GCE

Physics B

H557/01: Fundamentals of physics

A Level

Mark Scheme for June 2022

Oxford Cambridge and RSA Examinations

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 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.

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

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 via the RM Assessor messaging system in the first instance.

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. On each blank page a "seen" annotation must be inserted to confirm that the page has been checked. For additional objects (if present), a "seen" annotation must be inserted on each page to confirm that it has been checked.
   Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there.

7. There is a NR (No Response) option. Award NR (No Response)
   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (eg 'can't do', 'don't know')
   - OR if there is a mark (eg a dash, a question mark) which isn't an attempt at the question

   The hash key (#) on your keyboard will enter NR.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question)

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 the Principal Examiner or 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 RM Assessor messaging system.

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. **Level of response (LoR)**

Read through the whole answer from start to finish, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance.

Using a 'best-fit' approach based on the science content of the answer, first decide which set of level descriptors, Level 1 (L1), Level 2 (L2) or Level 3 (L3), **best** describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme.

Once the level is located, award the higher or lower mark. For the higher mark use just the level annotation, e.g. for 6 marks use L3. For the lower mark use the level annotation with one mark omitted, e.g. for 5 marks use L3 ^.

The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met. **The lower mark** should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.

In summary:
- the **science** content determines the **level**
- the **communication statement** determines the **mark within a level**.

Level of response questions on this paper are **37b (ii)** and **38(a)** indicated by * in the markscheme

8. Annotations available in RM Assessor

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
✗	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
✓	Correct response
AE	Arithmetic error
?	Wrong physics or equation

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

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	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
(1)m	a method mark, awarded if a correct method is used
(1)e	an evaluation mark, awarded for correct substitution and evaluation

Section A: MCQs

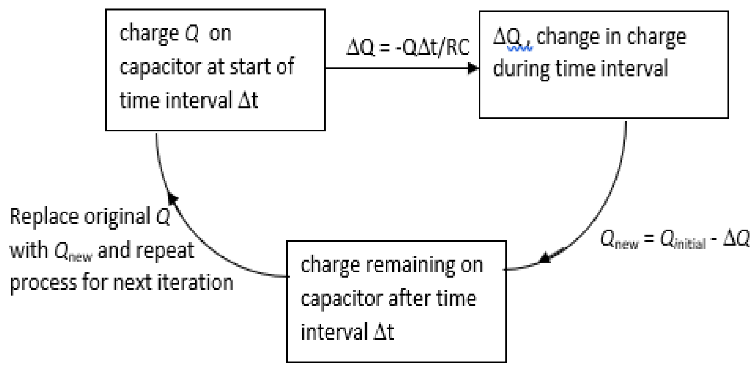
Question			Answer	Marks	Guidance
1			C	1	
2			B	1	
3			A	1	
4			B	1	
5			C	1	
6			B	1	
7			B	1	
8			A	1	
9			B	1	
10			A	1	
11			C	1	
12			C	1	
13			C	1	
14			C	1	
15			B	1	
16			B	1	
17			B	1	
18			C	1	
19			A	1	
20			D	1	
21			D	1	
22			C	1	
23			D	1	
24			C	1	
25			D	1	
26			B	1	
27			C	1	
28			B	1	
29			C	1	
30			B	1	
			Total	30	

Section B

Question			Answer	Marks	Guidance
31	(a)		Equal spacing between equipotentials (of equal potential difference). (1)	1	**Allow** AW e.g. "height is proportional to equipotentials" Ignore reference to straight or parallel lines
31	(b)		h ($= v^2/2g = 400/(2 \times 1.6)$) = 125 m (1) assumption: field strength constant (up to greatest height reached) (1)	2	Bald correct answer gains mark. Must have correct evaluation. **Allow** the maximum height is very much less than the radius of the moon / constant g / there is little or no air resistance
			Total	**3**	

Question			Answer	Marks	Guidance
32	(a)		Constant wavelength (1) Greater spreading (1)	2	Must be the same wavelength as original and be constant for all wavefronts Must show at least 3 wavefronts Must have diagram that is symmetrical which shows wavefronts extending further beyond dotted lines than original, with more of each wavefront curved
32	(b)		Wave (fronts) from adjacent slits meet in phase (1) (because) the path difference between adjacent slits is one wavelength.(1)	2	**Allow** AW using idea of superposition e.g. constructive interference or phasor addition Must refer to path difference for this marking point **Allow** integer multiples of wavelength
			Total	**4**	

Question			Answer	Marks	Guidance
33			Assume the relativistic principle of the invariance of the speed of light (1) Distance / 2 OR time / 2 (1) velocity = (3335.586-3335.564)/2 x 3 x 10^8/1800.00 (1) = 1830 (m s^{-1}) (1)	4	**Allow** 'the speed of light is the same travelling to the spacecraft and away from the spacecraft' and similar **Allow** 'the speed of the spacecraft is significantly less than the speed of light' **Not** 'the speed of light is 3 x 10^8 ms^{-1}' First mark for recognising that the distances (or times) must be halved. **Allow** alternative methods / calculations **Allow** 1800 only if evaluated from calculation as 1800 appears in the stem of the question **Allow** MAX 2 marks for calculation correctly evaluated by missing division by 2. Can also gain the assumption mark to give 3 marks for the question.
			Total	**4**	

Question			Answer	Marks	Guidance
34	(a)		(area under graph is calculated by use of) ½ qV (at two points) (1) (which is) energy transferred / increase in energy (in the capacitor) / work done as the p.d increases from 0.4 V to 1.2 V (1) as capacitance = Q/V, the gradient gives the capacitance (1)	3	**Not** QV unless fully explained in terms of integral calculation or AW **Not** just area of triangle is ½ qV **Not** just 'energy stored' unless explained – e.g. "energy stored as p.d. increases from 0.4V to 1.2V" **Allow** reference to Q increases from 1.7 mC to 5mC Must have equation and be clear that gradient is capacitance to be awarded mark
34	(b)		rearrange equation to $\Delta Q = -Q\Delta t/RC$ (1) add (negative) ΔQ calculated to original charge Q to find charge remaining after Δt seconds (1) repeat process (to find new Q after each iteration)(1)	3	Candidates may draw flow diagrams or tables – check that these illustrate the marking points listed – e.g.  **Allow** use of example calculations / tables to show iterations that illustrate marking points listed. Blank table without calculations can be credited for full marks as long as row and column headings clearly show the marking points **Do not allow** use of $Q=Q_0e^{-t/RC}$
			Total	**6**	

Question			Answer	Marks	Guidance
35	(a)		Three calculations of constant Er^2: 2.24 x 10^4 , 2.25 x 10^4, 2.24 x 10^5 (1) If relationship holds, Er^2 = constant (1)	2	**Allow** calculations in form E / (1 / r^2) **Allow** E / (1 / r^2) = constant OR E = constant / r^2
35	(b)		Potential varies as 1/*r* compared with field strength which varies as 1/r^2 (1) E.g. doubling the *r* will halve the potential and quarter the field strength (1)	2	must include quantitative example
			Total	**4**	
			Total Section B	**21**	

Section C

Question			Answer	Marks	Guidance
36	(a)		sin i = $c_1\Delta t/x$, sin r = $c_2\Delta t/x$ leading to sin i/sin r = $(c_1\Delta t/x)/(c_2\Delta t/x)$ (1)	1	This is a medium level 'show that' question so the response must be complete to gain the mark.
36	(b)		angle of refraction in glass calculated to 19.37° recognised as angle of incidence at glass:water boundary (1) Angle of refraction in water calculated as 22.1° (1) OR Recognition that this is physically the same as light striking the water surface from air at 30° to the normal: Angle of refraction in water = $\sin^{-1}$(sin30 x 226/300) (1) = 22.1° (1)	2	Bald correct answer gains both marks. **Allow** use of 19 ° for angle of refraction in glass leading to 21.7° **Allow** use of 19.4 ° for angle of refraction in glass leading to 22.2 ° **Allow** use of refractive indices n_1 = 1.5075 n_2 = 0.8805 – for this method allow one mark for correct method with values substituted for both refractive indices
36	(c)	(i)	Polychromatic light disperses / different wavelengths travel at different velocities in glass / different wavelengths have different refractive indices (1)	1	**Allow** different colours as AW for polychromatic light / different wavelengths
36	(c)	(ii)	The angle of refraction is constructed from the emergent ray whereas the angle of incidence is predetermined (1)	1	Expect the idea that constructing the refracted ray from the emergent ray leads to more uncertainty – mistakes in drawing, thick pencil lines etc.
36	(c)	(iii)	A constant uncertainty in angle (1) will not produce a constant uncertainty in sine as there is a non-linear relationship between angle and sine (1)	2	The second mark requires a clear statement of the relationship between angle and sine 'they are not proportional' would still gain the mark.
36	(c)	(iv)	State method or show evidence of taking maximum or minimum gradient through range bars (1) max gradient ~ 1.80, min gradient ~ 1.30 (1) Correct precision in final value e.g. 1.5 +/- 0.3 (1)	3	Must have explanation / evidence of one correct max or minimum line drawn on graph AND values read from graph from at least a third of the line Must have both gradients to score 2nd marking point **Allow** max gradient values between 1.75 and 1.85 and min gradient values 1.25 and 1.35 Must be to 1 SF rounded correctly – can only be 0.3 or 0.4 Can score 1st and 3rd marking points for 2/3 marks
			Total	**10**	

Question			Answer	Marks	Guidance
37	(a)	(i)	(t =) 300/1.9 = 158 s (1)	1	need own value **not** 160 s or 157 s **allow** RA leading to 304kmh^{-1}
37	(a)	(ii)	Power = ½ x 7.15 x 10^5 x (3x 10^5/3600)^2/158 (1) = 1.57 x 10^7 W (1)	2	**allow** power = 1.6 x 10^7 W **allow** 1.552 x 10^7 from use of 160s **allow** P=Fv method with force and average velocity for full credit **allow** MAX 1 for using v in kmh^{-1} leading to 2.0 x 10^8 W
37	(b)	(i)	Power = ½ x 1.2 x 1.5 x 13.5 x (3 x 10^5/3600)^2 x (3 x 10^5/3600) (1) = 7.0 x 10^6 W (1)	2	**Do not allow** credit for using v in kmh^{-1} leading to incorrect final answer

Question			Answer	Marks	Guidance
37	(b)	(ii)*	**Level 3 (5–6 marks)** Marshals argument in a clear manner and includes clear explanation of **all** strands including : Correct and clear calculation of initial acceleration including sensible estimate of passenger mass. Clear understanding that the mass increase will not affect the power required to overcome air drag. Clear explanation linking effect of travelling through the tunnel. *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)** Covers **all** strands at a superficial level and does not include enough depth for level 3. Correct method of calculation of initial acceleration, some understanding that the drag is independent of mass but not necessarily well explained. Superficial explanation of the effect of a tunnel. OR covers **all** strands with two well-explained. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.*	**6**	**Indicative scientific points may include:** **Initial acceleration:** • Estimate of passenger mass: 60 – 80 kg • Mass of full train: around 800 000 kg • Calculation of force from F=ma • Acceleration of loaded train for example = 1.9 km $h^{-1}s^{-1}$x 715/800 = 1.7 km h^{-1} s^{-1} OR 0.472ms^{-2} **Power used to overcome drag:** • No change in <u>power</u> to over come drag • Because mass is not one of the variables in the equation / mass does not affect power required • Power = *Fv*; *F* and *v* constant **Travelling through tunnel:** • Power required will increase • Power = Fv so if F increases then P increases (to maintain constant v) • Because air cannot travel around the train as easily • Leading to increased pressure in front of the train • Density of air striking the face of the train increases • Density is one of the terms in the drag equation • Drag is proportional to air density • (Drag) force will increase • Drag coefficient will increase • Increased turbulence (will increase drag) • Air pressure at rear of train decreases

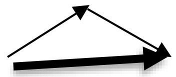
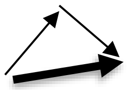
Question			Answer	Marks	Guidance
			Level 1 (1–2 marks) Makes at least two independent points (possibly from only one strand), that are relevant to the argument but does not link them together and shows only superficial engagement with the argument. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit		
			Total	**11**	

Question			Answer	Marks	Guidance
38	(a)*		**Level 3 (5–6 marks)** Marshals argument in a clear manner and includes clear explanation of **all** strands including : Clear description of experimental method. Clear understanding of sources of uncertainty and systematic error. Clear descriptions of suggestions to reduce uncertainties in both variables. Understanding that air is not an ideal gas. *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)** Covers **all** strands at a superficial level and does not include enough depth for level 3. OR covers **all** strands with two well-explained. *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)** Makes at least two independent points (possibly from only one strand), that are relevant to the argument but does not link them together and shows only superficial engagement with the argument. *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.* **0 marks** No response or no response worthy of credit	6	**Indicative scientific points may include:** **Experimental description:** • Vary temperature of water bath • Take readings of length of column and temperature • Plot graph of L vs T (^oC) • Extrapolate to zero length to find absolute zero in ^oC **Requirement for uniform diameter:** • Volume of gas is proportional to length of column only if diameter is constant. • Charles' law relates volume and absolute temperature. • Non-uniform diameter leads to error (in V). **Sources of uncertainty / accurate value / non-ideal gas:** • Temperature – assumption is that temperature of the gas is equal to that of the water. Changing water temperature slowly will reduce uncertainty (and systematic error), OR stirring (to ensure uniform temperature) / difficulty in reading scale in water reduced by using a digital thermometer / probe (and data logger) OR use a thermometer with better resolution • Length – difficulty in reading scale in water – reduced by having eye level horizontal (to reduce parallax error) / ensuring ruler is vertical / parallel to glass tube OR using optical aid such as travelling microscope or hand lens OR longer air column • Expansion of glass in capillary tube (reduces bore) – have thinner walled-tube / use lower temperatures • Air does not behave as an ideal gas. **Allow** V vs T graph if diameter measured / volume calculated for credit within Strands 1 and 2 and also for expansion of glass in strand 3

Question			Answer	Marks	Guidance
38	(b)	(i)	V = 5.0 x 10^{-3} x *L* (1) (pV = nRT) 1.0 x 10^{5} x 5.0 x 10^{-3} x *L* = 0.24 x 8.31 x 298 (1) *L* = 1.19 m (1)	**3**	**Allow** V = AL or worded statement This mark is the "reasoning/explanation" mark – allow credit if seen numerically within pV=nRT **Not** just statement of pV = nRT for explanation mark **Not** argument that 'at equilibrium, pressure of gas inside cylinder = atmospheric pressure /pressure on lower and upper surface of disk are equal' since this is in the stem of the question **Not** statement of ideal gas as this is in the stem of the question Must have own value
38	(b)	(ii)	Pressure exerted (on both sides of disk) due to momentum change of particles (and disk) on collision with disk. (1) Increased temperature increases velocity / energy / momentum of particles / frequency of collisions hence greater force on the lower side of the disk than the upper (1) so disk moves upwards until the rate of change of momentum on both sides of the disk is the same OR disk moves upwards so that the frequency of collision is lower on the inside surface of the disk (1)	**3**	. **Allow** speed **Allow** disk moves upwards until pressure / force on both sides of disk is the same

Question			Answer	Marks	Guidance
38	(b)	(iii)	pV calculated as 900 Nm (1) $\sqrt{\overline{c^2}} = \sqrt{\frac{3 \times 900}{0.24 \times 6 \times 10^{23} \times 6.6 \times 10^{-26}}}$ (1) =533 m s^{-1}(1) **OR** T = 298 × 1.8 /1.2 (1) $\sqrt{\overline{c^2}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 298 \times 1.8}{1.2 \times 6.6 \times 10^{-26}}}$ (1) = 529 m s^{-1} (1)	3	First step can be implicit. Bald correct answer gains all marks. **Allow** 530 or 532 m s^{-1} from use of 6.02 x10^{23} Calculation of just mean square velocity scores MAX 1
			Total	15	

Question			Answer	Marks	Guidance
39	(a)		Energy required to separate (to infinity) all nucleons of a nucleus from one another. (1) Determine the total mass of individual nucleons and subtract this from the mass of the nucleus and convert to energy via mc^2.(1)	2	**Not** just mass deficit
	(b)	(i)	Correct calculation of total binding energies: U-234 = -1778 MeV; Xe-137 = -1151 MeV; Sr-94 = - 808 MeV (1) ΔE = -1778 – (-1151 + - 808) = 180 MeV	2	**Allow** slight variations in reading from graph. Ignore minus signs for first mark **penalise** CON for errors in + and – signs in final evaluation Suggested range of final answer 165 – 195 MeV First step can be implicit but working and own answer required.
		(ii)	mass = $3.89 \times 10^{-25} \times (1400 \times 10^{6} \times 3.2 \times 10^{7}/(200 \times 1.6 \times 10^{-13}))$ (1) = 540 kg	2	**Allow** show that value, correct values and ecf values from b(i) using 180 MeV gives 605kg ; 181 MeV gives 602kg
	(c)		number fissions required per second = $1400 \times 10^{6}/200 \times 1.6 \times 10^{-13} = 4.375 \times 10^{19}$ (1) (Therefore, minimum activity required = 4.375×10^{19}) N (= activity/decay constant) = $4.375 \times 10^{19}/(0.693/1600) = 1.0 \times 10^{23}$ (1) mass = 0.039 kg (1) This assumes that all U-233 nuclei produced in one second capture neutrons in the same time interval / all U-234 undergo fission in the same time interval. (1)	4	This uses the 'show that' value from (b) (i). If 180 MeV used, mass required = 0.043 kg **Allow** ecf answer to **b(i)**
			Total	**10**	

Question			Answer		Guidance
40	(a)		dots on screen show particle-like behaviour (1) pattern of bright and dark bands shows wave-like behaviour (1)	**2**	**Allow** alternative wording – e.g. "spots" or "points" as long as discrete and individual implied **Not just** random for particle property
40	(b)	(i)	  Correct completion of triangles (1) Correct direction of arrows (1)	**2**	
40	(b)	(ii)	relative probability = $(25/19)^2$ (1) = 1.7 (1) (answer to 2 s.f.)	**2**	First mark for in-range resultant phasor. Allow 24-26mm and 18-20mm
40	(c)	(i)	wavelength = 5.5×10^{-12} m (1) $\sin \theta = 5.5 \times 10^{-12} / 1.0 \times 10^{-6}$ m (1) angle = 3.2×10^{-4} degrees (1)	**3**	
40	(c)	(ii)	Calculation of rest energy of electron = 0.51 MeV (1) Gamma factor = 1 + 50 keV/0.51 MeV (1) = 1.097 (1) v = 1.23×10^8 m s^{-1} (1)	**4**	Must give own value
			Total	**13**	
			Total Section C	**59**	

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