OXFORD AQA
INTERNATIONAL QUALIFICATIONS

INTERNATIONAL A-LEVEL

PHYSICS

PH04

Unit 4 Energy and Energy resources

Mark scheme

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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 www.oxfordaqa.com

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	Divides electrical power by 0.86 ✓2 Uses $E = mgh$ or $P(t) = \dot{m}gh$ ✓ 375 or 370 (kg) ✓		3	1 × AO1 1 × AO2 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
01.2	Uses $P = V_{rms}I_{rms}$ or $P = \frac{V_0 I_0}{2}$ or $I_0 = I_{rms}\sqrt{2}$ ✓ 1.6(2) (A) ✓	If no subscripts seen assume rms. Expect $I_{rms} = 1.14$ (A) Allow use of both $P = \frac{V^2}{R}$ and $P = I^2R$ for mp1 If not other marks awarded allow calculation of $V_0 = V_{rms}\sqrt{2}$	2	1 × AO1 1 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
01.3	**Figure 1**'s station doesn't destroy (large areas of) habitat by **flooding** or by occupying more area **OR** **Figure 1**'s station has smaller impact on river because of (temporary) removal of only (a small) part of the flow ✓	Reason must be related to the difference between hydroelectric power stations. Condone the idea that wildlife cannot traverse the dam.	1	AO1

Question	Answers	Additional comments/Guidelines	Mark	AO
01.4	Base load has to be available all of the time ✓ Max 2 from ✓✓ • Idea that river HEP has variable flow and will not provide a constant output • Idea that river HEP could sustain a constant output if river were reliable enough. • Idea that the reservoir will not sustain constant output if the level drops too much / while water is pumped into reservoir • Idea that reservoir could sustain a constant output if reservoir were big enough / water from dam can be used when (normal) flow is not enough	Ignore start up or shut down times or times to change power levels. Ignore/reject references to amount of power generated. Ignore references to long term and provides base power.	3	1 × AO1 2 × AO2
Total			**9**	

Question	Answers	Additional comments/Guidelines	Mark	AO
02.1	Uses $A = 4\pi r^2$ ✓ Uses power = $\frac{kA\Delta\theta}{L}$ ✓ 32 to 34 ✓	Allow 0.02864 - 0.02736 for the radius. Expect $A = 9.85 \times 10^{-3}$ (m^2) Expect 20.3 (W) Condone use of % sign in the answer	3	1 × AO1 2 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	Uses $Q = mc\Delta\theta$ with their m✓ Uses $m = 4\pi r^2 t\rho$ **OR** $m = \frac{4}{3}\pi\rho(r_2^3 - r_1^3)$ ✓ 1460 (J) **ecf from 02.1** ✓	Only penalise mixing up d and r once in 2.1 and 2.2 if use of d is seen clearly in working. Condone working out mass with volume of 1 sphere for mp2 Condone ecf for wrong area with $m = At\rho$ For mp3 allow 1436 OR 1470 OR 1403 (J) ecf for using d 5812 OR 5879 OR 5745 (J)	3	1 × AO1 2 × AO2
Total			**6**	

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	Max 2 ✓✓ • Idea that $\Delta E_k = \Delta Ep$ • $\Delta E_k = 1.6 \times 10^{-14} - 2 \times 4.0 \times 10^{-15} = 8 \times 10^{-15}$ (J) • Correct substitution into $E_p = \frac{1}{4\pi\varepsilon_0}\frac{Q^2}{r}$ 2.9×10^{-14} (m) ✓	Expect to see $8.0 \times 10^{-15} = \frac{(1.6\times10^{-19})^2}{4\pi\times8.85\times10^{-12} r}$ Condone missing substitution for ε_0	3	1 × AO1 1 × AO2 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	Max 2 ✓✓ • They can be moving in opposite directions / range of directions / a specified direction • Correct qualitative or quantitative statement about the (total) **change** of kinetic energy **OR** the (total) kinetic energy available to change into potential energy • Idea that closest approach is when kinetic energy is zero (if travelling in opposite directions). • Idea or use of distance of closest approach is inversely proportional to the (change in) kinetic energy Correct statement about the distance of closest approach for their directions / range of directions. (Must follow from some correct physics, although this may not be enough to gain the other marks.) ✓	If no direction (or range of directions) is given, first bullet point cannot be awarded but assume they are travelling in opposite directions for other bullet and marking points ΔE_k increases by a factor of 4 so d is quartered gains bullet 4 and MP3. Condone doubling $(\Delta)E_k$ to halve r for bullet 4 and MP3 Condone an incorrect number for MP3 if larger or smaller is correct. Ignore references to momentum. **Expect something like** Opposite directions ΔE_k is greater / 3.2×10^{-14} J Distance of closest approach is smaller Multiple directions are possible ΔE_k can have a range of values / 3.2×10^{-14} J to 0 Distance of closest approach may be larger or smaller (or the same) Close to parallel ΔEk is (very) small / close to 0 Distance of closest approach is large(r)	3	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.3	Idea that there is a range of kinetic energies / velocities of particles (of a gas or plasma) so some nuclei will get close enough to fuse ✓	Accept the idea that other nearby nuclei may affect the distance of closest approach	1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.4	**Any two from** ✓✓ Kinetic theory requires no intermolecular forces / potential energy but this is not true in a plasma (because there are large electrostatic or magnetic forces / is potential energy between ions) Kinetic theory requires that the volume of the particles is insignificant compared with the volume of the gas but this is not true in a plasma (because the ions may be very close together) Kinetic theory requires that the duration of collisions is insignificant compared with the time between collisions but this is not true in a plasma (because the ions interact over a large range of distances)	Allow collisions are not elastic **due to fusion occurring**. Condone motion is not random **due to (external) electric and/or magnetic fields** (because gas particles are neutral and plasma particles are charged) Ignore any reference to non-identical particles.	2	AO4

Question	Answers	Additional comments/Guidelines	Mark	AO
03.5	Use of $E_k = \frac{3}{2}kT$ OR $\frac{3RT}{2N_A}$ ✓ 7.7×10^8 (K) ✓		2	AO1
Total			**11**	

Question	Answers	Additional comments/Guidelines	Mark	AO
04.1	Uses $E = mc^2$ ✓ Divides by 1.6×10^{-13} to get 934 (MeV) to at least 3 sf ✓		2	1 × AO1 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
04.2	Attempts to find the mass defect ✓ 12.9 (MeV) ✓	Expect to see $2 \times 3.016029 - 4.002603 - 2 \times 1.007823$ $= 0.0138$ (u) Condone one missing $\times 2$ for mp1 Allow ecf for their answer to 4.1 930 MeV gives 12.8 (MeV) 931.5 MeV also gives 12.9 (MeV)	2	1 × AO2 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
04.3	Increase in binding energy (per reaction) $= 1.23489 - 0.35593$ (= 0.87896 (pJ)) ✓ Each hydrogen cycle has two second-stage reactions / 3rd stage requires two 2nd stage reactions (so total contribution $= 2 \times 0.87896 = 1.75792$ (pJ) $=$ 1.75792×10^{-12} (J)) ✓	Candidates must articulate the reason for the factor of 2 in order to get MP2 Allow $^{3}_{2}He$ for 2nd stage reactions.	2	1 × AO2 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
04.4	Two protons fusing to produce one deuteron ✓ All details correct: ${}^{1}_{1}\mathrm{p} + {}^{1}_{1}\mathrm{p} \rightarrow {}^{2}_{1}\mathrm{H} + {}^{0}_{1}\mathrm{e}^{(+)} + \nu$ ✓	Allow ${}^{1}_{1}\mathrm{H}$ for proton. Allow β for positron Penalise antineutrino and/or electron	2	1 × AO1 1 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.5	MAX 3 for any of the following: ✓✓✓ • Divides mass of hydrogen by mass of 1 mol to get number of moles **AND** multiplies by Avogadro number to find number of hydrogen nuclei • Dividing by 4 to get number of hydrogen cycles • Multiplies a number of cycles/hydrogen nuclei by 4.5×10^{-12} to get energy released • Divides an energy by 4×10^{26} to get time **AND** converts to years **OR** MAX 3 for any of the following: ✓✓✓ • Divides 4×10^{26} by 4.5×10^{-12} to get number of reactions per second • Multiplies the number of reactions per second by 4 to find the number of hydrogen ions used per second • Divides by Avogadro number to find number of moles **AND m**ultiplies by molar mass converted per second • Divides 2×10^{30} by mass per second to get time **AND** converts to years 1.1×10^{11} (years) ✓	If $E = mc^2$ is used allow only 2nd and 4th bullet point Expect to see 1.2×10^{57} Expect to see 3.0×10^{56} Expect to see 5.4×10^{45} (J) Expect to see 3.5×10^{18} (s) Expect to see 8.9×10^{37} Expect to see 3.6×10^{38} Expect to see 5.9×10^{11} (kg) Expect to see 3.4×10^{18} (s) 1.07×10^{11} to 3SF. Allow 1 SF answer. Correct answer gets 4 marks	4	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.6	Electrostatic repulsion is greater / greater electrostatic potential energy as each nucleus has a greater charge ✓ …so plasma will need a higher temperature so that kinetic energy of the nuclei is sufficient ✓		2	1 × AO1 1 × AO2
Total			**14**	

Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	Use of maximum power available $= \frac{1}{2}\pi r^2 \rho v^3$ $= \frac{1}{2}\pi\left(\frac{135}{2}\right)^2 \times 1.2 \times 11.4^3$ ✓ 13 MW ✓	Allow MP1 with POT errors or if diameter is used (expect 50.8 MW if diameter is used) 12.7 MW	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.2	Idea that not all of the moving air interacts with the **blades** ✓ Idea that the wind requires speed/momentum/kinetic energy to leave rear of turbine (so cannot transfer 100%) ✓	Condone rotor for blades. Condone appropriate part of turbine blocking some of the wind in MP1. Accept reference to the Betz limit (59.3%) for MP2 Do not accept ideas of objects blocking wind in front of turbine. Ignore references to the angle of the turbine.	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.3	Uses $f = \frac{\omega}{2\pi}$ to get 13.5 (revolutions min^{-1}) ✓	Allow 13, reject 14 13.46450819 Condone 13.47	1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.4	Uses power = torque × angular velocity = $4.0 \times 10^6 \times 1.41$ ✓ Uses energy = power × time = $5.6 \times 10^6 \times 5$ to give 28(.2) (MJ) ✓	Look for 5.6 (MW) but condone use of wrong value for torque for MP1	2	1 × AO1 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
05.5	Uses $T = I\alpha$ with T between 0.4×10^6 and 4.4×10^6 ✓ Uses resultant torque = 3.6×10^6 (Nm) to give 0.051 (rad s^{-2}) ✓		2	1 × AO1 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
05.6	Use of $E_k = \frac{1}{2} I\omega^2$ ✓ 7.1×10^7 (J) ✓	Expect $\frac{1}{2} \times 7.1 \times 10^7 \times 1.41^2$	2	AO2

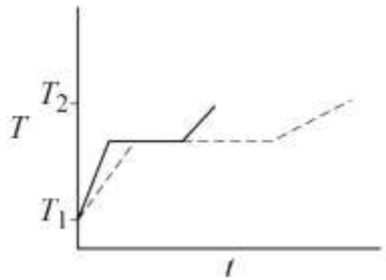
Question	Answers	Additional comments/Guidelines	Mark	AO
05.7	MAX 3 ✓✓✓ • Angular acceleration reduces with time (for the first 55 s) • …because the (net) torque reduces with time **AND** reference to $T = I\alpha$ • Idea that opposing torque **from the generator** increases with time (as the power output of the generator increases) • Angular acceleration is zero from t = 50 s to t = 55 s since the resistive torque is equal and opposite to the torque applied by the wind (to the rotor)	Accept explanation for changing torque from generator in terms of increasing back emf Do not allow references to torque due to air resistance. Ignore references to forces increasing or decreasing, only credit answers which refer to torques for bullet points 2 and 3. Reject answers which refer to balanced forces for bullet point 4. Accept resultant torque is 0 if resistive torque and torque due to the wind are identified. Condone thrust torque or driving torque for torque applied by the wind.	3	AO3
Total			**14**	

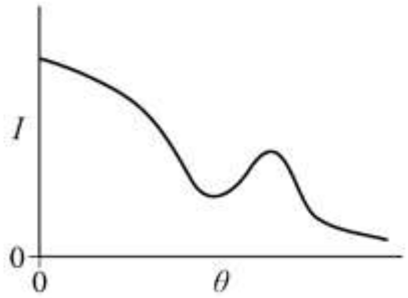
Question	Answers	Additional comments/Guidelines	Mark	AO
06.1	Attempts to use the area under the graph ✓ Counts 26 to 28 squares **OR** recognises that one $(5x5)$ square is equivalent to 1.25 J **OR** Use of the trapezium rule with at least 4 trapeziums **OR** breaking into triangles and squares if at least 4 triangles along length of curve ✓ Answer in the range 32.5 (J) to 35 (J) ✓	Condone for mp2 $(\mathbf{10} \times \mathbf{10})$ **squares** 6.5 to 7.0 squares **OR** one is equivalent to 5.0 J $(\mathbf{1} \times \mathbf{1})$ **squares** 650 to 700 squares **OR** one is equivalent to 0.05 J	3	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
06.2	Uses $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ or correct use of $n = \frac{pV}{RT}$ or $N = \frac{pV}{kT}$ ✓ 440 OR 444 (K) ✓	Allow errors in read offs for MP1.	2	1 × AO1 1 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
06.3	Uses $pV = nRT$ to attempt to find the number of moles in the pump ✓ Additional quantity of air / their number of moles ✓ 26 or 27 if justified ✓	Expect to see $\frac{1\times10^5\times2.5\times10^{-4}}{8.3\times290}$ or $\frac{4.5\times10^5\times0.85\times10^4}{8.3\times440}$ or $\frac{4.5\times10^5\times0.85\times10^4}{8.3\times \text{thier T in 6.2}}$ If $1.0(4)\times10^{-2}$ (mol) seen award first 2 marks. Allow ecf only for incorrect T from 6.2	3	1 × AO1 1 × AO2 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
06.4	Work (W) is done on the gas ✓ No time or short time for any heat transfer (Q) ✓ Correct reference to the 1st law equation AND connects internal energy to temperature ✓	Ignore references to friction. Accept small value of ΔQ because time is short. Condone wrong direction of work in MP3 but not MP1.	3	1 × AO1 1 × AO2 1 × AO3
Total			**11**	

Question	Key	Answer	AO
07	D	the potential energies and the translational, rotational and vibrational kinetic energies of all of the molecules.	AO1
08	B		AO3
09	C	ignoring energy losses from the water heater	AO4
10	C	window, door, wall	AO3
11	A	1.0 | 2.8	AO2
12	C	Air molecules are seen to move randomly.	AO1
13	B	4×10^{17} kg m^{-3}	AO2
14	D	140 MeV	AO3

15	**B**		AO3
16	**B**	7 | 0.0005	AO2
17	**D**	**1** and **2** and **3**	AO1
18	**A**	**P**, **Q**, **R**	AO3
19	**B**	20	AO2
20	**A**	300 h	AO2
21	**C**	An additional light source was present for part of the time.	AO3

Total 15 marks