Grade 12 Physics, Explained

Unit 10 · Nature and Propagation of Light

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. corpuscles
2. ether
3. phase
4. wavefront
5. plane wavefront
6. secondary wavelets
7. envelope
8. rectilinear propagation

K · 4

Each carries 0.5 mark.

2 Label the diagram

1. i
2. glass, speed v
3. air, speed c
4. r

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **b.** cylindrical — K · 1

A long, narrow source gives wavefronts that are cylinders with the source along their axis.

ii. **c.** 1.9×10^8 m/s — A · 1

$\mu = c/v$, so $v = 3.0 \times 10^8 / 1.6 = 1.9 \times 10^8$ m/s.

iii. **a.** zero — K · 1

A wavefront joins points in the same phase, so their phase difference is zero.

iv. **c.** 451 nm — A · 1

The frequency stays the same and the speed falls μ times, so $\lambda = 600/1.33 = 451$ nm.

v. **b.** perpendicular to each other — U · 1

A ray shows the direction the wave travels, which is always at right angles to the wavefront.

4 Short answers

a. MARKING SCHEME — K · 2

- ✓ Any one, e.g. Newton: light is a stream of particles; Huygens: light is a wave spreading through a medium.
- ✓ Any second, e.g. Newton's theory predicts light is faster in water or glass than in air; Huygens' predicts it is slower (correct); or Huygens' theory explains interference and diffraction, Newton's doesn't.

b. MARKING SCHEME — U · 2

- ✓ The wavelets are not equally strong in every direction.
- ✓ Their strength straight back is zero, so there is no backward wave.

c. MARKING SCHEME — A · 3

- ✓ $v = 2.0 \times 10^8$ m/s.
- ✓ 667 nm in air.
- ✓ 444 nm in glass.

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5 Long answer

ANSWER U · 4

A plane wavefront AB meets the boundary XY at an angle; A touches it first. While B travels BB′ = ct to the boundary, the wavelet from A grows into the second medium to radius AA′ = vt.
The tangent A′B′ from B′ to this wavelet is the refracted wavefront.
In triangle ABB′, sin i = BB′/AB′ = ct/AB′; in triangle AA′B′, sin r = AA′/AB′ = vt/AB′.
Dividing, $\frac{\sin i}{\sin r} = \frac{c}{v}$, a constant for the two media: Snell's law, with μ = c/v.

MARKING SCHEME

- ✓ BB′ = ct while the wavelet from A grows to AA′ = vt.
- ✓ The tangent A′B′ is the refracted wavefront.
- ✓ sin i = ct/AB′ and sin r = vt/AB′.
- ✓ sin i/sin r = c/v = μ, a constant.

6 Numerical problems

a. **ANSWER** A · 4

i. BB′ = AB′ sin i = 8.0 × sin 50° = **6.13 cm** (= ct).
ii. AA′ = vt = BB′/μ = 6.13/1.33 = **4.61 cm**.
iii. sin r = AA′/AB′ = 4.61/8.0 = 0.576, so r = **35.2°**.

MARKING SCHEME

- ✓ BB′ = 6.13 cm.
- ✓ AA′ = BB′/μ.
- ✓ AA′ = 4.61 cm.
- ✓ r = 35.2°.

b. **ANSWER** A · 4

i. v = c/μ = 2.0 × 10^8 m/s; t = 0.020/2.0 × 10^8 = **1.0 × 10^{-10} s**.
ii. In air t = 0.020/3.0 × 10^8 = 6.7 × 10^{-11} s: **3.3 × 10^{-11} s** longer.
iii. In glass λ = 500/1.5 = 333 nm, so 0.020/333 × 10^{-9} = **60 000 wavelengths**; in air 0.020/500 × 10^{-9} = **40 000**.

MARKING SCHEME

- ✓ t = 1.0 × 10^{-10} s in glass.
- ✓ 3.3 × 10^{-11} s longer than in air.
- ✓ 60 000 wavelengths in glass.
- ✓ 40 000 in air.

7 Think

ANSWER HA · 3

Behind any opening, the wavelets from the edge of the wavefront spread sideways into the shadow, but this spreading is noticeable only over a distance comparable to the wavelength. Light's wavelength (about 500 nm) is tiny compared with a window, so the wide front rebuilds itself almost straight and the shadow is sharp. Sound's wavelength (about a meter) is comparable to a door, so its wavelets spread well round the corner.

MARKING SCHEME

- ✓ Wavelets from the edges spread into the shadow.
- ✓ The spreading matters only when the opening is comparable to the wavelength.
- ✓ Light's wavelength is tiny; sound's is about a door's width.

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8 Activity: Check Snell's law with a glass block

(not marked)

WHAT STUDENTS SHOULD FIND

The ratio sin i ÷ sin r comes out about the same each time, near 1.5 for ordinary glass: Snell's law. By the wave theory this ratio is c/v, so light travels about 1.5 times slower in glass than in air.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	10	7	13	3	**33**

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