Inexpensive single and double slits using a fine-toothed comb

Alan J. DeWeerd
Department of Physics, University of Redlands, Redlands, CA 92373

For single-slit diffraction and double-slit interference experiments, commercially-made slits are usually the most expensive parts, especially since the prices of laser pointers have become very low. One option is to use razor blades to cut slits in either paint[1] or electrical tape[2] on microscope slides. However, this takes some practice, and there is some risk of injury, so it may not be reasonable to expect students to make their own slits this way. Also, measuring the width and the separation of the slits produced requires a microscope.[2] A simple, inexpensive alternative is to use the gaps of a fine-toothed comb as slits.

Plastic flea combs intended for pets have two sets of fine teeth, one slightly more coarse than the other, and can be found online for about $1 each. If photos are available, it is a good idea to count the teeth before purchasing combs because some have finer teeth than others. Making single and double slits from a comb was extremely easy. Black electrical tape was used to mask off the area around one or two of the gaps between teeth as shown in Figure 1. Care had to be taken to avoid bending the teeth when attaching the tape. Single-slit diffraction and double-slit interference patterns were produced using a laser pointer. Binder clips were used as inexpensive mounts[1] for the laser pointer and the comb, but the large index card acting as a screen was taped to a wall. Figure 2 shows the patterns produced using the finer side of the comb.

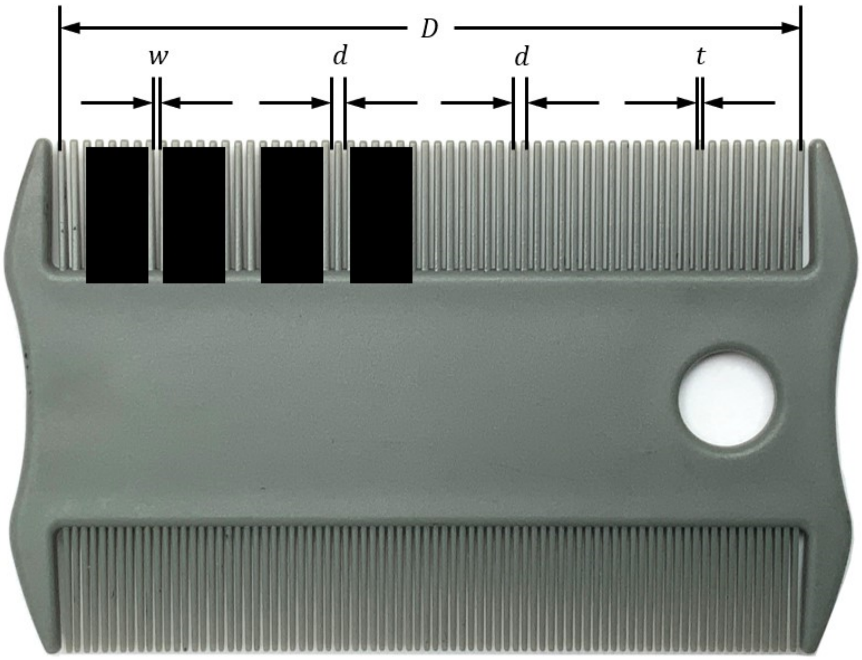

Fig. 1. Black electrical tape masked off the area around one or two of the gaps between teeth of the comb. The width of a gap is *w*, the distance between the centers of adjacent gaps or adjacent teeth is *d*, the width of a tooth is *t*, and the distance from the first fine tooth to the N^{th} one is *D*.

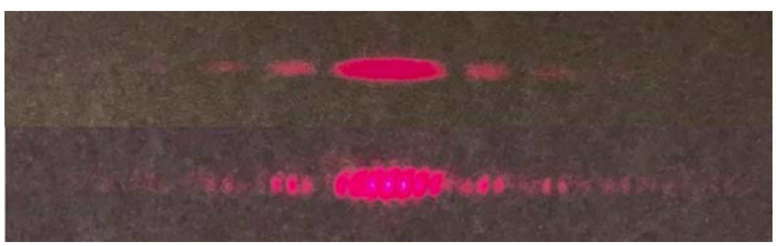

Fig. 2. Patterns for single and double slits using the finer side of the comb. (Black paper was used as a screen for these photos.)

In order to make this a quantitative experiment, the dimensions of the patterns formed should be related to the dimensions of the slits. If a feature on the screen a distance y from the center is at an angle θ, as shown in Figure 3, then

$$\tan\theta = \frac{y}{L}, \tag{1}$$

where L is the distance to the screen. If $y << L$, the small angle approximation of $\tan\theta \approx \sin\theta$ applies. For single-slit diffraction, dark bands occur where there is destructive interference between light waves leaving with a separation of half the slit width. The path length difference for the first dark band is a half wavelength, so the angle (θ_{d1}) to it is given by

$$\frac{w}{2}\sin\theta_{d1} = \frac{\lambda}{2}, \tag{2}$$

where w is the width of the single slit and λ is the wavelength. Using the small angle approximation along with equations (1) and (2), the distance from the middle of the central maximum to first dark band is

$$y_{d1} \approx \frac{\lambda L}{w}. \tag{3}$$

For double-slit interference, bright bands occur where there is constructive interference between light waves from the two slits. This occurs when the path difference is equal to an integer number of wavelengths, so the angle (θ_{cn}) to the n^{th} bright band is given by

$$d\sin\theta_{cn} = n\lambda, \tag{4}$$

where d is the distance between the centers of the slits. Using the small angle approximation along with equations (1) and (4), the distance from the central maximum to the n^{th} bright band is

$$y_{cn} \approx \frac{n\lambda L}{d}, \tag{5}$$

or the distance between adjacent bright bands is

$$\Delta y_c \approx \frac{\lambda L}{d}. \tag{6}$$

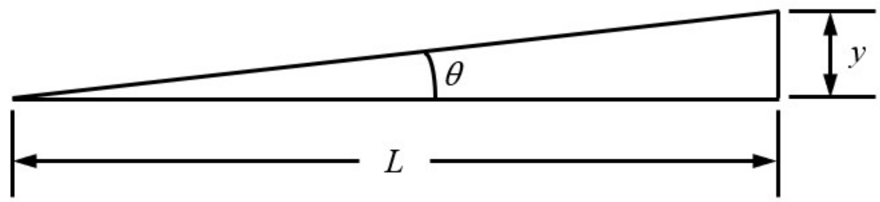

Fig. 3. The distance from the slit(s) to screen is *L*, the distance the center of the pattern on the screen to a feature is *y*, and the angle is θ.

It was easy to measure the dimensions of the slits created. The separation of two slits was determined using a ruler, but directly measuring that small distance accurately would have been difficult. However, as shown in figure 1, d is also the distance between the centers of adjacent teeth, so the distance between the first tooth and the N^{th} tooth is

$$D = (N - 1)d. \tag{7}$$

Using an enlarged photo of the comb made it easier to count the teeth. The finer side had 82 teeth in 74 mm, so the separation of two slits was 0.91 mm. The coarser side had 60 teeth in 74 mm, so the separation was 1.25 mm. If the width of a tooth is t, then the width of a gap is

$$w = d - t. \tag{8}$$

Vernier calipers were used to measure the widths of the teeth. The finer and coarser teeth were 0.65 mm and 0.83 mm wide, respectively, so the widths of the slits were 0.26 mm and 0.42 mm. If calipers aren't available, measuring the width of ten teeth squeezed together and dividing by ten works almost as well.

The wavelength of the red laser pointer was 650 nm, and the comb was placed 4 m from the screen. For the single-slit diffraction, the distance between the first dark band on each side of the center was measured and divided by two to get y_{d1}. For double-slit interference, the distances between the centers of several bright bands were averaged to get Δy_c. Table I shows the result for the single-slit and double-slit experiments, along with the expected values calculated using equations (3) and (6), respectively. The measurements agree well with the expected values.

Table I. Data for the single-slit and double-slit experiments, along with the expected values calculated using equations (3) and (6), respectively.

	Dimensions		Single Slit: y_{d1} (mm)		Double Slit: Δy_c (mm)	
	w (mm)	d (mm)	Measured	Expected	Measured	Expected
Finer	0.26	0.91	10.5	10.0	3.0	2.9
Coarser	0.42	1.25	6.5	6.2	2.3	2.1

Using a fine-toothed comb, students can safely and easily make the single and double slits suitable for experiments. It is simple to switch between single and double slits of the same width to observe how the pattern changes due to the addition of a second slit. The two sides of a flea comb with different slit widths and separations also allow students to observe the effects of those factors. A green laser pointer could also be used to see the effect of the light's wavelength. One drawback is that since the dimensions of the slits are very large compared to the wavelength of visible light, the viewing screen must be placed a few meters away in order to make the patterns large enough to measure well. It is simple for students to measure the widths and the separations of the slits, so they can be used for quantitative experiment, not just qualitative demonstrations.

References

1. Dave Van Domelen, "Binder clip optics bench for Young's double-slit experiment," *Phys. Teach.* **50**, 116-117 (Feb. 2012).
2. Robert D. Polak, Nicolette Fudala, Jason T. Rothchild, Sam E. Weiss, and Marcin Zelek, "Easily accessible experiments demonstrating interference," *Phys. Teach.* **54**, 120-121 (Feb. 2016).