



# Western Australian Certificate of Education ATAR course examination, 2016

## 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

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In words

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#### Time allowed for this paper

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

Number of additional  
answer booklets used  
(if applicable):

#### Materials required/recommended for this paper

##### *To be provided by the supervisor*

This Question/Answer booklet  
Formulae and Data booklet

##### *To be provided by the candidate*

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener,  
correction fluid/tape, eraser, ruler, highlighters

Special items: 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.



## 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
<b>Total</b>					100

## Instructions to candidates

- The rules for the conduct of the Western Australian Certificate of Education ATAR course examinations are detailed in the *Year 12 Information Handbook 2016*. Sitting this examination implies that you agree to abide by these rules.
- Write your answers in this Question/Answer booklet.
- 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.

- 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.
- Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.
- The Formulae and Data booklet is not to be handed in with your Question/Answer booklet.

See next page

**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.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

Suggested working time: 50 minutes.

**Question 1****(2 marks)**

List **two** properties of electric or magnetic fields that are shown on field diagrams.

One: \_\_\_\_\_

\_\_\_\_\_

Two: \_\_\_\_\_

\_\_\_\_\_

**Question 2****(3 marks)**

A 78.5 kg hiker climbs up a mountain. He moves from an elevation of 155 m above sea level to the top of a peak which is 983 m above sea level. Calculate his gain in potential energy. Include units with your answer.

Answer \_\_\_\_\_ Unit \_\_\_\_\_

**See next page**

## Question 3

(5 marks)

A cannon fires a cannon ball horizontally at speed of  $50.0 \text{ m s}^{-1}$  from the top of a bridge that is 100 m above the surface of a lake below. Ignoring air resistance, calculate the velocity of the cannon ball just before it hits the water.

Answer \_\_\_\_\_  $\text{m s}^{-1}$  at an angle of \_\_\_\_\_ to the water.

See next page

## Question 4

(5 marks)

Sirius appears as the brightest star in the night sky. It is actually a binary star consisting of Sirius A, a large blue-white star, and Sirius B, a white dwarf. Our view of the Sirius star system is such that there are times when Sirius B is coming toward us and times when it is going away from us. When Sirius B is moving toward us:

(a) Sirius A will be (1 mark)

- A moving toward us, relative to Sirius B.
- B moving away from us, relative to Sirius B.

Your answer \_\_\_\_\_

(b) Compared to the speed of light approaching us from Sirius A, the speed of the light approaching us from Sirius B will be (1 mark)

- A the same.
- B less.
- C greater.

Your answer \_\_\_\_\_

(c) An astronomer views a spectrum of the visible light from Sirius B. Describe **one** feature of this spectrum that would indicate Sirius B is moving toward the astronomer. (2 marks)

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(d) Big Bang theory predicts the Sirius system should be (1 mark)

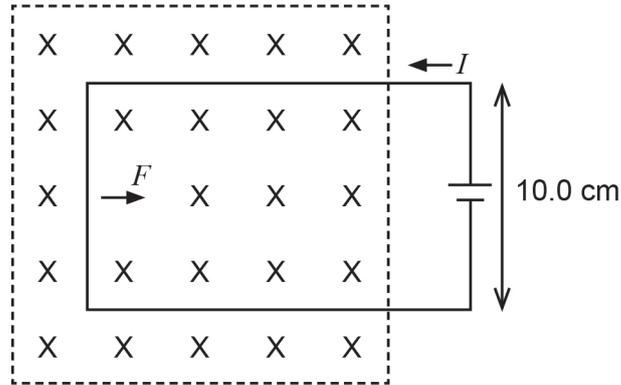
- A moving toward us.
- B moving away from us.
- C keeping a constant distance.

Your answer \_\_\_\_\_

Question 5

(3 marks)

A rectangular wire loop is placed into a uniform magnetic field, with the plane of the loop perpendicular to the magnetic field. The wire carries a current  $I$  of 0.250 A. The magnetic field is directed into the page. A force  $F$  of  $3.20 \times 10^{-2}$  N is measured. Calculate the magnitude of the magnetic field strength. Include appropriate units.

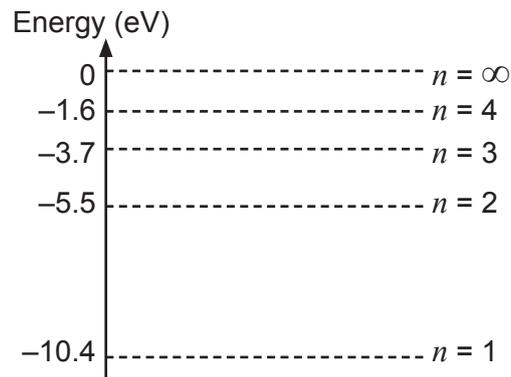


Answer \_\_\_\_\_ Unit \_\_\_\_\_

## Question 6

(4 marks)

Some of the electron energy levels for atomic mercury are shown in the following diagram.



Indicate which one of the following transitions is the most energetic by circling it.

$$n = 4 \text{ to } n = 3$$

$$n = 2 \text{ to } n = 1$$

$$n = 4 \text{ to } n = 1$$

Determine the frequency and wavelength of the light emitted when the atom makes the most energetic of the above transitions.

Frequency is \_\_\_\_\_ Hz

Wavelength is \_\_\_\_\_ m

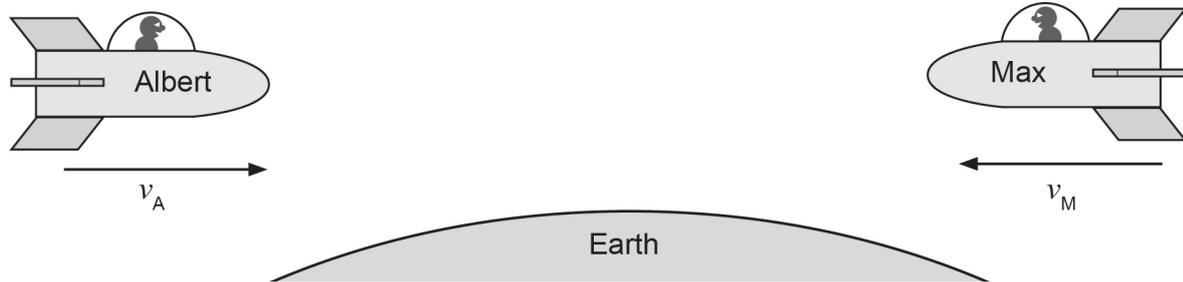
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Question 7

(4 marks)

Two spaceships, 'Albert' and 'Max' are travelling toward each other. Each has a speed of  $0.750c$  as measured in the Earth's reference frame.



Calculate the velocity of Max as measured by the crew on spaceship Albert.

Answer \_\_\_\_\_  $\text{m s}^{-1}$

Question 8

(4 marks)

An AC generator has 131 coils in a square of side length 0.137 m which rotates at 309 rpm in a magnetic field of strength 0.113 T. Determine both the peak emf and the rms emf generated.

Answer peak \_\_\_\_\_ V

Answer rms \_\_\_\_\_ V

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**Question 9****(4 marks)**

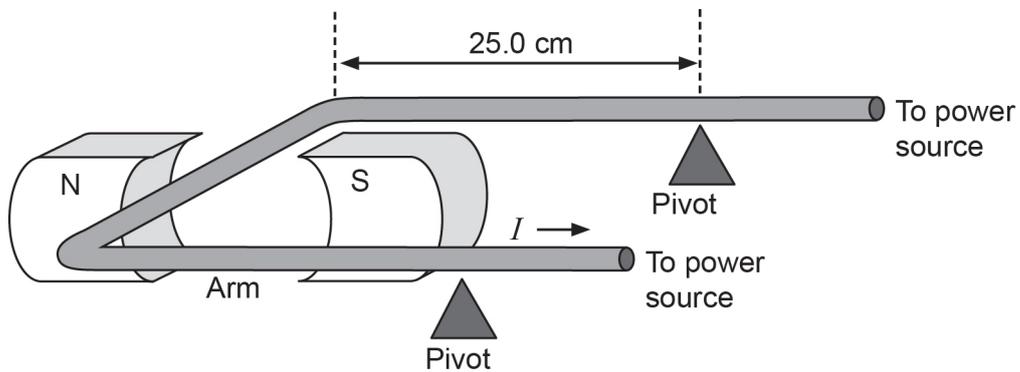
The most probable electron-proton distance in a hydrogen atom in its ground state is  $5.29 \times 10^{-11}$  m. Determine the electrostatic force in newtons exerted on the proton by the electron in this state.

Answer \_\_\_\_\_ N

Direction \_\_\_\_\_

**Question 10****(4 marks)**

A wire carrying a current of 1.68 A has  $8.75 \times 10^{-2}$  m of its length passed through a  $4.44 \times 10^{-2}$  T magnetic field at right angles to it as shown below. The circuit is part of an apparatus that is able to measure the torque produced by the current passing through the magnetic field.



Given that the arm has a length of 25.0 cm from the wire in the field to the pivot point, calculate the torque produced. Include direction with your answer.

Answer \_\_\_\_\_ N m

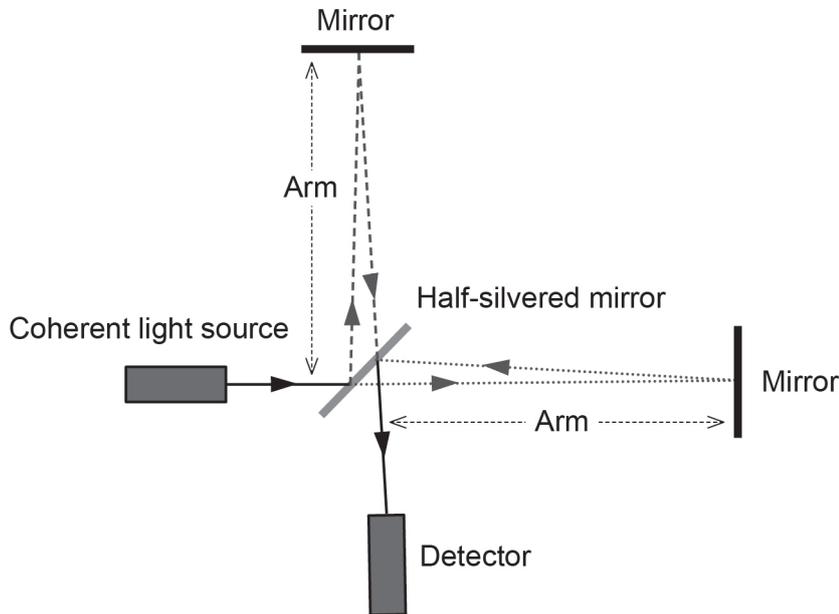
Direction \_\_\_\_\_

**See next page**

Question 11

(5 marks)

An interferometer is a device that splits a single beam of laser light into two and sends the two separate beams in two perpendicular directions. The beams are reflected at the ends of their separate paths, return and are recombined to form an interference pattern at the detector.



- (a) The laser used in an interferometer is a near infra-red, 808 nm laser. If the two reflected beams are initially in phase and the interference pattern changes to produce perfect destructive interference ( $180^\circ$  out of phase) due to a change in length of one of the arms, calculate the change in length of the arm. (3 marks)

Answer \_\_\_\_\_ m

This device is used to detect gravitational waves. As a gravitational wave passes through the interferometer, it creates a small change in length of one or both arms.

- (b) An interferometer, with 4 km long perpendicular arms, recently detected gravitational waves. Describe how the direction of the gravitational wave relative to the interferometer would affect its detection. (2 marks)

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## Question 12

(6 marks)

Muons are created in the upper atmosphere with speeds of  $0.990c$  or more. Their average lifetime is  $2.20 \mu\text{s}$  measured at low speeds in the laboratory. A simple calculation shows that most should only travel about 660 m before decaying. Thus, very few muons should ever reach sea level.

- (a) Using relativistic mechanics, calculate how far a muon can travel according to an observer on Earth. (4 marks)

Answer \_\_\_\_\_ m

- (b) Explain why many more muons reach the surface of Earth than predicted classically. (2 marks)

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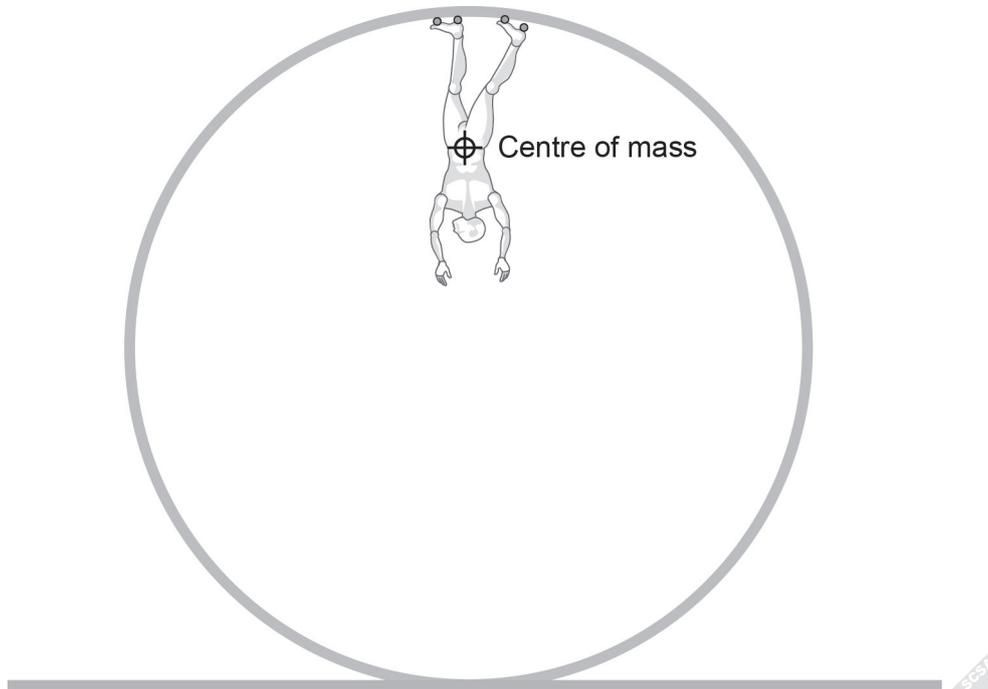
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## Question 13

(5 marks)

A 53 kg skater is attempting to complete a loop that is 2.50 m in radius. Estimate the minimum speed at the top of the loop needed for the skater to maintain contact with the top of the loop.

Answer \_\_\_\_\_ m s<sup>-1</sup>

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.

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****(12 marks)**

An electron microscope creates a coherent beam of electrons which then travels through two narrow slits. The resulting interference pattern is detected on a photographic plate. The speed of the electrons is 1.00% of the speed of light.

(a) Show that the de Broglie wavelength of the electrons used is  $2.43 \times 10^{-10}$  m. (2 marks)

(b) Describe what you expect to see on the photographic plate. (2 marks)

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(c) Explain the behaviour of the electrons in this experiment. (2 marks)

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- (d) If the experiment were to be repeated using protons, at what speed would a proton need to travel to have the same de Broglie wavelength as the electrons? (2 marks)

Answer \_\_\_\_\_ m s<sup>-1</sup>

- (e) Calculate the potential difference required for the electron microscope to accelerate the electrons to 1.00% of the speed of light. (4 marks)

Answer \_\_\_\_\_ V

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## Question 15

(16 marks)

On February 6 1971, during the Apollo 14 mission, astronaut Alan Shepard hit a golf ball on the Moon. The golf club launched the ball at an angle of  $24.1^\circ$  to the ground with an initial speed of  $45.0 \text{ m s}^{-1}$ .

- (a) Construct a free body diagram below, showing the force(s) acting on the golf ball about halfway between it being struck and its highest point. (2 marks)



- (b) Calculate the horizontal and vertical components of the initial velocity. (2 marks)

Answer  $u_h$  \_\_\_\_\_  $\text{m s}^{-1}$

Answer  $u_v$  \_\_\_\_\_  $\text{m s}^{-1}$

- (c) Assuming the golf ball travelled over a level surface, calculate the

- (i) time taken to hit the surface (2 marks)

Answer \_\_\_\_\_ s

- (ii) horizontal distance the golf ball travelled. (2 marks)

Answer \_\_\_\_\_ m

See next page

- (d) The highest point on the Moon's surface is  $1.08 \times 10^4$  m higher than the mean radius of the Moon. If the golf ball is hit horizontally from this peak, determine the initial velocity required for the golf ball to completely circle the Moon and return to approximately the same spot. (4 marks)

Answer \_\_\_\_\_ m s<sup>-1</sup>

- (e) Explain, with reference to relevant formulae, why the gravitational field on the Moon's surface is less than the field on Earth's surface. (4 marks)

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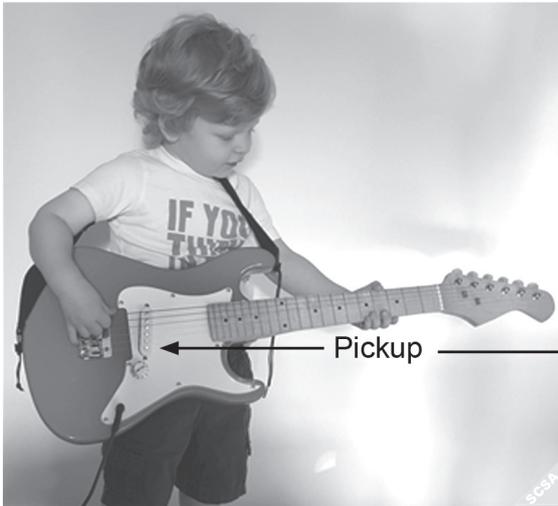
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Question 16

(13 marks)

An electric guitar pickup works by converting the vibrations of the strings to an electrical current which is then amplified. The amplified current is then sent to a speaker that converts the fluctuations in the current to sound.



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- (a) Refer to the diagram to explain how the vibration of a metal string is converted to an electrical current that varies at the string's frequency. (5 marks)

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- (b) Using an appropriate formula, describe **two** changes to the design of the pickup that would enable it to supply a larger potential difference. (3 marks)

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- (c) If the pickup is removed from the guitar, the strings will oscillate for longer before becoming motionless. Explain what makes the guitar strings come to rest quicker with the pickup in place. (2 marks)

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- (d) A 5.50 cm section of wire is moved at  $25.0 \text{ m s}^{-1}$  through a magnetic field of 43.0 mT. Calculate the maximum potential difference generated and give its units. (3 marks)

Answer \_\_\_\_\_ Units \_\_\_\_\_

See next page

Question 17

(8 marks)

The elementary particles of the Standard Model are shown below.

Mass →	≈ 2.3 MeV/c <sup>2</sup>	≈ 1.275 GeV/c <sup>2</sup>	≈ 173.07 GeV/c <sup>2</sup>	0	≈ 126 GeV/c <sup>2</sup>
Charge →	2/3	2/3	2/3	0	0
Spin →	1/2	1/2	1/2	1	0
	<b>u</b>	<b>c</b>	<b>t</b>	<b>g</b>	<b>H</b>
	up	charm	top	gluon	Higgs boson
Quarks	≈ 4.8 MeV/c <sup>2</sup>	≈ 95 MeV/c <sup>2</sup>	≈ 4.18 GeV/c <sup>2</sup>	0	
	-1/3	-1/3	-1/3	0	
	1/2	1/2	1/2	1	
	<b>d</b>	<b>s</b>	<b>b</b>	<b>γ</b>	
	down	strange	bottom	photon	
Leptons	0.511 MeV/c <sup>2</sup>	105.7 MeV/c <sup>2</sup>	1.777 GeV/c <sup>2</sup>	91.2 GeV/c <sup>2</sup>	
	-1	-1	-1	0	
	1/2	1/2	1/2	1	
	<b>e</b>	<b>μ</b>	<b>τ</b>	<b>Z</b>	
	electron	muon	tau	Z boson	
Gauge bosons	<2.2 eV/c <sup>2</sup>	<0.17 MeV/c <sup>2</sup>	<15.5 MeV/c <sup>2</sup>	80.4 GeV/c <sup>2</sup>	
	0	0	0	±1	
	1/2	1/2	1/2	1	
	<b>ν<sub>e</sub></b>	<b>ν<sub>μ</sub></b>	<b>ν<sub>τ</sub></b>	<b>W</b>	
	electron neutrino	muon neutrino	tau neutrino	W boson	

(a) If up (u) and down (d) quarks are the building blocks of nucleons, suggest a combination of three quarks that would produce a

(i) proton: \_\_\_\_\_ (1 mark)

(ii) neutron: \_\_\_\_\_ (1 mark)

(b) Identify **one** type of gauge boson and describe its role in the nucleus. (2 marks)

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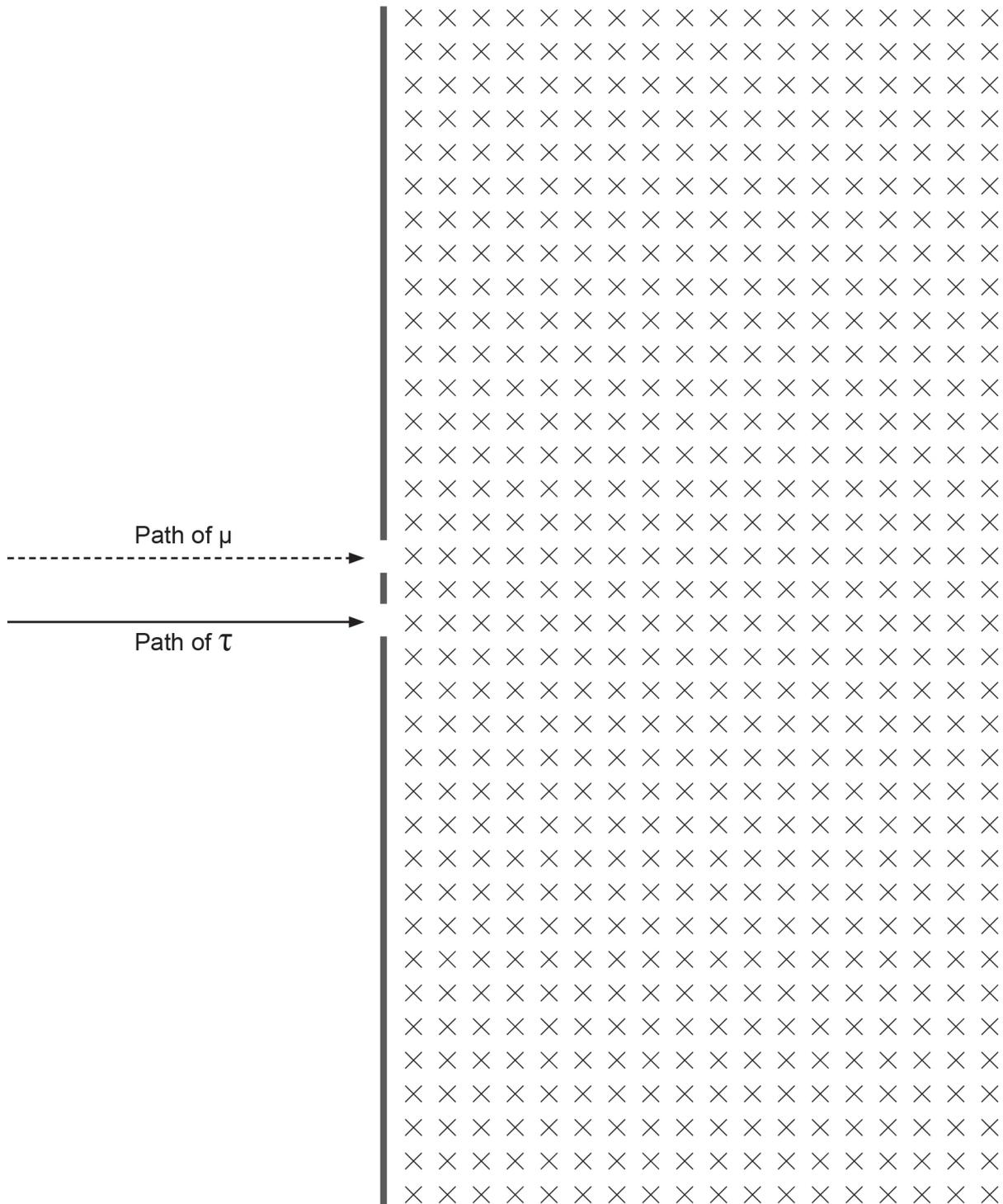


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- (c) Muons and taus are created in a particle accelerator and accelerated to the same velocity. Sketch their paths if the two particles were directed into a magnetic field as shown in the diagram below. (4 marks)



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## Question 18

(17 marks)

A person climbs a ladder and holds a can of paint as shown in the photograph below.



**Position A**

The ladder is 2.78 m long from the ground to the roof gutter of the house and rests on the gutter 2.40 m above the ground. The woman stands with her feet 0.500 m above the ground. The ladder has a negligible mass, the woman has a mass of 58.0 kg and the can of paint has a mass of 4.25 kg.

- (a) Calculate the force that the roof gutter exerts on the ladder in Position A. Assume that this force acts at a right angle to the ladder. (7 marks)

Answer \_\_\_\_\_ N

See next page



Position B

- (b) Explain how the force exerted on the ladder by the roof gutter changes as the can of paint is moved from Position A to Position B (shown above). (3 marks)

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- (c) State whether the ladder and person are in equilibrium in Position B. Explain your reasoning. Calculations are **not** required. (4 marks)

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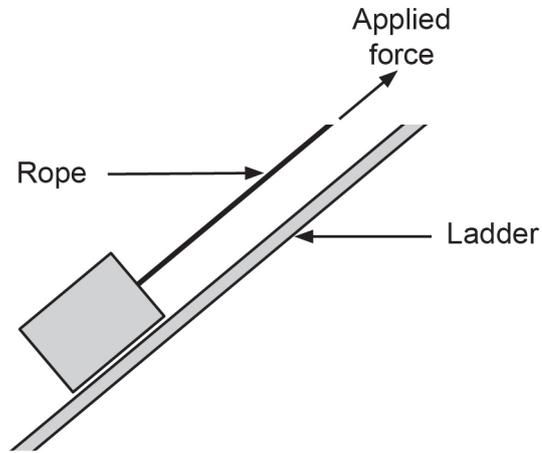


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## Question 18 (continued)

- (d) The ladder is then extended to form a  $40.0^\circ$  angle to the ground. The ladder is used as a ramp to pull a  $35.1 \text{ kg}$  box onto the roof by a rope parallel to the ladder. Calculate the tension in the rope if the box is stationary as shown. Assume that friction is negligible. (3 marks)



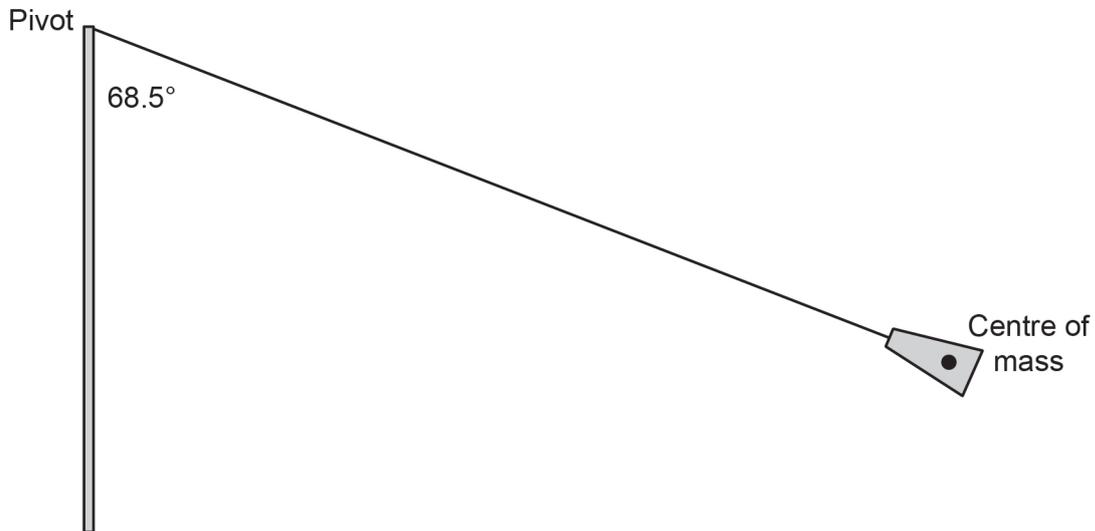
Answer \_\_\_\_\_ N

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## Question 19

(8 marks)

A student is conducting an experiment by tying a rubber stopper to a string and swinging it in a horizontal circle as shown in the diagram below. The stopper has a mass of 0.123 kg and the distance along the string from the pivot to the centre of mass of the stopper is 1.43 m.



- (a) On the diagram, draw and label the forces acting on the stopper. (2 marks)
- (b) Show that the tension in the string is 3.29 N. (2 marks)
- (c) Calculate the speed of the stopper. (4 marks)

Answer \_\_\_\_\_ m s<sup>-1</sup>

See next page

## Question 20

(16 marks)

A light beam is directed toward a metal surface and electrons are ejected from it. The wavelength of the incident beam is varied between 238 nm (ultraviolet) and 464 nm (green). The maximum kinetic energy of the ejected photoelectrons is measured and recorded in the table below.

- (a) Complete the following table by calculating the missing energy of the incident photons for each wavelength. Show your working in the space below. (2 marks)

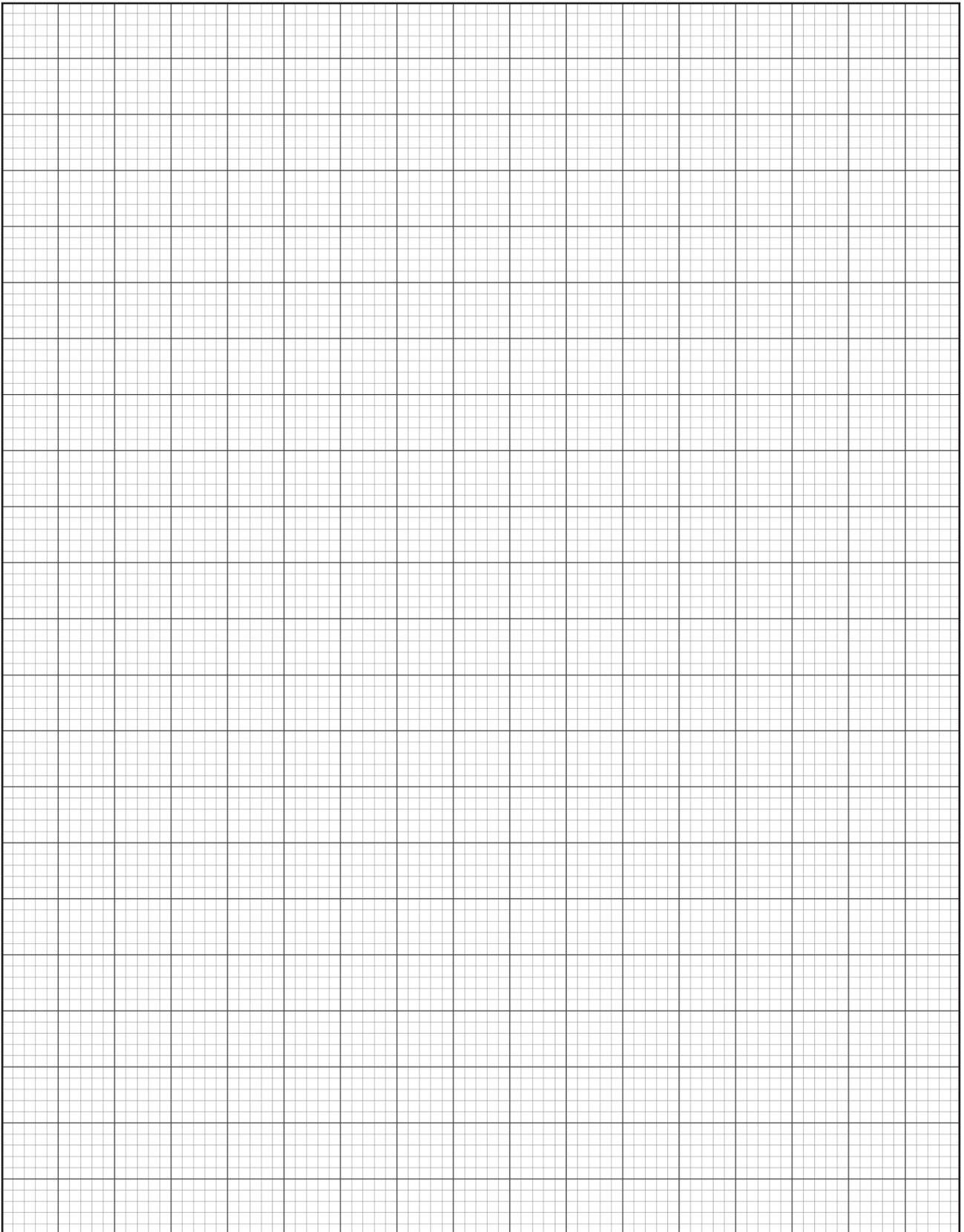
Wavelength of incident light (nm)	Energy of incident light (eV)	Maximum kinetic energy of photoelectrons (eV)
238		3.12
250	4.97	2.87
284	4.38	2.28
351		1.44
416	2.99	0.89
464	2.68	0.58

- (b) Plot the data from the table above on the grid provided, demonstrating the relationship between the energy of the incident photons on the horizontal axis and the maximum kinetic energy of photoelectrons on the vertical axis. Draw the line of best fit. (4 marks)
- (c) Using your graph, determine the work function of the metal. Express your answer in appropriate significant figures and include units. (4 marks)

Answer \_\_\_\_\_ Units \_\_\_\_\_

See next page

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

**See next page**

Question 20 (continued)

- (d) Explain how the failure of red light to cause the emission of electrons demonstrates the particle nature of light. (3 marks)

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- (e) In this photoelectric effect investigation, light is best described as a particle. There are other characteristics that demonstrate light to be a wave. State **one** such characteristic and describe how this demonstrates wave behaviour. (3 marks)

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End of Section Two

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**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****(16 marks)**

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## Question 21 (continued)

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- (a) How long, in Earth years, does light take to reach Earth from HD 189733b? (1 mark)

Answer \_\_\_\_\_ years

- (b) Explain how a large planet orbiting a relatively small star makes the planet easier to discover. (1 mark)

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- (c) Calculate the mean radius of orbit of HD 189733b. (6 marks)

Answer \_\_\_\_\_ m

See next page

(d) Particles ejected from the star are moving toward the planet's surface. At a point where the planet's magnetic field is at a right angle to the particles' motion, explain the protective effect of the magnetic field, if any, against the following:

(i) an electron arriving from the star (2 marks)

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(ii) a UV photon arriving from the star. (2 marks)

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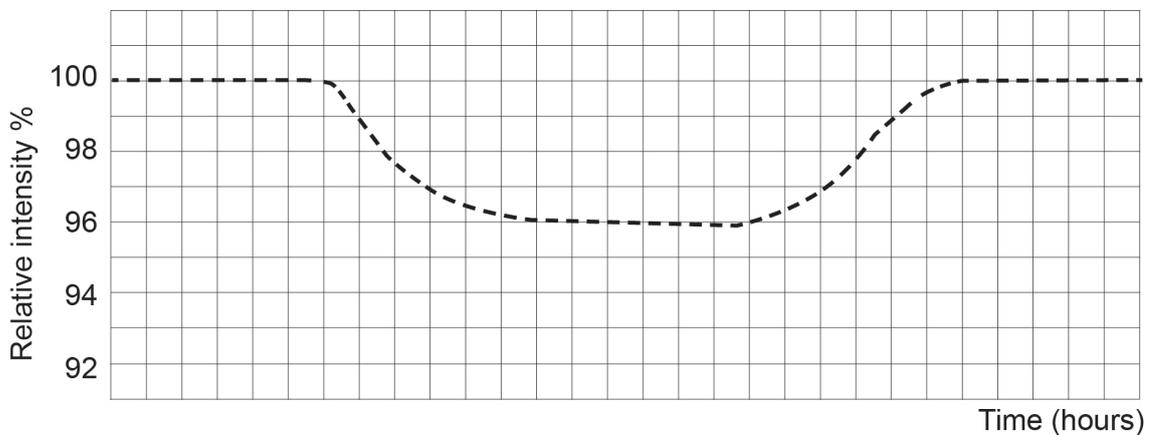
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(e) Below is a plot showing the dip in light intensity, due only to the planet dimensions, as the planet passes in front of its star. Modify the given plot by sketching how the light intensity drops when including the effect of a strong bow shock. (4 marks)



Light intensity variation

See next page

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## Question 22

(20 marks)

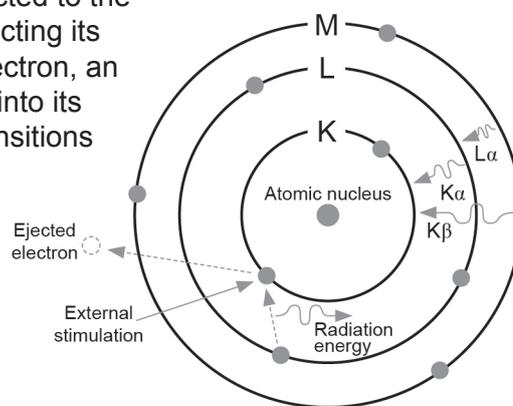
**X-ray fluorescence (XRF) analysis and application**

Art forgery is the creating and selling of works of art which are credited falsely to other artists. Modern dating and analysis techniques have made the identification of forged artwork much easier.

X-ray fluorescence is the emission of characteristic X-rays having specific photon energies from a material that has been excited. This is widely used for chemical analysis, such as in determining the materials used in paintings.

In order to excite an atom to produce an X-ray that is unique to that element, external stimulation in the form of high-energy particles or X-rays removes an inner K shell electron. The X-ray source uses a known element and bombards it with accelerated electrons as a form of external stimulation. As an electron in the atom falls back to replace the removed electron, it produces an X-ray of a known energy. This specific X-ray is then directed to the unknown material, providing external stimulation and ejecting its innermost electron. Following the ejection of an inner electron, an electron from the unknown element's outer shells drops into its place producing unique energy transitions. The main transitions are given names:

- L→K transition is traditionally called  $K\alpha$ ,
- M→K transition is called  $K\beta$ ,
- M→L transition is called  $L\alpha$ , and so on.



Each of these transitions yields a fluorescent photon which can be detected and analysed. Once sorted, the intensity of each characteristic radiation is related directly to the amount of each element in the material.

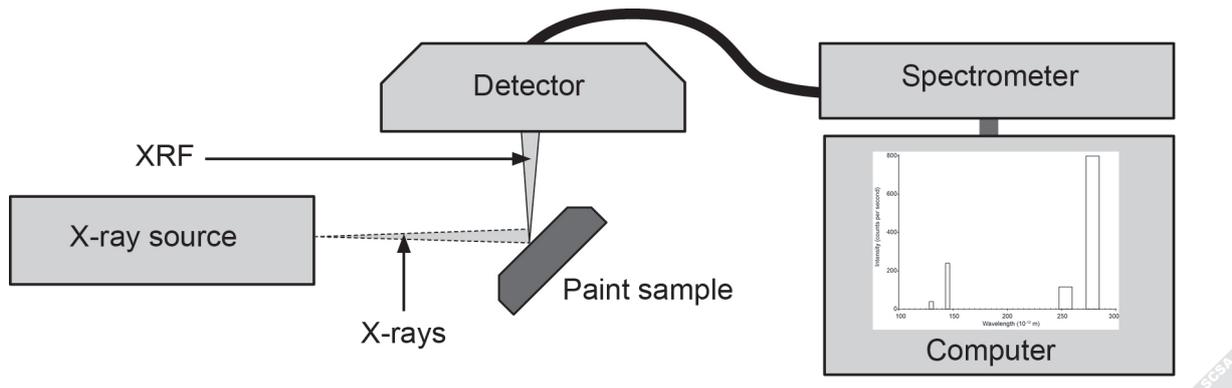
Atomic number	Element	Symbol	$K\alpha$ energy (keV)	$K\beta$ energy (keV)
22	titanium	Ti	4.511	4.931
30	zinc	Zn	8.639	9.572
45	rhodium	Rh	20.216	22.724
50	tin	Sn	25.271	28.486

Table 1: Characteristic  $K\alpha$  and  $K\beta$  fluorescent X-ray energies for various elements.

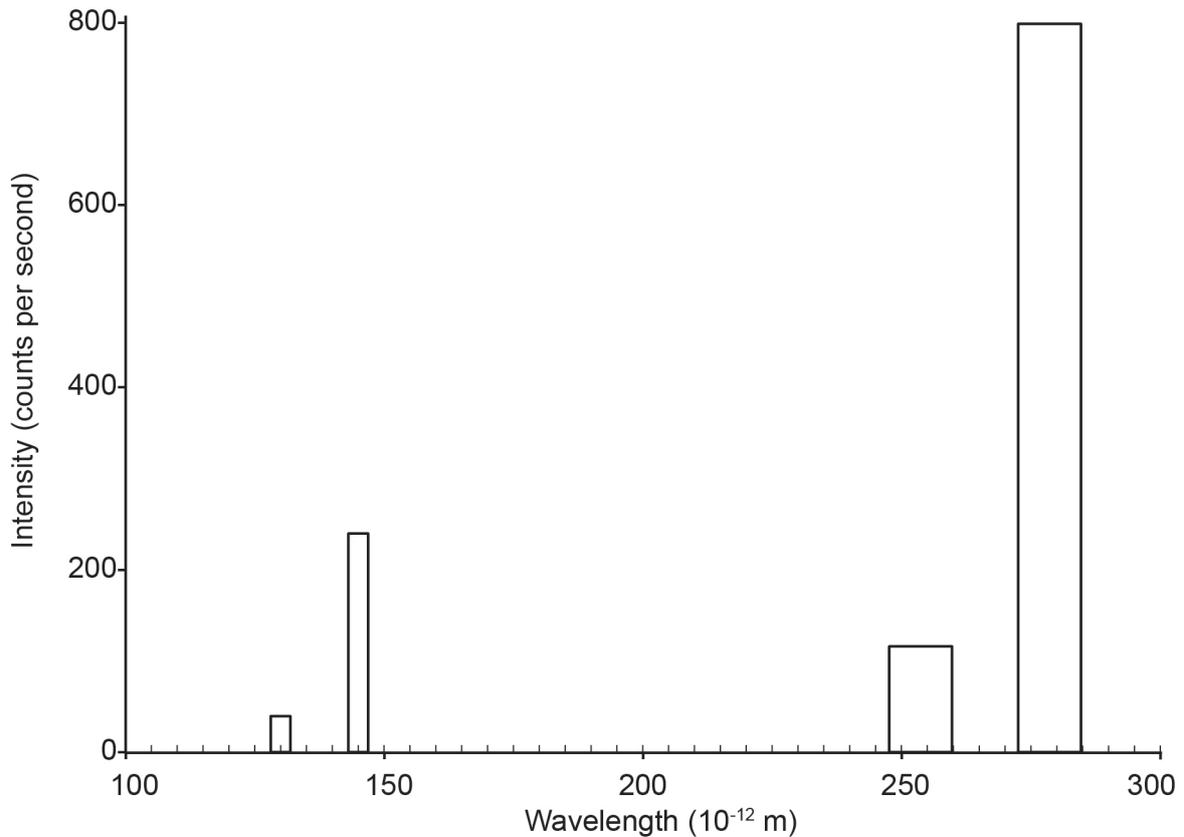
The most straightforward and frequent application of XRF in the art industry is to determine the elements that make different paint colours. The question of whether a particular painting is a forgery or an authentic one, can be determined if the presence of a particular paint provides evidence for the age of the painted area. For example, titanium white (titanium dioxide,  $TiO_2$ ) has only been available since about 1920 as a replacement for zinc white (zinc oxide,  $ZnO$ ) which was widely used from 1850 until it was replaced around 1920.

A painting offered for sale recently was claimed to be painted in about 1890. An XRF elemental mapping was carried out on the white areas of the suspect painting. The analysis was performed as shown in the diagram on page 33.

See next page



The incident X-ray beam consisted of the  $K\alpha$  emission from rhodium in the X-ray source. The XRF results are shown below.



**The resultant X-ray fluorescence spectrum**

- (a) The rhodium is bombarded with high energy electrons to produce the  $K\alpha$  photons. The energy required to remove the electron from the K shell is greater than the  $K\alpha$  energy. Explain where the extra energy goes. (2 marks)

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See next page

## Question 22 (continued)

- (b) Consider the XRF spectrum on page 33.  $K\alpha$  produces one of the peaks at  $130 \times 10^{-12}$  m and  $145 \times 10^{-12}$  m, while  $K\beta$  produces the other. Which emission,  $K\alpha$  or  $K\beta$ , is more likely to occur? Explain your answer. (3 marks)

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- (c) The equipment set up as discussed in the article is used to detect titanium.

- (i) Explain why it would **not** be possible to detect the  $K\alpha$  fluorescent X-ray from tin. (2 marks)

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- (ii) The electrons that bombard rhodium in the X-ray source have an energy of 60.0 keV. If one of these incident electrons caused an electron to be ejected from the K shell of a rhodium atom, calculate the maximum speed of the ejected electron. Ignore any relativistic effects. (4 marks)

Answer \_\_\_\_\_ m s<sup>-1</sup>

See next page

- (d) Looking at the resultant XRF spectrum, is there any evidence of titanium dioxide present in the painting? Justify your answer. (6 marks)

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- (e) Is the painting a forgery? Explain your reasoning. (3 marks)

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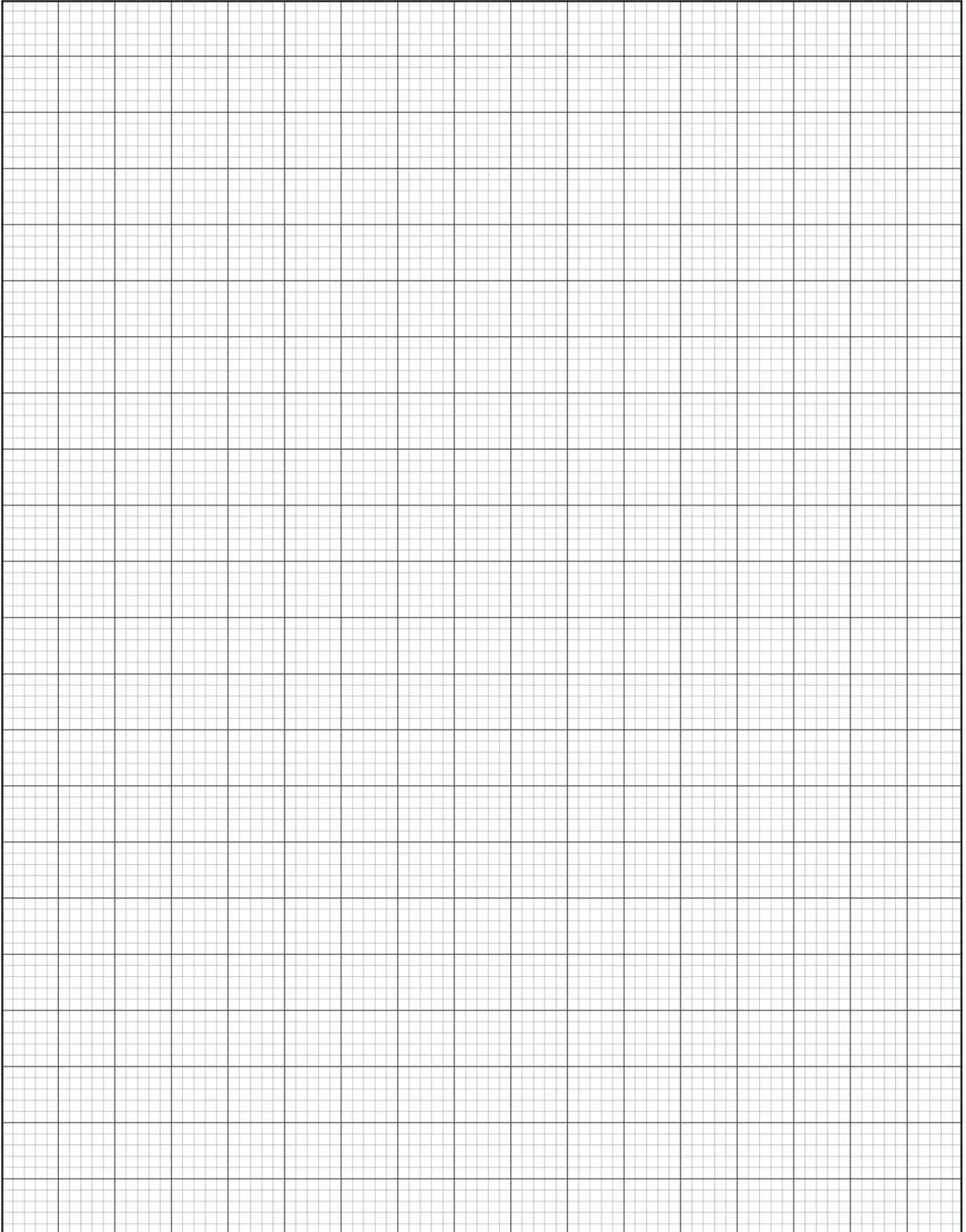
End of questions

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





Question 20



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## ACKNOWLEDGEMENTS

- Question 11** Diagram: Stannered. (2007). *File:Interferometer.svg*. Retrieved June, 2016, from <https://commons.wikimedia.org/wiki/File:Interferometer.svg>  
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- Question 16** Pickup diagram adapted from: Race, P. (2016). *Banjo pickups, 2016* (Magnetic pickups). Retrieved June, 2016, from [http://creekdontrise.com/acoustic/banjo\\_pickups/banjo\\_pickup.htm](http://creekdontrise.com/acoustic/banjo_pickups/banjo_pickup.htm)
- Question 17** Standard Model image: MissMJ. (2006). *File:Standard Model of Elementary Particles.svg*. Retrieved June, 2016, from [https://commons.wikimedia.org/wiki/File:Standard\\_Model\\_of\\_Elementary\\_Particles.svg](https://commons.wikimedia.org/wiki/File:Standard_Model_of_Elementary_Particles.svg)  
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- Question 21** Introductory text (paras 1–3) adapted from: Kelley, P. (2015, September 29). *Earth-like planets around small stars likely have protective magnetic fields, aiding chance for life*. Retrieved June, 2016, from <http://phys.org/news/2015-09-earth-like-planets-small-stars-magnetic.html#nRlv>  
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- Question 22** Introductory text information adapted from:  
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