2025/24341

Government of **Western Australia**
School Curriculum and Standards Authority

ATAR course sample examination

Question/Answer booklet

PHYSICS

Place one of your candidate identification labels in this box.
Ensure the label is straight and within the lines of this box.

WA student number: In figures

In words

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time: three hours

Number of additional answer booklets used (if applicable):

Materials required/recommended for this paper

To be provided by the supervisor
This Question/Answer booklet
Formulae and Data booklet

To be provided by the candidate
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course examination, drawing templates, drawing compass and a protractor

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

PHY

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One Short response	12	12	50	58	30
Section Two Problem-solving	6	6	90	98	50
Section Three Comprehension and data analysis	2	2	40	38	20
				Total	100

Instructions to candidates

1. The rules for the conduct of the Western Australian external examinations are detailed in the *Year 12 Information Handbook: Part II Examinations*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.

3. You must be careful to confine your answers to the specific questions asked and to follow any instructions that are specific to a particular question.

4. When calculating answers, show all your working clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning.

   In calculations, give final answers to three significant figures and include appropriate units where applicable.

   If you repeat any question, ensure that you cross out the answer you do not wish to have marked.

5. Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

6. The Formulae and Data booklet is not to be handed in with your Question/Answer booklet.

Section One: Short response **30% (58 Marks)**

This section has **12** questions. Answer **all** questions. Write your answers in the spaces provided.

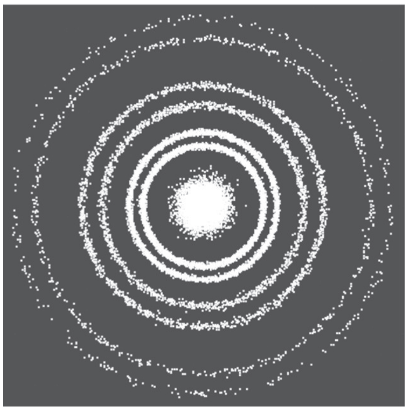
When calculating numerical answers, show your working or reasoning clearly. Unless otherwise instructed, give final answers to **three** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 50 minutes.

Question 1 **(4 marks)**

When electrons are fired through a crystal, a pattern like the one shown in the diagram below is detected on a screen. It displays alternating light and dark bands of exposure.

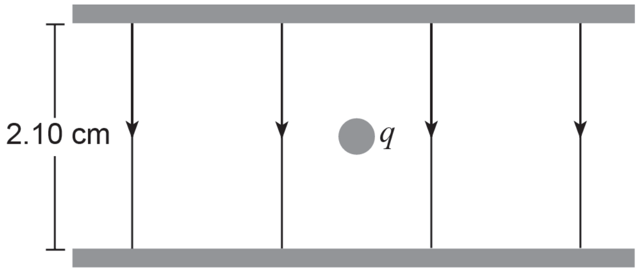


Explain how this pattern is formed and how it supports de Broglie's hypothesis that all matter has a wavelength.

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 2 **(5 marks)**

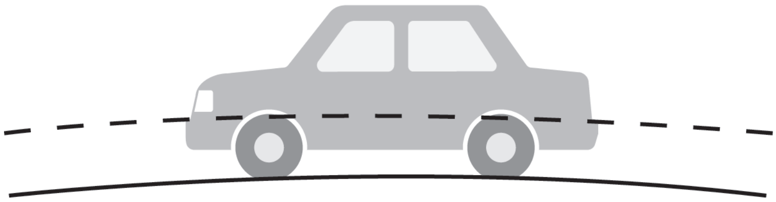
A negatively charged dust particle q remains stationary in a uniform electric field as shown in the diagram below. The particle has a mass of 3.70 µg. The distance between the plates is 2.10 cm and the potential difference across them is 1.20×10^2 V.



Calculate the charge on the dust particle q.

Answer: ______________ C

Question 3 **(4 marks)**



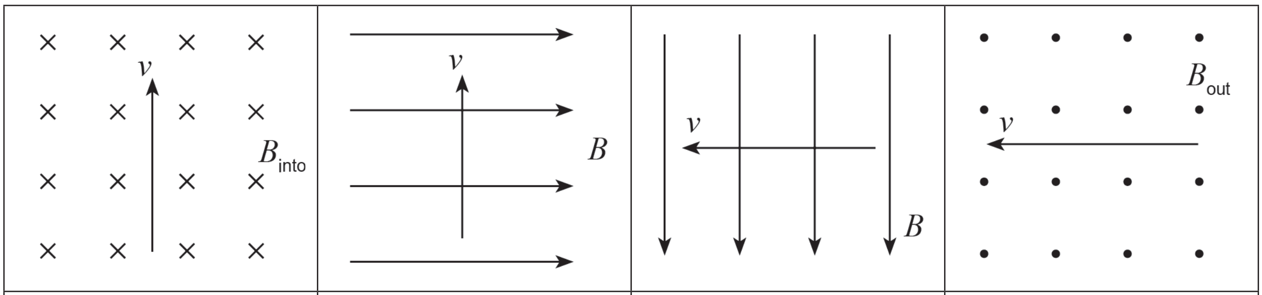
The diagram above illustrates a 905 kg car, moving at a speed of 72.0 km hr^{-1}, travelling over a bridge with a radius of curvature of 80.0 m to its centre of mass.

Calculate the total upward reaction force between the road and the car when it is at the top of the bridge.

Answer: ______________ N

Question 4 **(4 marks)**

Four charged particles are fired into uniform magnetic fields, as shown below. In situations A and B, the particles are electrons, while in C and D, they are protons. The initial direction of the velocity is given by v.



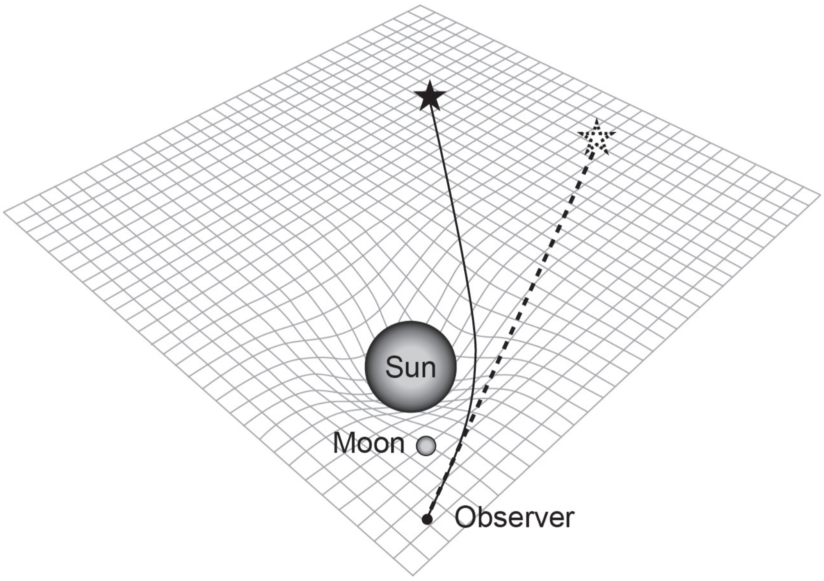
A (electron)	B (electron)	C (proton)	D (proton)

Complete the table below by placing **one** tick in the correct column for each situation, indicating how the particle is deflected.

Case	Left of page	Right of page	Into the page	Out of the page	Up the page	Down the page	Not deflected
A							
B							
C							
D							

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 5 **(4 marks)**



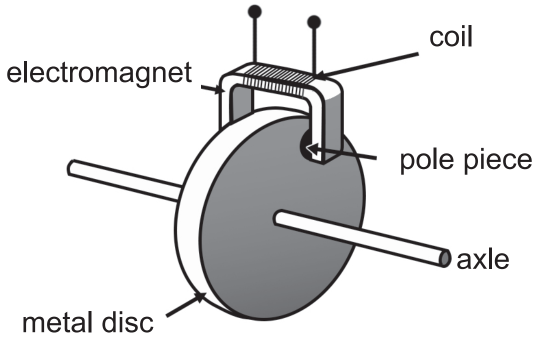
The diagram above illustrates how a massive object, such as our Sun, can influence the perceived position of distant stars as observed from Earth. This effect was first detected during a total solar eclipse when the Sun's light was blocked by the Moon.

By labelling the relevant parts, use the diagram to explain how the position of a distant star appears to change when the Sun passes between the star and Earth.

Question 6 **(4 marks)**

A metal disc is rotated in a magnetic field as shown in the diagram to the right.

Explain why the metal disc will heat up if it is spun quickly. You must reference specific laws in your answer.



Question 7 **(4 marks)**

Calculate the frequency of a photon with a momentum of 3.05×10^{-24} N s.

Answer: ________________ Hz

Question 8 **(4 marks)**

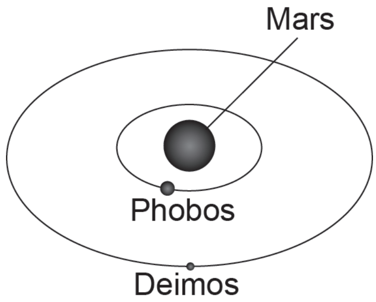
The closest star system to our solar system is Alpha Centauri. It is 4.2441 ly away.

If Earth launched a spacecraft to explore Alpha Centauri, estimate how long, in years, it would take to get there if the spacecraft travelled in a straight line, at an average non-relativistic speed of 2.50×10^5 km hr^{-1}.

Answer: ________________ years

Question 9 **(5 marks)**

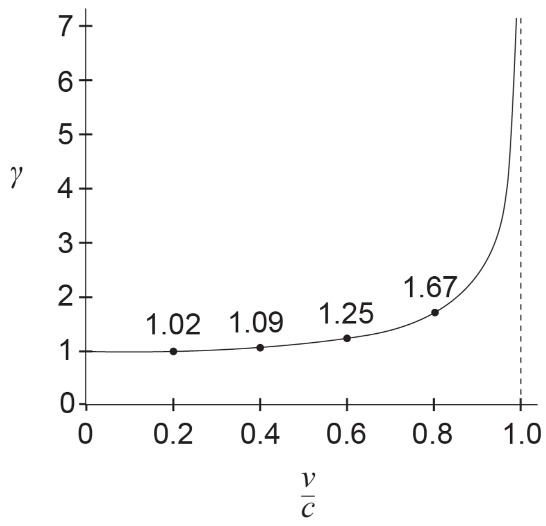
Phobos and Deimos are two moons that orbit Mars as shown in the diagram to the right. Their average radii of orbit are 9.38×10^3 km and 2.35×10^4 km respectively.



Assuming their orbits are circular, calculate the ratio of the orbiting period of Phobos to Deimos.

Answer: $\frac{T_P}{T_D}$ = ____________________

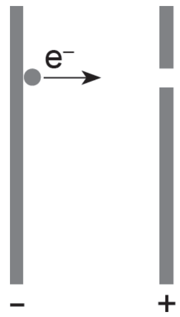
Question 10 **(6 marks)**



The graph above shows the relationship between gamma $\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$ and beta $\beta = \dfrac{v}{c}$.

It shows that for speeds less than 50% of the speed of light, γ is close to 1. Therefore, for particles moving at speeds less than 0.500 c, relativistic effects, such as length contraction or time dilation, do not apply.

The diagram on the right shows a stationary electron between a set of parallel plates.

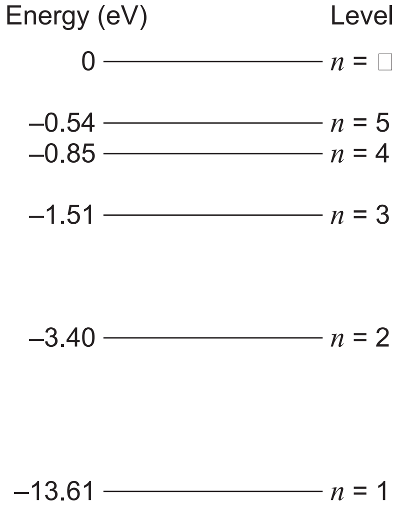


Determine the maximum potential difference across the plates that the stationary electron can move through before relativistic effects must be considered.

Answer: ______________ V

Question 11 **(8 marks)**

The diagram on the right shows some energy levels of a hydrogen atom. Photons with wavelengths between 96.2 nm and 132 nm bombard a hydrogen atom. Only certain wavelengths are absorbed by the electron in the ground state in the hydrogen atom.



(a) Calculate the wavelengths absorbed in nanometres (nm). (7 marks)

Answer: ________________ nm

(b) How many photons are released by the hydrogen atom when the electron returns to the ground state? (1 mark)

Answer: ________________

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 12 **(6 marks)**

A group of students measured the mass and volume of an object made from an unknown substance. They expressed their values with the absolute uncertainties of their instruments. Their results are below.

Mass = 3.6 g ± 0.1 g
Volume = 24.2 mL ± 0.2 mL

The density of an object is calculated by dividing its mass by its volume. Calculate the density of the object in g mL^{-1} and include the absolute uncertainty. Give your answer to the correct number of significant figures.

Answer: ______________ g mL^{-1} ± ______________ g mL^{-1}

End of Section One

Section Two: Problem-solving **50% (98 Marks)**

This section has **six** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Give final answers to **three** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 90 minutes.

Question 13 **(13 marks)**

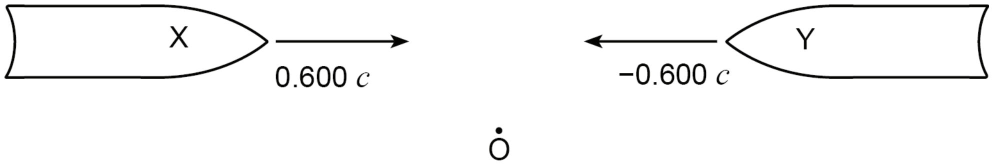


Figure 1: Spaceships X and Y, as seen by observer O

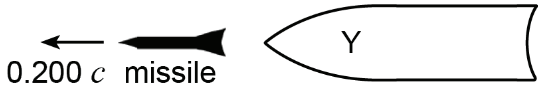


Figure 2: Missile, as seen by Y

Two spaceships, X and Y, are moving towards each other each with a velocity of 0.600 c relative to observer O (Figure 1). Y fires a missile after warning X it is straying into its territory. The missile travels at 0.200 c relative to Y (Figure 2).

(a) Calculate the velocity of Y as measured by X. (3 marks)

Answer: ________________ c

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(b) Calculate the velocity of the missile as measured by X. (4 marks)

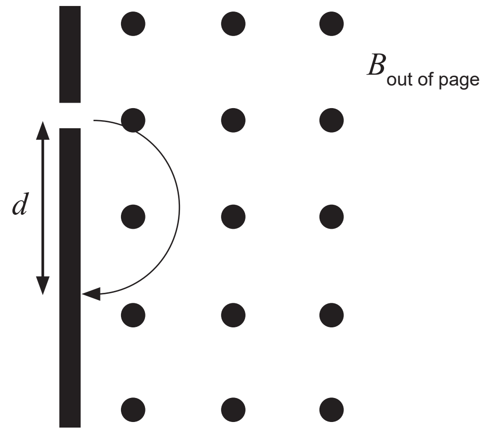
Answer: ______________ c

(c) X's radio receivers are tuned to a very narrow band of radio frequencies. Y transmitted the warning signal using this same narrow frequency band. X did not respond to the warning signal sent by Y before Y fired the missile. Explain why X failed to detect the signal and what X could have done to receive the warning signal. (4 marks)

(d) Determine the speed that observer O sees the gap between X and Y closing. (2 marks)

Answer: ______________ m s^{-1}

Question 14 **(18 marks)**



A proton with a rest energy of 938 MeV and a total energy of 1131 MeV is fired into a uniform 4.50 T magnetic field at right angles to the field. It follows a circular path and hits a plate at a distance d from the entrance point as shown in the diagram above.

(a) Calculate the speed of the proton as it enters the magnetic field. Express your answer in terms of c to **three** significant figures. (7 marks)

Answer: ________________ c

(b) Calculate the magnitude of the momentum of the proton as it enters the magnetic field.
(6 marks)

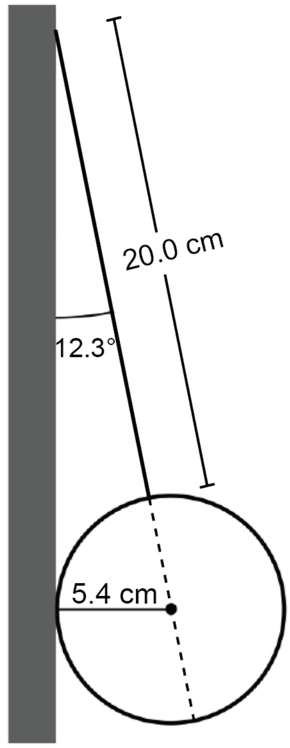
Answer: ________________ N s

(c) Use your answer from part (b) to calculate the distance d shown in the diagram on page 18.
(5 marks)

Answer: ________________ m

Question 15 **(20 marks)**

A metal sphere of radius 5.4 cm and mass 8.95 kg is attached to a wall by a 20.0 cm lightweight nylon string. The string makes an angle of 12.3° to the wall, as shown in the diagram to the right. There is a vertical frictional force of 8.45 N between the sphere and the wall parallel to the wall.



(a) Calculate the tension in the string. (4 marks)

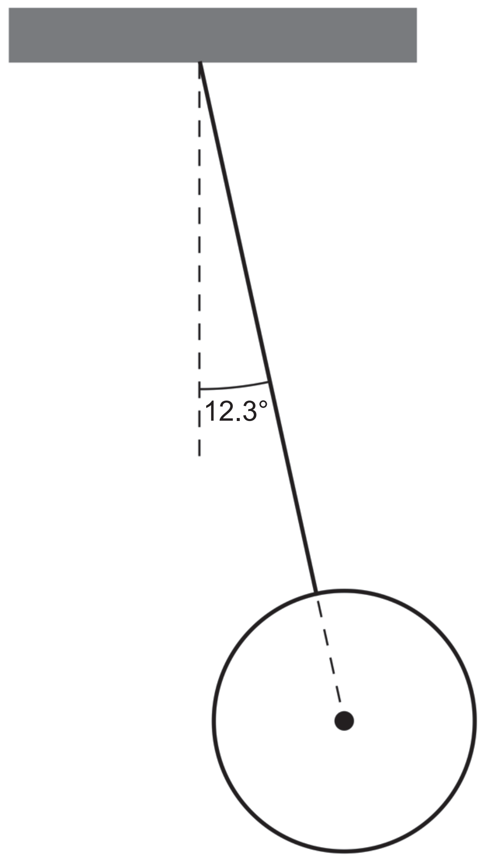
Answer: ________________ N

(b) Calculate the net reaction force of the wall on the metal sphere. If you could not get an answer to part (a), use 1.00×10^2 N. (5 marks)

Answer: ________________ N at ________________ ° to the horizontal

(c) The metal sphere is now suspended by the same 20.0 cm string from a frictionless hook in the ceiling. It is released and swings back and forth, with the maximum angle of the string from the vertical being 12.3°.

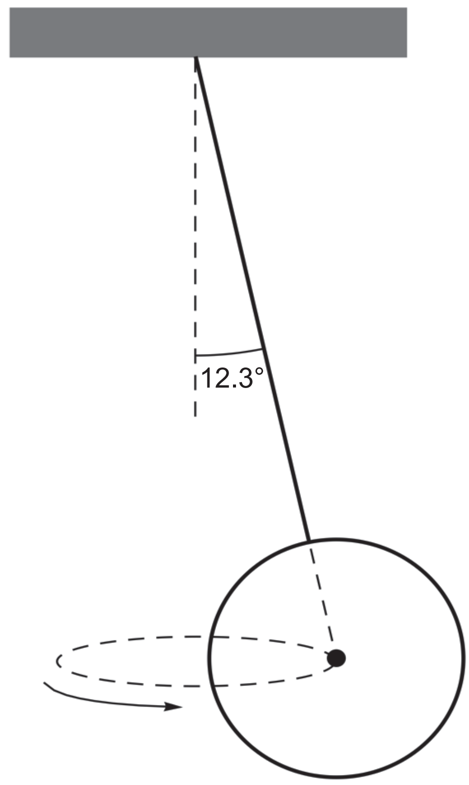
Calculate the tension in the string at the bottom of its swing. (8 marks)



Answer: ______________ N

(d) The metal sphere is now swung in a circle maintaining the angle of 12.3°.

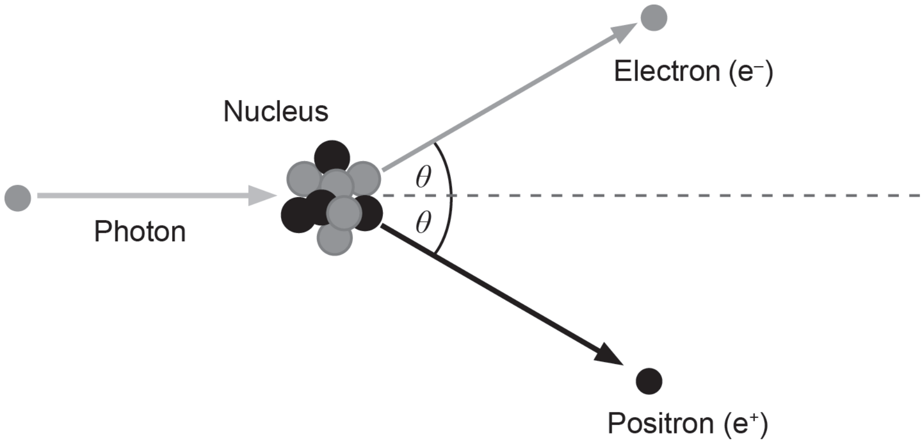
Calculate the tension in the string. (3 marks)



Answer: ______________ N

Question 16 **(16 marks)**

In some situations pure energy can be converted to matter. One such process is called pair production.



The diagram above shows a photon colliding with a heavy nucleus. The photon is annihilated during the collision. The collision produces an electron and a positron.

(a) Calculate the maximum wavelength of the photon required for the reaction to take place, assuming that energy is conserved. (6 marks)

Answer: ______________ m

(b) Using your answer from part (a), calculate the momentum of the incoming photon. If you could not get an answer to part (a), use 1.20×10^{-12} m. (3 marks)

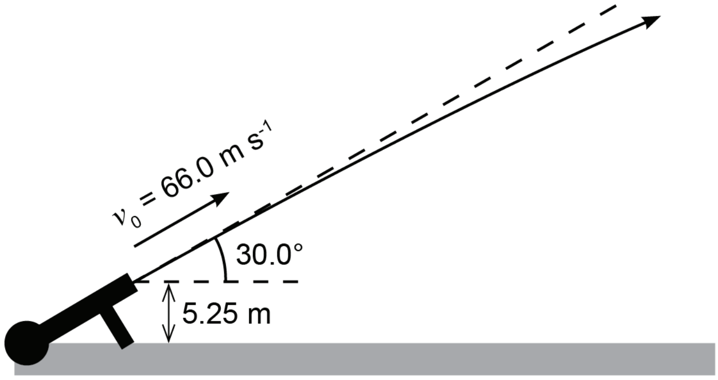
Answer: ______________ N s

(c) After the collision, the momentum of the electron and positron are equal in magnitude, 2.3865×10^{-22} N s. The momentum of the heavy nucleus is 0.784×10^{-22} N s. Assuming momentum is conserved, calculate the value of θ using your answer from part (b) on page 22 and components of the momentum vector. (7 marks)

Answer: ________________ °

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 17 **(19 marks)**



The diagram above displays a cannon firing a 5.00 kg cannon ball at an angle of 30.0° to the horizontal. The cannon ball leaves the end of the cannon, which is 5.25 m above ground level. The launch velocity is 66.0 m s^{-1}.

(a) Calculate the maximum height the cannon ball reaches above ground level. (5 marks)

Answer: ________________ m

(b) Calculate how far from the base of the cannon the cannon ball lands. (6 marks)

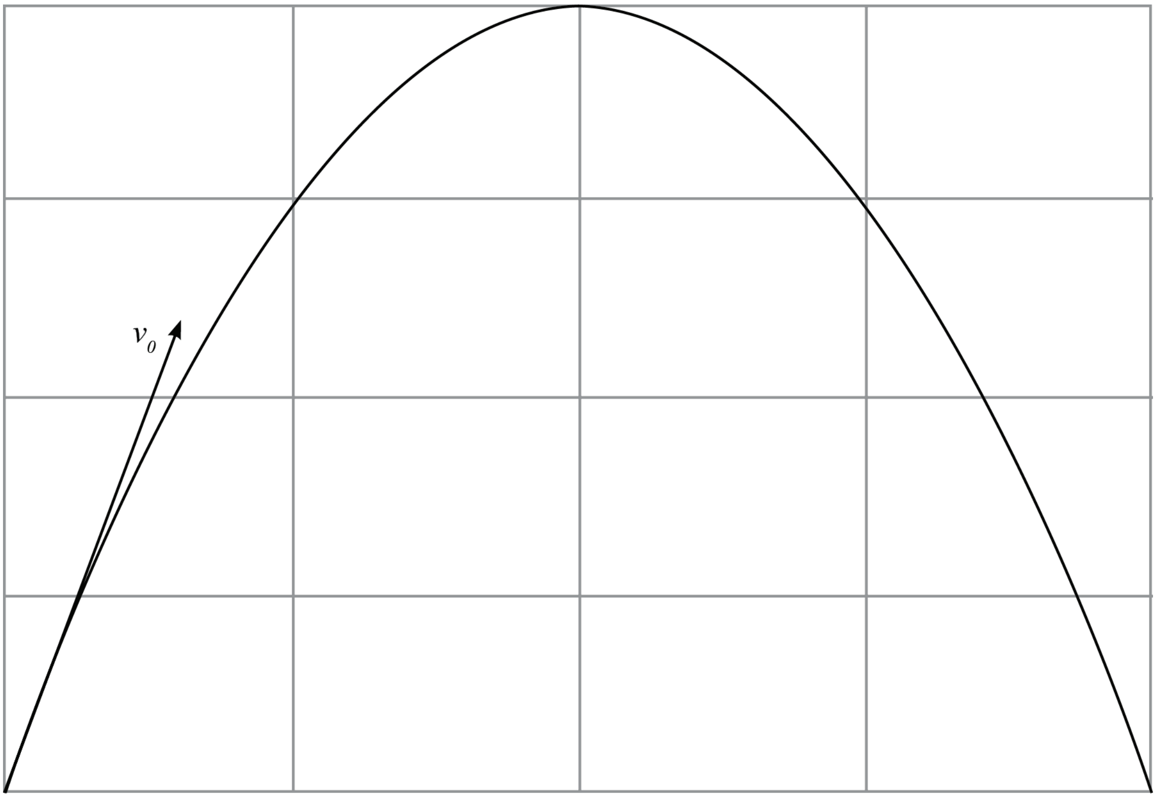
Answer: ________________ m

(c) Determine at what time/s the cannon ball is 2.00 m above the launch height. (4 marks)

Answer/s: ______________ s ______________ s

(d) The diagram below shows the path of a projectile, without taking air resistance into account.

On the same diagram, draw the path of an identical projectile fired at the same velocity and angle when air resistance is a factor. Your diagram must show where it lands. (4 marks)

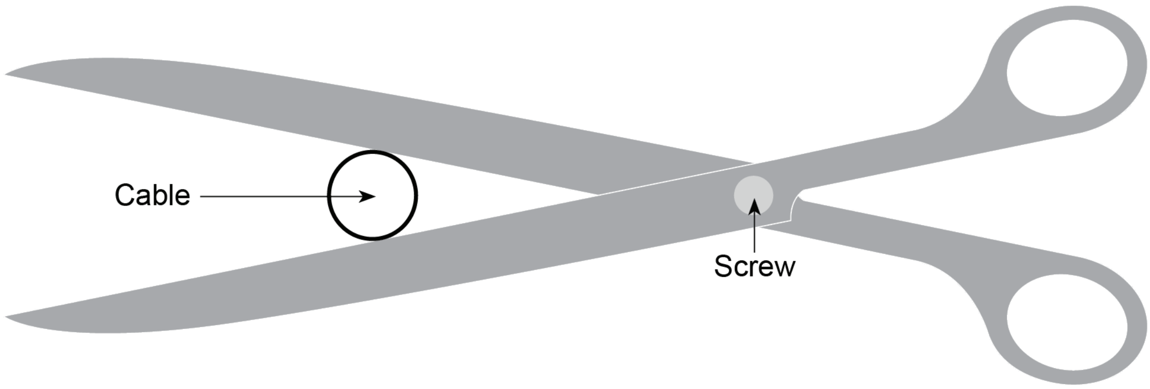


A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

Question 18 **(12 marks)**

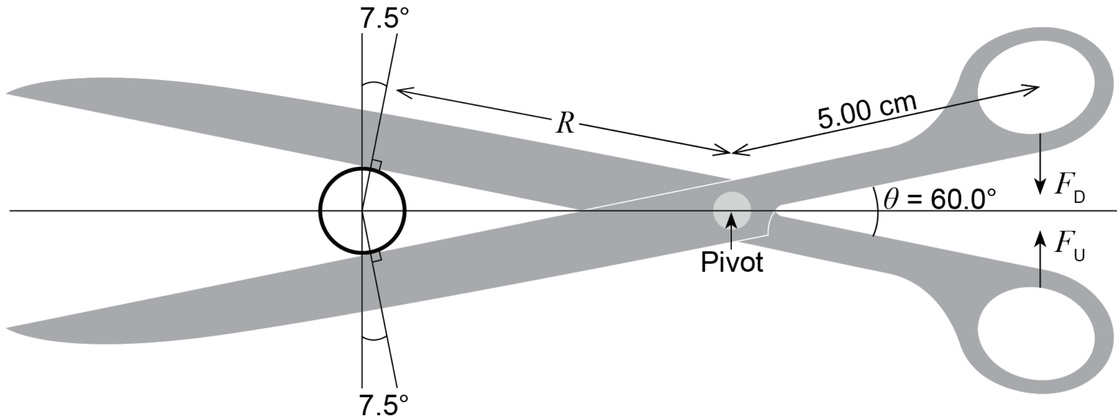
Alistair and Andrew are putting up Christmas decorations. In order to do this, they must cut a thick cable with scissors. Alistair puts the cable between the ends of the blades and tries to cut the cable but it does not work. Andrew, being an ex-Physics teacher, tells Alistair to put the cable closer to the screw holding the two blades together. This time, with the same force, Alistair is able to cut the cable.

(a) By labelling the relevant parts on the diagram below, explain why the cable was able to be cut when Alistair put it closer to the screw. (5 marks)



(b) Alistair can exert a force of 1.20 × 10^2 N vertically on each handle of the scissors. The distance between the pivot and where those forces are applied is 5.00 cm. The cable requires a total vertical force of 2.50 × 10^2 N to be cut. The angle between the handles is 60.0° and the angle between the applied force of the blades and the vertical is 7.5°.

With reference to the diagram below, calculate the distance R (to **three** significant figures) from the pivot to the point of contact between the blades and the cable. As the scissors are symmetrical, only one blade needs to be considered. (7 marks)



Answer: ______________ m

End of Section Two

This page has been left blank intentionally

Section Three: Comprehension and data analysis **20% (38 Marks)**

This section has **two** questions. You must answer **both** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Unless otherwise instructed, give final answers to **three** significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 40 minutes.

Question 19 **(18 marks)**

'Luminosity', L, is defined as the total energy output per second of a star. The luminosity of our sun is approximately 3.84×10^{26} W. But how bright it appears to an observer depends on how far away it is. The apparent brightness of a star decreases rapidly with distance as the power is spread out over a far greater surface area. The diagram below shows doubling the distance decreases the apparent brightness by a factor of four and tripling it decreases the brightness by a factor of nine.

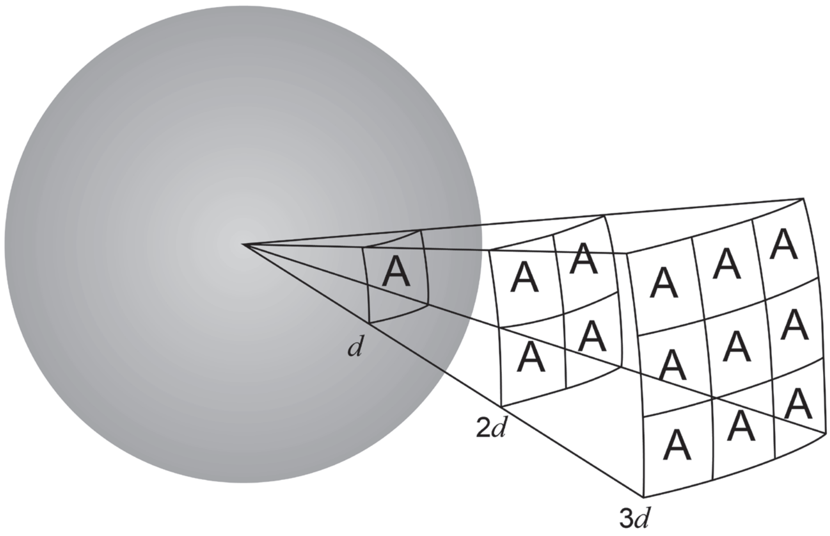


Figure 3: Apparent brightness varies with distance from the source

The equation for apparent brightness is detailed below.

$$b = \frac{L}{4\pi d^2}$$

b = apparent brightness in W m^{-2}
L = luminosity in W
d = distance in m

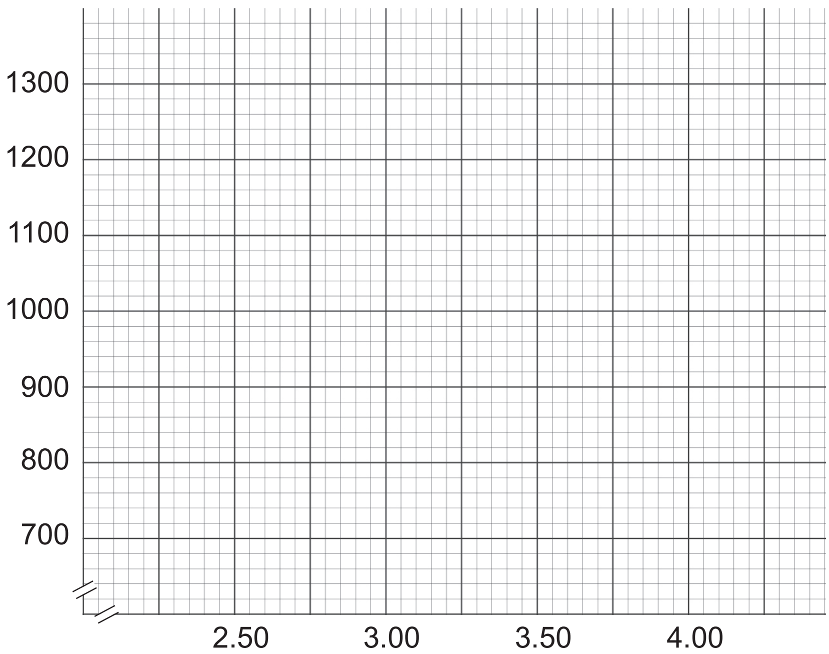
Question 19 (continued)

In 2011, NASA launched the spacecraft Juno on a mission to Jupiter. It measured the apparent brightness of our Sun as the distance from the Sun increased. Some of the results are in the following table.

Distance d ($\times 10^9$ m)	160	170	180	190	200
Apparent brightness b (W m^{-2})	1180	1040	930	840	760
$\frac{1}{d^2}$ ($\times 10^{-23}$ m^{-2})					

(a) Complete the table above by calculating $\frac{1}{d^2}$. Give your answers to **three** significant figures. (3 marks)

(b) On the grid below, graph apparent brightness b versus $\frac{1}{d^2}$. Include a line of best fit and label the axes. (4 marks)



A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate that you have redrawn it on the spare grid.

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

(c) (i) Calculate the gradient of your line of best fit from part (b) on page 30. Indicate clearly on the graph the **two** points used in your calculation. Give your answer to **two** significant figures and provide the correct unit. (5 marks)

Answer: ______________ Unit: ______________

(ii) Use the calculated gradient from part (c)(i) to calculate the luminosity of our Sun. (3 marks)

Answer: ______________ W

(iii) Calculate the percentage difference between your answer calculated in part (c)(ii) and the value provided in the text on page 29. (3 marks)

Answer: ______________ %

Question 20 **(20 marks)**

Regenerative braking in trains

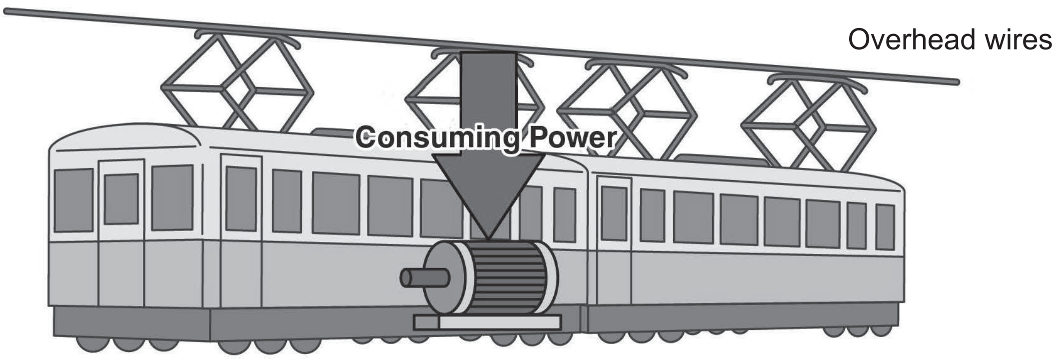
A generator and a motor have the same basic structure. They both have rotating coils in permanent magnetic fields. When current flows through a wire in a magnetic field, it experiences a force. This force is used by motors to produce torque, which spins the coil and mechanical energy is produced. In a generator, mechanical energy is supplied to the coil and due to Lenz's Law, a current is induced to try and stop the coil rotating. This also happens in motors when the coil spins. The emf produced is called the 'back' emf. This reduces the effective emf supplied to the motor.

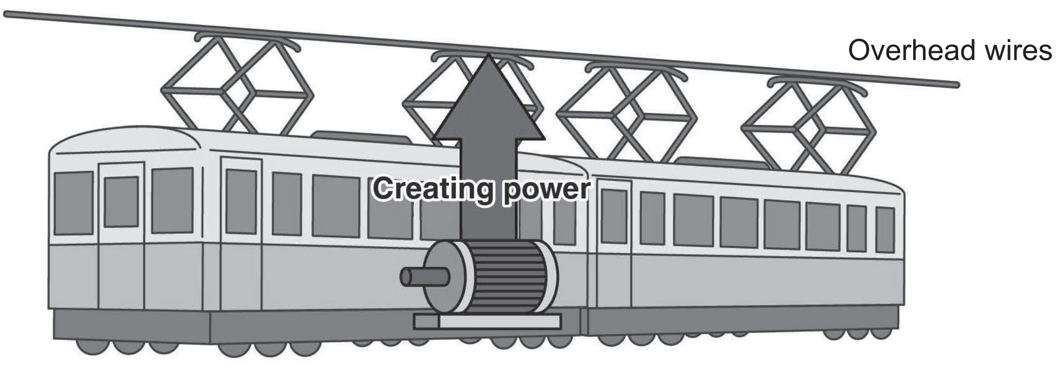
$$V_{net} = V_{applied} - V_{back}$$

As the motor speeds up, the back emf increases to the point where it equals the applied voltage and the motor is at maximum speed. Most electrical appliances that have motors in them have an optimum operating frequency.

If the motor is disconnected from the supply, the coil has momentum and continues to spin which continues to produce a back emf.

On electric trains the conventional braking system is called dynamic braking, where the kinetic energy of the train is wasted as heat, produced by the friction between the wheels and the brake discs. Regenerative braking uses the kinetic energy to produce a back emf. This process slows the train down. As the train slows, the electric motors generate electricity that is returned to the electrical distribution system. This generated electricity is then used within the system to power other trains or to offset the electrical demands of other parts of the system such as lighting in stations.





DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Regenerative braking saves energy and reduces the wear on mechanical brakes. This technique is most effective in trains that stop often enough to make the recovery of the energy worthwhile.

(a) Explain why the train slows down when the motor is disconnected from the supply. Include an appropriate law of Physics in your answer. (4 marks)

(b) (i) Calculate the maximum back emf produced by a 50 Hz AC motor if the armature consists of a 25.0 cm^2 coil with 50 turns spinning in a 0.370 T magnetic field. (3 marks)

Answer: ______________ V

(ii) Calculate the root mean square, rms, voltage induced in the coil. (1 mark)

Answer: ______________ V

DO NOT WRITE IN THIS AREA AS IT WILL BE CUT OFF

Question 20 (continued)

(iii) Calculate the net voltage supplied to the motor if the applied rms voltage is 32.0 V. (2 marks)

Answer: ______________ V

(iv) Explain what would happen to the net voltage if the load was decreased and the coil spun faster. (3 marks)

(c) If the electric motor in a train seizes (the armature containing the coils stops moving), it will overheat. Explain why overheating happens. (3 marks)

(d) Trains that have regenerative braking systems do not rely exclusively on this system. Explain why it would be unsafe to rely solely on regenerative braking to stop trains.

(4 marks)

End of questions

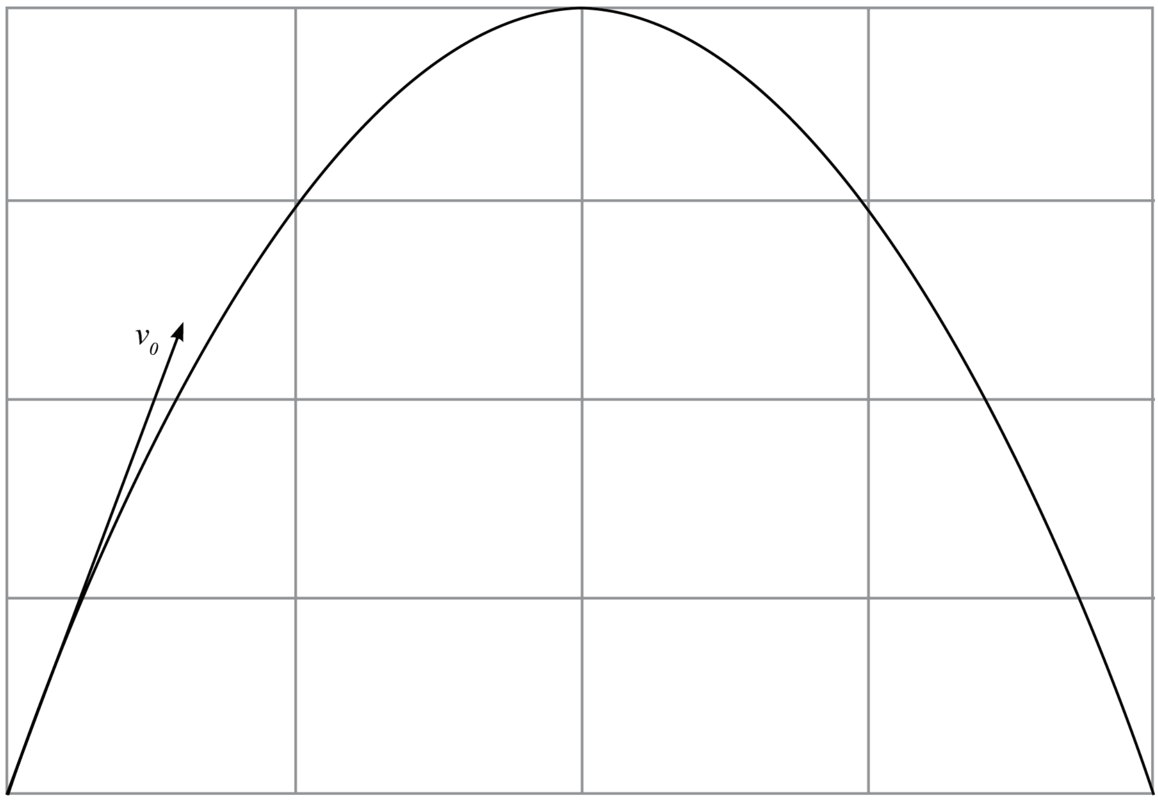
Supplementary page

Question number: ______________

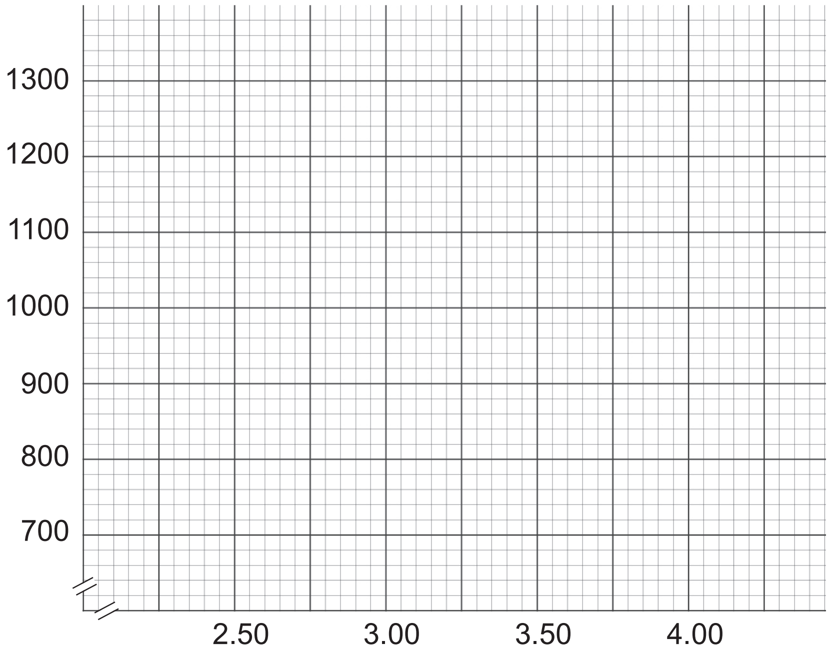
Supplementary page

Question number: ________________

Spare grid for Question 17(d)



Spare grid for Question 19(b)



Published by the School Curriculum and Standards Authority of Western Australia
303 Sevenoaks Street
CANNINGTON WA 6107