Mark schemes

1. (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]

2. (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

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

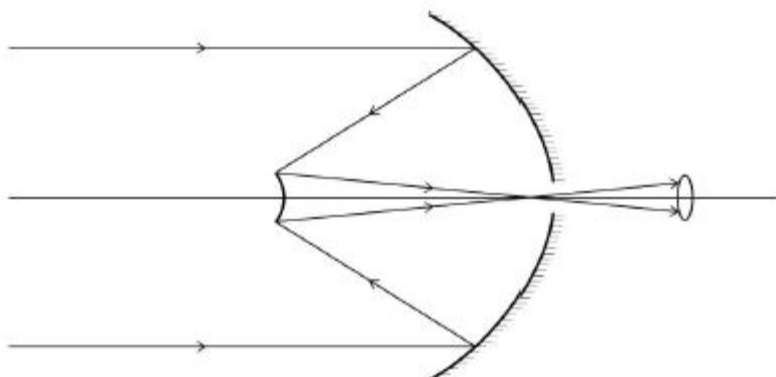   *Correct calculations can gain both marks, using any wavelength*

Max 2

[7]

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 = $\dfrac{450 \times 10^{-9}}{0.21}$ = 2.14 × 10⁻⁶ (rad) ✓

Smallest detail = 2.14 × 10⁻⁶ × 12.5 × 10⁶ = 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 ✓

$$\text{Ratio} = \frac{2.4^2}{.21^2} = 130$$

OR calculates both areas and states Hubble is much bigger ✓

> *MP1 is for student showing they know dependence on area.*
> *Condone collecting power ∝ d² 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 $M = f_o/f_e$ to give

$f_e = f_o/M = 5.03/178$ ✓

$= 0.028$ 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 $= 325/3 \times 10^7 = 1.1 \times 10^{-5}$ ✓

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]

5. (a) 2 rays brought to red focus and two rays brought to blue focus on PA

Blue ray focus closer to lens than red ray ✓

> *Accept one ray of each colour provided they pass through the PA*
>
> *Accept rays that stop at the PA*
>
> *Accept violet for blue*
>
> *Accept any two colours in the right order*
>
> *Accept initials for colours*
>
> *Accept hand-drawn rays unless obviously curved*
>
> *Rays can bend at centre of lens or at either (or both) surfaces(s)*

1

(b) Concave convex ✓

1

(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 in marking this question.

Mark	Criteria
6	All 4 aspects analysed, including calculation of resolving power/ratio of resolving powers for two telescopes. 6 marks can be awarded even if there is an error and/or parts of one aspect missing.
5	A good attempt to analyse 3 aspects, which must include quantitative or algebraic discussion of resolution **or** collecting power
4	Two aspects successfully discussed and one partially discussed. Whilst there will be gaps, there should only be an occasional error.
3	Two aspects discussed, or one discussed and two others covered partially. There may be several errors and omissions in the discussion.
2	Only one aspect discussed successfully, or makes a partial attempt at more than one aspect.
1	None of the four aspects covered without significant error; at least one relevant comment.
0	No relevant analysis.

The following statements are likely to be present.

A Structure

Similarity: both use reflecting (parabolic) surface.L1

Difference: Radio – no secondary reflector, detector placed at focal point of primary, wire mesh for dish L1

Treat as neutral: radio telescope arrays, optical only during dark

B Positioning

Similarity: both capable of being on Earth's surface as little absorption by atmosphere at optical or radio wavelengths. The presence of both on the planet can be inferred if reference is made to altitude. L2

Difference: Light pollution requires optical telescopes to be away from centres of population; distortions due to atmosphere require optical to be high up; obscuration by clouds requires optical to be high up or in dry places/radio telescopes need to be located in a (radio) quiet area/radio can be at lower altitude. L2

Treat as neutral: comments about placing either A or B in space,

C Collecting power

D^2: much larger D for radio means much greater collecting power /8× greater (but sources tend to be very weak) compared to optical.

$CPB/CPA = 110^2/39.3^2 = 7.8$

D Resolving power

λ/D; B large D but extremely large λ means generally low resolving power compared to A.

So A likely to provide more detailed image.

Evidence of calculations, eg

For optical min λ angle = 8.9×10^{-9} rad

For radio min λ angle = 2.3×10^{-5} rad

(could compare max λ angle; 4.6×10^{-8} and 9.1×10^{-3})

6

[8]

6.   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]