Cambridge Assessment International Education

Cambridge Pre-U

PHYSICS **9792/03**

Paper 3 Written Paper 3 **October/November 2020**

MARK SCHEME

Maximum Mark: 140

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

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This document consists of **22** printed pages.

Generic Marking Principles

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1: Marks must be awarded in line with: • the specific content of the mark scheme or the generic level descriptors for the question • the specific skills defined in the mark scheme or in the generic level descriptors for the question • the standard of response required by a candidate as exemplified by the standardisation scripts.
GENERIC MARKING PRINCIPLE 2: Marks awarded are always **whole marks** (not half marks, or other fractions).
GENERIC MARKING PRINCIPLE 3: Marks must be awarded **positively**: • marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate • marks are awarded when candidates clearly demonstrate what they know and can do • marks are not deducted for errors • marks are not deducted for omissions • answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.
GENERIC MARKING PRINCIPLE 4: Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5: Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).
GENERIC MARKING PRINCIPLE 6: Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

1	Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
2	The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
3	Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
4	The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
5	‘List rule’ guidance For questions that require ***n*** responses (e.g. State **two** reasons …): • The response should be read as continuous prose, even when numbered answer spaces are provided. • Any response marked *ignore* in the mark scheme should not count towards ***n***. • Incorrect responses should not be awarded credit but will still count towards ***n***. • Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response. • Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science.

6	<u>Calculation specific guidance</u> Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'. For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values. For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme. Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.
7	<u>Guidance for chemical equations</u> Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme. State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Question	Answer	Marks
1(a)(i)	force is attractive / towards proton	**1**
	force is perpendicular to velocity / towards centre of circle	**1**
1(a)(ii)	$F = e^2 / 4\pi\varepsilon_0 r^2$	**1**
1(a)(iii)	$F = mv^2 / r$	**1**
1(a)(iv)	$mv^2 / r = e^2 / 4\pi\varepsilon_0 r^2$… …followed by completion of algebra to get $v = e / \sqrt{(4\pi\varepsilon_0 mr)}$	**1**
1(b)	kinetic energy $= ½\, mv^2$	**1**
	$= ½\, me^2 / 4\pi\varepsilon_0 mr$ $= e^2 / 8\pi\varepsilon_0 r$	**1**
	total energy = kinetic energy + potential energy $= e^2 / 8\pi\varepsilon_0 r - e^2 / 4\pi\varepsilon_0 r = -e^2 / 8\pi\varepsilon_0 r$	**1**
1(c)	energy = $13.6 \times 1.6 \times 10^{-19}$ (= 2.18×10^{-18} J)	**1**
	radius $= e^2 / 8\pi\varepsilon_0 E$ $= (1.6 \times 10^{-19})^2 / (8\pi \times 8.85 \times 10^{-12} \times 2.18 \times 10^{-18})$	**1**
	= **5.29×10^{-11} m**	**1**

Question	Answer	Marks
2(a)	force diagram showing weight downwards and normal contact force perpendicular to the surface of the bowl, leading to $F = mg \sin\theta$	**1**
	$\sin\theta \approx \theta$ <u>and</u> $x = r\theta$, leading to $F = mg\,(x / r)$	**1**
	acceleration = force / mass = gx / r	**1**

Question	Answer	Marks
2(b)(i)	acceleration is towards the equilibrium position	**1**
	magnitude of acceleration is proportional to displacement (from equilibrium)	**1**
2(b)(ii)	$\omega^2 = g / r$	**1**
	$\omega = 2\pi / T$ leading to $T = 2\pi \sqrt{(r/g)}$	**1**
2(b)(iii)	at greater amplitude the maximum speed of the ball is greater (and so time is constant)	**1**
2(c)(i)	e.g. use a fiducial marker	**1**
2(c)(ii)	timed for 11 oscillations rather than 10	**1**
2(c)(iii)	evidence that the anomalous value is disregarded	**1**
	T given as **1.18 s**	**1**
2(d)(i)	human reaction time is a smaller proportion of the measured time	**1**
2(d)(ii)	*either*: to reduce <u>random</u> error *or*: to identify anomalous measurements	**1**
2(e)	$1.18 = 2\pi \sqrt{(r / 9.81)}$ r = **0.348 m**	**1**

Question	Answer	Marks
3(a)	<u>any three of</u> • charges on the two plates initially equal and opposite • charge moves, through the resistor, from one plate to the other to leave both plates uncharged • energy stored between the plates is dissipated in the resistor • rate of change (of charge or energy) decreases with time	**3**
3(b)(i)	maximum current at $t = 0$ and gradient always negative down to zero current at the end	**1**
	smooth exponential decay curve	**1**
3(b)(ii)	straight line through the origin	**1**
3(c)(i)	area under 3.1 = total initial charge Q stored on capacitor	**1**
	area under Fig. 3.1 = $\boldsymbol{CV_0}$	**1**
3(c)(ii)	$Q = VC$ and so gradient of 3.2 = gradient of I–V graph / C	**1**
	gradient of I–V graph = 1 / R so gradient of Fig. 3.2 = **1 / *RC***	**1**

Question	Answer	Marks
4(a)	e.m.f. is proportional to the rate of change of magnetic flux (linkage)	**1**
	the magnetic flux (linkage) created by the solenoid increases with current	**1**
	(shorter time for change of current means) greater rate of change of flux (linkage)	**1**
4(b)	all values of 1 / t correct (0.476; 0.248; 0.167; 0.121; 0.101)	**2**
	column heading given as $\mathbf{(1 / \mathit{t}) / s^{-1}}$	**1**

Question	Answer	Marks
4(c)	all five points plotted correctly	**2**
	acceptable line of best-fit	**1**
4(d)(i)	correct method for gradient	**1**
	value of gradient in range (76 ± 2) (× 10^{-3})	**1**
4(d)(ii)	gradient = kI_0, leading to calculation of k as **(d)(i)** / 4.60	**1**
	either: **V s A^{-1}** or **Ω s** or **Wb A^{-1}** if value of k includes the 10^{-3} factor, or *or*: **mV s A^{-1}** or **mΩ s** or **mWb A^{-1}** if value of k does not include 10^{-3} factor	**1**
4(e)	<u>any two from</u>: • move small coil closer to solenoid • more turns on coil • more turns on solenoid • use a soft-iron core in small coil	**2**

Question	Answer	Marks
5(a)(i)	no forces between particles (except during collisions)	**1**
	collisions between particles are (perfectly) elastic	**1**
	particles occupy negligible volume (compared with volume of gas)	**1**
5(a)(ii)	(at very low pressure,) gas occupies very large volume/particles are further apart	**1**
	larger distance between particles means any (finite) forces between them become negligible	**1**
	larger volume of gas means (finite) volume of particles becomes negligible	**1**

Question	Answer	Marks
5(b)(i)	Use of $pV = nRT = RT$ in this instance	1
	$\boldsymbol{T = y_0 / R}$**,** where R is the molar gas constant	1
5(b)(ii)	line starting at $pV = y_0$ when $p = 0$	1
	horizontal straight line	1

Question	Answer	Marks
6(a)(i)	<u>any five points from:</u>	
	• for a mode of decay to be possible, it must yield a drop in total mass	1
	• decay products would be thallium–205 (from α), lead–209 (from β^+), and polonium–209 (from $\times^-$)	1
	• mass of lead–209 is greater than bismuth–209, so not $\times^+$ decay	1
	• mass of polonium–209 is greater than bismuth–209, so not $\times^-$ decay	1
	• alpha decay would produce thallium–205 and helium–4 (combined mass of 204.974428 + 4.002603 = 208.977031)	1
	• this is less than the mass of bismuth–209 **or** 208.980399 – 204.974428 = 4.005971 > mass of α therefore α decay	(1)
6(a)(ii)	$N = (10000 / 209) \times 6.02 \times 10^{23} = 2.88 \times 10^{25}$ nuclei $\lambda = \ln 2 / 1.9 \times 10^{19} = 3.648 \times 10^{-20}\ \text{yr}^{-1}$	1
	$A = \lambda N = (\ln 2 / 1.9 \times 10^{19}) \times 2.88 \times 10^{25}$ $= 1.05 \times 10^{6}\ \text{yr}^{-1}$	1
	100 years is such a small proportion of the half-life that the activity can be considered approximately constant over this time, and so: number $\approx At = 1.05 \times 10^{6} \times 100$ $= \mathbf{1.(05) \times 10^{8}}$	1

Question	Answer	Marks
6(a)(iii)	fall in mass during reaction = 208.982430 – (208.980399 + 0.000549) = 0.001482 u = $0.001482 \times 1.66 \times 10^{-27} = 2.46 \times 10^{-30}$ kg	**1**
	energy = $\Delta mc^2 = 2.46 \times 10^{-30} \times (3.00 \times 10^8)^2$ = 2.21×10^{-13} J	**1**
	= $2.21 \times 10^{-13} / 1.60 \times 10^{-13}$ = **1.38 MeV**	**1**
6(b)	$I = I_0 e^{-\mu x}$ where $\mu = 0.189$ cm^{-1} and $I = 0.05\ I_0$	**1**
	$e^{-\mu x} = 0.05 \Rightarrow \mu x = (0.189\text{ cm}^{-1})\ x = -\ln(0.05)$	**1**
	$x = -\ln(0.05) / \mu = 2.996 / (0.189\text{ cm}^{-1}) = 15.85$ cm = 0.159 m	**1**

Question	Answer	Marks
7(a)	standard candle	**1**
7(b)(i)	increase in observed wavelength	**1**
7(b)(ii)	star is moving away from Earth	**1**
7(c)	the red shift observed / the speed of recession is greater for galaxies that are further away **or** speed is proportional to distance	**1**
	This implies that, at some point in the past, all galaxies were initially at the same point	**1**

Question	Answer	Marks
8(a)(i)	<table><tr><th colspan="3">Linear mechanics</th><th colspan="3">Rotational mechanics</th></tr><tr><td>velocity</td><td>v</td><td>m s^{-1}</td><td>**angular velocity**</td><td>ω</td><td>**rad s^{-1}**</td></tr></table>	**1**
	<table><tr><th colspan="3">Linear mechanics</th><th colspan="3">Rotational mechanics</th></tr><tr><td>acceleration</td><td>a</td><td>m s^{-2}</td><td>**angular acceleration**</td><td>α</td><td>**rad s^{-2}**</td></tr></table>	**1**
	<table><tr><th colspan="3">Linear mechanics</th><th colspan="3">Rotational mechanics</th></tr><tr><td>mass</td><td>m</td><td>kg</td><td>**moment of inertia**</td><td>I</td><td>**kg m^2**</td></tr></table>	**1**
	<table><tr><th colspan="3">Linear mechanics</th><th colspan="3">Rotational mechanics</th></tr><tr><td>force</td><td>F</td><td>N</td><td>**torque**</td><td>Γ</td><td>**N m**</td></tr></table>	**1**
8(a)(ii)	$\alpha = \Gamma / I$	**1**
8(b)(i)	Considers a ring at radius r and thickness δr.	**1**
	Correct expression for mass or moment of inertia of ring $\delta m = 2\, m\, r\, \delta r / R^2$ or $\delta I = 2\, m\, r^3\, \delta r / R^2$	**1**
	Carries out correct integration: $I = \int_{r=0}^{r=R} \frac{2mr^3 dr}{R^2} = \left[\frac{mr^4}{2R^2}\right]_{r=0}^{r=R}$	**1**
	Uses correct limits to obtain $I = ½\, mR^2$	**1**

Question	Answer	Marks
8(b)(ii)	**Method 1:** as in **(b)(i)** but integrated from $r = r$ to $r = R$ Leading to $I = \int_{r=r}^{r=R} \frac{2mr^3dr}{R^2} = \left[\frac{mr^4}{2R^2}\right]_{r=r}^{r=R} = \frac{mR^4}{2R^2} - \frac{mr^4}{2R^2} = \frac{1}{2}m\left(R^2 - \frac{r^4}{R^2}\right)$	**4**
	Method 2: subtracts moment of inertia of 'missing' central cylinder of radius r:	**(1)**
	Mass of removed central cylinder: $m' = \frac{\pi r^2}{\pi R^2}m = \frac{r^2}{R^2}m$	**(1)**
	Moment of inertia of removed central cylinder: $I' = \frac{1}{2}\left(\frac{r^2}{R^2}m\right)r^2 = \frac{1}{2}m\frac{r^4}{R^2}$	**(1)**
	Moment of inertia of hollow disc: $= I_{TOT} = \frac{1}{2}mR^2 - \frac{1}{2}m\frac{r^4}{R^2} = \frac{1}{2}m\left(R^2 - \frac{r^4}{R^2}\right)$	**(1)**
8(c)(i)	There is no (external) resultant torque	**1**
8(c)(ii)	Angular momentum is conserved so that $\frac{2}{5}mr_1^2\omega_1 = \frac{2}{5}mr_2^2\omega_2$	**1**
	Use of $T = \frac{2\pi}{\omega}$ to obtain: $T_2 = \left(\frac{r_2}{r_1}\right)^2 T_1 = 10^{-4}T_1$	**1**
	T_2 = 0.0025 days = 220 s (216 s)	**1**

Question	Answer	Marks
8(c)(iii)	Correct argument (e.g. from dependence of RKE on *r* through I and ω^2	**1**
	conclusion that rotational KE increases	**1**
	GPE transferred to RKE as star shrinks	**1**

Question	Answer	Marks
9(a)(i)	1.45 / sin(25) = 3.43 m	**1**
9(a)(ii)	horizontal line at about F = 3600 N for about 3.5 m	**1**
9(a)(iii)	area (under the graph)= total / input work done (in loading the satellite)	**1**
9(a)(iv)	(useful work done) $m\,g\,\Delta h$ = 832 × 9.81 × 1.45 = 11830 J and (input work done) = $F \times d$ = 3600 × 3.43 = 12348 J	**1**
	(difference between input and useful work) 12348 – 11830 = 518 J	**1**
	(work done against friction 518 = $F \times$ 3.43) F = 150.6 N = 151 N	**1**
	or	
	component of weight down slope = 832 kg × g × sin(25°) (= 3449 N)	**(1)**
	friction force = force up slope – component of weight down slope	**(1)**
	3.6 kN – 3449 N = 150.6 N	**(1)**
9(b)(i)	Gravitational potential energy at infinity = 0 J	**1**
	Work needs to be done to give mass the energy to reach infinity / forces are attractive	**1**

Question	Answer	Marks
9(b)(ii)	$E = -G\,M\,m\,/\,r$ $E = -6.67 \times 10^{-11} \times 832 \times 5.97 \times 10^{24} / (6.27 \times 10^{6} + 3.58 \times 10^{7})$ $E = (-)\ 7.86 \times 10^{9}$ J	**1**
9(b)(iii)	$W = \int_{r_E}^{r_0} F\,\mathrm{d}r$	**1**
	$W = \text{-GMm} \int_{r_E}^{r_0} \frac{\mathrm{d}r}{r^2}$	**1**
9(b)(iv)	$W = GMm\,(\frac{1}{r_o} - \frac{1}{r_E})$ $r_0 = 3.58 \times 10^{7} + 6.37 \times 10^{6} = 4.217 \times 10^{-7}$ m $W = 6.67{\times}10^{-11} \times 5.97{\times}10^{24} \times 832 \times (1\,/\,(3.58{\times}10^{7} + 6.37 \times 10^{6}) - 1\,/\,6.37 \times 10^{6})$	**1**
	$= 4.41 \times 10^{10}$ J / 4.42×10^{10} J	**1**
9(c)(i)	$mv^2 / r = GMm / r^2$	**1**
	$\text{v} = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67\,x10^{-11}\,x5.97\,x10^{24}}{4.21x10^{7}}}$	**1**
	$= 3080$ m s^{-1} (3076 m s^{-1})	**1**
	or	
	$r = 4.2 \times 10^{3}$ km (graph) or 3.58×10^{7} m + $6.37{\times}10^{6}$ m (in question) = 4.22×10^{7} m	**(1)**
	T = 1 day (geostationary) = 86400 s	**(1)**
	$v = 2\pi r\,/\,T = 3066$ m s^{-1}	**(1)**

Question	Answer	Marks
9(c)(ii)	(as satellite slows down) moves to a lower orbit / moves towards Earth / (‘spirals’ towards the Earth)	1
	accelerating / increasing its speed (until it has sufficient speed to maintain a closer orbit)	1
9(c)(iii)	Extra energy needed to raise rocket / fuel as well as satellite	1
	Extra energy needed to do work against frictional forces / air resistance	1

Question	Answer	Marks
10(a)	atoms have a set of discrete energy levels, absorb photons and become excited	1
	when an excited atom returns to a lower energy state, photons are emitted with <u>energy</u> equal to the <u>difference between two energy levels</u>	1
10(b)(i)	396.75 nm 400.75 nm	1
10(b)(ii)	$\Delta\lambda / \lambda = v / c$ (396.75 nm – 393.0 nm) / 393.0 nm $= v / 3.0 \times 10^8$	1
	$v = 2.86 \times 10^6$ m s^{-1}	1
10(b)(iii)	$v \approx H_0 d$	1
	$d \approx 3 \times 10^6 / 79\,000$ m s^{-1} Mpc^{-1} $\times 3.09 \times 10^{22}$	1
	$= 1.(2) \times 10^{24}$ m $= 1.2 \times 10^{21}$ km	1
10(c)(i)	$I = 1280 / \cos 20$	1
	$= 1362$ W m^{-2}	1

Question	Answer	Marks
10(c)(ii)	$P = I \times 4\pi r^2$ $= 1362 \times 4\pi \times (1.50 \times 10^{11})^2$	1
	$= 3.9 \times 10^{26}$ W	1
10(c)(iii)	e.g. some energy is absorbed by the atmosphere	1
	wavelengths other than visible light emitted	1
10(d)(i)	$\lambda = 525 \times 10^{-9}$ nm $\pm$ 20 nm $\lambda \times T = 2.898 \times 10^{-3}$	1
	T = 6000 K allow 5500 K	1
10(d)(ii)	Similar shape with peak shifted to the right **and** lower throughout	1
10(d)(iii)	$L = 4\pi \sigma r^2 T^4$ $3.9 \times 10^{26} = 4\pi \times 5.67 \times 10^{-8} \times r^2 \times (5800)^4$	1
	$r = 7 \times 10^8$ m (7.8×10^8 m)	1
10(d)(iv)	reasoned answer e.g. using total power of Sun estimate, *L* likely to be bigger, so *r* bigger	1

Question	Answer	Marks
11(a)(i)	Change in entropy = $(1.38 \times 10^{-23}$ J $K^{-1})\ln(8.0658 \times 10^{67})$	1
	$= 2.1578 \times 10^{-21}$ J K^{-1}	1
11(a)(ii)	Candidate gives a reason why 'very highly unlikely' is effectively impossible e.g. though possible, extremely unlikely to occur in an exceedingly long time (e.g. age of Earth).	1
11(b)(i)	$\Delta S = k \ln(2^N)$ or $\Delta S = kN\ln(2)$	1

Question	Answer	Marks
11(b)(ii)	$pV = nRT$ $n = pV/RT$ $n = (100\,\text{kPa})(2.0 \times 10^{-4}\,\text{m}^3) / (283\,\text{K})(8.31\,\text{J mol}^{-1}\,\text{K}^{-1})$	**1**
	$= 8.50 \times 10^{-3}\,\text{mol}$	**1**
	$N = (6.02 \times 10^{23}\text{mol}^{-1})(8.50 \times 10^{-3}\,\text{mol}) = 5.12 \times 10^{21}$	**1**
11(b)(iii)	$\Delta S = k \ln (2^N) = kN \ln 2$ $= (1.38 \times 10^{-23}\,\text{J K}^{-1})(5.13 \times 10^{21}) \times 0.693$	**1**
	$= 0.049\,\text{J K}^{-1}$	**1**
11(c)(i)	(absolute) temperature	**1**
11(c)(ii)	B because it has more quanta	**1**
11(c)(iii)	7 quanta on 9 atoms 6 345 ways 9 quanta on 16 atoms 1 307 504 ways Total before 1 313 849 ways	**1**
	6 quanta on 9 atoms 3 003 ways 10 quanta on 16 atoms 3 268 760 ways Total after 3 271 763 ways Difference = + 1 957 914	**1**
11(c)(iv)	The smaller solid A is at a higher temperature	**1**
	because entropy increases when energy flows from smaller to bigger solid.	**1**
11(d)(i)	Change in entropy $= -(3600\,\text{kJ}) / (500\,\text{K})$ $= -7200\,\text{J K}^{-1}$.	**1**

Question	Answer	Marks
11(d)(ii)	Energy transferred to sink = 3600 kJ – 1000 kJ = 2600 kJ	1
	Entropy increase of sink = (2600 kJ) / (300 K) = 8667 J K^{-1}.	1
11(d)(iii)	Efficiency = 1000 kJ / 3600 kJ = 0.28 = 28%	1
11(d)(iv)	The entropy increase of the sink is bigger than the fall in that of the source so overall entropy increases (not contradicting 2nd Law) – it is possible	1

Question	Answer	Marks
12(a)(i)	L = (2000 m s^{-1})(cos 30°) × 2 × (2000 m s^{-1})(sin 30°) / (9.81 m s^{-2})	1
	= 353 119 m = 3.53 × 10^5 m	1
12(a)(ii)	$v^2 - u^2 = 2as$ height = ((2000 m s^{-1}) × sin (30°))^2 / (2 × 9.81 m s^{-2})	1
	= 5.1 × 10^4 m	1
12(a)(iii)	Air resistance not accounted for	1
	Change in g with height	1
	Spin effects	**(1)**
	Change in air resistance with height	**(1)**
	Earth is not flat	**(1)**
	Other reasonable suggestions possible 2 max	**(2)**

Question	Answer	Marks
12(b)	Quoting time or length dilation formula involving $(1 - v^2/c^2)^{½}$ $(1 - (400\,000 \text{ m s}^{-1})^2 / (300\,000\,000 \text{ m s}^{-1})^2)^{½} = 0.999\,999\,1111$	**1**
	$1 - 0.999\,999\,1111 = 8.9 \times 10^{-7}$	**1**
	This is <u>approximately</u> one in a million Algebra leading to proportional change in time = ½ v^2/c^2 $v^2 = 2 \times c^2 / 1\,000\,000$ $v = 424\,000 \text{ m s}^{-1}$.	**1**
12(c)(i)	Fall for 8 A = 0.05 V so using idea of internal resistance fall for 200 A = 200 / 8 × 0.05 V = 1.25 V	**1**
	Terminal voltage = 13.5 V – 1.25 V = 12.25 V (12.3 V) or $r = 6.25 \times 10^{-3}$ ohm method	**1**
12(c)(ii)	Battery would rise in temperature and affect 'internal resistance'.	**1**
12(d)(i)	Chooses at least two p.d.s and associated currents	**1**
	Compares values of internal resistance and *r* is not constant	**1**
12(d)(ii)	$V = E - kI^2$.	**1**
12(d)(iii)	$k = (E - V) / I^2$. $= (12.0 \text{ V} - 11.5 \text{ V}) / (1\ .0 \text{ A})^2 = 0.50 \text{ V A}^{-2}$ example	**1**
	two sets of data done to check	**1**
12(d)(iv)	Check on any data	**1**

Question	Answer	Marks
12(e)	Model does not give exact answers but does gives value which can be They are simple to apply	**1**
	Not perfect but gives ideas for future research and experiments	**1**
	Other reasonable comments 2 max	**(2)**

Question	Answer	Marks
13(a)(i)	The speed decreases as it passes into glass	**1**
13(a)(ii)	The particles slow down upon leaving the glass	**1**
	The angle they make with the normal increases	**1**
13(b)(i)	Diffraction at single slit or two slit interference	**1**
	Idea of superposition.	**1**
13(b)(ii)	Newton’s status and fame gave all his theories greater credibility OR Any reasonable comment suggesting scientists are not always objective	**1**
13(c)(i)	Time diff = 9 km / (6 – 3) kph + 9 km / (6 + 3) kph – 2 × 9 km / 6 kph = 3h + 1h – 3h	**1**
	= 1h	**1**

Question	Answer	Marks
13(c)(ii)	Time diff $= L / (c + u) + L / (c - u) - 2L / c$	**1**
	$= (L(c - u) + L(c+u))/(c^2 - u^2) - 2L / c$	**1**
	$= 2L / c(1 - u^2 / c^2) - 2L / c$ $= 2L(1 + u^2 / c^2) / c - 2L / c$ $= 2Lu^2 / c^3$	**1**
13(d)(i)	Extra time $= 2 \times 1.5\ \text{m} \times (3 \times 10^4\ \text{m s}^{-1})^2 / (3 \times 10^8\ \text{m s}^{-1})^3$.	**1**
	$= 1.0 \times 10^{-16}$ s	**1**
13(d)(ii)	Frequency $=$ speed / wavelength $= (3 \times 10^8\ \text{m s}^{-1}) / (600 \times 10^{-9}\ \text{m})$ $= 5 \times 10^{14}$ Hz	**1**
	Period $= 2 \times 10^{-15}$ s	**1**
13(d)(iii)	Period of light of 2 fs is 20 times bigger than extra time of 0.1 fs	**1**
	phase change is 0.1 fs / 2 fs $\times 2\pi = 0.314$ rad less than 0.5 rad or recalculation for 11 m showing shift is greater than 0.5 rad	**1**
13(d)(iv)	There is no aether or The speed of light is invariant	**1**

Question	Answer	Marks
13(e)	Any **two** from: • Newton's motion works very well at normal speeds / normal gravity fields • All particles show wave properties • Light shows particle properties • Einstein's photons were not like Newton's corpuscles • Light (travels like waves but) interacts as particles Any sensible suggestion based on physics or how science works 2 max	**2**