A-level
PHYSICS
7408/3BA

Paper 3 Section B Astrophysics

Mark scheme

June 2023

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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. 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.

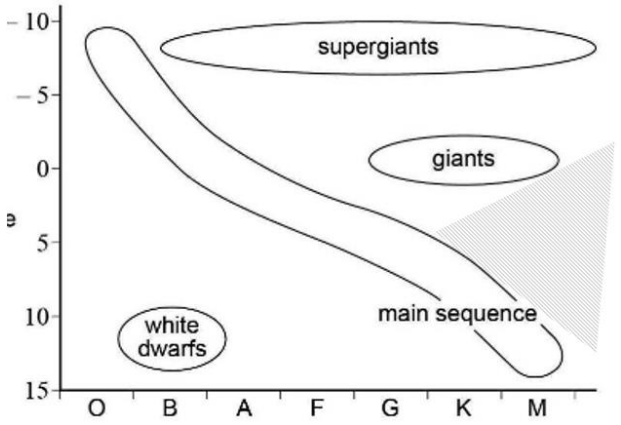
Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the indicative content to reach the highest level of the mark scheme.

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

Question	Answers	Additional comments/Guidance	Mark	AO
01.1	Diagram with 1 AU, 1 pc **and** $\frac{1}{3600}$ ° labelled ✓	Allow 1 arc second **or** 1″ **or** 2.8 x 10^{-4} ° **or** 4.8 x 10^{-6} rad for angle. 1 AU can be shown as Sun–Earth distance. Condone 'au' for 'AU'. 1 pc can be either long side. Condone label *d* for 1 pc.	1	1 × AO1

Question	Answers	Additional comments/Guidance	Mark	AO
01.2	B ✓		1	1 × AO1

Question	Answers	Additional comments/Guidance	Mark	AO
01.3	evidence of 10^x seen **OR** evidence of $0.11 - (-7.84)$ seen✓ $d = 390$ (pc) ✓	 condone $0.11 + 7.84$ provided m-M seen. Calculator value is 389.0451	2	2 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
01.4	Line coming in from the right to mag 5/class G **then** to giants and **then** to white dwarfs (in that order) ✓	Condone lack of arrow. The shaded area shows the acceptable region for the initial line (from protostar).  	1	1 × AO1

Question	Answers	Additional comments/Guidance	Mark	AO
01.5	(GRB produced when) supergiant collapses ✓ (and) forms a neutron star **OR** a black hole ✓	Ignore references to 'supernova'	2	1 × AO2 1 × AO3

Total			**7**

Question	Answers	Additional comments/Guidance	Mark	AO
02.1	Final image at infinity. ✓	Accept answers which describe how the telescope is set up with named lenses unless f_o and f_e are used e.g. the focal plane/point of the eyepiece and objective lenses are co-incident. **OR** 'distance between lenses is $f_o + f_e$' Condone 'rays leaving eyepiece/entering eye are parallel' If F_o and F_e are used they must be defined.	1	1 × AO1

Question	Answers	Additional comments/Guidance	Mark	AO
02.2	100 converging 5 converging ✓		1	1 × AO1

Question	Answers	Additional comments/Guidance	Mark	AO
02.3	(Each step on magnitude scale is 2.51) (Hence) $2.51^{x} = 40$ $x = \log_{2.51}(40) = 4(.01)$ **OR** Adding 6 to their x ✓ $(6 + 4 =)10$ ✓	Condone trial and error (2.51^{1}, 2.51^{2},…). Award MAX 1 if no working shown for a bald correct answer.	2	2 × AO2

Question	Answers	Additional comments/Guidance	Mark	AO
02.4	(Collecting power of telescope is) $\left(\frac{60}{7}\right)^2 = 73$ or 74 (times greater than naked eye) ✓ 73 (or 74) is greater than 40 so the astronomer can see WASP-82. ✓	MP1 can be given for 73 or 74 seen. Accept $\left(\frac{7}{60}\right)^2 = 0.014$ for MP1 Allow an ecf in MP2 from '8.6 times greater' $\left(\frac{60}{7} = 8.6\right)$, with idea that 8.6 is less than 40 and therefore astronomer cannot see Wasp-82. Allow ecf in MP2 for an arithmetic error in MP1.	2	2 × AO3

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr><td>02.5</td><td>Two clear reasons given ✓✓
Correct justification linked to one reason ✓
<table><tr><th>Reason</th><th>Justification</th></tr><tr><td>Better/greater quantum efficiency</td><td>A greater proportion of (incident) photons are detected</td></tr><tr><td>Can expose for long periods / many images can be combined</td><td>More light is collected / better image contrast</td></tr><tr><td>Can operate remotely</td><td>The telescope can be positioned where light pollution/atmospheric absorption is minimised</td></tr><tr><td>Idea that it can detect (more) wavelengths beyond the visible</td><td>More energy is collected from the star</td></tr></table>MAX 3</td><td>If no justification given then MAX 2.

In the first row:
Do not allow ‘efficiency’ alone.
The reason and justification marks can both be awarded for an answer based on the definition of ‘quantum efficiency’ e.g.a greater proportion/ percentage of the incident photons are detected (by the CCD).
In the justification condone ‘light’ for ‘photons’ and condone ‘number’ for ‘proportion’

Treat ‘image processing’ as neutral.

Ignore references to resolution.</td><td>3</td><td>3 × AO1</td></tr>
<tr><td>Total</td><td></td><td></td><td>9</td><td></td></tr>
</table>

Question	Answers	Additional comments/Guidance	Mark	AO
03.1	An object that has an escape velocity greater than the speed of light. **OR** An object that has a gravitational field strength that is so great that light cannot escape. ✓	Reject idea of 'beyond' or 'past' the event horizon if the direction is unclear. Do not accept 'mass' 'density' 'light cannot escape' 'light cannot escape its gravity' on their own.	1	1 × AO1

Question	Answers	Additional comments/Guidance	Mark	AO
03.2	$R_s = \frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 6.5 \times 10^9 \times 1.99 \times 10^{30}}{(3 \times 10^8)^2}$ 1✓ Angle subtended by region around event horizon of black hole $= \frac{1.917 \times 10^{13} \times 2 \times 1000}{5.3 \times 10^7 \times 9.46 \times 10^{15}} = 7.64 \times 10^{-8}$ (rad) 2a✓ resolution of EHT $= (\frac{1.3 \times 10^{-3}}{1.3 \times 10^7} =) 1(.0) \times 10^{-10}$ (rad) **OR** resolution of Hubble $= (\frac{410 \times 10^{-9}}{2.4} =) 1.71 \times 10^{-7}$ (rad) 3✓ Both resolutions calculated correctly **and** conclusion drawn that EHT is better than Hubble. 4✓	Condone rounding errors in this question. Award MP1 for $R_s = 1.9(17) \times 10^{13}$(m) seen Condone missing mass of Sun (1.99×10^{30}) in MP1 Condone missing '2' in MP2. Award MP2 for $7.6(4) \times 10^{-8}$ **OR** $3.8(2) \times 10^{-8}$ seen. Allow POT error in MP1 and MP3 ALTERNATIVE $R_s = \frac{2GM}{c^2} = \frac{2 \times 6.67 \times 10^{-11} \times 6.5 \times 10^9 \times 1.99 \times 10^{30}}{(3 \times 10^8)^2}$ ✓ One resolution calculated 2✓ Determination of the size of the object that can be resolved by a telescope at the distance of black hole For EHT size = $5(.0) \times 10^{13}$ (m) **OR** For Hubble size = 8.6×10^{16} (m) 3✓ Both sizes calculated correctly **and** conclusion drawn that EHT is better than Hubble. 4✓	4	4 × AO3

Question	Answers	Additional comments/Guidance	Mark	AO
03.3	Evidence of difference in wavelength = $374.96 - 373.53$ ✓ $(= 1.43\ \text{nm})$ Evidence of sum of wavelengths = $374.96 + 373.53$ ✓ $(= 748.49\ \text{nm})$ $\left(z = \frac{\Delta\lambda}{\lambda} = \frac{0.72}{374.25} = 1.9 \times 10^{-3}\right)$ $(v = zc = 1.9 \times 10^{-3} \times 3.00 \times 10^{8} =)$ $5.7 \times 10^{5}\ (\text{m s}^{-1})$ ✓	MP1 can be given for determination of $\Delta\lambda$ $(= 0.72\ \text{nm})$ MP2 can be given for determination of average $(= 374.25$ or $374.24(5)\ \text{nm})$ Alternative method for z: $z = \frac{374.96 - 373.53}{374.96 + 373.53} = 1.9 \times 10^{-3}$	3	3 × AO2
Total			**8**	

<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>
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>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>A fair attempt to analyse all three areas, with two areas discussed succcessfully and one area partially.</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 successfully 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 successfully, or makes a partial attempt at two areas.</td></tr>
<tr><td>1</td><td>One of the three areas covered partially. There are likely to be many errors or omissions.</td></tr>
<tr><td>0</td><td>No relevant analysis.</td></tr>
</table>
</td>
<td>
Area 1: Stars compared for colour

M40 B will appear more red than M40 A as it is cooler.
M40 A is an F/G star; M40 B is a K class star
Therefore M40 A is white/yellow-white and M40 B is orange
Ignore calculation of λ_{max} unless linked correctly to colour.
Classes are related to colour/temperature

Area 2: Stars compared for brightness

M40 A will appear (~ 1.5 times) brighter than M40 B, as the apparent magnitude is 0.4 less than that of M40 B.
Difference in magnitude = 0.4
Ratio in brightness = $2.51^{0.4} = 1.5$

Area 3: Distance discussed

Powers compared:
Using $P = \sigma A T^4$ gives
For A: $P = 5.67 \times 10^{-8} \times 4\pi \times (6.3 \times 10^9)^2 \times 6000^4 = 3.66 \times 10^{28}$ W
For B: $P = 5.67 \times 10^{-8} \times 4\pi \times (1.1 \times 10^{10})^2 \times 4700^4 = 4.22 \times 10^{28}$ W

As power output of A is less than that of B but A appears brighter, A must be closer and therefore they are not a binary.
</td>
<td>6</td>
<td>4 × AO2
2 × AO3</td>
</tr>
</table>

Total			**6**

Question	Answers	Additional comments/Guidance	Mark	AO
05.1	Line of best fit <u>drawn through origin</u>. ✓ Evidence of $\frac{\Delta v}{\Delta d}$ used. ✓ Age in range 4.1 to 5.1 × 10^{17} s ✓	Accept lines that intersect *v* / km s $^{-1}$= 12000 somewhere between *d* / Mpc = 160 and 200 Do not accept use of H = 65 km s^{-1} Mpc^{-1} unless obtained from gradient.	3	1 × AO2 2 × AO3

Question	Answers	Additional comments/Guidance	Mark	AO
05.2	expansion is accelerating **OR** rate of expansion is increasing ✓ (due to) dark energy ✓	Treat descriptions of how the rate is increasing as neutral Do not allow ‘dark matter’	2	2 × AO1
Total			**5**	