2025/24345

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

PHYSICS

ATAR course sample examination

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% (58 Marks)**

Question 1 **(4 marks)**

Explain how this pattern is formed and how it supports de Broglie's hypothesis that all matter has a wavelength.

Description	Marks
destructive and constructive interference of the waves produced by moving electrons forms the pattern	1
destructive is dark and constructive is light	1
this demonstrates wave behaviour	1
this supports de Broglie's hypothesis that all matter behaves like a wave	1
Total	**4**

Question 2 **(5 marks)**

Calculate the charge on the dust particle q.

Element	Description	Marks
Uses electrostatic force	$F = mg$	1
Uses two expressions for E	$\frac{\Delta V}{d} = \frac{F}{q}$	1
Rearranges for q	$q = \frac{Fd}{\Delta V} = \frac{mgd}{\Delta V}$	1
Substitutes correctly converted values	$q = \frac{\left(3.70\times10^{-9}\right)(9.80)(0.0210)}{1.20\times10^{2}}$	1
Calculates correct value	$q = 6.35\times10^{-12}$ C	1
Total		**5**

Question 3 **(4 marks)**

Calculate the total upward reaction force between the road and the car when it is at the top of the bridge.

Element	Description	Marks
Derives correct expression for F_c	$F_c = mg - R$	1
Rearranges for R	$R = mg - \frac{mv^2}{r}$	1
Converts km h^{-1} to m s^{-1}	$\frac{72.0}{3.60} = 20.0$ m s^{-1}	1
Calculates correct answer	$R = (905)\left(9.80 - \frac{(20.0)^2}{80.0}\right)$ $= 4.34\times10^{3}$ N	1
Total		**4**

Question 4 **(4 marks)**

Complete the table below by placing **one** tick in the correct column for each situation, indicating how the particle is deflected.

Case	Left of page	Right of page	Into the page	Out of the page	Up the page	Down the page	Not deflected
A		✓					
B				✓			
C				✓			
D					✓		

Description	Marks
A. tick indicating right of page	1
B. tick indicating out of the page	1
C. tick indicating out of the page	1
D. tick indicating up the page	1
Total	**4**

Question 5 **(4 marks)**

By labelling the relevant parts, use the diagram to explain how the position of a distant star appears to change when the Sun passes between the star and Earth.

Description	Marks
massive objects like the Sun curve spacetime	1
the curvature determines the motion of light around the mass	1
light from a distant star (labelled on diagram) changes direction around the Sun (follows the curvature of spacetime)	1
the observer on Earth sees the star in a different position (labelled on diagram)	1
Total	**4**

Question 6 **(4 marks)**

Explain why the metal disc will heat up if it is spun quickly. You must reference specific laws in your answer.

Description	Marks
according to Faraday's law, the spinning conductor moving through the magnetic field will induce an emf that generates eddy currents	1
Lenz's law states that the direction of an eddy current is such that it produces a magnetic field that interacts with the external magnetic field to cause a force opposing the motion of the metal disc	1
eddy currents generate heat due to the resistance of the metal	1
when the disc is spun quickly, the induced eddy currents are larger and the heating effect is more pronounced	1
Total	**4**

Question 7 **(4 marks)**

Calculate the frequency of a photon with a momentum of 3.05×10^{-24} N s.

Element	Description	Marks
Uses $E = pc$		1
Equates two photon energy equations	$pc = hf$	1
Isolates frequency	$f = \frac{pc}{h} = \frac{\left(3.05\times10^{-24}\right)\left(3.00\times10^{8}\right)}{6.63\times10^{-34}}$	1
Calculates correct answer	$f = 1.38\times10^{18}$ Hz	1
	Total	**4**

Question 8 **(4 marks)**

If Earth launched a spacecraft to explore Alpha Centauri, estimate how long, in years, it would take to get there if the spacecraft travelled in a straight line, at an average non-relativistic speed of 2.50×10^{5} km hr^{-1}.

Element	Description	Marks
Converts ly to km	$\left(4.2441\right)\left(9.46\times10^{12}\right) = 4.0149\times10^{13}$ km	1
Calculates number of hours	$\frac{4.0149\times10^{13}}{2.50\times10^{5}} = 1.606\times10^{8}$ h	1
Converts hours to years	$\frac{1.606\times10^{8}}{(24)(365)}$	1
Calculates correct answer	1.83×10^{4} years	1
	Total	**4**
Note: if candidates use 1.00 year $= 365.25$ days, $t = 1.83\times10^{4}$ years.		

Question 9 **(5 marks)**

Assuming their orbits are circular, calculate the ratio of the orbiting period of Phobos to Deimos.

Element	Description	Marks
Creates expressions for the period of each moon using Kepler's 3rd Law	$T_P^2 = \frac{4\pi^2 r_P^3}{GM}$ and $T_D^2 = \frac{4\pi^2 r_D^3}{GM}$	1
Divides T_P^2 by T_D^2 and simplifies	$\frac{T_P^2}{T_D^2} = \frac{r_P^3}{r_D^3}$	1
Takes the square roots of both sides to obtain ratio $\frac{T_P}{T_D}$	$\frac{T_P}{T_D} = \sqrt{\frac{r_P^3}{r_D^3}}$	1
Converts to m and substitutes correct values	$\frac{T_P}{T_D} = \sqrt{\frac{\left(9.38\times10^6\right)^3}{\left(2.35\times10^7\right)^3}}$	1
Calculates correct value	$\frac{T_P}{T_D} = 0.252$	1
	Total	**5**

Question 10 **(6 marks)**

Determine the maximum potential difference across the plates that the stationary electron can move through before relativistic effects must be considered.

Element	Description	Marks
Equates electrical potential energy to kinetic energy	$Vq = \frac{1}{2}mv^2$	1
Isolates V correctly	$V = \frac{mv^2}{q}$	1
Uses m_e and q (electron charge)		1
Uses 0.500 $c = 1.50\times10^8$ m s^{-1}		1
Substitutes into V	$V = \frac{\left(9.11\times10^{-31}\right)\left(1.50\times10^8\right)^2}{(2)\left(1.60\times10^{-19}\right)}$	1
Calculates correct answer	$V = 6.40\times10^4$ V	1
	Total	**6**

Question 11 **(8 marks)**

(a) Calculate the wavelengths absorbed in nanometres (nm). (7 marks)

Element	Description	Marks
Calculates largest energy (shortest wavelength) of incoming photons	$\frac{\left(6.63\times10^{-34}\right)\left(3.00\times10^{8}\right)}{96.2\times10^{-9}}=2.0676\times10^{-18}$ J	1
Converts to eV	$\frac{2.0676\times10^{-18}}{1.60\times10^{-19}}=12.92$ eV	1
Calculates the maximum energy absorbed by electron	$-13.61+12.92=-0.69$ eV	1
Chooses correct highest level	-0.85 eV	1
Calculates wavelength $1\rightarrow2$	$\left(-3.40-\left(-13.61\right)\right)\left(1.60\times10^{-19}\right)=\frac{hc}{\lambda}$ $\lambda=\frac{\left(6.63\times10^{-34}\right)\left(3.00\times10^{8}\right)}{\left(-3.40-\left(-13.61\right)\right)\left(1.60\times10^{-19}\right)}$ $\lambda=122$ nm	1
Calculates $1\rightarrow3$	$\left(-1.51-\left(-13.61\right)\right)\left(1.60\times10^{-19}\right)=\frac{hc}{\lambda}$ $\lambda=\frac{\left(6.63\times10^{-34}\right)\left(3.00\times10^{8}\right)}{\left(-1.51-\left(-13.61\right)\right)\left(1.60\times10^{-19}\right)}$ $\lambda=103$ nm	1
Calculates $1\rightarrow4$	$\left(-0.85-\left(-13.61\right)\right)\left(1.60\times10^{-19}\right)=\frac{hc}{\lambda}$ $\lambda=\frac{\left(6.63\times10^{-34}\right)\left(3.00\times10^{8}\right)}{\left(-0.85-\left(-13.61\right)\right)\left(1.60\times10^{-19}\right)}$ $\lambda=97.4$ nm	1
	Total	**7**

(b) How many photons are released by the hydrogen atom when the electron returns to the ground state? (1 mark)

Element	Description	Marks
Calculates correct number of lines from answer in part (a)	6	1
	Total	**1**

Question 12 **(6 marks)**

The density of an object is calculated by dividing its mass by its volume. Calculate the density of the object in g mL^{-1} and include the absolute uncertainty. Give your answer to the correct number of significant figures.

Element	Description	Marks
Calculates percentage uncertainty for mass	$\frac{0.1}{3.6} \times 100\% = 2.78\%$	1
Calculates percentage uncertainty for volume	$\frac{0.2}{24.2} \times 100\% = 0.83\%$	1
Adds percentages	$2.78\% + 0.83\% = 3.61\%$	1
Performs calculation for density	$\frac{3.6}{24.2} = 0.15$ g mL^{-1}	1
Expresses density with uncertainty	0.15 ± 0.0054 g mL^{-1}	1
2 significant figures		1
	Total	**6**

Section Two: Problem-solving **50% (98 Marks)**

Question 13 **(13 marks)**

(a) Calculate the velocity of Y as measured by X. (3 marks)

Element	Description	Marks
Uses correct sign convention in equation of choice i.e. velocities must be opposite directions		1
Substitutes correct values into equation	$u' = \frac{(-0.600\,c - 0.600\,c)}{(1 + 0.36)}$	1
Calculates correct answer	$u' = -0.882\,c$	1
	Total	**3**

(b) Calculate the velocity of the missile as measured by X. (4 marks)

Element	Description	Marks
Uses velocity of Y relative to X from part (a)		1
Uses correct sign conventions		1
Calculates the velocity of the missile as measured by X	$u = \frac{(-0.882\,c - 0.200\,c)}{(1 + (-0.882\,c)(-0.200\,c))}$	1
Calculates correct answer	$u = -0.920\,c$	1
	Total	**4**

Alternative solution

Element	Description	Marks
Calculates the velocity of missile in O's frame of reference using correct sign convention	$u = \frac{(-0.200\,c - 0.600\,c)}{(1 + (0.200)(0.600))}$	1
Calculates correct answer	$u = -0.714\,c$	1
Calculates the velocity of the missile as measured by X	$u' = \frac{(-0.714\,c - 0.600\,c)}{(1 - (-0.714\,c)(0.600\,c))}$	1
Calculates correct answer	$u' = -0.920\,c$	1
	Total	**4**

(c) X's radio receivers are tuned to a very narrow band of radio frequencies. Y transmitted the warning signal using the same narrow frequency band. X did not respond to the warning signal sent by Y before Y fired the missile. Explain why X failed to detect the signal and what X could have done to receive the warning signal. (4 marks)

Description	Marks
due to approaching source of signal, Doppler effect occurs	1
wavelength of wave received by X is shortened	1
X's receiver does not pick up shorter wavelengths	1
can be fixed by tuning X's receiver to a shorter wavelength	1
Total	**4**
Note: candidates do not have to state each point separately to obtain full marks. Must mention moving source, shorter wavelength and change of receiver input.	

(d) Determine the speed that observer O sees the gap between X and Y closing. (2 marks)

Element	Description	Marks
Adds the speeds	$0.600\,c + 0.600\,c = 1.20\,c$	1
Converts to m s^{-1}	$(1.20)\left(3.00\times10^{8}\right) = 3.60\times10^{8}$ m s^{-1}	1
	Total	**2**

Question 14 **(18 marks)**

(a) Calculate the speed of the proton as it enters the magnetic field. Express your answer in terms of c to **three** significant figures. (7 marks)

Element	Description	Marks
Uses correct equation	$E = \dfrac{mc^2}{\sqrt{1-\dfrac{v^2}{c^2}}}$	1
Squares both sides	$E^2 = \dfrac{\left(mc^2\right)^2}{1-\dfrac{v^2}{c^2}}$	1
Isolates $\dfrac{v}{c}$	$\dfrac{v}{c} = \sqrt{1-\dfrac{\left(mc^2\right)^2}{E^2}}$	1
Inserts correct values	$\dfrac{v}{c} = \sqrt{1-\dfrac{\left(\left(1.67\times10^{-27}\right)\left(3.00\times10^{8}\right)^2\right)^2}{\left(\left(1131\times10^{6}\right)\left(1.60\times10^{-19}\right)\right)^2}}$	1
Calculates $\dfrac{v}{c}$	$\dfrac{v}{c} = \sqrt{1-0.6898}$	1
Calculates v	$v = 0.557\,c$	1
3 significant figures		1
	Total	**7**

Question 14 (continued)

(b) Calculate the magnitude of the momentum of the proton as it enters the magnetic field. (6 marks)

Element	Description	Marks
Uses correct equation	$E^2 = p^2c^2 + m^2c^4$	1
Isolates p^2c^2	$p^2c^2 = E^2 - m^2c^4$	1
Isolates p	$p = \sqrt{\dfrac{E^2 - m^2c^4}{c^2}}$	1
Substitutes correct values	$p = \sqrt{\dfrac{\left(\left(1131\times10^{6}\right)\left(1.60\times10^{-19}\right)\right)^2 - \left(1.67\times10^{-27}\right)^2\left(3.00\times10^{8}\right)^4}{\left(3.00\times10^{8}\right)^2}}$	1
Simplifies expression	$p = \dfrac{1.008\times10^{-10}}{3.00\times10^{8}}$	1
Calculates correct answer	$p = 3.36\times10^{-19}$ N s	1
	Total	**6**

(c) Use your answer from part (b) to calculate the distance d shown in the diagram on page 18. (5 marks)

Element	Description	Marks
Uses $\dfrac{mv^2}{r} = qvB$		1
Isolates r	$r = \dfrac{mv}{qB}$, where $p = mv$	1
Uses correct values	$r = \dfrac{3.36\times10^{-19}}{\left(1.60\times10^{-19}\right)\left(4.50\right)}$	1
Calculates correct r	$r = 0.467$ m	1
Doubles to obtain distance d	$d = 0.934$ m	1
	Total	**5**

Question 15 **(20 marks)**

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

Element	Description	Marks
Uses $\sum F = 0$		1
Equates vertical frictional force and $T\cos 12.3°$ to weight force	$8.45 + T\cos 12.3° = (8.95)(9.80)$	1
Rearrange for T correctly	$T = \dfrac{87.7 - 8.45}{\cos 12.3°}$	1
Calculates correct answer	$T = 81.1\,\text{N}$	1
	Total	**4**

(b) Calculate the net reaction force of the wall on the metal sphere. If you could not get an answer to part (a), use 1.00 × 10^2 N. (5 marks)

Element	Description	Marks
Calculates horizontal force of the wall on the metal sphere	$F_{\text{horizontal}} = T\sin 12.3°$ $= 81.1\sin 12.3°$ $= 17.3\,\text{N}$	1
Uses Pythagorean theorem to determine the magnitude of net reaction force of the wall on the metal sphere	$F_{\text{net}} = \sqrt{8.45^2 + 17.3^2}$	1
Calculates correct magnitude of net reaction force	$F_{\text{net}} = 19.2\,\text{N}$	1
Uses correct values for trigonometric function selected	$\tan\theta = \dfrac{8.45}{17.3}$	1
Calculates correct angle for net reaction force	$\theta = 26.0°$ to the horizontal	1
	Total	**5**
Note: if uses 1.00×10^2 N, $F_{\text{horizontal}} = 21.3\,\text{N}$, $F_{\text{net}} = 22.9\,\text{N}$ at $21.6°$ to the horizontal.		

Question 15 (continued)

(c) Calculate the tension in the string at the bottom of its swing. (8 marks)

Element	Description	Marks
Determines equation for change in height of metal sphere	$\Delta h = 0.254 - 0.254\cos 12.3°$	1
Calculates correct change in height	$\Delta h = 0.006\ \text{m}$	1
Equates conservation of energy equations	$\frac{1}{2}mv^2 = mg\Delta h$	1
Rearranges conservation of energy to isolate v and substitutes correctly	$\frac{1}{2}v^2 = g\Delta h$ $v = \sqrt{2g\Delta h}$ $v = \sqrt{2(9.80)(0.006)}$	1
Calculates correct answer for v	$v = 0.343\ \text{m s}^{-1}$	1
Uses correct equation for T	$T = \frac{mv^2}{r} + mg$	1
Substitutes correct values	$T = \frac{(8.95)(0.343)^2}{0.248} + (8.95)(9.80)$	1
Calculates correct answer	$T = 92.0\ \text{N}$	1
	Total	**8**

(d) Calculate the tension in the string. (3 marks)

Element	Description	Marks
Uses correct trigonometric function	$\cos 12.3° = \frac{mg}{T}$	1
Rearranges for T correctly	$T = \frac{(8.95)(9.80)}{\cos 12.3°}$	1
Calculates correct answer	$T = 89.8\ \text{N}$	1
	Total	**3**

Question 16 **(16 marks)**

(a) Calculate the maximum wavelength of the photon required for the reaction to take place, assuming that energy is conserved. (6 marks)

Element	Description	Marks
States $m(\text{electron}) = m(\text{positron})$		1
Uses $mc^2 = hf$	$2mc^2 = hf$	1
Substitutes $\frac{c}{\lambda}$ for f	$2mc^2 = \frac{hc}{\lambda}$	1
Isolates λ	$\lambda = \frac{h}{2mc}$	1
Substitutes correct values	$\lambda = \frac{6.63\times10^{-34}}{2\left(9.11\times10^{-31}\right)\left(3.00\times10^{8}\right)}$	1
Calculates the correct answer	$\lambda = 1.21\times10^{-12}$ m	1
	Total	**6**
Note: candidates can use $0.511\,\text{MeV/c}^2$ for the mass of the electron and positron.		

(b) Using your answer from part (a), calculate the momentum of the incoming photon. If you could not get an answer to part (a), use 1.20×10^{-12} m. (3 marks)

Element	Description	Marks
Equates $E = \frac{hc}{\lambda} = pc$ to obtain p	$p = \frac{h}{\lambda}$	1
Substitutes correct values	$p = \frac{6.63\times10^{-34}}{1.21\times10^{-12}}$	1
Calculates correct answer	$p = 5.48\times10^{-22}$ N s	1
	Total	**3**
Note: if uses 1.20×10^{-12} m, $p = 5.52\times10^{-22}$ N s .		

Question 16 (continued)

(c) After the collision, the momentum of the electron and positron are equal in magnitude, 2.3865×10^{-22} N s. The momentum of the heavy nucleus is 0.784×10^{-22} N s. Assuming momentum is conserved, calculate the value of θ using your answer from part (b) on page 22 and components of the momentum vector. (7 marks)

Element	Description	Marks
Uses conservation of momentum in horizontal direction.	$\sum p_i = \sum p_f$ $p_{\text{proton}} = p_{\text{nucleus}} + 2p_{\text{horizontal}}$	1
Uses 2 x momentum		1
Takes correct component of momentum of electron and positron	$p_{\text{horizontal}} = p\cos\theta$	1
Sets up conservation of momentum equation	$5.48\times10^{-22} = 0.784\times10^{-22} + (2)\left(2.3865\times10^{-22}\right)\cos\theta$	1
Isolates $\cos\theta$	$\cos\theta = \dfrac{5.48\times10^{-22} - 0.784\times10^{-22}}{(2)\left(2.3865\times10^{-22}\right)}$	1
Calculates $\cos\theta$	$\cos\theta = 0.9839$	1
Calculate θ	$\theta = 10.3°$	1
	Total	**7**
Note: if uses $p = 5.52\times10^{-22}$ N s from part (b), $\theta = 7.14°$.		

Question 17 **(19 marks)**

(a) Calculate the maximum height the cannon ball reaches above ground level. (5 marks)

Element	Description	Marks
Calculates vertical component of velocity	$v_{\text{vertical}} = 66.0\sin 30.0°$ $= 33.0 \text{ m s}^{-1}$	1
Uses $v_f^{\,2} = v_i^{\,2} + 2as$ with a negative	$0^2 = 33.0^2 + 2(-9.80)(s)$	1
Rearranges for s	$s = \dfrac{0^2 - 33.0^2}{(2)(-9.80)}$	1
Calculates s	$s = 55.56 \text{ m}$	1
Calculates correct height above ground level	$h = 55.56 + 5.25$ $= 60.8 \text{ m}$	1
	Total	**5**

(b) Calculate how far from the base of the cannon the cannon ball lands. (6 marks)

Element	Description	Marks
Uses $s = v_i\Delta t + \frac{1}{2}a\Delta t^2$ with correct substitution	$-5.25 = (33.0)(\Delta t) - \left(\frac{1}{2}\right)(9.80)(\Delta t^2)$	1
Rearranges equation to equal zero	$4.90(\Delta t^2) - 33.0(\Delta t) - 5.25 = 0$	1
Correctly solves for Δt	$\Delta t = 6.89$ s	1
Calculates $v_{\text{horizontal}}$	$v_{\text{horizontal}} = 66.0\cos 30.0°$ $= 57.2$ m s^{-1}	1
Uses $s_{\text{horizontal}} = (v_{\text{horizontal}})(\Delta t)$	$s_{\text{horizontal}} = (57.2)(6.89)$	1
Calculates correct answer	$s_{\text{horizontal}} = 394$ m	1
	Total	**6**

Alternative solution one

Element	Description	Marks
Uses $v_f^{\,2} = v_i^{\,2} + 2as$ with a and s negative	$v_f^{\,2} = 33.0^2 + 2(-9.80)(-5.25)$	1
Calculates correct value for v_f	$v_f = 34.5$ m s^{-1}	1
Uses $v_f = v_i + a\Delta t$ with v_f and a negative	$-34.5 = 33.0 + (-9.80)(\Delta t)$	1
Solves correctly for Δt	$\Delta t = 6.89$ s	1
Uses $s_{\text{horizontal}} = (v_{\text{horizontal}})(\Delta t)$	$s_{\text{horizontal}} = (66.0\cos 30.0°)(6.89)$	1
Calculates correct answer	$s_{\text{horizontal}} = 394$ m	1
	Total	**6**

Alternative solution two

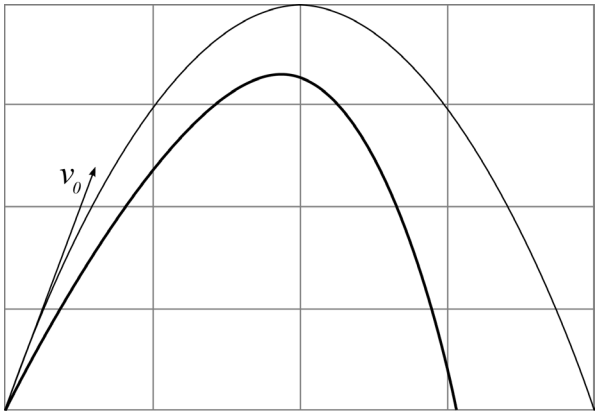
Element	Description	Marks
Uses $v_f = v_i + a\Delta t$ to calculate Δt to highest point	$0 = 33.0 + (-9.80)(\Delta t)$	1
Calculates correct value for Δt	$\Delta t = 3.37$ s	1
Uses $s = v_i\Delta t + \frac{1}{2}a\Delta t^2$ to calculate t to ground	$s = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $60.8 = (0)(\Delta t) + \frac{1}{2}(9.80)(\Delta t^2)$ $\Delta t = \sqrt{\frac{60.8}{4.90}}$ $\Delta t = 3.52$ s	1
Calculates total Δt	$3.37 + 3.52 = 6.89$ s	1
Uses $s_{\text{horizontal}} = (v_{\text{horizontal}})(\Delta t)$	$s_{\text{horizontal}} = (66.0\cos 30.0°)(6.89)$	1
Calculates correct answer	$s_{\text{horizontal}} = 394$ m	1
	Total	**6**

Question 17 (continued)

(c) Determine at what time/s the cannon ball is 2.00 m above the launch height. (4 marks)

Element	Description	Marks
Uses $s = v_i\Delta t + \frac{1}{2}a\Delta t^2$ with $s = 2.00$ m and a negative	$2.00 = 33.0\Delta t + \frac{1}{2}(-9.80)\Delta t^2$	1
Rearranges equation to equal zero	$4.90(\Delta t^2) - 33.0(\Delta t) + 2.00 = 0$	1
Substitutes correct values into quadratic equation to solve for Δt	$\Delta t = \frac{33.0 \pm \sqrt{(-33.0)^2 - 4(4.90)(2.00)}}{2(4.90)}$	1
Solves both values of Δt	$\Delta t = 6.12\times10^{-2}$ s and 6.67 s	1
	Total	**4**

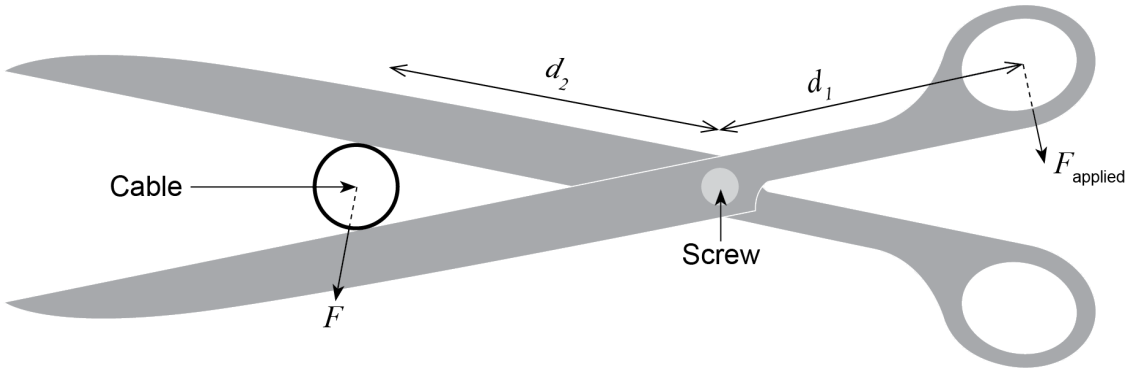
(d) On the same diagram, draw the path of an identical projectile fired at the same velocity and angle when air resistance is a factor. Your diagram must show where it lands. (4 marks)



Description	Marks
not as steep	1
not as high	1
not as far	1
not symmetrical	1
Total	**4**

Question 18 **(12 marks)**

(a) By labelling the relevant parts on the diagram below, explain why the cable was able to be cut when Alistair put it closer to the screw. (5 marks)



Description	Marks
labels the diagram appropriately, showing forces and distances from the screw	1
total force exerted by Alistair x distance to pivot ($\left(F_{applied}\right)\left(d_1\right)$) remains constant	1
$\left(F\right)\left(d_2\right)=\left(F_{applied}\right)\left(d_1\right)$	1
$\Rightarrow d_2 \propto F_{applied}$	1
as the cable moves closer to the screw, d_2 decreases causing F to increase	1
Total	**5**

Question 18 (continued)

(b) With reference to the diagram below, calculate the distance R (to **three** significant figures) from the pivot to the point of contact between the blades and the cable. As the scissors are symmetrical, only one blade needs to be considered. (7 marks)

Element	Description	Marks
Uses $\Sigma acm = \Sigma cm$ around pivot to solve problem		1
Uses $\frac{2.50\times10^{2}}{2}=1.25\times10^{2}$ for required downward force		1
Uses $\frac{1.25\times10^{2}}{\cos 7.5°}\times R$ for Σacm	$\left(\frac{1.25\times10^{2}}{\cos 7.5°}\right)(R)=126.1R$ Nm	1
Uses $\left(1.20\times10^{2}\right)\left(\cos 30.0°\right)\left(0.05\right)$ for Σcm	$\left(1.20\times10^{2}\right)\left(\cos 30.0°\right)\left(0.0500\right)=5.196$ Nm	1
Substitutes correct values into $\Sigma acm = \Sigma cm$	$126.1R=5.196$	1
Calculates correct answer	$R=0.0412$	1
3 significant figures	$R=4.12\times10^{-2}$ m	1
	Total	**7**
Note: accept correct answer in cm.		

Section Three: Comprehension and data analysis **20% (38 Marks)**

Question 19 **(18 marks)**

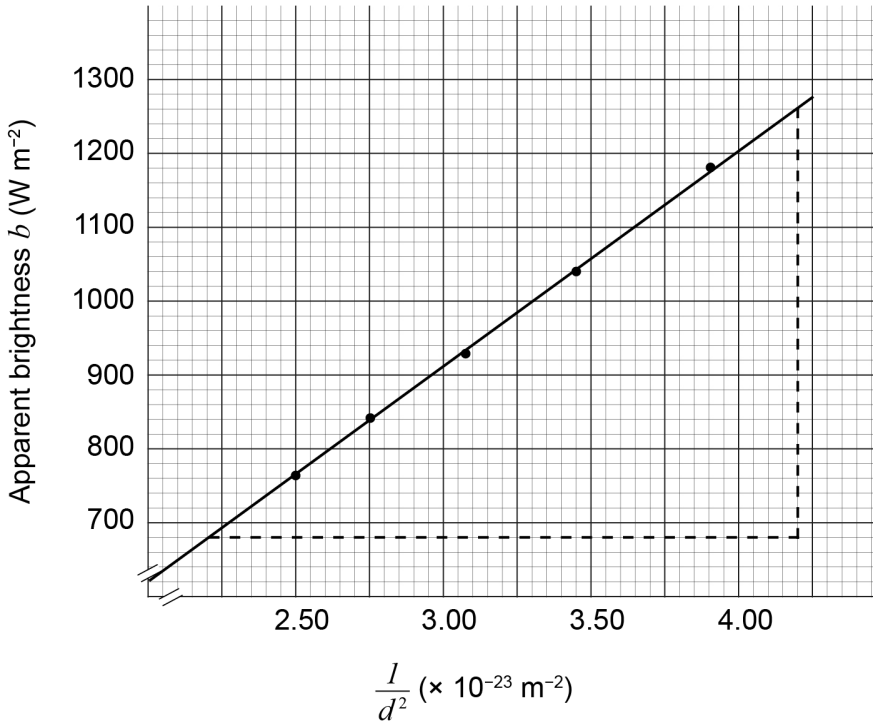
(a) Complete the table above by calculating $\frac{1}{d^2}$. Give your answers to **three** significant figures. (3 marks)

Distance d (× 10^9 m)	160	170	180	190	200
Apparent brightness b (W m^{-2})	1180	1040	930	840	760
$\frac{1}{d^2}$ (× 0^{-23} m^{-2})	3.91	3.46	3.09	2.77	2.50

Description	**Marks**
Calculates correctly any 4 values of $\frac{1}{d^2}$	1
Calculates correctly all 5 values of $\frac{1}{d^2}$	1
3 significant figures	1
Total	**3**

Question 19 (continued)

(b) On the grid below, graph apparent brightness b versus $\frac{1}{d^2}$. Include a line of best fit and label the axes. (4 marks)



Description	Marks
axes labelled with correct values and units	1
points plotted accurately	1
all points plotted	1
appropriate line of best fit	1
Total	**4**

(c) (i) Calculate the gradient of your line of best fit from part (b) on page 30. Indicate clearly on the graph the **two** points used in your calculation. Give your answer to **two** significant figures and provide the correct unit. (5 marks)

Element	Description	Marks
Clearly indicates two points (not data points)		1
Places coordinates in equation correctly	Gradient $= \frac{\Delta y}{\Delta x}$ $= \frac{1260 - 680}{4.20\times10^{-23} - 2.20\times10^{-23}}$	1
Calculates correct gradient of line of best fit (allowed range)	$2.9\times10^{25} \pm 0.1\times10^{25}$	1
Uses correct unit	W	1
2 significant figures		1
	Total	**5**

(ii) Use the calculated gradient from part (c)(i) to calculate the luminosity of our Sun. (3 marks)

Element	Description	Marks
Uses gradient $= \frac{L}{4\pi}$	$2.9\times10^{25} = \frac{L}{4\pi}$	1
Rearranges for L	$L = \left(2.9\times10^{25}\right)\left(4\pi\right)$	1
Calculates correct answer	$L = 3.6\times10^{26}$ W	1
	Total	**3**
Note: accept answer with 3 significant figures (3.64×10^{26} W).		

(iii) Calculate the percentage difference between your answer calculated in part (c)(ii) and the value provided in the text on page 29. (3 marks)

Element	Description	Marks
Uses correct equation (divides difference by given value)	$\frac{3.84\times10^{26} - 3.6\times10^{26}}{3.84\times10^{26}}$	1
Calculates correct answer	6.2×10^{-2}	1
Expresses as a percentage	6.2%	1
	Total	**3**
Note: accept answer with 3 significant figures (6.25%).		

Question 20 **(20 marks)**

(a) Explain why the train slows down when the motor is disconnected from the supply. Include an appropriate law of Physics in your answer. (4 marks)

Description	Marks
when disconnected from the supply, the coil continues to spin	1
the back emf continues to be produced	1
Lenz's law states the induced current flows in such a way to try and stop the coil rotating	1
as the coil is still attached to the wheels, this slows the train down	1
Total	**4**

(b) (i) Calculate the maximum back emf produced by a 50 Hz AC motor if the armature consists of a 25.0 cm^2 coil with 50 turns spinning in a 0.370 T magnetic field. (3 marks)

Element	Description	Marks
Uses correct equation	$\text{emf}_{max} : \varepsilon_{max} = 2\pi NBAf$	1
Substitutes correct values	$\varepsilon_{max} = 2\pi(50)(0.370)\left(25.0\times10^{-4}\right)(50)$	1
Calculates correct answer	$\varepsilon_{max} = 14.5 \text{ V}$	1
Total		**3**

(b) (ii) Calculate the root mean square, rms, voltage induced in the coil. (1 mark)

Element	Description	Marks
Calculates correct ε_{rms}	$\varepsilon_{rms} = \frac{\varepsilon_{max}}{\sqrt{2}}$ $\varepsilon_{rms} = \frac{14.5}{\sqrt{2}}$ $= 10.3 \text{ V}$	1
Total		**1**

(b) (iii) Calculate the net voltage supplied to the motor if the applied rms voltage is 32.0 V. (2 marks)

Element	Description	Marks
Correctly substitutes into equation	$V_{net} = V_{applied} - V_{back}$ $= 32.0 - 10.3$	1
Calculates correct answer	$V_{net} = 21.7 \text{ V}$	1
Total		**2**
Note: candidates cannot get the second mark if their expression is incorrect.		

(b) (iv) Explain what would happen to the net voltage if the load was decreased and the coil spun faster. (3 marks)

Description	Marks
if f increases, back emf increases	1
but the applied voltage remains constant	1
hence, the net voltage would decrease	1
Total	**3**

(c) If the electric motor in a train seizes (the armature containing the coils stop moving), it will overheat. Explain why overheating happens. (3 marks)

Description	Marks
if the coil is not moving no back emf is produced	1
as net voltage increases, current in the coil increases	1
extra current produces heat in the coil	1
Total	**3**

(d) Trains that have regenerative braking systems do not rely exclusively on this system. Explain why it would be unsafe to rely solely on regenerative braking to stop trains. (4 marks)

Description	Marks
back emf depends on frequency of rotation and speed of the train	1
as the train slows, the back emf reduces and the braking effect decreases	1
the train requires a fixed distance to stop or may need to brake in an emergency	1
hence, a mechanical braking system is required to ensure the train can brake quickly	1
Total	**4**

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