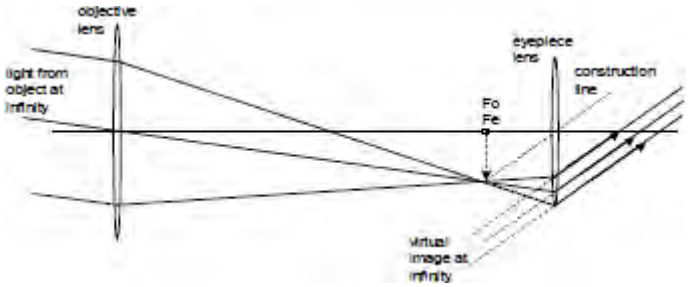
M1.(a) Both focal points labelled, on the principal axis, and coincide, with fo>fe ✓
Three <u>off-axis</u> rays through objective lens correct ✓
Three rays through eyepiece correct, parallel to a construction line. ✓

Accept point or length labelled. Allow single point F.
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 2 rays drawn, or there is no principal axis, max 2.



3

(b) (i) Using
$f_o + f_e = 21$
$f_o / f_e = 210$ ✓

Evidence of both equations needed for the mark.

Gives
$211\ f_e = 21$
$f_e = 21 / 211 = 0.10$ m
and $f_o = 21$ m (20.9) ✓

Alternative: $f_o = 4410 / 211 = 0.10$ m
If 210 used rather than 211 in substitution, max 1.

If the correct answer is obtained by inspection, max 1.

2

(ii) Large diameter allows fainter objects to be viewed, (as the collecting power is proportional to d^2) ✓
Larger diameter allows better resolution (as smallest resolvable angle is proportional to 1 / d) ✓

Allow: more light, better collecting power, brighter image, able to see more distant objects (not just further).

Allow references to more detail or clearer images for this mark.

Ignore references to magnification or field of vision.

2

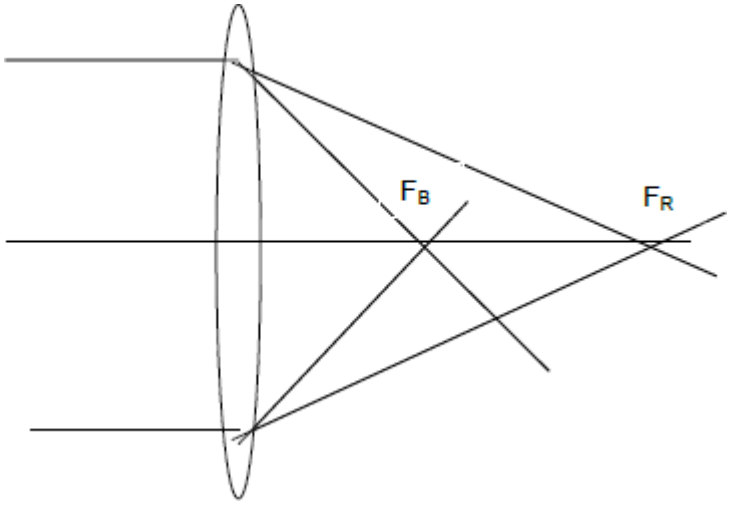
(c) *Diagram showing two focal points with blue focal point closer to lens than red focal point.*

Colours must be labelled. Allow wavelengths or frequencies if correct way round.

Rays need to be focused.

Allow 1 ray for each colour if principal axis drawn and foci labelled.

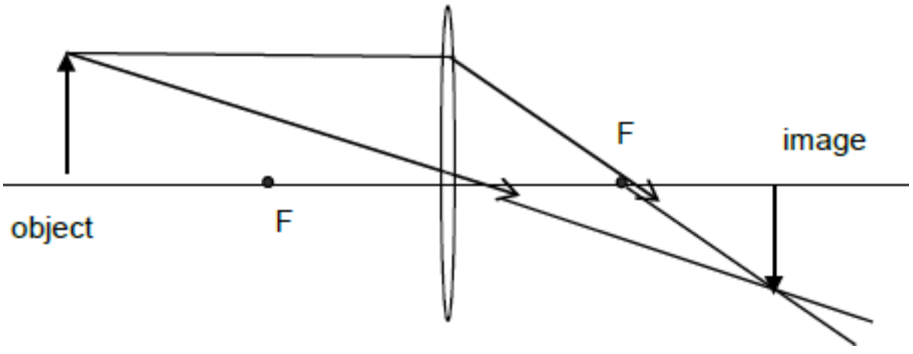
If other colours included, they must be correct.
Allow violet for blue.
Incident rays do not need to be parallel to the principal axis.



1

[8]

M2.*(a)*



Arrows are not essential

Condone only one focus if it is the one used for the construction ray. Construction ray must have focus labelled to get the mark.

Lose the second mark if the image is same size or magnified

Image line is needed for second mark.

One construction ray correct ✓

Other construction ray to form diminished image ✓

(The parallel construction ray must pass through a labelled F)

Object, image labelled correctly. ✓

3

(b) *u = 128 cm*

Allow c.e. for incorrect v

v = 200 − 128 = 72 cm ✓

Condone u and v the wrong way round.

Use of 1 / f = 1 / u + 1 / v

To give 1 / f = 1 /128 + 1 / 72

f = 46 cm ✓

2

(c) *Objective.*

No credit for unsupported answer.

As M = fo / fe, for magnification fo > fe ✓

As telescope length = fo + fe, lens must be objective (so that telescope not too long.) ✓

2

[7]

M3. (a) *3 parallel off-axis rays through objective lens correct* ***(1)***

rays continued through to the eyepiece emerging parallel to construction line ***(1)***

correct position of labelled foci ***(1)***

3

(b) (i) *use of $f_o + f_e = 3.7$*

and $f_o/f_e = 50$

(to give $51f_e = 3.7$) ***(1)***

$f_o = 3.6$ (m) and $f_e = 0.074$ (m) ***(1)***

2

(ii) use of s = rθ

to give θ = 23/380000 = 6(.053) × 10^{-5} rad ***(1)***

use of M = θ_2/θ_1

to give θ_2 = 50 × θ_1 = 3(.026) × 10^{-3} (rad) ***(1)***

2

(c) diagram to show dispersion of different colours in the correct order ***(1)***
rays crossing each other or principal axis correctly ***(1)***

2

[9]

M4. *(a) (i) (use of* $\theta = \frac{\lambda}{d}$ *gives)* $\frac{\theta_{reflector}}{\theta_{refractor}} = \frac{d_{refractor}}{d_{reflector}}$ ***(1)***

$= \left(\frac{0.9}{1.52}\right) = 0.59(2)$ ***(1)***

(ii) use of, energy collected per sec $\propto$ *= area* $\propto$ *=* d^2 ***(1)***

$\frac{P_{refl}}{P_{refr}} = \left(\frac{d_{refl}}{d_{refr}}\right)^2 = \left(\frac{1.52}{0.9}\right)^2 = 2.85$ ***(1)***

3

(b) (i) correct diagram showing four parallel co-axial rays, with outer rays brought to focus at a point closer to mirror than inner rays ***(1)***

(ii) (use of) parabolic mirror ***(1)***

2

(c) (i) correct diagram showing two mirrors, one concave, one convex **(1)**

(ii) mirror blocks light so less light hits objective mirror **(1)**
light diffracted passing secondary mirror affects image **(1)**

3

[8]

M5. (a) three parallel rays refracting through objective **(1)**
rays pass through intermediate image at point labelled F_o, F_e with $f_o > f_e$ **(1)**
rays leave eyepiece parallel to construction ray (which need not be shown) **(1)**

3

(b) (i) separation ($= f_o + f_e$) = 0.10 + 0.50 = 0.60 m **(1)**

(ii) (use of $m = \frac{f_o}{f_e}$ gives) $m = \frac{0.5}{0.1} = 5$ **(1)**

$\alpha = m\alpha = 5 \times \frac{3500}{380000} = 0.046$ rad **(1)**

[or $\alpha = \frac{3500}{380000}$

$\alpha' = 5\alpha = 0.046$ rad]

(iii) edges of the image will appear coloured **(1)**

4

[7]

M6. (a) diagram to show:
correct curvature of mirrors **(1)**
rays crossing in the hole in the objective mirror **(1)**

2

(b) (i) $\theta \left(= \frac{\lambda}{d}\right) = \frac{2.0 \times 10^{-6}}{3.8}$ **(1)**

$= 5.3 \times 10^{-7}$ rad **(1)** $(5.26 \times 10^{-7}$ rad)

(ii) visible wavelengths shorter (than infra red) **(1)**
$\therefore$ smaller resolving angle ($\therefore$ better resolving power) **(1)**

4

(c) (i) water vapour **(1)** (or carbon dioxide)

(ii) longer wavelengths absorbed **(1)**
shifts peak of graph to shorter wavelengths **(1)**
star appears hotter [or reference to appropriate equation] **(1)**

max 3

[9]