

# Markscheme

November 2018

Physics

Standard level

Paper 3

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**Section A**

Question		Answers	Notes	Total
1.	a	$m^{\frac{3}{2}}$ ✓	Accept other power of tens multiples of $m^{\frac{3}{2}}$ , eg: $cm^{\frac{3}{2}}$ .	1
1.	b	<p>measured uncertainties «for one oscillation and for 20 oscillations» are the same/similar/OWTTE</p> <p><b>OR</b></p> <p>% uncertainty is less for 20 oscillations than for one ✓</p> <p>dividing «by 20» / finding mean reduces the random error ✓</p>		2

(continued...)

(Question 1 continued)

Question			Answers	Notes	Total
1.	c	i	<p>Straight line touching at least 3 points drawn across the range ✓</p>	<p><i>It is not required to extend the line to pass through the origin.</i></p>	1
1.	c	ii	<p>theory predicts proportional relation «<math>T \propto \frac{1}{d}</math>, slope = <math>Td = \frac{c}{\sqrt{g}}</math> = constant » ✓</p> <p>the graph is «straight» line <u>through the origin</u> ✓</p>		2

(continued...)



Question		Answers	Notes	Total
2.	a	to provide a constant heating rate / power <b>OR</b> to have $m$ proportional to $t$ ✓		1
2.	b	due to heat losses « $VIt$ is larger than heat into liquid» ✓ $L_v$ calculated will be larger ✓		2
2.	c	heat losses will be similar / the same for both experiments <b>OR</b> heat loss presents systematic error ✓ taking the difference cancels/eliminates the effect of these losses <b>OR</b> use a graph to eliminate the effect ✓		2

**Section B**

**Option A — Relativity**

Question			Answers	Notes	Total
3.	a		a set of rulers and clocks / set of coordinates to record the position and time of events ✓		1
3.	b	i	<p><b>ALTERNATIVE 1:</b>                      the time in frame S' is <math>t' = \frac{L}{c}</math> ✓                      but time is absolute in Galilean relativity so is the same in S ✓</p> <p><b>ALTERNATIVE 2:</b>                      In frame S, light rays travel at <math>c + v</math> ✓</p> <p>so <math>t = \frac{L}{(c+v)-v} = \frac{L}{c}</math> ✓</p>	<i>In Alternative 1, they must refer to S'</i>	2
3.	b	ii	<p><math>x = x' + vt</math> and <math>x' = L</math> ✓                      «substitution to get answer»</p>		1

Question			Answers	Notes	Total
4.	a		$\frac{0.82c + 0.40c}{1 + \frac{0.82c \times 0.40c}{c^2}} \checkmark$ $0.92c \checkmark$		2
4.	b	i	$\Delta t' = \frac{120}{0.40c} \checkmark$ $\Delta t' = 1.0 \times 10^{-6} \text{ «s» } \checkmark$		2
4.	b	ii	$\gamma = \left\langle \frac{1}{\sqrt{1 - 0.82^2}} \right\rangle = 1.747 \checkmark$ $\Delta t = \left\langle \gamma \left( \Delta t' + \frac{v \Delta x'}{c^2} \right) \right\rangle = 1.747 \times \left( 1.0 \times 10^{-6} + \frac{0.82c \times 120}{c^2} \right)$ <p><b>OR</b></p> $\Delta t = \frac{120}{1.747 \times (0.92 - 0.82)c} \checkmark$ $2.3 \times 10^{-6} \text{ «s» } \checkmark$		3



Question			Answers	Notes	Total
5.	a	i	$\gamma = \left\langle \frac{1}{\sqrt{1-0.745^2}} \right\rangle = 1.499 \checkmark$ $x' = \left\langle \gamma(x - vt) \right\rangle = 1.499 \times (1.0 - 0) \checkmark$ $\left\langle x' = 1.5 \text{ m} \right\rangle$		2
5.	a	ii	$t' = \left\langle \gamma \left( t - \frac{vx}{c^2} \right) \right\rangle = 1.499 \times \left( 0 - \frac{0.745c \times 1}{c^2} \right) \left\langle = -\frac{1.11}{c} \right\rangle$ $\left\langle ct' = -1.1 \text{ m} \right\rangle$ <p><b>OR</b></p> $\text{using spacetime interval } 0 - 1^2 = (ct')^2 - 1.5^2 \Rightarrow \left\langle ct' = -1.11 \right\rangle \checkmark$		1

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	b	i	line through event E parallel to $ct'$ axis meeting $x'$ axis and labelled P ✓	<p>The diagram shows two frames: S frame (horizontal axis <math>x</math>, vertical axis <math>ct</math>) and S' frame (rotated axes <math>x'</math> and <math>ct'</math>). A horizontal line from event E on the <math>x</math>-axis is extended to the <math>ct'</math> axis. A vertical line from event E is extended to the <math>x'</math> axis. The intersection of these two lines is labeled P.</p>	<b>1</b>

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	b	ii	point on $x'$ axis about $\frac{2}{3}$ of the way to P labelled Q ✓	<p>The diagram shows two frames: S frame (horizontal axis <math>x</math>, vertical axis <math>ct</math>) and S' frame (rotated axes <math>x'</math> and <math>ct'</math>). A point <math>E</math> is on the <math>x</math>-axis. A point <math>P</math> is on the <math>x'</math>-axis. A point <math>Q</math> is marked on the <math>x'</math>-axis between the origin and <math>P</math>. A dashed line is drawn parallel to the <math>x'</math>-axis, passing through <math>E</math>.</p>	<b>1</b>

(continued...)

(Question 5 continued)

Question			Answers	Notes	Total
5.	c	i	ends of rod must be recorded at the same time in frame $S'$ ✓ any vertical line from E crossing $x'$ , no label required ✓ right-hand end of rod intersects at R «whose co-ordinate is less than 1.0 m» ✓		<b>3</b>
5.	c	ii	0.7 m ✓		<b>1</b>

Option B — Engineering physics

Question			Answers	Notes	Total
6.	a		taking torques about the pivot $R \times 4.00 = 36.0 \times 2.5 \checkmark$ $R = 22.5 \text{ «N» } \checkmark$		2
6.	b	i	$36.0 \times 2.50 = 30.6 \times \alpha \checkmark$ $\alpha = 2.94 \text{ «rad s}^{-2}\text{» } \checkmark$		2
6.	b	ii	the equation can be applied only when the angular acceleration is constant $\checkmark$ any reasonable argument that explains torque is not constant, giving non constant acceleration $\checkmark$		2
6.	c	i	«from conservation of energy» Change in GPE = Change in rotational KE $\checkmark$ $W \frac{L}{2} = \frac{1}{2} I \omega^2 \checkmark$ $\omega = \sqrt{\frac{36.0 \times 5.00}{30.6}} \checkmark$ « $\omega = 2.4254 \text{ rad s}^{-1}$ »		3
6.	c	ii	$L = 30.6 \times 2.43 = 74.4 \text{ «Js» } \checkmark$		1

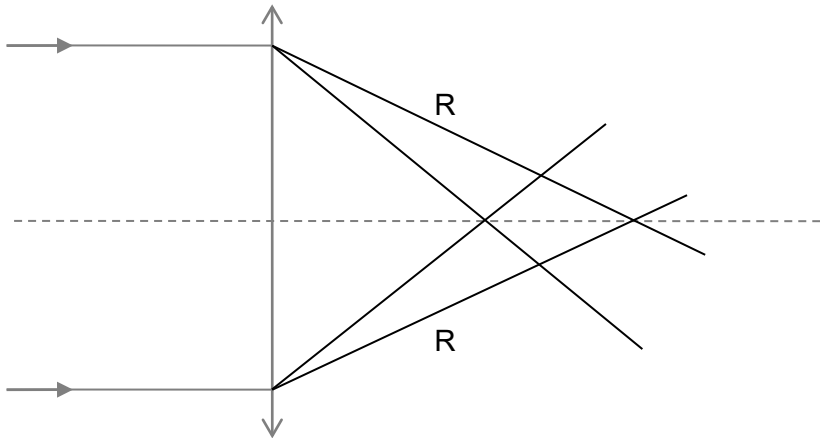
Question			Answers	Notes	Total
7.	a	i	<p><b>ALTERNATIVE 1:</b></p> $P_c = P_B = \frac{P_A V_A}{V_B} \checkmark$ $= \frac{2.8 \times 10^6 \times 1 \times 10^{-4}}{2.8 \times 10^{-4}} \llcorner = 1.00 \times 10^6 \text{ Pa} \llcorner \checkmark$ <p><b>ALTERNATIVE 2</b></p> $2.80 \times 10^6 \times 1.00^{\frac{5}{3}} = P_c \times 1.85^{\frac{5}{3}} \checkmark$ $P_c = 2.80 \times 10^6 \times \frac{1.00^{\frac{5}{3}}}{1.85^{\frac{5}{3}}} \llcorner = 1.00 \times 10^6 \text{ Pa} \llcorner \checkmark$		2
7.	a	ii	<p><b>ALTERNATIVE 1:</b></p> <p>Since <math>T_B = T_A</math> then <math>T_C = \frac{V_C T_B}{V_B} \checkmark</math></p> $= \frac{1.85 \times 385}{2.8} \llcorner = 254.4 \text{ K} \llcorner \checkmark$ <p><b>ALTERNATIVE 2:</b></p> $\frac{2.80 \times 1.00}{385} = \frac{1.00 \times 1.85}{T_c} \llcorner \text{K} \llcorner \checkmark$ $T_c = 385 \times \frac{1.00 \times 1.85}{2.80} \llcorner = 254.4 \text{ K} \llcorner \checkmark$		2

(continued...)

(Question 7 continued)

Question			Answers	Notes	Total
7.	b		work done = « $p\Delta V = 1.00 \times 10^6 \times (1.85 \times 10^{-4} - 2.80 \times 10^{-4}) = -95$ » « J » ✓ change in internal energy = « $\frac{3}{2}p\Delta V = -\frac{3}{2} \times 95 = -142.5$ » « J » ✓ Q = -95 - 142.5 ✓ « - 238 J »	Allow positive values.	3
7.	c	i	net work is $288 - 238 = 50$ « J » ✓ efficiency = « $\frac{288 - 238}{288} = 0.17$ » ✓		2
7.	c	ii	along B → C ✓		1

Option C — Imaging

Question			Answers	Notes	Total
8.	a		each incident ray shown splitting into two ✓ each pair symmetrically intersecting each other on principal axis ✓ for red, intersection further to the right ✓	 <p><i>For MP3, at least one of the rays must be labelled.</i></p>	3
8.	b	i	rays diverge after passing through lens <b>OR</b> the extension of the rays will intersect the principal axis on the side of incident rays/as if they were coming from the focal point/points in the left side/OWTTE ✓		1
8.	b	ii	by placing a diverging lens next to the converging lens <b>OR</b> make an achromatic doublet ✓		1



Question			Answers	Notes	Total
9.	a		proper construction lines ✓ image at intersection of proper construction lines ✓		2
9.	b	i	distance of intermediate image from objective is $\frac{1}{v} = \frac{1}{20} - \frac{1}{24}$ <i>ie:</i> $v = 120$ «mm» ✓ distance of intermediate image from eyepiece is $\frac{1}{u} = \frac{1}{60} - \left(-\frac{1}{240}\right)$ <i>ie:</i> $u = 48$ «mm» ✓ lens separation 168 «mm» ✓		3

(continued...)

(Question 9 continued)

Question			Answers	Notes	Total
9	b	ii	<p><b>ALTERNATIVE 1:</b></p> <p>eyepiece: <math>m = \frac{-v}{u} = \frac{240}{48} = 5</math></p> <p><b>AND</b></p> <p>objective <math>m = \frac{-v}{u} = \frac{-120}{24} = -5 \checkmark</math></p> <p>Total <math>m = -5 \times 5 = -25 \checkmark</math></p> <p><b>ALTERNATIVE 2:</b></p> <p><math>m = \left(\frac{240}{60} + 1\right) \times \left(-\frac{120}{24}\right) \checkmark</math></p> <p><math>m = -25 \checkmark</math></p>	Accept positive or negative values throughout.	2

Question			Answers	Notes	Total
10.	a	i	$\ll \sin \theta_c = \frac{n_1}{n_2} \gg n_1 = 1.52 \times \sin 84.0^\circ \checkmark$ $n_1 = 1.51 \checkmark$		2
10.	a	ii	to have a critical angle close to $90^\circ \checkmark$ so only rays parallel to the axis are transmitted $\checkmark$ to reduce waveguide/modal dispersion $\checkmark$		1 max
10.	b	i	long path is $\frac{12 \times 10^3}{\sin 84^\circ} \checkmark$ $= 12066 \ll \text{m} \gg \checkmark$ $\ll \text{so } 66 \text{ m longer} \gg$		2
10.	b	ii	speed of light in core is $\frac{3.0 \times 10^8}{1.52} = 1.97 \times 10^8 \ll \text{m s}^{-1} \gg \checkmark$ time delay is $\frac{66}{1.97 \times 10^8} = 3.35 \times 10^{-7} \ll \text{s} \gg \checkmark$		2
10.	b	iii	no, period of signal is $1 \times 10^{-8} \ll \text{s} \gg$ which is smaller than the time delay/OWTTE $\checkmark$		1

Option D — Astrophysics

Question			Answers	Notes	Total
11.	a		In cluster, stars are gravitationally bound <b>OR</b> constellation not ✓ In cluster, stars are the same/similar age <b>OR</b> in constellation not ✓ Stars in cluster are close in space/the same distance <b>OR</b> in constellation not ✓ Cluster stars appear closer in night sky than constellation ✓ Clusters originate from same gas cloud <b>OR</b> constellation does not ✓		2 max
11.	b	i	$d = 275 \text{ «pc»}$ ✓		1
11.	b	ii	because of the difficulty of measuring very small angles ✓		1

Question			Answers	Notes	Total
12.	a	i	$\lambda = \left\langle \frac{2.9 \times 10^{-3}}{4600} \right\rangle = \left\langle 630 \text{ nm} \right\rangle \checkmark$		1
12.	a	ii	black body curve shape $\checkmark$ peaked at a value from range 600 to 660 nm $\checkmark$		2
12.	a	iii	$\frac{L}{L_{\odot}} = \left( \frac{0.73 R_{\odot}}{R_{\odot}} \right)^2 \times \left( \frac{4600}{5800} \right)^4 \checkmark$ $L = 0.211 L_{\odot} \checkmark$		2
12.	b		$M = \left\langle 0.21^{\frac{1}{3.5}} M_{\odot} \right\rangle = \left\langle 0.640 M_{\odot} \right\rangle \checkmark$		1
12.	c		Obtain «line» spectrum of star $\checkmark$ Compare to «laboratory» spectra of elements $\checkmark$		2
12.	d		red giant $\checkmark$ planetary nebula $\checkmark$ white dwarf $\checkmark$		3

Question		Answers	Notes	Total
13.	a	measured redshift «z» of star ✓ use of Doppler formula <b>OR</b> $z \sim v/c$ <b>OR</b> $v = \frac{c\Delta\lambda}{\lambda}$ to find $v$ ✓		2
13.	b	use of gradient or any point on the line to obtain any expression for either $H = \frac{v}{d}$ or $t = \frac{d}{v}$ ✓ correct conversion of $d$ to m and $v$ to m/s ✓  $= 4.6 \times 10^{17}$ «s» ✓		3