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

Western Australian Certificate of Education
Sample Examination, 2016

Question/Answer Booklet

PHYSICS

Please place your student identification label in this box

Student Number: In figures

In words ______________________

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Time allowed for this paper
Reading time before commencing work: ten minutes
Working time for paper: three hours

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 non-programmable calculators approved for use in the WACE examinations, 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 notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

2013/42115(v2)

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short response	14	14	50	54	30
Section Two: Problem-solving	7	7	90	90	50
Section Three: Comprehension	2	2	40	36	20
				Total	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2016*. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

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

   When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

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

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question that you are continuing to answer at the top of the page.

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

Section One: Short response **30% (54 Marks)**

This section has **14** questions. Answer **all** questions.

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

When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of **two** significant figures and include appropriate units where applicable.

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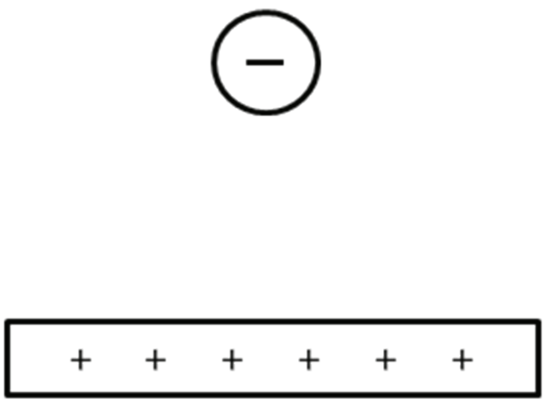
Suggested working time: 50 minutes.

Question 1 **(3 marks)**

Draw the resultant electric field with at least **five** lines for each of the following situations.

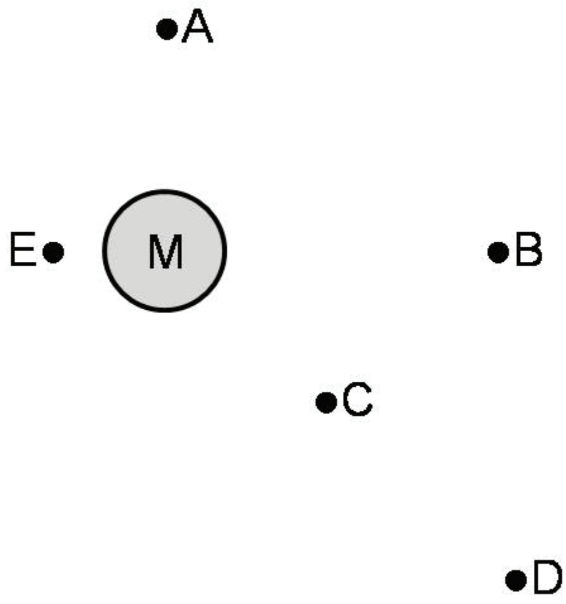
Two opposite but equally-charged spheres

A charged sphere near a charged conductive plate



Question 2 **(4 marks)**

The diagram below shows five points, labelled 'A' to 'E', in free space around a large mass M. You may wish to use a ruler to help you to answer this question.



	Point	Point
Which two points have the same magnitude of gravitational field strength due to M?		
	Point	**Point**
Which two points experience the same direction of gravitational field due to M (as viewed in this diagram)?		
	Point E	**Point B**
What is the ratio of the gravitational field strength at E to the gravitational field strength at B?	:	

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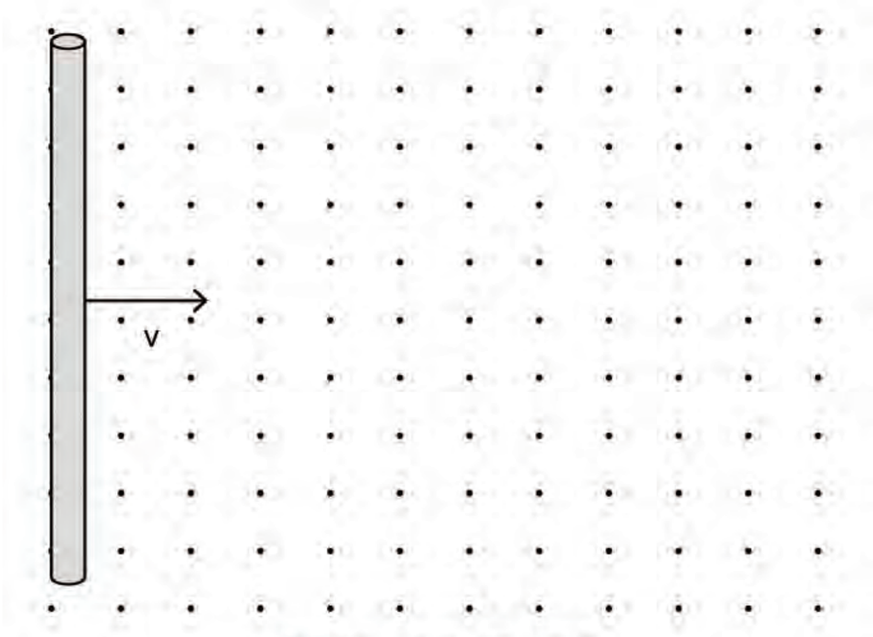
Question 3 **(3 marks)**

A 12.5 cm long piece of copper wire is moved at a constant velocity of 6.56 m s^{-1} through a magnetic field of 0.150 T. Calculate the potential difference between the ends of the wire and indicate on the diagram which end of the wire is positive.



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Question 4 **(4 marks)**

All hadrons are composed of different combinations of fundamental particles called quarks.

Baryons are made from a combination of three quarks; antibaryons are made from a combination of three antiquarks; and mesons are made from two quarks; a quark and an antiquark.

All quarks have a baryon number of $+\frac{1}{3}$; all antiquarks have a baryon number of $-\frac{1}{3}$; and all baryons have a baryon number of +1.

(a) A pion is a meson. Determine the baryon number of the pion. (1 mark)

Baryon number **must** be conserved in all reactions.

(b) Determine, by applying conservation of baryon number, whether the following reaction can take place. Justify your answer with appropriate workings. (3 marks)

proton + neutron $\rightarrow$ proton + pion

Question 5 **(4 marks)**

Bathroom scales measure weight (a force) but give the reading in kilograms (mass). A particular scale shows a person's mass as being 70 kg at the Earth's equator. The spinning of the Earth contributes to the scale's reading. What would the scale read at the South Pole, with the same person standing on it? (Circle the correct answer.)

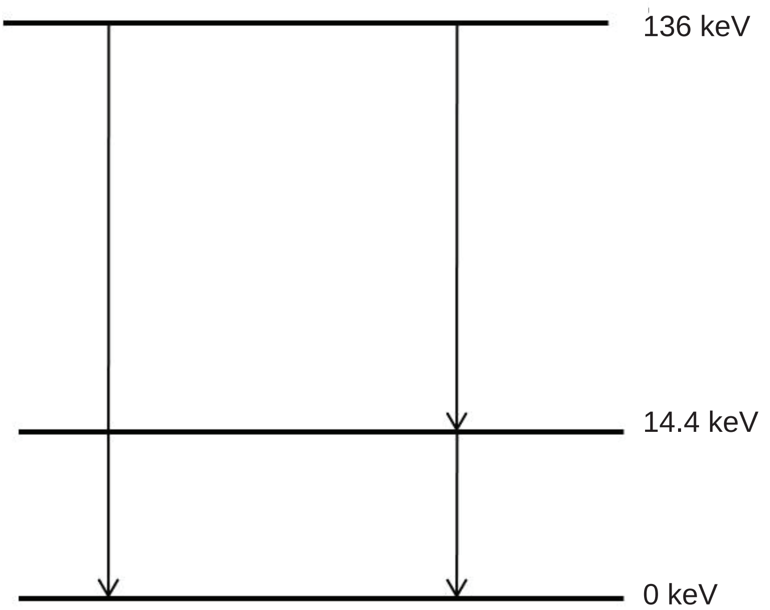
the same less than 70 kg more than 70 kg

Explain your reasoning: ______________________________

Question 6 **(4 marks)**

When a radioactive isotope undergoes gamma decay, a nucleus in an excited state decays to a lower energy state of the same isotope by the emission of a photon. This decay is similar to the emission of light when an electron in an atom moves from a higher energy level to a lower one. The isotope $^{57}_{26}Fe$ can decay to the ground state in the two ways shown on the energy level diagram below.

Calculate the wavelength of the photon emitted in the transition from the level with energy of 136 keV to the level with energy of 14.4 keV.

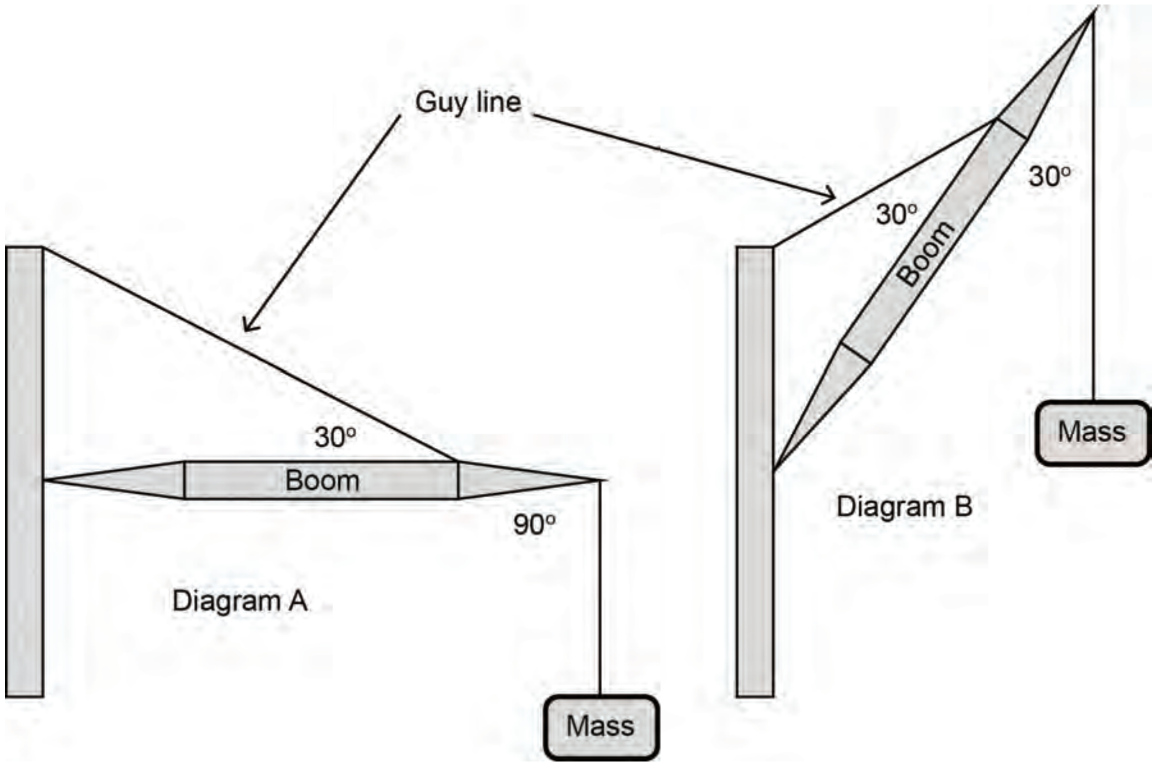


Question 7 **(5 marks)**

Mick is watering the lawn and wants to estimate the initial velocity of the water coming from the hose. Use information from the photograph to estimate the magnitude of the initial velocity of the water. Express your answer to an appropriate number of significant figures.

Question 8 **(4 marks)**

A crane (Diagram A) lifts a mass by raising its boom (Diagram B). Explain how this affects the tension in the guy line as the crane shifts the mass from its initial position in Diagram A to its position in Diagram B.



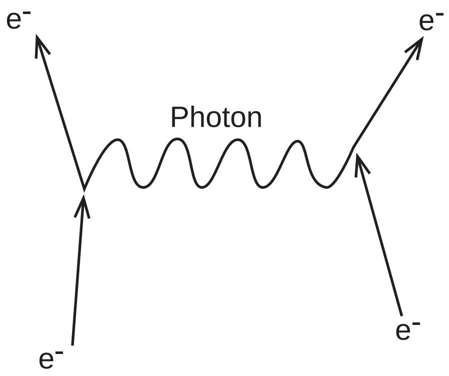
Question 9 **(4 marks)**

Describe briefly how Edwin Hubble's observations of the redshifts of galaxies were used to formulate Hubble's Law and explain how Hubble's Law is used to support the Big Bang theory.

Question 10 **(3 marks)**

The Standard Model categorises all particles as being matter (fermions) or force carriers (gauge bosons). The gauge bosons are exchange particles that are responsible for the interactions between matter involving three of the four fundamental forces.

Describe how exchange particles prevent you from falling through the chair you are sitting on. The Feynman diagram below may assist you.



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Question 11 **(4 marks)**

In the Stanford Linear Accelerator Center (SLAC), beams of electrons and positrons are accelerated and focused so they collide head-on.

Calculate the momentum, in kg m s^{-1}, of an electron that has been accelerated to a speed of 0.400c and explain why the force required to accelerate the electron uniformly must change as its speed increases.

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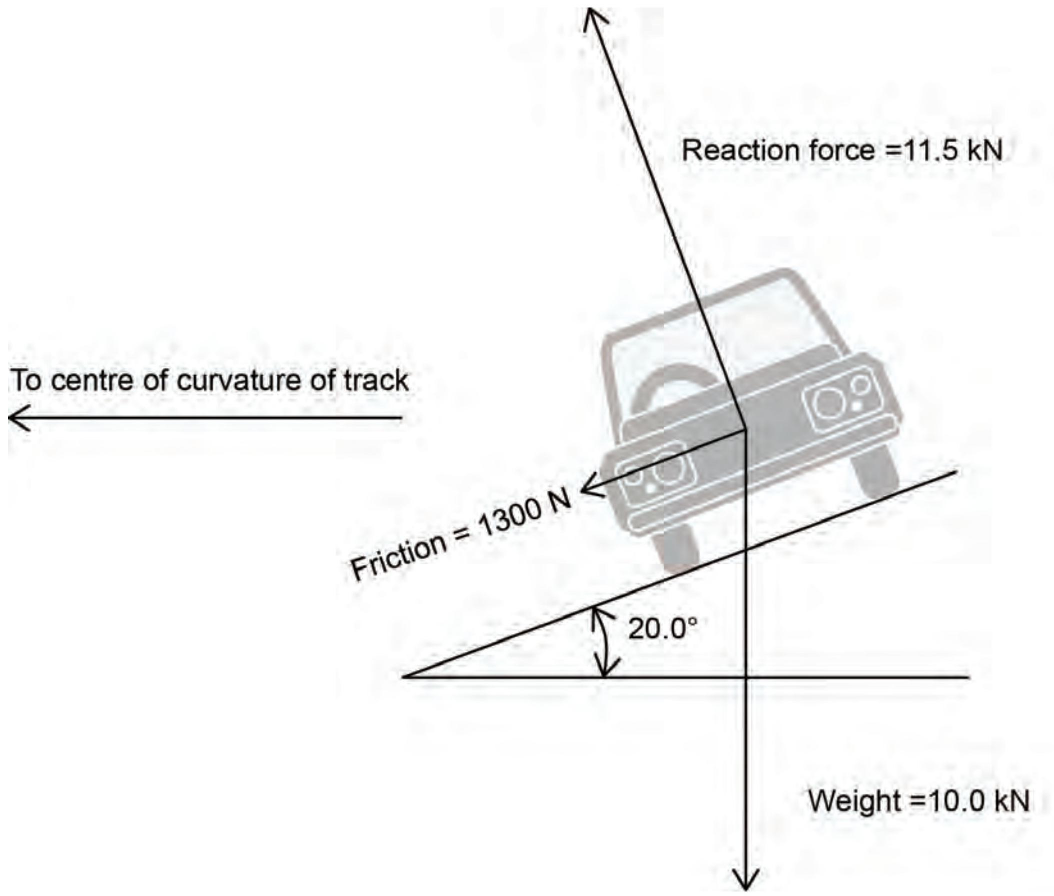
Question 12 **(5 marks)**

The diagram below shows the forces acting on a car following a curve on a banked track. The car is travelling at 17.0 m s^{-1} without slipping. Calculate the radius of the track.



Question 13 **(4 marks)**

Louis de Broglie thought that if a wave could behave like a particle, then perhaps a particle could behave like wave. He proposed that the wavelength of a material particle was related to its linear momentum $p = mv$.

Compare, through calculation, the de Broglie wavelength for a 5 kg ball travelling at 14 m s^{-1} to an electron that has been accelerated through a potential difference of 100 V and is now travelling at 5.9×10^6 m s^{-1}.

From these results, determine which of these particles has a wavelength in the X-ray region of the electromagnetic spectrum.

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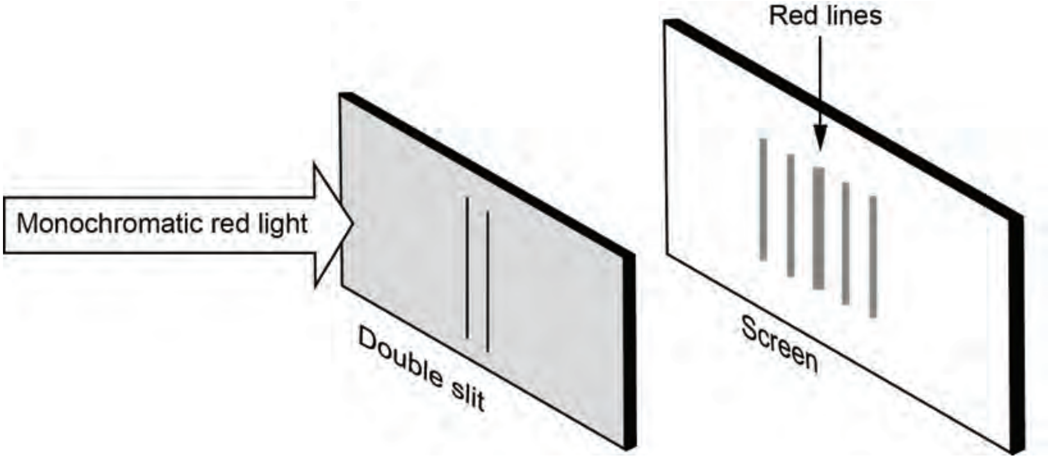
Question 14 **(3 marks)**

The pattern observed when monochromatic light passes through a piece of cardboard with twin slits close together is often considered evidence for the wave theory of light. A diagram of an experiment set up in a classroom is provided below.



Explain how the pattern of red lines is formed on the screen and why this is considered to be evidence for the wave theory of light.

End of Section One

Section Two: Problem-solving 50% (90 Marks)

This section has **seven (7)** questions. Answer **all** questions. Write your answers in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

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Suggested working time: 90 minutes.

Question 15 (10 marks)

An uncharged drop of oil is given **seven** excess electrons. It is then introduced into the space between two horizontal plates 25.0 mm apart with a potential difference between them of 1.50 kV. The drop of oil remains stationary.

(a) Calculate the magnitude of the electric field strength between the plates. (2 marks)

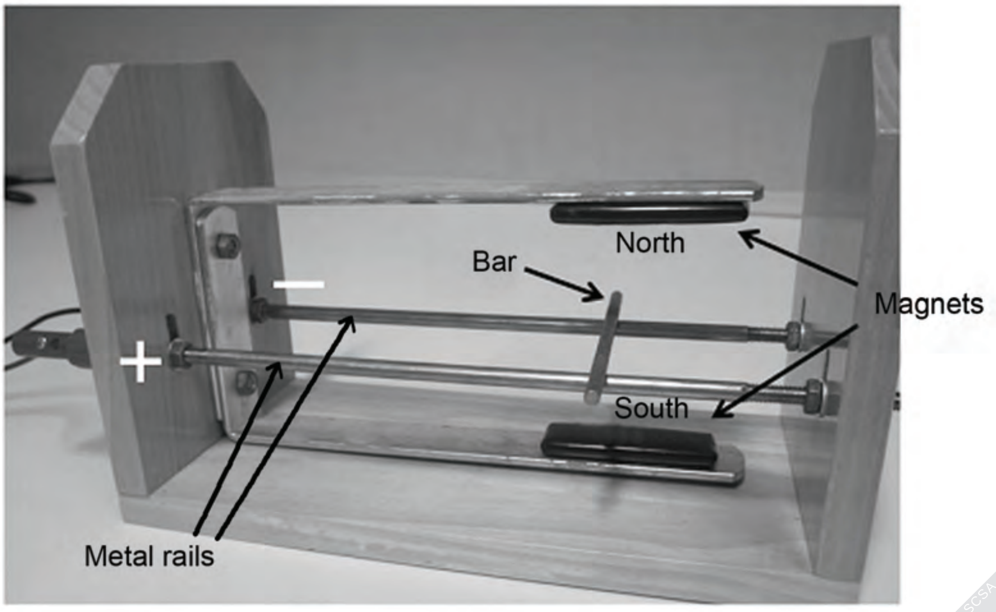
(b) Is the top plate positive or negative? Explain your reasoning. (2 marks)

(c) Calculate the magnitude of the electric force acting on the oil drop. (3 marks)

(d) Calculate the mass of the oil drop. (3 marks)

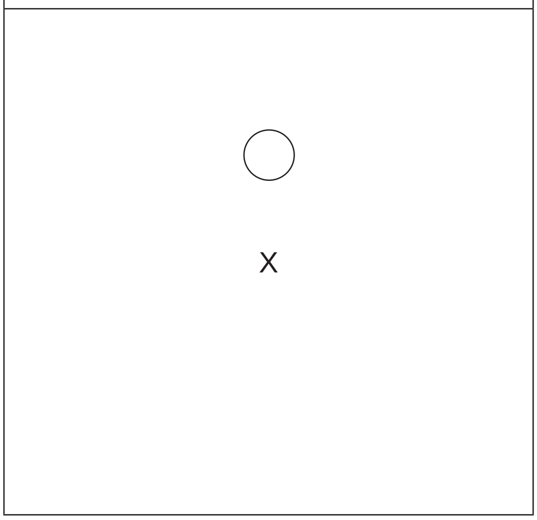
Question 16 **(10 marks)**

An apparatus that demonstrates the interactions between a current and a magnetic field is shown below. There are two metal rails on which a metal bar is free to roll. Contact between the rails and bar allows a current to flow through them from the power pack attached to the metal rails. Two magnets provide a uniform magnetic field around the bar.

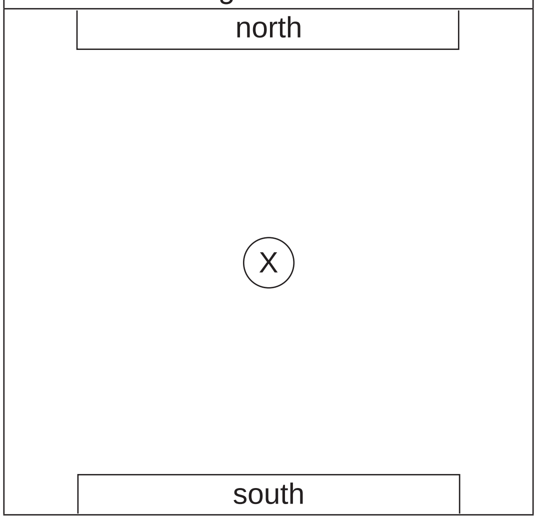


(a) Draw the magnetic fields associated with the following situations. (4 marks)

The bar carrying current into the page



The current carrying bar in a uniform magnetic field



(b) The rails are 8.50 cm apart and the magnetic field strength due to the magnets is $B = 1.50 \times 10^{-3}$ T.

Calculate the magnitude of the force acting on the bar when an electric current of 5.00 A is passed through the bar.

On the photograph on page 18, draw and label the direction of the force and current.

(4 marks)

(c) The apparatus in the photograph is then tilted at a small angle to the horizontal by lifting the left side when the current is flowing. The bar rolls toward the right-hand side, away from where the power supply is connected, due to the effects of gravity acting on the bar.

Describe **two** changes that could be made, either to the circuit or apparatus, to enable the force due to the current's interaction with the magnetic field to hold the bar stationary.

(2 marks)

Question 17 **(12 marks)**

The planet Jupiter has a mass of 1.90×10^{27} kg, a radius of 71 500 km and many moons.

The closest moon, Metis, has a mass of 9.56×10^{16} kg and a mean orbital radius of 1.28×10^{5} km. Metis has an average planetary radius of 21.5 km.

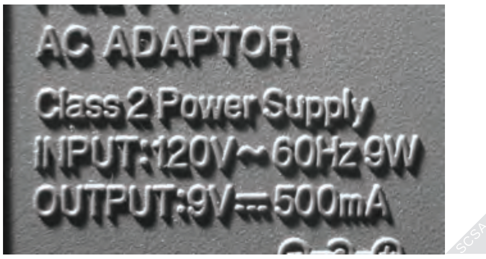
(a) Calculate the gravitational force of attraction between Jupiter and Metis. (3 marks)

(b) Calculate the time it takes in hours for Metis to orbit around Jupiter. (4 marks)

(c) Calculate the magnitude and direction of the net gravitational force acting on a 1.00 kg mass resting on the surface of Metis that faces Jupiter. (5 marks)

Question 18 **(13 marks)**

This photograph shows the information on a compliance plate on the outside of a small transformer used in a house in another country.



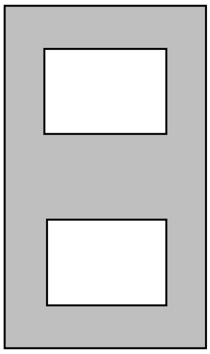
(a) Determine the ratio of windings of primary:secondary coils in the transformer. (2 marks)

(b) Using the information on the compliance plate, calculate the power output of the transformer to determine the percentage efficiency of the transformer. (3 marks)

(c) Explain why the input voltage must consist of an alternating current rather than a direct current. (2 marks)

(d) The following photograph shows the coils and core inside the transformer case.

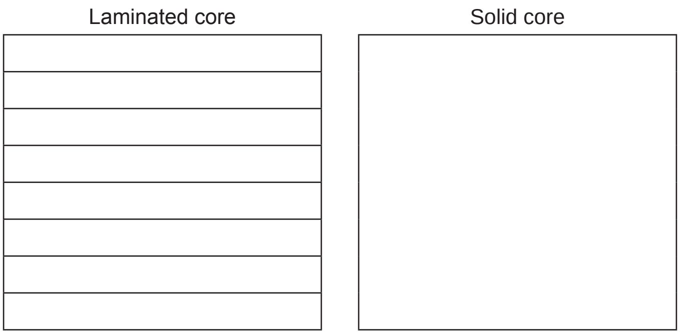
For small commercial transformers, the coils are placed around the centre pillar of the core, which is shaped like this:



Describe the purpose and properties of the core. (2 marks)

(e) The photograph above shows the laminae (a number of thin iron sheets separated by non-electrically conductive material, such as plastic) that make up the core.

Use the following diagrams, which represent the centre pillar of the transformer, and any relevant formula to explain why a transformer with a laminated core is more efficient than a transformer with a solid core. (4 marks)



Question 19 **(12 marks)**

A group of astronauts is sent on a mission to collect data about an exoplanet that could possibly sustain human life. The spacecraft travels at a constant speed of 0.850c.

Two identical clocks that have been synchronised carefully on the Earth are to be used during the mission. One clock is left with an observer on Earth and the other is placed on the spacecraft. In the Earth's frame of reference, the clocks are observed to tick once every second.

(a) How much time, in seconds, would pass between ticks of the clock on the moving spacecraft in the spacecraft's reference frame? (1 mark)

(b) How much time, in seconds, would appear to pass between ticks of the clock on the moving spacecraft according to an observer in the Earth's frame of reference? (2 marks)

(c) Explain why the values in (a) and (b) are different. (3 marks)

When measured on the Earth, the spacecraft is 119 m in length.

(d) Calculate the length of the moving spacecraft, in metres, as measured by an observer in the Earth's frame of reference. (2 marks)

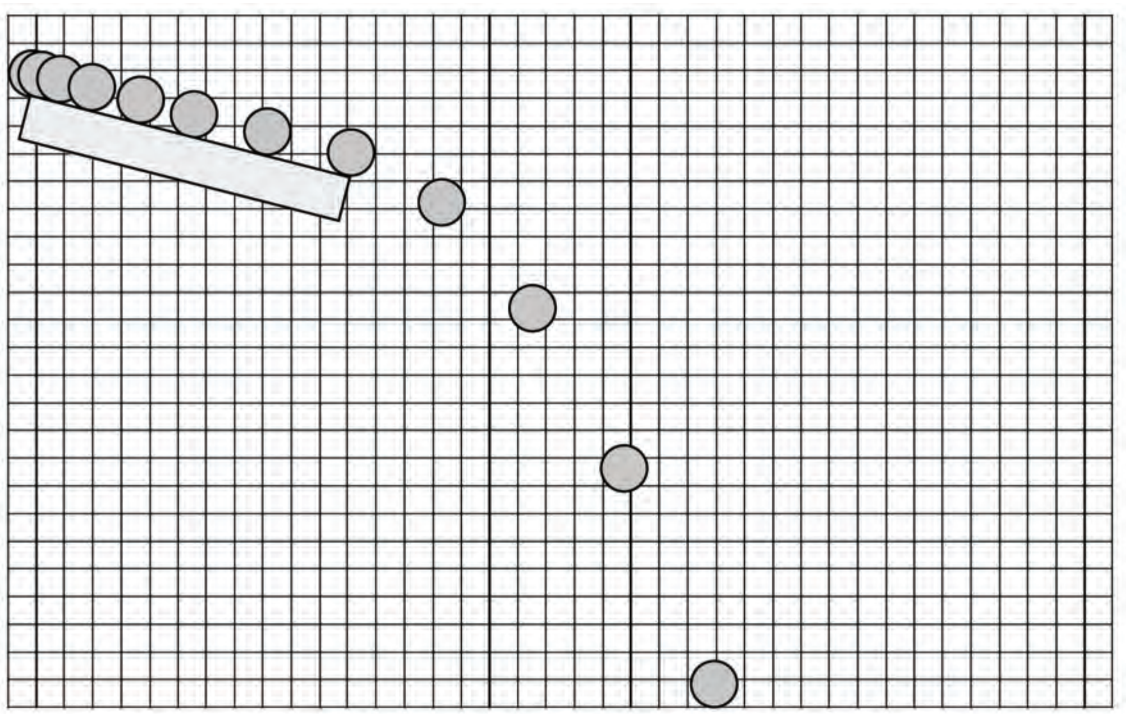
(e) Would the Earth observer notice any change in the height or width of the spacecraft? Explain your answer. (2 marks)

A rocket probe is launched from the spacecraft. The rocket probe moves at 0.500c relative to the spacecraft.

(f) To an observer in the Earth's frame of reference, what would be the speed of the rocket probe in terms of the speed of light? (2 marks)

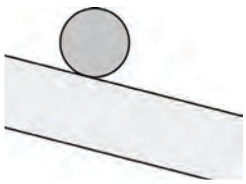
Question 20 **(19 marks)**

Below is a diagram of a photograph taken using a strobe light flashing at 10.0 Hz. The camera is able to take multiple photographs of a single ball moving down a frictionless inclined plane over a short period of time. Each square on the background grid measures 5.0 cm × 5.0 cm. Ignore air resistance unless instructed otherwise.



(a) Draw and label the force(s) acting on the ball while it is on the inclined plane below.

(2 marks)



As the ball leaves the inclined plane, its motion changes.

(b) (i) Describe the horizontal and vertical accelerations just after the ball has left the inclined plane. (2 marks)

(ii) How would each of these accelerations be affected if air resistance was considered? (2 marks)

(c) Use the diagram to determine the horizontal velocity of the ball after it has left the inclined plane. Express your answer to an appropriate number of significant figures. (3 marks)

(d) The angle of the plane to the horizontal is 14°. Determine the component of gravitational acceleration that acts along the inclined plane. (2 marks)

Question 20 (continued)

(e) Calculate the horizontal component of the ball's acceleration. Given that the ball starts from rest on the first strobe light flash and reaches the end of the inclined plane on the eighth flash, use the horizontal component of acceleration to determine the ball's horizontal velocity component as it leaves the inclined plane. (5 marks)

(f) Use the motion of the ball to calculate the length of the inclined plane. (3 marks)

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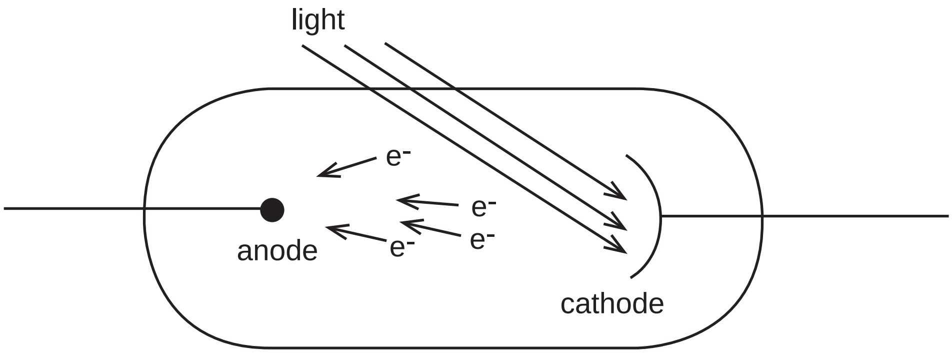
Question 21 **(14 marks)**

A group of students set up a photocell to investigate the photoelectric effect and determine a value for Planck's constant.



The photocell works when incident light falls on a metal cathode and causes electrons to be ejected with a certain kinetic energy from the metal. These electrons then move across the cell to the anode. The kinetic energy of an ejected electron is equal to the energy of the incident light minus the work function W (the energy required to remove the electron from the metal).

$$E_k = hf - W$$

To determine the kinetic energy of the electrons, a reverse voltage is applied to the anode and cathode so that it will just completely stop the electrons from reaching the anode. This is called the 'stopping voltage'. At this point, the work done by the electric field must equal the kinetic energy of the ejected electrons:

$$E_k = q_e V$$

The students then shone incident light that had passed through a filter of known wavelength onto a photocell. The photocell was connected to a circuit that allowed the students to adjust the stopping voltage so that zero current flowed through the tube.

The students combined several relationships to produce the following equation:

$$q_e V = \frac{hc}{\lambda} - W$$

The data was recorded and processed in the table below.

Filter colour	Wavelength (nm)	$\frac{1}{\lambda}$ (m^{-1})	Stopping voltage (V)
Blue	426	2.35×10^6	1.12
Green	464	2.16×10^6	0.88
Yellow	493	2.03×10^6	0.72
Orange	534	1.87×10^6	0.57
Red	589	1.70×10^6	0.33

(a) Plot stopping voltage on the *y*-axis against $\frac{1}{\lambda}$ on the grid below. Draw the *x*-axis in the middle of the grid, and extend the *y*-axis to ± 2 volts. (3 marks)

A spare grid is provided at the back of this Question/Answer Booklet. If you need to use it, cross out this attempt.

Question 21 (continued)

(b) Given the aim of the experiment, explain why the students graphed $\frac{1}{\lambda}$. (1 mark)

(c) Determine the gradient of the line of best fit and give its units. (3 marks)

(d) Use the gradient from part (c) to determine the experimental value in J s for Planck's constant. (2 marks)

(e) Use the graph to determine the work function, and give its units. (3 marks)

(f) Explain what information the intercept with the x-axis provides and how this supports Einstein's theory that light is made up of photons. (2 marks)

End of Section two

Section Three: Comprehension **20% (36 Marks)**

This section has **two (2)** questions. You must answer **both** questions. Write your answers in the spaces provided.

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Suggested working time: 40 minutes.

Question 22 **(19 marks)**

Muons and Relativity

Muons are subatomic particles that were discovered in 1936 by researchers studying cosmic radiation. The researchers noticed that some particles' paths in a magnetic field curved in a direction indicating negative charge, with path curvature indicating a mass between a proton mass and an electron mass.

Researchers first thought these particles were hadrons (heavy particles made of quarks). Hadrons such as protons and neutrons consist of three quarks and are called baryons. The new particles were thought to be mesons, that is, hadrons containing two quarks. Hadrons may emit either a neutrino or an antineutrino when they decay.

Further investigation showed that muons emit both a neutrino and an antineutrino when they decay, indicating that muons are leptons – fundamental particles that are not made of quarks. The most familiar lepton is the electron. Muon decay can be summarised as:

$$\text{muon} \rightarrow \text{electron} + \text{neutrino} + \text{antineutrino}$$

Most naturally-occurring muons are created when cosmic rays collide with atoms in the upper atmosphere, approximately 10 km above the Earth. A muon has a rest mass of $\frac{106 \text{ MeV}}{c^2}$, a charge of -1 and an average lifetime of 2.2×10^{-6} s.

Question 22 (continued)

(a) The table below contains information about some subatomic particles. Complete the last column of the table by writing baryon, meson or lepton to indicate the group of particles to which the individual particle belongs. (4 marks)

Particle	Quark structure	Decay products	Baryon, meson or lepton
Lambda	charm, up, down	proton, pion, kaon	
Tau		tau neutrino, electron, electron anti-neutrino	
Kaon+	strange, charm	muon and muon neutrino	
Xi	up, strange, strange	lambda and pion	

(b) Muons travel at almost the speed of light. Calculate the average distance that a muon created in the upper atmosphere would travel before it decayed. Assume that its speed is equal to c and that there are no relativistic effects. (2 marks)

(c) Muons created by cosmic rays in the upper atmosphere can be detected by detectors on the Earth's surface. This means that the muons have travelled much further than expected. An explanation of this phenomenon involves the effects of relativity.

Explain how relativity affects the muons and enables them to travel over a greater distance than that calculated in part (b). (3 marks)

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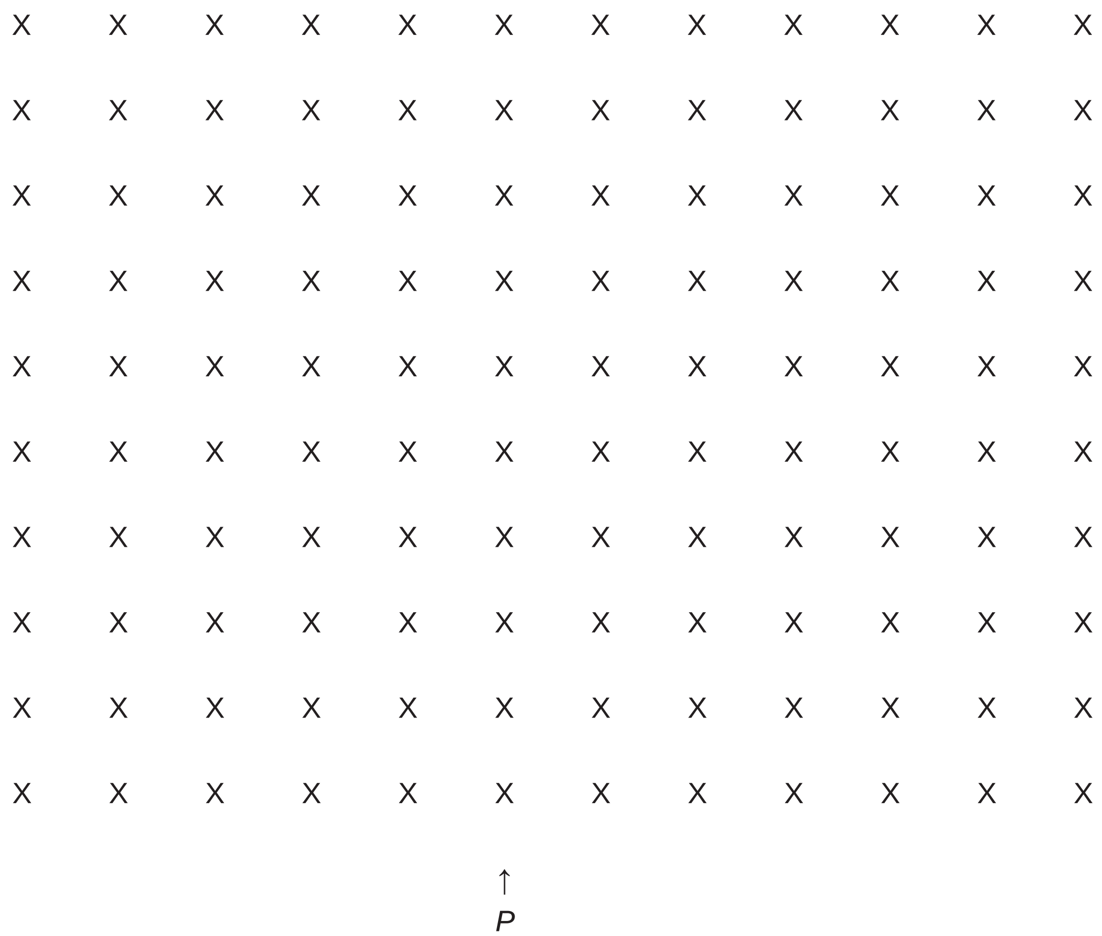
(d) Express the rest mass of a muon in kilograms, and compare this to the rest mass of a proton. (3 marks)

(e) On the diagram below sketch and label two lines representing the paths you would expect a proton and a muon to follow in the given magnetic field. Assume both particles are injected into the field at *P* with the same velocity. (3 marks)



See next page

Question 22 (continued)

(f) Injecting and directing a charged particle using magnetic and electric fields is a commonly-used phenomenon. It is used in old (cathode ray tube) television technology as well as in high-technology applications such as the CERN Large Hadron Collider.

Using formulae from your Formulae and Data Booklet, show the derivation of the formula below that determines a particle's velocity from its mass (m) and charge (q), having been accelerated through a potential difference (V). You must show all steps.

(4 marks)

$$v = \sqrt{\frac{2Vq}{m}}$$

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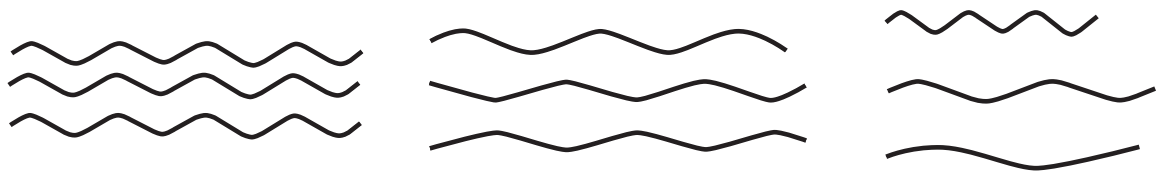
Question 23 **(17 marks)**

The Laser

Since their invention by Theodore Maiman in 1960, lasers have been used in numerous applications. A laser is a device that produces a light beam with the following properties:

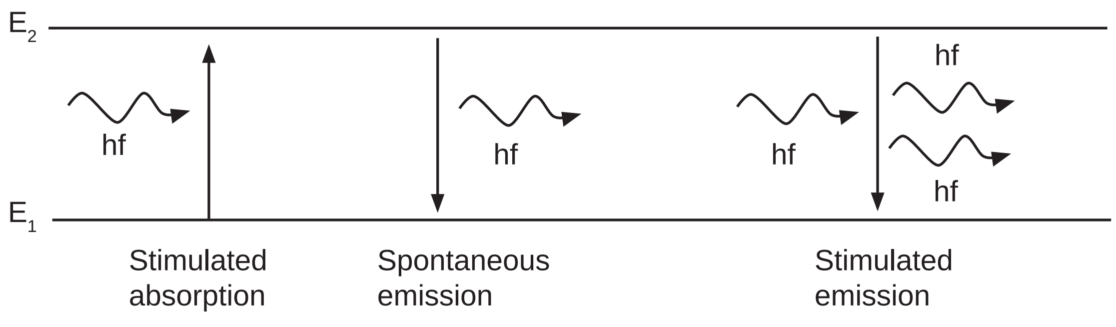
- The light beam it produces is very nearly monochromatic.
- The light is coherent, with the waves all exactly in phase with each other.
- The light beam hardly diverges at all.
- The light beam is extremely intense.

(a) Which of diagrams (i), (ii) or (iii) illustrates correctly the radiation emitted by a laser? Circle your answer. (1 mark)



(i) (ii) (iii)

The word 'laser' is an acronym for light amplification by stimulated emission of radiation. The key to the laser is the presence of metastable levels. Metastable levels are atomic energy levels at which electrons can exist with longer than normal lifetimes. Electrons in these excited energy levels may exist here with lifetimes of 10^{-3} s instead of the usual 10^{-9} s.



Stimulated absorption occurs when an electron is initially in the lower energy level, E_1 and is raised to the level E_2 by the absorption of a photon of energy hf.

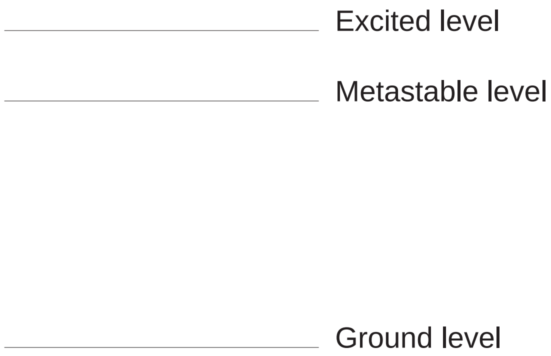
Spontaneous emission occurs when an electron, initially in the upper energy level E_2 decays to the lower energy level by emitting a photon of energy hf.

Stimulated emission occurs when a photon of energy hf is incident upon the excited atom (electron at E_2). This incident photon causes a transition from E_2 to E_1. In stimulated emission, the emitted light wave is exactly in phase with the incident one, so the result is a beam of coherent light.

The probability of stimulated emission occurring is exactly the same as that of stimulated absorption occurring.

Question 23 (continued)

The simplest type of laser is a three-level laser that uses an assembly of atoms or molecules that have a metastable level above the ground level, as shown in the diagram below. Electrons are excited from the ground level to the excited level, from which they then decay to the metastable level.



To create a laser there must be a **population inversion**. In a normal population of electrons, the ground level is occupied to the greatest extent. A population inversion describes an assembly of electrons in which the majority are in energy levels above the ground level.

There are a number of ways of producing a population inversion. One is called optical pumping. Here an external light source is used, some of whose photons have the right frequency to raise the ground level electrons to the excited level and then decay spontaneously to the metastable level. Photons with the correct frequency from the external light source can also be used to stimulate emission of the electrons in the metastable level, creating a laser beam. This leads to amplification of the initial photon, as more photons with the same wavelength are emitted through stimulated emission.

Three-level lasers only work effectively as pulsed lasers, as virtually all of the electrons need to be shifted to the upper excited level at the same time. This creates a population inversion, with photons being emitted at the same time as photons from the optical source are being absorbed by ground level electrons, rather than stimulating emission.

(b) Circle your responses to the following: (2 marks)

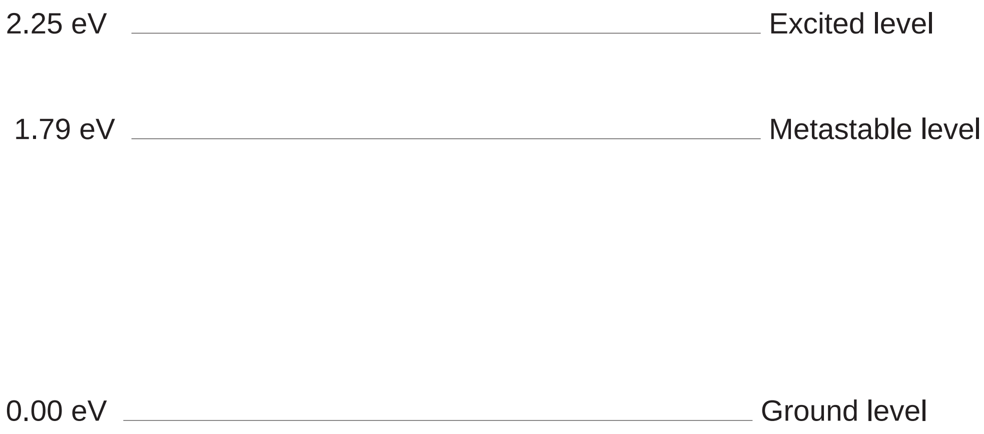
(i) The electrons in a population inversion are mostly located in the:

ground level metastable level excited level

(ii) The pulse in a pulsed laser describes the:

movement of electrons input light output light

One of the first lasers to be developed was the three-level ruby laser. The ruby laser is based on the three energy levels in the chromium ion Cr^{3+}, as shown in the diagram below. A ruby is a crystal of aluminium oxide $A\ell_2O_3$ in which some of the $A\ell^{3+}$ ions have been replaced with Cr^{3+} ions, which are responsible for the red colour.



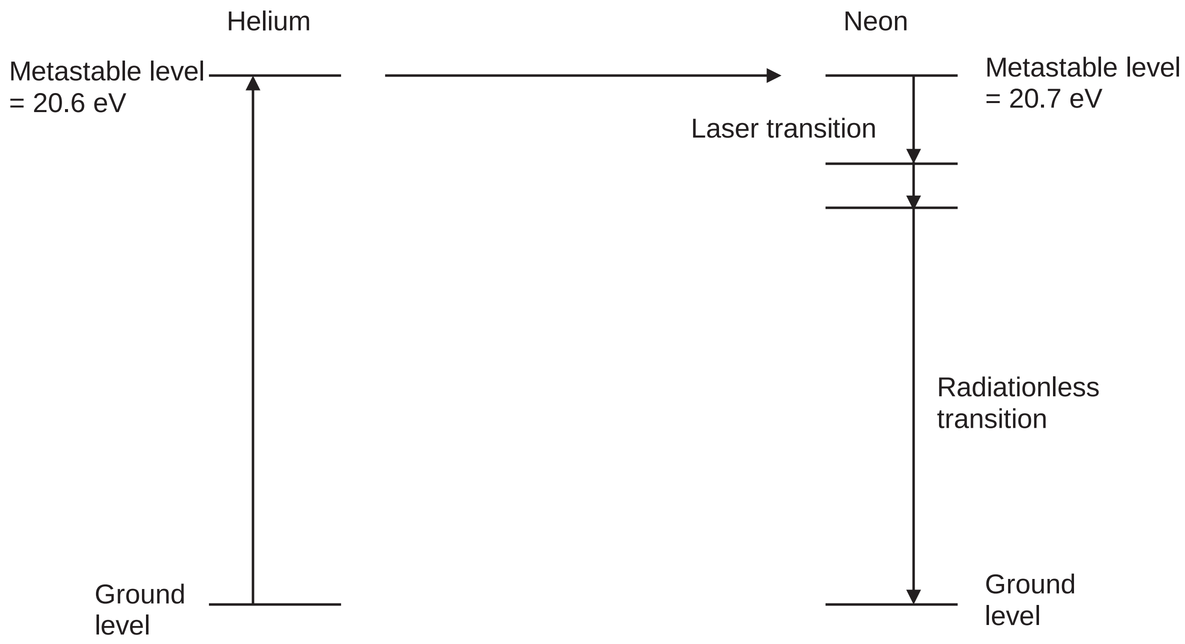
(c) Sketch on the diagram above the **three** transitions required to produce the laser light. (3 marks)

(d) Calculate the wavelength, in metres, of the photon required for optical pumping in a ruby laser. (2 marks)

(e) Calculate the wavelength, in metres, of the photon that is produced in the laser transition in a ruby laser. (2 marks)

Question 23 (continued)

A commonly-used laser is the helium-neon gas laser, as shown in the diagram below. This laser achieves population inversion in a different way.



A mixture of helium and neon gas at low pressure is placed into a glass tube. An electric discharge in the gas excites the helium atoms, which then collide with the neon atoms, exciting them. Photons produced in spontaneous emission initiate stimulated emission and amplification of the laser transition begins.

(f) The energy of the metastable level of the neon atom is greater than that of the helium atom. Where does the extra energy come from to excite the neon atom? (1 mark)

(g) Explain why the helium-neon laser, unlike the ruby laser, can be operated continuously. (2 marks)

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(h) A certain helium-neon laser emits red light with a wavelength of 633 nm at a power level of 2.50 mW. What minimum number of excited electrons per second producing an emission is required to produce this beam? (3 marks)

(i) The final transition in the neon atom produces no radiation (i.e. no photon is emitted). State how the neon atom could lose this energy. (1 mark)

End of questions

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ACKNOWLEDGEMENTS

Section Three

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Published by the School Curriculum and Standards Authority of Western Australia
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