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

ATAR course examination, 2017

Question/Answer booklet

PHYSICS

Place one of your candidate identification labels in this box.

Ensure the label is straight and within the lines of this box.

Student number: In figures

In words

Number of additional answer booklets used (if applicable):

Time allowed for this paper

Reading time before commencing work:	ten minutes
Working time:	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: non-programmable calculators approved for use in this examination, drawing templates, drawing compass and a protractor

Important note to candidates

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

Ref: 17-067

PHY

2018/1641
Web version of 2017/61455

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of examination
Section One Short response	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 the Western Australian external examinations are detailed in the *Year 12 Information Handbook 2017*. Sitting this examination implies that you agree to abide by these rules.

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

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

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

   In estimates, give final answers to a maximum of two significant figures and include appropriate units where applicable.

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

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

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

Section One: Short response 30% (54 Marks)

This section has **13** 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.

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.

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

Suggested working time: 50 minutes.

Question 1 **(2 marks)**

Although light exhibits many wave properties, representing it as a mechanical wave fails when considering light travelling from the Sun to Earth. Explain briefly what conclusion can be drawn.

Question 2 **(2 marks)**

A deep-space probe moves away from the Earth with a speed of $0.55c$. In its frame of reference an antenna on the probe rotates every 23.0 s. Calculate the time for **one** rotation when observed from Earth.

Answer ______________ s

Question 3 **(4 marks)**

(a) Draw an arrow indicating the direction of the magnetic field at point P due to the magnet shown. (2 marks)

(b) Describe the effect on a positively-charged particle travelling into the page at P. (2 marks)

Question 4 **(4 marks)**

(a) Draw an arrow indicating the direction of the magnetic field at point P due to the current-carrying wire Q as shown. (2 marks)

(b) Describe the effect on a positively-charged particle travelling into the page at P due to the current-carrying wire. (2 marks)

Question 5 **(4 marks)**

An LED can emit three different colours with three different temperatures (K), i.e., 3000 K (warm white), 4000 K (natural white) and 6000 K (white), with three different radiation energies, $U_{3000\text{ K}}$, $U_{4000\text{ K}}$ and $U_{6000\text{ K}}$ respectively.

(a) If the intensity is the same for each colour, then the relative electrical energy consumption (U) for each colour is (1 mark)

A $U_{3000\text{ K}} > U_{4000\text{ K}} > U_{6000\text{ K}}$.
B $U_{3000\text{ K}} = U_{4000\text{ K}} = U_{6000\text{ K}}$.
C $U_{3000\text{ K}} < U_{4000\text{ K}} < U_{6000\text{ K}}$.
D There is no correlation in terms of energy consumption.

Your answer ____________________

(b) Which LED emits the greatest proportion of long wavelength radiation? (1 mark)

A 3000 K (warm white)
B 4000 K (natural white)
C 6000 K (white)
D They are all the same.

Your answer ____________________

(c) Which LED emits the greatest proportion of high frequency radiation? (1 mark)

A 3000 K (warm white)
B 4000 K (natural white)
C 6000 K (white)
D They are all the same.

Your answer ____________________

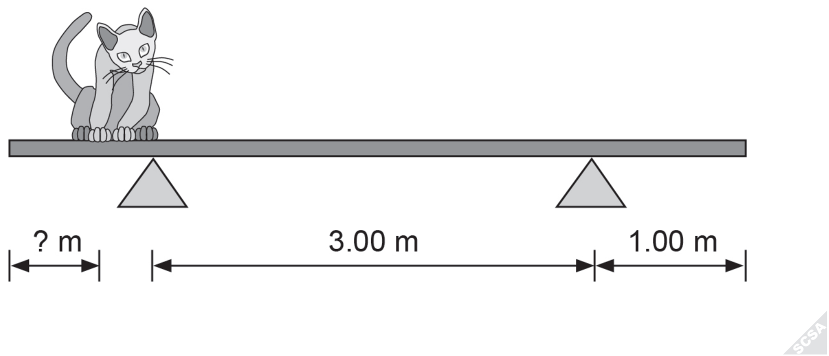
(d) Which LED emits the greatest proportion of fast photons? (1 mark)

A 3000 K (warm white)
B 4000 K (natural white)
C 6000 K (white)
D They are all the same.

Your answer ____________________

Question 6 **(3 marks)**

A large cat (m = 8.00 kg) is on a uniform 5.00 m long, 4.00 kg beam resting on two supports.



Determine the distance from the end of the beam at which the cat will make the system unstable.

Answer ______________________ m

Question 7 **(2 marks)**

On which **two** postulates is the special theory of relativity based?

One: ____

____

____

Two: ____

____

____

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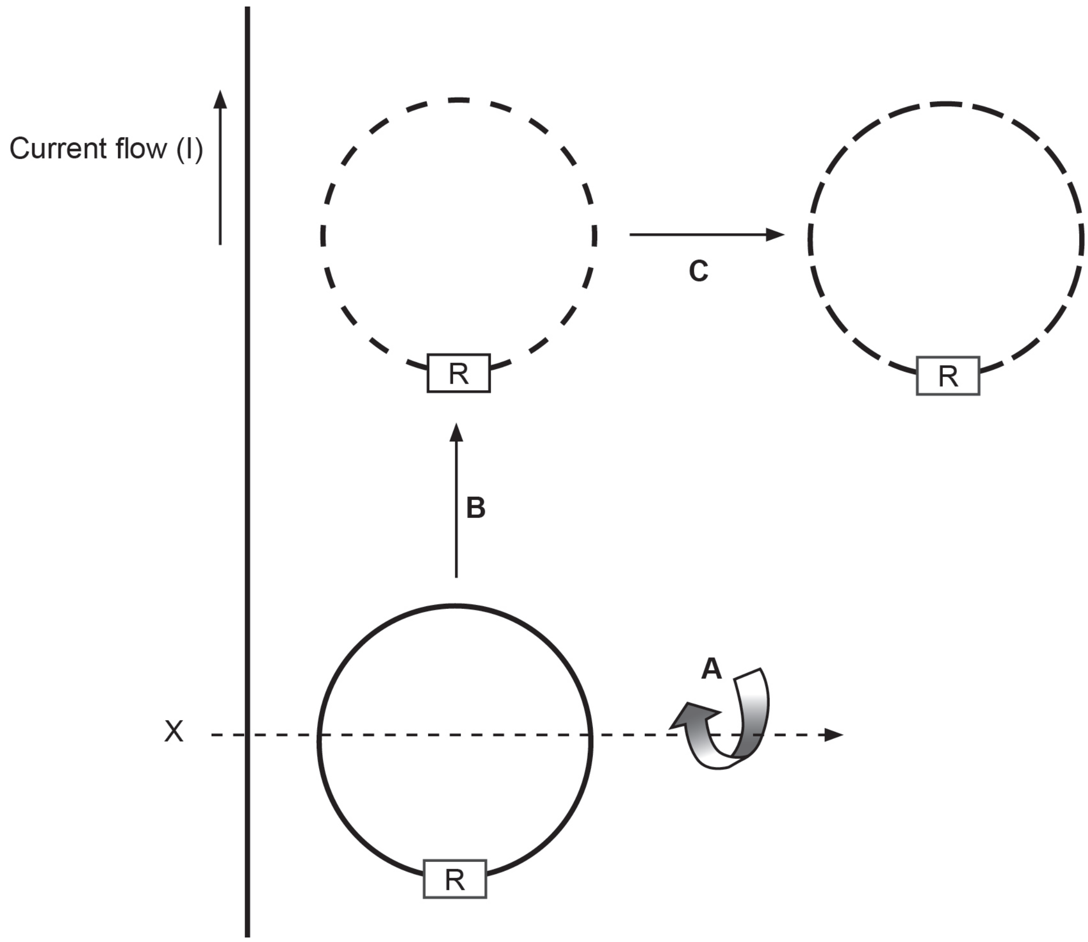
Question 8 **(8 marks)**

A circular wire loop is placed near a long, straight wire carrying a constant current in the direction shown. The loop moves three times:

- A – it rotates once, uniformly along the X-axis with the resistor R moving out of the page initially
- B – it moves parallel to the straight wire with constant speed
- C – it moves away perpendicularly from the straight wire with constant speed.



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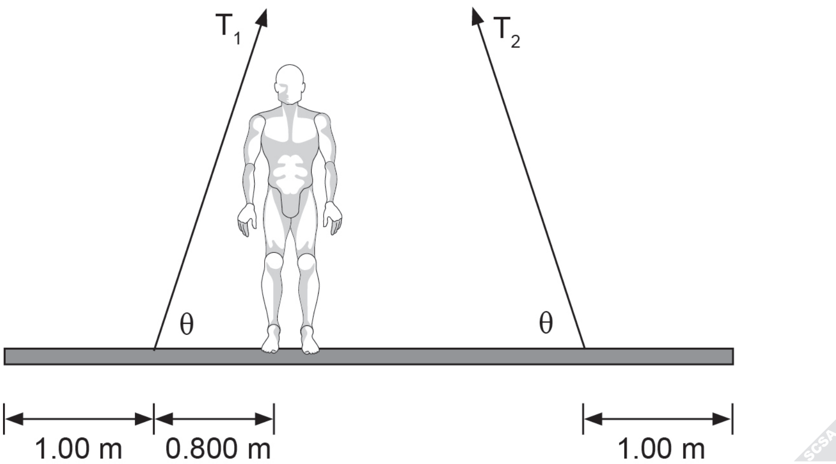
Complete the table in terms of Motions A, B and C by sketching the emf induced in the loop and state whether the direction of emf is clockwise, anticlockwise or not relevant.

Motion	Possible induced emf in the circular loop with respect to time	The direction of emf (clockwise/anticlockwise/ not relevant)
A		
B		
C		

Question 9 **(5 marks)**

A window washer (m = 65.0 kg) is on a 5.00 m long, 15.0 kg scaffold supported by two ropes attached to it. The angle between scaffold and rope (θ) is 75.0°.



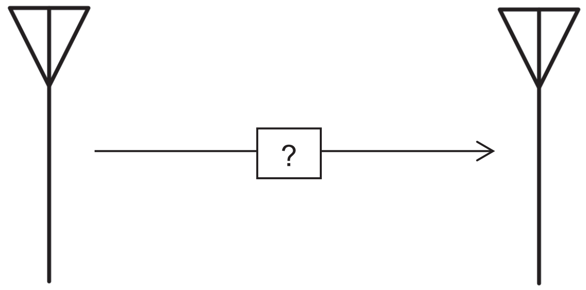
Calculate the tension in each rope in the above situation, given that the scaffold is in equilibrium.

T_1 ______________ N

T_2 ______________ N

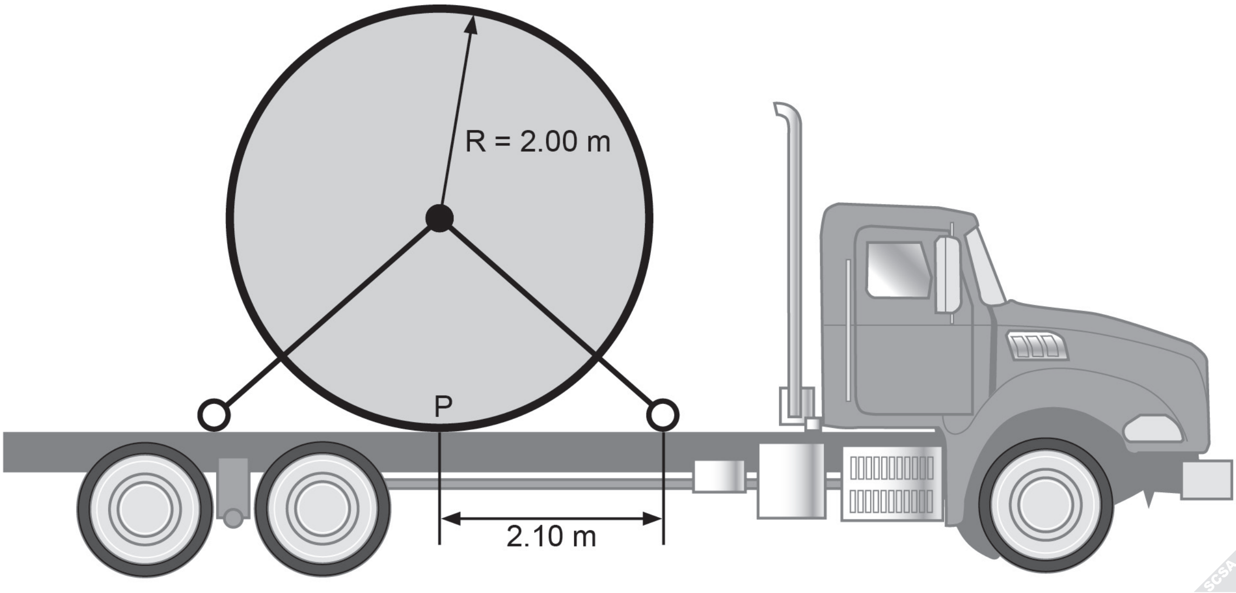
Question 10 **(4 marks)**

A radio antenna is able to convert electrical signals into radio signals, transmitting information to distant receivers. The antenna does this by oscillating a charge along its length. Describe the waves produced and how the signal is able to be picked up by the receiving antenna.



Question 11 **(4 marks)**

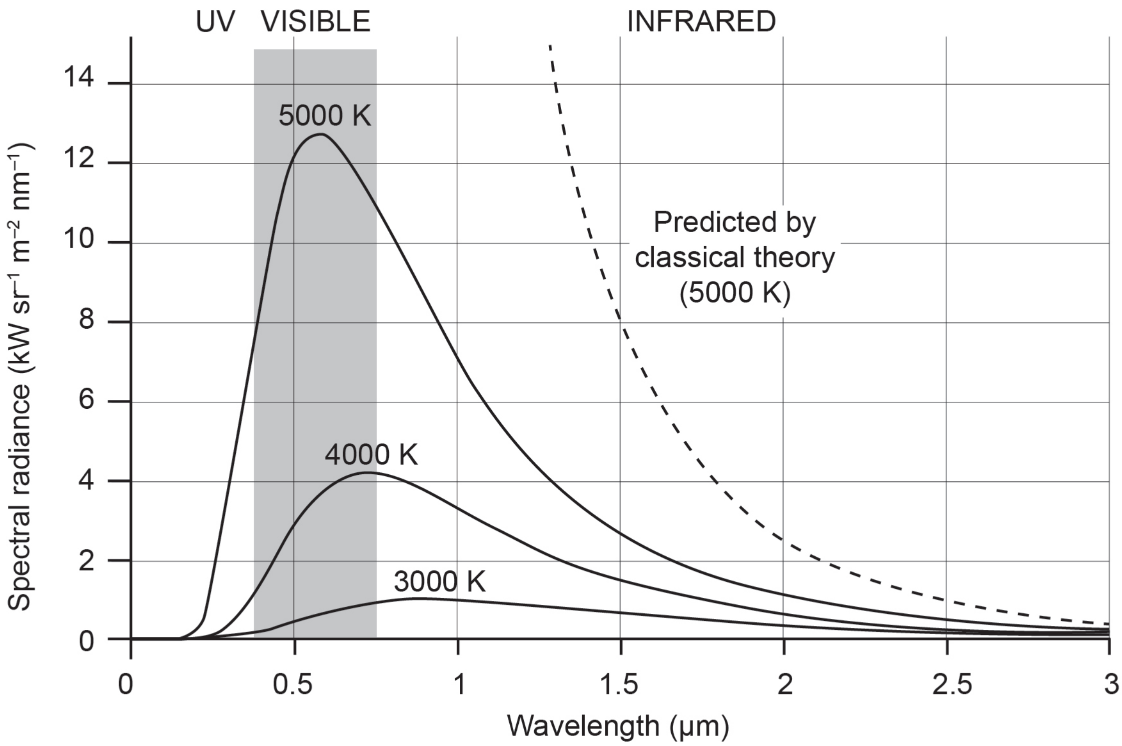
A truck transports a large 5.50×10^3 kg cylinder that has a radius of 2.00 m. The cylinder is fixed to the truck by four ropes, two on each side, on ring attachments as shown in the diagram below. If the maximum load on each of the ropes (T) is 5.50 kN, calculate the maximum allowable acceleration of the truck when it moves forward.



Answer ____________________ m s^{-2}

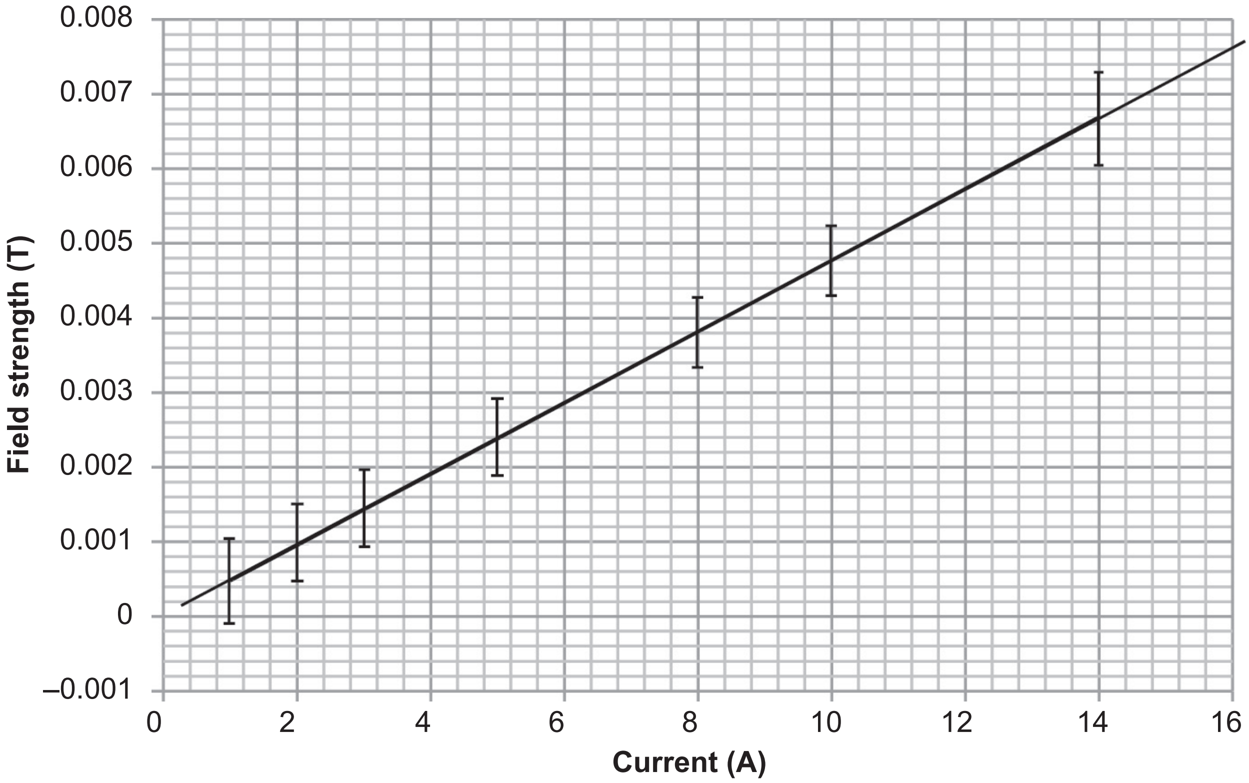
Question 12 **(5 marks)**

Describe the characteristics of a black body and use the black body radiation curves shown below to explain why the concept of light quanta was necessary.



Question 13 **(7 marks)**

The magnetic constant μ_0 is the magnetic permeability of a vacuum. An iron alloy would have a different permeability μ_a. To determine its permeability, a large block of the iron alloy had an insulated current-carrying wire pass through its middle. A measure of the magnetic field strength 1.00 m from the wire was made as the current was varied as shown on the graph below.



(a) Use $B = \frac{\mu}{2\pi}\frac{I}{r}$ to determine a gradient for the graph above and hence the magnetic constant μ (where $\mu = \mu_0 \mu_a$). (3 marks)

μ = ____________________ (no units required)

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(b) Use the gradient and the vertical error bars in the graph on page 14 to comment on the uncertainty of your answer to part (a). Express your answer in the appropriate significant figures. (4 marks)

Answer ____________________ ± ____________________ (no units required)

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.

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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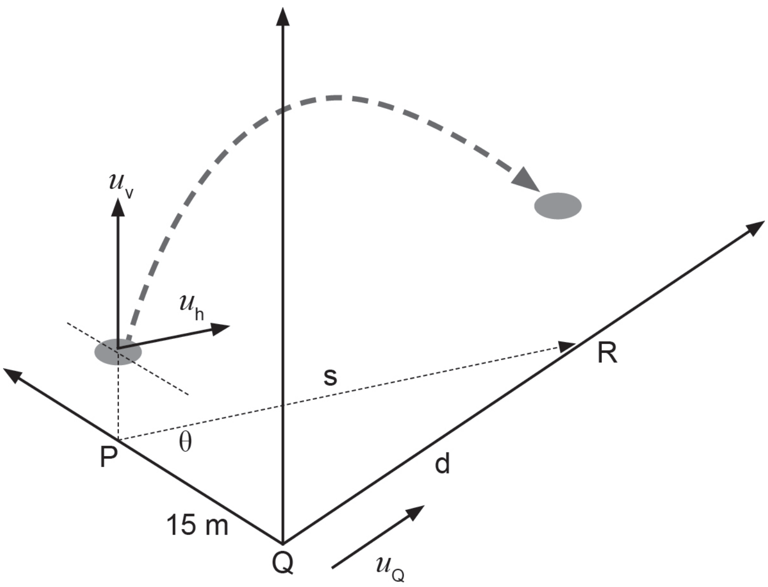
Suggested working time: 90 minutes.

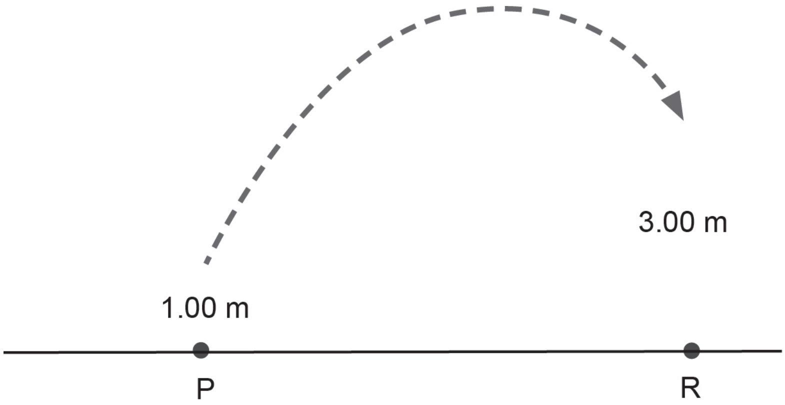
Question 14 **(13 marks)**

Paul kicks a ball from point P to point R. At the same instant, Quinn starts from point Q and runs forward, to catch the ball at point R. The horizontal distance between P and Q when Paul kicks the ball is 15.0 m. The initial vertical velocity (u_v) of the ball is 12.0 m s^{-1} and its horizontal velocity (u_h) is 10.0 m s^{-1}. Ignore air resistance throughout this question.



(a) Calculate the magnitude of the initial velocity of the ball. (2 marks)

Paul kicks the ball 1.00 m above the ground. Quinn jumps and catches the ball when it is 3.00 m above the ground at point R.



(b) (i) Show by calculation that the total time taken by the ball in the air to get from 1.00 m above the ground to 3.00 m above the ground could be either 0.180 s or 2.27 s. (3 marks)

(ii) Which of these two calculated time values in part (b)(i) is more appropriate for the ball to travel to Quinn? State a reason why. (2 marks)

Question 14 (continued)

(c) Determine the horizontal distance (s) the ball will cover before Quinn catches it at point R. (2 marks)

Answer ______________________ m

(d) Determine the average speed at which Quinn would need to travel from point Q to be able to catch the ball at point R. (3 marks)

Answer ______________________ m s^{-1}

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(e) Determine the ground angle (θ) at which Paul needs to kick the ball as shown on the initial diagram so that the ball travels to point R. (1 mark)

Answer ______________________

Question 15 **(10 marks)**

Photons with sufficient energy can, on interacting with matter, produce an electron-positron pair.

(a) (i) Show that the lepton number is conserved in such an interaction. (3 marks)

(ii) Given $E = mc^2$, determine the minimum frequency of a photon that could produce an electron-positron pair. (4 marks)

Answer ____________________ Hz

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A neutron will decay into a proton and an electron as shown in the equation below.

$$n \rightarrow p^{+} + e^{-} + ?$$

(b) (i) Demonstrate that the baryon number is preserved in the way that the equation is written above but the lepton number is not. (2 marks)

(ii) Identify the third particle in the decay to ensure that the lepton number is conserved. (1 mark)

Question 16 **(9 marks)**

Use the Standard Model in the Formulae and Data Booklet provided to answer the following questions.

(a) Identify the elementary particle responsible for mediating each of the following phenomena and complete each sentence. (3 marks)

The elementary particle responsible for the weak force is the ______________.

The elementary particle responsible for the strong force is the ______________.

The elementary particle responsible for the electrostatic force is the ______________.

A table of the characteristics of the four forces can be drawn as shown.

Force	Relative strength	Range (m)
Strong	1	10^{-15}
Weak	10^{-6}	10^{-18}
Electromagnetic	10^{-2}	infinite
Gravitational		infinite

(b) (i) The relative strength of the gravitational force would **best** be described as (1 mark)

A 10^{12}.
B 10^{-4}.
C 10^{-12}.
D 10^{-38}.

Your answer ______________

(ii) Give an appropriate reason for your choice. (2 marks)

____

____

____

____

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(c) The order of evolution of forces directly after the big bang is best thought of as (1 mark)

A gravitational first, then strong and weak last.
B weak first, then strong and gravitational last.
C strong first, then weak and gravitational last.
D simultaneous, i.e. all forces were created at the same moment.

Your answer ____________________

(d) A graviton is the proposed particle that mediates gravity but is as yet undiscovered. Suggest a characteristic for the graviton and give a reason why. (2 marks)

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Question 17 **(13 marks)**

One way of accelerating a spacecraft without using fuel is to 'slingshot' the craft around a planet. The Juno probe that entered Jupiter's atmosphere recently in 2016 used this method, travelling around Earth after the initial launch. The probe reached a maximum velocity of 7.36×10^4 m s^{-1} as it went past the Earth at a height above the surface of 559 km.

(a) Use appropriate formulae and calculations to show that the probe was able to move away from the Earth and not be captured in orbit around it. (6 marks)

(b) The Juno probe was launched from Earth on 5 August 2011 and entered Jupiter's orbit on 5 July 2016, a trip of 1796 days. It had an average velocity of 7.15×10^4 m s^{-1}. Assume there was no effect from gravitational fields.

(i) Compared to a clock on Earth, would a clock on the Juno probe be reading faster or slower? (1 mark)

A faster
B slower

Your answer ____________________

(ii) Calculate the time difference between the two clocks. (4 marks)

Answer ____________________ s

(iii) Apart from gravitational effects, what **two** assumptions did you make in your calculations? (2 marks)

One: ____________________

____

Two: ____________________

____

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Question 18 **(20 marks)**

Three light sources are used to determine the photoelectric properties of an elemental material surface; ultraviolet (338 nm), violet (386 nm) and yellow (585 nm). These light sources can be used to help determine the work functions given in the following table.

Element	Symbol	Work function (eV)
Potassium	K	2.29
Calcium	Ca	2.87
Scandium	Sc	3.50
Titanium	Ti	4.33
Chromium	Cr	4.50
Cobalt	Co	5.00

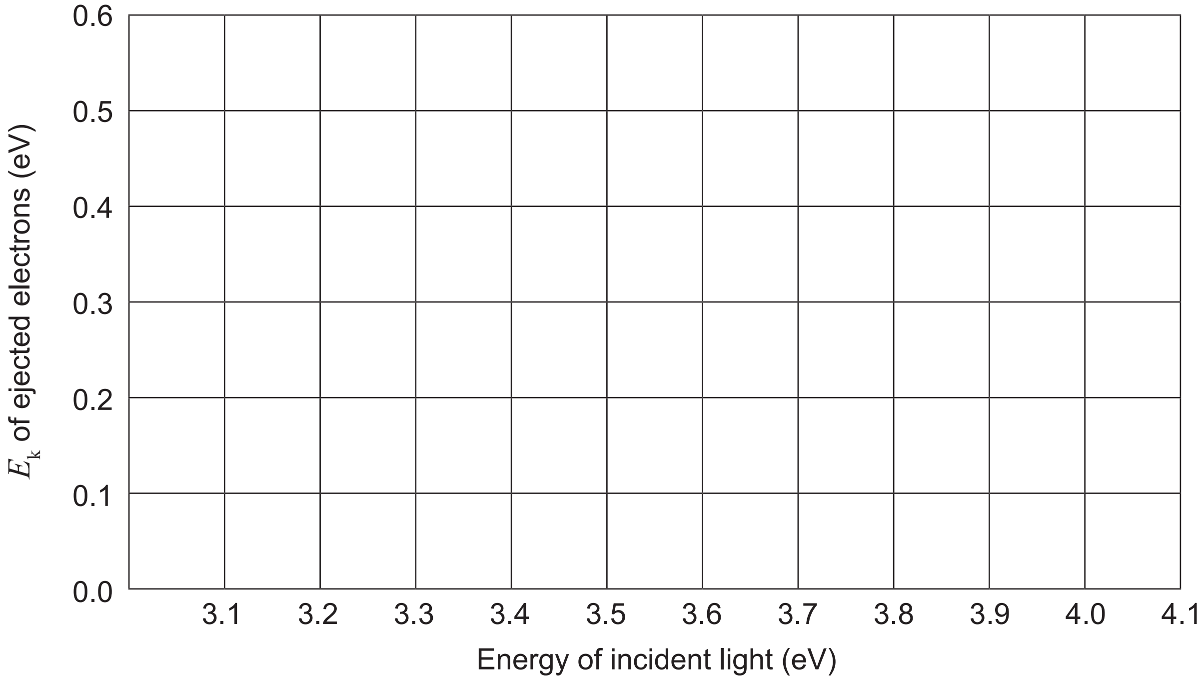
(a) Explain what is meant by the term 'work function' as it relates to the photoelectric effect. (2 marks)

(b) (i) Calculate the maximum kinetic energy, in electron volts of an ejected photoelectron when ultraviolet light is used on a scandium surface. (4 marks)

Answer ______________ eV

(ii) Sketch a graph of the kinetic energies of photoelectrons versus the energy of light incident on a scandium surface. (2 marks)

Incident light on scandium



(c) When the violet light is used on an unknown material, a stopping potential difference of 0.350 V reduces the photocurrent to zero.

(i) Calculate the work function of this material. (4 marks)

Answer ______________ eV

(ii) From the table on page 26, determine the possible element in the material. (1 mark)

Answer ______________

Question 18 (continued)

(iii) Explain what happens when the yellow (585 nm) light is incident on the unknown surface. Include a calculation to support your answer. (4 marks)

(d) Explain how the photoelectric effect demonstrates one of the properties of light. (3 marks)

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Question 19 **(12 marks)**

A group of students wanted to verify Kepler's laws of planetary motion. They chose to collect data on four moons of Jupiter.

(a) Complete the following table, using the data provided for the moons. (2 marks)

Moon	Orbital radius (r) ($\times 10^6$ m)	Orbital period (T) ($\times 10^3$ s)	r^3 ($\times 10^{24}$)	T^2 ($\times 10^9$)
Metis	128	25.5	2.10	0.65
Adrastea	129	25.8	2.15	0.67
Amalthea	181	43.0	5.93	1.85
Thebe	222	58.3		

(b) Plot the data from the table above onto the grid on page 31, demonstrating the relationship described by Kepler's laws of planetary motion. Draw the line of best fit. (4 marks)

(c) Using your graph, determine Kepler's constant (the ratio of r^3 to T^2). Express your answer in the appropriate significant figures. (3 marks)

$\frac{r^3}{T^2}$ = ______________________ $m^3 s^{-2}$

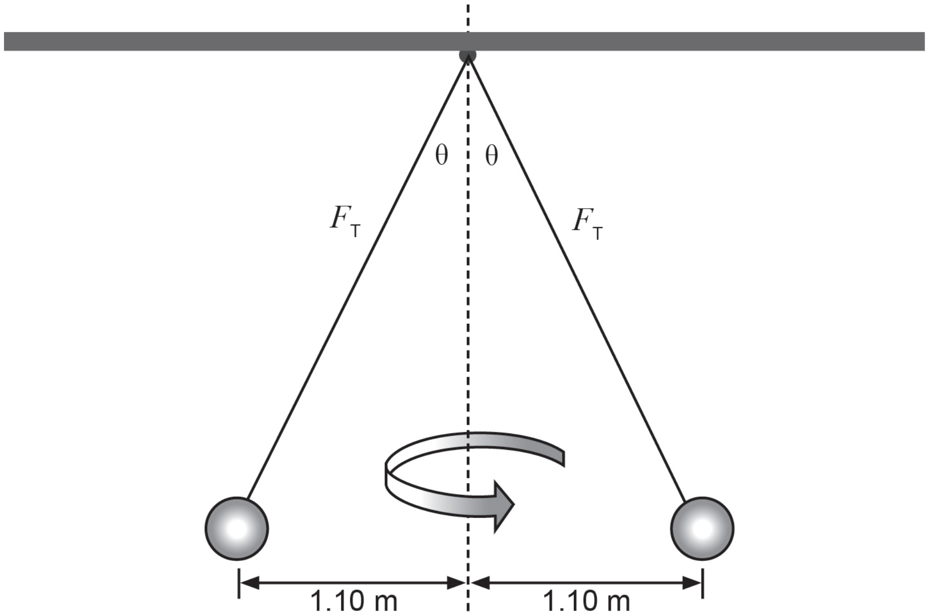
(d) Use your graph to determine the mass of Jupiter. (3 marks)

Answer ______________________ kg

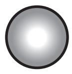
A spare grid is provided at the end of this Question/Answer Booklet. If you need to use it, cross out this attempt.

Question 20 **(13 marks)**

Two identical, electrically-charged spherical balls tied to the ends of cords of negligible mass revolve freely in a horizontal plane as shown in the diagram below. The electric charge on each ball is 7.00×10^{-6} C. The radius of the circle of motion is 1.10 m. The period (T) of revolution is 2.50 s and the mass of each ball is 0.200 kg. (Ignore the interference by any magnetic field interaction, including Earth's magnetic field.)



(a) On the ball below complete a labelled, free body diagram of the force(s) acting on one of the balls. (3 marks)



(b) Show by calculation that the magnitude of the velocity of each ball is 2.76 m s^{-1}. (1 mark)

(c) Determine the angle (θ) and the tension (F_T) of one of the cords. (6 marks)

Answer ______________ N at an angle of ______________

(d) In completing the calculations for part (c), why it is reasonable to consider the gravitational attraction between the two spheres to be negligible? Use a formula to support your answer. (3 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.

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: 40 minutes.

Question 21 **(22 marks)**

Scanning electron microscopy (SEM): a powerful surface probing-technique

Scanning electron microscopes use an energetic electron beam to examine the surface of objects on a very small scale. The basic principle of the electron microscope is similar to that of the optical microscope, but, due to the wavelength of visible light, the resolution of optical microscopy is limited to the micrometre range. However, the resolution of an electron microscope depends on the energy of electrons and can easily reach the nanometre range. Thus, the magnification of an electron microscope can be as high as 1 000 000 times, while the magnification of an optical microscope is limited to about 1200 times.

The major components of an electron microscope are shown on page 35. The first section at the top of the diagram contains the electron gun, consisting of a filament to create electrons and a positively-charged anode plate that attracts and accelerates the electrons. With a large potential difference of up to 100 kV, a high-energy electron beam is directed toward the sample.

The electron beam manipulation component consists of a condenser lens, an objective lens and apertures located in the middle section of the microscope column. These control the size, shape and position of the electron beam on the surface of a test sample.

The electron beam interacts with the surface of the sample, resulting in several physical processes, such as backscattered electrons, secondary electrons, X-rays, cathode luminescence, current flow in the sample and transmitted electrons. All of these are very useful in determining the surface characteristics and composition of a sample using the various detector systems.

One such detector examines the range of frequencies of X-rays emitted from the sample during bombardment by the electron beam of an electron microscope. The information is used to identify the elemental composition of the sample.

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(a) An electron is accelerated to 0.189*c* by the SEM.

(i) Ignoring relativistic effects, calculate the accelerating potential needed to achieve this velocity. (4 marks)

Answer ____________________ V

Question 21 (continued)

(ii) Ignoring relativistic effects, calculate the wavelength of this electron. (3 marks)

Answer ______________________ m

(b) Infer what information the detectors are able to measure to allow researchers to determine the composition of the material. (3 marks)

An ultra-high voltage electron microscope (UHVEM) Hitachi H-3000 was installed in 1997 at Osaka University in Japan. The electron acceleration voltage of the H-3000 is in the range from 500 kV to 3500 kV, which enables researchers and scientists to investigate three-dimensional microstructures on an atomic scale from nanometres to picometres.

(c) The H-3000 used an acceleration voltage of 2000 kV to accelerate an electron from rest.

(i) Calculate the speed of the electron according to the classic model of energy conservation. (3 marks)

Answer ______________________ m s^{-1}

(ii) Explain the behaviour of the electron, taking relativistic effects into account. (3 marks)

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Question 21 (continued)

The diagram below shows a simple model of a condenser lens (magnetic lens). Assume the magnetic field is 3.5×10^{-3} T in the centre region and runs parallel to the axis of the electron beam. The electron has a spiral trajectory along the axis as shown. The electron has a speed of 6.3×10^{7} m s^{-1} and its circular component (perpendicular to the electron beam axis) is about 1% of this speed.

(d) Estimate the maximum cross-sectional diameter of the electron beam. For simplicity, assume circular motion of electrons due to the magnetic field. Express your answer in the appropriate significant figures. (5 marks)

Answer ______________________ m

(e) Estimate the expected magnification of the H-3000. (1 mark)

____

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Question 22 **(14 marks)**

Moving molten iron in the Earth's core and magnetic field variations

(a) The Swarm satellite system allows scientists to look past the magnetic fields generated by the ionosphere (a layer of the atmosphere containing particles ionised by radiation). Infer how the ionosphere would generate magnetic fields. (2 marks)

Question 22 (continued)

(b) Estimate the strength of the magnetic field detected by a satellite at a height of 460 km above the Earth's surface, if the Earth's magnetic field measures 5×10^{-5} T at the surface. Express your answer in the appropriate significant figures. (4 marks)

Answer ______________________ T

(c) The Earth's magnetic field is thought to be generated by convection currents in the iron/nickel molten outer core. Explain how a magnetic field could be generated by a convection current of molten iron/nickel. (2 marks)

____

____

____

____

(d) The jet is detected by changes in the Earth's magnetic field due to the presence of 'flux lobes'. Explain how the flux lobes are produced. (3 marks)

(e) In the article, one professor thought the 'acceleration of the jet was due to push-back from magnetic fields'. Elaborate, using appropriate physics principles. (3 marks)

End of questions

Supplementary page

Question number: ____________

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

Supplementary page

Question number: ______________

Supplementary page

Question number: ______

Supplementary page

Question number: ____________

Supplementary page

Question number: ______________

Spare grid

ACKNOWLEDGEMENTS

Question 12 Kule, D. (2010). *Black body.svg* [Diagram]. Retrieved March, 2017, from https://commons.wikimedia.org/w/index.php?curid=10555337

Question 21 *Key components of a scanning electron microscope* [Image]. (n.d.). Retrieved January, 2017, from http://science.howstuffworks.com/scanning-electron-microscope.htm

Question 21(d) Right-hand diagram adapted from: *Transmission electron microscopy*. (n.d.). Retrieved January, 2017, from https://cmrf.research.uiowa.edu/transmission-electron-microscopy (5th image down)

Question 22 Adapted from: Coghlan, A. (2016, December 19). Molten iron river discovered speeding beneath Russia and Canada. *New Scientist Daily News*. Retrieved December, 2016, from www.newscientist.com/article/2116536-molten-iron-river-discovered-speeding-beneath-russia-and-canada/

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