Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2022

Physics

Higher level

Paper 2

22 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**		direction of motion is different / ***OWTTE*** ✓ *mv* / magnitude of momentum is different «even though *v* the same» ✓		**2**
1.	**b**		use of $ma=mg-T$ «$3.5 \times 2.4 = 3.5g - T$» ***OR*** $T = 3.5(g-2.4)$ ✓ 26 «N» ✓	*Accept 27* N ***from g = 10*** m s^{-2}	**2**
1.	**c**		proper use of kinematic equation ✓ $\sqrt{(2 \times 2.4 \times 0.95)}$ = 2.14 «m s^{-1}» ✓	*Must see either the substituted values **OR** a value for v to at least three s.f. for **MP2**.*	**2**

Question			Answers	Notes	Total
1.	d		***ALTERNATIVE 1*** **«**$v^2 = u^2 + 2as \Rightarrow 0 = 2.1^2 - 2a \times 0.35$**»** leading to a= 6.3 «m s^{-2}» ***OR*** « x=1/2(u+v)t » leading to t = 0.33 « s » ✓ F_{net} = « ma = 1.5 x 6.3 = » 9.45 «N» ✓ Weight down ramp = 1.5 x 9.8 x sin(30) = 7.4 «N» ✓ friction force = net force – weight down ramp = 2.1 «N» ✓ ***ALTERNATIVE 2*** kinetic energy initial = work done to stop 0.5 x 1.5 x $(2.1)^2$ = F_{NET} x 0.35 ✓ F_{net} = 9.45 «N» ✓ Weight down ramp = 1.5 x 9.8 x sin(30) = 7.4 «N» ✓ friction force = net force – weight down ramp = 2.1 «N» ✓	*Accept 1.95* N *from g = 10* m s^{-2}*.* *Accept 2.42* N *from u = 2.14* ms^{-1}.	**4**
1.	e		static coefficient of friction > dynamic/kinetic coefficient of friction / $\mu_s > \mu_k$ ✓ «therefore» force of dynamic/kinetic friction will be less than the force of static friction ✓ there will be a net / unbalanced forward force once in motion «which results in acceleration» ***OR*** reference to net F = ma ✓		**3**

Question			Answers	Notes	Total
2.	**a**		energy required for milk entering in 1 s = mass x specific heat x 73 ✓ 16 kW ***OR*** 16000 W ✓	***MP1*** *is for substitution into* $mc\Delta T$ *regardless of power of ten.* *Allow any correct unit of power (such as* Js^{-1} ***OR*** kJs^{-1}*) if paired with an answer to the correct power of 10 for* ***MP2****.*	**2**
2.	**b**		Underestimate / more energy or power required ✓ because energy transferred as heat / thermal energy is lost «to surroundings or electrical components» ✓	*Do not allow general term "energy" or "power" for* ***MP2.***	**2**
2.	**c**		the temperature has increased so the internal energy / « average » KE «of the molecules» has increased ***OR*** temperature is proportional to average KE «of the molecules». ✓ «therefore» the «average» speed of the molecules or particles is higher ***OR*** more frequent collisions « between molecules » ***OR*** spacing between molecules has increased ***OR*** average force of collisions is higher ***OR*** intermolecular forces are less ***OR*** intermolecular bonds break and reform at a higher rate ***OR*** molecules are vibrating faster. ✓		**2**

Question			Answers	Notes	Total
2.	**d**	**i**	conduction/conducting/conductor «through metal»✓		**1**
2.	**d**	**ii**	use of $P = e\sigma AT^4$ where T = 357 K ✓ use of $A = 2\pi r l$ « = 0.236 m^2» ✓ P = 87 «W» ✓	*Allow 85 – 89 W for* ***MP3.*** *Allow* ***ECF*** *for* ***MP3.***	**3**
2.	**d**	**iii**	convection «is likely to be a significant loss» ✓ «due to reduction in density of air near pipe surface» hot air rises «and is replaced by cooler air from elsewhere » ***OR*** «due to» conduction «of heat or thermal energy» from pipe to air ✓		**2**

Question			Answers	Notes	Total
3	**a**		movement of B means that path distance is different « between BM and AM » ***OR*** movement of B creates a path difference «between BM and AM» ✓ interference ***OR*** superposition «of waves» ✓ maximum when waves arrive in phase / path difference = n x lambda ***OR*** minimum when waves arrive «180° or π » out of phase / path difference = (n+½) x lambda ✓		**3**
3.	**b**		wavelength = 26 cm ✓ peak to peak distance is the path difference which is one wavelength ***OR*** this is the distance B moves to be back in phase «with A» ✓	*Allow 25 – 27* cm *for* ***MP1****.*	**2**

Question			Answers	Notes	Total
3.	**c**		«$\frac{\lambda}{2}$» = 13 cm ✓ $f = «\frac{c}{\lambda} = \frac{340}{0.13} =»$ 2.6 «kHz» ✓	*Allow ½ of wavelength from* ***(b)*** *or data from graph for* ***MP1.*** *Allow* ***ECF*** *from* ***MP1****.*	**2**
3.	**d**		***ALTERNATIVE 1*** use of $f' = f\frac{v}{v+u_0}$ (+ sign must be seen) ***OR*** f' = 2987 «Hz» ✓ « Δf » = 13 «Hz» ✓ ***ALTERNATIVE 2*** Attempted use of $\frac{\Delta f}{f} \approx \frac{v}{c}$ « Δf » = 13 «Hz» ✓		**2**

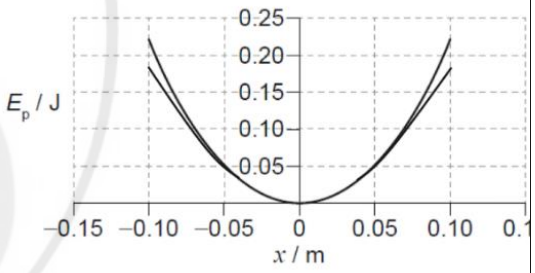
Question			Answers	Notes	Total
4.	a		***ALTERNATIVE 1*** attempt to use potential divider equation or similar method ✓ «$6.0 \times \frac{40}{(40+60)}$» = 2.4 «V» ✓ ***ALTERNATIVE 2*** «current = $\frac{6}{60+40}$» = 0.06 «A» ✓ 40 x 0.06 = 2.4 «V» ✓		**2**

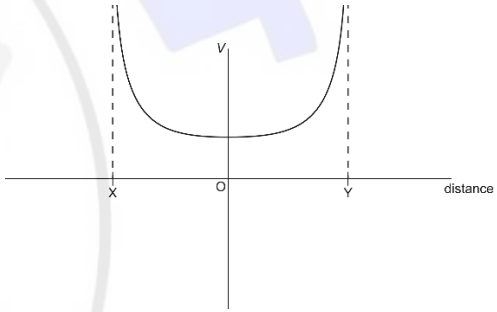
Question			Answers	Notes	Total
4.	b		***ALTERNATIVE 1*** Pd across Q = 2.4 V so I = 0.15 « A » ✓ and pd across S is 6.0 – 2.4 = 3.6 « V » ✓ $R = \frac{V}{I} = \frac{3.6}{0.15} =$ 24 «Ω» ✓ ***ALTERNATIVE 2*** pd at PR junction = pd at QS junction ✓ so $\frac{S}{Q} = \frac{R}{P}$ ***OR*** $S = \frac{16 \times 60}{40}$ ✓ 24 «Ω» ✓ ***ALTERNATIVE* 3** $I = \frac{40 \times 0.06}{16} = 0.15$ «A» ✓ 6.0 = (16+S)(0.15) ***OR*** $2.4 = (6)(\frac{16}{S+16})$ ✓ R= 24 «Ω» ✓	*Allow **ECF** for **MP3** from incorrect **MP1** or **MP2**.*	**3**
4.	c	i	recognition that 4L leads to 4R / « $\frac{\rho 4L}{A}$ » = 4R ✓ «because the volume of S is constant new area is» $\frac{A}{4}$ ✓ 16 x 24 = 384 «Ω» ✓		**3**

Question			Answers	Notes	Total
4.	**c**	**ii**	«total» power has decreased ✓ Because current in the branch has decreased «and $P=I^2R$ » ***OR*** Because resistance has increased in branch «and $P = \frac{V^2}{R}$ » ✓	*Allow opposite argument as **ECF** from **(c)(i)** (if candidate deduces a lower resistance).* *Allow "power doesn't change" if candidate has no change of resistance from **(b)** to **(c)(i)**.*	**2**

Question			Answers	Notes	Total
5.	**a**		3 quarks / example with three quarks «eg up up down» ✓ integer / zero / 1 / no fractional «electron» charge ***OR*** held together by the strong force / gluons ***OR*** half integer spin **OR** baryon number = 1 ***OR*** colour neutral ✓		**2**
5.	**b**		A «Decay of the strange antiquark is a» weak «interaction» ✓ B «Decay of the u to a gluon and eventually to d and anti-d is a» strong «interaction» ✓		**2**
5.	**c**		weak «interaction» ✓ strangeness is not conserved and this is possible only in weak interactions ***OR*** the weak interaction allows change of quark flavour ***OR*** only the weak interaction has a boson / an exchange particle / a W+ to conserve the charge ***OR*** neutrinos are only produced via the weak interaction ✓		**2**

Question			Answers	Notes	Total
6.	a		***For both models:*** displacement is $\propto$ to acceleration/force «because graph is straight and through origin» ✓ displacement and acceleration / force in opposite directions «because gradient is negative» ***OR*** acceleration/«restoring» force is always directed to equilibrium ✓		**2**
6.	b		attempted use of $\omega^2 = (-)\frac{a}{x}$ ✓ suitable read-offs leading to gradient of line = 28 « s^{-2}» ✓ $T = \frac{2\pi}{\omega}$ «$= \frac{2\pi}{\sqrt{28}}$» ✓ T = 1.2 s ✓		**4**

Question			Answers	Notes	Total
6.	c		time period increases ✓ because average ω «for whole cycle» is smaller ***OR*** slope / acceleration / force at large x is smaller ***OR*** area under graph B is smaller so average speed is smaller. ✓		2
6.	d		same curve ***OR*** shape for small amplitudes «to about 0.05 m» ✓ for large amplitudes «outside of 0.05 m» E_p smaller for model B / values are lower than original / spread will be wider ✓ ***OWTTE***	*Accept answers drawn on graph – e.g.*  	2

Question			Answers	Notes	Total
7	a		use of $\frac{kQ}{r}$ ✓ $\frac{(8.99\times10^{9})(4\times10^{-6})}{0.15}$ ***OR*** 240 «kV» for one charge calculated ✓ 480 «kV» for both ✓	***MP1*** *can be seen or implied from calculation.* *Allow* ***ECF*** *from* ***MP2*** *for* ***MP3****.*	**3**
7	b		symmetric curve around 0 with potential always positive, “bowl shape up” and curve not touching the horizontal axis. ✓ clear asymptotes at X and Y ✓		**2**

Question			Answers	Notes	Total
7	c	i	force is towards *O* ✓ always ✓		2
7	c	ii	***ALTERNATIVE 1*** motion is not SHM ✓ «because SHM requires force proportional to r and» this force depends on $\frac{1}{r^2}$ ✓ ***ALTERNATIVE 2*** motion is not SHM ✓ energy-distance «graph must be parabolic for SHM and this» graph is not parabolic ✓		2

Question			Answers	Notes	Total
8	a		$Q = «CV = 1.5 \times 28 \times 10^{-6}» = 0.042$ «mC» ✓	*Award **MP** for full replacement or correct answer to at least 2 significant figures.*	1
8	b	i	$E_i = \frac{1}{2} \times (28\ x\ 10^{-6})(1.5)^2 = 3.15 \times 10^{-5}$ «J» ✓ total capacitance = 50 «μF» ***OR*** pd = « $\frac{42 \times 10^{-6}}{50 \times 10^{-6}}$ = » 0.84 «V» ***OR*** charge on C_1 after switch moved to B = 0.0235 «mC» ✓ $E_f = \frac{1}{2} \times (28\ x\ 10^{-6})(0.84)^2 = 9.9 \times 10^{-6}$ «J» ✓ energy lost = $3.2 \times 10^{-5} - 9.9 \times 10^{-6} = 22$ «μJ» ✓		4
8	b	ii	energy transferred to electromagnetic radiation «to environment» ***OR*** energy is transferred as thermal energy / heat «to circuit components» ✓		1

Question			Answers	Notes	Total
8	c	i	initial deflection by voltmeter falling to zero reading✓ emf is induced «only» while the field / flux is changing		2
8	c	ii	attempted use of $\varepsilon = \frac{\Delta \Phi}{\Delta t}$ ***OR*** $NA\frac{\Delta B}{\Delta t}$ ✓ $\varepsilon = \frac{5 \times 7.5 \times 10^{-3} \times 6.4 \times 10^{-4}}{3 \times 10^{-3}}$ ✓ 8.0 «mV» ✓		3

Question			Answers	Notes	Total
9	a		${}^{40}_{20}\text{Ca}$ ✓ ${}^{0}_{-1}\text{e} + \bar{\upsilon}_{\text{e}}$ ***OR*** ${}^{0}_{-1}\beta + \bar{\upsilon}_{\text{e}}$ ✓	*Full equation* ${}^{40}_{19}\text{K} \rightarrow {}^{40}_{20}\text{Ca} + {}^{0}_{-1}\text{e} + \bar{\upsilon}_{\text{e}}$	**2**
9	b	i	total K-40 decayed = $\frac{12\ \mu\text{mol}}{0.11}$ =109 «μmol» ✓ so total K-40 originally was 109 + 340 = 449 «μmol» ✓		**2**

Question			Answers	Notes	Total
9	b	ii	***ALTERNATIVE 1*** $\lambda = \frac{\ln(2)}{t_{\frac{1}{2}}}$ used to give λ = 5.3 x 10^{-10} per year ✓ $340 = (449)(e^{-5.3\times10^{-10}\times t})$ ***OR*** $\ln\left(\frac{340}{449}\right) = -5.3\times10^{-10}\times t$ ✓ t =5.2 x 10^8 «years»✓ ***ALTERNATIVE 2*** $p = \frac{340}{449}$ = 0.76 «remaining» ✓ $n = \frac{\ln(p)}{0.693} = \frac{\ln(0.76)}{0.693} = 0.40$ ✓ t = 0.40 x 1.3 x 10^9 = 5.2 x 10^8 «years» ✓ ***ALTERNATIVE 3*** $p = \frac{340}{449}$ = 0.76 «remaining» $0.76 = (\frac{1}{2})^{\frac{t}{1.3\times10^9}}$ t = 0.40 x 1.3 x 10^9 = 5.2 x 10^8 «years»	*Allow 5.3 x 10^8 years for final answer.* *Allow **ECF** for **MP3** for an incorrect number of half-lives.*	**3**

Question			Answers	Notes	Total
9	c		«use the mass of the sample to» determine number of potassium-40 atoms / nuclei in sample ✓ «use a counter to» determine (radio)activity / A of sample ✓ use $A = \lambda N$ «to determine the decay constant / λ»✓		3