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Basketball backboard and hoop lighting apparatus

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BASKETBALL BACKBOARD AND HOOP LIGHTING APPARATUS

**MIM 1502
Senior Capstone Design Project**

Technical Design Report

Night Hoops Light

Spring Quarter 2002

End-Term Report

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Copyright

“We the team members,

Anas Bukhash

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1. INTRODUCTION

Americans own millions of basketball hoops that are mostly used for recreational purposes. A typical consumer's basketball hoop is outdoors, where the lighting may be a problem. The amount of daylight sets the time allowed for the use of these basketball hoops. The use of house floodlights or streetlights at night can be inadequate and distracting to the players. With or without the lights the basketball game becomes unplayable and forced to end when sunlight is not available.

Project Objectives

The goal of the Night Hoops lighting project is to allow basketball games to continue after the sun goes down. This project provides a lighting apparatus that can be placed on any existing basketball backboard and hoop. The apparatus adequately illuminates the hoop, backboard and an area of approximately one square meter under the hoop. These critical areas determine a person's shot while playing basketball. The decision process used by hand to eye coordination to make a shot requires the hoop, backboard and area underneath to be illuminated by the lighting apparatus. The effects of shadows on the hoop and backboard must be considered in the design of the lighting apparatus and therefore eliminated [3].

With the main goal of this project being the illumination of the areas mentioned above for any existing basketball backboard and hoop there are some additional project objectives. Since the lighting apparatus is being designed for the average owner of a basketball hoop it must be easy to install. No permanent modifications to the existing basketball backboard and hoop are needed to install the lighting apparatus. All mounting hardware is included in the packaging and the only tool required is a stepladder. This tool is common to the majority of households and helps to maintain the easy installation objective.

Along with easy installation another project objective is minimal maintenance. Maintenance of a product reduces its marketability and consumer purchases of the product. The lighting apparatus must be portable so that it can be transported from hoop to hoop. The portability of the apparatus is to allow it to be transferred from one hoop to another when a new hoop is purchased or for occasional transfer. Due to the high placement of the apparatus for installation an everyday portability is not a goal. Also the product must be affordably priced. Mark J. O'Donoghue, the project sponsor, is suggesting a sixty to seventy dollar price range.

Project Constraints

There are several project constraints that need to be considered. The lighting apparatus must provide a sufficient amount of light. This amount of light is defined by the ergonomics of light. The light must be intense enough to fully light up the hoop, backboard and area underneath yet not so intense as to distract the player. The tendency of light to be “blinding” or distracting can be analyzed using the principles of light and how the human eye reacts to them. This will be covered in detail in the ergonomics of light section of this report.

The design must be resistant to vibration. In playing basketball there is a high amount of vibrations produced from the basketball bouncing off the backboard and hoop. This will affect the way in which the lighting apparatus is mounted, the selection of light bulbs and the selection of components of the lighting apparatus. All of the components of the design must be resistant to many cycles of vibration associated with basketball games.

Since most backboards and hoops are outside, the lighting apparatus must be designed for all seasons. The lighting apparatus must endure the winters of Maine and the summers of Florida and everything in between. A major consideration in weather resistance is the effects condensation has on the lighting components and ways to eliminate condensation within the lighting apparatus.

Working with the project sponsor, a target retail price of sixty to seventy dollars was set. To meet this goal we must minimize cost for all the components involved in the lighting apparatus. Typically manufacturing costs for a production part run about fifty percent of retail price. The basketball backboard and hoop lighting apparatus should initially be manufactured for the sixty to seventy dollar price range so that costs can be cut in mass production to get down to a manufacturing cost of around thirty five dollars.

The major design constraint faced by this project is the portion of the backboard and hoop chosen to mount the lighting apparatus. The design area chosen is shown in Figure 1.1 & 1.2.

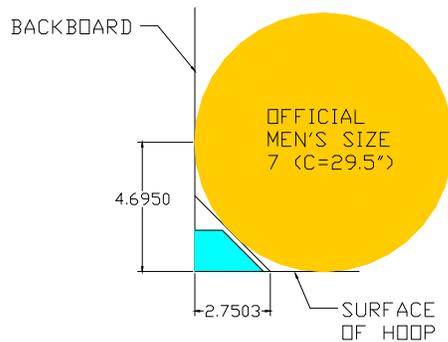


Figure 1.1 - Design Area



Figure 1.2 - Actual Design Area

The design area chosen for the lighting apparatus is the area on the hoop and backboard where a standard basketball will never come in contact with, due to the geometries of a basketball, standard hoop and backboard. Figure 1.1 shows the simple geometries of a standard size basketball with that of a backboard and hoop. The aqua colored trapezoid represents the space occupied by the lighting apparatus. The vertical line in the figure represents the backboard and the horizontal line the hoop. The 4.695” dimension is the radius of the ball and also the distance from the junction of the hoop and backboard to the point which the ball touches the backboard or the hoop. The 2.75” dimension is the point on the backboard and hoop where a 45-degree isosceles triangle would intersect the planes of the hoop and backboard therefore displaying the maximum three-sided design area. This design area is most constrained on top of the hoop as shown in Figure 1.1 & 1.2. The ball comes closer to the lightface on the top of the hoop than on the sides. The area to the side of the hoop increases due to the expanding hoop, which limits how close the ball can get. This is better illustrated in the following section.

1.3 Design Area

Figures 1.3 and 1.4 illustrate the design area:

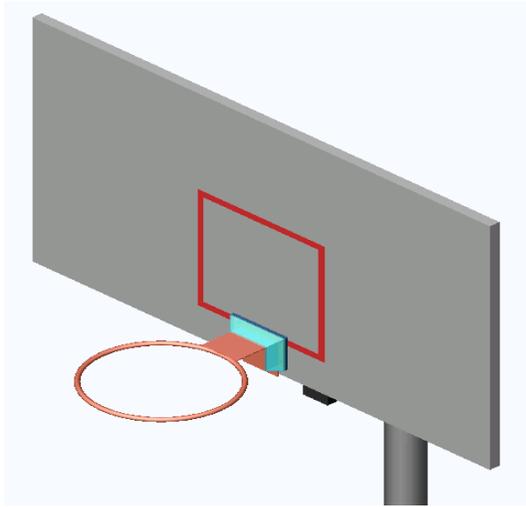


Figure 1.3 - Hoop and lighting apparatus

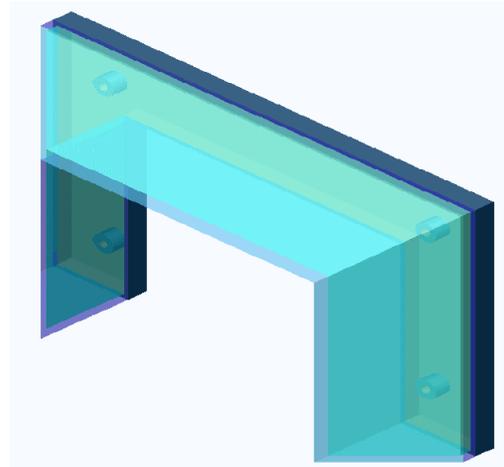


Figure 1.4 - Lighting apparatus

In figure 1.2 the aqua colored solid model outlines the U-shaped design area. The light could not be wrapped underneath since not all hoop designs have that area available. Several hoop models are spring loaded and the spring takes up that area. The area underneath can be utilized for placement of a power source on the hoops that are not spring loaded. This area cannot be utilized by additional lighting due to the variability in hoop designs. Figure 1.3 shows the 45-degree lens face that maximizes the design area on top of the hoop. The U-shaped design area also lends itself well to the ergonomics of lighting, which is described in more detail in section 3. The U-shape provides multiple light angles and lens options to correctly direct and diffuse the light. The light will have to come from more than one source to properly light the hoop, backboard and area underneath.

After conducting some testing we realized that the upper left and right corners of our outside lens caused problems, especially if the ball was not inflated to the right amount. To eliminate this problem we decided to trim the corners by half an inch on both sides. Figures 1.3A and 1.4A illustrate the new design:

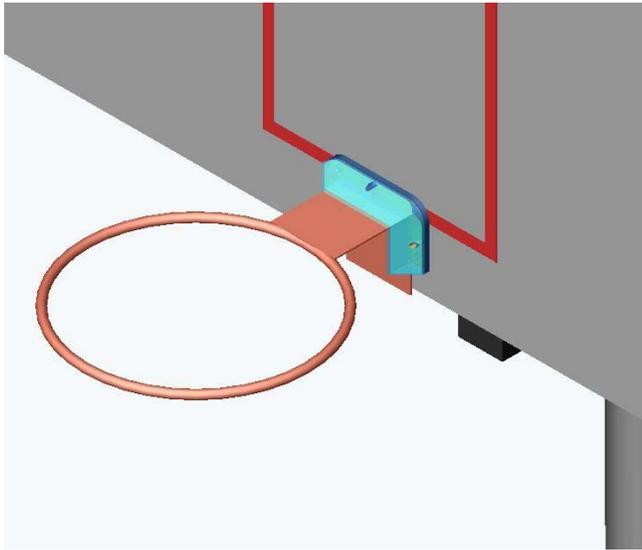


Figure 1.3A – Updated hoop and lighting apparatus

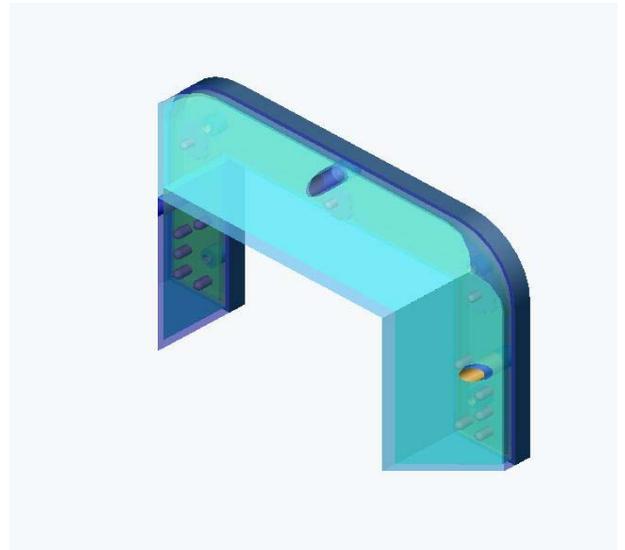


Figure 1.4A – Updated lighting apparatus

1.4 Design Introduction

The basic design has a few major components. The first of the components is the lights. The lights are the most important part. All the other components get designed around the requirements of the lights. The second part of the design is the power source. The only function of the power source is to give the lights the energy to turn on. The black box under the backboard in Figure 1.3A is the power source. Once the lights and the power source are selected a housing can be designed to put the lights in. A picture of the housing can be seen in Figures 1.3A and 1.4A. After the lights and electronics are put into the housing a mounting method is needed. A Velcro like material will be used for this application. Using a material of this type will maintain the portability of the design while provide a secure attachment to the backboard. The design area just described has not been chosen for any existing basketball products. This goes for existing products and patents, which are discussed in the following section.

2. State of the Art

In the state of the art two main sections are discussed. The existing products that can be found on the market and the patents that we found related to the Night Hoops project. In the section concerning existing products, we found two companies; Huffly Sports Corporation and Game Lights. Huffly Sports manufactures two products that are similar to our design; the “Twilight Lighted Basketball Net” and the

“Light It Up Backboard System”. Game Light’s product is called the “Hoop Light”. All of these designs will be explained in detail along with the patents in the upcoming sections.

2.1 Existing Lighting Products

Huffy Sports “Twilight Lighted Basketball Net” product consists of a round tube containing light emitting diodes (LEDs). This round tube could be placed in any standard net. The tube is threaded through the net and is activated by the first basket to go through the hoop. A #2032 battery, a typical watch battery, which lasts approximately 100 hours, powers the product. This product has a price of approximately \$12.50. The lighted loop of LEDs does not provide sufficient light for play, which is evident when watching the promotional video of the product.

Huffy Sports second product the “Light It Up Backboard”, consists of a specially designed backboard and rim. The rim and the square on the backboard illuminates using fiber optic technology. The product is activated through an on/off switch, and is powered by four AA batteries. The price for the backboard and the hoop is approximately \$200.00. The fiber optics provide a dull red glow of light.



Figure 2.1 - Hoop Light

The Game lights product, The Hoop Light, consists of a steel pole that is attached to the existing basketball pole shown in figure 2.1. The steel pole extends up eight to ten feet and over eight to ten feet from the existing mounting pole, depending on the model type. A halogen light bulb and housing are attached to the L-shaped pole lights the backboard, hoop, and a thirty by thirty foot space underneath. The product is activated through a switch and is powered from an AC outlet. The halogen bulb found in this product only has a life of approximately 2000 hours, and the price range is \$79.95 – \$129.95.

The disadvantages found in all three products are numerous. For the Huffy products in general, they use light sources, which provide insufficient light. The “Twilight Lighted Basketball Net” shuts off if no

baskets are scored in two minutes frustrating unskilled players even more. And for Huffy Sports “Light It Up Backboard System”, the backboard system has a price range that is too high compared to competing products. It also requires the purchase of an entire backboard and hoop.

The Game lights product has two disadvantages, the first being that it not recommend slam dunking the ball after attaching the product, because it may damage the product. Second, the product has to be assembled in a completely different way if you had an adjustable basketball hoop height pole. The pole used for adjustable height hoops requires the mounting pole to be free of obstructions such as the hoop light steel pole. The Hoop Light’s light bulb and part of its steel pole is in the field of play, therefore high thrown balls may hit the product and cause damage or disrupt play. The halogen light that it uses is sensitive to vibration and temperature changes.

2.2 Patent Research

There are three different types of patents that relate to basketball lighting; the luminescent backboard (#5711727), the backboard light strips (#5305998), and the illuminated rim (#5403000). The luminescent backboard shown in Figure 2.2 consists of a specially designed expensive backboard system, which is a system that consists of two main light sources. One is the backboard area itself and the other is the area around the rim.

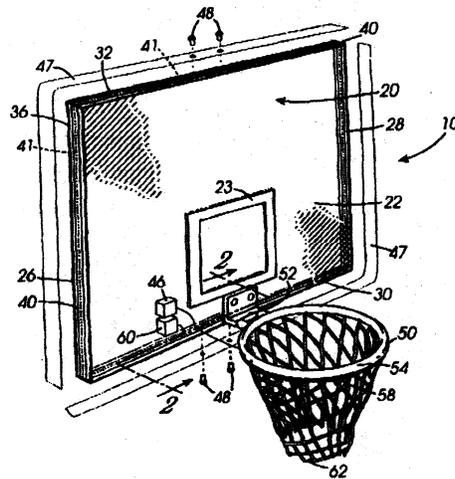


Figure 2.2 - Luminescent Backboard

The backboard is made up of two glass pieces with a luminescent film sandwiched in between, which provides the illumination. The square box area also illuminates as soon as the main light sources are

turned on. This happens due to a special fluorescent compound that it is coated with. Even the net found on this product is made of a material that provides a shine. The main disadvantage to this patent design is the high costs associated with the unique design.

The backboard light strips, the second patent found, are a product where the light is provided through strips that could be either molded into the backboard itself, or on the other hand drilled or adjusted to the back of it. The strips are then connected to an AC power source illuminating the area. Some disadvantages include the difficulty of mounting such a product to the backboard itself. Mounting it to the front would require a new special design made for that purpose or permanent modifications to the backboard. Mounting it on the back would require a special semi or fully transparent backboard to allow use of this product. Therefore, in both cases special designs of the backboard would be required, and those designs would most probably recommend a high price. The power source that would be used could range from an AC/DC or solar power. Along with the light strips the patent contains an illuminated rim. The steel rim is specially made with a hollow interior where the light source is placed. To emit this lightning from the inside of the rim, there are some small openings made to allow this illumination. The third patent, the illuminated rim, the idea is to use a form of chemical that is contained in small containers and when broken immediately emit a glow to produce illumination. This is only a short-term solution for any chemical illumination like “glow-sticks” or “glow-rings” fade after a day’s use.

2.3 Lessons Learned

From the information gathered in the state of the art research many advantages and disadvantages are highlighted. The lighting apparatus design by the basketball backboard and hoop lighting design team take into consideration all the disadvantages discussed in the existing products. The lighting apparatus design will not be considered to be in the field of play, since it is positioned in an area the basketball cannot reach. It will be easy to install and adjust and the U-shaped design shown in section 1 should provide both those elements. The retail price discussed of \$70.00, has only the Hoop Light as a competitor and therefore the lighting apparatus design should work hardest to overcome the Hoop Light disadvantages. As the design process continues research on existing designs ensures that the advantages are kept and disadvantages are overcome.

3. Ergonomics of Light

Ergonomics of light helps to understand how to maximize the benefits of using light. Understanding ergonomics helps promote a safer environment for everybody to use.

3.1 Human Eye

Light Ergonomics in this project is one of the most important factors. The light and power sources both depend on how much light is actually needed. The ability of this product to provide sufficient lighting will prove to the consumer whether the product is great or not. To assess how much light is needed, a clearer understanding of how light is perceived had to be understood [1].

Light is perceived through the retina. The retina, the sensory membrane that lines the eye, is composed of several layers including one containing the rods and cones. It functions as the immediate instrument of vision by receiving the image formed by the lens and converting it into chemical and nervous signals which reach the brain by way of the optic nerve [16].

The cones and rods are two different types of light-sensitive receptors found in the retina. Cones are responsible for color vision, while rods help us see in dim light. The cones are designed to detect the three primary colors of red, green and blue. The rods are activated at very low levels of light for night vision. The blue component of light helps us distinguish between near by objects and those further away. Objects near by appear in warmer and more intense tones whereas objects further away appear in bluish and pale tones [15, 16].

The eye is an optical system designed to create images on the retina. The eye is composed of the cornea, the aqueous humour, the iris, the lens, and the vitreous humour. These combine to enable the eye to react quickly and easily to different lighting levels that varies by factors of 10^5 . It has an extremely low sensitivity threshold (equivalent to the light from a faint star in the night sky).

Glare reduces the ability to see clearly and is unpleasant. A distinction is made between direct glare (e.g. extreme light from a light source) and reflected glare (light reflected from surfaces). The goal is to decrease or even eliminate glare from the lighting apparatus. Using just the right amount of light or by diffracting and diffusing the light source can reduce or even eliminate glare. The design of the light apparatus will diffuse the light [7].

3.2 Light Measurements

Light can be measured by 4 different means. Any of the following may be used depending on what measurement is mostly suited:

- Flux of light (i.e. amount of light energy)
- Light incident per unit area on a surface
- Light emitted by a lamp per unit solid angle in a given direction
- Light propagating in a beam (or emitted by a surface) per unit area and per unit solid angle.

These quantities may be defined either as radiometric measures or as photometric measures of light. Radiometric measures of light are specified either as spectral quantities, i.e. as functions of the wavelength of the light, or as total quantities summed over a range of wavelengths. Photometric measures of light are weighted averages of the spatial quantities in which the eye response function $v(\lambda)$ is used as the weighting function. In consequence the radiometric quantities may have values that are functions of wavelength, or a value that is a sum over a specified wavelength range whereas the photometric quantities have a single numeric value. The names, units and symbols for these quantities are as follows (radiometric units are for total not spectral quantities):

Table 3.1 - Radiometry & Photometry

	Radiometry			Photometry		
	Quantity	Unit	Symbol	Quantity	Unit	Symbol
Energy Flow	Radiant Power	Watt (W)	ϕ_r	Luminous flux	Lumen (lm)	ϕ
On a surface	Irradiance	Wm^{-2}	E_r	Illuminance	Lux (lx)	E
From a source	Radiant Intensity	Wsr^{-1}	I_r	Luminous intensity	Candela (cd)	I
Propagating in a beam	Radiance	$Wm^{-2}sr^{-1}$	L_r	Luminance	cdm^{-2}	L

To know how much light is needed, Photometry had to be investigated or examined. In Photometry there are a few terms that are used over and over again. The term lumens is used to quantify a light source. More precisely Lumen is the total flux of light emitted and is measured in lumens. The term Illuminance is used to measure the amount of light reaching a surface, more precisely it's the density of light falling on a surface and is measured in lux (1 lux = 1 lumen/meter²) [4, 5].

3.2.1 Lumen

Lumen is the total flux emitted by a light source. By definition there are 683 lumens per Watt of radiant power at a wavelength of 555 nm. The lumen is the standard unit for the luminous power of a light source. It is defined by:

$$\text{Luminous power in lumens } [\phi] = \text{Radiant power in Watts}[\phi_r] \times 683 \text{ lumens/Watt} \times \text{luminous efficacy} [16].$$

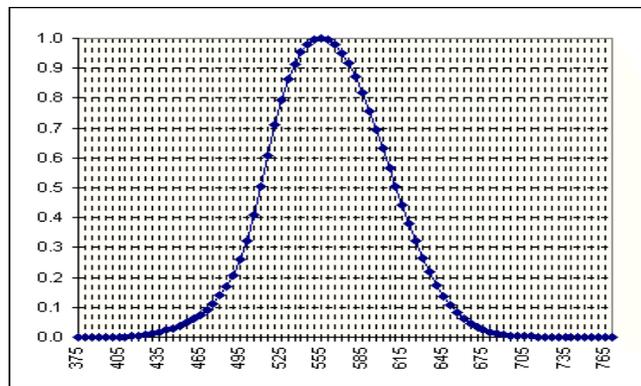


Figure 3.1 - Luminous Efficiency vs. Wavelength

The luminous power is the part of the power perceived as light by the human eye. The value 683 lumens/Watt is based upon the sensitivity of the eye at 555 nm, the peak efficiency of the photopic(daylight) vision curve. The luminous efficiency is 1 at a wavelength of 555 nm. Figure 3.1 above demonstrates how luminous efficiency is related to the wavelength. The vertical axis represents the efficiency while the horizontal represents the wavelength. This figure represents a Bell Curve. Efficiency peaks when wavelength is 555 nm and drops proportionally at the same rate on both sides of the spectrum as seen in figure 3.1.

3.2.2 Illuminance

Illumination, also called illuminance, is a measure of the degree to which a surface is illuminated and is thus distinguished from the intensity of the light source. Illumination is measured in lux, where one lux is one lumen per square meter. Another unit of illumination is the footcandle. One footcandle is equal to one lumen incident per square foot of illuminated surface. One lux equals 0.0929 footcandle [7].

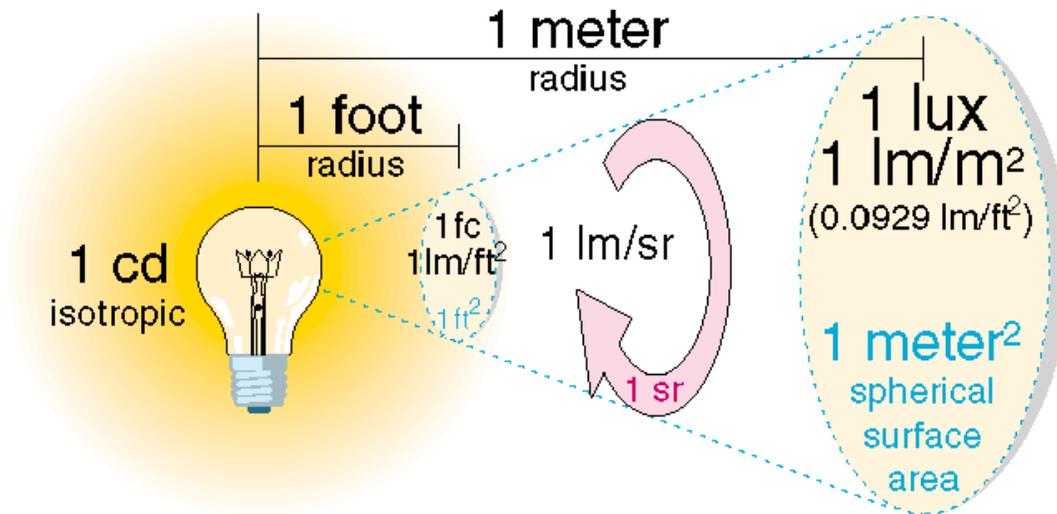


Figure 3.2 - Illuminance

What we see is only the light that hits our eyes. Illuminance is defined by the luminous flux from a light source that falls on a surface. Illuminance reduces with the square of the distance between the light source and the surface. Illuminance E is the ratio between the luminous flux and the area to be illuminated. An illuminance of 1 lux occurs when a luminous flux of 1 lumen falls evenly on an area of 1 m² (see Figure 3.2).

The unit of measurement of Illuminance is the lux [lx]. Based on the definitions for illuminance luminous intensity and solid angle $W = A/r^2$, we obtain the following formula for illuminance:

$$E = \phi / A, \tag{i}$$

ϕ = luminous flux in lumen

A = area

The Inverse Square Law defines the relationship between irradiance from a point source and the distance to the measurement surface. It states that the intensity per unit area varies inversely proportional to the

square of the distance between the source and the surface.

$$E = I / r^2 \tag{ii}$$

r = distance of the light source to the object

I = luminous intensity

It is assumed that the light falls perpendicular to the surface it illuminates. If the surface is at an angle α then equation (ii) must be multiplied by $\cos \alpha$. Table 3.2 below contains common examples of light sources and their corresponding illuminance values [2, 3].

Table 3.2 - Conversion from Lux to Lumens

Illuminance to Lumens Chart		
Activity	LUX	Lumens
Public spaces with dark surroundings	20 - 50	45 - 113
Working spaces where visual tasks are only occasionally performed	100 - 200	225 - 450
Note: Lux to Lumens conversion assumes light source is 1.5 meters away		

Table 3.2 has some common standards used by the International Commission on Illumination (CIE). Based on the standards it was determined a light source with an illuminance value between 20 and 200 lux was required. The lighting product would be placed on the rim, which was on average assumed to be about 1.5 meters away from a player. Using 1.5 meters as the distance implied that it required a light source that would give out between 45 and 450 Lumens [15].

Experimentation values were needed to back up the values thought to be correct. Using a light source in a dark area and a lightmeter at eye level (1.5 meters away from the light source) 100 lux was sufficient light. Meanwhile at ground level (3 meters away from the light source) 50 lux would be sufficient. The numbers that were collected experimentally fell well within the standards. Therefore, it was concluded that 100 lux would be needed which translates to a light source that is capable of giving out 225 lumens.

4. Design Alternatives

The project can be broken up into several design components, which are discussed in this section. For each design component there are several alternatives that must be researched and compared to reach one choice. After the alternatives are identified and compared a decision for the final design is made and reflected in other design component areas. Light source design alternatives are discussed in section 4.1, comparing major sources of light to be considered for use in the lighting apparatus. In section 4.2 a power circuit analysis is performed for the light source chosen. In section 4.3 power source alternatives are discussed for the light source chosen in section 4.1. Lens design alternatives are discussed in section 4.4 and methods of mounting the lens housing and power source are discussed in section 4.5

4.1 Light Design Alternatives

The light selection is a critical aspect of the prototype. The amount of light each type provides will give the number of bulbs needed. The number of bulbs and the size of the bulbs will give the area needed. The power consumption of the light source will give the amount of power needed, which determines the type of power source. It is clear that the type of light used dictates most of the remaining design. A comparison of the lighting options is shown below in Table 4.1. Three main types of light sources are compared against each other as well as a form of light emitting diode (LED) known as “ultrabright” or “superbright”. Table 4.1 compares the light sources using categories common to all light sources; vibration resistance, life in hours, output of light measured in lumens, Watts, temp of light surface, value of lumens per Watt and cost of each.

Table 4.1 - Lighting Options

	Vibration Resistant	Life (hrs)	Lumens	Watts	Temp	Lumens/Watt	Cost (ea.)
Incandescent	No	2,000	700	60	High	11.67	1.00
Halogen	No	4,000	600	20	High	30	8.00
Fluorescent	Yes	10,000	200 - 500	5, 9	Low	40 - 55	5.00
LED	Yes	100,000	9	0.1	Low	90	0.35

4.1.1 Incandescent Lights

The first light source is the incandescent light bulb. This option offers a high luminous output and low cost yet has many disadvantages. The incandescent bulb uses a filament, which lacks necessary vibration resistance for our application. As can be seen in Table 4.1 incandescent light sources have the lowest life

and lumens per Watt value. The low life of 2000 hours goes against the goal of providing an easy to maintain lighting apparatus and the high temperature of the light bulb could lead to problems with the lens plastic material [7].

4.1.2 Halogen Lights

The second option listed in Table 4.1 above is the halogen bulb. Halogen bulbs provide an excellent amount of light with 600 lumens shown in the table being the low value. Halogen bulbs can go up to 10,000 lumens. This is, however, the only major advantage they have. Halogen bulbs get up to extremely high temperatures (up to 1200° on the surface) and that could cause other difficulties in our design such as ventilation while keeping the overall design weather proof. Other disadvantages include no protection against vibration, high cost and low lumen/Watt value. However, when compared to incandescent light sources a halogen light source has an advantage in the lumens/Watt category [7].

4.1.3 Fluorescent Lights

The next option is the fluorescent bulbs. These bulbs offer many good features that will work with the overall design. A long life of 10,000 hours is the main advantage along with being resistant to vibration and having the highest lumen per Watt value when compared to the incandescent and halogen. The major difficulty with fluorescent lights is the physical size of the bulb along with necessary ballast may not fit into the chosen design area [7].

4.1.4 Light Emitting Diodes

The last option is LED or light emitting diodes. The last row in Table 4.1 is highlighted because of the superior properties the new technology of “superbright” LEDs exhibit in the majority of the categories. LEDs have a life of 100,000 hours which translates into about 11 years of continuous use. The low power consumption of LEDs yields a lumen per Watt value nearly double the next highest value of fluorescent. This fact alone makes them an excellent candidate for the design. The major benefits of this type of lighting is that it provides a relatively large amount of lumens for its power consumption and also the physical size of the LEDs are small enough to fit into virtually any space in the design.

LEDs have long been used as indicator lights but now with new technology they can be used for lighting applications as well. Specifically, there are new materials and new production processes that make the LEDs brighter. The way this works is that an LED has a semiconductor chip inside of an epoxy encapsulation. On the semiconductor chip there is a p-n junction (Figure 4.1) which when sufficient

voltage is applied an electron jumps from the negative side to the positive side. Opposites attract so when an electron recombines with a positive charge, the electric potential energy is converted into electromagnetic energy. The recombination of the two charges causes a quantum of electromagnetic energy to be emitted as a photon. The photon of light has a frequency characteristic of the semiconductor material [8].

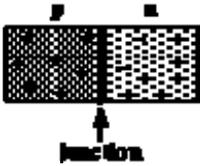


Figure 4.1 - LED Semiconductor Chip p-n Region

This partially explains why LEDs have some of the features that make them work well in the basketball lighting application. Other types of lighting use a deteriorating material to generate light and along with this they generate a lot of heat causing them to have a short operating life. The p-n junction does not deteriorate therefore these issues will not come up when using LEDs. The p-n junction in combination with the epoxy encapsulation (refer to Figure 4.2) makes LEDs resistant to vibration [8,9].

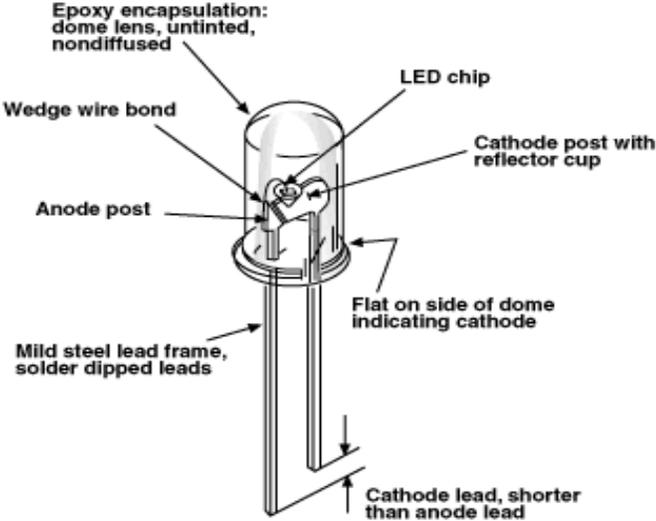


Figure 4.2 - LED Diagram

4.1.5 Light Source Decision Making

As can be seen in Table 4.1 there are multiple alternatives with multi-decision attributes, this classifies as multi-attribute decision-making. There are three methods for evaluating multi-attribute decision making; dominance rule, lexicographic rule, and weighting attributes [10].

The dominance rule states that when alternative A is inferior to another alternative B in all decision making attributes, then A is dominated by B. Therefore, the decision is to drop A and go with alternative B. This rule does not apply to this situation because none of the alternatives (refer to Table 4.1) is superior in all attributes. LEDs are the best in all categories except lumens, which eliminates it from being dominant.

The lexicographic rule requires a ranking system, which ranks the alternatives according to their most important attributes. If there are any ties the next most important attribute is considered. For these purposes the ranking is in order from most important to least as follows: lumens/Watt, Vibration Resistant, Life, Cost (ea.), and Temperature. Using this ranking method LEDs are the choice because it has the highest value in the lumens/Watt category.

The weighting attributes method requires the relative worth of the attributes to be considered. The best decision will have the maximum sum of the weighted attributes. The general formula for this is:

$$W = \sum_{i=1}^n w_i a_i \quad (i)$$

where W is the total weight, w_i is the weight of the attribute and a_i is the attribute value. Three attributes were considered and weighted for this evaluation; Life (1/1000), lumens/Watt (2), Cost (-1). Using these weights and the values in Table 4.1 the following overall weights were found: Incandescent = 24.34, Halogen = 56, Fluorescent = 115, LED = 279.65. Using this method the choice is LED [10].

4.1.6 Selection of LEDs

The LEDs chosen are made by two companies Liteon Inc. and Lumileds Lighting. These LEDs were chosen because they provide the highest luminous flux available for their respected sizes. The LEDs from Liteon Inc. are 5mm in diameter with a viewing angle of 8°. These LEDs provide an intense 9 lumens of luminous flux at a current of 50mA inside the 8° viewing angle. The small angle in which the light is permitted to pass through creates a concentrated beam useful in illuminating longer distances. The LEDs have an amber/yellow (595nm) color, which is good for night vision.

The second choice for LEDs comes from Lumileds Lighting which provides the highest luminous flux rated LEDs available. This line of LEDs is called Luxeon and the LED selected is the Star Power Light Source model. This LED provides 55 lumens of luminous flux at a current of 350mA with a viewing

angle of 140°. These LEDs are suitable for illuminating large areas a short distance away. The LEDs chosen are red-orange in color (617 nm) because this color provides the highest luminous flux value in the Star line of 55 lumens. Light in the amber to red region is not only best for preserving night vision but it is the lowest priced color in the LED market.

4.2 Power Circuit Analysis

In considering power source options, the first thing that must be considered is the circuit of the LEDs. The Liteon 5mm LED draws a current of 50 mA, requiring a forward voltage of 2 volts and the Luxeon Star LED draws a current of 350mA, requiring a forward voltage of 2.95 volts. These LEDs must be run by the same voltage source and with the least amount of resistors as possible to minimize power consumption. Because of the low current value of the LED a current limiting resistor is required to ensure the current supplied to the LED does not go over 50 mA or 350 mA, whichever the case. A current over its rated limit supplied to the LED would cause the LED to fail. The impedance of the resistor is calculated using the amount of voltage supplied along with the forward voltage and current requirements of the LED. Equations (i-iii) shows calculated resistor impedance using a supply voltage of 12 volts, forward voltage of 2.0 volts and current draw of 50 mA. The resistor value, R, is in ohms, Ω .

$$V = IR \quad (i)$$

$$\frac{12.0V - 2.0V}{50mA} = R \quad (ii)$$

$$R = 200\Omega \quad (iii)$$

As Figure 4.2 shows the required resistor value is 200 ohms for a supply voltage of 12.0 volts. To minimize the value of the resistor, the numbers of resistors and thus the power consumption of the circuit LEDs can be placed in series to increase the total forward voltage. This increase in total forward voltage reduces the voltage drop and thus the value of the resistor. Also the more LEDs in series the less resistors needed because current is the same for things in series. Using a supply voltage of 12 volts 5 Liteon 5mm LEDs can be placed in series for a total of 10 volts for forward voltage and a resulting resistor value of 40 ohms. Similarly the Luxeon Star LED can be placed 3 in series for a total of 8.85 volts forward voltage and a resulting resistor value of 9 ohms. Two sets of 5 Liteon LEDs and one set of 3 Luxeon LEDs are set up in parallel. A schematic of the circuit is shown in Figure 4.3.

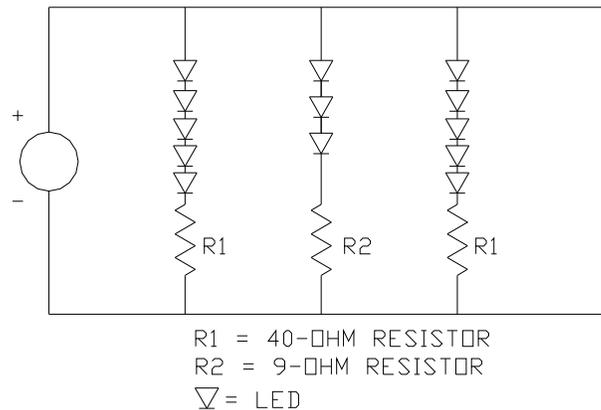


Figure 4.3 - Parallel circuit outline

The circuit shown in Figure 4.3 can be set up for prototyping purposes using a breadboard but a printed circuit board can be designed after a final arrangement of LEDs is completed. The resistors used for R1 will be YAGEO 1% metal film fixed resistors which are ¼ Watt rated resistors and have +/- 1% resistance tolerance. These are well suited for the low power consumption of 0.1 Watt of the LED and the 1% tolerance only fluctuates a 40-ohm resistor by 0.4 ohms keeping the current supplied to the LED well within safe range. The resistor used for R2 is a YAGEO 5% metal film 2-Watt resistor to handle the 1.1 Watts consumed dropping the voltage by 3.1 volts with a current of 350mA.

Using the theoretical resistor values and power supply voltage and recommended LED current ratings the theoretical power consumption of the circuit can be determined. The power consumed by the Liteon LEDs is 0.5 Watts plus the power of 0.1 Watts dissipated by the resistor for each string of 5 Liteon LED. The power consumption of the Luxeon Star LEDs is 3.1 Watts plus the power of 1.1 Watts dissipated by the resistor. This totals 4.9-Watts total theoretical power consumption. The governing aspect of the setup of the circuit is the supply voltage. This voltage must be supplied in one of three ways.

4.3 Power Source Design Alternatives

It is important to use the lighting apparatus for extended amounts of time. This requires a dependable power source to meet the needs of the end user. The power source is located outdoors away from outlets and is separate from the light itself. For these reasons the power source must be weather proof, easy to mount and low maintenance.

There are a few options to consider when dealing with power sources. Since LEDs are the chosen light source the power must be provided in direct current (DC). The three main options for this application the first is the use of an AC to DC converter plugged into an outlet using an extension cord. The other two are a solar panel or batteries. Also the option of rechargeable batteries being charged by either the AC to DC converter or solar panel exists. These options are discussed and compared to achieve a decision.

4.3.1 AC to DC Converter

Using an extension cord connected to a converter is beneficial in that it will be able to supply as much power as necessary. This method is also a low maintenance option; once it is plugged in nothing else needs to be done. There are several inexpensive converters ranging from 3 volt to 24-volt outputs. The major disadvantage to this is the extension cord that must be run from an outlet to the base of the basketball hoop pole. This requires the basketball hoop to be within approximately 75 feet of an outlet. Also the wire provided with the converter must be kept out of the way by running it down the pole or some alternative.

4.3.2 Solar Panels

Solar panels offer a stand-alone power source that is free of costs after initial purchase. Since the light operates only at night the energy captured by the solar panel during the day must be stored for use at night. This storage capability comes in the form of rechargeable batteries. This interesting design alternative is possible due to the small power consumption of the LED light source chosen.

Incorporating solar panels into this design is achievable; however, it will be difficult to meet some of the project goals with this solution. One problem is that solar panels are relatively expensive which will raise the cost of the final product. The other problem is that because this design is to be applied to existing hoops, there is no guarantee that a solar panel will get the necessary exposure to the sun. Yet if these conditions can be overcome solar panels can be found at any low voltage output, work well with rechargeable batteries and new solar technology offers more efficient solar panels that require less space.

A circuit was constructed using the schematic in section 4.2, through field testing the circuit consumed 6.5 Watts. Enough energy must be obtained during the average 4 hours of sunlight per day by the solar

panel to operate the light for 6 hours per night. 6 hours at 6.5 Watts is 39 Watt-hour consumed each day at ~12 volts. This translates into 3.25 Amp-hours per day consumed by the circuit.

3.25Ah/day is multiplied by 1.2 to compensate for battery charge and discharge. The result is 3.9 Ah/day consumed and dividing that number by the number of sun hours per day gives the solar panel current rating. So 3.9 Ah/day divided by 4 sun hours per day results in 0.975 Amps required by the solar panel. A 12 volt 0.975 Amp solar panel is required for the circuit. These solar panels are available at \$149.00 each retail and are 14" x 40". Higher efficiency solar panels with reduced sizes exist but with higher efficiency comes higher cost. A battery must be chosen to store the energy captured by the solar panel [14,17].

4.3.3 Batteries

Batteries will most likely be used in the form of rechargeable batteries with one of the other options. The batteries that are selected will be chosen based on how long a fully charged battery will be able to power the lights, how many recharge cycles they can handle and how the battery responds to deep discharge. Sealed Lead Acid (SLA) batteries meet all these requirements and are the battery of choice when dealing with a solar storage system [18].

SLA batteries last up to 5 years based on how often they are recharged and how deep they are discharged. They are also maintenance free and inexpensive. The main requirement of the battery will be its ability to handle days with no sun and keeping a 20% reserve. Taking the 3.25 Ah/day consumed by the circuit with a 3 continuous cloudy day assumption and keeping 20% reserve a 12 Ah capacity battery is required. SLA batteries are adversely affected by cold weather so a multiplier of 1.5 is used for wintertime operation in 25° F temperatures. The result is an 18Ah battery for operation of the circuit for 42 hours a week at a cost of 30\$ for the one battery.

4.3.4 Selection of Converter

In keeping the goal of \$70 retail price the solar panel/rechargeable battery combo is not chosen due to the additional cost of \$180. The most economical and reliable power source is the AC to DC converter, which is the chosen power source for our design. The converter must be weather proofed some how to ensure its reliability.

The power source chosen is a 12-volt AC to DC converter. The amperage being drawn by the circuit is ~0.52 A so a 12 volt converter with an amperage rating greater than 600mA is needed.



Figure 4.4 - Two different designs for power supplies

Figure 4.4 illustrates the two main different designs for the power supplies. The upper design is a general type of power supply that helps in the design of a power source housing due to the two exiting wires. The lower design is a more common type of power supply, but requires more difficult weatherproofing.

The idea behind choosing a power supply with two wire extensions is to provide an easier method for weatherproofing it. The power supply will be weatherproofed using a plastic housing with gaskets sealing the exiting wires. The power supply would be attached to the top of the plastic housing to minimize possible water contact.

4.4 Light Housing Design Alternatives

The light source housing will be made of two pieces, a front and a back. The front will be made of the diffusing lens material, Acrylite® DF. This is an acrylic material that allows 88% of the light to pass through while have a haze rating of 94%. A completely translucent material has a light transmission value of 100% and a haze of 0%. The high haze rating allows for high diffusion of light to greatly reduce glare and point source location. Yet 88% of the light flux is allowed through. Traditionally acrylic has been a brittle material yet this grade of Acrylic exhibits high impact strength and flexural stress.

Acrylite® DF exhibits properties close to that of certain types of polycarbonate, which is a common indoor lighting lens. The major drawback of polycarbonate is that it is not weather resistant. It does not respond well to extreme temperatures but most importantly it is not resistant to the effects of the sun.

Extended exposure to the ultra-violet rays of sunlight causes polycarbonate to turn yellow and become brittle. Acrylic materials are not affected by ultra-violet rays and are overall extremely resistant to weather. For those reasons Acrylite® DF was chosen as the material of the light source design. A data sheet can be found in the appendix for Acrylite® DF grade 22 and figure 4.5 illustrates an example of Acrylite® DF applications [19].



Figure 4.5 - Acrylite® DF

Figure 4.6 illustrates the two pieces of the light housing. The back will be made out of the same Acrylite® DF material to avoid problems with thermal expansion and weather resistance. This is also done to lower cost by having the whole housing manufactured at once in a plastic molding shop. The maximum design area of a 2.75 x 2.75 right triangle mentioned in Section 1.3 is reduced by a half an inch on each side to compensate for compression of the basketball and the thickness of the mounting mechanism. The dimensional drawings are located in the Appendix [19].



Figure 4.6 – Two piece light housing

The interface between the two pieces will be a compressible rubber seal. This will help insure that the housing is weatherproof.

4.5 Mounting Design Alternatives

There are two major requirements that the mounting design needs to meet: maintain easy portability and also be easily adapted to fit any existing backboard.

4.5.1 Mounting of Power Source:

The power source can be mounted in two locations depending on the preferences and hoop location of the customer. If the backboard and hoop include a pole then the 3M Dual Lock fasteners can be used for attachment of the power source on the backside of the pole. In a situation where there is no pole the power supply would be attached to a wall or other flat surface using the 3M Dual Lock recloseable fasteners. The 3M Dual Lock fasteners are provided for the consumer.

The 3M Dual Lock fastener works by attaching two strips of the product together and therefore the mushroom-like shaped heads found on each interact with each other resulting in a firm lock between these two surfaces which is illustrated in figure 4.7.



Figure 4.7 - 3M Dual Lock

The 3M Dual Lock fastener have many advantages they are plasticizer resistant, moisture resistant, U.V. resistant, solvent resistant, high tensile strength, vibration dampening, and the adhesive can be used on many rigid surfaces (ex: bare metals, fiberglass, glass, wood, and most forms of plastic).

The type of fastener chosen was the SJ-3560 due to its VHB adhesive, which is suited for outdoor applications. Table 4.2 shows the properties of the SJ-3560 that makes it the best choice out of the other fastener choices. The dynamic shear and tensile engagement are both over 30-lbs/sq. inch. Looking at the lens design there is enough room to mount the design with 6 sq. inches of fastener, which is more than adequate [12, 13].

Table 4.2 - 3M Dual Lock SJ-3560 specifications

<u>SJ-3560</u>	
Fastener Material-Polyolefin	
Adhesive Material-VHB acrylic	
<i>Properties & Characteristics</i>	<i>Value</i>
Thickness (when attached)	0.23 Inches
Dynamic Tensile Engagement	38 Lbs/Sq.Inch
Dynamic Shear	31.7 Lbs/Sq.Inch
Operating Temp. Range (Continuous)	(-20 to158) Fahrenheit

4.5.2 Mounting of Light Housing

Due to the high fastening strength and low profile of 0.23 inches, 3M Dual Lock can be used to mount the light housing to the backboard.

5. Conclusion

Comparing many alternatives and picking the alternatives that met our project goals arrived at the final design for the Night Hoops project. The design process was sequential in that the first piece of data that was needed was how much light is needed for lighting a basketball hoop and backboard. This has to consider how light is perceived and quantified. Once it was understood that if the amount of lux at a

given distance can be found the rating of the light source could be found. This rating is in lumens and can be translated into the light source characteristics. A value of 225 lumens was agreed on, based on research of standards and field-testing with a light meter.

Once the 225 lumen value was determined the results of a multi-attribute decision making study was compared to the 225 lumen value. From the four light sources considered a form of light emitting diode (LED) with high lumen output was chosen using a multi-attribute analysis. The 225 lumen value dictates the number of LEDs to be used. This in turn makes the power circuit and power source requirements known. The specifications of the LED require a DC power supply and a circuit set up with the LEDs in series and parallel. Each series of LEDs have their own current limiting resistor, limiting the current to each LED. This circuit provides a size that must be incorporated into the design area and a DC power supply. The three types of DC power supplies; batteries, solar panel and AC to DC converter all satisfy the requirements for the circuit. In considering the goal of achieving a retail price of 70\$ the choice is the cheap and reliable DC power of the AC to DC converter.

With the light source, and power source chosen the design of the light housing comes next. The design area has been set by the geometries of the basketball and the hoop. The design area is reduced with consideration of the compression of the basketball and thickness of mounting fastener. The size of the LEDs and associated circuit can be doubled and still fit into the design area. With that the dimensions of the light housing are drawn. Figure 4.8 illustrates the Night Hoops Light assembly.

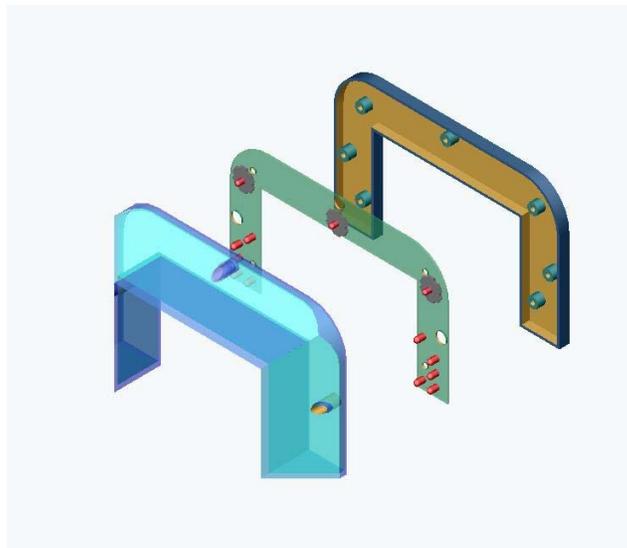


Figure 4.8 - Night Hoop Light lens assembly

The material of the light housing must be of a clear plastic, which gives two practical options of Acrylic or polycarbonate resins. An acrylic material was chosen that exhibits the desirable high impact strength and flexural stress properties of polycarbonate but the acrylic material is more resistant to the effects of the sun and weather than polycarbonate. In choosing a material that satisfies the weatherproofing goal and easy maintainability, the next step is to obtain a material or manufacturing process which diffuses the light efficiently and provides ergonomic lighting free of glare. A grade of acrylic resin named Acrylite® DF 22 is made for light diffusing purposes and lends itself well to outdoor environments.

The whole lighting apparatus is designed from socket to light so the last step is to attach the apparatus to the various existing basketball hoop designs. Starting from the top and working down, the light housing is attached to the backboard with a 3M-fastener product called Dual Lock SJ 3560 whose data sheet is located in the appendix. These fasteners offer portability option, they do not cause any permanent damage to the hoop or back board and have a high tensile and shear stress values. A wire comes out of the bottom of the light housing and runs behind the backboard to the AC to DC converter power source, which is mounted to the pole with releasable cable ties. This is if a pole exists. The cable ties are 28” long to adjust to any diameter 8” and below. They are weatherproof being made of heavy-duty nylon and can be fastened and removed to provide portability. If no pole is present for mounting the extra Dual Lock fasteners included with the lighting apparatus can be used to mount the power source to a surface. The mounting options are kept flexible to accommodate to different consumers wants and needs [11].

The cost of the Night Hoops Light construction is highlighted in the bill of materials located in the Appendix. One bill is for the solar/battery combo and the other one is for the AC to DC converter option. The light is unchanged between the two. The main costs are attributed to initial tooling charges for the light housing design and to the solar panel converter. These costs can be reduced through mass production thus reaching our goal of \$70.

Future recommendations for the Night Hoops Light design would be for better weatherproofing of the connection between the light housing and the power source. Also the battery should be placed in a housing or the terminals weather proofed. The brackets for the mounting of the solar panel should be determined in order to provide optimal angle to the sun and positioned out of the field of play.

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