Apparatus Competition 2019

Erin Woodcock, Zachary Dale, and Ralf Widenhorn

Contact:

ralfw@pdx.edu

Phone: 503 725 3898

Portland State University

Department of Physics

Ralf Widenhorn

P.O. Box 751

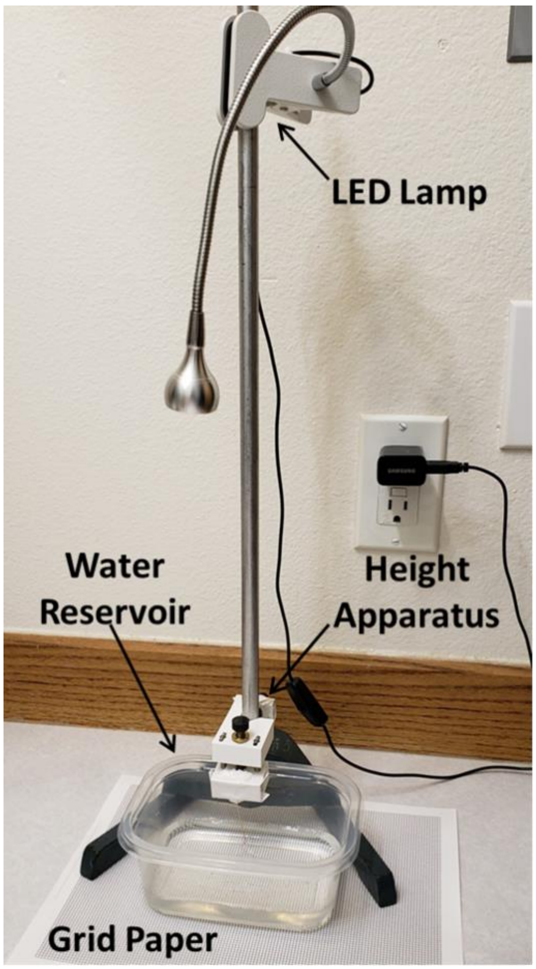
Portland, OR 97207-0751

Apparatus for teaching the refraction of light by fluidic lenses formed by water-walking insects.

Abstract

This apparatus is used to simulate a water-walking insect's leg on the surface of water in order to observe the shadows created by fluidic lenses formed by the leg on the water surface. The apparatus accomplishes this by using wires coated in a hydrophobic material to simulate the insect leg. The wires are attached to a sample stage that is lowered to the water's surface using a micrometer screw. The apparatus can be used to create lab activities for physics students to help them better understand geometrical optics as well as the interactions between solids, fluids, and air.

Construction of the Apparatus



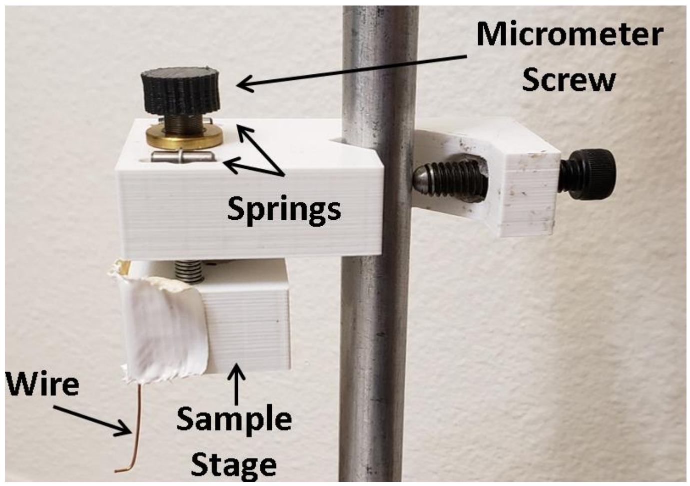


Fig. 1: Left: *The full experimental setup; the height apparatus and LED lamp are connected to the ring stand, with a water (or other transparent liquid) reservoir and grid paper underneath the apparatus to measure the shadow size.* ***Right:*** *The height apparatus; the wire is taped to the sample stage, which is lowered to the liquid's surface using the micrometer screw.*

Parts list

The apparatus shown in Fig. 1 is built with inexpensive commercially available parts and a 3D printed holder for the wire leg.

Lamp: (S16.76)
https://www.amazon.com/Newhouse-Lighting-Energy-Efficient-Clamp-Light/dp/B00FIYJXAQ/ref=sr_1_4?keywords=clip+lamp+desk&qid=1560280298&s=gateway&sr=8-4

3D printed holder ($0.20):
The 3D printer file can be found here:
https://github.com/psuphysicsedres/Fluidic-Lens-Apparatus

Ring stand screw ($2.74):
https://www.mcmaster.com/thumb-screws

Threaded bushing for ring stand screw ($4.56):
https://www.thorlabs.com/thorproduct.cfm?partnumber=F19MSN1P

Micrometer screw ($6.48):
https://www.thorlabs.com/thorproduct.cfm?partnumber=F25US150

Threaded bushing for micrometer screw ($5.57):
https://www.thorlabs.com/thorproduct.cfm?partnumber=F25USN2P

Springs ($0.70 ea. x2 = $1.40):
https://www.mcmaster.com/9654k971

Dowel pins ($0.10 ea. x4 = $0.40):
https://www.mcmaster.com/98381a470

Water container ($0.72):
https://www.amazon.com/Glad-Food-Storage-Containers-Salad/dp/B000RA6GMY/ref=sr_1_2?keywords=food+storage+container&qid=1560230286&s=pantry&sr=8-2

Wires with different coatings: ($1)

Ring stand ($10.39):
https://www.opentip.com/search.php?cPath=12410&products_id=5395095&gclid=EAIaIQobChMIn9bxxdXg4gIVGNtkCh2AFQzcEAkYASABEgL9SvD_BwE

Use of the Apparatus

The apparatus can be used to create a lab assignment for physics students to explore geometrical optics using a commonly observed real world phenomenon. Water striders deform the water surface such that the shadows formed on the bottom of a pond on a sunny day are more easily visible than the insect itself (see left panel of Fig. 2).

Some instructive lab activities related to this phenomenon are:

- experimental measurement of contact angles for different materials
- a comparison of dimple depth and shadow width for materials with different contact angles
- a comparison of shadow sizes at different water depths and/or distances between the LED lamp and the water surface
- a comparison of dimple depth and shadow width for fluids (e.g. water, ethanol, vegetable oil) with different indices of refraction and surface tension
- a comparison of dimple depth and shadow width for various leg radii
- computational modeling of the water surface and resultant shadows.

The goal for such a lab assignment is to improve student understanding of geometrical optics, with respect to lenses and Snell's law, as well as the physics of interactions between a fluid and solid at the air-fluid-solid interface, with respect to surface tension, buoyancy force, and contact angles. Because of the complexity of the equations required to model the water's surface, this type of lab is well-suited for a computationally-oriented introductory physics course. It is also well-suited for an intermediate level experimental physics class.

The wire can be raised and lowered into the water using the 3D printed apparatus (see right panel of Fig. 1). A micrometer screw, when turned clockwise, is used to push the sample stage down, while the springs are used to provide tension and allow the stage to be raised as the micrometer screw is turned counter-clockwise. One full turn of the micrometer screw changes the height of the sample stage by 200 µm. The apparatus and lamp are attached to a ring stand (see left panel Fig. 1), the wire leg is taped to the sample stage, and it is lowered to where the simulated leg is just above the water's surface. The wire leg is then incrementally lowered using the apparatus and the resulting shadow cast on the lower surface of the water reservoir is measured using grid paper with a grid spacing of 1 mm placed below the reservoir (see right panel of Fig. 2). The shadow size is measured in this fashion until the wire leg fully penetrates the water's surface, resulting in the disappearance of the shadow.

***Fig. 2**: **Left:** Image of a water strider on a water surface, demonstrating the shadows caused by the fluidic lenses produced by the water strider's legs. **Right:** A Polytetrafluoroethylene (PTFE) coated wire used to simulate a water-walking insect's leg on a water surface, lowered on to the surface using the height apparatus. Note the shadow at the bottom of the container and the distortion of the grid lines by the fluidic lens.*