Oxford Cambridge and RSA

GCE

Physics A

H556/03: Unified physics

Advanced GCE

Mark Scheme for June 2019

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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.

Here are the subject specific instructions for this question paper.

CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks These are awarded as <u>independent</u> marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks These are <u>method</u> marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks These are <u>compensatory</u> method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks These are accuracy or <u>answer</u> marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

SIGNIFICANT FIGURES

If the data given in a question is to 2 sf, then allow an answer to 2 or <u>more</u> significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the <u>entire</u> paper.
Any exception to this rule will be mentioned in the Guidance.

Annotations available in Scoris:

Annotation		Meaning
✓	Correct response	Used to indicate the point at which a mark has been awarded (**one tick per mark awarded**).
✗	Incorrect response	Used to indicate an incorrect answer or a point where a mark is lost.
AE	Arithmetic error	Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
BOD	Benefit of doubt given	Used to indicate a mark awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done.
BP	Blank page	Use BP on additional page(s) to show that there is no additional work provided by the candidates.
CON	Contradiction	No mark can be awarded if the candidate contradicts himself or herself in the same response.
ECF	Error carried forward	Used in numerical answers only, unless specified otherwise in the mark scheme. Answers to later sections of numerical questions may be awarded up to full credit provided they are consistent with earlier incorrect answers. Within a question, ECF can be given for AE, TE and POT errors but not for XP.
L1	Level 1	L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded.
L2	Level 2	L2 is used to show 4 marks awarded and L2^ is used to show 3 marks awarded.
L3	Level 3	L3 is used to show 6 marks awarded and L3^ is used to show 5 marks awarded.
POT	Power of 10 error	This is usually linked to conversion of SI prefixes. Do not allow the mark where the error occurs. Then follow through the working/calculation giving ECF for subsequent marks if there are no further errors.
SEEN	Seen	To indicate working/text has been seen by the examiner.
SF	Error in number of significant figures	Where more SFs are given than is justified by the question, do not penalise. Fewer significant figures than necessary will be considered within the mark scheme. **Penalise only once in the paper.**
TE	Transcription error	This error is when there is incorrect transcription of the correct data from the question, graphical read-off, formulae booklet or a previous answer. Do not allow the relevant mark and then follow through the working giving ECF for subsequent marks.
XP	Wrong physics or equation	Used in numerical answers only, unless otherwise specified in the mark scheme. Use of an incorrect equation is wrong physics even if it happens to lead to the correct answer.
^	Omission	Used to indicate where more is needed for a mark to be awarded (what is written is not wrong but not enough).

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

Annotation	Meaning
/	alternative and allowable answers for the same marking point
not	Answers which are not worthy of credit and which negate an otherwise correct answer. Sometimes written as **do not allow**.
Ignore	Statements which not worthy of credit
Allow	Answers that can be allowed
( )	Words which are not essential to gain credit
___	Underlined words must be present in answer to score the mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Question			Answer	Marks	Guidance
1	(a)		n (= pV/RT) = $2.4 \times 10^5 \times 1.2 \times 10^{-3}/8.31 \times \underline{290}$ n = 0.12 (mol)	C1 A1	**Allow** any correct rearrangement of the equation **Allow** use of $pV = NkT$ and $n = Nk/R$ or $n = N/N_A$ (n = 0.1195)
	(b)		pV = constant (or $p_1V_1 = p_2V_2$) $p_{final} = 2.4 \times 10^5 \times 1.2/1.5$ = $1.9(2) \times 10^5$ (Pa)	C1 C1 A1	Alternative method: $p = nRT/V$ (p must be the subject) **Allow** use of $p = NkT/V$ (with $N = 7.2 \times 10^{22}$ and $k = 1.38 \times 10^{-23}$) Substitute $p = 0.12 \times 8.31 \times 290 / 1.5 \times 10^{-3}$ **ECF** from 1a for incorrect n and/or T $p = 1.9(3) \times 10^5$ (Pa)
	(c)	(i)	$\Delta p = (2.4 - 1.0) \times 10^5 = 1.4 \times 10^5$ (Pa) upwards force (= ΔpA) = $(2.4 - 1.0) \times 10^5 \times 1.1 \times 10^{-4}$ = 15 (N)	C1 C1 A0	Alternative method: Downwards force (from trapped air) = $pA = 2.4 \times 10^5 \times 1.1 \times 10^{-4}$ = 26.4 (N) **and** upwards force (from atmosphere) = $pA = 1.0 \times 10^5 \times 1.1 \times 10^{-4}$ = 11.0 (N) So total upwards force = 26.4 – 11.0 = 15.4 (N) **Ignore** any attempt to calculate weight **Special case: Allow** 1/2 for the use of $\Delta p = 2.4 \times 10^5$ (Pa) giving upwards force = 26.4 (N)

Question			Answer	Marks	Guidance
		(ii)	*m* = 0.3 + 0.05 (= 0.35) (kg)	**C1**	0.050 + (10^3 x 0.3 x 10^{-3})
			(Resultant force = upwards force – *W* = *ma*) 15.4 – (0.35 × 9.81) = 0.35*a* **or** *a* = 12/0.35	**C1**	Alternative approach: *a* = (15.4/*m*) - g **ECF** for incorrect value of *m* **No ECF ci** (since we are told that upwards force = 15(.4)(N))
			a = 34 (m s^{-2})	**A1**	Upwards force = 15 (N) gives *a* = 33 (m s^{-2})
	(d)		• (initial) upward force unchanged • (initial) downwards force/weight increases • (initial) resultant force decreases • (initial) acceleration decreases • (initial) rate of change in momentum of rocket decreases • time taken to expel water increases • valid conclusion that the maximum height depends on more than one factor	**B1 x 3**	**Maximum 3** marks from 7 marking points: **Ignore** comments which assume an increase in pressure **Ignore** heavier **Allow** net or unbalanced or total for resultant **Allow** fuel for water e.g. the height depends on the bottle's velocity and its height when all the water has been expelled / the height depends on both the acceleration and the time taken to expel the water
			Total	**13**	

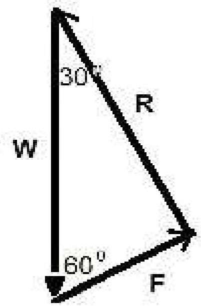
Question			Answer	Marks	Guidance
2	(a)		superscripts 1,60,0 subscripts 0,28,-1 $\bar{\nu}_{(e)}$ (nu-bar)	B1 B1 B1	 recognisable correct symbol required If superscripts and subscripts included, both must be 0
	(b)	(i)	Beta radiation would not penetrate/ would be absorbed by the lead	B1	**Not** gamma radiation would be stopped **Ignore** reference to alpha radiation
		(ii)1	$\ln N = -\mu d + \ln N_0$ compared to y = mx + c (so m = - μ and c = $\ln N_0$)	B1	**or** $\ln N = \ln(N_0 e^{-\mu d}) = \ln N_0 - \mu d$
		(ii)2	5.70 ± 0.14	B1 B1	Both answers must be to 2d.p. **Allow** ± 0.13 **not** second B1 mark without correct working shown e.g. ln300 – ln260 or (5.83-5.56)/2 **Allow** $\Delta N/N$ (= 40/300) but only if $\Delta(\ln N) \approx \Delta N/N$ is quoted
		(ii)3	Point plotted correctly to within ½ small square Best fit and worst fit line(s) drawn	B1 B1	**Ignore** accuracy of length of error bar **ECF (ii)2** for incorrect value(s) in table **ECF (ii)2** for incorrect value(s) in table Best fit line should have an equal scatter of points about the line Worst fit line should be steepest/shallowest possible line that passes through <u>all</u> the error bars (allow ±½ small square tolerance vertically)

Question			Answer	Marks	Guidance
		(ii)4	gradient of best fit line = (-) μ = (-) 54 (m^{-1})	**B1**	**Allow** 51 to 56 **Allow** value of μ up to 4 SF **ECF(ii)3** for wrongly plotted point
			large triangle used to determine gradient of best fit line	**B1**	Δd > 25mm (seen from graph or working)
			calculation of absolute uncertainty using <u>their</u> values in the formula (│wfl gradient – bfl gradient│)	**B1**	**ECF (ii)3** for worst fit line **Ignore** any POT error in gradients **Allow** value of absolute uncertainty up to 3 SF only
			uncertainty and value of μ to same number of dp	**B1**	e.g. 53.4 ± 5.6 or 54 ± 6
		(ii)5	$\mu d_{½}$ = ln2 (or 0.693)	**C1**	**ECF (ii)4** for μ <u>Alternative method</u>: ln(N_0 /2) =7.67 (C1)
			$d_{½}$ = 0.013 (m)	**A1**	then use of graph to give $d_{½}$ = 0.013±0.001 (m) (A1)
			Total	**15**	

Question			Answer	Marks	Guidance
3	(a)		• (Induced) e.m.f. is caused by a change in (magnetic) flux (linkage) / (Induced) e.m.f. is proportional (or equal to) the <u>rate</u> of change of (magnetic) flux (linkage) • The peaks are inverse / e.m.f. changes from positive to negative because: the rate of change of magnetic flux linking the coil changes sign **or** the flux (linkage) increases and then decreases **or** description in terms of Lenz's law as seen by coil to conserve energy • The e.m.f.becomes zero because: the (rate of) change of magnetic flux is zero when the magnet is in the middle of the coil • The second peak has a larger negative amplitude because: the <u>rate</u> of change of flux linkage is greater (when the magnet leaves the coil compared to when it enters) • The pulses have different widths because: the second Δt is shorter (since magnet accelerates) **or** areas under curves must be the same (because total change of flux linkage is the same on entering and leaving coil) / area under curve = $V\Delta t = N\Delta\varphi$ (so bigger V leads to smaller Δt)	B1 x 3	**Maximum 3** marks from 4 marking points. **Not** voltage or p.d. or current for e.m.f. **Accept '**cutting of field lines by coil' for 'change in flux' <u>Answers to any of the last three points must link clearly to the correct graph characteristic</u> **Allow** the North (or South) pole first approaches then recedes **Ignore** magnet approaches then recedes / field increases then decreases **Not** torch is inverted **Allow** no field lines are being cut **Allow** the magnet is accelerating / is travelling faster when it exits the coil

Question			Answer	Marks	Guidance
	(b)	**(i)**	$Q = 9.0 \times 10^{-3} \times 2 \times 80 = 1.44$ (C)	**C1**	
			$W = (Q^2/2C =)\ 1.44^2/2 \times 0.12$	**C1**	**ECF** for incorrect Q e.g. 2/3 for use of $Q = 0.72$(C) giving $W = 2.2$(J)
			$W = 8.6(4)$ (J)	**A1**	
		(ii)	($W = Pt$ so $8.6 = 0.050t$)		
			$t = 8.6/0.050 = 170$ (s)	**A1**	**ECF (b)(i)** for incorrect W
	(c)		**see page 14**	**B1 x 6**	
			Total	**13**	

Question			Answer	Marks	Guidance
3	(c)		**Level 3 (5 - 6 marks)** Clear determination of input energy, procedure and analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear, relevant and substantiated.* **Level 2 (3 – 4 marks)** Clear determination of input energy and procedure, but no analysis **or** Clear analysis but limited determination of input energy and/or limited procedure **or** Attempted determination of input energy, basic procedure, and an attempt at analysis *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)** A limited selection from the scientific points worthy of credit. *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.*	B1 x 6	**Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc.** Candidates can gain full credit for investigating the efficiency of either: Method 1(M1): GPE (*nmgh*) to energy conversion in LED (*Pt*) **or** Method 2(M2): GPE (*nmgh*) to energy stored in capacitor ($\frac{1}{2}CV^2$ or $\frac{1}{2}Q^2/C$) <u>L1 maximum for any answers which do not use GPE as input energy</u> **Indicative scientific points may include:** **Determination of input energy** • record the number of inversions, *n* • (use electronic / top pan balance to) measure mass of magnet *m* • (use mm ruler to) measure tube length l_t and magnet length l_m • calculate $h = l_t - l_m$ • calculate (GPE =) *nmgh* **Procedure** • invert torch *n* times (with torch switched off) • make sure that the magnet falls the full height h between inversions • M1 switch torch on and (use stopwatch to 0.1 s to) measure time *t* taken until LED goes out (use video with timer for greater accuracy) • M1 use a darkened room or view LED through tube • M2 (use voltmeter across capacitor to) measure final p.d. V_f • M2 (with coulombmeter) measure final charge Q_f stored by capacitor • repeat experiment for different *n* **Analysis of efficiency** • M1 calculate $W = Pt$ where P = 50 mW • M2 calculate $W = \frac{1}{2}CV_f^2$ or $\frac{1}{2}Q_f^2/C$ • calculate efficiency = *W/nmgh* • compare efficiency values for different *n* • plot suitable graph e.g. efficiency against *n* / *W* against *nmgh* • plot *t* against *n* (M1) / V^2 or Q^2 against *n* (M2) with justification • discuss shape / gradient of graph

Question			Answer	Marks	Guidance
4	(a)		W (= mg) = 8.0 × 9.81 F = (W sin30 = 78.5 × 0.5 =) 39 (N) R = (W cos30 = 78.5 × 0.87) = 68 (N)	C1 A1 x 2	= 78(.5) (N) **not** 80 (N) **Allow** 8g **Allow** 1/2 for *F* and *R* the wrong way round  Credit full marks for use of a scale drawing which gives answers correct to ±2N **Special case:** Allow 2/3 for use of W = 80 (N) giving F = 40 (N) and R = 69 (N)
	(b)	(i)	F = (mv^2/r =) 8.0 × 1.5^2/2.0 F = 9.0 (N)	C1 A1	 **Allow** answer to 1s.f.

Question			Answer	Marks	Guidance
	(b)	(ii)	• Suitcase accelerates / changes its velocity / (constantly) changes direction / has a resultant force acting on it / is no longer in equilibrium • The resultant force must act (horizontally) towards centre of circle / to the left • The centripetal force can only be provided by (an increase in) *F* • Increased vertical component of *F* means the vertical component of *R* must decrease (in order to balance *W*) So *R* must decrease	B1 x 4 A0	Any answer that mentions **centrifugal** force scores 0/4 **Ignore** any statement that treats the centripetal force as an extra force **Allow** net or unbalanced or total for resultant throughout **or** $F\cos30^0 - R\sin30^0$ increases (from 0 to 9.0 (N)) / the (magnitude of the) horizontal component of *F* must exceed the (magnitude of the) horizontal component of *R* **not** a resultant force acts towards **Y** e.g. Friction is the only force able to provide the centripetal force / only *F* has a component to the left **Allow** *F* provides the centripetal force **Not** the horizontal force must increase / increases **or** $F\sin30^0 + R\cos30^0 = W$ / *W* is the vector sum of *F* and *R* / $W = (F^2 + R^2)^{½}$ (and *F* increases while *W* remains constant)
			Total	9	

Question			Answer	Marks	Guidance
5	(a)		**Level 3 (5 - 6 marks)** Clear procedure or correct determination of wavelength, plus reasonable estimation of uncertainty in λ or (sin) θ *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)** Description of procedure or correct determination of λ, but no estimation of uncertainty **or** Clear estimation of uncertainty in wavelength but limited description of procedure and/or determination of λ or (sin) θ **or** Some description of procedure, an attempt to determine the wavelength, and an attempt to estimate uncertainty in some of the measurements (e.g. in x) *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)** A limited selection from the scientific points worthy of credit. *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.*	B1 x 6	**Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc.** L1 maximum for any answers which use formula $\lambda = ax/D$ **Indicative scientific points may include:** **Procedure** • use formula $n\lambda = d\sin\theta$ • n = 1 since first order spectrum • find d using number of lines/mm = 300 mm^{-1} • find θ using distance of grating from plastic ruler = 0.50 m and x = 0.10 m (**not** protractor) **Determination of wavelength** • calculate d (= $10^{-3}/300$) = 3.3 x 10^{-6} m • use x = 0.10 m and distance to grating = 0.50 m to calculate tan θ (= 0.2) • θ = 11.3^{o} • sin θ = 0.196 • alternatively, calculate hypotenuse of triangle (using Pythagoras's theorem) = 0.51 m, giving sinθ (= $0.10/2600^{½}$) = 0.196 • **allow** use of small angle rule (sin$\theta \approx$ tan$\theta \approx \theta$ = 0.2) • calculate λ (= 0.196 × $10^{-3}/300$) = 650 nm **Estimation of uncertainty** • negligible uncertainty in d (and n) • uncertainty in sin θ is found using uncertainty in distance measurements • uncertainty in each distance measurement is ± 1.0 mm **or** ± 0.5 mm **or** ± 2.0 mm • maximum % uncertainty in tan θ / θ / sin θ = 3% • so % uncertainty in λ = % uncertainty in sin θ = 3%

Question			Answer	Marks	Guidance
5	(b)	(i)	$E = (hc/\lambda) = 6.63 \times 10^{-34} \times 3(.00) \times 10^{8} / 486 \times 10^{-9}$ $E = 4.09 \times 10^{-19}$ (J)	M1 A0	This is a 'show that' question so the mark is for giving the full substitution of values leading to an answer correct to 3 SF
		(ii)	(vertical) arrow pointing downwards from -1.36 to -5.45	B1 B1	
			Total	**9**	

Question			Answer	Marks	Guidance
6	(a)		Observed frequency is different to source frequency when source moves relative to observer.	B1	**Allow** synonyms for 'observed' e.g. perceived / detected / measured **Allow** any correct description of relative motion e.g. when source moves towards an observer (but **not** when source / observer moves) **Allow** the change in observed frequency / the apparent change or shift in frequency when source moves relative to observer **Allow** wavelength in place of frequency Answers must convey the difference between observed frequency and source frequency rather than a change in source frequency
	(b)		• Pulses (of ultrasound waves) are aimed at / reflected from the (moving) blood (cells in the artery). • The probe / transducer is placed at an angle (usually 60^0) (to the artery) • The (detected) frequency of returning/reflected waves is different to that of the emitted waves. • (Knowing the speed of ultrasound in blood and) the ratio of the frequencies enables the speed (of blood flow) to be calculated/**AW**	B1 x 2	**Max** 2 marks from 4 marking points **Allow** ultrasound is emitted at an angle **Allow** there is a change in frequency when the wave is reflected **Allow** v found using formula $\Delta f = 2fv\cos\theta/c$ with c defined as velocity of (ultra)sound (in the medium) **not** light

Question			Answer	Marks	Guidance
	(c)	(i)	T = 0.50 (s) **or** f = 2.0 (Hz)	C1	
			v = ($2\pi r/T$ =) $2\pi \times 0.60/0.5$	M1	**Allow** 1.2π/0.5 or 2.4π
			v = 7.5 (m s^{-1})	A0	= 7.54 (m s^{-1}) Alternative method: ω = 4π or 12.6 (rad s^{-1}) **(C1)** v (= r ω) = 0.60 x 12.6 or 2.4π **(M1)** = 7.54 (m s^{-1}) **(A0)**
		(ii)	Δf (≈ vf/c) = (7.5 x 1700) / 330	C1	Note that c represents the velocity of sound
			Δf = 40 (Hz) (or 39Hz)	A1	
		(iii)	y-axis labelled with correct scale	B1	**Allow** as a minimum one labelled point i.e. 1740 **or** 1660 **ECF(c)(ii)** for incorrect Δf
		(iv)	**X** labelled at lowest point of circle on Fig. 6.1	B1	
	(d)		Accuracy is (a quality denoting) the closeness of the measured value to the true value	B1	**Allow** readings/results/data/values/measurements for *measured value*; actual/real/allowed/correct for *true*
			Precision is (a quality denoting) the closeness of agreement between measured values (obtained by repeated measurements)	B1	**Allow** measurements are close together/are similar/have small range/have low spread/have low scatter/have good agreement/are all close to the average
			Total	**11**	

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