

Markscheme

May 2022

Physics

Higher level

Paper 2

© International Baccalaureate Organization 2022

All rights reserved. No part of this product may be reproduced in any form or by any electronic or mechanical means, including information storage and retrieval systems, without the prior written permission from the IB. Additionally, the license tied with this product prohibits use of any selected files or extracts from this product. Use by third parties, including but not limited to publishers, private teachers, tutoring or study services, preparatory schools, vendors operating curriculum mapping services or teacher resource digital platforms and app developers, whether fee-covered or not, is prohibited and is a criminal offense.

More information on how to request written permission in the form of a license can be obtained from <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

© Organisation du Baccalauréat International 2022

Tous droits réservés. Aucune partie de ce produit ne peut être reproduite sous quelque forme ni par quelque moyen que ce soit, électronique ou mécanique, y compris des systèmes de stockage et de récupération d'informations, sans l'autorisation écrite préalable de l'IB. De plus, la licence associée à ce produit interdit toute utilisation de tout fichier ou extrait sélectionné dans ce produit. L'utilisation par des tiers, y compris, sans toutefois s'y limiter, des éditeurs, des professeurs particuliers, des services de tutorat ou d'aide aux études, des établissements de préparation à l'enseignement supérieur, des fournisseurs de services de planification des programmes d'études, des gestionnaires de plateformes pédagogiques en ligne, et des développeurs d'applications, moyennant paiement ou non, est interdite et constitue une infraction pénale.

Pour plus d'informations sur la procédure à suivre pour obtenir une autorisation écrite sous la forme d'une licence, rendez-vous à l'adresse <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

© Organización del Bachillerato Internacional, 2022

Todos los derechos reservados. No se podrá reproducir ninguna parte de este producto de ninguna forma ni por ningún medio electrónico o mecánico, incluidos los sistemas de almacenamiento y recuperación de información, sin la previa autorización por escrito del IB. Además, la licencia vinculada a este producto prohíbe el uso de todo archivo o fragmento seleccionado de este producto. El uso por parte de terceros —lo que incluye, a título enunciativo, editoriales, profesores particulares, servicios de apoyo académico o ayuda para el estudio, colegios preparatorios, desarrolladores de aplicaciones y entidades que presten servicios de planificación curricular u ofrezcan recursos para docentes mediante plataformas digitales—, ya sea incluido en tasas o no, está prohibido y constituye un delito.

En este enlace encontrará más información sobre cómo solicitar una autorización por escrito en forma de licencia: <https://ibo.org/become-an-ib-school/ib-publishing/licensing/applying-for-a-license/>.

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 ° 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 $g = 10 \text{ m s}^{-2}$	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	<p>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» ✓</p> <p>$F_{net} = ma = 1.5 \times 6.3 = 9.45$ «N» ✓ Weight down ramp = $1.5 \times 9.8 \times \sin(30) = 7.4$ «N» ✓ friction force = net force – weight down ramp = 2.1 «N» ✓</p> <p>ALTERNATIVE 2 kinetic energy initial = work done to stop $0.5 \times 1.5 \times (2.1)^2 = F_{NET} \times 0.35$ ✓ $F_{net} = 9.45$ «N» ✓ Weight down ramp = $1.5 \times 9.8 \times \sin(30) = 7.4$ «N» ✓ friction force = net force – weight down ramp = 2.1 «N» ✓</p>	<p>Accept 1.95 N from $g = 10$ m s⁻². Accept 2.42 N from $u = 2.14$ ms⁻¹.</p>	4
1.	e	<p>static coefficient of friction > dynamic/kinetic coefficient of friction / $\mu_s > \mu_k$ ✓</p> <p>«therefore» force of dynamic/kinetic friction will be less than the force of static friction ✓</p> <p>there will be a net / unbalanced forward force once in motion «which results in acceleration»</p> <p>OR</p> <p>reference to net $F = ma$ ✓</p>		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 kJJs^{-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 $T = 357 \text{ K}$ ✓ use of $A = 2\pi r l$ « = 0.236 m ² » ✓ $P = 87 \text{ «W»}$ ✓	<i>Allow 85 – 89 W for MP3.</i> <i>Allow ECF for MP3.</i>	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	<p>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» ✓</p> <p>interference OR superposition «of waves» ✓</p> <p>maximum when waves arrive in phase / path difference = $n \times \lambda$ OR minimum when waves arrive «180° or π » out of phase / path difference = $(n + \frac{1}{2}) \times \lambda$ ✓</p>		3
3.	b	<p>wavelength = 26 cm ✓</p> <p>peak to peak distance is the path difference which is one wavelength</p> <p>OR</p> <p>this is the distance B moves to be back in phase «with A» ✓</p>	Allow 25 – 27 cm for MP1 .	2

Question		Answers	Notes	Total
3.	c	$\left\langle \frac{\lambda}{2} \right\rangle = 13 \text{ cm} \checkmark$ $f = \left\langle \frac{c}{\lambda} = \frac{340}{0.13} \right\rangle = 2.6 \text{ «kHz»} \checkmark$	<p>Allow $\frac{1}{2}$ of wavelength from (b) or data from graph for MP1.</p> <p>Allow ECF from MP1.</p>	2
3.	d	<p>ALTERNATIVE 1</p> <p>use of $f' = f \frac{v}{v + u_0}$ (+ sign must be seen) OR $f' = 2987 \text{ «Hz»} \checkmark$</p> <p>$\langle \Delta f \rangle = 13 \text{ «Hz»} \checkmark$</p> <p>ALTERNATIVE 2</p> <p>Attempted use of $\frac{\Delta f}{f} \approx \frac{v}{c}$</p> <p>$\langle \Delta f \rangle = 13 \text{ «Hz»} \checkmark$</p>		2

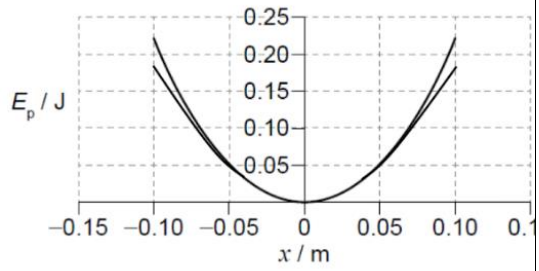
Question		Answers	Notes	Total
4.	a	<p>ALTERNATIVE 1</p> <p>attempt to use potential divider equation or similar method ✓</p> $\llcorner 6.0 \times \frac{40}{(40 + 60)} \rceil = 2.4 \llcorner V \rceil \checkmark$ <p>ALTERNATIVE 2</p> $\llcorner \text{current} = \frac{6}{60 + 40} \rceil = 0.06 \llcorner A \rceil \checkmark$ $40 \times 0.06 = 2.4 \llcorner V \rceil \checkmark$		2

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

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

Question		Answers	Notes	Total
5.	a	<p>3 quarks / example with three quarks «eg up up down» ✓</p> <p>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 ✓</p>		2
5.	b	<p>A «Decay of the strange antiquark is a» weak «interaction» ✓</p> <p>B «Decay of the u to a gluon and eventually to d and anti-d is a» strong «interaction» ✓</p>		2
5.	c	<p>weak «interaction» ✓</p> <p>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 ✓</p>		2

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

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

Question		Answers	Notes	Total
7	a	<p>use of $\frac{kQ}{r}$ ✓</p> <p>$\frac{(8.99 \times 10^9)(4 \times 10^{-6})}{0.15}$ OR 240 «kV» for one charge calculated ✓</p> <p>480 «kV» for both ✓</p>	<p>MP1 can be seen or implied from calculation.</p> <p>Allow ECF from MP2 for MP3.</p>	3
7	b	<p>symmetric curve around 0 with potential always positive, “bowl shape up” and curve not touching the horizontal axis. ✓</p> <p>clear asymptotes at X and Y ✓</p>		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		$Q = \ll CV = 1.5 \times 28 \times 10^{-6} \gg = 0.042 \ll \text{mC} \gg \checkmark$	<i>Award MP for full replacement or correct answer to at least 2 significant figures.</i>	1
8	b	i	$E_i = \frac{1}{2} \times (28 \times 10^{-6})(1.5)^2 = 3.15 \times 10^{-5} \ll \text{J} \gg \checkmark$ total capacitance = 50 $\ll \mu\text{F} \gg$ OR $\text{pd} = \ll \frac{42 \times 10^{-6}}{50 \times 10^{-6}} = \gg 0.84 \ll \text{V} \gg$ OR charge on C_1 after switch moved to B = 0.0235 $\ll \text{mC} \gg \checkmark$ $E_f = \frac{1}{2} \times (28 \times 10^{-6})(0.84)^2 = 9.9 \times 10^{-6} \ll \text{J} \gg \checkmark$ energy lost = $3.2 \times 10^{-5} - 9.9 \times 10^{-6} = 22 \ll \mu\text{J} \gg \checkmark$		4
8	b	ii	energy transferred to electromagnetic radiation $\ll \text{to environment} \gg$ OR energy is transferred as thermal energy / heat $\ll \text{to circuit components} \gg \checkmark$		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		${}_{20}^{40}\text{Ca}$ ✓ ${}_{-1}^0\text{e} + \bar{\nu}_e$ OR ${}_{-1}^0\beta + \bar{\nu}_e$ ✓	<i>Full equation</i> ${}_{19}^{40}\text{K} \rightarrow {}_{20}^{40}\text{Ca} + {}_{-1}^0\text{e} + \bar{\nu}_e$	2
9	b	i	total K-40 decayed = $\frac{12 \mu\text{mol}}{0.11} = 109 \text{ «}\mu\text{mol}\text{»}$ ✓ so total K-40 originally was $109 + 340 = 449 \text{ «}\mu\text{mol}\text{»}$ ✓		2

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

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