AQA A-LEVEL PHYSICS · 7408

PHYSICS



MARK SCHEME

3.9.1 TELESCOPES: OPTICAL

SCORE	PERCENTAGE
/29	%

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Q1.

(a) 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

(b) $M = 3.2 \times 10^{-4} / 1.8 \times 10^{-6}$ ✓

=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

(c) 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 × 1.8×10^{-6} rad = 54 m ✓

This is 54/325 = 1/6th size of asteroid ✓

would not be suitable for viewing detail ✓

OR

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Angular size of asteroid = $325/3 \times 10^{7} = 1.1 \times 10^{-5}$ ✓

As $1.1 \times 10^{-5} > 1.8 \times 10^{-6}$ asteroid can be seen / $1.1 \times 10^{-5} / 1.8 \times 10^{-6}$ 6 times minimum angular resolution ✓

Too small for detail to be seen ✓

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 magnification and compare angular size with the resolution of the eye.

1
2

[8]

Q2.

Diagram of Cassegrain telescope with

Both mirrors correct ✓

The first mark is for a concave primary mirror and convex secondary.

Condone lack of shading. No gap needed in primary.

Primary should not look like two mirrors

Condone flat secondary if labelled convex. Do not condone concave secondary

1

Two rays correct. ✓

The second mark is for the two rays, initially parallel to the principal axis, reflecting from the primary mirror to the secondary, and then crossing (as they pass through the primary).

Ignore arrows on rays. No lens needed, but ignore rays after lens if drawn.

Poorly drawn rays eg curved, loses mark.

1

[2]

Q3.

(a) B brighter with support (eg diameter of B bigger) ✓

(The brightness of the image is determined by the collecting power and) collecting power related to D^2 or area ✓

Calculation of areas or d^2 ✓

Allow 'reflecting telescope' B

An unsupported answer gains no marks

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Ignore references to resolving power or unit W

1

(b) Two objects will just be resolved when the first minimum/edge of the airy disc in the diffraction pattern of one image ✓

Correct diagrams can gain both marks

1

Coincides with central maximum/centre of the airy disc of the other. ✓

Ignore references to formula

1

(c) B is better because it has a larger diameter ✓

Minimum angular separation/angular resolution depends on 1/D

No mark awarded for an unsupported answer

The first is for arguing that B is better due to larger diameter

The second mark is for identifying the relationship between angular resolution and diameter

Correct calculations can gain both marks, using any wavelength

Max 2

[7]

Q4.

(a) Principal axis drawn and principal foci shown to coincide on it ✓

three non-axial rays drawn correctly with final virtual image shown ✓

PA needs to be drawn

2

(b) Mirrors do not suffer from chromatic aberration, ✓

Mirrors can be larger and therefore have greater collecting powers ✓

Mirrors can be larger and therefore have smaller minimum angular resolution ✓

Parabolic mirrors with axial rays do not suffer from spherical aberration ✓

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(c) **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.**

L3 5−6 marks	clear description of what is meant by apparent magnitude, with discussion of logarithmic scale; explanation of	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text

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	Hipparcos scale in terms of visibility of stars	is legible.
L2 3−4 marks	Either apparent magnitude or Hipparcos scale discussed in detail, with other not discussed fully or containing errors	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.
L1 1−2 marks	Either one discussed fully and other not at all, or both discussed with some errors.	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.
0 marks	Little or no discussion of relevant content.	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

(d) **The following statements could be present**

- *apparent magnitude is based on how bright a star appears on the Earth*
- *this depends on how bright a star actually is and how far away it is*
- *larger values of apparent magnitude are given to dimmer stars*
- *the difference of 1 on the apparent magnitude scale is associated with a difference in brightness of a factor of 2.51.*

The Hipparcos scale assumed the brightest stars have a magnitude of 1 and the dimmest a magnitude of 6.
Magnitude 1 stars are 100 times brighter than magnitude 6 stars.

Applying apparent magnitude to the Hipparcos scale means that some stars (the brightest) have a negative apparent magnitude.

6

[12]

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Q1.

This question required students to demonstrate an understanding of angular magnification and resolving power in a particular context.

(a) This was answered well by the vast majority of students, with 82.9% gaining both marks. Those who did not gain both marks usually confused D and f, made a power of ten error, or rearranged their equation incorrectly.

(b) This question proved to be slightly more demanding. Although it can be seen as a two-step calculation, many students chose to combine the equations to provide the answer in one go. Students should always be encouraged to set out their answers clearly as marks can often be awarded for evidence of correct working even if the their final answer is incorrect. 62.4% of students gained all three marks.

(c) This question required students to make a judgement to demonstrate their understanding of the Rayleigh criterion as a limit. Many answers were seen that compared the angular size of the asteroid with the resolution of the telescope correctly, but then simply stated that the asteroid could be seen without any comment about the level of detail. Students who calculated the separation of objects that could be just resolved at the distance of the asteroid made better progress, but an answer that went on to suggest that this would not allow detail to be seen were rare. Only 3% of students scored all three marks; the proportion failing to gain even a single mark was 43.6%. Surprisingly, 9.4% of students made no attempt at all at this question.

Q2.

Much of the work on ray diagrams has been removed from the specification but the two main types of telescope remain. Most students were able to draw this ray diagram without difficulty. However, a large number of refracting telescopes were seen. Other issues included drawing a convex or flat secondary mirror, or drawing the primary as two curves so they look like two mirrors, rather one continuous curve, with or without a gap. Problems with the rays tended to be related to where they cross with several students drawing them so they crossed before the secondary mirror rather than after, or drawing them so that they meet at the eyepiece.

Q3.

This question required students to compare the properties of two different telescopes. There was evidence of confusion between collecting power and resolving power.

(a) Many students correctly chose the correct answer, but failed to explain why. It should be noted that, in a simple choice like this, any unsupported answer does not gain credit. Other common errors included using the resolving power or calculating the area using the equation for a sphere. A number of students incorrectly maintained that A was the correct answer as the image would be smaller and therefore the light from it would be concentrated into a smaller area. Students had a choice of approaches regarding the calculation, an example of the expectation that students will be able to make a judgement about their approach, rather than be directed to perform a specific calculation.

(b) This question proved to be significantly more demanding with few students showing anything other than a rudimentary knowledge of the Rayleigh criteria.

Specifically, many students simply quoted the equation or talked in general terms about seeing two objects close together. Those that made more progress in terms of the diffraction patterns often failed to gain marks due to lack of clarity, mentioning a maximum (rather than the central maximum) or suggesting that the two central maxima need to be fully separated. For example those that mentioned the Airy disc needed to make it clear that the centre and edge of the discs are significant. Some good answers were seen that made use of a graph of intensity against angle for the two sources.

(c) A common error that prevented students from getting both marks was to make general statements (bigger diameter means the resolving power is better), rather than more specifically referring to the correct equation or the inverse relationship. It was pleasing to note how many students dealt with the fact that a smaller angle is better without problem.

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