

# Markscheme

**May 2025**

**Physics**

**Higher level**

**Paper 2**

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## Subject Details: Physics HL Paper 2 Markscheme

### Mark Allocation

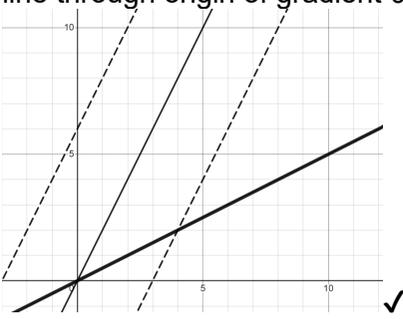
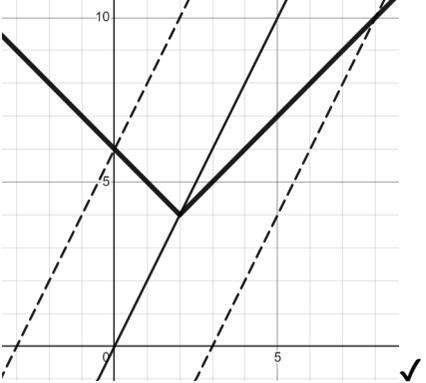
**Candidates are required to answer ALL questions. Maximum total = [90 marks].**

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>It is a ratio between two forces therefore units cancel out.</p> <p><b>OR</b></p> <p><math>\mu = F_f/N</math>, therefore units cancel out. ✓</p>		1
1.	b	<p>uses the static coefficient ✓</p> <p><math>F = 0.36 \times 1.2 \times 9.8 = 0.36 \times 11.76</math></p> <p><b>OR</b></p> <p><math>F = 4.2 \text{ «N»}</math> ✓</p>	<p><i>Must see full substitution OR answer to 2 (or more) significant figures for MP2.</i></p>	2

1.	c	<p><b>ALT 1</b></p> <p><math>F_f = 0.28 \times 1.2 \times 9.8 = 3.29 \text{ «N»} \checkmark</math></p> <p>W done over 0.35 m = <math>(14 - 3.29) \times 0.35 = 3.75 \text{ «J»} \checkmark</math></p> <p><math>d = \text{«}3.75 \text{ J} / 3.29 \text{ N} = \text{» } 1.14 \text{ «m»} \checkmark</math></p> <p><b>ALT 2</b></p> <p><math>a = (14 - 0.28 \times 1.2 \times 9.8) / 1.2 = 8.92 \text{ «m s}^{-2}\text{»} \checkmark</math></p> <p><math>v = \sqrt{(2)(8.92)(0.35)} = 2.50 \text{ «m s}^{-1}\text{»} \checkmark</math></p> <p><math>d = \text{«}2.5^2 / (2 \times 0.28 \times 9.8) = \text{» } 1.14 \text{ «m»} \checkmark</math></p>	<p><i>Allow ECF from MP1.</i></p> <p><i>Only award marks from one ALT.</i></p>	3
1.	d	<p><b>ALT 1</b></p> <p><math>\tau</math> of F = <math>F \times 0.15</math> <b>OR</b> <math>\tau</math> of weight = <math>1.2 \times 9.8 \times 0.03 \checkmark</math></p> <p>equals both to get <math>F = 2.4 \text{ «N»} \checkmark</math></p> <p><b>ALT 2</b></p> <p><math>\tau</math> of F = <math>F(.162)(\sin 68)</math> <b>OR</b> <math>\tau</math> of weight = <math>(1.2)(9.8)(.162/2)(\sin 22) \checkmark</math></p> <p>equals both to get <math>F = 2.4 \text{ «N»} \checkmark</math></p>		2

1.	d	ii	Because «static» friction has a «maximum» value greater than $F$ ✓	<i>Must see a comparison between <math>F</math> and friction (e.g. frictional force is larger than <math>F</math>).</i>	1
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Question		Answers	Notes	Total
2.	a	<p>line through origin of gradient 0.5 (by eye)</p> 		1
2.	b	<p>two lines of gradient -1 and 1 from E (by eye)</p> 		1

2.	c		«simultaneous for» the passenger ✓  because line joining $T_B$ and $T_F$ is parallel to $x'$ axis «so identify the same time coordinate» ✓	<i>Accept equivalent description based on non-simultaneous for the observer.</i>	2
2.	d		6 «m» ✓		1

Question	Answers	Notes	Total
<p>3. a</p>	<p><b>ALT 1</b></p> <p>Use of <math>pV = nRT</math> to get <math>T_B = 1200 \text{ «K»}</math></p> <p><i>AND</i></p> $P_C = \left\langle \frac{P_A V_A^{\frac{5}{3}}}{V_C^{\frac{5}{3}}} = \frac{(2 \times 10^6)(1 \times 10^{-3})^{\frac{5}{3}}}{(1 \times 10^{-2})^{\frac{5}{3}}} \Rightarrow 43089 \text{ «Pa» } \checkmark \right.$ <p><math>T_C = 4.3 \times 10^4 \times 1200 / 2.0 \times 10^5</math></p> <p><b>OR</b></p> <p><math>T_C = 258 \text{ «K» } \checkmark</math></p> <p><b>ALT 2</b></p> $P_C = \left\langle \frac{P_A V_A^{\frac{5}{3}}}{V_C^{\frac{5}{3}}} = \frac{(2 \times 10^6)(1 \times 10^{-3})^{\frac{2}{3}}}{(1 \times 10^{-2})^{\frac{2}{3}}} \Rightarrow 43089 \text{ «Pa» } \checkmark \right.$ <p>Use of <math>p_C V_C = nRT_C = (43089)(1 \times 10^{-2}) = (0.2)(8.31) T_C</math></p> <p><b>OR</b></p> <p><math>T_C = 259 \text{ «K» } \checkmark</math></p>	<p><i>Must see full substitution OR answer to 3 (or more) significant figures.</i></p>	<p><b>2</b></p>

3.	b	Use of $\Delta U = -3/2 n R \Delta T$ ✓ $W = \langle (3/2)(0.2)(8.31)(1200-259) \rangle = \langle - \rangle 2350 \langle J \rangle$ ✓		2
3.	c	work done by the gas in the isothermal process is larger ✓ net work is done by the gas ✓ net/total work is positive ✓ work done by the gas is greater than work done on the gas ✓		1 max

Question			Answers	Notes	Total
4.	a		<p>sound waves are longitudinal <b>OR</b> light waves are transverse ✓</p> <p>sound waves cannot travel through vacuum <b>OR</b> light waves travel can travel through vacuum ✓</p> <p>sound waves are propagated due to pressure changes <b>OR</b> light waves are propagated due to electric or magnetic field changes ✓</p> <p>speed of sound not the same between inertial reference frames <b>OR</b> speed of light same in all inertial reference frames ✓</p> <p>Speed of sound is «generally» slower <b>OR</b> speed of light is «generally» faster. ✓</p>		2 max
4.	b	i	<p>Wavelength = 0.68 «m» ✓</p> <p>Period = 0.002 «s» ✓</p>	Accept 0.67 – 0.70 m for wavelength.	2
4.	b	ii	<p><math>v = \lambda/T = 0.68 / 0.002 = \gg 340 \text{ «m s}^{-1}\text{»}</math> ✓</p>	<p>Allow ECF from 4bi</p> <p>Allow <math>v = 335 - 350 \text{ m s}^{-1}</math></p>	1

4.	c	i	<p>«apparent» change in the frequency/wavelength/pitch✓                  caused by a compression/stretching of wavefronts « due to relative motion»  <b>OR</b>                  meets wavefronts more or less frequently ✓</p>		2
4.	c	ii	$440 \cdot \frac{340 + v}{340} = 540 \cdot \frac{340 - v}{340} \checkmark$ <p>so <math>v = 34.7 \text{ «m s}^{-1}\text{»} \checkmark</math></p>		2
4.	c	iii	<p>Use of <math>\frac{v}{c} = \frac{\Delta\lambda}{\lambda} = \frac{(659 \times 10^{-9}) - (656.1 \times 10^{-9})}{(656.1 \times 10^{-9})} \checkmark</math></p> <p><math>v = 1.33 \times 10^6 \text{ «m s}^{-1}\text{»}</math></p> <p><b>OR</b>  <math>0.00442 c \checkmark</math></p>		2

Question			Answers	Notes	Total
5.	a	i	86 ✓		1
5.	a	ii	<p><b>ALT 1</b></p> <p>mass defect = <math>226.02540 - 222.01757 - 4.00260 = 0.00523</math> «u» ✓</p> <p><math>0.00523 \times 931.5 = 4.87</math> «MeV» ✓</p> <p><b>ALT 2</b></p> <p>initial energy = <math>(226.02540)(931.5) = 210542.66</math> «MeV»</p> <p><b>OR</b></p> <p>final energy = <math>(222.01757 + 4.00260)(931.5) = 210537.79</math> «MeV» ✓</p> <p><math>210542.66 - 210537.79 = 4.87</math> «MeV» ✓</p>	<p><i>Must see full substitution or answer to at least 2 significant figures.</i></p>	2
5.	a	iii	<p><math>p_\alpha = p_{Rn}</math> ✓</p> <p>«Use of <math>KE = p^2/2m</math> to get <math>KE_\alpha/KE_{Rn} = 222/4</math> so»</p> <p><math>KE_\alpha = 222/226</math> OR <math>0.982</math> ✓</p>		2
5.	b	i	<p>«a few» alpha particles bounce back from the foil ✓</p> <p>«most» alpha particles pass through «undeflected» ✓</p> <p>«some» alpha particles were scattered/deviated from their path ✓</p>		2 max
5.	b	ii	<p>«nucleus is» small <b>AND</b> dense ✓</p> <p>«nucleus is» positively charged</p> <p><b>OR</b></p>		2

			a nucleus «is postulated» ✓		
5.	b	iii	$E = (4.8 \times 10^6)(1.6 \times 10^{-19}) = 7.68 \times 10^{-13}$ «J» ✓ $q_{Au} = (79)(1.6 \times 10^{-19}) = 1.264 \times 10^{-17}$ «C» <b>OR</b> $q_{\alpha} = (2)(1.6 \times 10^{-19}) = 3.2 \times 10^{-19}$ «C» ✓ $\frac{(8.99 \times 10^9)(1.26 \times 10^{-17})(3.2 \times 10^{-19})}{(7.68 \times 10^{-13})} =$ $d = \llcorner = \gg 4.7 \times 10^{-14}$ «m» ✓		3
5.	b	iv	Use of $\frac{\text{radius of Au nucleus}}{\text{radius of Al nucleus}} = \frac{A_{Au}^{1/3}}{A_{Al}^{1/3}}$ ✓ $197^{1/3}/27^{1/3} = 1.9$ ✓		2

Question		Answers	Notes	Total
6.	a	<p>reads <math>\lambda = 5.0 \times 10^{-7}</math> «m» ✓</p> <p><math>\Phi = \ll h c / \lambda = \gg \frac{1.24 \times 10^{-6}}{5 \times 10^{-7}}</math> <b>OR</b> 2.48 «eV» ✓</p>	<p><i>Must see full substitution or answer to 3 or more significant figures for MP2.</i></p>	2

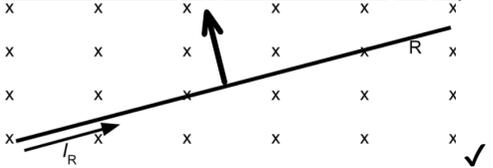
6.	b	<p><b>ALT 1</b>  <math>\llcorner hf \text{ OR } hc/\lambda = (1.24 \times 10^{-6}) / (4.0 \times 10^{-7}) = \gg 3.1 \llcorner V \gg \checkmark</math></p> <p><math>\llcorner 3.1 - 2.5 = \gg 0.6 \llcorner V \gg \checkmark</math></p> <p><b>ALT 2</b>  <math display="block">\frac{(6.63 \times 10^{-34})(3 \times 10^8)}{(4 \times 10^{-7})} - (4 \times 10^{-19}) = 9.73 \times 10^{-20} \llcorner J \gg \checkmark</math></p> <p><math>\llcorner (9.73 \times 10^{-20}) / (1.6 \times 10^{-19}) \gg = 0.6 \llcorner V \gg \checkmark</math></p>		2
6.	c	<p>Particle nature suggests photons have energy related to frequency/wavelength <math>\checkmark</math></p> <p>Intensity does not change photon energy</p> <p><b>OR</b></p> <p>Intensity not related to E necessary to release electron. <math>\checkmark</math></p> <p>One photon of sufficient energy is necessary to release an electron</p> <p><b>OR</b></p> <p>photon must have sufficient energy to release electron. <math>\checkmark</math></p> <p>If light is a wave, higher intensity should provide energy with time to eject an electron. <math>\checkmark</math></p>		2 max

Question			Answers	Notes	Total
7.	a	i	Weight and Buoyancy drawn in proper directions (by eye) and correctly identified ✓	<p><i>Allow any sensible identification of the forces (e.g. mg for <math>F_g</math>)</i></p> <p><i>Do not allow "gravity" for weight.</i></p>	1
7.	a	ii	<p>Weight = <math>\rho_c \cdot A \cdot H \cdot g</math></p> <p><b>OR</b></p> <p>Buoyancy = <math>\rho_w \cdot A \cdot D \cdot g</math> ✓</p> <p><math>\rho_c \cdot A \cdot H \cdot g = \rho_w \cdot A \cdot D \cdot g</math> ✓</p> <p>&lt;&lt;algebraic manipulation to show the relationship&gt;&gt;</p>		2

7.	b		<p>When cork is released, upthrust/buoyant force is larger than weight  <b>OR</b>                      buoyant force is increased when cork submerged. ✓</p> <p>«net» force/acceleration is proportional to displacement  <b>OR</b>                      quotes <math>a = \omega^2 x</math> OR <math>a \propto x</math> ✓</p> <p>«net» force/acceleration is in opposite direction of displacement  <b>OR</b>                      «net» force/acceleration is directed towards equilibrium ✓</p>		2 max
7.	c	i	<p>solid state volume is less than liquid state  <b>OR</b>                      molecules/particles/atoms are closer in solids so volume is smaller ✓</p> <p>Same mass in smaller volume «so larger density»  <b>OR</b>                      More mass per unit volume ✓</p>		2
7.	c	ii	4 «°C» ✓	<p>Allow 3.9 °C - 4.1 °C.                      Accept answer in Kelvin (e.g. 277 K) if proper unit shown.</p>	1

7.	d	i	<p>«(H -32 ) / H = 920 / 1030 so» H = 300 «m» <b>OR</b> D = 268 «m» ✓  m = 920 x 300 x 4200 <b>OR</b> 1.16x10<sup>9</sup> «kg» ✓</p>	<p><i>Must see either full substitution or answer to 3 or more significant figures.</i></p>	2
7.	d	ii	<p><math>\frac{1}{40} m_{12} = (\frac{1}{40} m + m)v</math> ✓  v = 0.29 «m s<sup>-1</sup>» ✓</p>		2
7.	e	i	<p>use of <math>\Delta T = 6</math> «°C» ✓</p> <p><math>\frac{\Delta Q}{\Delta t A} = \ll \frac{2.3 \cdot 6}{0.019} = \gg</math> 730 «W m<sup>-2</sup>» ✓</p>		2

7.	e	ii	$m = (\rho A)(22) = (1000)(A)(22) = 22000A$ <b>AND</b> $\Delta T = 2$ «°C» ✓ $Q/A = \ll mc\Delta T \gg = (22)(1000)(4200 * 2) = 1.85 \times 10^8$ «J m <sup>-2</sup> » <b>OR</b> $Q/A = \ll mL \gg = (22)(1000)(330000) = 7.26 \times 10^9$ «J m <sup>-2</sup> » ✓ $Q/A = 7.4 \times 10^9$ «J m <sup>-2</sup> » ✓		3
7.	e	iii	«the thicker the layer the» lower the rate of transfer ✓		1
7.	e	iv	if solid water were denser than liquid, ice layer would sink <b>OR</b> water at 4°C sinks to bottom ✓  ice layer «would isolate water below ice to» maintain conditions «above freezing » ✓  this insulates the lake <b>OR</b> prevents the lake from freezing completely ✓		2 max

Question			Answers	Notes	Total
8.	a	i	Use of $F = BIL$ OR $F/L = BI$ ✓ = $1.0 \text{ «N m}^{-1}\text{»}$ ✓		2
8.	a	ii	Arrow drawn perpendicular (by eye) as shown. 	Arrow can be drawn anywhere along the wire.	1
8.	b	i	$\frac{F}{L} = \frac{\mu_0 I_R I_Z}{2\pi r}$ <b>AND</b> $\frac{F}{L} = B_R I_Z$ ✓  Combine to give the result ✓	<b>Must see subscripts on both I and B for full marks. Award [1 max] for correct derivations with incomplete subscripts.</b>	2
8.	b	ii	$\text{kg m s}^{-2} \text{ A}^{-2}$ ✓	Allow fractional answers such as: $\frac{\text{kg m}}{\text{s}^2 \text{ A}^2}$	1
8.	c	i	the magnetic field produced by the wire/ $I_R$ is constant. ✓  therefore the «magnetic» flux/field through the coil is constant. ✓		2

8.	c	ii	$\Delta B = \frac{\mu_0}{2\pi} \left( \frac{10^{-2}}{0.1} \right) \text{ OR } 2 \times 10^{-5} - 4 \times 10^{-6} = 1.6 \times 10^{-5} \text{ «T» } \checkmark$ $\Delta \phi = A \Delta B = (\pi)(0.02^2)((2 \times 10^{-5}) - (4 \times 10^{-6})) = 2.5 \times 10^{-8} - 5.03 \times 10^{-9}$ $= 2.01 \times 10^{-8} \text{ «Wb» } \checkmark$ $\varepsilon = \frac{n \Delta \phi}{\Delta t} = \frac{(20)(2.01 \times 10^{-8})}{0.5} = 8.0 \times 10^{-7} \text{ «V» } \checkmark$		3
8.	c	iii	<p>Anticlockwise/counterclockwise/CCW <math>\checkmark</math></p> <p>magnetic field from the wire is «increasing» into the page <b>OR</b> induced field must be out of the page <math>\checkmark</math></p>		2
8.	d		<p>sine graph with half the period, i.e. one large square/5 small squares (by eye) <math>\checkmark</math></p> <p>and twice the amplitude, i.e. four small squares (by eye) <math>\checkmark</math></p>		2

8.	e	i	<p>use of <math>qvB = mv^2/r</math></p> <p><b>OR</b></p> $r = \frac{mv}{qB} \checkmark$ $1.6 \times 10^{-19} \times 4.0 \times 10^{-6} = \frac{9.11 \times 10^{-31} \times 9 \times 10^5}{r}$ <p><b>OR</b></p> $r = \frac{(9.11 \times 10^{-31})(9 \times 10^5)}{[(1.6 \times 10^{-19})(4 \times 10^{-6})]} \checkmark$ <p><math>r = 1.28</math> <b>OR</b> <math>1.3</math> «m» <math>\checkmark</math></p>		3
8.	e	ii	<p>Force/Field decreases as electron moves away from the wire <math>\checkmark</math></p> <p>Hence radius increases. <math>\checkmark</math></p>		2