Government of Western Australia
School Curriculum and Standards Authority

Western Australian Certificate of Education Examination, 2014

Question/Answer Booklet

PHYSICS
Stage 3

Place one of your candidate identification labels in this box.

Ensure the label is straight and within the lines of 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

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: 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.

Ref: 14-116

PHY3

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	13	13	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 2014*. 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.

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

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

This section has **13** 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.

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Suggested working time: 50 minutes.

Question 1 **(2 marks)**

Astronomers study stars using a variety of electromagnetic frequencies. Place the following sections of the electromagnetic spectrum in order from longest wavelength to smallest: visible, infra red, X-ray and radio.

______________ ______________ ______________ ______________

Question 2 **(4 marks)**

Electromagnetic radiation (emr) is said to have both wave and particle properties. State and describe an example of each of these properties of emr.

Question 3 **(2 marks)**

An exotic hadron, initially seen over 40 years ago, has recently been confirmed at the European Organization for Nuclear Research (CERN). The Z(4430) particle consists of four quarks: a charm, an anti-charm, a down, and an anti-up.

Use the following table to show the calculation required to determine the charge of the Z (4430) particle.

Table of quarks		
Name	**Symbol**	**Electrostatic charge**
Up	u	+ ⅔ e
Down	d	-⅓ e
Strange	s	-⅓ e
Charm	c	+ ⅔ e
Bottom	b	-⅓ e
Top	t	+ ⅔ e

Question 4 **(3 marks)**

A space probe travels along a line from the Earth to Uranus at a constant speed of 0.95c relative to the solar system. Just as it reaches midway between the two planets, it sends laser beams out to the Earth and Uranus at the same time. At what speed do the laser beams approach the Earth and Uranus, respectively?

Speed of laser beam approaching the Earth: ______________________________

Speed of laser beam approaching Uranus: ______________________________

To an observer on Uranus, will the light from the space probe appear red shifted, or blue shifted? Circle the correct answer.

red shifted   blue shifted

Question 5 **(5 marks)**

An aircraft attempts to land along a north-south aligned landing strip. It approaches from the south and has an air speed of 133 km hr^{-1}. The wind is blowing from the west at 45.0 km hr^{-1}. Draw a vector diagram to show the direction the aircraft needs to head and calculate its actual velocity, in m s^{-1}, relative to the runway. Show **all** workings.

Question 6 **(4 marks)**

The images below show hydrogen spectra.

Image 1: Bright lines on a black background.

Image 2: Dark lines on a continuous spectrum.

For each, name the type of spectrum and describe how it is created.

Image 1 spectrum type: ____________________

Created: ____________________

____

Image 2 spectrum type: ____________________

Created: ____________________

____

Question 7 **(5 marks)**

Shown below are three diagrams A, B and C representing fields. Use the diagrams to fill in the blanks in the following sentences. Any field diagram can be used more than once.

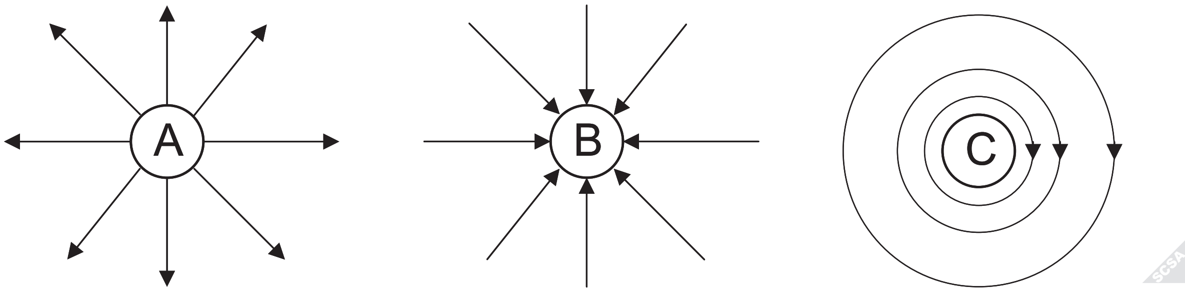

Diagram ________________ could represent the gravitational field of a mass.

Diagram ________________ could represent the electric field around a positively charged particle.

Diagram ________________ could represent the electric field of a negatively charged particle.

Diagram ________________ could represent the magnetic field around a wire carrying current that is directed ______________ the page.

Question 8 **(3 marks)**

Describe briefly the relationship between the mass and energy of an accelerating object as its speed approaches, but cannot exceed, the speed of light in vacuum, c.

____

____

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Question 9 **(5 marks)**

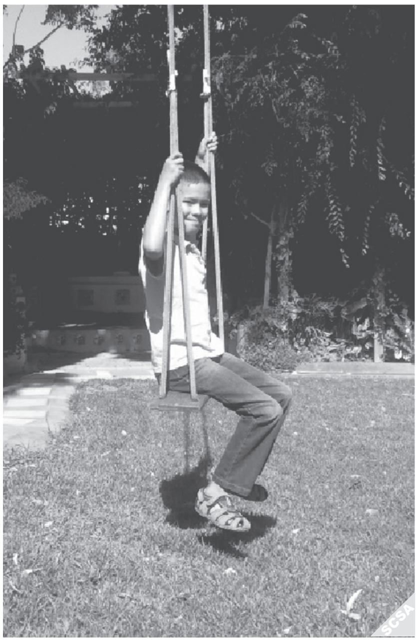
Use the information given in the Formulae and Data Booklet to calculate the orbital period, in seconds, of the Moon around the Earth.

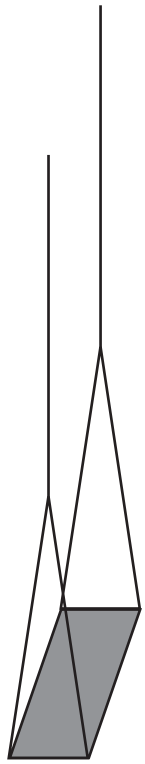
Question 10 **(4 marks)**

During a chase scene in a movie, an actor drops onto the top of an elevator that is descending at a constant speed of 1.00 m s^{-1}. The time taken to land on top of the elevator is 6.10×10^{-1} s. Determine the distance in metres the elevator is below the actor when she starts her drop. Show **all** workings.

Question 11 **(6 marks)**

Shown are a photograph and diagram of a child's swing suspended 7.00 metres below the branch of a large tree. The wooden seat has a mass of 1.00 kg and is supported by ropes as shown in the diagram below. When the seat is horizontal, the ropes that **attach to the seat** each make an angle of 15.0° to the vertical.



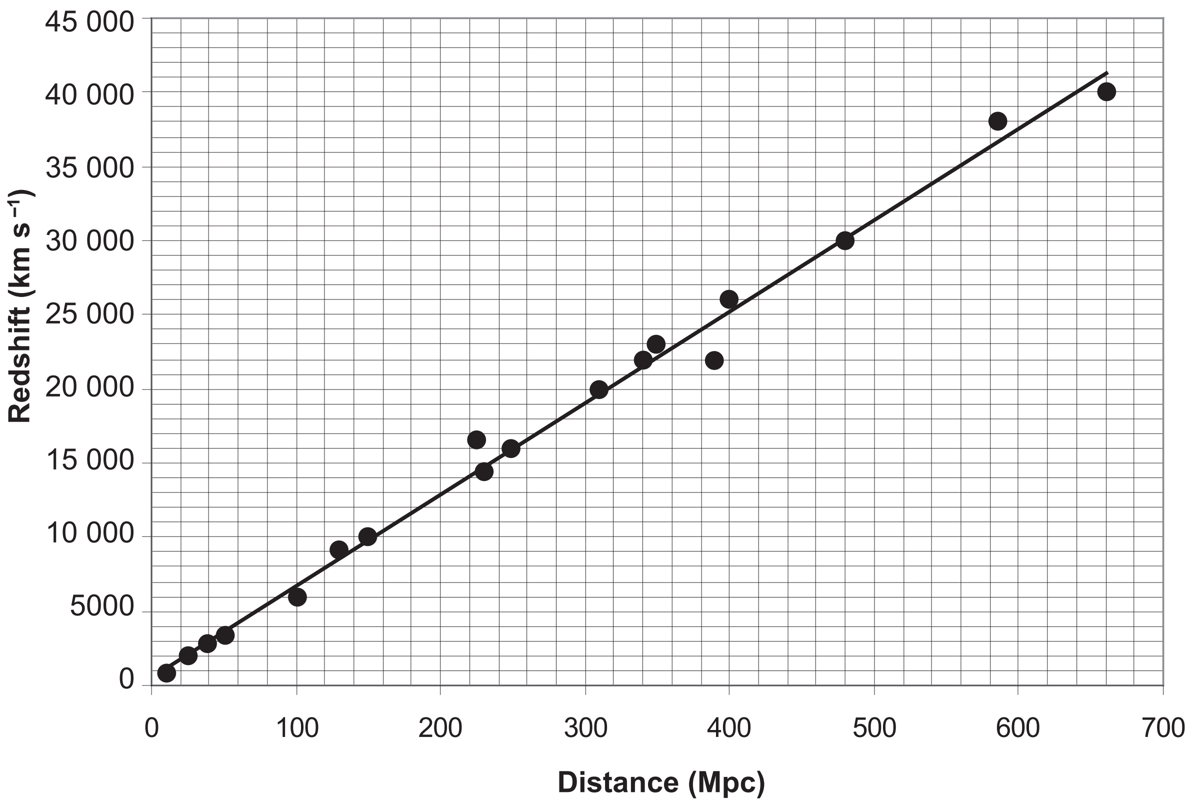


Calculate the maximum tension in each of the angled sections of the rope that attach to the seat when a 27.0 kg boy is sitting on the swing and moving with a tangential velocity of 4.00 m s^{-1}. Show **all** workings.

Question 12 **(5 marks)**

Hubble's law can be used to estimate the maximum size of the observable Universe. The graph below indicates the relationship between recessional speed of a star (or galaxy) and the distance to that star (or galaxy).

Distances are given in megaparsecs (Mpc) where 1 Mpc = 3.26 light years.



(a) The vertical axis is labelled 'redshift' with units for velocity (km s^{-1}). Explain briefly the relationship between redshift and the speed of the object. (2 marks)

(b) Use the gradient of the graph to extrapolate a value for the maximum distance, in Mpc, for a galaxy to be observed from the Earth. Show **all** workings. (3 marks)

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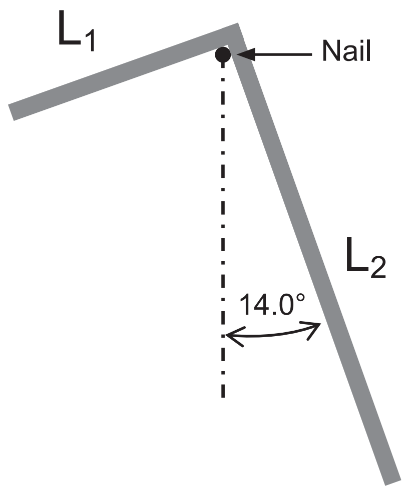
Question 13 **(6 marks)**

A thin metal rod is bent into a right angle and hung on a nail from a wall, as shown in the diagram. Assume that there is no contact between the rod and wall. The longer side (L_2) is 0.800 m long and makes an angle of 14.0° to the vertical. The rod has uniform density and constant thickness. Calculate the length of the shorter side, L_1. Show **all** workings.



End of Section One

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

This section has **seven (7)** 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.

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Suggested working time: 90 minutes.

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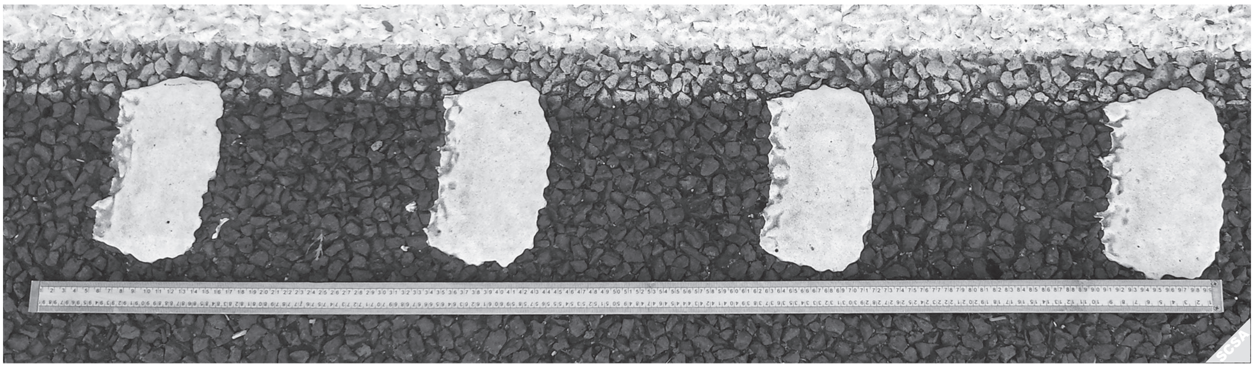
Question 14 **(12 marks)**

Along the sides of some roads are rumble strips made of raised painted markers that are intended to get a driver's attention if a car strays across them. One part of a strip is photographed below. A metre ruler has been included to give an idea of scale.



(a) Estimate the frequency of the vibration if a car is travelling at 95 km hr^{-1}. Use appropriate significant figures and unit for the value. Show **all** assumptions and workings. (5 marks)

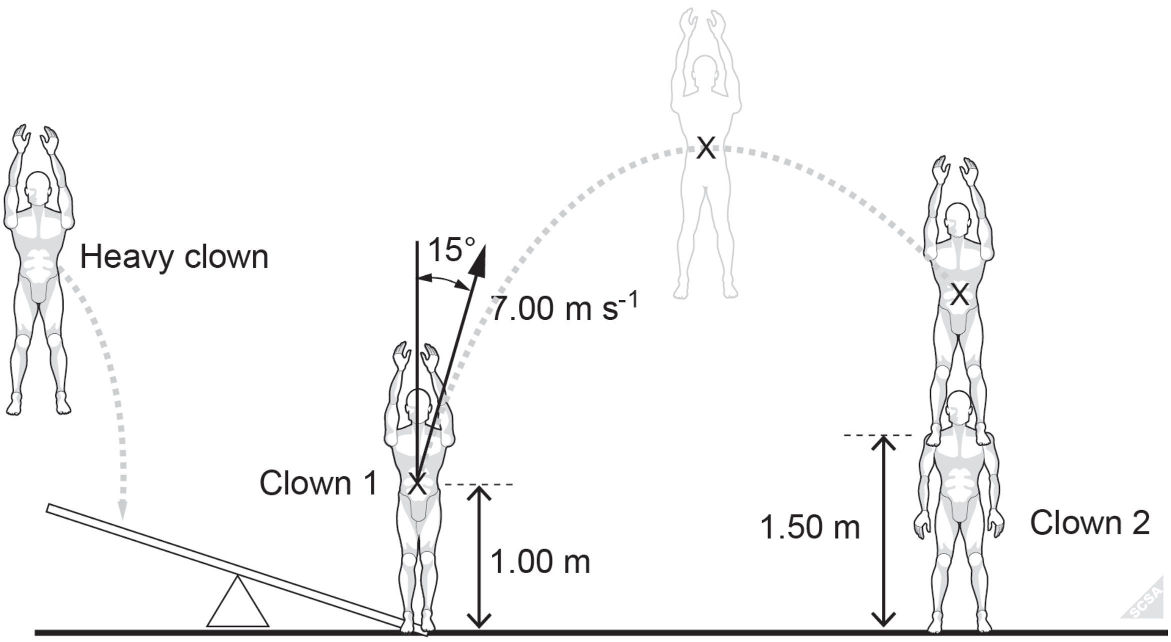
(b) An old car slows down to stop on the side of the road. As it crosses the rumble strip, the frequency of sound decreases along with the speed and the vibrations cause the dashboard to rattle. The intensity of vibration of the dashboard varies and becomes very loud at one particular frequency. Explain this phenomenon, using appropriate physics terminology and concepts. (4 marks)

(c) In another car, a test signal with a constant frequency and amplitude is being played on the radio. This test signal matches closely the frequency produced while driving over the rumble strip at a constant speed. Despite both sounds maintaining a constant frequency and amplitude, a fluctuation in the amplitude can be heard by the car's occupants, for whom the sounds grow louder and quieter. Explain this phenomenon, using appropriate physics terminology and concepts. (3 marks)

Question 15 **(10 marks)**

Clown 1 is standing on a seesaw. As part of the circus act a heavy clown will jump from a height and land on the opposite side of the seesaw to Clown 1. This will launch Clown 1 into the air with a velocity of 7.00 m s^{-1} at an angle of 15° to the vertical.

Clown 1 will travel through the air and land on the shoulders of Clown 2, following the trajectory shown with a dotted line (diagram is not drawn to scale). The centre of mass of Clown 1 is shown with an 'X'.



(a) On the diagram above, draw an arrow to show the direction of acceleration of Clown 1's centre of mass at the point of maximum height. (1 mark)

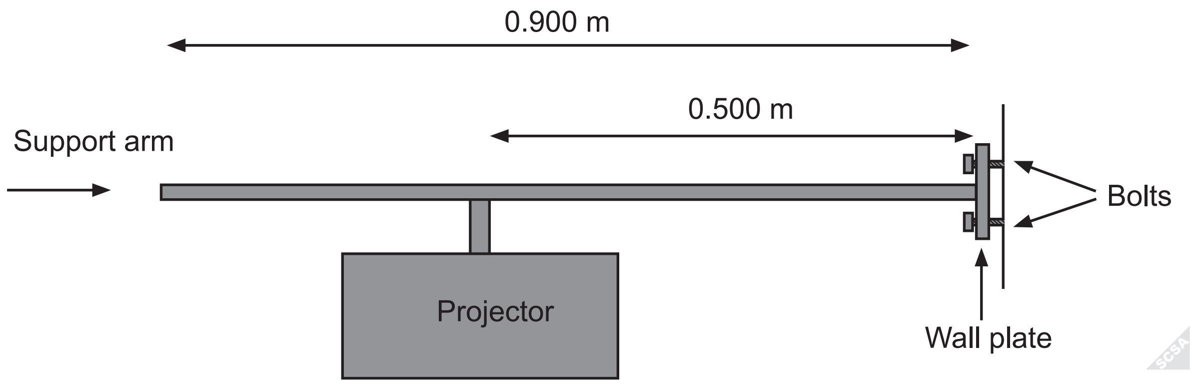
(b) Describe qualitatively **two** effects of air resistance on projectile motion in this case. (2 marks)

(c) Show by calculation that the total time Clown 1 is in the air is just over 1.1 s. Ignore air resistance. (4 marks)

(d) Determine the initial horizontal distance between Clown 1 and Clown 2. Ignore air resistance. Show **all** workings. (3 marks)

Question 16 **(10 marks)**

The diagram below shows a data projector with a mass of 7.00 kg. The projector is mounted on its uniform horizontal support arm at a distance of 0.500 m from the wall plate. The support arm itself is 0.900 m long and has a total mass of 1.00 kg.



The assembly is held in place by bolts as shown in the diagram above. The upper bolt is 4.00 cm above the support arm and the lower bolt is 4.00 cm below the support arm. The wall plate does not touch the wall and is supported only by the bolts.

(a) Calculate the **horizontal force** in newtons exerted by the **upper bolt** used to attach this projector to the wall. Show **all** workings.
Hint: Take the bottom bolt of the wall plate as a pivot point. (4 marks)

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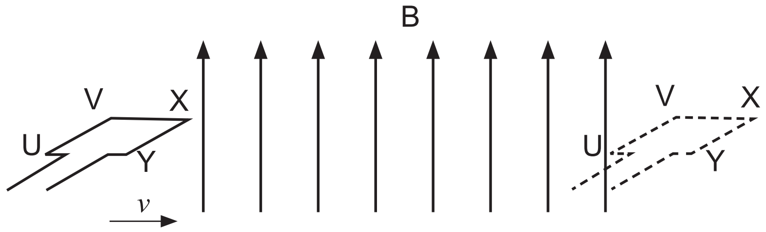
(b) Explain quantitatively the effect on the centre of mass of the projector/support arm system as the projector is moved further away from the wall. (3 marks)

(c) Explain quantitatively the effect on the horizontal force exerted by the upper bolt as the projector is moved further away from the wall, assuming the system maintains its stability. (3 marks)

Question 17 **(17 marks)**

As a rectangular coil loop (UVXY) is moved from left to right, it enters a uniform magnetic field, B, as shown in the diagram below. The plane of the loop is perpendicular to the magnetic field lines. According to Faraday's law, an emf must be induced in the loop. Assume that the emf induced in the U-V-X-Y direction is negative, while in the Y-X-V-U direction the emf is positive.



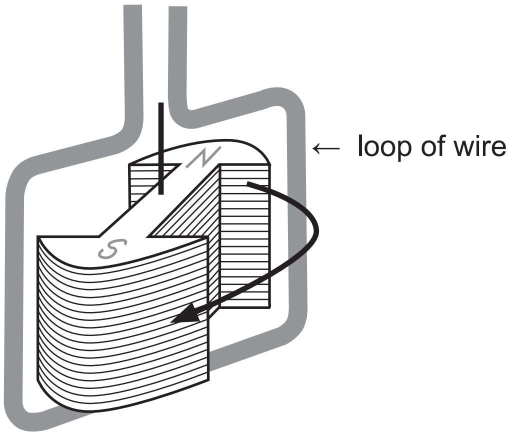
(a) A meter is connected to the loop to measure the emf generated in the circuit during one movement through the field. Fill in the following details of the meter: (2 marks)

Type of meter: ______________ Unit of measurement: ______________

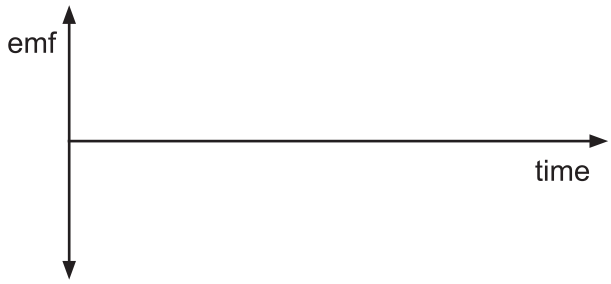
(b) During a second movement through the field, a light globe is attached between U and Y, making a circuit. Explain why the loop requires a force when entering and leaving the magnetic field. (4 marks)

(c) Given that the velocity of the loop is constant, complete the graph below for the emf induced in the loop over the time that it moves into and out of the field. (4 marks)

(d) Another method of generating an emf is to move the magnet in a circular motion as shown in the diagram below.



(i) Complete the graph below for the emf induced in the loop of wire over one complete rotation of the magnet. (3 marks)



(ii) The loop of wire above is a square 5.00 × 5.00 cm. If the magnet rotates once every 1.00 s and has a magnetic field strength of 0.789 T, calculate the magnitude of the maximum emf generated. Assume that the field is completely reversed in the loop during the magnet's rotation. Show **all** workings. (4 marks)

Question 18 **(13 marks)**

A hydrogen atom, in an excited energy level, undergoes relaxation by emitting a photon. The energy values are given by $E_n = -\frac{13.6}{n^2}$ eV. The initial state of the electron is in energy level n = 4 and the final state after relaxation is ground state (n = 1).

(a) Does the average radius of the electron orbital remain the same, increase or decrease in value during this transition? Circle the correct answer. (1 mark)

remains the same increases decreases

(b) Use the formula $E_n = -\frac{13.6}{n^2}$ eV to complete the energy level diagram below. The diagram is **not** drawn to scale. (2 marks)

n=4	____________________	E_4 = ...eV
n=3	____________________	E_3 = -1.51 eV
n=2	____________________	E_2 = -3.40 eV
Ground state n=1	____________________	E_1 = ...eV

(c) On the diagram above, draw in all the possible transitions when an electron undergoes relaxation from n = 4 to the ground state. (3 marks)

(d) (i) Calculate the wavelength of the photon emitted from the E_3 to E_2 transition. Show **all** workings. (4 marks)

(ii) The transitions of E_4 to E_2 and E_3 to E_2 produce red and green photons. Explain which transition produces which colour. (3 marks)

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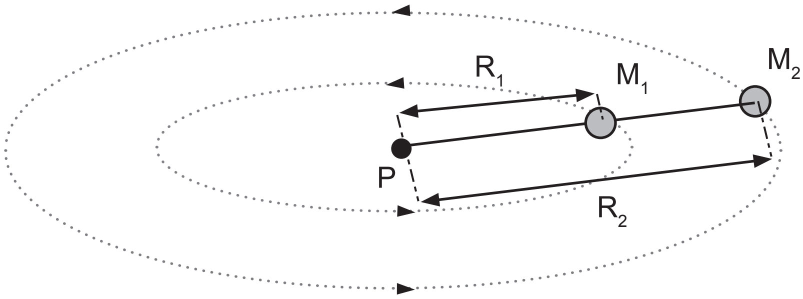
Question 19 **(10 marks)**

A string linking two balls M_1 and M_2, (shown in the figure below) allows them to revolve in circular motion on the horizontal plane with radii R_1 and R_2. The periods of revolution of M_1 and M_2 are the same and equal to T. Ignore gravitational force and air resistance force.



(a) Draw a free body diagram for M_1. (3 marks)

(b) Complete the following for M_1 and M_2.

(i) Write an appropriate expression for the tangential velocity v_1 of M_1 in terms of R_1, R_2 and T. (2 marks)

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Question 19 (continued)

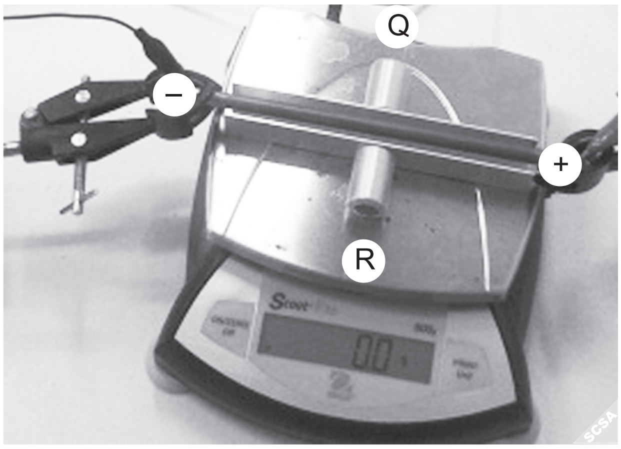
(ii) Write an appropriate expression for the tension F_1 acting in the string between M_1 and M_2, in terms of the mass m_2, the radius R_2 and the period T. (2 marks)

(iii) Write an appropriate expression for the tension F_2 acting in the string between P and M_1, in terms of the masses m_1 and m_2, the radii R_1 and R_2 and the period T. (3 marks)

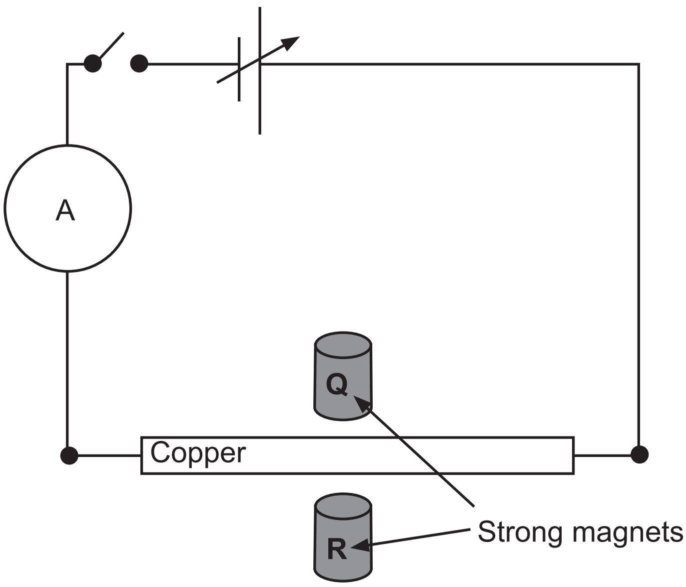
See next page

Question 20 **(18 marks)**

Jake wanted to determine the strength of a magnetic field by conducting an investigation. In this investigation, two identical cylindrical permanent magnets, each 2.0 cm in diameter, were placed opposite each other on either side of an aluminium channel. A current was passed along a 20 cm copper rod, which in turn was placed perpendicularly in the magnetic field. The interaction between the permanent magnets and the current-carrying wire produced a downward force acting on the magnets which was measured using a digital balance. Photographs of the equipment are shown below, as is a schematic diagram of the circuit.



Close up of magnets and copper rod on digital balance



(a) Using the photograph above, for magnets labelled Q and R, write either 'North' or 'South' in the space below to indicate which pole the magnet would need to have next to the channel to provide the magnets with a force directed downward (into the pan of the balance). (2 marks)

For magnet Q, the ______________________ pole would be next to the channel.

For magnet R, the ______________________ pole would be next to the channel.

Question 20 (continued)

(b) A table of results for this investigation is shown below:

Potential difference (V)	**Current (A)**	**Scale reading (g)**	**Force (N)**
0.00	0.00	0.00	0.0
2.0	0.94	0.30	
4.0	1.81	0.70	6.9×10^{-3}
6.0	2.67	0.90	
8.0	3.66	1.3	1.3×10^{-2}
12	5.30	1.9	1.9×10^{-2}

(i) Complete the last column in the table above with values expressed to **two** significant figures. (2 marks)

(ii) Use the data from the table to plot a straight line graph on the grid provided, demonstrating the relationship between the current and force. (4 marks)

(iii) Use your graph to determine the force that should be measured when a current of 4.0 A flows through the copper rod. Express your answer using appropriate significant figures. (3 marks)

(iv) Determine the gradient of your line of best fit. Include units in your answer. (3 marks)

(v) Use your gradient to determine the experimental value of the magnetic field strength. Include units in your answer. Show **all** workings. (4 marks)

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

End of Section Two

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

This section has **2** questions. You must answer **both** 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.

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Suggested working time: 40 minutes.

Question 21 **(18 marks)**

It is generally accepted that around 65 million years ago the Earth was struck by a fast-moving object approximately 10 km in diameter. This impact is believed to have left a scar on the Earth in the form of the Chicxulub Crater and to have been responsible for the extinction of the dinosaurs.

In 2013 the 'Chelyabinsk meteor' entered the Earth's atmosphere over Russia. This meteor had a mass of approximately 12 kilotonnes, measured about 20 metres in diameter and released about 1.8×10^{15} J, causing extensive damage, though mostly to arable land and not populated cities.

Events such as this have sparked interest in cataloguing such Near Earth Objects (NEOs) and then determining if they have an orbit that might put them on a collision course with the Earth. If a NEO is deemed to have an orbit that puts it on a collision course with the Earth then various possibilities exist for preventing the collision. These methods of prevention fall into two categories, either deflection or destruction of the NEO. With either method, early intervention is desirable. The Earth is orbiting the Sun at 30.0 km s^{-1} and to avoid an impact scientists have to ensure that the NEO and the Earth are not in the same position in space at the same time. The section of the Earth's orbit in which a collision is possible is known as the 'impact window'.

Essentially deflection strategies seek to alter the velocity of the NEO so that it intersects the Earth's orbit before or after the Earth is in that position. It is estimated that a velocity change of a NEO of $\frac{3.5 \times 10^{-2}}{t}$ m s^{-1} is sufficient to avoid a collision where 't' is the time in years to impact.

One possible method of deflecting a NEO is to use a 'gravity tractor'. A gravity tractor is a massive spacecraft that is brought near to the NEO. Gravity will act between the spacecraft and the NEO and both objects will mutually attract each other. In time the NEO will gradually change the direction of its orbit. Once the NEO moves out of its normal path and comes close to the spacecraft, thrusters fire, moving the spacecraft further away from the NEO and allowing the spacecraft to continue to act as a gravity tractor. The gravity tractor method requires the earliest of interventions.

(a) Estimate the velocity of the of the Chelyabinsk meteor. Give your answer to an appropriate number of significant figures. Show **all** workings. (4 marks)

(b) (i) The width, in Earth diameters, of the impact window is (circle your answer): (1 mark)

less than one one more than one

(ii) Calculate the length of time that an 'impact window' has for any collision of an object with the Earth to occur. Ignore the size of the object. Show **all** workings. (3 marks)

Question 21 (continued)

(c) The NEO Apophis is on an orbit that will bring it close to the Earth in 2036. It has an assumed mass of 4.00×10^{10} kg and diameter of 325 m.

(i) Suppose that a spacecraft arrives and begins interacting with Apophis in 2016. Determine the change in velocity required to avoid a collision with the Earth. (3 marks)

(ii) If a gravity tractor type of intervention is decided upon, and does not begin interacting until 2021, then Apophis will require a change in velocity of 2.33×10^{-3} m s^{-1}. Determine the mass of the gravity tractor spacecraft needed, given that the centres of mass will be 175 m apart. (4 marks)

(d) When using a gravity tractor, explain why 'the earliest of interventions' is desirable if an asteroid is to be deflected sufficiently to avoid collision with the Earth. (3 marks)

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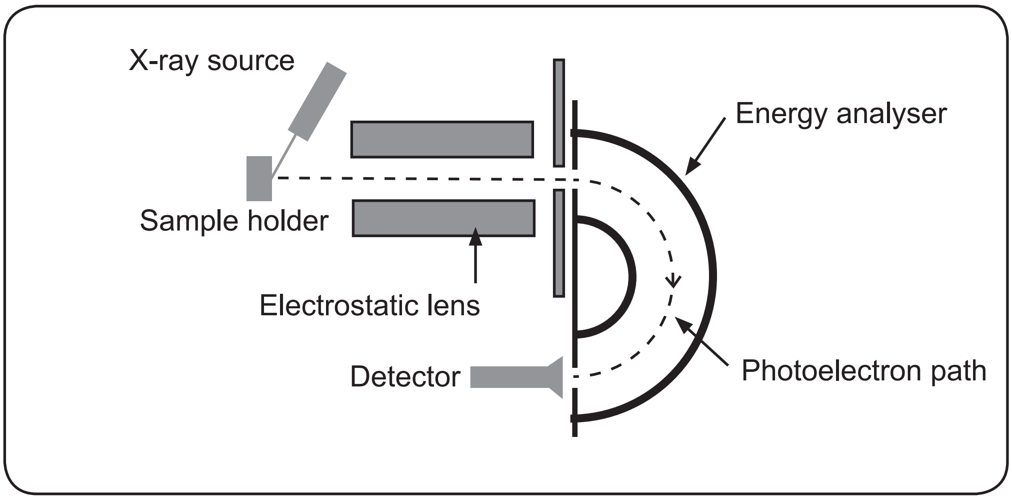
Question 22 **(18 marks)**

An X-ray photoelectron spectroscope (XPS) measures the energy distribution of electrons emitted from a sample material. The essential components of an XPS are an X-ray source, a sample holder, an electrostatic lens, an energy analyser and a detector, all in an ultra-high vacuum. This is shown in the diagram below.



Schematic diagram of an X-ray photoelectron spectroscopy unit (vacuum system and cooling system are not shown for clarity)

In the X-ray source, electrons are accelerated through a large potential difference, then stopped suddenly. The change in kinetic energy of these electrons creates a range of very high-energy X-ray photons, which are directed at the sample to be analysed in the XPS. In the sample, atoms absorb the incident photons and then emit electrons ('photoelectrons'). By using a wide range of incident photon energies, an XPS can measure with great accuracy the kinetic energies of photoelectrons emitted from the outermost to the deepest energy levels of the atoms in a sample.

The minimum energy needed to release a photoelectron from the outermost energy level of a sample is called the work function, W. The maximum kinetic energy E_k of a photoelectron emitted from the outermost energy level is related to the work function by the equation:

$$W = hf - E_k$$

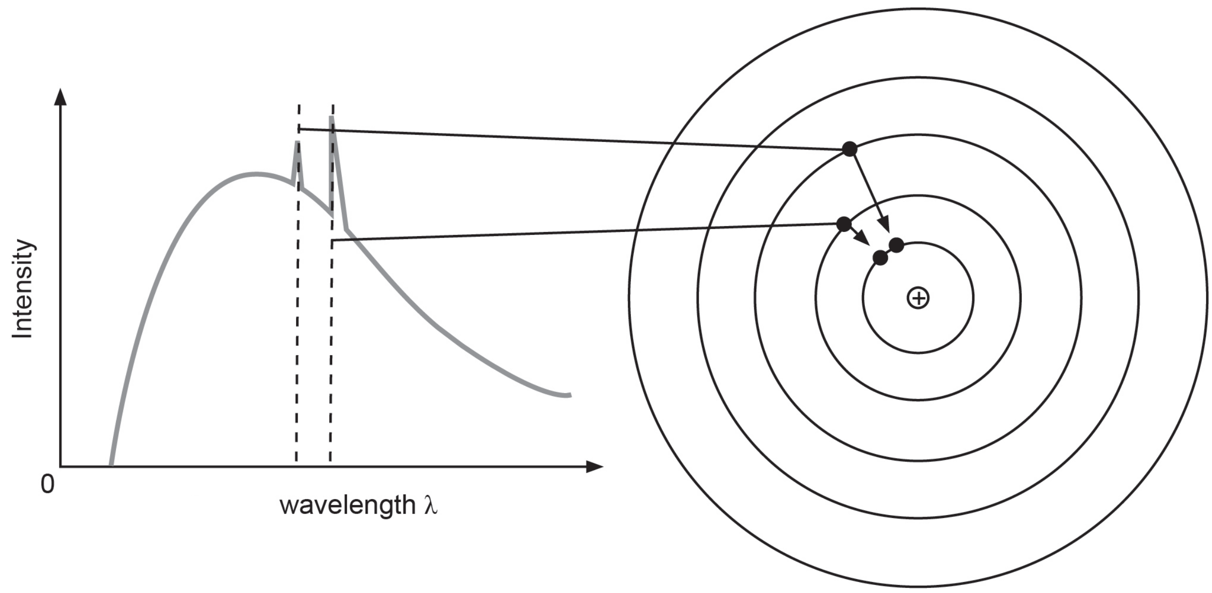
where h is Plank's constant and f is the frequency of the incident photon. W is usually quoted in electron volts. Using $h = 4.14 \times 10^{-15}$ eV s allows calculation in electron volts without the need for conversion to joules.

The binding energy (E_b) of an electron at any energy level in an atom is the energy needed to move the electron from its original level to the outermost level, as in the equation below:

$$E_k = hf - E_b - W.$$

An XPS that can scan a wide range of photoelectron kinetic energies, from a few to thousands of electron volts, can identify the chemical composition of a sample, since electron binding energies in each element are distinctive.

(a) The spectrum produced by an X-ray tube consists of two features. One is a smooth curve due to *bremsstrahlung* (the electron losing its energy as high energy photons). The second consists of peaks which are characteristic for the metal in the target of the tube. Explain what is meant by 'characteristic peaks', with reference to the diagram below. (3 marks)



Question 22 (continued)

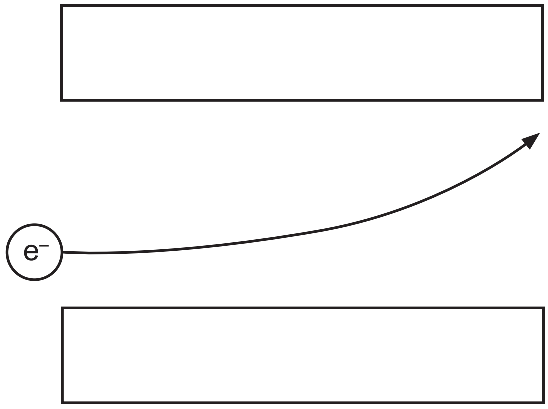
(b) A 1486.6 eV X-ray is used for (i), (ii) and (iii) below, which relate to X-ray photoelectron spectrometry.

(i) Determine the minimum accelerating potential difference required to produce 1486.6 eV photons in the X-ray tube, rounding your answer to **two** significant figures. (2 marks)

(ii) Calculate the wavelength of the 1486.6 eV X-rays. Show **all** workings. (2 marks)

(iii) The 1486.6 eV X-rays are directed onto a sample containing silicon, which has a work function of 4.50 eV. A photoelectron from a distinct energy level with binding energy of 99.7 eV is ejected from the sample. Calculate the kinetic energy and speed of this photoelectron. Show **all** workings. (5 marks)

(c) Complete the simplified electrostatic lens diagram below. The electron shown is initially moving from left to right. Write the appropriate charge sign in each box to make the electron move along the path shown. Draw the field in the space between the boxes to aid your diagram. (3 marks)



(d) The energy analyser section of an XPS consists of parallel, curved plates that can be electrically charged. A photoelectron passing between these plates is affected by them. Explain how the voltage on the plates results in only photoelectrons having a specific energy reaching the detector. (3 marks)

End of questions

Additional working space

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Question 20

ACKNOWLEDGEMENTS

Section One

Question 3	Data source: CERN. (n.d.). *Large Hadron Collider Beauty experiment* (LHCb). (n.d.). Retrieved January 9, 2014, from http://lhcb-public.web.cern.ch/lhcb-public/
Question 6	Adapted from: Sassospicco. (2007). *Spectrum* [Image 1] (Public domain). Retrieved February 13, 2014, from http://en.wikipedia.org/wiki/
	Adapted from: Sassospicco. (2007). *Spectrum* [Image 2] (Public domain). Retrieved February 13, 2014, from http://en.wikipedia.org/wiki/

Section Two

Question 17 (d)	Adapted from: Egmason. (2010). *Alternator* [Diagram]. Retrieved February 13, 2014, from http://en.wikipedia.org/wiki/File:Alternator_1.svg. Used under the Creative Commons Attribution-Share Alike 3.0 Unported licence.

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