Access Tuition

A-Level Physics

Telescopes

Mark Scheme

Time available: 83 minutes
Marks available: 45 marks

Mark schemes

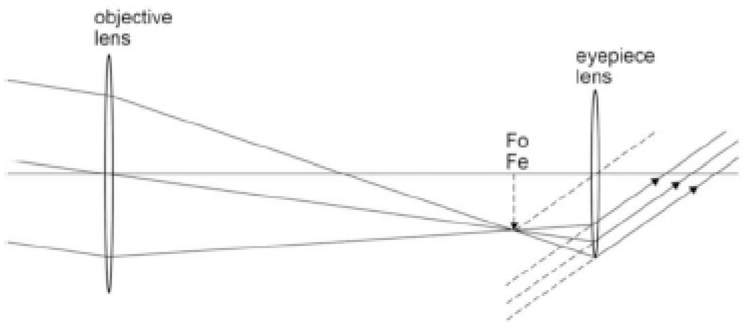
1. (a) Two pairs of rays drawn parallel to the principal axis coming to different foci. Outer rays focus closer to lens than inner rays. ✓

1

(b) Both focal points labelled, on the principal axis, and coincide, with $f_o >> f_e$ ✓

Three off-axis rays through objective lens correct ✓

Three rays through eyepiece correct, parallel (to a construction line) ✓



$f_o >> f_e$ by at least a factor of 2 for this mark. (Accept point or length labelled. Allow single point F.) TBA

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

(c) $f_o / f_e = 750$ $f_e + f_o = 17.4$

$f_e = (f_e + f_o)/751$ ✓

$= 17.4/751$

$f_e = 2.3(17) \times 10^{-2}$ m ✓

Accept any correct unit

Use of $f_e = (f_e + f_o)/750$ without explanation scores 1

2

(d) Resolution is limited by the diameter of the objective ✓
so it will make no difference ✓
OR
CCD has better resolution due to having smaller pixels ✓
so the stars could be more easily seen as separate (OWTTE) ✓

(candidates may combine these ideas)

CCDs have higher quantum efficiency and/or can be exposed for a long time ✓
so dimmer or more distant binaries can be observed ✓

CCDs can detect a wider range of wavelengths ✓
enabling the observation of more binary pairs. ✓

CCD is more convenient in use – with a specific example of why. ✓

General principle is difference followed by consequence.

Examples of 'convenience' include use when astronomer not present, sending image direct to computer, other sensible reason.

Max 3

[9]

2. (a) Rayleigh criterion identifies the minimum subtended angle between two objects whose (images) can be resolved. ✓$_1$

(Minimum angle is when) the central maximum of (the diffraction pattern of light from) one object coincides with the first minimum of (the diffraction pattern) of the second object. ✓$_2$

2

(b) Telescope is detecting U-V/wavelengths smaller than visible light ✓$_1$

1

Which is absorbed by (ozone in) the atmosphere so must be in space ✓$_2$

Explains why U-V light gives better resolution ✓$_3$

MP3 needs ref to λ/D or good detail about diffraction.

2

(c) Quantitative comparison of collecting power or resolution✓$_1$

Arecibo brighter image or more detail ✓$_2$

Links spherical aberration to detail of image ✓$_3$

e.g. Collecting power $\frac{305^2}{76^2}$ *= 16 times brighter*

or calculation of resolutions

There is no absolute conclusion

- Image from Arecibo will be brighter

- Lovell likely to be better detail because no spherical aberration

No mention of the effect of shape – MAX 2

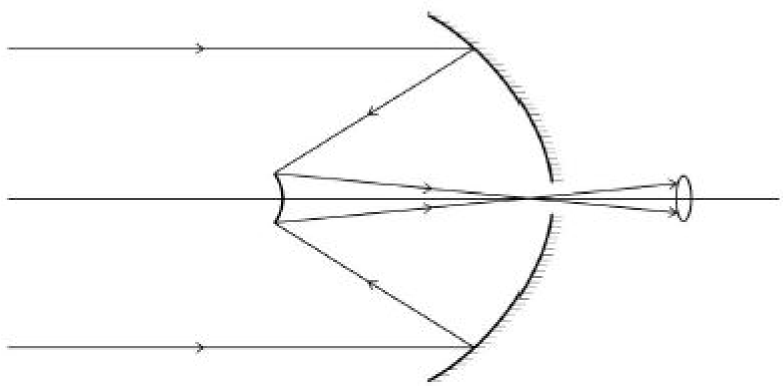
3

[8]

3. (a) Diagram of Cassegrain telescope with

both mirrors correct ✓

two rays correct ✓



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

Condone lack of shading. Hole in primary can be inferred from rays passing through.

Primary must not look like two mirrors.

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

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 on the principal axis after secondary and before passing through primary. Condone crossing after primary if before a lens.

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

Poorly drawn rays, eg curved, loses mark.

2

(b) Resolution = $\frac{450 \times 10^{-9}}{0.21}$ = 2.14×10^{-6} (rad) ✓

Smallest detail = $2.14 \times 10^{-6} \times 12.5 \times 10^{6}$ = 27 m ✓

Sensible comment about comparison and decision made ✓

For MP2 student may find angle subtended by 1 km crater

(8.0×10^{-5} rad) then compare angles for MP3

MP3 for example 27 m is 1/40th of crater.

3

(c) Collecting power ∝ area ✓

Ratio $= {2.4^2}/{.21^2} = 130$

OR calculates both areas and states Hubble is much bigger ✓

MP1 is for student showing they know dependence on area.

Condone collecting power ∝ d^2 if it is clear that d is diameter.

MP2 for clear comparison

2

(d) At least 2 clear comparisons made ✓ ✓

Decision made about which telescope, justified in terms of the impact of at least one comparison on the image (likely to be reflecting).✓

Problems of refractors:

Can suffer spherical aberration and chromatic aberration.

Reflecting are lighter. Reflecting are shorter. Mirrors do not suffer from chromatic aberration.

Problems of reflectors:

Spider/secondary mirror block some of the light/reduce image brightness/cause diffraction effects.

Ignore discussion of cost/difficulty of construction/air trapped in refracting telescope.

3

[10]

4. (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 $\times 1.8 \times 10^{-6}$ 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 × 10^7 = 1.1 × $10^{–5}$ ✓

As 1.1 × $10^{–5}$ > 1.8 × $10^{–6}$ asteroid can be seen / 1.1 × $10^{–5}$ / 1.8 × $10^{–6}$ 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]

5. (a) Concave mirror with parallel incident rays reflecting to different focal points. ✓

PA does not need to be drawn.

1

Rays further from PA brought to focus nearer the mirror. ✓

1

(b) **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.**

Mark	Criteria	QoWC
6	All three aspects covered: A full comparison of location in terms of the affect of atmosphere on the GTC, and the difficulties of maintaining, servicing and obtaining data from IUE. A quantitative comparison of the collecting power with conclusion that GTC has 530x collecting power of IUE. A quantitative comparison of minimum angular resolution, with conclusion that GTC is 5x better.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible
5	Two of the three aspects fully covered, with some detail missing from the third.	
4	One aspect fully covered, with some detail missing from the other two Or Two aspects fully covered, with little or no relevant information about the third.	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.
3	All three aspects partially covered, with some detail missing from each Or One aspect fully covered, with little or no relevant information about the other two.	
2	Two aspects partially covered, with little or no relevant information about the third.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g

1	One aspect partially covered, with little or no relevant information about the other two.	allow meaning to be derived although errors are sometimes obstructive.
0	Little or no relevant information about any of the three aspects.	The student's presentation, spelling punctuation and grammar seriously obstruct understanding.

The following statements are likely to be present:

Location

- light must travel through some of the atmosphere to reach GTC which affects the amount of light arriving and resolution.
- IUE In orbit needs its own power source,
- and information needs to be sent to ground for analysis.
- position of IUE inconvenient as, if something goes wrong, it is difficult to service an orbiting satellite.

Collecting power

- Collecting power is proportional to D^2.
- So ratio is $10.4^2 / 0.45^2 = 530$
- GTC has 530x collecting power.
- GTC better as bigger diameter telescopes make brighter images.

Minimum angular resolution

- Minimum angular resolution is proportional to 1 / D
- $\theta = \lambda / D$ so ratio of min angular resolution is $(1 \times 10^{-6} / 10.4) / (2 \times 10^{-7} / 0.45) = 0.2$
- GTC is 5× better at resolving
- GTC better as bigger diameter telescopes make clearer images.

6

(c) QE. = $\dfrac{\text{no. of photons arriving at detector and being detected}}{\text{total arriving at detector}}$

1

For CCD QE> 80%✓

For eye QE = 1%✓

Both needed

1

[10]