UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

Pre-U Certificate

MARK SCHEME for the May/June 2012 question paper

for the guidance of teachers

9792 PHYSICS

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

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UNIVERSITY of CAMBRIDGE
International Examinations

1	(a)	new velocity labelled in correct direction correct triangle completed with change in velocity labelled in correct direction	(1) (1) (1)	[3]
	(b) (i)	loss of P.E. = 560 × 9.81 × 25.0 = 137 340 J K.E. at top = ½ × 560 × 10^2 = 28 000 J gain of K.E. = 137 340 – 40 000 = 97 340 J K.E. at bottom = 125 340 J = ½ × 560 × v^2 $v = \sqrt{(2 \times 125\,340 / 560)} = 21.2$ m s^{-1}	(1) (1) (1) (1) (1)	[5]
	(ii)	weight of carriage = 560 × 9.81 = 5494 N (force 1 or 2) $m \times a = m \times (v^2/r) = 560 \times 21.16^2 / 18.0 = 13930$ N so upward force from track = 19 420 N (force 2 or 1)	(1) (1) (1)	[3]
	(iii)	diagram showing two forces with upward force larger than force down	(1)	[1]
	(iv)	upward force is an (electrical) contact force (allow reaction) downward force is a gravitational force	(1) (1)	[2]
				[Total: 14]
2	(a) (i)	an oscillation in which frictional forces are zero (negligible)	(1)	[1]
	(ii)	a oscillation where the amplitude is decreasing OR an oscillation where frictional forces exist OR where the energy of the oscillation is decreasing	(1)	[1]
	(iii)	an oscillation where the amplitude is maintained by energy being supplied by an external source	(1)	[1]
	(b) (i) 1.	at the resonant frequency $\omega = 2\pi f = 2\pi \times 35.5 = 223$ rad s^{-1} use of A = 0.0114 in equation $E = ½mA^2\omega^2$ $= ½ \times 0.046 \times 0.0114^2 \times 223^2 = 0.149$ J	(1) (1) (1)	[3]
	2.	amplitude read correctly as 0.0041 m giving energy as $½ \times 0.046 \times 0.0041^2 \times (40\pi)^2 = 0.0061$ J	(1) (1)	[2]
	(ii)	same starting point and lower graph peak maximum amplitude at lower frequency within original shape	(1) (1)	[2]
				[Total: 10]
3	(i)	minimum work required = mgh = 50 × 9.81 × 400 = 196 000 J	(1)	[1]
	(ii)	gravitational potential = gh = 9.81 × (600 – 200) = 3920 m^2 s^{-2} OR N m kg^{-1} OR J kg^{-1}	(1) (1)	[2]
	(iii)	attempt to make lines cross contour lines at right angles subtract [1] for every two glaring discrepancies of this (to minimum zero)	(2)	[2]
	(iv)	the gravitational field is vertically downward / into page	(1)	[1]

(b) **(i)** attempt to make lines cross equipotentials at right angles (1)
arrows in the correct direction (1) [2]

(ii) **1.** work done = QV (1)
$= 50 \times 10^{-6}$ C × 400 V = 0.020 J (1)

2. work done = 50×10^{-6} C × – 400 V = – 0.020 J (1) [3]

[Total: 11]

4 **(a)** **(i)** **1.** work done = $p\Delta V = 5.7 \times 10^{6}$ Pa x $(3.1 - 2.0) \times 10^{-5}$ m^3 (1)
= 62.7 J (1)

2. zero (1) [3]

(ii) $\frac{P_B V_A}{T_A} = \frac{P_B V_B}{T_B}$ (1)

$T_B = \frac{P_B V_B T_A}{P_A V_A} = \frac{5.7 \times 10^{6} \times 2.0 \times 10^{-5} \times 300}{1.0 \times 10^{5} \times 36 \times 10^{-5}}$ (1)

$T_B = 950\,K$ (1) [3]

(b)

section of cycle	heat supplied to the gas / J	work done on the gas / J	increase in the internal energy of the system / J
A → B	0	235	**235 A**
B → C	246	**– 63 C**	**183 B** (sum of 246 and –63)
C → D	0	– 333	**– 333 D**
D → A	**–85 E**	**0 C**	235 + 183 –333 = **– 85 E**

A (1), **B** (1), **CC** (1), **D** (1), **EE** (1) (5) [5]

(c) **(i)** efficiency = $\frac{396 - 235}{246}$ (1) [1]

= 0.65 or 65%

OR $1 - T_1/T_2 = 1 - 300 / 950 = 0.68$ or 68%

(ii) **two** reasons e.g.

the graph is idealised so will (curl at the corners) not be the exact shape (1)

friction will reduce forces (1)

the gas is not an ideal gas (1) [2]

[Total: 14]

5 **(a)** $^{210}_{84}\text{Po} \rightarrow {}^{4}_{2}\alpha + {}^{206}_{82}\text{Pb}$ [2]

(1) (1)

(b) **(i)** ratio =(–) 1 (1) [1]

(ii) ratio $= m_{Pb}/m_{\alpha}$ (1)

= 206/4 = 51.5 (1) [2]

(iii) ratio $= (m_{\alpha}/m_{Pb}) \times (v_{\alpha}/v_{Pb})^2$ (1)

= 51.5 (1) [2]

(c) $N = N_0 e^{-\lambda t}$

$\ln (N/N_0) = -\lambda t$ (1)

$\ln(850/24000) = -3.3406 = -(\ln 2 / 138) \times t$ (1)

$t = 138 \times 3.3406 / \ln 2 = 665$ days ($= 5.75 \times 10^7$ s) (1) [3]

[Total: 10]

6 (a) (i)	values	$n = 1$	$E_1 = -13.6$ (eV)		
		$n = 2$	$E_2 = -3.40$ (eV)		
		$n = 3$	$E_3 = -1.51$ (eV)		
		$n = 4$	$E_4 = -0.85$ (eV)		
		$n = 5$	$E_5 = -0.54$ (eV) – 1 for each error	(2)	
(ii)	lines shown not to scale but sensibly positioned			(1)	[3]

(b) all shown (1) [1]

(c) (i) photon energy = –0.54 – (–3.40) = 2.86 eV (1) [1]

(ii) photon energy = 2.86 eV × 1.6 × 10^{-19} J eV^{-1} = 4.58 × 10^{-19} J (1)
wavelength = hc/E (1)
= 6.63 × 10^{-34} × 3.0 × 10^{8} / 4.58 × 10^{-19} = 4.34 × 10^{-7} m (1) [3]

(d) infra-red transition – any excluding falls to levels 1 or 2 (1) [1]

(e) ultra-violet (1) [1]

[Total: 10]

7 (a) (i) sin 0.0000255 = 1.50 × 10^{11} / x (1)
x = 1.50 × 10^{11} / sin 0.0000255 = 3.37 × 10^{17} m (or tan) (1) [2]

(ii) luminosity = luminous flux × area = 3.6 × 10^{-9} × $4\pi r^2$ (1)
= 3.6 × 10^{-9} × $4\pi(3.37 \times 10^{17})^2$ = 5.14 × 10^{27} (1)
W(att) or J s^{-1} (1) [3]

(iii) luminous flux $\propto 1/d^2$ (1)
3.6 × 10^{-9} × $(3.37 \times 10^{17})^2$ = 8.3 × 10^{-11} × y^2 (1)
$y = \sqrt{(360 / 8.3)} \times 3.37 \times 10^{17} = 2.22 \times 10^{18}$ m (1) [3]

(b) $\lambda_{max} \propto 1/T$
λ_{max} for Sun = 540 nm, λ_{max} for Y = 800 nm, (1)
540 × 5800 = 800 × T_y (1)
T_y = 540 × 5800 / 800 = 3900 (± 200) K (1) [3]

[Total: 11]

8 **(a)**	resistivity = (resistance × cross section area) / length		(2)	[2]
(b)	$A = l^2$	substitution for area	(1)	
	$R = \rho l/tl = \rho/t$	cancel l from equation	(1)	[2]
(c) (i)	$1/R = 1/R_C + 1/R_L$	recall formula – realise layers are in parallel	(1)	
	$1/1600 = 1/1650 + 1/R_L$	correct substitution	(1)	
	$R_L = 52\,800\,\Omega$	answer 53 000 (Ω)	(1)	[3]
(ii)	$52\,800 = (\rho \times 0.9)/(0.4 \times 0.05)$	substitution – ignore powers of ten errors	(1)	
	$\rho = 1170$ (Ω m)	correct value for ρ	(1)	[2]
(d) (i)	$d\varphi/dt = (-)\ \varepsilon/N$	use formula	(1)	
	$= (-)\ (84 \times 10^{-3} \times 1)/60$			
	$= 1.4 \times 10^{-3}$	answer	(1)	
	units: Wb s^{-1} or V	unit	(1)	[3]
(ii)	induced emf		(1)	
	is directly proportional to		(1)	
	the rate of change in flux (linkage)		(1)	[3]

(iii) any **two** consistent points from:

- Lenz's law a consequence of law of conservation of energy (1)
- magnetic field created by induced current in coil repels permanent magnetic field (1)
- work has to be done to move the magnet through the coil because it is repelled (1)
- this energy is converted to electrical energy dissipated in the coil's complete circuit (1) [2]

(e)	3 complete oscillations drawn	(1)	
	period kept constant	(1)	
	reasonably symmetrical and steady decrease in amplitude	(1)	[3]

[Total: 20]

9 **(a)** the acceleration (or force) is directly proportional to the displacement (from the equilibrium point) (1)
and is always directed towards that point (1)
OR
accept formula $a = -\omega^2 x$ with explanation of each symbol and significance of minus sign (2) [2]

(b) $d^2x/dt^2 = -\omega^2 x$ (1) [1]

(c)

	B	C	D	E	F
displacement	+	0	–	0	+
velocity	0	–	0	+	0
acceleration	–	0	+	0	–

displacement line symmetrical about D (+0–0+ or –0+0–) (1)
displacement line correct (1)
acceleration line opposite to displacement line. (1)
velocity line has B D & F as zero with answers to C and E consistent with their displacement line. (1) [4]

(d) **(i)** phase difference between displacement and velocity is $\pi/2$ OR $3\pi/2$ radians OR 90° (1)

(ii) displacement and acceleration are exactly out of phase OR out of phase by π radians OR 180° (1) [2]

(e) **(i)** **1.** amplitude = 8 cm, T = 2.0 s so f = 0.5 (Hz) (1) [1]

(ii) **1.** $F = mA\omega^2$
$= 0.02 \times 0.08 \times (2\pi/2)^2$ convert to kg and m and substitute (1)
= 0.0158 (N) answer 0.016 (N) (1) [2]

2. negative cos graph of any amplitude (1)
for at least 3.5 s (1) [2]

(f)	**(i)**	idea that $I = \Sigma r^2 \Delta m$ or equivalent integral expression		(1)	
		with r and Δm defined accept clear labelling on diagram		(1)	[2]
	(ii)	$mg \times I \sin\theta = ½ I\omega^2 + ½ mv^2$ $0.20 \times 9.81 \times 2.5 \sin 25 = (½\ 0.10 \times 10^{-4}\ \omega^2) + (½\ 0.20 \times 3.72^2)$ $2.073 = (0.05 \times 10^{-4}\ \omega^2) + (1.384)$ $\omega^2 = 13.78 \times 10^4$			
	•	see formula quoted or used i.e. RKE = $½ I\omega^2$		(1)	
	•	total energy equation quoted in symbols or used or stated in words i.e. $mgh = ½ I\omega^2 + ½ mv^2$ or $mg \times I \sin\theta = ½ I\omega^2 + ½ mv^2$		(1)	
	•	correct substitution		(1)	
	•	answer $\omega = 371$ (rad s^{-1}) OR alternative method and correct answer for candidates who work out or know that $I = ½mr^2$		(1) (4)	 [4]

[Total: 20]

10 (a)	**(i)**	same mass		(1)	
	(ii)	opposite charge or opposite spin		(1)	[2]
(b)	**(i)**	$\Delta E = c^2 m$ $= (3.00 \times 10^8)^2 \times 2 \times 9.11 \times 10^{-31}$ $= 1.64 \times 10^{-13}$ (J)	correct substitution ans: 1.6×10^{-13} (J)	(1) (1)	 [2]
	(ii)	$f = (½\ \Delta E)/h$ $= (½ \times 1.64 \times 10^{-13})/6.63 \times 10^{-34}$ $= 1.24 \times 10^{20}$ (Hz)	halve energy in **(b)(i)** ans: 1.2×10^{20} (Hz)	(1) (1)	 [2]
(c)	**(i)**	there is a range of energies energy per decay is constant / energy is conserved (anti neutrino) particle has the remaining energy		(1) (1) (1)	
	(ii)	78 = 79 + –1 hence antineutrino must have zero proton number		(1)	[4]
(d)		e.g. $400 = 800\ e^{-\mu 8}$ $\ln 2 = 8\mu$ $\mu = 0.0866$ mm^{-1} OR 86.6 m^{-1}	accept either $C = C_0\ e^{-\mu x}$ or $I = I_0\ e^{-\mu x}$		
		$C_0 = 800$ (s^{-1}) consistent values for x and C from graph $\mu = 0.087$ OR 87 unit: m^{-1}		(1) (1) (1) (1)	 [3] [1]

(e) (i) $\lambda = h/mv$ giving expression for angular momentum, $mvr = nh/2\pi$ (1) [1]

(ii) angular momentum = $(4 \times 6.63 \times 10^{-34})/2 \times 3.142$
= 4.22×10^{-34} (J s) (1)

units must be same as those for h i.e. J s (1) [2]
accept kg m^2 s^{-1}

(iii) $E_I = \{9.11 \times 10^{-31} \times (1.6 \times 10^{-19})^4\} / \{8 \times (8.85 \times 10^{-12} \times 6.63 \times 10^{-34})^2\}$
$= 21.68 \times 10^{-19}$ (J)

correct values for symbols used (1)
correct substitution (1)
answer 2.2×10^{-18} (J) (1)
[3]

there is no credit for quoting 13.6 eV from memory or for simply converting this value to joules

[Total: 20]

11 (a) the laws of physics are the same for all inertial (uniformly moving) observers (1) [1]

(b) the speed of light is a constant for all inertial (uniformly moving) observers (1) [1]

(c) (i) gamma-rays are part of the electromagnetic spectrum
OR
all EM waves travel at the speed of light (1) [1]

(ii) photons have momentum (1)
momentum would not be conserved (1) [2]

(d) (i) the speed of light in the laboratory is independent of the speed of the source (1) [1]

(ii) c (or 3.0×10^8 ms^{-1}) accept 'the speed of light'. (1) [1]

(iii) if a clock moves relative to an observer then its rate is slower than the rate of a clock at rest relative to the same observer (look for clarity of explanation and correct explanation) (2) [2]
note: partial answer scores one mark, e.g. time passes at different rates for differently moving observers OR moving clocks run at different rates / run slow

(iv) $\gamma = \dfrac{1}{\sqrt{1-0.20^2}} = 1.021$ (1)
half-life in laboratory reference frame = 1.021 × 18 ns = 18.4 ns (1) [2]

(e) **(i)** $\frac{t'}{t} = 1 + \frac{300^2}{2(3.0 \times 10^8)^2} = 1 + 5 \times 10^{-13}$
or 1.0000000000005
award 1 mark for correct substitution rounded to 1 (no more than 12 zeros after dec. pt.) (2) [2]

(ii) **1.** $\Delta t = 5 \times 10^{-13} \times 50 \times 3600\,\text{s} = 90\,\text{ns}$ (1)

2. decreases the time (1) [2]

(iii) any **three** points from:
calculation that a drift of 5 ns per hour is 250 ns total in 50 hours (i.e. greater than expected time difference) (1)
calculation that 100 ns gain/loss per day is about 200 ns in 50 hours (again greater than expected time difference) (1)
such large variations in clock rates must cast doubt on the conclusion (1)
if changes in rate can be monitored they can be corrected for and so the results might be valid (1)
if changes in rate occur unpredictably and have this magnitude then the conclusion is invalid (1) [3]
allow other valid points

(f) red shift is increased/ greater (than expected from simple Doppler shift formula) (1)
time dilation reduces the frequency of the light source relative to terrestrial source (1) [2]

[Total: 20]

12 **(a)** valid choice of experimental evidence e.g. electron diffraction experiments (Thompson or Davis and Germer) / electron diffraction rings (1) [1]

(b) **(i)** increased energy results in shorter wavelength/ higher frequency (1)
spacing is reduced (1) [2]

(ii) calculate resultant amplitude by superposition (1)
probability is proportional to amplitude squared (1) [2]

(iii) **three** points from:
electrons can reach the minimum by two (or more) paths (1)
all paths contribute to the resultant amplitude (1)
the path differences result in phase differences (1)
the resultant amplitude is zero (1)
the probability of arrival is proportional to amplitude-squared so is also zero (1) [3]
N.B. 3 marks can only be awarded if the answer explains why no electrons arrive at the minimum

(c) (i) t = 10 ms
approx. 10 dots distributed at random – no discernible/regular pattern (1)

t = 50 ms
larger number of dots – pattern emerging (1)

t = 5 s
similar shading to pattern at 2 hours (1) [3]

(ii) interference effects occur even with single electrons OR electrons interfere with themselves (1)

interference effects are not caused by the interaction of different electrons (1) [2]

(d) (i) wavefunction collapses (1)

more detail must be given for 2 marks:
e.g. before observation there are non-zero values spread across the screen, after observation the amplitude is zero everywhere except at the point of observation
OR before observation the wavefunction is a spreading wave, after observation it is a spike o.w.t.t.e. (2) [2]

(ii) any **one** point from:
the theory cannot explain how the wavefunction collapses (1)
the physical description is discontinuous (1)
quantum theory can only account for the behaviour of the unobserved wavefunction (1) [1]

(iii) four points from:
description of 'Many-Worlds Interpretation'
- the wavefunction represents a superposition of all possible paths/outcomes (1)
- each alternative path/outcome exists in a different world (1)
- the world 'splits' into many worlds each representing a different experimental outcome (1)

avoidance of 'the Measurement problem'
- the wavefunction does not collapse so the problem goes away (1)
- in each world an observer detects an electron at a different position on the screen (1)

[4]

[Total: 20]

13 (a) $\Delta U = Q + W$ used correctly (at least U and W identified) (2)
compression: work is done on the gas so its internal energy rises and its temperature goes up (1)
expansion: work is done by the gas so its internal energy falls and its temperature goes down (1) [4]

(b) (change of state – liquid to gas) bonds broken /latent heat absorbed (1)
work done by gas as it expands (increase in volume) (1) [2]

(c)	heat flows from hot to cold and pipes are at a lower temperature than the inside of the refrigerator	(1)	[1]
(d)	a measure of the number of ways	(1)	
	in which the energy can be distributed amongst the particles of the body	(1)	[2]
(e)	if more energy is supplied there will be	(1)	
	more ways in which it can be distributed amongst the particles of the body (so the entropy increases)	(1)	
	OR		
	$\Delta S = \Delta Q/T$ used appropriately with terms defined	(2)	[2]
(f)	zero	(1)	[1]
(g)	**(i)** decrease		
	(ii) increase		
	must have both **(i)** and **(ii)** correct for 1 mark	(1)	[1]
(h)	that it never decreases	(1)	
	OR		
	that it tends to a maximum	(1)	[1]
(i)	**three** points from:		
	electrical work W from supply is ultimately dumped as heat in the environment	(1)	
	when heat is dumped in the environment it increases entropy	(1)	
	this adds to the heat Q_1 extracted from the inside of the refrigerator	(1)	
	total heat dumped increases entropy more than heat Q_2 absorbed reduces it	(2)	[3]
	note: accept answers that refer to the entropy change of the refrigerator and environment in terms of $\Delta S_{OUT} = W + Q_2/T_{OUT} > \Delta S_{IN} = -Q_1/T_{IN}$ for 3 marks as long as terms are used correctly		
(j)	temperature of the room will increase	(1)	
	two points from:		
	heat dumped > heat extracted	(1)	
	energy flows into the system	(1)	
	electrical energy input transferred to heat in room	(1)	[3]

[Total: 20]