Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2023

Physics

Higher level

Paper 2

17 pages

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Subject Details: Physics HL Paper 2 Markscheme

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***". Either answer can be accepted.

7. An alternative markscheme is indicated in the "Answers" column under heading ***ALTERNATIVE 1*** *etc*. Either alternative can be accepted.

8. Words inside chevrons **« »** in the "Answers" column are not necessary to gain the mark.

9. Words that are <u>underlined</u> are essential for the mark.

10. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

11. 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.

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

13. 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. "ECF acceptable" will be displayed in the "Notes" column.

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

Question			Answers	Notes	Total
1.	a		$M = \text{«}\frac{gr^2}{G} = \text{»}\ \frac{2.7\times10^{-3}\times(2.3\times10^{5})^2}{6.67\times10^{-11}}$ ✓ 2.1×10^{18} «kg» ✓		2
1.	b		0.25 - 0.26 «N» ✓		1
1.	c	i	***ALTERNATIVE 1*** the engine exerts an upward/opposing force <<on the probe>> ✓ <<upward>> force is greater than weight/grav force ***OR*** there is an upward resultant/net force ✓ « by NII » this causes deceleration/reduction in speed ✓ ***ALTERNATIVE 2*** the engine/probe exerts a force on the fuel molecules/gas ✓ <<by NIII>> an equal and opposite force acts on the engine/probe ✓ « by NII » this causes deceleration/reduction in speed ✓ ***ALTERNATIVE 3*** engine causes change in momentum to fuel molecules/gas ✓ « by conservation of momentum » the probe has an equal and opposite change in momentum ✓ this results in deceleration/reduction in speed ✓	*Marks may only be awarded from one alternative.* *Examiners should determine which alternative provides the most marks.* ***MP3*** *must have a reduction in speed not just a change in speed*	3

Question			Answers	Notes	Total
1.	c	ii	***ALTERNATIVE 1*** net force on probe = 12 – 0.26 = **«** 11.7 **»** «N» ✓ change in momentum = 0.64 x 95 = **«** 60.8 Ns **»** ✓ time = **«** 60.8/11.7 **»** = 5.2 to 5.3 **«** s **»** ✓ any answer to 2 s.f. ✓ ***ALTERNATIVE 2*** net force on probe = 12 – 0.26 = **«** 11.7 **»** «N» ✓ acceleration **«** =F/m **»** = 11.7/95 **«** =0.12 **»** ✓ time = **«** 0.64/0.12 **»** = 5.2 to 5.3 **«** s **»** ✓ any answer to 2 s.f. ✓	*Allow ECF from 1b*	**4**
1.	d	i	$v_{esc} = \sqrt{2\left(\frac{GM}{r^2}\right)r}$ **«** $= \sqrt{2gr}$ **»** ***OR*** similar seen ✓	*Watch out for incorrect answers that equate forces e.g. $mv^2/r = GMm/r^2$ and then include a factor of ½ to give the final expression.*	**1**
1.	d	ii	35 «m s^{-1}» ✓		**1**

Question			Answers	Notes	Total
1.	e		time to reach surface $= \text{«}\sqrt{\frac{2\times1.9}{2.7\times10^{-3}}} = \text{»} 37.5$ «s» ✓ distance travelled horizontally = « 34×37.5 » = 1300 «m» ✓	*Check units match power of ten e.g. 1.3 km scores both marks* *Award [1 max} for 21 <<m>> (g taken as 9.81)* *Watch for ECF from incorrect t.*	**2**

Question			Answers	Notes	Total
2.	a	i	the angle of refraction ought to be greater than the angle of incidence ***OR*** the ray should refract away from the normal ✓ because ray goes from high refractive index/<<optically>> more dense/slower medium to low refractive index/optically less dense/faster medium✓	*Do not allow use of e.g n_1 unless medium one is described e.g. n_{air}*	**2**
2.	a	ii	there should be a <<transmitted>> ray in the oil ***OR*** total internal reflection is not possible ✓ because ray goes from low refractive index/<<optically>> less dense/faster medium to high refractive index/<<optically>> more dense/slower medium✓		**2**
2.	b		Use of Snell's Law **«** $\frac{\sin i}{\sin r} = \frac{1.60}{1}$ **»** ✓ $i = \sin^{-1}$ **«**$1.60 \times \sin 32^\circ$**»** $= 58$ **«** $^\circ$ **»** ✓	*'Use of' requires a substitution NOT just a statement of a formula* *Accept 1.0 rad (unit must be included to show a deliberate attempt to use rad rather than a calculator mistake)*	**2**

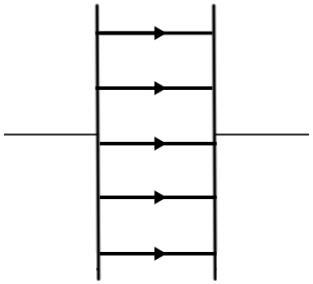
Question			Answers	Notes	Total
2.	**c**		$\frac{\sin i}{\sin r} = \frac{1.33}{1.60}$ and $\sin r = 1$ ✓ $i = \text{«}\sin^{-1} 0.831\text{»} = 56\text{«}^\circ\text{»}$ ✓	*Accept 0.98 rad (unit required)*	**2**
2.	**d**	**i**	Oscillations **«** of electric field vector **»** in one/same plane ✓	*Do not allow oscillations in one direction*	**1**
2.	**d**	**ii**	Rotation/change of alignment of polarizing filter ✓ changes intensity ✓		**2**
2.	**e**	**i**	position X because light reflects off the medium of higher refractive index ✓	*Allow correct references to optical density or speed as in previous questions* *A statement of X and that the refractive index of oil is greater than the refractive index of air is sufficient*	**1**
2.	**e**	**ii**	Use of $2d\text{n} = m\lambda$ ✓ 2.1×10^{-7} **«**m**»** ✓ any answer to 2 s.f. ✓	*'Use of' requires a substitution NOT just a statement of a formula*	**3**

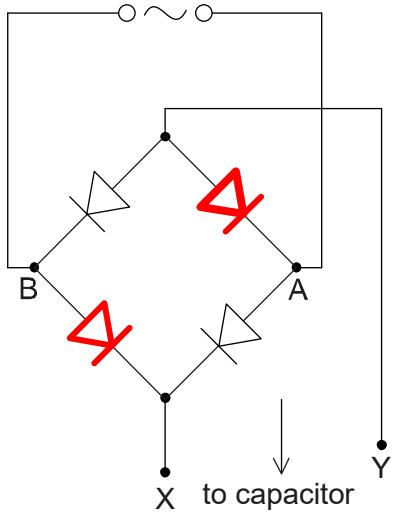
Question			Answers	Notes	Total
3.	a	i	Resistance « $= \frac{12^2}{150} =$»0.96«Ω» ✓		1
3.	a	ii	total wire length = (0.6 x 8) + (0.03 x 7) ***OR*** 5.01 «m» ✓ Use of $\rho = \frac{RA}{l}$ ***OR*** area = «$\frac{\rho l}{R} =$» 7.83×10^{-6} «m^2» ✓ radius « $= \sqrt{7.83x10^{-6} / \pi =}$ » 1.6 x 10^{-3} «m» ✓	*Allow answers in mm provided unit and power of ten match (i.e 1.6 mm)* *'Use of' requires a substitution NOT just a statement of a formula* *Allow ECF from ai).*	3
3.	b		mass of ice = 900 x 0.6 x 0.21 x 0.5 x 10^{-3} ***OR*** 0.0567 <<kg>> ✓ energy required = 0.336 x 10^6 x 0.0567 ***OR*** 1.91 x 10^4 <<J>>✓ time = «$\frac{1.91 \times 10^4}{150} =$» 130 «s» ✓	*Be careful to check for ECF from **MP1** and **MP2**.*	3

Question			Answers	Notes	Total
3.	c		***ALTERNATIVE 1*** emf of almost discharged cell is lower than nominal value ✓ I/power decreases, so longer time ✓ ***ALTERNATIVE 2*** internal R of battery increased ✓ I decreases, so longer time ✓ ***ALTERNATIVE 3*** power of the battery/heater is lower ✓ energy is provided at a slower rate, so time is longer ✓	***MP1*** *and* ***MP2*** *must be taken from the same alternative.*	**2**
3.	d		advantage of batteries argument ✓ cost reduction argument ✓ improved storage argument ✓ environmental argument ✓	*e.g. allows energy from renewables to be stored for later use, easy transportation of energy,* *e.g. to make batteries for cars affordable* *e.g. so electric cars can have a longer range* *e.g. so they last longer before disposal, to reduce impact of mining for lithium* *Do not allow vague statements e.g., "more environmentally friendly", "more sustainable", "to reduce pollution", "to reduce the use of fossil fuels" etc.*	**2 max**

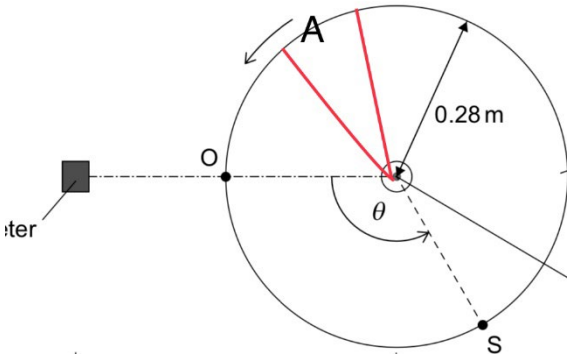
Question			Answers	Notes	Total
4.	a	i	neutron ***OR*** $^{1}_{0}$n ✓		1
4.	a	ii	nucleus <<is positive and>> repels proton ✓ proton must be close to nucleus for nuclear force to be effective ✓ <<this corresponds to high electric potential energy and>> therefore high initial kinetic energy required ✓		3
4.	b		Use of $A = A_0 e^{-\lambda t}$ ✓ « $\ln\frac{0.0012}{1.5} = -1.1\times10^{-4}\ t$ » $t = 6.5 \times 10^{4}$ «s» ✓	*Allow 18 hours* *'Use of' requires a substitution NOT just a statement of a formula*	2
4.	c	i	particle–antiparticle ✓	*Allow lepton – antilepton, matter - antimatter*	1
4.	c	ii	electron ✓	*Do not allow antipositron*	1
4.	c	iii	any reference to momentum conservation ***OR*** energy and momentum cannot be both conserved ✓ a nucleus redistributes the momentum ✓		2
4.	c	iv	annihilation with an electron ✓		1

Question			Answers	Notes	Total
5.	**a**		Excited state - electron bound to atom/nucleus/proton ***OR*** *Ionised state – electron free from/not bound to atom* ✓		**1**
5.	**b**		Electron/atom loses energy ***OR*** electron/atom moves to a lower energy state ✓ by emitting a/one photon ✓		**2**
5.	**c**	**i**	visible **«**light**»** ✓	*Accept orange/red light*	**1**
5.	**c**	**ii**	Use of $E = \frac{hc}{\lambda}$ ***OR*** energy change $= «\frac{hc}{\lambda} =» 3.0 \times 10^{-19}$ **«**J**»** ✓ conversion to eV giving 1.88 ***OR*** 1.89 **«** eV **»** ✓ transition is from 2 to 3 ✓	*'Use of' requires a substitution NOT just a statement of a formula* *A bald statement of 1.88 OR 1.89 <<eV>> scores **MP1** and **MP2**.*	**3**

Question			Answers	Notes	Total
6.	a	i	equally spaced, horizontal, straight lines (minimum 3) ✓ Correct direction ✓	*Ignore edge effects* 	2
6.	a	ii	Use of $C = \frac{\varepsilon A}{d}$ ✓ « area $= 2.71 \times 10^{-2}$ «m^2» » length $= 0.16$ ***OR*** 0.17 «m» ✓	*'Use of' requires a substitution NOT just a statement of a formula* *Watch for ECF from an incorrect area calculation.*	2
6.	a	iii	maximum charge on capacitor $= 75 \times 10^{-12} \times 16 \times 10^{3} = 1.2 \times 10^{-6}$ «C» ✓	*Check the unit and the power of ten match e.g. 1.2 μC is acceptable.*	1
6.	b	i	2.8×10^{6} «$N\,C^{-1}$» ✓	*Ignore negative sign*	1
6.	b	ii	charge at breakdown $= 75 \times 10^{-12} \times 9 \times 10^{3} = 6.75 \times 10^{-7}$ «*C*» ✓ « $\frac{0.675\ \mu c}{1.2\ \mu c} = 0.56$ » this corresponds to 0.6 «s» on graph ✓	*Allow calculation using maximum voltage* *Allow range of 0.6 to 0.7* «*s*» *Allow ECF from aiii)*	2
6.	c		«the internal resistance unchanged and» capacitance increases ✓ so the time constant increases « and it takes longer » ✓	*Allow* $\tau = RC$ *for* ***MP2***	2

Question			Answers	Notes	Total
6.	d	i	diagram correct ✓	 *Award [0] if there are any additions to the diagram.*	1
6.	d	ii	***ALTERNATIVE 1*** when A is positive and B negative bottom right diode and top left diodes conduct making X positive and Y negative✓ when A is negative and B positive top right and bottom left diodes conduct making X positive and Y negative ✓ whatever polarity of supply, X is always positive and Y negative «so charge can only flow in one direction» ✓ ***ALTERNATIVE 2*** A diode only conducts/allows a flow of charge in one direction ✓ During one half cycle one pair of diodes conduct <<and in the other half cycle the other pair conducts>> ✓ Current is always X to Y ✓		3

Question			Answers	Notes	Total
7.	a	i	average intensity at Ceres orbit $= \left(\frac{3.8 \times 10^{26}}{4 \times \pi \times (4.4 \times 10^{11})^2} \right)$ «$= 156\ \text{W m}^{-2}$» ✓ average incident intensity $= \frac{156}{4}$ = <<39>> ✓ temperature «$= \left(\frac{39}{5.67 \times 10^{-8}} \right)^{\frac{1}{4}}$» $= 160$ <<K>> ✓	*Allow ECF from **MP1** and **MP2***	**3**
7.	a	ii	«kinetic» energy of decay products is converted to/transferred as thermal energy ✓ «primarily» by conduction ✓		**2**
7.	b	i	gases have no/weaker intermolecular forces/bonds <<than for solids>> ✓ gases larger intermolecular distances <<than for solids>> ✓ molecules in gases move freely <<but in solids do not>> ✓ <<same temperature so>> same *Ek* ✓	*Accept reverse arguments*	**3 max**
7.	b	ii	4.9×10^{-21} «J» ✓		**1**
7.	b	iii	<<use of $\frac{GM}{r}$ >> << - >> $\frac{(6.67 \times 10^{-11} \times 9 \times 10^{20})}{4.7 \times 10^{5}}$ ***OR*** << - >>1.3×10^{5} seen ✓	*Award [1] for correct substitution*	**1**

Question			Answers	Notes	Total
8.	a	i	about 11 o'clock position on turntable ✓	*In the region shown*  	1
8.	a	ii	maximum frequency shift occurs when velocity of source relative to frequency meter is maximum ✓ <<maximum velocity of source is>>when S moves directly towards frequency meter ✓		2

8.	**b**		***ALTERNATIVE 1*** $\Delta f = 10.5$ «Hz» ✓ $\frac{10.5}{440} = \frac{v_s}{330}$ ✓ v_s = 7.9 <<m s-1>> $v_s = 7.9$ «m s^{-1}» ✓ $\omega = «\frac{v}{r} =»$ 28 ✓ rad s^{-1} ✓ ***ALTERNATIVE 2*** Observed frequency = 450.5 ***OR*** 430 <<Hz>> ✓ Use of f' = f ($v/v \pm u_s$) ✓ u_s = 7.7 <<m s^{-1}>> ✓ omega <<= v/r>> = 28 ✓ rad s^{-1} ✓	*Range 10 – 11 Hz* *Range 7.5 - 8.3 m s^{-1}* *Range 27 - 30 rad s^{-1}* *Range 450 – 451* ***OR*** *429 - 431* *Range 7.5 - 8.0* *Range 27 – 30*	**5**