

GCE

Physics B

H557/02: Scientific literacy in physics

A Level

Mark Scheme for June 2022

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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 3**

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor 3 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 scoris and mark the **required number** of practice responses (“scripts”) and the **required number** of 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 Assessor 50% and 100% (traditional 50% 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, email or via the Assessor messaging system.

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.)*

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 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 scoris 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:

- Read through the whole answer from start to finish.
- Decide the level that **best fits** the answer – match the quality of the answer to the closest level descriptor.
- To select a mark within the level, consider the following:

Higher mark: A good match to main point, including communication statement (in italics), award the higher mark in the level

Lower mark: Some aspects of level matches but key omissions in main point or communication statement (in italics), award lower mark in the level.

Level of response questions on this paper are **4 c** and **9**

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. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

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

Question		Answer	Marks	Guidance
1	a	(Zero net force) zero acceleration. (1)	1	'no velocity change' accepted for zero acceleration. Don't accept 'terminal velocity' as a synonym for no acceleration. Accept 'speed' for velocity.
	b	Calculation of $r = 7.9 \times 10^{-7}$ m (1) Working through to $v = 6.6 \times 10^{-5}$ m s ⁻¹ (1)	2	Other routes expected. Allow ecf within this two-mark show-that question.
	c	i	2	Allow edge effects. Allow larger gap in middle due to gap in plates. Must have 3 lines on each side.
		ii	2	Accept, 4.76×10^{-19} 4.77×10^{-19}
		iii	2	Need some idea of continuous charge range Accept quarks have fractional/smaller charge.
			9	

Question			Answer	Marks	Guidance
2	a	i	Iron has high <u>permeability/more permeable</u> (1) High permeability increases <u>flux</u> (for a given number of current turns) AW (1) Any two from: <ul style="list-style-type: none"> • Changing flux in iron generates (changing) emf • Changing emf generates currents/eddy currents • Eddy currents reduce flux in core • Laminations reduce eddy currents (by setting up insulating barriers) • (Reducing eddy currents) reduces (thermal) energy losses 	4	Second mark is for explaining what 'high permeability' means. Allow 'good conductor of flux' (AW) for second point.
		ii	Reduce air gap (1) As air has lower permeability than iron (1) or Shorten the magnetic circuit AW (1) As shortening the circuit acts in similar manner as shortening a resistive wire in an electrical circuit AW (1) or Having greater cross sectional area core (1) As this give more routes for flux AW (1)	2	Or 'air gaps have lower permeance' AW Accept reduces resistance to flux (AW).
	b	i	Find (greatest value of) rate of flux density change from the gradient of the line where it crosses the x-axis/maximum gradient (1) Multiply this value by the cross-sectional area to get rate of change of flux (1) Multiply this value by number of turns of coil to reach value of maximum emf (1)	3	Must have reference to gradient to access second two marks. Don't credit quoting equation without reference to gradient.
		ii	$\mathcal{E}_{\max} = 2 \times \pi \times (1/T) \times B_{\max} \times A \times N$ $= 2 \times \pi \times (17.5 \times 10^{-3} \text{ s})^{-1} \times 0.16 \text{ T} \times 1.5 \times 10^{-4} \text{ m}^2 \times 220 (1)$ $= 1.9 \text{ (V)} (1)$	2	Answer of 8.6 mV (uses $N = 1$) gets 1 mark
Total				11	

Question			Answer	Marks	Guidance
3	a	i	Any two from: <ul style="list-style-type: none"> • Nearest the unstrained resistance (1) • Choosing a resistance near to that of the gauge will increase sensitivity (1) • (as) the change on the voltmeter will be greater for a given change in strain resistance if the two resistors are of similar value AW (1) 	2	Can obtain both marks by repeated calculation of e.g. p.d. across 470 Ω and then 100 Ω (or 2000 Ω) when gauge is 310 Ω and comparing. Accept 'greater range of output p.d.s' AW
		ii	$V = 6 \times (470/780)$ (1) = 3.62 (V) (1)	2	Need own value. Can calculate using current.
		iii	$3.57 = 6 \times (470/(470 + R))$ $R = ((6 \times 470) - (3.57 \times 470))/3.57$ (1) $R = 319.9 / 320$ (Ω) (1)	2	Bald answer gains both marks
	b		Calculation of resistance of gauge 1 = 316 Ω OR resistance of gauge 1 = 1.02 of original resistance leading to 316 Ω (1) Calculation of resistance of gauge 2 = 304 Ω OR resistance of gauge 2 = 0.98 of original resistance leading to 303 Ω (1) $V = 6 \times (303/619)$ (1) = 2.94 V (1)	4	Bald correct answer to 3 s.f. gains all marks. Other routes possible. Ecf from incorrect resistance calculations. Values that should be seen appended (unrounded) below table: 2 marks max if correct potential divider equation used on incorrect resistor values. 1 mark from the last two if the p.d. across gauge 1 calculated. If 1% change in R used expect 2.97V gains 2 marks
Total				10	
Total Section A				30	

gauge	length	c.s.area	Volume	resistance
1	0.11918 m	$1.8218 \times 10^{-10} \text{ m}^2$	$2.1712 \times 10^{-11} \text{ m}^3$	315.98 Ω
2	0.11682 m	$1.8586 \times 10^{-10} \text{ m}^2$		303.59 Ω
unstrained	0.118 m	$1.84 \times 10^{-10} \text{ m}^2$		309.75 Ω

Section B

Question			Answer	Marks	Guidance
4	a	i	(Upward) force on wire produces equal and opposite force (1) of same type AW(1) on the magnets/yoke/scales	2	2nd mark for stating clearly the meaning of the law (i.e. same type of force on different bodies) One mark for 'every action has an equal and opposite reaction' Accept comparison of force on wire to force on magnet/yoke/scales for second mark
		ii	$B = 9.8 \text{ N kg}^{-1} \times 1.4 \times 10^{-3} \text{ kg} / (3.1 \text{ A} \times 0.04 \text{ m})$ (1) $= 0.11 \text{ T}$ (1)	2	
		iii	Field strength = gradient \times (9.8 N kg ⁻¹ / 0.04 m) AW (1) as gradient = $\Delta m / \Delta I$ (1). Best fit line gives weighted mean of gradient/avoids including outliers (1) AW	3	Accept 'gradient = BL/g' for first mark
	b	i	Force oscillates at (50 Hz) (1) as direction of current changes in the wire at (50 Hz) (1)	2	Second mark needs clear link to direction of current changing. Stating alternating current is insufficient Marking points can be independent.

	<p>ii Level 3 (5–6 marks) <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Clear explanation of resonance and conditions for resonance; accurate and clear calculation; valid and accurate conclusion</p> <p>Level 2 (3–4 marks) Description of resonance may be limited. Conclusion may be missing but attempted calculations are accurate</p> <p>Level 1 (1–2 marks) Superficial description of resonance/calculations attempted inaccurate or incomplete (for example, assuming wavelength is 0.9 m)</p> <p>0 marks No response or no response worthy of credit</p>	6	<p>Indicative scientific points may include:</p> <p>Resonance:</p> <ul style="list-style-type: none"> • (for all oscillators) driving frequency = oscillating frequency • When driving frequency = natural frequency, large amplitude oscillations develop • Until energy loss per cycle = energy input per cycle • If natural frequency of wire = 50 Hz, resonance will occur <p>Calculation:</p> <ul style="list-style-type: none"> • Standing wave set up along wire of wavelength = 1.80 m • $c = (37/0.0046)^{1/2}$ • $c = 89.7 \text{ m s}^{-1}$ • $f = c/\lambda = 49.8 \text{ Hz}$ <p>Or showing tension is 37.3 N using $v = f \lambda$ with $f = 50 \text{ Hz}$ and $\lambda = 1.8 \text{ m}$</p> <p>Conclusion:</p> <ul style="list-style-type: none"> • As natural frequency = driving frequency at a tension of 37 N, resonance will occur • Resulting in large scale oscillations
	Total	15	

Question		Answer	Marks	Guidance
5	a	$\frac{mv^2}{r} = \frac{GMm}{r^2} \quad [1]$ $v = \frac{2\pi r}{T} \quad [1]$ $\frac{m4\pi^2 r^2}{r T^2} = \frac{GMm}{r^2} \Rightarrow \frac{T^2}{r^3} = \frac{4\pi^2}{GM} \quad [1]$	3	Any correct routes gain full marks. Can use angular frequency. $mr\omega^2 = \frac{GMm}{r^2} \quad [1]$ $\omega = \frac{2\pi}{T} \quad [1]$ $\frac{4\pi^2 r^3}{T^2} = GM \rightarrow \frac{T^2}{r^3} = \frac{4\pi^2}{GM} \quad [1]$
	b	$M = 4\pi^2 r^3 / T^2 G$ $= 4\pi^2 \times (1.07 \times 10^9 \text{ m})^3 / ((6.18 \times 10^5 \text{ s})^2 \times 6.67 \times 10^{-11}) \quad (1)$ $= 1.898 \times 10^{27} \text{ kg} = 1.9 \times 10^{27} \text{ kg} \quad (1)$	2	Need own value
	c	i Total energy (k.e. + p.e) remains constant (1) As it approaches planet the gpe becomes more negative (as gpe = -GMm/r) (1) k.e. must increase (1)	3	Third mark for bare energy transfer from p.e to k.e
		ii Total energy/kg = $v^2/2 + (-GM/r)$ At closest approach, Total energy/kg $= \frac{1}{2} \times (5.8 \times 10^4)^2 - \{(6.67 \times 10^{-11} \times 2 \times 10^{27}) / 7.4 \times 10^7\}$ $= 1.682 \times 10^9 \text{ J kg}^{-1} - 1.803 \times 10^9 \text{ J kg}^{-1}$ $= -1.21 \times 10^8 \text{ J kg}^{-1} \quad (1)$ At greatest distance, P.E./kg = $-GM/(1.0 \times 10^9)$ $= -1. \times 10^8 \text{ J kg}^{-1} \quad (1)$ KE/kg = Total energy/kg – P.E./kg $= -1.21 \times 10^8 \text{ J kg}^{-1} - (-1.33 \times 10^8 \text{ J kg}^{-1})$ $= 1.2 \times 10^7 \text{ J kg}^{-1} = v^2/2 \quad (1)$ $v = 4900 \text{ m s}^{-1} \quad (1)$	4	Other routes possible. Bald correct answer gains all marks. Allow unrounded value of $M = 1.898 \times 10^{27} \text{ kg}$ from (b) which gives At closest approach, PE/kg = $-1.71 \times 10^9 \text{ J kg}^{-1}$ Total energy/kg = $-2.92 \times 10^7 \text{ J kg}^{-1} \quad (1)$ At greatest distance, P.E./kg = $-1.27 \times 10^8 \text{ J kg}^{-1} \quad (1)$ KE/kg = $9.74 \times 10^7 \text{ J kg}^{-1} \quad (1)$ $v = 14000 \text{ m s}^{-1} \quad (1)$
	d	If it is travelling too fast it will not be captured by Jupiter AW (1) If the k.e. is greater than the magnitude of the g.p.e. the spacecraft will pass Jupiter (1) Total energy must be negative for a (stable) orbit.(1)	3	Accept 'enough k.e. to escape potential well'
Total			15	

Question			Answer	Marks	Guidance
6	a	i	Amplitude is constant(1)	1	Accept maximum displacement
		ii	Line of same frequency $\frac{1}{4}$ cycle ahead of displacement (1)	1	
		iii	Line of same frequency, $\frac{1}{2}$ cycle ahead of displacement (1)	1	Will be mirror image of original graph
	b	i	Displacement is calculated using mean velocity per cycle (1)	1	
		ii	$a = -3.465/-3.46/-3.47$ (1) $v_{\text{new}} = -0.353/-0.3532/-0.3533/-0.35325$ (1) $x_{\text{new}} = 0.1022$ (1)	3	Do not accept fewer than 3 s.f. Do not accept fewer than 3 s.f. Do not accept fewer than 3 s.f.
		iii	From graph, $T/4 = 0.325 \pm 0.005 \text{ s} \Rightarrow 1.28 \text{ s} \leq T \leq 1.32 \text{ s}$ \Rightarrow Frequency = $0.77 \pm 0.01 \text{ Hz}$ (1) Frequency from calculation = 0.87 Hz (1) Comments – any two from: <ul style="list-style-type: none"> • Difficulty measuring $T/4$ (and hence T) from graph • Iterative model over estimates acceleration during each iteration/holds a constant during each iteration. • Iterative model has oscillator stationary for initial 0.05 s 	4	Allow estimating $T/4$ starting at the ‘dot’ at $t = 0.05 \text{ s}$ giving $T = 1.1 \text{ s}$ and $f = 0.91 \text{ Hz}$ NB graph deliberately does not have minor gridlines
	c		Reasoning: energy proportional to A^2 (1) Ratio of squares of heights of consecutive peaks/troughs will show constant ratio (if student is correct) (1) Ratios of squares tested for at least 3 consecutive pairs (1) Logical conclusion from data for an accepted test (1)	4	If incorrect reasoning proposed eg energy proportional to A , candidate can still access final 3 marks. Allow use of gradient to find v and hence v^2
Total				15	

Question	Answer	Marks	Guidance
7	$n = 8.5 \times 10^{24}$ (1) Total distance = $8.5 \times 10^{24} \times 1.2 \times 10^{-4} = 1.0 \times 10^{21}$ m (1) $t = 1.02 \times 10^{21} / 3.0 \times 10^8 = 3.4 \times 10^{12}$ s (1) (= 106 000 years)	3	Bald answer for time gains three marks
	Total	3	
	Total Section B	49	

Question		Answer	Marks	Guidance
8	a	Charged particles (in solar wind) promote electrons (in atmospheric atoms/ions) to higher energy levels AW (1) the electrons fall down to lower energy levels, emitting photons (1) $E = 6.6 \times 10^{-34} \times 3 \times 10^8 / 5.58 \times 10^{-7} = 3.5 \times 10^{-19} \text{ J}$ (1)	3	Accept: transfer energy to the electron Accept: electron losing energy by emitting a photon
	b	i		
		ii		
		iii		
			Total	

Answer for Question 8a:
Charged particles (in solar wind) promote electrons (in atmospheric atoms/ions) to higher energy levels AW (1)
the electrons fall down to lower energy levels, emitting photons (1)
 $E = 6.6 \times 10^{-34} \times 3 \times 10^8 / 5.58 \times 10^{-7} = 3.5 \times 10^{-19} \text{ J}$ (1)

Answer for Question 8b i:
 $r = mv/qB$ (1)
 $= 9.1 \times 10^{-31} \times 5 \times 10^5 / (1.6 \times 10^{-19} \times 40 \times 10^{-6})$
 $= 0.071 \text{ m}$ (1)

Answer for Question 8b ii:
vertical component = $4.5 \times 10^5 \text{ m s}^{-1}$ (1)
horizontal component = $2.1 \times 10^5 \text{ m s}^{-1}$ (1)
time for one revolution = $8.7 \times 10^{-7} \text{ s}$ (1)
vertical displacement per revolution = 0.39 m (1)

Answer for Question 8b iii:
Any two from:

- Radius will decrease AW
- Due to strengthening field and or deceleration of electrons AW
- as $r = mv/Bq$
- Distance d will decrease AW
- Due to transfer of energy away from electrons AW

Guidance for Question 8b ii:
Bald answer for vertical displacement gains four marks
Accept: $v_v = 5 \times 10^5 \cos 25$ (1)
 $V_h = 5 \times 10^5 \sin 25$ (1)

Ecf for time from incorrect velocity,
Ecf for vertical displacement
Eg. If cos and sin mixed $t = 4.02 \times 10^{-7} \text{ s}$ and vertical displacement = 0.0085 m

Guidance for Question 8b iii:
Second bullet point must be linked to first

Question	Answer	Marks	Guidance
9	<p>Level 3 (5–6 marks) The energy required to overcome the coulomb repulsion is correctly calculated. The average energy of the protons in the core is calculated, and a comparison of the two energies made. The ratio may be given. The Boltzmann factor for the process is calculated and the tiny value is highlighted. The mass of protons required to produce the rate of fusion is estimated and a clear conclusion drawn.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) The energy required to overcome Coulomb repulsion is calculated. And/or distance of closest approach is calculated. The average energy of the protons in the core is calculated, and a comparison of the two energies made. The combined energy of collision may be omitted. The ratio may be given. The Boltzmann factor for the process is calculated. Conclusions may be attempted.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Calculations are attempted and at least one is correctly developed <i>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.</i></p> <p>0 marks No response or no response worthy of credit</p>	6	<p>Indicative scientific points may include: Energy required to overcome Coulomb repulsion between protons separated by $2 \times 10^{-14}\text{m}$</p> <ul style="list-style-type: none"> $E = 2.3 \times 10^{-14} \text{ J}$ Average energy of protons $= kT = 2.1 \times 10^{-16} \text{ J}$ or $= 1\frac{1}{2} kT = 3.1 \times 10^{-16} \text{ J}$ Average energy of reacting proton pair $= 4.2 \times 10^{-16} \text{ J}$ from kT or $= 6.2 \times 10^{-16} \text{ J}$ from $1\frac{1}{2}kT$ <p>Closest approach distance</p> <ul style="list-style-type: none"> with energy of $4.2 \times 10^{-16} \text{ J}$ for the proton pair $5.5 \times 10^{-13} \text{ m}$ If using $2.1 \times 10^{-16} \text{ J}$ gives distance $1.1 \times 10^{-12} \text{ m}$ <p>Boltzmann factor</p> <ul style="list-style-type: none"> Ratio of energies = 55 (37 from $1\frac{1}{2}kT$ or 111 or 74) Boltzmann factor for process, $F_B = 1.7 \times 10^{-24}$ (using kT) remembering that both protons possess the average energy (if $2.1 \times 10^{-16} \text{ J}$ used, $f = 2.9 \times 10^{-48}$) <p>Linking Boltzmann factor to probability of reaction Showing/commenting that such a low probability requires a mass of protons greater than the mass of the Sun to produce the rate of fusion given in the question. (Estimated number of protons in sun = 1.2×10^{57} number of fusions per second $1.2 \times 10^{57} \times f_B$)</p>
	Total	6	

Question		Answer	Marks	Guidance
10	a	$1400 \times (1.5 \times 10^{11})^2 = \text{power at probe} \times (1.4 \times 10^{10})^2$ (1) power at probe = 1.6×10^5 (W m ⁻²) (1)	2	
	b	1300 K (2 sf) (1)	1	Ecf from (a)
	c	Help forecasts of CME, solar flares, changes in solar wind etc (1) The modern world depends on devices that are sensitive to electromagnetic variations AW example required (1)	2	e.g. navigation systems, high voltage power grid etc Accept protecting economies for second mark
		Total	5	

In article:
predict when the Earth is likely to experience a severe
bout of 'space weather' and take precautions

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