Unit 13 · Polarization

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 27

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

Malus's law applies only to polarized light. The polarizer first passes half of the unpolarized light, 25 W/m^2; the analyzer then passes 25 cos^2 45° = **12.5 W/m^2**.

MARKING SCHEME

✓ The mistake: Malus's law used on the unpolarized light.
✓ The polarizer passes half: 25 W/m^2.
✓ 12.5 W/m^2.

2 Show that

ANSWER A · 2

Brewster's law gives tan θp = μ, and the critical angle gives sin C = 1/μ, so μ = 1/sin C. Hence $\tan\theta_p = \frac{1}{\sin C}$.

MARKING SCHEME

✓ tan θp = μ and sin C = 1/μ.
✓ So tan θp = 1/sin C.

3 Predict, then explain

ANSWER HA · 3

Prediction: **yes**, some light gets through.
The first passes 25 W/m^2. The middle one, at 30°, passes 25 cos^2 30° = 18.75 W/m^2, now vibrating at 30°. The last is at 60° to that: 18.75 cos^2 60° = **4.7 W/m^2**. The middle filter turns the light's direction partway, so the last filter no longer meets light at 90°.

MARKING SCHEME

✓ Yes, light gets through.
✓ 25 → 18.75 W/m^2 after the middle filter.
✓ 4.7 W/m^2 leaves the last.

4 Check the readings

ANSWER A · 3

i. I = 24 cos^2 θ gives 24, 18, 12, **6.0** and 0: the reading at **60**° is wrong; it should be 6.0 W/m^2.
ii. cos^2 θ = 3/24 = 0.125, cos θ = 0.354, θ = **69.3**°.

MARKING SCHEME

✓ I = 24 cos^2 θ.
✓ The 60° reading should be 6.0 W/m^2.
✓ θ = 69.3°.

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5 A real setting

ANSWER A · 3

tan $\theta p = 1.52$, so she looks at **56.7**° from the normal. The reflected light vibrates along the window's surface, so she turns the filter's axis **at right angles to that**, in the plane of incidence, and the reflection disappears.

The light going into the glass is only **partially** polarized.

MARKING SCHEME

- ✓ $\theta p = 56.7°$.
- ✓ The filter's axis in the plane of incidence (across the reflected light's vibration).
- ✓ The transmitted light is only partially polarized.

6 Work backwards

ANSWER A · 2

$\theta p = 90° - 31.2° = 58.8°$, so $\mu = \tan 58.8° =$ **1.65**.

MARKING SCHEME

- ✓ $\theta p = 58.8°$.
- ✓ $\mu = 1.65$.

7 What if?

ANSWER HA · 3

Going from glass to air, $\tan \theta p = 1/1.60 = 0.625$, so $\theta p =$ **32.0**°.

The critical angle is $\sin^{-1}(1/1.60) = 38.7°$. Since 32.0° is less than that, **yes**, light gets out: it refracts out at 58.0°, at right angles to the reflected ray.

MARKING SCHEME

- ✓ $\tan \theta p = 1/1.60$, $\theta p = 32.0°$.
- ✓ Critical angle 38.7°.
- ✓ $32.0° < 38.7°$, so light gets out.

8 Correct the misconceptions

ANSWER U · 3

1. The chains **absorb** the light vibrating along them; light vibrating at right angles to them gets through.
2. At Brewster's angle the **reflected** light is completely polarized; the refracted light is only partially polarized.
3. Turning a polarizer doesn't change the brightness of unpolarized light (half always gets through); only polarized light is dimmed, to darkness twice a turn.

MARKING SCHEME

- ✓ Chains absorb the light along them.
- ✓ The reflected light, not the refracted, is completely polarized.
- ✓ Turning doesn't dim unpolarized light.

9 Design it

ANSWER HA · 3

$I = ½\ I_0 \cos^2 \theta = 0.15\ I_0$, so $\cos^2 \theta = 0.30$, $\cos \theta = 0.548$, $\theta =$ **56.8**°.

The most is **50%** (axes parallel); the least is **0** (axes crossed).

MARKING SCHEME

- ✓ $\cos^2 \theta = 0.30$.
- ✓ $\theta = 56.8°$.
- ✓ Between 0 and 50%.

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10 Make your own

HA · 2

ANSWER

μ must be more than $\tan 60^\circ = 1.73$. For example, μ **= 2.0**: $\theta p = \tan^{-1} 2.0 =$ **63.4**°. Any μ above 1.73 works.

MARKING SCHEME

✓ $\mu > \tan 60^\circ = 1.73$.

✓ A suitable example, e.g. $\mu = 2.0$ gives 63.4°.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	10	11	**27**

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