Year 13 Science: Interference, double slits and diffraction gratings

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Two speakers in phase emit sound of wavelength 0.40 m. At point P the path difference is 1.00 m. Is P loud or quiet?

2. Light of wavelength 600 nm passes through slits 0.300 mm apart onto a screen 1.50 m away. Find the fringe spacing.

3. Find the slit spacing d of a grating with 300 lines per mm.

4. Yellow light of 589 nm shines on that grating. Find the angle of the second-order maximum.

5. What is the highest order maximum that grating gives for 589 nm light?

Exam-style question: a grating on the lab wall

Aroha shines a red laser of wavelength 635 nm through a diffraction grating with 500 lines per mm, onto a wall 1.50 m from the grating. The wall is wide enough to catch every beam.

6. Calculate the angle of the first-order maximum.

7. Calculate the distance on the wall from the central maximum to the first-order maximum.

8. Explain why the first-order maximum is bright.

9. Aroha changes to a violet laser of wavelength 405 nm. Describe and explain how the pattern changes, including how many maxima there are.

Fix the mistake

10. Correct this statement: "For a grating, $\sin\theta = x/L$, so I used $n\lambda = dx/L$ at 40°."

11. Correct this statement: "The grating has 600 lines per mm, so d = 600 mm."

12. Correct this statement: "$d \div \lambda = 3.13$, so there are 3 maxima."

13. Correct this statement: "Dark fringes are where no light reaches the screen from the slits."

Answer key (for parents and tutors)

1. Two speakers in phase emit sound of wavelength 0.40 m. At point P the path difference is 1.00 m. Is P loud or quiet?
   1.00 ÷ 0.40 = 2.5 wavelengths, a half number, so P is quiet (destructive interference).
2. Light of wavelength 600 nm passes through slits 0.300 mm apart onto a screen 1.50 m away. Find the fringe spacing.
   $\Delta x = \lambda L \div d = (600 \times 10^{-9} \times 1.50) \div (0.300 \times 10^{-3}) = 3.00 \times 10^{-3}$ m = 3.00 mm.
3. Find the slit spacing d of a grating with 300 lines per mm.
   $d = 1 \div (300 \times 10^{3}) = 3.33 \times 10^{-6}$ m.
4. Yellow light of 589 nm shines on that grating. Find the angle of the second-order maximum.
   $\sin\theta = 2 \times 589 \times 10^{-9} \div 3.333 \times 10^{-6} = 0.3534$, $\theta = 20.7°$.
5. What is the highest order maximum that grating gives for 589 nm light?
   $d \div \lambda = 3.333 \times 10^{-6} \div 589 \times 10^{-9} = 5.66$, so the 5th order (n = 6 would need sin θ greater than 1).
6. Calculate the angle of the first-order maximum.
   $d = 1 \div (500 \times 10^{3}) = 2.00 \times 10^{-6}$ m; $\sin\theta = 635 \times 10^{-9} \div 2.00 \times 10^{-6} = 0.3175$, $\theta = 18.5°$ (Achieved).
7. Calculate the distance on the wall from the central maximum to the first-order maximum.
   The angle is too large for $x = n\lambda L \div d$, so $x = L \tan\theta = 1.50 \times \tan 18.5° = 1.50 \times 0.3348 = 0.502$ m (Merit; Achieved if the small-angle formula gives 0.476 m).
8. Explain why the first-order maximum is bright.
   At that angle light from each slit travels exactly one wavelength further than light from the slit next to it, so all the waves arrive in phase and superpose constructively, and because so many slits add together the maximum is bright (Merit for path difference and phase, Excellence for linking to superposition from many slits).
9. Aroha changes to a violet laser of wavelength 405 nm. Describe and explain how the pattern changes, including how many maxima there are.
   With a shorter wavelength, $\sin\theta = n\lambda \div d$ is smaller, so every maximum moves closer to the centre. The highest order rises: for red $d \div \lambda = 3.15$, so 3 orders and 7 maxima; for violet $d \div \lambda = 4.94$, so 4 orders and 9 maxima (Excellence for the explanation and both counts).
10. Correct this statement: "For a grating, $\sin\theta = x/L$, so I used $n\lambda = dx/L$ at 40°."
    x/L is only a small-angle approximation; for a grating find θ from $n\lambda = d \sin\theta$, then $x = L \tan\theta$ if needed.
11. Correct this statement: "The grating has 600 lines per mm, so d = 600 mm."
    d is the gap between lines: $1 \div 600$ mm = 1.67×10^{-3} mm = 1.67×10^{-6} m.
12. Correct this statement: "$d \div \lambda = 3.13$, so there are 3 maxima."
    There are 3 orders on each side plus the central maximum: 7 in all.
13. Correct this statement: "Dark fringes are where no light reaches the screen from the slits."
    Light from both slits arrives there, but 180° out of phase, so the waves cancel.