

17.1 Optical instruments, path differences and refraction

Name: _____ Class: _____ Date: _____

Total: 10 marks

KEY WORDS resolving power • optical path length

Objective

Calculate telescope magnification and grating resolving power; Relate Michelson fringe counts to double-pass optical path changes; Trace surface normals before applying Snell and reflection laws. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

For relaxed astronomical viewing at infinity, telescope lens separation is $f_{\text{objective}} + f_{\text{eyepiece}}$; angular magnification magnitude is their ratio. Two converging lenses invert the image. Finite final-image distance changes the adjustment, so first check the viewing condition.

Resolving power is $R = \lambda / \Delta\lambda$. An ideal grating gives $R = mN$ for order m and N illuminated slits. This is distinct from peak position $d \sin\theta = m\lambda$: more illuminated slits sharpen peaks, while slit spacing mainly changes their angular positions. Use matching wavelength units.

Evacuating a gas cell of length L in a Michelson arm changes double-pass optical path by $2L(n-1)$. N fringes imply $N\lambda$, so $n-1 = N\lambda / (2L)$. Moving a mirror by Δx changes path by $2\Delta x$. One fringe is one wavelength of optical path, not mirror displacement.

Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$ and reflection angles use the local surface normal. Adjacent rectangular faces have perpendicular normals; trace complementary internal angles before substitution. From index n into air, $\sin\theta > 1/n$ gives total internal reflection; equality is the critical grazing case.

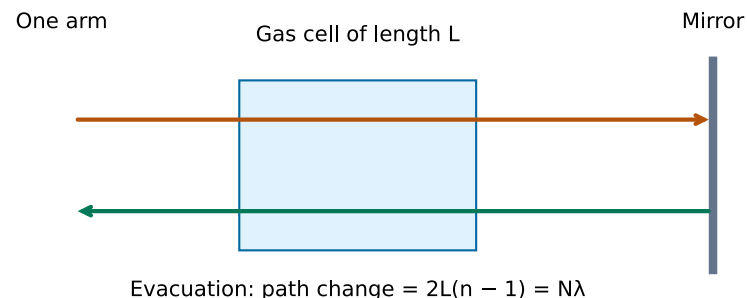
■ Worked method

A Michelson interferometer sends light twice through a gas cell of length L . Evacuation changes path by $2L(n-1)$. N fringes correspond to path change $N\lambda$.

$$n - 1 = \frac{N\lambda}{2L} = \frac{(120)(500 \times 10^{-9} \text{ m})}{2(0.10 \text{ m})} = 3.0 \times 10^{-4}.$$

Thus $n = 1.00030$. Moving a mirror is also double-pass; a fringe is not one wavelength of mirror motion.

Two passages through the same cell



2 Practice

2.1 A relaxed-view telescope has separation 72 cm and eyepiece focal length 12 cm. Angular magnification magnitude is: [1]

- A. 4
- B. 5
- C. 6
- D. 12
- E. 60

2.2 A grating just resolves 400 nm and 402 nm. Approximate resolving power is: [1]

- A. 2
- B. 100
- C. 200
- D. 400
- E. 800

2.3 Moving one Michelson mirror by 150 nm changes round-trip optical path by _____ nm. Show your relation and units. [2]

2.4 Decide whether this claim is true. Justify it: Snell's-law angles should be measured from the surface itself. [2]

3 Exam-style questions

3.1 A grating with spacing $d = 2.0$ micrometres illuminates $N = 5000$ slits at wavelength 600 nm. Find the largest physically allowed order and its ideal resolving limit in wavelength. State the different roles of spacing and illuminated slit count. [4]

Solutions

2.1 Answer: B. Objective focal length is $72-12=60$ cm; $60/12=5$.

Compare the rejected options: 4; 6; 12; 60. Use the stated model and conditions.

2.2 Answer: C. $R \approx 400/2=200$; wavelength and separation use the same units.

Compare the rejected options: 2; 100; 400; 800. Use the stated model and conditions.

2.3 300. The light crosses the changed distance outbound and returning.

2.4 False. They are measured from its normal; the surface angle is complementary.

3.1 $|m\lambda/d| \leq 1$ gives $m \leq 3.33$, hence largest integer order 3. $R = mN = 15000$ and $\Delta\lambda = \lambda/R = 600 \text{ nm}/15000 = 0.040 \text{ nm}$. Spacing sets the order angles; illuminated slit count narrows the peaks and improves resolution. Award order condition, order, resolving limit and distinction. The ideal limit assumes uniform illumination.