Unit 13 · Polarization

ANSWER KEY · FOR TEACHERS

Full marks 33

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

1 Key words

1. polarization
2. plane-polarized
3. analyzer
4. Malus's law
5. polarizing angle
6. Brewster's law
7. double refraction
8. optical activity

Each carries 0.5 mark. K · 4

2 Label the diagram

1. air
2. glass, $\mu = 1.50$
3. θp
4. r

Each carries 0.5 mark. K · 2

3 Multiple choice

i. **b.** a transverse wave — K · 1

Only transverse waves, which vibrate across the direction of travel, can be polarized.

ii. **b.** 24 W/m^2 — A · 1

The polarizer passes half, 32 W/m^2; then I = 32 cos^2 30° = 32 × 0.75 = 24 W/m^2.

iii. **c.** 59.8° — A · 1

tan θp = 1.72, so θp = 59.8°.

iv. **b.** at right angles to the plane of incidence, along the surface — U · 1

Only the part vibrating along the surface (perpendicular to the plane of incidence) is reflected at Brewster's angle.

v. **c.** twice — U · 1

The light is cut off whenever the axes are crossed, at 90° and 270°: twice a turn.

4 Short answers

a. MARKING SCHEME — K · 2

- ✓ Any one, e.g. unpolarized light vibrates in all directions across the ray; polarized light in one direction only.
- ✓ Any second, e.g. a turned analyzer doesn't change unpolarized light's brightness, but dims polarized light to darkness twice a turn; ordinary lamps give unpolarized light, a polaroid or reflection at Brewster's angle gives polarized light.

b. MARKING SCHEME — U · 2

- ✓ Reflected glare is polarized horizontally; the glasses' vertical axis blocks it.
- ✓ The sky's light is only partially polarized.

c. MARKING SCHEME — A · 3

- ✓ θp = 54.5°.
- ✓ r = 35.5°.
- ✓ 90° between the rays.

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5 Long answer

ANSWER U · 4

The reflected ray leaves at θp from the normal and the refracted ray at r on the other side; with 90° between them, the three angles make up the straight line of the surface: θp + 90° + r = 180°, so r = 90° − θp.

By Snell's law, μ = sin θp/sin r = sin θp/sin(90° − θp).

Since sin(90° − θp) = cos θp, μ = sin θp/cos θp = **tan θp**.

MARKING SCHEME

- ✓ Reflected and refracted rays at 90°.
- ✓ So r = 90° − θp.
- ✓ μ = sin θp/sin r by Snell's law.
- ✓ sin(90° − θp) = cos θp, so μ = tan θp.

6 Numerical problems

a. **ANSWER** A · 4

i. Half gets through: **40 W/m^2**.

ii. 40 cos^2 35° = 40 × 0.671 = **26.8 W/m^2**.

iii. 40 cos^2 70° = 40 × 0.117 = **4.7 W/m^2**.

iv. cos^2 θ = 0.25, cos θ = 0.5, θ = **60**°.

MARKING SCHEME

- ✓ 40 W/m^2.
- ✓ 26.8 W/m^2.
- ✓ 4.7 W/m^2.
- ✓ 60°.

b. **ANSWER** A · 4

i. tan θp = 1.60, θp = **58.0**°.

ii. r = 90° − 58.0° = **32.0**°.

iii. tan θp = 1.60/1.33 = 1.203, θp = **50.3**°.

iv. sin C = 1/1.60 = 0.625, C = **38.7**°.

MARKING SCHEME

- ✓ θp = 58.0°.
- ✓ r = 32.0°.
- ✓ 50.3° under water.
- ✓ C = 38.7°.

7 Think

ANSWER HA · 3

Sound in air is a longitudinal wave: the air vibrates along the direction the wave travels, so there is no direction across the ray to choose between. Polarization picks one direction of vibration across the ray, so only transverse waves can be polarized. That light can be polarized and sound can't shows that light is transverse and sound longitudinal.

MARKING SCHEME

- ✓ Sound in air is longitudinal: it vibrates along the direction of travel.
- ✓ Polarization needs vibration across the ray.
- ✓ So light must be transverse.

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8 Activity: Find the polarizing angle of a tabletop

(not marked)

WHAT STUDENTS SHOULD FIND

Seen nearly straight down or nearly along the surface, the reflection stays bright. At an angle in between, about 55° to 60° from the straight-down direction, it almost disappears: there the reflected light is nearly completely polarized along the surface (Brewster's angle), and the sunglasses' vertical axis blocks it. Tilting the glasses 90° brings it back.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	9	8	13	3	**33**

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