Markscheme

May 2017

Physics

Standard level

Paper 3

17 pages

Section A

Question			Answers	Notes	Total
1	a		in order to keep the temperature constant ✓ in order to allow the system to reach thermal equilibrium with the surroundings/OWTTE ✓	*Accept answers in terms of pressure or volume changes only if clearly related to reaching thermal equilibrium with the surroundings.*	**1 max**
	b		recognizes b as gradient ✓ calculates b in range 4.7×10^4 to 5.3×10^4 ✓ Pa m ✓	*Award* ***[2 max]*** *if POT error in b.* *Allow any correct SI unit, eg* $kg\ s^{-2}$.	**3**
	c		$V\propto H$ thus ideal gas law gives $p\propto\frac{1}{H}$ ✓ **so** graph **should be** «a straight line through origin,» as **observed** ✓		**2**
	d		$n=\frac{bA}{RT}$ ***OR*** correct substitution of one point from the graph ✓ $n=\frac{5\times10^4\times1.3\times10^{-3}}{8.31\times300}=0.026\approx0.03$ ✓	*Answer must be to 1 or 2 SF.* *Allow ECF from (b).*	**2**

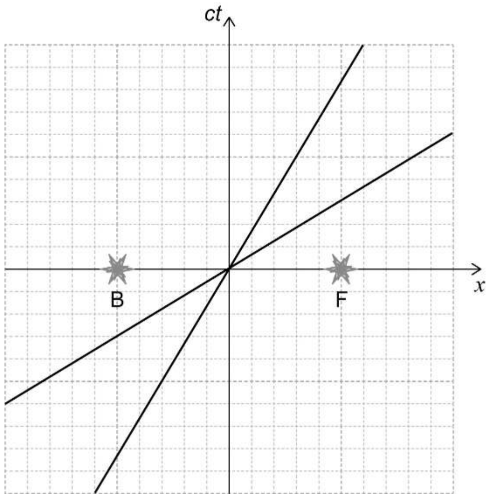
Question			Answers	Notes	Total
1	e		very large $\frac{1}{H}$ means very small volumes / very high pressures ✓ at very small volumes the ideal gas does not apply ***OR*** at very small volumes some of the assumptions of the kinetic theory of gases do not hold ✓		**2**

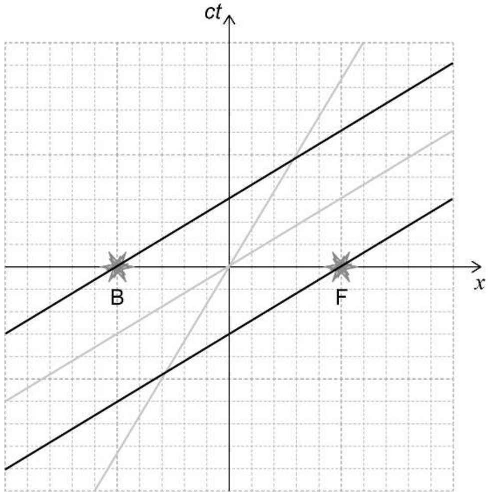
Question			Answers	Notes	Total
2	**a**		$g = \frac{4\pi^2 \times 1.60}{2.540^2} = 9.7907$ ✓ $\Delta g = g(\frac{\Delta L}{L} + 2\times\frac{\Delta T}{T}) =$ «$9.7907 \times \left(\frac{0.01}{1.60} + 2\times\frac{0.005}{2.540}\right) =$» 0.0997 ***OR*** 1.0 % ✓ hence $g = (9.8 \pm 0.1)$ «m s^{-2}» ***OR*** $\Delta g = 0.1$ «m s^{-2}» ✓	*For the first marking point answer must be given to at least 2 dp.* *Accept calculations based on* $g_{max} = 9.8908$ $g_{min} = 9.6913$. $\frac{g_{max} - g_{min}}{2} = 0.099 \approx 0.1$	**3**
	b		$\frac{T}{T_0} = 1.01$ ✓ $\theta_{max} = 22$ «°» ✓	*Accept answer from interval 20 to 24.*	**2**

Section B

Option A — Relativity

Question			Answers	Notes	Total
3	a		a set of coordinate axes and clocks used to measure the position «in space/time of an object at a particular time» ***OR*** a coordinate system to measure x,y,z,and t / OWTTE ✓		**1**
	b	i	magnetic only ✓ there is a current but no «net» charge «in the wire» ✓		**2**
	b	ii	electric only ✓ *P* is **stationary** so experiences no magnetic force ✓ relativistic contraction will increase the density of protons in the wire ✓		**3**

Question			Answers	Notes	Total
4	a		Δt_P / observer sitting in the train ✓		1
	b		$\gamma = \frac{\Delta t_Q}{\Delta t_P} =$ «$= \frac{1}{0.30}$» $= 3.3$ ✓ to give $v = 0.95c$ ✓		2
	c		$\gamma = 1.25$ ✓ «length of train according Q» = 125/1.25 ✓ «giving 100 m»		2
	d	i	 axes drawn with correct gradients of $\frac{5}{3}$ for ct' and 0.6 for x' ✓	*Award **[1]** for one gradient correct **and** another approximately correct.*	1

4	**d**	**ii**	 lines parallel to the x' axis and passing through B and F ✓ intersections on the ct' axis at B′ and F′ shown ✓ light at the front of the train must have been turned on first ✓		**3**
	d	**iii**	$\Delta t' = 1.25 \times \frac{0.6 \times 100}{3 \times 10^{8}}$ ✓ «2.5×10^{-7} s»	*Allow ECF for gamma from (c).*	**1**
	d	**iv**	according to P: $\left(3 \times 10^{8} \times 2.5 \times 10^{-7}\right)^{2} - 125^{2} =$ «–» 10000 ✓ according to Q: $\left(3 \times 10^{8} \times 0\right)^{2} - 100^{2} =$ «–» 10000 ✓		**2**
	e		$u' = \frac{-0.7 - 0.6}{1 + 0.7 \times 0.6}$ **c** ✓ $=$ «–» 0.92c ✓		**2**

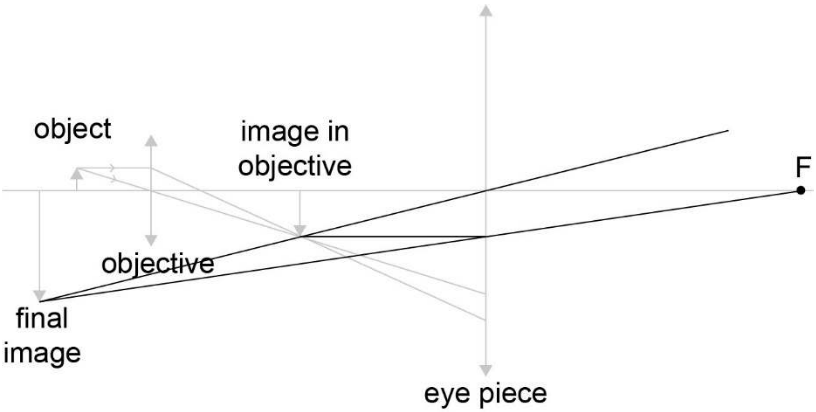
Option B — Engineering physics

Question			Answers	Notes	Total
5	a	i	$\frac{M}{3}vR$ ✓		1
	a	ii	*evidence of use of:* $L = I\omega = (MR^2 + \frac{M}{3}R^2)\omega$ ✓		1
	a	iii	evidence of use of conservation of angular momentum, $\frac{MvR}{3} = \frac{4}{3}MR^2\omega$ ✓ «rearranging to get $\omega = \frac{v}{4R}$»		1
	a	iv	initial KE $= \frac{Mv^2}{6}$ ✓ final KE $= \frac{Mv^2}{24}$ ✓ energy loss $= \frac{Mv^2}{8}$ ✓		3

Question			Answers	Notes	Total
5	b	i	α «$= \frac{3}{4}\frac{\Gamma}{MR^2}$» $= \frac{3}{4}\frac{0.01}{0.7\times 0.5^2}$ ✓ «to give $\alpha = 0.04286\ \text{rad s}^{-2}$»	*Working **OR** answer to at least 3 SF must be shown*	1
	b	ii	$\theta = \frac{\omega_i^2}{2\alpha}$ «from $\omega_f^2 = \omega_i^2 + 2\alpha\theta$» ✓ θ «$= \frac{v^2}{32R^2\alpha} = \frac{2.1^2}{32\times 0.5^2\times 0.043}$» $= 12.8$ ***OR*** 12.9 «rad» ✓ number of rotations «$= \frac{12.9}{2\pi}$» $= 2.0$ revolutions ✓		3

Question			Answers	Notes	Total
6	a		«a process in which there is» no thermal energy transferred between the system and the surroundings ✓		**1**
	b		A to B ***AND*** C to D ✓		**1**
	c	i	$T=\frac{PV}{nR}$ ✓ $T\left(=\frac{512\times10^{3}\times1.20\times10^{-3}}{0.150\times8.31}\right)\approx 493$ «K» ✓	*The first mark is for rearranging.*	**2**
	c	ii	$P_B=\frac{P_aV_A}{V_B}$ ✓ $P_B=267\text{ kPa}$ ✓	*The first mark is for rearranging.*	**2**
	d	i	«B to C adiabatic so» $P_BV_B^{\frac{5}{3}}=P_CV_C^{\frac{5}{3}}$ ***AND*** $P_CV_C=nRT_C$ «combining to get result» ✓	*It is essential to see these 2 relations to award the mark.*	**1**
	d	ii	$T_C=\left(\frac{P_BV_B^{\frac{5}{3}}}{nR}\right)V_C^{\frac{-2}{3}}$ ✓ $T_C=$ «$\left(\frac{267\times10^{3}\times(2.30\times10^{-3})^{\frac{5}{3}}}{0.150\times8.31}\right)(2.90\times10^{-3})^{\frac{-2}{3}}$» $=422$ «K» ✓		**2**
	e		the isothermal processes would have to be conducted very slowly / OWTTE ✓		**1**

Option C — Imaging

Question			Answers	Notes	Total
7	a	i	an image formed by extensions of rays, not rays themselves ***OR*** an image that cannot be projected on a screen ✓		**1**
	a	ii	$\frac{1}{v}=\frac{1}{3.0}-\frac{1}{4.0}$ ✓ «$v=12$ cm»		**1**
	a	iii	$u=18-12=6.0$ «cm» ✓ $v=-24$ «cm» ✓ «$\frac{1}{f}=\frac{1}{6.0}-\frac{1}{24}\Rightarrow$» $f=8.0$ «cm» ✓	*Award* ***[2 max]*** *for answer of 4.8 cm.* *Minus sign required for MP2.*	**3**
	a	iv	line parallel to principal axis from intermediate image meeting eyepiece lens at P ✓ line from arrow of final image to P intersecting principal axis at F ✓ 		**2**

Question			Answers	Notes	Total
7	b	i	object is far away so intermediate image forms at focal plane of objective ✓ for final image at infinity object must also be at focal point of eyepiece ✓ «hence 87.5 cm»	*No mark for simple addition of focal lengths without explanation.*	**2**
	b	ii	angular magnification $=\frac{85.0}{2.50}=34$ ✓ angular diameter $34\times 7.8\times 10^{-3}=0.2652\approx 0.27$ «rad» ✓		**2**
	c		chromatic aberration is the dependence of refractive index on wavelength ✓ but mirrors rely on reflection ***OR*** mirrors do not involve refraction ✓ «so do not suffer chromatic aberration»		**2**

Question			Answers	Notes	Total
8	a	i	longer distance without amplification ✓ signal cannot easily be interfered with ✓ less noise ✓ no cross talk ✓ higher data transfer rate ✓		**2 max**
	a	ii	infrared radiation suffers lower attenuation ✓		**1**
	b		$\text{loss} = 10\log\frac{2.4}{15}$ «$= -7.959$ dB» ✓ $\text{length} =$ «$\frac{7.959}{0.30} =$»$26.53 \approx 27$ «km» ✓		**2**
	c		a thin core means that rays follow essentially the same path / OWTTE ✓ and so waveguide (modal) dispersion is minimal / OWTTE ✓		**2**

Option D — Astrophysics

Question			Answers	Notes	Total
9	a	i	stars fusing hydrogen «into helium» ✓		**1**
	a	ii	$M = M_{\odot}(4\times10^{5})^{\frac{1}{3.5}} = 39.86M_{\odot}$ ✓ «$M \approx 40M_{\odot}$»	*Accept reverse working.*	**1**
	a	iii	$4\times10^{5} = 13^{2}\times\frac{T^{4}}{6000^{4}}$ ✓ $T \approx 42000$ «K» ✓	*Accept use of substituted values into $L = \sigma 4\pi R^{2}T^{4}$.* *Award **[2]** for a bald correct answer.*	**2**
	a	iv	$4\times10^{-11} = 4\times10^{5}\times\frac{1\text{AU}^{2}}{d^{2}}$ ✓ $d = 1\times10^{8}$ «AU» ✓	*Accept use of correct values into $b = \frac{L}{4\pi d^{2}}$.*	**2**
	b		the gravitation «pressure» is balanced by radiation «pressure» ✓ that is created by the production of energy due to fusion in the core / OWTTE ✓	*Award **[1 max]** if pressure and force is inappropriately mixed in the answer.* *Award **[1 max]** for unexplained "hydrostatic equilibrium is reached".*	**2**

Question			Answers	Notes	Total
9	c		the Sun will evolve to become a red giant whereas Theta 1 Orionis will become a red super giant ✓ the Sun will explode as a planetary nebula whereas Theta 1 Orionis will explode as a supernova ✓ the Sun will end up as a white dwarf whereas Theta 1 Orionis as a neutron star/black hole ✓		3

Question			Answers	Notes	Total
10	**a**		black body radiation / 3 K ✓ highly isotropic / uniform throughout ***OR*** filling the universe ✓	*Do not accept: CMB provides evidence for the Big Bang model.*	**2**
	a	**ii**	«$\lambda = \frac{2.9\times10^{-3}}{2.8}$» ≈ 1.0 «mm» ✓		**1**
	b		the universe is **expanding** and so the wavelength of the CMB in the past was much smaller ✓ indicating a very high temperature at the beginning ✓		**2**
	c	**i**	«$z=\frac{v}{c}\Rightarrow$» $v = 0.16\times3\times10^{5}$ «$= 0.48\times10^{5}\ \text{km s}^{-1}$» ✓ «$d=\frac{v}{H_0}\Rightarrow v=\frac{0.48\times10^{5}}{68}=706$» ≈ 710 «Mpc» ✓	*Award **[1 max]** for POT error.*	**2**
	c	**ii**	$z=\frac{R}{R_0}-1\Rightarrow\frac{R}{R_0}=1.16$ ✓ $\frac{R_0}{R}=0.86$ ✓		**2**