CAMBRIDGE INTERNATIONAL EXAMINATIONS

Pre-U Certificate

MARK SCHEME for the May/June 2014 series

9792 PHYSICS

9792/03 Paper 3 (Part B Written), maximum raw mark 140

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Section A

1	(a)	(i)	$\omega = 2\pi / T = 2\pi / 27.5$	[1]	
			$= 0.228\,\text{rad}\,\text{s}^{-1}$	[1]	
		(ii)	speed $= 2\pi r / T = 2\pi \times 16.0 / 27.5 = 3.66\,\text{m}\,\text{s}^{-1}$	[1]	
		(iii)	acceleration $= v^2 / r = 3.66^2 / 16 = 0.835\,\text{m}\,\text{s}^{-1}$	[1]	
		(iv)	0	[1]	
			(rad) s^{-2}	[1]	[6]
	(b)		(pair of weight of passenger is) force (passenger exerts) <u>on</u> the Earth	[1]	
			by gravity	[1]	
			(pair of force seat exerts on passenger is) force passenger exerts <u>on</u> the seat	[1]	[3]
	(c)	(i)	force = mass × acceleration	[1]	
			$= 62.4 \times 0.835 = 52.1\,\text{N}$	[1]	
		(ii)	resultant always towards centre of rotation	[1]	
			W arrows the same on passenger in all positions	[1]	
			S arrows so $W + S$ can (approximately) equal resultant	[2]	
			One off for each mistake to minimum zero.		[6]
					[15]
2	(a)		$(F =)\ GMm / r^2 = ma$	[1]	
			$v = 2\pi r / T$ **or** $\omega = \pi / T$	[1]	
			apply giving $GMm / r^2 = m\,(2\pi r / T)^2$ **or** $mr\,(2\pi / T)^2$	[1]	
			F = ma cancelling m and rearranging to show only $T^2 = kr^3$ **and** states k is constant	[1]	[4]
	(b)		reorganise as $M = 4\pi^2 r^3 / T^2 G$ at some stage **or** see $(365 \times 24 \times 3600)$	[1]	
			correct substitution $M = 4\pi^2 (1.50 \times 10^{11})^3 / (365 \times 24 \times 3600)^2 \times (6.67 \times 10^{-11})$	[1]	
			$= 2.01 \times 10^{30}\,\text{kg}$	[1]	[3]
	(c)		need to have something rotating around the Earth with period measured	[1]	
			use the Moon or a man-made satellite at known distance (from the centre of the Earth)	[1]	[2]
	(d)		accept valid example		
			e.g. rotation of galaxies, statement **and** explanation	[2]	[2]
			(1 mark only for examples correct but not Newtonian physics)		
					[11]

3 **(a)** (electric field strength is) force per unit charge [1]
positive charge [1] [2]

(b) **(i)** electric field strength $= Q / 4\pi\varepsilon_0 r^2$ [1]
$= 1.6 \times 10^{-19} / 4\pi \times 8.85 \times 10^{-12} \times (2.8 \times 10^{-10})^2$ [1]
$= 1.84 \times 10^{10}$ N C^{-1} [1]

(ii) Force = *Ee* OR working from scratch [1]
$= 1.84 \times 10^{10} \times 1.6 \times 10^{-19} = 2.94 \times 10^{-9}$ N [1] [5]

(c) **(i)** attraction (A) from 4 nearest negative ions **and** repulsive (R) from positive ions [1]
A > R [1]
R ≈ A/2 [1]

(ii) zero (N) [1]

(iii) to move it back into place [1]

(iv) an equilibrium position **or** opposes the charge [1]
of minimum potential energy (for the whole network) [1] [7]

[14]

4

t / s	V / V	ln$V$
0	12.0	2.48
10	4.25	1.45
20	1.09	0.09
30	0.51	–0.67
40	0.19	–1.66
50	0.066	–2.72

(a) all ln V / V values for 2 marks
deduct 1 mark for each mistake to minimum of zero [2] [2]

(b) 2 marks for all points plotted with + or – half a small square [2]
deduct 1 mark for each mistake to minimum of zero [2] [2]

(c) reading for 20 s circled [1] [1]

(d)	log value drops by 0.693 for a factor of 2	[1]	
	e.g. 4.158 fall is 6 half lives ; t_6 = 40 s so half life = 6.7 ± 0.2 s	[1]	[2]
	OR		
	use of gradient (– 0.104 ± 0.003)	[1]	
	$t_{\frac{1}{2}}$ in range 6.5 to 7.7 (s)	[1]	

(e)	calculates number of half lives:	[1]	
	e.g. 100 s is 100 / 6.7 = 15 half lives	[1]	
	original charge = $CV = 2.4 \times 10^{-6} \times 12 = 2.88 \times 10^{-5}$	[1]	
	therefore charge remaining = $2.88 \times 10^{-5} / 2^{15} = 8.8 \times 10^{-10}$ C	[1]	[4]
	OR		
	uses $V = V_o\, e^{-\lambda \times 100}$ or similar expression	(1)	
	$V = 12\, e^{10.3} = 4.0 \times 10^{-4}$	(1)	
	$Q = C \times V = 4.0 \times 10^{-4} \times 2.4 \times 10^{-6}$	(1)	
	$= 9.6 \times 10^{-10}$ (C)	(1)	

(f)	**(i)**	capacitance unit = C / V; resistance unit = V / A = Vs / C	[1]	
		unit of CR = CVs / VC = s	[1]	
	(ii)	CR = 9.6 s	[1]	
		marked correctly at 9.6 and 48.0	[1]	[4]
				[15]

5	**(a)**	**(i)**	$V/T = 4.2 \times 10^{-3} / 306 = 8.3 \times 10^{-3} / T$	[1]	
			$T = 8.3 \times 306 / 4.2 = 605$ K	[1]	
		(ii)	work done = $p\Delta V = 1.12 \times 10^5 \times (8.3 \times 10^{-3} - 4.2 \times 10^{-3})$	[1]	
			$= 1.12 \times 10^5 \times 4.1 \times 10^{-3} = 460$ J	[1]	[4]
	(b)		$300^2 + 400^2 + 500^2 + 1000^2 = 1\,500\,000$	[1]	
			mean square speed = 375 000; rms speed = 612 m s^{-1}	[1]	[2]
	(c)	**(i)**	$½m\langle c^2\rangle = 3kT/2$; $0.5 \times 4.7 \times 10^{-26} \times \langle c^2\rangle = 3 \times 1.38 \times 10^{-23} \times 306 / 2$	[1]	
			$\sqrt{(\langle c^2 \rangle} = \sqrt{2.7 \times 10^5} = 520$ m s^{-1}	[1]	
		(ii)	at twice the temperature k.e. is twice so speed is × 1.41 = 730 m s^{-1} OR via speed $\propto \sqrt{T}$	[1]	[3]
	(d)		peak moves to the right	[1]	
			area beneath both graphs approximately equal	[1]	[2]
					[11]

6	**(a)**	**(i)**	k.e. = $\frac{1}{2}mv^2 = 0.5 \times 6.6 \times 10^{-27} \times (3.0 \times 10^7)^2$	[1]	
			$= 3.0 \times 10^{-12}$ J	[1]	
		(ii)	reorganise equation (at some stage) to $r = Q_\alpha Q_{Au} / 4\pi\varepsilon_0 E$	[1]	
			$r = (79 \times 1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19}) / (4 \times 3.14 \times 8.85 \times 10^{-12} \times 3.0 \times 10^{-12})$	[1]	
			$= 1.2 \times 10^{-14}$ m	[1]	[5]
	(b)		headings: quarks, leptons and force carriers or bosons	[1]	
			quarks: up, down		
			leptons; electron, neutrino,		
			force carriers: photon, gluon,	[3]	[4]
			deduct one mark for each one incorrectly placed to minimum zero		
					[9]
7	**(a)**		wavelength of maximum intensity inversely proportional to temperature		
			so 5800 K / T = 480 nm / 520 nm	[1]	
			T = 520 nm × 5800 K / 480 nm = 6280 K	[1]	[2]
	(b)		$L = 4\pi\sigma r^2 T^4$ so $r^2 = L/4\pi\sigma T^4$	[1]	
			$= 4.8 \times 10^{29} / 4\pi \times 5.67 \times 10^{-8} \times 6280^4 = 4.33 \times 10^{20}$	[1]	
			$r = \sqrt{4.33 \times 10^{20}} = 2.08 \times 10^{10}$ m	[1]	[3]
					[5]

Section B
Candidates answer three questions

8	(a)		atoms / nuclei of an element contain the same number of protons	[1]	
			and differing numbers of neutrons	[1]	[2]
	(b)	(i)	a neutron in the nucleus decays into a proton and an electron (plus an antineutrino)	[1]	[1]
		(ii)	half life = 0.698 / $1.44 \times 10^{-11} = 4.8 \times 10^{10}$ year	[1]	[1]
	(c)	(i)	$A_{Rb} = A_0$ e (to the power $-1.44 \times 10^{-11} \times 4.0 \times 10^9$)	[1]	
			= 0.94	[1]	
			valid comment that little change has occurred	[1]	[3]
		(ii)	positive intercept on the R axis	[1]	
			straight line sloping gently upwards	[1]	
			slight curve of slightly lower gradient towards the end	[1]	[3]
		(iii)	a larger ratio implies an older sample	[1]	
			need to know the initial value of R	[1]	
			need to know the initial amount / percentage of rubidium	[1]	[3]
		(iv)	any sensible suggestion e.g. half life too long; meteorite contamination; leakage; rick melting; non-uniformity in rock crystal	[1]	[1]
	(d)	(i)	recalls $F = mv^2/r$ for circular motion and $F = BQv$	[1]	
			rearrange to $r = mv/BQ$	[1]	[2]
		(ii)	curve of larger radius starting from common entry point into field	[1]	[1]
		(iii)	any correct method leading to	[1]	
			$0.68 \times 87/86 = 0.688$	[1]	
			$\Delta B = 7.9 \times 10^{-3}$ (T)	[1]	[3]
					[20]

9	(a)	(induced) emf is produced across the coil	[1]	
		proportional to the rate of change of flux linkage	[1]	[2]
	(b)	change in flux linkage **or** induced emf / p.d. in coil A **or** B	[1]	
		current induced / power in circuit for A **or** no induced current / power in coil B	[1]	
		magnetic field around coil A **or** no magnetic field around B	[1]	
		opposition to motion of magnet in A **or** no opposition to motion in B	[1]	
		accelerator is less than g / de-acceleration is g / magnet in free fall in B	[1]	[5]

(c)	**(i)**	$E/n = d\phi/dt = 2.0/400 = 5.0 \times 10^{-3}$ (Wb s^{-1})	[1]	
	(ii)	magnet is accelerating so rate of change of flux is increasing, hence increase (in magnitude) of E	[1]	
		direction of emf opposes change producing it so change in sign (answers accepted in terms of N and S pole)	[1]	[3]
(d)	**(i)**	$v = \omega r = 2\pi fr$	[1]	
		$= 2 \times 3.14 \times 50 \times 1.9 \times 10^{-2} = 5.97\,\mathrm{m\,s^{-1}}$	[1]	[2]
	(ii)	$E = (-)BAN\omega \sin(\omega t)$	[1]	[1]
	(iii)	$E = BAN\omega \sin(2\pi t/T)$	[1]	
		$= 1.7 \sin(2\pi \times 0.0018/0.020)$	[1]	
		$= 0.91\,\mathrm{V}$	[1]	[3]
	(iv)	time axis correctly labelled at $T = 20$ ms for one cycle	[1]	
		(1.8, 0.9 and 5.0,1.7) points that sine curve seems to go through	[1]	[2]
	(v)	vertical coil moving parallel to lines of flux so not cutting them	[1]	
		horizontal coil has zero flux linkage but maximum cutting rate	[1]	[2]
				[20]

10	**(a)**		(from Fig 10.1) $\delta\theta = v\delta t/r$	[1]	
			(from Fig 10.2) $\delta\theta = \delta v/v$	[1]	
			equate to eliminate $\delta\theta$	[1]	[3]
	(b)	**(i)**	$(R_1 + R_2)\cos\theta = mg$	[1]	
		(ii)	$(R_1 + R_2)\sin\theta$	[1]	
		(iii)	division of (ii) by (i)	[1]	[3]
	(c)	**(i)**	energy cannot be created or destroyed	[1]	
			only transferred from one form to another	[1]	[2]
		(ii)	recall and use $\rho = M/V$	[1]	
			substitute and arrange to $\rho = (2I)/\pi l R^4$	[1]	[2]
		(iii)	correct substitution into equation	[1]	
			$\rho = 1800\,\mathrm{kg\,m^{-3}}$	[1]	[2]
		(iv)	number of revolutions $= 6700 \times 60/2\pi = 64\,000$	[1]	[1]
		(v)	loss in rotational k.e. $= \frac{1}{2}I(\omega_f^2 - \omega_i^2)$	[1]	
			$= \frac{1}{2} \times 0.176 \times (6700^2 - 2880^2)$	[1]	
			$= 3.22 \times 10^6$ (J)	[1]	[3]

(vi)	power = $3.22 \times 10^6/6.67 = 4.83 \times 10^5$ (W)	[1]	[1]
(vii)	torque = $I\alpha$	[1]	
	= $0.176 \times (6700 - 2880)/6.67$	[1]	
	= 101 N m or equivalent unit	[1]	[3]
			[20]

11	**(a)**	**(i)**	kinetic energy and (electrical) potential energy	[1]	
			kinetic energy positive and potential energy negative	[1]	[2]
		(ii)	**any two from:**		
			electron is in a bound state	[1]	
			work must be done to remove the electron / ionise the atom	[1]	
			otherwise the electron would have enough energy to escape	[1]	
					[MAX 2]
		(iii)	(absolute) size of PE > (absolute) size of KE	[1]	[1]
	(b)		using diagrams or written explanations **any three from:**	[3]	
			electron waves form standing wave patterns in atom		
			more detail of standing wave patterns		
			energy level associated with standing wave pattern		
			intermediate values of energy not allowed		
			correct reference to equation for hydrogen levels		
			electrons can only make (quantum) jumps from one orbit to another		
			and explanation of stable ground state	[3]	
			there is a lowest allowed energy level		
			when $\lambda = 2\pi r$		
			so electron cannot fall into the nucleus		
					[MAX 5]
	(c)	**(i)**	uncertainty in the (x-component) of momentum of the electron	[1]	[1]
		(ii)	uncertainty in the (x-component) of the position of the electron	[1]	[1]
		(iii)	Δx decreases and Δp increases	[1]	[1]
		(iv)	link between momentum and k.e.	[1]	
			increased uncertainty in momentum implies increased uncertainty in k.e.	[1]	[2]
		(v)	for very small orbits the uncertainty in the k.e. becomes large enough to make the total energy positive	[1]	
			if the total energy becomes positive the electron will escape	[1]	[2]
	(d)	**(i)**	related to the probability of finding the electron at that position in the atom	[1]	[1]

		(ii)	**any two from:** the (3D) electron standing wave pattern in the atom a probability distribution for the position of the electron inside the atom density related to probability of electron being found in that part of the atom density related to amplitude squared (intensity) of wave (function)	[2]	
					[20]
12	**(a)**	**(i)**	freely falling pendulum will not swing, so period is infinite idea that it is apparently weightless	[1] [1]	[2]
		(ii)	lunar pendulum has longer time period gravity is weaker on the Moon	[1] [1]	[2]
	(b)		diagram(s) showing light path in moving clock is greater than light path in rest clock idea that the speed of light is constant for both observers use of T = distance / c so longer path leads to longer period	[2] [1] [1]	[4]
	(c)		the method will not work any one from time dilation affects the rate at which time passes so it affects all clocks in the same way there will be no time difference between the two clocks there is no relative motion between the two clocks	[1] [1]	[2]
	(d)	**(i)**	the real system has to work against frictional forces so energy is transferred to heat the amplitude of the oscillation decays with time	[1] [1]	[2]
		(ii)	the heat increases the entropy of the universe the arrow of time points from low entropy (past) to high energy (future)	[1] [1]	[2]
	(e)	**(i)**	the atom / apparatus / cat are all in one of two definite states at every moment (un-decayed / un-triggered / alive or decayed / triggered / dead if the atom decays during the hour then the atom / apparatus / cat all change to the second state at that instant when the box is opened the existing state is discovered	[1] [1] [1]	
		(ii)	the state of the atom / system is described by a superposition of wave functions representing the two possible states as time goes on the decayed state becomes more prominent and the un-decayed state becomes less prominent when the box is opened the wave function collapses into one of two definite states	[1] [1] [1]	

		(iii)	the state of the atom / system is described by a superposition of wave functions representing the two possible states	[1]	
			the decayed and un-decayed states exist in two parallel worlds	[1]	
			a different observer opens the box in each parallel world and in one he discovers a live cat and in another he discovers a dead one. There is no wave function collapse	[1]	
					[MAX 6]
					[20]
13	**(a)**	**(i)**	basic description e.g. degree of disorder	[1]	
			addition of extra detail e.g. a measure of the number of ways of distributing energy or particles among available states	[1]	[2]
		(ii)	the entropy of the universe tends to a maximum (does not decrease)	[1]	[1]
		(iii)	more energy in the system	[1]	
			increase the number of ways in which this can be distributed	[1]	[2]
	(b)	**(i)**	$W = Q_1 - Q_2$	[1]	[1]
		(ii)	$(Q_1 - Q_2) / Q_1$	[1]	[1]
		(iii)	zero	[1]	[1]
		(iv)	if efficiency is 100% then Q_2 is zero and there is no increase in entropy of the environment (heat sink)	[1]	
			there is a decrease in entropy of the heat source as heat Q_1 is extracted	[1]	
			there is a net decrease in entropy of the universe (violating the 2nd law)	[1]	[3]
		(v)	maximum efficiency when the entropy change is zero	[1]	
			this is when $Q_1 / T_1 = Q_2 / T_2$	[1]	
			$Q_2 / T_2 = 300 / 800 = 0.375$	[1]	
			maximum efficiency = 1 – 0.376 = 0.625 (62.5%)	[1]	[4]
	(c)	**(i)**	flow from hot to cold increases the total entropy flow from cold to hot decreases the total entropy	[1]	
			when heat is transferred from body 1 to body 2, Q / T_2 must be greater than Q / T_1, otherwise the 2nd law is violated. Only possible if $T_1 > T_2$	[1]	[2]
		(ii)	entropy of water decreases as it turns to ice	[1]	
			latent heat is released to the environment	[1]	
			entropy of environment increases by a greater amount (so total entropy rises)	[1]	[3]
					[20]