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ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Physics 6451
Specification A

PHA8/W Turning Points in Physics

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.

PHA8/W: Turning Points in Physics

Question 1		
(a)	$R\ (= r_0A^{1/3}) = 1.3 \times 10^{-5} \times (238)^{1/3}$ ✓ $= 8.0(6) \times 10^{-15}\,\text{m}$ ✓	**2**
(b)	(use of inverse square law e.g. $\frac{I_1}{I_2} = \left(\frac{x_1}{x_2}\right)^2$ gives) $10 = \left(\frac{x_2}{0.03}\right)^2$ ✓ $x = 0.095\,\text{m}$ ✓ (0.0949 m)	**2**
(c)	(use of $A = A_0\exp(-\lambda t$ gives) $0.85 = 1.0 \exp(-\lambda 52)$ ✓ $\lambda = \frac{\ln(100/0.85)}{52}$ ✓ $= 3.1(3) \times 10^{-3}\,\text{s}^{-1}$ ✓	**3**
(d)	it only emits γ rays (✓) relevant properties of γ radiation e.g. may be detected outside the body/weak ioniser and causes little damage (✓) it has a short enough half-life and will not remain active in the body after use (✓) it has a long enough half-life to remain active during diagnosis (✓) the substance has a toxicity that can be tolerated by the body (✓) it may be prepared on site (✓) any three ✓✓✓	**3**
	Total	**10**

Question 2		
(a)	diagram/description of electric wave and magnetic wave in phase ✓ diagram/description/statement that electric wave is at 90º to the magnetic wave ✓ diagram/description/statement that direction of propagation/travel is perpendicular to both waves ✓	**3**
(b) (i)	(conduction) electron (in the metal) absorbs a photon and gains energy *hf* ✓ work function of a metal is the minimum energy needed by an electron to escape from the metal (surface) ✓ an electron can only escape if *hf* ≥ work function ✓ any two (✓✓)	**4**
(ii)	the photon is the quantum of em radiation/light ✓ classical wave theory could not explain threshold frequency ✓ classical wave theory was replaced by the photon theory ✓ [or photons can behave as waves or particles] [or photons have a dual wave/particle nature] any two (✓✓)	
	Total	**7**

Question 3			
(a)	(i)	emission of (conduction) electrons from a heated metal (surface) or filament/cathode ✓ work done on electron = eV ✓	3
	(ii)	gain of kinetic energy (or $\frac{1}{2}mv^2$) = eV; rearrange to give required equation ✓	
(b)	(i)	work done = force × distance moved in direction of force ✓ force (due to magnetic field) is at right angles to the direction of motion/velocity [or no movement in the direction of the magnetic force ∴ no work done] ✓ electrons do not collide with atoms ✓ any two (✓✓) [alternative for 1st and 2nd marks (magnetic) force has no component along direction of motion ✓ no acceleration along direction of motion (✓) or acceleration perpendicular to velocity]	7
	(ii)	$r = \frac{mv}{Be}$ $\left(\text{or } Bev = \frac{mv^2}{r}\right)$ ✓ $v^2 = \frac{2eV}{m}$ ✓ $\therefore r^2 \left(= \frac{m^2v^2}{B^2e^2}\right) = \frac{m^2}{B^2e^2} \times \frac{2eV}{m} = \frac{2mV}{B^2e}$ ✓	
	(iii)	(rearranging the equation gives) $\frac{e}{m} = \frac{2V}{B^2r^2}$ ✓ $\frac{e}{m} = \frac{2 \times 530}{(3.1 \times 10^{-3})^2 \times (25 \times 10^{-3})^2}$ = $1.7(6) \times 10^{11}\,\text{C kg}^{-1}$ ✓	
		Total	**10**

Question 4		
(a)	electrons have a wave-like nature ✓ there is a (small) probability that an electron can cross the gap [or an electron can tunnel across the gap] ✓ transfer is from − to + only ✓	**3**
(b)	constant height mode: gap width varies as tip scans across at constant height ✓ current due to electron transfer is measured ✓ current decreases as gap width increases (or vice versa) ✓ variation of current with time is used to map surface ✓ [or constant current mode: current due to electron transfer is measured (✓) feedback used to keep current constant by changing height of probe tip (✓) height of probe tip changed to keep gap width constant (✓) variation of height of probe tip with time used to map surface (✓)]	**max 3**
	Total	**6**

Question 5		
(i)	time taken $\left(\frac{\text{distance}}{\text{speed}} = \frac{34}{0.95 \times 3.0 \times 10^8}\right) = 1.1(9) \times 10^{-7}\,\text{s}$ ✓	
(ii)	use of $t = \frac{t_0}{(1 - v^2/c^2)^{1/2}}$ where $t_0 = 18\,\text{ns}$ and t is the half-life in the detectors' frame of reference ✓ $\therefore t = \frac{18 \times 10^{-9}}{(1 - 0.95^2)^{1/2}} = 57(.6) \times 10^{-9}\,\text{s}$ ✓ time taken for π meson to pass from one detector to the other = 2 half-lives (approx) (in the detectors' frame of reference) ✓ 2 half-lives correspond to a reduction to 25%, so 75% of the π mesons passing the first detector do not reach the second detector ✓ **alternatives** for first 3 marks in (ii) 1. use of $t = \frac{t_0}{\sqrt{(1 - v^2/c^2}}$, where $t_0 = 18\,\text{ns}$ $= \frac{18}{(1 - 0.95^2)^{1/2}} = 57.6\text{(ns)}$ journey time in detector frame (= 2t) = 2 × 57.6 ns (≈ 2 half-lives) 2. use of $t = \frac{t_0}{\sqrt{(1 - v^2/c^2}}$, where $t = 119\,\text{ns}$ = journey time in detector frame $t_0 = 119\sqrt{1 - 0.95^2} = 37\,\text{ns}$ journey time in rest frame = 2 × 18 ns (2 half-lives)	5
	Total	**5**

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