

Interference, resonance and the Doppler shift

AP Physics 2 (algebra-based) · Worksheet answers

Each answer shows the formula, the substitution and the final value with its unit. Compare your method as well as your number, because AP markers award credit for the correct relationship and a justified sign or direction.

Level: AP Physics 2 (algebra-based) · **Curriculum:** AP P2 Unit 14

Problem 1 Path difference and interference

1. Path difference = $4.5 \text{ m} - 3.0 \text{ m} = \mathbf{1.5 \text{ m}}$.
2. $1.5 \text{ m} / 0.50 \text{ m} = \mathbf{3.0 \text{ wavelengths}}$.
3. A whole number of wavelengths means the sounds arrive in phase, so the interference is **constructive** and the microphone detects a loud signal.

Problem 2 Wavelength of a sound note

1. $\lambda = v / f = 343 / 440 = \mathbf{0.780 \text{ m}}$.
2. $T = 1 / f = 1 / 440 = \mathbf{2.27 \times 10^{-3} \text{ s}}$ (2.27 ms).

Problem 3 Fringe spacing from a double slit

1. $\lambda = 5.00 \times 10^{-7} \text{ m}$ and $d = 1.0 \times 10^{-4} \text{ m}$.
2. $\Delta y = \lambda L / d = (5.00 \times 10^{-7} \times 1.5) / (1.0 \times 10^{-4}) = \mathbf{7.5 \times 10^{-3} \text{ m (7.5 mm)}}$.

Problem 4 Converting wave quantities

1. $0.25 \text{ mm} = 0.25 \times 10^{-3} \text{ m} = \mathbf{2.5 \times 10^{-4} \text{ m}}$.
2. $\lambda = c / f = 3.0 \times 10^8 / 4.6 \times 10^{14} = 6.52 \times 10^{-7} \text{ m} = \mathbf{652 \text{ nm}}$.

Problem 5 Fundamental of a string

1. $\lambda = 2L = \mathbf{1.30 \text{ m}}$.
2. $f_1 = v / \lambda = 260 / 1.30 = \mathbf{200 \text{ Hz}}$.
3. $f_3 = 3 \times 200 = \mathbf{600 \text{ Hz}}$.

Problem 6 Phase flips in an oil film

1. Light goes from low index (1.00) to higher index (1.45), so the phase **flips** by half a cycle.
2. Light goes from 1.45 to 1.33, a lower index, so there is **no flip**.
3. Only one reflection flips, so the rays differ by **half a cycle** before path difference is added.

Problem 7 Pipes open and closed

- $f = nv / 2L = n \times 340 / 1.00$: **340 Hz, 680 Hz, 1020 Hz.**
- $f = nv / 4L = n \times 340 / 2.0$ with n odd: **170 Hz and 510 Hz.**

Problem 8 Doppler shift of a horn

- $f' = f v / (v - v_s) = 500 \times 340 / 320 = \mathbf{531 \text{ Hz.}}$
- $f' = 500 \times 340 / 360 = \mathbf{472 \text{ Hz.}}$

Problem 9 Reading a fringe graph

- Peaks are at 0, 4, 8 mm, so $\Delta y = \mathbf{4.0 \text{ mm.}}$
- $\lambda = \Delta y d / L = (4.0 \times 10^{-3} \times 3.0 \times 10^{-4}) / 2.0 = \mathbf{6.0 \times 10^{-7} \text{ m (600 nm).}}$
- The fringe at +8 mm is the second order, so the path difference is $\mathbf{2\lambda = 1200 \text{ nm.}}$

Problem 10 Angles in a double slit

- $\sin \theta = m\lambda / d = 2 \times 600 \times 10^{-9} / 4.0 \times 10^{-6} = 0.30$, so $\theta = \mathbf{17.5^\circ.}$
- $\sin \theta$ cannot exceed 1, so $m \leq d / \lambda = 6.67$ and the highest order is $\mathbf{m = 6.}$

Problem 11 Soap film thickness

- Only the top reflection flips by half a cycle, so the rays are already half a cycle apart. A path difference of half a wavelength inside the film ($2nt = \lambda/2$) adds another half cycle and brings them back in phase.
- $t = \lambda / (4n) = 560 / (4 \times 1.33) = \mathbf{105 \text{ nm.}}$

Problem 12 Anti-reflection coating

- Both reflections go from lower to higher index, so **both flip.**
- Equal flips cancel out, so reflection is weak (destructive) when the extra path $2nt$ equals half a wavelength.
- $t = \lambda / (4n) = 550 / (4 \times 1.38) = \mathbf{99.6 \text{ nm.}}$

Problem 13 Beats from two sources

- $f_{\text{beat}} = 6 / 2.0 = \mathbf{3 \text{ Hz.}}$
- The string was at 437 Hz or 443 Hz.
- Tightening raises the string frequency. A higher beat rate means the gap grew, so the string was above the fork: **443 Hz.**

Problem 14 Red against violet fringes

- Red: $y = \lambda L / d = 700 \times 10^{-9} \times 1.0 / 2.0 \times 10^{-4} = \mathbf{3.5 \text{ mm.}}$ Violet: $y = 400 \times 10^{-9} \times 1.0 /$

$$2.0 \times 10^{-4} = \mathbf{2.0 \text{ mm.}}$$

2. Every colour has a bright fringe at the centre, so it is white. Violet is nearest the centre and red is furthest out in each first-order band.

Problem 15 Resonance tube lengths

$$1. \lambda = v / f = 343 / 512 = \mathbf{0.670 \text{ m.}}$$

$$2. \text{Resonance occurs at } L = \lambda/4 = \mathbf{0.168 \text{ m}} \text{ and } L = 3\lambda/4 = \mathbf{0.502 \text{ m.}}$$

Problem 16 Slit separation from a pattern

$$1. \text{Each third-order fringe lies } y_3 = 3\lambda L / d \text{ from the centre, so the separation is } 2y_3 = 6\lambda L / d.$$

$$2. d = 6\lambda L / (2y_3) = 6 \times 633 \times 10^{-9} \times 3.20 / 0.0608 = \mathbf{2.00 \times 10^{-4} \text{ m}} \text{ (0.200 mm).}$$

Problem 17 Colours reflected by a bubble

$$1. 2nt = (m + \frac{1}{2})\lambda, \text{ so } \lambda = 2nt / (m + \frac{1}{2}).$$

$$2. 2nt = 2 \times 1.33 \times 380 = 1011 \text{ nm. } m = 1 \text{ gives } 1011 / 1.5 = \mathbf{674 \text{ nm}}; m = 2 \text{ gives } 1011 / 2.5 = \mathbf{404 \text{ nm}}; m = 0 \text{ gives } 2022 \text{ nm and } m = 3 \text{ gives } 289 \text{ nm, both outside the visible range.}$$

$$3. \text{Red and violet are strongly reflected, so the film looks } \mathbf{magenta}.$$

Problem 18 Wavelength squeezed by motion

$$1. \lambda_0 = v / f = 343 / 650 = \mathbf{0.528 \text{ m.}}$$

$$2. \text{In one period the source moves } 30 / 650 = 0.0462 \text{ m, so } \lambda' = 0.528 - 0.046 = \mathbf{0.482 \text{ m.}}$$

$$3. f' = v / \lambda' = 343 / 0.4815 = \mathbf{712 \text{ Hz.}}$$

Problem 19 Closed pipe claim, spot the error

$$1. f_1 = v / 4L = 340 / (4 \times 0.85) = \mathbf{100 \text{ Hz.}}$$

$$2. \text{Only odd multiples occur: } \mathbf{300 \text{ Hz and } 500 \text{ Hz.}}$$

3. The student treated the pipe as open at both ends. A closed end forces a node, so 200 Hz does not fit: no whole number of half wavelengths can end on a node at one end and an antinode at the other.

Problem 20 Design a wavelength measurement

1. Measure the slit-to-screen distance L (metre rule or tape) and the distance across N fringes (ruler on the screen). Apparatus: laser, double slit slide, clamp, screen, tape measure.

2. Measure across 10 fringes and divide by 10, use a large L and repeat the measurement.

3. Plot fringe spacing Δy (vertical) against L (horizontal) for several L values. The graph is a straight line through the origin with **gradient λ / d** , so $\lambda = \text{gradient} \times d$.