

Markscheme

May 2025

Physics

Higher level

Paper 2

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Subject Details: Physics HL Paper 2 Markscheme**Mark Allocation**

Candidates are required to answer ALL questions. Maximum total = [90 marks].

1. Each row in the “Question” column relates to the smallest subpart of the question.
2. The maximum mark for each question subpart is indicated in the “Total” column.
3. Each marking point in the “Answers” column is shown by means of a tick (✓) at the end of the marking point.
4. A question subpart may have more marking points than the total allows. This will be indicated by “max” written after the mark in the “Total” column. The related rubric, if necessary, will be outlined in the “Notes” column.
5. For numerical answers, a correct answer with no working is awarded full marks UNLESS stated otherwise in the “Notes”. For correct numerical answers with working the working must be checked. If the working contains minor omissions or errors full marks are awarded. If the working contains wrong Physics or wrong method the correct answer obtained will be the result of numerical coincidence. In that case the answer is penalized.
6. An alternative wording is indicated in the “Answers” column by a slash (/). Either wording can be accepted.
7. An alternative answer is indicated in the “Answers” column by “OR” between the alternatives. Either answer can be accepted.
8. Words in angled brackets « » in the “Answers” column are not necessary to gain the mark.
9. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
10. If the candidate’s answer has the same “meaning” or can be clearly interpreted as being of equivalent significance, detail and validity as that in the “Answers” column then award the mark.
11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
12. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in a marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then error carried forward (ECF) marks should be awarded. When marking, indicate this by adding ECF on the script. When ECF is not to be applied “Do not allow ECF” will be displayed in the “Notes” column.
13. Do not penalize candidates for errors in units or significant figures, unless it is specifically referred to in the “Notes” column.
14. Allow alternative formats such as c for rad or use of E for scientific notation.

Question			Answers	Notes	Total
1.	a		<p>ALT 1</p> <p>KE before is $\frac{1}{2} \times 3.0 \times 6.0^2 = 54 \text{ J} \checkmark$</p> <p>KE after is $\frac{1}{2} \times 3.0 \times 2.0^2 + \frac{1}{2} \times 6.0 \times 4.0^2 = 54 \text{ J} \checkmark$</p> <p>ALT 2</p> <p>In elastic collisions relative velocity remains constant in magnitude \checkmark</p> <p>$6 - 0 = -2 - 4 \checkmark$</p>	Ignore references to conservation of momentum	[2]
	b	i	<p>$F = \frac{6.0 \times 4.0}{40 \times 10^{-3}} \text{ OR } F = \frac{3.0 \times (6.0 - (-2.0))}{40 \times 10^{-3}} \checkmark$</p> <p>$F = 6.0 \times 10^2 \text{ N} \checkmark$</p>	Allow ECF from a wrong time interval. If the final answer is incorrect, award MP1 for [1max] for any attempt to use rate of change of momentum or mass x acceleration with wrong data values for masses and velocities.	[2]
	b	ii	<p>Alternative 1</p> <p>$\Delta E_K = \frac{1}{2} \cdot 6.0 \cdot 4.0^2 \text{ OR } 48 \text{ J} \checkmark$</p> <p>$P = \ll \frac{\Delta E_K}{\Delta t} = \gg \frac{48}{40 \times 10^{-3}} = 1200 \text{ W} \checkmark$</p> <p>Alternative 2</p> <p>$\bar{P} = \bar{F} \frac{u+v}{2} \checkmark$</p> <p>$\bar{P} = 600 \times \frac{0+4.0}{2} = 1200 \text{ W} \checkmark$</p>	Award [2] if 1200 <<W>> is seen as the answer without working Award [1] for 2400 W. Allow ECF from bi) in ALT 2.	[2]

	b	iii	KE is $\frac{1}{2} \times (3.0 + 6.0) \times 2.0^2 = 18 \text{ J} \checkmark$ PE is $54 - 18 = 36 \text{ J} \checkmark$	<i>Allow ECF from MP1</i>	[2]
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Question		Answers	Notes	Total
2.	a	<p>ALT 1 (in solids)</p> <p>reference to particle/atomic vibrations OR kinetic energy transferred ✓</p> <p>via collisions OR between adjacent particles/atoms ✓</p> <p>ALT 2 (in metallic conductors)</p> <p>reference to motion of electrons ✓ that collide with atoms/ions ✓</p>		[2]
	b	<p>$\ll \frac{\Delta Q}{\Delta t} = kA \frac{\Delta T}{\Delta x} = \frac{1.3 \times 18 \times (22 - 13)}{0.25} \gg 8.4 \times 10^2 \quad \checkmark$</p> <p>Unit is W / Js⁻¹ / kgm² s⁻³ ✓</p>	Ignore the sign in MP1	[2]
	c	i	<p>Identifies gradient as rate of thermal energy transfer OR temperature difference is decreasing ✓</p>	[1]
	c	ii	<p>ALT 1</p> <p>$N_0 = \frac{PV}{kT_0}$ and $N = \frac{PV}{kT}$ OR 295 and 279 seen ✓</p> <p>$\frac{\Delta N}{N_0} = \frac{\frac{PV}{k \times 279} - \frac{PV}{k \times 295}}{\frac{PV}{k \times 295}} \quad \checkmark$</p> <p>$\ll \frac{\Delta N}{N_0} = \frac{16}{279} = \gg 0.057 \text{ OR } 5.7 \% \quad \checkmark$</p>	[3]

		<p>ALT 2</p> <p>$NT = \text{constant}$ OR $nT = \text{constant}$ OR 295 AND 279 seen ✓</p> <p>$\ll \frac{N_2}{N_1} \text{ OR } \frac{n_2}{n_1} = \gg \frac{295}{279}$ seen ✓</p> <p>5.7 % ✓</p>	<p><i>Award only MP1, [1] max, if work shown in Celsius</i></p>	
	d	<p>The heat transfer is irreversible / spontaneous / from hot to cold</p> <p>OR</p> <p>Heat is removed from the room, so entropy decreases ✓</p> <p>The same heat is deposited at a lower temperature, so outside entropy increase is larger ✓</p> <p>The entropy change of the Universe/isolated system always increases ✓</p>	<p><i>For MP1, allow an argument stating that the entropy of the room may have increased due to the increase in mass.</i></p>	[2 max]

Question		Answers	Notes	Total	
3.	a	$E = \ll \frac{120}{8.0 \times 10^{-2}} = \gg 1.5 \times 10^3 \text{ NC}^{-1} \text{ OR } \text{Vm}^{-1} \checkmark$		[1]	
	b	i	$F = \ll eE = \gg 3.2 \times 10^{-19} \times 1.5 \times 10^3 \text{ OR } 4.8 \times 10^{-16} \text{ N } \checkmark$ $a = \ll \frac{F}{m} = \gg \frac{4.8 \times 10^{-16}}{4 \times 1.67 \times 10^{-27}} \text{ OR } 7.2 \times 10^{10} \text{ ms}^{-2} \checkmark$	<p>Allow ECF from a).</p> <p>Award [1] if they use a charge of e and a mass of 2u obtaining the right result.</p>	[2]
	b	ii	<p>ALT 1</p> $t = \sqrt{\frac{2s}{a}} \checkmark$ $t = \ll \sqrt{\frac{2 \times 8.0 \times 10^{-2}}{7.2 \times 10^{10}}} = \gg 1.5 \times 10^{-6} \text{ s } \checkmark$ <p>ALT 2</p> $v = \sqrt{2as} \ll = 1.06 \times 10^5 \text{ ms}^{-1} \gg \checkmark$ $t = \ll \frac{v}{a} = \gg 1.5 \times 10^{-6} \text{ s } \checkmark$	<p>Award [2] if $1.5 \times 10^{-6} \ll \text{s} \gg$ is seen as the answer without working.</p>	[2]
	b	iii	240 eV \checkmark	Accept $3.8 \times 10^{-17} \text{ J}$	[1]
	c		$F_m = F_e \text{ OR } qvB = qE \text{ OR } B = F_e / qv \checkmark$ $B = \ll \frac{E}{v} = \frac{1.5 \times 10^3}{5.0 \times 10^5} = \gg 3.0 \times 10^{-3} \text{ T } \checkmark$	<p>Award [2] if $3.0 \times 10^{-3} \ll \text{T} \gg$ is seen as the answer without working.</p> <p>Allow ECF from a) and b) i)</p>	[2]

	d		Horizontal / undeflected path ✓		[1]

Question		Answers	Notes	Total	
4.	a	<p>Light comes from a single source ✓</p> <p>Waves need to have a constant phase difference / in phase ✓</p> <p>«To produce» a fixed/stable/clear/constant pattern «over time»</p> <p>OR</p> <p>Only coherent light has this property/produces this pattern ✓</p>		[2 max]	
	b	i	<p>Alternative 1</p> $s = \frac{\lambda D}{d} \Rightarrow \phi = \frac{s}{D} = \frac{\lambda}{d} \checkmark$ $\phi = \frac{720 \times 10^{-9}}{0.12 \times 10^{-3}} = 6.0 \times 10^{-3} \text{ rad } \checkmark$ <p>Alternative 2</p> $d \sin \frac{\phi}{2} = \frac{\lambda}{2} \Rightarrow \phi = 2 \sin^{-1} \frac{\lambda}{2d} \checkmark$ $\phi = 2 \sin^{-1} \frac{720 \times 10^{-9}}{2 \times 0.12 \times 10^{-3}} = 6.0 \times 10^{-3} \text{ rad } \checkmark$ <p>Alternative 3</p> <p><<With small angle approximation>> $d \frac{\phi}{2} = \frac{\lambda}{2} \Rightarrow \phi = \frac{\lambda}{d} \checkmark$</p> $\phi = \frac{720 \times 10^{-9}}{0.12 \times 10^{-3}} = 6.0 \times 10^{-3} \text{ rad } \checkmark$	<p>Award [2] if 6.0×10^{-3} «rad» is seen as the answer without working</p> <p>Do not penalize if answer in degrees (0.34°)</p> <p>Award [1] for an answer of 0.012 or 0.003 «rad»</p>	[2]
	b	ii	The energy missing at P ₁ and P ₂ is found at the maxima ✓	[1]	
	c		<p>Waves arrive in phase</p> <p>OR</p> <p>path difference is zero</p> <p>OR</p> <p>distance is the same ✓</p>	[1]	

	d	<p>Considers the largest wavelength OR $\theta = 90^\circ$ ✓</p> $d \sin \theta = n\lambda \Rightarrow n = \frac{10^{-3} \sin 90^\circ}{580 \cdot 650 \times 10^{-9}} = 2.65 \quad \checkmark$ <p>So the second order/$n = 2$ ✓</p>	<p><i>Award [2] if smallest wavelength used and an answer of $n = 3$.</i></p>	<p>[3]</p>
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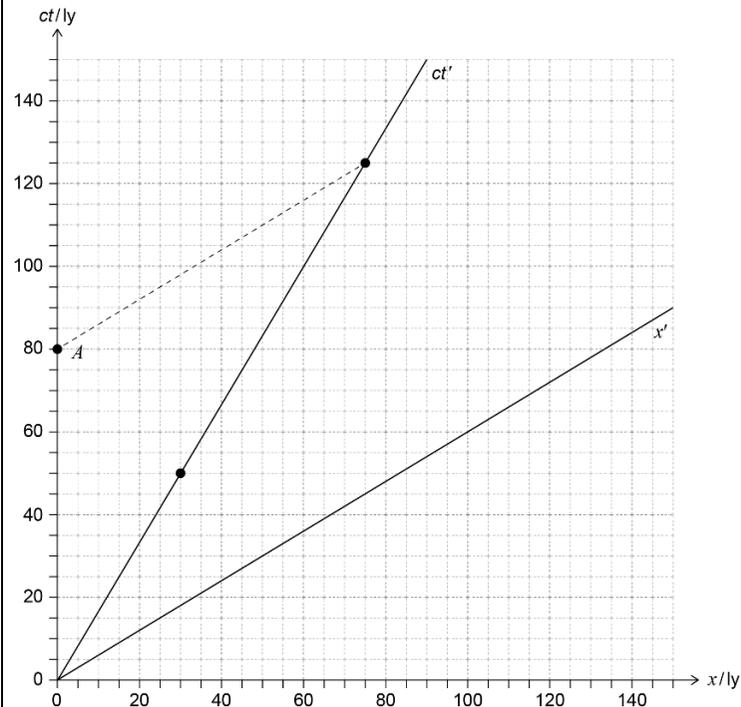
Question			Answers	Notes	Total
5.	a		Compton scattering provides evidence for «the energy and » the momentum of the photon / refers to the collision between photon and electron ✓ The photoelectric effect provides evidence for the energy of photons ✓		[2]
	b		The photon loses energy / transfers energy to the electron ✓ $E = \frac{hc}{\lambda}$ / lower energy implies longer wavelength ✓		[2]
	c	i	$E = \ll \frac{hc}{\lambda} = \gg \frac{1.24 \times 10^{-6}}{7.47 \times 10^{-12}} \text{ OR } 0.166 \text{ MeV} \quad \checkmark$		[1]
	c	ii	$E = \ll 0.194 - 0.166 = \gg 0.028 \text{ MeV} \quad \checkmark$	Accept 0.024 from the value given as show that. Allow ECF from c) i) Accept $4.5 \times 10^{-15} \text{ J}$.	[1]
	c	iii	$7.47 \times 10^{-12} - 6.40 \times 10^{-12} = 2.43 \times 10^{-12} (1 - \cos \theta) \checkmark$ « $\cos \theta = 0.5597$ so » $\theta = 56.0^\circ \quad \checkmark$	Accept angle in radians (0.98 « rad »). Award [2] if 56 «°» or 0.98 « rad » are seen as the answer without working	[2]

Question			Answers	Notes	Total
6.	a		$\gamma = \frac{1}{\sqrt{1-0.60^2}} \text{ OR } \frac{5}{4} \text{ OR } 1.25 \quad \checkmark$ $t = \gamma t' \Rightarrow t' = \frac{4}{5} \times 50 = 40 \text{ yr} \quad \checkmark$	<p>Award MP1 if seen isolated or within an equation.</p> <p>Award [2] if 40 <<yr>> is seen as the answer without working</p>	[2]
	b	i	<p>45 degree line starting at (30, 50) and ending on Earth's time axis (at A) \checkmark</p>		[1]

b

ii

Alternative 1



Line from A parallel to S space axis intersects S time axis at B: $ct = 125 \text{ ly} \checkmark$
 Knowing scale on S time axis gives S time at B of $40+40+20 = 100 \text{ yr} \checkmark$
 Time of travel is $100 - 40 = 60 \text{ yr} \checkmark$

Alternative 2

Distance separating P and Earth in S is $\frac{30}{\gamma} = 24 \text{ ly} \checkmark$

$$cT = 0.60cT + 24 \checkmark$$

$$T = \frac{24}{0.40c} = 60 \text{ yr} \checkmark$$

Accept 55 to 65 years for those using Alt 1

[3]

MP1 for Alt. 3 can be explicit from graph in (b) i

		<p>Alternative 3 Travel time for signal for Earth is 30 years so event A has time coordinate $50 + 30 = 80$ yr ✓</p> <p>S time for A is $ct' = \gamma(ct - \frac{v}{c}x) = \frac{5}{4} \times 80 = 100$ ly ✓</p> <p>Time of travel is $100 - 40 = 60$ yr ✓</p> <p>Alternative 4</p> <p>Calculate time elapsed between signal emitted and signal received as: $\Delta t = 30$ ✓ $\Delta x = -30$ ✓</p> <p>Use of Lorentz transformation to get $\Delta t' = 60$ ✓</p>	<p><i>If candidates use positive Δx and a negative velocity, award [2]</i></p>	
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Question			Answers	Notes	Total
7.	a	i	Mention of core temperature and density ✓ Core temperature implies high kinetic energy/high speed OR needed to overcome repulsion/e.m. force ✓ Density needed to increase frequency/number/probability of collisions ✓	<i>Ignore reference to mass.</i> <i>Do not award MP1 if radius and/or surface temperature are mentioned.</i>	[3]
	a	ii	<<Inwards>> gravitational force/pressure/ ✓ <<Outwards>> thermal/gas/radiation pressure/force ✓		[2]
	b		$\Delta m = 2M_{H1} - (M_{H2} + m_e) =$ $2 \times 1.007276 - 2.013550 - 0.000549 \checkmark$ $= 4.53 \times 10^{-4} \text{ u}$ $Q = 4.53 \times 10^{-4} \times 931.5 = 0.422 \approx 0.42 \text{ MeV} \checkmark$	<i>Accept $6.8 \times 10^{-14} \text{ J}$ as final answer.</i> <i>Award [1] for final answer of 0.93 MeV, if positron ignored.</i> <i>Award [1] for final answer of $1.5 \times 10^{-13} \text{ J}$ if positron ignored.</i>	[2]
	c	i	Hydrogen mass to be lost $0.1 \times 1.5 \times 10^{30} \text{ OR } 1.5 \times 10^{29} \text{ kg} \checkmark$ Number of reactions per second $\frac{3.8 \times 10^{26}}{4.3 \times 10^{-12}} \text{ OR } 8.8 \times 10^{37} \text{ s}^{-1}$ OR Time for one reaction $\frac{4.3 \times 10^{-12}}{3.8 \times 10^{26}} \text{ OR } 1.1 \times 10^{-38} \text{ s}$ OR Total mass (4H or He-4) in each reaction is $4 \times 1.67 \times 10^{-27} \text{ kg} \checkmark$ $T = \frac{0.1 \times 1.5 \times 10^{30}}{8.8 \times 10^{37} \times 4 \times 1.67 \times 10^{-27}} \text{ OR } 2.5 \times 10^{17} \text{ s OR } 8.1 \times 10^9 \text{ a} \checkmark$	<i>Award MP1 if seen isolated or in a calculation.</i> <i>Award MP2 if 4 x mass of H seen isolated or in calculation.</i> <i>Allow ECF from MP2 if they use H instead of 4H as the mass in each reaction.</i>	[3]

	c	ii	The luminosity/power output has remained constant ✓	<i>Accept rate of fusion or similar.</i>	[1]
	c	iii	<p>8.1 x 10⁹ years = 2.5 x 10¹⁷ seconds OR Energy produced while on the main sequence = $L \times t$ ✓ Mass loss = $\frac{3.8 \times 10^{26} \times 2.55 \times 10^{17}}{c^2} = 1.1 \times 10^{27} \text{ kg}$ ✓</p>		[2]
	d		<p>$\lambda = \frac{2.9 \times 10^{-3}}{T}$ ✓ $\lambda = 5.0 \times 10^{-7} \text{ m}$ ✓</p>		[2]
	e	i	<p>P is approaching ✓ wavelength decrease ✓ mention of Doppler/blueshift ✓</p>		[2 max]
	e	ii	<p>$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$ AND $v = \frac{2\pi R}{T}$ ✓ $T = \lambda_0 \frac{2\pi R}{c\Delta\lambda}$ ✓ $T = 656.2797 \times \frac{2\pi \times 7.0 \times 10^8}{3 \times 10^8 \times 4.4 \times 10^{-3}} = 2.19 \times 10^6 \text{ s} \approx 25 \text{ days}$ ✓</p>	<i>Do not penalize the use of observed wavelength.</i>	[3]

Question			Answers	Notes	Total
8.	a	i	Identifies length of cylinder as $v\Delta t$ so volume as $S \times v \times \Delta t$ to show the result ✓		[1]
	a	ii	$\Delta p = \Delta m \times v$ OR $\rho \times S \times v \times \Delta t \times v$ ✓ Force is $\frac{\Delta p}{\Delta t} = \frac{\rho \times S \times v \times \Delta t \times v}{\Delta t}$ Hence result ✓	Award [1] if solved through $F = ma$ replacing $a = \frac{\Delta v}{\Delta t}$ (therefore not using v as about constant through interval Δt)	[2]
	b	i	Identifies orbital velocity as $v = \sqrt{\frac{GM}{r}}$ ✓ $E_k = \frac{1}{2}mv^2 = \frac{GMm}{2r}$ so $E_T = \frac{GMm}{2r} - \frac{GMm}{r}$ Hence result ✓		[2]
	b	ii	The total energy is reduced OR the satellite gets closer to the surface ✓ «From $v = \sqrt{\frac{GM}{r}}$ » the satellite moves faster ✓ «From $\rho S v^2$ » the opposing force increases « because v and ρ increase » ✓ The satellite burns / crashes / falls to Earth ✓		[4]
	c	i	$P = \frac{\Delta E}{\Delta t}$ ✓ $P = \left\langle \frac{-4.5 \times 10^9}{30 \times 24 \times 3600} \right\rangle = -1.7 \times 10^3 W$ ✓	Ignore sign	[2]
	c	ii	Average height 417.5 km ✓ $v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(6.38 + 0.4175) \times 10^6}}$ OR $7.7 \times 10^3 ms^{-1}$ ✓	Accept 417.5 ± 0.3 for MP1	[2]
	c	iii	$\Delta T = \frac{Q}{mc}$ ✓ $\Delta T = \left\langle \frac{4.5 \times 10^9}{4.2 \times 10^5 \times 500} \right\rangle = 21K$ OR $21^\circ C$ ✓	Award [2] if 21 is seen as the answer without working	[2]

	c	iv	<p>Attempt to use $P = F v$ ✓ $1.7 \times 10^3 W = F \times 7.7 \times 10^3 ms^{-1}$ ✓ $F = 0.22 N$ ✓</p>	<p>Allow ECF from c) i). Ignore sign. MP3 will vary depending on their values of c) i) and c) ii, between 0.21 and 0.23</p>	[3]
	d		<p>$V = \frac{E}{E \text{ density}}$ ✓ $V = \left\langle \frac{4.5 \times 10^9}{8.5 \times 10^9} \right\rangle = 0.53 m^3$ ✓</p>	<p>Award [2] if $0.53 \ll m^3 \gg$ is seen as the answer without working</p>	[2]