Cambridge Assessment International Education
Cambridge Pre-U Certificate

PHYSICS **9792/03**

Paper 3 Written Paper **May/June 2018**

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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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.

Question	Answer	Marks
1(a)	the planets move in elliptical orbits with the Sun at one focus	**1**
	the Sun planet line sweeps out equal areas in equal times	**1**
	the orbital period squared of a planet is proportional to its mean distance from the Sun cubed	**1**
1(b)	use $GMm/r^2 = mv^2/r$ and eliminate m	**1**
	$v = 2\pi r/T$ OR equivalent with ω	**1**
	get something like $GM/r = (2\pi r/T)^2$ and hence answer	**1**
1(c)(i)	substitute all the values in correctly AND correct final sign	**1**
	see this as (–) 5.01×10^9 with just 3 sig. figs.	**1**
1(c)(ii)	because the zero of gravitational p.e. is at infinity	**1**
	so work would have to be done to reach zero GPE/to move away OR gravitational forces / gravity are / is attractive	**1**
1(c)(iii)	$\frac{1}{2}mv^2 = 6.26 \times 10^7\,m$	**1**
	$v = \sqrt{\left(2 \times 6.26 \times 10^7\right)} = 11\,200\ (\mathrm{m\,s^{-1}})$	**1**

Question	Answer	Marks
2(a)	motion in which the acceleration is proportional to the displacement	**1**
	and in the opposite direction / towards equilibrium position	**1**
2(b)(i)	velocity graph starting at a +ve maximum AND constant amplitude by eye	**1**
	always 90° out of phase with displacement graph	**1**
	acceleration graph sine wave starting at origin;	**1**
	180° out of phase with displacement graph ;	**1**
2(b)(ii)1	correct differentiation to get $v = \frac{dx}{dt} = 2\pi f\ a\cos 2\pi ft$; correct substitution $v = 0.002 \times 2\pi \times 55 \times 1$; $v_{max} = 0.691$ (m s^{-1}) ; OR $v_{max} = \omega a = 2\pi fa$; correct substitution $v = 0.002 \times 2\pi \times 55 \times 1$; $v_{max} = 0.691$ (m s^{-1}) ;	**3**
2(b)(ii)2	max. acceleration = $a\omega^2$ / $(2\pi f)^2 a$ / $(2\pi \times 55.0)^2 \times 0.00200$)	**1**
	= 239 (m s^{-2}) (ignore sign)	**1**

Question	Answer	Marks
2(b)(ii)3	$E = \frac{1}{2} ma^2 (2\pi \times 55)^2$ **or** $E = \frac{1}{2} mv_{max}{}^2 = 0.5 \times 0.00431 \times 0.691^2$	**1**
	= 0.00103 (J)	**1**
2(c)(i)	period of fundamental frequency = 0.002 s ;	**1**
	frequency = 500 (Hz)	**1**
2(c)(ii)	period = 0.6 – 0.7 ms	**1**
	frequency = 1400 – 1550 – 1550 (Hz)	**1**

Question	Answer	Marks
3(a)(i)	Faraday's law as <u>e.m.f</u> proportional to rate of flux cut / rate of change of flux-linkage	**1**
	$\mathrm{d}N\phi/\mathrm{d}t$ is rate of change of flux-linkage / OR $N\phi$ is flux linkage	**1**
	Lenz's law that emf tends to <u>oppose</u> change shown by minus sign in expression	**1**
3(a)(ii)	$7200 = \mathrm{d}\phi/\mathrm{d}t \times 800$	**1**
	rate of cutting = 7200/800 = 9(.0)	**1**
3(b)(i)	curve downwards	**1**
	of uniform curvature (of a circle) by eye	**1**
3(b)(ii)1	force due to electric field equals force due to magnetic field / $Ee = Beu$	**1**
	$E = V_H / w$ where w is the width of the semiconductor	**1**
	$V_H = Buw$	**1**

Question	Answer	Marks
3(b)(ii)2	V_H =0.28 × 56 × 0.0090 = 0.14 V (140 mV)	**1**
3(b)(ii)3	far side with a +	**1**
3(b)(iii)	far more charge carriers in a metal (than in a semiconductor)	**1**
	(drift) velocity is much smaller	**1**

Question	Answer	Marks
4(a)	density of oxygen = 0.23 × 1.29	**1**
	mass in 1 m^3 = 0.30 kg (0.2967 kg)	**1**
4(b)	oxygen mean square speed = 228 000 $m\,s^{-1}$	**1**
	root mean square speed = 478 $m\,s^{-1}$	**1**
	water vapour mass = 3 × 1.38 × 10^{-26} × 293/635^2	**1**
	= 3.01 × 10^{-26} (kg)	**1**
	carbon dioxide temperature = 653 (K)	**1**

Question	Answer	Marks
4(c)(i)	**1** to the right	**1**
	2 many more molecules with higher speed (than with lower speed) / equal areas either side of line	**1**
4(c)(ii)	$v = \sqrt{\left(2 \times 1.38 \times 10^{-23} \times 293 / \left(4.65 \times 10^{-26}\right)\right)}$	**1**
	= 417 ($\mathrm{m\,s^{-1}}$)	**1**
4(c)(iii)	L with peak to left	**1**
	H with peak to the right	**1**
	peak of L > peak give > peak of H	**1**
	shape of graphs not symmetrical, i.e. larger area to right of peak	**1**

Question	Answer	Marks
5(a)(i)	$3.00 \times 10^{8} \times 3600 \times 24 \times 365$; 9.46×10^{15} (m) ; OR $3.00 \times 10^{8} \times 3600 \times 24 \times 365.25$; 9.47×10^{15} (m) ;	**2**
5(a)(ii)	base line length = $2 \times 1.50 \times 10^{11}$ m, $\theta = 3.0 \times 10^{11}/1.72 \times 10^{17}$ OR 1.74×10^{-6} radians seen	**1**
	(= 1.74×10^{-6} radians = $1.74 \times 10^{-6} \times 57.3$) = 9.99×10^{-5} degrees	**1**

Question	Answer	Marks
5(a)(iii)	cepheids can be used as standard candles ; luminosity / total power can be obtained from period ; inverse-square law can be used for Cepheids ; parallax methods cannot be used for great distances / idea of smallest angle that can be measured by a telescope ; **2 marks max.**	**2**
5(b)(i)	$T \times 5.1 \times 10^{-7} = 2.90 \times 10^{-3}$ $T = 2.90 \times 10^{-3} / 5.1 \times 10^{-7} = 5690$ (K)	**1**
	Accept for full marks: 5.0×10^{-7} m and 5800 K 5.2×10^{-7} m and 5576 K	**1**
5(b)(ii)	$L = F \times 4\pi d^2$ (where L is total output)	**1**
	$L = 4\pi \times 3.7 \times 10^{-8} \times (1.88 \times 10^{17})^2 / = 1.643 \times 10^{28}$ (W))	**1**
	Correct use of Stefan's law seen, e.g. $1.643 \times 10^{28} = 4\pi \times 5.7 \times 10^{-8} \times r^2 \times 5686^4$ OR $r^2 = L / 4\pi\sigma T^4$	**1**
	$r = 4.70 \times 10^9$ (m)	**1**

Question	Answer	Marks
6(a)	reference to line <u>emission or absorption spectrum</u> / discrete λ or f emitted / absorbed	**1**
	discrete wavelengths / frequencies related to discrete energies / $\Delta E = hf$	**1**
	correspond to <u>discrete energy jumps</u> inside atoms / between energy levels	**1**
6(b)(i)	values –13.6, –3.40, –1.51, –0.85(0), –0.54(4), 0	**1**
	all negative signs present	**1**
6(b)(ii)	11.0 eV	**1**
	0.8 eV	**1**
	there could be an elastic collision / no excitation / the 11.0 eV will not be absorbed by the atom	**1**
	it could cause excitation but <u>only</u> to raise the level of the electron from level 1 to level 2	**1**
	leaving the scattered electron with 11 – (–3.4 – (–13.6)) = 11 – 10.2 = 0.8 eV	**1**

Question	Answer	Marks
7(a)(i)	all arrows directed towards the centre	**1**
	all arrows the same length by eye	**1**
7(a)(ii)	bottom: vertically upwards	**1**
	and length equal to $F + W$ by eye	**1**
	left: direction and length consistent with completion of vector triangle	**1**
	right: direction and length consistent with completion of vector triangle	**1**

Question	Answer	Marks
7(b)(i)	moment of inertia $I = mR^2$	1
7(b)(ii)	diagram showing ring of radius r and thickness δr / or from diagram	1
	correct expression for mass of ring, e.g. $2\pi r\sigma \mathrm{d}r$ / $2\pi r\rho t\ \mathrm{d}r$ / $2Mr\delta r/R^2$	1
	correct integration for moment of inertia of disc e.g. $I = \int 2\pi r\sigma \mathrm{d}r \times r^2 = 2\pi\sigma\int r^3\ \mathrm{d}r = 2\pi\sigma \times \frac{1}{4}\ r^4$	1
	the mass of the disc $M = \pi R^2\sigma$ so $I = \frac{1}{2}\ MR^2$ (σ = surface density)	1
7(c)(i)	gradient zero at 0 s and 8 s	1
	gradient increasing until 4 s	1
	gradient decreasing from 4 s to 8 s	1
7(c)(ii)	torque = moment of inertia × angular acceleration / $\Gamma = I\alpha$; angular velocity = angular acceleration × time / $\omega = \alpha t$; **OR** area under graph = angular impulse OR change of angular momentum ; angular velocity = area / moment of inertia OR $\omega = \Delta L/I$;	2
	= 4.8	1
	rad s^{-1}	1
7(c)(iii)	$KE = \frac{1}{2}\ I\omega^2$ / $KE = 0.5 \times 0.0050 \times 4.8^2$	1
	= 0.058 (J)	1

Question	Answer	Marks
8(a)(i)	activity or rate of decay is (–)dN/dt / activity proportional to N / constant fraction decaying per unit time / probability of decay per unit time constant	**1**
	algebra leading from first mark to dN/dt = $-\lambda N$	**1**
8(a)(ii)	$\mathrm{d}/\mathrm{d}t\,(N_0\,e^{-\lambda\tau}) = -\lambda\, N_0\, e^{-\lambda\tau} = -\lambda\, N$	**1**
8(b)(i)	2.16, 0.93 for right hand column	**2**
	count rate column 5.58, 3.16 1 mark for each	**2**
8(b)(ii)	plotting of points to less than half a small square: all points correct 2 marks one point incorrect 1 mark two or more points incorrect 0 marks	**2**
	uses at least half of available space in both directions axes labelled correctly with quantity and unit sensible choice of scales (e.g. not 3, 6, 9)	**1**
	ALTERNATIVES **1** Uses the log graph **(MAX 2)** $\lambda = -$ gradient ; $20 < t_{\frac{1}{2}} < 23$; **2** Uses count rate values (exponential decay curve) **(MAX 1)** $20 < t_{\frac{1}{2}} < 23$;	**2**

Question	Answer	Marks
8(c)(i)	the mass of all the particles in a nucleus is greater than differs from the nuclear mass ; the nuclear binding energy is the energy equivalent of this difference ; **OR** equal to the work required to separate all nucleons in nucleus ; to infinity / great distance ;	**2**
8(c)(ii)	mass of 38 p = 38.2974: mass of 52 n = 52.4508 total 90.7484	**1**
	mass defect = 90.7484 – 89.907 = 0.841 u	**1**
	(0.841 u = 783 MeV) = 8.70 MeV per nucleon and 2 or 3 s.f.	**1**
8(c)(iii)	graph starting (for hydrogen) at zero	**1**
	reaching a peak (for iron) between 8–10 MeV and A = 40 – 80	**1**
	falling after this by less than 50% to A = approx. 250	**1**

Question	Answer	Marks
9(a)(i)	the positive plate has a charge on it of +4.0 μC	**1**
	the negative plate has a charge on it of –4.0 μC	**1**
9(a)(ii)1	($Q = CV = 8.6 \times 10^{-6} \times 2.8$ V) = 2.4×10^{-5} (C)	**1**
9(a)(ii)2	the rate of charging will vary with internal resistance / internal resistance only affects rate or time of charging / when fully charged current is zero / there are no lost volts	**1**
	the (final) charge only depends on the emf	**1**

Question	Answer	Marks
9(a)(ii)3	energy = $\frac{1}{2}CV^2 = 0.5 \times 8.6 \times 10^{-6} \times 2.8^2$	**1**
	$= 3.4 \times 10^{-5}$ (J)	**1**
9(b)	reorganise to $\ln q = \ln q_0 - t/RC$	**1**
	$t/RC = (\ln 68 \times 10^{-6}) - (\ln 18 \times 10^{-6}) = (-9.596) - (-10.925)$ (= 1.329)	**1**
	$t = 1.329 \times 47\,000 \times 3.8 \times 10^{-6} = 0.24$ s (0.2374)	**1**
9(c)(i)	graph in phase with voltage	**1**
	Max. charge = CE marked on axis in correct position AND correct graph	**1**
9(c)(ii)	**1** cosine curve (or – cosine curve)	**1**
	starting with maximum value	**1**
	2 $Q = CE \sin 2\pi ft$	**1**
	$dQ/dt = CE\,2\pi f \cos 2\pi ft$ so peak current = $CE\,2\pi f$	**1**
9(c)(iii)1	$\sin^2$ curve with frequency twice that of the frequency of the charge	**1**
	max value is $\frac{1}{2}CE^2$	**1**
9(c)(iii)2	capacitor is discharging at these times / no energy is dissipated / current and voltage are out of phase	**1**
	at these times energy will be returned to the supply	**1**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>10(a)</td><td>simple answer (1 mark)
time is the same for all observers / passes at same rate ;
developed answer (2 marks)
e.g. the interval between two events is the same for all observers ;
clocks in all reference frames run at the same rate ;
events that are simultaneous for one observer are simultaneous for all observers ;

any two different valid points
2 marks max.</td><td>2</td></tr>
<tr><td>10(b)(i)</td><td>
<table>
<tr><td></td><td>Time recorded by X during experiment</td><td>State whether the time recorded by Y is equal to / less than / more than the time recorded by X.</td><td>Write an expression for the time recorded by Y in terms of the time recorded by X, and v and c.</td></tr>
<tr><td>experiment 1</td><td>T_1</td><td>Less than (1)</td><td>$T_1\sqrt{1-\frac{v^2}{c^2}}$ (1)
(accept $T_1\frac{1}{\gamma}$)</td></tr>
<tr><td>experiment 2</td><td>T_2</td><td>Equal to</td><td>T_2 (1 mark for both)</td></tr>
<tr><td>experiment 3</td><td>T_3</td><td>More than (1)</td><td>$T_3 / \sqrt{1-\frac{v^2}{c^2}}$ (1)
(accept γT_3)</td></tr>
</table>
</td><td>5</td></tr>
<tr><td rowspan="2">10(b)(ii)</td><td>the results from experiments 1 and 3 show that time passes at different rates for observers in relative motion</td><td>1</td></tr>
<tr><td>if absolute time was correct then the clocks would agree in all three experiments</td><td>1</td></tr>
<tr><td>10(c)(i)</td><td>time = distance/speed = $4.2 \times 3.0 \times 10^8 \times 3.2 \times 10^7 / 6.0 \times 10^4 = 6.7 \times 10^{11}$ s = $6.7 \times 10^{11} / 3.2 \times 10^7$ = 21 000 years (20 938)</td><td>1</td></tr>
</table>

Question	Answer	Marks
10(c)(ii)	time dilation factor is $\sqrt{\left(1-\frac{v^2}{c^2}\right)} = 0.99999998 \approx 1$	**1**
	so very slightly less than 20 000 years would pass inside the spacecraft – much longer than one human lifetime.	**1**
10(c)(iii)	using velocity in units of *c* and time in units of years: time taken on trip = time taken as measured from Earth $\times \sqrt{\left(1-\frac{v^2}{c^2}\right)} = (8.4c\,/\,v) \times \sqrt{\left(1-\frac{v^2}{c^2}\right)} = 5$	**1**
	simplification: $(5v\,/\,8.4c)^2 = (1 - \frac{v^2}{c^2})$ $0.354v^2\,/\,c^2 = 1 - \frac{v^2}{c^2}$ $1.354v^2 = c^2$	**1**
	$v = 0.86c$	**1**
10(c)(iv)	<u>length contraction will occur.</u> ; second mark for link to reference frames, e.g. 4.2 light years is measured in an inertial reference frame at rest with respect to the Earth ; the astronaut is in a different inertial reference frame ; **2 marks max.**	**2**
10(d)(i)	two events that are simultaneous for one observer can occur at different times for an observer in relative motion	**1**

Question	Answer	Marks
10(d)(ii)	<u>if time was absolute events that are simultaneous for one observer would be simultaneous for all observers</u> ; first point required + any additional valid point some observers cannot agree on simultaneity / order of events so this undermines the idea of absolute time ;	**2**

Question	Answer	Marks
11(a)(i)	$\Delta p = h/2\pi x = 6.63 \times 10^{-34} / 2\pi \times 7.30 \times 10^{-15}$	**1**
	$\Delta p = 1.45 \times 10^{-20}$ (kgms^{-1})	**1**
11(a)(ii)	$p = mv$ and $E_K = mv^2 = \frac{1}{2}(mv)^2 / m$	**1**
	$E_K = p^2 / 2m$ or $p = \sqrt{(2mE_K)}$	**1**
11(a)(iii)	$(\Delta E_K = \Delta p^2 / 2m) = 6.29 \times 10^{-14}$ (J)	**1**
11(a)(iv)	$\frac{1}{2} mv^2 = 6.29 \times 10^{-14}$ $v = 8.68 \times 10^6\ \text{m s}^{-1}$	**1**
	$v << c$ so relativistic effects negligible (or gamma-factor close to 1)	**1**
11(a)(v)	conversion: 8.0 MeV = 1.3×10^{-12} J OR 6.29×10^{-14} = 393 keV	**1**
	comparison: 6.26×10^{-14} J << 1.3×10^{-12} J OR 393 keV << 8.0 MeV	**1**
	conclusion: so uncertainty in KE has little/no effect on stability	**1**

Question	Answer	Marks
11(b)(i)	(EPE = $Q_1Q_2 / 4\pi\varepsilon_0 r$) = $-(1.60 \times 10^{-19} \times 79 \times 1.60 \times 10^{-19}) / (4 \times \pi \times 8.85 \times 10^{-12} \times 7.3 \times 10^{-15})$	**1**
	= $(-)2.5 \times 10^{-12}$ J	**1**
	= -2.5×10^{-12} J	**1**
11(b)(ii)	using results from **(a)**: the uncertainty in KE for a particle trapped inside the nucleus will be $E_K = \Delta p^2 / 2m$ which is proportional to $1 / m$; ΔE_K(electron) = $(m_n / m_e)\, \Delta E_K$(neutron) = $(1.67 \times 10^{-27} / 9.11 \times 10^{-31}) \times 6.26 \times 10^{-14} = 1.15 \times 10^{-10}$ J ; to remain in nucleus total electron energy (KE + PE) must be < 0 (i.e. negative) ; KE = 1.15×10^{-10} J > PE = 2.5×10^{-12} J so total energy is positive and electron is not trapped (not in a bound state) ; OR derive uncertainty in KE starting from de Broglie relation ;; then final two marking points above ;;	**4**
11(c)	in order to make predictions about the future we need to know positions and momenta of particles in the present ; present values + physical theories lead to predictions ; for accuracy we need precise values ; the uncertainty principle means that a precise measurement of position results in great uncertainty in momentum therefore it is impossible to have precise values to feed into our theories ; this is a fundamental aspect of nature and not a result of poor measuring equipment ; small uncertainties in present positions / momenta result in larger and larger errors in prediction as time moves forward ; the best theory for predicting the future is quantum theory but this is an indeterministic / probabilistic theory ; **3 marks max.**	**3**

Question	Answer	Marks
12(a)(i)	light will diffract as it leaves the torch causing the beam to spread out ; reference to single slit or circular hole diffraction pattern or equation ; the amount of diffraction depends on the diameter of the torch ; the torch would need infinite diameter to produce a cylindrical beam ; any two valid points, but must refer to diffraction **2 marks max.**	**2**
12(a)(ii)	reference to superposition or interference pattern from two slits ; idea that photon is represented by a wavefunction that is spread out on the screen ; wavefunction collapses when an observation is made ; we can only predict the probability that the photon arrives at any particular position ; 3 different points. **3 marks max.**	**3**

Question	Answer	Marks
12(a)(iii)	entropy of the universe would decrease ; this would violate the second law of thermodynamics ; **first two points and one other relevant correct point, e.g.** this would involve heat flow from lower to higher temperatures which is impossible ; heat extracted from objects inside the refrigerator lowers their entropy ; heat dumped in the environment increases its entropy ; work done is transferred to heat which is dumped in the environment ; extra heat from work ensures that entropy will increase ; **3 marks max.**	**3**
12(b)(i)	Bonds form and latent heat of fusion is released	**1**
	Heat / thermal energy transferred to the environment.	**1**
12(b)(ii)	**1 the water:** entropy decreases ; structure becomes more ordered so there is a smaller number of ways of distributing the energy amongst the particles ; **2 the surroundings: max 2** heat transferred to the environment increases its entropy ; the number of ways of distributing energy amongst particles in the environment increases ; because overall entropy of Universe must increase / cannot decrease ; **4 marks max.**	**4**

Question	Answer	Marks
12(b)(iii)	for water to freeze the entropy of the universe must not decrease OR this would violate the second law of thermodynamics because entropy of the universe would decrease	**1**
	at 10°C the decrease of entropy from the water would be greater than the increase of entropy of the surroundings	**1**
12(c)	As $v \rightarrow c$ denominator on RHS $\rightarrow 0$; so $m \rightarrow \infty$ OR m increases without limit OWTTE ; THEN EITHER $E = mc^2$; this requires infinite energy and is therefore impossible ; OR $a = F / m \rightarrow 0$ / as $v \rightarrow c$ acceleration decreases toward zero ; approaches a constant maximum velocity (c) / cannot exceed c ;	**4**