A-LEVEL
PHYSICS
7408/2

Paper 2

Mark scheme

June 2020

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.

Further copies of this mark scheme are available from aqa.org.uk

Physics - Mark scheme instructions to examiners

1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the Examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

2. Emboldening

2.1 In a list of acceptable answers where more than one mark is available 'any **two** from' is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.
2.2 A bold **and** is used to indicate that both parts of the answer are required to award the mark.
2.3 Alternative answers acceptable for a mark are indicated by the use of **or**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

3. Marking points

3.1 Marking of lists

This applies to questions requiring a set number of responses, but for which candidates have provided extra responses. The general principle to be followed in such a situation is that 'right + wrong = wrong'.

Each error / contradiction negates each correct response. So, if the number of errors / contradictions equals or exceeds the number of marks available for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by 'Ignore' in the mark scheme) are not penalised.

3.2 Marking procedure for calculations

Full marks can usually be given for a correct numerical answer without working shown unless the question states 'Show your working'. However, if a correct numerical answer can be evaluated from incorrect physics then working will be required. The mark scheme will indicate both this and the credit (if any) that can be allowed for the incorrect approach.

However, if the answer is incorrect, mark(s) can usually be gained by correct substitution / working and this is shown in the 'extra information' column or by each stage of a longer calculation.

A calculation must be followed through to answer in decimal form. An answer in surd form is never acceptable for the final (evaluation) mark in a calculation and will therefore generally be denied one mark.

3.3 Interpretation of 'it'

Answers using the word 'it' should be given credit only if it is clear that the 'it' refers to the correct subject.

3.4 Errors carried forward, consequential marking and arithmetic errors

Allowances for errors carried forward are likely to be restricted to calculation questions and should be shown by the abbreviation ECF or *conseq* in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

3.5 Phonetic spelling

The phonetic spelling of correct scientific terminology should be credited (eg fizix) **unless** there is a possible confusion (eg defraction/refraction) with another technical term.

3.6 Brackets

(…..) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

3.7 Ignore / Insufficient / Do not allow

'Ignore' or 'insufficient' is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

'Do **not** allow' means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.

3.8 Significant figure penalties

Answers to questions in the practical sections (7407/2 – Section A and 7408/3A) should display an appropriate number of significant figures. For non-practical sections, an A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the **final** answer in a calculation to a specified number of significant figures (sf). This will generally be assessed to be the number of sf of the datum with the least number of sf from which the answer is determined. The mark scheme will give the range of sf that are acceptable but this will normally be the sf of the datum (or this sf -1).

An answer in surd form cannot gain the sf mark. An incorrect calculation **following some working** can gain the sf mark. For a question beginning with the command word 'Show that…', the answer should be quoted to **one more** sf than the sf quoted in the question eg 'Show that X is equal to about 2.1 cm' –

answer should be quoted to 3 sf. An answer to 1 sf will not normally be acceptable, unless the answer is an integer eg a number of objects. In non-practical sections, the need for a consideration will be indicated in the question by the use of 'Give your answer to an appropriate number of significant figures'.

3.9 Unit penalties

An A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the correct unit for the answer to a calculation. The need for a unit to be quoted will be indicated in the question by the use of 'State an appropriate SI unit for your answer'. Unit answers will be expected to appear in the most commonly agreed form for the calculation concerned; strings of fundamental (base) units would not. For example, 1 tesla and 1 Wb m^{-2} would both be acceptable units for magnetic flux density but 1 kg m^2 s^{-2} A^{-1} would not.

3.10 Level of response marking instructions

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

Determining 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. i.e. if the response is predominantly level 2 with a small amount of level 3 material it would be placed in level 2.

The exemplar materials used during standardisation will help you to determine the appropriate level. 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	28 (°C) ✓		1	
01.2	The energy transferred reduces the number of nearest atomic neighbours OR allows atoms to move their centre of vibration OR breaks some of the (atomic) bonds OR crystalline to amorphous ✓ (owtte)	First alternative must not imply total loss of intermolecular forces or neighbours. A reference to 'breaking <u>the</u> bonds' implies all the bonds and does not gain the mark. No mark for saying bonds weaken. However these errors in discussing the bonds does not prevent a mark coming from another point Last alternative might be expressed as 'atoms change from fixed positions to them being able to slide around each other'. Ignore any references to changes in separation. An explanation that involves increasing the kinetic energy will lose the mark. So will any description that implies it becomes a gas.	1	
01.3	The (total or mean) kinetic energy remains constant. ✓ The (total or mean) potential energy increases. ✓		2	

01.4	The <u>mean</u> speed/<u>mean</u> kinetic energy increases ✓	Ignore references to larger separation (because it's not always true): collisions (as it is not a gas) or measures of randomness (which are usually too vague). Condone use of average for mean. Don't allow velocity instead of speed. During this time interval the atoms are all in the liquid form so no credit for references that indicate a change of state.	1	
01.5	Using both $\Delta Q = mc\Delta\theta$ **and** $\Delta Q = P\Delta t$ ✓ $\left(c = \frac{P\Delta t}{m\Delta\theta} = \frac{35 \times (14.8 - 11.2) \times 60}{0.25 \times (110 - 28)} = 369\right)$ $c = 370$ ✓ (allow 365–375) $\text{J kg}^{-1}\text{ K}^{-1}$ ✓ (or $\text{J kg}^{-1}\text{ C}^{-1}$)	First mark can be given by seeing the substitution which may have some errors for example not using exactly 28. These will be penalised in the second mark. Correct answer gains first two marks NB 400 $\text{J kg}^{-1}\text{ K}^{-1}$ shows candidate has wrongly made calculations for the solid. No mark for the unit if a solidus is used because of the uncertainty of whether the K is on the top or bottom line. (which is correct J / kg / K or J / kg K ?) However allow a prefix if kilojoules are used for example.	3	

Question	Answers	Additional comments/Guidelines	Mark	AO
01.6	(Using both $\Delta Q = ml$ and $\Delta Q = P\Delta t$) $l\left(=\frac{P\Delta t}{m}\right) = \frac{35 \times ((11.2-1.8) \times 60)}{0.25}$ $= 79\ \text{kJ kg}^{-1}$ ✓ hence M = gallium ✓ (condone an ecf consistent with the calculation provided a comment is made if the value falls outside the range of the table)	The calculation yields1.3 kJ kg^{-1} if the 60 seconds is omitted. Interim stage heat supplied = 19.7 kJ A valid calculation must be shown to gain this second mark.	2	

Total			**10**

Question	Answers	Additional comments/Guidelines	Mark	AO
02.1	$\frac{GmM}{r^2}(=ma)=mr\omega^2$ OR $\frac{GMm}{r^2}=\frac{mv^2}{r}$ ✓ $\omega^2=\left(\frac{2\pi}{T}\right)^2$ OR $v=\frac{s}{t}=\frac{2\pi r}{T}$ ✓ $\frac{GM}{r^2}=r\frac{4\pi^2}{T^2}$ results in $T^2=\left(\frac{4\pi^2}{GM}\right)r^3$ ✓	The starting point must be from relating forces or accelerations – not a remembered equation produced at a later stage in the manipulation of the equation. Middle mark may be given when seen as a substitution and can be a stand-alone mark. Last mark is only given if accompanied with the working and must eventually be in the form with T^2 and r^3 .	3	AO1.1b AO1.1a ×2 MS 2.1 ×2
02.2	$\left(\frac{T_U^2}{T_M^2}=\frac{r_U^3}{r_M^3}\right)$ $r_U=r_M\left(\frac{T_U}{T_M}\right)^{2/3}$ OR Substitution of data in equation in any of its forms ✓ $(r_U=)$ radius = $2.6(5)\times10^8$ (m) ✓	The first mark is for converting the equation into a proportion with or without substitution of data. Eg $r_U=1.29\times10^8\left(\frac{4.14}{1.41}\right)^{2/3}$ Last mark is for evaluating the correct answer Answer only gains both marks	2	AO1.1b AO2.1d M2 ×2

Question	Answers	Additional comments/Guidelines	Mark	AO
02.3	Rearranging $T^2 = \frac{4\pi^2}{GM} r^3$ To give $M = \frac{4\pi^2}{T^2 G} r^3$ or $M = \frac{4\pi^2}{Gk}$ Or substitution of data ✓(allow use of their calculated *k* from **02.2**) Conversion of T to seconds for Miranda $T = 1.41 \times 24 \times 3600 = 1.22 \times 10^5$ s ✓ (or $T^2 = 2.48 \times 10^{10}$) Substitution into equation and determination of *M* $M = 8.5(6) \times 10^{25}$ kg ✓	Give full credit for use of Umbriel period and their answer to 02.2 Alternative: Conversion of T to seconds for Umbriel $T = 4.14 \times 24 \times 3600 = 3.58 \times 10^5$ s ✓ Determine *k* from $T^2 = kr^3$ for Miranda (or Umbriel) ✓ $k = 6.9 \times 10^{-15}$ Converting to seconds mark stands alone use of $k = \frac{4\pi^2}{GM}$ to find $M = 8.56 \times 10^{25}$ kg✓ No ecf for final answer mark.	3	AO2.1b ×3

Question	Answers	Additional comments/Guidelines	Mark	AO
02.4	$\frac{GM\cancel{m}}{(d/2)} = \frac{1}{2}\cancel{m}v^2$ OR $v = \left(\frac{4GM}{d}\right)^{1/2}$ OR stating the escape velocity depends on M/d ✓ Any correct calculation of an escape velocity or ratio M/d or $\left(M/d\right)^{1/2}$ ✓ Last mark only given with three correct relevant calculations Correct conclusion = Titania ✓	Full credit may be given for answers that use *r* rather than *d*. Table to help identify 2nd mark Name / m/d / $(m/d)^{½}$ / *v*: Ariel / 1.09×10^{15} / 3.31×10^{7} / 540 Oberon / 1.99×10^{15} / 4.46×10^{7} / 729 Titania / 2.21×10^{15} / 4.70×10^{7} / 768	3	AO2.1a AO3.1a ×2 M2 ×2

Name	m/d	(m/d)^{½}	*v*
Ariel	1.09×10^{15}	3.31×10^{7}	540
Oberon	1.99×10^{15}	4.46×10^{7}	729
Titania	2.21×10^{15}	4.70×10^{7}	768

Question	Answers	Additional comments/Guidelines	Mark	AO
02.5	(On Ariel surface $g = \frac{GM}{r^2} = \frac{6.67\times10^{-11}\times1.27\times10^{21}}{(1.16\times10^6/2)^2}$) $g = 0.25$ (m s^{-2}) ✓ (spring supplies the same potential energy so $(\cancel{m}gh)_{Earth} = (\cancel{m}gh)_{Ariel}$) $9.8 \times 1.0 = 0.25 \times h$ OR (comparing $s = \frac{v^2-u^2}{2a}$) $h = \frac{0-20}{-2\times0.25}$ ✓ $h = 39$ or 40 m, so it could not ✓ {allow ecf for arithmetic errors only}	The second mark can be given for the idea that the gravitational potential energy gained on the Earth is the same as that on Ariel with or without data. Or that the initial kinetic energy is the same in both cases. Last mark allow ecf for arithmetic errors only. Condone incorrect use of signs.	3	AO2.1f ×3 M2 ×2

Total			***14***

Question	Answers	Additional comments/Guidelines	Mark	AO
03.1	Arrow pointing up labelled magnetic force or F_M and arrow pointing down labelled electric force or F_E ✓	As location A is given in the question the base of the arrows do not need to sit exactly on A but arrows, if extended, should pass through A. Care – in some cases A can look like an arrow head.	1	AO1.1b
03.2	Statement that electric and magnetic forces balance OR $qE = Bqv$ OR $E = vB$ OR $1.5 \times 10^5 \times 0.12$ ✓ electric field strength = $E = 1.8 \times 10^4$ (V m^{-1}) ✓	A correct final answer gains both marks	2	AO1.1b AO2.1b M2
03.3	(centripetal force or $F_c = \frac{mv^2}{r}$, equals force due to the magnetic field or $F_m = Bqv$) $F = \frac{mv^2}{r} = Bqv$ and hence $r = \frac{mv}{Bq}$ ✓	Condone use of F to represent both F_c and F_m Allow an interchange between use of q and Q. Note F = is required	1	AO2.1c
03.4	$r \left(= \frac{mv}{Bq} = \frac{1.0\times10^{-26}\times1.5\times10^5}{0.12\times1.6\times10^{-19}} \right) = 0.078(1)$ ✓ distance (= $2r$) = 0.16 (m) ✓ (0.156 m)	ecf on second mark. second mark given only if mv/Bq used.in an calculation.	2	AO1.1b ×2 M2

Question	Answers	Additional comments/Guidelines	Mark	AO
03.5	(using an energy approach) work done by field equals gain in KE $qV = \frac{1}{2}mv^2$ ✓1a (so $v = \sqrt{\frac{2qV}{m}} = \left(\frac{2\times 1.6\times 10^{-19}\times \frac{6000}{2}}{1.2\times 10^{-26}}\right)^{1/2}$) mark for using the $V/2$ either in an equation or via a substitution ✓2a $= 2.8(3) \times 10^5$ (m s^{-1}) ✓3a OR (using a force approach) Force on ion = $ma = qE$ ✓1b ($E = V/d$ $a = \frac{6000 \times 1.6 \times 10^{-19}}{1.2 \times 10^{-26} \times d} = 8.0 \times 10^{10}/d$ Using $v^2 = u^2 + 2as$) Mark for using equation for *E* and equation of motion either in symbols or via a substitution ✓2b $v = 2.8 \times 10^5$ (m s^{-1}) ✓3b	1a in words or equation which can be awarded even if the ion is not singly charged (candidates can wrongly think it has a charge of 3e) 2a for making use of half the pd ie 3000 V 3a Only allow ecf using 6000V giving $v = 4.0 \times 10^5$ m s^{-1}	3	AO1.1b AO2.1f ×2 M2 ×2

03.6	A smaller mass gives a smaller time interval ✓$_1$ (The explanation can come from a Force or a Work done approach) The ions are given the same force ✓$_{2a}$ (so) smaller mass has higher acceleration and smaller time interval ✓$_{3a}$ OR Work done on ions or kinetic energy gained is the same ✓$_{2b}$ (so) smaller mass is given greater speed and smaller time interval ✓$_{3b}$ Award any two of the three marks	condone use of 'lighter' for 'smaller mass'	3 max 2	AO3.1b ×2

Total			**11**

Question	Answers	Additional comments/Guidelines	Mark	AO
04.1	$V_{rms}\left(=\frac{V_{peak}}{\sqrt{2}}=\frac{15}{\sqrt{2}}\right)=10.6\ (V)$ ✓ {allow 11 V to 2 sig figs}		1	AO1.1b
04.2	(Peak voltage 3 divisions corresponding to 15 V) y-voltage gain = 5 (V div^{-1}) ✓		1	AO2.1d M2
04.3	A horizontal line drawn at 10.6 V ✓	Tolerance – must be between 10 and 11 up from the centre Allow ecf from 04.1	1	AO2.1d M2
04.4	(Period T = corresponds to 8 divisions $T = 8 \times 5.0 \times 10^{-4}$ s = 0.0040 s Frequency = $1/T$ = 1/0.0040) = 250 (Hz) ✓	Answer only gains the mark.	1	AO2.1h M2

04.5	Time constant = 4×10^{-4} (s) ✓$_1$ {only needs 1 sig fig} The second and third mark can come from the following alternatives. Note the mark is for the method so allow arithmetic slips and imprecise measurements. Make use of the equation $V_t = V_o e^{-\frac{t}{\text{time constant}}}$ ✓$_{2a}$ Substitute values for V_t and V_o (confirmed by the graph) and calculate the (unknown) time constant. ✓$_{3a}$ OR $\text{Ln}2\ (= 0.69) = = \frac{t_{\frac{1}{2}}}{\text{time constant}}$ ✓$_{2b}$ Substute time for *V* to decrease to half its value (confirmed by the graph) and calculate the time constant ✓$_{3b}$ OR The voltage falls to $1/e$ or 37% in a time constant ✓$_{2c}$ {owtte} Find the time that corresponds to this fall in voltage confirmed by the graph (normally the start of the discharge This gives the τ directly) ✓$_{3c}$	To use a number of small divisions rather than grid divisions is not an arithmetic error. This error comes from not knowing how the oscilloscope is used. Full marks can be awarded from consideration of the charging part of the cycle. The equation can be presented in a number of variations using RC or τ for example. Typical calculation might be: $\frac{V_t}{V_o} = \frac{1}{12}$ in 2 time divisions. Substitution into the equation will give τ V_t and V_o both need to be defined in relation to the graph OR *V* halves its value in 0.5 time divisions. Substituting gives τ $t_{\frac{1}{2}}$ needs to be defined in relation to the graph OR 37% of 3 divisions is 1.1 divisions which occurs in time ¾ time divisions giving τ	3	AO2.1g AO2.1h AO3.1a M2 ×2

Question	Answers	Additional comments/Guidelines	Mark	AO
04.6	Reduce the time-base setting ✓$_{1a}$ Uncertainty is due to the smallness of the divisions and this action means the waveform/trace stretched horizontally/in x-direction. ✓$_{2a}$ {owtte} OR Increase the y-gain ✓$_{1b}$ Uncertainty is due to the smallness of the divisions and this action means the waveform/trace stretched vertically/in y-direction. (The trace will need to be moved vertically to fit on the screen) ✓$_{2b}$ {owtte}	$_1$ Stated answer must be a practicable change $_2$ Explanation must refer to both the trace and its relation to uncertainty and follow a correct change.	2	AO3.2b ×2

Total			**9**

Question	Answers	Additional comments/Guidelines	Mark	AO
05.1	Electromagnetic ✓	Reject electrostatic as it is not one of the fundamental forces.	1	AO1.1a
05.2	Arrow drawn at X in a direction radially away from the centre of the gold nucleus ✓		1	AO1.1b
05.3	Answer number 5 or 6 plus one consistent justification ✓ One more consistent justification ✓ List of justifications: Cannot be 1, 2, or 3 as these s alpha's deflect up Or must be 5 to 9 as these all alpha's deflect down. Cannot be 4 as this would backscatter or is scattered at 180° Cannot be 7, 8 or 9 as the deflection would be too small Or must be 2, 3, 5, 6 as these have a greater deflection than alpha1.	First mark must come with at least one justification. The second mark is possible to obtain with two consistent justifications even if the first mark is missed. E.g. if an answer 7 is given then quoting the first two justifications gains a mark.	2	AO1.1b AO3.1b

Question	Answers	Additional comments/Guidelines	Mark	AO
05.4	(Using of potential energy $= \frac{Qq}{4\pi\varepsilon_0 r}$) Substituting the values of the two charges multiplied together into an equation $(2 \times 1.6 \times 10^{-19})(79 \times 1.6 \times 10^{-19})$ ✓1 PE = $\frac{2\times79\times(1.6\times10^{-19})^2}{4\pi\times8.9\times10^{-12}\times5.5\times10^{-14}}$ or 6.58×10^{-13} (J) ✓2 (loss of KE = $\frac{1}{2}mv^2$ = gain in PE} $\left(v = \left(\frac{2 \times 6.58 \times 10^{-13}}{6.8 \times 10^{-27}}\right)^{1/2}\right)$ $v = 1.4 \times 10^7$ (m s^{-1})✓3	2 The substitution may be inferred at the next stage of the calculation that uses KE = $\frac{1}{2}mv^2$ = PE	3	AO1.1b AO2.1h ×2 M2 ×2

05.5	Using by substitution or rearrangement $R = r_o A^{1/3}$ ✓ $R_{Ag} = 5.7 \times 10^{-15}$ (m) ✓	$\left(R_{Ag} = R_{Au} \times \left(\frac{A_{Au}}{A_{Ag}}\right)^{1/3}\right)$ $\left(R_{Ag} = 6.98 \times 10^{-15} \times \left(\frac{107}{197}\right)^{1/3}\right)$ The use of the equation must involve both nuclei.	2	AO1.1b ×2 M2 ×2
05.6	Nucleons are incompressible / Nucleons have a constant separation / Neutrons and protons have similar masses / Neutrons and protons have similar volumes ✓	A mark can be given for ‘nucleons touch’ but it must be implied that this is with all 12 neighbours’.	1	AO3.1a

Total			**10**

Question	Answers	Additional comments/Guidelines	Mark	AO
06.1	U-235 (absorbs) a neutron with added information ✓[1] U-235/6 then divides/splits and gives out more neutrons ✓[2] U-238 absorbs/scatters neutrons ✓[3]	[1] Possible added information : To become U-236 absorbs a slow moving neutron absorbs a thermal neutron If no marks awarded but the first two marking points are made without identifying the isotope give one mark [3] If the answer implies that U-238 in any way is involved in fission this mark is lost	3	AO2.1e ×2
06.2	Substitution into or manipulation of the equation $N_t = N_0 e^{-\lambda t}$ to give the ratio $\frac{N_0}{N_t}$ with N_t for the present day and N_0 being in the past ✓[1a] $\left(\frac{N_0}{N_t} = e^{+\lambda t} = e^{+\left(1.54 \times 10^{-10} \times 2.0 \times 10^{9}\right)} = 1.36\right)$ Mass of U-238 (= 1.36×0.993) = 1.35 kg (3 sf) ✓[2a] OR working with half-lives (Half life = 4.50 × 10^9 year) Number of half-lives = 4/9 or 0.44 ✓[1b] $\left(\frac{N_0}{N_t} = 2^{(4/9)} = 1.36\right)$ Mass of U-238 (= 1.36×0.993) = 1.35 kg (3 sf) ✓[2b]	Must be to 3 sig figs Calculation may be in grams [1b] Half life = $ln2/1.54 \times 10^{-10}$ = 4.50 × 10^9 (year) Number of half-lives = 2.00× $10^9/4.50 \times 10^9$	2	AO2.1f ×2 M2 ×2

06.3	Ratio $\left(\frac{N_{235}}{N_{238}+N_{235}}\right)$ = 3.6% to 3.7% so yes ✓ A valid calculation must be performed to gain the mark eg with an ecf from **06.2**	$\left(\frac{N_{235}}{N_{238}+N_{235}} = \frac{52}{1400+52}\right.$ using 06.2 data $\left.= \frac{52}{1350+52}\right)$ Condone using ratio $\frac{N_{235}}{N_{238}}$ $\left(\frac{N_{235}}{N_{238}} = \frac{52}{1400}\right.$ using 06.2 data = $\left.\frac{52}{1350}\right)$ = 3.7% to 3.9% .	1	AO1.1b M2

Total			**6**

7	8	9	10	11	12	13	14	15	16	17	18	
D	**A**	**C**	**D**	**C**	**D**	**B**	**D**	**C**	**D**	**A**	**B**	
19	20	21	22	23	24	25	26	27	28	29	30	31
A	**C**	**A**	**A**	**A**	**D**	**C**	**C**	**D**	**D**	**A**	**B**	**B**