

# Markscheme

**May 2019**

**Physics**

**Standard level**

**Paper 3**

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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	i	error in $m_1 + m_2$ is 1% <b>OR</b> error in $m_1 - m_2$ is 40% <b>OR</b> error in $a$ is 1% ✓ adds percentage errors ✓ so error in $g$ is 42% <b>OR</b> 40% <b>OR</b> 41.8% ✓	Allow answer 0.42 or 0.4 or 0.418. Award [0] for comparing the average value with a known value, e.g. $9.81 \text{ m s}^{-2}$ .	3
1.	a	ii	$g = 9.996 \text{ «ms}^{-2}\text{»}$ <b>OR</b> $\Delta g = 4.20 \text{ «ms}^{-2}\text{»}$ ✓ $g = (10 \pm 4) \text{ «ms}^{-2}\text{»}$ <b>OR</b> $g = (10.0 \pm 4.2) \text{ «ms}^{-2}\text{»}$ ✓	Award [1] max for not proper significant digits or decimals use, such as: $9.996 \pm 4.178$ or $10 \pm 4.2$ or $10.0 \pm 4$ or $10.0 \pm 4.18 \text{ «ms}^{-2}\text{»}$ .	2
1.	b	i	the acceleration would be small/the time of fall would be large ✓ easier to measure /a longer time of fall reduces the % error in the time of fall and « hence acceleration » ✓	Do not accept ideas related to the mass/moment of inertia of the pulley.	2
1.	b	ii	the percentage error in the difference of the masses is large ✓ leading to a large percentage error/uncertainty in $g$ /of the experiment ✓	Do not accept ideas related to the mass/moment of inertia of the pulley.	2

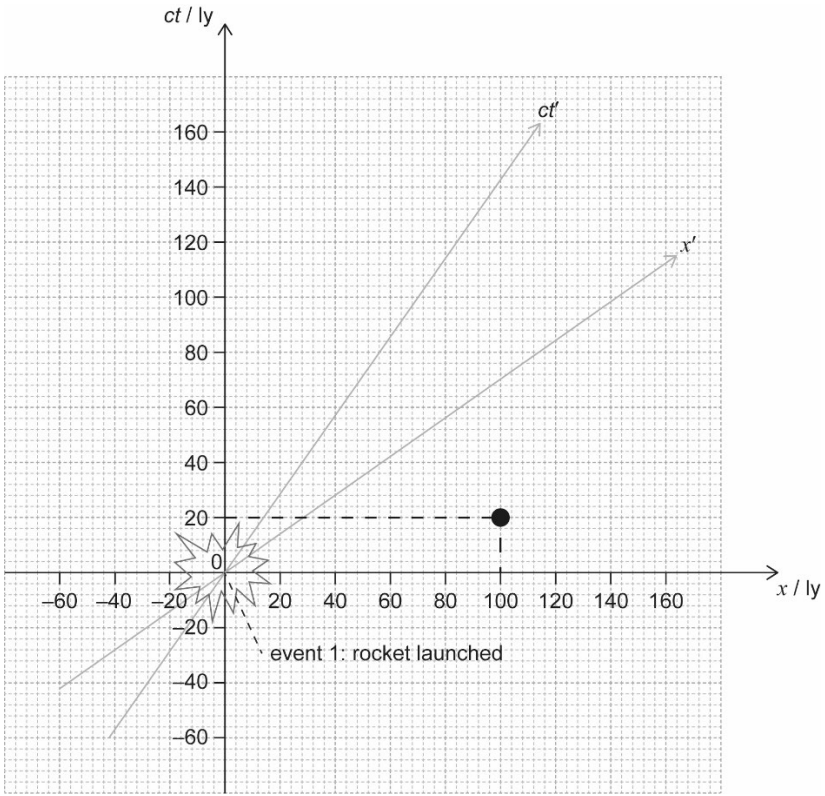
Question		Answers	Notes	Total
2.	a	theory « $H = cD^{\left(\frac{2}{3}\right)}$ » predicts that $H^3 \propto D^2$ ✓ graph « of $H^3$ vs $D^2$ » is a straight line through the origin/graph of proportionality ✓	Allow $H = cD^{\left(\frac{2}{3}\right)}$ gives $H^3 = c^3D^2$ for MP1.  Do not award MP2 for “the graph is linear” without mention of origin.	2
2.	b	evidence of gradient calculation to give gradient = 3.0 ✓ $c^3 = 3.0 \Rightarrow c = 1.4$ ✓ $m^{\frac{1}{3}}$ ✓		3
2.	c	the load/the thickness of paper/the type of paper/ the number of times the paper is rolled to form a cylinder ✓		1

### Section B

#### Option A — Relativity

Question			Answers	Notes	Total
3.	a		$c-v \checkmark$		1
3.	b		$c \checkmark$		1
3.	c		$c \checkmark$		1

Question			Answers	Notes	Total
4.	a	i	<p>time of travel is <math>\llcorner \frac{3230}{0.98 \times 3.0 \times 10^8} \llcorner = 1.10 \times 10^{-5}</math> «s» ✓</p> <p>which is <math>\llcorner \frac{1.10 \times 10^{-5}}{2.20 \times 10^{-6}} \llcorner = 5.0</math> half-lives ✓</p> <p>so fraction arriving as muons is <math>\llcorner \frac{1}{2^5} \llcorner = \frac{1}{32}</math></p> <p><b>OR</b></p> <p>3% ✓</p>	Award [3] for a bald correct answer.	3
4.	a	ii	<p>time of travel corresponds to <math>\llcorner \frac{1.10 \times 10^{-5}}{5.0 \times 2.20 \times 10^{-6}} \llcorner = 1.0</math> half-life ✓</p> <p>so fraction arriving as muons is <math>\frac{1}{2}</math></p> <p><b>OR</b></p> <p>50% ✓</p>	Award [2] for a bald correct answer.	2
4.	b		<p>observer measures the distance to the surface to be shorter « by a factor of 5.0 » / length contraction occurs ✓</p> $\left( \frac{\frac{3230}{5.0}}{0.98 \times 3.0 \times 10^8} \right)$ <p>so time of travel again corresponds to <math>\llcorner \frac{\left( \frac{\frac{3230}{5.0}}{0.98 \times 3.0 \times 10^8} \right)}{(2.20 \times 10^{-6})} \llcorner = 1.0</math> half-life ✓</p>		2

Question	Answers	Notes	Total
<p>5. a</p>	 <p>point as shown ✓</p>		<p>1</p>

(continued...)



(Question 5 continued)

Question		Answers	Notes	Total
5.	b	<p><b>ALTERNATIVE 1</b> the rocket would have to travel faster than the speed of light ✓ so impossible ✓</p> <p><b>ALTERNATIVE 2</b> drawing of future lightcone at origin ✓ and seeing that the asteroid explodes outside the lightcone so impossible ✓</p> <p><b>ALTERNATIVE 3</b> the event was observed at +20 years, but its distance (stationary) is 100 ly ✓ so the asteroid event happened 80 years before <math>t = 0</math> for the galactic observer ✓</p>		2
5.	c	$100^2 - 20^2 = 9600$ «ly <sup>2</sup> » ✓	Also accept 98 (the square root of 9600). Allow negative value.	1
5.	d	i	$9600 = 120^2 - c^2t^2$ ✓ $ct = \leftarrow 69.3$ «ly» / $t = \leftarrow 69.3$ «y» ✓	Allow approach with Lorentz transformation. 2

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	d	ii	line from event 2 parallel to $x'$ axis intersects $ct'$ axis at a negative value ✓ event 2 occurred first ✓		2
5.	e		use of $\tan \theta = \frac{v}{c}$ with the angle between the time axes ✓ to get $(0.70 \pm 0.02)c$ ✓		2

Option B — Engineering physics

Question			Answers	Notes	Total
6.	a	i	<p>equations of motion are: <math>TR = \frac{1}{2}MR^2\alpha</math> and <math>\frac{Mg}{4} - T = \frac{M}{4}a</math></p> <p><b>OR</b></p> $\frac{M}{4}gR = \frac{1}{2}MR^2\alpha + \frac{M}{4}Ra \checkmark$ <p>use of <math>a = \alpha R \checkmark</math></p> <p>combine equations to get result <math>\checkmark</math></p>	<p><i>Allow energy conservation use.</i></p> <p><i>This is a show that question, so look for correct working.</i></p> <p><i>Do not allow direct use of tension from a ii).</i></p>	3
6.	a	ii	<p>use of <math>T = \frac{1}{2}MR\alpha</math> to find <math>T = \frac{1}{2}MR \times \frac{g}{3R} \checkmark</math></p> <p>« cancelling to show final answer »</p>		1
6.	b		<p><math>a = 3.27 \text{ «ms}^{-2}\text{»} / a = g/3 \checkmark</math></p> $t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 0.50}{3.27}} \checkmark$ <p>= 0.55 «s»</p>	<p><i>Do not apply ECF from MP1 to MP2 if for a=g, giving answer 0.32 s.</i></p>	2

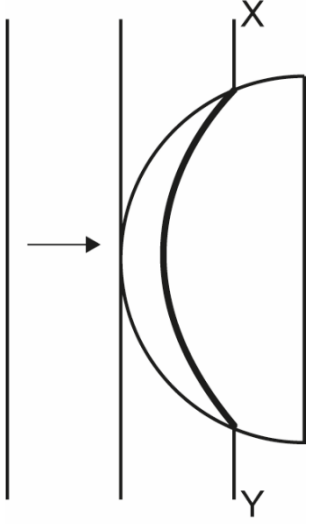
(continued...)

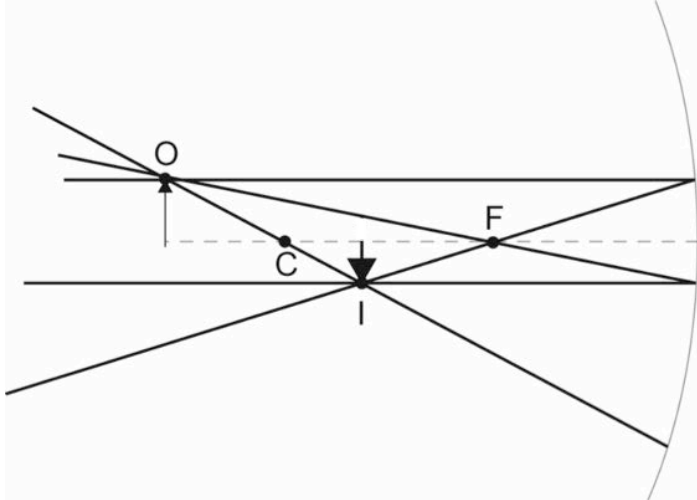
(Question 6 continued)

Question			Answers	Notes	Total
6.	c	i	<p><b>ALTERNATIVE 1</b></p> $\Delta L \llcorner = \Gamma \Delta t = TR \Delta t \llcorner = \frac{12 \times 9.81 \times 0.20 \times 0.55}{6} \checkmark$ $\Delta L = 2.2 \llcorner \text{Js} \llcorner \checkmark$ <p><b>ALTERNATIVE 2</b></p> $\omega = \llcorner \alpha \Delta t = \frac{g}{3R} \Delta t = \frac{9.81 \times 0.55}{3 \times 0.20} \Rightarrow 8.99 \llcorner \text{rads}^{-1} \llcorner \checkmark$ $\Delta L \llcorner = I \omega \llcorner = \frac{1}{2} \times 12 \times 0.20^2 \times 8.99 = 2.2 \llcorner \text{Js} \llcorner \checkmark$	Award [2] for a bald correct answer.	2
6.	c	ii	$\omega = \llcorner \alpha \Delta t = \frac{g}{3R} \Delta t = \frac{9.81 \times 0.55}{3 \times 0.20} \Rightarrow 8.99 \llcorner \text{rads}^{-1} \llcorner \checkmark$ $E_K = \llcorner \frac{1}{2} I \omega^2 = \frac{1}{4} MR^2 \omega^2 = \frac{1}{4} \times 12 \times 0.20^2 \times 8.99^2 \Rightarrow 9.7 \llcorner \text{J} \llcorner \checkmark$	Award [2] for a bald correct answer.	2

Question			Answers	Notes	Total
7.	a		substitution of $P = \frac{nRT}{V}$ in $P_X V_X^{\frac{5}{3}} = P_Y V_Y^{\frac{5}{3}}$ ✓ manipulation to get result ✓		2
7.	b	i	$e \llcorner = 1 - \frac{T_c}{T_h} = 1 - \frac{340}{620} \llcorner = 0.45$ ✓		1
7.	b	ii	heat into gas « is along AB » and equals $Q_{in} \llcorner = \Delta U + W = 0 + 540 \llcorner = 540 \llcorner \text{«J»}$ ✓ heat out is $(1 - e)Q_{in} = (1 - 0.45) \times 540 = 297 \llcorner \text{«J»} \approx 3.0 \times 10^2 \llcorner \text{«J»}$ ✓	Award [2] for bald correct answer.	2
7.	b	iii	$T_B V_B^{\frac{2}{3}} = T_C V_C^{\frac{2}{3}} \Rightarrow \frac{V_C}{V_B} = \left( \frac{T_B}{T_C} \right)^{\frac{3}{2}}$ ✓ $\frac{V_C}{V_B} = \left( \frac{620}{340} \right)^{\frac{3}{2}} = 2.5$ ✓	Award [2] for bald correct answer.	2
7.	c	i	$\Delta S \llcorner = \frac{Q}{T} = \frac{540}{620} \llcorner = 0.87 \llcorner \text{«JK}^{-1}\llcorner \llcorner$ ✓		1
7.	c	ii	the Carnot cycle has the maximum efficiency « for heat engines operating between two given temperatures » ✓ real engine can not work at Carnot cycle/ideal cycle ✓ the second law of thermodynamics says that it is impossible to convert all the input heat into mechanical work ✓ a real engine would have additional losses due to friction <i>etc</i> ✓		2 max

Option C — Imaging

Question	Answers	Notes	Total
8.	smooth curve of correct curvature continuous at the boundary as shown ✓ wavelength must be half the one in air; judge by eye ✓		2

Question			Answers	Notes	Total
9.	a	i	F half-way between C and mirror vertex and on the principal axis ✓		1
9.	a	ii	 <p>one correct ray ✓</p> <p>second correct ray that allows the image to be located ✓</p> <p>image drawn ✓</p>		3
9.	a	iii	image will be less bright / dimmer ✓		1

(continued...)

(Question 9 continued)

Question		Answers	Notes	Total
9	b	<p>«image distance is <math>\frac{1}{v} = \frac{1}{1.5} - \frac{1}{3.8 \times 10^8}</math> ie» <math>v = 1.5</math> «m» ✓</p> <p><math>m = -\frac{1.5}{3.8 \times 10^8}</math> ✓</p> <p>image diameter is <math>\frac{1.5}{3.8 \times 10^8} \times 3.5 \times 10^6 = 1.4</math> «cm» ✓</p>	Award <b>[3]</b> for bald correct answer.	3



Question			Answers	Notes	Total
10.	a	i	$\llcorner \sin \theta_c = \frac{n_1}{n_2} \rceil \llcorner \sin \theta_c = \frac{1.276}{1.620} \checkmark$ $\theta_c = 51.97^\circ \checkmark$	<i>Award [2] for bald correct answer.</i>	2
10.	a	ii	angle of refraction at air-core boundary is $90^\circ - \theta_c$ $\llcorner = 90.00^\circ - 51.97^\circ = 38.03^\circ \rceil \checkmark$ $1.000 \times \sin \theta_{\max} = 1.620 \times \sin 38.03^\circ \checkmark$ $\theta_{\max} = 86.41^\circ \checkmark$		3
10.	a	iii	$\llcorner \theta_{\max}$ is almost $90^\circ$ which means that $\rceil$ a ray entering the core almost at any angle will be totally internally reflected/will not escape $\checkmark$		1
10.	a	iv	rays will follow very different paths in the core $\checkmark$ leading to waveguide dispersion/different arrival times/pulse overlap $\checkmark$		2
10.	b		<i>Reference to 2 of:</i> secure/encrypted transfer of data $\checkmark$ high bandwidth/volume of data transferred $\checkmark$ high quality/minimal noise in transmission $\checkmark$ free from cross talk $\checkmark$ low $\llcorner$ specific $\rceil$ attenuation $\checkmark$		2 max

Option D — Astrophysics

Question			Answers	Notes	Total
11.	a	i	$L_X = 5.0^{3.5} L_\odot = 279.5 L_\odot \checkmark$	<i>Correct working or answer to 4 sig figs required.</i>	1
11.	a	ii	$\frac{L_X}{L_\odot} = 280 = \frac{R_X^2 T_X^4}{R_\odot^2 T_\odot^4} \checkmark$ $\frac{T_X}{T_\odot} \llcorner = \sqrt[4]{\frac{280}{3.2^2}} \llcorner = 2.3 \checkmark$	<i>Award [2] for bald correct answer.</i>	2
11.	b	i	the position of the star is recorded 6 months apart <b>OR</b> the radius/diameter of the Earth orbit clearly labelled on a diagram $\checkmark$  the parallax is measured from the shift of the star relative to the background of the distant stars $\checkmark$	<i>For MP2 accept a correctly labelled parallax angle on a diagram.</i>  <i>Award MP2 only if background distance stars are mentioned.</i>	2
11.	b	ii	$d = \frac{1}{0.125} = 8.0 \llcorner \text{pc} \llcorner \checkmark$ $d = 8.0 \times 3.26 \times \frac{9.46 \times 10^{15}}{1.5 \times 10^{11}} \llcorner \text{AU} \llcorner \checkmark$ $\llcorner = 1.64 \times 10^6 \text{ AU} \llcorner$		2

(continued...)

(Question 11 continued)

Question			Answers	Notes	Total
11.	b	iii	<p><b>ALTERNATIVE 1</b></p> $\frac{b_x}{1400} = \frac{\frac{280}{4\pi(1.6 \times 10^6)^2}}{\frac{1}{4\pi(1)^2}}$ <p><b>OR</b></p> $b_x = \frac{279.5}{4\pi \times (1.6 \times 10^6 \times 1.5 \times 10^{11})^2} \text{ and } b_{\odot} = \frac{L_{\odot}}{4\pi \times (1.5 \times 10^{11})^2} \checkmark$ <p><math>b_x = 1.5 \times 10^{-7} \text{ «W m}^{-2}\text{» } \checkmark</math></p> <p><b>ALTERNATIVE 2</b></p> $\frac{b_x}{b_{\odot}} = \frac{L_x}{L_{\odot}} \times \left(\frac{d_{\odot}^2}{d_x^2}\right) \text{ OR } \frac{b_x}{b_{\odot}} = \frac{280}{(1.6 \times 10^6)^2} \text{ OR } \frac{b_x}{b_{\odot}} = 1.094 \times 10^{-10} \text{ Wm}^{-2} \checkmark$ <p><math>b_x = 1.09375 \times 10^{-10} \times 1400 \quad b_x = 1.5 \times 10^{-7} \text{ Wm}^{-2} \checkmark</math></p>	<p>Award [2] for bald correct answer.</p> <p>Allow ECF from MP1 to MP2</p>	2

(continued...)

(Question 11 continued)

Question			Answers	Notes	Total
11.	c	i		<p>Allow any region with <math>L</math> below Sun and left to the main sequence.</p>	1

11.	c	ii	<p>an electron degeneracy « pressure develops that opposes gravitation » /reference to Pauli principle ✓</p>		1
11.	c	iii	<p>thermal energy/internal energy ✓</p>		1
11.	c	iv	<p>« temperature decreases so » luminosity decreases ✓</p>		1

Question			Answers	Notes	Total
12.	a	i	« the received » wavelength is longer than that emitted ✓	<i>Allow context of Doppler redshift as well as cosmological redshift.</i>	1
12.	a	ii	$v = zc = 0.15 \times 3.0 \times 10^5 = 4.5 \times 10^4 \text{ «kms}^{-1}\text{» ✓}$ $d = \frac{v}{H_0} = \frac{4.5 \times 10^4}{72} = 625 \text{ «Mpc» ✓}$	<i>Award [2] for bald correct answer.</i> <i>Accept in other units, eg, <math>1.95 \times 10^{25} \text{m}</math>.</i>	2
12.	b	i	the radiation has a black body spectrum/it is black body radiation ✓ the radiation is highly isotropic/uniform ✓ matched the « predicted » wavelength/temperature if the Big Bang had increased/cooled by expansion ✓		2 max
12.	b	ii	peak wavelength read off graph as $(1.1 \pm 0.05) \text{ «mm» ✓}$ substitution into Wien's law to get $T = (2.5 \text{ to } 2.8) \text{ «K» ✓}$		2