**Behind the Black Box**

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| **5-Part Plan Title:** | **Behind the Black Box** |
| **Engineering Grand Challenge(s) Covered:** | **Advance Health Informatics** |
|  | **Engineer the Tools of Scientific Discovery** |
| **Fellow Contributor(s):** | **Max Jin** |
| **Grade Level(s):** | **10-12** |

1. Subject / Subject Area(s): Biology, Physics, and Engineering
2. Time Required: 45 minutes
3. Group Size: 3-4 per group
4. Expendable Cost per group: Attached
5. Summary: Students will first learn the fundamentals of human physiology pertaining to the heart and how it works. Then they will apply principles learned in physics to determine how a pulse oximeter works. Next, they will utilize the pulse oximeter to look at their own electrocardiograms, heart rate, and arterial oxygen saturation level. Finally, a brief discussion will be held on how engineers determine deficiencies in the world today and tackle these problems.
6. Engineering Connection: Medical devices are essential elements of modern medical care, including everything from CT scanners and pacemakers to blood pressure cuffs and robots used by surgeons. In the United States, the industry currently employs more than 400,000 Americans directly and 2 million people indirectly. Today, the United States is struggling with a large and growing talent and development gap, so they need qualified engineers. Biomedical engineers can fill this gap with their understanding of the human body system and how mechanical and electrical devices can improve everyday life as well as patient stays’ in hospitals. In this experiment, the students examine a pulse oximeter and how it utilizes what engineers know about the human body to work.
7. Key Search Words: Pulse oximetry, Beer-Lambert Law, Biomedical Engineering
8. Education Standards: See attached standards grid for a complete mapping to all pertinent STEM standards:
   * Common Core Math Standards: A-SSE, A-APR, F-IF, F-BF
   * Next Generation Science Standards: ETS1, ETS2, PS4.C
   * NC Essential Science Standards: BIOL: 1.2.1  
     Physics: 2.2.2, 2.3.1, 2.3.2
   * NC Engineering Connection Standards: 2.1-2.3, 3.1
9. Learning Objectives (After this activity, students should be able to): Explain and review how the heart works, how different materials affect light transmission, and how engineers can apply the fundamentals of science learned in class.
10. Materials List: Attached
11. Introduction: Have you ever been in the hospital? While at the hospital, were you intrigued by all that equipment hooked up to patients in the hospital? The United States accounts for the majority of the 350 billon dollar medical device industry thus medical equipment can be seen everywhere. Understanding how these devices work not only determines what is necessary and unnecessary in the new era of increasing health care costs, but also enriches our understanding of basic fundamental scientific principles. As engineers, we should constantly question the status quo and see how the world can be improved in small ways.
12. Motivation: In the past, the arterial oxygen saturation levels of patients in the hospital were measured by taking periodic blood samples and analyzing them several times a day using bulky, expensive laboratory equipment. This method was not only inconvenient for doctors, nurses, and patients, but it also failed to provide accurate real-time or dynamic measurements of arterial oxygen saturation level. This deficiency led to the development of non-invasive pulse oximetry in the early 1980’s. Pulse oximetry is a non-invasive method of determining arterial oxygen saturation levels through utilizing a light emitting diode to measure the differences in red and infrared light absorption and reflection of oxygenated and deoxygenated hemoglobin.
13. Vocabulary / Definitions:

Electrocardiogram: a simple, painless test that records the heart's electrical activity.

Hemoglobin: a protein molecule in red blood cells that carries oxygen from the lungs to the body's tissues and returns carbon dioxide from the tissues back to the lungs.

1. Procedure:
   * Before the activity — One class should be devoted to human physiology, especially how the heart works and the electrical signals generated that make the heart contract. Another class should be devoted to the physics of wavelength transmission, reflection, and absorption.
   * With the students — One class will be devoted to understanding the pulse oximeter and utilizing it in practice to generate an ECG, measure the number of heart beats per minute, and determine the arterial oxygen saturation level.
   * Cleanup —Carefully and precisely put away the electronic equipment and tools.
2. Safety Issues and Guidelines: Take precautions to not overload electronic equipment
3. Troubleshooting Tips: Attached
4. Contributor: Max Jin
5. Supporting Program: Duke Boeing Grand Challenge K12 Outreach Fellows Program