Young’s double slit: finding the rule

Name: Class:

For a hundred years after Newton, the orthodox account of light was that it is a stream of particles. In 1801 Thomas Young let sunlight through a single pinhole, split the narrow beam with a slip of card, and let the two halves fall on a wall. Where they overlapped he found not one patch of light but a row of bright and dark bands. Two waves arriving out of step can cancel one another; two streams of particles cannot. In this setup, the pinhole is a laser and the card a pair of slits, but the reasoning is the same as the idea you have from the ripple tank: what happens at a point depends on the difference between the distances the two waves travelled to reach it. By the end you will have a formula for the spacing of the bands.

> Throughout: λ is the wavelength, d the distance between the two slits, D the distance from the slits to the screen, y the distance of a point on the screen from the middle of the pattern, and s the distance from one bright band to the next. θ is marked on Figure 2.

Readings marked **[sim]** come from the simulation. Figure 1 is printed at true size, so measure it with a ruler.

A Why one source has to light both slits

1. **[sim]** Young’s light went through one pinhole before it reached the two slits, and a modern version uses one laser for both. Switch on *Two independent sources* and watch both strips of the screen. Say what happens to the pattern, and why a second lamp will not do.

B The pattern on the screen

Figure 1 is the screen for λ = 600 nm, d = 0.30 mm and D = 1.50 m, printed as a negative: the **dark** bands on the paper are where the light is **brightest**.

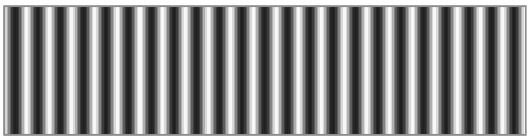


Figure 1 — printed to scale. Do not enlarge or reduce.

1. Do not measure a single band. Measure from the centre of one dark band to the centre of another well away from it, counting the gaps you cross.

   Number of gaps: _____ Distance across them: _____ mm, so s = _____ mm

2. **[sim]** Set the simulation to those three values and read its fringe spacing. Does it agree with yours, to the precision a ruler can manage?

C What decides where a band falls

[sim] The simulation gives the true distances S_1P and S_2P from each slit to the marker. Put it on the middle bright band, then on each band out to one side in turn, numbered m = 0, 1, 2, … outwards. *Nearest bright* lands it exactly.

m	y / mm	S_1P / mm	S_2P / mm	$S_2P - S_1P$ / nm	in units of λ
0					
1					
2					
3					

1. Write down what the path difference is at a bright band, using m for a whole number. path difference = _____

Both distances are about 1500 mm and they differ by less than a thousandth of a millimetre. The pattern on the screen is what makes it visible, by turning a difference in path into a position you can measure.

D From the geometry to a formula

The slits are a fraction of a millimetre apart and the screen metres away, so the two paths to a point are very nearly parallel. Figure 2 draws them so. The dashed line is drawn from S_1 at right angles to the path from S_2, cutting off the extra distance the

light from S_2 must travel.

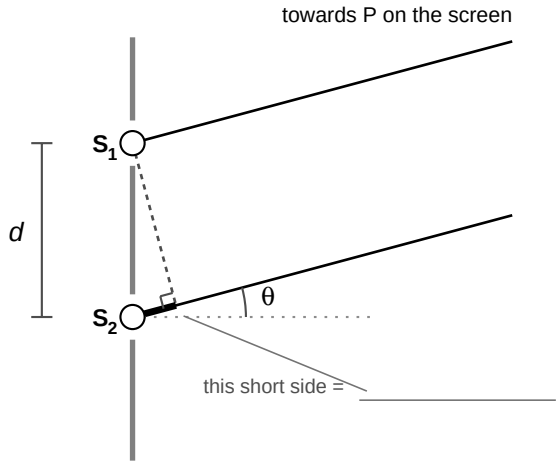


Figure 2 — not to scale. The angle is opened out so the little triangle can be seen at all; in the real apparatus it is a fraction of a degree.

1. The heavy segment is that extra distance — the path difference. Use the right-angled triangle to write it in terms of *d* and θ, and fill in the blank on Figure 2.
2. Combine that with your rule from C1. A bright band appears at an angle θ when: _____ = *m*λ
3. **[sim]** This is only useful if θ is small. Put the marker on the *m* = 1 band and read θ, then work out sin θ and tan θ.

   θ = _____ ° sin θ = _____ tan θ = _____
4. So for small angles you may swap one for the other. The marker is *y* from the middle of the pattern and the screen is *D* away, so tan θ = _____
5. Put 3 and 4 into your equation from 2 and rearrange for *y*, the distance of the *m*th bright band from the middle. y_m = _____
6. The fringe spacing *s* is the distance from one band to the next. Write *y* for the band after the *m*th one, subtract, and simplify.

   $s = y_{m+1} - y_m$ = _____
7. *m* has gone. Say in one sentence what that means about the bands across the screen — and check it against Figure 1.

E Testing it, in the simulation

[sim] Let's test out the formula. Use the *Graph* panel: set the bench, press *Record this point*, repeat.

1. Leave λ and *d* alone. Record a point at *D* = 1.00, 1.50, 2.00, 2.50 and 3.00 m. Choose *s against D*. Is it a straight line through the origin, and what does that tell you about how *s* depends on *D*?

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2. Read the gradient off the panel. Your formula says the gradient of *s* against *D* should be equal to a particular combination of the other two quantities. Write it down, work out its value, and compare.

   gradient should be _____ = _____ mm m^{-1} panel reads _____ mm m^{-1}
3. *Clear* the graph. Hold *D* at 1.50 m and record five points with different *d*. Plot *s* against 1/*d*. Why would a plot against *d* have curved, and this one not?

F The same rule, a different wave

[sim] Switch the wave to **Microwaves**: λ = 30 mm, *d* = 250 mm, *D* = 1.20 m.

1. Before you look at the screen, use your formula to predict the fringe spacing. Then read what the simulation measures.

   predicted *s* = _____ cm measured *s* = _____ cm
2. They do not quite agree, and the gap is too big to blame on the reading. **Just two steps** of your derivation were only ever approximations. Which are they, and what has changed to make them show?
