CAMBRIDGE INTERNATIONAL EXAMINATIONS

Pre-U Certificate

MARK SCHEME for the May/June 2013 series

9792 PHYSICS

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

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CAMBRIDGE
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Section A

1	(a)	(i)	$F = GMm/r^2$ plus values on top line	(1)	
			$r = (6.37 \times 10^6) + (0.39 \times 10^6) = 6.76 \times 10^6$	(1)	
			$F = 724$ (N)	(1)	[3]
		(ii)	$a = F/m = 724.4/83 = 8.73$	(1)	[1]
		(iii)	$a = v^2/r$ therefore $v = \sqrt{ar}$	(1)	
			$= \sqrt{(8.73 \times 6.76 \times 10^6)} = 7680$	(1)	[2]
		(iv)	circumference $= 2\pi r = 2\pi \times 6.76 \times 10^6$	(1)	
			time = circumference/speed	(1)	
			$= 2\pi \times 6.76 \times 10^6/7680 = 5530$ s (= 1 hr, 32 min, 18 sec)	(1)	[3]
	(b)		e.g. jumping from a wall, doing a high jump, diving into a swimming pool	(1)	[1]
	(c)		the astronaut is not weightless	(1)	
			Any one from there is no air resistance on the astronaut the force on the astronaut is causing his acceleration (towards the Earth) the astronaut is not moving relative to his surroundings	(1)	
			Any one from you are in free fall you have friction of air on you your surroundings are moving relative to you	(1)	[3]

[Total: 13]

2	(a)	(i)	$T = 2\pi\sqrt{(2.6 / 9.81)} = 3.23$ s	(1)	[1]
		(ii)	$\omega = 2\pi/T = 1.94$ rad s^{-1}	(1)	[1]
		(iii)	$A = 2.6 \sin 2.3 = 0.1043$ m	(1)	
			$E = ½mA^2\omega^2 = ½ \times 0.87 \times 0.1043^2 \times 1.94^2 = 0.0178$ J	(1)	
			OR $h = 2.6 - 2.6 \cos 2.3$ ($= 2.09 \times 10^{-3}$)	(1)	
			$mgh = 0.87 \times 9.81 \times (2.09 \times 10^{-3}) = 0.0178$ J	(1)	[2]

(b) **straightforward details** MAX 3
e.g. measure the period with a stopwatch, OR use a light gate
measure the angle of swing with a protractor) OR with ruler an correct calculation
repeat the procedure to include large angles

enhanced details MAX 3
e.g. preliminary trials to get measuring device in the right place
make the period long by the use of a long support string
method of release clear
coordination between angle and period for single or half swings
do the experiment in a vacuum
repeat procedure at same angle

sophisticated details# MAX 1
clear diagram of light gate procedure for single swings
digital recording, i.e. slow motion, and explanation of how actual times are obtained

OVERALL MAXIMUM 5 with no diagram [6]

[Total: 10]

3 (a)

capacitance /μF	potential difference / V	charge / μC	energy / μJ
4.0	9.0 [1]	36	162
3.0	3.0 [1]	9 [1] ecf	13.5 [1] ecf
X = 9.0 [1]	3.0	27 [1]	40.5 [1]
		from Q = CV	from ½ QV or = ½CV^2

[7]

(b) (i) 1 36 (μC) (1)
2 432 (μJ) (1) [2]

(ii) energy is lost in the charging process (1)
because *V* needs to be increased as the charge builds up
e.g. while charging the area beneath the QV graph is a triangle of area ½QV (1) [2]

[Total: 11]

4 (a) (i) $3.8 \times 10^{-5} \times 20 = 7.6 \times 10^{-4}$ (Wb) (1) [1]

(ii) E = (–) dNφ/ dt = 7.6×10^{-4} / 0.0050 (1)
= (–) 0.152 (V) (1) [2]

(b) (i) $3.8 \times 10^{-5} \times 800$ / 0.005 (1)
= 6.08 (V) (1) [2]

(ii) no energy loss in secondary as second coil terminals are not connected (1)
all energy loss is in primary or core (1) [2]

(iii) a transformer or equivalent (1)
example of use (1) [2]

[Total: 9]

5 (a) volume of molecules very much smaller than volume of container (1)
all collisions elastic (1)
no force on molecules except on contact OR time of collision is negligible compared to the time between collisions (1)

[3]

(b) movement of particles in a fluid (liquid or gas)
molecules in fluid collide with particles
random movement of large particles
that are (just) visible (under a microscope)
other relevant point
1 mark for each point to maximum 3 [3]

(c) **(i)** T = 296 K (1)
average k.e. = 3/2 kT = 3/2 × 1.38 × 10^{-23} × 296 = 6.13 × 10^{-21} (J) (1) [2]

(ii) 6.13 × 10^{-21} = ½ × 5.31 × 10^{-26} × $\langle c^2 \rangle$ (1)
$\sqrt{\langle c^2 \rangle} = \sqrt{(2 \times 6.13 \times 10^{-21} / 5.31 \times 10^{-26})}$ = 481 (m s^{-1}) (1) [2]

(d) **(i)** internal energy is sum of kinetic and potential energies of the molecules (1) [1]

(ii) 1. no change, <u>and</u> 2. no change (1)
1. as internal energy (includes) the random kinetic energy of the molecules (1)
2. internal potential energy is due to elastic potential energy between molecules (1)
3. internal energy decreases (1)
because molecules have lower average speeds (1) [5]

[Total: 16]

6 **(a)** loss of mass = (1.6744 – 1.6730 – 0.00091) × 10^{-27} kg (1)
= 4.89 × 10^{-31} kg (1)
E = mc^2 = 4.89 × 10^{-31} × $(3 \times 10^8)^2$ = 4.40 × 10^{-14} (J) (1) [3]

(b) **(i)** (4.40 – 2.3) × 10^{-14} = 2.1 × 10^{-14} (J) (1) [1]

(ii) 2.1 × 10^{-14} J = ½mv^2: v = $\sqrt{(2 \times 2.1 \times 10^{-14} / 9.11 \times 10^{-31})}$ = 2.15 × 10^8 m s^{-1} (1)
momentum = mv = 9.11 × 10^{-31} × 2.15 × 10^8 = 1.96 × 10^{-22} N s (1) [2]

(c) directions opposite and arrow of electron very much larger than arrow of proton (1) [1]

(d) third body was a neutrino
had no charge and small mass
diagram showing different angles possible
neutrino takes some of the energy
1 mark for each point made to maximum 3 + 1 for equation + 1 for correct neutrino symbol
(5) [5]

$^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$

[Total: 12]

7	**(a)**	**(i)**	the total power radiated by a star	(1)	[1]
		(ii)	the intensity of radiation at a distance from the star (at the Earth)	(1)	[1]
	(b)	**(i)**	the (surface) temperature of the star	(1)	[1]
		(ii)	the elements present on the star the speed of recession of the star	(1) (1)	[2]
	(c)	**(i)**	$v = 3.0 \times 10^{8} \times 26.5 \times 10^{-9} / 516.7 \times 10^{-9}$ $= 1.54 \times 10^{7}$ (m s^{-1})	(1) (1)	[2]
		(ii)	$d = v/H_0$ OR $= 1.54 \times 10^{7} / 2.3 \times 10^{-18}$ $= 6.7 \times 10^{24}$ (m)	(1) (1)	[2]

[Total: 9]

Section B

8 (a) (i) (speed is constant but) direction is continuously changing (towards centre) (1)
velocity is changing) with time (so body accelerates) (1)
by Newton's 2^{nd} Law a force is required / for acceleration towards centre (1) [3]

(ii) $a = v^2/r$ (1) [1]

(b) $(R - mg) = m \times (v^2/r)$ $(R - 200) = 200/9.8 \times (4.7^2/2.8)$ (1)
giving R = 161 + 200 = 361 (N) (1) [2]

(c) (i) Mass of small ring $dm = \rho 2\pi r.dr$ (1)
Integral set up with limits from r_1 to r_2 ($r_1 = 0$, $r_2 = R$) (1)
Identifies and substitutes total mass of disc $M = \rho\pi R^2$ (1)
$I = ½ MR^2$ (1) [4]

$$I = \int (r^2 \Delta m) = \int_2^{r2} p2\pi r^3 dr = [\frac{1}{2} p\pi R^4] = \frac{1}{2} MR^2$$

(ii) $10.1 = 44.8 \times (1.40 - 0)/t$ (1)
t = 6.21 (s) (1) [2]

(iii) $t = (118 \times 1.40)/10.1 = 16.4$ s (1)
$\Delta t = 16.4 - 6.2 = 10.2$ (s) (1) [2]

(iv) 1. angular momentum is conserved (1)
I increases so ω decreases (1)
ω decreases so T increases (1) [3]
Allow last 2 marks even if conservation of k.e. is suggested

2. $T_1 = 2\pi/1.40 = 4.49$ s $T_2 = 4.49 + 0.66 = 5.15$ so $\omega_2 = 1.22$ rad s^{-1} (1)
$I_1 \omega_1 = I_2 \omega_2$; $118 \times 1.40 = I_2 \times 1.22$; $I_2 = 135$ kg m^2 (1) [3]
Do not allow any marks here if conservation of k.e. is used
uses principle of conservation of angular momentum (1)

[Total: 20]

9	**(a)**	Resultant (force)	(1)	
		force (exerted on a body) is proportional to the rate of change in momentum	(1)	[2]
	(b)	dm/dt = F/v = 34700 kN/2.6 km s^{-1}	(1)	
		dm/dt = 13 300 (kg s^{-1})	(1)	[2]
	(c) (i)	Working line shown and clear conversion of natural logs to exponentials	(1)	[1]
	(ii)	In table		
		m/m_o = 0.88	(1)	
		Δv_r = 7.7(4)	(1)	[2]
	(iii)	8 points correctly plotted (ecf their table values)	(2)	
		One mark lost for each error, minimum of zero		
		Best fit smooth curve drawn	(1)	[3]
	(iv)	With V = 2.6×10^3 ; (m/m_o) = 0.15 m = $0.15 \times 2.04 \times 10^6$ = 306 000 kg	(1)	
		With V = 8.0×10^3 ; (m/m_o) = 0.54 m = $0.54 \times 2.04 \times 10^6$ = 1 101 600 kg	(1)	
		Difference in mass = 796 000 kg	(1)	[3]
	(d) (i)	$E = -(GM_E m_S)/(R + h)$	(1)	[1]
	(ii)	The amount of work done on the mass	(1)	
		(in moving the mass) from infinity to the point (where the satellite is)	(1)	[2]
	(iii)	KE = $0.5 \times 152 \times (7.7 \times 10^3)^2 = 4.5 \times 10^9$	(1)	
		PE = total energy – KE = $-4.5 \times 10^9 - 4.5 \times 10^9 = -9.0 \times 10^9$	(1)	
		$-9.0\times10^9 = -\frac{6.67\times10^{-11}\times5.98\times10^{24}\times152}{r}$		
		$r = 6.736\times10^7$	(1)	
		$h = 6.736\times10^7 - 6.36\times10^6 = 3.76\times10^5$ m	(1)	[4]

[Total: 20]

10	**(a)**	**(i)**	Reciprocal of capacitance	(1)	[1]
		(ii)	$I = Q/t$ = (120)/2.4	(1)	
			= 50 mA (i.e. getting the power of 10 correct)	(1)	[2]
		(iii)	(During the charging process charge builds up on the capacitor plates)		
			The increasing charge repels oncoming charge more and more	(1)	
			so less charge is added to the plates each second OR as p.d. across capacitor rises there is less p.d. across resistance of circuit 1 so less current	(1)	[2]
	(b)	**(i)**	Reasonable sized tangent drawn to graph at t = 30 ms	(1)	
			Mandatory mark for any marks on this question		
			and so Q = 42 mC	(1)	
			Rate of flow of charge between 1.40 and 1.54 (C s^{-1})	(1)	[3]
		(ii)	1 t/CR has no units so CR has same units, s, as t	(1)	
			2 e.g $60 \times 10^{-3} = 120 \times 10^{-3} \times e^{-0.02/CR}$	(1)	
			$CR = 0.0289$	(1)	
			3 C from (a)(i) is 120×10^{-3} C / 2000 V = 6.0×10^{-5} F		
			e.g. so $R = 0.0289/6.0 \times 10^{-5} = 480$ (Ω)	(1)	
			4 Mark for each of following terms:		
			$-Q_0/CR$	(1)	
			$e^{-t/CR}$	(1)	[6]
	(c)	**(i)**	Quote Coulomb's law	(1)	
			Reference to work done to move Q_2 through small distance i.e. $\delta W = F\delta x$ [ignore references to 'against the field']	(1)	
			Mathematical integration statement with limits. Accept summation with limits.		
			$W = \int \delta W$ from ∞ to r or $W = \sum \delta W$ from ∞ to r	(1)	
			Integration statement only (ignore limits omission)		
			$\int Q_1Q_2/4\pi\varepsilon_0 x^2 \, dx$	(1)	
			See substitution $W = Q_1Q_2/4\pi\varepsilon_0$ [1/r – 1/∞] [ignore any confusion resulting from misplaced minus signs. Look for essential idea]	(1)	[5]
		(ii)	Explains that the zero of p.e. is at infinity	(1)	[1]
			(no credit for just inserting the limit in the integration)		

[Total: 20]

11 (a) Basic answer: Motion affects the rate of clocks (or rate at which time passes) (1)
More detail: Moving clocks run slow / time passes more slowly in a moving reference frame (2)

Idea of comparison between rest and moving frames:
Compared to a clock at rest (1)

Maximum 3 marks [3]

(b) The effect is so small that it can be neglected. (1)
Calculation of time dilation factor: $\gamma \sim 1 + 0.5 \times 10^{-14} = 1.000000000000005$ (1)
Calculation of time difference = $5 \times 10^{-15} \times 3 \times 10^{5}/30 = 5 \times 10^{-11}$ s (i.e. 50 ps) (1) [3]

(c) (i) 1.048 (not using approximation) (2) [2]
(Award 1 mark only if approximation has been used to give $\gamma = 1.045$)

(ii) Time elapsed on station clock = $3.0 \times 10^{5} / 30 = 10^{4}$ s = 2 h, 47 min 40 sec (1)
Time elapsed on train clock = $10^{4} / 1.048 = 9542$ s (1)
Adjustment required = 458 seconds (7 minutes 38 seconds) (1)
Train clock must be put forward (1) [4]

(iii) Agree. Traveller has lived through a different amount of time than a person who stayed at the station (1)
Less time has elapsed for traveller so he has travelled into the future relative to the station (1) [2]

(d) Correct basic shape:
Horizontal from γ-intercept (at v = 0) (1)
γ close to 1 (<1.5) for v< 50 ms^{-1}, rising rapidly for large *v* (1)
$\gamma = 1$ (marked on γ-axis) when *v* = 0 (1)
Curve appears asymptotic to speed = 100 m/s (1) [4]

(e) Any two from:
No time dilation effects
No length contraction / mass increase with velocity
Infinite energies (from $E = mc^2$)
Faster communications
No limiting speed for travel (or information transfer)
(2) [2]

[Total: 20]

12 (a) It is mainly empty space (1)
It has structure / atoms are not fundamental (1)
Nuclear matter has extremely high density (1)
Maximum 2 marks [2]

(b) (i) $(F) = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{(1.6 \times 10^{-19})^2}{(1 \times 10^{-15})^2}$ (1)

229 N (1)
This is very large / ezuivalent to a weight of 23 kg i.e. recognition that this force is comparable to macroscopic forces (1) [3]

(ii) 1. Strong and attractive because it balances/overcomes proton-proton repulsion. (1)
2. Short range because it has no macroscopic effects / it is negligible compared to electrostatic forces over the distance of the atom / otherwise all nucleons would clump together (1) [2]

(c) (i) $\Delta t \approx \frac{h}{2\pi mc^2}$ (1) [1]

(ii) Mesons (have mass so they) cannot travel at or above the speed of light (1)
The maximum distance a meson can travel is about (no more than) $R \sim c\Delta t$ (1)
Strong interaction cannot exceed the distance a meson can travel during Δt (1)
Maximum mark 2 [2]

(iii) Use of $R \sim c\Delta t$ to give an expression for mass: $m \approx \frac{h}{2\pi cR}\left(\approx \frac{h}{2\pi cx^2\Delta t}\right)$ (2)

3.5×10^{-28} (kg) (1) [3]

(iv) State that about 1/5 of a proton mass and 400 electron masses. (1)
Must be a new kind of subatomic particle. (1) [2]

(d) (i) For a long range they must exist for a long time (Δt must be large without limit) (1)
The uncertainty in energy must be very small (ΔE must be very small) (1)
Hence rest mass m ($= \Delta E / c^2$) must also be (arbitrarily) small (1) [3]

(ii) Full credit for an explanation in terms of exchange particles that identifies and explains either the increased rate of exchange of force-carriers or the increased energy/momentum associated with each exchange at short distance.

e.g. At shorter distances the exchange particles exist for a shorter time so they can exchange more energy/transfer more momentum and create a stronger force.
e.g. At short distances the field is stronger so more exchange particles can be created and exchanged thereby increasing the force.

Give part credit for answers that refer to the coulomb's law / inverse-square law (i.e. as r gets smaller $1/r^2$ gets bigger) but limit maximum to 1 mark if exchange particles are not mentioned. (2) [2]
Maximum 2 marks

[Total: 20]

13 (a) (i) The Law of Conservation of Energy OR The 1st Law of Thermodynamics.

(ii) The Second Law of Thermodynamics
Need to identify both laws for 1 mark (1) [1]

(b) The Second Law (no mark)
If time runs from past to future entropy increases, but if time is reversed entropy decreases (1) [1]

(c) (i) Entropy is related to the arrangement or organisation of particles in the egg (1)
The original state is low entropy and the final state high entropy (1)

The original state is low entropy because it is more ordered or has a lower probability or is realised in fewer ways than the final state (1) [3]

(ii) There are a very large number of ways in which the particles can be arranged. (1)
Mixing is a random process (1)
The number of ways in which the egg can be in a scrambled/mixed state is much
greater than the number of ways it can be in an unmixed state (1)
Hence it is much more likely to end up in a mixed state (1)
The mixed state represents a (macroscopic) equilibrium (1)
Maximum mark 3
(N.B. these marks can be observed in either c(i) or c(ii)) [3]

(d) Idea that the direction from past to future is aligned with or defined by the direction of increase of entropy (or the direction of ever increasing 'disorder') (2) [2]
Accept the idea that the universe is moving from a state of low entropy to one of high entropy or from a state of low probability to one of higher probability

(e) (i) There is only one way in which the universe can exist (1)
so there is no distinction between past and future (nothing changes) (1) [2]

(ii) Yes – if the gas molecules start in some ordered state
(e.g. all released from one corner of the box) (1)
Then the arrow would point toward an equilibrium state in which they are distributed more or less evenly throughout the container. (1)

Yes – while entropy is increasing. (1)
Discussion of number of ways linked to different macroscopic states – e.g. low number of ways of finding the majority in a single small space, large number of ways of finding them spread throughout the container. (1)

Not possible to define an arrow of time when the molecules are evenly spread. (1)
Not possible to define an arrow of time when entropy is close to a maximum. (1)
Maximum 3 marks [3]

(iii) Idea that random particle motions have a small but non-zero probability of moving all the particles into a small region once again. In this case entropy would decrease for a while before increasing once again so there could be a reversal. (2)
OR
Idea that it is a dynamical equilibrium so fluctuations away from equilibrium will occur and some might be quite large, providing periods of time during which entropy decreases – again a reversal of time's arrow. (2)
Maximum 2 marks [2]

(f) Irreversibility requires large numbers of particles (1)
System/universe must have started in a state of low probability/entropy (1)
Random shuffling results in large scale states that can exist in a large number of indistinguishable ways (1)
Systems move from large-scale states that have low probability to large-scale states that have a high probability (1)
Equilibrium states can exist in many more ways than non-equilibrium states. (1)
Look for: large numbers / low entropy initial state / random shuffling / toward states which can exist in large numbers of different ways
Answer must give some explanation for irreversibility to gain full marks
Maximum 3 marks [3]

[Total: 20]