Poisson spot with magnetic levitation

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In this paper we describe a unique method for obtaining the famous Poisson spot without adding obstacles to the light path, which could interfere with the effect. A Poisson spot is the interference effect from parallel rays of light diffracting around a solid spherical object, creating a bright spot in the center of the shadow.

A brief history on nature of light

When Newton published his theory of color in 1672, he gave experimental evidence that light is composed of corpuscles (particles of matter), which were emitted in all directions from a source. In 1678, Dutch physicist Christiaan Huygens believed that light was made up of waves, much like water waves, vibrating up and down perpendicular to the direction the light travels, and therefore formulated a way of visualizing wave propagation. This became known as Huygens' principle.

In 1803, Thomas Young studied the effect of projecting monochromic light that passed between two slits , spaced very close to each other, cut in a screen. When the light from the slits was projected onto another screen, an interference of light waves (the production of light and dark areas) was observed as predicted by Huygens' principle.

In 1817 the French Académie des Sciences proposed as their prize topic for the 1819 Grand Prix a mathematical theory to explain diffraction. One of the judges of the committee was Siméon-Denis Poisson, a supporter of the particle model. Augustin Fresnel, who believed that light should be treated as a wave and not as a particle, entered into the competition to elucidate the nature of light by developing a set of equations to explain light diffraction using a wave model. Fresnel could write the equations for the wave model of light, but he couldn't solve them. However, Poisson, who was a great mathematician, was able to solve these Fresnel equations and obtain what he called an absurd result. According to these solutions, if one places a solid sphere in front of a beam of light, instead of the sphere blocking the light and casting a shadow in back of the sphere, there would be a bright spot at the center, caused by the diffraction of the light wave around the sphere. Poisson felt that this impossible experimental result would be the final nail needed for the coffin and would bury Fresnel's theory and the wave theory of light for good. However, Dominique Arago, another member of the judging committee and also a believer in the particle theory, almost immediately verified the spot experimentally. Fresnel won the competition, and, although it has been called "the Spot of Arago" or "the Spot of Fresnel," the spot goes down in history with the name "Poisson's bright spot," like a curse. Arago's experiment put an end (at least for the better part of a century) to the wave/corpuscle controversy.

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One general method of obtaining the Poisson spot is by sandwiching a solid spherical object in between two glass slides; this demonstrates the interference pattern. However, there is an apparent distortion from the slides that causes difficulty in measuring the fringe spacing. To avoid distortion, it is necessary to remove the interference due to the device that holds the sphere. This was accomplished using a commercially available magnetic levitation device. We purchased a magnetic levitation kit from ART TEC (http://www.arttec.net) for $38 (see Fig. 1), assembled the components, made some slight modification to the device, and were able to successfully levitate a small spherical object (Fig. 2).

The magnetic levitation device uses a Hall effect probe to determine the proximity of a magnetic field in conjunction

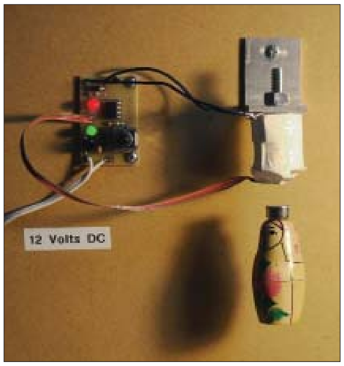

Fig. 1. ART TEC Magnetic Levitation Kit.

Fig. 2. Levitation of sphere.

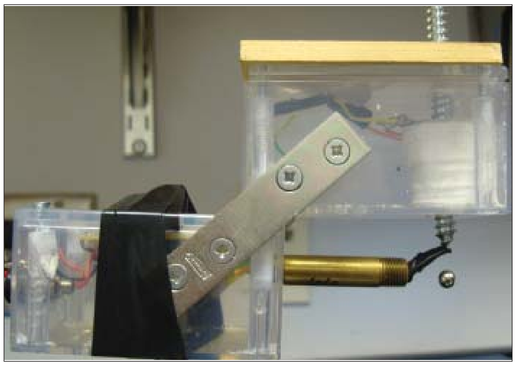

Fig. 3. Levitation apparatus.

with a magnetic coil and feedback loop circuit to keep a constant distance between the Hall effect probe and the object being levitated. Once we were able to levitate an object, the challenge became levitating smaller objects under more stable conditions. As we moved to levitating smaller objects, we observed a significant amount of noise that would decompose the levitation effect. In other words, the magnet would launch the sphere in a random direction. Our first step in increasing the stability of the levitation device was to replace the flat core provided by the kit with a pointed core, a wood screw, which concentrated the magnetic field lines, making a tighter "sweet spot." Using a screw as the core allowed us to tune the position of the "sweet spot" by moving the screw up and down in the coil. Our next step was to encase the apparatus, which provided us with a more consistent spacing between the coil, core, and Hall effect probe (see Fig. 3). Our final step to optimize the levitation device was to use batteries rather than the 12-V dc power supply that came with the kit, because we seemed to be picking up 60-Hz noise from the wall outlet.

Since the smallest object we could levitate was wider than the beam from the HeNe laser, we used a small focal length diverging lens along with a converging lens to collimate the beam; we then projected the pattern onto a simple CCD chip connected to a computer. The pattern can also be projected directly onto a screen. With this new apparatus design, we were able to obtain a very well-defined Poisson spot with visible fringing without any interference from the apparatus.

Jose D'Arruda *has taught physics and astronomy at UNCP for 35 years and was department chair for 23 years. He received Distinguished Service to Education Award, North Carolina Science Teachers Association Award (2000), the UNC Board of Governors (BOG) Teaching Excellence Award 2007, and the SMT teaching award in 2009.He received his BS from University of Massachusetts Lowell and his MS and PhD from University of Delaware.*

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2005 high school physics taking by region

In 2005, about one out of every three seniors graduating from high school in the US had taken at least one physics course prior to graduation. As with any average, the national number does not provide "local" details. This map highlights the proportion of seniors who have taken at least one physics course prior to graduation in each of the nine geographic divisions defined by the US Census Bureau (See http://www.census.gov/econ/census07/www/geography/regions_and_divisions.html for details.) The physics-taking rate is above the national average in the Northeast region, and students in the East South Central states take high school physics at lower rates. The factors driving the differences in physics taking are many and varied. At least some of these fluctuations may be explained by the availability of physics; we know that physics is more readily available in larger high schools. We have recently begun a new series of reports detailing findings from our 2008-09 Nationwide Survey of High School Physics Teachers; the first of these reports examines the availability of physics in US high schools. You may access these reports at http://www.aip.org/statistics/trends/hstrends.html. If you have any questions or comments, please contact Susan White in the Statistical Research Center at the American Institute of Physics at swhite@aip.org.