Cambridge Pre-U

Cambridge International Examinations
Cambridge Pre-U Certificate

PHYSICS (PRINCIPAL) | **9792/03**

Paper 3 Written Paper | **For Examination from 2016**

SPECIMEN MARK SCHEME

3 hours

MAXIMUM MARK: 140

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CAMBRIDGE International Examinations

Section 1

1	(a)	new velocity labelled in correct direction	(1)	
		correct triangle completed	(1)	
		with change in velocity labelled in correct direction	(1)	[3]
	(b) (i)	loss of PE = 560 × 9.81 × 25.0 = 137 340 (J)	(1)	
		KE at top = $\frac{1}{2}$ × 560 × 10^2 = 28 000 (J)	(1)	
		gain of KE = 137 340 – 40 000 = 97 340 (J)	(1)	
		KE at bottom = 125 340 (J) = $\frac{1}{2}$ × 560 × v^2	(1)	
		$v = \sqrt{\left(\frac{2 \times 125340}{560}\right)} = 21.2\,(\mathrm{m\ s^{-1}})$	(1)	[5]
	(ii)	weight of carriage = 560 × 9.81 = 5494 (N) (force 1 or 2)	(1)	
		$m \times a = m \times \frac{v^2}{r} = 560 \times \frac{21.16^2}{18.0} = 13\,930\,(\mathrm{N})$	(1)	
		so upward force from track = 19 420 (N) (force 2 or 1)	(1)	[3]

[Total: 11]

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)	at the resonant frequency $\omega = 2\pi f = 2\pi \times 35.5 = 223\ \mathrm{rad\ s^{-1}}$	(1)	
		use of $A = 0.0114$ in equation $E = \frac{1}{2} mA^2\omega^2$	(1)	
		$= \frac{1}{2} \times 0.046 \times 0.0114^2 \times 223^2 = 0.149\,(\mathrm{J})$	(1)	[3]
	(ii)	amplitude read correctly as 0.0041 m	(1)	
		giving energy as $\frac{1}{2} \times 0.046 \times 0.0041^2 \times (40\pi)^2 = 0.0061\,(\mathrm{J})$	(1)	[2]

[Total: 8]

3	(a) (i)	minimum work required = mgh = 50 × 9.81 × 400 = 196 000 (J)	(1)	[1]
	(ii)	change in gravitational potential = gh = 9.81 × (600 – 200) = 3920	(1)	
		$\mathrm{m^2\,s^{-2}}$ **or** $\mathrm{N\,m\,kg^{-1}}$ **or** $\mathrm{J\,kg^{-1}}$	(1)	[2]
	(iii)	attempt to make lines cross contour lines at right angles subtract 1 mark for every two glaring discrepancies of this (to minimum zero)	(2)	[2]

(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 $\times$ 400 V $= 0.020$ (J) (1)

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

[Total: 10]

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

stage 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) efficiency $= \frac{396 - 235}{246} = 0.65$ or 65% (1) [1]

accept $1 - \frac{T_1}{T_2} = 1 - \frac{300}{950} = 0.68$ or 68%

[Total: 12]

5	**(a)**	**(i)**	$\log (T / s) = \log (k / sm^{-n}) + n \log (r / m)$	(1)	
			gradient = n	(1)	
			y-Intercept = $\log (k / sm^{-n})$ **accept** $\log k$	(1)	[3]
		(ii)	5 points plotted correctly and straight trend line drawn	(1)	
			gradient calculated correctly	(1)	
			$n = 1.5 \pm 0.1$	(1)	[3]
		(iii)	rearranges the equation to give $M = \frac{4\pi^2}{k^2 G}$ **or** $k = 3.2 \times 10^{-8}$ (ignore units)		
			by antilogging intercept	(1)	
			$M = 5.65$ **or** 5.7×10^{26} (kg)	(1)	[2]

[Total: 8]

6	**(a)**		${}^{210}_{84}\text{Po} \rightarrow {}^{4}_{2}\alpha + {}^{206}_{82}\text{Pb}$		
			${}^{4}_{2}\alpha$	(1)	
			${}^{206}_{82}\text{Pb}$	(1)	[2]
	(b)	**(i)**	ratio = (–) 1	(1)	[1]
		(ii)	ratio $= \frac{m_{Pb}}{m_{\alpha}}$	(1)	
			$= \frac{206}{4} = 51.5$	(1)	[2]
		(iii)	ratio $= \frac{m_{\alpha}}{m_{Pb}} \times \left(\frac{v_{\alpha}}{v_{Pb}}\right)^2$	(1)	
			$= 51.5$	(1)	[2]
	(c)		$N = N_0 e^{-\lambda t}$		
			$\ln\left(\frac{N}{N_0}\right) = -\lambda t$	(1)	
			$\ln\left(\frac{850}{24000}\right) = -3.3406 = -\left(\frac{\ln 2}{138}\right) \times t$	(1)	
			$t = 138 \times \left(\frac{3.3406}{\ln 2}\right) = 665$ (days) $(= 5.75 \times 10^{7}$ s)	(1)	[3]

[Total: 10]

7	**(a)**	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]
	(b)	$(I =) \dfrac{(1.2 \times 0.22)}{(1.26 \times 10^{-6} \times 2000)}$	(1)	
		105 (A)	(1)	[2]
	(c) (i)	e.g. it might melt the coil, the wire would have to be too thick **or** not a long coil **or** diameter << 0.22 m	(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: 8]
8	**(a)**	the result from the 2000 experiment <u>and</u> it has the smallest range of uncertainty (accept smallest uncertainty)	(1)	[1]
	(b) (i)	an error which results all values being higher or lower than expected	(1)	[1]
	(ii)	there might be systematic errors in this experiment	(1)	
		which would shift the result away from the true value without affecting the precision of the measurement	(1)	[2]
	(iii)	any **two** from if different experiments are consistent the result is more reliable comparison of different results can reveal the presence of systematic errors if the range of results from two experiments overlap this is a good indication that the true value lies in the region of overlap		[2]
	(iv)	any **two** from methods to measure G involve measuring gravitational forces between masses these forces are very small for laboratory sized objects gravitational forces are very weak (gravity is very weak) all masses have gravity so it is difficult/impossible to isolate the apparatus		[2]
				[Total: 8]

9 **(a)** $\sin 0.0000255 = \dfrac{1.50 \times 10^{11}}{x}$ (1)

$x = \dfrac{1.50 \times 10^{11}}{\sin 0.0000255} = 3.37 \times 10^{17}$ (m) accept use of tangent (1) [2]

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

[Total: 5]

Section 2

10 **(a)** **(i)** similarity: same mass (1)

(ii) difference: opposite charge or opposite spin (1) [2]

(b) **(i)** $\Delta E = c^2 m$ (1)
$= (3.00 \times 10^8)^2 \times 2 \times 9.11 \times 10^{-31}$ correct substitution
$= 1.64 \times 10^{-13}$ (J) (1) [2]

(ii) $(f =)\ \dfrac{1}{2}\dfrac{\Delta E}{h}$ halve energy in **(b)(i)** (1)

$= \dfrac{1}{2} \times (1.64 \times 10^{-13})/(6.63 \times 10^{-34})$

$= 1.24 \times 10^{20}$ (Hz) (1) [2]

(c) **(i)** there is a range of energies (1)
energy per decay is constant **or** energy is conserved (1)
(anti neutrino) particle has the remaining energy (1) [3]

(ii) 78 = 79 + –1 hence antineutrino must have zero proton number (1) [1]

(d) e.g. $400 = 800\ e^{-\mu 8}$ accept either $C = C_0\ e^{-\mu x}$ or $I = I_0\ e^{-\mu x}$
$\ln 2 = 8\mu$
$\mu = 0.0866\ mm^{-1}$ **or** $86.6\ m^{-1}$

$C_0 = 800\ (s^{-1})$ (1)
consistent values for x and C from graph (1)
$\mu = 0.087$ **or** 87 (1) [3]
m^{-1} (1) [1]

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

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

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

(iii) $(E_I) = \dfrac{9.11\times10^{-31}\times(1.6\times10^{-19})^4}{8\times(8.85\times10^{-12})^2\times(6.63\times10^{-34})^2} = 21.68\times10^{-19}$ (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) (i) (speed is constant but) direction is continuously changing (towards centre) (1)
(velocity is changing) with time (so body accelerates) (1)
by Newton 2 (1)
a force is required (for acceleration towards centre) (1)
max [3]

(ii) $a = \dfrac{v^2}{r}$ (1) [1]

(b) $R - mg = \dfrac{mv^2}{r}$ or $R = 200 + \dfrac{20\times4.7^2}{2.8} = 200 + 161$ (1)

$R = 361$ (N) (1) [2]

(c) (i) $I = \int(r^2\Delta m) = \int_r^{r_1}\rho2\pi r^3\,\mathrm{d}r = [\tfrac{1}{2}\rho\pi R^4] = \tfrac{1}{2}MR^2$

mass of small ring $\mathrm{d}m = \rho2\pi r.\mathrm{d}r$ (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)

$I = \tfrac{1}{2}MR^2$ (1) [4]

(ii) $10.1 = 44.8\times\dfrac{(1.40-0)}{t}$

states or uses $T = I\alpha$ (1)
$t = 6.21$ (s) (1) [2]

(iii) $t = \dfrac{(118\times1.40)}{10.1} = 16.4$ (s) (1)

$\Delta t = 16.4 - 6.2 = 10.2$ (s) **or** their 2nd time – their 1st time **(i)** (1) [2]
allow $\Delta t = 10.45$ from use of $t = 6$ s (from **(c)(iii)**)

(iv) 1. angular momentum is conserved (1)
I increases so ω decreases (1)
ω decreases so T increases (1) [3]

(v) **2.** $T_1 = \frac{2\pi}{1.40} = 4.49$ s $\quad T_2 = 4.49 + 0.66 = 5.15$ *so* $\omega_2 = 1.22$ *rad* s^{-1}

$I_1\omega_1 = I_2\omega_2$

$118 \times 1.40 = I_2 \times 1.22$ hence $I_2 = 135$ (kg m^2)

calculation of new T or new ω	(1)	
states or applies principle of conservation of angular momentum, using ω or T	(1)	
(new moment of inertia =)135 (kg m^2)	(1)	[3]

[Total: 20]

12 **(a)**

resultant (force)	(1)	
force (exerted on a body) is proportional to the rate of change in momentum	(1)	[2]

(b)

$\frac{dm}{dt} = \frac{F}{v} = \frac{34700 \times 10^3}{2.6 \times 10^3}$	(1)	
= 13 300 (kg s^{-1})	(1)	[2]

(c) **(i)**

working line shown and clear conversion of natural logs to exponentials	(1)	[1]

(ii) <u>in table</u>

$\left(\frac{m}{m_o}\right) = 0.88$	(1)	
$\Delta v_r = 7.7(4)$	(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 $V = 2.6 \times 10^3$; $\frac{m}{m_o} = 0.15$ $\quad m = 0.15 \times 2.04 \times 10^6 = 306\,000$ kg	(1)	
with $V = 8.0 \times 10^3$; $\frac{m}{m_o} = 0.54$ $\quad m = 0.54 \times 2.04 \times 10^6 = 1\,101\,600$ kg	(1)	
difference in mass = 796 000 (kg)	(1)	[3]

(d) **(i)**

$E = -\frac{(GM_E m_S)}{(R + h)}$	(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)	
$PE = \text{total energy} - KE = -4.5 \times 10^9 - 4.5 \times 10^9 = -9.0 \times 10^9$	(1)	
$-9.0 \times 10^9 = -\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 152}{r}$		
$r = 6.736 \times 10^7$	(1)	
$h = 6.736 \times 10^7 - 6.36 \times 10^6 = 3.76 \times 10^5$ (m)	(1)	[4]

[Total: 20]

13 **(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)** At speeds close to the speed of light, the length of a moving object is less than its proper length for a stationary observer (owtte) (1) [1]

(ii) $I = I_0 \times \sqrt{1 - \frac{v^2}{c^2}} = 1.0 \times \sqrt{1 - \frac{\left(\frac{c}{2}\right)^2}{c^2}}$ [1]

$= 0.866$ (m) **or** 0.87 (m) [1]

(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) $\lambda = \frac{1}{\sqrt{1 - 0.20^2}} = 1.021$ (1)

half-life in laboratory reference frame $= 1.021 \times 18\,\text{ns} = 18.4\,\text{(ns)}$ (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 decimal point) (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** 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)
max [3]

(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]

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 rate 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)
max [3]

(ii) identifies aperture width as Δx (1)
uses $\Delta p \geq \dfrac{h}{2\pi\Delta x}$ to calculate $\Delta p = 1.05 \times 10^{-24}$ (kg m s^{-1}) for electron (1) [2]

(iii) comparison with value of p, $2.73 \times 10^{-23}\ \text{kg m s}^{-1}$, 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]

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

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

(c) heat flows from hot to cold <u>and</u> 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 <u>more energy is supplied</u> there will be (1)
<u>more ways in which it can be distributed</u> amongst the particles of the body (so the entropy increases) (1) [2]
or $\Delta S = \frac{\Delta Q}{T}$ used <u>and</u> used appropriately with terms defined

(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 **or** that it tends to a maximum (1) [1]

(i) any **three** 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 <u>increases entropy more</u> than heat Q_2 absorbed reduces it (2)
max [3]

accept answers that refer to the entropy change of the refrigerator and environment in terms of $\Delta S_{OUT} = W + \frac{Q_2}{T_{OUT}} > \Delta S_{IN} = -\frac{Q_1}{T_{IN}}$ for 3 marks as long as terms are used correctly

(j) temperature of the room will increase (1)
any **two** from
heat dumped > heat extracted (1)
energy flows into the system (1)
electrical energy input is transferred to heat in room (1)
max [3]

[Total: 20]