

# Chapter 1

## Introduction to the MAE 221 Laboratory

### 1.0 Introduction

Welcome to the MAE 221 Laboratory. This course contains 12 lab sessions. In the first four, you will work with practical electronic circuits and data acquisition tools that are fundamental to laboratory experiments and general engineering practice. In the fifth session you will undertake a small independent project in which you construct a more substantial and practical device using these basic building blocks. With each new device that is encountered, you will be required to summarize its performance and applications in a brief technical reference sheet which will be handed in and graded. This will not only serve as an exercise to help you understand each device, but will also be a useful reference in future years. The final six laboratory sessions will consist of experiments in thermodynamics. In these experiments your knowledge of electric circuits and data acquisition tools will be applied in your investigation of various thermodynamic phenomena. After completing each experiment you will present your methods, results, and conclusions in a technical report similar to that which you would prepare in an industrial setting.

The textbooks used in this course are as follows:

The Art of Electronics, 2<sup>nd</sup> edition (main text)  
Paul Horowitz and Winfield Hill  
Cambridge University Press  
isbn: 0 521 37095 7

Student Manual for the Art of Electronics (supplement)  
Thomas C. Hayes, Paul Horowitz  
Cambridge University Press  
isbn: 0 521 37709 9

The two textbooks are made to be used together. The former deals slightly more with theory while the latter is more of a laboratory guide. Although the Student Manual actually contains detailed instructions for laboratory sessions, we will only use it as a reference. The main text is a standard electronics reference and contains probably everything you will ever need to know about electronics. The wealth of information can be intimidating so in each chapter of this manual we have listed the pertinent sections. Both texts will also be used in MAE 224 in the spring semester.

### 2.0 Laboratory Assignments and Grading.

Grades in the MAE 221 laboratory will be assigned based on written assignments and completion of laboratory activities. **In the laboratory, you will work with a partner; however, all written work must be completed individually.**

Each electronics lab is worth 8% of the final grade, and is broken down in the following way:

- pre-lab questions            2%/lab
- laboratory activities        2%/lab
- technical reference sheet    4%/lab

Each laboratory chapter in this manual (with the exception of the first lab) will contain pre-lab questions that must be answered **prior to** the laboratory. These questions provide you with knowledge necessary for meaningful and

efficient completion of lab activities so it is important that you do them in advance. To provide extra incentive, lab instructors will ‘check you off’ on completion of these questions at the beginning of the lab and this will contribute to your laboratory activities grade. The instructors will not collect the pre-lab questions at this time since you may need to use them as a reference in your lab work. At specified points in the laboratory, you will be required to demonstrate working devices to the instructors. Instructors will also keep track of your completion of these activities and this will generate your ‘laboratory activities’ grade. After completion of the laboratory activities, you will be required to generate one or more technical reference sheets (to be discussed in the next section). **The reference sheets and pre-lab questions will then be handed in together at the beginning of the next laboratory session.** These items constitute the grades for pre-lab questions and the technical reference sheet.

The thermodynamics labs are each worth 10% of the grade, and will be solely determined by a technical report handed in for each laboratory experiment. **Thermodynamics lab reports are due at the beginning of the next lab session.**

### 3.0 The Technical Reference Sheet

The two primary types of documents that you will generate in this course are the technical reference sheet (electronics) and the technical report (thermodynamics). Since you will not encounter technical reports until the latter part of the course, only technical reference sheets will be discussed here.

The technical reference sheet is a relatively brief summary (1-2 pages) of an electronic device, and it serves two purposes. First, it is the primary means by which you will demonstrate your knowledge of devices and circuits encountered in the laboratory; but more importantly, this document can be used as a reference later in this course, and in subsequent work. The technical reference sheet should contain the following information:

1. A description of the device including relevant drawings and alternative configurations
2. A description of device operation, including equations that govern its operation and rules of thumb
3. How the device is used, with specific examples of applications
4. Typical specifications, limitations, and caveats
5. Address any questions asked in the lab manual

A sample reference sheet for light emitting diodes (LED’s) can be found at the end of this chapter.

### 4.0 The Laboratory Notebook

In addition to the documentation that you will submit for grades, it is essential that you use a bound laboratory notebook to record all pertinent observations, ideas, calculations, and data. This will be invaluable in your preparation of reports after the completion of the laboratory session. Keeping good notes is a skill that must be practiced and is essential for your professional career. Not only will it support your daily activities, but your recorded notes can be used to prove ownership of intellectual property or to demonstrate due diligence in case of an engineering failure.

- The following guidelines will help you in maintaining an effective notebook:
- Use a bound notebook so that pages are not lost. A spiral notebook is sufficient in this lab. In your professional career, you will probably use a more durable hard-covered notebook with pre-numbered pages.
- Always use ink. Cross out mistakes neatly – do not obliterate them.
- Record the date
- All raw data should be included. Computer printouts should be permanently bonded to the pages of your notebook so that they are not lost.
- Work out your calculations in detail. If you make a mistake, it will be much easier to find.

- Record models and serial numbers of lab instruments that are used. If a problem is later discovered with an instrument, you can easily determine whether or not it could have affected your measurements.
- Include all important observations. The ability to identify important information comes with experience and your understanding of the underlying principles of the experiment or device. If you are unsure whether or not to include an observation, record it and/or discuss it with a lab instructor. It is better to note an unimportant fact than to leave out an important detail and possibly render your data useless.

In determining what information to include, it is helpful to think about the potential audience that you are writing for. In general, anybody with your level of expertise should be able to understand and use your notes. This person could be your successor, an expert witness in court, or you several years later.

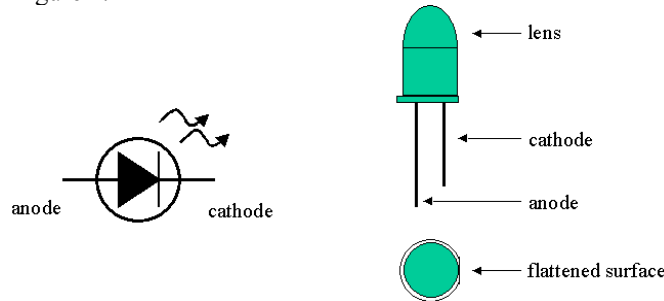
## 5.0 Fall 2002 MAE 221 Laboratory Schedule

<b>Week</b>	<b>Assignments</b>
*9/13 – 9/20	Chapter 1: Introduction to the MAE 222 Laboratory Chapter 2: Laboratory Equipment and Basic Resistive Devices
9/23 – 9/27	Chapter 3: Filters and Operational Amplifiers
9/30 – 10/4	Chapter 4: Power Sources and Power Control
10/7 – 10/11	Chapter 5: A Variety of Sensors and their Calibration
10/14 – 10/18	Chapter 6: Independent Projects
10/21 – 10/25	Midterm week. No lab
10/28 – 11/1	Fall Recess
11/4 – 11/8	Thermodynamics Experiment: Phase Change
11/11 – 11/15	Thermodynamics Experiments
11/18 – 11/22	Thermodynamics Experiments
11/25 – 11/27	Thermodynamics Experiments (Thurs. lab must make up)
Thurs. 11/28, Fri. 11/29	Thanksgiving Break
Mon. 12/2 – Thurs. 12/6	Thermodynamics Experiments
Mon. 12/9 – Thurs. 12/13	Thermodynamics Experiments

\* The first Monday lab will be held on Friday, Sept. 13.

## The Light Emitting Diode

A diode is a semiconductor device that allows current to flow in one direction. A light emitting diode (LED) is a diode that glows with intensity roughly proportional to the amount of current flowing through it. The schematic symbol and a physical diagram of an LED are given in Figure 1.



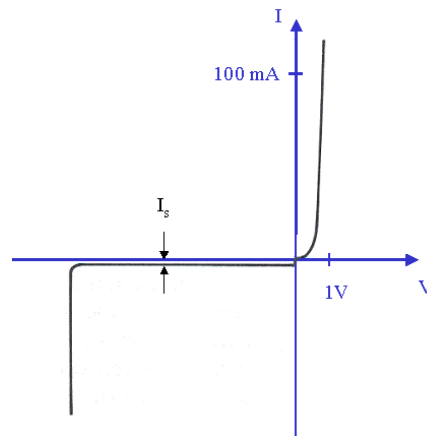
**Figure 1: Schematic Diagram and Physical Drawing of an LED**

The arrow within the symbol indicates the direction of positive (+ to -) current flow, which is always from the anode to the cathode. Significant current flow in the opposite direction is not possible because the 'back resistance' is high. The cathode can be located by finding flattened surface as shown in Figure 1. LED's are presently available in 5 different colors: blue, blue-green, orange, red, orange-red, white, yellow, and infrared.

### Operation:

In the forward biased direction (when the anode is made more positive than the cathode), current through the LED is dependent on the applied voltage (V) and absolute temperature (T). More specifically,

$$I = I_s \left( e^{\frac{eV}{kT}} - 1 \right),$$



**Figure 3: I-V Characteristic for an LED**

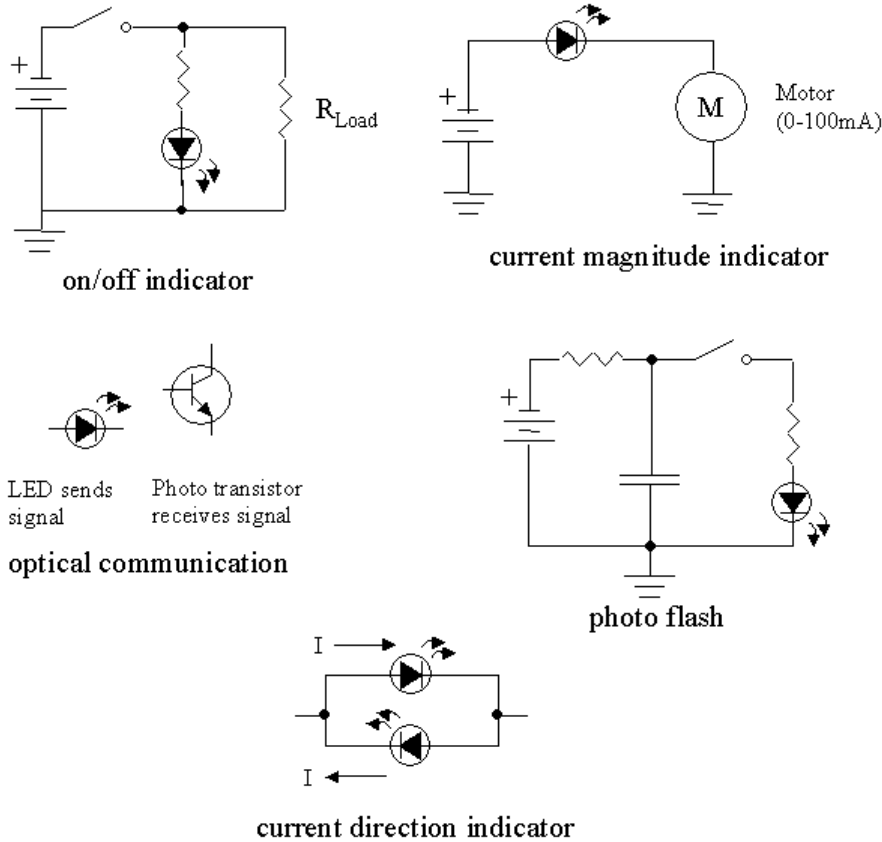
where  $e$  is the charge of an electron ( $1.6 \times 10^{-19}$  C), and  $k$  is Boltzmann's constant ( $1.38 \times 10^{-23}$  J/K).  $I_s$  is the magnitude of the nearly constant reverse current when the LED is reverse biased (the cathode is more positive than the anode). This current is very small and for most practical purposes is assumed to be zero when reverse biased. The relationship between current and voltage (the I-V characteristic) for a typical LED is shown graphically in Figure 3. For forward biased voltages, conduction effectively begins at about 0.7V and the slope of the I-V curve is very steep.

**Applications:** *(These are sample applications. In the laboratory you will be introduced to specific applications that should be discussed in detail including any relevant equations and drawings.)*

Some typical applications are depicted in Figure 2 and briefly discussed below:

- on/off indicator: if the LED is connected in parallel with a load, the LED will glow when the load is drawing current.

- current magnitude indicator: because the intensity is roughly proportional to the current flowing through the LED, it can be used as a simple current magnitude indicator.
- optical communication: radiation emitted by an LED can be received by a photo transistor. This makes the LED useful for data communication (ie. a television remote control) or it can be used to measure mechanical motion. For example when used with an optical interruptor the LED/photo transistor pair can be used to measure the speed of a rotating shaft.
- photo flash: by charging a capacitor and subsequently discharging through an LED, a photographic-like flash can be constructed. The LED is vastly superior to a bulb in longevity, as long as maximum ratings are not exceeded.
- current direction indicator: if two LED's are connected in parallel with opposite polarity, current can flow in both directions but only one LED will conduct (and hence glow) at a time. If this is used, for example, with a DC motor, the LED's can be used to indicate the direction of rotation of the motor.



**Figure 2: LED Applications**

**Typical Parameters and Values:**

Characteristics for a typical LED (the standard red MV502XA manufactured by Fairchild Semiconductor):

- maximum current: 100mA
- maximum power dissipation: 180mW
- maximum reverse voltage: 5V
- beam angle: 90 degrees typical (MV5023A). Other variants range from 60 to 180 degrees. (this is the spreading angle of the emitted light beam, and is dependent on the lens)

**Caveat:**

Due to the steepness of the I-V curve in forward conduction, very large currents can be generated in the LED with the application of modest voltages. Therefore, always put a resistor in series with the LED in order to protect it.