Tyndall's Historical Experiment

Instruction Manual

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INDUSTRIAL FIBER OPTICS

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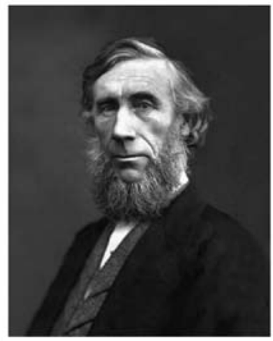
JOHN TYNDALL (1820 - 1893) Irish
Physicist, Naturalist and Educator


John Tyndall

The story of John Tyndall is one of courage, passion and idealism. It is the story of the highest personal success achieved by almost any man of humble beginnings in his time.

When Tyndall was born in 1820 his family was virtually unknown outside its small village of Leighlinbridge in Ireland's second-smallest county.

Seventy-three years later when he died of an accidental overdose of medicine. Tyndall had won worldwide acclaim as a scientist, embracer of controversy, education proponent and mountaineering pioneer.

His original researches and his work with top scientists of his era opened up new fields of science and laid the groundwork for future scientific endeavour.

Tyndall's major scientific contributions were in physical chemistry. He is the founder of the science of light scattering (nephelometry). His instruments are the basis of many instruments such as fluorimeters, turbimeters and ultraviolet spectrometers. His major research was done with the transmission and absorption of gases, liquids and vapors, and he laid the basis for infrared spectroscopy.

Tyndall is also credited with the first atmospheric pollution measurements using infrared and scattering measurement instruments to monitor London's atmosphere.

He showed that ozone, the upper layer of atmosphere so vital to life on Earth, was an oxygen cluster rather than a hydrogen compound.

He observed perhaps the first controlled photochemical reaction and made important contributions to thermodynamics. Tyndall was the inventor of the fireman's respirator and made other less well known inventions, including improved fog horns.

One of his most important inventions, the light pipe, led to the development of fiber optics, a technology now playing an increasing role in telecommunications, electronics and medicine. The modern light pipe instrument is known as the gastroscope, which enables internal observation of a patient's stomach without surgery.

Tyndall made negative radiation studies of the moon and predicted the blackness of space as well as working on solar chemistry, which today has solar energy ramifications.

Science and society owe a tremendous debt to John Tyndall, for he furthered the cause of knowledge and improved our quality of life.

Tyndall also made major contributions to the study of evolution through his work on absorption of heat in the atmosphere and by his introduction of thermodynamics to the evolution debate. His contribution to physics was considerable, delving into magnetism, electricity, molecular physics, optics, sound, the properties of materials, diamagnetism and heat.

He initiated the practical teaching of scientific subjects in our schools. His lectures, liberally illustrated by exciting experiments, brought science to people in a way that made it truly popular. An exceptional educationalist, he strongly influenced the direction of university and school physics teaching.

Among his friends he numbered 19th century giants in the world of science and literature - Louis Pasteur, James Faraday, Charles Lister, Thomas Huxley, Leslie Stephens, Thomas Carlyle and Alfred Lord Tennyson. Tyndall's social life was as varied as his scientific and mountaineering exploits and he was a much sought-after guest in London's high society. A man who was shaped by the luminaries of his generation he came to shape a generation himself.

Tyndall traveled extensively in Europe, mostly among his beloved mountains, and on a major lecture tour of America. He did more than most to popularize and make respectable the sport of mountaineering. He was first to climb the Weisshorn (14,804 ft.) and would have been the first to climb the Matterhorn, but his guides refused to venture upon the last peak in 1862. But the next-to-last peak and the ridge which stretches from it to the final peak were named after him, and he did become the first person to traverse the mountain from the Italian to the Swiss side in 1868. He also climbed the highest Alpine peak, Mont Blanc (15,781 ft.), several times. He pioneered solo ascents.

A disciple and successor of Faraday as director of the prestigious Royal Institution of London and a close associate of Darwin and Huxley, Tyndall was a bold and original thinker in his own right. He established new doctrines upon which modern science is based, overcoming scientific controversies that were rampant in the middle and late 19th century.

His bid to win official recognition of the value of science and to professionalize it led him to form the exclusive X-club which became a major pressure group to wrest scientific authority from traditionalist mathematical scientists and to transfer it to evolutionists such as himself.

As a physicist, his work was brilliant and many-faceted. As an educator and lecturer he became one of the ablest popularists of science of his generation, and a pioneer of practical teaching. As a mountaineer he was in the vanguard of those who conquered age-old peaks and age old-fears. As a controversialist he steeped himself in the burning religious and political issues of the day.

At his death, many monuments had already been erected to him and landmarks named after him, and others were to follow. Scientific terms such as tyndallization - a sterilization process still favored in Europe – and Tyndall blue and the Tyndall cone are also permanent monuments to his work.

TYNDALL'S LIGHT-GUIDING EXPERIMENT

Long before the laser was invented, scientists tried to figure out how to make light go around corners or between places that could not be connected by a straight line. They tried many different devices like mirrors and special tubes, but none received much attention until John Tyndall came along.

In 1870, before members of the prestigious British Royal Society, Tyndall demonstrated how to guide a light beam through a falling stream of water. His method is shown in Figure 1. The tank of water had a horizontal pipe extending out one side which allowed water to flow out in an arc to a collection pan on the floor. A bright light was directed into the pipe and the light rays traveled within the water until they were broken up by the turbulence of the water hitting the collection pan.

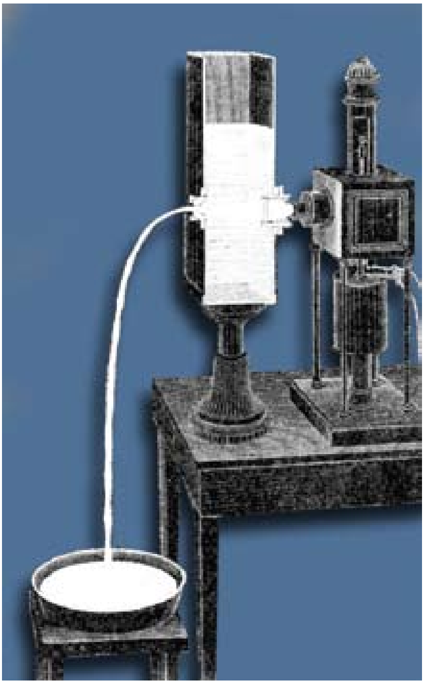


Figure 1:
John Tyndall's "light guiding" experiment (recreation from Daniel Colladon, "La Fontaine Colladon," La Nature 2nd half year 1884, p. 325).

Tyndall knew light was trapped temporarily inside the stream of water, but he couldn't explain why. Today, using a combination of mathematics and science, the explanation is very straightforward. Tyndall's 1870 experiment demonstrated the principle known as "total internal reflection." Simply stated: Total internal reflection is a special optical condition in which optical rays cannot escape the material in which they are traveling.

John Tyndall's work is significant today because it is the first recorded conformation of the scientific principle which forms the basis of all modern fiber optic telephone communication networks.

MODERN RECREATION

Here you will recreate John Tyndall's experiment and observe a laser light beam trapped inside a falling stream of water.

Equipment Needed:

- Cylindrical beaker with valve
- Laser*
- 120-VAC to 12-VDC power adapter*
- 1500 ml (3 pints) water*
- Books of different thicknesses*
- 5-gallon plastic pail*
- Paper or cloth towels*

* Items not included In project kit

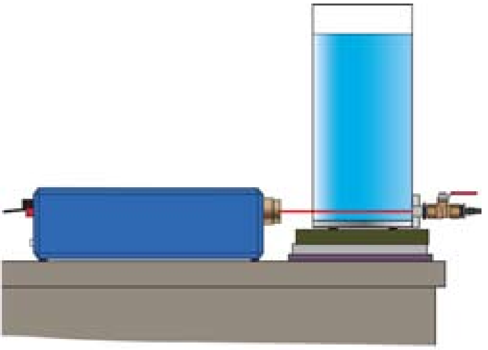


Figure 2: Side view of experiment set-up.

Procedure:

1. Choose a flat, level table about 60 × 90 cm (2 × 3 feet) in size and 75 cm (30 inches) in height on which to place equipment.
2. Position the plastic beaker or cylinder so the valve protrudes over the table edge as shown in Figure 2.
3. Check the laser to ensure the laser beam shutter is closed.
4. Plug one end of the power adapter into the laser, and the other into a 120-VAC electrical outlet.
5. Align the laser so the beam will focus through the center of the valve when turned on. Use books or any other material to raise the height of the beaker so that the laser light beam is in the center of the valve as shown in Figure 3.
6. Make sure no one is in the path of the laser beam.
7. Open the laser beam shutter.
8. Open the valve in the beaker. Hold your hand in front of the valve to check the position and alignment of the laser beam, then adjust the position of the beaker to center with the beam. DO NOT LOOK INTO THE VALVE OR INTO THE LASER.
9. Close the valve, being careful not to disturb the alignment.
10. Pour 1500 ml of water into the cylinder.

11. Mentally determine the path the falling stream of water will take. Center the 5-gallon pail to collect the falling water, based on your estimation.
12. Place towels on the floor around the collection pail to absorb any splashed water.
13. Open the beaker valve briefly, adjusting the alignment of the collection pail as required to minimize splashing.
14. Dim the room lights.
15. Open the valve in the cylinder.
16. Observe the path of the red laser beam traveling down the inside of the water stream into the pail.
17. After the water has drained, close the valve on the cylinder.
18. Close the laser beam shutter and turn off the laser.
19. Dry off any items which got wet.
20. Return all items to proper storage containers and locations.

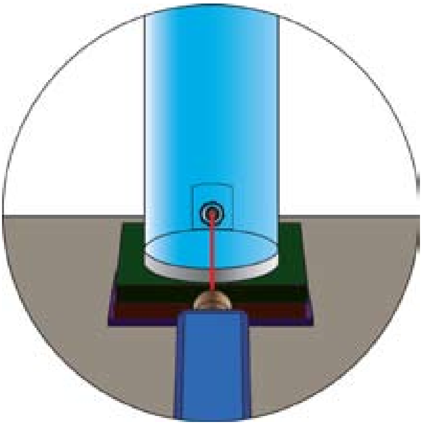


Figure 3: Rear view of experiment with laser beam aimed directly into the valve opening.

Results:

You have experienced for yourself that water can transmit light by total internal reflection — in ways which might have astounded our forefathers. The understanding of this principle led us today to the development of sophisticated technologies that produce optical fibers with hundreds of uses. Angioplasty (the medical technique which sends a tiny optical probe through human veins to view and perform precise surgery inside blood vessels and the heart), is only one of many fiber optic and laser applications. Industrial Fiber Optics encourages you to learn more about the important ways lasers and fiber optics can work singly and together to create incredible new tools to benefit science and society.

Questions:

1. Describe where you see the laser light, once the laser and stream of water are in motion.
2. Where is the majority of the laser light visible?
3. How does the light get down to the bottom of the 5-gallon pail?
4. Do you suppose this is the same principle used for water fountains lit by internal beams of light?

Rules for Laser Safety

- Lasers produce a very intense beam of light. Treat them with respect. Most educational lasers have an output of less than 3 milliwatts, and will not harm the skin.
- Never look into the laser aperture while the laser is turned on! PERMANENT EYE DAMAGE COULD RESULT.
- Never stare into the oncoming beam. Never use magnifiers (such as binoculars or telescopes) to look at the beam as it travels – or when it strikes a surface.
- Never point a laser at anyone's eyes or face, no matter how far away they are.
- When using a laser in the classroom or laboratory, always use a beam stop, or project the beam to areas, which people won't enter or pass through.
- Never leave a laser unattended while it is turned on – and always unplug it when it's not actually being used.
- Remove all shiny objects from the area in which you will be working. This includes rings, watches, metal bands, tools, and glass. Reflections from the beam can be nearly as intense as the beam itself.
- Never disassemble or try to adjust the laser's internal components. Electric shock could result.