Effectively illustrating interference phenomenon to the introductory physics student.

The ideas surrounding waves in any introductory physics classroom are perhaps one of the most fascinating as well as challenging topics for students. As with so many concepts taught in the physics curriculum, students have the highest level of comfort with events with which they have had direct experience. The master teacher makes every effort to capitalize on this. It is relatively simple to introduce waves as a topic, since most students at some point in their lives have recognized a wave, albeit probably of the watery variety. The challenge of the teacher is first to insure correct prior knowledge. Then the teacher must stretch that knowledge and experience that exists within the student so that it can be a good platform to build future learning and understanding. To this platform, the master instructor anchors new ideas that the student readily understands and believes. The best teachers connect events that are so discrepant that they seemingly defy all logic; these teachers require their students to develop conviction to support their conclusions. For many students, waves, as a unit, quickly goes from the very tangible to the inaccessible. One such area that can become quickly inaccessible to students is that of interference.
The easiest place to begin talking about waves is in their descriptions. Students quickly comprehend the how and why behind describing single waves. Wavelength, amplitude, and frequency are easy ideas upon which students can get a foothold. It is not long, however, before students become quickly confounded by multiple waves of the same type and their interactions with one another. From both the teacher and the student points of view a smooth progression of ideas really needs to take place. The master teacher can do this so seamlessly, that the students never realize the tremendous obstacles that they have overcome to reach a comprehensive understanding of the material.

A model of how a master teacher might tender the subject of interference to students starts with a simple overhead projector wave tank. Most physics programs have this as a standard equipment item. If it is not, the creative physics instructor could easily fashion a demonstration tank from an inexpensive plastic picture frame or could use a small aquarium to achieve a similar result. Most teachers offer a demonstration to the students that uses two point sources creating in phase concentric circles. From this, students observe areas of constructive and destructive interference handily, but they still do not have a strong sense of the mechanics behind their observation.

Master teachers find innovative ways to get their ideas across. David Chandler writes about his own classroom innovation. To simulate interference patterns he uses tear off strips from pin-fed computer paper. In his article, Chandler describes how one can have students create two point sources near
the top of a piece of graph paper. Students each get two of the paper strips and then they draw waves onto the thin strips by having the crests and troughs alternate over and under the holes in the strips. Chandler then has his students attach the strips to their point sources on the graph paper using push pins and a cardboard backing. He makes certain that the students construct and attach the strips so that that the waves are in phase with each other. By pivoting the paper strips around the paper, students can find the nodes and antinodes of the two strip combination. This is a small scale representation of what many master physics teachers do with meter sticks on the chalk board. Chandler also suggests giving each student a different distance between sources and then putting up the papers so that students can readily examine that as the distance between sources increases the spacing of the nodal and antinodal lines also increases.

This activity will help to crystalize within the student the mechanics behind what was first observed in the wave tank. Also, Chandler has carefully thought out each detail right down to using graph paper where many teachers would use plain white paper. With minor modification the paper strips could be made to originate out of phase with one another and the students could study the resulting patterns produced. In the past, this has been difficult for many teachers to show since a simple ripple tank demonstrator typically only has one vibrating armature with both point sources vibrating in sync.
The creative teacher looks for new ways to effectively introduce old concepts. To move from an analysis of in-phase waves to out-of-phase waves this person might use an ingenious design by Yu Hao, Xie Qi-cheng, and Li Zhen-di for an apparatus that demonstrates the progression of two water drop point sources from in-phase to out-of-phase. In their paper they depict a device that looks like an Atwood machine. Hanging below each side of the large pulley are two water chambers that permit water droplets to drain through the bottom of each chamber into some soft plastic tubing. The water droplets fall from the chamber and through the tubing into a ripple tank below. The rate of water flow is controlled by the diameter of the tubing and the height of water in the chambers. The two chambers are replenished with water by a single reservoir above the apparatus. Floats in the hanging chambers keep the height of the water at a constant level. By rotating the pulley either clockwise or counterclockwise, the water chambers change their height with respect to one another and with respect to the ripple tank below. This permits phase shifting the source droplets in realtime. Using this set up, students can easily observe the full gamut of phase differences from 0 to 180 to 360. The device also allows for easy changing of the frequency of the drops by changing the water level in one or both of the chambers. As a result, this same demonstration apparatus can be used to show students the beat interference pattern. Dishman and Stein note in their paper that introductory physics texts often include a discussion of the time dependence of beats at a given point in space, but give
short shrift to the spatial dependence of beats by ignoring it entirely. This apparatus clearly demonstrates the spatial dependence of beats.

Effective instruction requires the teacher to smoothly make the transition from in phase to out of phase, and then from beats to beat frequency. Seeing the beat patterns formed in a ripple tank can cinch up student comprehension when they are later given the chance to listen to beats. Too many teachers use only the tuning forks and resonating boxes to teach students about beats and beat frequency. A common problem faced by many inexperienced teachers is that students do not have enough of a foundation of knowledge to even know what they should be hearing. The best instructors will have shown the students the patterns in the ripple tank so that students will have a concept upon which they can latch their audible experience. Derrick E. Boucher describes a scene that resonates with anyone who has ever taught physics:

I went into the storage cabinets in my teaching lab and emerged with the standard pair of tuning forks mounted on wooded sound boxes. With a bit of fiddling, I set the adjustable tuning fork so that when both forks were struck a satisfying beat pattern of about 5 to 10 Hz could be heard. Well, satisfying to me at least. After years in physics, one develops a keen ear and eye for physical phenomena; I knew what I was listening for, and heard it readily. But to a student who hasn't the least idea what a “beat” sounds like, the 10 to 15 seconds of audible beats from this standard device may not effectively get the point across, even when repeated several times.

Boucher goes on to describe how the audible distinguishing of beats can be enhanced by electronic demonstration of the
phenomenon. He suggests using two signal generators capable of producing a sinusoidal signal between 100Hz and 5000Hz with a standard stereo amplifier. He also suggests wiring in a dual trace oscilloscope so that students can “see” and hear the beats simultaneously. Of course the students can not “see” the beats like they would in a ripple tank, but the setup does allow students to make a visual connections to the sound that they hear.

Of all of the interference effects that can be witnessed, ironically those involving light can be the most difficult for a student to “see.” Even after studying other types of interference effects it is still difficult for students to notice light interference effects that go on around them. The difficulty stems primarily from the fact that to see light interference effects requires that at least some of the light be coherent. The next logical step for the best teachers would include a lesson about coherent light. Laser work well in this effort. According to Sawicki, Isaac Newton observed that a narrow beam of sunlight striking a dusty mirror produced interference fringes. The scattering of light from the dust and the reflection of light from the back of the mirror produce fringes that can be easily seen without any special equipment. Sawicki laments that even though this is very easily observed, he has yet to see this example in an introductory physics textbook and few, if any, students ever notice this phenomenon on their own.

Gonzalez, Bravo, and Juarez take this simple experiment
further by introducing the use of a coherent light source. They note that one can make a dusty mirror by using chalk. However, rubbing a clean plane mirror with children’s modeling clay produces an improved effect by yielding a brighter image. Their simple set up has a laser shining a beam through a small hole in the center of screen. The beam is both scattered by the dust and reflected by the mirror. The thickness of the mirror provides the phase difference in the light so that as it is reflected and joined up with a scattered part of a beam interference fringes are produced. This is certainly an investigation that typical beginning physics students can setup and witness, but they might be challenged by a more quantitative treatment of this demonstration.

In a similar vein, Mahoney describes interference using a laser and a convex mirror. Using a 4cm diameter, 40cm focal length convex mirror, one can reflect a He-Ne beam off the surface of the mirror. Double reflections from the glass surface and the mirror backing produce large fringe patterns (13cm) that can be observed on an opposing wall. Mahoney’s goal was to convince students that interference effects can be easily observed when using coherent light.

Teaching the subject of wave interference certainly is not without its challenges. It is essential, however, for teachers to find every opportunity to be creative and innovative when teaching the subject. Providing small integral steps for the students to gain larger and larger understanding will reap tremendous benefits for both student and teacher alike. Many
students suffer through a series of hand waving lectures at the hands of poor instructors. Then the students are required to make huge leaps of faith to fill gaps in their understanding. Seeing is believing. Taking the students through a series of increasingly difficult demonstrations will do much to increase the credibility of the teacher and the subject matter. It makes each step plausible to the students. After all, climbing from one step to the next in a staircase is possible for nearly anyone. Climbing from the 1st staircase to 90th one in a high-rise is daunting for almost anyone.


