Version 1.0

General Certificate of Education (A-level)
June 2012

# Physics B: Physics in Context PHYB5

## (Specification 2455)

## Unit 5: Energy under the microscope

# 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 candidates' 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 candidates' 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.

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 from: aqa.org.uk



Set and published by the Assessment and Qualifications Alliance.

The Assessment and Qualifications Alliance (AQA) is a company limited by guarantee registered in England and Wales (company number 3644723) and a registered charity (registered charity number 1073334).
Registered address: AQA, Devas Street, Manchester M15 6EX.

**NOTES**

Letters are used to distinguish between different types of marks in the scheme.

**M** indicates OBLIGATORY METHOD MARK
This is usually awarded for the physical principles involved, or for a particular point in the argument or definition. It is followed by one or more accuracy marks which cannot be scored unless the M mark has already been scored.

**C** indicates COMPENSATION METHOD MARK
This is awarded for the correct method or physical principle. In this case the method can be seen or implied by a correct answer or other correct subsequent steps. In this way an answer might score full marks even if some working has been omitted.

**A** indicates ACCURACY MARK
These marks are awarded for correct calculation or further detail. They follow an M mark or a C mark.

**B** indicates INDEPENDENT MARK
This is a mark which is independent of M and C marks.

**ecf** is used to indicate that marks can be awarded if an error has been carried forward (ecf must be written on the script). This is also referred to as a ‘transferred error' or 'consequential marking'.

Where a correct answer only (**cao**) is required, this means that the answer must be as in the Marking Scheme, including significant figures and units.

**cnao** is used to indicate that the answer must be numerically correct but the unit is only penalised if it is the first error or omission in the section (see below).

Marks should be awarded for **correct** alternative approaches to numerical question that are not covered by the marking scheme. A correct answer from working that contains a physics error (PE) should not be given credit. Examiners should contact the Team Leader or Principal Examiner for confirmation of the validity of the method, if in doubt.

**GCE Physics, Specification B: Physics in Context, PHYB5, Energy Under The Microscope**

| | | | | | |
|---|---|---|---|---|---|
| 1 | a | i | one adiabatic correctly indicated B→C **OR** D→A<br>both correct B→C **AND** D→A | C1<br>A1 | 2 |
| 1 | a | ii | $Q$ or $\Delta Q$ or heat transfer | B1 | 1 |
| 1 | a | iii | $\Delta U$ or <u>change/increase/decrease</u> in internal energy | B1 | 1 |
| 1 | a | iv | check whether $pV$ is constant/$pV$ should be constant<br>use data/coordinates from at least three points(explicit) | M1<br>A1 | 2 |
| 1 | b | i | Efficiency = $\frac{p_{useful}}{p_{hot}} = \frac{p_{source} - 33}{p_{source}} = 2/5$ or<br>$P_{hot}$ = 55 kW or $P_{useful}$ = 22 kW<br><br>$P_{useful}$ = 22 kW and $P_{source}$ 55 kW | C1<br>A1 | 2 |
| 1 | b | ii | Use of $E = mc\theta$<br>132 seen **or** 1.42 (kg s$^{-1}$) **or** clear use of 4 cylinders<br>mass flow rate= 5.677<br>5.7 (kg s$^{-1}$) any 2 sf answer from some working | C1<br>C1<br>A1<br>B1 | 4 |
| 1 | c | i | Use of maximum efficiency formula = $\frac{T_H - T_C}{T_H}$<br><br>max possible efficiency = 33% 0.3(3)<br>Efficiency quoted = 40% (0.4)<br>so agree with the reviewer | C1<br><br>M1<br>M1<br>A1 | 4 |
| 1 | c | ii | For source entropy change 488 or 0.488 **or** 122 or 0.122<br>(allow use of their data)<br>or For the sink 110 440 or 0.440 **or** 110 or 0.110<br><br>correct total change - 48 or -0.048 **or** -12 or -0.012<br><br>J K$^{-1}$ **or** kJ K$^{-1}$ | C1<br><br><br><br>A1<br><br>B1 | 3 |
| 1 | c | iii | impossible since entropy cannot decrease | B1 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | a | i | electrons are produced by heating a metal.<br>electrons liberated from the surface or deeper in the metal<br>or<br>energy to remove electrons is variable<br>or<br>energy supplied for electrons to leave may be greater than the work function | B1<br>B1 | Max 2 |
| 2 | a | ii | attempt to use $eV = ½\, mv^2$ or calculates KE correctly $9.2×10^{-16}$J<br>$1.6 × 10^{-19}\, V = ½\; 9.1 × 10^{-31} × (4.5 × 10^7)^2$<br>or $eV = 9.2×10^{-16}$J (equates $eV$ to correct $E_k$)<br>5800 (5759) (5765)(V) | C1<br>C1<br>A1 | 3 |
| 2 | b | i | Into the page<br>applied LHR remembering that electrons are opposite direction to the current | M1<br>A1 | 2 |
| 2 | b | ii | $Bev = \frac{mv^2}{r}$<br>or $r=mv/Bq$<br>correct substitution ignore errors in powers of 10<br>0.18(3) (m) | C1<br>C1<br>A1 | 3 |
| 2 | c | i | New mass = $\frac{9.1\times10^{-31}}{\sqrt{1-\left(\frac{4.5\times10^7}{3\times10^8}\right)^2}}$ or $\frac{m}{m_o} = \frac{1}{\sqrt{1-\left(\frac{4.5\times10^7}{3\times10^8}\right)^2}}$<br>9.213 (9.21)$×10^{-31}$ (kg) seen<br>increase in mass = 0.1 or 0.11 × $10^{-31}$ kg<br>or<br>calculates ratio of new to rest mass (1.011 of rest mass)<br>(Allow even if candidate thinks this is the answer)<br>1.1(4) % | B1<br>B1<br>B1<br>B1 | 4 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | c | ii | **Potential difference**: higher OR states answer to (b)(i) is too small<br><br>extra energy to increase the mass<br>or<br>as mass increases acceleration would decrease unless pd is greater to increase the (average)force (OWTTE)<br>or<br>Answers in terms of $eV = ½\ mv^2$ stating $v$ constant so $V \alpha m$<br><br>**Path radius:** larger<br><br>Larger mass deflected less by same force<br>or<br>larger mass requires larger force to produce the same radius of curvature<br>or<br>same force acting on larger mass so central acceleration in lower<br>or<br>radius is proportional to *mv* so higher *m* gives higher *r* for given *v*<br>or<br>Explanations using equation with constant quantities identified | M0<br>A1<br><br>M0<br>A1 | 2 |
| 2 | d | i | Force required toward A/ A has to attract electrons<br>A has to be positive | B1<br>B1 | 2 |
| 2 | d | ii | $eE = Bev$ or $v = E/B$<br>$E$ = 63000 V m$^{-1}$ or algebra leading to $V = Bvd$<br>Use of $E = V/d$ or substitution (condone incorrect powers of 10)<br>$V$ = 2210 V | C1<br>C1<br>C1<br>A1 | 4 |
| 3 | a | i | electron antineutrino | B1 | 1 |
| 3 | a | ii | conservation of lepton number | B1 | 1 |
| 3 | b | i | Time for the radioactive atoms the body to halve<br>Time for number of atoms of an element in the body to halve<br>Time for activity (of atoms of) a given radioactive sample to halve<br>Due to natural bodily functions (owtte) | B1<br><br><br>B1 | 2 |
| 3 | b | ii | Effective decay constant = $1.438 \times 10^{-6}$ (s$^{-1}$)<br>or attempt to use half-life = 0.69/decay constant<br>$4.8 \times 10^5$ s<br>correct conversion of their half life in s to days(5.56 if correct) | B1<br>B1<br><br>B1 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | c | i | Use of $A = \lambda N$ | C1 | |
| | | | 240 ($\times 10^9$) = 1.47 $\times 10^{-5} N$ | C1 | |
| | | | $N$ = 1.63 $\times$ $10^{16}$ or 2.7$\times 10^{-8}$ (mol) | A1 | 4 |
| | | | mass = $\dfrac{theirN}{6.02\times10^{23}}\times123$ (3.3µg if correct) | B1 | |

| | | | | | |
|---|---|---|---|---|---|
| 3 | c | ii | Recognition of 4 half lives<br>or $15 = 240e^{-1.47\times10^{-5}t}$ | C1 | 2 |
| | | | 52 hours | A1 | |

| | | | | | |
|---|---|---|---|---|---|
| 3 | d | i | The half-life of iodine-123 is too short<br>Much of its activity would disappear before it reaches the hospital<br>**or**<br>half-life of iodine-131 is long<br>so there would be little decay before it reaches the hospital | B1<br>B1 | 2 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | d | ii | lower total dose needed to produce same initial activity<br>shorter half -life so disappears from the body more quickly<br>no beta particles /lower energy gamma to produce ionisation in the body | B1<br>B1 | Max 2 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | e | | The marking scheme for this question includes an overall assessment for the quality of written communication (QWC). There are no discrete marks for the assessment of QWC but the candidate's QWC in this answer will be one of the criteria used to assign a level and award the marks for this question.<br><br>Descriptor – an answer will be expected to meet most of the criteria in the level descriptor.<br><br>**Level 3 - good**<br>• claims supported by an appropriate range of evidence<br>• good use of information or ideas about physics, going beyond those<br>• given in the question<br>• argument well-structured with minimal repetition or irrelevant points<br>• accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling<br><br>**Level 2 - modest**<br>• claims partly supported by evidence<br>• good use of information or ideas about physics given in the question but limited beyond this the argument shows some attempt at structure<br>• the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling | | 6 |

| | | | | | |
|---|---|---|---|---|---|
| | | | **Level 1 - limited**<br>• valid points but not clearly linked to an argument structure<br>• limited use of information about physics<br>• unstructured<br>• errors in spelling, punctuation and grammar or lack of fluency<br><br>**Level 0**<br>• incorrect, inappropriate or no response<br><br>1-2 will make some relevant but superficial comments on one or two of the **bold** sections<br><br>3-4 should comment on **1** and make some significant comments on two of the other **bold section**<br><br>5-6 will make significant comments on all the bold sections for 5 the answer will comment on but lack detail in one section<br><br>The final mark within a band will take account of both the physics and the quality of communication in the response | | |
| 4 | a | i | Attempt to use KE = 3/2 $kT$ expect $0.75 = 3/2 \times 1.38 \times 10^{-23}\ T$<br>Or correct conversion to J $0.75 \times 1.6 \times 10^{-19}$<br>Correct equations $0.75 \times 1.6 \times 10^{-19} = 3/2\ 1.38 \times 10^{-23}\ T$<br>5800 K | C1<br><br>C1<br>A1 | 3 |
| 4 | a | ii | Attempt to use *energy* = $qQ/4\pi\varepsilon_o r$<br>arrives at 1.9(2) $\times 10^{-9}$ or uses (2 × 0.75) or twice candidate's energy from (i)<br>$9.6 \times 10^{-10}$ m | C1<br>C1<br>A1 | 3 |
| 4 | a | iii | For fusion nuclei have to touch or separation has to be nuclear diameter<br>energy has to be sufficient to overcome the nuclear repulsion (between protons)<br>Close enough for nuclear strong force to act<br>answer to 4 a (ii) is much greater that $10^{-15}$ m<br>or is greater that atomic radius<br>or is greater than the range of the strong force | B1<br>B1<br>B1 | Max 3 |
| 4 | b | i | Use of $pV=NkT$<br>(Allow incorrect powers of 10 or rearrangement to make $N$ subject)<br>$1\times10^{16}\times1=N\times1.38\times10^{-23}\times1.5\times10^{6}$<br>$4.8\ (3)\times 10^{32}$ | C1<br><br>C1<br>A1 | 3 |
| 4 | b | ii | $1.67 \times 10^{-27}$ or $1.7 \times 10^{-27}$ used<br>8.0 -8.2 $\times 10^{5}$ (kg m$^{-3}$) Allow ecf for $N$ from (b)(i) | C1<br>A1 | 2 |

| | | | | | |
|---|---|---|---|---|---|
| 4 | c | i | Number of protons = moles of proton/mass of protons /Mass per second × Avogadro constant used<br>Or<br>No of protons = mass per second/proton mass<br>(allow if numerical equation seen with a subject)<br><br>4.18 or 4.19 or 4.21 × $10^{38}$ correct to at least 2 sf from correct working | B1<br><br><br><br><br>B1 | 2 |
| 4 | c | ii | Attempt to use $E = mc^2$ with any mass and substitution for $c$<br>Energy radiated = 5 × $10^9$ ×$c^2$ energy radiated 4.5 × $10^{26}$ J<br>Number of helium nuclei formed = 1.05×$10^{38}$ (allow 1 × $10^{39}$)<br>Approximate BE per nucleon from article = 4.28(4.5) × $10^{-12}$ J<br>(Which is consistent) | C1<br>A1<br>B1<br>B1 | 4 |
| 5 | a | i | power output(it) increases | B1 | 1 |
| 5 | a | ii | boron rods <u>absorb</u> neutrons<br>if fewer neutrons there are <u>fewer fission reactions</u> taking place | B1<br>B1 | 2 |
| 5 | b | | Fuel rod/rod containing uranium/rods containing U-235 | B1 | 1 |
| 5 | c | | **1** moderator/slows down neutrons<br>when they lose energy colliding with (protons in the) water molecules<br>**2** Coolant/removes (internal) energy from the fuel rods<br>Transfers energy to the heat exchanger<br>Or explains transfer of energy from fuel to water is due to temperature difference | C1<br>A1<br>B1<br>B1 | 4 |
| 5 | d | i | 5.5 - 6% | B1 | 1 |
| 5 | d | ii | 126 -130 | B1 | 1 |
| 5 | d | iii | uses 1.45 × $10^{-11}$J or estimates minimum 117 or 118<br>1.45 × $10^{-11}$ = 0.5×117 × 1.7 ×$10^{-27}$ × $v^2$<br>1.2(18) × $10^7$ m $s^{-1}$ | C1<br>C1<br>A1 | 3 |
| 5 | d | iv | neutrons take some of the energy so speed of nuclei lower<br>For them to move in opposite directions neutron would need to have zero total momentum when released (unlikely).<br>Neutron(s) could be emitted in any direction/will have momentum | B1<br>B1 | 2 |

**UMS conversion calculator** www.aqa.org.uk/umsconversion