OCR
Oxford Cambridge and RSA

GCE

Physics A

H556/03: Unified physics

A Level

Mark Scheme for June 2023

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM AssessorAssessorOnline Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **number of required** standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% (traditional 40% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone or the RM Assessor messaging system, or by email.

5. **Crossed Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

   Rubric Error Responses – Optional Questions
   Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the highest mark from those awarded.*(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple Choice Question Responses
When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add a tick to confirm that the work has been seen.

7. Award No Response (NR) if:
    - there is nothing written in the answer space

    Award Zero '0' if:
    - anything is written in the answer space and is not worthy of credit (this includes text and symbols).

    Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor **comments box** is used by your team leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**
If you have any questions or comments for your team leader, use the phone, the RM Assessor messaging system, or e-mail.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:
    a. **To determine the level** – start at the highest level and work down until you reach the level that matches the answer
    b. **To determine the mark within the level**, consider the following

Descriptor	Award mark
On the borderline of this level and the one below	At bottom of level
Just enough achievement on balance for this level	Above bottom and either below middle or at middle of level (depending on number of marks available)
Meets the criteria but with some slight inconsistency	Above middle and either below top of level or at middle of level (depending on number of marks available)
Consistently meets the criteria for this level	At top of level

11. **Annotations**

Annotation		Meaning
	Correct response	Used to indicate the point at which a mark has been awarded (**one tick per mark awarded**).
	Incorrect response	Used to indicate an incorrect answer or a point where a mark is lost.
AE	Arithmetic error	Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
BOD	Benefit of doubt given	Used to indicate a mark awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done.
BP	Blank page	Use BP on additional page(s) to show that there is no additional work provided by the candidates.
CON	Contradiction	No mark can be awarded if the candidate contradicts himself or herself in the same response.
ECF	Error carried forward	Used in numerical answers only, unless specified otherwise in the mark scheme. Answers to later sections of numerical questions may be awarded up to full credit provided they are consistent with earlier incorrect answers. Within a question, ECF can be given for AE, TE and POT errors but not for XP.
L1	Level 1	L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded.
L2	Level 2	L2 is used to show 4 marks awarded and L2^ is used to show 3 marks awarded.
L3	Level 3	L3 is used to show 6 marks awarded and L3^ is used to show 5 marks awarded.
POT	Power of 10 error	This is usually linked to conversion of SI prefixes. Do not allow the mark where the error occurs. Then follow through the working/calculation giving ECF for subsequent marks if there are no further errors.
SEEN	Seen	To indicate working/text has been seen by the examiner.
SF	Error in number of significant figures	Where more SFs are given than is justified by the question, do not penalise. Fewer significant figures than necessary will be considered within the mark scheme. **Penalised only once in the paper.**

Annotation		Meaning
TE	Transcription error	This error is when there is incorrect transcription of the correct data from the question, graphical read-off, formulae booklet or a previous answer. Do not allow the relevant mark and then follow through the working giving ECF for subsequent marks.
XP	Wrong physics or equation	Used in numerical answers only, unless otherwise specified in the mark scheme. Use of an incorrect equation is wrong physics even if it happens to lead to the correct answer.
^	Omission	Used to indicate where more is needed for a mark to be awarded (what is written is not wrong but not enough).

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
/	Used to indicate the point at which a mark has been awarded (**one tick per mark awarded**).
Reject	Used to indicate an incorrect answer or a point where a mark is lost.
Not	Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
Ignore	Statements which are irrelevant
Allow	Answers that can be accepted
( )	Words which are not essential to gain credit
___	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

12. **Subject Specific Marking Instructions**

CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

M marks These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

A marks These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

C marks These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

B marks These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

SIGNIFICANT FIGURES

If the data given in a question is to 2 sf, then allow an answer to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>1</td><td>(a)</td><td>(i)</td><td>X marked on orbit at closest point to Mars</td><td>B1</td><td>Horizontal line through centre of X must pass through or touch the label ‘Mars’
Allow a single dot/circle marked on the orbit</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>orbits in an <u>ellipse</u> / orbit is <u>elliptical</u>

with (COG of) Mars at one focus</td><td>B1

B1</td><td>Allow a general statement even if not applied to MAVEN
eg (all) orbits are elliptical
Ignore references to Sun or other planets

Not the Sun at one focus</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>$T^2 \propto r^3$

Correct calculations involving at least two sets of data which lead to a (reasonably) constant value</td><td>C1

A1</td><td>Not $T^2 = r^3$
Allow T^2/r^3 = (any) constant or T^2 = (any) constant × r^3
Allow $T_1{}^2/ T_2{}^2 = r_1{}^3/ r_2{}^3$
May be inferred from a subsequent calculation

For example, T^2/r^3 (or r^3/T^2) calculated correctly at least twice:
Allow a constant value calculated for one set of data and then applied to at least one other object
Calculations do not need corresponding names of objects
Ignore number of sf; ignore any incorrect calculations
Ignore statements about whether or not Kepler’s 3rd Law applies

Values below are for benefit of markers, POTs removed
<table>
<tr><td>Object</td><td colspan="2">T^2/r^3</td><td colspan="2">r^3/T^2</td></tr>
<tr><td></td><td>T(hr)</td><td>T(s)</td><td>T(hr)</td><td>T(s)</td></tr>
<tr><td>MAVEN</td><td>7.4</td><td>9.6</td><td>1.4</td><td>10.5</td></tr>
<tr><td>Phobos</td><td>7.1</td><td>9.3</td><td>1.4</td><td>10.8</td></tr>
<tr><td>Deimos</td><td>7.4</td><td>9.6</td><td>1.4</td><td>10.4</td></tr>
<tr><td>Areostationary</td><td>7.8</td><td>10.1</td><td>1.3</td><td>9.9</td></tr>
</table></td></tr>
</table>

Question			Answer	Mark	Guidance
1	b	(ii)			**Ignore** comments about potential collisions / mass / orbital period / speed / direction
			(MAVEN needs) to see the whole planet / atmosphere **or** not just part of the planet / atmosphere	**B1**	**Allow** (if placed in an areostationary orbit, then) MAVEN would always orbit above the same place / it could only see one location / it could not see multiple locations / it could not see (atmosphere at) the poles / it could only see part of the (atmosphere of) Mars
			(MAVEN needs) to be in / near to the atmosphere	**B1**	**Allow** (if placed in an areostationary orbit, MAVEN's orbital radius would be large that) it would not pass through the atmosphere / it could not analyse the atmosphere **Not** MAVEN is too close to see the atmosphere properly Note: Atmosphere does not need to be seen to award first BI Atmosphere must be mentioned somewhere in the response to award second B1
			Total	**7**	

Question			Answer	Mark	Guidance
2	(a)	(i)	use (vernier / digital / dial) calliper(s) **or** micrometer	B1	
			(taking readings) at different positions / orientations (along the wire)	B1	**Ignore** take multiple readings
		(ii)	exclude the 0.495 (mm) anomaly	M1	May be inferred from calculations
			add the remaining 4 values and divide by 4 / calculate mean of the remaining values	A1	**Allow** the correct calculation which leads to 0.455 **Ignore** references to median or mode or average
			calculate half the range of the remaining values	A1	**Allow** the correct calculation which leads to 0.005 **Ignore** difference between mean and highest (or lowest) value **Ignore** references to resolution of the measuring instrument
	(b)	(i)	$\varepsilon = I(R + r)$	M1	**Allow** $\varepsilon = V + Ir$ **and** $V = IR$
			$R = \rho L/A$ **and** $A = \pi d^2/4$	M1	**Allow** $A = \pi r^2$ **and** $r = d/2$ **Allow** area formula by inference, if clear
			clear steps leading to given equation	A1	

Question			Answer	Mark	Guidance
2	(b)	(ii)1	(gradient = Δy/Δx where Δx ≥ 0.35) gradient = **5.0 (A^{-1} m^{-1})**	C1	**Allow** answer to 1sf Mark is **either** for the correct gradient **or** for working which would lead to 5.00 ± 0.10, seen anywhere in the question
			$\rho = \frac{\pi \times (0.455 \times 10^{-3})^2 \times 1.45 \times gradient}{4}$ ρ = **1.2×10^{-6} (Ω m)**	A1	Correct to at least 2sf **Allow** the correct answer with no working shown for ρ if the gradient (or working for the gradient) is correct **Allow ECF** for gradient ($\rho = 2.358 \times 10^{-7} \times$ gradient)

Question			Answer	Mark	Guidance
2	(b)	(ii)2	r = y-intercept × ε = 0.40 × 1.45 r = **0.58(Ω)**	**B1**	Mark is for working leading to the correct value of r. r = 0.58(Ω) seen either in working or on answer line implies B1
			y-intercept$_{MAX}$ = 0.73 (A^{-1})	**M1**	**Allow** answers in the range 0.70 to 0.75 **Ignore** any attempt to calculate uncertainty in gradient
			EITHER Fractional uncertainty in r = 0.05/1.45 + 0.33/0.40 = 0.034 + 0.825 = 0.86	**A1**	Expect answers in the range 0.78 – 0.91 (or 78% to 91%) **Ignore** units if given
			0.86 x 0.58 = 0.5(Ω) to 1sf so ***r* = 0.6 ± 0.5** (Ω)	**A1**	Expect answers for absolute uncertainty in the range 0.45–0.53 Value and uncertainty must be given to same number of dp
			OR r_{MAX} = y-intercept$_{MAX}$ × ε_{MAX} = 0.73 x 1.5 = 1.1(Ω)	**(A1)**	Expect answers in the range 1.05 - 1.13
			1.1 – 0.58 = 0.5(Ω) to 1sf so ***r* = 0.6 ± 0.5** (Ω)	**(A1)**	Expect answers for absolute uncertainty in the range 0.45–0.55 Value and uncertainty must be given to same number of dp Special case: **allow** abs unc of 0.55 giving r = 0.6 ± 0.6 (Ω)
			Total	**14**	

Question			Answer	Mark	Guidance
3	(a)	(i)	• remnant of a (red) super giant star • star can no longer generate (enough) energy by fusion / gravitational force exceeds radiation pressure • formed by (gravitational) collapse / implosion of core (of massive star) **or** gravitational force in core exceeds electron degeneracy pressure • star undergoes a (Type II) supernova (explosion) • core has mass above Chandrasekhar limit / 1.4 x solar mass (and below limit for black hole / 3 solar masses) • (in the core) protons combine with / capture electrons to produce neutrons	**B1 x 2**	Credit any correct statement, ignoring incorrect statements unless they contradict a previous credited bullet point **Allow** any star with mass greater than 10 solar masses **Allow** star cannot fuse iron without losing energy **Ignore** star runs out of fuel / fusion stops

Question			Answer	Mark	Guidance
3	(a)	(ii)			Credit any correct statement, ignoring incorrect statements unless they contradict a previous credited bullet point **Ignore** references to size / temperature / luminosity / spin / radio waves / composed (mainly/only) of neutrons
			either: extremely / very dense	**B1**	**Not** high density (must be extremely / very high density)
			or: has a very strong gravitational field		
			or: supported by neutron degeneracy pressure		
			or: fusion is no longer taking place		
			or: core has mass above Chandrasekhar limit / 1.4 x solar mass (and below limit for black hole / 3 solar masses)		Do not credit this point here if already credited in 3(a)(i)

Question			Answer	Mark	Guidance
3	(b)		$\rho = \frac{m}{V}$ **and** $V = \frac{4}{3}\pi r^3$ ($\approx 4\ r^3$)	**C1**	Formulae may be inferred from either calculation **Allow** m/r^3 = constant
			density of neutron star ≈ **5×10^{17}** kg m^{-3}	**A1**	**Ignore** number of s.f. in answer Volume of neutron star ≈ 4×10^{12} m^3
			density of nucleus ≈ **4×10^{17}** kg m^{-3}	**A1**	**Ignore** number of s.f. in answer Volume of nucleon ≈ 4×10^{-45} m^3 $m_{nucleon}$ ≈ u = 1.66×10^{-27} kg to 3 sf (**allow** 1.67×10^{-27} kg) If the calculation of separate densities is not shown explicitly then the two **A1** marks may be scored for either: • ratio of densities ≈ 0.8 **or** 1.2 • m/r^3 = 2.0×10^{18} (kg/m^3) for star **and** 1.7×10^{18} (kg/m^3) for nucleon • r^3/m = 5.0×10^{-19} (kg/m^3) for star **and** 6.0×10^{-19} (kg/m^3) for nucleon
	(c)	(i)	number of large squares = 11± 1	**C1**	May be inferred from calculation Any valid method allowed (counting squares, trapezium rule, splitting area into regular shapes) **Allow** number of medium squares = 44 ± 4 **Allow** number of small squares = 1100 ± 100
			no of squares × area of each = 11 x 1 x 10^{-25} = **1.1×10^{-24}** (J)	**A1**	**Allow** answers in the range 1.00×10^{-24} to 1.20×10^{-24} **Allow** answer to 1s.f.

Question			Answer	Mark	Guidance
3	(c)	(ii)	300 pc ≈ 300 × 3.1 × 10^{16} m (= 9.3 × 10^{18} m)	C1	Mark is for working leading to the correct distance. Distance does not need to be seen explicitly but 9.3 × 10^{18} m implies C1
			ratio of areas = $\frac{4\pi(300 \times 3.1 \times 10^{16})^2}{3000} = \frac{1.09 \times 10^{39}}{3000}$ (= 3.6×10^{35})	C1	Mark is for working leading to the correct ratio. Ratio does not need to be calculated but 3.6 × 10^{35} implies C1 **Allow** calculation of inverse ratio (= 2.8 × 10^{-36}) **Ignore** unit if one is given
			energy = ratio of areas × area under curve = **4.0 × 10^{11}** (J)	A1	Mark is for correct answer; **allow** answer to 1s.f. Answer = 3.6 × 10^{35} × candidate's answer to 3c(i) **Allow ECF** for incorrect calculation of area / energy in 3c(i) Expect an answer in the range 3.6 × 10^{11} to 4.4 × 10^{11} Note: candidates could also calculate the answer by using ratio of energies = ratio of powers or intensity of pulsar = intensity at telescope
			Total	**11**	

Question			Answer	Mark	Guidance
4	(a)		zero acceleration / constant velocity	B1	**Ignore** constant speed
			weight = drag (+ upthrust)	B1	**Allow** W or mg or gravitational force for weight **Allow** air resistance for drag **Allow** resistive forces for drag (+ upthrust)
			zero <u>resultant</u> force (vertically)	B1	**Allow** zero net / overall force (vertically) **Ignore** object is in equilibrium / forces are balanced **Not** there are no resultant <u>forces</u> (plural)

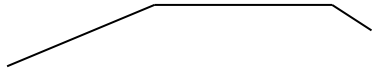
Question			Answer	Mark	Guidance
4	(b)	(i)	Any two points from this list of three: • $v \propto r^2$ • (so) droplets with a small(er) radius have a small(er) v • (so) water droplets in mist must have a smaller radius (than water droplets of rain) Alternatively, **allow** any two points from the list below: • $v \propto (\rho_s - \rho_f)$ • $\rho_f \approx \rho_s$ for water droplets in mist giving $v \approx 0$ • $\rho_s > \rho_f$ (**or** $\rho_s \neq \rho_f$) for water droplets in air giving $v > 0$ (**or** $v \neq 0$) • ρ_f is greater in mist than air (with ρ_s constant) so v is smaller for water droplets in mist than for water droplets in air ORA	**B1 x 2**	**Allow** v increases with r (squared) OAW ORA ORA **Allow** density of water is similar to density of mist so $v \approx 0$ **Allow** water/rain is more dense than air so $v > 0$ **Allow** density of mist is greater than density of air so v is smaller for water droplets in mist than for water droplets in air ORA

4	(b)	*(ii)	**Level 3 (5–6 marks)** Clear description (must check for *terminal* velocity) **and** Clear analysis (**either** correct answer for lowest *v* (allowing POT error) **or** method which at least partially verifies the expression) *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some description (several points made, leading to a measurement of velocity) **and** limited analysis (as below) **or** Limited description **and** clear analysis (see above) *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description (eg at least one valid point made) **or** Limited analysis eg • incorrect expression used with correct values • incorrect values used in correct expression • 'plot a graph' but with incorrect axes / no mention of how to use the graph to verify the expression *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit*	**B1** **× 6**	Use the annotations e.g. L2 for 4 marks, L2^ for 3 marks etc. Place the appropriate number of ticks below the annotation. **Indicative scientific points may include:** **Description of experiment to measure terminal velocity *v*** • Use a long, clear tube containing the liquid • Check the tube is vertical using a spirit level or plumb line • Measure a distance *d* using metre rule or tape measure • Measure a time *t* using a stopclock **or** light gates **or** give details of a video method • Describe a method to reduce parallax error • Describe a method to check that the spheres have reached *v* • Repeat using a different liquid and/or a different metal sphere • Possibly use several spheres with different values of *r*, measuring diameter *d* of spheres using callipers or micrometer **Analysis** • Calculate $v = d / t$ • Calculate $r = d / 2$ • Verify expression by plotting a suitable graph e.g. *v* against r^2 • and see if the results lie on a straight line through the origin • Verify expression by substituting into expression • e.g. calculating *g* from gradient and comparing result to 9.81 or comparing measured *v* to value of *v* predicted from expression • Steel spheres – lower ρ_s than lead so lower *v* • Sunflower oil – much higher η than water so lower *v* • Estimate lowest $v = 0.075$ m s^{-1} using steel and sunflower oil
			Total	**11**	

Question			Answer	Mark	Guidance
5	(a)	(i)	*(W* = ½ *C V*^{2} so) 400 × 10^6 = 0.5 × *C* × (24 × 10^3)^2 ***C* = 1.4 (F)**	 **C1** **A1**	**Allow** *W* = ½ *Q V* **and** *C* = *Q* / *V* (*Q* = 3.3 × 10^4 (C) so) *C* = *Q* / *V* = 3.3 × 10^4 / 24 × 10^3
		(ii)	(putting capacitors in parallel) increases the total capacitance **ORA**	**B1**	**Allow** $C_T = C_1 + C_2 + \ldots$ **or** capacitors add together (in parallel) **Ignore c**apacitors in parallel can store more charge/ energy
	(b)		power ≈ 400 × 10^6 / 10^{-3} = 4.0 × 10^{11}(W) power required is equivalent to output of ≈ 400 power stations **or** time taken for power station to release stored energy = 400 × 10^6 / 10^9 = 0.40s 0.4s is (much) longer than 1 ms	**M1** **A1** **(M1)** **(A1)**	**Allow** ECF (a)(i) for incorrect POT in 400GW **Allow** this is <u>much</u> more than could be provided by one power station **or** 4.0 × 10^{11}(W) » 1GW **Ignore** comments about household supply **Allow** ECF (a)(i) for incorrect POT in 400GW **Allow** it would take more time / too long

5	(c)		(mass defect in u =) (2.014102 + 3.016049 – 4.002603 – 1.008665) u (= 0.018883 u)	C1	**Allow** ECF for mass defect throughout unless **XP** Mark is for correct working leading to the answer. Answer does not need to be calculated but 0.018883 u (not just 0.018883) implies C1 **Allow** negative answer
			(mass defect in kg =) $0.018883 \times 1.661 \times 10^{-27}$ $(= 3.1365 \times 10^{-29})$	C1	Mark is for substituting u = 1.661×10^{-27} (kg), seen anywhere in the working **Allow** 1.66×10^{-27} or 1.67×10^{-27} for 1.661×10^{-27} Answer need not be calculated but 3.1365×10^{-29} implies first two C1 marks
			(energy per fusion reaction in J = mc^2 =) $3.1365 \times 10^{-29} \times (3.00 \times 10^8)^2$ $(= 2.82 \times 10^{-12})$	C1	Mark is for multiplying mass defect by $(3.00 \times 10^8)^2$, seen anywhere in the working Answer need not be calculated but 2.82×10^{-12} implies all three C1 marks
			(number of fusion reactions = $\frac{\text{energy needed}}{\text{energy per fusion reaction}}$ = $400 \times 10^6 / 2.82 \times 10^{-12}$ =) **1.4×10^{20}**	A1	**Ignore** unit if given **Allow** ECF (a)(i) or (b) for incorrect POT in 400GW Note for markers: calculation in kg $3.34542 + 5.00966 – 6.64832 – 1.67539 (\times 10^{-27})$ $= (8.35508 – 8.32372) \times 10^{-27} (= 3.136 \times 10^{-29}$ kg) Note for markers: calculation in J $3.01088 + 4.50869 – 5.98349 – 1.50785 (\times 10^{-10})$ $= (7.51957 – 7.49134) \times 10^{-10} (= 2.82 \times 10^{-12}$ J)
			Total	**9**	

Question			Answer	Mark	Guidance
6	(a)		$P = V^2 / R$ $R = 12^2 \div 40 =$ **3.6** (Ω)	**C1** **A1**	**Allow** $I = P/V$ (= 3.3A**) and** $R = V/I$ Correct to at least 2sf
	(b)	**(i)**	**Either** (thermal/heat) energy required per unit mass to change solid to liquid <u>at constant temperature</u> **or** (thermal/heat) energy released per unit mass when liquid changes to solid <u>at constant temperature</u>	 **B1** **(B1)**	**Ignore** $L = E/m$ unless letters are defined **Allow** energy per kg /energy of 1kg for energy per unit mass **Allow** energy required to melt unit mass at constant temperature **Allow** energy released when unit mass solidifies at constant temperature
		(ii)	(Energy =) $Pt = mL$ $m = \frac{40 \times 60}{9.4 \times 10^4}$ = **2.6 × 10^{-2}** (kg)	**C1** **A1**	**Allow** $E = Pt$ **and** $E = mL$ seen separately Formulae may be implied from subsequent calculation Correct to at least 2sf 2.553×10^{-2} to 4sf so annotate 2.5×10^{-2} as AE

Question			Answer	Mark	Guidance
6	(b)	(iii)	Any two from • not all the heat / energy is used to melt the PLA **or** some heat / energy is 'lost' (to environment / surroundings) • some heat / energy / time is used to raise temperature of PLA up to **or** above its melting point / 160°C • (PLA not all applied to same spot so) PLA needs (time) to move from one place to another • PLA needs (time) to solidify	**B1 × 2**	For environment, **allow** printer or any named part of printer (e.g. nozzle, print head, print bed, build plate, hot-end, cables) **Allow** energy transfer is not 100% efficient **Not** energy is lost through sound or light **Not** PLA needs time to melt
		(iv)	a single line (or curve) starting at **A** which gradually and continuously rises to 160°C followed by an initial flat section at 160°C after a flat section at 160°, the line (or curve) rises and then falls back to 160°C a second flat section at 160°C followed by a single line (or curve) which gradually and continuously falls, ending at **B**	**B1** **B1** **B1**	Note: this flat-topped shape gains the first and third marks 

Question			Answer	Mark	Guidance
6	(c)	(i)	Any two points from the following: • (high-energy X-ray) photon interacts with nucleus / travels close to nucleus / disappears • Positron is the antiparticle of an electron • energy (of X-ray photon) is transformed into matter and antimatter • particle and antiparticle pair produced / (mechanism known as) pair production occurs	**B1 x 2**	**Ignore** references to scattering, Compton effect and photoelectric effect **Not** • atom instead of nucleus • approaches instead of travels close to • two photons annihilate • photon annihilates • electron and positron annihilate **Allow** photon is absorbed by nucleus **Allow** electrons and positrons are antiparticles (of each other) **Allow** energy (of photon) is transformed into mass **Ignore** electron positron pair (this is a rewording of the stem which states that X-ray photons produce electrons and positrons) **Allow** pair creation

6	(c)	***(ii)**	**Level 3 (5–6 marks)** Clear explanation of both scans **and** Clear discussion (compares the risks of either having a scan to fit a bolus or not, to a patient undergoing radiotherapy for skin cancer) *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Limited explanations of both scans **or** clear explanation of one scan **and** Basic discussion (e.g. compares the risks of one scan to the other) *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited explanation for example • CAT scan only • PET scan only • both scans attempted but with several errors **or** Limited discussion (eg compares advantages and disadvantages of having a CAT scan) *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit*	**B1 × 6**	Use the annotations (for example) L2 for 4 marks, L2^ for 3 marks etc. Place the appropriate number of ticks below the annotation. **Indicative scientific points may include:** **Explanation** CAT scan • Thin fan-shaped beam of X-rays • Ring of detectors rotate around patient • Images of slices produced • Instruments move along patient to take several 2D images • Software produces 3D image PET scan • Positron-emitting tracer injected • Positron annihilates electron producing two gamma photons • Gamma photons travel in opposite directions • Ring of gamma detectors around patient • Delay time between arrival of photons locates annihilation • Software produces 3D image **Discussion - balance of benefits and risks of having the scan** • Both types of scan deliver radiation dose to healthy tissue but • a bolus would mean a lower dose is needed during radiotherapy • Both types of scan are expensive / use NHS resources • but radiotherapy also costly and less would be needed with bolus • Scans can be long / scary / cause discomfort • but the same is true of radiotherapy and less would be needed • Both types of scan are risky but with a bolus the • improved effectiveness of radiotherapy may save a patient's life
			Total	**18**	

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