AQA

A-level
Physics

7408/3BA - Paper 3

Section B - Astrophysics

Mark scheme

June 2018

Version/Stage: 1.0 Final

Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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Physics - Mark scheme instructions to examiners

1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the Examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

2. Emboldening

2.1 In a list of acceptable answers where more than one mark is available 'any **two** from' is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.
2.2 A bold **and** is used to indicate that both parts of the answer are required to award the mark.
2.3 Alternative answers acceptable for a mark are indicated by the use of **or**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

3. Marking points

3.1 Marking of lists

This applies to questions requiring a set number of responses, but for which candidates have provided extra responses. The general principle to be followed in such a situation is that 'right + wrong = wrong'.

Each error / contradiction negates each correct response. So, if the number of errors / contradictions equals or exceeds the number of marks available for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by 'Ignore' in the mark scheme) are not penalised.

3.2 Marking procedure for calculations

Full marks can usually be given for a correct numerical answer without working shown unless the question states 'Show your working'. However, if a correct numerical answer can be evaluated from incorrect physics then working will be required. The mark scheme will indicate both this and the credit (if any) that can be allowed for the incorrect approach.

However, if the answer is incorrect, mark(s) can usually be gained by correct substitution / working and this is shown in the 'extra information' column or by each stage of a longer calculation.

A calculation must be followed through to answer in decimal form. An answer in surd form is never acceptable for the final (evaluation) mark in a calculation and will therefore generally be denied one mark.

3.3 Interpretation of 'it'

Answers using the word 'it' should be given credit only if it is clear that the 'it' refers to the correct subject.

3.4 Errors carried forward, consequential marking and arithmetic errors

Allowances for errors carried forward are likely to be restricted to calculation questions and should be shown by the abbreviation ECF or *conseq* in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

3.5 Phonetic spelling

The phonetic spelling of correct scientific terminology should be credited (eg fizix) **unless** there is a possible confusion (eg defraction/refraction) with another technical term.

3.6 Brackets

(…..) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

3.7 Ignore / Insufficient / Do <u>not</u> allow

'Ignore' or 'insufficient' is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

'Do **not** allow' means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.

3.8 Significant figure penalties

Answers to questions in the practical sections (7407/2 – Section A and 7408/3A) should display an appropriate number of significant figures. For non-practical sections, an A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the **final** answer in a calculation to a specified number of significant figures (sf). This will generally be assessed to be the number of sf of the datum with the least number of sf from which the answer is determined. The mark scheme will give the range of sf that are acceptable but this will normally be the sf of the datum (or this sf -1).

An answer in surd form cannot gain the sf mark. An incorrect calculation **following some working** can gain the sf mark. For a question beginning with the command word 'Show that…', the answer should be

quoted to **one more** sf than the sf quoted in the question eg 'Show that X is equal to about 2.1 cm' – answer should be quoted to 3 sf. An answer to 1 sf will not normally be acceptable, unless the answer is an integer eg a number of objects. In non-practical sections, the need for a consideration will be indicated in the question by the use of 'Give your answer to an appropriate number of significant figures'.

3.9 Unit penalties

An A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the correct unit for the answer to a calculation. The need for a unit to be quoted will be indicated in the question by the use of 'State an appropriate SI unit for your answer'. Unit answers will be expected to appear in the most commonly agreed form for the calculation concerned; strings of fundamental (base) units would not. For example, 1 tesla and 1 Wb m^{-2} would both be acceptable units for magnetic flux density but 1 kg m^2 s^{-2} A^{-1} would not.

3.10 Level of response marking instructions

Level of response mark schemes are broken down into three levels, each of which has a descriptor. The descriptor for the level shows the average performance for the level. There are two marks in each level.

Before you apply the mark scheme to a student's answer read through the answer and annotate it (as instructed) to show the qualities that are being looked for. You can then apply the mark scheme.

Determining a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the descriptor for that level. The descriptor for the level indicates the different qualities that might be seen in the student's answer for that level. If it meets the lowest level then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer. With practice and familiarity you will find that for better answers you will be able to quickly skip through the lower levels of the mark scheme.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level. i.e. if the response is predominantly level 2 with a small amount of level 3 material it would be placed in level 2.

The exemplar materials used during standardisation will help you to determine the appropriate level. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the example to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the example.

You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the indicative content to reach the highest level of the mark scheme

An answer which contains nothing of relevance to the question must be awarded no marks.

Question	Answers	Additional Comments/Guidance	Mark	ID details
01.1	$D = 0.305$ m ✓ Use of $\theta = \lambda / D$ To give $\lambda = 1.8 \times 10^{-6} \times 0.305$ $= 5.5 \times 10^{-7}$ m ✓	The first mark is for the correct D. The second mark is for the final answer. Allow 1 max for one POT error. Allow ecf for incorrect D unless 5.03 m used. Award full credit if factor of 1.22 included (to give 4.5×10^{-7} m)	1 1	AO1/1a AO2/1d
01.2	$M = 3.2 \times 10^{-4} / 1.8 \times 10^{-6}$✓ $=178$ Use of $M = fo/fe$ to give $fe = fo/M = 5.03/178$ ✓ $= 0.028$ m ✓	The first mark is for evidence of use of angular magnification equation. The second mark is for evidence of the use of the magnification focal lengths equation. The third is for the final answer. Do not credit 0.03. Allow ecf for M. Allow 2 max for one POT error.	1 1 1	AO2/1d AO2/1h AO2/1d
01.3	Either Telescope can resolve objects down to 1.8×10^{-6} rad At 3.0×10^{4} km, this angle is subtended by an object of size 3.0×10^{4} km $\times 1.8 \times 10^{-6}$ rad $= 54$ m ✓ This is 54/325 = 1/6th size of asteroid ✓ would not be suitable for viewing detail. ✓ OR Angular size of asteroid = 325/3 x 10^{7} = 1.1 x 10^{-5}. ✓ As 1.1 x 10^{-5} >1.8×10^{-6} asteroid can be seen/ 1.1 x 10^{-5} /1.8	The first mark is for the calculation. The second mark is for the comparison. Allow ecf. The angular resolution of the telescope should be quoted. The third mark is for reaching the judgement. This mark cannot be given if simple statement that asteroid can be seen. Condone correct use of sin and tan. Full credit can also be given if they use	1 2	AO3/1a AO3/1b

	$\times 10^{-6}$ 6 times minimum angular resolution. ✓ Too small for detail to be seen. ✓	magnification and compare angular size with the resolution of the eye.		

Total			**8**

Question	Answers	Additional Comments/Guidance	Mark	ID details
02.1	Curve with a single peak ✓ Steepest part of LHS steeper than steepest part of RHS✓	If multiple curves seen all of them must be correct. Do not condone curves with negative gradient on LHS	2	AO1/1a
02.2	Mention of use of peak wavelength ✓ Quoting use of Wien's law and that wavelength is in metres ✓ Use of $\lambda_{max}T = 0.0029\ \mathrm{m\ K}$ ✓ and mention of temperature in kelvin. ✓	This mark may be awarded for a label on the wavelength axis of the graph. Do not condone biggest or maximum. If no peak in graph 2 max. Only the first mark can be awarded if there is a suggestion that 'm' in the equation represents 'milli', or K represents Boltzmann's constant. Ignore references to Stefan's Law.	3	AO2/1g

<table>
<tr><th>Question</th><th>Answers</th><th>Additional Comments/Guidelines</th><th>Mark</th></tr>
<tr><td>2.3</td><td>

The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the '*Mark Scheme Instructions*' document should be used to assist in marking this question.

<table>
<tr><th>Level</th><th>Criteria</th><th>QoWC</th></tr>
<tr><td>6 marks</td><td>Correct calculations of power output. Comparison of brightness, Leading to similar distance away and therefore binary (or not if supported).</td><td rowspan="2">The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.</td></tr>
<tr><td>5 marks</td><td>There may be an error in the calculations but POT errors can be condoned.</td></tr>
</table>

</td><td>

Stars compared for colour:

Cygnus B will appear more red than Cygnus A as it is cooler Or both stars orange. (L1)

Ignore calculation of λ_{max} unless linked correctly to colour.

Stars compared for brightness.

Cygnus A will appear (approximately 2 times) brighter than Cygnus B, as the apparent magnitude is approximately 1 less than that of Cygnus B. (L2)

Difference in magnitude = 0.9
ratio in brightness = $2.51^{0.9} = 2.3$

Distance discussed
Powers compared: (L2)

Using $P=\sigma AT^4$

Gives
For A: $P = 5.67 \times 10^{-8} \times 4\pi \times (4.7 \times 10^8)^2 \times 4500^4 = 6.45 \times 10^{25}W$ (L2/3)
For B: $P = 5.67 \times 10^{-8} \times 4\pi \times (4.1 \times 10^8)^2 \times 4100^4 = 3.38 \times 10^{25}W$ (L2/3)

As power output of **A** is about twice that of **B**, and **A** appears about twice as bright, they must both be about the same distance away.(L2/3)

</td><td>6</td></tr>
</table>

	4	Attempt to calculate power outputs or quantitative analysis of brightness, with some relevant comment. Condone some errors including POT, missing “4” or use of “4/3”. Do not condone more serious errors in calculation. If the brightness is the wrong way round (B>A) ignore brightness comparison.	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.	**Evaluation** Being about the same distance away is consistent with idea that they form a binary system. (L2/3)	
	3	Only a qualitative response. Reference to r and T suggesting that Power output of A greater than B. This can be seen in an (incorrect) equation. OR straight forward comparison of brightness. (eg A is			

	about twice as bright).	
2	Two aspects of star correct – eg A brighter than B, both appear orange (do not accept red), B redder than A.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
1	Only one aspect statement comparing stars correct. eg A brighter than B, both appear orange (do not accept red), B redder than A.	
0	Unsupported evaluation or no relevant analysis	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

02.4	K ticked		1	AO1/1a

Total			**12**

Question	Answers	Additional Comments/Guidance	Mark	ID details
03.1	Quasars are produced by (supermassive) black holes. ✓ These black holes are at the centre of (active) galaxies (active galactic nuclei.) ✓		2	AO1/1a
03.2	Using $v = cz$ gives $v = 3 \times 10^8 \times 0.0415$✓ $= 1.25 \times 10^7 = 1.25 \times 10^4$ kms^{-1} Using 1pc = 3.26 lyr $d = 5.81 \times 10^8$ lyr $= 5.81 \times 10^8/3.26$✓ $= 1.78 \times 10^8$ pc $= 1.78 \times 10^2$ Mpc (= 5.5 x 10^{24} m) Using $v = Hd$ ($H = v/d = 1.25 \times 10^4/1.78 \times 10^2 = 70$ kms^{-1} Mpc^{-1}) Age of Universe = $1/H = d/v$ ✓ $= 5.81 \times 10^8 \times 9.47 \times 10^{15}/1.25 \times 10^7 = 4.42 \times 10^{17}$ s✓	The first mark is for use of zc The second mark is for a calculation of d The third mark is for using the idea that the age of the Universe is 1/H The fourth mark is for the answer. Allow own H for 3rd and 4th marks.	4	AO2/2b

Question	Answers	Additional Comments/Guidance	Mark	ID details
03.3	Both quasar and galaxy should have same brightness (and therefore similar received power).✓ Use of Inverse square law eg Power of quasar/(distance to quasar)^2 = power of galaxy / (distance to galaxy)^2 ✓ Or $1000/d^2 = 1/1$ So distance to quasar = $(1000)^{½}$ = about 30 times greater than distance to galaxy. ✓	The first mark is for relating the similar "brightness". Accept intensity. Accept in form of equation linking quasar and galaxy. The second mark is for applying the inverse square law. Simply quoting it does not get this mark. The final mark is for coming to a valid conclusion related to the distance to the quasar compared to the distance to the galaxy Do not accept answers involving square roots. These are standalone marks..	1 2	AO2/1c AO3/1b
Total			**9**	

Question	Answers	Additional Comments/Guidance	Mark	ID details
04.1	it is the radiation coming from all parts of the Universe✓ when the Universe cooled sufficiently for matter and radiation to 'decouple', with the combination of protons and electrons to form neutral atoms ✓ this radiation has been red-shifted into the microwave region as the Universe has expanded✓ OR This is (em) radiation from all parts of the Universe, ✓ the spectrum has a peak in the microwave region / corresponds to a temperature of $2.7\ \mathrm{K}$ ✓ It can be interpreted as the radiation left over from the Big Bang / the photons having been stretched to longer wavelengths and lower energies. ✓	One mark is for stating that CMBR comes from all parts of Universe. Accept Isotropic condone homogeneous condone same at all points in universe Another is for referencing the idea that the radiation has a peak in the microwave region The third is for linking it to the Big Bang theory. Condone "left over heat from Big Bang"	3	AO1a
04.2	(The Big Bang theory suggests that a very brief period of) fusion occurred (when the Universe was very young), resulting in the production of helium from fusing hydrogen. ✓ Fusion stopped as the Universe then expanded and cooled ✓ resulting in a relative abundance of hydrogen and helium in the ratio of $3{:}1$/ cooled too rapidly for the creation of larger nuclei, or suitable relevant observation✓	One mark is for linking helium production to fusion in the early Universe. This mark can also be awarded for description of proton and neutron creation/ 7:1 ratio	3	AO1a
Total			**6**	