GCE

Physics B

Unit **H557/02:** Scientific literacy in physics

Advanced GCE

Mark Scheme for June 2018

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

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.

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

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)		Transmitted intensity falls to minimum (after second filter is turned through 90^o) and then rises to maximum at 180°/after half a rotation/when planes of polarisation are parallel ✓ AW Filters only transmit light oscillating in one plane/plane of polarisation of filter 2 must match that of filter 1 AW ✓	2	For m.p. 2 candidate must be clear that filters only pass light in one plane (of oscillation)
	(b)	i	p.d. across LDR minimum at 0^o **and** 180^o/when planes of polarisation are parallel✓ p.d. across LDR maximum at 90^o **and** 270^o/when planes of polarisation are crossed✓ Resistance of LDR falls as light intensity rises ✓ Low(er) proportion of total resistance when light intensity high(er) ✓	4	Or 180^o **and** 360^o ORA. Look for clear link between light level and resistance ORA Fourth marking point can be given for correct and clear use of potential divider equation
		ii	$\frac{3.01}{6.00} = \frac{R_{LDR}}{(R_{LDR} + 400 \times 10^3 \Omega)}$ ✓ Calculation to $R_{LDR} = 4.03 \times 10^5 \Omega$ / 403 kΩ ✓	2	Correct bald answer merits both marks. Must use max p.d. value Unrounded R_{LDR} = 402.6755853…kΩ
			Total	8	

Question			Answer	Marks	Guidance
2	(a)		If (on average, at least) one neutron emitted in reaction interacts with U-235 nucleus **to produce further emission** ✓ AW Can be controlled by absorbing (a proportion of) emitted neutrons (so that they cannot lead to further neutron emissions) ✓ AW	2	Accept that all 3 neutrons are captured by U-235 nuclei Not just 'use control rods'. Need to be clear that the neutrons are not captured by U-235. 'control rods to absorb neutrons' just meets the m.p.2
	(b)		Binding energy per nucleon of U-235 is less negative than the (average) binding energy per nucleon✓ of the products ✓ ORA	2	Accept for one mark: Binding energy of the products is more negative/less than the binding energy of uranium-235. ORA.
	(c)		$E = (16 \times 10^{6}\ \text{eV} \times 1.6 \times 10^{-19}\ \text{J eV}^{-1}) = 2.56 \times 10^{-12}\ \text{J}$ ✓ $m = E/c^2 = (16 \times 1.6 \times 10^{-19}\ \text{J} \times 10^{6})/(9 \times 10^{16}\ \text{m}^2\ \text{s}^{-4})$ ✓ $= 2.8 \times 10^{-29}$ (kg) ✓	3	Correct bald answer gains three marks ($E = 2.56 \times 10^{-12}$ J) Unrounded $m = 2.8444\ldots \times 10^{-29}$ (kg) Answer 1.78×10^{-10} kg gets one mark only.
	(d)		number of fissions available = 1.6×10^{8} kg/3.9×10^{-25} kg $= 4.1 \times 10^{32}$ ✓ energy available = $4.1 \times 10^{32} \times (16 \times 10^{6} \times 1.6 \times 10^{-19}\ \text{J}) \times (30/100)$ $= 3.15 \times 10^{20}$ J ✓ time = 3.15×10^{20} J / 1.4×10^{18} J year^{-1} = 225 years ✓ More reserves may be found + reason (e.g. better detecting techniques/deeper core samples etc.) ✓ OR Fewer reserves + reason (e.g. assumptions are made that similar rocks will yield similar amounts)	4	Accept answers in range 220 – 231 years for three marks. If 2.8×10^{-29} kg used instead of 3.9×10^{-25} kg expect answer in region of 3×10^{6} years award two marks. Alternative method: number of fission reactions required per year = 1.8×10^{30}✓ number of uranium atoms available = 4.1×10^{32}✓ $4.1 \times 10^{32} / 1.8 \times 10^{30}$ = 228 years✓ Allow internal ecf Ignore arguments relating to changing energy consumption. Allow any reasoned reservation of the implicit assumptions used in the calculation. Accept increasing efficiency of power stations.

Question			Answer	Marks	Guidance
					Note that the question states that the rate of energy production is unchanged.
			Total	**11**	

Question			Answer	Marks	Guidance
3	(a)		mass of ^{40}K = (0.012/100) × 5 x 10^{-4} kg= 6.0 × 10^{-8} kg ✓ amount of ^{40}K = 6.0 × 10^{-8} kg/0.040 kg = 1.5 × 10^{-6} mol no of ^{40}K nuclei, N = 1.5 × 10^{-6} mol × 6.0 × 10^{23} mol $^{-1}$ = 9.0 × 10^{17} ✓ Decay constant $\lambda = \ln(2)/T_{½} = \ln(2)/4.1 \times 10^{16}$ s = 1.69 × 10^{-17} s $^{-1}$ ✓ Activity of 1 banana = λN = 1.69 × 10^{-17} s $^{-1}$ × 9.0 × 10^{17} = 15 Bq ✓	4	Allow ecf within question Forgetting to convert 0.012% to 1.2 x 10^{-4} is a POT error leading to an answer of 1500 (2 s.f.) This gains three marks.
	(b)		On average over the 20 years, time since ingesting banana = 10 years ✓ Number of bananas eaten in 20 years = 20 × 52 × 2 = 2080 ✓ No of decays in this time from 2080 bananas = 2080 × 10 years × 3.16 × 10^{7} s year $^{-1}$ × 15 Bq = 9.86 × 10^{12} decays Energy absorbed = 9.86 × 10^{12} × 8.3 × 10^{-14} J = 0.818 J ✓ Dose = 0.818 J / 70 kg = 0.0117 Gy ✓ Equivalent dose in Sv = dose in Gy as quality factor = 1 equivalent dose = 0.0117 Sv = 11.7 mSv (≈ 10 mSv)✓	5	m.p. 1 requires realisation that not all bananas will have been in the body for 20 years. Answer of 23.4 mSv gains four marks. Alternative method: Number of bananas eaten in 20 years = 20 × 52 × 2 = 2080✓ Calculating energy from one banana over 20 years (= 8.01 x 10^{-4}) ✓ Calculating dose over 20 years from one banana (= 11.4 x 10^{-6} Sv) ✓ Total dose = ½ ✓x 2080 x 11.4 x10^{-6} = 11.8 mSv✓ e.c.f time from above, and activity from (a) or use of any value in the range 10 – 20 Bq. Ignore attempts to find mean activity over this time.
	(c)		No of cancers = 60 × 10^{6} × 0.0117 Sv × (5/100) = 35 000 ✓	1	10 mSv ⇒30 000
	(d)		Any two from: • Mass of ^{40}K in 1 banana = 6.0 × 10^{-8} kg [from (a)] number of bananas' worth in body = 2.0 × 10^{-5} kg/6.0 × 10^{-8} kg = 330 ✓ • calculation of equivalent dose over twenty years from equilibrium level of ^{40}K = 3.8 mSv.	2	These marks are independent Allow 333

Question			Answer	Marks	Guidance
			• ingested bananas will have little effect of amount of ^{40}K in body/any extra is excreted • assumption that all potassium ingested remains in body is incorrect. • ^{40}K in body has other sources, not just bananas/other environmental sources of radiation are significantly greater than the dose from ingested ^{40}K ✓		
			Total .	**12**	

Question			Answer	Marks	Guidance
Section B					
4	(a)	i	$t = \sqrt{(2s/a)} = \sqrt{(2 \times 56/9.8)}$ ✓ = 3.4 s (2 s.f.) ✓	2	Accept 3.38 s
		ii	Force on body of mass *m* = *mg* Acceleration $a = F/m = mg/m$ ✓ $mg/m = g$ independent of mass ✓ AW	2	m.p.1 is for *W*=*mg* and *F*=*ma* m.p.2 is for equating these and eliminating *m* Arguing that $g = (-)GM/r^2$,independent of mass *m* gives one mark. Can gain both marks for clearly expressed non-algebraic reasoning.
	(b)	i	a = 9. 80 (m s^{-2}) ✓ v = 3.92 (m s^{-2}) ✓ s = 0.39 (m) ✓	3	Unrounded value is 9.7969… Unrounded value is 3.922 Unrounded value is 0.392 Do not penalises excessive sig. figs. in this question

Question			Answer	Marks	Guidance
4	(b)	ii	**Level 3 (5–6 marks)** Marshals argument in a clear manner. Makes clear, unambiguous comparison of results. Clearly explains the limits of iterative modelling and explains how the model can be improved. Shows understanding of the observational situation and the limits of precision of simple observation. Clearly draws all the ideas together to a logical conclusion. *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)** Correctly retrieves data from graph and shows some understanding of limits of iterative modelling but this understanding may be incompletely expressed. Makes correct statements of the observational situation but does not draw these together into a reasoned conclusion. *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)** Retrieves data from graph and makes sensible comparison between the two predicted times. May make a superficial comment about iterative modelling but does not drill down to the fundamental reason for the inaccuracy. May make a superficial comment about the observational situation. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant* **0 marks** No response or no response worthy of credit	6	**Indicative scientific points may include:** **Model:** • time to fall = 3.85 to 3.90 s • model holds acceleration / velocity constant over each time interval • holding acceleration constant will suggest higher average velocity • model underestimates time of fall • model can be improved by reducing time intervals • reducing time interval between calculations produces a model closer to continually varying acceleration. **Observational situation:** • less than one second/about ½ second difference between model without drag and model including drag. • Time difference (of about ½ s) could be to be detected (if balls dropped simultaneously) • If balls not dropped simultaneously, timing technology insufficiently accurate to distinguish drop times. • Difference in time for fall between similar (but different) masses difficult to observe if *K* values similar • Observations would be naked eye/not have modern equipment (video etc) • Subjective element in observational judgements.
			Total	**13**	

Question			Answer	Marks	Guidance
5	(a)	i	Any three from: Evacuating apparatus reduces interactions (over a given path length) ✓ Deflections can affect outcome of experiment✓ Alpha particles highly ionising ✓ So **lose their energy** in a short distance through interactions with air particles✓	3	AW throughout. Or ‘no particles in their way’ .
		ii	$r = 79 \times 1.6 \times 10^{-19} \times 2 \times 1.6 \times 10^{-19} \times 9 \times 10^{9} / 4.5 \times 10^{6} \times 1.6 \times 10^{-19}$ ✓ $= 5.056 \times 10^{-14}$ m $= 5.1 \times 10^{-14}$ m ✓ Smaller r because a more energetic alpha particle would get closer to the nucleus before its electric potential energy is equal to its initial k.e. AW ✓	3	Accept 5.0×10^{-14} m Correct bald answer gains m.p.1 & m.p.2 Not just ‘smaller r’.
	(b)	i	Gamma factor = (150 MeV + 0.51 MeV)/0.51 MeV✓ = 295✓ $v = 3 \times 10^{8} \times \sqrt{(1 - 1/295^{2})}$ ✓ $= 3.00 \times 10^{8}$ to 3 s.f. (calculator value $= 2.99998 \times 10^{8}$) ✓	4	Ecf within question. If rest energy from numerator omitted, gamma factor = 294. Two marks maximum for the question. Must show clear working credit mp4 for e.g. ‘$\sqrt{(1 - 1/295^{2})} = 0.999994 \approx 1$’
		ii	$p = 1.5 \times 10^{8} \times 1.6 \times 10^{-19}$ J$/3.00 \times 10^{8}$ m s^{-1} $= 8.03 \times 10^{-20}$ N s✓ $\lambda = h/p = 6.63 \times 10^{-34}$ J s$/8.03 \times 10^{-20}$ N s $= 8.25 \times 10^{-15}$ m ✓ $\sin\theta = 1.2 \times 8.25 \times 10^{-15}$ m$/3 \times 10^{-14}$ m $= 0.33$✓ $\theta = 19^{o}$ (.4) ✓	4	ECF within question Correct bald answer gains all four marks Algebraic reasoning that $\lambda = hc/E$ gains credit for first mark.
	(c)		via diffraction, Ag radius/Au radius $= (107/197)^{1/3}$✓	4	Algebraic reasoning gains first and third marks. Working must be shown.

Question			Answer	Marks	Guidance
			= 0.82 ✓ via closest approach, Ag radius/Au radius = Ag nuclear charge/Au nuclear charge = 47/79✓ = 0.59 (which is significantly $<$ 0.82) ✓		Allow complete calculations. Do not credit 0.81. (rounding error)
			Total	**18**	

Question			Answer	Marks	Guidance
6	(a)		Conductance $G = 1/R = 1/0.13\ \Omega$✓ (= 7.69 S) conductivity = 7.69 S × 1.5 m/(π × (2.5 ×10^{-4} m)^2) ✓ = 5.9 x 10^7 S m^{-1} (2 s.f.) ✓	3	Correct bald answer gains all 3 marks allow calculation of resistivity followed by $\sigma = 1/\rho$ for three marks. If resistivity (= 1.7 x 10^{-8} Ωm) given on answer line, one mark only.
	(b)		$v = I/nae$ =2.3 A/(8.5 x 10^{28} m^{-3} × π × (2.5 ×10^{-4} m)^2 ×1.6 × 10^{-19} C) ✓ = 8.6 x 10^{-4} m s^{-1} ✓	2	m.p.1. is for correct rearrangements and substitution m.p.2 is correct evaluation. Correct bald answer gets both marks.

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>6</td><td>(c)</td><td></td><td>Level 3 (5–6 marks)
Marshals argument in a clear manner. All technical vocabulary is used with accuracy and clarity. Explains basic model of conduction in both metals and semiconductors and clearly explains how this results in different variations of conductivity.
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)
Describes the two different mechanisms of conduction but the description lacks detail and precision. Technical vocabulary used correctly but not always with complete clarity.
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)
Attempts description of at least one type of behaviour and makes relevant points but the answer is limited and superficial.
There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant
0 marks No response or no response worthy of credit.</td><td>6</td><td>Indicative scientific points may include:
Semiconductors
• Far fewer ‘free’ electrons m^{-3} than in conductors
• Increased temperature increases energy of atoms in the semiconductor
• Increased temperature reduces fraction E/kT
• Definition/explanation of Boltzmann factor in relation to this context
• smaller fraction E/kT increases magnitude of $e^{-E/kT}$
• Linking higher Boltzmann factor to increased number density of charge carriers
Conductors:
• Conductivity decreases with increasing temperature
• Cloud of free electrons AW
• Interact with positive ions in lattice
• Electrons accelerate between interactions with lattice due to electric field
• Increase temperature increases lattice vibration
• Reduces mean free path (AW) of free electrons
• Increase in drift velocity lower than increase field strength would suggest</td></tr>
<tr><td></td><td></td><td></td><td>Total .</td><td>11</td><td></td></tr>
</table>

Section C					
Question			**Answer**	**Marks**	**Guidance**
7	**(a)**	**i**	$0 = hf_0 - \phi \Rightarrow \phi = h f_0$ ✓ $\phi = 6.63 \times 10^{-34}$ J s × 0.5 × 10^{15} Hz = 3.3×10^{-19} J ✓	**2**	Allow f_0 in the range (0.47 – 0.52) × 10^{15} Hz giving 3.12×10^{-19} J ≤ ϕ ≤ 3.45×10^{-19} J Accept bald answer in range
		ii	Work function is (minimum) energy required for an electron to escape (the surface) AW ✓ Not all photons interact with electrons on the surface (those 'deeper' in the metal require more energy to escape) AW ✓	**2**	
	(b)		Same gradient ✓ *x*-intercept at 1.0 x 10^{15} Hz ✓	**2**	Allow f_0 in the range (0.94 – 1.04) × 10^{15} Hz
			Total	**6**	

Question			Answer	Marks	Guidance
8			**Level 3 (5–6 marks)** Marshals argument in a clear manner. All technical vocabulary is used with accuracy and clarity. Makes relevant calculations which are clearly linked to the argument. Recognises reduction in reflected light implies greater transmission, increasing efficiency. *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)** Describes superposition in terms of path difference between light reflecting from the two surfaces and considers effect of change of medium on velocity and/or wavelength of light. *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)** Attempts description of superposition but does not consider the thickness of the layer nor the effect on the efficiency/ or considers effect of change of medium on velocity and wavelength of light. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant* **0 marks** No response or no response worthy of credit	6	**Indicative scientific points may include:** • Reflection on boundaries introduces a path difference • Reflected light from boundaries superposes • Principle of superposition stated • reflected waves meeting in antiphase cancel • antiphase if path difference = $(n + ½)\lambda$ • velocity of light reduced when entering a region of higher refractive index • wavelength reduced in material of higher refractive index • velocity in silicon monoxide layer = 2×10^{8} m s^{-1}. • wavelength of light in monoxide layer = 613 nm/1.5 = 410 nm • path difference = 200 nm • path difference ~ ½ λ • reduced reflected intensity • greater proportion of incident light transmitted • greater proportion of incident light interacts with electrons in silicon layer
			Total	**6**	

Question			Answer	Marks	Guidance
9	a		Change in velocity $\Delta v = V_m + 2V_M - (-V_m) = 2V_m + 2V_M$ ✓ Change in momentum = $m\,\Delta v = m \times 2V_m + 2V_M$✓ ($= 2m\,(V_m + V_M)$)	2	Can argue directly from momentum but vector nature must be clear. (e.g., original momentum of probe is negative if final momentum positive)
	b		*Any two points from:* • Change of momentum of planet = - [2m($V_m + V_M$)] • Negligible change in velocity of planet (AW) • (As the) planet is so much more massive than the spaceprobe (M » m). ✓	2	Or equal and opposite to answer to (a)/same magnitude as (a)
	c		ΔV_{grav} /Min energy required kg^{-1} = -GM/5.2 AU - (-GM/1 AU) = (6.67 × 10^{-11} N m^{2} kg^{-2} × 2.0 × 10^{30} kg) × (1/1.5 x 10^{11} m - 1/7.8 × 10^{11} m) ✓ =7.2 × 10^{8} J kg^{-1} ✓ k.e. of probe kg^{-1} = ½ (4.2 × 10^{4} m s^{-1})^{2} ✓ = 8.82 × 10^{8} J kg^{-1} (which > 7.2 × 10^{8} J)✓	4	No credit for marking points 1 and 2 if p.e. given as : 1.71 x 10^{8} J kg^{-1} (using 5.2 AU) 2.12 x 10^{8} J kg^{-1} (using 1/4.2 AU) Accept Δp.e. of probe = 2.6 x 10^{12} J for one mark Accept k.e. of probe = 3.2 x 10^{12} J for one mark
			Total	**8**	

Question			Answer	Marks	Guidance
10			Energy produced by solar cells over 8 hours = 62 100 W × (8 × 3600) s =1.788×10^9 J ✓ Energy to lift plane = 2300 kg × 9.81 N kg^{-1} × 7000 m = 1.58×10^8 J ✓ Energy to charge batteries = 9.4×10^5 J kg^{-1} × 630 kg =5.92×10^8 J ✓ 1.58×10^8 J + 5.92×10^8 J = 7.5×10^8 J < 1.788×10^9 J ✓	4	Accept arguments showing power required during day is less than useful power received from the Sun. Accept 1.57×10^9 J (using 9.8 N kg^{-1})

Question			Answer	Marks	Guidance
11			Intensity at 5.2 AU = 1.4 kW m^{-2}/$(5.2)^2$ = 0.052 kW m^{-2} ✓ Incident power = 0.052 kW m^{-2} × 60 m^2 = 3.1 kW ✓ Efficiency = (500 W/3100 W) × 100% =16% ✓	3	ecf throughout

Solar Impulse 2 Data from p 3 of ANA
Number of solar cells: 17 000
Total area of solar cells: 270 m^2
Mass of batteries: 630 kg
Energy storage in batteries: 9.4×10^5 J kg^{-1}
Total mass of plane: 2300 kg
Efficiency of solar cells: 23 %
Wingspan: 72 m

Juno Data from p 4 of ANA
number of solar cells: 19 000
total area of solar cells: 60 m^2
mass of spacecraft: 3600 kg

OCR (Oxford Cambridge and RSA Examinations)
The Triangle Building
Shaftesbury Road
Cambridge
CB2 8EA

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk

Oxford Cambridge and RSA Examinations
is a Company Limited by Guarantee
Registered in England
Registered Office; The Triangle Building, Shaftesbury Road, Cambridge, CB2 8EA
Registered Company Number: 3484466
OCR is an exempt Charity

OCR (Oxford Cambridge and RSA Examinations)
Head office
Telephone: 01223 552552
Facsimile: 01223 552553