8825-6709M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2025

Physics

Higher level

Paper 2

19 pages

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. Words in angled brackets **« »** in the "Answers" column are not necessary to gain the mark.

8. Words that are underlined are essential for 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. 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.

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 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.

13. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

14. CNA refers to a correct numerical answer.

15. Allow reasonable substitutions where in common usage, *eg* ^{c} for rad.

Question			Answers	Notes	Total
1	a	i	$V = \frac{4}{3}\pi\left(3.5\times10^{-3}\right)^3 = 1.8\times10^{-7}\ \text{m}^3$ ✓	*Must see full substitution OR answer to 2 (or more) significant figures*	**[1]**
1	a	ii	$F_b = \rho Vg = (1000)\ (1.8\text{x}10^{-7})\ (9.8) = 0.00176$ ✓ $m = \frac{W}{g} = \frac{1.6\times10^{-3}}{9.8} = 1.63\times10^{-4}\ \text{kg}$ ✓ $a = \frac{\sum F}{m} = \frac{F_b - F_g}{m} = \frac{1.6\times10^{-4}\ \text{N}}{1.63\times10^{-4}\ \text{kg}} = 0.98\ \text{m s}^{-2}$ ✓		**[3]**
1	b		As the speed of the droplet increases, the drag force increases ✓ net force changes/decreases ✓		**[2]**

Question			Answers	Notes	Total
1	c	i	net force/acceleration becomes zero ✓ weight and drag force cancel out buoyancy force ✓		[2]
1	c	ii	Use of $F_d = 6\pi\eta rv$ ✓ $«v = \frac{F_b - F_g}{6\pi\eta r} = \frac{\left(1.8\times10^{-3}\right)-\left(1.6\times10^{-3}\right)}{6\pi(0.0011)(0.0035)}» = 2.2\,\text{ms}^{-1}$ ✓	*Allow ECF from 1(a).*	[2]

Question			Answers	Notes	Total
2	a		«Changing the variable resistor» changes the current in the «circuit» ✓ V = ε – Ir, so as I changes, V changes ✓	*Do not allow arguments based on Ohm's law.*	**[2]**
2	b		**ALTERNATIVE 1** Recognition that the gradient is internal resistance **OR** The attempt to use gradient ✓ $\text{«}r = \frac{6\text{V}}{8\text{A}}\text{»} = 0.75\ \Omega$ ✓ **ALTERNATIVE 2** Reads 24.7 ± 0.1 V from graph ✓ Use $r = (\varepsilon - V)/I$ and any data point to give 0.75 ± 0.02 Ω✓	*Must see full substitution OR answer to 2 (or more) significant figures for MP2.* *Candidates may use the y-intercept value or solve using two discrete data points from the graph.*	**[2]**

Question			Answers	Notes	Total
2	c		Use of $\varepsilon = I(R + r)$ **OR** Reference to y-intercept *(I = 0)* ***OR*** Line extrapolated back to y-axis ✓ 24.7 V ✓	*Accept 24.6 - 25.2 V for MP2.*	**[2]**
2	d	i	Use of $\Delta S = \frac{\Delta Q}{T}$ ✓ $= \frac{(0.012\ \text{kg})(2.3 \times 10^6)}{100 + 273} = 74\ \text{J K}^{-1}$ ✓		**[2]**
2	d	ii	greater number of possible arrangements (microstates) of particles in steam ✓ greater disorder in particles in steam ✓ greater number of possible ways to distribute energy in steam ✓ Since ΔQ is positive, $\Delta S = \frac{\Delta Q}{T}$ *is positive* ✓		**[1 max]**

Question			Answers	Notes	Total
3	a		**ALTERNATIVE 1** Recognition that at maximum displacement, $E_T = E_E$ ✓ $E_E = ½ k\Delta x^2$; since $\Delta x = x_o$, $E_T = ½ kx_o^2$ ✓ **ALTERNATIVE 2** $\omega = \frac{2\pi}{T} = \frac{2\pi}{2\pi\sqrt{\frac{m}{k}}} = \sqrt{\frac{k}{m}}$ ✓ $E_T = \frac{1}{2}m\omega^2 x_0^{\,2} = \frac{1}{2}m(\sqrt{\frac{k}{m}})^2 x_0^{\,2}$ ✓ **ALTERNATIVE 3** $F = ma;\ kx_0 = m(\omega^2 x_0)$ to give $k = m\omega^2$ ✓ $E_T = \frac{1}{2}(m\omega^2)\, x_0^2 = \frac{1}{2}k\, x_0^2$ ✓		**[2]**
3	b		$E = \frac{1}{2}kx_0^{\,2} = (0.5)(24.5)(0.15)^2 = 0.2756 = 0.28$ J ✓		**[1]**
3	c		Use of $v_{max} = \omega x_o$ **OR** $v_{max} = \sqrt{\frac{k}{m}}x_o$ **OR** $KE_{max} = \frac{1}{2}m(v_{max})^2$ ✓ 1.4 **OR** $\sqrt{2}$ ✓		**[2]**

Question			Answers	Notes	Total
4	**a**	**i**	$I = \frac{F}{BL} = \frac{0.084}{(1.2)(0.6)} = 0.12\ \text{A}$ ✓	*Must see full substitution OR answer to 2 (or more) significant figures for MP2.*	**[1]**
4	**a**	**ii**	Down the page ✓		**[1]**
4	**a**	**iii**	Current «in the rod» creates a magnetic field **OR** Reference to a hand rule ✓ The magnetic field is into the page on the right side of the wire **OR** out of the page on the left side of the wire ✓ Therefore the net field is larger/stronger on the right side of the wire **OR** the net field is smaller/weaker on the left side of the wire. ✓	*Allow a drawing of the wire's magnetic field on the given diagram for MP2*	**[3]**

Question			Answers	Notes	Total
4	a	iv	**ALTERNATIVE 1** The loop is enclosing a larger area of flux density as the rod moves to the right ✓ So the force induced to the left will oppose this change ✓ **ALTERNATIVE 2** An external source of energy must be exerting the force on the rod to the right ✓ This force induces electrical energy that must as a result oppose the change that created it ✓ **ALTERNATIVE 3** As a result of the motion the magnetic flux increases ✓ The induced current must oppose this so be anticlockwise/up the metal rod ✓		**[2]**
4	b		*Use of* $I_1 = I_2 = 0.117$ ✓ $\frac{F}{L} = \mu_0 \frac{I^2}{2\pi r} = 4\pi \times 10^{-7} \frac{0.117^2}{2\pi(0.6)}$ = 4.6×10^{-9} ✓ kg s^{-2} ✓	*Allow ECF from 4a(i).* *MP3 should be awarded for correct units regardless of value.*	**[3]**

Question			Answers	Notes	Total
5	a		Recognition that g is the gradient of the tangent line at 15 Mm ✓ $g = \frac{\Delta V_g}{\Delta r} = \frac{70 \text{ MJ kg}^{-1}}{12 \text{ Mm}} = -6.0 \text{ N kg}^{-1}$ ✓	*Accept range 5 - 7 N kg^{-1}.*	**[2]**
5	b	i	1.4 Mm ✓	*Allow 1.35 - 1.45 Mm.*	**[1]**
5	b	ii	Recognition that this is from V = - 94 to V = - 38 **OR** ΔV = 56 MJ kg^{-1} ✓ $m = \frac{W}{\Delta V} = \frac{8.1\times10^{10}}{56\times10^{6}} = 1446\,\text{kg} = 1400\,\text{kg}$ ✓	*MP1 allow ΔV= 54 - 56 MJ kg^{-1}.* *Allow ECF for MP2.*	**[2]**

Question			Answers	Notes	Total
6	a	i	Strong nuclear force ✓	*Allow strong force.*	**[1]**
6	a	ii	**ALTERNATIVE 1** Protons repel each other so no nuclei could form ✓ Unless an attractive force exists to overcome this repulsion ✓ **ALTERNATIVE 2** Deviation from Rutherford scattering / drop off of scattering at high energies (≥28 MeV) ✓ This is due to strong nuclear force acting on alpha particle ✓ **ALTERNATIVE 3** The binding energy per nucleon is mostly constant above a certain point (A~60) ✓ this is the consequence of an attractive <<short range>> force ✓ **ALTERNATIVE 4** Most nuclei have large binding energies ✓ Indicating that a strong force keeps nucleons together ✓	*MP1 is required to award MP2*	**[2]**
6	b	i	$^{40}_{19}\mathrm{K} \rightarrow {}^{40}_{20}\mathrm{Ca}$ ✓ $+{}^{0}_{-1}\beta + \bar{\nu}$ both shown ✓		**[2]**

Question			Answers	Notes	Total
6	b	ii	$\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{(9.11\times10^{-31})(580)} = 1.3\times10^{-6}$ m ✓		[1]
6	c	i	$\lambda = \frac{\ln 2}{(1.28\times10^{9})(365)(24)(3600)} = 1.72\times10^{-17}$ s^{-1} ✓	*Must see full substitution OR answer to **3** (or more) significant figures.*	[1]
6	c	ii	$N_0 = \frac{5}{39.1}\times0.00012\times6.02\times10^{23} = 9.24\times10^{18}$ ✓ $A_o = \lambda N_o = (1.72\text{x}10^{-17})\ (9.24\text{x}10^{18}) = 159$ Bq ✓		[2]
6	c	iii	**ALTERNATIVE 1** $0.98 = e^{-\lambda t}$ ✓ ln (0.98) = - (1.72x10^{-17}) t to give t = 1.2x10^{15} s or 3.7x10^{7} years ✓ **ALTERNATIVE 2** $0.98 = \left(\frac{1}{2}\right)^{n}$ ✓ $n = \frac{\ln(0.98)}{\ln(0.50)} = 0.029$ to give $t = (1.28\text{x}10^{9})(0.029) = 3.7\text{x}10^{7}$ years ✓		[2]

Question			Answers	Notes	Total
7	a	i	The outward «radiation/thermal» pressure/force is balanced by the «inward» gravitational pressure/force ✓	*Need to see reference to gravitational force/pressure. Do not accept "gravity".*	**[1]**
7	a	ii	Nuclei need to have sufficiently high speed/energy to overcome repulsive force ✓ Nuclei need to be sufficiently close for the strong nuclear force to cause attraction ✓		**[2]**
7	a	iii	The core of star A is at a much higher temperature than the surface ✓ Gas/plasma in the hot core becomes less dense and moves to the surface of the star **OR** Gas/plasma at the cool surface becomes more dense and moves toward the core ✓		**[2]**
7	b	i	$d = \left(\frac{1}{0.74}\right)(3.26)(9.46 \text{ x } 10^{15}) = 4.2 \text{ x } 10^{16} \text{ m}$ ✓	*Distance must be stated in metres.*	**[1]**

Question			Answers	Notes	Total
7	b	ii	$\frac{L_A}{L_S} = \left(\frac{0.9R_s}{R_s}\right)^2 \left(\frac{5200}{5800}\right)^4 = 0.52$ ✓	*Must see full substitution OR answer to 2 (or more) significant figures.* *Allow the reverse fraction, leading to 1.92.*	**[1]**
7	b	iii	Use of $b = \frac{L}{4\pi d^2}$ ✓ $b_A = \frac{0.52L_S}{4\pi(4.16\times10^{16})^2}$ ✓ $b_A = (2.4\times10^{-35})L_S$ Wm^{-2} ✓	*Allow ECF from b(i) in denominator and b(ii) in numerator.* *Allow ECF for MP3.*	**[3]**
7	c	i	$\lambda_{max} = \frac{2.9\text{x}10^{-3}}{5200} = 5.58\text{ x }10^{-7}$ m **OR** 558 nm ✓	*Must see full substitution OR answer to 3 (or more) significant figures.*	**[1]**

Question			Answers	Notes	Total
7	c	ii	Use of $c = f\lambda$ OR $E = \frac{hc}{\lambda}$ ✓ $E = \frac{(6.63\times10^{-34})(3\times10^{8})}{5.57\times10^{-7}} = 3.6\times10^{-19}\,J$ **OR** 2.25 eV ✓		**[2]**
7	c	iii	Star A is moving toward Earth ✓ Therefore the wavefronts are closer together «and the wavelength is reduced» ✓	*MP1 must be correct to earn MP2* *For MP2 we need to see the connection to wavefronts.*	**[2]**
7	c	iv	$v = \frac{\Delta\lambda}{\lambda}c = \frac{0.007}{100}\times3\times10^{8} = 21000$ ✓ 21 km s^{-1} ✓	*Allow ECF for MP2.* *Do not award MP1 for use of the Doppler formulas for sound and mechanical waves.*	**[2]**
7	d		Stellar gases absorb specific wavelengths of light ✓ «Absorption» spectrum is observed on Earth ✓ The observed spectral lines are compared to known chemical spectra ✓		**[3]**

Question			Answers	Notes	Total
8	a	i	$V = \pi r^2 h = \pi 0.9^2 \times 24 = 61.07 \text{m}^3$ ✓ $P = \frac{(4200)(8.31)(273+15)}{61.07} = 0.16$ MPa ✓	*Allow MP1 to be seen in MP2.*	**[2]**
8	a	ii	F = 4*PA* = 4(1.6 x 10^5) (15 x 24 x 1.8) «= 4.14 x 10^8 N» ✓ F = *mg* cos θ = m (9.8) (cos 4) «= 9.78 m N» ✓ $m = \frac{4PA}{g\cos\theta} = \frac{4.14\times10^8}{9.78} = 4.3\times10^7 \text{kg}$ ✓	*Do not award MP2 if the cos θ term is omitted.* *Allow ECF for MP3.*	**[3]**
8	a	iii	Even weight/mass distribution ✓ Shape of the airbags/they do not touch ✓ Deformation at the end of the airbags ✓		**[1 max]**
8	a	iv	Internal energy / U decreases ✓ ΔQ=0 and therefore ΔU = -W **OR** «Adiabatic expansion causes» *T* decreases ✓		**[2]**
8	b	i	$a = \frac{2s}{t^2} = \frac{2(14)}{8^2} = 0.44 \text{ m s}^{-2}$ ✓		**[1]**

Question			Answers	Notes	Total
8	b	ii	**ALTERNATIVE 1** $F_g = mg\sin\theta = (4.5 \times 10^6)(9.8)(\sin 4)$ « $= 3.08 \times 10^6$ N » **OR** $F_{net} = ma = (4.5 \times 10^6)(0.44)$ «$= 1.97 \times 10^6$ N» ✓ Friction = $F_g - F_{net} = 3.08 - 1.97 = 1.11$ MN ✓ **ALTERNATIVE 2** $a_{net} = g \sin\theta - a = (9.81)(\sin 4) - 0.4375$ «$= 0.2468$ m s^{-2}» ✓ $F = ma = (4.5 \times 10^6)(0.2468) = 1.11$ MN ✓	*Must see full substitution OR answer to 3 (or more) significant figures for MP2.*	**[2]**
8	b	iii	F_N/N/Normal force perpendicular to slope AND mg/W/weight vertically downwards ✓ F_d/drag/F_F/Friction opposing motion and parallel to the slope ✓	*Do not allow g / gravity for the downward force.* *Ignore additional forces.*	**[2]**

Question			Answers	Notes	Total
8	c	i	$\theta = 2\pi revolutions = 2\pi\frac{s}{2\pi r} = \frac{7}{0.9} = 7.78$ rad ✓		[1]
8	c	ii	Frictional forces on the top and bottom « of the rod » are in opposite directions ✓ A « net/unbalanced anticlockwise »torque is produced ✓		[2]
8	d	i	$\omega = \frac{v}{r} = \frac{2}{0.9} = 2.22\,\text{rad}\,\text{s}^{-1}$ ✓		[1]
8	d	ii	***Alternative 1*** $t = \frac{\left(\frac{C}{8}\right)}{v} = \frac{\left(\frac{2\pi r}{8}\right)}{2.0} = 0.35\,\text{s}$ ✓ ***Alternative 2*** $t = \frac{\left(\frac{\pi}{4}\right)}{\omega} = 0.35$ s ✓	*Allow 0.35-0.36 s.*	[1]
8	d	iii	Use of $v = \omega x_0 \cos(\omega t + \phi)$ and $\phi = \frac{\pi}{4}$ ✓ $v = \omega x_0 \cos(\omega t + \phi) = (2.22)(0.9)\cos\left((2.22)(3) + \frac{\pi}{4}\right) = 0.79\,m\,s^{-1}$ ✓		[2]