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

# 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

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: 16-066

PHY

2017/1529
Web version of 2016/59024

## 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<br>Short response | 13 | 13 | 50 | 54 | 30 |
| Section Two<br>Problem-solving | 7 | 7 | 90 | 90 | 50 |
| Section Three<br>Comprehension | 2 | 2 | 40 | 36 | 20 |
| | | | | **Total** | 100 |

## Instructions to candidates

1. 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.

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. 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.

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. 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: 50 minutes.

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**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 ______________

**Question 3** **(5 marks)**

A cannon fires a cannon ball horizontally at speed of 50.0 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 ______________________ m $s^{-1}$ at an angle of ______________________ to the water.

**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)

________________________________________

________________________________________

________________________________________

________________________________________

(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 ____________________

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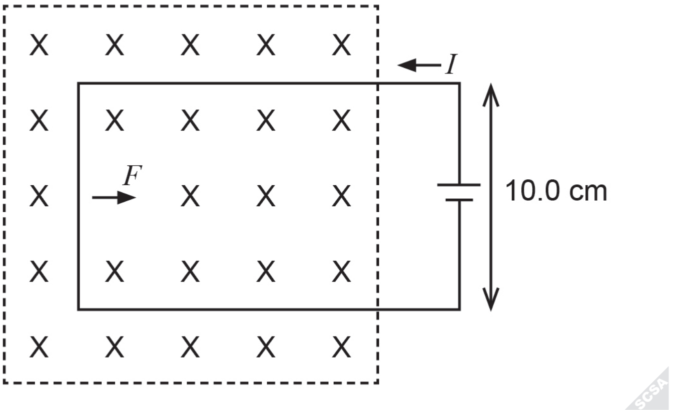
**Question 5** **(3 marks)**

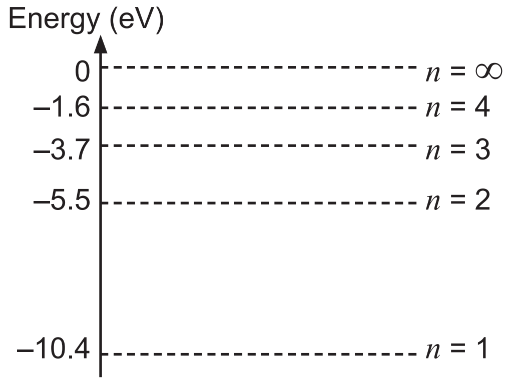
A rectangular wire loop is placed into a uniform magnetic field, with the plane of the loop perpendicular to the magnetic field. The wire carries a current $I$ of 0.250 A. The magnetic field is directed into the page. A force $F$ of $3.20 \times 10^{-2}$ N is measured. Calculate the magnitude of the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

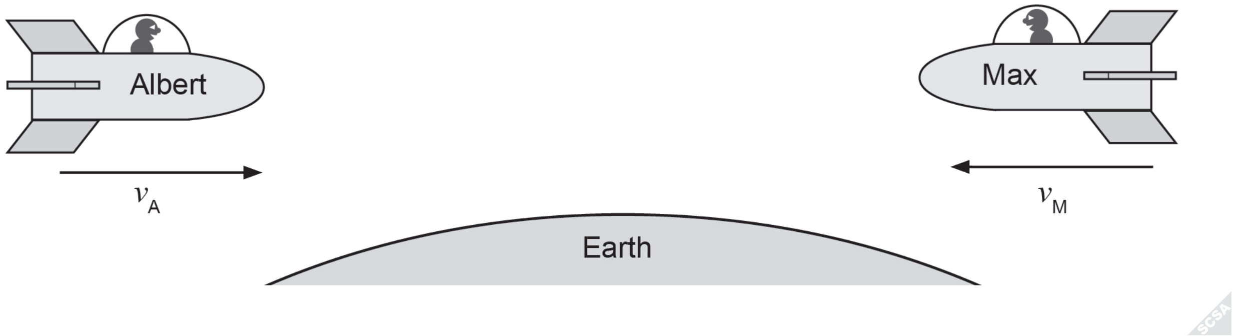
$n = 4$ to $n = 3$ $n = 2$ to $n = 1$ $n = 4$ to $n = 1$

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

**Question 7** **(4 marks)**

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




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

Answer ______________ 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)**

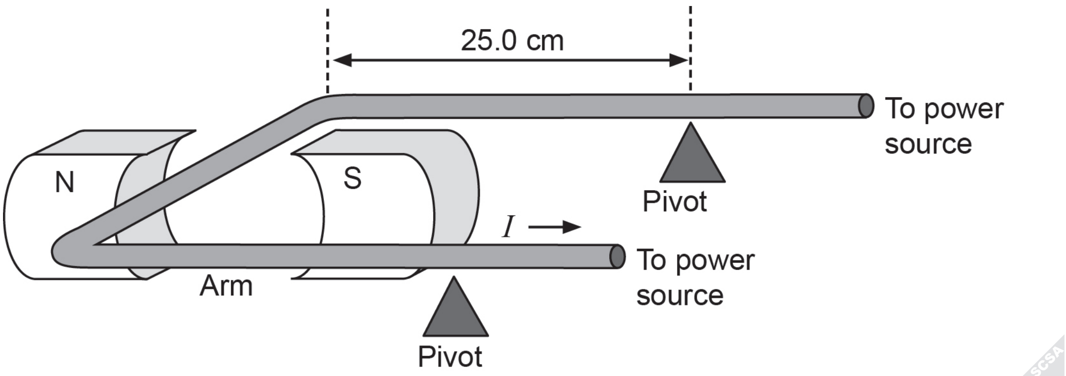
The most probable electron-proton distance in a hydrogen atom in its ground state is $5.29 \times 10^{-11}$ m. Determine the electrostatic force in newtons exerted on the proton by the electron in this state.

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.



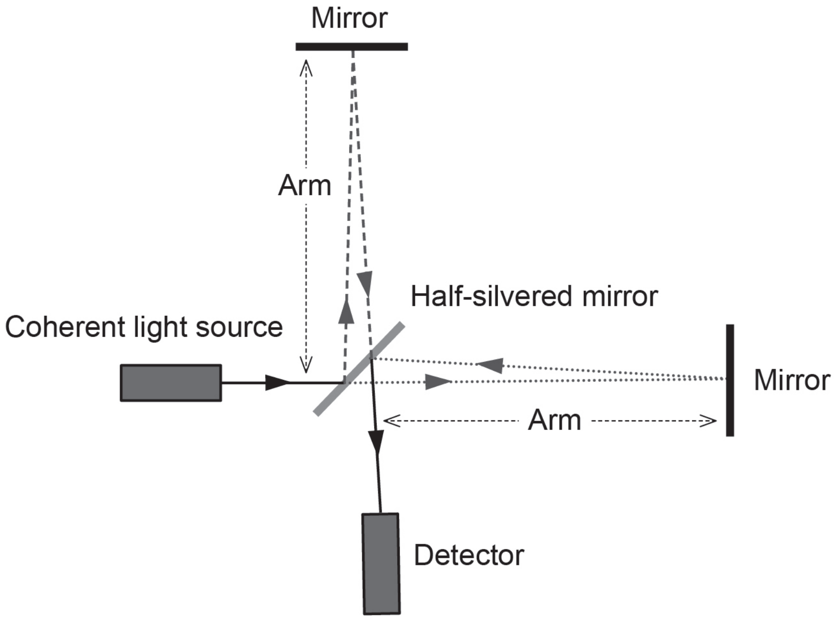

Given that the arm has a length of 25.0 cm from the wire in the field to the pivot point, calculate the torque produced. Include direction with your answer.

Answer ______________________ N m

Direction ______________________________________________________

**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° 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)

**Question 12** **(6 marks)**

Muons are created in the upper atmosphere with speeds of 0.990$c$ or more. Their average lifetime is 2.20 μs 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.

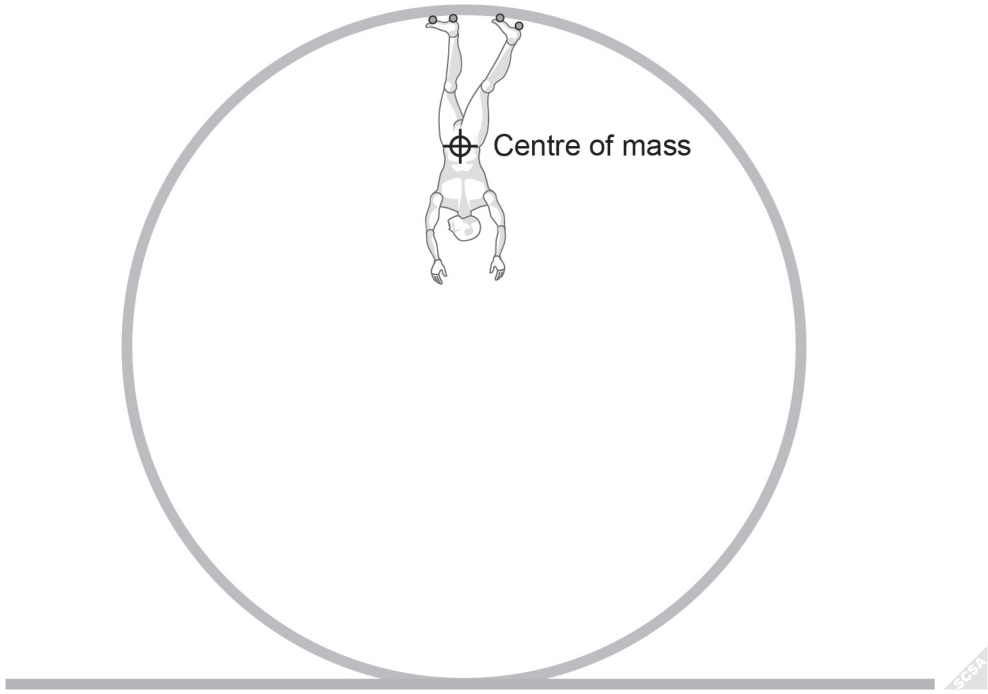
(a) Using relativistic mechanics, calculate how far a muon can travel according to an observer on Earth. (4 marks)

Answer ______________________ m

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

**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$^{-1}$

**End of Section One**

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See next page

**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)**

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)

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

(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 ______________________ $m\ s^{-1}$

(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

**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° to the ground with an initial speed of 45.0 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 $u_h$ ______________ m s$^{-1}$

Answer $u_v$ ______________ 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

(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 $s^{-1}$

(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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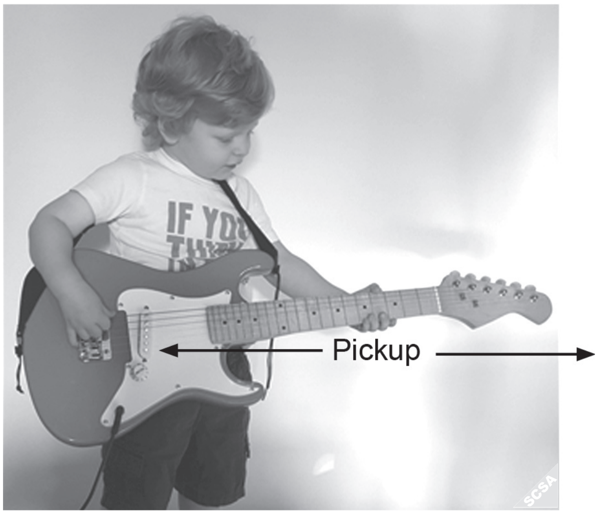
**Question 16** **(13 marks)**

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.




For copyright reasons this image cannot be reproduced in the online version of this document, but may be viewed at http://creekdontrise.com/acoustic/banjo_pickups/banjo_pickup.htm

(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)

(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)

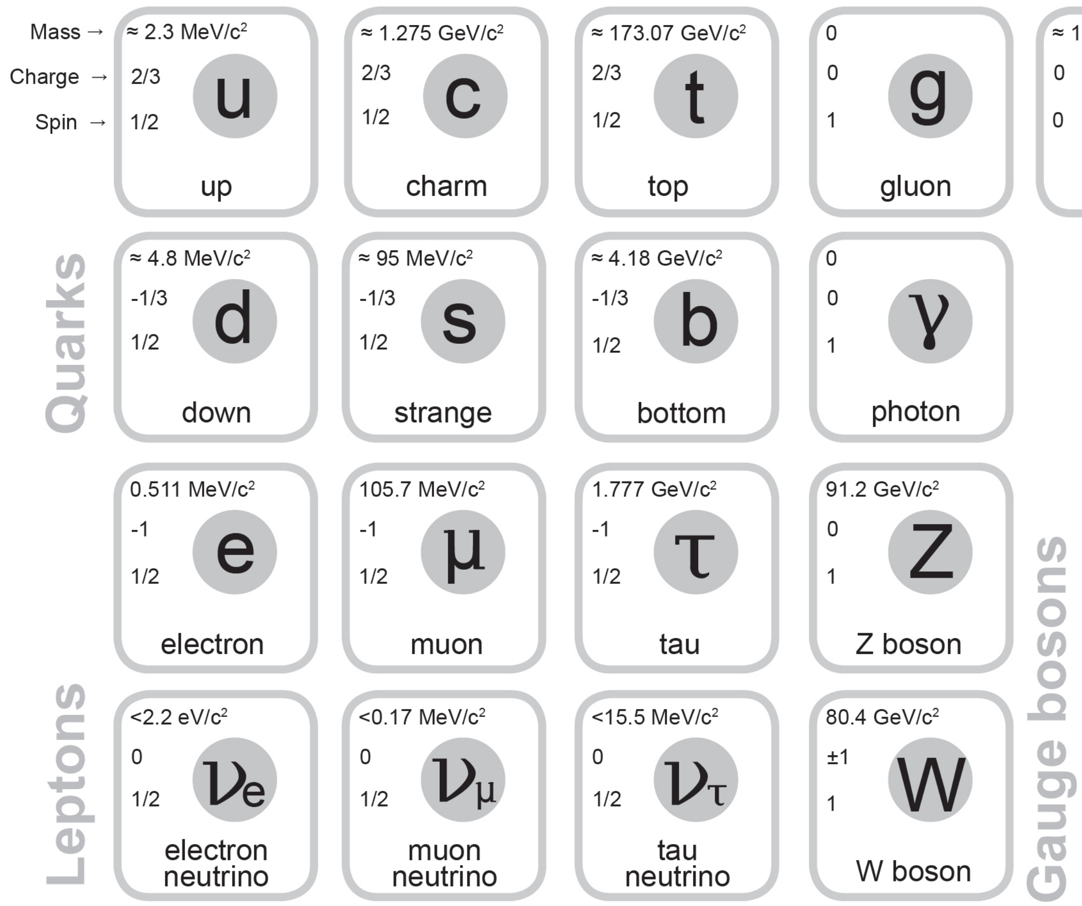
(c) If the pickup is removed from the guitar, the strings will oscillate for longer before becoming motionless. Explain what makes the guitar strings come to rest quicker with the pickup in place. (2 marks)

(d) A 5.50 cm section of wire is moved at 25.0 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 ______________

**Question 17** **(8 marks)**

The elementary particles of the Standard Model are shown below.




(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)

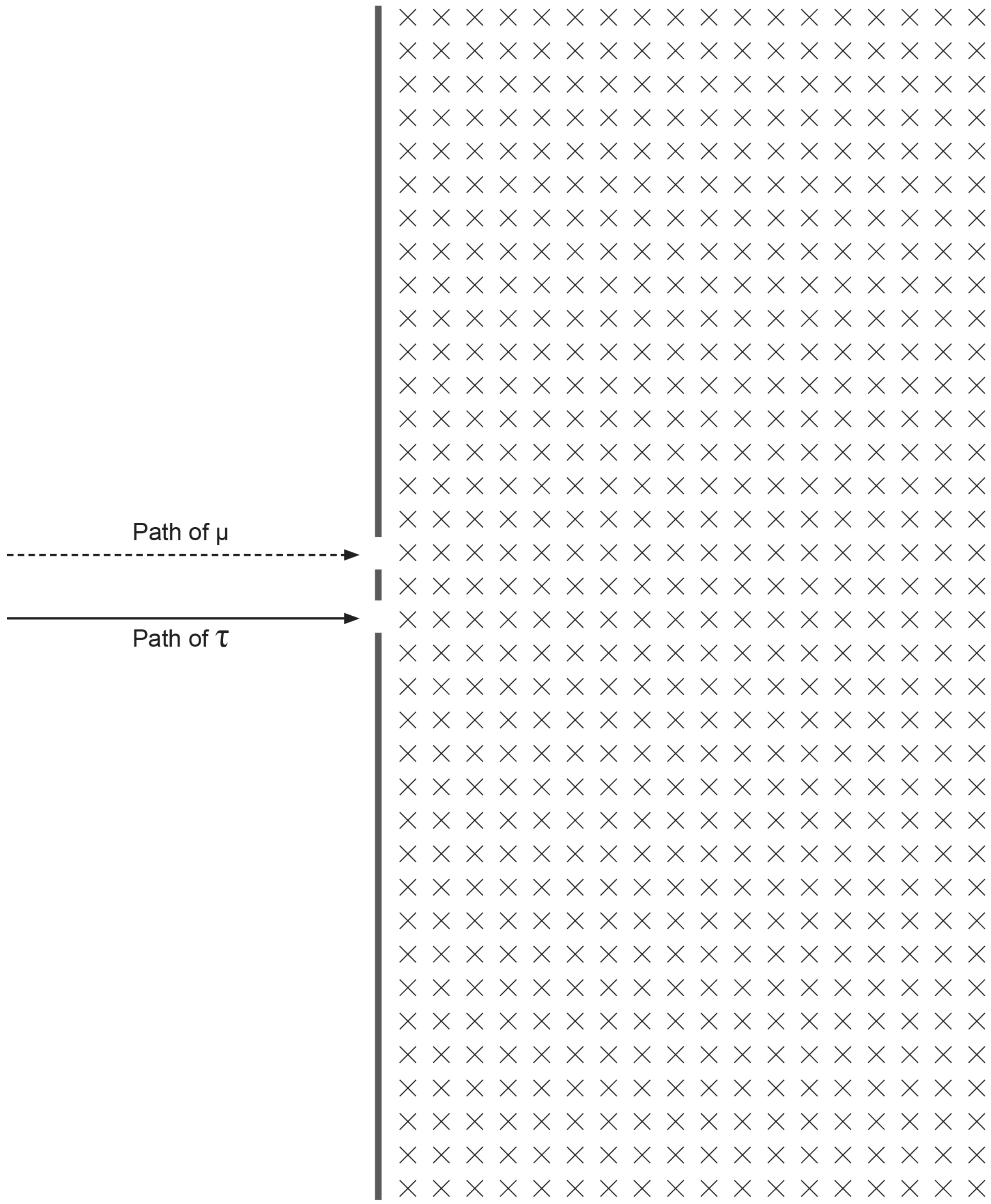
______

______

______

______

(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)



**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

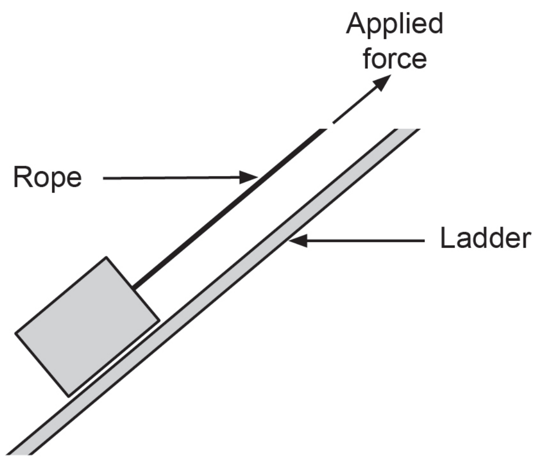
**Position B**

(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)

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

**Question 18** (continued)

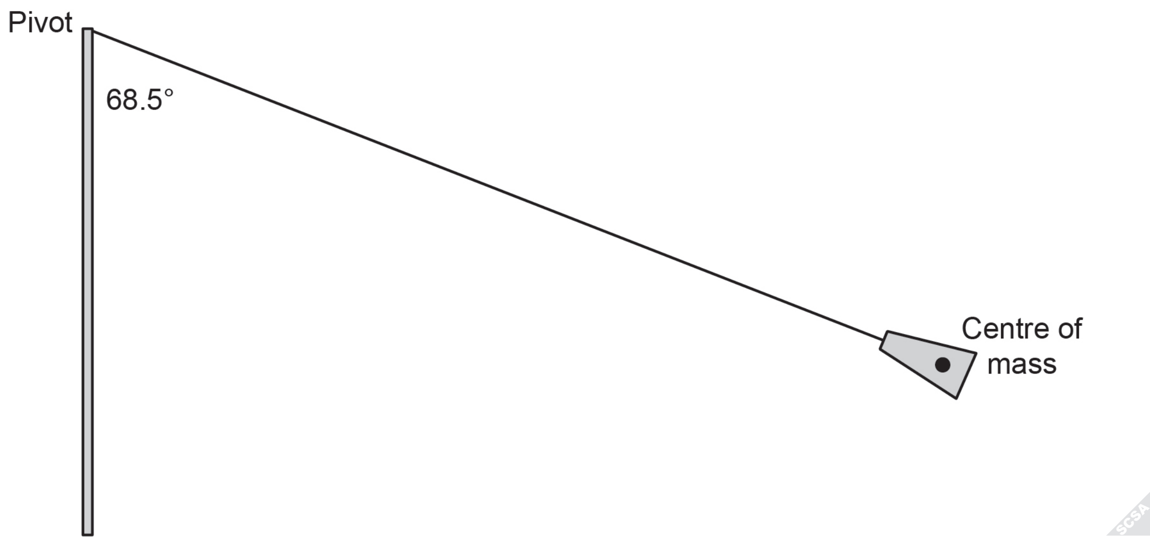
(d) The ladder is then extended to form a 40.0° angle to the ground. The ladder is used as a ramp to pull a 35.1 kg box onto the roof by a rope parallel to the ladder. Calculate the tension in the rope if the box is stationary as shown. Assume that friction is negligible. (3 marks)




Answer ______________________ N

**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$^{-1}$

**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 ______________________

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** (continued)

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

(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)

**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.

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Suggested working time: 40 minutes.

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**Question 21** **(16 marks)**





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**Question 21** (continued)



(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)

____________________

____________________

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

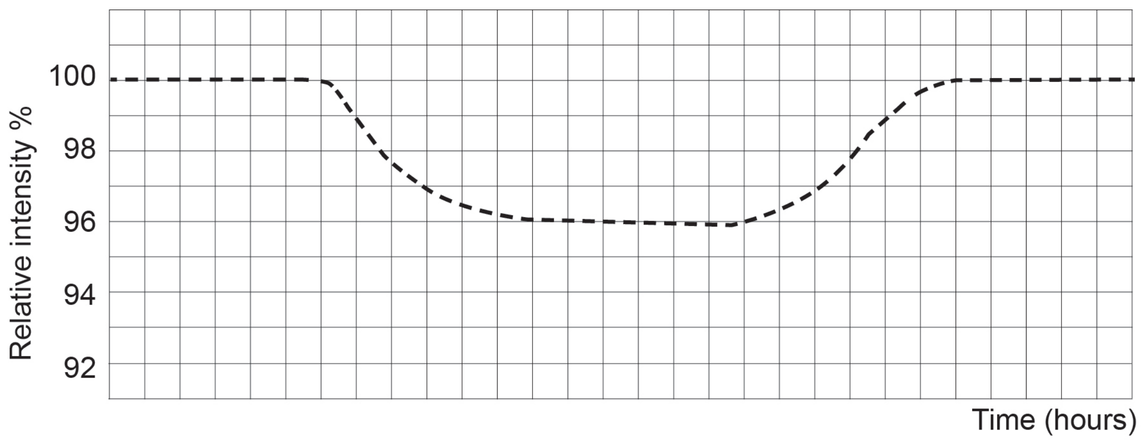
Answer ____________________ m

(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)

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

(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**

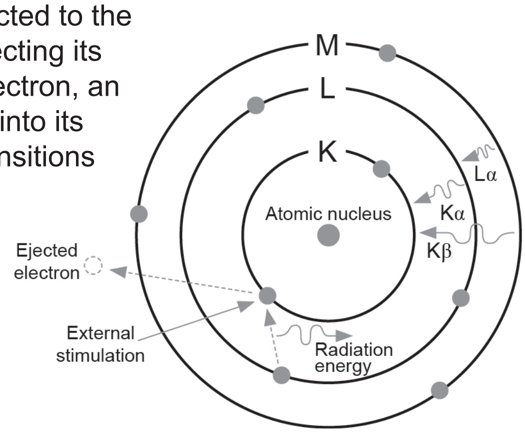
**Question 22** **(20 marks)**

**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.

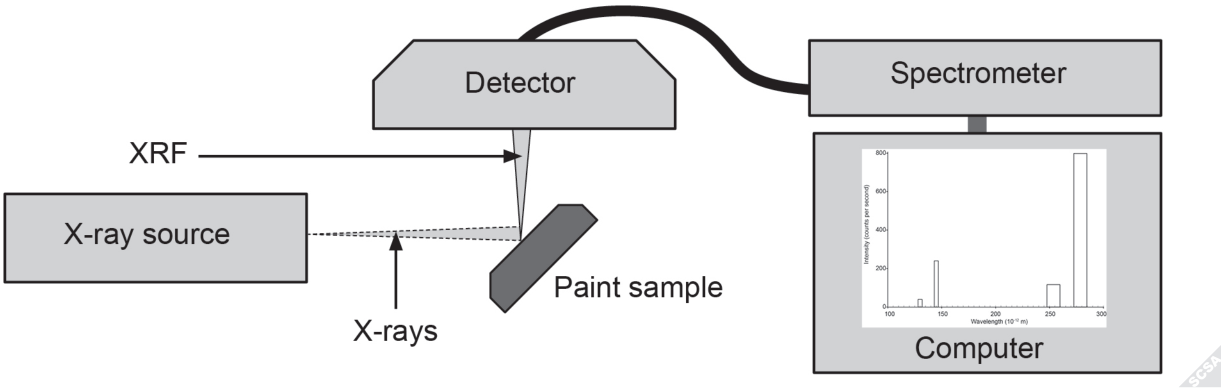
Each of these transitions yields a fluorescent photon which can be detected and analysed. Once sorted, the intensity of each characteristic radiation is related directly to the amount of each element in the material.

| 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 |

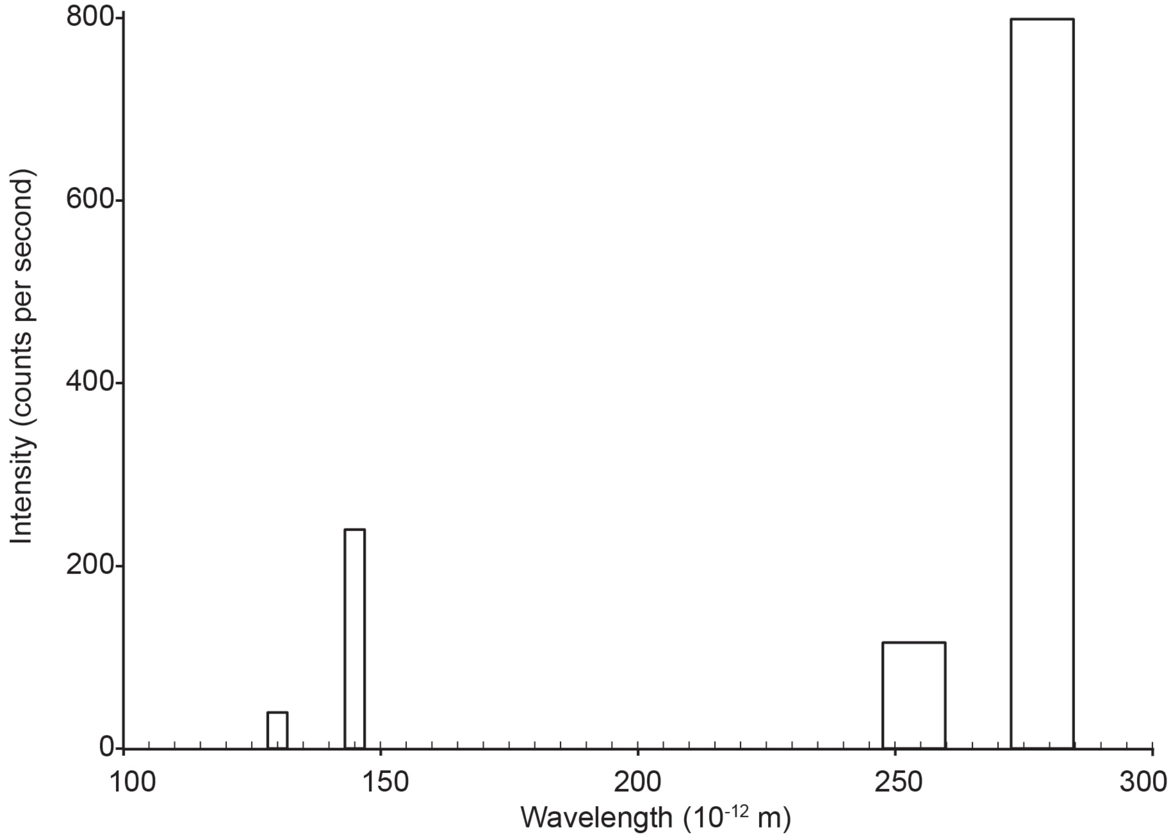
Table 1: Characteristic K$\alpha$ and K$\beta$ fluorescent X-ray energies for various elements.

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.




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)

**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)

(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)

(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$^{-1}$

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

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

**End of questions**

Additional working space

Question number: ____________

Additional working space

Question number: ____________

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**Question 20**

## ACKNOWLEDGEMENTS

**Question 11**

Diagram: Stannered. (2007). *File:Interferometer.svg*. Retrieved June, 2016, from https://commons.wikimedia.org/wiki/File:Interferometer.svg
Used under Creative Commons Attribution-ShareAlike 3.0 Unported licence.

**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

**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
Used under Creative Commons Attribution 3.0 Unported licence.

**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

Introductory text (paras 4–5) adapted from: Hall, S. (2013, October 9). *Detecting the magnetic fields of exoplanets may help determine habitability*. Retrieved June, 2016, from www.universetoday.com/105383/detecting-the-magnetic-fields-of-exoplanets-may-help-determine-habitability/

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**Question 22**

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