A-level
PHYSICS
7408/3BA

Paper 3 Section B Astrophysics

Mark scheme

June 2024

Version: 1.0 Final

246A7408/3BA/MS

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 Examiner.

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.

No student should be disadvantaged on the basis of their gender identity and/or how they refer to the gender identity of others in their exam responses.

A consistent use of 'they/them' as a singular and pronouns beyond 'she/her' or 'he/him' will be credited in exam responses in line with existing mark scheme criteria.

Further copies of this mark scheme are available from aqa.org.uk

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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. ie 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	AO
01.1	Determination of focal length of objective OR adds their f_o and f_e ✓ 1.67 (m) CAO ✓	$f_o = M \times f_e = 75 \times 0.022 = 1.65$ (m) No sf penalty Condone 2 sf 1.7	2	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
01.2	Determination of angle subtended by Jupiter at unaided eye OR uses: distance to Jupiter = diameter of Jupiter ÷ angle subtended with their diameter OR their angle ✓ distance = 6.2×10^8 (km) ✓ CAO	E.g. $1.7 \times 10^{-2} / 75 = 2.3 \times 10^{-4}$ (rad) $2 \times 7.0 \times 10^4 / 2.3 \times 10^{-4}$ In MP1 allow use of trig and angle in degrees or radians. Condone use of 1.7×10^{-2} degrees. Do not award MP1 if both angle and diameter are incorrect.	2	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
01.3	Idea that chromatic aberration is caused by dispersion of light passing through lens OR different colours/wavelengths being refracted by different amounts/to different focal points. ✓ Idea that effect is greatest at greatest curvature/edge of lens OR least at centre of lens OR Idea that light can only travel through part of lens with little curvature ✓ therefore chromatic aberration is **reduced**. ✓	Marks can be given for labelled diagram. Credit answers that suggest edges of lens act like a triangular prism. MP3 is contingent on MP2.	3	1 × AO1 2 × AO3

Question	Answers	Additional comments/Guidance	Mark	AO
01.4	(Diameter (d) is reduced and therefore:) Idea that the image is dimmer $_1$✓ collecting power proportional to area / d^2 $_2$✓ Idea that the image less clear $_3$✓ minimum angular resolution is proportional to $1/d$ $_4$✓	Treat any comments about the path through the atmosphere as neutral. For $_3$✓ do not allow 'lower resolution' for 'less clear' Alternative for $_3$✓$_4$✓ Idea that the image is more clear as spherical aberration is reduced as only rays near axis form image	4	AO3
Total			**11**	

Question	Answers	Additional comments/Guidance	Mark	AO
02.1	Determines s and r in consistent units OR Uses $A = 2 \times$ parallax angle $= 2 \times (1 \div (\frac{79}{3.26}))$ ✓ 2.3×10^{-5} degrees CAO ✓	eg for MP1 • $s = 2 \times 1.5 \times 10^{11}$ m; $r = 79 \times 9.46 \times 10^{15}$ m • $s = 2 \div 2.06 \times 10^{5}$ pc; $r = 79 \div 3.26$ pc • tan $(A/2)$ = orbital radius ÷ distance to star with consistent units $A = 4.0 \times 10^{-7}$ rad $= 2.3 \times 10^{-5}$ degrees Evidence for MP1 can be seen in **Figure 2**.	2	AO2

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	Use of $m - M = 5 \log (d/10)$ with two correctly substituted from m, M or d 1✓ Obtains correct value of m, M or d 2✓ Compares **their** value with value given in question 3✓ Makes comment about significance of difference between **their** values related to the distance AND some idea of whether the astronomer's suggestion is valid consistent with their values.4✓	If no other mark given, award 1 mark for recognition that 0.40 pc is a lot less than the distance to nearest known star and therefore determination must be incorrect. For MP2 expect to see $d = 2.3$ **pc** OR $m = 9.7$ OR $M = 20.5$ Alternative for MP1 and MP2 using m, M and d in $m - M = 5 \log (d/10)$ 1✓ seeing -3.2 for LHS and -7.0 for RHS 2✓ MP3 and MP4 cannot be awarded without a comparison of the distances. MP4 is for a recognition of the large difference between their calculated value and value given in question eg by proportion, >>, 6 x bigger, significantly bigger etc. If a difference is calculated in MP3, for MP4 to be awarded the difference must compared to one of the distances.	4	AO3
Total			**6**	

Question	Answers	Additional comments/Guidance	Mark	AO
03.1	Use of $\lambda_{max}T =$ constant to determine their λmax, their T or their constant✓ Comparison with $\lambda_{max} = 0.48 \times 10^{-6}$ (m) OR $T = 6.0(4) \times 10^{3}$ (K) OR constant = 0.0029 m K AND conclusion that the graph is consistent.✓	Throughout the answer: Allow 0.47 to 0.49 μm for λ_{max} from the graph Allow 6.17×10^{3} to 5.92×10^{3} (K) for their calculated T. Allow 2.82×10^{-3} to 2.94×10^{-3} (m K) for their calculated constant.	2	1 × AO3 1 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
03.2	Using $P = \sigma AT^4$ to give $P = 5.67 \times 10^{-8} \times 4\pi \times (9.6 \times 10^{6})^2 \times 6000^4$ ✓ 8.5×10^{22} (W) ✓	In MP1 condone **one** error from • missing the 4 • missing the π • doubling the radius and using it as r in an area calculation • POT errors Condone σ for 5.67×10^{-8} Allow full credit for use of their T from **03.1** eg $T = 6.04 \times 10^{3}$ (K) gives 8.75×10^{22} (W)	2	2 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
03.3	✓ in top box (white dwarf, F)		1	AO3

Question	Answers	Additional comments/Guidance	Mark	AO
03.4	Shorter wavelengths will have been removed (more) OR star's observed spectrum has lower intensity at shorter wavelengths OR (observed) peak of black-body is at a greater value of λ (than shown in Figure 3)/shifted to the right. ✓ ($\lambda_{max}T$ = constant,) therefore the (observed/estimated) value of T is lower than the actual T / value of T in **03.1** ✓	Allow reverse arguments MP2 is contingent on MP1	2	AO3
Total			**7**	

Question	Answers	Additional comments/Guidance	Mark	AO
04.1	Idea that Hubble's Law is used to estimate the age of the Universe. ✓ So no, as Andromeda is approaching / is blue-shifted ✓	Allow determination of H^{-1} or H for the values in the question. Accept idea that age is related to gradient of graph of v against d. Allow "Hubble's Law is only used with receding/redshifted galaxies."	2	AO3

Question	Answers	Additional comments/Guidance	Mark	AO
04.2	Calculates mass of black hole = $1.60 \times 10^{8} \times 1.99 \times 10^{30}$ $_1$✓ Use of $R_s = \frac{2 \times 6.67 \times 10^{-11} \times \ their\ mass\ of\ black\ hole}{(3 \times 10^{8})^2}$ $_2$✓ $= 4.7 \times 10^{11}$ m $_3$✓	Correct answer gets $_1$✓$_2$✓ Correct answer with correct unit gets $_1$✓$_2$✓$_3$✓ Also accept 4.7×10^{8} km 3.1 AU 1.5×10^{-5} pc 5.0×10^{-5} ly Unit mark is based on correct calculation.	3	2 × AO2 1 × AO1

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr><td>04.3</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 marking this question.
<table>
<tr><th>Mark</th><th>Criteria</th></tr>
<tr><td>6</td><td>All three areas (as outlined alongside) covered with at least two aspects covered in some detail.
6 marks can be awarded even if there is an error and/or parts of one aspect missing.</td></tr>
<tr><td>5</td><td>Two areas successfully discussed and one covered partially. Whilst there will be gaps, there should only be a very occasional error.</td></tr>
<tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.</td></tr>
<tr><td>3</td><td>One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.</td></tr>
<tr><td>2</td><td>Only one area discussed or makes a partial attempt at two areas.</td></tr>
<tr><td>1</td><td>Only one area covered, and that partially.</td></tr>
<tr><td>0</td><td>No relevant analysis.</td></tr>
</table>
</td><td>
Treat 1 point from an area as partial and
2 points from an area as complete
Note that 'supermassive' must be seen at least once for P1 and/or F1 to be rewarded.
Properties
P1 Associated with a supermassive black hole
P2 Large power output (for their size) OR power output ~ 10^{42} W/idea of bright absolute magnitude
P3 Distant
P4 Small (relative to host galaxy)/about size of solar system
Treat any comment about age as neutral.

Evidence
E1 (seen) in centre of (active) galaxies (producing jets)
E2 Bright radio source OR far brighter than their host galaxy
E3 Large red-shift
E4 Rapid fluctuations in power output.

How quasar forms
F1 (merging causes) material/stars to move towards the supermassive black hole(s)

F2 Black hole(s) become active 'consuming' nearby stars/material and emitting radiation
</td><td>6</td><td>AO1</td></tr>
<tr><td>Total</td><td></td><td></td><td>11</td><td></td></tr>
</table>