

Markscheme

November 2025

Physics

Higher level

Paper 2

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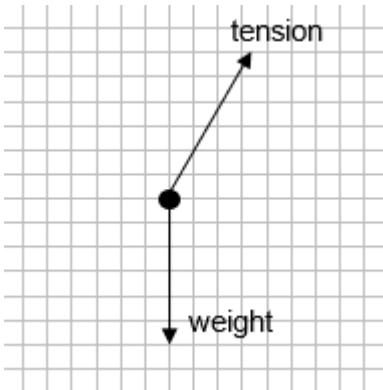
Subject Details: Physics HL Paper 2 Markscheme

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. 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**”. Either answer can be accepted.
7. An alternative markscheme is indicated in the “Answers” column under heading **ALTERNATIVE 1** etc. Either alternative can be accepted.
8. Words inside chevrons « » 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. “ECF acceptable” will be displayed in the “Notes” column.
14. CNA refers to a correct numerical answer.
15. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the “Notes” column.

Question		Answers	Notes	Total
1.	a	3 ✓		[1]
1.	b	<p>Chooses 3->2 transition ✓</p> $\lambda = \frac{hc}{\Delta E} \quad \checkmark$ $\lambda = \llcorner \frac{1.24 \times 10^{-6}}{1.89} \Rightarrow 6.56 \times 10^{-7} \text{ m}$ <p>OR</p> $\lambda = \llcorner \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{1.89 \times 1.6 \times 10^{-19}} \Rightarrow 6.58 \times 10^{-7} \text{ m} \quad \checkmark$	<p><i>Ignore sign.</i></p> <p><i>Award [3] for CNA (correct numerical answer)</i></p> <p><i>Allow ECF from MP1 if they choose an incorrect transition</i></p> <p><i>Do not penalize 657 nm</i></p> <p><i>Award [1] max if they calculate a wavelength using a single energy level instead of a ΔE.</i></p>	[3]

Question			Answers	Notes	Total
2.	a	i	 <p>Labelled vertical weight / W / mg / F_g and tension / T / F_T in approximately correct direction ✓ With vertical T component equal to weight ✓</p>	<i>Ignore other forces drawn for MP1</i>	[2]
2.	a	ii	$T \sin 30^\circ = ma$ OR $T \cos 30^\circ = mg$ ✓ $a = g \tan 30^\circ = 5.66 \approx 5.7 \text{ m s}^{-2}$ ✓	<i>Accept reversed trig functions if 60° used. Award [2] for CNA</i>	[2]
2.	b		The ball is in equilibrium / forces are balanced / net force is zero / no acceleration / the vertical weight must be balanced by a vertical tension ✓ The angle is zero ✓	<i>For MP2, accept an answer of 10° if from the students' answer it can be understood that they interpreted the vertical as the perpendicular line to the ceiling of the truck, so that their answer of 10° implies that the string is vertically downwards.</i>	[2]

Question		Answers	Notes	Total
2.	c	$\mu mg = m \frac{v^2}{R} \checkmark$ $v = \llcorner \sqrt{0.6 \times 9.8 \times 75} \gg 21 \text{ ms}^{-1} \checkmark$	Award [2] for a CNA.	[2]
2.	d	<p>ALTERNATIVE 1</p> <p>KE $\frac{1}{2} \times 1400 \times 15^2$ OR $1.6 \times 10^5 \text{ J} \checkmark$</p> <p>Work done by drag force $520 \times \pi \times 75$ OR $1.2 \times 10^5 \text{ J} \checkmark$</p> <p>This is less than the KE so the truck will make it \checkmark</p> <p>ALTERNATIVE 2</p> <p>Truck decelerates at $\frac{520}{1400}$ OR $0.371 \text{ ms}^{-2} \checkmark$</p> <p>Speed at gas station is $\sqrt{15^2 - 2 \times 0.371 \times \pi \times 75}$ OR 7.0 ms^{-1}</p> <p>OR</p> <p>truck stops after a distance $\llcorner \frac{15^2}{2 \times 0.371} \gg 303 \text{ m} \checkmark$</p> <p>Speed is not zero</p> <p>OR</p> <p>$303 \text{ m} > 75 \pi$</p> <p>OR</p> <p>$303 \text{ m} > 236 \text{ m} \checkmark$</p>	Allow MP3 for a consistent conclusion if any previous calculation is wrong.	[3]

Question			Answers	Notes	Total
3.	a		$\ll 8.99 \times 10^9 \times \left(\frac{9Q}{0.30^2} + \frac{Q}{0.06^2} \right) = 3.26 \times 10^7 \text{ so } \gg Q = 9.6 \times 10^{-6} \checkmark$ <p>C ✓</p>		[2]
3.	b	i	$qvB = m \frac{v^2}{R} \checkmark$ <p>Hence answer</p>		[1]
3.	b	ii	Force is perpendicular to the velocity / F acts as centripetal / F does no work / F only changes direction of velocity ✓	<i>Do not accept reference to centripetal acceleration only</i>	[1]
3.	c		loss of energy / speed reduced ✓ so radius decreases ✓	<i>MP2 scores only if MP1 is scored.</i>	[2]

Question			Answers	Notes	Total
4.	a	i	600 «counts per hr »✓		[1]
4.	a	ii	<p>ALTERNATIVE 1 Subtract their background rate to 3000 to get the initial count rate e.g. initial count rate 2400 counts per h ✓ Attempt to read t for $\frac{1}{2}$, $\frac{1}{4}$ or $\frac{1}{8}$ this initial count rate plus their background rate ✓ Half-life is 10 h ✓</p> <p>ALTERNATIVE 2 Use of decay equation with $A_0 = 3000$ (their ai) and one point correctly read from graph ✓ calculate decay constant ✓ Use <i>half life</i> = $\frac{\ln 2}{\lambda}$ to get $T_{1/2} = 10$ h ✓</p>	<p><i>Allow ECF from a i)</i></p> <p><i>Allow ECF from MP1, i.e. max [2] for answer of about 14 h if background rate not used</i></p> <p><i>Accept 9 to 11 hours for MP3</i></p>	[3]
4.	a	iii	<p>The BE «per nucleon» is greater for $^{204}_{82}\text{Pb}$ ✓ Because $^{204}_{82}\text{Pb}$ is more stable/tightly bound than $^{204}_{83}\text{Bi}$ ✓</p>	<i>Award [1] if they recognize Pb as more stable but conclude incorrectly.</i>	[2]
4.	a	iv	The alpha particles would be absorbed / have low penetration / short range / ✓		[1]
4.	b		<p>$\Delta m = 203.932254 - (203.928034 + 0.000549) = 3.671 \times 10^{-3}$ u ✓ $Q = 3.671 \times 10^{-3} \times 931.5 \approx 3.42$ MeV ✓</p>	<p><i>Allow ECF from MP1</i> <i>Award [1] if electron mass is neglected and $Q = 3.93$ MeV or 6.30×10^{-13} J</i> <i>Award [2] for a CNA</i> <i>Accept final answer in J (5.48×10^{-13})</i></p>	[2]

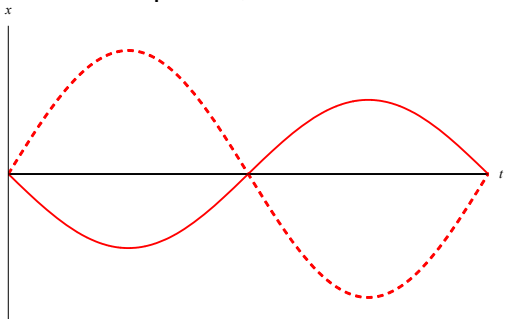
Question		Answers	Notes	Total
5.	a	<p>ALTERNATIVE 1</p> $\Delta U = \frac{3}{2}Rn\Delta T = \frac{3}{2}P\Delta V \checkmark$ $Q = \frac{3}{2}P\Delta V + P\Delta V = \frac{5}{2}P\Delta V \checkmark$ $Q = \frac{5}{2} \times 22 \times 10^3 \times (3.2 - 4.5) \times 10^{-2} = -7.15 \times 10^2 \approx -700 \text{ J} \checkmark$ <p>ALTERNATIVE 2</p> $Q = \frac{3}{2}Rn\Delta T + P\Delta V = \frac{3}{2} \frac{PV}{T} \Delta T + P\Delta V \checkmark$ <p>temperature at C: $\frac{560 \times 3.2}{4.5} = 398 \text{ K} \checkmark$</p> $Q = \frac{3}{2} \times \frac{1000}{560} \times (398 - 560) + 22 \times 10^3 \times (3.2 - 4.5) \times 10^{-2} = -7.15 \times 10^2 \text{ J} \checkmark$	<p><i>Do not penalize absence of minus sign</i></p> <p><i>Allow use of $n = 0.21 \text{ mol}$</i></p>	[3]
5.	b	$Q_{\text{in}} = \langle \Delta U + W = 0 + 480 \Rightarrow \rangle 840 \text{ J} \checkmark$ <p>ALTERNATIVE 1</p> $\eta = \frac{W}{Q_{\text{in}}} = \frac{Q_{\text{in}} - Q_{\text{out}}}{Q_{\text{in}}} \checkmark$ $\eta = \frac{840 - 715}{840} = 0.149 \approx 0.15 \checkmark$ <p>ALTERNATIVE 2</p> <p>Net work done $(125 \pm 20) \text{ J}$ by counting squares in loop \checkmark</p> $\eta = \frac{125}{840} = 0.15 \pm 0.02 \checkmark$	<p><i>Allow $\eta = 0.17$ if rounded 700 J is used</i></p> <p><i>Award [3] for a CNA</i></p>	[3]

Question		Answers	Notes	Total
6.	a	<p>ALTERNATIVE 1 Energy conservation after heavier block falls a distance h gives $\frac{1}{2} \frac{mr^2}{2} \omega^2 + \frac{1}{2} mv^2 + \frac{1}{2} \times 2mv^2 = 2mgh - mgh \checkmark$ $\omega = \frac{v}{r} \text{ so } v^2 = \frac{4gh}{7} \checkmark$ $v^2 = 2ah \Rightarrow \frac{4gh}{7} = 2ah \checkmark$ Hence $a = \frac{2g}{7}$</p> <p>ALTERNATIVE 2 Moment of inertia of system $\frac{1}{2}mr^2 + mr^2 + 2mr^2 = \frac{7}{2}mr^2 \checkmark$ Net torque = mgr, so $mgr = \frac{7}{2}mr^2 \times \alpha \checkmark$ $\alpha = \frac{a}{r} \checkmark$ Hence $a = \frac{2g}{7}$</p> <p>ALTERNATIVE 3 $2mg - T_1 = 2ma$ and $T_2 - mg = ma \checkmark$ $(T_1 - T_2)r = \frac{mr^2}{2} \frac{a}{r} \Rightarrow T_1 - T_2 = \frac{ma}{2} \checkmark$ Adding equations of MP1: $-\frac{ma}{2} + mg = 3ma \checkmark$ Hence $a = \frac{2g}{7}$</p>		[3]
6.	b	No, because there is a non-zero external torque on the system / the system has angular acceleration \checkmark		[1]

Question		Answers	Notes	Total
7.	a	«All pairs of rays which are symmetrical with respect to the dotted line have» zero phase/path difference ✓ so interfere constructively at M ✓	<i>Award [1] for a generic reference that a path difference of an integer number of wavelengths produces constructive interference.</i>	[2]
7.	b	First diffraction minimum at / value use of $\theta = 0.04 \text{ rad}$ ✓ $\theta = \frac{\lambda}{b} \Rightarrow \lambda = b\theta = 1.3 \times 10^{-5} \times 0.04 = 5.2 \times 10^{-7} \text{ m}$ ✓	<i>Award full marks for a CNA</i> <i>Allow ECF from MP1</i>	[2]

Question			Answers	Notes	Total
8.	a		The flux is increasing / there is an induced emf/current ✓ The induced current will be counter-clockwise / current is induced in a direction that creates a force that opposes the change ✓ A magnetic force to the left / opposing will act on the rod ✓ (bringing it to rest)		[3]
8.	b	i	«The current in the circuit will be clockwise so there will be a magnetic force accelerating the rod that then» moves to the right ✓		[1]
8.	b	ii	<p>ALTERNATIVE 1 Since the induced emf BLv opposing the cell's emf is proportional to speed ✓ It will eventually equal the emf of the cell resulting in zero current and hence zero net force on the rod ✓</p> <p>ALTERNATIVE 2 «As in 8a, » there is a counter-clockwise induced current / a force to the left ✓ This current / force increases with v until resultant current/ force is zero ✓</p>		[2]

Question			Answers	Notes	Total
9.	a	i	<p>ALTERNATIVE 1 One mole contains 6.02×10^{23} atoms and has mass 63.5 g ✓ Mass of one atom is $\frac{63.5 \times 10^{-3}}{6.02 \times 10^{23}} = 1.055 \times 10^{-25} \approx 1.1 \times 10^{-25}$ kg ✓</p> <p>ALTERNATIVE 2 The atom has mass 63.5 u ✓ I.e. $63.5 \times 1.661 \times 10^{-27} = 1.055 \times 10^{-25} \approx 1.1 \times 10^{-25}$ kg ✓</p>	<p>Award full marks for a CNA</p> <p>Accept similar calculation for a mass of 0.4 kg ($n = 6.3$)</p>	[2]
9.	a	ii	<p>Volume of copper = $\frac{0.0635}{8940}$ ✓</p> <p>$V = \left\langle \frac{0.0635}{(8940 \times 6.02 \times 10^{23})} \right\rangle = 1.2 \times 10^{-29} \text{ m}^3$ ✓</p>	<p>Award full marks for a CNA</p> <p>Accept similar calculation for a mass of 0.4 kg</p>	[2]
9.	a	iii	<p>Side of cube $a = \sqrt[3]{1.180 \times 10^{-29}} = 2.277 \times 10^{-10} \approx 2 \times 10^{-10}$ m ✓</p>	<p>Allow ECF from a ii</p> <p>Award the mark for the CNA</p>	[1]
9.	b		<p>$Q \ll \text{mL} = 0.400 \times 206 \times 10^3 \gg = 82.4 \text{ kJ}$ ✓</p>		[1]

Question			Answers	Notes	Total
9.	c		Internal energy is greater in the liquid phase ✓ in liquid the intermolecular potential energy is greater / the separation is greater / energy has been added ✓ kinetic energy is unchanged / temperature is the same / internal energy is the sum of kinetic and potential energies ✓		[3]
9.	d	i	wave «created by the hammer» is reflected / two «identical» waves in opposite directions ✓ the right and left waves superpose / add up / interfere ✓	<i>Accept reference to constructive and destructive interference in MP2</i>	[2]
9.	d	ii	Antinodes at both ends, a node in the middle ✓	<i>Accept only one wave or wave and envelope, either solid or broken lines.</i>	[1]
9.	d	iii	Opposite line i.e. phase difference of π ✓ Smaller amplitude, ✓ 	<i>Labelling not necessary</i> <i>MP2 only scores if MP1 scores</i>	[2]
9.	e	i	The standing wave is longitudinal/sand moves horizontally / sand is pushed/vibrates OR there are nodes and antinodes ✓ « sand moves» away from antinodes/ to nodes ✓		[2]

Question			Answers	Notes	Total
9.	e	ii	<p>ALTERNATIVE 1 Wavelength in air is $2d$ ($= 3.6$ cm) ✓ Frequency of wave in copper is the same as that in the air in the tube ✓</p> $\frac{v_{\text{Cu}}}{2L} = \frac{v_{\text{air}}}{2d} \checkmark$ $v_{\text{Cu}} = \frac{L}{d} \times v_{\text{air}} = \frac{34}{1.8} \times 330 = 6.2 \times 10^3 \text{ m s}^{-1} \checkmark$ <p>ALTERNATIVE 2 Wavelength in air is $2d$ ($= 3.6$ cm) ✓</p> $f = \frac{330}{3.6 \times 10^{-2}} = 9.167 \times 10^3 \text{ Hz} \checkmark$ $\lambda_{\text{Cu}} = 68 \text{ cm} \checkmark$ $v_{\text{Cu}} = 9167 \times 0.68 = 6.2 \times 10^3 \text{ m s}^{-1} \checkmark$	Award [4] for a CNA Allow ECF from wrong wavelengths	[4]

Question			Answers	Notes	Total
10.	a		<p>Reference to an experimental evidence e.g. Compton or photoelectric effect ✓</p> <p>Brief reference to the transfer of momentum and/or energy of a photon in the example given e.g. photon scatters from an electron transferring momentum and/or energy or photon strikes «and ejects» an electron transferring momentum and/or energy. ✓</p>	<p><i>Accept any correct reference to the experiment quoted even if only about energy transfer.</i></p>	[2]
10.	b	i	<p>Energy incident per second/power is $N \frac{hc}{\lambda}$ ✓</p> <p>Intensity is power per area ✓</p> <p>so $I = \frac{N hc}{A \lambda}$</p>	<p><i>Allow [1] if student consistently uses energy instead of power.</i></p>	[2]
10.	b	ii	<p>Use of photon momentum $\frac{h}{\lambda}$ ✓</p> <p>Force is rate of change of total momentum $N \frac{2h}{\lambda}$ ✓</p> <p>Pressure is force per unit area $\frac{N 2h}{A \lambda}$ and substitution $\frac{N h}{A \lambda} = \frac{I}{c}$ to get result ✓</p>		[3]

Question			Answers	Notes	Total
10.	c	i	$F = \langle PA \Rightarrow \frac{2 \times 420}{3 \times 10^8} \times 1600 \text{ OR } 4.48 \times 10^{-3} \text{ N } \checkmark$ $a = \langle \frac{F}{m} \Rightarrow \frac{2 \times 420 \times 1600}{3 \times 10^8 \times 1400} \text{ OR } 3.2 \times 10^{-6} \text{ ms}^{-2} \checkmark$		[2]
10.	c	ii	$s = \frac{1}{2}at^2 \Rightarrow t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 6.1 \times 10^{11}}{3.2 \times 10^{-6}}} \checkmark$ $t = 6.175 \times 10^8 \text{ s} = 19.6 \approx 20 \text{ years } \checkmark$	<p><i>Award full marks for a correct answer in seconds or years.</i></p> <p><i>Award full marks for a CNA</i></p>	[2]
10.	c	iii	The intensity of light on the sail will not remain constant/the force due to the Sun/Earth/Jupiter/other planets is ignored/sail may not be flat/light may be incident at an angle/part of the radiation may be absorbed/any other reasonable statement ✓		[1]
10.	d	i	Any position along the dotted line between the spacecraft and the centre of the ellipse ✓		[1]
10.	d	ii	<p>Jupiter is at a focus of the ellipse ✓</p> <p>Speed is a maximum, potential energy is a minimum hence the spacecraft is closest to Jupiter</p> <p>OR</p> <p>The angular momentum mvr of the spacecraft is conserved and since speed is maximum the spacecraft is closest to Jupiter</p> <p>OR</p> <p>reference to Kepler' second law ✓</p>	<i>Accept not at the centre for MP1</i>	[2]

Question			Answers	Notes	Total
10.	e	i	$\omega^2 r = G \frac{M}{r^2} \quad \text{OR} \quad \frac{GM}{r} = \frac{2\pi r}{T} \quad \checkmark$ $M = \rho \frac{4\pi r^3}{3} \quad \checkmark$ <p>Manipulation to show the result e.g.</p> $T^2 = \frac{4\pi^2}{G\rho \frac{4\pi r^3}{3}} r^3 \quad \checkmark$		[3]
10.	e	ii	$\rho = \frac{3\pi}{GT^2} = \frac{3\pi}{6.67 \times 10^{-11} \times (2.9 \times 60 \times 60)^2} \quad \checkmark$ $\rho = 1.3 \times 10^3 \text{ kg m}^{-3} \quad \checkmark$	Allow ECF from MP1	[2]