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

PHYSICS

ATAR course examination 2021

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.

Section One: Short response **30% (53 Marks)**

Question 1 **(4 marks)**

Electrons with 12.2 eV of energy are incident on the hydrogen atoms. Calculate the energies of all scattered electrons in eV.

Element	Description	Marks
Student calculates the maximum transition possible is from 1 to 3.	-13.60 + 12.2 = -1.40 eV	1
Calculates energies transferred to electrons in the atom	13.60 – 1.51 = 12.09 eV 13.60 – 3.40 = 10.2 eV	1
Calculates energies of scattered electrons	12.2 – 12.09 = 0.11 eV 12.2 – 10.2 = 2.00 eV	1
Student includes elastic collision where incident electrons retain all their energy	12.2 eV	1
	Total	**4**

Question 2 **(3 marks)**

Using information from the Formulae and Data Booklet, calculate the mass of a bottom quark in kg.

Element	Description	Marks
Student uses correct value from data sheet	4.18 GeV/c^2	1
Student converts eV to Joules	$4.18 \times 10^{9} \times 1.6 \times 10^{-19} = 6.69 \times 10^{-10}$J	1
Student correctly calculates mass	$6.69 \times 10^{-10} / 9 \times 10^{16} = 7.43 \times 10^{-27}$ kg	1
	Total	**3**

Question 3 **(4 marks)**

Calculate the magnitude and give the direction of the forces on sides AB and CD of the loop, using the directions provided in the table below. Write your answers in the table below.

1 mark for each correct box.

Description	Marks
Directions correct	1−2
Forces correctly calculated	1−2
Total	**4**

Side	Force (N)	Direction (up, down, left, right, into the page, out of the page, no force)
AB	$F = BIl = 1.52 \times 10^{-3} \times 3.50 \times 5.00 \times 10^{-2} = 2.66 \times 10^{-4}$ N	down
CD	2.66×10^{-4} N	up
Note: 1 mark if AB = CD but value incorrect. 1 mark for direction of AB opposite to CD if AB is incorrect.		

Question 4 **(5 marks)**

A proton in a linear particle accelerator is given an energy of 0.100 TeV. Using the equation for mass-energy equivalence, calculate the speed of the proton in terms of c. Give your answer to 5 significant figures.

Element	Description	Marks
Uses relativistic energy formula	$E = \gamma mc^2$	1
Converts TeV to Joules	$0.100 \times 10^{12} \times 1.60 \times 10^{-19} = 1.60 \times 10^{-8}$ J	1
Uses correct algebra	$1/\gamma = 1.67 \times 10^{-27} \times 9.00 \times 10^{16} / 1.60 \times 10^{-8}$ $= 9.393750 \times 10^{-3}$	1
Correctly calculates answer	$\sqrt{1 - x^2} = 9.393750 \times 10^{-3}$ $1 - x^2 = 8.824254 \times 10^{-5}$ $x = 0.9999559$	1
Gives answer in terms of c and to 5 significant figures	$v = 0.99996\ c$	1
	Total	**5**
Note: $E_k = (\gamma - 1)mc^2$ is also acceptable		

Question 5 **(4 marks)**

(a) State **two** main differences between hadrons and leptons. (2 marks)

1 mark per difference

Description	Marks
Differences between hadrons and leptons explicitly stated	1−2
Total	**2**
• Hadrons are made of quarks (not fermions), leptons are fundamental particles (fermions) • Leptons are generally less massive than hadrons • Hadrons are subject to the strong nuclear force that holds the nuclei together, and leptons are subject only to the weak nuclear force	
Note: Answer must include reference to hadrons and leptons	

(b) Identify an example of a hadron and a lepton from the list provided and write your choice in the spaces below. (2 marks)

Description		Marks
Correctly identifies particles		1−2
	Total	**2**
Hadron	(i) proton, (ii) meson, (iv) neutron or (vi) baryon	
Lepton	(iii) tau neutrino or (v) muon	

Question 6 **(5 marks)**

(a) Calculate the distance between A and C. (3 marks)

Element	Description	Marks
Uses moments to solve problem	$\Sigma cm = \Sigma acm$	1
Uses 1.00 m as distance from B to COM of beam	(5.00)(9.80) x BC $\cos\Theta$ = (15.0)(9.80) x 1.00 $\cos\Theta$ BC = 3.00 m	1
Correctly calculates answer	AC = 6.00 + 3.00 = 9.00 m	1
	Total	**3**

(b) Ignoring friction, calculate the angle of the slope measured from the horizontal. (2 marks)

Element	Description	Marks
Uses $s = ut + 0.5\ at^2$ where $u = 0$ and $a = g\sin\Theta$	$9.00 = 0.5 \times 9.80 \sin\Theta \times 3.30^2$	1
Correctly calculates answer	$\sin\Theta = 0.1687$ $\Theta = 9.71°$	1
	Total	**2**

Question 7 **(4 marks)**

A bobo doll can never be tipped over. Even if its head is held on the ground, it will stand back up when released. Explain how this works. You must include in your answer the relevant conditions required for static equilibrium. Use the diagram on the right to illustrate your answer.

Description	Marks
Diagram shows labelled line of action of the weight force to the left of the pivot (where the base of the bobo doll touches the ground).	2
Person holding doll down provides a balancing torque to keep the doll in static equilibrium	1
When opposing moment holding head on the ground is removed, the restoring moment of the weight force rights the doll	1
Total	**4**

Question 8 **(4 marks)**

Complete the following table for an anti-proton

1 mark for each box

Name	Symbol	Quark composition	Electric charge	Mass (GeV/c^2)
proton	p	uud	1	0.938
anti-proton	$\overline{p}$	$\overline{u}\,\overline{u}\,\overline{d}$	-1	0.938

Question 9 **(5 marks)**

A space station is shaped like a huge hollow doughnut that is rotating uniformly. The outer radius is 4.60 x 10^2 m. What is the period of rotation of the station if a person standing on the outer wall inside the station experiences the same weight force she would experience on Earth?

Element	Description	Marks
Centripetal force is supplied by the reaction force.	$mv^2/r = R$	1
Reaction force equals mg	$mv^2/r = mg$	1
Correctly rearranges formula to calculate velocity	$v = \sqrt{rg} = \sqrt{4.60 \times 10^2 \times 9.80} = 67.1$ m s^{-1}	1
Period is circumference over time	$T = 2\pi r/v$	1
Correctly calculates period	$T = 43.0$ s	1
	Total	**5**

Question 10 **(4 marks)**

(a) Calculate the power supplied as heat to the pipe as the magnet continues to fall. (3 marks)

Element	Description	Marks
Power = change in potential energy per second. $h/t = v$	$P = \Delta mgh/t = mgv$	1
	$P = 0.0550 \times 9.80 \times 0.0851$	1
Correctly calculates answer	$P = 4.59 \times 10^{-2}$ W	1
	Total	**3**

(b) Silver has a higher electrical conductivity than copper. How would your answer to part (a) change if the pipe was now made of silver? Circle your answer. (1 mark)

Description	Marks
(ii) Decrease	1
Total	**1**

Question 11 **(7 marks)**

(a) Through what potential difference would a proton at rest need to be accelerated for it to achieve a speed of 6.00 x 10^5 m s^{-1}? (3 marks)

Element	Description	Marks
Kinetic energy gained = potential energy lost	$Vq = mv^2/2$	1
Correctly rearranges formula for V	V = 1.67 x 10^{-27} x (6.00 x 10^5)^2 / 2 x 1.60 x 10^{-19}	1
Correctly calculates answer	1.88 x 10^3 V	1
	Total	**3**

(b) What would be the final velocity of an electron accelerated from rest across the same potential difference? If you could not obtain an answer to part (a), use 2.00 kV as the potential difference. (3 marks)

Element	Description	Marks
Same as part a only rearranges for v	$v = \sqrt{2\,V\,q/m}$	1
Uses m(e)	$v = \sqrt{\frac{2 \times 1.88 \times 10^3 \times 1.60 \times 10^{-19}}{9.11 \times 10^{-31}}}$	1
	v = 2.57 x 10^7 m s^{-1}	1
If uses 2.00 kV	v = 2.65 x 10^7 m s^{-1}	
	Total	**3**

(c) What is the ratio of the kinetic energies between the proton and electron once they cross the same potential difference? (1 mark)

Description	Marks
1:1	1
Total	**1**

Question 12 **(4 marks)**

(a) Briefly explain the origin of CMB as part of the Big Bang theory. (2 marks)

Description	Marks
The Big Bang theory states the original temperature of the universe would need to be very high/high energy.	1
The universe would have given off (black body) radiation in all directions.	1
Total	**2**

(b) How does the study of CMB provide evidence that the universe is expanding? (2 marks)

Description	Marks
Originally the radiation given off would have had much shorter wavelengths and higher energy.	1
As the universe expanded, so did the wavelengths of this background radiation and it became less energetic microwaves.	1
Total	**2**

Section Two: Problem-solving **50% (93 Marks)**

Question 13 **(13 marks)**

(a) Estimate the threshold frequency for potassium from the graph above. (2 marks)

Description	Marks
0.37 – 0.38 x 10^{15} Hz	1
Max 2 significant figures	1
Total	**2**

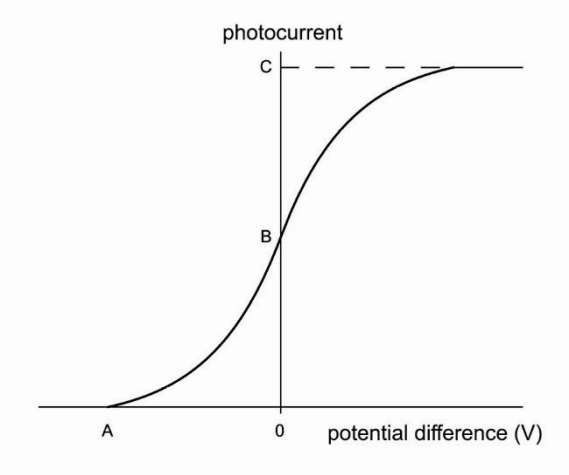
(b) Estimate the work function for potassium from the graph above. (2 marks)

Description	Marks
1.4 – 1.5 eV	1
Max 2 significant figures	1
Total	**2**

(c) Using your value from part (b), estimate the maximum velocity of a liberated electron if light with a frequency of 1.20 x 10^{15} Hz shines on a potassium metal plate. Give your answer to two significant figures. (6 marks)

Element	Description	Marks
Converts eV to Joules	2.24 x 10^{-19} – 2.40 x 10^{-19} J	1
Uses correct equation	$mv^2/2 = hf - W$	1
Rearranges for v	$v = \sqrt{2(hf - W)/m}$	1
Correct substitution	$v = \sqrt{\frac{2\,(\,6.63 \times 10^{-34} \times 1.20 \times 10^{15} - 2.40 \times 10^{-19})}{9.11 \times 10^{-31}}}$	1
Correctly calculates answer	1.1 x 10^{6} m s^{-1} (same for all values)	1
2 significant figures		1
	Total	**6**

(d) Below is a graph of photocurrent vs potential difference. On this graph, draw the resulting curve when light of the same frequency but lower power is shone on the same metal. (3 marks)



Description	Marks
Start at A	1
Lower value than B at y intercept	1
Lower value than C for steady photocurrent	1
Total	**3**

Question 14 **(13 marks)**

(a) Calculate the strength of the electric field. (1 mark)

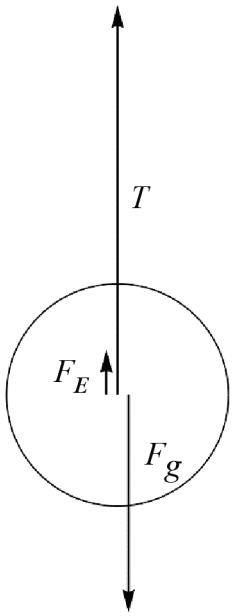
Description	Marks
$E = V/d$ = 180/1.20 = 1.50 x 10^2 V m^{-1} or N C^{-1}	1
Total	**1**

(b) Calculate the tension in the string. (4 marks)

Element	Description	Marks
Derives correct expression for T using F_E in opposite direction to mg	$T = mg - Eq$	1−2
Uses correct values	T = (0.200 x 9.80) – (1.50 x 10^2 x 2.72 x 10^{-3})	1
Correctly calculates answer	1.55 N	1
Total		**4**

Question 14 (continued)

(c) (i) Draw a free body diagram of the forces acting on the sphere in this position. Label all forces. Do not show the net force acting on the sphere. (3 marks)



Description	Marks
Each force labelled correctly and in correct direction	1−3
Total	**3**
Note: If more than three forces provided, award a maximum of 2 marks.	

(ii) Derive an expression for the net force acting on the sphere in terms of the forces in your diagram. (1 mark)

Description	Marks
$F_N = T + Eq - mg$ (follow through marks for consistency with diagram as long as there are 3 forces)	1
Total	**1**

(iii) Calculate the tension in the string at the bottom of its swing. (4 marks)

Element	Description	Marks
Rearranges equation correctly for T	$T = mv^2/r - Eq + mg$	1
Correct substitution of values	T = (0.200 x 2.80^2 / 0.800) – (1.50 x 10^2 x 2.72 x 10^{-3}) + (0.200 x 9.80)	1−2
Correctly calculates answer	3.51 N	1
Total		**4**

Question 15 **(11 marks)**

(a) Calculate the vertical and horizontal components of her launch velocity. (2 marks)

Element	Description	Marks
Vertical component	$v_V = 3.10 \times \sin 55.0° = 2.54$ m s^{-1}	1
Horizontal component	$v_H = 3.10 \times \cos 55.0° = 1.78$ m s^{-1}	1
	Total	**2**

(b) Calculate the time it takes for her to reach the ground, assuming she is vertical at impact. (5 marks)

There are 3 different alternatives to solve this problem.

1. Quadratic equation

Element	Description	Marks
$s = ut + 0.5\ at^2$		
s and a are negative, u is positive.	$-1.25 = 2.54t - 4.90t^2$	1
Uses v_V for u		1
Rearranges equation correctly to equal 0	$4.90t^2 - 2.54t - 1.25 = 0$	1
Substitutes correct values into quadratic formula	$t = 2.54 \pm \sqrt{-2.54^2 - 4 \times 4.90 \times -1.25} / 2 \times 4.90$	1
Correctly calculates answer	$t = 0.827$ s	1
	Total	**5**

2. Calculates final vertical velocity

Element	Description	Marks
$v^2 = u^2 + 2as$		
a and s are negative	$v_V^2 = 2.54^2 + (2 \times -9.80 \times -1.25)$	1
uses v_V		1
Solves for v correctly	$v_V = \pm 5.56$ m s^{-1}	1
$v = u + at$, v and a are negative	$-5.56 = 2.54 - 9.80t$	1
Correctly calculates answer	$t = 0.827$ s	1
	Total	**5**

3. Splits flight into up and down sections

Element	Description	Marks
Calculate time to apex using v_V	$v = u + at$ $t = 0.259$ s	1
Calculates how high she goes	$s = ut + 0.5\ at^2$ $s = 0.329$ m	1
Adds 1.25 to answer	$s = 1.58$ m	1
Calculates how long to fall to ground	$s = ut + 0.5\ at^2$ $t = 0.568$ s	1
Adds two times correctly	0.827 s	1
	Total	**5**

Question 15 (continued)

(c) Calculate her range R (2 marks)

Element	Description	Marks
$s = vt$ Uses v_H	s = 1.78 x 0.827	1
Correctly calculates answer	s = 1.47 m	1
	Total	**2**

(d) Calculate the gymnast's kinetic energy at the top of her flight. (2 marks)

Element	Description	Marks
Uses v_H	E_k = 0.5 x 42.5 x 1.78^2	1
Correctly calculates answer	67.3 J	1
	Total	**2**

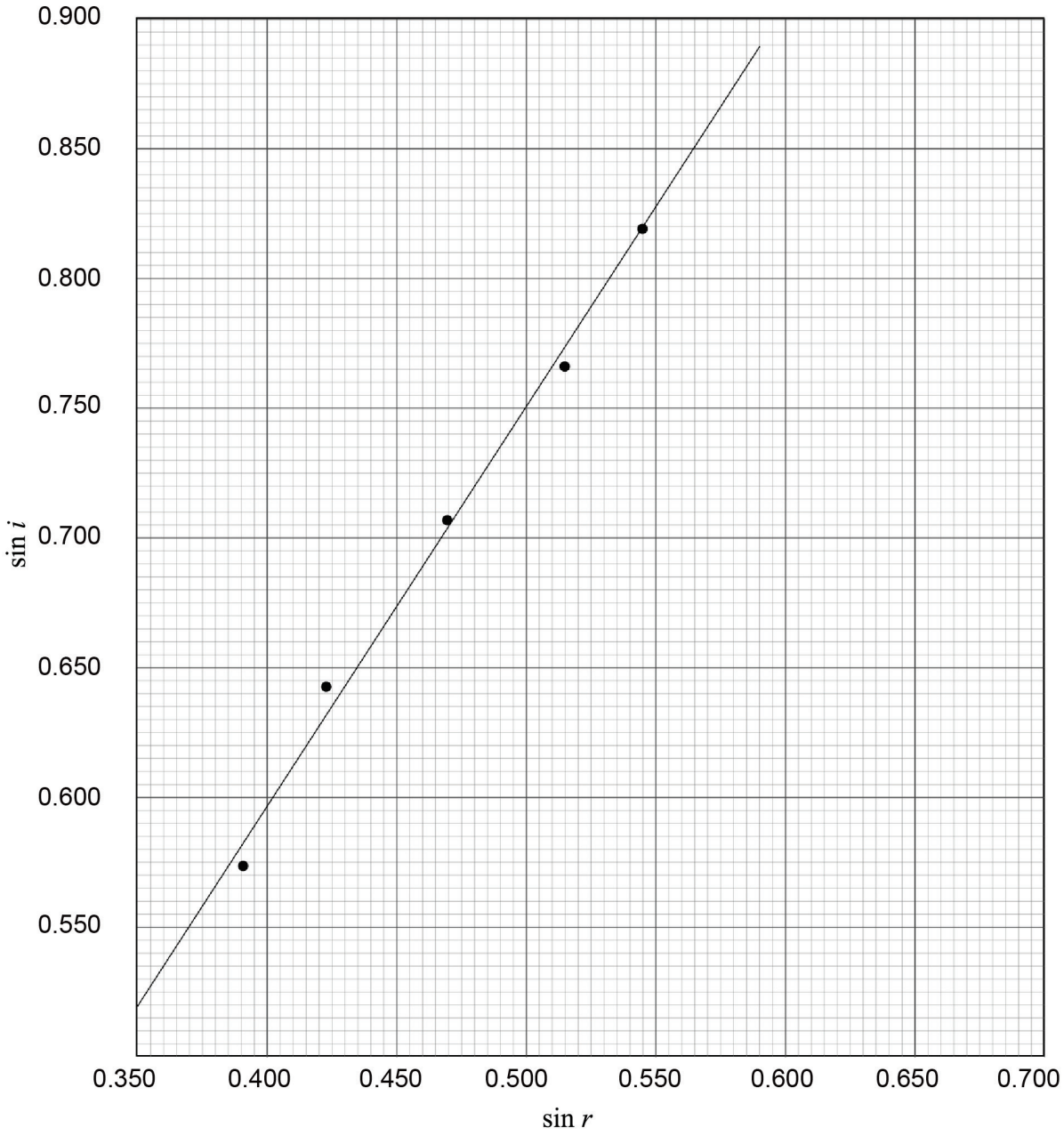
Question 16 **(18 marks)**

(a) Complete the table giving the values of sine to three significant figures. (2 marks)

i(degrees) ± 1°	35	40	45	50	55
sin i	0.573	0.643	0.707	0.766	0.819
r(degrees) ± 1°	23	25	28	31	33
sin r	0.391	0.423	0.469	0.515	0.545

Description	Marks
Correct values	1
3 significant figures	1
Total	**2**

(b) Graph $\sin i$ vs $\sin r$ on the graph below. Include a line of best fit. (3 marks)



Description	Marks
All points plotted	1
Accurate plot	1
LOBF	1
Total	**3**

Question 16 (continued)

(c) The refractive index of air (n_1) is 1.00. Using your line of best fit, determine the refractive index of the prism (n_2). Indicate clearly which two points on your line of best fit you used in your calculation. Give your answer to two significant figures.

(4 marks)

Element	Description	Marks
2 points clearly shown on graph		1
Calculates gradient correctly	1.52 – 1.55	1
Realises gradient equals RI		1
Max 2 significant figures	1.5 or 1.6 (must be consistent)	1
	Total	**4**

(d) There are two phenomena described in this question that support the wave behaviour of light. List them below. (2 marks)

Description	Marks
refraction	1
dispersion	1
Total	**2**

(e) The tolerance for all angles was ± 1˚. How does the percentage error change as the angle measured increases? Use calculations in your answer. (3 marks)

Element	Description	Marks
Calculates percentage error for 2 angles	eg. 1/35 x 100 = 2.85% 1/ 60 x 100 = 1.67%	1
Expresses as percentage		1
States percentage error decreases as angle increases		1
	Total	**3**

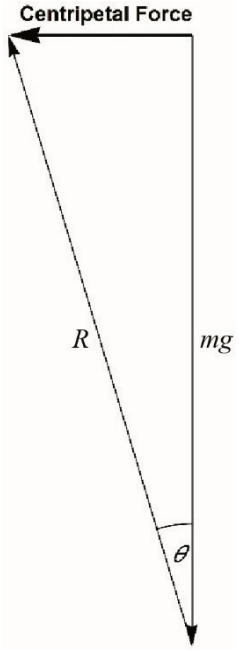
(f) Using the following trigonometric identity, calculate the percentage error of the sine of an angle of incidence of 50.0˚. (4 marks)

Element	Description	Marks
Uses 50.0° as angle and 1° as error		1
Substitutes angles correctly	$\sin(50.0 + 1) = \sin 50.0 \cos 1 \pm \cos 50.0 \sin 1$	1
Correctly calculates answer	0.766 ± 0.011	1
Calculates % error correctly	0.011/0.766 x 100 = 1.4 %	1
	Total	**4**

Question 17 **(13 marks)**

(a) Draw a vector diagram showing how the weight force and the upthrust produce a resultant centripetal force. Indicate the resultant force and include the angle Θ shown in the free body diagram. (3 marks)

Description	Marks
All forces labelled correctly	1
Right angle triangle with resultant horizontal	1
Θ correctly placed	1
Total	**3**



(b) Calculate the centripetal force on a 5.60 x 10^3 kg aeroplane banking at an angle of 15.0˚ to the vertical while maintaining constant altitude. (3 marks)

Element	Description	Marks
Uses correct trigonometric function	$\tan 15.0° = F_c / mg$	1
Substitutes correct values into equation and isolates F_c correctly	$F_c = mg \tan 15.0°$ = 5.60 x 10^3 x 9.80 x 0.268	1
Calculates correct answer	1.47 x 10^4 N	1
	Total	**3**

(c) If the aeroplane is travelling at 4.50 x 10^2 km h^{-1}, calculate the radius of the circular path it takes when banking while maintaining constant altitude. (3 marks)

Element	Description	Marks
Converts km h^{-1} to m s^{-1}	450 / 3.6 = 125 m s^{-1}	1
Substitutes values and rearranges equation correctly	r = 5.60 x 10^3 x 125^2 / 1.47 x 10^4	1
Correctly calculates answer	5.95 x 10^3 m	1
	Total	**3**

Question 17 (continued)

(d) With reference to your vector diagram in part (a) and the text, explain why aeroplanes need to increase their speed to maintain altitude when banking. (4 marks)

Description	Marks
Upthrust counters weight force	1
Upthrust is directly proportional to forward speed	1
Upthrust acts perpendicular to wings	1
As seen in diagram, only vertical component of upthrust counters weight therefore needs to increase speed to maintain altitude	1
Total	**4**

Question 18 **(14 marks)**

(a) Using conservation of relativistic energy, calculate the mass of the combined particle m_C. Give your answer in terms of m, the mass of each of the original particles. (4 marks)

Element	Description	Marks
$E_{before} = E_{after}$	2 x $mc^2/\sqrt{1-0.600^2}$ = $m_Cc^2/\sqrt{1-0^2}$	1
Realises v_{after} = 0 m s^{-1}		1
Simplifies equation	2 m / 0.800 = m_c	1
Expresses m_C in terms of m	m_C = 2.50 m	1
	Total	**4**

(b) Explain why the velocity of the combined particle has to be 0 m s^{-1}. (2 marks)

Description	Marks
Σp before = 0 as velocities are in opposite directions and masses are identical.	1
(Conservation of momentum means) p after = 0 therefore v after = 0	1
Total	**2**

(c) Using the formulas for relativistic velocity addition and relativistic momentum, find the momentum of the system before the collision, as determined by X. Express your answer in terms of m and c, the speed of light. (5 marks)

Element	Description	Marks
Adds velocities correctly	v_A = 0.600c + 0.600c / 1 + 0.600^2	1
From O's pov, v_B = 0		1
Correctly calculates v_A	0.88235 c	1
Uses rel p formula	p = m x 0.88235c / $\sqrt{1 - 0.88235^2}$	1
Correctly calculates p in terms of mc	p = 1.87 mc	1
	Total	**5**

(d) With the use of a calculation, show that your answer in part (c) is the same as the momentum of the system after the collision, as determined by X. (4 marks)

Element	Description	Marks
Uses relative. momentum equation for combined particle and substitutes values of mass from part (a) and 0.600c for v. Uses γ from part (a).	$p = \gamma mv$ = 1.25 x 2.50 m x 0.600 c	2
Correctly calculates answer	p = 1.87 mc	1
States momentum is the same as momentum in part c		1
	Total	**4**

Question 19 **(10 marks)**

(a) Calculate the strength of the wire's magnetic field felt by the compass in the position described in Figure 2. (3 marks)

Element	Description	Marks
Uses correct equation, constants	B = 1.26 x 10^{-6} x 3.70/6.28 x 5.00 x 10^{-2}	1
Converts mm to m		1
Correctly calculates answer	B = 1.48 x 10^{-5} T	1
	Total	**3**

(b) Calculate the strength of the horizontal component of the Earth's magnetic field. (4 marks)

Element	Description	Marks
Uses 80.0° as angle of resultant B of Earth and wire		1
Uses correct trigonometric function	tan 80.0° = 1.48 x 10^{-5} / B_{EH}	1
Rearranges expression correctly for B of Earth	B_{EH} = 1.48 x 10^{-5} / tan 80.0°	1
Correctly calculates answer	B_{EH} = 2.62 x 10^{-6} T	1
	Total	**4**

(c) The Earth's magnetic field is at an angle of 66.0˚ to its surface in Perth. This is called the angle of dip. Use this information to calculate the overall strength of the Earth's magnetic field in Perth. (3 marks)

Element	Description	Marks
Uses B_{EH} and 66.0° to calculate B		1
Uses correct trigonometric function	B cos 66.0° = 2.62 x 10^{-6}	1
Correctly calculates answer	6.44 x 10^{-6} T	1
	Total	**3**

Section Three: Comprehension **20% (38 Marks)**

Question 20 **(20 marks)**

(a) List **two** properties of X-rays that make them suitable for X-ray fluorescence spectrometry. (2 marks)

Description	Marks
Short wavelength	1
High energy	1
Could also mention high penetrative ability	
Total	**2**

(b) Explain how we now know that Rembrandt's original painting had lances of different length and some of the people were in different positions. (2 marks)

Description	Marks
Depending on its energy, the X-ray beam penetrates into different depths of the painting's surface.	1
This allows us to examine different layers of paint and even detect corrections made by Rembrandt without having to remove any paint. It is already known today that Rembrandt lengthened lances or changed the positioning of figures in the picture.	1
Total	**2**

(c) Give **two** advantages of using X-ray spectrometry to analyse old paintings. (2 marks)

Description	Marks
Expensive paintings can harmlessly be investigated before restoration. (This ensures sophisticated preservation of valuable art objects.)	1
It also allows the paintings to be restored securely in the buildings where the public can still enjoy them.	1
Total	**2**
Note: Accept other correct, relevant answers	

(d) Explain why the fluorescent radiation is element specific. (3 marks)

Description	Marks
Energy level values are dependent on Z, the charge on the nucleus.	1
Z is directly proportional to the number of protons in the nucleus, which defines the element.	1
Fluorescent wavelengths correspond to energy transitions; therefore are element-specific.	1
Total	**3**

Question 20 (continued)

(e) (i) Estimate the values of the M and L energy shells for iron (Fe) displayed in Figure 2 and place them in the corresponding spaces below. (3 marks)

Description	Marks
Level 3: (7.1 – 7.2) x 10^3 eV or 7.1 – 7.2 keV	1
Level 2: (6.3 – 6.4) x 10^3 eV or 6.3 – 6.4 keV	1
Max 2 Sig Figs	1
Total	**3**

(ii) Estimate the wavelength of the photon given off when an electron falls from the M shell to the L shell in an iron atom. (4 marks)

Element	Description	Marks
Converts keV to Joules	$(0.7 \rightarrow 0.9) \times 10^3 \times 1.60 \times 10^{-19}$ $= (1.12 \rightarrow 1.44) \times 10^{-16}$ J	1
Substitutes c/λ for f in $E = hf$	$E = ch/\lambda$	1
Correctly calculates answer	$\lambda = \frac{3.00 \times 10^8 \times 6.63 \times 10^{-34}}{(1.12 \rightarrow 1.44) \times 10^{-16}}$ $= (1.4 \rightarrow 1.8) \times 10^{-9}$m	1
Max 2 significant figures		1
	Total	**4**
Note: Ranges expressed do not include incorrect answers from part (i). Do not penalise for consequential errors		

(iii) To which part of the electromagnetic spectrum does this wavelength belong? (1 mark)

Description	Marks
X-rays or UV (or answer consistent with e(ii) wavelength value)	1
Total	**1**

(f) How would the graph in Figure 2 change if the operators of the spectrometer increased the power of the X-ray beam while keeping the wavelength constant? Explain your answer.

(i) Change: (1 mark)

Description	Marks
Peaks would be higher	1
Total	**1**

(ii) Explanation: (2 marks)

Description	Marks
If power is increased while λ is constant, more photons per second are hitting the target	1
More photons per second will increase the intensity of photons emitted	1
Total	**2**

OR

(i) Change (1 mark)

Description	Marks
Peaks will be the same	1
Total	**1**

(ii) Explanation: (2 marks)

Description	Marks
If power is increased while λ is constant, more photons per second are hitting the target	1
As all emitted wavelengths have increased, the relative abundance remains constant.	1
Total	**2**

Question 21 **(18 marks)**

(a) Calculate the drift velocity of electrons if a current of 3.00 A is flowing in a copper wire with a cross-sectional area of 1.00 mm^2. (3 marks)

Element	Description	Marks
Converts mm^2 to m^2	1.00×10^{-6} m^2	1
Substitutes correct values	$v_D = 3.00 / 8.50 \times 10^{28} \times 1.60 \times 10^{-19} \times 1.00 \times 10^{-6}$	1
Correctly calculates answer	2.21×10^{-4} m s^{-1}	1
Total		**3**

(b) With reference to the text, explain why V_H reduces to zero when the strip is moved in the correct direction at the correct speed. (4 marks)

Description	Marks
$F_M = Bvq$	1
When v = 0 relative to magnetic field, no magnetic force is exerted on charges	1
No separation of charge means no electric field is established	1
No electric field between edges means no potential difference detected	1
Total	**4**

(c) Explain why increasing the magnitude of the magnetic field will increase V_H for a stationary strip when equilibrium is restored. (3 marks)

Description	Marks
$F_M = Bvq$. If B increases, so does F_M on charges	1
If F_M increases, more electrons will move further to one side of the strip/increased charge separation which increases the strength of the electric field produce	1
If electric field increases, V_H increases	1
Total	**3**

Question 21 (continued)

(d) The article says: '*By substitution, it can be shown that:* $F_E = \frac{V_H q}{w}$ *'*. Derive this equation from information supplied in the article. (2 marks)

Description	Marks
$E = F/q = V_H/d$ where $d = w$	1
$F = V_H q/w$	1
Total	**2**

(e) Calculate V_H if the dimensions of the copper strip are w = 3.00 cm and d = 0.100 cm, B = 3.50 T and I = 26.0 A. Use electrons as the charge carriers in your calculation. (6 marks)

Element	Description	Marks
At equilibrium, $F_M = F_E$		1
Substitutes expressions for field strengths	$Bv_D q = V_H q/w$	1
Isolates V_H correctly and simplifies	$V_H = Bwv_D$	1
Substitutes I/nAq for v_D	$V_H = BwI/nAq$	1
Uses correct values in calculation	$V_H = \frac{3.50 \times (3.00\times10^{-2}) \times 26.0}{(8.50\times10^{28}) \times (3.00\times10^{-2}) \times (1.00\times10^{-3}) \times (1.60\times10^{-19})}$	1
Correctly calculates answer	6.69×10^{-6} V	1
	Total	**6**

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