Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2024

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 <u>underlined</u> 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.

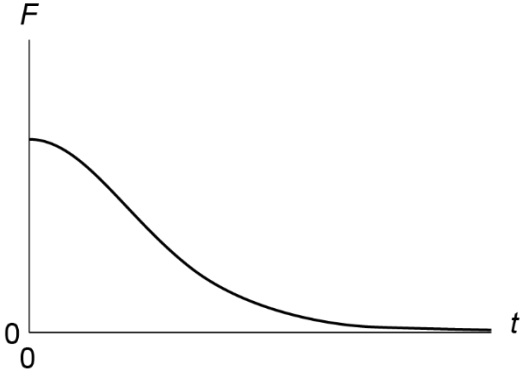
11. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

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.

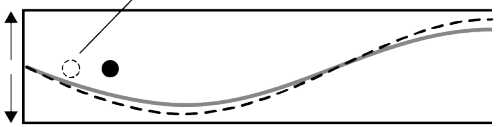
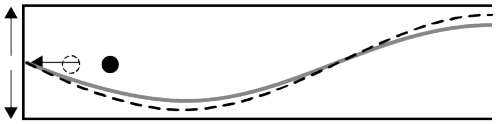
14. Allow reasonable substitutions where in common usage, *eg* ^{c} for rad.

Question			Answers	Notes	Total
1.	(a)		$v = \ll \sqrt{2gh} = \gg \sqrt{2 \times 9.81 \times 28}$ **OR** 23.4 $\ll m\,s^{-1} \gg$ ✓	*Starting point can be suvat equations or conservation of energy.* *Answer must be seen to at least 3 s.f. or correct substitution shown.* *Allow 23.7 for use of g = 10*	**[1]**
	(b)	(i)	$[k] = \frac{\text{N}}{\text{m}^2\,\text{s}^{-2}} = \frac{\text{kgm s}^{-2}}{\text{m}^2\,\text{s}^{-2}}$ ✓ $[k] = \text{kgm}^{-1}$ ✓	*kg m s^{-2}* **OR** *m^2 s^{-2} seen for MP1*	**[2]**
	(b)	(ii)	***ALTERNATE 1*** Resistance/drag force/friction increases with speed ✓ Until it becomes equal to the weight ✓ Net force/acceleration is then zero **«**and so speed is constant**»**✓ ***ALTERNATE 2*** Resistance force increases with speed ✓ Until GPE lost no longer converted to KE ✓ But to thermal energy/work done against resistive force ✓		**[2 max]**
	(c)	(i)	28 <<m>>✓	*Accept range 25 to 31 <<m>> for those who counted squares* *Do not allow displacement or distance travelled. A value is required.*	**[1]**
		(ii)	***Alternate 1*** $mg = kv^2$ with v = 9.5 m s^{-1} ✓ $k = \text{«}\frac{mg}{v^2} = \frac{2.7 \times 10^{-3} \times 9.81}{9.5^2} = \text{»} 2.9 \times 10^{-4}$ ✓	*Allow 3.0 x 10^{-4} for use of g = 10.* *Allow ECF for MP2 from incorrect read off from graph.* *Ignore any units on k.*	**[2]**

			Alternate 2 Determination of acceleration from gradient of a tangent at any point other than t = 0✓ Use of $mg - kv^2 = ma$ to find k✓ For example: Gradient at t = 1 s is 3.9 «m s^{-2}» and speed is 7.4 «m s^{-1}» $k = «\frac{mg - ma}{v^2} = \frac{2.7 \times 10^{-3} \times (9.81 - 3.9)}{7.4^2} =» 2.9 \times 10^{-4}$	*Do not award MP1 for simply calculating the gradient and equating it to k. For MP1 there needs to be a recognition that the gradient is the acceleration.* *Range for Alternate 2* *(2.5 to 3.3) x 10^{-4}*	
	(c)	(iii)	Any curve starting at a non zero value approaching/reaching zero✓  	*Ignore wrong curvature /gradient of curve.* *Curve must intersect axis at t = 0*	**[1]**
	(c)	(iv)	Energy dissipated is $«mgh - \frac{1}{2}mv_t^2 = 2.7 \times 10^{-3} \times (9.81 \times 28 - \frac{1}{2} \times 9.5^2) =» 0.620$ «J» ✓ Correct reading of time 3.6 <<s>>✓ Power = $\frac{0.620}{3.6} = 0.17$ «W» ✓	*Allow ECF from MP2 to MP3* *Watch for ECF from incorrect value of v in cii)*	**[3]**
	(d)		***ALTERNATE 1*** $\Delta p =$ «$2.7 \times 10^{-3} \times (7.8 + 9.5) =» 0.0467$ «Ns» ✓ $\ll 1.1 = \frac{\Delta p}{\Delta t}$ so $T = \frac{0.0467}{1.1} =\gg 0.042 \ll s \gg$ ✓	*Watch for ECF from incorrect value of v in cii).*	**[2]**

			ALTERNATE 2 $a = \ll \frac{F}{m} = \gg \frac{1.1}{2.7\times10^{-3}} = 407 \ll \text{m s}^{-2} \gg$ ✓ $T = \ll \frac{9.5+7.8}{407} = \gg 0.042 \ll s \gg$ ✓	*Award [1] for t = 0.076 << s >> using an impact speed of 23 m s^{-1}.*	

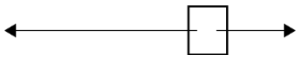
Question			Answers	Notes	Total
2.	(a)	(i)	$Q = \ll mc\Delta\theta = \gg 0.035 \times 2100 \times 10 = 735 \ll J \gg$ ✓ Average power $\ll \frac{735}{4 \times 60} \gg = 3.1 \ll W \gg$ ✓	*MP1 can be awarded for a correct substitution or value*	**[2]**
	(a)	(ii)	$Q = \text{«}3.06 \times 60 \times 60 = \text{»} 1.10 \times 10^4$ **«J»** ✓ $L = \text{«}\frac{Q}{m} = \frac{1.10 \times 10^4}{0.035} = \text{»} 3.1 \times 10^5$ **«**Jkg^{-1}**»** ✓	*Allow 3.1 x10^5 OR 3.2 x 10^5 <<J kg^{-1} >> Watch for ECF from ai).*	**[2]**
	(b)		The internal energy of the liquid water is greater than that of ice✓ As the <<random>> kinetic energy <<of the molecules>> is the same ***OR*** the <<intermolecular>> potential energy for water is greater✓		**[2]**

Question			Answers	Notes	Total
3.	(a)		The transfer/propagation of energy/momentum/information✓ Through oscillations/vibrations of medium/fields✓ Positions of maximum and minimum amplitude ***OR*** crests and troughs travel through a medium ✓		**[2 max]**
	(b)	(i)	The incoming wave is reflected «from the closed end»✓ <<The reflected and incoming wave>> superpose/interfere✓		**[2]**
	(b)	(ii)	$\lambda = \text{«}\frac{4L}{3} = \frac{4\times 1.20}{3} = \text{»} 1.6 \text{«m»}$ ✓		**[1]**
	(b)	(iii)	$c = \ll \lambda f = 1.60 \times 210 = \gg 336$ ***OR*** $340 \ll \text{m s}^{-1} \gg$ ✓ Any answer to 2 ***OR*** 3 s.f. ✓	*Allow ECF from incorrect wavelength in bii)*	**[2]**
	(c)	(i)	new position  To the left of the equilibrium position on the same level✓	*Accept any distance to the left*	**[1]**
	(c)	(ii)	 Left horizontal arrow ✓	*Accept any arrow to the left inside the tube.*	**[1]**
	(d)	(i)	$\omega = \ll 2\pi f = \gg 2\pi \times 210 = 1.319 \times 10^3 \ll \text{rad s}^{-1} \gg$ ✓ $\ll Energy = \frac{1}{2} m\omega^2 x_o^2 = \frac{1}{2} \times 1.8 \times 10^{-6} \times \left(1.319 \times 10^3\right)^2 \times \left(4.2 \times 10^{-3}\right)^2 = \gg$	*MP1 can be awarded for a correct substitution or value*	**[2]**

			2.7×10^{-5} ***OR*** 2.8×10^{-5} ≪ J ≫ ✓		
		(ii)	***ALTERNATE 1*** $\frac{1}{2}m\omega^2x^2=\frac{1}{2}\times(\frac{1}{2}m\omega^2x_0^2)$ ✓ $x=\frac{x_0}{\sqrt{2}}=\frac{4.2}{\sqrt{2}}=3.0$ «mm» ✓ ***ALTERNATE 2*** $\frac{1}{2}m\omega^2(x_0^2-x^2)=\frac{1}{2}m\omega^2x^2$ ✓ $x=\frac{x_0}{\sqrt{2}}=\frac{4.2}{\sqrt{2}}=3.0$ «mm» ✓ ***ALTERNATE 3*** Recognition that potential energy is 1.4 x 10^{-5} «J» ✓ $x=$ «$\sqrt{\frac{2\times14\times10^{-3}}{1.8\times10^{-6}\times(1.33\times10^3)^2}}$ =»3.0 «mm» ✓	*For Alternate 3 allow ECF from the energy value from di).*	**[2]**
	(e)		***ALTERNATE 1*** the pipe can only support standing waves with frequencies that are odd multiples of the first harmonic frequency ✓ first harmonic frequency is 70 Hz ✓ ***ALTERNATE 2*** <<the new wavelength would be 2.4 m so>> a node would be formed at the open end ✓ An antinode is required at the open end to form a standing wave ✓		**[2]**

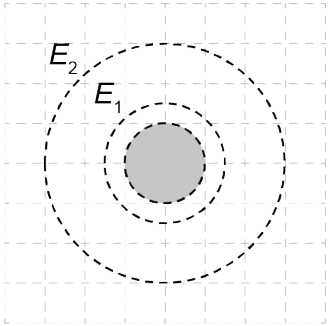
Question			Answers	Notes	Total
4.	(a)		Conservation of «electric» charge✓	*Do not accept 'Kirchoff's law' as the sole answer.* *If conservation of charge and Kirchoff's Law are stated award [1].* *If conservation of charge is listed along with other fundamental laws e.g. conservation of energy, award [0].*	**[1]**
	(b)	(i)	***ALTERNATE 1*** Identification that the p.d across r is 0.300 V ***OR*** current in external R is $\frac{1.20}{5.00} = 0.240$ «A» ✓ «$V = E - Ir \Rightarrow r = \frac{E-V}{I} = \frac{0.300}{0.240} =$»1.25 «Ω» ✓ ***ALTERNATE 2*** Current is $I = \frac{E}{R+r}$ and so $V = E - \frac{Er}{R+r}$ ✓ $r = 1.25$ «Ω» ✓		**[2]**
	(b)	(ii)	V decreases✓ Current increases, so pd across r increases ✓	*Do not award marks from a calculation. These points must be stated.*	**[2]**
	(c)	(i)	Vertically down arrow from the proton✓	*If more than one arrow is included the velocity must be clearly labelled.*	**[1]**
	(c)	(ii)	$evB = \frac{m_p v^2}{R}$ ✓ $f = \frac{1}{T} = \frac{v}{2\pi R}$ ✓	*Both q and e are acceptable for the charge.*	**[3]**

			Algebra leading to required expression «$= \frac{eB}{2\pi m_p}$» ✓		
		(iii)	$f = «\frac{1.6\times10^{-19}\times2.5}{2\pi\times1.67\times10^{-27}} =»3.8\times10^{7}$ «Hz» ✓		**[1]**

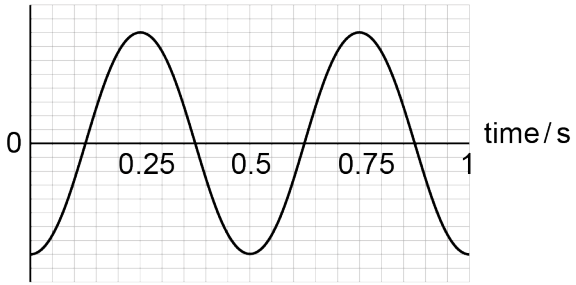
Question			Answers	Notes	Total
5.	(a)		$\frac{GMm}{R^2}$ ***OR*** mg N  Arrow for *N* <u>and</u> correct labelling✓ $\frac{GMm}{R^2} - N = m\omega^2 R$ result follows✓	*N arrow must be shorter than weight. Award [0] if there are extra forces or incorrect length arrows in the diagram. On diagram allow Weight, W, F_g, gravitational force but not gravity. Allow rotated diagrams if the surface of the asteroid is shown. For MP2 the algebra must follow from a diagram with correct length arrows.*	**[2]**
	(b)		$N \geq 0$, so $m\left(\frac{GM}{R^2} - \omega^2 R\right) \geq 0$ gives result ***OR*** <<max>> ω when N = 0, so $m\left(\frac{GM}{R^2} - \omega^2 R\right) = 0$ gives result ✓		**[1]**
	(c)	(i)	Selection of solar constant, 1360 seen✓ **«**Intensity is proportional to d^{-2} so**»** **«**$\frac{I}{1360} = \frac{\frac{P}{4\pi(4d)^2}}{\frac{P}{4\pi d^2}}$**»** $I = \frac{1360}{4^2} =$ **«**85.0 W m^{-2}**»** ✓	*Allow ECF for MP2 from incorrect solar constant.*	**[2]**
	(c)	(ii)	$\sigma T^4 = 85$ ***OR*** $T = \sqrt[4]{\frac{85}{5.67 \times 10^{-8}}}$ ✓ $T = 196.7 \approx 2.0 \times 10^2$ **«**K**»** ✓	*Award [2] for 140 K, if factor of ¼ is included*	**[2]**

Question			Answers	Notes	Total
6.	(a)	(i)	A particle without structure/constituents/component particles✓		**[1]**
	(a)	(ii)	Electromagnetic, weak <<nuclear>>, strong< <nuclear>> <<and gravitational>>✓	*Allow electroweak for electromagnetic and weak*	**[1]**
	(a)	(iii)	Weak✓ Decay violates strangeness **«**and only the weak interaction does**»**✓	*For MP2 allow comments that suggest that strangeness has changed in the interaction*	**[2]**
	(b)	(i)	According to $E = \Delta mc^2$ / identifies mass energy equivalence ✓ energy is released when nucleons come together / a nucleus is formed «so nucleus has less mass than individual nucleons» ***OR*** energy is required to «completely» separate the nucleons / break apart a nucleus «so individual nucleons have more mass than nucleus» ✓		**[2]**
	(b)	(ii)	$Q = 224 \times 7.679917 + 4 \times 7.073915 - 228 \times 7.645074$ ✓ $Q = 5.520$ **«**MeV**»** ✓	*Allow* $8.8 \times 10^{-13} J$ *Award [1max] if answer is negative.*	**[2]**
	(b)	(iii)	Nuclei exist in energy levels ***OR*** <<After the decay>> radium is in an excited <<nuclear>> energy level/state✓ Gamma ray is emitted when radium falls to a lower <<nuclear>> energy level/state✓		**[2]**

Question			Answers	Notes	Total
7.	(a)	(i)	Path difference is $\frac{b}{2}\sin\theta \approx \frac{b\theta}{2}$ ✓ Phase difference is $\frac{2\pi}{\lambda}\frac{b\theta}{2}$ ✓ i.e. $\frac{\pi b\theta}{\lambda}$	*Use of approximation for θ could be in MP1 or MP2.*	**[2]**
	(a)	(ii)	For destructive interference at first minimum, phase difference is π✓ Result follows ***OR*** Path difference = $\frac{\lambda}{2}$ ✓ Result follows from MP1 of ai)		**[1]**
	(b)	(i)	$\ll \theta = \gg 1.22 \times \frac{1200 \times 10^{-9}}{6.5}$ ***OR*** 2.25 x 10^{-7} <<*rad*>>✓ $s =$ **«**$\frac{1.22 \times 1200 \times 10^{-9} \times 1.3 \times 10^{26}}{6.5}$ **=»**2.9×10^{19} **«**m**»** ✓	*Award [1] for 2.4 x 10^{19} <<m>> for neglecting 1.22* *Allow ECF for substitution for distance in light years.*	**[2]**
	(b)	(ii)	Diffraction angle **«**$1.22 \times \frac{\lambda}{b}$**»** increases so angular separation required between objects increases, so resolution is not improved ***OR*** Longer wavelengths will increase the linear size that needs to be resolved larger, so resolution is not improved✓	*Clear argument must be seen. Do not allow bald answer that the resolution is not improved.*	**[1]**

Question			Answers	Notes	Total
8.	(a)		***ALTERNATE 1*** $E_T = «\frac{2GMm}{3R} - \frac{GMm}{R} =» -\frac{1}{3}\frac{GMm}{R}$ ✓ $E_T < 0$ hence it will not escape✓ ***ALTERNATE 2*** $\frac{1}{2}mv^2 = \frac{2GMm}{3R} \Rightarrow v = \sqrt{\frac{4GM}{3R}}$ ✓ $v < v_{esc}$ hence it will not escape✓	*Argument necessary to get second MP. Do not accept a bald statement that it will not escape.* *Allow ECF from MP1.*	**[2]**
	(b)	(i)	$g = «\frac{\Delta V_g}{\Delta r} =» \frac{2.2\times10^6}{\frac{8.5\times10^6}{2}}$ ✓ $g = 0.52 \ll \text{N kg}^{-1} \gg$ ✓	*Ignore negative sign*	**[2]**
	(b)	(ii)	 << $-\frac{GM}{x} + \frac{2GM}{3R} = -\frac{2GM}{3R} + \frac{GM}{R}$ thus>> $x = 3R$ ✓ Circle of radius $3R$ drawn✓		**[2]**

Question			Answers	Notes	Total
9.	(a)	(i)	***ALTERNATE 1*** In time Δ*t*, rod moves a distance *v*Δ*t*✓ Flux increases by *B*(*Lv*Δ*t*)✓ **«**By Faraday**»** induced emf is the rate of change of flux: $\frac{BLv\Delta t}{\Delta t}$ ✓ **«**=*BLv***»** ***ALTERNATE 2*** <<From $\varepsilon = -\frac{N\Delta\Phi}{\Delta t}$>> Recognition that $\Phi = BA$ ✓ Recognition that N = 1 ✓ Recognition that $\frac{\Delta A}{\Delta t} = Lv$ ✓ <<Leading to V = vBL ***OR*** ε =BLv> ***ALTERNATE 3*** **«**In steady state**»** electrons stop drifting and so net force is zero✓ $qvB = qE$ ✓ Substitution of $E = \frac{V}{L}$ to get result✓	*ALT 1: Correct MP2 scores MP1* *ALT2:* *V and ε are interchangeable. Ignore negative sign.*	**[3]**
	(a)	(ii)	The left end✓		**[1]**
	(b)	(i)	Zero✓		**[1]**

	(b)	(ii)	emf  Cosine ***OR*** negative cosine function✓ Period 0.5 s✓		**[2]**
	(c)		***Alternate 1*** The capacitance will increase✓ Since the voltage stays the same, the charge will increase✓ ***Alternate 2*** The voltage stays the same✓ The capacitance will increase, the charge will increase✓	*Do not award a mark for simply stating that the charge increases.*	**[2]**

Question			Answers	Notes	Total
10.	(a)	(i)	The energy of the electron is discrete/quantized✓		**[1]**
	(a)	(ii)	***ALTERNATE 1*** $v \propto \frac{1}{\sqrt{r}}$ ✓ Leading to $\frac{v_2}{v_1} = \frac{1}{\sqrt{4}} = \frac{1}{2}$ ✓ ***ALTERNATE 2*** $E_K = -E_T = \frac{13.6}{n^2}$ «eV» $\Rightarrow \frac{\frac{1}{2}mv_2^2}{\frac{1}{2}mv_1^2} = \frac{\frac{13.6}{4}}{\frac{13.6}{1}} = \frac{1}{4}$ ✓ Leading to $\frac{v_2}{v_1} = \frac{1}{\sqrt{4}} = \frac{1}{2}$ ✓ ***ALTERNATE 3*** Use of quantization condition: $\frac{mv_2r_2}{mv_1r_1} = \frac{2 \times h}{1 \times h}$ ✓ $\frac{v_2}{v_1} = 2 \times \frac{1}{4} = \frac{1}{2}$ ✓		**[2]**
	(b)		The Bohr model predicts a specific orbit radius for each level/state✓ The wavefunction assigns a probability «distribution» for the electron to be at various distances from the nucleus <<for each level/state>> ***OR*** the Bohr radius is the most likely electron distance <<from the nucleus>>✓		**[2]**

	(c)		$\Delta p = \ll \frac{h}{4\pi\Delta x} = \gg \frac{6.63\times10^{-34}}{4\pi\times3\times10^{-15}} \ll = 1.76\times10^{-20} \gg \ll$ N s $\gg$ ✓ $E_K = \text{«}\frac{(\Delta p)^2}{2m_n} = \frac{(1.76\times10^{-20})^2}{2\times1.67\times10^{-27}} =\text{»}\ 9.2\times10^{-14}$ ***OR*** 9.3×10^{-14} «J» *or* 0.58 «MeV» ✓		**[2]**