INTERNATIONAL A-LEVEL

PHYSICS

PH04

Unit 4 Energy and Energy resources

Mark scheme

January 2023

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231XPH04/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

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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	Answers	Additional comments/Guidelines	Mark	AO
01.1	90 (for 70 Ω) and 10 (for 400 Ω) ✓	Allow 92 and 10.2	1	AO3

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidelines</th><th>Mark</th><th>AO</th></tr>
<tr>
<td>01.2</td>
<td>Uses $I = \frac{k}{r^2}$ with 2 data sets ✓

Uses $I = \frac{k}{r^2}$ with 3 data sets ✓

Qualified conclusion, consistent with correct calculations ✓</td>
<td>Allow ecf from 01.1
Ignore units with any constant or power.
Allow a comparison of ratio of intensities to ratio of d^2 e.g. $\frac{90}{23} = 3.9$ and $\frac{10^2}{5^2} = 4$.

Possible calculated values are shown below:
<table>
<tr><th>R / Ω</th><th>d / cm</th><th>I / W m^{-2}</th><th>P / W</th><th>Id^2</th></tr>
<tr><td>70</td><td>5.06</td><td>92</td><td>2.83</td><td>2250</td></tr>
<tr><td>200</td><td>9.89</td><td>22.5</td><td>2.89</td><td>2300</td></tr>
<tr><td>400</td><td>15.17</td><td>10.2</td><td>2.83</td><td>2250</td></tr>
</table>
Allow 1 mark max for use of $\frac{d}{2}$ as r if accompanied by a consistent conclusion.</td>
<td>3</td>
<td>AO3
AO3
AO3</td>
</tr>
</table>

Question	Answers	Additional comments/Guidelines	Mark	AO
01.3	One pair from: Ensure constant pd across, or current in, lamp ✓ (because) power of lamp affects the intensity ✓ Keep face of LDR at same angle to lamp ✓ (because) area of incident radiation affects the intensity ✓ Measure distance of lamp from same position (from LDR) ✓ So any systematic offset can be corrected for ✓	Condone "keep power of lamp constant" for first marking point. Allow: Use a smaller lamp ✓ To approximate more closely a point source ✓ Repeat complete investigation at different orientation to lamp ✓ Idea that filament is not a point source ✓ Condone "keep temperature of LDR constant" for one mark.	2	AO4 AO4
Total			**6**	

Question	Answers	Additional comments/Guidelines	Mark	AO
02.1	Evidence of determining an angle of rotation between 146° and 151° ✓ Multiplies by $\frac{\pi}{180}$ or $\frac{2\pi}{360}$ to give a value that rounds to 2.6 ✓	Alternative method: Measures arc length (~90 mm) and radius (35 mm) ✓ Uses $\theta = \frac{s}{r}$ to give a value that rounds to 2.6 ✓	2	AO3 AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	1.2 (s) ✓	$\theta = \frac{1}{2}\alpha t^2$	1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	Use of $\omega^2 = 2\alpha\theta$ **OR** $\theta = \frac{1}{2}\alpha t^2$ with $\omega = \alpha t$ ✓ 6.7 (rad s^{-1}) ✓	Expect $\theta = 2\pi$. Condone $\theta = \pi$ for MP1.	2	AO2 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
02.4	Moment of inertia of **X** is greater (than **Y**) ✓ Torque is the same for **X** and **Y** ✓ Refers to $T = I\alpha$ to state that (angular) acceleration of **X** is smaller (than **Y**) ✓	Comment about difference in mass negates MP1. Accept reverse arguments for MP1 and MP3.	3	AO3 AO2 AO2
Total			**8**	

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	Relevant statement about plasma, energy extraction, or safety ✓ Relevant discussion ✓	e.g. Achieving/maintaining/containing high temperature plasma; extracting energy from plasma/neutrons; shielding from high energy neutrons	2	AO1 AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	Calculates mass difference ✓ Converts their mass difference to energy in joules ✓ 2.6×10^{-13} (J) ✓	For MP1, condone calculation error if correct working seen. Expect 2.87×10^{-30} kg or 1.73×10^{-3} u. MP2: e.g. uses $E = mc^2$ **OR** uses 931.5 MeV **and** 1.60×10^{-19}. Allow power of ten error for eV to J conversion. Allow 2.5×10^{-13} (J).	3	AO2 AO2 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	Reaction 1 occurs twice because: reaction 2 has to occur twice; or because 2 He-3 are required ✓ Reaction 2 occurs twice because 2 He-3 are required ✓		2	AO3 AO3
Total			**7**	

Question	Answers	Additional comments/Guidelines	Mark	AO
04.1	Idea that energy is stored in PSS when energy from wind farm exceeds demand ✓ Idea that PSS used when wind farm is unable to meet demand e.g. when wind speeds are low/zero ✓		2	AO2 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.2	Uses the efficiency correctly ✓ Uses $P = \frac{1}{2}\pi r^2 \rho v^3$ ✓ 15 (m s^{-1}) ✓	MP1: e.g. calculates input power $2.3/0.28 = 8.2\text{ MW}$. Condone power of ten error for their power. Condone use of diameter for radius 9.3 m s^{-1} gains 2 marks	3	AO2 AO2 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.3	$E_p = E_k$ **OR** $mgh = \frac{1}{2}mv^2$ seen ✓ 110 (m s^{-1}) ✓	No credit for suvat methods.	2	AO2 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.4	momentum of water decreases/changes ✓ (rate of) change of momentum produces a force (from blade on water) ✓ force is exerted on blade by water or correct reference to Newton's 3rd Law ✓ force acts at a distance from centre of mass/axle or relevant reference to $T = Fr$ ✓		4	AO2 AO2 AO3 AO3
Total			**11**	

Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	Calculates total mass difference **OR** finds difference between U-238 and U-237 **OR** adds U-237 mass to neutron mass ✓ Decay can't happen because: total mass increases **OR** because difference in uranium nuclide masses is less than neutron mass **OR** mass of U-237 + neutron > mass of U-238 ✓	Expect total mass difference of 0.0061 u or 1.10×10^{-29} kg. Difference in uranium nuclide masses = 1.00206 u. Mass of U-237 + neutron = 238.00698 u.	2	AO2 AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.2	Basic description of chain reaction ✓ Detail of nuclear process of fission ✓ Detail about chain reaction ✓	MP1: e.g. neutron causes fission of uranium-235 leading to more neutrons. MP2: e.g. neutron absorbed by U-235 nucleus; a U-236 nucleus formed. MP3: e.g. fission produces several neutrons that go on to induce further fissions (of U-235 nuclei).	3	AO1 AO1 AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.3	Water/heavy water **OR** graphite/carbon ✓		1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
05.4	(neutrons are) in thermal equilibrium with the fuel/moderator ✓	Allow idea that neutrons have same (kinetic) energy as fuel/moderator (atoms)	1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.5	Idea that chain reaction requires number of neutrons per fission to be $>= 1$ ✓ Idea that fission probability depends on KE/speed of neutron ✓	MP2: e.g. faster neutrons are less likely to be absorbed by U-235 nuclei (to induce fission). Condone "won't be" for "are less likely to be".	2	AO1 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.6	$2.5 \times 10^{-2} = 2.0 \times 10^{6} \times (0.84)^{n}$ ✓ 105 ✓	Allow 104.	2	AO3 AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
05.7	Energy to heat solid to melting point: $3.3 \times 10^5 \times 1200 \times (98 - 20) = 3.09 \times 10^{10}$ J **OR** Energy to heat liquid to 560 °C: $3.3 \times 10^5 \times 1300 \times (560 - 98) = 1.98 \times 10^{11}$ J ✓	MP1: one SHC calculation MP2: latent heat calculation MP3: final value For MP1: do not allow 1250 for c. Value of c must match the state of matter.	3	AO3 AO2 AO2
	Energy to melt solid: $3.3 \times 10^5 \times 110000 = 3.63 \times 10^{10}$ J ✓	Allow power of ten errors for MP1 and MP2.		
	2.65×10^{11} (J) ✓	3.65×10^{10} (J) gains 2 marks		

Question	Answers	Additional comments/Guidelines	Mark	AO
05.8	Comment about problem related to nature of radiation ✓	MP1: e.g. steel/lead/very thick concrete shielding needed for gamma; thermal energy released so needs cooling (in water)	2	AO2
	Comment about problem related to half-life ✓	MP2: e.g. store for at least 5 half-lives/150 years		AO2
Total			**16**	

Question	Answers	Additional comments/Guidelines	Mark	AO
06.1	Compares state 1 and state 2 using an ideal gas equation ✓ Provides evidence that the condition $d_2 > d_1$ or $V_2 < V_1$ leads to $\frac{T_2}{T_1} < 40$ ✓	Expect to see, after some working: $\frac{d_2T_2}{d_1T_1} = \frac{p_2}{p_1} = 40$ **OR** $\frac{V_1T_2}{V_2T_1} = \frac{p_2}{p_1} = 40$ For full credit there must be a link between density and volume in the answer.	2	AO2 AO2

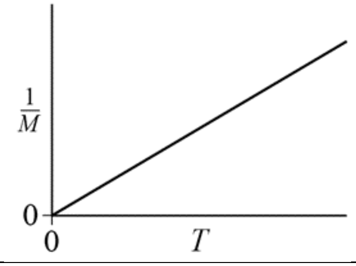
Question	Answers	Additional comments/Guidelines	Mark	AO
06.2	Work is done on air (by compressor blades) ✓ Little time for heat transfer so $Q \sim 0$ ✓ Uses first law to explain why internal energy increases or why ΔU is positive (and so temperature increases) ✓	Mention of "adiabatic" process scores MP2.	3	AO2 AO2 AO2

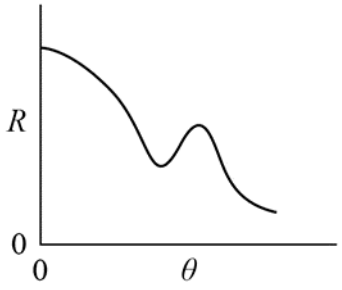
Question	Answers	Additional comments/Guidelines	Mark	AO
06.3	Substitution into formula ✓ Manipulation of formula (either using logs or roots) ✓ 860 (K) ✓	MP2: Condone manipulation of an incorrect substitution e.g. $40 = \left(\frac{300}{T_2}\right)^{3.5}$	3	AO3 AO4 AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
06.4	Use of $Q = \frac{kA\Delta\theta}{l}$ for either material ✓ Correct substitution e.g. $\frac{0.74(1600-\theta_1)}{250\times10^{-6}} = \frac{27(\theta_1-970)}{2.0\times10^{-3}}$ ✓ 1100 (K) ✓	Condone mismatch between k and $\Delta\theta$ in MP1 but not in MP2. Condone power of ten errors for l in MP1 and MP2. 3 sf answer is 1080 (K)	3	AO2 AO2 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
06.5	Converts rpm to rad s^{-1} ✓ Uses $P = T\omega$ ✓ 1.8×10^4 (N m) ✓	MP1: expect 1050 rad s^{-1} Answer of 1.93×10^3 gains MP2. Allow 2 marks for using revs per second, giving 1.14×10^5 (N m)	3	AO2 AO2 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
06.6	Attempt to get area under curve ✓ Counts squares (39–41 ‘big’ squares) **OR** determines energy per square (‘big’ = 2.5 MJ, ‘little’ = 0.1 MJ) **OR** uses a geometrical method ✓ Answer between 0.97×10^8 and 1.03×10^8 (J) ✓	MP1: Area must be between 35 m^3 and 75 m^3 Accept 1 sf answer of 1×10^8 (J)	3	AO3 AO3 AO3
Total			**17**	

Question	Key	Answer	AO
7	**A**	$-45 \quad -60$	AO1
8	**B**	$2.0 \quad 10 \quad 1.0$	AO2
9	**D**	the ideal gas equation	AO1
10	**B**		AO1
11	**D**	3.1×10^{28}	AO1
12	**C**	$\frac{v}{\sqrt{2}}$	AO1
13	**C**	$1500 \text{ J kg}^{-1} \text{ K}^{-1}$	AO2
14	**A**	increase increase	AO1
15	**C**	$\frac{Ze^2}{2\pi\varepsilon_0 E}$	AO1
16	**B**	Nucleons have less potential energy in the nucleus than as separate nucleons.	AO1

17	**D**		AO1
18	**D**	4.8 fm	AO3
19	**C**	$^{62}_{28}\text{Ni}$	AO1
20	**A**	$\frac{2mL^2}{3}$	AO2
21	**A**	8 clockwise	AO2