Cambridge Assessment International Education
Cambridge Pre-U Certificate

PHYSICS **9792/03**

Paper 3 Written Paper 3 **May/June 2019**

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)	*either* acceleration towards centre of circle / at right-angles to velocity	**1**
	or acceleration due to force towards centre of circle / at right-angles to velocity	**(1)**
1(b)(i)	no tendency to slide or rotate	**1**
	linked to either no sideways force or torque / moment relative to passenger	**1**
1(b)(ii)	vertical component of contact force = $mg = N \cos \theta$	**1**
	horizontal component of contact force = $N \sin \theta = mg (\sin \theta / \cos \theta)$ $= mg \tan \theta$	**1**
	centripetal force = $mv^2 / r = mg \tan \theta$ and completion of algebra to get to $\tan \theta = v^2 / rg$	**1**
1(c)	zero from X to A and from C to Y	**1**
	plateau between A and B and taller plateau between B and C	**1**
	plateaus between A and B and between B and C in opposite directions	**1**
	magnitudes of plateaus labelled A–B: 5° and B–C: 10° (9.9°)	**1**
1(d)	**either** passengers on different sides of the train have different radius so no **or** width of carriage / train very much smaller than radius of curve so yes **or** front part of carriage / train enters the curve before the rear so no **or** length of carriage / train very much smaller than radius of curve so yes	**1**

Question	Answer	Marks
2(a)	charge / voltage	**1**
2(b)(i)	4.0×10^{-4} (s)	**1**
2(b)(ii)	(0.10 s is) 250 time constants **or** 0.10 s >> time constant	**1**
2(c)(i)	–0.63, –0.76, –0.89, –1.02, –1.14, –1.27 2 marks all values correct	**max 2**
2(c)(ii)	all six points plotted correctly	**1**
	acceptable best-fit straight line through points	**1**
2(d)(i)	y-intercept identified as ln I_0	**1**
	I_0= 0.60 (mA)	**1**
2(d)(ii)	gradient identified as –1 / time constant	**1**
	time constant = 0.80 (s)	**1**
2(d)(iii)	(resistance = time constant / capacitance = $0.80 / (40 \times 10^{-6})$) = 20 (kΩ)	**1**
2(d)(iv)	(e.m.f. = $I_0 R$ = $(0.60 \times 10^{-3}) \times (20 \times 10^{3})$) = 12 (V)	**1**

Question	Answer	Marks
3(a)	energy needed / work done to move the masses	**1**
	from infinity to the distance of separation	**1**
3(b)(i)	(mass of planet =) $\frac{4}{3}\pi R^3 \rho$	**1**
3(b)(ii)	(gravitational potential energy =) $-\frac{4}{3}\pi R^2 \rho G m$	**1**
3(c)(i)	(for an object of mass m) kinetic energy at surface = gain in potential energy (needed to escape)	**1**
	$\frac{1}{2} m v^2 = \frac{4}{3}\pi R^2 \rho G m$	**1**
	clear completion of algebra to arrive at $v = \sqrt{\frac{8\pi G R^2 \rho}{3}}$	**1**
3(c)(ii)	($v = \sqrt{}$ [$8 \times 3.14 \times 6.67 \times 10^{-11} \times (1.74 \times 10^6)^2 \times 3.34 \times 10^3 / 3$]) 2.38×10^3 (m s^{-1})	**1**
3(d)(i)	$(3/2)kT = ½ m\langle c^2 \rangle$ and T = 373 K	**1**
	$(3/2) \times 1.38 \times 10^{-23} \times 373 = ½ \times 2 \times 1.67 \times 10^{-27} \langle c^2 \rangle$	**1**
	r.m.s. speed = 2.15×10^3 (m s^{-1})	**1**
3(d)(ii)	many molecules have speeds (sufficiently) <u>greater</u> than the r.m.s. speed and so escape owtte	**1**

Question	Answer	Marks
4(a)(i)	induced e.m.f. is equal / directly proportional to rate	**1**
	of change of / cutting (magnetic) flux / flux linkage	**1**
4(a)(ii)	direction of induced e.m.f. will oppose the change that caused it	**1**
4(b)(i)	flux cut = flux density × area / $4.7 \times 10^{-5} \times \sin 50° \times \pi \times 8.0^2$	**1**
	$= 7.2 \times 10^{-3}$	**1**
	unit given as Wb	**1**
4(b)(ii)	time for one rotation = 1 / 200 = 5.0×10^{-3} s	**1**
	e.m.f. = $(7.2 \times 10^{-3}) / (5.0 \times 10^{-3})$ = 1.4 (V)	**1**
4(b)(iii)	**either** correct reasoning, making appropriate use of Lenz's Law or Fleming's Right-Hand Rule, to conclude that if current were to flow in the blade it would flow <u>from the centre outwards</u>	**1**
	or correct reasoning, making appropriate use of Fleming's Left-Hand Rule, to conclude that the force acting on a positively charged particle is towards the <u>outer</u> end of the blade.	**(1)**
	hence the <u>outer</u> end is at the higher potential	**1**
4(b)(iv)	**either** both rotor blades have the same e.m.f. induced across them	**1**
	or both rotor blades have the same end at the higher potential	**(1)**
	hence potential difference between the two ends is <u>zero</u>	**1**

Question	Answer	Marks
5(a)	e.g. collisions are perfectly elastic e.g. particles occupy negligible volume e.g. no (long-range) intermolecular forces between particles e.g. motions are random (any two points to max 2)	**max 2**
5(b)(i)&(ii)	specks / lights jiggling around owtte	**1**
	smoke particles observed being bombarded by invisible air particles	**1**
5(c)(i)	$pV = nRT$ **or** $1.00 \times 10^5 \times V = 5.00 \times 8.31 \times 300$	**1**
	$V = 0.125$ (m^3)	**1**
5(c)(ii)	'A' plotted at correct point: $p = 1.00$ ($\times 10^5$ Pa); $V = 0.125$ (m^3)	**1**
5(c)(iii)	curved line with negative decreasing gradient passing through A	**1**
5(d)(i)	horizontal straight line with one end at A	**1**
	other end at $V = 0.25$ m^3 (0.249)	**1**
5(d)(ii)	work done by gas = area under graph **or** $p\,\Delta V$ or $W = 1.0 \times 10^5 \times 0.125$	**1**
	= 12.5 (kJ)	**1**
5(d)(iii)	thermal energy supplied = increase in internal energy – work done on gas = 18.7 – (– 12.5)	**1**
	= 31.2 (kJ)	**1**

Question	Answer	Marks
6(a)(i)	radioactive decay is a random process	**1**
6(a)(ii)	e.g. surround the experiment with a lead shield e.g. correct for background count rate e.g. time for longer than one minute any sensible suggestion related to accuracy / validity of readings	**1**
6(a)(iii)	386 (cpm)	**1**
6(a)(iv)	correct calculation of N or λ	**1**
	$A = \lambda N$ *or* $A = (52 \times 10^{-3} / 238) \times 6.02 \times 10^{23} \times \ln 2 / (4.5 \times 10^{9} \times 365 \times 24 \times 3600)$	**1**
	640 Bq / 2.0×10^{10} yr^{-1}	**1**
	640 **and** unit given as Bq	**1**
6(a)(v)	(percentage $= 100 \times 386 / (60 \times 642)$) $= 1.0$ %	**1**
6(b)	there are no other emissions (apart from those from uranium-238)	**1**
6(c)	same volume of solution	**1**
	same distance between test tube and radiation detector	**1**

Question	Answer	Marks
7(a)	speed of galaxies is directly proportional to their distance from Earth	**1**
7(b)	measure/observe wavelengths of spectral lines/light	**1**
	velocity can be determined from the shift in wavelength or v $\propto \Delta\lambda/\lambda$	**1**
7(c)(i)	**either** the observed light has an increased wavelength **or** the light observed is redshifted	**1**
	this tells us that galaxies are moving away from Earth	**1**
7(c)(ii)	galaxies all moving away from a point implies that they all originated from that point	**1**
	(since speed $\propto$ distance) all galaxies have been travelling for same time so were at that single point at the same moment in time	**1**

Question	Answer	Marks
8(a)	moment of inertia depends on distance of mass from axis **or** reference to $I = \Sigma\, mr^2$	**1**
	(when pivoted at end) there is more mass farther from axis	**1**
8(b)(i)	$\delta m = m\delta x / L$	**1**
8(b)(ii)	$\delta I = mx^2\delta x / L$	**1**

Question	Answer	Marks
8(b)(iii)	$I = \Sigma\ \delta I$ **or** $I = \Sigma\ mx^2\delta x / L$ (idea of summation)	**1**
	$I = \int_0^L \frac{mx^2 dx}{L}$ (sets up integral including correct limits)	**1**
	$I = \left[\frac{mx^3}{3L}\right]_0^L$ (integrates)	**1**
	shows that $I_P = \frac{1}{3}mL^2$ follows from their integral	**1**
8(b)(iv)	using result above on two rods, each of length $L / 2$ and mass $m / 2$: $I_C = 2 \times \frac{1}{3}\left(\frac{m}{2}\right)\left(\frac{L}{2}\right)^2$	**1**
	$= \frac{1}{12}mL^2$	**1**
	or By integration: $I_C = 2\int_0^{L/2} \frac{mx^2 dx}{L}$	**(1)**
	$= \frac{1}{12}mL^2$	**(1)**

Question	Answer	Marks
8(c)(i)	CM at 5.0 / 2 m above ground	**1**
	ΔGPE = mgh = 200 × 9.81 × (5.0 / 2) = 4905 J	**1**
8(c)(ii)	Conservation of energy: RKE = ½ $I\omega^2$ = ½ (1 / 3 mL^2) ω^2 = 4905 J	**1**
	ω^2 = 6ΔGPE / mL^2 **or** ω = 1 / L $\sqrt{(6\Delta \text{GPE} / m)}$	**1**
	ω = 2.43 rad s^{-1} / $v = r\omega$	**1**
	= 5.0 × 2.27 = 12(.1) (m s^{-1})	**1**
8(d)	New moment of inertia = ($I + mb^2$)	**1**
	Angular momentum is conserved	**1**
	$I\omega = (I + mb^2)\ 0.99\ \omega$	**1**
	Rearranged to give $I = 99\ mb^2$	**1**

Question	Answer	Marks
9(a)	amplitude = 0.014 (m)	**1**
	frequency = 12 / 2π = 1.9 (Hz)	**1**
9(b)(i)	v = (–) 0.17 sin (12t)	**1**
	v = – *0.17* sin (12t) 1 mark for negative sign	**1**
9(b)(ii)	a = (–) 2.0 cos (12t)	**1**

Question	Answer	Marks
9(c)	a_{max} = 0.90 m s^{-2} AND v_{max} = 0.081 m s^{-1}	1
	$\omega = a_{max} / v_{max}$ = 11(.1) (s^{-1})	1
	$f = (\omega / 2\pi)$ = 1.8 (Hz) (1.77 Hz)	1
	$A = v_{max} / \omega$	1
	= 7.3 × 10^{-3} (m) (7.29 × 10^{-3} m)	1
9(d)(i)	attempt to use Pythagoras's theorem	1
	$a_{max} = \sqrt{(8.0^2 + 1.5^2 + 1.5^2)}$ = 8.3 (m s^{-2})	1
9(d)(ii)	oscillations might not be in phase owtte	1
9(e)(i)	<u>resonance</u> mentioned	1
	more detail: e.g. ground vibration frequency close to natural frequency of building	1
9(e)(ii)	any 2 from: natural frequency of building vibrations mass of building stiffness of building height of building / position of centre of gravity level of damping included in design of building	max 2
9(f)	Suitable test explained: e.g. r × PGA = constant	1
	applied for at least 3 values	1
	conclusion that data does / does not support proposal with valid justification either way.	1

Question	Answer	Marks
10(a)(i)	angular momentum = mvr	**1**
	h / λ substituted for mv AND $n\lambda / 2\pi$ substituted for r	**1**
	rearranged to show that $L = \dfrac{nh}{2\pi}$	**1**
10(a)(ii)	$\Delta L = \dfrac{(n+1)h}{2\pi} - \dfrac{nh}{2\pi} = \dfrac{h}{2\pi}$	**1**
10(a)(iii)	photon must have angular momentum $h / 2\pi$	**1**
	because angular momentum is conserved	**1**
10(b)(i)	KE and (electrostatic) PE	**1**
10(b)(ii)	use of $\dfrac{mv^2}{r} = \dfrac{e^2}{4\pi\varepsilon_0 r^2}$	**1**
	to get $KE = \dfrac{e^2}{8\pi\varepsilon_0 r}$	**1**
	$EPE = -\dfrac{e^2}{4\pi\varepsilon_0 r}$	**1**
	Total energy $= -\dfrac{e^2}{8\pi\varepsilon_0 r}$	**1**

Question	Answer	Marks
10(b)(iii)	if energy is quantised then *r* must also be quantised	**1**
	extra detail: e.g. link between *r* and *n* demonstrated algebraically (*r* proportional to n^2)	**1**
10(c)(i)	$\Delta E = -13.6 - -3.4$ eV = (–) 10.2 eV	**1**
	1.63×10^{-18} (J)	**1**
	$\lambda = 1.22 \times 10^{-7}$ (m)	**1**
10(c)(ii)	$-\dfrac{13.6\,\text{eV}}{n^2} = -\dfrac{e^2}{8\pi\varepsilon_0 r}$	**1**
	$r = \dfrac{n^2 e^2}{8\pi\varepsilon_0 (13.6\text{eV})}$ (expression for r)	**1**
	Difference of n^2 values, i.e. $(2^2 - 1^2)$ seen	**1**
	($\Delta r = \dfrac{\left(1-2^2\right)e^2}{8\pi\varepsilon_0 (13.6\,\text{eV})}$)= (–) 1.6×10^{-10} m	**1**

Question	Answer	Marks
11(a)(i)	analogy with mechanical waves – e.g. sound / water waves consist of vibrating particles in a medium so light should too light can travel through a vacuum so there must be something present in the vacuum to support the light waves	**max 1**
11(a)(ii)	the speed of light would be constant relative to the aether	**1**
	the speed of light measured by an observer moving through the aether would be a relative velocity (i.e. speed of light minus observer's velocity)	**1**
11(b)(i)	phase difference between paths path difference between paths time difference between paths relative speed of light along each path	**max 1**
11(b)(ii)	they assumed the earth was moving through the aether motion through the aether would make light travel faster along one path than the other (introduce a time / phase / path difference) rotation would change the time difference (e.g. rotation through 90° would reverse the time difference) orbital motion affects Earth's velocity through aether	**max 2**
11(b)(iii)	fringes did not change / null result	**1**
11(b)(iv)	The laws of physics are the same in all inertial reference frames owtte	**1**
	The speed of light is the same for all (inertial) observers	**1**

Question	Answer	Marks
11(b)(v)	Einstein dispensed with the aether hypothesis owtte speed of light is independent of the motion of the observer / apparatus so time taken on each path is the same and there is no shift in fringe positions / no phase difference since laws of physics are the same in all inertial reference frames the results of MM experiment should be the same whatever the velocity of the apparatus statement that experiment in **(b)** was carried out in an inertial frame	**max 3**
11(c)(i)	$d\sqrt{\left(1-\frac{v^2}{c^2}\right)}$	**1**
11(c)(ii)	$\frac{d}{v}\sqrt{\left(1-\frac{v^2}{c^2}\right)}$	**1**
11(c)(iii)	$\frac{d}{v}$	**1**
11(c)(iv)	the two observers do not agree about the synchronisation of clocks A and B **or** reference to the relativity of simultaneity	**1**
	observer at rest relative to AB thinks time on A is the same as B (i.e. d / v) when rocket passes	**1**
	rocket observer thinks that B started before A so that time on clock A is less than d / v	**1**

Question	Answer	Marks
11(d)	in reference frame of photon: length contraction makes distance between Sun and Earth smaller so time is reduced	**1**
	or In Earth's reference frame: Time dilation factor for photon reduces the time for the journey	**(1)**
	$\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}} = \dfrac{1}{\sqrt{1-\dfrac{c^2}{c^2}}} = \dfrac{1}{0} = \infty$ **and** so journey is instantaneous owtte	**1**

Question	Answer	Marks
12(a)	de Broglie wavelength depends on velocity: $\lambda = \dfrac{h}{mv}$	**1**
	need a single wavelength / monochromatic source (to get a clear pattern distinct fringes)	**1**
12(b)	to ensure (near) normal incidence / avoid having a range of incidence angles	**1**
	to create a distinct pattern **or** to avoid effects that lead to an indistinct pattern (e.g. centres of patterns displaced / projected slit separation different)	**1**
12(c)	$\lambda = \dfrac{h}{mv} = \dfrac{6.63 \times 10^{-34}}{1.2 \times 10^{-24} \times 200}$	**1**
	2.8×10^{-12} (m)	**1**

Question	Answer	Marks
12(d)	Uses $x = \frac{D}{a}$	**1**
	$= \frac{2.76 \times 10^{-12} \times 1.2}{100 \times 10^{-9}}$	**1**
	$=3.3 \times 10^{-5}$ (m)	**1**
12(e)	need to maximise the fringe separation fringe separation $\propto$ 1 / a so slit separation must be as small as possible fringe separation $\propto \lambda$ so wavelength must be as large as possible to make λ large we need to make v small $\lambda \propto 1 / v$ from de Broglie relation	**max 4**
12(f)(i)	initial conditions for each molecule are the same	**1**
	but they arrive at different positions on the screen	**1**
	or initial conditions for each molecule are the same	**(1)**
	but we cannot predict where they will arrive on the screen	**(1)**
	or they arrive at random positions on the screen	**(1)**
	we can only predict the probability of where they will arrive	**(1)**

Question	Answer	Marks
12(f)(ii)	Prior to detection the molecule is described by a wavefunction that has a value everywhere on the screen	1
	When they arrive the wavefunction collapses (everywhere except where the molecule is detected).	1
	or Position where the molecule arrives on screen	**(1)**
	Depends on the slit through which it did not pass	**(1)**
12(g)	Quantum theory works on the atomic scale Quantum effects are not usually apparent on the macroscopic / human scale Classical physics works well on the macroscopic / human scale Physicists want to see if quantum / interference effects occur with large / macroscopic objects Physicists want to establish whether there is a cut-off between the quantum and classical worlds	**max 3**

Question	Answer	Marks
13(a)(i)		**4**

condensation at 100 °C	decreases	stays the same	increases	
total energy of water	X			1
total entropy of water	X			
[redacted]				
total energy of Universe		X		1
total entropy of Universe			X	

cooling from 100 °C to 20 °C	decreases	stays the same	increases	
total energy of water	X			1
total entropy of water	X			
[redacted]				
total energy of Universe		X		1
total entropy of Universe			X	

Question	Answer	Marks
13(a)(ii)	the entropy of an isolated / closed system / the Universe tends to a maximum	**1**
13(a)(iii)	entropy of the Universe / surroundings has increased	**1**
	total entropy increase of Universe / surroundings > decrease of entropy of the water	**1**

Question	Answer	Marks
13(b)(i)	nett entropy change: $\Delta S = \frac{-Q}{T_{outside}} + \frac{Q}{T_{inside}}$ **or** $\Delta S_{out} = \frac{(-)Q}{T_{outside}}$ **and** $\Delta S_{in} = \frac{Q}{T_{inside}}$	1
	$\Delta S_{overall}$ must be greater or equal to zero **or** $\Delta S_{out} \leq \Delta S_{in}$	1
	shows that if $T_{out} < T_{in}$ entropy would decrease	1
13(b)(ii)	heat supplied to building = Q + W	1
	entropy change $\geqslant$ 0 so minimum work when entropy change = 0	1
	$\Delta S = \frac{Q+W}{T_{in}} - \frac{Q}{T_{out}}$ (= 0)	1
	$\frac{Q+W}{T_{in}} = \frac{Q}{T_{out}}$	1
	leading to $W = Q\left(\frac{T_{in}}{T_{out}} - 1\right)$	1
13(c)(i)	past and future can be distinguished thermodynamically	1
	past = low entropy and future = high entropy	1
	or the direction from the past to the future	**(1)**
	is the same as the direction of increasing entropy	**(1)**

Question	Answer	Marks
13(c)(ii)	equilibrium corresponds to maximum entropy **or** entropy is not changing	**1**
	so a direction of change cannot be linked to it **or** there is no distinction (in terms of entropy) between past and future	**1**
13(c)(iii)	it is not in equilibrium **or** its entropy will continue to increase **or** it has a (thermodynamic) arrow of time	**1**