

Markscheme

May 2026

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. An alternative wording is indicated in the “Answers” column by a slash (/). Either wording can be accepted.
6. An alternative answer is indicated in the “Answers” column by “**OR**” between the alternatives. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under the heading **ALTERNATIVE 1** etc. Any alternative can be accepted.
8. Words in angled brackets « » in the “Answers” column are not necessary to gain the mark.
9. Words that are underlined are essential for the mark.
10. The order of marking points does not have to be as in the “Answers” column, unless stated otherwise in the “Notes” column.
11. 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. Where this point is considered to be particularly relevant in a question it is emphasized by **OWTTE** (or words to that effect) in the “Notes” column.
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.
13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. “Allow ECF” will be displayed in the “Notes” column.
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.
15. Allow reasonable substitutions where in common usage, *eg* ° for rad.

Question			Answers	Notes	Total
1	a		$1.3 \times 9.8 \times 1.6 \times \sin 25$ OR $8.6 \text{ J } \checkmark$	Accept use of $g = 10$ leading to 8.8. Do not penalize intermediate rounding of $1.6 \sin 25 = 0.7$ leading to answers in the range 8.7-9.1	[1]
	b	i	$E_k = \left\langle \frac{1}{2} \times 1.3 \times 2.4^2 \right\rangle = 3.7 \text{ J } \checkmark$		[1]
	b	ii	ALTERNATIVE 1 Work done = $8.6 - 3.7$ OR 4.9 OR $E_g - E_k$ $\checkmark$ $\left\langle W_f = \mu \times 1.3 \times 9.8 \times \cos 25 \times 1.6 \text{ so } \right\rangle \mu = 0.26 \checkmark$ ALTERNATIVE 2 $\left\langle v^2 = 2ad \text{ so } \right\rangle a = 1.8 \text{ ms}^{-2} \checkmark$ $\left\langle a = g(\sin 25 - \mu \cos 25) \text{ so } \right\rangle \mu = 0.26 \checkmark$	Accept in the range 0.25 - 0.29 due to rounding, use of $g = 10$ or use of given value of 9 J. For the work done, accept other consistent alternatives, e.g. $9 - 3.7$ Allow ECF from b) i) Allow ECF from MP1	[2]
	c		$E_g = E_k + E_{rk} \checkmark$ $v = \omega r$ OR $E_{rk} = \frac{1}{2} \times \frac{2}{5} \times mr^2 \times \frac{v^2}{r^2} \checkmark$ $v = 3.1 \text{ m s}^{-1} \checkmark$	Accept CNA Allow [2] for $v = 2 \text{ ms}^{-1}$ if they use the previous kinetic energy as the total here.	[3]
	d		the moment of inertia is larger / same mass but further from centre / more energy goes into rotational $\checkmark$		[1]

Question			Answers	Notes	Total
2	a		« $220 \times 2 \times 30 = 13200$ » = 1.3×10^4 J ✓		[1]
	b		«average»velocity / speed / kinetic energy of the particles increases ✓ collisions «with the walls» produce a larger change in momentum OR frequency of collisions «with the walls» are increased ✓	Do not allow MP2 if collisions explicitly refer to collision between particles only. Allow MP2 for a reference that the pressure arises from the rate of change in momentum. Accept “more collisions” for MP2 .	[2]
2	c		$W = 0$ OR $\Delta U = Q$ ✓ $13200 = \frac{3}{2} n \times R \times T$ OR $= \frac{3}{2} \frac{PV}{T} \Delta T$ OR $n = \frac{PV}{RT}$ OR $n = 18.7$ ✓ $\Delta T = 57$ K or °C ✓	Allow 56 if 13000 used. Allow ECF from a) Accept CNA	[3]
	d		ALTERNATIVE 1 $TV^{\frac{2}{3}} = \text{constant}$ ✓ $T = 220$ K ✓ ALTERNATIVE 2 $P = \frac{350}{293} \times 101 = 121 \text{ kPa}$ OR use of $PV^{\frac{5}{3}} = \text{constant}$ using $P = 121$ kPa ✓ use of $\frac{PV}{T} = \text{constant}$ so $T = 220$ K ✓	Accept CNA Allow ECF from c) Award [1] for a final T of 184 or 185 K	[2]

Question			Answers	Notes	Total
3	a		$\frac{\sin 45}{\sin r} = \frac{1450}{1480} \quad \checkmark$ $r = 46.2^\circ \quad \checkmark$	Do not penalize intermediate rounding Accept CNA	[2]
	b		$\ll \frac{\sin \theta}{1} = \frac{1450}{1480} \quad \text{so} \gg \theta = 78.4^\circ \quad \checkmark$		[1]
	c		sound refracts away from the normal $\checkmark$ continues bending away / curves $\checkmark$ «eventually» undergoes total internal reflection $\checkmark$ total internal reflection depends on the number of layers / speed increase on those layers $\checkmark$ propagates along a layer / within some layers $\checkmark$	MP2 to MP5 also scores MP1.	[3] max

Question			Answers	Notes	Total
4	a		force per unit charge $\checkmark$ on a positive / small / test / point charge $\checkmark$	Accept $E = \frac{F}{q}$ with symbols identified for MP1.	[2]
	b		both are negative OR both are positive $\checkmark$	Accept both are the same	[1]

	c	ALTERNATIVE 1 (working where the field is zero) $\frac{Q_R}{0.02^2} = \frac{Q_S}{0.03^2} \checkmark$ $\frac{Q_S}{Q_R} = \frac{0.03^2}{0.02^2} \text{ OR } 2.25 \text{ OR } \frac{9}{4} \checkmark$ ALTERNATIVE 2 (assuming field is negligible from other charge at the extreme points) $\frac{Q_R}{1^2} = 4.5 \text{ AND } \frac{Q_S}{1^2} = 11 \checkmark$ $\frac{Q_S}{Q_R} = \frac{11}{4.5} \text{ OR } 2.4 \checkmark$ ALTERNATIVE 3 (use of simultaneous equations) $\frac{kQ_R}{0.01^2} - \frac{kQ_S}{0.04^2} = -4.5 \times 10^5 \text{ OR } \frac{kQ_R}{0.04^2} - \frac{kQ_S}{0.01^2} = 11 \times 10^5 \checkmark$ $\frac{Q_S}{Q_R} = 2.25 \text{ OR } Q_S = -1.3 \times 10^{-8} \text{ AND } Q_R = -5.8 \times 10^{-9} \checkmark$	Award [1] if not clear which charge is identified as larger. For ALT 2, accept any ratio between 11/4.1 to 11/4.5. Award [1] in ALT 2 if no working shown. For ALT 3, accept consistent work from the equations. Accept either convention, field is positive right or field is positive left.	[2]
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Question			Answers	Notes	Total
5	a		The length of an object measured by an observer at rest / the longest possible length ✓		[1]
	b		$\Delta s^2 = \ll 1^2 - 4^2 \gg -15 \text{ km}^2$ ✓	Ignore the sign. Accept $(-)1.5 \times 10^7$	[1]
	c		ALTERNATIVE 1 realization that A and B are on the x' axis/parallel to x' axis ✓ « from the gradient » $v = 0.25c$ ✓ ALTERNATIVE 2 $\Delta t' = 0$ so $\Delta t = \frac{v\Delta x}{c^2}$ ✓ « $\frac{1}{c} = \frac{v \times 4}{c^2}$ » $v = 0.25c$ ✓	Accept CNA Accept $7.5 \times 10^7 \text{ ms}^{-1}$ Award [1] if they recognize x' axis and calculate a correct gradient leading to a velocity slightly different than $0.25c$.	[2]
	d		ALTERNATIVE 1 $-15 \text{ km} = 0^2 - x^2$ ✓ $x = 3.9 \text{ km}$ ✓ ALTERNATIVE 2 $\gamma = 1.03$ ✓ $\Delta x' = \gamma(\Delta x - v\Delta t) = 1.03(4 - 0.25) = 3.9 \text{ km}$ ✓	Accept $x = \sqrt{15}$ Accept $\frac{L}{\gamma} = \frac{4}{1.03}$ Allow ECF from a) Accept CNA	[2]

Question			Answers	Notes	Total
6	a		$qV = \frac{1}{2}mv^2 \quad \checkmark$ $v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 1200}{1.673 \times 10^{-27}}} \quad \text{OR} \quad 4.8 \times 10^5 \text{ ms}^{-1} \quad \checkmark$		[2]
	b		at this speed «of 0.0015c» relativistic effects can be ignored / velocity is much lower than c $\checkmark$		[1]
	c		$qvB = \frac{mv^2}{R} \quad \text{so} \quad R = \frac{mv}{qB} \quad \checkmark$ $R = \frac{1.673 \times 10^{-27} \times 4.8 \times 10^5}{1.6 \times 10^{-19} \times 0.14} = 0.036 \text{ m} \quad \checkmark$	Accept CNA	[2]
	d		(different radii imply) different mass / other particles / neutrons «in the nucleus» $\checkmark$		[1]
	e		uses the largest wavelength $\checkmark$ $2 \times 520000 \times 656.478 \times 10^{-9} = \sin \theta_1 \quad \text{so} \quad \theta_1 = 43.06^\circ \quad \checkmark$	Accept CNA Award [1] if they use the shortest wavelength.	[2]

Question			Answers	Notes	Total
7	a		β^- / beta minus ✓		[1]
	b		the energy spectrum of the beta particle is continuous ✓ so the energy of the decay must be shared with another particle emitted ✓	Allow [1] max if they refer to conservation of momentum	[2]
	c		adds up masses ✓ $2.232 = 2.260 \times e^{-\lambda t}$ so $t = 2.77 \times 10^{16} \text{ s}$ ✓ conversion to years so $t = 8.78 \times 10^8 \text{ y}$ ✓	Accept CNA Allow ECF from MP1 if they subtract, i.e. for $2.204 = 2.232 \times \dots$ Allow ECF for MP3 . i.e. a correct conversion to years from a wrong answer.	[3]
	d	i	the «approximate» constancy of the graph for the larger nuclei/from the peak / the negative slope after the peak ✓	Accept any reference to this section of the graph, e.g. “decrease as nucleon number gets larger”, “after peak where value is within 7 – 9” (or any suitable value), etc.	[1]

	d	ii	ALTERNATIVE 1 $37 \times 1.007276 + 50 \times 1.008665 - 86.89$ OR 0.812462 ✓ $\frac{0.812462 \times 931.5}{87} = 8.7 \text{ MeV / nucleon}$ ✓ ALTERNATIVE 2 $37 \times 938 + 50 \times 940 - 86.89 \times 931.5$ OR 767.965 ✓ $\frac{767.965}{87} = 8.8 \text{ MeV / nucleon}$ ✓	Allow ECF from MP1	[2]
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Question			Answers	Notes	Total
8	a		$m = \rho V = 1600 \times 41000 \times 0.021 \times 10^{-3} \text{ m}$ OR $m = 1380 \text{ kg}$ ✓	Actual value is 1378 kg.	[1]
	b		$n = \frac{PV}{RT}$ OR $n = \frac{102000 \times 3700}{8.31 \times 288}$ OR $n = 158000$ ✓ $n \times 0.004$ OR 158000×0.004 OR 631 kg ✓	Allow ECF from MP1 Accept equivalent use of $PV = NkT$	[2]
	c		Calculates $F_b = 1.2 \times 3700 \times g$ ✓ sets Newton's 2nd law $F_b - mg = m \times 2.2$ OR $m = 3626 \text{ kg}$ ✓ subtracts to get $m_c = 1600$ ✓	Accept CNA Combined mass is 1626 if they use show that values. Allow ECF for MP3	[3]

	d	i	«at very low pressure» there are few molecules to transfer thermal energy / no transfer in vacuum ✓	Allow reference to air instead of vacuum. Accept no transfer as no contact	[1]
	d	ii	$P_{in} = P_{out}$ OR $P_{in} = \epsilon \sigma A T^4$ ✓ $\epsilon = \frac{120}{5.67 \times 10^{-8} \times 14 \times 243^4} = 0.043$ ✓	Accept CNA Award MP2 if they use $T = 288$ leading to final answer of 0.022.	[2]
	e	i	$\frac{6400^2}{6439^2}$ seen ✓ 0.988g OR 9.68 ms^{-2} ✓	Allow backwards calculations to get M of Earth. Allow calculations where students recall and use the mass of the Earth. MP2 scores MP1	[2]
	e	ii	$v^2 = 2gh$ ✓ $v = \sqrt{2 \times 9.7 \times 4000} = 279 \text{ ms}^{-1}$ ✓	Do not award MP2 if they use $g = 10$ or 9.8 Award [2] as CNA for an answer of 279. Award [1] for an answer of 280 unless this comes from rounding with correct procedure.	[2]

	f	i	the positive area represents the increase in speed/velocity «from where he jumps from rest until max speed» ✓ the negative area represents the decrease in speed/velocity « until terminal velocity » ✓	<i>Award [1] if they identify «change in» speed/velocity without any specific detail.</i>	[2]
	f	ii	positive area is larger «as the difference represents the terminal speed» ✓		[1]
	g		«air resistance will increase» decelerating/slowing down the skydiver ✓ the skydiver keeps falling / reaches «a lower» terminal/constant speed/velocity ✓		[2]
	h		λ in the range 10^{-6} - 10^{-4} m (these are the limits given in the booklet) ✓ converted to frequency so f in the range 10^{12} - 3×10^{14} Hz ✓	<i>Allow ECF for MP2</i> <i>Allow other methods to estimate the frequency of infrared, e.g. using Wien's law for a temperature of 298 K (found in some scripts).</i> <i>Accept CNA for full marks, i.e accept a plain answer if in the range accepted.</i>	[2]

Question			Answers	Notes	Total
9	a		tangent to X ✓ S closest to large magnet ✓	<i>Allow magnet drawn as a figure on the magnetic field line, in a tangential direction.</i>	[2]
	b	i	number of magnetic field lines passing a given area OR $B \times A$ where B is magnetic field strength and A is area OR The product of magnetic field strength over an area ✓	<i>Accept statements along the lines of: how much magnetic field passes through a surface</i>	[1]
	b	ii	«according to Faraday» the rate of change of magnetic flux «through a coil» induces an emf ✓ «rate of change is increasing as magnet is accelerating so » reading will be increasing ✓	<i>Faraday's law does not need to be fully spelled out, a reference, i.e. a justification of why the voltage arises is enough.</i>	[2]
	c	i	tangent drawn / correct section identified (between $t = 0.35$ and $t = 0.40$ s) ✓ voltage calculated ✓ magnitude between 0.8 and 1.9 V ✓	<i>Ignore the sign.</i> <i>Award [3] for a calculation of the gradient of the tangent at any point in the interval $t = 0.35 - 0.40$ or using two points within the interval $\Delta t = 0.35 - 0.40$ leading to a value within 0.8 and 1.9.</i>	[3]

	c	ii	north pole coming in, so current is counterclockwise as seen from above ✓ reversed/clockwise when magnet is moving away ✓	Allow MP2 if they do not score MP1 for the mention of the opposite direction to the one they stated in MP1 .	[2]
	d	i	$v = 4\pi\sqrt{0.15^2 - 0.10^2}$ ✓ $v = 1.4 \text{ m s}^{-1}$ ✓	Allow use of the equation given to obtain time ($t=0.067, 0.183, 0.317, 0.433 \text{ s}$ and equivalent values differing by integer multiples of the period 0.5 s) and then use of derivative to obtain the velocity. Accept CNA	[2]
	d	ii	$T = 0.5$ OR $f = 2$ ✓ « $T = 2\pi\sqrt{\frac{m}{k}}$ so » $m = 0.032 \text{ kg}$ ✓	Accept CNA Allow ECF from MP1	[2]
	d	iii	«mechanical» energy is dissipated in the resistor OR reference to damping by the interaction OR reference to current induced ✓	Allow damping if any reference to the interaction between magnet and magnetic field of the current. Do not allow electric force Do not award the mark if they say that the resistor decreases the current (as there was no current before connecting it).	[1]
	e	i	«energy produced» $1 \times 10^9 \times 365 \times 24 \times 3600$ OR $3.15 \times 10^{16} \text{ J}$ ✓ «mass of each fission» $\frac{0.235}{N_A}$ ✓ « conversion of MeV to get total mass $\frac{3.15 \times 10^{16}}{200 \times 10^6 \times 1.6 \times 10^{-19}} \times \frac{0.235}{6.02 \times 10^{23}} =$ » 380 kg ✓	Accept CNA Allow calculation of 235 u for MP2 Allow ECF from MP1 or MP2	[3]

	e	ii	nuclear energy is released as thermal energy ✓ thermal energy used to vaporize water / obtain kinetic energy ✓ water vapor / kinetic energy used to drive turbines / turn a generator / rotate the magnetic field / obtain electrical energy ✓		[2] max
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