

Markscheme

November 2017

Physics

Higher level

Paper 3

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Section A

Question			Answers	Notes	Total
1.	a		single smooth curve passing through all data points ✓	<i>Do not accept straight lines joining the dots Curve must touch some part of every x</i>	1
1.	b	i	tangent drawn at 80 °C ✓ gradient values separated by minimum of 20 °C ✓ 9.0×10^{-4} «kJ kg ⁻¹ K ⁻² » ✓	<i>Do not accept tangent unless “ruler” straight. Tangent line must be touching the curve drawn for MP1 to be awarded. Accept values between 7.0×10^{-4} and 10×10^{-4}. Accept working in J, giving 0.7 to 1.0</i>	3
1.	b	ii	kJ kg ⁻¹ K ⁻² ✓		1
1.	c	i	« $0.1 \times 4.198 \times 10 =$ » 4.198 «kJ» or 4198 «J» ✓	<i>Accept values between 4.19 and 4.21</i>	1
1.	c	ii	percentage uncertainty in $\Delta T = 10\%$ ✓ « $2\% + 5\% + 10\% =$ » 17% ✓ absolute uncertainty = « $0.17 \times 4.198 =$ » 0.7 «kJ» therefore 2 sig figs OR absolute uncertainty to more than 1 sig fig and consistent final answer ✓	<i>Allow fractional uncertainties in MP1 and MP2 Watch for ECF from (c)(i) Watch for ECF from MP1 Watch for ECF from MP2 Do not accept an answer without justification</i>	3

Question		Answers	Notes	Total
2.	a	« $\varepsilon = IR + Ir$ »	<i>No mark for stating data booklet equation</i>	2
		$\frac{1}{I} = \frac{R}{\varepsilon} + \frac{r}{\varepsilon} \checkmark$ identifies equation with $y = mx + c \checkmark$ « hence $m = \frac{1}{\varepsilon}$ »	<i>Do not accept working where r is ignored or $\varepsilon = IR$ is used</i> OWTTE	
2.	b	« – » $r \checkmark$	<i>Allow answer in words</i>	
3.	a	«to reduce» random errors \checkmark	OWTTE <i>Do not accept just “to find an average” or just “reduce error”</i> Ignore any mention to accuracy	1 max
		to reduce absolute uncertainty \checkmark		
3.	b	to improve precision \checkmark	OWTTE MP2 must be correctly justified	2
		as the literature value is within the range «9.7 – 11.1» \checkmark		
		hence it is accurate \checkmark		

Section B

Option A — Relativity

Question			Answers	Notes	Total
4.			light is an EM wave ✓ speed of light is independent of the source/observer ✓		2
5.	a		a co-ordinate system in which measurements «of distance and time» can be made ✓	<i>Ignore any mention to inertial reference frame.</i>	1
5.	b		closing speed = c ✓ 2 «s» ✓		2
5.	c		u and v are velocities with respect to the same frame of reference/Earth AND u' the relative velocity ✓	<i>Accept 0.4c and 0.6c for u and v</i>	1
5.	d		$\frac{-0.4 - 0.6}{1 + 0.24}$ ✓ «-» $0.81c$ ✓		2
5.	e	i	$\gamma = 1.25$ ✓ so the time is $t = 1.6$ «s» ✓		2
5.	e	ii	gamma is smaller for B ✓ so time is greater than for A ✓		2

Question		Answers	Notes	Total
6.	a	the length of an object in its rest frame OR the length of an object measured when at rest relative to the observer ✓		1
6.	b	world lines for front and back of tunnel parallel to ct axis ✓ world lines for front and back of train ✓ which are parallel to ct' axis ✓		3
6.	c	realizes that $\gamma = 1.25$ ✓ $0.6c$ ✓		2

(continued...)

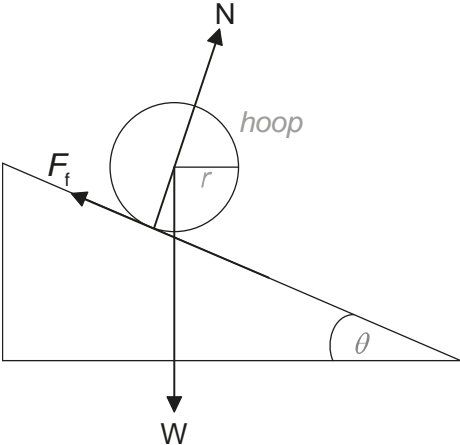
(Question 6 continued)

Question		Answers	Notes	Total
6.	d	<p>ALTERNATIVE 1</p> <p>indicates the two simultaneous events for t frame ✓</p> <p>marks on the diagram the different times «for both spacetime points» on the ct' axis «shown as $\Delta t'$ on each diagram» ✓</p> <p>ALTERNATIVE 2: (no diagram reference)</p> <p>the two events occur at different points in space ✓</p> <p>statement that the two events are not simultaneous in the t' frame ✓</p>		2

Question		Answers	Notes	Total
7.	a	Λ momentum = 900 ✓ $E_{\text{proton}} = \llcorner \sqrt{pc^2 + (mc^2)^2} = \sqrt{630^2 + 938^2} = \gg 1130 \llcorner \llcorner \text{MeV} \gg \llcorner$ ✓ $E_{\text{pion}} = \llcorner \sqrt{270^2 + 140^2} = \gg 304 \llcorner \llcorner \text{MeV} \gg \llcorner$ ✓ so rest mass of $\Lambda = \llcorner \sqrt{(1130 + 304)^2 - 900^2} = \gg 1116 \llcorner \llcorner \text{MeV c}^{-2} \gg \llcorner$ ✓		4
7.	b	$\llcorner E = \gamma mc^2 \text{ so} \gg \llcorner \gamma = \llcorner \frac{1434}{1116} = \gg 1.28 \llcorner$ ✓ to give $0.64c$ ✓		2

Question		Answers	Notes	Total
8.	a	this is gravitational time dilation OR black hole gives rise to a «strong» gravitational field ✓		2 max
		clocks in stronger field run more slowly OR the clock «signal» is subject to gravitational red-shift ✓		
		the clock is subject to gravitational red shift OR the clock has lost gravitational potential energy in moving close to the black hole ✓		
8.	b	ALTERNATIVE 1 (10 ks is in observer frame):		2
		$\Delta t' = 10000 \sqrt{1 - \frac{6.0 \times 10^5}{7.0 \times 10^8}} \quad \checkmark$	Allow 9996 Allow ECF if 10 is used instead of 10000	
		9995.7 so 9995 «ticks» ✓		
		ALTERNATIVE 2 (10 ks is in rocket frame):		
$\Delta t = \frac{10000}{\sqrt{1 - \frac{6.0 \times 10^5}{7.0 \times 10^8}}} \quad \checkmark$	Allow ECF if 10 is used instead of 10000			
		10004 «ticks» ✓		

Option B — Engineering physics

Question		Answers	Notes	Total
9.	a	weight, normal reaction and friction in correct direction ✓ correct points of application for at least two correct forces ✓	<p><i>Labelled on diagram.</i></p>  <p><i>Allow different wording and symbols</i> <i>Ignore relative lengths</i></p>	2

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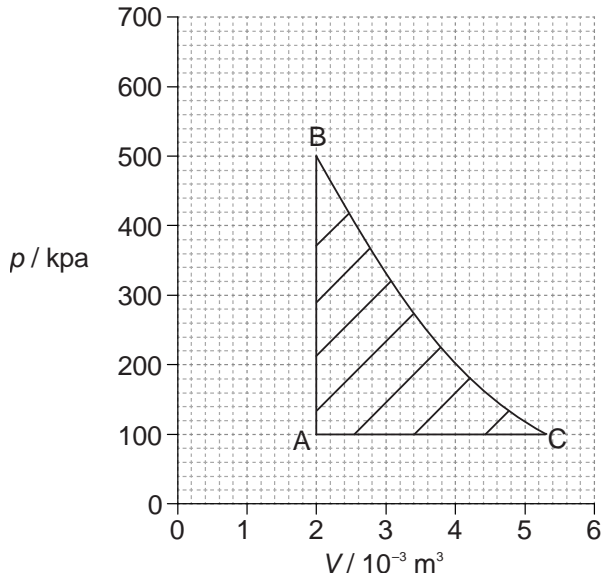
(Question 9 continued)

Question		Answers	Notes	Total
9.	b	<p>ALTERNATIVE 1</p> $ma = mg \sin \theta - F_f \checkmark$ $I\alpha = F_f \times r$ <p>OR</p> $mr\alpha = F_f \checkmark$ $\alpha = \frac{a}{r} \checkmark$ $ma = mg \sin \theta - mr \frac{a}{r} \rightarrow 2a = g \sin \theta \checkmark$ <p>ALTERNATIVE 2</p> $mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 \checkmark$ <p>substituting $\omega = \frac{v}{r}$ « giving $v = \sqrt{gh}$ » \checkmark</p> <p>correct use of a kinematic equation \checkmark</p> <p>use of trigonometry to relate displacement and height « $s = h \sin \theta$ » \checkmark</p>	<p>Can be in any order</p> <p>Accept answers using the parallel axis theorem (with $I = 2mr^2$) only if clear and explicit mention that the only torque is from the weight</p> <p>For alternative 2, MP3 and MP4 can only be awarded if the previous marking points are present</p>	4

(continued...)

(Question 9 continued)

Question		Answers	Notes	Total
9.	c	1.68 «ms ⁻² » ✓		1
9.	d	<p>ALTERNATIVE 1</p> $N = mg \cos \theta \quad \checkmark$ $F_f \leq \mu mg \cos \theta \quad \checkmark$ <p>ALTERNATIVE 2</p> $F_f = ma \text{ «from 9(b)» } \quad \checkmark$ <p>so $F_f = \frac{mg \sin \theta}{2} \quad \checkmark$</p>		2
9.	e	$F_f = \mu mg \cos \theta \quad \checkmark$ $\frac{mg \sin \theta}{2} = mg \sin \theta - \mu mg \cos \theta$ <p>OR</p> $mg \frac{\sin \theta}{2} = \mu mg \cos \theta \quad \checkmark$ <p>algebraic manipulation to reach $\tan \theta = 2\mu \quad \checkmark$</p>		3

Question		Answers	Notes	Total
10.	a	$500\,000 \times (2 \times 10^{-3})^{\frac{5}{3}} = 100\,000 \times V^{\frac{5}{3}} \checkmark$ $V = 5.25 \times 10^{-3} \text{ « m}^3 \text{ » } \checkmark$	<i>Look carefully for correct use of $pV^\gamma = \text{constant}$</i>	2
10.	b	correct vertical and horizontal lines \checkmark curve between B and C \checkmark	<i>Allow tolerance ± 1 square for A, B and C</i> <i>Allow ECF for MP2</i> <i>Points do not need to be labelled for marking points to be awarded</i> 	2
10.	c	use of $PV = nRT$ OR use of $\frac{P}{T} = \text{constant} \checkmark$ $T = \text{« } 5 \times 290 = \text{» } 1450 \text{ « K » } \checkmark$		2

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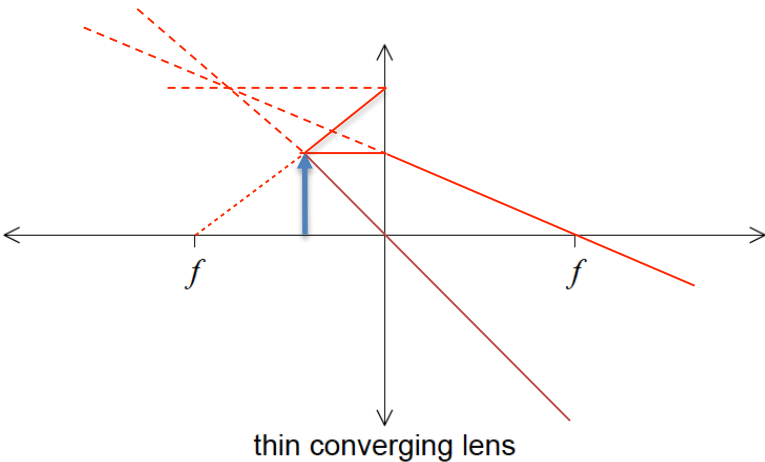
(Question 10 continued)

Question		Answers	Notes	Total
10.	d	area enclosed ✓ work is done by the gas during expansion OR work is done on the gas during compression ✓ the area under the expansion is greater than the area under the compression ✓		2 max

Question			Answers	Notes	Total
11.	a	i	density = 785 « kgm ⁻³ » ✓ $\left\langle \frac{4}{3}\pi(0.03)^3 \times 785 \times 9.8 \Rightarrow 0.87 \text{ « N} \right\rangle$ ✓	Accept answer in the range 784 to 786	2
11.	a	ii	$\frac{0.87}{\frac{4}{3}\pi(0.03)^3 \times 1080 \times 9.8}$ OR $\frac{0.87}{1080 \times 1.13 \times 10^{-4}}$ OR $\frac{785}{1080} \checkmark$ 0.727 or 73% ✓	Allow ECF from (a)(i)	2
11.	b		use of drag force to obtain $\frac{4}{3}\pi r^3 \times 0.04 \times g = 6 \times \pi \times 0.0011 \times r \times v$ ✓ $v = 0.071 \text{ « ms}^{-1} \text{ »}$ ✓		2

Question		Answers	Notes	Total
12.	a	<p>ALTERNATIVE 1</p> <p>the time between undulations is $\frac{3}{5.6} = 0.536$ « s » ✓</p> <p>$f = \frac{1}{0.536} = 1.87$ « Hz » ✓</p> <p>«frequencies match» <u>resonance</u> occurs so amplitude of vibration becomes greater ✓</p> <p>ALTERNATIVE 2</p> <p>$f = \frac{v}{\lambda} = \frac{5.6}{3}$ ✓</p> <p>$f = 1.87$ « Hz » ✓</p> <p>«frequencies match» <u>resonance</u> occurs so amplitude of vibration becomes greater ✓</p>	<p><i>Must see mention of “resonance” for MP3</i></p> <p><i>Must see mention of “resonance” for MP3</i></p>	3
12.	b	«to increase damping» reduce Q ✓		1

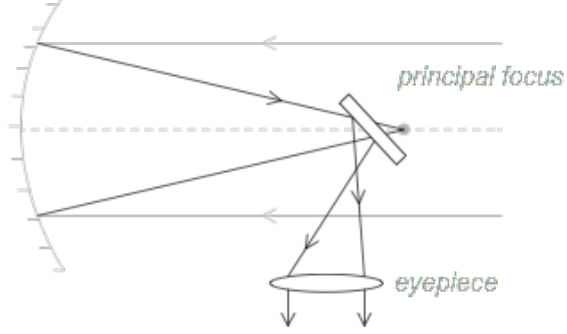
Option C — Imaging

Question			Answers	Notes	Total
13.	a	i	with object placed between lens and focus ✓ two rays correctly drawn ✓  <p style="text-align: center;">thin converging lens</p>	<i>Backwards extrapolation of refracted rays can be dashes or solid lines</i> <i>Do not penalize extrapolated rays which would meet beyond the edge of page</i> <i>Image need not be shown</i>	2
13.	a	ii	«just less than» the focal length <i>or</i> f ✓		1
13.	b	i	$\frac{1}{10} + \frac{1}{v} = \frac{1}{2}$ ✓ $v = 2.5$ «m» ✓		2
13.	b	ii	real, smaller, inverted ✓	<i>All three required — OWTTE</i>	1

(continued...)

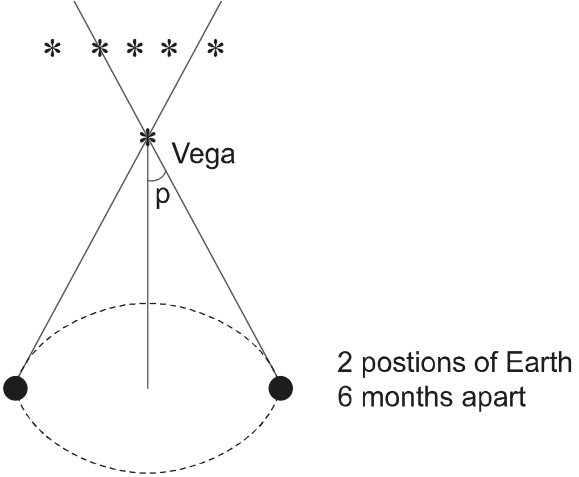
(Question 13 continued)

Question			Answers	Notes	Total
13.	c	i	two correct rays coming from Q ✓ locating Q' below the main axis AND beyond f to the right of lens AND at intercept of rays ✓	Allow any two of the three conventional rays. 	2
13.	c	ii	$\frac{h}{h'} = \frac{-x}{x'}$ OR 2.5 or 10×0.3 «m» ✓ «-» 0.075 «m» ✓		2
13.	c	iii	towards Q ✓	Accept move to the left	1
13.	c	iv	spherical aberration ✓ top of the shape «R» is far from axis so no paraxial rays ✓	For MP2 accept rays far from the centre converge at different points	2

Question		Answers	Notes	Total
14.	a	plane mirror to the left of principal focus ✓ two rays which would go through the principal focus ✓ two rays cross between mirror and eyepiece AND passing through the eyepiece ✓	eg: <i>parabolic reflector</i> 	3
14.	b	$\frac{2 \times 1737}{363300} = \frac{0.0120}{f} \checkmark$ $f = 1.25 \text{ «m» } \checkmark$	Allow ECF if factor of 2 omitted answer is 2.5 m	2
14.	c	$M = \frac{1.25}{0.05} = 25 \checkmark$		1
14.	d	parabolic/convex mirror instead of flat mirror ✓ eyepiece/image axis same as mirror ✓		1 max

Question		Answers	Notes	Total
15.	a	realization that θ min is the critical angle ✓		3
		$\theta = \text{«} \sin^{-1} \frac{1.48}{1.5} \text{»} \Rightarrow 80.6 \text{ «}^\circ \text{»} \checkmark$	Accept 1.4 rad Accept 0.16 rad	
		$\beta = \text{«} 90 - 80.6 \text{»} \Rightarrow 9.4 \text{ «}^\circ \text{»} \checkmark$		
15.	b	because the critical angle is nearly 90° ✓		3
		then only rays that are «almost» parallel to the fibre pass down it ✓		
		so pulse broadening is reduced ✓	OWTTE	
16.	a	evidence of finding the gradient ✓		2
		$\mu = \text{«} - \text{gradient} \text{»} \Rightarrow 59.9 \text{ «} \text{cm}^{-1} \text{»} \checkmark$		
16.	b	$I = \frac{I_0}{25000} \checkmark$		2
		$\text{«} \ln 25000 = \mu x \text{»} \Rightarrow x = 0.17 \text{ «} \text{cm} \text{» or } 1.7 \text{ «} \text{mm} \text{»} \checkmark$		

Option D — Astrophysics

Question			Answers	Notes	Total
17.	a	i	«nuclear» fusion ✓	<i>Do not accept “burning”</i>	1
17.	a	ii	brightness depends on luminosity and distance/ $b = \frac{L}{4\pi d^2}$ ✓ Vega is much further away but has a larger luminosity ✓	<i>Accept answer in terms of Jupiter for MP2</i>	2
17.	b	i	a group of stars forming a pattern on the sky AND not necessarily close in distance to each other ✓	<i>OWTTE</i>	1
17.	b	ii	the star’s position is observed at two times, six months apart, relative to distant stars ✓ parallax angle is half the angle of shift ✓  <p>2 positions of Earth 6 months apart</p>	<i>Answers may be given in diagram form, so allow the marking points if clearly drawn</i>	2

(continued...)

(Question 17 continued)

Question			Answers	Notes	Total
17.	b	iii	$\frac{1}{0.13} = 7.7 \text{ «pc» } \checkmark$ so $d = 7.7 \times 3.26 = 25.1 \text{ «ly» } \checkmark$		2

18.	a		two stars orbiting a common centre «of mass» \checkmark	<i>Do not accept "stars which orbit each other"</i>	1
18.	b		$\text{« } \lambda \times T = 2.9 \times 10^{-3} \text{ »}$ $T = \frac{2.9 \times 10^{-3}}{115 \times 10^{-9}} = 25217 \text{ «K» } \checkmark$		1
18.	c		use of the mass-luminosity relationship or $\left(\frac{M_{\text{Sirius}}}{M_{\text{Sun}}}\right)^{3.5} = 1 \checkmark$ if Sirius B is on the main sequence then $\left(\frac{L_{\text{SiriusB}}}{L_{\text{Sun}}}\right) = 1 \text{ «which it is not» } \checkmark$	<i>Conclusion is given, justification must be stated</i> <i>Allow reverse argument beginning with luminosity</i>	2

(continued...)

(Question 18 continued)

Question			Answers	Notes	Total
18.	d	i	$\left(\frac{L_{\text{SiriusB}}}{L_{\text{Sun}}}\right) = 0.025 \checkmark$ $r_{\text{Sirius}} = \sqrt[3]{0.025 \times \left(\frac{5800}{25000}\right)^4} \approx 0.0085 r_{\text{Sun}} \checkmark$		2
18.	d	ii	white dwarf ✓		1
18.	e	i	Sirius A on the main sequence above and to the left of the Sun AND Sirius B on white dwarf area as shown ✓	<p><i>Both positions must be labelled</i></p> <p><i>Allow the position anywhere within the limits shown.</i></p>	1

(continued...)

(Question 18 continued)

Question			Answers	Notes	Total
18.	e	ii	arrow goes up and right and then loops to white dwarf area ✓		1

19.	a		galaxies are moving away OR space «between galaxies» is expanding ✓	<i>Do not accept just red-shift</i>	1
19.	b		« $\frac{\Delta\lambda}{\lambda} = \frac{1.04}{115} = \frac{v}{c}$ » ✓ 0.009c ✓	<i>Accept 2.7×10^6 «ms⁻¹»</i> <i>Award [0] if 116 is used for λ</i>	2

Question		Answers	Notes	Total
20.	a	interstellar gas/dust «from earlier supernova» ✓ gravitational attraction between particles ✓ if the mass is greater than the Jean's mass/ M_j the interstellar gas coalesces ✓ as gas collapses temperature increases leading to nuclear fusion ✓	<i>MP3 can be expressed in terms of potential and kinetic energy</i>	4
20.	b	fluctuations in CMB due to differences in temperature/mass/density ✓ during the inflationary period/epoch/early universe ✓ leading to the formation of galaxies/stars/structures ✓ gravitational interaction between galaxies can lead to collision ✓		3 max

(continued...)

(Question 20 continued)

Question		Answers	Notes	Total
20.	c	<p>ALTERNATIVE 1</p> <p>kinetic energy of galaxy $\frac{1}{2}mv^2 = \frac{1}{2}mH^2r^2$ «uses Hubble's law» ✓</p> <p>potential energy = $\frac{GMm}{r} = G\frac{4}{3}\pi r^3\rho\frac{m}{r}$ «introduces density» ✓</p> <p>KE = PE to get expression for critical ρ ✓</p> <p>ALTERNATIVE 2</p> <p>escape velocity of distant galaxy $v = \sqrt{\frac{2GM}{r}}$ ✓</p> <p>where $H_0r = \sqrt{\frac{2GM}{r}}$ ✓</p> <p>substitutes $M = \frac{4}{3}\pi r^3\rho$ to get result ✓</p>		3