CAMBRIDGE INTERNATIONAL EXAMINATIONS

Pre-U Certificate

MARK SCHEME for the October/November 2013 series

9792 PHYSICS

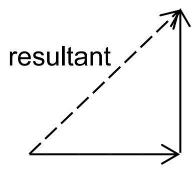
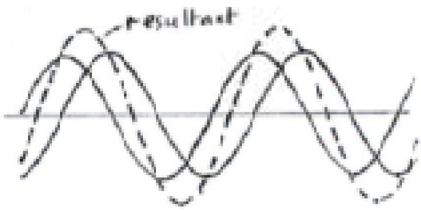
9792/03 Paper 3 (Part B Written), maximum raw mark 140

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

CAMBRIDGE
International Examinations

Section A [80 marks]

Q	Marking Points	Marks	Totals	
1 (a)	wave approaching slit with same wavelength as wave leaving slit wave emerging from slit as almost as if from a point source	1 1	2	
(b) (i)	**1** (path difference =) $5.2 \times 10^{-6} \times \sin 10° = 9.03 \times 10^{-7}$ (m)	1		
	2 $d \sin\theta = \lambda$ $\sin\theta = 5.9 \times 10^{-7} / 5.2 \times 10^{-6}$ $\theta = 6.51$ (degrees) **ecf from (b)(i)1**	 1 1		
	3 $5.9 \times 10^{-7} / 5.2 \times 10^{-6} = 0.113$ $1/0.113 = 8.8$, so maximum 8 $8 + 8 + 1$ (at $\theta = 0°$) = 17	1 1 1		
(ii)	**1** either diagram showing a phase difference of 90° resultant wave indicated and with an amplitude of $1.41a$ 	1 1		
	2 intensity α amplitude^2 intensity of two waves in phase = 4 × intensity of one wave intensity of resultant here is $(1.41a)^2$ = 2 × intensity of one wave (intensity = maximum intensity ×) $\frac{1}{2}$	 1 1 1	11	**13**

2 (a)	<u>first law</u>: planets move in elliptical orbits with the Sun at one focus <u>second law</u>: Sun-planet line sweeps out equal areas in equal times <u>third law</u>: orbital period squared of a planet is proportional to its mean distance from the Sun cubed **maximum 2 marks for all circular orbits**	1 1 2	4	
(b)	acceleration = $v^2 / r = F / \text{m} = (–)GM / r$ $v = 2\pi r / T$ combine to get $4\pi^2 r^3 / T^2 = GM$ and hence $r^3 \alpha T^2$	1 1 1	3	

(c) (i)	$(29.5/1)^2 = r_s^3/(1.50 \times 10^{11})^3$ $r_s = \sqrt[3]{2.937 \times 10^{36}}$ $= 1.43 \times 10^{12}$ (m)	1 1 1		
(ii)	**any one from** Saturn and Earth are considered as point masses the Sun's mass is so large that other masses are insignificant in comparison	1	4	
(d)	use of $4\pi^2r^3/T^2 = GM$ $r^3 = (23.4 \times 24 \times 3600)^2 \times 6.67 \times 10^{-11} \times 1.99 \times 10^{30}/4\pi^2$ $r = \sqrt[3]{1.734 \times 10^{31}} = 2.4 \times 10^{10}$ (m)	 1 1	2	**13**

3 (a) (i)	(electric field strength) is the force acting per unit <u>positive</u> charge	1		
(ii)	equally spaced, parallel straight lines with arrows down over most of space between plates curved lines shown at edges (showing weaker, non-uniform field)	1 1		
(iii)	**1** (W =) VQ	1		
	2 (W =) Fd	1		
(iv)	$VQ = Fd$ so force per unit charge (electric field strength) = F/Q = V/d (as potential gradient)	1 1	7	
(b) (i)	use of $F = q_1q_2/4\pi\varepsilon_0 d^2$ and knowing what each term represents (F =) $1 \times 10^{-6} \times 4 \times 10^{-6}/4 \times 8.85 \times 10^{-12} \times (0.06)^2 = 9.99$ (N) **accept 10 (N)**	1 1		
(ii)	$1/d^2 = 4/(6.0 - d^2)$ $4d^2 = 6.0 - d^2$ $2d = 6.0 - d$, so $d = 2.0$ (cm) **or** 0.02 m	1 1 1		
(iii)	**any three from** field lines at right angles to equipotential lines more equipotential lines around 4 μC charge than 1 μC charge equipotential lines dipping towards neutral point equipotential lines encompassing both charges further out	3	8	**15**

4 (a) (i)	$3 \times 1.38 \times 10^{-23} \times (27 + 273)/2 = 6.2 \times 10^{-21}$ Joules **or** J	1 1		
(ii)	**1** <u>m</u>: mass of a molecule	1		
	2 <u>$\langle c^2 \rangle$</u>: mean value of all the squares of the speeds of the molecules	1		

	3 $\frac{1}{2}m < c^2 >$: mean value of kinetic energy of a molecule	1	5	
(b)	$c_n / c_o = (32/28)^{\frac{1}{2}} = (0.875)^{\frac{1}{2}}$ = 1.07	1 1	2	
(c)	(… equals) the work done on the system plus heat supplied to the system	1 1	2	
(d) (i)	($W = p\,\Delta V$) = $8.00 \times 10^6 \times (7.10 - 3.00) \times 10^{-5}$ = 328 (J)	1 1		
(ii)	($Q = mc\Delta\theta$) = $1.27 \times 10^{-3} \times 1.01 \times 10^3 \times 900$ 1154 (J)	1 1		
(iii)	1154 – 328 = 826 (J) **ecf from (d)(i) and (d)(ii)**	1	5	**14**

5 (a) (i)	the random nature of decay (of a particular nucleus) implies that the only factor affecting the decay is the number N of particles present the fixed probability of decay per unit time is the decay constant λ (hence) the rate of decay dN/dt must be negative and so equals $-N\lambda$	1 1 1		
(ii)	rearrange to get $dN/N = -\lambda dt$ integrate to get $\ln N = -\lambda t + c$ at $t = 0$, $N = N_0$, so $c = \ln N_0$ rearrange and take antilogs to get $N/N_0 = e^{-\lambda t}$	1 1 1 1	7	
(b)	for Ni-59, $\lambda = \ln 2/80000 = 8.66 \times 10^{-6}$ hence activity = $2.1 \times 10^{12} \times e^{-8.66 \times 0.001} = 2.08 \times 10^{12}$ (Bq) for Ni-63, $\lambda = \ln 2/92 = 7.53 \times 10^{-3}$ hence activity = $2.1 \times 10^{12} \times e^{-7.53} = 0.123 \times 10^{12}$ (Bq)	1 1 1 1	4	
(c)	Ni-59: its (low) activity remains approximately constant for a long time Ni-63: activity will decrease to the same low level after a long time	1 1	2	**13**

6 (a) (i)	$E_1 = -13.6\,\text{eV}/1$, $E_3 = -13.6\,\text{eV}/9 = -1.51$ (eV) $E_n = -1.51\,\text{eV} - (-13.6\,\text{eV}) = 12.1$ (eV) $= 12.1 \times 1.60 \times 10^{-19} = 1.94 \times 10^{-18}$ (J)	1 1 1		
(ii)	$E = hc/\lambda$ so $\lambda = hc/E$ $= 6.63 \times 10^{-34} \times 3.00 \times 10^8 / 1.94 \times 10^{-18} = 1.07 \times 10^{-7}$ (m)	1 1	5	

(b) (i)	**any two from** radiation from a moving source will have its wavelength altered **or** there is a Doppler effect / shift the change (in wavelength) depends on speed of the radiation and the speed of the source galaxy is moving away (receding) from the Earth	2		
(ii)	use of $\Delta\lambda / \lambda$ is approximately equal to v / c and knowing what each term represents (v =) $3.00 \times 10^8 \times (1.28 - 1.03) / 1.03 = 7.3 \times 10^7$ (m s^{-1})	1 1	4	
(c)	**any three from** all galaxies are receding from our own galaxy / show the same effect more distant galaxies are receding at greater rates going back in time means the galaxies must have been closer go back long enough and all galaxies must have been at the same place which is known as the Big Bang	3	3	**12**
		Section A total 80		

Section B [60 marks]

7 (a)	direction of <u>oscillation</u> of molecules / particles is parallel to the direction of travel/wave propagation	1 1	2	
(b)	**any two points that refer to <u>both</u> types of waves**	2	2	
(c) (i)	**1** correctly identified particle (labelled O) which is π radians out of phase with particle X	1		
	2 arrow drawn (at X) pointing vertically upwards	1		
(ii)	twice distance from X to horizontal axis = 2×0.06 cm = 0.12 (cm)	1	3	

Progressive waves	Standing waves
Transfer energy	Store energy
There is a varying phase relationship between particles in a wave	Particles between adjacent nodes are in phase
All particles have the maximum displacement	Only the antinodal particles have the maximum displacement.

(d)	evidence that $\frac{1}{6}$ of wavelength / 2π has been sought	1		
	distance between given peak and drawn adjacent peak is $\frac{1}{6}$ of wavelength	1		
	a complete wave is drawn reasonably consistently placed relative to the given wave	1	3	
(e) (i)	droplets are at the nodes **or** where there is no net displacement	1		
(ii)	evidence that candidate realises that λ = 2 × nodal separation λ = (2.4 × 2) × 0.25 = 1.2 cm $f = v / \lambda$ = 9.7 / 1.2 = 8.1 (Hz)	1 1 1	4	
(f) (i)	**1** (see table below) **one mark for each correct column**	2		
	2 All points plotted and smooth line of best fit (curve) drawn	1		
(ii)	**1** $180 = 10\,log\left(\frac{P_w}{P_s}\right)$ and $200 = 10\,log_{10}\left(\frac{P_{ps}}{P_s}\right)$ $\frac{20}{18} = log\left(\frac{P_{ps}}{P_s}\right) / log\left(\frac{P_w}{P_s}\right)$ $\left(\frac{P_{ps}}{P_w}\right) = \frac{10^{20}}{10^{18}} = 10^2 = 100$	 1 1		
	2 the <u>rate</u> at which the shrimp provides energy exceeds that of the whale, but the whale's wave carries far more energy / is more intense	1	6	**20**

Table for (f)(i) 1:

P	$x = 10log_{10}\left(\frac{P}{P_s}\right)$
$10P_S$	10
$5\ P_S$	**7 or 6.99**
P_S	**0**
0.1 P_S	-10

8 (a)	acceleration is proportional to displacement acceleration directed to equilibrium point	1 1	2	
(b) (i)	$v = -A\omega sin(\omega t)$	1		
(ii)	(from graph in Fig. 8.2) T = 0.58 (s) A = 0.65 (cm) $\omega = 2\pi / T$ **or** substitution v = –0.65 × 10.83 sin (10.83 × 0.94) v = (–) 1.25 (cm s^{-1})	 1 1 1 1		
(iii)	a arrow upwards v arrow upwards	1 1		

(iv)	$\omega = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$ seen See substitution for ω^2 in $a = -\omega^2 x$	1 1	9	
(c) (i)	amplitude gradually decreases with time / decreases by the same fraction each second **or** energy transferred at a low rate (from oscillator) giving slow reduction in amplitude over time	1		
(ii)	**1** (from graph in Fig. 8.5) A = 13.0 (cm) and A = 9.0 (cm) ln A = 2.6 and ln A = 2.2	 1 1		
	2 sensible scale for time t and all points correctly plotted **ecf points from table** straight line graph **no ecf**	1 1		
	3 gradient = –0.24 **ecf from line of best fit** **minus sign required**	1		
	4 ln $A = -0.25t + 2.8$ **ecf from (c)(ii)3**	1		
	5 exponential equation for A $A = A_0 e^{-0.24t}$ or $A = 16e^{-0.24t}$ **ecf gradient from (c)(ii)3**	1 1	9	**20**

9 (a) (i)	**any three from** electrons experience a force (as they move) in the magnetic field direction of force given by Fleming's LHR build-up of electrons at (upper) surface / E field created between (upper and lower) surfaces V_H is pd between surfaces when electric and magnetic forces balance	3		
(ii)	force due to electric field vertically upwards <u>and</u> force due to magnetic field vertically downwards	1		
(iii)	**1** recalls $F_B = Bev$ (or BQv) recalls $F_E = Ee = V_H e/d$ equates F_B to F_E $Bev = \frac{V_H}{d}e$ substitutes for v and A correctly and cancels $\frac{BeI}{ntde} = \frac{V_H}{d}e$	1 1 1 1		
	2 identifies t = 0.56 mm correct identification of quantities in $B = (V_H nte)/I$ or equivalent equation **must see value of e** $B = \frac{Vnte}{I} = \frac{62\times10^{-3}\times4.3\times10^{21}\times0.56\times10^{-3}\times1.6\times10^{-19}}{140\times10^{-3}}$ = 0.17 (T)	1 1 1	11	

(b) (i)	$(82.4 - 82.0) \times 10^{-3} \times 9.81 = 3.9 \times 10^{-3}$ (N)	1		
(ii)	**any three from** current (flow in rod) produces magnetic field around the rod this field interacts with the permanent field (of the U-shaped magnet) reference to Newton's 3rd law / upward force on rod equals downward force on magnet (rod is fixed) magnet (or balance) is moveable and so this additional force is recorded a correct reference to Fleming's LHR	3		
(iii)	**1** arrow from lower to upper magnetic pole **or** lower pole marked as the North pole / upper pole labelled South	1		
	2 uses $l = 6.7$ cm recalls and correctly substitutes in $F=BIl$ $I = \frac{F}{Bl} = \frac{3.9\times10^{-3}}{28.6\times10^{-3}\times6.7\times10^{-2}}$ = 2.03 (A)	1 1 1		
	3 (82.0 – 0.4 =) 81.6 (g)	1	9	**20**

10 (a)	light is diffracted as it enters the microscope **accept other instrumental limits to resolution as an alternative to a diffraction limit** we cannot be sure which direction the light has come from so we cannot be sure of the location of the object that scattered the light (owtte)	1 1	2	
(b)	gamma-rays have a shorter wavelength there would be 'less diffraction' and so a sharper image (owwte) elaboration on 'less diffraction' referring to angles of scattering **or** angle to minimum of diffraction pattern **or** else correct use of the Rayleigh criterion formula	1 1 1	3	
(c) (i)	photons have momentum it is a collision so momentum / energy are transferred **or** momentum is conserved **give credit for making analogy between photon / electron collision and particle collisions**	1 1		
(ii)	The shorter the wavelength the greater the momentum transfer correct use of de Broglie relation (inverse proportion) **or** a clarity that it is the uncertainty in the amount of momentum transferred that has increased	1 1		

(iii)	**any three from** demonstrates an understanding of the meaning of Δx and Δp HUP implies reducing uncertainty in position increases uncertainty in momentum relates minimising Δx to use of shorter wavelengths (or gamma-rays) **or *vice versa*** relates minimising Δp to use of longer wavelengths (or light) **or *vice versa*** uncertainty in momentum is along x-axis **plus** realises that there is a reciprocal relationship between position and momentum (measurements) in the Heisenberg thought experiment (e.g. using gamma-rays reduces the uncertainty in position but increases the uncertainty in momentum)	3 1	8	
(d)	calculates the uncertainty in momentum from $\Delta p = \frac{h}{2\pi\Delta x}$ obtains $\Delta p = 8.8 \times 10^{-35}$ kg m s^{-1} (approx.) shows that this is tiny compared with original linear momentum (mv = 160 kg m s^{-1})	1 1 1	3	
(e)	demonstrates an understanding of the distinction between deterministic and indeterministic need to know initial conditions and rules to predict the future quantum theory / HUP, etc. tells us it is impossible to know / measure the present states precisely hence future states can only be predicted statistically **give credit for valid arguments referring to determinism versus indeterminism** accept answers that give clear and relevant examples showing indeterministic quantum processes and contrasting them with deterministic processes – e.g. the Copenhagen interpretation of the double slit experiment	1 1 1 1	4	**20**

11 (a) (i)	it would not obey the law of conservation of energy (owtte)	1		
(ii)	it would not obey the second law of thermodynamics elaboration required for second mark: e.g. entropy would decrease **or** it would involve an increase in order (decrease in disorder)	1 1	3	
(b) (i)	the energy output of the generator is greater than the amount of energy needed to turn the motor and generator **or** its efficiency is greater than 100%	1		
(ii)	first kind – it creates more energy than it uses	1		

(iii)	**any explanation of why it cannot work from** the energy output of the generator cannot exceed the energy input there is no external source of energy so there will be no excess **any two explanations of why it stops from** the only energy in the system is put there at the beginning when it is initially spun energy losses from system (friction in bearings/ohmic heating) therefore system's energy reduces and it eventually stops accept valid alternative approaches – e.g. using an energy flow (Sankey) diagram to show that the system must be inefficient	1 1 2	6	
(c) (i)	Lenz's law tells us the <u>direction</u> of the induced emf (induced currents) in electromagnetic induction direction of induced emf (current) is such as to oppose the change that caused the induction (owwte)	1 1		
(ii)	falling magnet creates a changing flux-linkage in copper walls and hence an induced emf (currents) induced (emf leads to induced) currents in create a magnetic force on the falling magnet upwards (opposing change) idea of balanced forces and terminal velocity	1 1 1 1		
(iii)	force would increase velocity (cause acceleration) higher velocity would increase force energy would be created from nothing	1 1 1	9	
(d)	**any two from** this would be equivalent to building a perpetual motion machine of the second kind it would violate the second law of thermodynamics the efficiency is limited because entropy has to increase overall heat engines need a large temperature difference to achieve a high efficiency thermal energy has very high entropy **or** electrical energy has low entropy it would result in a decrease of entropy	2	2	**20**

12 (a) (i)	speed of light **accept** *c*	1		
(ii)	$c - v$ correct application of relative velocity idea from A's reference frame e.g. in 1s (for A) the pulse moves *c* metres ahead of A and B moves *v* metres ahead of A so the pulse has moved $c - v$ metres ahead of B in one second (as seen by A).	1 1		
(iii)	speed of light **accept** *c*	1		

(iv)	B's measuring instruments do not agree with A's because they are in a different reference frame **or** in relative motion e.g. B's clocks run slow (time dilation) **accept** that B's rulers contract or separated clocks have a synchronisation error	1 1	6	
(b) (i)	when the clock is moved it runs slow, so it loses time as it is transported this is caused by relativistic time dilation	1 1		
(ii)	the distant clock has 'lost time' so the time difference is reduced	1		
(iii)	increasing speed increases the time dilation effect but the journey time is shorter so it runs slowly for a shorter time these two effects oppose one another (and might cancel out) **do not award** for 'no difference' unless accompanied by a valid explanation	1 1 1		
(iv)	both start at the same time because the speed of light is the same in both directions so they are both started at a time d/c after the flash is emitted they keep time because they are both in the same reference frame (or at rest with respect to each other)	1 1 1		
(v)	relative velocity to clock X is therefore ($c - v$) relative velocity to clock Y is therefore ($c + v$) **or** clock Y (seen from rocket) is approaching the light pulse clock X moving away from it light travels further in the rocket frame to reach X than Y therefore light reaches Y before X so Y starts before X moving observer sees light travelling at c in both directions (relative to rocket) – award mark if this is implied by the rest of the argument	1 1 1		
(vi)	moving observers will not agree that clocks and calendars are synchronised, so they will see one event before the other **any additional detail from** e.g. the order of the observed events depends on the direction of travel of the observer **or** only observers at rest with respect to the two civilizations (or moving at right angles to the line connecting the civilisations) will agree **or** the time difference between the observed events will depend on the observer's velocity **award a maximum of 1 mark** for arguments that are based upon time of flight of light to distant observers if it does not include a discussion of relativistic simultaneity	1 1	14	**20**

Section A total 60