A-LEVEL
PHYSICS
7408/3BA

Paper 3 Section B Astrophysics

Mark scheme

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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.

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

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.

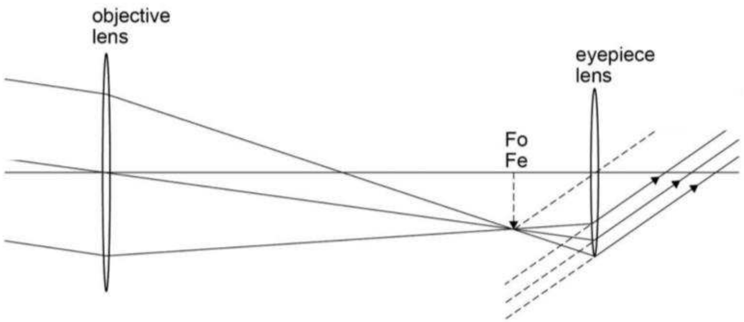
The exemplar materials used during standardisation will help you to determine the appropriate level. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's 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	AO
01.1	Two pairs of rays drawn parallel to the principal axis coming to different foci. Outer rays focus closer to lens than inner rays. ✓		1	AO1

Question	Answers	Additional Comments/Guidance	Mark	AO
01.2	Both focal points labelled, on the principal axis, and coincide, with $f_o > f_e$ ✓ Three off-axis rays through objective lens correct, as far as the eyepiece ✓ Three rays through eyepiece correct, parallel to a construction line ✓ 	$f_o > f_e$ judged by eye. Condone a single label F or '(principal) foci'. Ignore labels outside the space between the two lenses. Rays must be off-axis to get the second mark. Construction line does not need to be drawn. If only two rays drawn then max 2.	3	3 x AO1

Question	Answers	Additional Comments/Guidance	Mark	AO
01.3	(f_o / f_e = 750 and $f_e + f_o$ = 17.4) $f_e = (f_e + f_o)/751$ ✓ = 17.4/751 $f_e = 2.3(17) \times 10^{-2}$ m ✓	Accept any correct unit Use of $f_e = (f_e + f_o)/750$ without explanation scores 0 (Calculator value = 0.0231691079) If no other mark given award max 1 for 0.023 or 0.0232 but treat evidence of incorrect calculation as a talkout.	2	2 x AO2

Question	Answers	Additional Comments/Guidance	Mark	AO
01.4	Resolution is limited by the diameter of the objective ✓$_a$ so it will make no difference ✓$_b$ OR CCD has better resolution due to having smaller pixels ✓$_a$ so the stars could be more easily seen as separate (OWTTE) ✓$_b$ (candidates may combine these ideas) CCDs have higher quantum efficiency and/or can be exposed for a long time ✓$_a$ so dimmer or more distant binaries can be observed ✓$_b$ CCDs can detect a wider range of wavelengths ✓$_a$ enabling the observation of more binary pairs. ✓$_b$ Description of why CCD is more convenient in use ✓$_a$ with a specific example of why this helps in the observation of binary stars. ✓$_b$	General principle is difference ✓$_a$ followed by consequence. ✓$_b$ If no consequence relevant to observation of binary stars, then max 2 Examples of 'convenience' include use when astronomer not present, image can be stored and analysed (on computer). Ignore reasons based on cost.	Max 3	3 x AO3
Total			**9**	

Question	Answers	Additional Comments/Guidance	Mark	AO
02.1	The minima are caused when one star passes in front of the other. ✓ Deeper minima are caused by the cooler star passing in front of the hotter star. ✓	For mp2 it must be clear that dip size is related to temperature. NB this is NOT related to the diameter of the star.	1 1	1 x AO2 1 x AO3

Question	Answers	Additional Comments/Guidance	Mark	AO
02.2	The system is moving towards us AND mention of Doppler effect/red shift OR The system is moving so the light is blue shifted✓	Condone ‘star is, or stars are moving towards us’	1	AO3

Question	Answers	Additional Comments/Guidance	Mark	AO
02.3	$\Delta\lambda = \frac{486.498 - 485.672}{2} = 0.413$ nm ✓ $z = \frac{\Delta\lambda}{\lambda} = \frac{0.413}{486.085✓} = 8.50 \times 10^{-4}$ $v = zc = 8.50 \times 10^{-4} \times 3.00 \times 10^{8} = 2.55 \times 10^{5}$ m s^{-1} = 255 km s^{-1} ✓	Alternative for mp1 use of average and one of the other values. For mp2 must see evidence of correct use of average value (NB use of other wavelengths likely to give same answer to 3 sf). Average value (486.085) Final answer must be seen to more than 2sf For mp3 Allow ecf from mp1 and mp2 if answer is in range 250-260	2 1	2 x AO2 1 x AO3

Question	Answers	Additional Comments/Guidance	Mark	AO
02.4	Identifies period (T) is 2.5 days ✓ $v = \frac{2\pi R}{\textit{(their value of)}T}$ $R = \frac{v \times T}{2\pi} = \frac{2.55\times10^{5} \times 2.5\times24\times3600}{2\pi} = 8.76 \times 10^{9}$ m ✓	Allow ecf from **02.3** Use of 250 km s^{-1} gives 8.59×10^{9} m✓✓	1 1	1 x AO3 1 x AO2

Question	Answers	Additional Comments/Guidance	Mark	AO
02.5	hydrogen and helium ✓		1	AO1

Question	Answers	Additional Comments/Guidance	Mark	AO
02.6	Observable property of Neutron Star or White Dwarf ✓ Property of the other object AND coincident in space OR idea of how a property varies ✓	Observable properties WD – O or B class/ H-He absorption lines/ high temp AND not very bright abs mag. NS – radio emissions/Pulsars Variations include radio emissions from neutron star blocked by white dwarf ✓ Spectroscopic variation in white dwarf seen ✓	2	2 x AO3
Total			**11**	

Question	Answers	Additional Comments/Guidance	Mark	AO
03.1	High power/powerful radio emitter. ✓	Some indication of high power needed.	1	AO1

Question	Answers	Additional Comments/Guidance	Mark	AO
03.2	Use of $m - M = 5 \times \log\frac{d}{10}$ ✓ $M = m - 5 \times \log\frac{d}{10}$ $M = 12.8 - 5 \times \log\frac{760 \times 10^6}{10} = -26.6$ ✓		1 1	1 x AO1 1 x AO2

Question	Answers	Additional Comments/Guidance	Mark	AO
03.3	Quasar is brighter because more negative abs magnitude. ✓ Difference in absolute magnitudes $26.6 - 22.8 = 3.8$ ✓ Brighter by $2.51^{3.8}$ = 33 times ✓	Use of -27 (giving 48 times brighter) scores mp2 and mp3 Allow any value of absolute magnitude which rounds to -27. Use of apparent magnitudes scores no marks.	3	3 x AO2

Question	Answers	Additional Comments/Guidance	Mark	AO
03.4	$R_s = \frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 7.1 \times 10^{11} \times 1.99 \times 10^{30}}{3.00 \times 10^{8^2}} =$ ✓ $(2.1 \times 10^{15}\ \text{m})$ volume = $\frac{4}{3}\pi R_s{}^3 = \frac{4}{3}\pi 2.1 \times 10^{15^3} =$ ✓ $(3.9 \times 10^{46}\ \text{m}^3)$ $\rho = \frac{\text{mass}}{\text{volume}} = \frac{7.0 \times 10^{11} \times 1.99 \times 10^{30}}{3.7 \times 10^{46}\text{m}^3} = 3.7\ (3.67) \times 10^{-5}\ \text{kg m}^{-3}$ ✓	If the mass of the Sun is not included mp1 is not awarded – ecf for mp2 and mp3. 2.094×10^{15} m 3.85×10^{46} m^3	1 2	1 x AO1 2 x AO2
Total			**9**	

<table>
<tr><th>Question</th><th>Answers</th><th>Additional Comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr><td>04</td><td>
<table>
<tr><td>6</td><td>A coverage of all three aspects. There may be the occasional slip-up.</td></tr>
<tr><td>5</td><td>Two aspects are well covered and partial coverage of the other. There may be some misunderstanding – for example that stars are moving away from us.</td></tr>
<tr><td>4</td><td>Two aspects are well covered, or one well covered and a brief coverage of the others. There may be some misunderstanding – for example that stars are moving away from us.</td></tr>
<tr><td>3</td><td>Includes a clear coverage of one aspect and at least an attempt at another OR a partial coverage of all three.</td></tr>
<tr><td>2</td><td>Includes a clear coverage of one aspect OR a partial discussion of two.</td></tr>
<tr><td>1</td><td>Partial coverage of one aspect.</td></tr>
<tr><td>0</td><td>No relevant comment.</td></tr>
</table>
</td><td>There must be an attempt at a relevant calculation for 5 or 6 marks (this could be the age of universe).

Points made in a good answer could include:
Aspect 1 - RedShift
• Theory predicts that distant galaxies are all moving away from us
• The further away the galaxy the faster it moves
• Reference to Hubble’s Law

Aspect 2 -CMBR
• Theory predicts black body radiation at microwave wavelengths (2.7 K)
• from all directions which indicates that the universe was once very small/in a hot dense state
• Graph shows peak in microwave region
• General shape of graph is the same as a black body
• CMBR is not predicted by any other theory
• Condone suggestion that it’s leftover radiation from Big Bang
Aspect 3 - Hydrogen/Helium ratio and/or Wien’s Law calculation. Treat calculation of age of universe as partial Aspect 3. Answers</td><td>6</td><td>4 x AO1
2 x AO3</td></tr>
</table>

		which cover H/He and Wien's Law can be used to support partial Aspect 1 or 2. • Theory predicts 3:1 H/He ratio • In deep space (not stars) this is observed in practice • Calculation shows peak corresponds to 2.7 K (approx)		

Total			**6**