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ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Physics 6451
Specification A

PA10 The Synoptic Unit

Mark Scheme

2006 examination - June series

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Instructions to Examiners

1 Give due credit to alternative treatments which are correct. Give marks for what is correct; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the script to the Awards meeting if poor presentation forbids a proper assessment. In each paper candidates may be awarded up to two marks for the Quality of Written Communication in cases of required explanation or description. Use the following criteria to award marks:

2 marks: Candidates write legibly with accurate spelling, grammar and punctuation; the answer containing information that bears some relevance to the question and being organised clearly and coherently. The vocabulary should be appropriate to the topic being examined.

1 mark: Candidates write with reasonably accurate spelling, grammar and punctuation; the answer containing some information that bears some relevance to the question and being reasonably well organised. Some of the vocabulary should be appropriate to the topic being examined.

0 marks: Candidates who fail to reach the threshold for the award of one mark.

3 An arithmetical error in an answer should be marked AE thus causing the candidate to lose one mark. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks (indicated by ticks). These subsequent ticks should be marked CE (consequential error).

4 With regard to incorrect use of significant figures, normally two, three or four significant figures will be acceptable. Exceptions to this rule occur if the data in the question is given to, for example, five significant figures as in values of wavelength or frequency in questions dealing with the Doppler effect, or in atomic data. In these cases up to two further significant figures will be acceptable. The maximum penalty for an error in significant figures is **one mark per paper**. When the penalty is imposed, indicate the error in the script by SF and, in addition, write SF opposite the mark for that question on the front cover of the paper to obviate imposing the penalty more than once per paper.

5 No penalties should be imposed for incorrect or omitted units at intermediate stages in a calculation or which are contained in brackets in the marking scheme. Penalties for unit errors (incorrect or omitted units) are imposed only at the stage when the final answer to a calculation is considered. The maximum penalty is **one mark per question**.

6 All other procedures, including the entering of marks, transferring marks to the front cover and referrals of scripts (other than those mentioned above) will be clarified at the standardising meeting of examiners.

PA10: The Synoptic Unit

Question 1			
(a)	(i)	$F\left(=\dfrac{Q_1Q_2}{4\pi\varepsilon_0 r^2}\right)=\dfrac{1.6\times10^{-19}\times1.6\times10^{-19}}{4\pi\times8.85\times10^{-12}\times(1.5\times10^{-15})^2}$ ✓ $= 100\,\text{N}$ ✓ $(102\,\text{N})$	**3**
	(ii)	the strong nuclear force is attractive and greater than the electrostatic force (of repulsion) ✓	
(b)		gravitational force is attractive (and has an infinite range) ✓ electrostatic force is zero because neutrons are uncharged ✓ strong nuclear force is repulsive at very short distances ✓ gravitational force on a neutron star is due to entire star mass/all the neutrons ✓ at equilibrium separation, the strong nuclear force is equal (and opposite) to the gravitational force ✓	**max 3**
		Total	**6**

Question 2			
(a)	(i)	ΔE_p (= weight × height gain = 2.6 ×1.8) = 4.7 (J) ✓ (4.68 J) electrical energy supplied (= VIt = 5.8 × 1.3 × 6.2) = 47 (J) ✓ (46.7 J) [or p.e. gain per sec $\left(=\dfrac{Wh}{t}=\dfrac{2.6\times1.8}{6.2}\right)=0.76\,(\text{J s}^{-1})$ electrical power (= IV = 5.8 × 1.3) = 7.5 (W)] $\therefore$ efficiency $\left(=\dfrac{4.7}{47}\times100\right)$ or $\left(\dfrac{0.76}{7.5}\times100\right)$ = 10 (%) ✓ (allow C.E. for incorrect values of energies)	**5**
	(ii)	energy (or power) is wasted due to resistance of the wires ✓ friction at the bearings (of the motor) [or in the motor or the winding mechanism)] ✓ sound (created by motor) ✓ any two (✓✓)	
(b)		force on coil due to motor effect ✓ force on each side of motor coil due to magnetic field is proportional to the current ✓ this force(s) provides a couple (or torque) ✓ extra load (or weight) exerts an extra (or increased) turning effect (or torque or couple) ✓ current is limited by (circuit) resistance ✓ couple due to magnetic field cannot exceed couple due to weight (plus friction) ✓	**max 4**
		Total	**9**

Question 3			
(a)	(i)	a periodic/driving force acts on the pipe due to the pump ✓ pipe has a natural frequency of vibration ✓ frequency of periodic force or pump frequency increases with motor speed ✓ at a certain pump speed, frequency of periodic force or pump frequency = natural/fundamental frequency of vibration (of pipe) ✓ (∴) resonance occur(s) ✓	**max 5**
	(ii)	fit extra clamp(s) along the pipe ✓ to eliminate/change resonant frequencies ✓ [or use padding to damp vibrations] [or change pipe dimensions/materials to change resonant frequency]	
(b)	(i)	speed of teeth is the same ✓ angular speed = speed/radius ✓ radius of Y < radius of X (smaller wheel Y spins faster) ✓ [**alternatives** 1.speed the same ✓ speed = $\frac{2\pi r}{T}$ ✓ radius of Y < radius of X, so period of Y < period of X ✓ 2. speed the same ✓ X has more teeth than Y ✓ one rotation of X equals several rotations of Y ✓]	**max 4**
	(ii)	torque = force × radius of gear wheel ✓ Y has smaller radius than X, Y exerts a smaller torque than X ✓ [or work done per sec (on gear wheel) = torque × angular speed (✓) work done per sec by X = work done per sec on Y, so Y exerts less torque than X because it spins faster (✓)]	
		Total	**9**

Question 4			
(a)	(i)	E (= ½CV^2) = $0.5 \times 270 \times 10^{-6} \times 3.0^2$ ✓ = $1.2(2) \times 10^{-3}$ J ✓	**3**
	(ii)	W (=QV = CV^2 = $270 \times 10^{-6} \times 3.0^2$) = $2.4(3) \times 10^{-3}$ J ✓	
(b)	(i)	(at 0.3 V), E (= $0.5 \times 270 \times 10^{-6} \times 0.3^2$) = 0.012×10^{-3} (J) = 0.01 E_0 ✓ energy released by capacitor = 0.99 E_0 ✓ (= 99% E_0) [or energy released by capacitor = $1.22 \times 10^{-3} - 1.2 \times 10^{-5}$ = 1.21×10^{-3} (J) which is almost all the initial energy]	**8**
	(ii)	$RC = 1.5 \times 270 \times 10^{-6} = 4.05 \times 10^{-4}$ (s) ✓ (use of $V = V_0\, e^{-t/RC}$ gives) $2.0 = 3.0\, e^{-t/RC}$ ✓ t (= $-RC \ln(2.0/3.0)$) = $(-)4.05 \times 10^{-4} \times (-)0.405$ = $1.6(4) \times 10^{-4}$ s ✓ (allow C.E. for value of RC)	
	(iii)	energy of a photon = $\left(\frac{hc}{\lambda} = \frac{6.63\times10^{-34} \times 3.0\times10^{8}}{500\times10^{-9}}\right)$ = 4.0×10^{-19} (J) ✓ (3.98×10^{-19} J) energy released by capacitor when it discharges from 3.0 to 2.0 V = $1.2(2) \times 10^{-3} - (0.5 \times 270 \times 10^{-6} \times 2.0^2) = 6.8 \times 10^{-4}$ (J) ✓ number of photons released = $\frac{6.8\times10^{-4}}{4.0\times10^{-19}} = 1.7 \times 10^{15}$ ✓ (allow C.E. for energy of photon and energy released)	
		Total	**11**

Question 5		
(a)	resistance of wire decreases when temperature decreases ✓ pd across wire is constant, $V = IR$, (current increases) ✓	**2**
(b) (i)	**ln *I*** / **ln *v*** −1.03(0) / 0.69(3) −0.80(3) / 1.39 (or 1.386) −0.68 (or 0.677) / 1.79(2) −0.59 (or 0.587) / 2.08 (or 2.079) −0.51 (or 0.507) / 2.30(3) 1 mark for each column correct to 3 or 4 s.f. ✓✓ graph: axes labelled correctly ✓ suitable scales ✓ at least 4 points plotted correctly ✓ best fit line drawn ✓	**12**
(ii)	graph of ln I against ln v is a straight line ✓ ($I = \mathrm{k}\, v^{\mathrm{n}}$ gives) ln I = n ln v +ln k (or $\log_{10}$) which is the equation for a straight line graph of ln I against ln v ✓	
(iii)	y-intercept = ln k = −1.26 (± 0.10) ✓ k = 0.285 (± 0.040) ✓ gradient = n ✓ $\left(= \frac{0.625}{2.0}\right) = 0.31\ (\pm 0.02)$ ✓	
(c)	instrument is more sensitive at low speeds ✓ because change of current per unit change of speed is greater at low speeds ✓	**2**
	Total	**16**

Question 6		
(a) (i)	$\mathrm{u}\bar{\mathrm{d}}$ ✓	**3**
(ii)	X ≡ neutron (n) ✓ udd ✓	
(b) (i)	momentum is conserved and initial momentum is zero ✓ other particle must be emitted with equal and opposite momentum to the μ^+ meson ✓	**4**
(ii)	Y ≡ neutrino ✓ any **one** property: zero/negligible rest mass, zero charge, little interaction ✓	
	Total	**7**

Question 7			
(a)	(i)	heat water to 100 °C, energy (= 190 × 4200 × 79) = 63 (MJ) ✓ vapourise water, energy (= $190 \times 2.3 \times 10^6$) = 440 (MJ) ✓ (437 MJ) energy transferred (per sec) = (437 +63) MJ ✓ (= 500 MJ)	
	(ii)	mass of rocks (= $4.0 \times 10^6 \times 3200$) = 1.3×10^{10} (kg) ✓ (1.28×10^{10}) temperature fall of ΔT in one day, energy removed (= $1.28 \times 10^{10} \times 850 \times \Delta T$) = $1.1 \times 10^{13}\ \Delta T$ ✓ ($1.09 \times 10^{13}\ \Delta T$) (allow C.E. for value of mass of rocks) energy transfer in one day (= $500 \times 10^6 \times 3600 \times 24$) = 4.3×10^{13} (J) ✓ in one day $\Delta T \left(= \frac{4.3\times10^{13}}{1.1\times10^{13}} \right)$ = 3.9(1) K ✓	**7**
(b)		number of nuclei in 1 kg of ^{238}U $\left(= \frac{6.02\times10^{23}}{0.238} \right)$ = 2.5(3) × 10^{24} ✓ activity of 1 kg of ^{238}U $= \frac{\ln 2}{T_{1/2}} \times 2.53\times10^{24}$ ✓ $\left(= \frac{\ln 2}{4.5\times10^{9} \times 3.1\times10^{7}} \times 2.53\times10^{24} \right)$ = 1.2(6) × 10^7 (s^{-1}) ✓ energy released per sec per kg of ^{238}U = 1.2(6) × $10^7 \times 4.2 \times 1.6 \times 10^{-13}$ (J) ✓ (8.47×10^{-6} (J)) mass of ^{238}U needed $= \frac{500\times10^{6}}{8.47\times10^{-6}}$ = 5.9(0) × 10^{13} kg ✓	**5**
		Total	**12**

Question 8			
(a)		λ (= 2 × 38) = 76 (m) $f\left(=\frac{c}{\lambda}=\frac{3.0\times10^{8}}{76}\right)$ = 3.9(4) MHz ✓	**1**
(b)	(i)	angle between cable and horizontal $\left(=\sin^{-1}\frac{12}{14}\right)$ = 59° ✓ T = 110 cos 59° = 57 N ✓ (56.7 N) (allow C.E. for value of angle)	**max 7**
	(ii)	cross-sectional area (= $\pi(2.0\times10^{-3})^2$) $=1.3\times10^{-5}$ (m^2) ✓ (1.26×10^{-5} (m^2)) stress $\left(=\frac{\text{tension}}{\text{area}}\right)=\frac{57}{1.3\times10^{-5}}$ ✓ $=4.4\times10^{6}$ Pa ✓ (4.38×10^{6} Pa) (use of 56.7 and 1.26 gives 4.5×10^{6} Pa) (allow C.E. for values of T and area)	
	(iii)	breaking stress is ≈ 65 × stress copper is ductile copper wire could extend much more before breaking because of plastic deformation extension to breaking point unlikely any three ✓✓✓	
		Total	**8**

Quality of Written Communication: Q1 (b) and Q2 (b)	**2**