GCE

Physics B

H557/02: Scientific literacy in physics

A Level

Mark Scheme for June 2024

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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.

   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
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

12. **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 does 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)	Vertical tension = 550 x sin 32 (1) = 291 N (1)	2	If radian mode used on calculator giving 303 N max one mark
1		(ii)	upthrust = 870 + 291 = 1160 N (1)	1	No sf penalty
1		(iii)	force = 550 x cos 32 = 466 N (1) power = Fv = 466 x 5.8 = 2700 W (1) Reasoning, no acceleration so no net force hence (magnitude of) drag = (magnitude of) horizontal force. (1)	3	If radian mode used on calculator giving 459 N max one mark out of two for the calculation.
1	(b)		$x = 550 \times 240/(3.14 \times (6.0 \times 10^{-3})^2 \times 13.2 \times 10^9)$ (1) = 0.088 m (1)	2	POT error max 1
1	(c)		Tension will increase (1) Specified force(s) increase(s) (1)	2	Use of acceleration in explanation negates first mark.

Question			Answer	Mark	Guidance
2	(a)		First mark method: pairs of points separated by greater than ½ range. First point can be implicit (0,0). (1) Gradient value = 1.5 or 1.6 V m^{-1} to 2 s.f. (1)	2	Best practice is for the candidate to indicate the range on the graph. Check values correctly taken from y-axis Ecf on misreading graph
2	(b)		resistivity = $1.6 \times \pi \times (2.6 \times 10^{-4})^2 / 0.29$ (1) $= 1.17 \times 10^{-6}$ Ωm (1)	2	ecf from (a) (gradient of 1.5 gives 1.1×10^{-6} Ωm) one mark max if gradient not used.
2	(c)		greatest value = $1.6 \times \pi \times (2.65 \times 10^{-4})^2 / 0.28$ $= 1.26 \times 10^{-6}$ Ωm (2 s.f.) (1) Uncertainty = +/- 0.09×10^{-6} Ωm (1) OR Calculation of total percentage uncertainty = 7.3% (1) Calculation of absolute uncertainty $= 0.073 \times 1.17 \times 10^{-6} =$ +/- 0.09×10^{-6} Ωm (1)	2	Answers dependent on previous values – look for clear working to correct value using candidate's previous answers. If original value = 1.17×10^{-6} (gradient 1.6) Max value = 1.26×10^{-6} Ωm Min value = 1.09×10^{-6} Ωm If original value = 1.1×10^{-6} (gradient 1.5) Max value = 1.18×10^{-6} Ωm Min value = 1.02×10^{-6} Ωm ECF within question for both methods. Do not penalise s.f. uncertainty
2	(d)		Any three from: • Higher current leads to temperature increase • This will increase the resistance of the wire (for a given length) • A greater p.d. will be recorded for a given length • The resistivity of the wire will increase for shorter lengths of wire • The graph will be a curve of (slightly/marginally) decreasing gradient AW	3	Allow sketches for last marking point.

Question			Answer	Mark	Guidance
3	(a)		extension = 0.25 x 9.81 / 23.0 = 0.107 m (1)	1	Must show working or have own value
3	(b)	i	Graph shows that force is proportional to the negative of displacement from the equilibrium (up to and beyond this displacement (1) Hence $a \propto -s$,(which is a condition for SHM AW) (1)	2	Allow force is proportional to displacement and directed to equilibrium position or use of restoring force
3	(b)	ii	(For oscillations of greater amplitudes) the spring will not be extended (at top of oscillation) (1) the force on the mass will not increase beyond 2.45 N/its weight (in the positive direction) (1) OR Additional force introduced when mass strikes the unextended spring	2	Allow reference to spring being compressed/maximum compression/mass unsupported for one mark
3	(c)		Resonance will occur when (driving) frequency (/(frequency of generator) is equal to the natural frequency of the spring (1) Frequency = $1/2\pi \times (23/0.25)^{1/2}$ (1) = 1.5 Hz (1)	3	
3	(d)		Energy is transferred readily to the oscillator at resonance AW (1) Natural frequency = 9.1×10^{13} Hz (1) Frequency of IR = $3.0 \times 10^{8}/3.3 \times 10^{-6}$ = 9.1×10^{13} Hz (1)	3	Second mark can be gained by calculating the wavelength of IR equivalent to natural frequency of HCl (= 3.31×10^{-6} m)

Question			Answer	Mark	Guidance
4	(a)		Bright dots observed where waves from different slits meet in phase (1) (For this to happen) path difference is a whole/integer number of wavelengths (1)	2	Marking points can be independent Allow explanations in phasor terms
4	(b)	(i)	$\theta = \sin^{-1}(3 \times 1.75 \times 10^{-7} \times 300000)$ (1) $= 9^{o}$ (1)	2	
4	(b)	(ii)	$n = d/\lambda$ (1) $= 1/(3 \times 10^{5} \times 1.75 \times 10^{-7})$ = 19 (orders) (1)	2	Accept 18 orders if rounded slit separation of 3.3 $\times 10^{-6}$ m is used.
4	(b)	(iii)	$E_k =$ $(6.63 \times 10^{-34} \times (3 \times 10^{8}/1.75 \times 10^{-7})) - (4.3 \times 1.6 \times 10^{-19)})$ (1) $= 4.5 \times 10^{-19}$ J (1)	2	Accept 4.4×10^{-19} (intermediate rounding)

4	**(b)**	**(iv)**	Any three from: • Intensity is a measure of number of photons (striking the plate) per second • Energy of individual photons does not change with intensity • Electron ejection is the result of interaction with a single photon • Greater intensity leads to more electrons ejected s^{-1}/in unit time	3	AW throughout Must include reference to rate of ejection
4	**(c)**		Any four from: • (classical) particles do not diffract/superpose • Waves/wave theory cannot explain photoelectric effect (because) • Low intensity light should not allow ejection of electrons (as) • The energy of the light source is spread across the metal in the wave model • Phasor model allows for phasors to 'explore all possible paths' (and therefore explains diffraction) • Probability of photon arriving depends on resultant phasor amplitude/proportional to resultant amplitude^2	4	AW throughout

Question			Answer	Mark	Guidance
5	**(a)**		The alpha particle will experience a greater impulse from the nucleus (AW) (1) greater change of momentum (1) greater angular deflection (1)	3 LHH	AW throughout but the sense has to be the same as in the suggested answers. Allow ‘greater force’ for first marking point.
5	**(b)**	**i**	$r = 8.98 \times 10^{9} \times 2 \times 47 \times (1.6 \times 10^{-19})^{2}/(4.5 \times 1.6 \times 10^{-13})$ (1) $= 3.0 \times 10^{-14}$ (m) (1)	2 MM	
5	**(b)**	**ii**	(It is possible that) a more energetic alpha particle would get ‘closer’ before instantaneously stopping. AW (1)	1 L	

5	**(c)***		**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.* All aspects of the argument are covered in a clear manner.. Unambiguous statements about gamma factor, velocity and de Broglie wavelength. Final answer agrees with MS allowing for rounding differences. **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.* Reasoning sound but either does not explain the difference in closest approach or makes an error in one of the calculations/begins calculating with the assumption that $p = E/c$. **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.* Makes a correct evaluation of one aspect of the calculation or gives a logical explanation of the difference in distance of closest approach. **0 marks** No response or no response worthy of credit	6 LLMMHH	**Indicative scientific points may include:** Distance of closest approach: • Electrons are not repelled by nucleus • Electrons have opposite charge to nucleus/are negatively charged velocity of electrons: • γ = 250.511/0.511 = 490 • $v = \sqrt{\left(1 - \frac{1}{490^2}\right) 9 \times 10^{16}}$ • v (= 2.999994 x10^8) ~ c or v/c = 0.999998 de Broglie wavelength • λ = 6.63 x 10^{-34}/(250 x 1.6 x 10^{-13}/3.0 x 10^8) • λ = 5.0 x 10^{-15} m nuclear diameter d = 1.22 x 5.0 x 10^{-15}/sin 20^o = 1.8 x 10^{-14} m (accept angles of minimum 20^o – 25^0 giving d in range 1.4 x 10^{-14} m to 1.8 x 10^{-14}m)

5	**(d)**	**i**	Proton (1)	1	
		ii	Energy has been transferred to kinetic energy **and** rest energy (1) of the new particles (1)	2	Accept 'total energy' of new particles for both marks. 'Energy transferred to new particles' gains one mark.

6	**a**	**i**	Anti-neutrino/anti- electron neutrino	1	Accept $\bar{\upsilon}$ or ${}^{0}_{0}\bar{\upsilon}$ or ${}^{0}_{0}\bar{\upsilon}_{e}$
	a	**ii**	'mass defect' = 5.0×10^{-5} u = 8.305×10^{-32} kg (1) Energy released = 7.5×10^{-15} J (1)	2	
		iii	Some energy transferred to the (anti)neutrino	1	
	b	**i**	Decay constant = $0.693/(4.51 \times 10^{9} \times 3.2 \times 10^{7})$ = 4.8×10^{-18} s^{-1} (1) Number of nuclei = $9.6/4.8 \times 10^{-18} = 2.0 \times 10^{18}$ (1)	2	If conversion to seconds omitted leading to an answer of 6.2×10^{10} nuclei, award one mark.
		ii	$2/3 = e^{-\lambda t}$ (1) $-0.4055 = -1.54 \times 10^{-10}$ $yr^{-1} \times t$ (1) t = 2.6(4) x 10^{9} years (1)	3	Can use decay constant in seconds and convert to years at the end of the calculation. Look out for rounding differences. Max two marks if 1/3 used for ratio N/N_0 leading to 7.14×10^{9} years If conversion to seconds omitted leading to answer of 83.7 years, maximum two marks. One mark for answer in range 194 – 223 years by using 1/3 for ratio and no conversion to seconds.

	c	**i**	(At least one) neutron from original fission/per fission is captured (AW) by a U-235 nucleus (1) causing it to fission and the process repeats (AW) (1)	2	Concept of the process repeating required.
	c	**ii**	Number of fissions per second = $2.5 \times 10^{6} / 3.3 \times 10^{-12}$ $= 7.57 \times 10^{17}$ (1) Number of nuclei required to produce 7.57×10^{17} plutonium atoms per second = $7.57 \times 10^{17} / 3.4 \times 10^{-6}$ $= 2.23 \times 10^{23}$ (1) Mass = 0.088 kg (1) Reasoning: number of Pu nuclei fissioned per sec ≤ decay rate of Np AW	4	Alternative method: Power/energy = 7.6×10^{7} Np s^{-1} (1) Mass per second = 3.01×10^{-7} kg s^{-1}(1) Mass = 3.01×10^{-7} kg s^{-1}/ 3.4×10^{-6} = 0.088 kg (1)

7	**a**		Logarithmic scale allows a great **range** of values to be shown (1) Equal ranges of wavelengths do not have equal widths on the scale (1)	2	AW throughout Accept: Data needs processing AW
	b		Suggestion: Density/composition of atmosphere Explanation: More likelihood of gamma ray interacting with particle in atmosphere (per km) where density is greater Suggestion: energy of gamma rays Explanation: higher energy gamma rays have more energy to transfer through collisions/scattering	2	AW throughout Allow frequency or wavelength of gamma waves
8	**a**		$1.2 \times 2000 \times 10^{-9} / 6.5 = 0.37$ microrad	1	Accept more than 2 s.f. Must have own value.
	b	**i**	$0.60 \times 10^{-3} / 4121 = 0.15 \times 10^{-6}$ rad $pixel^{-1}$ (1) Camera detects shorter wavelengths which have lower (optical) resolution limits (1)	2	Need link to resolution limit for second mark

8	**b**	**ii**	**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.* Attempts all aspects of the question, calculations correct, clear reason for possible source of error. **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.* All calculations correct (no discussion) or at least two aspects of calculation correct or correct with error carried forward and discussion attempted and at least one reasonable point made. **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.* At least one calculation correct and an attempt at considering possible causes of error. **0 marks** No response or no response worthy of credit	6	**Indicative scientific points may include:** **Velocity calculation**: v = ((668-657)/657) x 3 x 10^{8} = 5.0 x 10^{6}m s $^{-1}$ Hubble constant conversion: 73 km s^{-1} Mpc^{-1} = 2.4 x 10^{-18} s^{-1} **Distance calculation**: 5 x 10^{6}/2.4 x 10^{-18} =2.12 x 10^{24} m = 223 million light years Angular breath of line AB = 0.32 mrad Width = 0.32 x 10^{-3} x 223 = 72,000 light years **Discussion**: Relevant points: determined value of Hubble constant has changed over the years. Hubble 'constant' may not be constant over time. Measurement of length AB may be inaccurate, resolution of image limits
9			$E_{total} = E_k + E_P$ (1) Energy per kg = (-6.67 x 10^{-11} x 6.0 x 10^{24}/1.5 x 10^{8}) + (1/2 x (1.1 x 10^{3})^{2}) (1) = - 2.063 x 10^{6} J kg^{-1} (1)	4 MHHH	Correct final answer gains four marks Allow ecfs within question

			At closest approach: $(-6.67 \times 10^{-11} \times 6.0 \times 10^{24} / 1.6 \times 10^{7})$ $+ 1/2\ v^2 = -2.063 \times 10^{6}$ J kg^{-1} $v = 6.8 \times 10^{3}$ m s^{-1} (1)		

Question			Answer	Mark	Guidance
10	**a**		g_{total} = -6.7 x 10^{-11} x ((2 x 10^{30}/(1.5 x 10^{11} + 1.5 x 10^{9})^2) + (6.0 x 10^{24}/(1.5 x 10^{9})^2)) (1) g_{total} = -(1) 5.99 x 10^{-3} N kg^{-1} (1)	3	Bald correct answer gains three marks. Two marks max if negative sign missing. Expect to see separate calculations leading to answer. ECF from separately calculated values to answer (g_{Sun}= - 5.81 x 10^{-3} N kg^{-1} , g_{Earth} = -1.8 x 10^{-4} N kg^{-1}) Allow one mark for one correct field strength magnitude, but not two marks for two correct field strengths leading to incorrect resultant field strength. If distance from sun taken as 1.5x 10^{11} m, g_{Sun}= - 5.9 x 10^{-3} N kg^{-1} , final answer = -6.1 x 10^{-3} N kg^{-1} (2 marks)
	b	**i**	v^2/r = $4\pi^2/T^2r$ = 5.99 x 10^{-3} T^2 = $4\pi^2$ x 1.515 x 10^{11}/5.99 x 10^{-3} = 9.98 x 10^{14} (1) T = 3.16 x 10^{7} (s) (1)	2	Ecf from **10 a** Answers which use field strength of Sun only (giving 3.21 x 10^{7} s) gain oe mark
	b	**ii**	Any three from: • Moon will have (small/negligible) effect on *g* at L2 • sometimes the Moon will be in line with the Sun and Earth and its distance from L2 will vary AW • Variation in field strength will affect orbit • Calculation to support argument (1)	3	Reason for variation of field strength required. e.g. maximum field strength due to Moon at closest point to JWST = -3.2 x 10^{-6} N kg^{-1} e.g. maximum total field strength = -6.0 x 10^{-3} N kg^{-1} e.g. orbital speed remains at 3.0 x 10^{4} m s^{-1} to 2 s.f.

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