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General Certificate of Education (A-level)
June 2013

# Physics A PHA5D

# (Specification 2450)

# Unit 5D: Nuclear and Thermal Physics

# Turning Points in Physics

# 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 events which all examiners participate in and is the scheme which was used by them in this examination.  The standardisation process ensures that the mark scheme covers the students' responses to questions and that every examiner understands and applies it in the same correct way.  As preparation for standardisation each examiner analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for.  If, after the standardisation process, examiners encounter unusual answers which have not been raised they are required to refer these to the Principal Examiner.

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**Section B – Turning Points in Physics**

| Question | Part | Sub-part | Marking guidance | Mark | Comment |
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| 1 | (a) | (i) | (at terminal velocity *v* ), weight of droplet ( or *mg*) = viscous drag (or $6\pi\eta r v$) ✓<br><br>mass ( *m*) of droplet = $(4\pi r^3 / 3) \times \rho$ , (where *r* is the droplet radius )✓<br><br>(therefore) $(4\pi r^3 / 3) \times \rho g = 6\pi\eta r v$ ( or rearranged) ✓<br>(hence) $r$ (= $(9\eta v / 2\rho g)^{1/2}$<br>$= \frac{9 \times 1.8 \times 10^{-5} \times 1.1 \times 10^{-4}}{2 \times 880 \times 9.8}$) gives $r = 1.0(3) \times 10^{-6}$ m ✓<br>note; some evidence of calculation needed to give final mark | 4 | *Backward working 3 marks max* ;<br>viscous force ( = $6\pi\eta r v$ ) = $6\pi \times 1.8 \times 10^{-5} \times 1.0 \times 10^{-6} \times 1.1 \times 10^{-4} = 3.7 \times 10^{-14}$ N ✓<br>weight = mg =<br>$\frac{4}{3}\pi (1.0 \times 10^{-6})^3 \times 880 \times 9.8 = 3.6 \times 10^{-14}$ N ✓<br>(allow 3.7)<br>(therefore) viscous force = weight as required for constant velocity ✓<br>Allow final answer for *r* in the range 1 to 1.05 × $10^{-6}$ to any number of sig figs |
| 1 | (a) | (ii) | ***m***= $((4\pi r^3/3) \times \rho) = \frac{4}{3}\pi (1.0 \times 10^{-6})^3 \times 880$ ) = $3.7 \times 10^{-15}$ kg ✓<br>( or correct calculation of $6\pi\eta r v / g$) | 1 | Allow ecf for *r* from a(i) in a correct calculation that gives *m* in the range 3.6 to 4.0 x $10^{-15}$ kg |

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| 1 | (a) | (iii) | electric force ( or *QV/d*) = droplet weight ( or *mg*) ✓<br>$Q = \left( \frac{mgd}{V} \right) = \frac{3.7\times10^{-15}\times9.8\times6.0\times10^{-3}}{680}$ ✓<br>[or *Q* (= viscous force × *d* /*V*<br>$= 6\pi \times 1.8\times10^{-5}\times 1.0\times10^{-6}\times1.1\times10^{-4}\times 6.0\times10^{-4} / 680$✓]<br>$Q = 3.2 \times 10^{-19}$ C ✓ | 3 | Allow ecf *m* (or *r*) from a(ii) (or a(i)).<br>Accept values in 1st mark line<br>Use of *e* instead of *Q or q* = 2 marks max<br>For the 2nd mark, allow use of viscous force calculation. Use of viscous force method does not get 1st mark.<br>If both methods are given and only one method gives Q = *ne* (where *n* = integer >1), ignore other method for 2nd mark and 3rd mark.<br>For the final mark, Q must be within $n\,e \pm 0.2 \times 10^{-19}$ from a correct calculation. |

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| 1 | (b) | | The weight of the second droplet is greater than the maximum electric force on it ✓<br>Alternative for 1st mark ;<br>weight = drag force + elec force ( owtte)<br>**Scheme using V for next 5 marks ;**<br>If *n* =1 for the second droplet , pd to hold it = 1580 V ( = *mgd* /*e*) ✓<br>which is not possible as *V* max = 1000 *V* ✓<br>If *n* = 2 , it would be held at rest by a pd of 790 V ( = 1580 /2 or 680 × 4.3 / 3.7 V) ✓<br>if *n* > 2 , it would be held at rest by a pd of less than 790 V ( or 790 / *n* V) ✓<br>So n =1(*e* ) must be the droplet charge ✓ | Max 4 | **Alternative schemes for last 5 marks**<br>**Q scheme** Using *QV/d* = *mg* for a stationary droplet gives *Q* = *mgd/V* = 2.53 x $10^{-19}$ C ✓<br>which is not possible as *Q* = *integer x e* ✓<br>(so) *Q* (=ne) < 2.53 x $10^{-19}$ C ✓ owtte)<br>Calculation to show<br>*Q*= 1*e* fits above condition ✓<br>*Q*= 2*e* does not fit above condition ✓<br>**F scheme**;- Calc of mg to give 4.2 (±0.2)x$10^{-14}$ N✓<br>Calc for Q = 1e of QV/d to give 2.6(±0.2) x $10^{-14}$ N✓<br>Calc for Q =2e of QV/d to give 5.3 (±0.2)x $10^{-14}$N ✓<br>mg> elec force for Q =1e or <2e for Q=2e✓<br>So n =1(*e* ) must be the droplet charge ✓ |

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| 2 | (a) | | (Matter) particles have wave-like properties (owtte) ✓<br>and an associated wavelength = *h* / *p* where *p* is the momentum of the particles ✓. | 2 | Accept *mv* or mass x velocity in place of *p*<br>Accept 'inversely proportional to momentum ( or *mv*)' after 'wavelength' |

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| 2 | (b) | | $E_K$ (= 0.021 eV ) = $0.021 \times 1.60 \times 10^{-19}$ or $3.36 \times 10^{-21}$ J ✓<br>(Using $E_K = \frac{1}{2} m v^2$ gives )<br>$mv = (2 m E_K)^{1/2} = (2 \times 1.67(5) \times 10^{-27} \times 3.36 \times 10^{-21})^{1/2}$<br>( = $3.35 \times 10^{-24}$ kg m s$^{-1}$) ✓<br>[OR<br>$v = (2 E_K / m)^{1/2} = (2 \times 3.36 \times 10^{-21} / \times 1.67(5) \times 10^{-27})^{1/2}$<br>( = $2.0 \times 10^3$ m s$^{-1}$)<br>$mv = (1.67(5) \times 10^{-27} \times 2.0 \times 10^3$ ( = $3.35 \times 10^{-24}$ kg m s$^{-1}$) ]<br>$\lambda = \frac{h}{mv} (= \frac{6.63 \times 10^{-34}}{3.35 \times 10^{-24}}) = 1.88 \times 10^{-10}$ m ✓<br>= $2.0 \times 10^{-10}$ m to 2 sf ✓ | 4 | For 2nd mark, allow individual values of *e* and *V* in place of $E_K$ value in data substitution<br>For 3rd mark, allow individual values of *m* and *v* in denominator<br>**Alternative** ;<br>Correct use of 0.021 eV in $\lambda = h/(2meV)^{1/2}$ ✓<br>$= \frac{6.63 \times 10^{-34}}{(2 \times 1.67(5) \times 10^{-27} \times 0.021 \times 1.6 \times 10^{-19})^{0.5}}$ ✓<br>= $1.88 \times 10^{-10}$ m ✓ = $2.0 \times 10^{-10}$ m to 2 sf ✓<br>Final sf mark - need to see some valid working |

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| 2 | (c) | | electron's momentum (*p*) is the same (as that of the neutron)and its mass is (much) smaller than neutron mass ✓<br>kinetic energy = $p^2 / 2m$ so kinetic energy of electron is (much) greater ✓<br>*Alternative for 2nd mark* ;- (so) electron's speed is (much) greater and as kinetic energy = $\frac{1}{2} mv^2$ , the electron's kinetic energy is (much) greater as $v^2$ is more significant than *m* (here)(owtte) | 2 | *2nd alternative for 2nd mark using* $\lambda = h / (2 mE_K)^{1/2}$<br>$\lambda = h / (2 mE_K)^{1/2}$ so (same $\lambda$ means) $mE_K$ ( in equation) is the same for electron as for the neutron) . So $E_K$ is (much) greater as electron mass is (much) smaller than neutron mass (owtte)<br>Note ; allow use of *eV* in place of $E_K$ *if eV* is identified as $E_K$ . |

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| 3 | (a) | | **Quality of written communication:**<br><br>**Good – Excellent (5-6 marks)**<br><br>The candidate provides a comprehensive, coherent and logical explanation which recognises what a stationary wave is and that the conditions for the formation of a stationary wave are present. They should know that nodes and antinodes are formed at alternate positions along XY which are equally spaced with nodes every half wavelength. They should know how the detector is used to locate the position of each node or antinode and how the wavelength is determined from the distance between two such positions. They may know that the nodes can be located more accurately than the antinodes and that their chosen two positions should be as far apart as possible.<br><br>Their answer should be well-presented in terms of spelling, punctuation and grammar.<br><br>**Modest – Adequate (3-4 marks)**<br><br>The candidate provides a logical explanation which recognises what a stationary wave is and what some of the conditions for the formation of a stationary wave are. They may know that nodes and antinodes are formed at alternate positions along XY with nodes every half- wavelength. They may know how the detector is used to locate the position of each node or antinode and how the wavelength is determined from the distance between two such positions. They may know that the nodes can be located more accurately than the antinodes and that their chosen two positions should be as far apart as possible. Their answer should be well-presented in terms of spelling, punctuation and grammar.<br><br>**Poor to Limited (1-2 marks)**<br><br>The candidate may recognise that the reflector reflects radio waves which then form a stationary wave pattern with the | 6 | **For top band ,**<br><br>explanation = at least b and e<br><br>description = at least f, g,h<br><br>***Explanation of stationary wave formation ;-***<br><br>a. radio waves from the transmitter are reflected back towards the transmitter✓<br>b. reflected and incident waves pass through each other ✓<br>c. both waves have same frequency (and speed) and amplitude✓<br>d. superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓<br>e. (equally spaced) nodes and antinodes formed along XY✓<br><br>***Description* of measurement of wavelength ;-**<br><br>f. Detector signal is zero ( or least) along XY at nodes ✓<br>g. distance between adjacent nodes is ½ $\lambda$ ✓<br>h. move detector along XY to measure distance between adjacent nodes and double to give the wavelength ✓<br>i. measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓ |

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| | | | incident waves. They may be unaware what the conditions for the formation of a stationary wave are and their understanding of nodes and antinodes may be poor. They may have some awareness that the stationary wave causes the detector signal to vary with position along XY and that the wavelength can be determined from this variation although they might not be able to link the wavelength to the changes of detector position correctly.<br><br>Their answer may lack coherence and may contain a significant number of errors in terms of spelling and punctuation.<br><br>**The explanations expected in a good answer should include most of the following physics ideas**<br><br>***Explanation of stationary wave formation ;-***<br>a. radio waves from the transmitter are reflected back towards the transmitter✓<br>b. reflected and incident waves pass through each other ✓<br>c. both waves have same frequency (and speed) and amplitude✓<br>d. superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓<br>e. equally spaced nodes and antinodes formed along XY✓<br><br>***Description* of measurement of wavelength ;-**<br>f. Detector signal is zero ( or least) along XY at nodes ✓<br>g. distance between adjacent nodes is ½ λ ✓<br>h. move detector along XY to measure distance between adjacent nodes and double to give the wavelength ✓<br>i. measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓ | | **For middle band ,**<br>explanation = at least any two of a-e<br>description = at least any two of f-i<br><br>**For lowest band ,**<br>Any 2 points ,must be 1 of each for 2 marks<br><br>***Explanation of stationary wave formation ;-***<br>a. radio waves from the transmitter are reflected back towards the transmitter✓<br>b. reflected and incident waves pass through each other ✓<br>c. both waves have same frequency (and speed) and amplitude✓<br>d. superposition (of reflected and incident waves) occurs to form a stationary wave (as above) ✓<br>e. (equally spaced) nodes and antinodes formed along XY✓<br><br>***Description* of measurement of wavelength ;-**<br>f. Detector signal is zero ( or least) along XY at nodes ✓<br>g. distance between adjacent nodes is ½ λ ✓<br>h. move detector along XY to measure |

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| | | | | | distance between adjacent nodes and double to give the wavelength ✓<br>i. measure distance over n nodes and divide by n-1 to give distance between adjacent nodes ✓ |

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| 3 | (b) | | Speed of radio waves (obtained by Hertz ) is the same as the speed of light ✓<br>Speed of electromagnetic waves (calculated or predicted by Maxwell) is the same as the speed of light ( or of radio waves) so radio waves are electromagnetic waves ✓ | 2 | |

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| 4 | (a) | | (Using $m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$ gives )<br>$2 = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$ or $\sqrt{1-\frac{v^2}{c^2}} = 0.5$ ✓<br>(Rearranging gives)<br>$v$ ( $= \sqrt{1-0.5^2}\ c$) = $0.866\ c$ or $2.6 \times 10^8$ m s$^{-1}$ ✓ | 2 | Accept either answer. |

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| 4 | (b) | | curve starts at $v$=0 , $m = m_o$ and rises smoothly ✓<br>curve passes through $2m_o$ at $v$ = 0.87 $c$ (± 0.03$c$ or in 2nd half of x-scale div containing 0.87c) ✓<br>curve is asymptotic at $v = c$ ( and does not cross or touch $v = c$ or curve back ) ✓ | 3 | 2nd mark ; ecf from 4a if plotted correctly<br>3rd mark ; There must be visible white space between the curve and the v = c line; also, the curve must reach $7m_o$ at least. |

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| 4 | (c) | | Energy = $mc^2$ so (as $v$ -> $c$ ) energy of particle increases as mass increases ✓<br>mass -> infinity as $v$ -> $c$ so energy -> infinity which is (physically) impossible ✓<br>[OR for one mark only<br>force = $ma$ so force increases as mass increases<br>Mass -> infinity as v->c so force -> infinity which is (physically ) impossible✓] | 2 | Alternative scheme for 1 mark only ; mass infinite at $v = c$ which is (physically) impossible ✓ |