Unit 18 · Dispersion

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 28

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

He divided by μ instead of $\mu - 1$. Dispersive power compares the spread with the **deviation**, and the deviation of a small prism is $(\mu - 1)$A, so $\omega = (\mu_v - \mu_r)/(\mu - 1) = 0.016 \div 0.517 =$ **0.031**, about three times his value.

MARKING SCHEME

- ✓ The error: the denominator must be $\mu - 1$ (from $\delta = (\mu - 1)$A), not μ.
- ✓ $\omega = 0.016 \div 0.517$.
- ✓ $\omega = 0.031$.

2 Design it

ANSWER A · 4

i. No deviation of yellow: $(\mu - 1)\text{A} = (\mu' - 1)\text{A}'$, so $0.52 \times 10^\circ = 0.62\text{A}'$ and $\text{A}' =$ **8.4**°.

ii. Crown spread $0.016 \times 10^\circ = 0.160^\circ$; flint spread $0.040 \times 8.4^\circ = 0.335^\circ$, the other way. Net: $0.335^\circ - 0.160^\circ =$ **0.18**°.

iii. The **flint's**: for the same deviation, flint glass spreads the colors more than twice as much (larger dispersive power), so it more than undoes the crown's spread and the colors come out spread its way.

MARKING SCHEME

- ✓ $(\mu - 1)\text{A} = (\mu' - 1)\text{A}'$ for no deviation.
- ✓ $\text{A}' = 8.4^\circ$.
- ✓ Net dispersion 0.18°.
- ✓ The flint's spread wins (larger dispersive power).

3 Which glass is it?

ANSWER HA · 3

Chromatic aberration $f_r - f_v = 30.5 - 29.6 = 0.9$ cm; mean focal length about 30.05 cm. $\omega = (f_r - f_v)/f = 0.9 \div 30.05 =$ **0.030**. This is close to crown glass's 0.031 and far from flint's 0.083, so the lens is **crown glass**.

MARKING SCHEME

- ✓ $f_r - f_v = 0.9$ cm and $f \approx 30$ cm.
- ✓ $\omega = 0.030$.
- ✓ Crown glass (close to 0.031).

4 Predict, then explain

ANSWER HA · 3

The bow is a circle of 42° (red) round the point opposite the Sun, which is 30° below the horizon. So the top of the red band is $42^\circ - 30^\circ =$ **12**° above the horizon, with **red on top** (outside) and violet, at 40°, inside it. As the Sun sinks, the point opposite it rises towards the horizon, so the bow **rises and grows**: at sunset it is a half circle whose top is 42° up.

MARKING SCHEME

- ✓ $42^\circ - 30^\circ = 12^\circ$ above the horizon.
- ✓ Red on the outside (top), violet inside.
- ✓ As the Sun sinks the bow rises, becoming a half circle (top at 42°) at sunset.

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5 Estimate it

ANSWER A · 2

Violet: $(700/400)^4 = 1.75^4 = \mathbf{9.4\ times}$. Blue: $(700/450)^4 = \mathbf{5.9\ times}$.

MARKING SCHEME

✓ Violet about 9.4 times red.

✓ Blue about 5.9 times red.

6 Show that

MARKING SCHEME A · 3

✓ $\omega = \omega'$ gives $1/f + 1/f' = 0$: zero power.

✓ $f'/f = -\omega'/\omega$: the larger ω has the longer focal length.

✓ The stronger (convex) lens has the smaller dispersive power.

7 What if?

MARKING SCHEME A · 3

✓ Half the focal length: half the aberration (0.62 cm).

✓ 2.7 times ω: 2.7 times the aberration (about 3.3 cm).

✓ A mirror has no chromatic aberration (reflection is the same for every color).

8 Correct the misconceptions

ANSWER U · 3

1. The sky is blue because of **scattering** (Rayleigh, $I \propto 1/\lambda^4$), not dispersion: nothing refracts the light into a spectrum there.
2. The reflection at the back of a raindrop is an **ordinary partial** reflection, not total internal reflection: most of the light goes out of the back.
3. Angular dispersion, $(\mu_v - \mu_r)A$, **does** depend on the angle A; only the dispersive power does not.

MARKING SCHEME

✓ Blue sky: scattering, not dispersion.

✓ The reflection in a raindrop is partial, not total.

✓ Angular dispersion depends on A; dispersive power does not.

9 Think

ANSWER HA · 2

The spread of colors is ω times the deviation, and diamond's refractive index (2.42) is so large that its deviations are very large: the same small fraction of a large deviation is a wide spread of colors. Its cut also sends light back and forth through many faces before it leaves, spreading the colors at each.

MARKING SCHEME

✓ Angular spread = $\omega \times$ deviation; diamond's high index gives large deviations, so a large spread.

✓ The light passes through many faces inside the cut stone, spreading the colors more.

10 Make your own

ANSWER HA · 2

For example: crown, $A = 10°$, $\mu = 1.52$, $\mu_v - \mu_r = 0.016$ (spread 0.16°), with flint, $\mu = 1.62$, $\mu_v - \mu_r = 0.040$, of $A' = 0.16 \div 0.040 = 4°$, the other way up (spread 0.16°): no dispersion. Deviation $0.52 \times 10° - 0.62 \times 4° = 5.2° - 2.48° = \mathbf{2.7}°$. Any pair with $(\mu_v - \mu_r)A = (\mu'_v - \mu'_r)A'$ and different glasses is right.

MARKING SCHEME

✓ The spreads $(\mu_v - \mu_r)A$ are equal and opposite.

✓ The net deviation worked out (not zero).

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See it at Science Playground

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- **String Prism** (exhibit): The strings show white light fanning into colors in the prism, red bent least and violet most, since glass's refractive index is largest for violet.
- **The Spectroscope** (exhibit): Look into the viewing window: white light spreads into a band of colors, its spectrum, and different light sources show slightly different patterns.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	12	10	**28**

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