OXFORD
INTERNATIONAL
AQA EXAMINATIONS

INTERNATIONAL A-LEVEL

PHYSICS

PH04

Unit 4 Energy and energy resources

Mark scheme

June 2022

Version: 1.0 Final

226XPH04/MS

Mark schemes are prepared by the Lead Assessment Writer 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 associates 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 associate understands and applies it in the same correct way. As preparation for standardisation each associate 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, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' 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 oxfordaqaexams.org.uk

Level of response marking instructions

Level of response mark schemes are broken down into levels, each of which has a descriptor. The descriptor for the level shows the average performance for the level. There are marks in each level.

Before you apply the mark scheme to a student's answer read through the answer and annotate it (as instructed) to show the qualities that are being looked for. You can then apply the mark scheme.

Step 1 Determine a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the descriptor for that level. The descriptor for the level indicates the different qualities that might be seen in the student's answer for that level. If it meets the lowest level then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer. With practice and familiarity you will find that for better answers you will be able to quickly skip through the lower levels of the mark scheme.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level, ie if the response is predominantly level 3 with a small amount of level 4 material it would be placed in level 3 but be awarded a mark near the top of the level because of the level 4 content.

Step 2 Determine a mark

Once you have assigned a level you need to decide on the mark. The descriptors on how to allocate marks can help with this. The exemplar materials used during standardisation will help. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the example to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the example.

You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the Indicative content to reach the highest level of the mark scheme.

An answer which contains nothing of relevance to the question must be awarded no marks.

Question	Marking guidance	Mark	Comments
01.1	80.2 or 80.3 or 80.4 (°C)	1	Only accept these values.

Question	Marking guidance	Mark	Comments
01.2	Determines freezing time ✓ Use of $E = Pt$ **OR** $Q = mL$ ✓ Allow 0.022 to 0.025 (kg) ✓	3	Allow 7 to 8 (mins) For MP2: If time used is within range 6.0 to 8.5, condone use in minutes. If time is outside this range, t must be used seconds. For MP2: condone use of 7.8 for Q. 2 sf answer only.

Question	Marking guidance	Mark	Comments
01.3	During changing state: (average) PE decreases **AND** (average) KE doesn't change ✓ During cooling: (average) KE decreases **AND** (average) PE doesn't change ✓	2	Allow alternative ways of referring to each time period. Condone reference to seconds rather than minutes. If no other mark awarded, allow 1 mark for a correct description of only the PE during both periods **OR** of only the KE during both periods **OR** of a decrease in PE while changing state <u>and</u> a decrease in KE during cooling.

Total		**6**

Question	Marking guidance	Mark	Comments
02.1	3 from: ✓ ✓ ✓ (temperature decrease means) internal energy of gas decreases **OR** mean kinetic energy/speed of particles decreases **OR** quotes kinetic energy equation frequency of collisions (with container) decreases **OR** (magnitude/rate of) momentum change/impulse (of collisions) decreases links (rate of) change of momentum to force links force to (change in) pressure eg pressure = force/area	3	Allow 1 mark for an explanation in terms of the pressure/Gay-Lussac law. For MP1: Condone lack of reference to "mean" for KE or speed. For MP3: Must be some reference to particles for the change in momentum or force. For MP4: Stating $p = \frac{F}{A}$ is insufficient unless referenced to an area of a container.

Question	Marking guidance	Mark	Comments
02.2	Use of $n = \frac{m}{M}$ **OR** $\rho = \frac{m}{V}$, with $pV = nRT$ ✓ Use of both equations with correct rearrangement to give required formula ✓	2	Do not allow credit if M (rather than m) is used as part of density equation in their derivation.

Question	Marking guidance	Mark	Comments
02.3	Uses a data point from the line of best fit ✓ Converts temperature to kelvin ✓ Substitutes into $p = \frac{\rho RT}{M}$ ✓ 3.9×10^{-2} (kg mol^{-1}) ✓	4	For MP1: Condone POT error For MP3, p must be in in correct POT. Allow alternative method using the gradient: Attempts to determine a gradient, with ΔT step of at least 130. Condone POT error. ✓ Determines a gradient value in the range 340 to 350. ✓ Equates their gradient value to $\frac{\rho R}{M}$ ✓ 3.8×10^{-2} or 3.9×10^{-2} (kg mol^{-1}) ✓ 2sf answers only. Accept answers of 38 or 39 if g mol^{-1} clearly the unit stated.

Total		9

Question	Marking guidance	Mark	Comments
03.1	2π <u>and</u> 60 seen in calculation to give a value that rounds to 1.47×10^3 ✓	1	

Question	Marking guidance	Mark	Comments
03.2	Quotes and uses $E = \frac{1}{2} I\omega^2$ ✓ Value that rounds to 9.9×10^7 **OR** 1.0×10^8 (J) ✓	2	For MP1: Do not allow 1.4×10^4 for ω For MP2: Expect 1.04×10^8 from 1.5×10^3 **OR** 9.9×10^7 from 1.47×10^3. For MP2: Allow 9.8×10^7 from $\omega = 1.46 \times 10^3$

Question	Marking guidance	Mark	Comments
03.3	Use of $T = I\alpha$ to get α (-1.30 rad s^{-2}) ✓ Use of $\omega = \omega_0 + \alpha t$ ✓ 1200 (rad s^{-1}) ✓ **OR** Use of $T\Delta t = \Delta(I\omega)$ to get $\Delta\omega$ (313) ✓ Subtracts their $\Delta\omega$ from 1.5×10^3 ✓ 1200 (rad s^{-1}) ✓	3	In either method, condone t not converted. Allow more than 2 sf answer. For MP1: Condone missing minus sign. For MP2: Allow recognisable ω_0, but must use negative value for α For MP2: Allow subtraction from recognisable ω_0

Question	Marking guidance	Mark	Comments
03.4	(Changing from steel to carbon fibre:) Lower density means lower moment of inertia (for same volume and shape) ✓ (lower moment of inertia means) greater angular speed needed to have same energy stored ✓ (so) breaking stress needs to be considered due to (large) centripetal force/acceleration due to greater/maximum angular speed ✓	3	Allow reverse arguments. MP1 is for linking density to moment of inertia ✓ E.g. (For same volume and shape), moment of inertia depends on mass, and mass depends on density MP2 is for considering the relationship between the moment of inertia, the angular speed and the energy stored ✓ MP3 is for linking breaking stress to centripetal force/acceleration or maximum angular speed ✓

Total		**9**

Question	Marking guidance	Mark	Comments
04.1	Max three from: ✓ ✓ ✓ Adds proton rest-mass to mass of B Calculates a mass defect **OR** a difference in rest-mass energies Multiplies rest-mass or mass defect in u by 931.5 MeV **OR** converts mass in u to kg <u>and</u> uses $E = mc^2$ Adds kinetic energy contributed by proton 16.6 (MeV) ✓ 3 sf answer, from some relevant working ✓	5	Expect 12.01394 u **OR** 1.996×10^{-26} kg Expect 0.01714 u, 2.847×10^{-29} kg **OR** 15.966 MeV. Condone not including proton mass (0.99014 u). Expect 15.966 MeV, or 16.014 MeV using $E = mc^2$. Expect 922.3 MeV without proton rest-mass. Allow 0.619 or 0.675 MeV

Question	Marking guidance	Mark	Comments
04.2	Momenta are equal (in magnitude) **AND** opposite (in direction) ✓ Momentum calculation to show velocity of alpha is 2x velocity of Be ✓ Uses $E_k = \frac{1}{2}mv^2$ with mass of Be as twice mass of alpha ✓ (So) KE of alpha is twice KE of Be ✓	4	For MP2 and MP3, treat u as a mass unit (not an initial velocity). Allow "8" for mass of Be and "4" for mass of alpha.

Question	Marking guidance	Mark	Comments
04.3	Converts MeV to J to get 4.64×10^{-13} J ✓ Quotes and uses either $V = \frac{Q}{4\pi\varepsilon_0 r}$ **OR** $W = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$ ✓ 6.0×10^{-15} (m) **OR** 5.95×10^{-15} (m) seen ✓	3	For MP1: allow "$2.9 \times 1.6 \times 10^{-13}$" For MP2 there must be a subject for the equation. For MP3, allow 5.96×10^{-15} Withhold MP3 if r^2 seen in working.

Question	Marking guidance	Mark	Comments
04.4	Two from: ✓ ✓ Small de Broglie wavelengths (attainable with electron diffraction) **OR** de Brogie wavelength comparable/same order of magnitude to nuclear radius Closest approach method depends on (kinetic) energy of alpha Closest approach only provides an upper limit **OR** closest approach provides an over-estimate	2	Allow electrons are not affected by strong nuclear force.

Total		**14**

Question	Marking guidance	Mark	Comments
05.1	Use of $I = \frac{P}{4\pi r^2}$ ✓ 4.0×10^{26} (W) ✓	2	Expect 3.96×10^{26} (W). Do not accept 1 sf answer.

Question	Marking guidance	Mark	Comments
05.2	Multiplies 900 by 2 other data ✓ 970 (MW) ✓	2	Condone power of ten errors or omissions.

Question	Marking guidance	Mark	Comments
05.3	Use of $\rho = \frac{m}{V}$ to get mass of 1350 kg ✓ Use of $Q = mc\Delta\theta$ ✓ 5.7×10^8 (J s^{-1}) ✓	3	For MP2, expect $\Delta\theta = 280$ °C. For MP2, condone using one temperature in K, or adding 273 to their temperature difference. Allow ecf for their mass or for using 0.75 for m.

Question	Marking guidance	Mark	Comments
05.4	Calculates area of floor ✓ Use of $\frac{kA\Delta\theta}{L}$ ✓ Correct conclusion based on comparison from relevant working ✓	3	MP1: Expect to see $\pi 21^2$ or $1385\ \text{m}^2$ MP2: Condone POT error for L or Q. Ecf for their area. MP3: Expect rate of heat transfer to be $410\ \text{kW}$ or L to be $1.8(4)\ \text{m}$, so unsuitable.

Total		**10**

Question	Marking guidance	Mark	Comments
06.1	Energy required to separate a nucleus into individual nucleons **OR** into constituent protons and neutrons ✓	1	Allow reverse description.

Question	Marking guidance	Mark	Comments
06.2	Uses proton number (90) and neutron number (142) to calculate mass of nucleons ✓ Calculates their mass defect **OR** difference in rest-mass energies between nucleons and Th nucleus ✓ Uses $E = mc^2$ with mass defect, total mass of nucleons **OR** mass of Th nucleus ✓ 2.90×10^{-10} (J) ✓	4	For MP1, expect 3.884×10^{-25} kg **OR** 233.89 u. For MP2, expect mass defect of 3.220×10^{-27} kg **OR** 1.913 u. For MP3, rest-mass energy of nucleons is 3.4958×10^{-8} J and of Th is 3.4668×10^{-8} J

Question	Marking guidance	Mark	Comments
06.3	Proton number = 91; nucleon number = 233 ✓	1	

Question	Marking guidance	Mark	Comments
06.4	Calculates one binding energy ✓ Calculates difference in their binding energies ✓ 2.9×10^{-11} (J) ✓	3	For MP1, expect, in MeV, 1771.723 for U, 1142.882 for Xe, and 812.166 for Sr. For MP2, expect 182.33 MeV. For MP2, do not allow ecf for inclusion of neutrons.

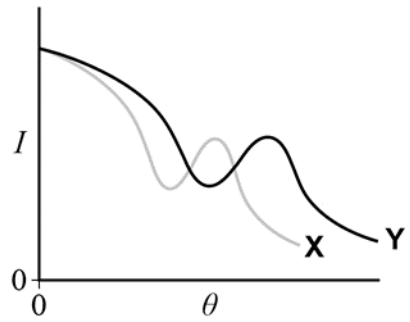
Question	Marking guidance	Mark	Comments
06.5	Different fissions produce different (pairs of) nuclides ✓ **OR** Different nuclides have different binding energy (per nucleon) ✓	1	Allow idea that reaction in **06.4** doesn't always happen

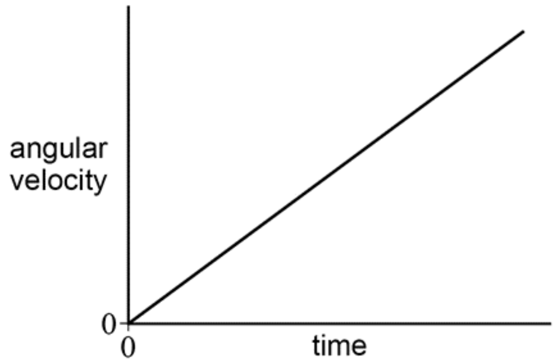
Question	Marking guidance	Mark	Comments
06.6	Quotes and uses $\rho = \frac{m}{V}$ to get volume ✓ Uses $V = \frac{4}{3}\pi r^3$ to get radius of 5.9×10^{-2} m ✓	2	For MP1, expect $V = 8.42 \times 10^{-4}$ m^3 For MP2, need to see either r^3 as subject or $r = \sqrt[3]{\ }$ Condone 5.8×10^{-2} m

Question	Marking guidance	Mark	Comments
06.7	Uses surface area of sphere **OR** shows that $\sigma = \frac{3}{r}$ ✓ $50\ (\mathrm{m^{-1}})$ ✓	2	For MP1, expect $A = 4.4 \times 10^{-2}\ \mathrm{m^2}$ Treat "50" as 2 sf answer. Allow answers that round to 50 from using different values of r $(0.058, 0.059$ or $0.06)$ in surface area equation.

Question	Marking guidance	Mark	Comments
06.8	Comment about condition needed to sustain a chain reaction ✓ Comment linking surface area or larger value of σ to (rate of) neutron loss ✓ Comment about consequence of neutron loss on rate of fission ✓	3	For MP1: e.g. at least 1 neutron (on average) per fission needed to proceed to next generation of fission For MP2: e.g. larger surface area leads to greater (rate of) neutron loss For MP3, e.g. fewer neutrons induce fission of uranium nuclei Do not allow idea that fewer neutrons are <u>produced</u> by fission events.

Total		**17**

Question	Key	Answer
07	**C**	-100 J -300 J
08	**A**	insulating the metal block
09	**B**	2
10	**B**	$\frac{2R}{p}$
11	**C**	+16 GJ
12	**A**	9.0×10^{20}
13	**B**	0.56 km s^{-1}
14	**B**	
15	**D**	2.9 fm
16	**D**	slow neutrons are more likely to be absorbed by the nuclear fuel.

17	**C**	a beta-plus particle.
18	**C**	2ω
19	**A**	
20	**C**	10 m
21	**A**