M1.(a) (i) largest distance = 2.57 + 1 = 3.57 AU ✓

$3.57 \text{ AU} = 3.57 \times 1.5 \times 10^{11}\text{m}$

$= 5.36 \times 10^{11}\text{(m)}$ ✓

The first mark is for the correct distance in AU.

The second mark is for the correct conversion to metres. Allow c.e.

2

(ii) angle = s / r

$= 5.4 \times 10^{5} / 1.73 \times 10^{11}$ ✓

$= 3.12 \times 10^{-6}$ (rad) ✓

Working needs to be shown for the first mark.

At least two sf needed for final mark.

2

(b) (i) mirrors correct ✓

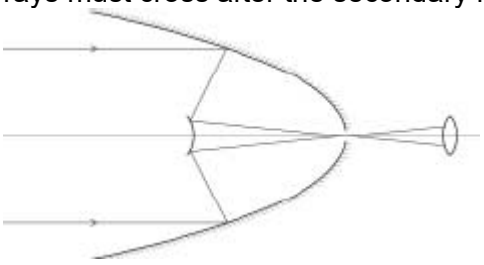
primary concave, secondary convex. No shading needed

primary mirror should be continuous i.e. not two mirrors

if no hole, evidence can be given by rays passing through

rays correct ✓

rays must cross after the secondary mirror



The lens does not need to be included.

2

(ii) angular resolution = λ / D D = $1 \times 10^{-6} / 3.3 \times 10^{-7}$ ✓

D = 3.0 m 2 sf needed ✓

Allow use of factor of 1.22.

Allow 1 sf if justified by discussion of approximate nature of calculation.

2

(c) minimum angular resolution is better / smaller than the size of the asteroid ✓

The first mark is for qualitative comparison.

details of about 1/10 the angular size of Vesta / 50km can be seen ✓

the second for the quantitative analysis.

2

[10]

M2.(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.	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible

	A quantitative comparison of minimum angular resolution, with conclusion that GTC is 5x better.	
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 allow meaning to be derived although errors are sometimes obstructive.
1	One aspect partially covered, with little or no relevant information about the other two.	
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. = $\frac{\text{no. of photons arriving at detector and being detected}}{\text{total arriving at detector}}$

1

For CCD QE> 80%✓

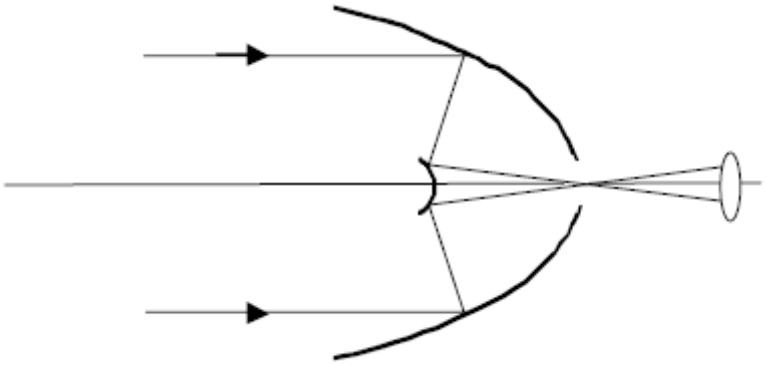
For eye QE = 1%✓

Both needed

1

[10]

M3. (a)



mirrors correct – concave primary and convex secondary ✓

both rays correct to eyepiece ✓

2

(b) (i)

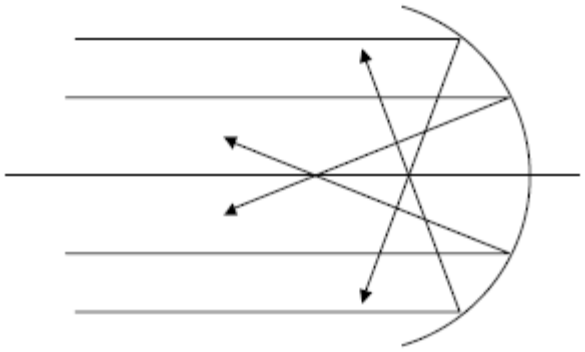


diagram to show two pairs of parallel rays being brought to a focus, those further from the axis being focused closer to the mirror ✓

1

(ii) (use of $\theta = /\lambda/D$)

to give $\theta = 630 \times 10^{-9}/0.15 = 4.2 \times 10^{-6}$ ✓

rad ✓

2

(iii) use of $s = r\theta$

to give $\theta = 4.8 \times 10^{3}/1.4 \times 10^{9} = 3.43 \times 10^{-6}$ ✓

(rad) ✓

claim unlikely to be valid as this angle is smaller than the minimum angular separation calculated in (ii) ✓

2

[7]