GCE

Physics B

H557/02: Scientific literacy in 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.

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 Assessor Assessor Online 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.

   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 available in RM Assessor

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
TE	Transcription error
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
SF	Error in number of significant figures
	Correct response
	Wrong physics or equation

12. **Annotations**

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
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

13. **Subject Specific Marking Instructions**

INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

Significant figure penalties

Significant figure penalties will be shown on the markscheme. There is a maximum of one significant figure penalty on each paper. Not all papers will include such penalties – this depends on the particular questions given in the paper. The question that attracts a significant figure penalty (if one do so) will be decided by the examiners at the standardisation meeting. You must not penalize such errors unless clearly stated in the markscheme.

Annotation on scripts

Each markworthy point should be registered with a tick – the total number of ticks on the paper should equal the number of marks awarded for non-LOR questions. Mark errors in physics with a cross and omissions with a carat. Centres and candidates who request scripts back find such annotations extremely useful.
LOR questions do NOT have ticks on the papers. These questions should only be annotated with L1, L2, L3.

Question			Answer	Mark	Guidance
1	(a)	(i)	$f = e^{-(1.2 \times 10^{-19}/(1.38 \times 10^{-23} \times 310))}$ $= 6.6 \times 10^{-13}$ (1)	1	If 1.4×10^{-23} used for k, $f = 9.8 \times 10^{-13}$ Don't accept 6.7×10^{-13}
1	(a)	(ii)	Particle makes multiple collisions (1) If particle gains energy in successive (AW) collisions it may reach energy required. (1)	2	Idea of multiple, successive, energy gaining collisions required for m.p.2. Not just 'gains energy through collisions'. Use of phrase 'getting lucky' is acceptable. Accept 'successful' for energy transferred to particle
1	(b)	(i)	BF relates to the probability of a given particle having energy ≥*E*. (1) If BF higher, number of particles with ≥*E* increases (1) This indicates more reactions per second/greater rate of reaction (1)	3	AW throughout: For example 'fraction of particles having enough energy to undergo a process' gains first marking point. NB the question is about the effect of the change in BF, not the cause of the change so explanations of the working of the enzyme do not gain marks.
1	(b)	(ii)	$6.7 \times 10^{-7} = e^{-E/(1.38 \times 10^{-23} \times 310)}$ (1) $\ln 6.7 \times 10^{-7} = - E/(1.38 \times 10^{-23} \times 310)$ (1) $E = 6.1 \times 10^{-20}$ (1)	3	Bald correct answer gains three marks One mark for correct algebraic rearrangement leading to *E* as the subject.

Question			Answer	Mark	Guidance
2	(a)	(i)	$(30 \sin 40)^2 = 2 \times 9.8 \times s$ (1) s = 19.0 m (2 s.f.) (1)	2	Many other routes possible. Working required. g = 9.81 m s^{-2} as in data book gives s = 18.95 m
2	(a)	(ii)	Time to max height = 30 sin 40/9.8 = 1.97 s (1) Time to fall 9.0 m = 1.36 s horizontal distance = (1.97 + 1.36) x 30 cos 40 (1) = 77 m (1)	3	If 20 m used, total time = 3.39 s, distance = 78 m Unrounded values from (a)(i) and here give 76.2 m If 2 x 1.97 = 3.94 s used for total time leading to an answer of 91 m, two marks max One mark max for other, incorrect time used with 30 cos40 to determine distance. Alternative routes possible, including quadratic solutions for vertical time in air. One mark for correct total time.
2	(b)		$30^2 = 0^2 + 2 a \times 1.4$ a = 321 m s^{-2} (1) F = 320 x 0.5 = 161 N (1)	2	Or work done = energy gained route Accept 160 N (as 2 s.f.)
2	(c)		$F = 4 \times 10^4 \times 0.05^2 \times \pi$ = 314 N (1) Pressure (difference) reduces (1) as volume of compressed gas increases (1)	3	Accept drag increases with velocity. Allow ‘as gas expands’

Question			Answer	Mark	Guidance
3	(a)		Fig. 3.2 a: inverse graph, symmetrical (1) Fig.3.2 b straight line through origin (1)	2	3.2 (a) need not be obviously asymptotic as the range of values is not given but should be clearly symmetrical and not have intercepts.
3	(b)		Linking equations to give $\overline{c^2} = \frac{3kT}{m}$ (1) Mean square velocity = 1.87 x 10^5 m^2 s^{-2} (1) Mean velocity = 432 m s^{-1} (1)	3	Working must be shown. Rearranging equations can be implicit and calculation of mean square velocity can be within the final calculation. If approximation $E \sim kT$ is used leading to answer 353 m s^{-1}, two marks .
3	(c)	i	Relative velocity (AW) before collision = 431.5 m s^{-1} (1) Relative velocity (AW) after collision = -431. 5 m s^{-1} (1) Therefore, velocity of atom relative to the cylinder = -433 m s^{-1}	2	Look for answers that cover these two points however expressed. e.g. v = u + Δv explained. Accept: work done by moving piston on gas molecule (increases its k.e. so it accelerates) for one mark.
3	(c)	ii	Increased k.e./speed of particles (1) Increased k.e. is presented as temperature increase (1) One of: More compression/smaller *V* will produce greater temperature rise /cause the graph line to curve upwards (1) or *pV* = *nRT*, increasing *T* gives increasing gradient on a *p* vs 1/*T* graph. (1) OR – for second and/or third mark Greater rate of collisions (with walls, at given volume)(1) Increases the pressure for a given volume (1)	3	AW, e.g. 'the pressure increase is even greater when the volume is reduced' This mark needs a clear link with 'given volume' AW

Question			Answer	Mark	Guidance
4	(a)		(coherent) waves travelling from both speakers superpose (1) When they meet in phase an antinode is formed (1) producing a maximum amplitude of wave on the oscilloscope (1)	3	Allow interfere for first marking point. Or a node is formed when they meet in antiphase (π radian/ 180^{o} phase difference) (1) producing a minimum amplitude of wave on the oscilloscope(1)
4	(b)	(i)	v = 3000 x 0.112 = 336 m s^{-1} (1)	1	
4	(b)	(ii)	Any three from: • The distance measured increases (1) • (but) the absolute (AW) uncertainty in the reading remains the same.(1) • (Therefore) the percentage/fractional uncertainty in the distance decreases (1). • This leads to a smaller absolute/AW uncertainty in the final value. (1)	3	
4	(c)	(i)	p = 6.63 x 10^{-34}/4.8 x 10^{-10} = 1.38 x 10^{-24} (kg m s^{-1}) (1)	1	Need clear working or own value
4	(c)	(ii)	k.e. = (1.38 x 10^{-24})^{2} /(2 x 9.11 x 10^{-31}) (1) = 1.0 x 10^{-18} (J) (1)	2	Or $v = p/m_e$) =1.38×10^{-24}/9.11×10^{-31}= 1.51×10^{6} m s^{-1} (1)k.e. = ½×9.11 × 10^{-31}×(1.51×10^{6})2 =1.0 x 10^{-18} (J) (1) Accept 1.05 x 10^{-18}(J); 1.1 x 10^{-18} (J) if 1.4 x 10^{-24} is used
4	(c)	(iii)	p.e. = - 8.98 x 10^{9} x (1.6 x 10^{-19})^{2}/(1.2 x 10^{-10}) (1) = -1.9 x 10^{-18} (J) (1)	2	Need negative sign for second mark, one mark max if negative sign is not shown.
	(c)	(iv)	Total energy is negative/ = -9. 0 x 10^{-19} (J) (1) Electron is bound as total energy is negative AW (1) Minimum size when total energy = 0. (1)	3	Ecf from (ii) and (iii) First mark can be for comparison of energies instead of the sum. Don't penalise leaving the negative sign out when assessing the first marking point. Allow 'when (magnitude of) k.e. = (magnitude of) p.e.' for third mark.

Question			Answer	Mark	Guidance
5	(a)	(i)	(number of ion pairs formed given by) area under line	1	accept calculation of area under line
5	(a)	(ii)	Energy transferred from alpha in each ionisation AW (1) k.e. = 240 000 x 30 = 7.2 x 10^6 eV = 7.2 MeV (1)	2	
5	(a)	(iii)	less ionising (1) therefore, fewer ionisations per cm AW (1) (therefore, travels further before all energy transferred)	2	Or interact less frequently with air molecules Or reverse argument
5	(b)	(i)	(working leading up to) $\frac{v_\alpha}{v_R} = \frac{220}{4}$ (1) (work leading up to) k.e. of alpha/total k.e. = 55/56 = 98%.	2	
5	(b)	(ii)	Atoms closer together so more ionisations per cm AW (1)	1	Not just 'atoms closer together'. Look for the understanding that the higher density means more interactions in a given distance.

Question			Answer	Mark	Guidance
5	(b)	(iii)	**Level 3 (5–6 marks)** *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* Correct and clear calculation of energy released in one decay. Correct and clear calculation of effective dose. Clear statements **and** explanations of 5at least two assumptions **Level 2 (3–4 marks)** *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* Correct and clear calculation of energy released in one decay OR correct ecf for effective dose from incorrect initial energy. AND Clear statements of at least one assumption and explanation OR correct, clear and complete calculation of effective dose. **Level 1 (1–2 marks)** *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* Attempts relevant calculations and makes some correct statements within longer calculations. States a relevant assumption. **0 marks** No response or no response worthy of credit	6	**Indicative scientific points may include:** **Calculation of energy of alpha particle:** • Mass defect = 6.21 x 10^{-3} u • Energy released per decay = 9.28 x 10^{-13} J • Alpha energy (= 98% of energy released, see (b) (i) = 9.11 x 10^{-13} J) **Dose (assuming constant activity)** • Energy transferred = 1.18 x 10^{-4} J • Dose = 0.029(5) Gy • Effective dose = 0.59 Sv **Assumptions:** • Energy/dose evenly distributed across cells • Not likely to be distributed evenly due to very short range in tissue • radius of tissue sample = 9.9 mm • Activity remains constant over two hour period • Reasonable assumption as half-life much greater than two hours • All alpha particles absorbed by tumour • Reasonable assumption as range in tissue is low.

Question			Answer	Mark	Guidance
6	(a)	(i)	Plane wavefronts or zero curvature (1)	1	ACCEPT not diverging or converging Don't accept parallel alone
6	(a)	(ii)	Concentric arcs centering on P with constant spacing (1)	1	
6	(a)	(iii)	Reasoning: curvature of waves from distant object= 0 (1) Curvature of waves leaving lens = +1.8 Distance to P = 1/1.8 = 0.56 (m) (1)	2	or 'u is very large so 1/u is about zero'
6	(b)	(i)	r.i. = 1.66 (1) velocity = 1.85×10^8 m s^{-1} (1)	2	
6	(b)	(ii)	Higher refractive index implies greater change of direction of wavefront/ray/greater added curvature AW (so focal length decreases leading to greater power)1 (1) Longer wavelengths will have greater focal lengths (with the same lens) (1)	2	Or shorter wavelengths have shorter focal length
6	(c)	(i)	Image height = object height x v/u = 4mm x (2/25) (1) = 3.2×10^{-4} m	2	
6	(c)	(ii)	Power required to focus at 25 cm = +54.0 D (1) Power required to focus at 50 cm = +52.0 D Power of lens required = 54 D – 52 D = +2.0 D (1)	2	First mark for either power Correct working must be shown. Accept 2.0 D (implicit positive value)
6	(d)		High index glass will allow thinner (AW) lenses for a given power(1) Particularly important for high power as the curvature of the lens is greater (1) For lower power, lighter lenses may be more comfortable (1)	3	AW throughout

Question			Answer	Mark	Guidance
7	a	i	24 = 2π*f* x max flux linkage 24/100π = max flux linkage (1) = 0.076 Wb turns (1)	2	Can use sin (2πft) where *t* = 0.02s. If calculators in degree mode answer = 0.7 Wb turns gains one mark
	a	ii	0.076 = 400 x 0.12^2 x *B* (1) *B* = 0.013 T (1)	2	Ecf from (a) (i)
	b		Any two modifications paired with explanations from pairs below: • Increasing number of turns (1) as this increases the flux linkage (1) • Increasing cross sectional area of generator (1) as this increases flux (1) • Decreasing length of magnetic circuit (1) as this increases flux (1) • Reducing any air gap (1) as reduction increases permeance of magnetic circuit/increases flux (1) • Lamination of core/stator/rotor (1) reduces eddy currents which produce an opposing field/flux/ produce energy losses through heating (1)	4	Second mark can be from equation for flux linkage Second mark can be from Faraday equation Second mark from Faraday equation if arguing from flux increase Allow improve permeability of rotor/stator material linked to reason Don't allow increase the current in the coil (not a change to the generator)
8	a		mass transferred per second = $\rho A v$ (1) k.e. = ½ *m* v^2 power = k.e. transferred per second= $\frac{1}{2} \rho A v^3$ (1)	2	Alternative routes possible

Question			Answer	Mark	Guidance
8	b		**Level 3 (5–6 marks)** *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* Correct and clear calculation of wind velocity at 10 m and clear explanation of all stages of method. **Level 2 (3–4 marks)** *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* Most calculations correct and some attempt at explanation of method OR all calculation clear and correct but no explanation. **Level 1 (1–2 marks)** *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* Attempts at least one stage of the calculations and explains the method up to this point or clearly and correctly calculates the input power/turbine. No response or no response worthy of credit	6	**Indicative scientific points may include:** **Explanation of method:** • (Total) input power can be calculated if efficiency and output power known. • Input power of a single turbine can be calculated. • Velocity of wind at turbine height can be calculated. **Calculations:** • Input power = 900/0.43 =2093 MW • Input power/turbine = 2093/85 = 24.6 MW • wind velocity at 90 m: $24.6 \times 10^6 = ½ \times 1.2 \times \pi \times 60^2 \times v^3$ $v = 15.4$ m s^{-1} • wind velocity at 10m: $15.4 = v_{10} \times 9^{1/7}$ $v_{10} = 11$ m s^{-1}

Question			Answer	Mark	Guidance
9	a		change in P.E. s^{-1} = 55 x 195 x 9.81 = 1.05 x 10^6 W (1) efficiency = 945/1050 = 90% (1)	2	
	b	i	v = 55 x 10^{-3}/ 7.9 x 10^{-3} (1) (= 6.96 m s^{-1})	1	Must have own value
	b	ii	F = (m/t (v – u)) (1)m = 1000 x 55 x 10^{-3} x 7 = (-) 385 N (1)e	2	Negative value is force acting on water. Allow negative value. 6.96 m s^{-1} gives 383 N
	b	iii	velocity of vane relative to the water, v = 3.5 m s^{-1} F = half the value in (b)(ii) = 192.5 N (1) Power = Fv =192.5 N x 3.5 m s^{-1} = 674 W (1)	2	One mark max if F not halved Unrounded pervious values gives 666 W
	b	iv	'Reflected' water has velocity in opposite direction to incident velocity (1) This means that Δv is larger in magnitude than in (b)(ii) (1) producing greater change in momentum (for the same mass of water per second) (1) So F ↑ and $P = Fv$ ↑ (for the same v of water relative to the vane) (1)	4	AW throughout – reverse arguments acceptable Beware simple quoting from article. Statement about interference between incident and reflected stream gains one mark. Linking this to energy/momentum/force considerations gains a second mark.