Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2021

Physics

Higher level

Paper 2

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

Question			Answers	Notes	Total
1.	a		$t = \sqrt{\frac{2d}{g}} = 0.22\ \text{s}$ ***OR*** $t = \sqrt{\frac{2\times 0.24}{9.8}}$ ✓	*Answer to 2 or more significant figures or formula with variables replaced by correct values.*	**1**
1.	b		increasing straight line from zero up to 0.2 s in x-axis ✓ with gradient = 10 ✓		**2**

Question			Answers	Notes	Total
1.	c		***ALTERNATIVE 1*** $t = \frac{1.37}{12}$ = «0.114 s» ✓ $y = \frac{1}{2} \times 10 \times 0.114^2 = 0.065\,\text{m}$ ✓ so (0.24-0.065) = 0.175>0.15 ***OR*** 0.065 < (0.24-0.15) «so it goes over the net» ✓ ***ALTERNATIVE 2*** $\text{«}0.24 - 0.15 = 0.09 = \frac{1}{2} \times 10 \times t^2$ so» $t = 0.134\,s$ ✓ $0.134 \times 12 = 1.6\,\text{m}$ ✓ $1.6 > 1.37$ «so ball passed the net already» ✓	*Allow use of* $g = 9.8$.	**3**

Question			Answers	Notes	Total
1.	d	i	***ALTERNATIVE 1*** $\text{KE} = \frac{1}{2}mv^2 + mgh = \frac{1}{2}0.0027 \times 10.5^2 + 0.0027 \times 9.8 \times 0.18$ ✓ 0.15 **«**J**»** ✓ ***ALTERNATIVE 2*** Use of $v_x = 10.5$ ***AND*** $v_y = 1.88$ to get $v = \text{«}\sqrt{10.5^2 + 1.88^2}\text{»} = 10.67$ **«**m s^{-1}**»** ✓ $KE = \frac{1}{2} \times 0.0027 \times 10.67^2 = 0.15$ **«**J**»** ✓		**2**
1.	d	ii	$\Delta v = 21$ **«**m s^{-1}**»** ✓ $F = \frac{0.0027 \times 21}{0.01}$ ***OR*** 5.67 **«**N**»** ✓ any answer to 2 significant figures **«**N**»** ✓		**3**

Question			Answers	Notes	Total
2.	a		«circular motion» involves a changing velocity ✓ «Tangential velocity» is «always» perpendicular to centripetal force/acceleration ✓ there must be a force/acceleration towards centre/star ✓ without a centripetal force the planet will move in a straight line ✓		2 max
2.	b		$F = \frac{(6.67\times10^{-11})(8\times10^{24})(3.2\times10^{30})}{(4.4\times10^{10})^2} = 8.8\times10^{23}$ «N» ✓		1
2.	c	i	$V_{planet} = \text{«}-\text{»}\frac{(6.67\times10^{-11})(8\times10^{24})}{9.1\times10^{6}} = \text{«}-\text{»}5.9\times10^{7}$ «J kg^{-1}» ✓ $V_{star} = \text{«}-\text{»}\frac{(6.67\times10^{-11})(3.2\times10^{30})}{4.4\times10^{10}} = \text{«}-\text{»}4.9\times10^{9}$ «J kg^{-1}» ✓ $V_{planet} + V_{star}$ = «–» 4.9 «09»x10^{9} «Jkg^{-1}» ✓	*Must see substitutions and not just equations.*	3
2.	c	ii	use of $v_{esc} = \sqrt{2V}$ ✓ v = 9.91 x 10^{4} « m s^{-1}» ✓		2

Question			Answers	Notes	Total
3.	a	i	$E_k = «\frac{3}{2}(1.38\times10^{-23})(373)» = 7.7\times10^{-21}$«J» ✓ $v = «\sqrt{\frac{3\times1.38\times10^{-23}\times6.02\times10^{23}\times 373}{0.018}}» = 720$«m s^{-1}» ✓		2
3.	a	ii	particles can be considered points «without dimensions» ✓ no intermolecular forces/no forces between particles «except during collisions» ✓ the volume of a particle is negligible compared to volume of gas ✓ collisions between particles are elastic ✓ time between particle collisions are greater than time of collision ✓ no intermolecular PE/no PE between particles ✓	*Accept reference to atoms/molecules for "particle"*	1 max
3.	b	i	«$mL = P$ t» so «$L = \frac{1600\times200}{0.14}$ » = 2.3 x 10^6 «J kg^{-1}» ✓ J kg^{-1} ✓		2
3.	b	ii	«all» of the energy added is used to increase the «intermolecular» potential energy of the particles/break «intermolecular» bonds/**OWTTE** ✓	Accept reference to atoms/molecules for "particle"	1
3.	c		use of mcΔT ✓ $0.86\times4200\times(100-T) = 0.3\times1800\times(T+10)$ ✓ $T_{eq} = 85.69$«°C» ≅ 86«°C» ✓	*Accept T_{eq} in Kelvin (*359 K*).*	3

Question			Answers	Notes	Total
3.	d	i	$P = \frac{v^2}{R}$ so $\frac{220^2}{1600}$ so $R = 30.25$ «Ω» ✓	*Must see either the substituted values* ***OR*** *a value for R to at least three s.f.*	1
3.	d	ii	use of parallel resistors addition so $R_{eq} = 15$ «Ω» ✓ $P = 3200$ «W» ✓		2

Question			Answers	Notes	Total
4.	a	i	$\frac{P}{4\pi d^2}$ is the power received by the planet/at a distance d «from star» ✓ $\frac{A}{4}$ is the projected area/cross sectional area of the planet ✓		2
4.	a	ii	use of $e\sigma AT^4$ ***OR*** $\frac{P}{4\pi d^2} \times \frac{A}{4} \times (1 - \alpha_p)$ ✓ with correct manipulation to show the result ✓		2
4.	b		$\sqrt[4]{\frac{1.36 \times 10^3 \times 0.87}{4 \times 5.67 \times 10^{-8}}}$ ✓ $T = 268.75$ «K» $\cong 270$ «K» ✓		2

Question			Answers	Notes	Total
5.	a		to charge a capacitor current must be direct ✓ diode will only allow current to flow in one direction ***OR*** the diode provides half wave rectification ✓		**2**
5.	b	i	$V_s = 15 \times 220 =$ **«**3300 V**»** ✓ $E = \frac{1}{2} C V^2 = \frac{1}{2} \times 30 \times 10^{-6} \times 3300^2$ ***OR*** 163**«**J**»** ✓	*Allow use of 220 V as an RMS value to calculate V_s = 467 V and E = 327 J for full marks if appropriate work is provided.* *Answer must be to 3 or more sf or working shown for **MP2***	**2**
5.	b	ii	$Q_0 = 0.0989 \approx 0.1$ **«**C**»** ✓	*Allow **ECF** from (b)(i) (Q = 30 μF x V)*	**1**
5.	b	iii	labels + on the lower side of the capacitor ✓		**1**
5.	c	i	the energy stored in the capacitor is delivered to the resistor/heart ✓		**1**
5.	c	ii	use of $Q = Q_0 e^{-\frac{t}{\tau}}$ to show that $0.37 = \frac{1}{e}$ ✓		**1**

Question			Answers	Notes	Total
5.	c	iii	***ALTERNATIVE 1*** reads from the graph $\tau = 1.6$ ms ✓ so $R = \frac{0.0016}{30 \times 10^{-6}} = 53$ **«Ω»** ✓ ***ALTERNATIVE 2*** reads a correct value from the graph for $\frac{Q}{Q_0}$ and t ✓ so $R = \frac{t}{\ln\left(\frac{Q}{Q_0}\right)\left(3 \times 10^{-5}\right)}$ ✓		**2**
5.	d		**«**the capacitors are in parallel hence**»** capacitances are added / more charge is stored ***OR*** C_{eq} is larger ***OR*** electrode capacitor charges and discharges ✓ **«**therefore**»** discharge takes longer/increases ✓		**2**

Question			Answers	Notes	Total
6.	a		«change is» $\pi / 180°$ ✓		1
6.	b		«to eliminate reflection» destructive interference is required ✓ phase change is the same at both boundaries / no relative phase change due to reflections ✓ therefore $2wn_{coating} = \left(m + \frac{1}{2}\right)\lambda_{air}$ ***OR*** $w = \frac{\lambda_{coating}}{4}$ ***OR*** $w = \frac{\lambda_{air}}{4n_{coating}}$ ✓		3
6.	c	i	central maximum of one diffraction pattern lies over the central/first minimum of the other diffraction pattern ✓		1
6.	c	ii	$\theta = «1.22\frac{\lambda}{b} = 1.22\frac{700\times10^{-9}}{4\times10^{-3}} =» 2.14\times10^{-4}$ «rad» ✓ $D = 14«0.05\text{ m}»$ ✓		2

Question			Answers	Notes	Total
7.	a		${}^{238}_{92}U \rightarrow$ «${}^{234}_{90}$»$Th +$ «${}^{4}_{2}$»α ✓	*Allow He for alpha.*	1
7.	b		udd $\rightarrow$ uud ***OR*** down quark changes to up quark ✓		1
7.	c		measure «radio»activity/«radioactive» decay/A for either ***OR*** take measurements with a Geiger counter. ✓ for Uranium measure number/N of radioactive atoms/***OWTTE*** ✓ for Thalium measure «rate of» change in activity over time. ✓ correct connection for either Uranium or Thalium to determine half life ✓		4
7.	d	i	links temperature to kinetic energy/speed of particles ✓ energy required to overcome «Coulomb» electrostatic repulsion ✓		2
7.	d	ii	«energy is released when» binding energy per nucleon increases		1
7.	d	iii	any use of (value from graph) x (number of nucleons) ✓ «$235 \times 7.6 - (89 \times 8.6 + 144 \times 8.2) =$» 160 «MeV» ✓		2

Question			Answers	Notes	Total
8.	a		«travelling» wave moves along the length of the string and reflects «at fixed end»✓ superposition/interference of incident and reflected waves ✓ the superposition of the reflections is reinforced only for certain wavelengths ✓		2 max
8.	b	i	$\lambda = 2\,l = 2 \times 0.62 =$ «1.24 m» ✓ $v = f\lambda = 195 \times 1.24 = 242$ «m s^{-1}» ✓	*Answer must be to 3 or more sf or working shown for **MP2.***	2
8.	b	ii	straight line through origin with negative gradient ✓		1
8.	b	iii	max velocity occurs at x = 0 ✓ $v =$ «$(2\pi)(195)\sqrt{0.004^2}$» $= 4.9$« m s^{-1}» ✓		2
8.	b	iv	$a = (2_\pi\ 195)^2 \times 0.004 = 6005$ «m s^{-2}»✓ $= 600$g ✓		2
8.	b	v	use of $E \propto A^2$ ***OR*** $x_o^{\,2}$ ✓ $A = 0.4\sqrt{2} = 0.57$ «cm» $\cong 0.6$ «cm» ✓		2
8.	c		$\frac{62}{3} = 21$«cm» ✓		1

Question			Answers	Notes	Total
9.	a		they express fundamental principles of nature ✓ allow to model situations ✓ allow to calculate unknown variables ✓ allow to predict possible outcomes ✓ allow to predict missing quantities/particles ✓ allow comparison of different system states ✓		1 max
9.	b		three correct conservation laws listed ✓ at least one conservation law correctly demonstrated ✓ all three conservation laws correctly demonstrated ✓		3

Question			Answers	Notes	Total
10.	a		electrons are ejected from the surface of a metal ✓ after gaining energy from photons/electromagnetic radiation ✓ there is a minimum **«threshold»** energy/frequency ***OR*** maximum **«threshold»** wavelength ✓		**2 max**
10.	b		**«**$eV = \frac{1}{2} mv^2$**»** and manipulation to get v ✓ $v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \times 1.4}{9.1 \times 10^{-31}}}$ ***OR*** 702 **«**km s^{-1}**»** ✓	*Must see either complete substitution or calculation to at least 3 s.f. for **MP2**.*	**2**
10.	c		$E = 2.3 + 1.4$ ✓ $\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{3.7 \times 1.6 \times 10^{-19}}$ ✓ $= 3.4 \times 10^{-7}$ m ***OR*** 340 nm ✓	*Must see an appropriate unit to award **MP3.***	**3**