UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

Pre-U Certificate

MARK SCHEME for the May/June 2011 question paper

for the guidance of teachers

9792 PHYSICS

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

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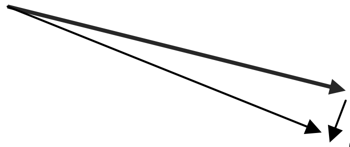
UNIVERSITY of CAMBRIDGE
International Examinations

Section A

1 (a)



new vector of same length and at (a small) angle to the given vector and δv shown (nearly at right angles to both) (they might start slightly separated from one another.) (1)

$\delta\theta = v\delta t/r$ (1)

$\delta\theta = \delta v/v$ (1)

so acceleration = $\frac{\delta v}{\delta t} = \frac{v\delta\theta}{r\delta\theta / v} = \left(\frac{v^2}{r}\right)$ (1) [4]

(b) (i) acceleration = $r\,\omega^2 = v^2/r$ (1)
acceleration = $0.16 \times (8\pi)^2 = 101\ \text{m s}^{-2}$ (1) [2]

(ii) force = ma = 0.20 × 101 = 20 N to 2 sig figs (1) [1]

(iii) *W* and *D* directions correct (1)
resultant smaller than *D* (1)

W and *D* directions correct (1)
same size resultant (1)

D correct direction (1)
resultant horizontal (1) [6]

Size of resultant may be indicated by relative sizes of arrows, or described in words or with mathematical relationship.

[Total: 13]

2 **(a)** **(i)** force per unit (positive) charge (1) [1]

(ii) $W = qV$ (1) [1]

(iii) work done = force × distance = Eqx (1)
$Eqx = qV$ so $E = V/x$ (1) [2]

(b) **(i)** $E = 24\text{ V} / 5 \times 10^{-4}\text{ m} = 48\,000$ (1)
V m^{-1} or N C^{-1} (1) [2]

(ii) $C = Q/V = 5.2 \times 10^{-9}\text{ C} / 24\text{ V} = 217$ (1)
pF **or** $= 2.17 \times 10^{-10}$ F (1) [2]

(iii) Energy = $\frac{1}{2}CV^2 = \frac{1}{2} \times (217 \times 10^{-12}) \times 24^2$ OR $\frac{1}{2} \times 5.2 \times 10^{-9} \times 24$ (1)
$= 6.24 \times 10^{-8}$ (J) (1) [2]

(c) uniform field in centre of plates (1)
weaker field near edges of plates (1)
field from top plate spreading away (1) [3]

[Total: 13]

3 **(a)** **(i)** speed = $2\pi r/t = (2\pi \times 3.84 \times 10^8)/(2.36 \times 10^6) = 1022\text{ m s}^{-1}$ (1) [1]

(ii) kinetic energy = $\frac{1}{2}mv^2 = \frac{1}{2} \times 7.35 \times 10^{22} \times 1022^2$ (1)
$= 3.84 \times 10^{28}$ (J) (1) [2]

(iii) g.p.e. $= -Gm_1m_2 / r$
$= -(6.67 \times 10^{-11} \times 7.35 \times 10^{22} \times 5.98 \times 10^{24}) / (3.84 \times 10^8)$ (1)
$= -7.63 \times 10^{28}$ (J) (1) [2]

(b)

distance from Earth / 10^8 m	gravitational potential energy / 10^{28} J	total energy / 10^{28} J	kinetic energy / 10^{28} J
3.56	– 8.24	**– 3.79** B	**4.45** D
3.84	Answer from **(a)(iii)** – 7.63	**– 3.79** A (1)	Answer from **(a)(ii)** 3.84
4.07	**– 7.20** C (1)	**– 3.79** B (1)	**3.41** D (1)

[4]

(c) maximum k.e. = $4.45 \times 10^{28}\text{ J} = \frac{1}{2} \times 7.35 \times 10^{22} \times v^2$ (1)
$v = \sqrt{(2 \times 4.45 \times 10^{28})/(7.35 \times 10^{22})} = 1100\text{ m s}^{-1}$ (1) [2]

[Total: 11]

4 **(a)** Diagram showing electric and magnetic fields at right angles to one another and to the direction of the particles (1)
Force on particles in the correct direction (1)
Force *Bqv* for magnetic field and *Eq* for electric field (1)
Slow (+) particles deflected in direction of field (1)
Fast (+) particles deflected in opposite direction to slow particles (1)
At one specific speed particles move straight through (1)

2 compulsory marks + any two others [4]

(b) Flux density as force per unit current in a wire of unit length (1)
Flux as flux density × area (1)
Flux linkage as flux × number of turns (1) [3]

(c) $B = 1.26 \times 10^{-6} \times 2000 \times I / 0.22$ (1)
$I = (1.2 \times 0.22) / (1.26 \times 10^{-6} \times 2000) = 105$ A (1) [2]

(d) **(i)** e.g. it might melt the coil, the wire would have to be too thick (1) [1]
not it would be too expensive/it would be dangerous

(ii) e.g. use more turns/wire diameter greater (1)
very low resistance/low resistivity/use low temperatures for superconductivity (1) [2]

[Total: 12]

5 **(a)** particle volume is negligible compared with container volume (1)
all collisions are elastic (1)
no forces between particles (except contact force when they collide) (1) [3]

(b) **(i)** $\sqrt{(<c^2>)} = \sqrt{(3kT/m)}$ (1)
$T = 296$ K (1)
$\sqrt{(<c^2>)} = \sqrt{(3 \times 1.38 \times 10^{-23} \times 296 / 5.3 \times 10^{-26})} = 480$ m s^{-1} (1) [3]

(ii) k.e. is the same for both but the mass is different (so the speed is different) (1) [1]

(c) Reference to the speed distribution of molecules (1)
There will be many molecules travelling much faster than the r.m.s. speed (1)
If these are hydrogen molecules they will have speed greater than escape speed (1)
With oxygen the r.m.s. speed is much less (1)
so the fraction reaching escape speed is much smaller. (1)

2 compulsory marks plus one other [3]

[Total: 10]

6 **(a)** (The count rate will be a fraction of the activity as) the counter will only collect a fraction of the emitted particles (1) [1]

(b) **(i)** $T = \ln 2/\lambda = \ln 2 / 4.6 \times 10^{-3} = 151$ s (1) [1]

(ii) $R = R_0 e^{-\lambda t}$ so $8.3 \times 10^3 = 7.6 \times 10^8 \times e^{-4.6 \times 10^{-3} t}$ (1)
$\ln (1.092 \times 10^{-5}) = -11.425 = -4.6 \times 10^{-3}$ t (1)
t = $11.425/4.6 \times 10^{-3} = 2480$ s (= 41 min) (1) [3]

(c) Application of inverse square law (1)
$234 / 3^2 = 26$ (counts per minute) (1) [2]

[Total: 7]

7 **(a)** A free oscillation is when there is repetition of the same forwards and backwards movement / no loss of energy (1)
Forced oscillations are when an external influence makes an object oscillate (1)
Damped oscillations are when the amplitude of the oscillation decreases (1) [3]

(b) Resonance is when a driver of the same frequency as the natural frequency of the driven causes a large amplitude oscillation for this building (1)
The oscillations of the ground are of the same frequency as parts of the building (1)

i.e. 1 mark for understanding the principle, 1 for applying it in this situation [2]

(c) The rubber absorbs energy from the earthquake (1)
The rubber dampens the oscillations (1) [2]

[Total: 7]

8 **(a)** $L = 4\pi\sigma r^2 T^4$ where $\sigma = 5.67 \times 10^{-8}$ (W m^{-2} K^{-4})
$L = 4\pi \times 5.67 \times 10^{-8} \times (6.96 \times 10^8)^2 \times 5700^4$ (1)
$= 3.64 \times 10^{26}$ W (1) [2]

(b) **(i)** $\lambda_{max} = 2.9 \times 10^{-3} / T = 2.9 \times 10^{-3} / 5700$ (1)
$= 5.1 \times 10^{-7}$ m (1) [2]

(ii) green (1) [1]

(c) $E = mc^2$ $\quad 3.64 \times 10^{26} = m \times (3.00 \times 10^8)^2$ (1)
mass lost per second = $m = 4.0 \times 10^9$ kg s^{-1} (1) [2]

[Total: 7]

9	(a)	Direction of oscillation or displacement (of molecules/particles)	(1)	
		is parallel to	(1)	
		the direction of travel or direction in which energy is transferred	(1)	[3]
	(b)	$340 = 20 \times 10^3\lambda$	(1)	
		λ = 17 mm		
		17 mm to 4.25 mm.	(1)	[2]
	(c) (i)	Displacement at L is 0.8 (units)		
		Displacement at M is 0.0 (units)		
		Displacement at N is –1.0 (units)		
		Evidence of subtraction	(1)	
		All three answers correct	(1)	[2]
	(ii)	Correct line through points	(1)	
		1.5 complete waves drawn (allow ecf for their wave shape)	(1)	[2]
	(d) (i)	Value of Δf = 0.45 kHz and f = 50.80 KHz	(1)	
		$0.45/50.80 = 2v/340$		
		Insect's speed, v = 1.5 (m s^{-1})	(1)	[2]
	(ii)	Diffraction	(1)	[1]
	(e) (i)	Evidence of attempt to determine gradient, dI/dx, at I = 8.4 W m^{-2} on graph or as stated coordinates.	(1)	
		Correct calculation of their gradient	(1)	
		Substitution in differential equation to give reasonable value for α	(1)	[3]
	(ii)	Units of α: m^{-1}	(1)	[1]
	(iii)	Solution to differential equation $I = I_0 e^{-\alpha x}$	(1)	[1]
	(iv)	From graph I_0 = 16.0 (W m^{-2})	(1)	
		From graph I = 12.4 (W m^{-2} at x = 0.4 m)	(1)	
		RHS approx. equal to LHS after substitution.	(1)	[3]
		$12.4 \approx 16\, e^{-(0.7 \times 0.4)}$		
		$12.4 \approx 12.1$		

[Total: 20]

10 (a) Substitution in $P = (1/2\ mv^2)/t$ (1)
$P = (0.5 \times 11600 \times 10^3 \times 20^2)/60 = 3.9/3.867 \times 10^6$ (W)
Power = 39 (MW) (1) [2]

(b) (i) $\ln P = 3\ln v + \ln(½A\rho)$
Intercept is $\ln(½A\rho)$ (1) [1]

(ii) Intercept value is 8.4 (1) [1]

(iii) Substitution with correct intercept only (1)

$½ (\pi\, l^2) \times 1.23 = e^{8.4} = 4447$
$l^2 = 2301$
$l = 48$ (47.98) (m)

Blade length = 48 (m) (1) [2]

(c) Torque = moment of inertia × acceleration (1)
Angular acceleration stated (1) [2]

(Accept $T = Ia$ with all symbols defined.)

(d) (i) General relationship
$I = \Sigma mR^2$ (1)
(*so* $I = MR^2$)
And idea that all mass is at the same radius, R. (1) [2]

(ii) $\omega = \frac{2\pi \times 4}{60} = 0.42$ (rad s^{-1})

Angular speed = 0.42 (rad s^{-1}) (1) [1]

(iii) 1 Conversions of minutes to seconds and kW to W (1)
Loss in RKE = average power × time
$= 0.5 \times 6.5 \times 10^3 \times 1800 = 5.85 \times 10^6$ (J)
RKE loss = 5.85 MJ (1) [2]

2 Assumption:
Rotational KE is equivalent to the work done against friction (1) [1]

(iv) Recalls $I = 2E/\omega^2$ (1)
Substitution $I = (2 \times 5.85 \times 10^6)/0.42^2 = 66.3 \times 10^6$ (1)
Moment of inertia = 6.6×10^7 (1)
Units are kg m^2 (1) [4]

(v) $I = M\,R^2$
$6.6 \times 10^7 = M \times 5.5^2$ (1)
$M = 2.2 \times 10^6$ kg (1) [2]

[Total: 20]

11 (a) (i) uud or up up down (1) [1]

(ii) Photon (1) [1]

(iii) Identifies the relationship $F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ (1)

Correct substitution for $Q_1Q_2 = e^2 = (1.60 \times 10^{-19})^2$ (1)

Correct substitution for $4\pi\varepsilon_0 F = 4\pi 8.85\text{x}\,10^{-12} 8.23x10^{-8} = 915.28x10^{-20}$ (1)

Radius of orbit $r = 0.0529$ (nm) Lose a mark if answer not in nm. (1) [4]

(b) (i) Quote formula from sheet and substitute for n values – expect to see minus sign. (1)

$$E_3 - E_2 = -13.6\text{eV}\left(\frac{1}{3^2} - \frac{1}{2^2}\right) = 1.89(\text{eV})$$

Energy difference = 1.89 (eV) (1) [2]

(ii) Conversion of eV to J (1)

Correct substitution (1)

$$\lambda = \frac{hc}{(E_3 - E_2)} = \frac{6.63x10^{-34}\,x3.00x10^{8}}{1.89x1.60x10^{-19}} = 6.58x10^{-7}\ (\text{m})$$

Wavelength = 6.6×10^{-7} (m) (1) [3]

(c) Any 4 marking points from the following:–

- Energy levels are fixed or discrete (1)
- Each level has its own principal quantum number, *n* (1)
- The standing waves are the fixed modes (1)
- The number of allowed standing waves in the circumference is one of the principal quantum numbers (see diagram for example)
  Accept mathematical expression $2\pi r = n\lambda$ (symbols explained) (1)
- Reference to the de Broglie wavelength (1)
- Packet or quantum of energy $E = hf$ absorbed or emitted between levels (1)
- Angular momentum is quantised (1)[4 max]

(d) 'Indeterministic'

- It is not possible to predict (for the electron/proton) a future value (1)
- from present knowledge of its position/energy level/trajectory/momentum/speed (1) [2]

(e) Correct substitution in Stefan's Law for the Sun or for Betelgeuse (1)
$L_S = 4\pi\sigma R_S^2 T_S^4$ or $L_B = 4\pi\sigma R_B^2 T_B^4$

Consistent replacements so that cancellation can be done
e.g. $\frac{L_S}{L_B} = \frac{R_S^{\ 2}(2T_B)^4}{(400R_S)^2 T_B^4} = \frac{16}{160000} = \frac{1}{10000}$ (1)

Ratio: $\frac{L_S}{L_B} = 10^{-4}$ (1) [3]

[Total: 20]

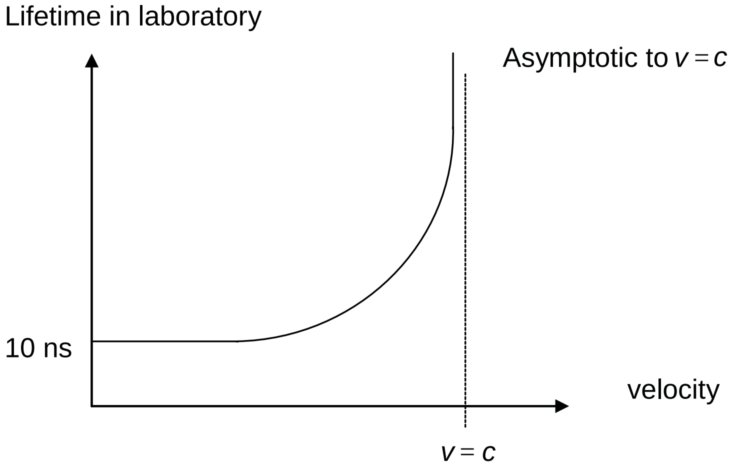
12 (a) Non-accelerated/constant velocity/constant speed <u>in a straight line</u> (1) [1]

(b) It is has the same value (is a constant) for all observers (1) [1]

(c) Simple correct statement
e.g. time appears to run slowly on moving clocks (1)

or a more detailed correct explanation:
Refers to two observers in relative motion (1)
Compares time interval between the same two events (e.g. ticks of moving clock) (1)
States correct qualitative relationship between time intervals as viewed from a defined reference frame (e.g. the time between ticks on the moving clock is greater than the time between ticks on the 'rest' clock when measured on the rest clock) (1)
[3 max]

(d)



Correct axes correctly labelled (no penalty for units or missing units) (1)
Starts at t = 10 ns on time axis (1)
Asymptotic to $v = c$ (labelled or implied by drawing) (1)
Correct shape curve (asymmetric – most of change after 0.8*c*) (1) [4]

(e) (i) Time passes more slowly in the moving reference frame (1)
The time dilation factor approaches infinity as v approaches c (1)
Justified by reference to the time dilation equation or the graph in (d) (1) [3]

(ii) time = distance / speed = 20 / 0.95 = 21 years (1) [1]

(iii) time dilation factor $\frac{1}{\sqrt{1-0.95^2}} = 3.2$ (or equivalent calculation) (2)

time elapsed = 21.1 / 3.20 = 6.59 years (1) [3]

(iv) When they reunite the travelling organisms have experienced less time than the stay-at-home organism <u>so they have travelled into the future</u> (1)
By 21.1 – 6.6 = 14.5 years (1) [2]

(v) The stay-at-home organisms are in the same reference frame throughout (1)
The travelling organisms are in different reference frames at different points in their journey (1)
The travelling organism undergoes several periods of acceleration (so changes its reference frame) (1)
The travelling organism is in a non-inertial reference frame during periods of acceleration (1)

(2 max. by making two different points) [2]

[Total: 20]

13 (a) $\Delta U = Q + W$ (or as a word equation), sign must be consistent with definitions as given by student (1)

ΔU = change in internal energy of a system
Q = heat supplied to system (accept ΔQ)
W = work done on a system (accept ΔW)

Accept different sign(s) if consistent with definitions. All three terms defined correctly (1) [2]

(b) Idea that *Q* and *W* transfer energy to the system and that the increase in energy of the system is equal to the energy supplied – so there is no energy created or destroyed. (1) [1]

(c) Simple statement: e.g. linking entropy to disorder without clarification (1)

or More detail: e.g. entropy of a system is related to the number of ways in which the energy in a system can be distributed among the particles in the system (or the particles can be distributed in space) (2)

or Accept $S = k \ln W$ with a clear explanation of the meaning of *W* and *k* identified as Boltzmann's constant (2)

or Accept equivalent correct explanations in terms of macroscopic thermodynamics (not on syllabus but may have been taught) (2) [2]

(d) (i) Chemical energy released in combustion (bond formation) is transferred to kinetic energy of the particles in the hot gaseous product (1) [1]

(ii) Number of ways increases (1)
or Kinetic energies are distributed randomly (1)
or The number of ways of distributing energy amongst the particle increases (2)
or The number of ways of distributing the particles in space increases (2) [2]

(iii) Demonstrates a clear understanding of *efficiency* (accept statements such as 'you can't get as much energy out as you put in') (1)
or Some of the heat supplied is transferred to the surroundings by the exhaust gases (1)
or Some of the heat supplied is transferred to the surroundings by the exhaust gases so the work done must be less than the energy supplied (2) [2]

(e) (i) efficiency = W / Q_1 or $(W / Q_1) \times 100\%$ (1) [1]

(ii) $W = Q_1 - Q_2$ (1)

efficiency = $\dfrac{(Q_1 - Q_2)}{Q_1} = 1 - \dfrac{Q_2}{Q_1}$ (1)

Use of second law: entropy of universe increases (1)

so $\dfrac{Q_2}{T_2} \geq \dfrac{Q_1}{T_1}$ (1)

Leading to $\dfrac{Q_2}{Q_1} \geq \dfrac{T_2}{T_1}$ (could be implied by substitution) (1)

efficiency $\leq 1 - \dfrac{T_2}{T_1}$ (mark is for inequality used correctly throughout derivation (1) [6]

(iii) Sensible estimates of T_1 expected range from 700 K to 1500 K (1)
Sensible estimate of T_2 (must be less than T_1) accept range 273 K to 400 K (1)
(Accept Celsius equivalents)

Value for efficiency consistent with estimates (must use K) allow ecf (1) [3]

[Total 20]

14 (a) (i) **Classical explanation** – intensity proportional to wave amplitude-squared **OR** intensity is energy delivered per second per unit area of wave front (1)

Quantum explanation – intensity proportional to the <u>rate</u> of arrival of photons or photons per second (1) [2]

(ii) **Classical explanation** – continuous absorption of energy from wave (1)

Quantum explanation – discrete absorption in quanta or photons (1) [2]

(b) **Rutherford's planetary model** –
electrons can orbit at any radius **or** with a continuous range of energies. (1)

Bohr's model – idea of discrete orbits or allowed radii or energy levels (quantised energy or angular momentum) (1) [2]

(c) Idea of quantum jumps between discrete energy levels (from diagram) (1)
Electron jumps in correct direction (from lower to higher energy) as photon is absorbed (could be from diagram) (1)
Discrete values of ΔE linked to discrete values of f or λ using $\Delta E = hf$ (1) [3]

(max. 2 marks if no relevant diagram is used)

(d) (i) According to **Newtonian mechanics**: particles (e.g. electrons) always have a definite position and momentum	(1)	
or uncertainty in position is not linked to uncertainty in momentum	(1)	
basic explanation of the **H.U.P**. e.g. the more precisely the position of a particle is defined, the greater the uncertainty in its momentum (or vice versa).	(1)	
or accept explanations based on wave mechanics – e.g. if electron wavelength is precisely defined (definite momentum) then the wave train must be infinitely long (infinite uncertainty in position)	(1)	
explanation of **incompleteness** – e.g. Einstein's view that quantum theory cannot describe the detailed properties of an electron so it is in some sense lacking	(1)	[3]
(ii) Identifies aperture width as Δx	(1)	
Uses $\Delta p \geq \frac{h}{2\pi\Delta x}$ to calculate $\Delta p = 1.05 \times 10^{-24}$ kg m s^{-1} for electron	(1)	[2]
(iii) Comparison with value of p, 2.73×10^{-23} kg m s^{-1}, to show significance (e.g. $\Delta p \approx 4\% \, p$ or $\Delta p \approx 0.039 \, p$)	(1)	
So electrons are likely to be scattered through a significant angle or emerging electrons will be travelling in a range of directions.	(1)	[2]
(e) Representation of photon by a wave function	(1)	
(Amplitude squared related to) probability of arrival on screen	(1)	
Diffraction at slit leading to chance of arrival anywhere on screen	(1)	
Random collapse of wave function leading to detection of photon	(1)	[4]

[Total: 20]