OCR
Oxford Cambridge and RSA

GCE

Physics B

Unit **H557A/02:** Scientific literacy in physics

Advanced GCE

Mark Scheme for June 2017

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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.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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.

Annotations available in RM Assessor

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
✗	Incorrect response
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
TE	Transcription error
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
SF	Error in number of significant figures
✓	Correct response
?	Wrong physics or equation

Question			Answer	Marks	Guidance
1	(a)		Any three from: • Waves reflect from the ends of the tube • superpose when they pass through one another • A formed when waves superpose in phase • N formed when waves superpose in antiphase	3	'Reflection' alone insufficient for first marking point. Accept 'interference' or 'superimpose' for 'superposition'. Do not credit 'constructive interference' for 'in phase' or 'destructive interference' for 'in antiphase'
	(b)		Even pattern: A N A N A✓ Explanation: same velocity so half wavelength gives twice frequency✓	2	Must make it clear that the relationship between wavelength and frequency depends on constant velocity. Quoting $v = f\lambda$ not sufficient without clear statement of constant v. .
	(c)		$\frac{pV}{\rho} = \frac{nRTV}{m}$ ✓ $\frac{p}{\rho} = \frac{RT}{M}$ ✓ As $v = \sqrt{\frac{kp}{\rho}}$, $v = \sqrt{\frac{kRT}{M}}$	2	Other routes acceptable. Clear and unambiguous working required. Look carefully for confusion between similar symbols.
	(d)		$\frac{f_{303}}{262} = \sqrt{\frac{303}{293}}$ ✓ $\frac{f_{303}}{262}$ = 1.017 ✓ frequency = 1.1017 x 262 = 266 Hz ✓	3	Correct bald answer gains three marks Credit $f \propto \sqrt{T}$ one mark Value 271 Hz gains zero marks
			Total	**10**	

Question			Answer	Marks	Guidance
2	(a)		p.d. across resistor = 6.0 V × (4.7 × 10^3 Ω /6.7 × 10^3 Ω) ✓ = 4.2 V ✓	2	Need own value and working shown Calculator value = 4.21 V
	(b)		*RC* = 2200 × 10^{-6} F × 6.7 × 10^3 Ω ✓ = 14.7 s ✓	2	Need own value and working shown Calculator value = 14.74 s
	(c)		4.7 kΩ at 4.0 or 4.2 V at *t* = 0, exponentially (by eye) decreasing to 0.0 V at *t* = 5 *RC*. ✓ 2.0 kΩ at 2.0 or 1.8 V at *t* = 0, exponentially (by eye) decreasing to 0.0 V at *t* = 5 *RC*. ✓	2	Lines must be labelled. Credit one mark if both lines labelled and start from correct p.d. at *t* = 0 s and show decrease of p.d. over time.
	(e)		$e^{-t/RC}$= 1 – 5/6 ✓ $-t/RC$ = ln (1/6) ✓ $-t/(15\ s)$= -1.79✓ *t* = 27 s ✓ (26.9) Alternative method: Horizontal line drawn on graph from p.d. = 5.0 V ✓ Vertical line to RC in range 1.7 – 1.9 RC (expected 1.8 RC) ✓ *t* = RC value x 1.8✓ *t* in range 25 s to 28 s ✓	4	26 s if 14.7 s used for time constant 26.3 s if 14.7 s used for time constant Correct bald answer gains four marks ECF from 2 (b)
			Total	**10**	

Question			Answer	Marks	Guidance
3	(a)		First two marking points, any two from: • air particles in random motion • when particles collide with sail the particles/sail experience change of momentum • Force on sail is rate of change of momentum • Pressure is force per unit area Third marking point: As large numbers of particles involved, force is the same on both sides.	3	Accept 'transfer of momentum' for change of momentum Accept equal numbers of collisions on both sides of sail
	(b)		m_{air} striking sail in 1 s = 18.0 m s^{-1} × 8.0 m^2 × 1.2 kg m^{-3}✓ = 172.8 kg ✓ $\frac{\Delta p}{\Delta t}$ = 172.8 kg × 18 m s^{-1} = 3110 N ✓ If all the air stopped at the sail there would be a build-up of air etc. therefore the assumption is suspect✓	4	173 N on answer line gains zero marks for calculation. .Any sensible suggestion e.g. • Sail starts moving • Particles bounce off sail Bald statement that assumption is incorrect gains zero
	(c)		accelerating force = 300 cos50✓ =193N ✓ $t = \sqrt{\frac{2 \times 50}{193/135}}$ ✓ = 8.4 s ✓	4	Correct bald answer gains four marks If sin50 used, 2 marks max : $t = \sqrt{\frac{2 \times 50}{230/135}}$ ✓ t = 7.7 s✓ (7.66)
			Total .	**11**	

Question			Answer	Marks	Guidance
Section B					
4	**(a)**		$4.5 \times 60 \times 60 \times 3 \times 10^8$ ✓ $= 4.9 \times 10^{12}$ m ✓ (calculator value = 4.86×10^{12} m)	**2**	4.8×10^{12} m one mark only (rounding error) Bald correct answer, 2 marks
	(b)	**i**	Number of pixels across diameter of Pluto = (diameter of Pluto on image/length of square) × 1024 ✓ = range: 580 to 650 ✓ resolution = 4.2 to 4.7 km pixel^{-1} ✓	**3**	Use of 1024^2 gives 0/3 Bald answer in range 4.2 to 4.7 km pixel^{-1} gains three marks.
	(b)	**ii**	angle subtended by Pluto at 770 000 km = 0.0035 rad✓ number of pixels across Pluto = $0.0035/5 \times 10^{-6}$ = 700 ✓ resolution = 2700 km/700 pixels = 3.9 km pixel^{-1} ✓ Sensible comment relating to value from 4 bi e.g. same order of magnitude, difficulty of establishing number of pixels across diameter in Fig. 4.1a✓	**4**	In calculation, discount use of data from image used in part 4 b i. More needed than ‘this answer seems to fit’

Question			Answer	Marks	Guidance
4	(c)		**Level 3 (5–6 marks)** Marshals argument in a clear manner. All relevant calculations are correctly made and the drop in power over the journey for both sources is compared. *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)** May make most of the correct calculations but the discussion lacks clarity and/or depth. For example, a statement is made about the intensity of sunlight but it is not linked to inverse square relationship. Answer may not conclude by linking results from the calculations to the comparison of power sources. *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 expected points but the answer is superficial and incomplete. *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:** **Solar power:** • Sunlight grows less intense with distance from the Sun • discussion of $1/r^2$ variation with arithmetical support (e.g. power of solar cells drops by 1600 ×) **RTG discussion:** • Number of plutonium nuclei at launch = 2.2×10^{25} (2 sf) • Activity at launch = 5.4×10^{15} Bq • Power at launch = 4800 W (3.0×10^{16} MeV s^{-1}) • Power at Pluto = 4500 W (2.8×10^{16} MeV s^{-1}) • Power loss during journey less than 10% • Power loss from rtg far less than power loss from Sun
			total	**15**	

Question			Answer	Marks	Guidance
5	(a)		First two marking points any two from: • Boltzmann factor indicates proportion of particles with sufficient energy to undergo a process AW: accept probability of having sufficient energy • bigger *f* at given temperature means more particles have enough energy to react (in stem) (ora) • greater activation energy means fewer particles react at any particular temperature o.r.a. Third marking point: **C** has smaller *f* i.e. fewer particles that can react (at any particular temperature) and so greater activation energy *E* ✓	3	or: *E* is larger ⇒ *E*/*kT* is larger✓ ⇒ exp(-*E*/*kT*) is smaller (at that value of *T*) ✓ so, at any *T*, the lowest value of *f* means the largest *E*, i.e. **C** ✓ Not sufficient just to state C has smaller *f* so greater *E*
	(b)	i	$4.9 \times 10^{-8} = e^{-\frac{E}{1.4\times10^{-23}\ \mathrm{J\,K^{-1}}\times 310\ \mathrm{K}}}$ ✓ $E = \ln(4.9 \times 10^{-8}) \times (-310\ \mathrm{K} \times 1.4 \times 10^{-23}\ \mathrm{J\,K^{-1}})$ ✓ $= 7.3 \times 10^{-20}$ J✓	3	Or: ln *f* = -*E*/*kT* for first mark Correct bald answer gains three marks If 1.38×10^{-23} used, value = 7.2×10^{-20} J
		ii	In random collisions **exchange** energy ✓ some particles gain energy in successive collisions ✓	2	Accept 'transfer' or 'gain' for exchange. Allow momentum for energy in first marking point. Insist on energy for second marking point. i.e. idea of particles 'getting lucky'.

Question			Answer	Marks	Guidance
5	(b)	iii	**Level 3 (5–6 marks)** Marshals argument in a clear manner. Relevant calculations are correctly made with accurate working, clear links between BF and rate of evaporation and reduction in average energy of particles remaining on the skin. *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)** May make most of the correct calculations but the discussion lacks clarity and/or depth.E.g., a link between BF and rate of evaporation may be made, but not the link between rate of evaporation and the skin sensation. *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 calculations and reaches some correct answers. Either answers purely qualitatively or does not use calculations in the succeeding discussion. *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:** • Clear working towards calculated value of BF • BF = 2×10^{-7} • BF about 4 times that of water at the same temperature • Rate of evaporation affected by BF • Particle explanation of rate sensitivity on BF • (Quicker) evaporation leads to (quicker) decrease of average energy of particles remaining • Hence temperature of remaining fluid drops more quickly • Skin is the ultimate source of energy for the particles in the liquid. • (Quicker) energy transfer from skin to liquid when the liquid cools
			total	**14**	

Question			Answer	Marks	Guidance
6	(a)		Charge: one negative charge on LHS, one on RHS as **neutrinos are neutral** ✓ Lepton number: neutrino and antineutrino sum to zero lepton **number as neutrino = +1 and antineutrino -1** ✓ Other conserved quantity: mass-energy; momentum✓	3	Accept cancel out Accept implicit assumption that the lepton number of muon and electron are the same. Don't accept 'mass' or 'energy' Accept spin, total energy, angular momentum
	(b)		Rest energy of electron = 9.1×10^{-31} kg × 9×10^{16} m^2 s^{-2} = 8.19×10^{-14} J ✓ = 0.51 MeV ✓ Ratio: muon/electron = 207 ✓ ORA	3	Or calculate mass of muon: Rest energy (J) = 1.7×10^{-11} J ✓ Mass = 1.9×10^{-28} kg ✓ Ratio = 207 ✓
	(c)		time of travel = 8000/(0.98 x 3 x 10^8) = 27 μs ✓ % remaining = 100 × $e^{-(0.693 \times 2.7 \times 10^{-5}/1.5 \times 10^{-6})}$ ✓ = 0.0004% ✓	3	All working must be shown. Intermediate value for time not required. Alternative method: no. of half-lives = 18.1 ✓ Fraction remaining = $1/2^{18.1}$✓ = 3.6×10^{-6} = 0.0004 %✓
	(d)	i	Muons are moving at an appreciable fraction of *c*✓ Relativistic factor appreciably greater than 1✓ Observed half life will be dilated as $t = \gamma\tau$✓	3	AW throughout. Credit discussion of fewer half-lives (or 'wristwatch time' dilated) leading to higher numbers reaching ground 1 mark.
		ii	Number of half lives from (c) = 18.1 ✓ Number of half-lives for 9% remaining = 3.47 ✓ γ = ratio 18.1.6/3.5 = 5.2 ✓	3	Other routes possible. Eg: log 0.000004 ✓/log 0.09 ✓ = 5.2 ✓ (5.1 if 0.000005 used) ECF from 6 (c) on this method. Calculation via speed of muons only worth 1 mark, leading to 5.03 OR: number of half-lives = 3.47✓ Time for 3.47 half-lives = 5.2×10^{-6} s✓ Dilation = $2.7 \times 10^{-5}/5.2 \times 10^{-6}$ s = 5.22✓ ECF from (c)
			total	**15**	

Section C					
7			(Equal) increments on the distance scale represent equal powers of ten AW✓ Such scales make it difficult to interpolate values ✓AW	2	
8			Cube Method: Number of atoms/m^3 = (10 500 kg m^{-3})/(1.8 × 10^{-25} kg) = 5.8 × 10^{28} ✓ Volume occupied by one atom = 1/5.8 x 10^{28} m^{-3} = 1.7 × 10^{-29} m^3 ✓ diameter (length of side of cube) = (1.7 × 10^{-29} m^3)$^{1/3}$ = 2.6 × 10^{-10} m ✓ Assumption: atoms are in simple cubic lattice ✓ Sphere method: Number of atoms/m^3 = (10 500 kg m^{-3})/(1.8 × 10^{-25} kg) = 5.8 × 10^{28} ✓ Volume occupied by one atom = 1/5.8 x 10^{28} m^{-3} = 1.7 × 10^{-29} m^3 ✓ This gives radius = 1.6 × 10^{-10} m , therefore diameter = 3.2 × 10^{-10} m ✓ Assumption: volume between spheres can be ignored. ✓	4	Correct bald answer gains 3 marks Accept: no gaps between atoms, atoms are cubes. It is not enough to give ‘atoms are spheres’ as an assumption.
9	a	i	0.2 m ✓	1	
		ii	One mark from: % uncertainty in distance measurement ~ 3% uncertainty in separation = 25% ✓ Second mark: both uncertainties correctly given and sensible comparison drawn.	2	ECF from (a) (i): 0.4 m give % uncertainty ~ 7%
		iii	Minimum angle = (2 × 10^{-3} m)/(6 m) = 0.0003 rad ✓ Uncertainty of the order ± 0.0001 rad ✓ Evidence of how uncertainty estimated ✓ SF penalty if uncertainty s.f. not consistent with value s.f. of angle.	3	Look for calculating maximum and/or minimum possible final values. Accept argument from % uncertainty
	b		Calculation of resolution to 0.0002 radian✓ (1 sf) Comment: suggests better resolution than eye but agree to 1 sf with smallest angle from experimental data (with uncertainty taken into account) ✓	2	Ignore s.f. error Second point needs to make a clear link to range of experimental results.

			total	**8**	
10			Either: angle in radian = 1.8(4) × 10^{-6} rad ✓ distance = (1.5 × 10^{11} m)/1.8(4) × 10^{-6} = 8.15 × 10^{16} m ✓ = 8.5 light years ✓ Or: sin (or tan) 0.38 arc seconds used ✓ distance = 1.5 x 10^{11}/ sin (0.38/3600) = 8.14 × 10^{16} m ✓ = 8.5 light years ✓ Or: Distance in parsecs = 1/0.38 = 2.63 pc✓ Calculation of 1 parsec = 3.1 x 10^{16}m ✓ Distance in light years = 2.63 x 3.1 x 10^{16}m / 10^{16} m = 8.2 light years.	**3**	If data sheet value of 1 light year is approximately 10^{16} m gives values 8.15 light years. Bald correct answer gains 3 marks as do alternative methods leading to correct answer Data sheet value of 1 light year = 10^{16} m If 9.6 x 10^{15} m used answer via parsecs= 8.5 light years.
11			Different parts of the atmosphere will have different refractive indices ✓ Leading to changing direction of light as it travels through the atmosphere and therefore a distorted image AW✓	**2**	Accept different air densities cause refraction . Second mark dependent on first.

Question			Answer	Marks	Guidance
12			**Level 3 (5-6 marks)** Clear description of process of absorption line formation including use of photon model of light and reference to energy levels within atoms. Discussion of inverse-square law and using it to find correct distance to star Y. *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)** Incomplete description of absorption line formation – perhaps omitting a clear description of the quantum aspect or the idea that different elements have different spectra. Reasonable attempt at description of inverse-square law and distance may be correctly calculated but the working may not be clear *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)** Little development of ideas, no attempt or poor attempt at calculating the distance. Discussion of spectra 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.*	6	**Indicative scientific points may include:** Absorption spectra: • Photons/light travelling through cold gas • Certain frequencies of light absorbed • Energy of photons matches energy differences between energy levels (in cold atoms) • Different elements have different spectral lines because of different energy levels. • Stars can be grouped into classes by their spectra which gives a good indication of the absolute brightness of a star. Absolute and apparent brightness: • Brightness of a star varies with 1/distance^2 from the star • Example to explain (eg 3 times the distance, 1/9 the apparent brightness) • $1/12^2 = 3/(\text{distance to } x)^2$ • Calculation to 20.8 parsec • Recognition that answer can be found from $12 \times (3)^{1/2}$
			total	**6**	

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