Final report

Problem Statement:
Clinicians and technicians in the developing world cannot run laboratory tests because current spectrophotometers are expensive, fragile, and lack adequate power sources. There is a need for a system that is accurate, low-cost, durable, and can withstand fluctuations in power. Ideally, the system would be designed using local and sustainable materials with a reduced number of parts.

Components:
1.) Light Source(s)
Generally any light source can be used as long as the wavelength can be narrowed down. Spectrophotometers commonly use tungsten filament lamps, which are a broad spectrum light source with a wavelength range of about 350-2500 nm. We chose to use several LEDs with narrow bands of emitting light due to their low cost and simplicity.

2.) Sample Cuvette(s)
The cuvette is generally made of either plastic, glass, or quartz. Cuvettes must be made precisely, so they are clear throughout so the results of the instrument are not affected. The plastic cuvettes are usually disposable, where glass and quartz are washed thoroughly in between uses.

3.) Detector(s)
There are also several different options for the photodetector. Notably photomultiplier tubes, light dependent resistors and photodiodes are potential choices for a spectrophotometer. Photomultiplier tubes are most commonly used, which generate a current based on the number of photons that enter a tube. A light dependent resistor varies its resistance based on the intensity of light that hits the receptor, so a simple circuit could be implemented to detect changes in voltage to detect the level of light. Lastly a photodiode could be used, which is a semiconductor that converts light energy into either current or voltage based on how the photodiode is implemented.

Figure: Equipment setup

User Interface:
The main objective for the interface design is to keep the device as user friendly as possible and durable. Someone that may not have a technical background should be able to use this low-cost spectrophotometer without running into any complications. Also, this device will be used in the field as a point-to-care spectrophotometer. With that said, the outer casing needs to
withstand high temperatures, humidity, and dust. The user will be able to move the device around without calibrating it each time. Replacement of components will be low cost and readily available. In the next sections certain components of the device are discussed.

**Outer Casing:**
The encasing for the spectrophotometer is made out of a lightweight, impact-resistant ABS plastic from McMaster Carr Inc. ABS plastic stands for Acrylonitrile Butadiene Styrene and it is known for its mechanical properties for handling high impact, heat resistance, as well as low weight. The dimensions of this encasing are 6.9” height x 4.9” width x 2.5” depth.

![Outer Casing Image]

**LED Selector Wheel:**
To keep this device as simple as possible, we came up with a way for the user to easily select what LED light that has a certain wavelength that shall be used to run a clinical test. The selector wheel can hold 5 different LED’s. The user will rotate the wheel until the wavelength desired (printed on the rim) is displayed upright. Now that LED light is in the path length of the cuvette. The selector can only rotate once around the axis preventing wire entanglement. When user has reached the farthest point, the wheel will hit a notch preventing it from turning. The design of the LED selector wheel is shown in figure??

![LED Selector Wheel Image]

**Display**
The display uses 4 LED seven segment displays to output data. The Arduino was programmed to output data to the display.

**Unit Buttons**
Since different clinical tests require different units the user will select which units the digital screen will display by pressing the button for either mg/dL or mol/L. What units to select will be described in the manual.
Selection of Clinical Tests

It was necessary for the team to investigate which diseases in the developing world are in most need of diagnosis. Prevalence of disease and urgency of diagnosis varied slightly depending on the article or resource referenced. However, most resources cited a core group of pathologies in need of diagnosis: malaria, diabetes, HIV/AIDS, and tuberculosis (TB). Ultimately, the research that proved most useful for determining which diseases our device should have the ability to diagnose was consultation with Dr. Amin Mohammad, professor of pathology at the TAMUHSC. His input helped to narrow our considerations down to hyperbilirubinemia, anemia, and diabetes. Hyperbilirubinemia will be diagnosed by measuring levels of bilirubin, anemia by measuring hemoglobin, and diabetes by measuring blood glucose levels.

The next step was to determine which method of preparation would be used on each of the samples to be tested. The ability to do this is limited by the availability of the necessary reagents. It is highly likely that inventories of reagents will vary between clinics in the developing world. For this reason, the tests to be implemented will utilize the reagents that are the most common and/or likely to be found. These reagents combinations can be found in kits through various distributors. Below is information regarding sample preparation and corresponding reagents.

Testing for Bilirubin
Test Kit Source: Chemhouse Diagnostic
Kit Type/Number: Total Bilirubin/021-0500
Specimen type: Serum
Reagents: Total Bilirubin Reagent (3,5-dichlorophenylidiazoniumtetafluoroborate), surfactant, sulfanilic acid, HCl, sodium nitrite
Wavelength of Maximum Absorption: 546 nm

Testing for Hemoglobin
Test Kit Source: Chemhouse Diagnostic
Kit Type/Number: Hemoglobin Reagent/055-0300
Specimen type: Whole Blood
Reagents: potassium cyanide, potassium ferricyanide, potassium phosphate, preservative
Wavelength of Maximum Absorption: 546 nm
Testing for Glucose
Test Kit Source: Chemhouse Diagnostic
Kit Type/Number: Glucose Oxidase Liquid Stable Reagent/053-1000
Specimen type: serum or plasma
Reagents: Glucose oxidase, phenol, 4-amino-antipyrine, peroxidase, EDTA, glucose standard, phosphate buffer pH 6.6
Wavelength of Maximum Absorption: 505 nm

Sample solutions would have to be prepared according to very specific methods in order to achieve precise results. These instructions are included in the Chemhouse Diagnostic kits and can be rewritten, simplified, and made mostly pictorial to improve the international functionality of our device. If solutions are properly prepared, associated wavelengths of maximum absorbance will be the ones listed above. Because hemoglobin and bilirubin require the same excitation wavelength, special calibration will have to be performed to assure that the two concentration measurements do not interfere with each other. Many of these reagents require specific environmental conditions, such as refrigeration. Unfortunately, this is a common trait of chemical reagents that does not work well with conditions in the developing world.

Our design team traveled to Temple, TX on April 5, 2013 to visit Dr. Amin Mohammad, MD at the TAMHSC working in the Clinical Pathology Lab. We were given valuable information and gained insight by seeing samples, diagnostic machines, and point of care devices first hand. During our meeting, we discussed several basic components to clinical diagnosis such as separation of serum from plasma, how to prepare saline solutions, various types of sample tubes, resources for sample specimens, preventing sample component interference, temporal constraints of testing, the possibility of send individual kits for each test, and much more. All of this discussion will affect the overall design of our device with specific implications on the packaging of reagents and sample preparation supplies.

Circuit Design

The device uses an Arduino Uno R2 Microcontroller, an open source microcontroller platform, controlling most of the functions of the device. The microcontroller was programmed using the Arduino Language which is a subset of the C/C++ Language.
The functions of the device are relegated to three basic circuits: the source circuit, the detector circuit, and the display circuit. Each circuit is connected to the microcontroller, which powers/manages each circuit.

The source circuit is essentially a simple series LED/Resistor circuit, and is responsible for being the source component in the spectrophotometer. It is driven by a 5V power supply on the Arduino Microcontroller, and is turned on and off by a hardware switch, rather than being managed by the software on the microcontroller.

The detector circuit is essentially a single phototransistor connected in series with a resistor. It is driven by the 5V power supply in the microcontroller, with one of the analog inputs in the board set to measure the voltage across the phototransistor. As light hits the phototransistor. The voltage across the phototransistor changes, which can be related to the intensity of light hitting the detector. A small portion of the software in the device is devoted to processing the signal coming from the detector circuit.

The display circuit is the output of the device that enables the user to read the data. It utilizes 4 7-segment LED displays, as well as 4 shift registers to display various quantitative information calculated by the device. Most of the software written so far is devoted to this portion of the device.

**Power**

Powering the device must be self-sustainable based on the inconsistent power supply of the location where the device will be operating. A simple plug into the wall would not be feasible, because potential power surges could damage our device or power may not be functioning.

**Batteries:**

The device will be powered by battery, so it can stand alone and not depend on some constant supply of power. Several options of batteries were considered to power the device based on different considerations such as life, voltage, charge, cost, and sustainability. In the end Nickel Metal Hydride were decided to be the best option for their ability to be recharged, and ability to hold capacity. The particular batteries found were AA batteries from eneloop, which have 1.2 V
2000 mAH and maintain 75% of their charge after 3 years. The arduino requires at least 7 V of power to operate correctly therefore our device will use 8 of these batteries in series to power the device at 9.6 V for 2000 mAH. It is expected this will provide about 3 hours of operation time for the device before the batteries need to be recharged. Using standard AA sized batteries also leaves the option of alkaline AA's to be used temporarily if there is a problem with the NiMH batteries

**Charging:**
Charging the batteries will be done with solar panels. The particular panels that were chosen individually generate 4.5 V and 30 to 90 mA depending on the amount of sunlight. A simple circuit with three panels connected in series with a diode, and the batteries will be used as a charging method. The panels are 60 mm$^2$, so several can be packed together. Three or 6 panels can be used, which would halve the time it takes to charge the batteries.