

# Properties of a Plasma: Half-Coated Fluorescent Bulbs

Part of a Series of Activities in Plasma/Fusion Physics  
to Accompany the chart  
*Fusion: Physics of a Fundamental Energy Source*

**Robert Reiland, Shady Side Academy, Pittsburgh, PA**

Chair, Plasma Activities Development Committee of the  
Contemporary Physics Education Project (CPEP)

**Editorial assistance:** G. Samuel Lightner, Westminster College, New Wilmington, PA and  
Vice-President of Plasma/Fusion Division of CPEP

**Advice and assistance:** T. P. Zaleskiewicz, University of Pittsburgh at Greensburg,  
Greensburg, PA and President of CPEP

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## Preface

This activity is intended for use in high school and introductory college courses to supplement the topics on the Teaching Chart, *Fusion: Physics of a Fundamental Energy Source*, produced by the Contemporary Physics Education Project (CPEP). CPEP is a non-profit organization of teachers, educators, and physicists which develops materials related to the current understanding of the nature of matter and energy, incorporating the major findings of the past three decades. CPEP also sponsors many workshops for teachers. See the homepage [www.CPEPweb.org](http://www.CPEPweb.org) for more information on CPEP, its projects and the teaching materials available.

The activity packet consists of this student activity and separate notes for the teacher. The Teacher's Notes include background information, equipment information, expected results, and answers to the questions that are asked in the student activity. The student activity is self-contained so that it can be copied and distributed to students. Teachers may reproduce parts of this document for their classroom use as long as they include the title and copyright statement. Page and figure numbers in the Teacher's Notes are labeled with a T prefix, while there are no prefixes in the student activity.

Developed in conjunction with the Princeton Plasma Physics Laboratory and funded through the Office of Fusion Energy Sciences, U.S. Department of Energy, this activity has been field tested at workshops with high school and college teachers.

We would like feedback on this activity. Please send any comments to:

Robert Reiland  
Shady Side Academy  
423 Fox Chapel Road  
Pittsburgh, PA 15238

e-mail: [robreiland1@comcast.net](mailto:robreiland1@comcast.net)  
voice: 412-968-3049

## **Properties of a Plasma: Half-Coated Fluorescent Bulbs**

### **Part of a Series of Activities in Plasma/Fusion Physics to Accompany the chart *Fusion: Physics of a Fundamental Energy Source***

In this activity you will study some of the properties of the plasma that is inside of an operating fluorescent bulb.

#### **Spectra of mercury vapor and phosphors in a fluorescent bulb and spectrum of an incandescent bulb:**

In this part of the activity you can study the mercury vapor spectrum emitted by the mercury from the uncoated side of a half-coated fluorescent bulb along with the spectrum from the phosphors that coat the other side and compare these to a continuous spectrum from a white light source such as an incandescent light bulb.

#### **Procedures:**

1. Once your teacher has turned on the half-coated fluorescent bulb, darken the room, and observe the color and brightness of each half of the bulb.

Since the source of the energy for the coated part of the bulb is the same mercury vapor that is producing violet light in the uncoated half of the bulb, what evidence do you have that some of the mercury spectrum from the uncoated half is not visible?

2. Examine the light from each half of the bulb separately through either a diffraction grating or a spectroscope or both.

Describe in detail the spectra of the two parts. If you have a spectroscope with which you can see the values of the wavelengths, include those along with the colors that you see.

Uncoated Part:

Coated Part:

3. Now you will examine the light from an incandescent light bulb and compare it to that from the coated half of the fluorescent bulb. If available, use a clear incandescent bulb as well as a normal frosted incandescent bulb.

As seen by the naked eye, is the appearance of the white light from the fluorescent bulb exactly the same as the appearance of the white light from the frosted incandescent bulb? If there is any difference, describe it as best you can.

As seen with a diffraction grating or spectroscope, are the spectra of the white light from the fluorescent bulb and from the frosted incandescent bulb exactly the same for each? For example, are both spectra completely continuous, or are there places in either spectrum where lines seem to stand out? If so, are any of these “lines” at the same wavelengths or of the same colors of lines as the mercury vapor spectrum? A sketch or drawing could be useful. Try to form a hypothesis that could be used to explain some or all of your observations. If you have a clear incandescent bulb, is there any difference in the spectrum from the clear bulb and that of the frosted bulb?

4. If your power supply can be adjusted to safely change the brightness of the fluorescent bulb, ask your teacher to do so, and again observe the spectra from both halves. Does the brightness of the source affect the location of the spectral lines produced?

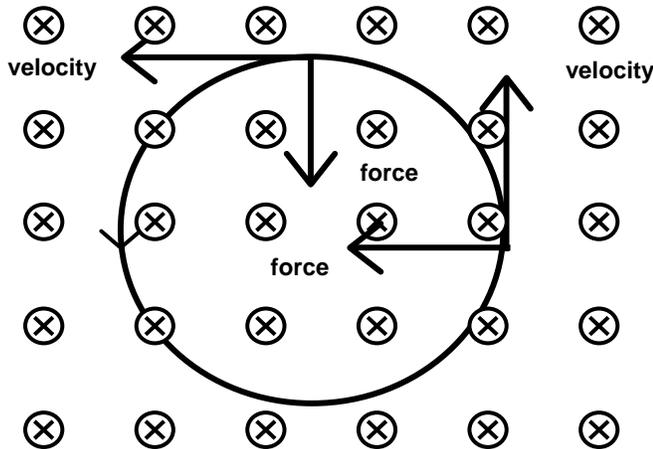
**Reactions of the plasma in the fluorescent bulb to magnets:**

In this part of the activity you will study the effects of a magnetic field on the plasma in a fluorescent bulb.

Introductory note on currents: Current direction as used in this activity is the direction of movement of positive charges. This means current is in the same direction as the velocity of positive ions, but is in the opposite direction as the velocity of electrons. Defined in this way, current goes from the positive terminal of a battery to the negative terminal; goes through a fluorescent bulb from the positive electrode to the negative electrode.

1. If you have studied the effects of magnetic fields on electrical currents before, think about what you expect to happen as you bring a horseshoe magnet or a pole of any other strong magnet toward the bulb in the middle of the uncoated part of the tube. Visualize the magnetic field as arcing away from the north pole of the magnet (and, for a horseshoe magnet, arching to the south pole). If the magnet is approaching the bulb with its north pole slightly above the center of the bulb (and south pole slightly below for a horseshoe magnet; other magnets vertical), the magnetic field through the bulb will be vertical and down. In a case like this many people expect that the plasma will be deflected downward in the direction of the magnetic field. Move the magnet toward the bulb, and look closely to see if this is what happens. Describe what happens.

2. Did you expect that the magnet would produce a deflection of the current (located as the glowing plasma) to one side of the bulb before it returns to the axis of the bulb just past the magnet? If you had studied the effects of magnets on electrical currents before, you might not have been surprised to see that the effect on the gas was perpendicular to the magnetic field producing it. The figure on the next page illustrates how a uniform magnetic field affects the motion of charged particles or electrical currents. The field between the poles of a horseshoe magnet isn't uniform, but the some of the qualitative features of the affect on the plasma current can be understood from the simpler case.



**Figure:** Motion of and forces on a positive charged particle when the particle's velocity is perpendicular to the uniform magnetic field (shown with x's as into the paper)

3. Since the magnetic force on the current will always be perpendicular to both the direction of the current and the direction of magnetic field, the simplest result would be circular motion as illustrated in the figure. However, what you see is a deflection of the current (located as the glowing plasma) to one side of the bulb before it returns to the axis of the bulb just past the magnet. Knowing which is the north pole of your magnet and thus the direction of the magnetic field through the bulb, you then should be able to use the above diagram to show that the first turn in the current is consistent with what is expected from the magnetic field. Remember that the direction of the positively charged particles in the bulb is from the positive to the negative electrode.

To understand why the curvature does not continue as it does in the figure, consider that something was driving the current down the axis of the tube, and this something, which is the electrical field produced by the potential difference across the ends of the tube (100 volts or more), is still present at the kink. It will limit how far the current can turn before the charges move out of the region of strong magnetic field. The forces from the non-uniform magnetic field and the electric field in combination then determine the shape of the kink.

4. Usually when the bulb is operating, there will be a place where the light is pulsing and may even be moving around. At such a location the plasma current is not constant in magnitude or direction. In the fluorescent tube, physical constraints due to the simple geometry of the electric field that drives the plasma and the tube walls prevent this from growing into a true plasma instability. But when things like this happen inside a fusion reactor, such as the toroid-shaped Tokamak, plasma instability often results. One of the ways to control such instabilities is with well-conceived magnetic fields that are given small adjustments as necessary. With the florescent tube you can show that this can work in a more trial and error way by bringing a strong magnet near the uncoated part of the tube and slowly moving it around until the light stops pulsing.