CAMBRIDGE INTERNATIONAL EXAMINATIONS

Cambridge Pre-U Certificate

MARK SCHEME for the May/June 2015 series

9792 PHYSICS

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

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CAMBRIDGE
International Examinations

Section A

1	(a)	correctly labelled vector triangle		[1]	
		from the vector triangle $\delta\theta = \delta v/v$		[1]	
		from the definition of the radian $\delta\theta = v\delta t/r$ (and reorganise)		[1]	[3]
	(b)	(i)	one revolution is 2π radians; 27.3 days = $27.3 \times 86\,400$ (s) = $2\,358\,720$ (s)	[1]	
			angular velocity = $2\pi/27.3$ days = $2\pi/2\,358\,720 = 2.66 \times 10^{-6}$ (rad s^{-1})	[1]	[2]
		(ii)	velocity = $2\pi r/T = 2\pi \times 3.84 \times 10^{8}/2\,358\,720 = 1023$ (m s^{-1})	[1]	
			acceleration = $v^2/r = 1023^2/3.84 \times 10^8 = 2.72 \times 10^{-3}$ (m s^{-2})	[1]	[2]
	(c)	(i)	**1.** $\frac{1}{2} \times 7.35 \times 10^{22} \times 1023^2$	[1]	
			= 3.85×10^{28} (J)	[1]	[2]
			2. loss of kinetic energy = $3.75 \times 10^{12} \times 86\,400 \times 365.(25) \times 1\,000\,000$	[1]	
			$(85 \times 10^{28} - 1.18 \times 10^{26}) = 3.828 \times 10^{28}$ (J)	[1]	[2]
		(ii)	radius <u>increases</u>	[1]	
			total energy (of system) is conserved	[1]	
			KE / velocity (of Moon) decreases and GPE (of Moon) increases	[1]	[3]
					[14]

2	(a)	acceleration / restoring force is proportional to displacement / centre of displacement / oscillation		[1]	
		acceleration / restoring force is in the opposite direction to displacement		[1]	[2]
	(b)	suitable example e.g. (simple) pendulum, mass-spring oscillator		[1]	[1]
	(c)	velocity drawn as a cosine wave		[1]	
		acceleration drawn as a minus sine wave		[1]	
		amplitude of graphs constant		[1]	[3]
	(d)	(i)	$\omega = 2\pi f$	[1]	
			$= 2\pi \times 879 = 5520$ — 3 or 4 significant figures only	[1]	
			rad s^{-1}	[1]	[3]
		(ii)	use of $E = \frac{1}{2} mA^2\omega^2 = 0.5 \times 0.0086 \times 0.0012^2 \times 5520^2$	[1]	
			= 0.189 (J)	[1]	[2]
		(iii)	6% of energy of one cycle = $0.189 \times 0.060 = 0.0113$ (J)	[1]	
			power output = $0.0113 \times 879 = 9.95$ (W)	[1]	[2]
					[13]

3 **(a)** $E = V/d$ [1]
$= 84/2.6 \times 10^{-4} = 323\,000$ ($N\,C^{-1}$) [1] [2]

(b) **(i)** **1** Q = CV = 200 μF × 120 V = 24 000 (μC) [1] [1]
2 E = QV = 120 V × 24 000 μC = 2.88 (J) [1] [1]
3 W = ½QV = 1.44 (J) [1] [1]

(ii) (some) energy is wasted as heat (in charging process) [1] [1]

(iii)

1000	1000	1000	both 1000 (μC)	[1]	
4.0	16.0	100	(1000/250) = 4.0 (V) (1000/10) = 100 (V)	[2]	
2000	8000	50 000	(0.5 × 1000 × 16) = 8000 (μJ) (0.5 × 1000 × 100) = 50 000 (μJ)	[2]	[5]

[11]

4 **(a)** **(i)** <u>diagram</u>
current and magnetic field directions at right-angles to each other [1]
negative charges/electrons (and positive charges) on one side [1]
distribution of charges consistent with Fleming's Left-Hand rule [1] [3]

(ii) magnetic force on moving charges/electrons [1]
electrons move to one side/potential difference/gradient produced/until magnetic force is balanced by electric field [1] [2]

(b) **(i)** number of electrons per second (passing a point)
$= 0.0052/1.6 \times 10^{-19} = 3.25 \times 10^{16}$ [1] [1]

(ii) volume occupied $= 3.25 \times 10^{16}/4.3 \times 10^{21} = 7.56 \times 10^{-6}$ (m^3) [1] [1]

(iii) $7.56 \times 10^{-6} = 0.0065 \times 0.0002 \times v$ [1]
$v = 5.8$ ($m\,s^{-1}$) [1] [2]

[9]

5 **(a)** **(i)** N is the number of molecules [1]
m is the mass of one molecule [1]
$<c^2>$ is the mean of the squares of all the molecules speeds [1] [3]

	(ii)	**1.**	KE = $3 \times 1.38 \times 10^{-23} \times 373/2 = 7.72 \times 10^{-21}$ (J)	[1]	[1]
		2.	$\frac{1}{2} mv^2 \propto T$ so at constant temperature $v^2 \propto 1/m$	[1]	
			$\frac{v_H^{\ 2}}{v_o^{\ 2}} = \frac{m_o}{m_H}$	[1]	
			$v_H/v_o = \sqrt{(5.34 \times 10^{-26}/3.34 \times 10^{-27})} = 3.98$	[1]	[3]
		3.	hydrogen molecules have higher speed	[1]	
			greater proportion have a speed greater than escape speed	[1]	[2]
(b)	**(i)**		(185/90) = 2.06	[1]	[1]
	(ii)	**1.**	area is dependent on the number of molecules	[1]	
			(fixed mass of gas) so number of molecules is constant	[1]	[2]
		2.	at the lower temperature there will be more molecules travelling slower/ fewer molecules travelling faster	[1]	[1]

[13]

6	**(a)**	**(i)**	probability of decay of a nucleus is always constant **or** it is not possible to predict when any given nucleus will decay	[1]	[1]
		(ii)	rate of decay $\propto -N$ OR $-dN/dt$ is (only) proportional to N	[1]	[1]
		(iii)	use of $N = N_0 e^{-\lambda T}$ when $N = \frac{1}{2} N_0$, $t = t_{½}$	[1]	
			$e^{-\lambda t_{½}} = \frac{1}{2}$	[1]	
			taking logs gives $-\lambda t_{\frac{1}{2}} = \ln \frac{1}{2}$ and $-t_{\frac{1}{2}} = \ln \frac{1}{2} / \lambda$ (= – 0.693/λ)	[1]	[3]
	(b)	**(i)**	${}^{1}_{0}n + {}^{14}_{7}N \rightarrow {}^{14}_{6}C + {}^{1}_{1}p$		
			left-hand side correct	[1]	
			right-hand side correct	[1]	[2]
		(ii)	$\lambda = \ln 2/5730 = 1.21 \times 10^{-4}$	[1]	
			$\frac{k}{1.52 \times 10^{12}} = \frac{k}{1.3 \times 10^{12}} \times e^{-1.21 \times 10^{-4} t}$	[1]	
			$\ln \frac{1.3}{1.52} = -1.21 \times 10^{-4} t$	[1]	
			$t = 1290$ year	[1]	[4]
		(iii)	large uncertainty because 1.3×10^{12} is uncertain (7% at best)	[1]	[1]

[12]

7	(a)	(i)	use of $\Delta E_n = -13.6\,\text{eV}/n^2$	[1]	
			use of $E = hf$	[1]	
			$n = 3$	[1]	[3]
		(ii)	$E_5 - E_2 = -13.6/4 + 13.6/25 = -2.856$ eV	[1]	
			convert –2.856 eV to 4.57×10^{-19} J	[1]	
			$f = 4.57 \times 10^{-19}/6.63 \times 10^{-34} = 689\ (\times 10^{12}$ Hz)	[1]	[3]
	(b)		$\Delta f = 24 \times 10^{12}$ (Hz)	[1]	
			$v = 3 \times 10^8 \times 24/617 = 11\,700\,000$ (m s^{-1})	[1]	[2]
					[8]

Section B

8	**(a)**	**(i)**	force per unit mass	[1]	[1]
		(ii)	(weight) W or $F = mg$ or $F = m_1g$	[1]	
			$m_1g = (–)\ Gm_1m_2 / R^2$	[1]	
			$g = GM_e / R^2$	[1]	[3]
		(iii)	g is inversely proportional to R^2 **or** g is proportional to $1 / R^2$ OR $g = k / R^2$	[1]	[1]
		(iv)	use of one data point from graph	[1]	
			calculation of M_E	[1]	
			use of a second data point from graph to calculate M_E	[1]	
			calculate average from two M_E values	[1]	[4]
	(b)	**(i)**	volume of sphere = $4 / 3\ \pi r^3$ and density = mass/volume	[1]	
			$\Delta m = 4 / 3\ \pi r^3\ (750)^3\ (2500 – 830)$	[1]	
			$\Delta m = 2.95 \times 10^{12}$ (kg)	[1]	[3]
		(ii)	$g_1 = 3.89 \times 10^{–4}$ (kg) and $g_2 = 1.29 \times 10^{–4}$ (kg) **or** $\Delta g = G\Delta m / R^2$	[1]	
			$R = (750 + 120)$	[1]	
			$\Delta g = 2.6 \times 10^{–4}$ ($\text{N kg}^{–1}$)	[1]	[3]
	(c)	**(i)**	$g = 4\pi^2 l\ T^2$	[1]	[1]
		(ii)	$T = 2\pi l^{1/2} / g^{–1/2}$	[1]	
			$\delta T / \delta g = 2\pi\ l^{1/2}\ (–1 / 2\ g^{–3/2})$ **or** $= –T / 2g$	[1]	
			$\delta T/T = –½\delta g / g$	[1]	[3]
		(iii)	$\delta T = (2.0 \times 0.000098) / 2 \times 9.81 = 9.989 \times 10^{–6}$ (s) **or** $= 10.0 \times 10^{–6}$ (s)	[1]	[1]
					[20]

9	**(a)(i)(ii)**		arrow labelled weight or mg acting downwards on both diagrams <u>and</u> equal in length	[1]	
			upward (contact) force in **(a)** and downward (contact) force in **(b)**	[1]	
			upward force in **(a)** > than weight and contact force in **(b)** << than contact force in **(a)**	[1]	[3]
	(b)	**(i)**	force given by mv^2 / r	[1]	
			$R = 0$ **or** $mg = mv^2 / r$	[1]	
			$v = 1.21\ \text{m s}^{–1}$	[1]	[3]

(ii)	**1.** energy cannot be created or destroyed		[1]	
	energy can only be transferred from one form to another		[1]	[2]
	2. use mgh and $\frac{1}{2}mv^2$		[1]	
	$mgh = mg2r + \frac{1}{2}mv^2$ OR $gh = g2r + \frac{1}{2}v^2$		[1]	
	$h = 0.3 + (0.5 \times 1.46)/9.81 = 0.3 + 0.075$		[1]	
	$h = 0.375$ (m)		[1]	[4]

(c)	the ball has (additional) rotational KE	[1]	
	additional GPE required	[1]	[2]

(d)	**(i)**	$v = r\omega$	[1]	
		$\omega = 1.7/7.4 \times 10^{-3} = 230$ (rad s^{-1})	[1]	[2]
	(ii)	rotational KE = $\frac{1}{2}I\omega^2 = 0.5 \times 4.2 \times 10^{-6} (0.23 \times 10^3)^2$	[1]	
		= 0.111 (J)	[1]	[2]
	(iii)	$I_1\omega_1 = I_2\omega_2$	[1]	
		$\omega_2 = (4.2 \times 10^{-6} \times 0.23 \times 10^3)/(4.2 + 0.2) \times 10^{-6} = 220$ (rad s^{-1})	[1]	[2]

[20]

10	**(a)**		region / area in which a charged object experiences a force	[1]	[1]
	(b)	**(i)**	force is the same	[1]	
			force is in the opposite direction	[1]	
			magnitude of charge is the same **or** opposite charges	[1]	[3]
		(ii)	acceleration of electron is greater (than that of proton)	[1]	
			mass of electron is much smaller (than that of proton)	[1]	
			acceleration is inversely proportional to mass	[1]	[3]
	(c)		(E =) $Q / 4\pi\varepsilon_0 r^2$	[1]	
			$= 1.6 \times 10^{-19}/4\pi\varepsilon_0(0.05)^2$	[1]	
			$= 5.75 \times 10^{-7}$	[1]	
			($E_{net} = 5.75 \times 10^{-7} \times 2\cos 45$) $= 8.13 \times 10^{-7}$ (N C^{-1})	[1]	[4]
	(d)	**(i)**	$\Delta W = F\Delta r$	[1]	
			$W = \int F dr = \int Q_1Q_2/4\pi\varepsilon_0 r^2\, dr$	[1]	
			limits between infinity and r	[1]	
			leading to $W = Q_1Q_2/4\pi\varepsilon_0 r$	[1]	[4]
		(ii)	equates KE = W	[1]	
			$r = 2 \times 79 \times (1.6 \times 10^{-19})^2 / 1.6 \times 10^{-12} \times 4\pi \times (8.85 \times 10^{-12})$	[1]	
			$= 2.27 \times 10^{-14}$ (m)	[1]	[3]

(iii) use $F = Q_1Q_2 / 4\pi\varepsilon_0 r^2$ [1]
(F =) 70.6 (N) [1] [2]

[20]

11 (a) the laws of physics are the same for all uniformly moving / inertial observers [1]
the speed of light is a constant [1] [2]

(b) $v^2 / c^2 > 1$ **or** $1 - v^2 / c^2$ is negative / less than zero **or** gamma factor is imaginary [1]
no solution for gamma factor **or** square root of a negative number cannot be found [1] [2]

(c) (i) any **one** from
lepton
fundamental particle with no charge
subatomic particle with no charge and very low mass [1] [1]

(ii) neutrinos are weakly interacting [1]
because they have no charge **or** almost no mass [1] [2]

(d) (i) a practical method of determining distance between CERN and Gran Sasso or position of CERN **and** Gran Sasso [1]
e.g. GPS, surveying
one method of achieving an accurate measurement e.g. triangulation, precision of instrument [1] [2]

(ii) any **three** from
measure time (of emission) at CERN **and** (of arrival) at Gran Sasso
use atomic clocks
need to synchronise clocks
repeat and average to eliminate random errors [3] [3]

(e) (i) $0.2 / 3 \times 10^8 = 0.67 \times 10^{-9}$ [1]
$0.67 \times 10^{-9} + 8 \times 10^{-9}$ [1]
8.67×10^{-9} (s) [1] [3]

(ii) any **two** from
experiment repeated 15 000 times
random errors are small **or** random errors cancel / average out
systematic errors affect accuracy and not precision **or** would make all measured times shorter than actual times [2] [2]

(f) any **three** from
repeat experiment **or** experiment must be repeatable
repeat experiment with different equipment
check experimental methods / setup
peer review claims
check / modify scientific theory [3] [3]

[20]

12	**(a)**	labelled diagram of practical setup		[1]	
		valid experiment using a gas		[1]	
		linear relationship (between variables) described or in sketch graph		[1]	
		extrapolation to absolute zero described or shown on graph		[1]	[4]
	(b)	mean KE / energy is proportional to temperature on the kelvin scale		[1]	
		mean KE = 3 / 2 kT OR mean KE tends to zero at 0K		[1]	[2]
	(c)	energy is transferred from the sample (to the surroundings)		[1]	
		bonds form		[1]	
		particles fall into a potential well/particles are attracted to each other OR increase in attraction / attractive force		[1]	[3]
	(d)	**(i)**	particles in a liquid are free to move / particles in a solid are less free to move / particles in a solid vibrate about a point	[1]	
			larger range of positions / states in a liquid leads to random arrangement / fewer range of positions / states leads to greater certainty of position	[1]	[2]
		(ii)	in $\Delta x \Delta p \geqslant h / 2\pi$, reducing Δx increases Δp	[1]	
			relates KE to $(\Delta p)^2 / 2m$	[1]	[2]
		(iii)	$\Delta x = 0$ or $\Delta p = 0$	[1]	
			which means $\Delta x \Delta p = 0$, but $\Delta x \Delta p \geqslant h / 2\pi$	[1]	
			or $\Delta p = 0$ which means 100% certainty in momentum / infinite uncertainty	(1)	
			KE not zero	(1)	
			or Δx is associated with Δp (at low temperatures)	(1)	
			KE cannot be zero	(1)	[2]
		(iv)	any **one** from sufficient energy to break bonds / stop bonds forming energy larger than latent heat of fusion	[1]	[1]
		(v)	any **two** from helium atoms must have (extremely) weak forces of attraction zero-point energy is greater than bond energy / minimum of potential well helium must have a low latent heat of fusion	[2]	[2]
	(e)	any **two** from high pressure increases latent heat of fusion work must be done (against pressure) to change state distance between Helium atoms decreases attractive force between atoms increases		[2]	[2]

[20]

13	**(a)**		an applied force / tension	[1]	
			long-chain molecules uncoil	[1]	
			long-chain molecules are more stretched out / linear	[1]	
			cross-links unbroken	[1]	[4]
	(b)	**(i)**	all for sections in a line	[1]	[1]
		(ii)	one	[1]	[1]
		(iii)	three different arrangements of $3l$	[1]	
			$3l$ labelled on at least one arrangement	[1]	[2]
	(c)	**(i)**	high entropy gives more ways **or** low entropy gives fewer ways	[2]	
			or entropy is a measure of <u>disorder</u>	(1)	
			number of ways linked to disorder	(1)	
			or $S = k \ln W$	(1)	
			where S is entropy and W is the number of ways	(1)	[2]
		(ii)	entropy-extension sketch graph entropy value at zero extension (on axis and not tending to infinity)	[1]	
			downward line	[1]	[2]
		(iii)	entropy of isolated system cannot decrease **or** entropy of the Universe is always increasing	[1]	[1]
		(iv)	any **three** from entropy of rubber band decreases overall entropy (of Universe) must increase / cannot decrease work done in stretching rubber band does not change the entropy of the Universe overall entropy (of Universe) increases with heat transfer to surroundings	[3]	[3]
	(d)		any **four** from heating rubber increases its entropy long-chain molecules curl up / contract tension in heated bands increase **or** there is a difference in tension in the bands **or** tension in bands changes the centre of mass / centre of gravity (of the wheel / bands) moves (closer to axle) there is a resultant moment (due to weight / centre of mass / centre of gravity) work done by wheel comes from heat supplied	[4]	[4]
					[20]