Government of Western Australia
School Curriculum and Standards Authority

PHYSICS

ATAR course examination 2016

Marking Key

Marking keys are an explicit statement about what the examining panel expect of candidates when they respond to particular examination items. They help ensure a consistent interpretation of the criteria that guide the awarding of marks.

2016/65168

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

Question 1 **(2 marks)**

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

Description	Marks
Field direction	1
Field density/strength/shape	1
Total	**2**

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.

Description	Marks
Δh=983-155= 828 m	1
$E_p = mg\Delta h$ =78.5×9.8×828 6.37×10^5	1
J	1
Total	**3**

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.

Description	Marks
Vertical $v_v^2 = u_v^2 + 2as$ $v_v = (0+2\times9.8\times100)^{½}$ = 44.3 m s^{-1}	1–2
Horizontal v_h = 50.0 m s^{-1} $v_f = (v_v^2 + v_h^2)^{½}$ = 66.8 m s^{-1}	1–2
$\theta = \tan^{-1}(44.3/50) = 41.5°$	1
Total	**5**

Question 4 **(5 marks)**

(a) Sirius A will be (1 mark)

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

Description	Marks
B	1
Total	**1**

(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.

Description	Marks
A	1
Total	**1**

(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)

Description	Marks
Absorption lines	1
are blue shifted	1
Total	**2**

(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.

Description	Marks
B	1
Total	**1**

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 3.20×10^{-2} N is measured. Calculate the magnitude of the magnetic field strength. Include appropriate units.

Description	Marks
$F = BI\ell$ $B = F/I\ell$ $= 3.20 \times 10^{-2} / (0.250 \times 0.100)$ $= 1.28$	1–2
T (unit)	1
Total	**3**

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

Description	Marks
n = 4 to n = 1	1
E = -1.6-(-10.4) = 8.8 eV = 1.41×10^{-18} J $f = E/h$ $= 2.12 \times 10^{15}$ Hz $\lambda = hc/E$ $= 1.41 \times 10^{-7}$ m	1–3
Total	**4**

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.

Description	Marks
Realise v and u are in the opposite directions (e.g. one is negative $-u$)	1
$u' = \dfrac{u - v}{1 - \dfrac{uv}{c^2}}$ $v_{MA} = \dfrac{-0.75c - (+0.75c)}{1 - \dfrac{(+0.75c)(-0.75c)}{c^2}}$ $= \dfrac{-1.50c}{1.5625} = -0.960c = 2.88 \times 10^8$ m s^{-1}	1–3
Total	**4**

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 given.

Description	Marks
$emf_{max} = -2\pi NBAf$ $= 2\pi \times 131 \times 0.113 \times 0.137 \times 0.137 \times 309/60$ $= 8.99$ V	1–3
$emf_{rms} = emf_{max}/\sqrt{2}$ $emf_{rms} = 6.36$ V	1
Total	**4**

Question 9 **(4 marks)**

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

Description	Marks
Information from the formula sheet: $\varepsilon_0 = 8.85 \times 10^{-12}$ $q_e = q_p = 1.60 \times 10^{-19}$	1
$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$ $= 1/(4\pi \times 8.85 \times 10^{-12}) \times (1.60 \times 10^{-19} \times 1.60 \times 10^{-19}) / (5.29 \times 10^{-11})^2$	1
$= 8.22 \times 10^{-8}$ N	1
Toward the electron	1
Total	**4**

Question 10 **(4 marks)**

A wire carrying a current of 1.68 A has 8.75×10^{-2} m of its length passed through a 4.44×10^{-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.

Description	Marks
$\tau = rF \quad F = I\ell B$ $\tau = rI\ell B$ $= 0.250 \times 1.68 \times 0.0875 \times 0.0444$ $= 1.63 \times 10^{-3}$ N m	1–3
Clockwise	1
Total	**4**

Question 11 **(5 marks)**

(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)

Description	Marks
The change in length will make the waves out of phase or $\lambda/2$ Change in path length is $(808 \times 10^{-9})/2 = 404 \times 10^{-9}$ m light travels twice along path to mirror, therefore change in arm length is $\lambda/4$ or 202×10^{-9} m	1–3
Total	**3**

(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)

Description	Marks
Gravitational wave travelling at the same angle to each arm, i.e. 45° between the two would mean no path difference. Whereas parallel to one and perpendicular to the other, results in max length difference.	1–2
Total	**2**

Question 12 **(6 marks)**

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

Description	Marks
$t=t_0/(1-v^2/c^2)^{½}$ $t=2.20\times10^{-6}/(1-(0.990c)^2/c^2)^{½}$ $=15.6$ μs	1–3
$s=vt=0.99\times(3\times10^8)\times15.6\times10^{-6}=4.63\times10^3$ m	1
Total	**4**

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

Description	Marks
The muon's lifetime is dilated according to an observer on Earth and/or the distance travelled is contracted from the muon's viewpoint. This results in many more than expected of them arriving at the surface.	1–2
Total	**2**

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.

Description	Marks
Estimates radius of path of centre of mass	1
Assume skater centre of mass is 1.0±0.2 m from top of loop so r is 1.5±0.2 m	1
$Fc=Fg$ $mv^2/r=mg$ $v=(g\times r)^{1/2}$ $=(9.8\times 1.5)^{1/2}$ $=3.8$ m s^{-1} (accept 3.5–4.1)	1–2
1 or 2 significant figures	1
Total	**5**

End of Section One

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

Question 14 **(12 marks)**

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

Description	Marks
$\lambda = \frac{h}{m_e v_e} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times0.01\times3.0\times10^{8}} = 2.43\times10^{-10}$ m	1–2
Total	**2**

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

Description	Marks
There will be a series of bright and dark fringes.	1
Bright line in the centre	1
Total	**2**

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

Description	Marks
The electrons exhibit wave behaviour	1
The wave behaviour exhibited could be • diffraction • constructive and destructive interference. Accept any wave behaviour consistent with the situation.	1
Total	**2**

(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)

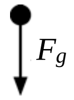
Description	Marks
$v = \frac{h}{\lambda . m_p} = \frac{6.63\times10^{-34}}{2.43\times10^{-10}\times1.67\times10^{-27}} = 1.63\times10^{3}$ m s^{-1}	1–2
Total	**2**

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

Description	Marks
$E_k = W$	1
$\frac{1}{2}mv^2 = Vq$ $V = \frac{1}{2}mv^2/q$ $= \frac{1}{2}(9.11\times10^{-31})\times(3\times10^{6})^2/(1.6\times10^{-19})$ = 25.6 V	1–3
Total	**4**

Question 15 **(16 marks)**

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



Description	Marks
One force drawn pointing straight down	1
No other forces drawn	1
Total	**2**

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

Description	Marks
u_h=45.0×cos24.1= 41.1 m s^{-1}	1
u_v=45.0×sin24.1= 18.4 m s^{-1}	1
Total	**2**

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

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

Description	Marks
$s=ut+1/2\ at^2$ where s=0 $u=1/2\ at$ $t=2u/a$=2(45.0×sin24.1)/1.62 t=22.7 s	1–2
Total	**2**

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

Description	Marks
$s=vt$= 45.0×cos24.1×22.7 = 932 m	1–2
Total	**2**

(d) The highest point on the Moon's surface is 1.08×10^4 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)

Description	Marks
$F_c=F_g$	1
$mv^2/r=GMm/r^2$ $v=(GM/r)^{½}$ $= (6.67\times10^{-11}\times7.35\times10^{22}/(1.08 \times 10^4+1.74\times10^6))^{½}$ $=1.67\times10^3$ m s^{-1}	1–3
Total	**4**

(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)

Description	Marks
Given $g = G M / r^2$ and G is constant	1
The Earth's mass is significantly greater $M_e : M_m$ is 5.97×10^{24} kg: 7.35×10^{22} kg Or 81 times larger	1
The radius is $r_e : r_m$ is 6.37×10^6 m: 1.74×10^6 m Or 3.66 times larger, squared is 13.4	1
the mass has the greater influence in this case hence weaker gravitational field on the Moon (max 2 marks if only one factor discussed)	1
Total	**4**
Note: calculating two values of 'g' without further explanation earns a maximum of 3 marks.	

Question 16 **(14 marks)**

(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)

Description	Marks
Magnet provides a field	1
Movement of string in magnetic field produces changes in the field	1
Change in field induces emf in pick up coil	1
Emf generates current	1
Fluctuations in the current correspond to the frequency	1
Total	**5**

(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)

Description	Marks
Uses $emf = - N (\Delta BA)/t$	1
to describe two of the following: N – increase number of turns B – increase the strength of the magnetic field or magnetic induction of wire A – increase diameter of coil (Not t)	1–2
Total	**3**

(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)

Description	Marks
The string will have an induced magnetic field which interacts with the pickup's magnetic field so as to oppose the string's motion.	1
Without the pickup converting the vibrational energy of the string to electrical energy, the string vibrates longer.	1
Total	**2**

(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)

Description	Marks
$emf_{max} = \ell vB$ = 0.055 × 25 × 0.043 = 0.0591	1–2
V	1
Total	**3**

Question 17 **(8 marks)**

(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)

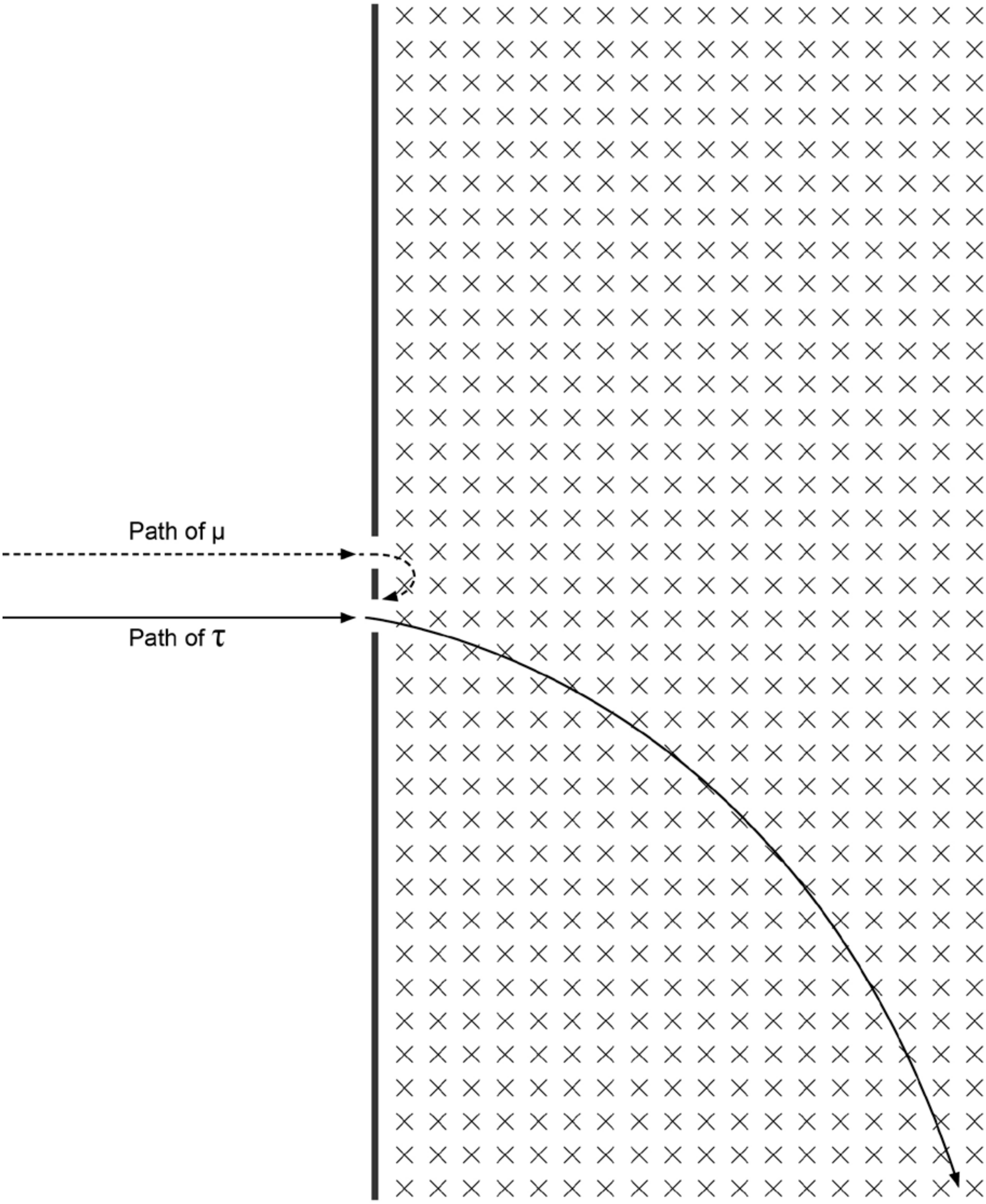
(ii) neutron: _______ _______ _______ (1 mark)

Description	Marks
(i) UUD	1
(ii) UDD	1
Total	**2**

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

Description	Marks
Identifies and describes one type of gauge boson	1–2
Examples: • Gluon: provides strong force between quarks • Photon: provides electrostatic force between protons • Higgs boson: provides mass to particles • W, Z boson: provides weak force (beta decay)	
Total	**2**

(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)



Description	Marks
Muon bends down	1
Tau bends down	1
Tau path radius greater than Muon path	1
Muon path radius close to 1/17 the radius of the Tau path (close quantification)	1
Total	**4**

Question 18 **(17 marks)**

(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)

Description	Marks
Calculate an angle θ=cos^{-1}(2.4/2.78)=30.3°	1
Apply angle to get a torque Paint + Person $\tau = mgr\tan\theta$ =(58+4.25)×9.8×0.5×tan(30.3) =178 N m	1–3
$ACWT = CWT$	1
$F_{gutter} \times r$=178 F_{gutter}=178/r=178/2.78 =64.1 N	1–2
Total	**7**

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

Description	Marks
As the paint tin moves from position A to B, the clockwise torque decreases	1
The required restoring torque from the gutter decreases	1
hence force from the gutter decreases.	1
Total	**3**

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

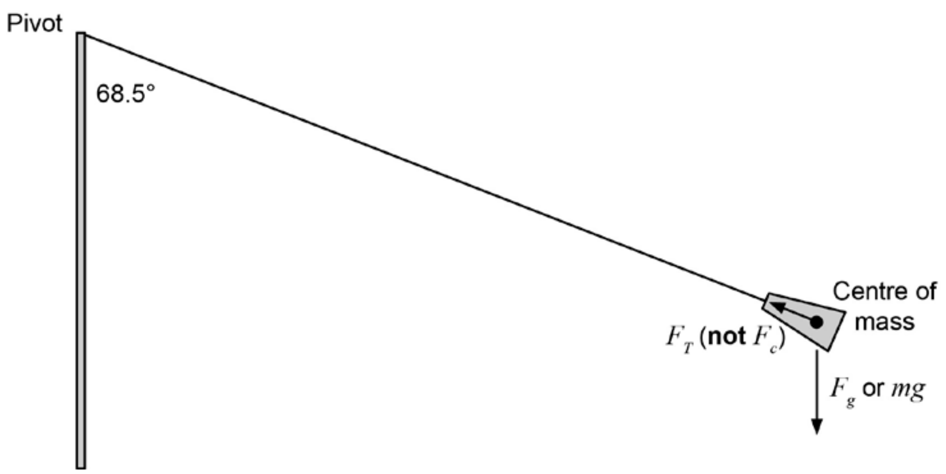
Description	Marks
The system is in equilibrium	1
Because ∑F = 0 and ∑τ = 0	1
Justifies why sum of forces is still zero	1
Justifies why sum of torques is still zero	1
Total	**4**
Example answer: The forces still sum to zero because the moment arm of the centre of mass has decreased so the friction forces required must be less than before. The torques still sum to zero because the paint can provides a counter clockwise torque that is insufficient to counter the torque due to the person's weight.	

(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)

Description	Marks
$F_{down} = mg = 35.1 \times 9.8$ $= 344$ N	1
$Tension = F_{down} \times \sin 40$ $= 35.1 \times 9.8 \times \sin 40 = 221$ N	1–2
Total	**3**

Question 19 **(8 marks)**

(a) On the diagram, draw and label the forces acting on the stopper. (2 marks)

Description	Marks
	
Two arrows and appropriate labels	1
No irrelevant forces shown	1
Total	**2**

(b) Show that the tension in the string is 3.29 N. (2 marks)

Description	Marks
$T\cos\theta = mg$ $T = 0.123 \times 9.8 / \cos 68.5$ $= 3.2889$ N $= 3.29$ N	1–2
Total	**2**

(c) Calculate the speed of the stopper. (4 marks)

Description	Marks
Horizontal radius = 1.43×sin(68.5)=1.33 m	1
$F_c = \frac{m\,v^2}{r} = T\,sin\theta$ 0.123v^2/1.33=3.29sin(68.5) v^2=33.1 v=5.75 m s^{-1}	1–3
Total	**4**

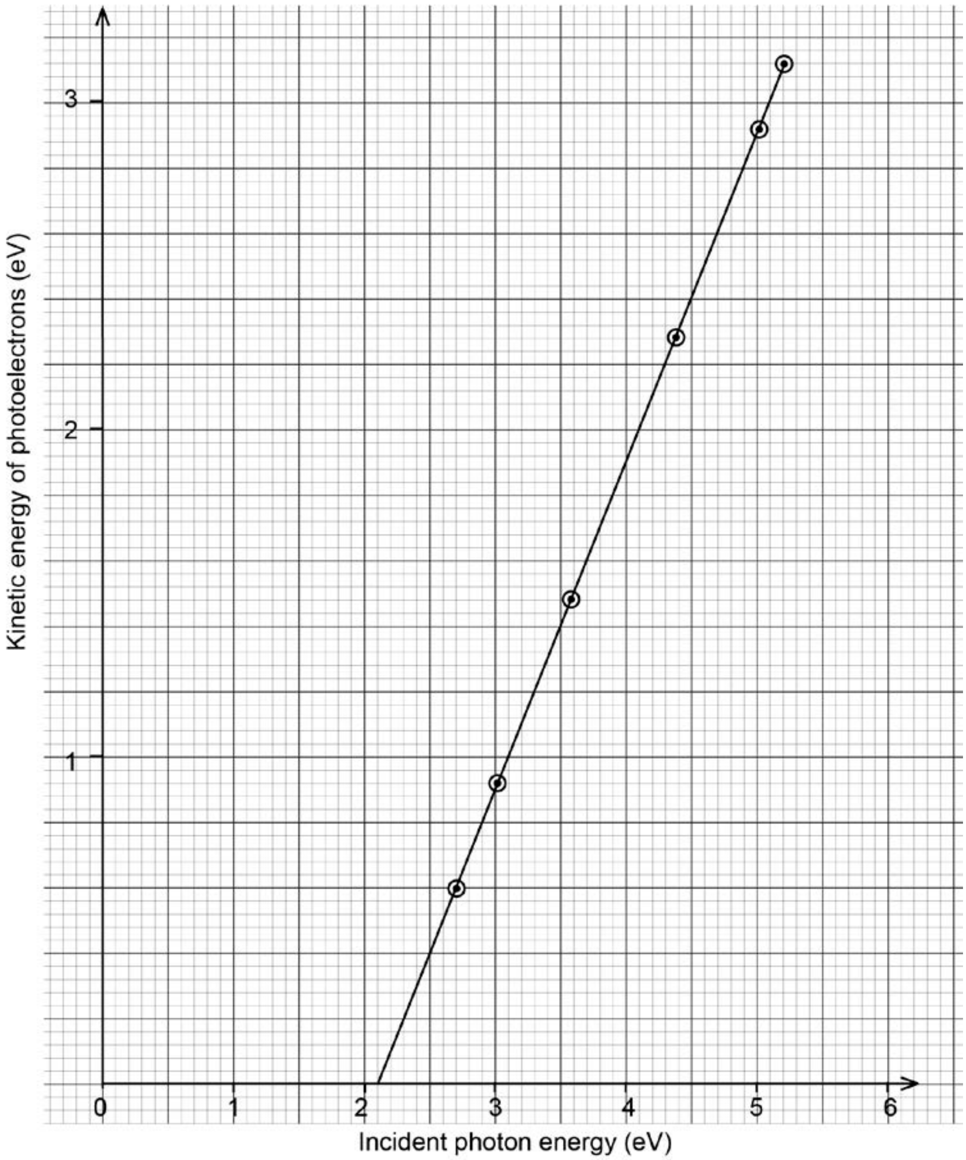
Question 20 **(16 marks)**

(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	**5.22**	3.12
250	4.97	2.87
284	4.38	2.28
351	**3.54**	1.44
416	2.99	0.89
464	2.68	0.58

Description	Marks
$E=hc/\lambda=$6.63×10^{-34} × 3 × 10^8/(238×10^{-9}) =8.35×10^{-19}/(1.6×10^{-19}) =5.22	1
$E=hc/\lambda=$6.63×10^{-34} × 3 × 10^8/(351×10^{-9}) =8.35×10^{-19}/(1.6×10^{-19}) =3.54	1
Total	**2**

(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)

<table>
<tr><th>Description</th><th>Marks</th></tr>
<tr><td>

Axes in correct places
Axes labelled
Data points plotted correctly
Line of best fit drawn correctly</td><td>1–4</td></tr>
<tr><td align="right">Total</td><td>4</td></tr>
</table>

(c) Using your graph, determine the work function of the metal. Express your answer in appropriate significant figures and include units. (4 marks)

Description	Marks
Line of best fit used	1
The work function is where it crosses the x-axis	1
2.1±0.1 (2 significant figures) eV (units)	1–2
Total	**4**

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

Description	Marks
Red light does not have sufficient energy cause the emission of electrons.	1
Classical physics relates the wave energy (intensity) transfer would build up to the eventual ejection of an electron over time, which doesn't happen.	1
Individual energy of the light particle must be higher than the work function of a metal.	1
Total	**3**

(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)

Description	Marks
States a phenomenon such as interference, diffraction or polarisation	1
Describes wave like phenomena using an example such as double slit, interferometer, diffraction grating, thin film, etc.	1–2
Total	**3**

End of Section Two

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

Question 21 **(16 marks)**

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

Description	Mark
63 years	1
Total	**1**

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

Description	Marks
Easier to detect due to the planet being closer to the size of a small star so capable of blocking more of its light than compared to a larger star. Greater change in luminosity	1
Total	**1**

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

Description	Marks
Extracts the mass from the text 0.85M Converts T to seconds (2.2×24×60×60)	1–2
Uses Kepler's 3rd law $T^2 = (4\pi^2/GM)r^3$ $r^3 = G \times 0.85MT^2/4\pi^2$	1–2
$r^3 = 6.67\times10^{-11}\times0.85\times1.99\times10^{30}\times(2.2\times24\times60\times60)^2/4\pi^2$ $r^3 = 1.03\times10^{29}$ $r = 4.69\times10^9$ m	1–2
Total	**6**

(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:

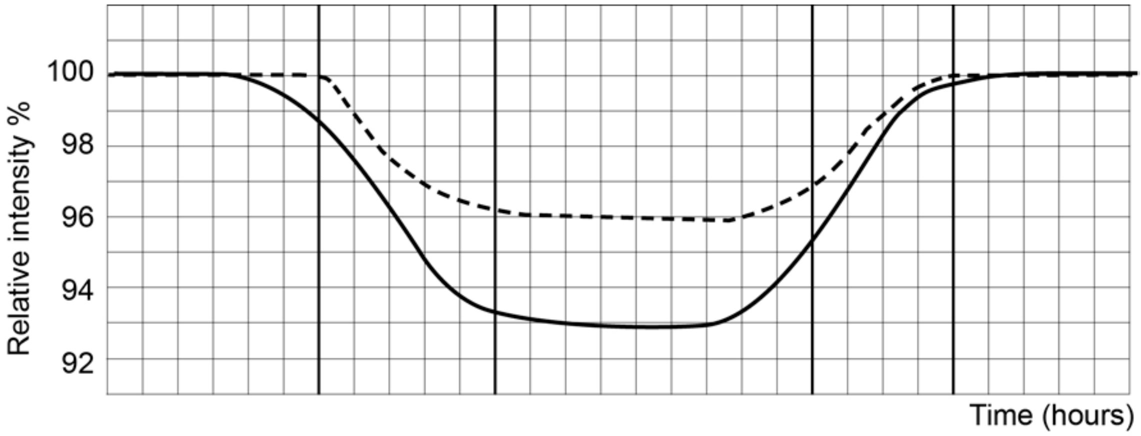
(i) an electron arriving from the star (2 marks)

Description	Marks
The charged particle will be affected by the planet's magnetic field.	1
The charge will move at a right angle to the magnetic field and less likely to reach the planet surface	1
Total	**2**

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

Description	Marks
The particle is not charged, nothing will happen to its path.	1–2
Total	**2**

(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 the bow shock. (4 marks)



Description	Marks
Solid line starts/leads on the flat part (at least by the fifth square)	1
Graph drops below the dotted line (starting from 100%)	1
Has a flat bottom (similar to dotted line)	1
Doesn't cross dotted line (e.g. line goes up after dotted line and returns to 100%)	1
Total	**4**

Question 22 **(20 marks)**

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

Description	Marks
Energy is given to the ejected electron as kinetic energy	1–2
Total	**2**

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

Description	Marks
Kα is the lower energy hence longer λ, i.e. 145×10^{-12} m.	1
The intensity corresponds to brightness or due to higher number of the photons produced	1
hence probability of Kα emission is greater than Kβ	1
Total	**3**

(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 Kα fluorescent X-ray from tin. (2 marks)

Description	Marks
The X-rays emitted from the Rh are not energetic enough. Rh produces Kα X-rays of 20.216 keV as stated in the article. Sn needs more than 25.271 keV to remove the Kα electron.	1–2
Total	**2**
Note: alternative answers could cite wavelengths or frequencies, or state that the equipment is not set up to detect that range.	

(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)

Description	Marks
Assume that the value of ionisation energy is about the Kβ value	1
E_k=(60.0-22.724) ×10^3=37276 eV	1
37276×1.6×10^{-19}=5.96×10^{-15}J 5.96×10^{-15}=$1/2mv^2$ =1/2(9.11×10^{-31})v^2 v^2= 1.309×10^{16} v=1.14×10^8 m s^{-1}	1–2
Total	**4**
Note: alternative answers could assume a value of ionisation energy e.g. slightly higher than the Kβ value.	

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

Description	Marks
Uses correct values from table (or reversed from graph) E=4.511 eV and/or 4.931	1–2
Calculates the λ of Ti from the table (or the graph) $\lambda=hc/E$=6.63×10^{-34}×3.00×10^8/(4.511×1.60 × 10^{-19}) J =2.76×10^{-10} m and/or 2.52×10^{-10} m Note: alternative answers could use ratios of wavelengths and energies.	1–3
Hence matches the present λ of Ti to the graph (or the table) Close to λ= 275×10^{-12} m and/or 250×10^{-12} m	1
Total	**6**

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

Description	Marks
The painting is most likely a forgery.	1
The confirmed presence of TiO_2 which was not available before 1920	1
Since the painting is said to have been done in 1890 it is unlikely to be original.	1
Total	**3**

End of questions

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