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*Review*

## Study of Light-Emitting Diodes

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### Abstract

LEDs, or light-emitting diodes, are cheap, easy to purchase, and thus commonly used in physics instruction as indicators of electric current or as sources of light. In our opinion LEDs represent a unique piece of equipment that can be used to collect experimental evidence, and construct and test new ideas in almost every unit of a general physics course (and in many advanced courses) either as “black boxes” that allow students to study certain properties of a system of interest, as physical systems that allow students to learn an astonishing amount of physics that they usually do not encounter in a regular introductory physics course, and as non-traditional devices that allow students to construct concepts that are traditionally a part of a general physics course.

**Key words:** Light emitting diodes; Data analysis; Sequence analysis.

### 1. Background

In this paper, we provide a classification of different uses of LEDs in a physics classroom according to the three directions noted above, including a brief description of relevant experiments (some already published and some new) and the questions that students or teachers might pose or that students would be able to answer after conducting these experiments and analyzing data. Future articles will describe experiments and reasoning related to the physics behind the LEDs that is accessible for high school and introductory college students Fig. 1. (We

found that different aspects of the functioning of an LED can be used to help students learn concepts in at least 11 curriculum units of the general physics course, where an example of a unit is energy, or geometrical optics, or dc circuits.) In addition, future articles will describe how the physics inherent in the functioning of an LED can help students learn new physics (in nine curriculum units), and how an LED can be used as a black box device (in 12 units). The goal of the series of papers is to create a systematic library of LED-based materials for all curriculum topics and provide readers with the description of

experiments and pedagogical treatment that would help their students construct, test, and apply physics concepts and mathematical relations.



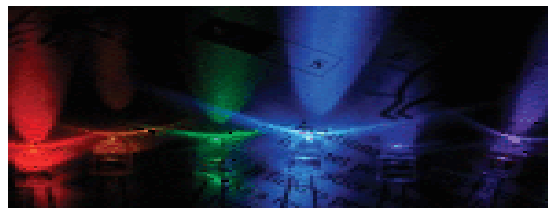
**Fig. 1.** The LED is eclipsing the incandescent bulb in many ways.

## 2. Material and Methods

A light-emitting diode was invented by Russian technician Oleg Losev in 1927 (Bhalotra, 1963). Nick Holonyak at General Electric developed the first practical visible-spectrum (red) LED in 1962. Soon after that, LEDs became available as electronic components and thus they gained the attention of the physics teaching community. The first paper on LEDs in *The Physics Teacher* appeared in 1974. In *TPT* alone, more than 20 papers dedicated to teaching with LEDs have been published (in this number we did not include the papers that employ LEDs simply as light indicators).

Awareness that LEDs can be used in teaching several introductory physics topics emerged as early as in 1991 (Griffiths, 1974). Jewett's article describes a number of activities with LEDs in the areas of electricity, optics, and modern physics. Since then many things have changed: technological inventions and improvements resulted in much brighter LEDs, more efficient LEDs, LEDs that cover a wide range of wavelengths including blue and UV, LEDs that emit white or pink light, etc. (see Fig. 2). At the same time important changes occurred in our knowledge of how students learn and, consequently, in how we teach. We have evidence that students' active participation in experiments (not mere

observation) make the use of experiments productive in education, and we have also developed general frameworks for the fuller use of experiments in physics instruction. (NCEP, 2008) Both technological advances and educational innovations inspired our series of articles about LEDs described above.



**Fig. 2.** A rainbow of LEDs: red, yellow, green, blue, ultraviolet, pink, and white.

## 3. Results and Discussion

The goal of this section is to provide a reader with a systematic review of the existing LED-related ideas and to show how LEDs can be used in almost every unit of a physics course (such as kinematics, energy, electric field, etc.). In the subsections we briefly describe experiments using LEDs in different units and questions that teachers and students might pose and answer while observing the experiments, collecting data, and analyzing and interpreting data (commonly the questions are posed after the students observe the experiments; in a few cases where the question/task comes before the experiment, we note this change). There are 13 subsections, one for each of the relevant units. In each subsection there is a table that has three rows demonstrating how to use LEDs in three different ways.

1. Row I treats LEDs as black box devices used to help students make a connection to relevant physical phenomena.

2. Row II helps students understand unit-relevant aspects of physics (that students investigate in row I) that explain how an LED works. Most of the experiments in row II are qualitative and focus on the conceptual aspects of LED physics.

3. Row III focuses on the new physics that students can develop after they understand LED physics in row II. Experiments and questions in row III ask students to collect more data about the same phenomenon to investigate it at a quantitative level.

Basically in most cases each subsequent row goes deeper and deeper into the same phenomenon. Row I shows the fact of the existence of a phenomenon, row II goes into a description and a conceptual explanation, and row III calls for a more rigorous description and a deeper explanation. Note that not every table has all three rows; the presence of a particular row depends on the unit.

In this paper we provide an outline of the experiments to be performed; the reader may need to consult the references mentioned for details about how to conduct the specific experiments that were proposed before. Further details regarding the original experiments suggested by the authors of this paper and details of the pedagogical treatment will be included in the subsequent articles.

Here, we provide an overview and some questions that teachers or students might pose or should be encouraged to pose about the experiments. In most cases the questions come after the experiment; blue arrows [←] in the tables indicate the cases when the question comes before the experiment. Double asterisks

[\* \*] indicate cases that are (to our best knowledge) new.

### Conclusion

We invite readers to try the experiments and assemble a set of equipment that can be used in most of the experiments. Creating containers with all of the materials for groups of students is the most helpful way to keep track of everything that one can do with LEDs. Once students start working with the LEDs, they will generate their own questions and design their own experiments. In future papers we will elaborate on the specific experiments and their pedagogical treatment consistent with inquiry-based instruction. We will provide instructional sequences with supporting questions that will allow your students to observe a phenomenon, to analyze it and propose multiple explanations for the mechanism, and finally test those explanations in new experiments

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