

Markscheme

May 2023

Physics

Standard level

Paper 3

21 pages

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Subject Details: Physics SL Paper 3 Markscheme

Candidates are required to answer **all** questions in Section A and **all** questions from **one** option in Section B. Maximum total = **35 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 underlined 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.

Section A

Question		Answers	Notes	Total
1.	a	height «of drop» OR velocity «of ball» OR kinetic energy «of ball» OR temperature/mass/radius/surface area/volume of ball ✓	<i>Allow reference to controlling spin on the ball</i> <i>Do not accept bald temperature, mass, surface area or volume.</i>	1

Question		Answers	Notes	Total
1.	b	refers to 2 non-adjacent points ✓ suitable calculation to analyze the proportionality ✓ identifies variation/difference in calculated values, «thus hypothesis not supported» ✓	<i>Award full marks if more than two points used appropriately.</i> <i>Allow [2 max] if they use at least three points to show that two increments in force are not consistent with the corresponding increments in pressure and therefore it is not a straight line.</i>	3

Question			Answers	Notes	Total
1.	c	i	N^2m^2 OR $\text{kg}^2\text{m}^4\text{s}^{-4}$ OR N^3Pa^{-1} ✓	<i>Award [0] if they convert to base units incorrectly.</i>	1
1.	c	ii	point plotted at (40 kPa, $49 \times 10^5 \text{ N}^3$) ✓	<i>Allow for the point to be plotted from 46 to $56 \times 10^5 \text{ N}^3$ at 40 kPa, as candidates may calculate or may plot from a graphical analysis.</i>	1
1.	d	i	15 % seen anywhere ✓ « $\Delta(F^3)$ » $\Rightarrow 39.4 \times 10^5 \times 0.15 = 5.9 \times 10^5$ ✓ $\pm 6 \times 10^5$ ✓	<i>MP1 is for the propagation of 5%. It can be shown differently, e.g. $3 \times 5\%$ Allow students to use 40×10^5 (from the graph). Award MP3 for any uncertainty rounded to 1 significant digit Award [3] for a BCA. Allow ECF from MP1 and MP2</i>	3
1.	d	ii	error bar drawn at 30 kPa from 34×10^5 to $46 \times 10^5 \text{ N}^3$ ✓	<i>Allow \pm half square on each side of the bar or one square overall ($\pm 2 \times 10^5$) Allow ECF from d(i).</i>	1
1.	d	iii	a «straight» line can be drawn that passes through origin ✓		1

Question		Answers	Notes	Total
2.	a	final temperature of equilibrium/water/cube OR mass of water/cube ✓	<p><i>Do not award mark if any additional incorrect measurement is included</i></p> <p><i>Accept temperature change if water or cube specified</i></p>	1
2.	b	smaller mass of cube OR hotter cube OR more mass of water OR colder water OR more precise thermometer ✓	<p><i>Accept reference to repeating the experiment and taking mean values.</i></p> <p><i>Accept any reasonable answer that increases change in temperature of the cube.</i></p> <p><i>Do not accept more accurate thermometer</i></p>	1
2.	c	cube specific heat will be too large/increased value/overestimate ✓ additional «thermal» energy transferred OR temperature rise of water will be larger OR temperature drop of cube will be smaller ✓		2

Section B

Option A — Relativity

Question			Answers	Notes	Total
3.	a		set of coordinates/axes to record position and time «of an event» OR a coordinate system which is at rest/not moving relative to the observer ✓	<i>Some mention of time and position for MP1</i> <i>Allow “set of clocks and rulers” as per MP1</i>	1
3.	b	i	magnetic ✓ «observer O sees» moving charge in a magnetic field ✓	<i>Do not allow electromagnetic</i> OWTTE	2
3.	b	ii	electric / electrostatic ✓ positive lattice ions are length contracted relative to e OR electrons sees positive wire ✓		2

Question		Answers	Notes	Total
4.	a	4.8 «light years» ✓		1
4.	b	«-» 0.48c ✓	Ignore sign	1
4.	c	$\gamma = 1.6$ ✓ $D = \frac{4.8}{1.6} = 3$ «ly» ✓	Allow ECF from MP1	2
4.	d	$= \frac{0.3c - 0.78c}{1 - \frac{0.78c \times 0.3c}{c^2}}$ ✓ «-»0.63c ✓	Award [2] if MP1 correct and correct answer given to 1 significant figure.	2
4.	e	$\Delta t_p = \frac{3\text{ly}}{(0.78 - 0.627)c}$ OR $\Delta t_p = 1.6 \left(\frac{4.8\text{ly}}{0.3c} - \frac{0.78c \times 4.8\text{ly}}{c^2} \right)$ ✓ = 19 OR 20 «years» ✓	Award [2] for BCA	2
4.	f	shuttle measures proper time ✓ as the events occur at the same place for the shuttle / shuttle is at both events ✓		2

Question		Answers	Notes	Total
5.	a	$0.6 c$ OR $= 1.8 \times 10^8 \text{ «ms}^{-1}\text{»} \checkmark$		1
5.	b	Line drawn at 45° from $ct = 2 \text{ km}$ to hit spaceship world line at $ct = 5 \text{ km}$ OR $ct = 1.2/(c-0.6c) + 2 = 5 \text{ «km»} \cdot \checkmark$ $t = \frac{5000}{c} = 1.7 \times 10^{-5} \text{ «s»} \checkmark$	<i>Award [2] for BCA</i>	2
5.	c	$(ct')^2 - 0 = 5^2 - 3^2$ OR $\gamma = 1.25 \checkmark$ $ct' = 4 \text{ «km»}$ OR $t' = 13 \text{ «}\mu\text{s»} \checkmark$	<i>Allow ECF from (b)</i> <i>Allow ECF from MP1</i>	2

Option B — Engineering physics

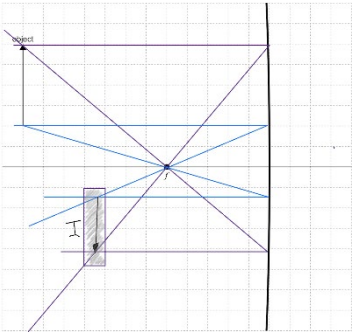
Question		Answers	Notes	Total
6.	a	$\Sigma \Gamma = 50 \times 0.5 + 40 \times 0.2$ OR 33 «Nm» ✓	Accept opposite rotational sign convention	1
6.	b	$\ll \alpha = \frac{20}{5} = \gg 4 \ll \text{rad s}^{-2} \gg \checkmark$		1
6.	c	$I = \frac{\Gamma}{\alpha}$ OR $33 = I \times 4 \checkmark$ $I = 8.25 \ll \text{kg m}^2 \gg \checkmark$	Allow ECF from (a) and (b) Award [2] for a BCA	2

Question			Answers	Notes	Total
6.	d	i	moment of inertia increases ✓ Angular momentum is conserved ✓	Allow algebraic expressions e.g. $\omega = \frac{L}{I}$ so ω decreases for MP2	2
6.	d	ii	$E_k \llcorner = \frac{1}{2} I \omega^2 \Rightarrow \frac{1}{2} (I \omega) \omega = \frac{1}{2} L \omega \checkmark$	Accept equivalent methods	1
6.	d	iii	$\llcorner E_k \Rightarrow \frac{1}{2} L \omega_1 = \frac{1}{2} L \omega_2$ OR $\frac{E_{k1}}{E_{k2}} = \frac{\omega_1}{\omega_2}$ OR $\llcorner L$ is constant so E_k is proportional to $\omega \checkmark$ 40 % \llcorner energy loss $\llcorner \checkmark$	MP1 is for understanding that angular momentum is constant so change in rotational kinetic energy is proportional to change in angular velocity Award [0] if $E = 0.5 I \omega^2$ is used with the same I value for both values of E Award [2] for BCA	2
6.	e		one example specified eg friction, air resistance, mass distribution not modelled ✓	Award [1] for any reasonable physical parameter that is not consistent with the model	1

Question		Answers	Notes	Total
7.	a	use of $pV = \text{constant}$ ✓ $P_B = 43 \text{ «kPa»}$ ✓	Award [2] for BCA	2
7.	b	concave curved line from B to locate C with a higher pressure than A ✓ vertical line joining C to A ✓	Allow ECF from MP1 i.e., award [1] for first process locating C at a lower pressure than A, then vertical line to A. Arrows on the processes are not needed. Point C need not be labelled.	2
7.	c	<p>ALTERNATIVE 1</p> use of $TV^{\frac{2}{3}} = \text{constant}$ «so $300(3V_A)^{\frac{2}{3}} = T_C(V_A)^{\frac{2}{3}}$ » ✓ $T_C = 624 \text{ «K» OR } T_C = 351 \text{ «°C»}$ ✓		2
		<p>ALTERNATIVE 2</p> use of $pV^{\frac{5}{3}}$ to get either $p_c = 43(3)^{\frac{5}{3}}$ OR $p_c = 268 \text{ «kPa»}$ ✓ « $T_c = 268 \times 300 / 129 = \text{so}$ » $T_C = 624 \text{ «K» OR } T_C = 351 \text{ «°C»}$ ✓		2

Question		Answers	Notes	Total
7.	d	<p>ALTERNATIVE 1 «the process is adiabatic so» $\Delta Q = 0$ ✓</p> <p>ALTERNATIVE 2 The compression is reversible «so $\Delta S = 0$» ✓</p>	OWTTE	1
7.	e	area under curve AB is less than area under curve BC ✓	<i>Do not allow ECF from part (b)</i>	1
7.	f	<p>«$W = 0$ so» $Q = \Delta U$ ✓</p> <p>«$\Delta U = \frac{3}{2} \times 53.2 \times R \times (351 - 27)$ so » $\Delta U = 2.15 \times 10^5$ «J» ✓</p>	Award [2] for BCA	2

Option C — Imaging

Question		Answers	Notes	Total
8.	a	one ray drawn correctly reflected ✓ bottom and top of image located within the accepted region ✓	 <p>Allow the image to be within 1 square wide in the shaded region in the diagram above. The bottom not closer than 1 square from the main axis.</p>	2
8.	b	real OR inverted OR smaller image or magnification < 1 ✓	Must have any two correct to score [1] Features to be consistent with (a)	1
8.	c	spherical aberration OR rays do not meet at common focus OR blurred image ✓ parabolic «shape» ✓		2

Question			Answers	Notes	Total
9.	a		$M = \llcorner \frac{25}{8} \Rightarrow 3.1 \checkmark$		1
9.	b	i	$\frac{1}{8} = \frac{1}{14} + \frac{1}{v}$ OR $v = 18.7 \checkmark$ $M = \frac{18.7}{14}$ OR $M = 1.33$ OR $M = 1.34 \checkmark$	<i>Do not allow ECF for wrong value for v</i>	2
9.	b	ii	$\frac{1}{8} = 1 / (25-18.66) + 1/v$ OR $v = -30.4 \checkmark$ $m = \llcorner m_1 \times m_2 = 1.33 \times \frac{30.4}{(25 - 18.66)} = 1.33 \times 4.8 \Rightarrow 6.4 \checkmark$	<i>Allow ECF from MP1</i> <i>Allow ECF from b(i)</i>	2
9.	c	i	better resolution «than the eye» \checkmark	<i>Allow reference to brighter, sharper or clearer image.</i>	1
9.	c	ii	no magnification OR $m=1 \checkmark$		1
9.	d		international means base line can be across countries/continents \checkmark greater distances increase the effective diameter of the dish \checkmark great diameter improves resolution \checkmark	OWTTE	2 max

Question		Answers	Notes	Total
10.	a	attenuation = $10 \log_{10}(0.015)$ OR = -18.2 ✓ length = $\frac{-18.2}{-0.3}$ OR 60.8 «km» ✓	Allow ECF from MP1 Ignore signs	2
10.	b	$\Delta t = 14 \times 10^{-5} \text{ s}$ ✓ $\left\langle \frac{27 \times 10^3}{14 \times 10^{-5}} = \frac{3 \times 10^8}{n} \right\rangle : n = 1.56$ ✓	Award MP1 if $\Delta t = 14 \times 10^{-5} \text{ s}$ is seen anywhere Allow ECF for MP2 , if candidates use $\Delta t = 18 - 3$ OR $\Delta t = 20 - 4$, accepting $n = 1.67$ or $n = 1.78$	2
10.	c	refractive index of fibre is less at the edges ✓ reduces time taken for the longer path signals ✓	OWTTE	2

Option D — Astrophysics

Question			Answers	Notes	Total
11.	a	i	cloud/body of dust and gas ✓	Award [1] for a reference to dust OR gas. Ignore further references to origin of cloud.	1
11.	a	ii	observation of light from/passing through nebula ✓ part of the model of stellar evolution ✓	MP1 is for any suitable comment that refers to making inferences from the radiation received, including measurement of luminosity or comparison to radiation on Earth to e.g., obtain chemical composition or wavelength shift.	1 max
11.	b	i	Star Y ✓ because parallax angle is greater OR star Y is closer «and that means movement relative to distant stars is greater» ✓	Allow reverse argument for star X	2
11.	b	ii	« distance = $\left(\frac{1}{0.019}\right) \times 3.26 \times 9.46 \times 10^{15}$ » 1.6×10^{18} «m» ✓		1
11.	b	iii	$\frac{\text{Luminosity of Star X}}{\text{Luminosity of Star Y}} = \frac{b_x d_x^2}{b_y d_y^2} \checkmark$ $= 10.8 \approx 11 \checkmark$	Award MP1 if ratio shown with distance or parallax angle. Award MP1 for any correct substitution into ratio expression Award [2] for BCA Allow ECF for incorrect distances from b(i) or b(ii) .	2

Question		Answers	Notes	Total
12.	a	Hydrogen ✓		1
12.	b	stars have same/similar L AND star B has lower T ✓ correct reference to luminosity formula ($L \propto AT^4$) ✓	MP1 Allow reverse argument i.e., star A has higher T	2
12.	c	Any evidence of correct identification that three dots bottom left represent white dwarfs ✓ line passing through all 3 white dwarfs OR line continuing from 3 white dwarfs with approximately same gradient, in either direction ✓	Award MP2 if no line drawn through the three dots but just beyond them in either direction	2
12.	d	«inward» gravitational force/pressure ✓ balanced by «neutron» degeneracy pressure/force ✓	Allow force or pressure OWTTE	2

Question		Answers	Notes	Total
13.	a	<p>ALTERNATIVE 1</p> <p>$v = 0.13 \times 3 \times 10^8$ OR 0.39×10^8 «m s⁻¹» OR $0.13 \times 3 \times 10^5$ OR 0.39×10^5 «km s⁻¹» ✓</p> <p>$d = \left\langle \frac{0.39 \times 10^8}{73 \times 10^3} \right\rangle \Rightarrow 530$ «Mpc» ✓</p> <p>ALTERNATIVE 2</p> <p>$d = \frac{cz}{H}$ ✓</p> <p>$\left\langle 3 \times 10^8 \times \frac{0.13}{73 \times 10^3} \right\rangle \Rightarrow 530$ «Mpc» ✓</p>	Award [2] for BCA	2

Question			Answers	Notes	Total
13.	b	i	<p>ALTERNATIVE 1</p> $\frac{R}{R_0} = 1 + z = 1.13 \quad \checkmark$ $\frac{R}{R_0} = \frac{t}{t_0} = 1.13 \quad \checkmark$ $t_0 = \left\langle \frac{13.4 \times 10^9}{1.13} \right\rangle = 11.9 \times 10^9 \text{ «years»} \quad \checkmark$ <p>ALTERNATIVE 2</p> <p>«distance light travelled from galaxy = » $530 \times 10^6 \times 3.26$ OR 1.7×10^9 «ly» \checkmark</p> <p>light emitted from galaxy 1.7×10^9 «years ago» \checkmark</p> <p>age when light was emitted «$13.4 \times 10^9 - 1.7 \times 10^9 =$» 11.7×10^9 «years ago» \checkmark</p>	<p>MP1 can be awarded if MP2 is clearly seen</p> <p>For MP2 allow $H_{\text{now}} / H_{\text{then}} = 1/1.13$ then $H_{\text{then}} = 1/t_0$</p> <p>Award [3] for BCA</p> <p>Allow ECF for MP3</p> <p>Accept $1.6 \times 10^{25} \text{ m}$ for MP1</p>	3
13.	b	ii	evidence from type Ia supernovae show an accelerating universe \checkmark	Accept distant galaxies are further away than expected	1