Government of **Western Australia**
Curriculum Council

WACE
Western Australian Certificate of Education

Western Australian Certificate of Education
Examination, 2011

Question/Answer Booklet

PHYSICS
Stage 3

Please place your student identification label in this box

Student Number: In figures

In words ____

____

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 Constants Sheet

To be provided by the candidate
Standard items: pens, pencils, eraser, correction fluid/tape, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the Curriculum Council for this course, 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.

Ref: 11-110X

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 2011.* Sitting this examination implies that you agree to abide by these rules.

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

3. Working and reasoning should be shown clearly when calculating or estimating answers.

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(s) that you are continuing to answer at the top of the page.

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

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

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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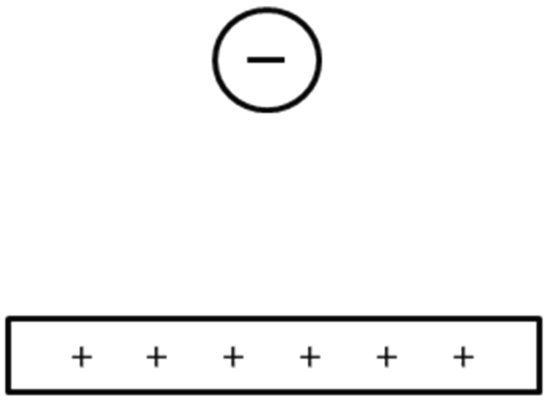
Suggested working time: 50 minutes.

Question 1 **(3 marks)**

Draw the resultant electric field with at least 5 lines for each of the following situations.

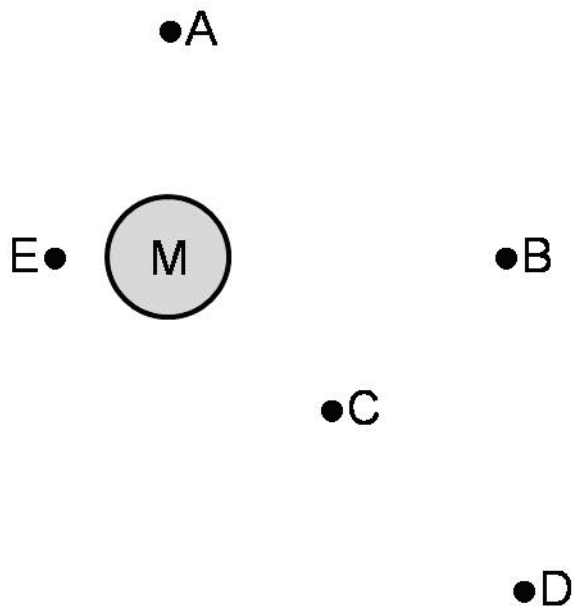
Two opposite but equally-charged spheres

A charged sphere near a charged conductive plate



Question 2 **(4 marks)**

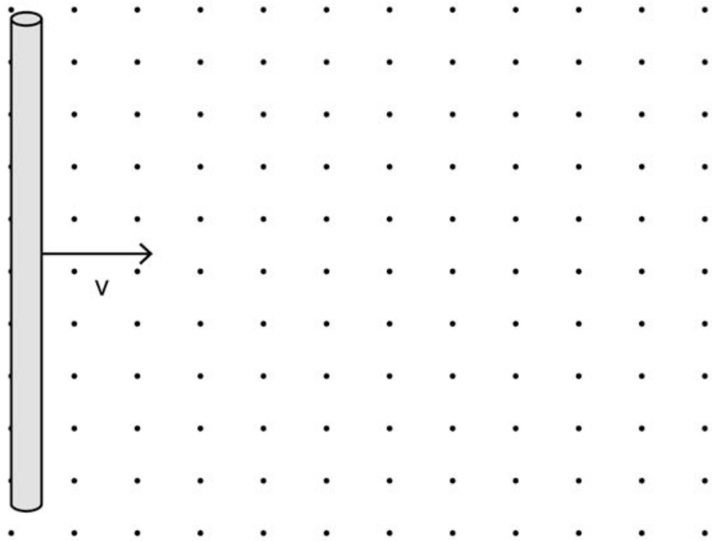
The diagram below shows five points, labelled 'A' to 'E', in free space around a large mass M. You may wish to use a ruler to help you answer this question.



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

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.



B field out of the page

Question 4 **(2 marks)**

An air compressor is located at the open end of a closed pipe. A maintenance worker walked away from the closed end of the pipe and noticed that the sound from the air compressor was getting louder and quieter as he moved toward the open end of the pipe. The worker found that the sound became louder every 1.50 metres. Calculate the frequency of the sound heard, given that the air was at 25°C.

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.)

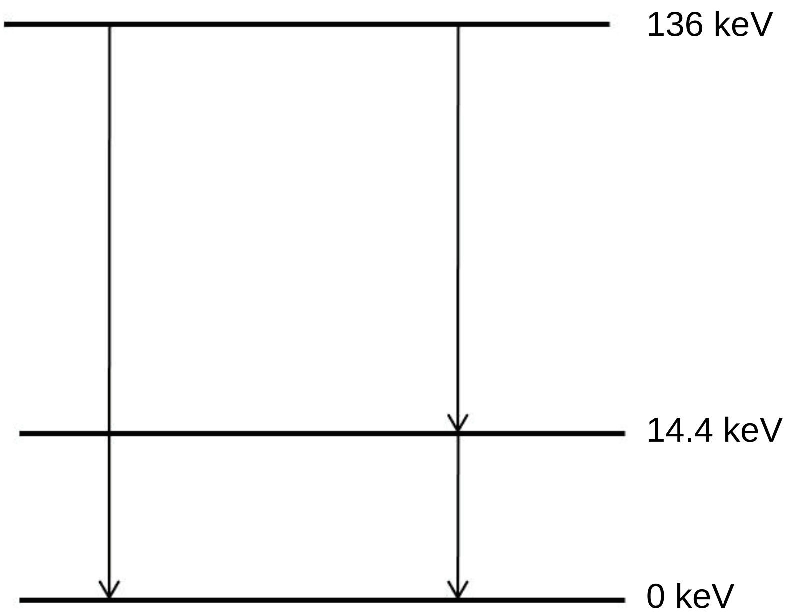
the same less than 70 kg more than 70 kg

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.

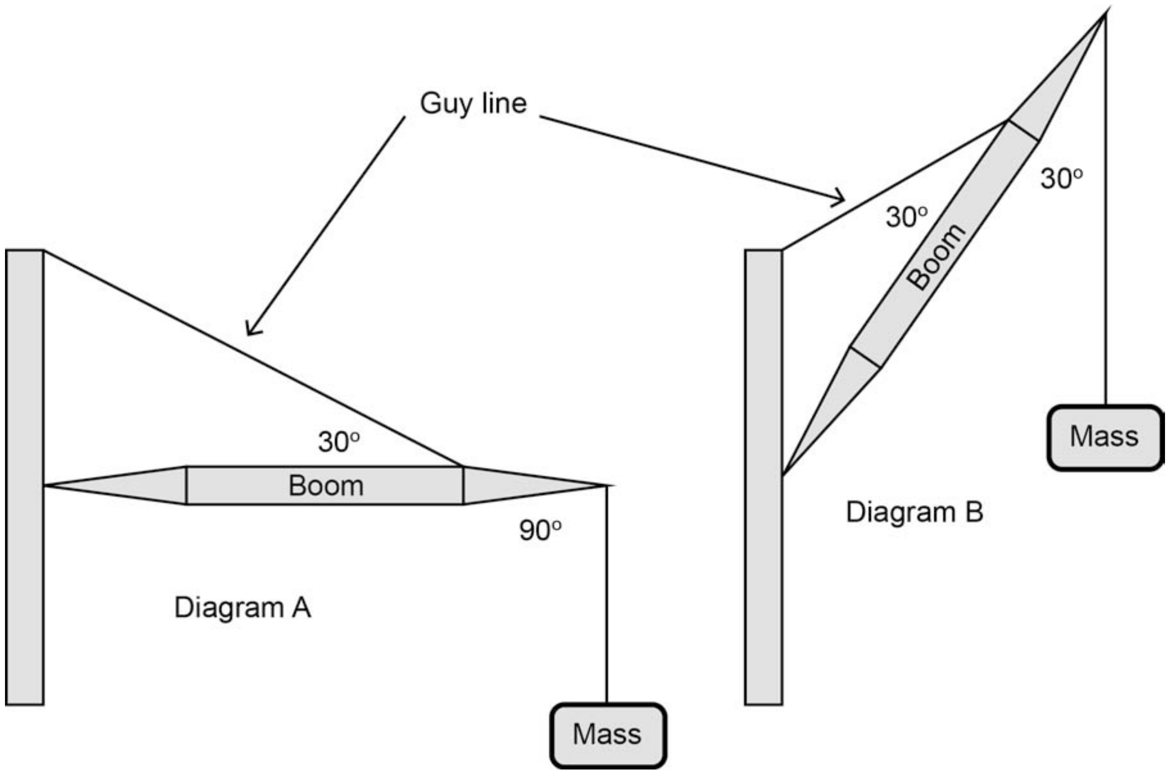


Question 7 **(5 marks)**

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.

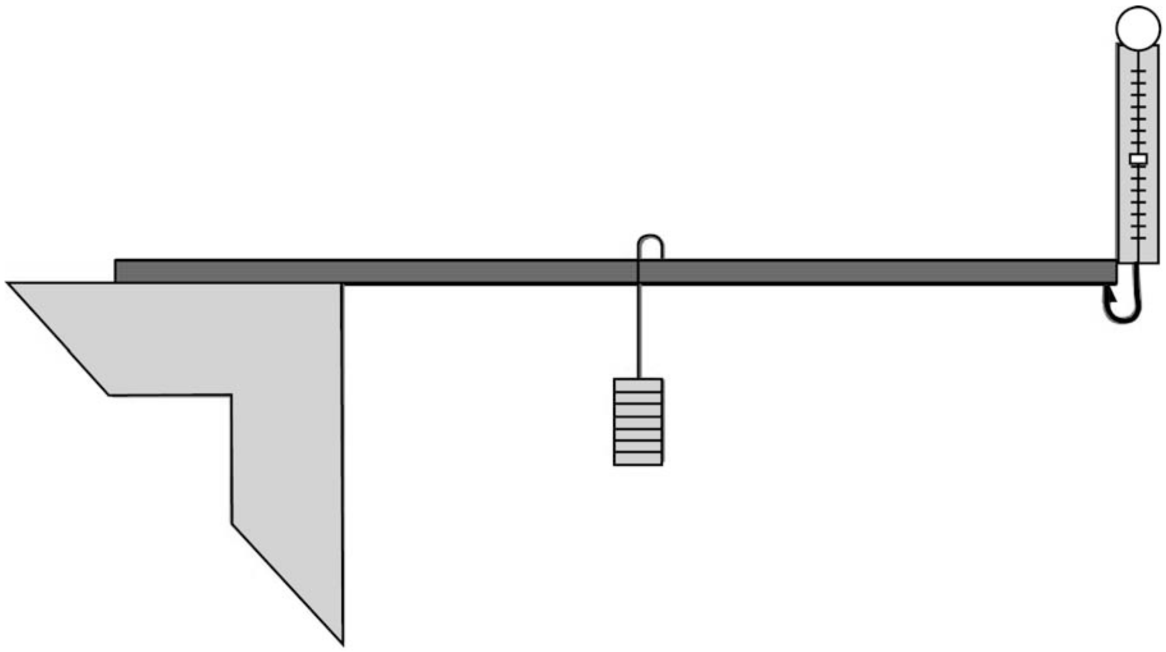


Question 9 **(4 marks)**

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 **(4 marks)**

A uniform 100 gram, metre-long ruler is placed on a table, with most of its length overhanging the edge. A 350 gram slotted mass is placed at the ruler's 500 mm mark, and a spring balance holds it up at one end, as shown in the diagram below.



The ruler is just lifted using the spring balance so that it touches the table in only one place. At this point the spring balance reads 2.20 N. Indicate on the diagram the fulcrum, or pivot point, for this action and label it 'A'.

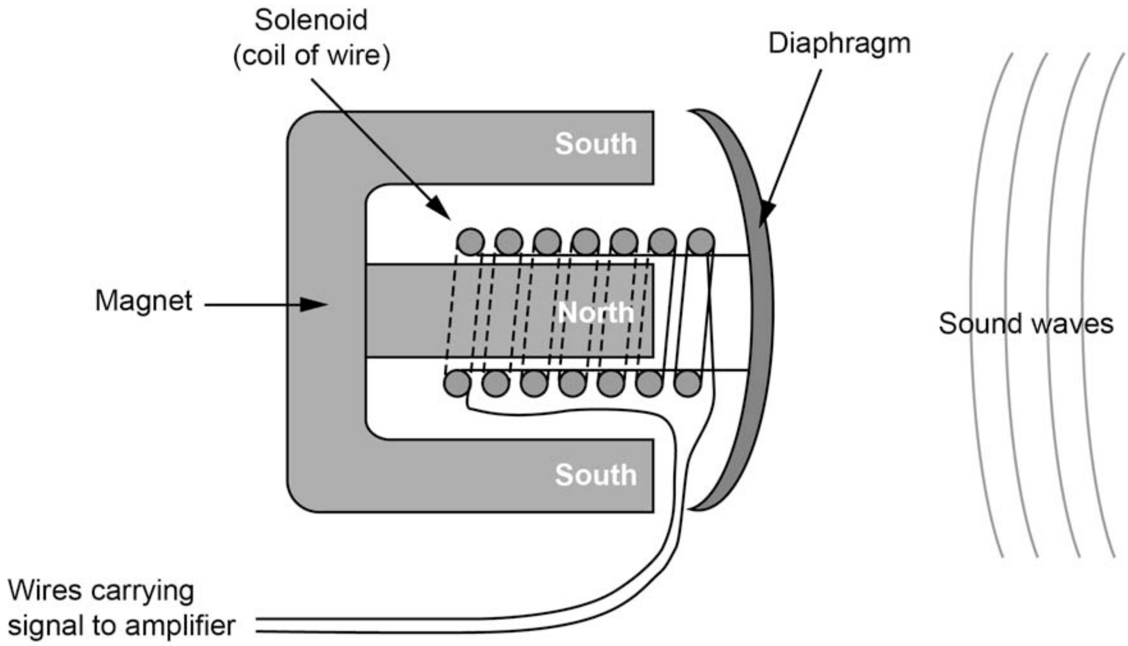
The ruler is then lowered slightly, changing the position of the fulcrum.

Label this new fulcrum, or pivot point, 'B'.

When the ruler is in this position, the spring balance reads 1.65 N. Determine the distance between the points 'A' and 'B'. Note that the angle that the ruler makes with the horizontal has not changed significantly and should not be considered in your calculations.

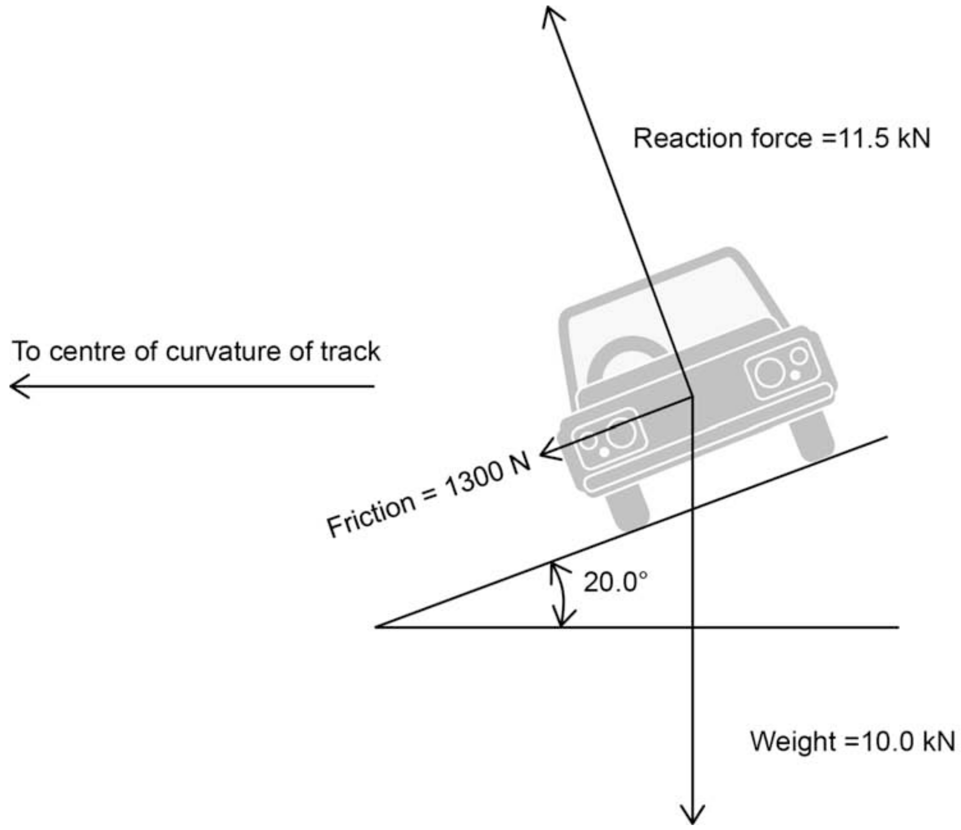
Question 11 **(4 marks)**

The diagram below shows a cross-section of a simple dynamic microphone. Describe how a musical note played near the diaphragm of the microphone can be detected by an amplifier. Your description should include an explanation of how the sound is converted to an electrical signal.



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 **(5 marks)**

Earthquakes cause seismic waves to travel through the Earth. These waves are detected by seismometers around the Earth. Two types of seismic waves are P and S waves. P waves are longitudinal and travel at a speed of 5.57 km s^{-1}. S waves are transverse and travel at a speed of 3.56 km s^{-1}.

Give **one** example of a transverse wave and **one** example of a longitudinal wave that you have studied (**not** P and S waves).

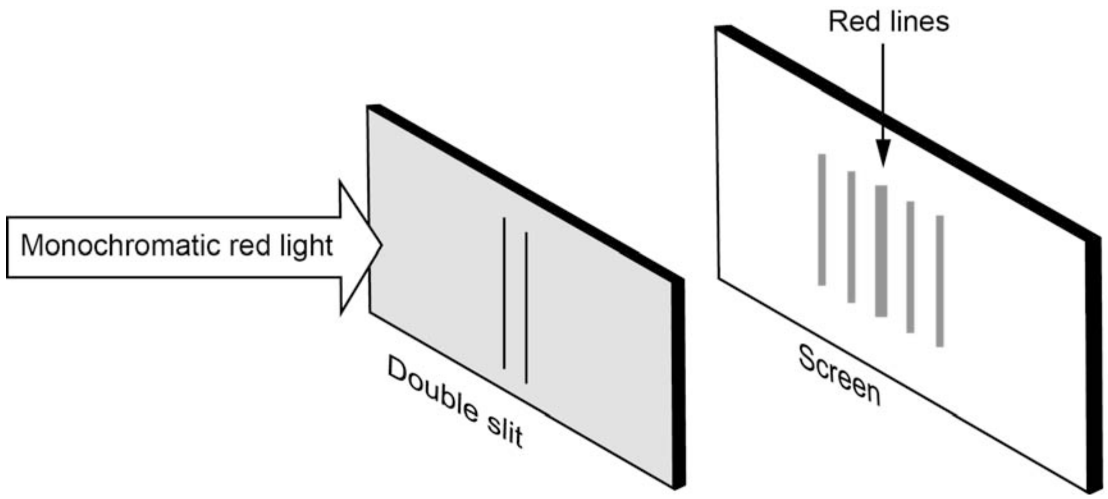
Transverse: ____________________

Longitudinal: ____________________

A seismometer records an earthquake. The P waves arrive 13.5 s before the S waves. Calculate the distance between the seismometer and the point of origin of the earthquake waves.

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. You must 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 7 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)

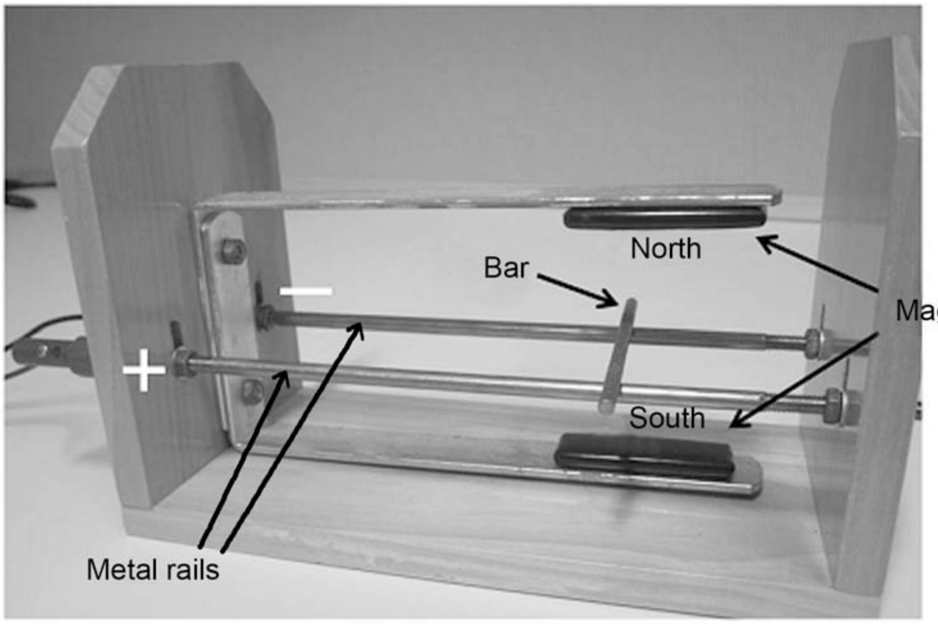
(b) Is the top plate positive or negative? Explain your reasoning. (2 marks)

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

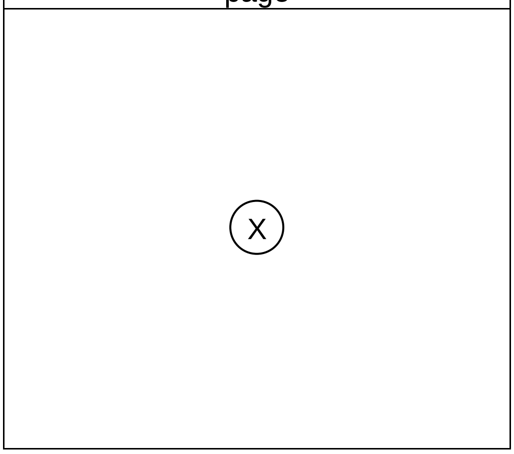
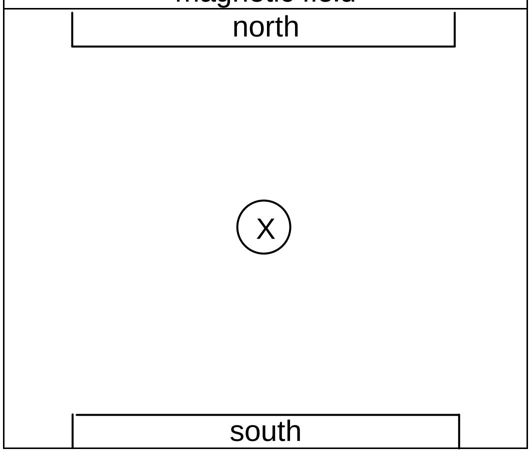
(d) Calculate the mass of the oil drop. (3 marks)

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.

Draw and label on the photograph on page 18 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.

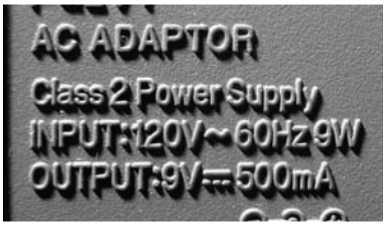
(a) Calculate the gravitational force of attraction between Jupiter and Metis. (3 marks)

(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)

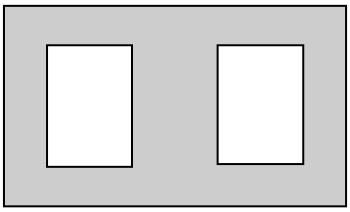
(b) Using the information on the compliance plate, calculate the power output of the transformer and use this information to determine the percentage efficiency of the transformer.

(3 marks)

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

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

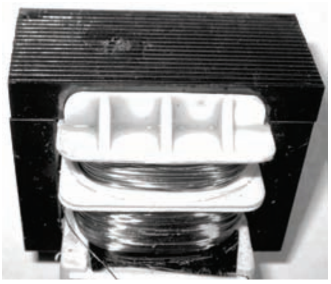
For small commercial transformers, the coils are placed around the centre pillar of the core, which is shaped like this:



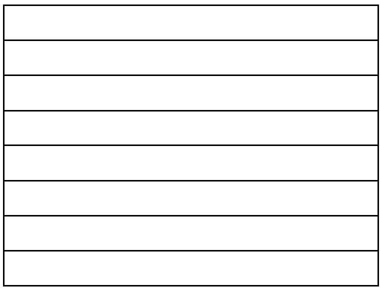
Describe the purpose and properties of the core. (2 marks)

(e) The photograph below shows the laminae (a number of thin iron sheets separated by non-electrically conductive material, such as plastic) that make up the core. These laminae are used to reduce 'eddy currents' or 'back emf' and make transformers more efficient.

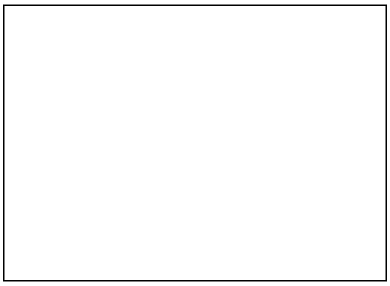
Use the following diagrams representing the centre pillar of the transformer and any relevant formula to explain why a transformer with a laminated core is more efficient than a transformer with a solid core. (4 marks)



Laminated core

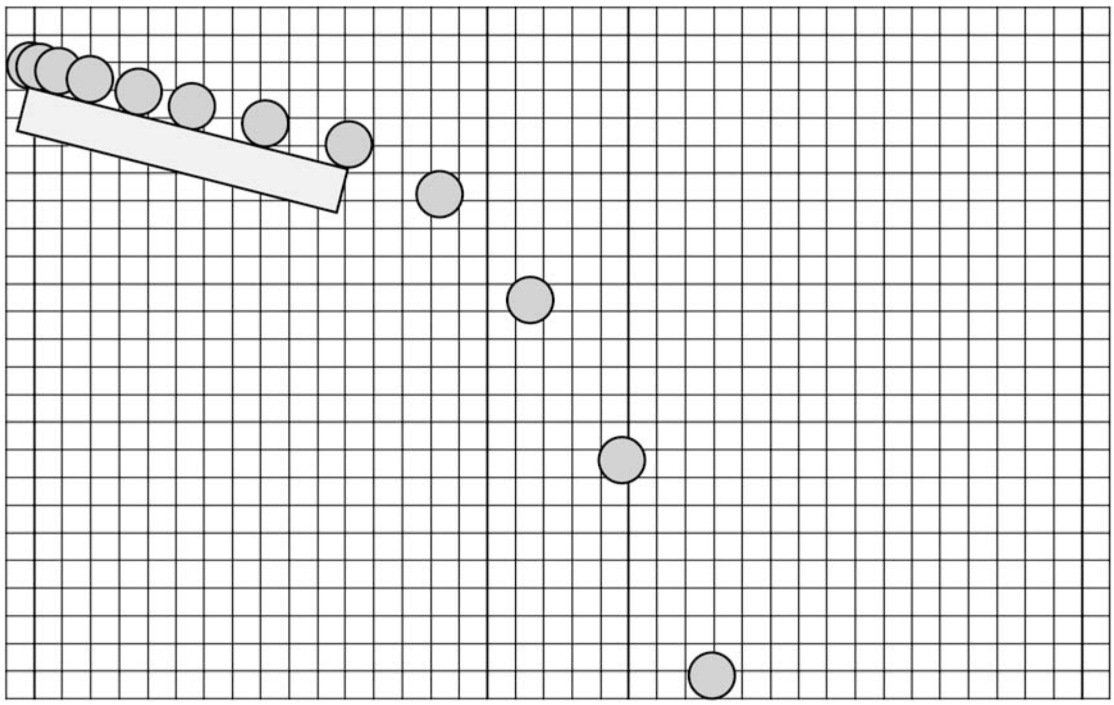


Solid core

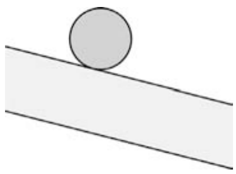


Question 19 **(19 marks)**

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)



(b) As the ball leaves the inclined plane, its motion changes. (4 marks)

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

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

(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)

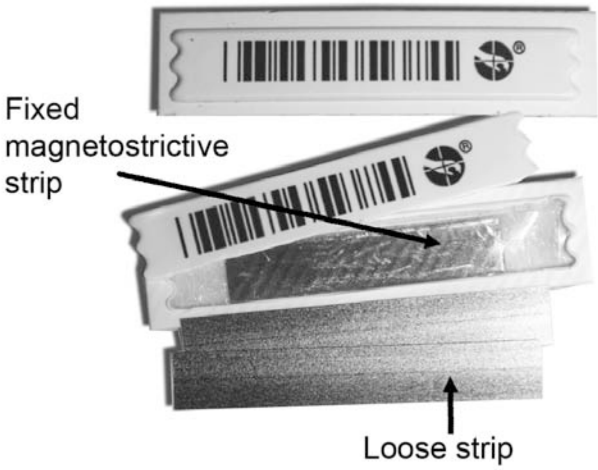
(d) The angle of the plane to the horizontal is 14°. Determine the component of gravitational acceleration that acts along the inclined plane. (2 marks)

(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)

Question 20 **(7 marks)**

Acousto-magnetic tags (pictured) are commonly used in stores for security purposes. A radio transmitter near the front door emits an electromagnetic pulse of 58.0 kHz. A fixed metal strip made of magnetostrictive material (metal that shrinks when in a magnetic field) contained in a tag vibrates at this frequency due to the changing magnetic field.



When the magnetostrictive strip vibrates it causes loose metal strips in the tag to vibrate and produce a sound. The frequency of the transmitter corresponds to the resonant frequency of the metal strips in the tag. A nearby receiver, on detecting a sound of 58.0 kHz frequency shortly after the transmitter has finished sending the electromagnetic pulse, activates the alarm.

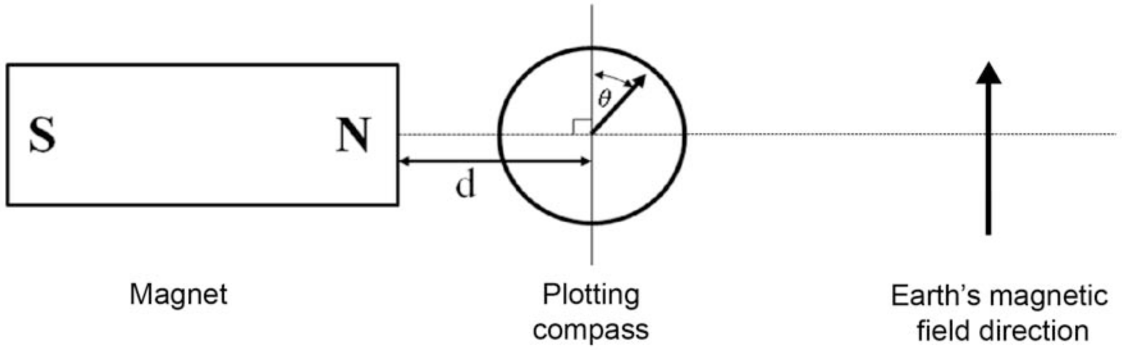
(a) The metal strips are 37.0 mm long. In the rectangle below draw the fundamental harmonic representing the wave formed in the metal strip and calculate the speed of sound in the metal. (3 marks)

(b) All radio frequencies cause the magnetostrictive material to vibrate at the same frequency as the radio signal. Explain why only a frequency of 58.0 kHz will activate the alarm. (4 marks)

Question 21 **(19 marks)**

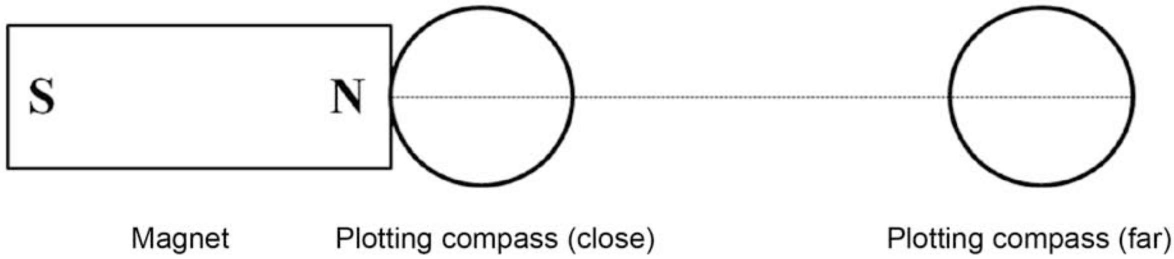
A student performed an experiment to investigate how the magnetic field strength of a bar magnet varied with distance from the magnet along a line through the long axis of the magnet. She measured the angle θ between the pointer of a plotting compass and geographic north, as she moved the plotting compass to various distances (d) away from the magnet. She measured the angle θ at intervals of 3.0 cm, as shown in Diagram A.

Diagram A



(a) On Diagram B, draw arrows on each of the plotting compasses to indicate the angle you would expect the needle of the compass to make when it is close to, and when it is far (more than 50 cm) from, the bar magnet. (2 marks)

Diagram B



(b) Both the Earth's magnetic field and the bar magnet's magnetic field affect the compass. Draw a vector diagram that shows these two magnetic fields and the resultant magnetic field experienced by the plotting compass shown in Diagram A. Use your diagram to derive a relationship between the Earth's magnetic field, the magnet's magnetic field and the angle θ. (3 marks)

(c) Calculate the strength of the magnetic field due to the bar magnet at a point on the axis, 10.0 cm from the end of the bar magnet, if the value of θ at this point is 82°, and the Earth's magnetic field strength is 2.0×10^{-5} T. (2 marks)

Question 21 continues on the next page

Parts (d), (e) and (f) of this question assess your understanding of uncertainty in measurements, interpretation of graphs and use of appropriate significant figures.

The compass that the student used to measure the angle θ was marked in divisions of 1°. The student could see when the needle was between divisions but could not judge accurately how close to a division it was. The student decided to express all her measurements of θ with an uncertainty of $\pm$ 1°. The student was confident that she placed the centre of the compass on the ruler accurately so decided not to express her measurements of d with any uncertainty.
The student's results are shown in the table below.

Distance from magnet (m)	$\frac{1}{d^2}$ **(m^{-2})**	**θ (°)**	**Tan θ**
0.15		58 $\pm$ 1	1.60 $\pm$
0.18		42 $\pm$ 1	0.90 $\pm$ 0.03
0.21		40 $\pm$ 1	0.84 $\pm$ 0.03
0.24		33 $\pm$ 1	0.65 $\pm$ 0.02
0.27		27 $\pm$ 1	0.51 $\pm$ 0.02
0.30		23 $\pm$ 1	0.42 $\pm$ 0.02

(d) Complete the table by filling in the values for $\frac{1}{d^2}$ and the uncertainty range for the value of tan θ for θ = 58°. You must show your calculation for determining the uncertainty range. (3 marks)

(e) Plot the graph of tan θ versus $\frac{1}{d^2}$ on the graph paper on page 31. Include error bars and a line of best fit. (5 marks)

(f) Mark and label the point on your graph where the strength of the Earth's magnetic field is equal to the strength of the magnetic field of the bar magnet. Use this point to determine the distance from the magnet where these fields are equal. (4 marks)

If you wish to make a second attempt at this item, the graph is repeated on page 43 of this booklet. Indicate clearly on this page if you have used the second graph and cancel the working on the graph on this page.

End of Section Two

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

This section contains **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 some particles whose 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.

(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	

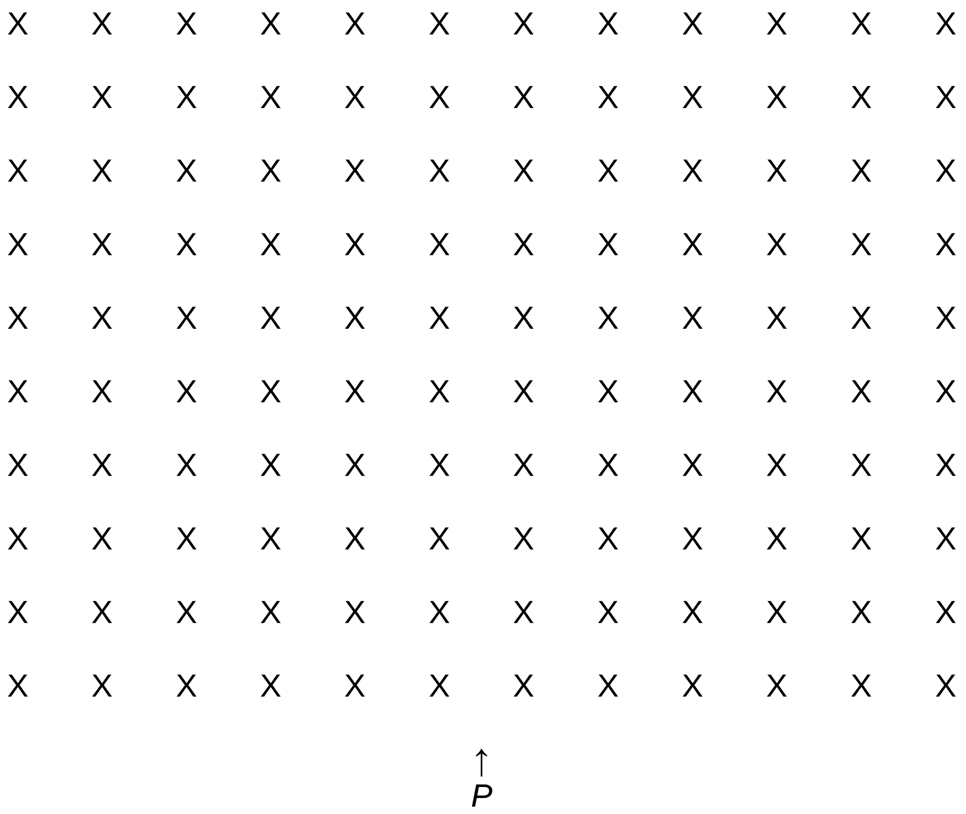
(b) Muons travel at almost the speed of light. Calculate the average distance that a muon created in the upper atmosphere would travel before it decayed. Assume that its speed is equal to c and that there are no relativistic effects. (2 marks)

(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 (b). (3 marks)

(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)



(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 Constants Sheet, 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.

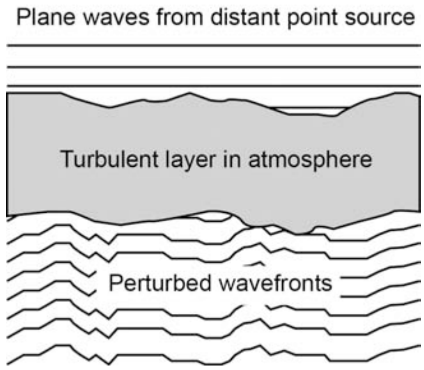
(4 marks)

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

Question 23 **(17 marks)**

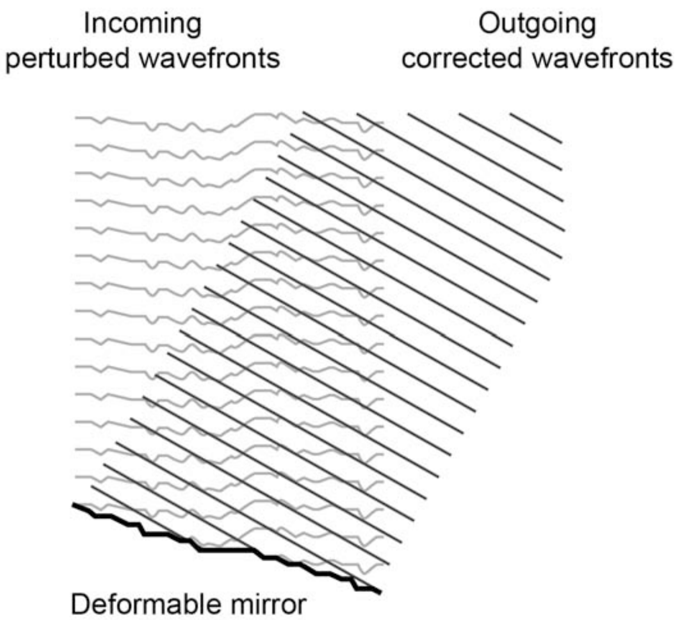
Adaptive Optics and Laser Guide Star

Telescopes with very large mirrors can gather a lot of light to allow viewing of dim, distant astronomical objects. As light waves pass through the atmosphere, tiny variations in the refractive index of the atmospheric gases distort the light's path, causing stars to appear to change position and twinkle. Large-diameter mirrors with fixed focal points thus suffer from image distortion when the position of an astronomical object seems to be in many different places when viewed from different places on the mirror.



Optical wave fronts from an astronomical object may be distorted by a layer of turbulence in the atmosphere. The amount of distortion has been exaggerated.

Adaptive optics is a technology used to improve the performance of large telescopes by reducing the effect of wavefront distortions caused by atmospheric distortion. Adaptive optics works by measuring the distortions in a wavefront and compensating for them with a deformable mirror. This requires a wavefront reference source to allow the telescope to correct the distortion of light caused by turbulence in the atmosphere. Turbulence changes the refractive index of the atmosphere in unpredictable ways. Monitoring the apparent motions of a bright star with known optical characteristics can provide a reference for adaptive optics. When the atmosphere's effects are subtracted, using a deformable tip-tilt mirror, the astronomical image produced is steady and clear.



A deformable mirror can correct distorted incoming wavefronts.

Many parts of the sky lack stars bright enough to use for judging atmospheric conditions. This limits the effectiveness of adaptive optics that use natural guide stars. A laser guide star is an artificial star-like light source created by shining a laser into the upper atmosphere. Such an artificial 'star' can be positioned anywhere that the astronomer wishes to observe, allowing any part of the sky to be viewed using adaptive optics.

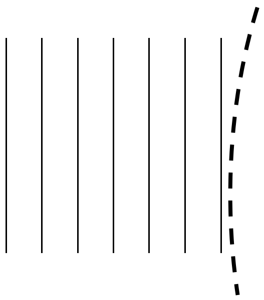
The bright line is a laser beam visible only because of atmospheric scattering.

A 'sodium beacon' is one type of laser guide star. It is created by shining a laser tuned to 589 nm (nanometres) into the upper atmosphere, exciting a naturally-occurring layer of sodium atoms at an altitude of about 90 km. The excited sodium atoms quickly decay, re-emitting the 589 nm light and giving the appearance of a glowing star.

Often, the laser is pulsed and the light from the laser guide star is measured a very short time after the pulse is emitted. This eliminates errors from scattered light at ground level, so that only light that has travelled down from the sodium layer is actually detected. The light returning from the sodium beacon, having travelled through most of the atmosphere, appears to have moved around in the sky in the same way as the light from astronomical objects.

(a) The following diagram shows light wavefronts moving from more dense air, where it moves slower, to less dense air, where it travels faster. Complete the diagram by sketching four more wave fronts in the less dense air.

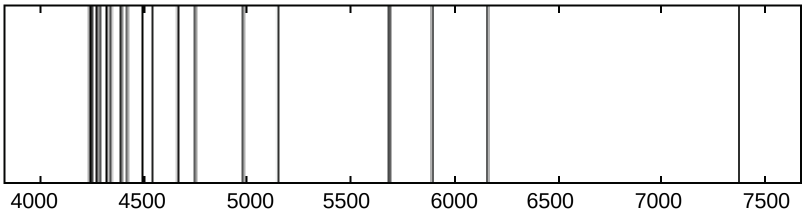
(2 marks)



(b) Calculate the time taken for a pulse from a laser to reach the sodium layer and for the re-emitted light to return to the Earth's surface. Assume that the decay time of excited sodium atoms is negligible. (3 marks)

(c) Calculate the energy in electron volts of a photon of light produced by the sodium beacon laser. (3 marks)

(d) When white light is shone through a gas consisting of sodium atoms and then passed through a prism, the white light's visible spectrum has several dark lines appear, as shown below. The scale is in angstroms ($\times 10^{-10}$ m). (4 marks)



(i) What type of spectrum is this considered to be? ______________________

(ii) Circle the part of the spectrum that corresponds to the light emitted by a sodium beacon laser.

(iii) Astronomers observe light that has passed through gases, such as in a nebula (a gas cloud in space) or a planet's atmosphere. Explain how the characteristics of this light are used to to determine the composition of the gases.

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Fluorescent angiography is a technique for examining the circulation of blood in the retina of the eye using a dye-tracing method. It involves the injection of sodium fluorescein, which circulates through the whole body, including the eye. The eye is then illuminated using blue light of wavelength 490 nm. The sodium fluorescein fluoresces, emitting yellow-green light that is photographed to create an angiogram.

(e) Using the energy level diagrams below, determine and draw on the diagrams the photon absorption and emission transitions for:

A the sodium beacon laser guide star

and

B the fluorescent angiography. You must show the calculations used for determining the absorption transition.

The energy level diagrams are simplified. A sodium atom has many energy level transitions available and therefore not all energy levels are shown. (5 marks)

A Laser guide star transitions		**B** Fluorescent angiography transitions
3.6 eV		3.6 eV
3.2 eV		3.2 eV
2.5 eV		2.5 eV
2.1 eV		2.1 eV
0 eV		0 eV

End of questions

Additional working space

Additional working space

Additional working space

ACKNOWLEDGEMENTS

Section One:

Question 7 Photograph of boy with hose. Used with kind permission of the examining panel.

Section Two:

Question 16 Photograph of apparatus. Used with kind permission of the examining panel.

Question 18 Photograph of compliance plate. Used with kind permission of the examining panel.

Question 18(d) Photograph of transformer coils and core. Used with kind permission of the examining panel.

Question 18(e) Photograph of transformer coil. Used with kind permission of the examining panel.

Question 20 Photograph of acousto-magnetic tags. Used with kind permission of the examining panel.

Section Three:

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Question 23 Adapted from: Gringer. (2008, December 29). *Atmos_struct_imaging* [Diagram]. Retrieved January 21, 2011, from: http://en.wikipedia.org/wiki/File:Atmos_struct_imaging.svg.

Adapted from: Tubbs, B. *Adaptive optics correct* [Diagram]. (2007, September 9). Retrieved January 21, 2011, from: http://en.wikipedia.org/wiki/File:Adaptive_optics_correct.png.

Adapted from: *Laser guide star system installed at the Very Large Telescope (European Southern Observatory) in Chile* [Photograph]. Retrieved January 21, 2011, from http://en.wikipedia.org/wiki/Laser_guide_star.

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