Unit 12 · Diffraction

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

4.6 mm is the distance from the center to the first dark band on **one** side. The central maximum runs from the first dark band on one side to the first on the other: its width is $2\lambda D/d$ = **9.1 mm**.

MARKING SCHEME

- ✓ The mistake: the half-width taken as the width.
- ✓ Width = $2\lambda D/d$.
- ✓ 9.1 mm.

2 Show that

ANSWER A · 2

The first dark band needs $\sin\theta = \lambda/d$. If $d < \lambda$, then $\lambda/d > 1$, and no angle has a sine greater than 1. So there is no dark band: the light spreads out over all angles from the slit.

MARKING SCHEME

- ✓ First minimum needs $\sin\theta = \lambda/d$.
- ✓ $d < \lambda$ makes $\lambda/d > 1$: impossible, so no minimum.

3 Predict, then explain

ANSWER HA · 3

Prediction: **red** is turned most by the grating.

For a grating $\sin\theta = n\lambda/(a+b)$, so the longest wavelength, red, has the largest angle. A prism does the opposite: it bends **violet** most, because glass's refractive index is largest for violet. The grating's spread depends only on the wavelength, the prism's on the glass.

MARKING SCHEME

- ✓ Red is turned most by the grating.
- ✓ $\sin\theta = n\lambda/(a+b)$: larger λ, larger angle.
- ✓ A prism bends violet most (refractive index largest for violet).

4 Read the data

ANSWER A · 3

i. $(a+b) = 10^{-2}/5500 = 1.82 \times 10^{-6}$ m. $\sin\theta_1 = 633 \times 10^{-9} \div 1.82 \times 10^{-6} = 0.348$, θ_1 = **20.4°** ✓; $\sin\theta_2 = 0.696$, θ_2 = **44.1°** ✓.

ii. The third order would need $\sin\theta_3 = 3 \times 0.348$ = **1.04**, more than 1: no such angle exists.

MARKING SCHEME

- ✓ $(a+b) = 1.82 \times 10^{-6}$ m.
- ✓ Both angles check out.
- ✓ $\sin\theta_3$ would be $1.04 > 1$.

5 A real setting

ANSWER A · 3

$$d\theta = \frac{1.22\lambda}{D} = \frac{1.22 \times 550 \times 10^{-9}}{2.5 \times 10^{-3}} = 2.68 \times 10^{-4} \text{ rad.}$$

At 160 m: $s = 160 \times 2.68 \times 10^{-4} \approx$ **4.3 cm**. Details closer together than about 4.3 cm blur into one.

MARKING SCHEME

- ✓ $d\theta = 1.22\lambda/D$.
- ✓ 2.68×10^{-4} rad.
- ✓ About 4.3 cm.

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6 Check the claim

ANSWER HA · 3

Dry, red: $\dfrac{\lambda}{2\mu\sin\theta} = \dfrac{650\times10^{-9}}{2\times0.85} = \mathbf{3.8\times10^{-7}\ m}$.

Oil, blue: $\mu\sin\theta = 1.5\times0.85 = 1.275$; $\dfrac{450\times10^{-9}}{2\times1.275} = \mathbf{1.8\times10^{-7}\ m}$.

The claim is **wrong**: the oil microscope with blue light resolves detail about 2.2 times finer.

MARKING SCHEME

- ✓ 3.8×10^{-7} m for the dry one in red.
- ✓ 1.8×10^{-7} m with oil in blue.
- ✓ The claim is wrong.

7 Estimate it

ANSWER HA · 3

Radio telescope: $1.22\times0.21/100 \approx \mathbf{2.6\times10^{-3}\ rad}$.

Eye: $1.22\times550\times10^{-9} \div 2.5\times10^{-3} \approx \mathbf{2.7\times10^{-4}\ rad}$.

The huge dish resolves about **ten times worse** than your eye, because its wavelength is so long. (That is why radio telescopes are made enormous, or linked across continents.)

MARKING SCHEME

- ✓ About 2.6×10^{-3} rad.
- ✓ Eye about 2.7×10^{-4} rad.
- ✓ The dish is about ten times worse: the long wavelength.

8 Correct the misconceptions

ANSWER U · 3

1. A **narrower** slit gives a wider central maximum (width $2\lambda D/d$).
2. More slits make a grating's maxima **sharper and brighter**, not fuzzier.
3. Resolving power depends on the objective's **diameter** (and the wavelength); a stronger eyepiece only enlarges the blur.

MARKING SCHEME

- ✓ A narrower slit spreads the light more.
- ✓ More slits make sharper maxima.
- ✓ Resolution depends on the objective's diameter, not the eyepiece.

9 Work backwards

ANSWER A · 2

$(a+b) = \lambda/\sin 30^\circ = 600\times10^{-9}/0.5 = \mathbf{1.2\times10^{-6}\ m}$.

Lines per cm $= 10^{-2}/1.2\times10^{-6} \approx \mathbf{8300}$.

MARKING SCHEME

- ✓ $(a+b) = 1.2\times10^{-6}$ m.
- ✓ About 8300 lines per cm.

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10 Design it

HA · 3

ANSWER

$N = 7.0 \times 10^5$ per meter. $\sin\theta = N\lambda = 7.0 \times 10^5 \times 577 \times 10^{-9} = 0.404$, $\theta = 23.8°$, $\cos\theta = 0.915$.

$\Delta\theta = 7.0 \times 10^5 \times 2.1 \times 10^{-9} \div 0.915 = 1.6 \times 10^{-3}$ rad = **0.092**°.

That is **more than 0.05**°: good enough.

MARKING SCHEME

✓ $\theta = 23.8°$.

✓ $\Delta\theta \approx 0.092°$.

✓ Good enough.

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

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