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ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Physics 6451

Specification A

PA10 The Synoptic Unit

Mark Scheme

2007 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.

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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)	mass of water (per second) (= volume (per second) × density = $3.2 \times 10^{-6} \times 1000$) = 3.2×10^{-3} kg (s^{-1}) ✓ energy per second gained by the water = $\frac{mc\Delta T}{t}$ = $3.2 \times 10^{-3} \times 4200 \times (45\text{-}15)$ ✓ = $4.0(3) \times 10^{2}$ J s^{-1} (or W) ✓	**3**
(b) (i)	circuit diagram; solar panel labelled or battery symbol with voltmeter in parallel ✓ ammeter and (variable) resistor in series with cell ✓ alter (variable) resistor until ammeter reads 100 mA (or voltmeter reads 6.0 V) ✓ check reading of the voltmeter is 6.0 V (or ammeter reads 100 mA) ✓	
(ii)	*solar cell panel*; power from solar cell panel (= current × pd = 0.100 A × 6.0 V) = 0.60 W (so) power per unit area (= $\frac{0.60}{0.150 \times 0.100}$) = 40 W m^{-2} ✓ *solar heating panel*; power per unit area (= $\frac{400}{1.60 \times 1.25}$) = 200 W m^{-2} ✓ [*alternative for 2 marks above*; power from solar cell panel (= current × pd = 0.100 A × 6.0 V) = 0.60 W (so) solar heating panel produces 670 times (=400/0.60) as much power as solar cell panel ✓ area of solar heating panel is 130 times (= $\frac{1.60 \times 1.25}{0.150 \times 0.100}$) greater than the solar cell panel ✓] $\therefore \frac{\text{power per unit area from solar heating panel}}{\text{power per area from solar cell panel}}$ (= $\frac{670}{130}$ or $\frac{200}{40}$) = 5 ✓	**7**
	Total	**10**

Question 2			
(a)	(i)	any 3 of the following 5 points; molecules move about at random colliding elastically (with each other or container) duration of impact << time between impacts (continuous) range of speeds each molecule travels at constant velocity between collisions ✓✓✓	**4**
	(ii)	mean E_K (= $\frac{3}{2}kT$) = 1.5 × 1.38 × 10^{-23} × 300 (= 6.2 × 10^{-21} J) ✓	
(b)	(i)	(½ mv^2 = E_K gives) $v = \left[\frac{2E_K}{m}\right]^{½} = \left(\frac{2\times6.2\times10^{-21}}{9.11\times10^{-31}}\right)^{½}$ ✓ = 1.2 × 10^5 m s^{-1} ✓	**max 4**
	(ii)	electrons move in random motion with drift motion superimposed ✓ a force on each (conduction) electron acts (or conduction electrons attracted) to + end of wire ✓ (conduction) electrons gain kinetic energy ✓ (conduction) electrons collide with (positive) ions (or atoms) ✓ (and) therefore lose kinetic energy ✓ process happens repeatedly (so progress is much slower than if there were no collisions) ✓	
		Total	**8**

Question 3		
(a) (i)	(rearranging $d \sin\theta = m\lambda$ gives) $d\ (= \frac{m\lambda_{\text{red}}}{\sin\theta_{\text{red}}}) = \frac{2\times630\times10^{-9}}{\sin 49.1}$ (= 1.67 × 10^{-6} m) ✓	3
(ii)	λblue (= $\frac{d\sin\theta_{\text{blue}}}{m}$) = $\frac{1.67\times10^{-6}\times\sin 33.5}{2}$ ✓ = 460 nm ✓	
(b) (i)	λglass (= $\frac{d\sin\theta}{m} = \frac{1.67\times10^{-6}\times\sin 29.8}{2}$) = 415 nm ✓ n red (= λ/λglass = 630 nm/415 nm) = 1.52 ✓ (or n = sin 49.1/sin 29.8 ✓ = 1.52 ✓)	4
(ii)	measure the angle of diffraction of the blue light in glass block (or repeat the above procedure with blue light) ✓ calculate n_b using Snell's Law and calculate the speed ratio ($\frac{c'_r}{c'_b}$) from $\frac{n_b}{n_r}$ ✓ (or calculate the wavelength of blue light in the glass block and use $\frac{c'_r}{c'_b} = \frac{f_r\lambda'_r}{f_b\lambda'_b}$ where $f_r = \frac{c_o}{\lambda_r}$ and $f_b = \frac{c_o}{\lambda_b}$)	
	Total	**7**

Question 4		
(a) (i)	gravitational field strength at the surface, $g_s = (-)\ \dfrac{GM}{R^2}$ ✓ gravitational field strength at height h, $g = (-)\ \dfrac{GM}{(R+h)^2}$ ✓ (where M is the mass of the Earth) $\therefore\ g/g_s = R^2/(R+h)^2$ which gives $g = g_s\ R^2/(R+h)^2$ ✓ (or substituting $GM = g_s\ R^2$ into the equation for g gives $g = g_s\ R^2/(R+h)^2$ ✓)	**5**
(ii)	$g\ (= \dfrac{GM}{r^2}) = \dfrac{6.67\times10^{-11}\times6.00\times10^{24}}{(6.40\times10^{6}+200\times10^{3})^2}$ ✓ $= 9.2\ \text{N kg}^{-1}$ ✓ (*alternative for 1st mark*, use of equation in (i) with correct substitution of values)	
(b)	force of gravity on astronaut (or weight of astronaut) = mg ✓ force of gravity equals (or provides) the centripetal force ✓ astronaut is in free fall ✓ astronaut appears weightless because no support (or reaction) force is needed ✓ (or weightlessness is misleading as astronaut is unsupported not weightless) (or astronaut is not weightless because (force of) gravity acts (on him/her))	**max 3**
	Total	**8**

Question 5		
(a)	deflection of wind blades causes momentum (or velocity) of wind to change direction ✓ force on the wind due to change of momentum (direction) ✓ equal and opposite force acts on blades ✓ force on each blade causes a torque (or turning effect or moment) ✓ turning effect on each blade is in the same direction ✓	**max 3**
(b) (i)	*data* **ln *v*** — **ln *P*** — **or** — **$\log_{10}$ *v*** — **$\log_{10}$ *P*** 0.41 — 3.00 — 0.176 — 1.30 0.69 — 3.91 — 0.301 — 1.70 0.99 — 4.79 — 0.431 — 2.08 1.25 — 5.56 — 0.544 — 2.41 1.44 — 6.09 — 0.623 — 2.64 1.59 — 6.57 — 0.690 — 2.85 1.70 — 6.90 — 0.740 — 3.00 for correct values to ±0.01 and 2 to 4 sig figs in each column (one mark only if log values given in the table) ✓✓	
(ii)	*graph* for suitable scales + correct labels ✓ for at least 6 points correctly plotted ✓ for best fit line ✓	**11**
(iii)	graph is a straight line in agreement with ln $P = n \ln v + \ln k$ ✓ according to y = mx + c with y = ln P and x = ln v ✓	
(iv)	n = gradient of line ✓ $\left(= \frac{6.90-1.84}{1.70-0}\right) = 3.0\ (\pm 0.2)$ ✓ y-intercept = ln k (= 1.81) (or log k = 0.80) ✓ ∴ k = 6.1 (W m^{-3} s^{3}) (± 0.4) ✓	
(c)	initial E_K per second $\left(= \frac{1}{2}\rho A v^3 = 0.5 \times 1.2 \times \frac{\pi}{4} \times (6.4)^2 \times 2.0^3\right) = 154$ (W) ✓ efficiency $\left(= \frac{\text{output power}}{\text{initial } E_K \text{ per sec}} = \frac{50}{154}\right) = 0.32\ (\pm 0.01)$ (or 32 ± 1%) ✓	**2**
	Total	**16**

Question 6		
(a) (i)	B $(= \frac{F}{IL}) = \frac{180}{12 \times 10^3 \times 0.83}$ ✓ $= 1.8 \times 10^{-2}$ T ✓	
(ii)	*force on X due to Y* B at X (due to Y) is unchanged ✓ F_X = BIL and I is reduced to 6 kA so F_X is reduced to 90 N (or halved) ✓ *force on Y due to X* B at Y (due to X) is reduced to 9 mT (or to half) ✓ F_Y = BIL and I is unchanged so F_Y is reduced to 90 N (or halved) ✓ [*alternative for either of above pair of marks* wires exert equal and opposite forces on each other ✓ ∴ force (on other wire) = 90 N ✓]	**6**
(b) (i)	the magnetic field due to each bar alternates in phase (or changes) with the current in the bar ✓ the force is zero when the current (and/or the field) is zero ✓ the current and the field reverse together so the force does not reverse ✓ the force on each bar varies periodically and makes the bar vibrate ✓ frequency of vibration is 2 × the ac frequency ✓	**max 4**
(ii)	clamp each bar (or apply a damping rod) along its length (or reposition the clamps or add more clamps) ✓	
		10

Question 7			
(a)	(i)	${}^{18}_{9}\mathrm{F} \rightarrow {}^{18}_{8}\mathrm{O}$ (✓) + ${}^{0}_{+1}$e + ν (✓) ✓✓	5
	(ii)	correctly labelled: d (or down quark) ✓ W^+ ✓ e^+, ν (or neutrino) ✓	
(b)	(i)	rest energy (mass) of the positron and the electron (= 2 × 0.51) = 1.02 MeV ✓ ∴ energy of each proton = 1.02/2 = 0.51 MeV	4
	(ii)	QR - PR (= cΔt = 3.0 × 10^8 × 0.40 × 10^{-9}) = 0.120 m ✓ (QR + PR = 1400 mm) ∴ PR = ½ (1400 - 120) mm ✓ = 640 mm ✓	
		Total	**9**

Question 8		
(a) (i)	volume of cylinder = ($\frac{\pi}{4}$ × $(0.60)^2$ × 1.50) = 0.42(4) m^3 ✓ mass of cylinder, m (= volume × density = 0.424 × 7800) ✓ = 3.3(1) × 10^3 kg	
(ii)	using $v^2 = u^2 + 2as$ with $a = g$ ✓ (or gain of E_K = loss of E_P or $\frac{1}{2}mv^2 = mgh$) ∴ v (= $(2gh)^{½}$ = $(2 \times 9.8 \times 0.80)^{½}$) = 4.0 m s^{-1} ✓	**4**
(b) (i)	momentum of hammer before impact (= 3300 × 4.0) = 1.3(2) × 10^4 kg m s^{-1} ✓ momentum of girder and hammer after impact = (1600 + 3300) V (where V is the velocity of the girder and hammer after the impact) ✓ (conservation of momentum gives) 4900 V = 1.3 × 10^4 ✓ ∴ V (= $\frac{1.3 \times 10^4}{4900}$) = 2.7 m s^{-1} ✓	
(ii)	friction force × distance moved = loss of E_K of the girder and the hammer ✓ friction force (= $\frac{0.5 \times 4900 \times 2.7^2}{0.025}$) = 7.1 × 10^5 N ✓ [*alternative for (b) (ii)* use of $v^2 = u^2 + 2\,as$ gives a (= $\frac{v^2 - u^2}{2s}$) = = $\frac{2.7^2 - 0}{2 \times 0.025}$ = 146 m s^{-2} ✓ $F = ma$ = 4900 × 146 = 7.1 × 10^5 N ✓] [*second alternative for (b) (ii)* for use of $F = \frac{\Delta p}{\Delta t}$ Δp = 4900 × 2.7 (= 1.32 × 10^4 kg m s^{-1}) Δt (= $\frac{2\Delta s}{v}$) = $\frac{2 \times 0.025}{2.7}$ (= 1.85 × 10^{-2} s) ✓ F (= $\frac{1.32 \times 10^4}{1.85 \times 10^{-2}}$) = 7.1 × 10^5 N ✓]	**6**
	Total	**10**

Quality of Written Communication: Q4 (b) and/or Q5 (a)	**2**