Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2019

Physics

Higher level

Paper 2

18 pages

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.

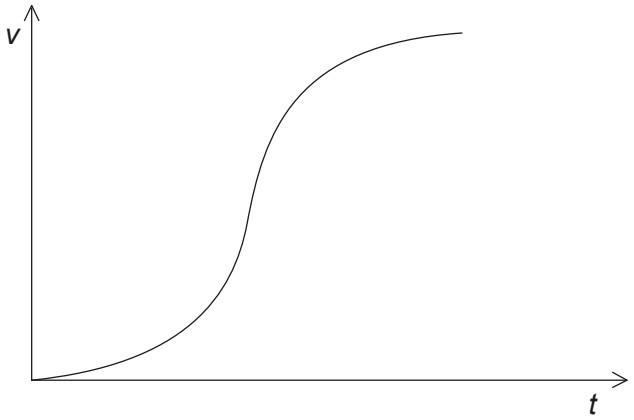
13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should 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.

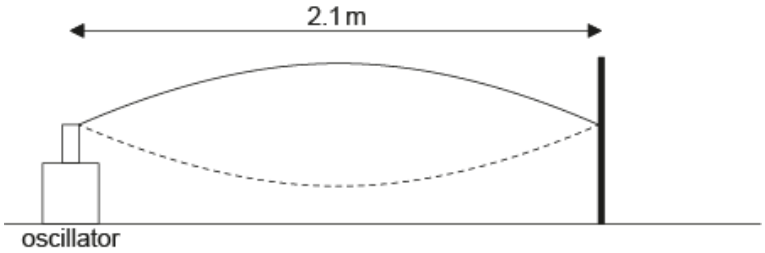
Question			Answers	Notes	Total
1.	a		links 0.84 to Δp ✓ $v = \text{«}\frac{0.84}{5.8\times10^{-2}}\text{=»}\ 14.5\ \text{«m s}^{-1}\text{»}$ ✓	*Award **[2]** for bald correct answer*	**2**
1.	b		use of $\Delta t = \text{«}(28-12)\times10^{-3}\text{=»}\ 16\times10^{-3}\ \text{«s»}$ ✓ $\bar{F} = \text{«}\frac{\Delta p}{\Delta t}\text{=»}\ \frac{0.84}{16\times10^{-3}}$ ***OR*** 53 «N» ✓	*Accept a time interval from 14 to 16 ms* *Allow ECF from incorrect time interval*	**2**
1.	c		$E_k = \frac{1}{2}\times5.8\times10^{-2}\times14.5^2$ ✓ $E_k = W$ ✓ $s = \text{«}\frac{W}{F} = \frac{\frac{1}{2}\times5.8\times10^{-2}\times14.5^2}{53}\text{=»}\ 0.12\ \text{«m»}$ ✓	*Allow ECF from (a) and (b)* *Allow ECF from MP1* *Award **[2]** max for a calculation without reference to work done, eg: average velocity × time*	**3**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
1.	d		 graph must show increasing speed from an initial of zero all the time ✓ overall correct curvature ✓		2

Question			Answers	Notes	Total
2	a		$N = \frac{pV}{kT}$ ***OR*** $N = \frac{1.0 \times 10^5 \times 0.36}{1.38 \times 10^{-23} \times 295}$ ✓ $N = 8.8 \times 10^{24}$ ✓	*Allow **[1 max]** for substitution with T in Celsius.* *Allow **[1 max]** for a final answer of n = 14.7 or 15* *Award **[2]** for bald correct answer.*	**2**
2.	b	i	use of $\frac{p}{T} = \text{constant}$ ***OR*** $p = \frac{nRT}{V}$ ***OR*** $\frac{NkT}{V}$ ✓ $p = 9.4 \times 10^4$ «Pa» ✓	*Allow ECF from (a)* *Award **[2]** for bald correct answer*	**2**
2	b	ii	$F = A \times \Delta p$ ✓ $F = 0.72 \times (1.0 - 0.94) \times 10^5$ ***OR*** 4.3×10^3 «N» ✓	*Allow ECF from (b)(i)* *Allow ECF from MP1*	**2**
2.	b	iii	force is «very» large ✓ there must be a mechanism that makes this force smaller ***OR*** assumption used to calculate the force/pressure is unrealistic ✓		**2**

Question			Answers	Notes	Total
3.	a	i	$v = \text{«}\frac{0.05}{0.20\times10^{-3}} = \text{»}\ 250\ \text{«m s}^{-1}\text{»}$ ✓		1
3.	a	ii	$\lambda = 0.30\ \text{«m»}$ ✓ $f = \text{«}\frac{250}{0.30} = \text{»}\ 830\ \text{«Hz»}$ ✓	*Allow ECF from (a)(i)* *Allow ECF from wrong wavelength for MP2*	2
3.	b		Q ✓ acceleration is proportional to displacement «and Q has larger displacement» ✓		2
3.	c	i	3 «points» ✓		1
3.	c	ii	first harmonic mode drawn ✓ 	*Allow if only one curve drawn, either solid or dashed.*	1

Question			Answers	Notes	Total
4.	a		magnetic force is to the left «at the instant shown» ***OR*** explains a rule to determine the direction of the magnetic force ✓ force is perpendicular to velocity/«direction of» motion ***OR*** force is constant in magnitude ✓ force is centripetal/towards the centre ✓	*Accept reference to acceleration instead of force.*	**2 max**
4.	b	i	$qvB = \frac{mv^2}{R}$ ✓ $R = \frac{1.67 \times 10^{-27} \times 2.0 \times 10^{6}}{1.6 \times 10^{-19} \times 0.35}$ ***OR*** 0.060 «m»	*Award MP2 for full replacement or correct answer to at least 2 significant figures.*	**2**
4.	b	ii	$T = \frac{2\pi R}{v}$ ✓ $T = «\frac{2\pi \times 0.06}{2.0 \times 10^{6}} = » 1.9 \times 10^{-7}$ «s» ✓	*Award **[2]** for bald correct answer*	**2**
4.	c		***ALTERNATIVE 1*** work done by force is change in kinetic energy ✓ work done is zero/force perpendicular to velocity ✓ ***ALTERNATIVE 2*** proton moves at constant speed ✓ kinetic energy depends on speed ✓	*Award **[2]** for a reference to work done is zero hence E_k remains constant* *Accept mention of speed or velocity indistinctly in MP2*	**2**

Question			Answers	Notes	Total
5.	**a**		$E = \frac{k \times q}{r^2}$ ✓ $E = \frac{8.99 \times 10^9 \times 6.0 \times 10^{-3}}{0.4^2}$ ***OR*** $E = 3.37 \times 10^8$ **«**NC^{-1}**»** ✓	*Ignore any negative sign.*	**2**
5.	**b**	**i**	$F = q \times E$ ***OR*** $F = 1.6 \times 10^{-19} \times 3.4 \times 10^8 = 5.4 \times 10^{-11}$ **«**N**»** ✓ $a = \text{«}\frac{5.4 \times 10^{-11}}{9.1 \times 10^{-31}} = \text{»}\ 5.9 \times 10^{19}$ **«**m s^{-2}**»** ✓	*Ignore any negative sign.* *Award **[1]** for a calculation leading to* $a = 3.7 \times 10^{38}$ **«**m s^{-2}**»** *Award **[2]** for bald correct answer*	**2**
5.	**b**	**ii**	the electron moves away from the point charge/to the right **«**along the line joining them**»** ✓ decreasing acceleration ✓ increasing speed ✓	*Allow ECF from MP1 if a candidate mistakenly evaluates the force as attractive so concludes that the acceleration will increase*	**3**

Question			Answers	Notes	Total
6.	**a**		$P = \frac{1}{2} \times A \times 1.2 \times 8^3$ ***OR*** $P = \frac{1}{2} \times A \times 1.32 \times 4^3$ ✓ P **«**in incoming beam**»** $= 1.4 \times 10^5$ **«** W **»** ***OR*** P **«**in outgoing beam**»** $= 1.9 \times 10^4$ **«** W **»** ✓ subtracts both P to obtain 1.2×10^5 **«** W **»** ✓	*Condone use of a wrong area or use of circumference in MP1.* *Allow ECF from MP2.* *Award **[1]** max for any attempt to use the formula for wind power which cubes the difference of velocities* *Award **[3]** for a bald correct answer*	**3**
6.	**b**		because some power is lost due to inefficiencies in the system/transfers to the surroundings ✓	*Accept power or energy indistinctly*	**1**

Question			Answers	Notes	Total
7.	**a**		*random*: it cannot be predicted which nucleus will decay ***OR*** it cannot be predicted when a nucleus will decay ✓ *spontaneous*: the decay cannot be influenced/modified in any way ✓	*OWTTE* *OWTTE*	**2**
7.	**b**	**i**	234×7.6 ***OR*** 4×7.07 ✓ $BE_U = «234 \times 7.6 + 4 \times 7.07 - 4.27 =» 1802$ «MeV» ✓ $\frac{BE_U}{A} = «\frac{1802}{238} =» 7.57$ «MeV» ✓	*Allow ECF from MP2* *Award **[3]** for bald correct answer* *Allow conversion to J, final answer is 1.2×10^{-12}*	**3**
7.	**b**	**ii**	states or applies conservation of momentum ✓ ratio is $«\frac{E_{k\alpha}}{E_{kTh}} = \frac{\frac{p^2}{2m_\alpha}}{\frac{p^2}{2m_{Th}}} = \frac{234}{4} » 58.5$ ✓	*Award **[2]** for bald correct answer*	**2**

Question			Answers	Notes	Total
8.	a	i	equating centripetal to electrical force $\frac{2ke^2}{r^2} = \frac{mv^2}{r}$ to get result ✓		1
8.	a	ii	uses (a)(i) to state $E_k = \frac{ke^2}{r}$ ***OR*** states $E_p = -\frac{2ke^2}{r}$ ✓ adds «$E_{TOT} = E_k + E_p = \frac{ke^2}{r} - \frac{2ke^2}{r}$» to get the result ✓		2
8.	a	iii	the total energy decreases ***OR*** by reference to $E_{TOT} = -\frac{ke^2}{r}$ ✓ the radius must also decrease ✓	*Award **[0]** for an answer concluding that radius increases*	2

(continued…)

(Question 8 continued)

Question			Answers	Notes	Total
8.	**b**	**i**	with $n = 3$, $v = \text{«}\sqrt{\frac{2\times 8.99\times 10^{9}\times (1.6\times 10^{-19})^{2}}{9.11\times 10^{-31}\times 9\times 2.7\times 10^{-11}}} = \text{»}\ 1.44\times 10^{6}\ \text{«m s}^{-1}\text{»}$ ✓ $\lambda = \frac{6.63\times 10^{-34}}{9.11\times 10^{-31}\times 1.44\times 10^{6}}$ ***OR*** $\lambda = 5.05\times 10^{-10}\ \text{«m»}$ ✓		**2**
8.	**b**	**ii**	$\frac{2\pi r}{\lambda} = \text{«}\frac{2\pi\times 9\times 2.7\times 10^{-11}}{5.1\times 10^{-10}} = 2.99\text{»} \cong 3$ ✓	*Allow ECF from (b)(i)*	**1**
8.	**c**		reference to fixed orbits/specific radii ***OR*** quantized angular momentum in Bohr model ✓ electron described by a wavefunction/as a wave in Schrödinger model ***OR*** as particle in Bohr model ✓ reference to **«**same**»** energy levels in both models ✓ reference to **«**relationship between wavefunction and**»** probability **«**of finding an electron in a point**»** in Schrödinger model ✓		**3 max**

Question			Answers	Notes	Total
9.	a		$E = \frac{1}{2}\frac{Q^2}{C}$ ***OR*** $V = \frac{Q}{C}$ ✓ $E = \text{«}\frac{1}{2}\frac{(48\times10^{-6})^2}{18\times10^{-6}} = \text{»}\ 6.4\times10^{-5}\ \text{«J»}$ ✓		**2**
9.	b	i	***ALTERNATIVE 1*** $Q_X + Q_Y = 48$ ✓ $\frac{Q_X}{18} = \frac{Q_Y}{12}$ ✓ solving to get $Q_X = 29\ \text{«}\mu\text{C»}$ $Q_Y = 19\ \text{«}\mu\text{C»}$ ✓ ***ALTERNATIVE 2*** $48 = 18\,\text{V} + 12\,\text{V} \Rightarrow V = 1.6\ \text{«V»}$ ✓ $Q_X = \text{«}1.6\times18 = \text{»}\ 29\ \text{«}Q_X = 1.6\times18 = 29\ \text{«}\mu\text{C»}$ ✓ $Q_Y = \text{«}1.6\times12 = \text{»}\ 19\ \text{«}\mu C\text{»}$ ✓	*Award **[3]** for bald correct answer*	**3**
9.	b	ii	***ALTERNATIVE 1*** $E_T = \frac{1}{2}\frac{(29\times10^{-6})^2}{18\times10^{-6}} + \frac{1}{2}\frac{(19\times10^{-6})^2}{12\times10^{-6}}$ ✓ $= 3.8\times10^{-5}\ \text{«J»}$ ✓ ***ALTERNATIVE 2*** $E_T = \frac{1}{2}\times18\times10^{-6}\times1.6^2 + \frac{1}{2}\times12\times10^{-6}\times1.6^2$ ✓ $= 3.8\times10^{-5}\ \text{«J»}$ ✓	*Allow ECF from (b)(i)* *Award **[2]** for bald correct answer* *Award **[1]** max as ECF to a calculation using only one charge*	**2**

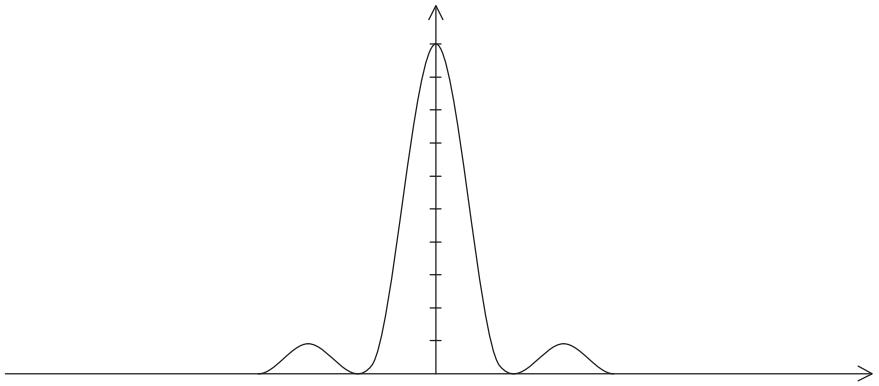
(continued…)

(Question 9 continued)

Question			Answers	Notes	Total
9.	**c**		charge moves/current flows **«**in the circuit**»** ✓ thermal losses **«**in the resistor and connecting wires**»** ✓	*Accept heat losses for MP2*	**2**
10.	**a**		there is a phase change ✓ of π ***OR*** as it is reflected off a medium of higher refractive index ✓		**2**
10.	**b**	**i**	$2d$ ✓	*Accept 2dn*	**1**
10.	**b**	**ii**	$2dn = \frac{\lambda}{2}$ ✓ $d = \text{«}\frac{\lambda}{4n} = \frac{656}{4 \times 1.38} = \text{»}\ 119\ \text{«nm»}$ ✓	*Award **[2]** for bald correct answer*	**2**
10.	**b**	**iii**	reflection from **«**front surface of**»** lens eliminated/reduced ***OR*** energy reaching sensor increased ✓ at one wavelength ✓	*Accept reference to reduction of glare for MP1*	**2**

(continued…)

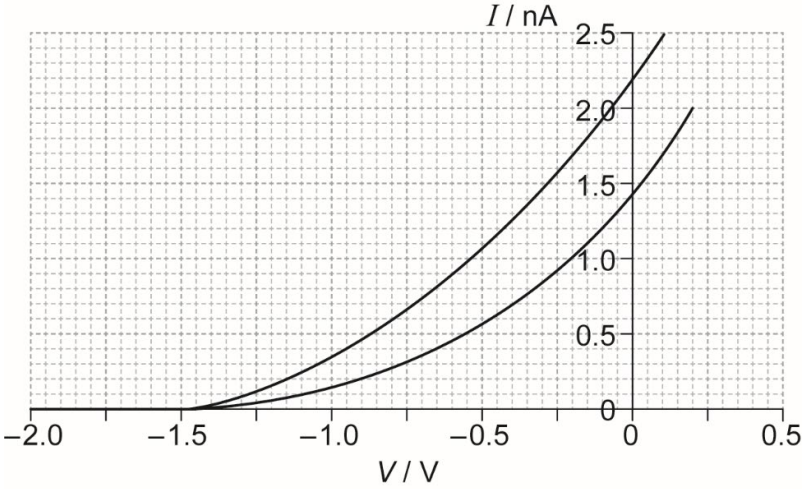
(Question 10 continued)

Question			Answers	Notes	Total
10.	**c**	**i**	standard single slit diffraction pattern with correct overall shape ✓ secondary maxima of right size ✓ 	*Secondary maximum not to exceed 1/5th of maximum intensity* *Ignore width of maxima*	**2**
10.	**c**	**ii**	use of $\theta = \frac{1.22\lambda}{b}$ ✓ $\theta = 2.9 \times 10^{-4}$ **«**rad**»** ✓	*Award **[2]** for bald correct answer*	**2**

Question			Answers	Notes	Total
11.	a	i	«low intensity light would» transfer energy to the electron at a low rate/slowly ✓ time would be required for the electron «to absorb the required energy» to escape/be emitted ✓	*OWTTE*	**2**
11.	a	ii	«in the photon theory of light» the electron interacts with a single photon ✓ and absorbs all the energy ***OR*** and can leave the metal immediately ✓	*Reference to photon-electron collision scores MP1*	**2**
11.	b	i	$\phi = \frac{hc}{\lambda} - E_{\text{K}}$ ✓ $E_{\text{K}} = 1.5$ «eV» ✓ $\phi =$ «$\frac{1.24 \times 10^{-6}}{480 \times 10^{-9}} - 1.5 =$» 1.1 «eV» ✓	*Allow reading from the graph of E_k=1.4 leading to an answer of 1.2 «eV».*	**3**

(continued…)

(Question 11 continued)

Question			Answers	Notes	Total
11.	**b**	**ii**	similar curve lower than original ✓ with same horizontal intercept ✓ 		**2**