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General Certificate of Education
June 2010

Physics A PHYA5/2D

Turning Points in Physics

Unit 5

Final

Mark Scheme

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.

Further copies of this Mark Scheme are available to download from the AQA Website: www.aqa.org.uk

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Instructions to Examiners

1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; 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 scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (eg relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (ie in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

QWC	descriptor	mark range
Good - Excellent	*see specific mark scheme*	**5-6**
Modest - Adequate	*see specific mark scheme*	**3-4**
Poor - Limited	*see specific mark scheme*	**1-2**
The description and/or explanation expected in a good answer should include a coherent account of the following points: *see specific mark scheme*		

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. 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.

4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.

5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.

6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.

7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

GCE Physics, Specification A, PHYA5/2D, Section A, Nuclear and Thermal Physics

Question 1		
(a)	using $Q = mc\Delta\theta$ = 3.00 × 440 × (84-27) ✓ 7.5×10^4 (J) ✓	**2**
(b)	using $Q = ml$ = 1.20 × 2.5 × 10^4 = 3.0×10^4 (J) ✓	**1**
(c)	(heat supplied by lead changing state + heat supplied by cooling lead = heat gained by iron) 3.0×10^4 + heat supplied by cooling lead = 7.5×10^4 ✓ heat supplied by cooling lead = $4.5 \times 10^4 = mc\Delta\theta$ $c = 4.5 \times 10^4/(1.2 \times (327 - 84))$ ✓ $c = 154$ (J kg^{-1} K^{-1}) ✓	**3**
(d)	any **one** idea ✓ no allowance has been made for heat loss to the surroundings or the specific heats may not be a constant over the range of temperatures calculated	**1**
	Total	**7**

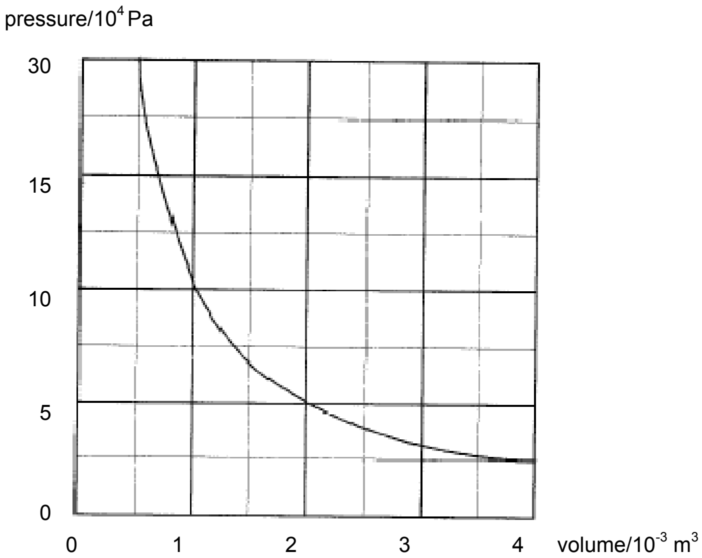
Question 2		
(a)	**The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria. **High Level (Good to excellent): 5 or 6 marks** The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question. The candidate can explain the role of the moderator and control rods in maintaining a critical condition inside the reactor. The explanation is given in a clear sequence of events and the critical condition is defined in terms of neutrons. To obtain the top mark some other detail must be included. Such as, one of the alternative scattering or absorbing possibilities or appropriate reference to critical mass or detailed description of the feedback to adjust the position of the control rods etc. **Intermediate Level (Modest to adequate): 3 or 4 marks** The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate. The candidate has a clear idea of two of the following: the role of the moderator, the role of the control rods or can explain the critical condition. **Low Level (Poor to limited): 1 or 2 marks** The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate. The candidate explains that a released neutron is absorbed by uranium to cause a further fission. Alternatively the candidate may explain one of the following: the role of the moderator, the role of the control rods or can explain the critical condition. **The explanation expected could include the following events that could happen to a released neutron.** a neutron is slowed by the moderator taking about 50 collisions to reach thermal speeds then absorbed by uranium-235 to cause a fission event one neutron released goes on to cause a further fission is the critical condition a neutron may leave the reactor core without further interaction a neutron could be absorbed by uranium-238 a neutron could be absorbed by a control rod a neutron could be scattered by uranium-238 a neutron could be scattered by uranium-235	**max 6**

(b)	it is easy to stay out of range or easy to contain an α source or β/γ have greater range/are more difficult to screen ✓ most (fission fragments) are (more) radioactive/unstable ✓ and are initially most likely to be beta emitters/(which also) emit γ radiation/are neutron **rich**/**heavy** ✓ **ionising** radiation damages body tissue/is harmful ✓	**max 3**
	Total	**9**

Question 3		
(a)	probability of decay per unit time/given time period **or** fraction of atoms decaying per second **or** the rate of radioactive decay is proportional to the number of (unstable) nuclei and nuclear decay constant is the constant of proportionality ✓	**1**
(b)	use of $T_{\frac{1}{2}} = \frac{ln2}{\lambda}$ $T_{\frac{1}{2}}$ = ln2/3.84 × 10^{-12} s ✓ (1.805 × 10^{11} s) = (1.805 × 10^{11}/3.15 × 10^{7}) = 5730 y ✓ answer given to 3 sf ✓	**3**
(c)	number of nuclei = N = 3.00 × 10^{23} × 1/10^{12} ✓ (= 3.00 × 10^{11} nuclei) (using $\frac{\Delta N}{\Delta t} = -\lambda N$) rate of decay = 3.84 × 10^{-12} × 3.00 × 10^{11} ✓ (= 1.15 Bq)	**2**
(d)	($N = N_0e^{-\lambda t}$ and activity is proportional to the number of nuclei $A \propto N$ use of $A = A_0e^{-\lambda t}$) 0.65 = 1.15 × $e^{-3.84 \times 10^{-12} t}$ ✓ $t = \frac{ln\left(\frac{1.15}{0.65}\right)}{3.84 \times 10^{-12}}$ or $\frac{ln\left(\frac{0.651}{1.15}\right)}{-3.84 \times 10^{-12}}$ ✓ t = 4720 y ✓	**3**
(e)	the boat may have been made with the wood some time after the tree was cut down the background activity is high compared to the observed count rates the count rates are low or sample size/mass is small or there is statistical variation in the recorded results possible contamination uncertainty in the ratio of carbon-14 in carbon thousands of years ago any two ✓✓	**2**
	Total	**11**

Question 4		
(a)	see below	3
(b) (i)	see below	2
(b) (ii)	see below	3

(a)



curve with decreasing negative gradient that passes through the given point which does not touch the x axis ✓

designated points	
pressure/10^4 Pa	volume/10^{-3} m^3
10	1.0
5.0	2.0
4.0	2.5
2.5	4.0

2 of the designated points ✓✓ (one mark each)

3

(b) (i)

$N = PV/kT = 5 \times 10^4 \times 2 \times 10^{-3}/1.38 \times 10^{-23} \times 290$ ✓

[or alternative use of $PV = nRT$
$5 \times 10^4 \times 2.0 \times 10^{-3}/8.31 \times 290 = 0.0415$ moles]
$= 2.50 \times 10^{22}$ molecules ✓

2

(b) (ii)

(mean) kinetic energy of a molecule $= \frac{3}{2}kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 290$ ✓

$(= 6.00 \times 10^{-21}$ J)

(total kinetic energy = mean kinetic energy × N)
$= 6.00 \times 10^{-21} \times 2.50 \times 10^{22}$ ✓

= 150 (J) ✓

3

(c)	all molecules/atoms are identical molecules/atoms are in random motion Newtonian mechanics apply gas contains a large number of molecules the volume of gas molecules is negligible (compared to the volume occupied by the gas) or reference to point masses no force act between molecules except during collisions or the speed/velocity is constant between collisions or motion is in a straight line between collisions collisions are elastic or **kinetic** energy is conserved and of negligible duration any 4 ✓✓✓✓	**max 4**
	Total	**12**

GCE Physics, Specification A, PHYA5/2D, Section B, Turning Points in Physics

Question 1		
(a) (i)	The number of electrons (per second) in the beam will increase ✓ because the filament will become hotter and will emit more electrons (per second) ✓	**2**
(a) (ii)	the speed (or kinetic energy) of the electrons will increase ✓ because the electrons (from the filament) are attracted towards the anode with a greater acceleration (or force) ✓ (or gain more kinetic energy in crossing a greater pd)	**2**
(b) (i)	(magnetic) force on each electron in the beam is perpendicular to velocity ✓ no work is done on each electron by (magnetic) force so ke (or speed) is constant ✓ magnitude of (magnetic) force is constant because speed is constant ✓ (magnetic) force is always perpendicular to velocity so is centripetal ✓	**max 3**
(b) (ii)	rearranging $r = \frac{mv}{Be}$ gives $\frac{e}{m} = \frac{v}{Br}$ ✓ $\frac{e}{m} = \frac{7.4 \times 10^6}{6.0 \times 10^{-4} \times 68 \times 10^{-3}}$ = 1.81×10^{11} ✓ C kg^{-1} ✓ for correct answer to 2 sf ✓	**4**
(b) (iii)	specific charge for the electron ≈ 2000 × specific charge of H^+ ✓ (accept = and accept any value between 1800 and 2000) which was the largest known specific charge before the specific charge of the electron was determined/measured ✓ (or which could be due to a much greater charge or a much smaller mass of the electron)	**2**
	Total	**13**

Question 2		
(a) (i)	work done (due to stopping potential *V*) = *eV* ✓ E_{Kmax} = work done due to stopping potential = (1.6 × 10^{-19} × 0.35) = 5.6 × 10^{-20} J ✓	**2**
(a) (ii)	(rearranging $hf = \phi + E_{Kmax}$) gives $\phi = hf - E_{Kmax}$ ✓ photon energy (= $hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{590 \times 10^{-9}}$) = 3.37 × 10^{-19} J ✓ $\phi = hf - E_{Kmax}$ = 3.37 × 10^{-19} – 5.6 × 10^{-20} = 2.8(1) × 10^{-19} J ✓	**3**
(b) (i)	photons have the same energy (as in a)) ✓ when a (conduction) electron in the metal absorbs a photon, it gains all the energy of the photon ✓ work function(of Y) is the minimum energy needed by an electron to escape ✓ work function of Y is greater than the energy gained by an electron (so electron cannot escape) ✓	**max 2**
(b) (ii)	wave theory predicts that incident light (of any frequency) would cause photoelectric emission (from any metal) ✓ and any **one** of the following points wave theory could not explain why light below a certain frequency (or below a threshold frequency) could not cause photoelectric emission ✓ **or** this (threshold) frequency is characteristic of the metal (or depends on the metal) ✓ **or** wave theory could not explain the instantaneous emission of photoelectrons ✓	**2**
	Total	**9**

<table>
<tr><th>Question 3</th><th></th><th></th></tr>
<tr><td>(a)</td><td>

The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The candidate gives a comprehensive explanation based on the knowledge that electrons have a wave-like nature so there is a finite probability of crossing the gap. They should recognise how the transfer of electrons across the gap is affected by the gap width and why a pd is necessary and why it should be constant. Their explanation should have the key ideas linked effectively in an appropriate sequence.

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The candidate includes the main idea that electrons can transfer or 'tunnel' across the gap because they have a 'wave-like' nature. They should show awareness that the transfer of electrons is in one direction only because a pd is applied and that the transfer is affected by the gap width. Their explanation should not include contradictory or incorrect physics ideas (eg the use of electrostatic attraction).

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

The candidate knows that electrons have a wave-like nature and this is relevant in this context. They may show some awareness of the effect of the gap width. They may not appreciate why the wave nature of the electron is relevant here. They may well introduce irrelevant or incorrect physics ideas in their explanation.

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

- electrons have a wave like nature
- there is a finite probability that electrons can cross the gap
- electrons can tunnel across the gap
- pd is necessary so electrons cross in one direction only (no net transfer of electrons for zero pd)
- the narrower the gap, the greater the number of electrons (per second) that cross the gap
- electrons transfer from – to +
- constant pd provides one less variable (to affect the current)
(de Broglie) wavelength is of the order of the gap width

</td><td>max 6</td></tr>
</table>

(b)	as the probe moves along, the gap width increases (as the current decreases) then decreases (as the current increases) ✓ the current decreases (or increases) because the tunnelling effect (or probability of crossing the gap) decreases (or increases) ✓	**2**
	Total	**8**

Question 4		
(a)	c is the same, regardless of the speed of the light source or the observer ✓	**1**
(b)	distance between detectors in rest frame of particles (= 25 × $(1- 0.98^2)^{1/2}$) = 5.0 m ✓ time taken in rest frame of particles $\left(= \frac{distance}{speed} = \frac{5.0}{0.98c}\right)$ = 1.7 × 10^{-8} s ✓ time taken to decrease by ¼ = 2 half lives ✓ half life (= 1.7 × 10^{-8}/2) = 8.5 × 10^{-9} s ✓ [**alternatively** time taken in rest frame of detectors $\left(= \frac{distance}{speed} = \frac{25.0}{0.98c}\right)$ = 8.5 × 10^{-8} s time taken in rest frame of particles (= 8.5 × 10^{-8} × $(1-0.98^2)^{1/2}$) =1.7 × 10^{-8} s)]	**4**
	Total	**5**