Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2024

Physics

Higher

Paper 2

14 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		«$0.20 \times 0.80T$» $= 0.16T$ ✓		1
	b		$\frac{1}{2} \times T \times 0.16T = 1800$ ✓ $T = 150$ ≪ s ≫ ✓	*Award MP1 for any recognition that area under graph is displacement.*	2

Question			Answers	Notes	Total
2	a	i	$mg \times 0.15 = \frac{1}{2}mv^2$ ✓ $v = \sqrt{2 \times 9.81 \times 0.15}$ *OR* 1.72 ≪ ms^{-1} ≫ ✓	*Award MP1 for recognition that KE of car at P is GPE lost.* *Do not award MP1 for answers based on suvat equations. MP2 can still be awarded for a correct answer.*	2
	a	ii	$N + mg = \frac{mv^2}{r}$ ✓ $N = 0.12 \times (\frac{1.72^2}{0.15} - 9.81)$ ✓ $N = 1.2$ «N» ✓	*Allow 1.1 or 1.2 depending on g and rounding of v.*	3

				Award [0] for answers based on N = W.	
	a	**iii**	***ALTERNATIVE 1*** the normal force is greater than zero ✓ ***ALTERNATIVE 2*** $min\,imum\ speed\ at\ P\ =\ \sqrt{9.81\times0.15}=1.2\ll m\,s^{-1}\gg$ ***AND*** actual speed is greater ✓	*Do not accept a statement of the value of N e.g. N = 1.2 <<N>>.*	**1**
	b	**i**	***ALTERNATIVE 1*** $mg\times0.45=\frac{1}{2}mv^2$ ✓ $v=\ll\sqrt{2\times9.81\times0.45}\gg\ =3.0\ \ll m\,s^{-1}\gg$ ✓ ***ALTERNATIVE 2*** $0.12\times v=(0.12+0.18)\times1.2$ ✓ $v=3.0$ **«**$\mathrm{m\,s^{-1}}$**»** ✓	*Do not award BCA.* *For ALT1 award MP1 for recognition that KE of car at P is GPE lost.* *For ALT1 do not award MP1 for answers based on suvat equations. MP2 can still be awarded for a correct answer.*	**2**
	b	**ii**	***ALTERNATIVE 1*** rate of change of momentum is the net force ✓ $Fd=\frac{1}{2}(m_1+m_2)u^2$ ✓ $F=$**«**$\frac{0.30\times1.2^2}{2\times0.20}$**»**$1.08\approx1.1$ **«**N**»** ✓ ***ALTERNATIVE 2*** rate of change of momentum is the net force ✓ $a=$**«**$\frac{u^2}{2d}=\frac{1.2^2}{2\times0.20}$**»**$3.6$ **«**$\mathrm{m\,s^{-2}}$**»** ✓ $F=$**«**$ma=0.30\times3.6=$**»**$1.08\approx1.1$ <<N>> ✓ ***ALTERNATIVE 3*** $t=\frac{2\times0.2}{1.2}\ OR\ 0.333\ll s\gg$ ✓	*Do not award BCA.* *MP1 can be awarded if an equation stated implies that force is rate of change of momentum or the final answer is clearly a force.*	**3**

			$\Delta p = (0.18 + 0.12) \times 1.2$ *OR* $0.36 \ll Ns \gg$ ✓ $F \ll = \frac{\Delta p}{\Delta t} = \frac{0.36}{0.333} = \gg 1.1 \ll N \gg$ ✓		
	b	**iii**	$\mu = \text{«}\frac{F}{(m_1 + m_2)g} = \text{»}\frac{1.08}{0.30 \times 9.81}$ ✓ $\mu = 0.367 \approx 0.37$ ✓	*Allow ECF from (bii).*	**2**

Question			**Answers**	**Notes**	**Total**
3	**a**		momentum of molecules/particles changes at each collision with container/walls ✓ so container/walls exert forces on molecules/particles✓ <<by N3>> molecules/particles exert a force on container/walls✓	*Award [1 max] for using 'gas' instead of 'molecules/particles'.*	**Max 2**
	b		<<An ideal gas>> has point particles/elastic collisions/no forces between molecules/zero intermolecular PE/cannot change phase/obeys the ideal gas equation for all P & T✓	*Accept opposite statements for real gas.*	**1**
	c		***ALTERNATIVE 1*** pressure due to gas in left container $3.0 \times 10^4 \times \frac{0.20}{0.30} = 2.0 \times 10^4$ **«**Pa**»** ✓ pressure due to gas in right container $9.0 \times 10^4 \times \frac{0.10}{0.30} = 3.0 \times 10^4$ **«**Pa**»** ✓ adding gives $P = 5.0 \times 10^4$ **«**Pa**»** ✓ ***ALTERNATIVE 2*** number of moles <<in a container is>> $\frac{3.0 \times 10^4 \times 0.20}{RT}$ ***OR*** $\frac{9.0 \times 10^4 \times 0.10}{RT}$ ✓		**3**

			$P \times 0.30 = (\frac{3.0\times10^4\times0.20}{RT} + \frac{9.0\times10^4\times0.10}{RT})RT$ ✓ $P = 5.0\times10^4$ <<Pa>> ✓ ***ALTERNATIVE 3*** Use of $P_1V_1 + P_2V_2 = P(V_1 + V_2)$ ✓ $3.0 \times 10^4 \times 0.2 + 9.0 \times 10^4 \times 0.1 = P(0.2 + 0.1)$ ✓ $P = 5.0 \times 10^4 \ll Pa \gg$ ✓		

Question			Answers	Notes	Total
4	**a**	**i**	the displacement/oscillation is at right angles/perpendicular to the direction of energy transfer/propagation✓	*Accept vibration/movement of particles for oscillation.*	**1**
	a	**ii**	P and Q are performing SHM ✓ <<in SHM>> acceleration is proportional to displacement so P✓ acceleration is a maximum at P ***AND*** zero/minimum at Q ✓	*MP2 can be expressed as an equation.*	**Max 2**
	a	**iii**	wavelength is 1.20 «m»✓ $T = \ll \frac{\lambda}{c} = \frac{1.20}{62} = 1.936 \times 10^{-2} \gg 1.9 \times 10^{-2} \ll s \gg$✓	*For MP2 the final answer must be to 2 s.f.* *Allow ECF from MP1 provided the answer is to 2 s.f.*	**2**
	a	**iv**	distance travelled is 4 × 0.04 ***OR*** 0.16 «m»✓ $v = \ll \frac{0.16}{1.936\times10^{-2}} = \gg 8.3$«m s^{-1}» ✓	*Allow ECF from (aiii).*	**2**

				Allow 8.3 or 8.4 <<m s^{-1} >>	
	b		 ✓	*Accept either the solid or dashed line alone, or 2 solid lines.*	**1**
	c		SHM helps understand wave motion ***OR*** Real/complex systems resemble SHM for small oscillations ***OR*** Complex oscillations can be modelled as a combination of SHM / reference to Fourier analysis ***OR*** If friction is small, SHM can be a good approximation to the real system / small damping ✓		**1**

Question			**Answers**	**Notes**	**Total**
5	**a**		X has a greater resistance ✓ The current is the same ***AND*** power is RI^2 ✓		**2**
	b		Y has greater power✓ voltage is the same ***AND*** power is $\frac{V^2}{R}$ ***OR***	*Allow ECF from (a)*	**2**

			voltage is the same, X has a smaller current ***AND*** power is *IV* ✓	*For MP2 allow a correct argument provided V is constant AND a correct expression for power is included.*	
	c	**i**	value of V/I increases ***OR*** I/V decreases✓ resistance increases with increasing voltage✓	*Allow a calculation of resistance at two points for MP1.* *Do not allow references to gradient of graph.*	**2**
	c	**ii**	<<trial and error to find voltages that add to 12 **«**V**»** for same current>> current is 0.050 **«**A**»** ✓ and voltage for Z is 4.0 **«**V**»**✓ power = <<IV=>> 0.2 **«**W**»**✓	*Award ECF for MP3 if the current chosen for Z matches the V for Z from the graph.*	**3**

Question			Answers	Notes	Total
6	**a**	**i**	**«**minimum**»** energy required to **«**completely**»** separate the nucleons of a nucleus ***OR*** energy released when nucleus is assembled from the nucleons✓	*Accept protons and neutrons for nucleons.*	**1**
	a	**ii**	Use of $Binding\ energy = mass\ of\ separate\ nucleons - mass\ of\ nucleus$ **«**$1105 = 54 \times 938 + 77 \times 940 - Mc^2$**»** ✓ $M = 122$ **«**$\mathrm{GeV\,c^{-2}}$**»** ✓	***Do not*** *allow BCA.* *Award ECF from using binding energy with incorrect sign.* *An answer that doesn't include binding energy scores [0].*	**2**

	b	**i**	<<nuclei with the>> same number of protons✓ different number of neutrons✓		**2**
	b	**ii**	binding energy per nucleon is a measure of stability so $^{131}_{54}\mathrm{Xe}$ has the greater binding energy per nucleon✓	*Correct mention of stability required to award the mark.* *Allow opposite comment for Xe 133.*	**1**
	b	**iii**	protons have 2 u quarks ***OR*** neutrons have one u quark✓ $N = << 2 \times 54 + 1 \times 77 = >> 185$ ✓	*For MP1 accept e.g proton uud.*	**2**
	c	**i**	accept range 5.2 days to 5.4 days✓		**1**
	c	**ii**	***ALTERNATIVE 1*** decay constant in range 0.128 to 0.133 **«**days^{-1}**»**✓ $\frac{A}{A_0} = e^{-\lambda \times 25}$ ✓ answer in range 0.036 to 0.040✓ ***ALTERNATIVE 2*** $n = \frac{25}{5.3} = \ll 4.7\ half\ lives \gg$✓ $\frac{A}{A_0} = 0.5^{4.7}$ ✓ answer in range 0.036 to 0.040✓	*Allow ECF from (c)(i)*	**3**

Question			Answers	Notes	Total
7	a		kinetic energy of wind to rotational/kinetic/mechanical energy of turbine/generator✓ rotational/kinetic/mechanical energy of turbine/generator to electrical energy✓		2
	b		wind stops at blades/air is incompressible/air is not turbulent/wind is normal to rotors/Betz limit ignored✓	*Do not allow answers that state that the quantities in the formula are constant.* *Do not credit answers discussing friction or energy losses to the surroundings.*	1
	c		$P = \frac{1}{2} \times 1.2 \times \pi \times 2.5^2 \times (6.8^3 - 2.6^3)$ ✓ *P* = 3500 W✓	*Do not award BCA. Calculations must be checked.* *Award [1 max] for 3704 W. (Not subtracting the wind after the blades).* *Award [0] for use of* $(6.8 - 2.6)^3$. *Unit required for MP2.*	2

Question			Answers	Notes	Total
8	a	i	the intensity of the maxima is not the same/intensity appears modulated by single slit diffraction pattern/there are secondary maxima and minima✓		1
	a	ii	diffraction minimum at 0.05 rad✓ $b = \ll \frac{\lambda}{\vartheta} = \frac{6.0 \times 10^{-7}}{0.05} = \gg 1.2 \times 10^{-5} \ll m \gg$✓	*Allow ECF from MP1.* *Award [0] for use of* $n\lambda = d \sin \vartheta$	2
	a	iii	diffraction occurs/light diffracts <<at each slit >> ✓		3

			light arrives <<from each slit>> at central max in phase/path difference to central max is zero ✓ constructive superposition/interference takes place ✓	*For MP2 do not allow general statements of phase/ path difference e.g. 2π or integer number of wavelengths. Question asks about central maximum.*	
	a	**iv**	amplitude << at $\theta = 0$ >> is the sum from the 2 slits/double that from a single slit✓ intensity is proportional to the square of the amplitude ***OR*** Intensity is proportional to (number of slits)^2✓	*Accept an equation for MP2.*	**2**
	b		***ALTERNATIVE 1*** smallest wavelength that can be resolved is $\Delta\lambda = << \frac{\lambda}{mN} = \frac{589.3}{2\times 400} >> 0.737 << \text{nm} >>$ ✓ so the 2 lines cannot be resolved since 0.6 < 0.737✓ ***ALTERNATIVE 2*** $\ll Required\ resolvance = \frac{\lambda}{\Delta\lambda} = \gg \frac{589.3}{0.6} \ll = 982 \gg$ ***AND*** $\ll Grating\ resolvance = mN = \gg 2\times 400 = \ll 800 \gg$ ✓ so the 2 lines cannot be resolved since 800 < 982 ✓	*Allow working based on resolvance.* *Accept calculations leading to comparison of N = 490 and 400.* *Accept calculations leading to comparison of m = 2.46 and 2.*	**2**

Question			Answers	Notes	Total
9	**a**		gravitational potential is the work/energy per unit mass in bringing a point mass from infinity to a point in space✓ this work is negative since the force is opposite to the displacement **OR** gravitational force is attractive ***OR***	*ALT1 MP1 'per unit mass' or 'per kg 'must be included.*	**2**

			gravitational force does work ***OR*** work done to bring the mass from the point to infinity would be positive ✓		
	b	**i**	the <<minimum>> speed of an object <<at the surface of a planet>> for the object to reach infinity/leave the gravitational field/escape the gravitational field.✓	*Do not allow 'overcome the force of gravity'.* *Award [0] for answers that state orbit.*	**1**
	b	**ii**	Use of 'GPE at surface R + KE of probe = GPE at new height r '✓ $-\frac{GMm}{R}+\frac{1}{2}m\left(0.9\sqrt{\frac{2GM}{R}}\right)^2=-\frac{GMm}{r}$ ✓ $\ll r=5.3R\ so \gg\ height=4.3R$ ✓	*Award ECF for MP3 from incorrect use of 0.9 factor.*	**3**

Question			Answers	Notes	Total
10	**a**		it confines magnetic field lines ***OR*** transfers magnetic flux to the secondary coil✓		**1**
	b		the alternating voltage in the primary coil produces <<an alternating current and thus>> an alternating magnetic field✓ «therefore» the magnetic flux in the secondary coil is changing with time✓ a changing magnetic flux induces an emf✓		**3**
	c	**i**	identifying 40 V as the peak voltage in the primary coil✓ $\frac{40}{600}=\frac{120}{N}\Rightarrow N=1800$ ✓		**2**

	c	**ii**	$\ll \frac{1}{2\times10^{-3}} = \gg 50 \ll Hz \gg$ ✓		**1**
	d	**i**	$2.5 = \frac{120}{\sqrt{2}} \times I_{\text{rms}}$ ✓ $I_{rms} = 0.029 \ll A \gg$ ✓		**2**
	d	**ii**	$2.5 = R \times (0.029)^2 \Longrightarrow R = 3000 \ll \Omega \gg$ ✓		**1**

Question			Answers	Notes	Total
11	**a**		**«**in the wave theory of light **»** low intensity light means low <<rate of>> transfer of energy. ✓ and so electrons would need time to accumulate the energy they need to escape **«**leading to an observable time delay**»** ✓		**2**
	b	**i**	$1.8 = \frac{1.24\times10^{-6}}{5.2\times10^{-7}} - \phi$ ✓ $\phi = 0.59$ eV ✓	*Accept 0.58 or 0.59.*	**2**
	b	**ii**	KE of electrons at collecting plate is **«**1.8 – 0.6=**»** 1.2 eV ✓ $\frac{1}{2}\times9.1\times10^{-31}\times v^2 = 1.2\times1.6\times10^{-19}$ ✓ $v = 6.5\times10^5 << \text{m s}^{-1} >>$ ✓	*Award [2] for v =9.2×10^5 m s^{-1} (using KE=2.4 eV).*	**3**