

INTERNATIONAL A-LEVEL PHYSICS

PH04

Unit 4 Energy and energy resources

Mark scheme

June 2026

Version: 1.0 Final

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.

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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	Converts 11 kW h into J OR Divides their number of J by 19.2×10^6 J) ✓ 2.1 (kg) ✓	Alternative for mp1: converts 19.2×10^6 J into kW h (5.33) OR divides 11 (kW h) by their number of kW h 2 sf only	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
01.2	Any three from: ✓✓✓ <ul style="list-style-type: none"> • uses $\Delta\theta = 80$ (K) • uses $E = mc\Delta\theta$ to determine energy out • uses $\text{efficiency} = 100 \times \frac{\text{energy out}}{\text{energy in}}$ • divides their 'energy in' by 19.2×10^6 (J) 0.20 (kg) ✓	Alternative: <ul style="list-style-type: none"> • divides their 'energy in' by 11 kW h and multiplies their answer by their answer to Question 01.1 • potential ecf answer from this approach. Calculator value = 0.199561	4	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
01.3	<p>Any two from: ✓✓</p> <ul style="list-style-type: none"> • $\frac{k_w A}{l_w} (\Delta\theta_w) = \frac{k_i A}{l_i} (\Delta\theta_i)$ OR $\frac{\Delta\theta_i}{\Delta\theta_w} = \frac{k_w l_i}{l_w k_i}$ • Evidence of $\Delta\theta_w = 95 - \theta_j$ AND $\Delta\theta_i = \theta_j - 22$ OR $\theta_j = 94.99$ (°C) OR $\Delta\theta_i = 73 - \Delta\theta_w$ • calculates their $\Delta\theta_w$ or $\Delta\theta_i$ <p>So temperature drop across outer wall is about 0.01 (K) (and therefore negligible). ✓</p>	<p>In BP1 condone missing A.</p> <p>Condone temperature differences for wall and insulator reversed for BP1 and BP3 only.</p> <p>In BP3 allow 1SF answer to subtraction</p> <p>Alternative bullets: 2 from: (do not mix routes)</p> <ul style="list-style-type: none"> • idea that, for the same rate of energy transfer by conduction and area, temperature drop is proportional to $l \div k$ • $l \div k$ for insulator is about 0.4 AND $l \div k$ for outer wall is about 6×10^{-5} OR $l \div k$ for insulator is about $7000 \times l \div k$ for outer wall (or reciprocals) • attempts to work out the temperature drop across the outer wall <p>Alternative BP3 for either route: evidence of attempt to work out $\frac{\Delta\theta_i}{\Delta\theta_w}$ (or reciprocal)</p> <p>For MP3 allow idea of temperature is the same on both sides of the wall or $\Delta\theta = 0$</p> <p>Alternative MP3 : $\frac{\Delta\theta_i}{\Delta\theta_w} = 1.5 \times 10^{-4}$ (or reciprocal) (and therefore $\Delta\theta_i$ is negligible)</p>	3	1 × AO3 2 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
01.4	Uses $P = \frac{kA\Delta\theta}{L}$ with consistent $\Delta\theta$, k and l ✓ 25 (W) ✓	Do not allow Boltzmann for k Allow ecf for their $\Delta\theta$. Do not accept 22 or 95 Allow one error in MP1 e.g. only using two consistent values In MP2, note, using the wall and <ul style="list-style-type: none"> $\Delta\theta = 0.011$ gives 26 $\Delta\theta = 0.0108$ gives 25 In MP2, do not accept use of 1sf $\Delta\theta$	2	AO1 AO2
Total			11	

Question	Answers	Additional comments/Guidelines	Mark	AO
02.1	Any three from: ✓✓✓ • converts 18 °C to kelvin • uses $pV = nRT$ with their T to determine one of their number of moles • subtracts their initial and final number of moles or atoms or mass • evidence of need to multiply their number of moles by 4 OR 0.004 0.037 (kg) ✓	Allow use of $pV = NkT$ i.e using number of atoms rather than moles; this requires use of avogadro in BP4 mp2 and mp3 may be combined eg using $\Delta n = \frac{\Delta pV}{RT}$	4	1 × AO1 2 × AO2 1 × AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
02.2	Uses volume of sphere equation (to calculate volume of the full balloon) ✓ Evidence of use of a pressure × their volume of balloon ✓ 640 J ✓	Condone use of diameter in MP1 Calculator value = 637.06	3	1 × AO1 2 × AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	Any two from: ✓✓ • calculates energy using $\frac{3}{2} kT$ • calculates c^2 using KE equation and their mass and energy • square roots their value of a recognisable c^2 1400 (m s ⁻¹) ✓	Allow use of $\frac{3R}{2N_A}T$ Note: use of $c^2 = \frac{3RT}{\text{molar mass}}$ gains BP1 and BP2 If no other mark given allow one mark for $\frac{1}{2} m(c_{\text{rms}})^2 = \frac{3}{2} kT$ or similar seen	3	AO2
Total			10	

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	<p>Any three from: ✓✓✓</p> <ul style="list-style-type: none"> evidence of converting 4.8 MeV to J uses charge on alpha = 2e and uses charge on lead nucleus = 82e evidence of $E = \frac{Q_1 Q_2}{4\pi\epsilon_0 R}$ uses their $R = R_0 (204)^{\frac{1}{3}}$ <p>$8.4 \times 10^{-15} \text{ (m)}$ ✓</p>	<p>Expect to see</p> <p>$7.7 \times 10^{-13} \text{ J}$</p> <p>$4.9 \times 10^{-14} \text{ m}$ (seeing this value is sufficient evidence for BP1, 2 or 3)</p> <p>In BP3, condone use of 9×10^9 for $(4\pi\epsilon_0)^{-1}$ but do not accept 'k' unsubstituted</p> <p>In BP4 $(204)^{\frac{1}{3}} = 5.9$</p> <p>Accept $8.3 \times 10^{-15} \text{ (m)}$</p>	4	<p>1 × AO1</p> <p>2 × AO2</p> <p>1 × AO3</p>

Question	Answers	Additional comments/Guidelines	Mark	AO
03.2	<p>Any 2 from ✓✓</p> <ol style="list-style-type: none"> Idea that the value of R is (much) greater than the nuclear radius / the alpha particle's closest approach can be some distance from the lead nucleus/alpha particle does not reach the nucleus Idea that the value depends on the (kinetic) energy of the alpha particle The calculation does not take into account any recoil of the nucleus. The value depends on the proton number not the nucleon number of the nucleus. 	Do not accept 'upper limit'.	2	<p>1 × AO3</p> <p>1 × AO1</p>

Total			6
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Question	Answers	Additional comments/Guidelines	Mark	AO																
04.1	The mark scheme gives some guidance as to what statements are expected to be seen in a 1- or 2-mark (L1), 3- or 4-mark (L2) and 5- or 6-mark (L3) answer. Guidance provided in the ‘Mark Scheme Instructions’ should be used to assist in marking this question.		6	AO1																
	<table><tr><th>Mark</th><th>Criteria</th></tr><tr><td>6</td><td>All three areas (as grouped alongside) covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.</td></tr><tr><td>5</td><td>All three areas covered, at least two in detail. Whilst there will be gaps, there should only be an occasional error.</td></tr><tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.</td></tr><tr><td>3</td><td>One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.</td></tr><tr><td>2</td><td>Only one area discussed, or makes a partial attempt at two areas.</td></tr><tr><td>1</td><td>None of the three areas covered without significant error.</td></tr><tr><td>0</td><td>No relevant comments.</td></tr></table>				Mark	Criteria	6	All three areas (as grouped alongside) covered in some detail. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.	5	All three areas covered, at least two in detail. Whilst there will be gaps, there should only be an occasional error.	4	Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be several gaps, there should only be an occasional error.	3	One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.	2	Only one area discussed, or makes a partial attempt at two areas.	1	None of the three areas covered without significant error.	0	No relevant comments.
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	0	No relevant comments.																		
In each area: for partial expect at least one of the comments, for full expect at least 3.																				
A Why moderator required 1. neutrons (produced in fission) are moving (very) fast/have high kinetic energy 2. probability of induced fission from fast neutrons very low 3. neutrons at thermal speeds more likely to be absorbed by uranium nucleus and cause further fission 4. U-235 needs to absorb a neutron to become U-236 / to increase likelihood of being fissile																				
B Process of moderation 1. high-speed neutrons incident on nucleus of moderator 2. neutrons scattered from nucleus 3. idea that the neutrons lose kinetic energy/speed in (many) collisions 4. neutrons slowed down to thermal speeds / are in thermal equilibrium with moderator																				
C Properties and name of moderator 1. low mass nucleus/mass of nucleus (almost) same as the neutron (do not accept ‘mass of water nucleus’ or mass of atom) 2. chemically or thermally stable 3. low neutron absorption 4. example eg water/hydrogen, heavy water/ deuterium, carbon / graphite / carbon dioxide, beryllium, lithium-7																				

Question	Answers	Additional comments/Guidelines	Mark	AO
04.2	Any two from: ✓✓ <ul style="list-style-type: none"> evidence of calculation of binding energy of U-236 or Y-102 uses their BE for U + 2.69×10^{-11} (J) = their BE for Y + their BE for I divides their BE for I by $(3 \times 10^8)^2$ 1.96×10^{-27} (kg) ✓	No POT penalty in MP1 and MP2 Expect to see U BE = 2.9×10^{-10} (J) Y BE = 1.4×10^{-10} (J) I BE = 1.8×10^{-10} (J) Accept 1.97×10^{-27} (kg) Accept answer to 2 or more sf	3	AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
04.3	<p>Xenon will have a higher binding energy per nucleon (because it is more stable) ✓</p> <p>Any two from: ✓✓</p> <ul style="list-style-type: none"> • idea that a nucleus releases energy in beta decay/ idea that the nucleus of xenon has less energy than the iodine nucleus • idea that the nucleus of xenon has less mass than the iodine nucleus • idea that nucleus of xenon has a greater mass defect • BE of xenon – BE of iodine = energy to produce beta & (anti)neutrino + KE of beta & (anti)neutrino • same number of nucleons so increase in BE = increase in BE per nucleon. 	In BP2 and BP3 penalise lack of reference to 'nucleus' once only	3	AO2
Total			12	

Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	$T\Delta t = \Delta(I\omega)$ ✓		1	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.2	<p>Measuring instruments Metre ruler / tape measure (marked in mm) AND Stopwatch/light gate(s) (and data logger) ✓</p> <p>Method Any three from: ✓✓✓</p> <ul style="list-style-type: none"> • Measure 38.0 cm (along slope) / between light gates • Release (from rest) and start timer/from top light gate • Stop time when it reaches lower mark/second light gate • Mark horizontal lines/use a leading or trailing edge with light gate. 	<p>Alternative using a video: Measuring instruments: Metre ruler AND Video recorder with some idea of how the time is obtained</p> <p>Method Any three from: ✓✓✓</p> <ul style="list-style-type: none"> • Measure 38.0 cm (along slope) • Start recording and (then) release (from rest) • Stop recording after it passes lower mark • Mark horizontal lines/film at right angles to the slope <p>In the light gate method it must be clear that t is not the time passing through a light gate.</p>	4	AO4

Question	Answers	Additional comments/Guidelines	Mark	AO
05.3	Idea that the object would slide/would not spin ✓ Idea that normal reaction force and weight act through the centre of mass (of the cylinder) so there is no turning effect ✓	Treat idea that cylinder would have a greater (linear) acceleration as neutral For MP2, accept the idea that forces on the cylinder act through the same point	2	AO3 AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.4	Determines circumference of cylinder OR Divides 38 cm by their circumference OR $38 = 3.4\theta$ seen ✓ 11 (rad) ✓	Expect to see $2\pi \times 3.4$ or 0.21 (m) $\left(\frac{38}{2\pi \times 3.4} \times 2\pi =\right) 11 \text{ (rad)}$	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.5	Any one from: ✓ <ul style="list-style-type: none"> • use of $\Delta E_p = mgh$ • $\sin \theta = \frac{\text{their } h}{0.38}$ 24° ✓	Expect to see $h = 0.155$ (m) Do not accept one step calculation using the incorrect trig function. Accept 0.42 if radians replaces degrees on the answer line	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
05.6	Any three from: ✓✓✓ <ul style="list-style-type: none"> calculates the translational KE calculates the angular speed (rotational KE =) $E_p(3.2) - (\text{their}) \text{ translational KE (J)}$ Uses their rotational $KE = \frac{1}{2} I (\text{their angular speed})^2$ $1.2(4) \times 10^{-3} \text{ (kg m}^2\text{)} \checkmark$	Expect to see translational $KE = 2.12 \text{ J}$ Expect to see angular speed $= 41.8 \text{ rad s}^{-1}$ Expect to see rotational $KE = 1.08 \text{ J}$ Only award MP4 if evidence of an energy approach seen	4	3 × AO2 1 × AO1

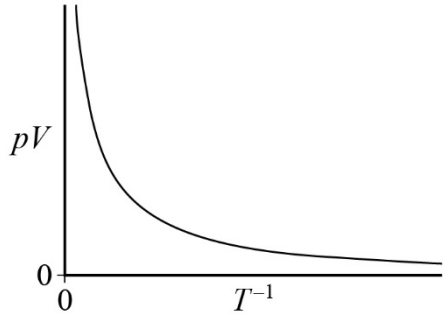
Question	Answers	Additional comments/Guidelines	Mark	AO
05.7	Idea that X has the greater moment of inertia as the mass is distributed further from the axis of rotation ✓ Idea that a greater proportion of X 's total energy will be rotational / lower proportion will be translational ✓ Therefore, for the same change in GPE, (average speed of) X will be slower/acceleration will be less so solid cylinder Y reaches bottom first ✓	Allow reverse argument Alternative for MP2 and MP3 (just considering the rotational motion) Condone: (Assuming) friction is the same, (radius is the same) so torque the same, so X angular acceleration is less ✓ Angular displacement same so time for X is longer therefore Y reaches bottom first ✓	3	1 × AO1 2 × AO2

Total			18	
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Question	Answers	Additional comments/Guidelines	Mark	AO
06.1	Evidence of: $\text{area} = \pi \left(\frac{d}{2}\right)^2$ OR $\text{volume per second} = \text{area} \times \text{length per second} = \text{area} \times v \checkmark$ idea that mass per second = density $\times$ volume per second or density $\times$ area $\times$ speed leading to correct answer $\checkmark$	Do not allow an answer in which v and V are indiscernable Take m to mean mass per second, but do not accept V as volume per second unless defined. Alternative: MP1 (maximum) power = $\frac{1}{2} \pi r^2 \rho v^3$ combined with E_k (per second) = $\frac{1}{2} m v^2$ MP2 uses $r = \frac{d}{2}$ and suitable algebra leading to correct answer	2	AO2

Question	Answers	Additional comments/Guidelines	Mark	AO
06.2	Use of max power = $\frac{1}{2} \pi r^2 \rho v^3 \checkmark$ Use of $m = \frac{\pi d^2 \rho \times \text{their speed}}{4} \checkmark$ $7.1 \times 10^5 \text{ (kg s}^{-1}\text{)} \checkmark$	Expect to see $v = 12.5 \text{ m s}^{-1}$ Award MP1 and MP2 for evidence of $m = \frac{1}{2} (P \pi^2 \rho^2 d^4)^{1/3}$ Condone confusing r and d once only in MP1 and MP2.	3	1 $\times$ AO1 2 $\times$ AO3

Question	Answers	Additional comments/Guidelines	Mark	AO
06.3	<p>General shape correct. i.e. a line that goes up from zero reaches a peak and goes back to zero with a curved peak to the right of centre. Line before peak should have a positive gradient and line afterwards should have a negative gradient throughout. ✓</p> <p>Two from ✓✓</p> <ul style="list-style-type: none"> • Straight line (0,0) to (at least) (0.5, 0.035) with an appropriate linear scale marked • Peak power at 0.60 V to 0.65 V • Line decrease to zero at 0.70 V to 0.72 V 		3	AO3
Total			8	

Question	Key	Answer	AO
07	B	$1.25T$	AO1
08	D	The potential energy of nitrogen increases by 500 J when 25 g of it boils.	AO2
09	C	53 W	AO2
10	B		AO3
11	B	The speed of a particle does not change when it collides with the container wall.	AO1
12	C	p decreases The time between particle collisions with the walls increases.	AO1
13	D	the mass of a carbon-12 $({}^{12}_6\text{C})$ atom in its ground state divided by 12	AO1
14	D	6 2	AO1
15	D	fully inserting control rods.	AO1
16	B	0.80 rad s^{-2} anticlockwise	AO2
17	A	$1.4 \times 10^{10} \text{ m}$	AO2

18	B	diffraction angle	intensity of electrons diffracted by a nucleus	AO3
19	D		13.5 6.0	AO3
20	B		$7.8 \times 10^{-10} \text{ kg}$	AO2
21	A		$\frac{P}{2}$	AO2

Total marks = 15