Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2022

Physics

Higher level

Paper 2

19 pages

International Baccalaureate®
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Subject Details: Physics HL Paper 2 Markscheme

Mark Allocation

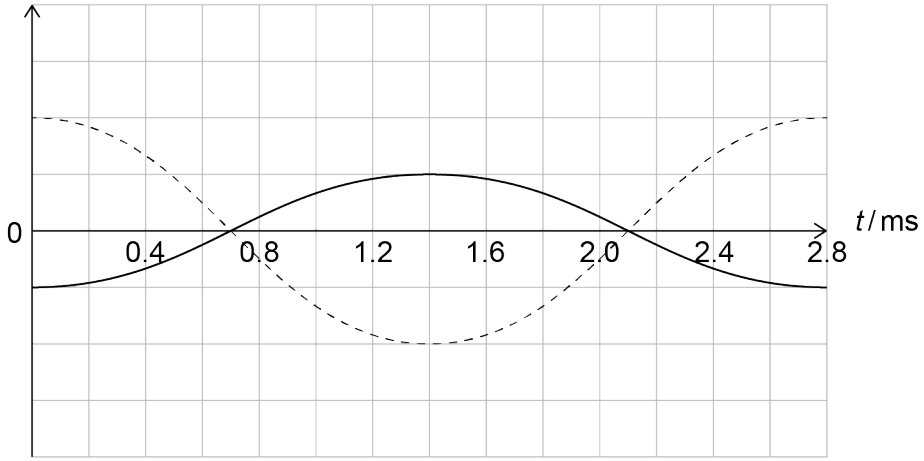
Candidates are required to answer ALL questions. Maximum total = [90 marks].

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

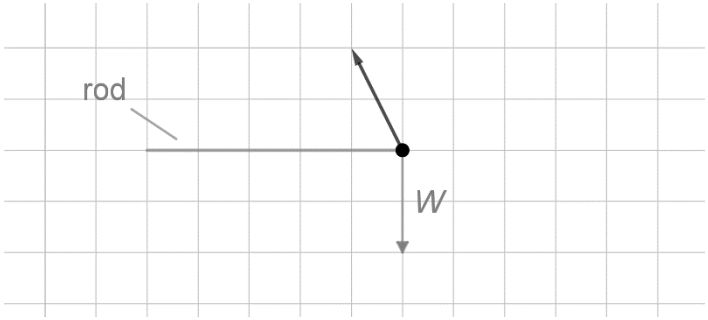
Question			Answers	Notes	Total
1.	a		*g* ***OR*** 9.81 «m s^{-2}» ***OR*** acceleration of gravity/due to free fall ✓	*Accept 10 «*m s^{-2}*».* *Ignore sign.* *Do* ***not*** *accept bald "gravity".* *Accept answer that indicates tangent of the graph at time t=0.*	1
1	b		Identification of air resistance/drag force «acting upwards» ✓ «that» increases with speed ✓ «until» weight and air resistance cancel out ***OR*** net force/acceleration becomes zero ✓	*A statement as "air resistance increases with speed" scores* ***MP1*** *and* ***MP2****.*	3
1	c	i	«loss in» GPE $=3.4\times10^{-5}\times9.81\times21$ «$=7.0\times10^{-3}$» «J» ***OR*** «gain in» KE $=0.5\times3.4\times10^{-5}\times9.0^2$ «$=1.4\times10^{-3}$» «J» ✓ energy transferred to air «$=7.0\times10^{-3}-1.4\times10^{-3}$» $=5.6\times10^{-3}$ «J» ✓ any calculated answer to 2 sf ✓	*Allow* ***[1]*** *through the use of kinematics assuming constant acceleration.* *Allow* ***ECF*** *from* ***MP1***	3
1	c	ii	«gravitational» potential energy «of the raindrop» into thermal/internal energy «of the air» ✓	*Accept heat for thermal energy* *Accept into kinetic energy of air particles* *Ignore sound energy*	1

Question			Answers	Notes	Total
2.	**a**	**i**	energy required $= 250 \times 4200 \times (30 - 15)$ ✓ energy available $= 0.30 \times 680 \times t \times A$ ✓ $A = \text{«}\frac{250 \times 4200 \times 15}{0.30 \times 680 \times 60 \times 60}\text{»}$ » 21 «m^2» ***OR*** 22 «m^2» ✓	*Allow **ECF** from **MP1** and **MP2**.* *Accept the correct use of 0.30 in either **MP1** or **MP2**.*	**3**
2	**a**	**ii**	Absorbed intensity $= (1 - 0.2) \times 680$ «$= 544$» «W m^{-2}» ***OR*** emitted intensity = $0.97 \times 5.67 \times 10^{-8} \times T^4$ ✓ $T = \sqrt[4]{\frac{544}{0.97 \times 5.67 \times 10^{-8}}} = 315$ «K» ✓ 42 «°C» ✓	*Allow **ECF** from **MP1** and **MP2.*** *Allow **MP1** if absorbed or emitted intensity is multiplied by area.*	**3**

Question			Answers	Notes	Total
2	b	i	can be liquefied ✓ has intermolecular forces / potential energy ✓ has atoms/molecules that are not point objects / take up volume ✓ does not follow the ideal gas law «for all T and p» ✓ collisions between particles are non-elastic ✓	*Accept the converse argument.*	**1 max**
2	b	ii	***ALTERNATIVE 1*** «constant p and V imply» $nT = \text{const}$ ✓ T increases hence n decreases ✓ ***ALTERNATIVE 2*** «constant p and n imply» V is proportional to T / air expands as it is heated ✓ «original» air occupies a greater volume **OR** some air leaves through opening ✓	***MP2** in **ALT 2** must come from expansion of air, not from expansion of water.* *Award **[0]** for an answer based on expansion of water.* *Award **[1] max** for an answer based on convection currents.*	**2**
2	c		photovoltaic cells output electrical energy ✓ electrical is a more versatile form of energy ✓	*Accept any reasonable advantage arising from the electrical output,.e.g., PV cells allow for the use of a long list of appliances, PV owners can sell excess power back to grid.* *Accept electrical energy can be stored.* *Do **not** accept references to efficiency for **MP2**.*	**2**

Question			Answers	Notes	Total
3.	**a**	**i**	oscillation in antiphase ✓ smaller amplitude than P ✓ displacement  		**2**
3	**a**	**ii**	wavelength $= \frac{2}{3} \times 0.80 = 0.53$ «m» ✓ speed $= \frac{0.53}{2.8 \times 10^{-3}} = 190$ «m s^{-1}» ✓	*Allow **ECF** from incorrect wavelength*	**2**
3	**b**	**i**	kg m s^{-2} ***OR*** m^2 s^{-2} seen ✓ kg m^{-1} ✓	*Award **[2]** for a **BCA***	**2**
3	**b**	**ii**	speed increases hence frequency increases ✓ by factor $\sqrt{2}$ ✓		**2**

Question			Answers	Notes	Total
3	c	i	travelling waves transfer energy ***OR*** standing waves don't ✓ amplitude of oscillation varies along a standing wave ***OR*** is constant along a travelling wave ✓ standing waves have nodes / antinodes ***OR*** travelling waves don't ✓ points in an internodal region have same phase in standing waves ***OR*** different phase in travelling waves✓		**1 max**
3	c	ii	***ALTERNATIVE 1*** critical angle = 13° «from $\sin\theta_c = \frac{340}{1500}$ » ✓ the angle of incidence is greater than θ_c hence the sound can't enter water ✓ ***ALTERNATIVE 2*** $\sin\theta_r = \frac{1500}{340}\sin 30°$ ✓ sine value greater than one hence the sound can't enter water ✓	*Conclusion must be justified, award **[0]** for **BCA***	**2**

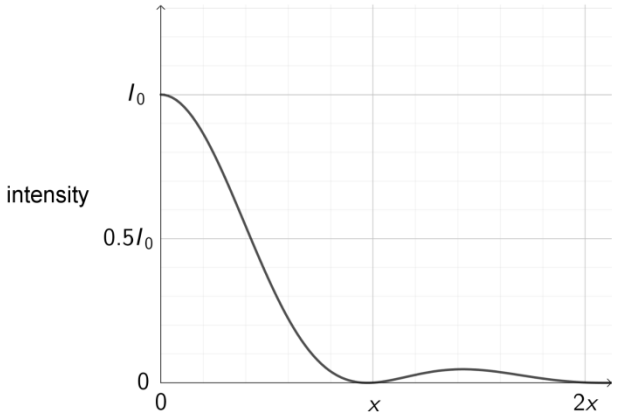
Question			Answers	Notes	Total
4.	**a**		horizontal component of any length to the left ✓ vertical component two squares long upwards ✓ E.g.  	*Ignore point of application.* *Award **[1] max** if arrowhead not present.*	**2**
4	**b**		***ALTERNATIVE 1*** the net/centripetal force has constant magnitude ✓ the direction of the net/centripetal force constantly changes ✓ this is achieved by «vector-» adding weight and the force from the rod ***OR*** the force from the rod is «vector» difference of the centripetal force and weight ✓ ***ALTERNATIVE 2*** at the top $F_{rod} = F_c - W$ ✓ at the bottom, $F_{rod} = F_c + W$ ✓ net F/F_c is constant so the force from the rod is different «hence is changing» ✓	*Accept reference to centripetal or net force indistinctly.* *Allow reference to centripetal acceleration.*	**3**

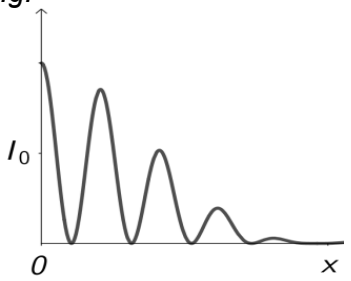
Question			Answers	Notes	Total
5.	**a**		infinite resistance ***OR*** no current is flowing through it ✓		**1**
5	**b**	**i**	$\frac{1.47}{50.0} = 29.4$ «mA» ✓		**1**
5	**b**	**ii**	$29.4(50.0 + r) = 139(10.0 + r)$ ✓ attempt to solve for *r*, e.g. $29.4 \times 50.0 - 139 \times 10.0 = r(139 - 29.4)$ ***OR*** 0.73 «Ω» ✓	*Do **not** allow working backwards from 0.7 Ω.*	**2**
5	**b**	**iii**	$139 \times 10^{-3}(10.0 + 0.73)$ ***OR*** $29.4 \times 10^{-3}(50.0 + 0.73)$ ✓ 1.49 «V» ✓	*Watch for **ECF** from 5(b)(i)*	**2**
5	**c**	**i**	charge/carriers are moving in a magnetic field ✓ there is a magnetic force on them / quote $F = qvB$ ***OR*** this creates a magnetic field that interacts with the external magnetic field ✓	*Accept electrons* *For **MP2**, the force must be identified as acting on charge / carriers*	**2**
5	**c**	**ii**	into the plane «of the paper» ✓		**1**

Question			Answers	Notes	Total
6.	a		according to $\Delta E = \Delta mc^2$ / 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» ✓	*Accept protons and neutrons*	**2**
6	b	i	$\left(m_{\text{polonium}} - m_{\text{lead}} - m_{\alpha}\right)c^2$ ***OR*** $\left(209.93676 - 205.92945 - 4.00151\right)$ ***OR*** mass difference = 5.8×10^{-3} ✓ conversion to MeV using 931.5 to give 5.4 «MeV» ✓	*Allow **ECF** from **MP1*** *Award **[2]** for a **BCA*** *Award **[1]** for 8.6×10^{-13} J*	**2**

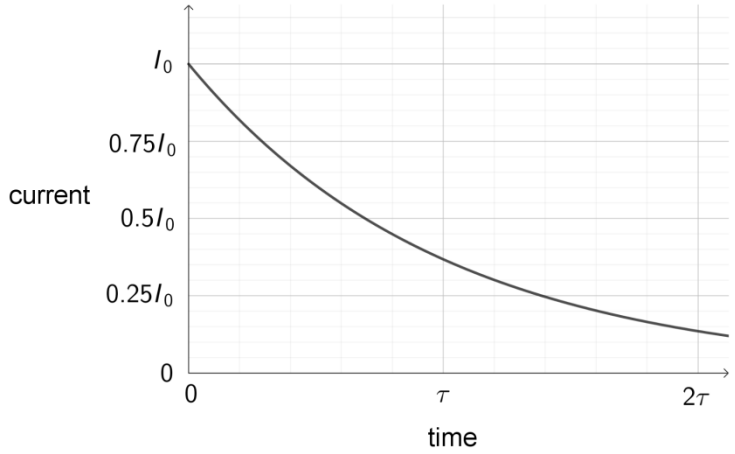
Question			Answers	Notes	Total
6	b	ii	***ALTERNATIVE 1*** energy ratio expressed in terms of momentum, e.g. $\frac{E_\alpha}{E_{\text{lead}}} = \frac{p_\alpha^2 / 2m_\alpha}{p_{\text{lead}}^2 / 2m_{\text{lead}}}$ ✓ $p_\alpha = p_{\text{lead}}$ hence $\frac{E_\alpha}{E_{\text{lead}}} = \frac{m_{\text{lead}}}{m_\alpha}$ ✓ $\frac{m_{\text{lead}}}{m_\alpha} \simeq \frac{206}{4} = 51.5 \Rightarrow E_\alpha = 51.5E_{\text{lead}}$ «so α has a much greater KE» ***OR*** m_{lead} «much» greater than m_{alpha} «so α has a much greater KE» ✓ ***ALTERNATIVE 2*** alpha particle and lead particle have equal and opposite momenta ✓ so their velocities are inversely proportional to mass ✓ but KE ∝ v^2 «so α has a much greater KE» ✓		**3**

Question			Answers	Notes	Total
6	b	iii	photon energy is determined by its wavelength ✓ photons are emitted when nucleus undergoes transitions between its «nuclear» energy levels ***OR*** photon energy equals the difference between «nuclear» energy levels ✓ photons have the same energy / a fixed value ***OR*** energy is quantized / discrete ✓		**3**
6	c		undecayed mass $= 5.0 \times e^{-5.8\times10^{-8}\times365\times24\times60\times60}$ «= 0.8 g» ✓ mass of decayed polonium «= 5.0 − undecayed mass» = 4.2 «g» ✓ mass of lead $\left«=\frac{206}{210}\times 4.2\right» = 4.1$ «g» ✓	*Allow **[2] max** for answers that ignore mass difference between Pb and Po (4.2* g*)* *Allow calculations in number of particles or moles for **MP1 and MP2*** *Allow **ECF** from **MP1** and **MP2***	**3**

Question			Answers	Notes	Total
7.	**a**	**i**	smooth curve decreasing from I_0 to 0 between 0 and x ✓ secondary maximum correctly placed ***AND*** of intensity less than 0.3 I_0 ✓  *E.g.*		**2**
7	**a**	**ii**	observed pattern goes beyond the rectangular shape/geometrical shadow ***OR*** observed pattern shows maxima/minima ✓ «this is explained by» interference/superposition of waves ✓	*Accept any correct description of the diffraction pattern for* ***MP1.***	**2**
7	**a**	**iii**	angle of the first minimum $= \frac{590 \times 10^{-9}}{0.10 \times 10^{-3}} =$ «0.0059 rad» ✓ width $= 2 \times 0.0059 \times 2.4 = 2.8 \times 10^{-2}$ «m» ✓	*$1.4x10^{-2}$ m scores* ***[1]*** *mark.* *Do* ***not*** *penalize the use of sin or tan in* ***MP2***	**2**

Question			Answers	Notes	Total
7	b		intensity at O increases ✓ fringes / a series of maxima and minima ✓ with intensity decreasing away from O ***OR*** intensity modulated by diffraction ✓	*Accept answers as sketches. For **MP1** expect the scale on the y-axis.* *E.g.*  	**2 max**
7	c		***ALTERNATIVE 1*** number of illuminated slits $= 2.0 \times 750 = 1500$ ✓ smallest resolvable difference $\left(= \frac{\lambda}{mN} = \frac{590}{1 \times 1500}\right) = 0.39$ «nm» ✓ $0.39 < 0.60$ hence the lines can be resolved ✓ ***ALTERNATIVE 2*** number of illuminated slits $= 2.0 \times 750 = 1500$ ✓ $\frac{\lambda}{\Delta\lambda}$ = 983 ✓ 1500 greater than 983 hence lines can be resolved✓	*Allow **ECF** from **MP2***	**3**

Question			Answers	Notes	Total
8	a		potential greater at Y ✓ «from $E = -\frac{\Delta V_e}{\Delta r}$» the potential increases in the direction opposite to field strength «so from X to Y» ***OR*** opposite to the direction of the field lines, «so from X to Y» ***OR*** «from $W = q\Delta V_e$» work done to move a positive charge from X to Y is positive «so the potential increases from X to Y» ✓		**2**
8	b	i	orbital radius $= 6.4\times10^6 + 5.0\times10^5$ «$= 6.9\times10^6$ m» ✓ KE $= \frac{1}{2}\times 8.0\times10^2 \times \frac{6.67\times10^{-11}\times6.0\times10^{24}}{6.9\times10^6}$ ***OR*** 2.3×10^{10} «J» ✓	*Award **[1] max** for answers ignoring orbital height (KE = 2.5x10^{10} J)*	**2**
8	b	ii	change in PE $= 6.67\times10^{-11}\times6.0\times10^{24}\times8.0\times10^2\left(\frac{1}{6.4\times10^6}-\frac{1}{6.9\times10^6}\right) =$ «3.6×10^9 J» ✓ energy needed = KE + ΔPE = 2.7×10^{10} «J» ✓	*Allow **ECF** from 8(b)(i).*	**2**

Question			Answers	Notes	Total
9.	**a**		«$\frac{1}{2}\times 1.5\times 10^{-10}\times 24^2$ =» 4.3×10^{-8} «J» ✓		**1**
9	**b**	**i**	«from $C=\varepsilon\frac{A}{d}$» capacitance decreases «by factor 4 / to 3.8 x 10^{-11} F» ✓ «from $V=\frac{q}{C}$» charge unchanged hence p.d. increases by factor 4 / to 96 «V» ✓	*Award **[1] max** for a reasoning without numbers.*	**2**
9	**b**	**ii**	work = (energy in the new arrangement) – (initial energy) ✓ «energy increased by factor 4 hence» work $=3\times 4.3\times 10^{-8}=1.3\times 10^{-7}$ «J» ✓	*Allow **ECF** from 9(a)* *Award **[2]** for a BCA*	**2**
9	**c**	**i**	exponential decrease from current = I_0 ✓ approximately correct values for time = τ ***AND*** 2τ ✓ 	*For **MP2**, the curve should be between 0.30 and 0.45 when time $t=\tau$ and below 0.20 when time $t=2\tau$*	**2**

Question			Answers	Notes	Total
9	c	ii	«activity vs time in» radioactive decay ***OR*** thermal energy transfer ✓	*Accept any other appropriate physics phenomenon, as X-ray absorption.* *Accept terminal velocity as the question can be interpreted as a phenomenon modelled with an exponential function (i.e. including growth).* *Do **not** accept dice throwing.*	**1**
9	d		without a capacitor, output voltage/current drops to zero «twice per cycle of input voltage» ✓ capacitor provides smoothing / smooths out voltage/current variations ✓ voltage/current output becomes constant / similar to direct current output ✓ voltage/current does not drop to zero ✓ by returning some of its energy/charge to the circuit «when input voltage is low» ✓		**2 max**

Question			Answers	Notes	Total
10.	**a**	**i**	strong «nuclear» force ✓		**1**
10	**a**	**ii**	***ALTERNATIVE 1*** attempt to apply conservation law of baryon number to the overall reaction ✓ baryon number of X is zero ✓ this is only possible if constituent quarks of X have an opposite baryon number ✓ «so quark-antiquark pair» ***ALTERNATIVE 2*** attempt to apply conservation law of charge to the overall reaction ✓ charge of X is -1 ✓ this is only possible is constituent quarks of X have charges of $-\frac{2}{3}$ and $-\frac{1}{3}$ ✓ «so quark-antiquark pair» ***ALTERNATIVE 3*** attempt to apply conservation law of baryon number ***OR*** charge to each vertex ✓ at first vertex, the unknown particle has charge $-\frac{1}{3}$ ***OR*** baryon number $\frac{1}{3}$ hence a quark ✓ at second vertex, the unknown particle has charge $-\frac{2}{3}$ ***OR*** baryon number $-\frac{1}{3}$ hence an antiquark ✓		**3**
10	**b**		10^8 x $1.6\text{x}10^{-19}$ ***OR*** $1.6\text{x}10^{-11}$ seen ✓ $\Delta t \cong \frac{6.63\times10^{-34}}{4\pi\times10^{8}\times1.60\times10^{-19}} = 3\times10^{-24}$ «s» ✓	*Award **[2]** for a **BCA*** *Award **[1]** for an answer of $5.3\text{x}10^{-43}$ s.* *Allow **ECF** from **MP1***	**2**