiation therapists as a treatment for some cancers.

(i) State how ionising radiation can damage cancer cells.

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____ (1 mark)

(ii) Describe *one* way that radiation therapists minimise their exposure to ionising radiation.

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____ (2 marks)

(iii) A radioactive source containing 8.50×10^{-6} kg of caesium-137 initially has an activity of 2.72×10^{10} Bq. The source is effective until its activity decreases to 6.80×10^{9} Bq. Caesium-137 has a half-life of 30 years.

Calculate the mass of caesium-137 in the source when it stops being effective.

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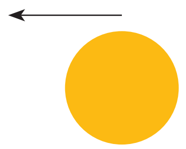
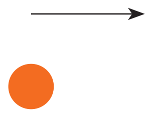
____ (3 marks)

19. The diagram below shows the motion of the nuclei produced following the alpha decay of a stationary americium-241 nucleus. The arrows show the direction in which each nucleus moves after the decay.

	neptunium nucleus	alpha particle
		
Mass (kg)	$3.936\,277 \times 10^{-25}$	6.6446×10^{-27}
Speed ($m\,s^{-1}$)	3.004×10^{5}	1.780×10^{7}

(a) Show that the total kinetic energy of the neptunium nucleus and the alpha particle is 1.071×10^{-12} J.

(3 marks)

(b) Explain why alpha particles emitted during alpha decay have a range of discrete kinetic energies.

(3 marks)

The equation for the alpha decay of americium-241 is:

$$^{241}_{95}\text{Am} \longrightarrow {}^{237}_{93}\text{Np} + \alpha$$

The mass of an americium nucleus is $4.002\,843 \times 10^{-25}$ kg.

(c) (i) Calculate the amount of energy that is released in the alpha decay of an americium-241 nucleus.

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______________________________ (4 marks)

(ii) Hence determine whether or not this alpha decay would be followed by the emission of gamma rays. Justify your answer.

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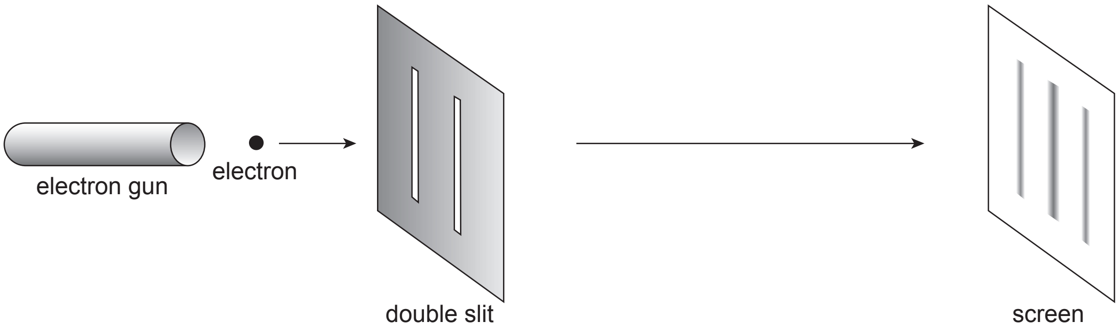
______________________________ (2 marks)

20. A beam of electrons passes through a double slit, and an interference pattern is observed on a screen. This pattern resembles the pattern seen when light produced by a laser passes through a double slit.



[This diagram is not drawn to scale.]

Explain how the results of this experiment provide evidence for the wave behaviour of electrons.

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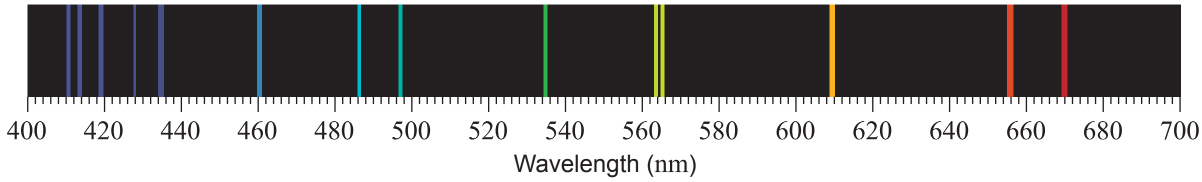
____ (3 marks)

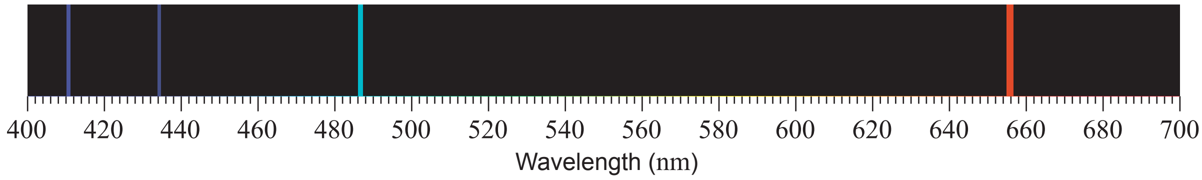
21. A spectroscope is used to obtain the visible part of the line emission spectrum for a particular star (shown below).

star

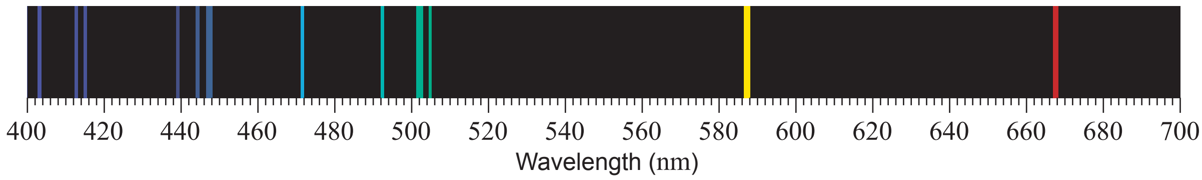


The spectrum obtained for the star is compared with the known line emission spectra of five elements (shown below).

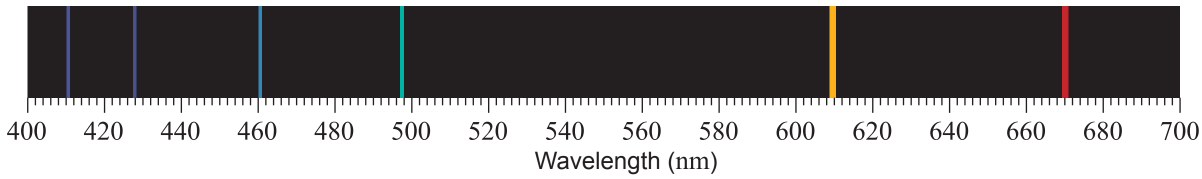
hydrogen



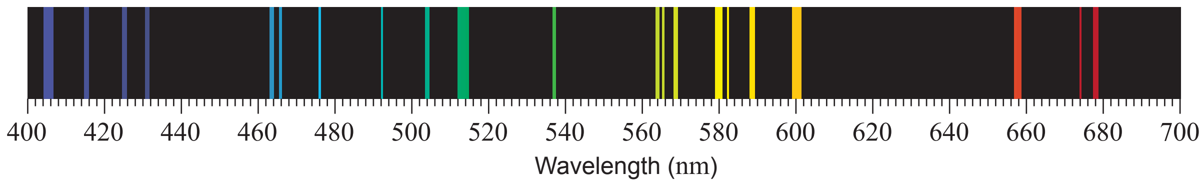
helium



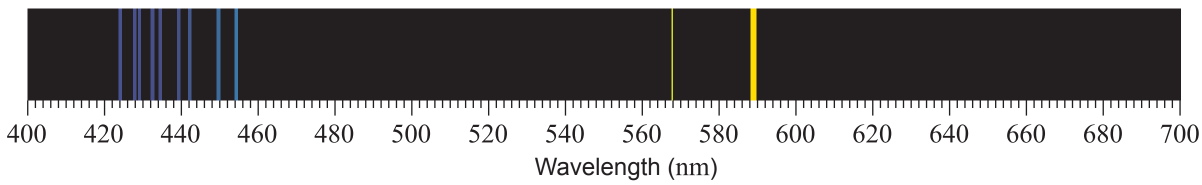
lithium



carbon



sodium



(a) Identify *two* elements that are present in the atmosphere of the star. Justify your answer.

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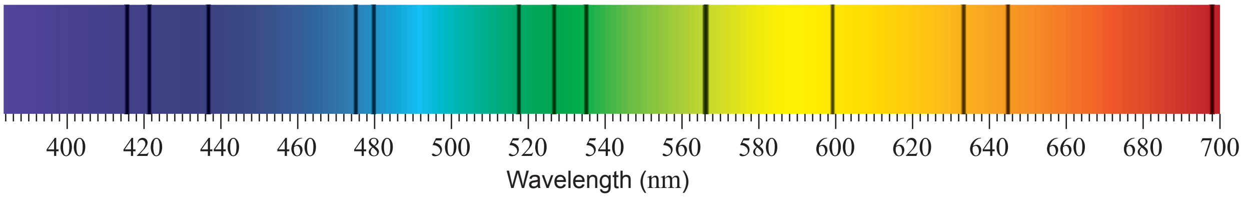
______________________________________ (3 marks)

(b) A line absorption spectrum for a star may be used to determine its speed. The line absorption spectrum of a star moving away from Earth is observed to have longer wavelengths than expected for the atoms producing these absorption lines.

A line absorption spectrum for a particular star is shown below.



The difference between the frequencies of the measured absorption lines from a star (f_S) and those measured in a laboratory (f_L) may be used to calculate the speed of a star.

Some of the absorption lines from the star were analysed, and the values for λ_L, f_L, and f_S are shown in the table below.

λ_L (nm)	f_L($\times 10^{14}$) Hz	f_S($\times 10^{14}$) Hz
405	7.41	5.70
435		5.29
546	5.49	4.23
577	5.20	4.00
610	4.92	3.77

(i) Show that the missing value for f_L is 6.90×10^{14} Hz.

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____ (2 marks)

(ii) *On page 15*, plot a graph of f_S (vertical axis) versus f_L (horizontal axis). Include a line of best fit. (6 marks)

(iii) Calculate the slope of the line of best fit.

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____ (2 marks)

Question 21 continues on page 17.

You may use this page if you wish to replace the graph you have plotted on page 15.

(iv) The difference between f_S and f_L is due to the star moving away from Earth at speed v.

The relationship between f_S and f_L is given by

$$f_S = \left(1 - \frac{v}{c}\right) f_L,$$ where c is the speed of light in a vacuum.

(1) Using the slope of the line of best fit that you calculated in part (b)(iii) on page 14, determine the speed of the star.

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____ (3 marks)

(2) Stars that are the greatest distance from Earth have the highest speeds.

On the graph that you drew on page 15, draw a line for a star that is further from Earth than the star that produces the line absorption spectrum on page 14. Justify your answer.

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____ (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. 14(b)(ii) continued).

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Question Booklet 3

- **Section B** (Questions 22 and 23) 30 marks
- Answer ***both*** questions in Section B
- Write your answers in this question booklet
- You may write on page 8 if you need more space
- Allow approximately 30 minutes

3

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SECTION B (Questions 22 and 23)

(30 marks)

*Questions 22 and 23 are extended-response questions. Answer **both** questions.*

Write your answers in this question booklet:

- Question 22, on pages 4 and 5, is worth 15 marks.
- Question 23, on pages 6 and 7, is worth 15 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 answers.

22. Both electric fields and magnetic fields can change the motion of a charged particle.

- Discuss the *similarities* and the *differences* between the effect of an electric field and the effect of a magnetic field on the motion of a charged particle.

  In your answer refer to a charged particle that is moving parallel to a field, and a charged particle that is moving perpendicular to a field.

(15 marks)

23. In one proposed form of spacecraft propulsion, a nuclear fission reactor supplies energy to an ion thruster.

- Describe how a nuclear fission reactor can release energy at a constant rate.
- Explain how the emission of discrete particles by an ion thruster changes the motion of a spacecraft.

(15 marks)

You may write on this page if you need more space to finish your answers to Questions 22 and 23. Make sure to label each answer carefully (e.g. 22 continued).