GCE

Physics B

H157/02: Physics in depth

AS Level

Mark Scheme for June 2022

Oxford Cambridge and RSA Examinations

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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 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 RM Assessor 3 and mark the 10 practice responses ("scripts") and the 10 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 3 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 3 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 3 **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 3 messaging system, or e-mail.

9. Assistant Examiners will send a brief report on the performance of candidates to your Team Leader (Supervisor) by the end of the marking period. The Assistant Examiner's Report Form (AERF) can be found on the RM Cambridge Assessment Support Portal (and for traditional marking it is in the *Instructions for Examiners*). Your report should contain notes on particular strength displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. Annotations available in RM Assessor 3:

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

11. 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

12. All question parts bearing mark totals > 1 should be annotated with ticks in the body of the text to show where marks have been awarded. Ticks must NOT be used in 6(b)(iv) or 8(c) — these should be annotated with X, L1^, L1, L2^, L2, L3^ or L3 only for marks 0 to 6.

Question			Answer	Marks	Guidance
			Section A		
1	(a)		$v^2=u^2+2as$ 0 = (35 m s^{-2})^2 + 2 × (-9.81 m s^{-2}) × height (1) height = {(1225 m^2 s^{-2})/19.62 m s^{-2}) = 62.436 m^2 ≈ 60 m (1)	2	Allow 2 or 3 s.f. for answers throughout Q1. Accept g = 10 m s^{-2} Must have evidence of evaluation, e.g. unrounded 62.4 m
	(b)		Time to drop to ground is t where $s = ½ gt^2$ t = √2s/g = √{124.9 m/(9.81 m s^{-2})} = 3.57 s (1) $s = u_{horiz}\, t$ = 15 m s^{-1} × 3.57 s = 53.55 m = 53.6 m (1)	2	Other approaches possible. Using 60 m from (a) ⇒ 3.49 s (1) & 52.46 m (1) ECF own time e.g. double correct value
	(c)		$v_{vert} = gt$ = 9.81 m s^{-2} × 3.57 s = 35.0 m s^{-1} (1) tan $\theta = v_{vert}/ u_{horiz}$ = 35.0 m s^{-1}/15 m s^{-1} = 2.33 ⇒ θ = 66.8° = 67° (1)	2	Can use $v_{\text{vert final}} = - v_{\text{vert initial}}$ No credit if 60 m and 54 m used ALLOW 3.49 s from above ⇒ arctan(34.3/15) = 66°
			Total	**6**	
2	(a)		T_{sound} = 96/2 = 48 μs f_{sound} = 1/48 μs = 20 830 Hz = 20 830 Hz = 21 000 Hz(1) f_{radio}/f_{sound} = 91.5 × 10^6 /20 830 Hz = 4392 Hz = 4400 Hz (1)	2	Ignore SF errors. Allow T = 97/2 = 48.5 μs and readings to round to either. T = 48.5 μs ⇒ f_{sound} =20 600 Hz ECF own f_{sound}
	(b)		Rate ≥ 2 × 24 kHz = 4.8 × 10^4 samples s^{-1}	1	ALLOW 48 kHz or 48k on answerline
			Total	**3**	
3	(a)		V = 4.5 V × 47 Ω/[36 Ω + 47 Ω](1) = 2.55 V / 2.5 V / 2.6 V (1)	2	Or I = 4.5 V /[36 Ω + 47 Ω] = 0.054A (1) $V = IR$ = 0.054A × 47 Ω = 2.55 V (1)
	(b)		**EITHER** e.m.f. shared between more resistances (1) so 47 Ω takes a reduced fraction of p.d.(1) **OR** extra resistance in circuit ⇒ I will drop (1) $V = IR$ will drop also(1)	2	'V will decrease' with weak justification, e.g. reference to some unspecified loss, gets 1 mark Allow reference to lost volts (in battery) for m.p.1 Allow ref. to $V = E - Ir$ here
			Total	**4**	
4	(a)		$\frac{1}{v} = \frac{1}{u} + \frac{1}{f} = \frac{1}{u} + P$ (1) $P = \frac{1}{v} - \frac{1}{u} = \frac{1}{0.18\text{ m}} - \frac{1}{(-0.36\text{ m})}$ = 8.3 D (1)	2	m.p.1 credits understanding that $P = 1/f$
	(b)		Converging wavelengths to right of lens (1) Wavefronts within lens closer than those in air (1) Wavefronts within lens plane or with smaller curvature (+ or -) than the wavefronts in air (1)	3	Equally spaced (by eye) for either m.p.1 or m.p.2
			Total	**5**	

Question			Answer	Marks	Guidance
5	(a)		$A = \pi r^2 = \pi \times (1.2 \times 10^{-3}\ \text{m}/2)^2 = 1.13 \times 10^{-6}\ \text{m}^2$ (1) $F = mg = 25\ \text{kg} \times 9.81\ \text{N kg}^{-1} = 245\ \text{N}$ $\sigma = F/A = 245\ \text{N} / 1.13 \times 10^{-6}\ \text{m}^2 = 2.17 \times 10^8\ \text{Pa}$ $= 2.2 \times 10^8\ \text{Pa}$ (1)	**2**	Allow $g = 10\ \text{N kg}^{-1}$
	(b)		$E = \sigma/\varepsilon \Rightarrow \varepsilon = \sigma / E = 2.2 \times 10^8\ \text{Pa}/2.1 \times 10^{11}\ \text{Pa}$ $\varepsilon = 1.05 \times 10^{-3}$ (1) extension $\Delta x = \varepsilon L = 1.05 \times 10^{-3} \times 3.5\ \text{m} = 3.7 \times 10^{-3}\ \text{m}$ elastic strain energy $= \frac{1}{2} F \Delta x$ $= 0.5 \times 245\ \text{N} \times 3.7 \times 10^{-3}\ \text{m}$ $= 0.45\ \text{J}$ (1)	**2**	Ecf own stress σ from (a) Alternative methods possible Using 250 N gives 0.46 J
	(c)		**EITHER** **Any 3 points from:** Falling load will accelerate (1) Wire must decelerate the load to rest/above calculation does not allow for deceleration (1) Stopping quickly requires large impulse/change in momentum (1) Tension/force in wire = weight of load + force needed to decelerate load (which may well exceed maximum force possible) (1) **OR** Falling load will gain kinetic energy (1) k.e. must be dissipated by transfer to elastic p.e. in wire (1) total stress = stress due to load + stress to stretch wire and this may exceed yield stress (1)	**3**	
			Total	**7**	
			Section A total	**25**	

Question			Answer	Marks	Guidance
Section B					
6	**(a)**	**(i)**	Constant force (7.8 – 7.9 kN) from 0 drops off suddenly at t_1 to a lower constant value (4 kN) (1) Higher value is weight of skycrane + weight of rover (1) Lower value is weight of skycrane alone (1)	**3**	
	(a)	**(ii)**	Weight of rover, W = 7.8 kN – 4.0 kN = 3.8 kN (1) $g = W/m$ = 3800 N/1030 kg = 3.7 N kg^{-1} (1)	**2**	
	(b)	**(i)**	Area of CCD sensor = 1600 × 1200 = 1 920 000 pixels^2 1 pixel^2 = 1.05 × 10^{-4} m^2/1 920 000 = 5.469 × 10^{-11} m^2 (1) 1 pixel = √(5.469 × 10^{-11} m^2) = 7.395 × 10^{-6} m (≈ 7 μm) (1)	**2**	A calculated unrounded answer is enough for the 'show that'
	(b)	**(ii)**	Magnification m = v/u = 19.5×10^{-3} m/100 m = 1.95×10^{-4} (1) m = pixel separation/x where x = separation of closest resolvable point on the distant object x = 7.395 × 10^{-6} m/1.95×10^{-4} = 0.038 m (< 4 cm) (1)	**2**	A calculated unrounded answer is enough for the 'show that'
	(b)	**(iii)**	Need to encode for colour of each pixel (1) No. of images= 8 × 10^9/(1600 × 1200 × 11) = 378.8 = 378 (1)	**2**	Two independent one-mark points Allow intermediate rounding

Question			Answer	Marks	Guidance
6	(b)*	(iv)	**(Level 3) (5 – 6 marks)** Makes calculations for both method A and method B to compare the transmission of data to Earth. Compares both methods and considers using A when Earth is visible to *Perseverance* but satellites are not. *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)** Makes calculations, with possible errors, for one method involving data rates. Chooses a method but without full justification. Probably does not consider combining the methods. *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 some relevant calculations, possibly with errors. May choose a method without any real justification, e.g. comparing some of the raw data speeds. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant* **(0 marks)** Insufficient or irrelevant science. Answer not worthy of credit.	**[6]**	**Indicative scientific points may include:** **Method A (Direct transmission to Earth)** • Data sent each Martian day between 11 MB and 69 MB • 8 GB will need between 115 and 730 days. • Should assume poor transmission rate to cover worst case. **Method B (Transmission via Mars satellite)** • Critical path is 256 000 bits s^{-1} to satellite so no need to analyse transmission satellite-Earth • Data sent thus each Martian day = 123 MB • 8 GB will need 65 days **Combination of the methods** • While satellites are not in view, *Perseverance* can transmit directly to Earth • May need to send data twice to avoid possible data loss • Data can be selected by AI systems on *Perseverance* to send the best cases. **Use the L1, L2, L3 annotations in Assessor; do not use ticks.**
			Total	**17**	

Question			Answer	Marks	Guidance
7	(a)	(i)	$f = 1/T = 1/1.53 \times 10^{-15}$ s $= 6.54 \times 10^{14}$ Hz (1) $\lambda = c/f = 3.00 \times 10^{8}$ m s^{-1}/6.54×10^{14} Hz $= 4.59 \times 10^{-7}$ m (1)	2	2, 3 or 4 s.f.
		(ii)	$n = \sin(15°)/\sin(9.7°) = 1.536$ (1) $n = c_{vacuum}/c_{glass} \Rightarrow c_{glass} = 3.00 \times 10^{8}$ m s^{-1}/1.536 $= 1.95 \times 10^{8}$ m s^{-1} ($\approx 2 \times 10^{8}$ m s^{-1}) (1)	2	A calculated unrounded answer is enough for the 'show that'
		(iii)	If $\lambda\uparrow$, $(A + B/\lambda^2)\downarrow$ and so $n\downarrow$ (1) Less refraction AW (1)	2	m.p.1 is for the change to RHS of equation: must be justified $\sin i/\sin r \downarrow$ so $\sin r \uparrow$ AND $\sin r \uparrow \Rightarrow r \uparrow$
	(b)	(i)	$c_x = 3.0 \times 10^{8}$ m s^{-1} $\times \sin(15°) = 7.76 \times 10^{7}$ m s^{-1} $c_y = 3.0 \times 10^{8}$ m s^{-1} $\times \cos(15°) = 2.90 \times 10^{8}$ m s^{-1} (1)	1	Allow $c_y = c\cos(15°) = 0.97\,c$ & $c_x = c\sin(15°) = 0.26\,c$. Allow 1 s.f.
		(ii)	c_x is unchanged (because there is no component of force in the x-direction) (1) c_y increases (because there is a component of force in (positive) y-direction) (1) c increases as $\sqrt{\{(\text{same})^2 + (\text{larger})^2\}}$ will be larger (1) the angle of refraction r will be smaller than 15° (as atan$\{c_x/c_y\}$ will be smaller)/ velocity will be closer to the direction of c_y (1)	4	mp1 & mp2 need to be explained in terms of force/acceleration mp3 does not need algebraic reasoning: any sound statement e.g. 'The vertical component is bigger and so the sum of the two components will be larger than before' mp4 as for mp3: can be justified without algebra e.g. 'A larger vertical component will pull the path further down in the y-direction.'
	(c)		Any two points from: In (a), light waves travel slower in glass/water than in vacuum (1) In (b) light corpuscles travel faster in glass/water than in vacuum (1) The corpuscle theory clashes with experimental observations so it must be wrong, showing light travels as a wave. (1)	2	
			Total	**13**	
			Section B total	**30**	

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td colspan="4">Section C</td></tr>
<tr><td>8 (a)</td><td>Acceptable best-fit straight line /one correct extreme fit line. (1)
Other extreme line through uncertainty bars drawn. (1)
Gradient accurately determined; needs triangle base ≥ 20. (1)
Uncertainty in gradient found (1)
λ (and $\Delta\lambda$) correctly deduced (1)</td><td>5</td><td>If best-fit not used, second extreme fit will get this mark
Any gradient correctly determined gets this mark.</td></tr>
<tr><td>(b)</td><td>Correctly identifies minima of ammeter readings with subsidiary minima of the single slit pattern and finds value of θ in the range 20° - 27° (1)
makes reasonable estimate of $\Delta\theta$ (1)
Substitutes into $b \sin \theta = \lambda$ where b = 7.5 cm (1)
Evaluates λ (and $\Delta\lambda$) consistent with own θ (1)</td><td>4</td><td><table><tr><td>θ /°</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td></tr><tr><td>λ / cm</td><td>2.6</td><td>2.7</td><td>2.8</td><td>2.9</td><td>3.05</td><td>3.2</td><td>3.3</td><td>3.4</td></tr></table></td></tr>
<tr><td>(c)*</td><td>(Level 3) (5 – 6 marks)
Evaluates both experiments and may suggest a way in which improvement could be made.
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)
Identifies a shortcoming of one experiment. May make a suggestion, possibly incomplete or inaccurate, of how improvement could be made. 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)
Incomplete or superficial description of one or both procedures without identifying shortcomings of either.
There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant

(0 marks)
Insufficient or irrelevant science. Answer not worthy of credit.</td><td>[6]</td><td>Indicative scientific points may include:

Procedural points of double-slit experiment
• Graphical method indicates uncertainty
• Small-angle approximation does not apply
• Small range of L chosen
Procedural points of single-slit experiment
• Measurements made for only one position
• Should have concentrated readings near the minima rather than having them evenly spaced
Comparisons
• Straight-line analysis in (a) using 16 data points v two measurements in (b)
• From (a), $\lambda \approx$ 2.3 cm ± 0.5 cm [ecf own (a)]
• From (b), $\lambda \approx$ 2.85 cm ± 0.05 cm [ecf own (b)]
• Readings do not agree within their uncertainties

Use the L1, L2, L3 annotations in Assessor; do not use ticks.</td></tr>
<tr><td></td><td>Section C Total</td><td>15</td><td></td></tr>
</table>

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