M17/4/PHYSI/SP3/ENG/TZ2/XX/M

Diploma Programme
Programme du diplôme
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Physics

Standard level

Paper 3

18 pages

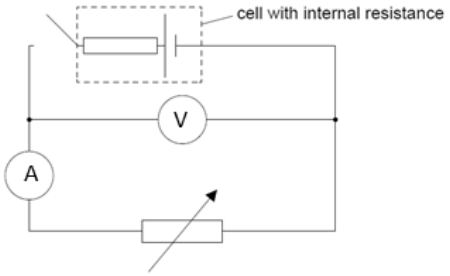
Section A

Question			Answers	Notes	Total
1.	**a**		it is not possible to draw a straight line through all the error bars ***OR*** the line of best-fit is curved/not a straight line ✓	*Treat as neutral any reference to the origin.* *Allow "linear" for "straight line".*	**1**
	b	**i**	$d = 0.35 \pm 0.01$ ***AND*** $\Delta d = 0.05 \pm 0.01$ **«**cm**»** ✓ **«**$\frac{\Delta d}{d} = \frac{0.05}{0.35}$**»** $= 0.14$ ***OR*** $\frac{1}{7}$ ***or*** 14 % ***or*** 0.1 ✓	*Allow final answers in the range of 0.11 to 0.18.* *Allow **[1 max]** for 0.03 to 0.04 if* $\lambda = 5 \times 10^6$ *m is used.*	**2**
	b	**ii**	28 to 30 % ✓	*Allow ECF from (b)(i), but only accept answer as a %*	**1**
	c	**i**	*a*: m^2 ✓ *b*: m ✓	*Allow answers in words*	**2**

(continued…)

(Question 1 continued)

Question			Answers	Notes	Total
	c	ii	***ALTERNATIVE 1*** – if graph on page 4 is used $d^2 = 0.040 \times 10^{-4}$ **«**m^2**»** ✓ $d = 0.20 \times 10^{-2}$ **«**m**»** ✓ ***ALTERNATIVE 2*** – if graph on page 2 is used any evidence that d intercept has been determined ✓ $d = 0.20 \pm 0.05$ **«**cm**»** ✓	*For MP1 accept answers in range of 0.020 to 0.060* **«***cm^2***»** *if they fail to use given value of "a".* *For MP2 accept answers in range 0.14 to 0.25* **«***cm***»** *.*	**2**

Question			Answers	Notes	Total
2.	a		correct labelling of both instruments ✓		1
	b		$V = E - Ir$ ✓	*For MP1 – do not award if only* $R = \frac{V}{I}$ *is used.*	3
			large triangle to find gradient and correct read-offs from the line ***OR*** use of intercept $E = 1.5\,\text{V}$ and another correct data point ✓	*For MP2 points at least 1A apart must be used.*	
			internal resistance $= 0.60\,\Omega$ ✓	*For MP3 accept final answers in the range of* $0.55\,\Omega$ *to* $0.65\,\Omega$.	

(continued…)

(Question 2 continued)

Question			Answers	Notes	Total
	c	**i**	a non-zero reading when a zero reading is expected/no current is flowing ***OR*** a calibration error ✓	*OWTTE* *Do not accept just "systematic error".*	**1**
	c	**ii**	the error causes **«**all**»** measurements to be high/different/incorrect ✓ effect on calculations/gradient will cancel out ***OR*** effect is that value for *r* is unchanged ✓	*Award **[1 max]** for statement of "no effect" without valid argument.* *OWTTE*	**2**

Section B

Option A — Relativity

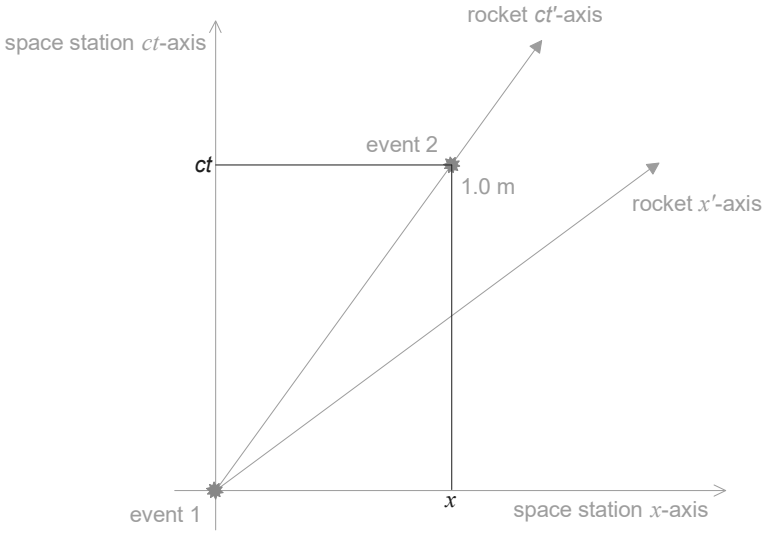
Question			Answers	Notes	Total
3.	**a**		the speed of light is a universal constant/invariant ***OR*** *c* does not depend on velocity of source/observer ✓ electric and magnetic fields/forces unified/frame of reference dependant ✓		**1 max**
	b		observer X will measure zero «magnetic or electric» force ✓ observer Y must measure both electric and magnetic forces ✓ which must be equal and opposite so that observer Y also measures zero force ✓	*Allow **[2 max]** for a comment that both X and Y measure zero resultant force even if no valid explanation is given.*	**3**

Question			Answers	Notes	Total
4.			***ALTERNATIVE 1*** *— for answers in terms of time* overall idea that more muons are detected at the ground than expected «without time dilation» ✓ « Earth frame transit time $= \frac{2000}{0.98c}$ » $= 6.8$ « μs » ✓ « Earth frame dilation of proper half-life $= 2.2\ \mu s \times 5$ » $= 11$ « μs » ***OR*** « muon's proper transit time $= \frac{6.8\ \mu s}{5}$ » $= 1.4$ « μs » ✓ ***ALTERNATIVE 2*** *– for answers in terms of distance* overall idea that more muons are detected at the ground than expected «without time dilation» ✓ « distance muons can travel in a proper lifetime $= 2.2\ \mu s \times 0.98c$ » $= 650$ « m » ✓ « Earth frame lifetime distance due to time dilation $= 650\ m \times 5$ » $= 3250$ « m » ***OR*** « muon frame distance travelled $= \frac{2000}{5}$ » $= 400$ « m » ✓	*Accept answers from **one** of the alternatives.*	**3**

Question			Answers	Notes	Total
5.	**a**	**i**	the gamma factor is $\frac{5}{3}$ ***or*** 1.67 ✓ $L = \frac{450}{\frac{5}{3}} = 270$ **«**m**»** ✓	*Allow ECF from MP1 to MP2.*	**2**
	a	**ii**	$u' = \text{«}\frac{u-v}{1-\frac{uv}{c^2}} = \text{»}\frac{0.20c-0.80c}{1-0.20\times0.80}$ ***OR*** $0.2c = \frac{0.80c+u'}{1+0.80u'}$ ✓ $u' = \text{«}-\text{»}\,0.71c$ ✓	*Check signs and values carefully.*	**2**
	b	**i**	$\Delta t' = \text{«}\gamma\left(\Delta t - \frac{v\Delta x}{c^2}\right) = \text{»}\frac{5}{3}\times\left(0 - \frac{(0.80c\times9000)}{c^2}\right)$ ✓ $\Delta t' = \text{«}-\text{»}4.0\times10^{-5}$ **«**s**»** ✓	*Allow ECF for use of wrong γ from (a)(i).*	**2**
	b	**ii**	lamp 2 turns on first ✓	*Ignore any explanation*	**1**

(continued…)

(Question 5 continued)

Question			Answers	Notes	Total
	c	i	x coordinate as shown ✓ *ct* coordinate as shown ✓  	*Labels must be clear and unambiguous.* *Construction lines are optional.*	**2**
	c	ii	«in any other frame» *ct* is greater ✓ the interval $ct' = 1.0$ «m» is proper time ***OR*** *ct* is a dilated time ***OR*** $ct = \gamma ct'$ «$= \gamma$» ✓	*MP1 is a statement* *MP2 is an explanation*	**2**
	c	iii	use of $c^2t^2 - x^2 = c^2t'^2 - x'^2$ ✓ $c^2t^2 - x^2 = 1^2 - 0^2 = 1$ «m^2» ✓	*for MP1 equation must be used.* *Award **[2]** for correct answer that first finds x (1.33 m) and ct (1.66 m)*	**2**

Option B — Engineering physics

Question			Answers	Notes	Total
6.	**a**	**i**	zero ✓		**1**
	a	**ii**	the torque of each force is $9.60\times10^{3}\times6.0=5.76\times10^{4}$ **«**Nm**»** ✓ so the net torque is $2\times5.76\times10^{4}=1.15\times10^{5}$ **«**Nm**»** ✓	*Allow a one-step solution.*	**2**
	b		the angular acceleration is given by $\frac{1.15\times10^{5}}{1.44\times10^{4}}$ **«**$=8.0\,\text{s}^{-2}$**»** ✓ $\omega=$ **«**$\alpha t=8.0\times2.00=$**»** 16 **«**s^{-1}**»** ✓		**2**
	c	**i**	$1.44\times10^{4}\times16.0=(1.44\times10^{4}+4.80\times10^{3})\times\omega$ ✓ $\omega=12.0$ **«**s^{-1}**»** ✓	*Allow ECF from (b).*	**2**
	c	**ii**	initial KE $\frac{1}{2}\times1.44\times10^{4}\times16.0^{2}=1.843\times10^{6}$ **«**J**»** ✓ final KE $\frac{1}{2}\times(1.44\times10^{4}+4.80\times10^{3})\times12.0^{2}=1.382\times10^{6}$ **«**J**»** ✓ loss of KE $=4.6\times10^{5}$ **«**J**»** ✓	*Allow ECF from part (c)(i).*	**3**

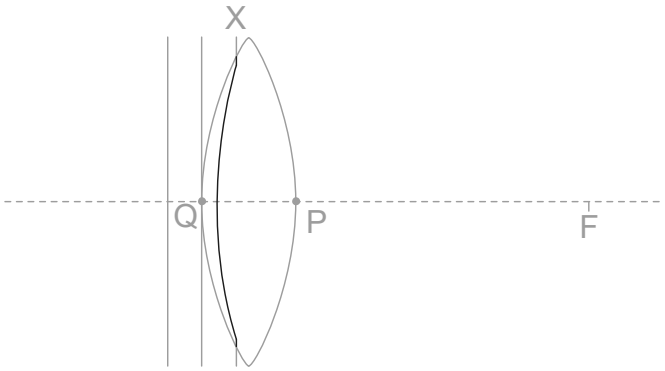
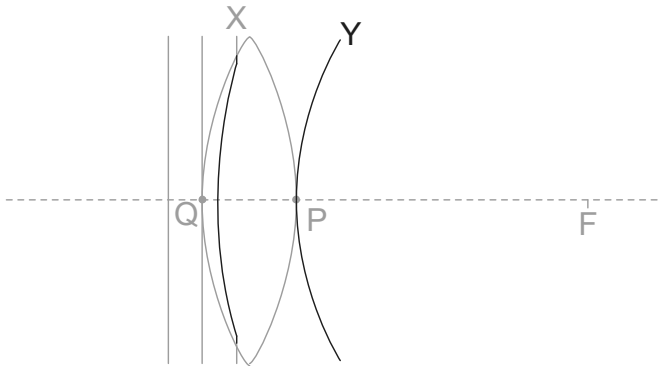
Question			Answers	Notes	Total
7.	a	i	$\Delta U = 0$ so $Q = \Delta U + W = 0 + 416 = 416$ «J» ✓	*Answer given, mark is for the proof.*	1
	a	ii	***ALTERNATIVE 1*** use $pV^{\frac{5}{3}} = c$ to get $TV^{\frac{2}{3}} = c$ ✓ hence $T_C = T_A\left(\frac{V_A}{V_C}\right)^{\frac{2}{3}} = 612 \times 0.5^{\frac{2}{3}} = 385.54$ ✓ «$T_C \approx 386\,\text{K}$» ***ALTERNATIVE 2*** $P_C V_C^{\gamma} = P_A V_A^{\gamma}$ giving $P_C = 1.26 \times 10^6$ «Pa» ✓ $\frac{P_C V_C}{T_C} = \frac{P_A V_A}{T_A}$ giving $T_C = 1.26 \times \frac{612}{2} = 385.54$ «K» ✓ «$T_C \approx 386\,\text{K}$»	*Answer of 386K is given. Look carefully for correct working if answers are to 3 SF.* *There are other methods:* *Allow use of $P_B = 2 \times 10^6$ «Pa» and $\frac{P}{T}$ is constant for BC.* *Allow use of $n = 0.118$ and $T_C = \frac{P_C V_C}{nR}$.*	2
	a	iii	$Q = \Delta U + W = \frac{3}{2}\frac{P_A V_A}{T_A}\Delta T + 0$ ✓ $Q = \frac{3}{2} \times \frac{4.00 \times 10^6 \times 1.50 \times 10^{-4}}{612} \times (386 - 612)$ ✓ «$-332\,\text{J}$»	*Answer of 330 J given in the question.* *Look for correct working or more than 2 SF.*	2

(continued…)

(Question 7 continued)

Question			Answers	Notes	Total
	a	**iv**	$e = \frac{Q_{in} - Q_{out}}{Q_{in}} = \frac{416 - 332}{416}$ ✓ $e = 0.20$ ✓	*Allow* $\frac{416 - 330}{416}$. *Allow e =0.21.*	**2**
	b		entropy is largest at B ✓ entropy increases from A to B because $T =$ constant but volume increases so more disorder **or** $\Delta S = \frac{Q}{T}$ and $Q > 0$ so $\Delta S > 0$ ✓ entropy is constant along CA because it is adiabatic, $Q = 0$ and so $\Delta S = 0$ ***OR*** entropy decreases along BC since energy has been removed, $\Delta Q < 0$ so $\Delta S < 0$ ✓		**3**

Option C — Imaging

Question			Answers	Notes	Total
8.	**a**	**i**	line of correct curvature as shown ✓  		**1**
	a	**ii**	line of approximately correct curvature as shown ✓  	*Judged by eye.* *Allow second wavefront Y, to have "passed" P as this is how this question is being interpreted by some.* *Ignore any waves beyond Y.*	**1**

(continued…)

(Question 8 continued)

Question			Answers	Notes	Total
	b		wave travels slower in glass than in air ***OR*** RI greater for glass ✓ wavelength less in glass than air ✓ hence wave from Q will cover a shorter distance «than in air» causing the curvature shown ✓	*OWTTE*	**2 max**
	c		realization that the two lenses must have a common focal point ✓ distance is $12 - 4.0 = 8.0$ «cm» ✓	*Accept MP1 from a separate diagram or a sketch on the original diagram.* *A valid reason from MP1 is expected.* *Award **[1 max]** for a bald answer of $12 - 4 = 8$ «cm».*	**2**

9.	**a**		states $f_o + f_e = 90$ ***AND*** $\frac{f_o}{f_e} = 17$ ✓ solves to give $f_o = 85$ ***AND*** $f_e = 5$ «cm» ✓	*Both needed.* *Both needed.*	**2**
	b		angle subtended by Moon is $\frac{0.16}{17} = 0.0094$ «rad» ✓ $0.0094 = \frac{D}{3.8 \times 10^8}$ ✓ $D = 3.6 \times 10^6$ «m» ✓	*Allow ECF from MP1.* *Allow **[2]** for an answer of 6.1×10^7 «m» if the factor of 17 is missing in MP1.*	**3**
	c		operation day and night ✓ operation at all wavelengths/no atmospheric absorption ✓ operation without atmospheric turbulence/light pollution ✓	*Accept any other sensible advantages.*	**2 max**

Question			Answers	Notes	Total
10.	**a**		calculation of critical angle at core–cladding boundary **«**$1.52 \times \sin\theta_C = 1.48$**»** $\theta_C = 76.8^\circ$ ✓ refraction angle at air–core boundary $90^\circ - 76.8^\circ = 13.2^\circ$ ✓ **«**$1.52 \times \sin 13.2^\circ = \sin A$**»** $A = 20.3^\circ$ ✓	*Allow ECF from MP1 to MP2 to MP3.*	**3**
	b	**i**	*attenuation*: output signal has smaller area ✓ *dispersion*: output signal is wider than input signal ✓	*OWTTE* *OWTTE*	**2**
	b	**ii**	attenuation $= \text{«}10 \log \frac{I}{I_0} = 10 \log \frac{77}{320} = \text{»} \text{«} - \text{»} 6.2 \text{«dB»}$ ✓ $\frac{-6.2}{5.1} = \text{«} - \text{»} 1.2 \text{«dB km}^{-1}\text{»}$ ✓	*Allow intensity ratio to be inverted.* *Allow ECF from MP1 to MP2.*	**2**

Option D — Astrophysics

Question			Answers	Notes	Total
11.	**a**		*core*: helium ✓ *outer layer*: hydrogen ✓	*Accept no other elements.*	**2**
	b		ratio of masses is $\left(\frac{10^4}{10^{-3}}\right)^{\frac{1}{3.5}} = 10^2$ ✓ ratio of volumes is $\left(\frac{10}{10^{-1}}\right)^3 = 10^6$ ✓ so ratio of densities is $\frac{10^2}{10^6} = 10^{-4}$ ✓	*Allow ECF for MP3 from earlier MPs*	**3**
	c	**i**	line to the right of X, possibly undulating, very roughly horizontal ✓	*Ignore any paths beyond this as the star disappears from diagram.*	**1**
	c	**ii**	gravitation is balanced by a pressure/force due to neutrons/neutron degeneracy/pauli exclusion principle ✓	*Do not accept electron degeneracy.*	**1**
	c	**iii**	$L = \sigma A T^4 = 5.67 \times 10^{-8} \times 4\pi \times (2.0 \times 10^4)^2 \times (10^6)^4$ ✓ $L = 3 \times 10^{26}$ **«** W **»** ***OR*** $L = 2.85 \times 10^{26}$ **«** W **»** ✓	*Allow ECF for **[1 max]** if πr^2 used (gives 7×10^{25} **«** W **»**)* *Allow ECF for a POT error in MP1.*	**2**
	c	**iv**	$\lambda = \frac{2.9 \times 10^{-3}}{10^6} = 2.9 \times 10^{-9}$ **«**m**»** ✓ this is an X-ray wavelength ✓		**2**

Question			Answers	Notes	Total
12.	**a**		theory in which all space/time/energy/matter were created at a point/singularity ✓ at enormous temperature ✓ with the volume of the universe increasing ever since ***or*** the universe expanding ✓	*OWTTE*	**2 max**
	b		CMB has a black-body spectrum ✓ wavelength stretched by expansion ✓ is highly isotropic/homogenous ✓ but has minor anisotropies predicted by BB model ✓ T **«**$= 2.7\,\text{K}$**»** is close to predicted value ✓	*For MP4 and MP5 idea of "prediction" is needed*	**2 max**
	c	**i**	$\frac{v}{c} = z \Rightarrow v = 0.084 \times 3 \times 10^5 = 2.52 \times 10^4$ **«**km s^{-1}**»** ✓ $d = \frac{v}{H_0} = \frac{2.52 \times 10^4}{68} = 370.6 \approx 370$ **«**Mpc**»** ✓	*Allow ECF from MP1 to MP2.*	**2**
	c	**ii**	type Ia have a known luminosity/are standard candles ✓ measure apparent brightness ✓ determine distance from $d = \sqrt{\frac{L}{4\pi b}}$ ✓	*Must refer to type Ia. Do not accept other methods (parallax, Cepheids)*	**3**