Team 6 – The Bobbers

Project Proposal and Feasibility Study

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Introduction

Background Information

Energy demands are increasing; Electricity is becoming more expensive, and the current technologies producing electricity also generate pollution. With this in mind, people are investigating alternative sources of renewable energy.

Waves are a form of this renewable energy. Winds across a body of water form waves, and these waves act as a giant capacitor for the wind energy. The waves are constantly undulating and are a virtually untapped resource.

Problem Statement

The goal of this project is to harness wave energy into useful energy, namely electricity. We want to convert the undulating power of waves into electricity by designing, building, and testing a prototype. We want to show the feasibility of such a mechanism by powering a small electrical device, such as a light bulb.

Design Description

By using the continuous wave action found in large bodies of water, our team hopes to convert this energy source into electricity. The basic idea is to have a large floatable device riding the surface of the waves. With each passing wave, the floating device (a giant bobber) will pull a tether attached to a generator. This translational energy will be converted to rotational energy used to power the generator. We hope to construct a model that will deliver a continuous amount of electricity so that we can demonstrate how a full scale system might operate. The figure below is our design.

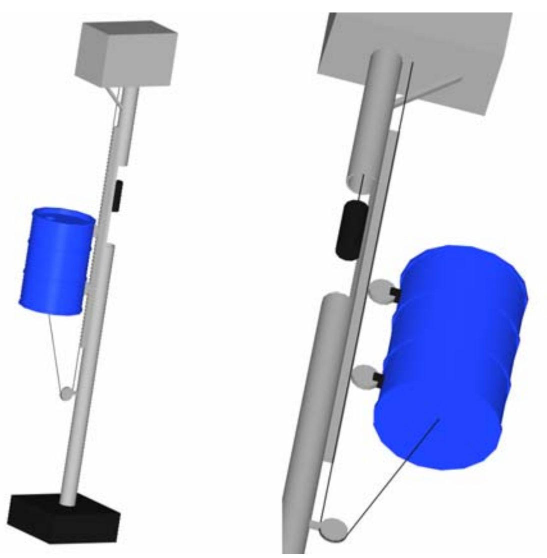


Figure 1: Preliminary Design

Project Objectives

In order to achieve this goal of harnessing wave energy into electrical energy, several project objectives have been formulated. These goals are meant to guide the development of the project. The objectives are as follows;

- To have a renewable non-polluting energy source
- To demonstrate wave energy is a feasible energy source
- To keep project cost minimal
- To design, build, and test a reasonably sized prototype

Components

The components necessary for the project are listed below.

- Generator/Alternator
- Gear box
- Floatation Device
- Flywheel
- Spring/Ratchet
- Framework/Anchor

Component Requirements

The requirements for the components are as follows.

- Generator –12 volt, DC output providing at least 120 watts at 300 RPM
- Gear Box – 1:64 ratio
- Flotation Device – provide 150 lb of buoyant force
- Flywheel – sustain continuous 300 RPM
- Spring/Ratchet – maintain line tension and unidirectional motion of input shaft
- Framework/Anchor – sustain wave impact and provide 500 lb of anchoring force

Lake Michigan Research

Wave Research

In order to integrate the components of our system, including the flywheel, generator, gearing system, and platform into a robust design, we needed to have accurate and reliable data regarding waves in Lake Michigan (our chosen testing ground). To obtain this data, we contacted and subscribed to online journals of the International Association of Great Lakes Research, or IAGLR (www.iaglr.org).

The IAGLR had access to two papers which we found pertinent to the data we needed. The first was *Wind and Wave Measurements Taken From A Tower In Lake Michigan*, a comprehensive study of wind and wave behavior of Lake Michigan with over 1300 documented hours of measurement. The data that we found most important was the average wave size: 0.68 meters (2.23 ft) and average wave period: 3.6 seconds. Another important piece of information was the fluctuations of water levels: 2 meters (6.56 ft).

The second paper that we found pertained to our project was *A Generalized Parametric Wind Wave Model* that discussed how waves in Lake Michigan changed in shape, force, and velocity as they reached the shore. This was relevant because the measurements taken from the tower as presented in the first paper were taken 2 kilometers (1.2 miles) offshore, where the water is 16 meters (53 ft) deep. Our project is to be launched in about 1.5 meter (5 ft) of water only about 15 meters (50 ft) offshore. Using this model, we can convert the tower's data into applicable data in order to create a theoretical model of waves for our proposed design site.

Legality of Project – Department of Natural Resources

We needed to find out about possible laws or permits that could hinder our ability to test the bobber. With this in mind, we called the law enforcement office of the Department of Natural Resources (DNR 269.685.6851). We were contacted by Lieutenant James, who told us that we did not need a permit to operate our device in Lake Michigan if it would only be in the lake for a day or two. He also told us that we could use our device in any state or local park, but we needed permission to use privately owned sections of the lake frontage. This concludes that as long as our device can be moved easily, there should be no regulations that would make this activity illegal.

Alternative Designs

Generator Types

We looked into a couple of different alternatives for generating electrical power from the linear power that we achieved with the bobber design. The biggest problem we ran into was the speed required by these devices. A car alternator was out of the question because the smallest pulley RPM that we could find to start charging from a car alternator was close to 1,200 RPM. Our device was putting out an average of 6 RPM. The most reasonable choice was converting an AC induction motor from a blower device into a DC generator. This is a process that has been done successfully in a couple of instances. The lowest RPM required using this process was about 80 RPM for electricity generation. This still required a gearbox, or gearbox alternative, but was much more reasonable than 1,200 RPM. This is also a cost-effective method because the motor could be found for free at any machine recycler or purchased on EBay for about $20. The motor would be ½ horsepower to 2 horsepower for our project. This is based on data taken from other similar projects which converted an AC induction motor to a DC generator by installing permanent magnets. The following site explains the process http://www.otherpower.com/otherpower_wind_alternators.html#conv . One of the problems that they were having is that the starting torque is high. This is a problem that we would be able to overcome because one of the advantages of wave power is a high starting torque, as opposed to the wind power projects that these motors were used on.

Generator vs. Alternator

Car Alternator:

- Turns on at 1,200 RPM minimum, goes to about 18,000 RPM
- Cheap- Buy on Ebay or at any used car parts dealer
  www.ebay.com remanufactured GM part #7801-3 100A alternator - $20
- AC power, but most come with voltage regulators

AC Induction Motor Conversion

- Produces power at 80 RPM minimum
- Cheap, conversion from AC induction motor
  www.ebay.com Baldor FR-56c ¾ hp single phase motor - $19.99
- AC Power, must be converted to DC

Generator or DC motor:

- Produces power at 300 RPM minimum
- More expensive
  www.surpluscenter.com part #C3NF-10002-B 12VDC 22A generator - $99
- DC power

Generator Placement

The placement of the generator is critical to our design because there are several factors that affect it. The generator can be placed in the water or above the water. In both cases, a mounting frame is required which will have to be designed such that it is corrosion resistant. It would also have to sturdy enough to withstand the forces applied by the generator, gearing system, and the floatation device. Below we discuss the characteristics and requirements of both options relating to placement.

1. The generator anchored at the bottom
   - As described, this mount would anchor the whole generator to the bottom of the lake and therefore act as an anchor for the whole device. This would require that the whole system be heavy enough such that it cannot be moved by the flotation device.
   - By placing the generator at the bottom, we recognize that it would have to be water tight. It has to be water tight because the components are made of metals and are therefore more liable to rust, and it is common knowledge that electricity and water do not mix.
   - When the generator is anchored at the bottom, there is the complication of installing the whole system because of the weight required to act as an anchor. Maintenance and repair would also involve going to the bottom of the lake, taking apart this whole system and doing work on it. This is not ideal, and we decided to place the generator above water.
2. The generator placed above the water level
   - When the generator is placed above the water level, it does not need to be completely water tight. This is good because it will save us time and money as the design will not have to be as robust.
   - With the generator above the water, we require a separate anchor that will hold our whole design. We are therefore constrained by the amount of weight we can place at the bottom because it would have to be enough such that we can actually carry it and place it at the bottom of the lake. This raises concerns about the feasibility of the project.

Floatation Devices

We made the following considerations when designing our flotation device or "bobber." We had considered a Styrofoam ball as a lightweight and environment resistant option. However finding a ball proved difficult and more costly than we has assumed. A thirty inch diameter ball from Barnard Limited (http://www.barnardltd.com) costs $93.00. To minimize cost we decided that we could use a commonly found drum. To be more specific this would be a 55 gallon drum. The choice lay between plastic and metal for material. The main reason metal was considered at all was that we could get it free of charge. However for corrosion and weight considerations we wanted a plastic drum. We were able to find a free 55 gallon plastic drum from the Physical Plant.

Other Accessories

1. Flywheel

Inherent in wave motion is the undulating motion. This motion does not provide a constant or even remotely constant force. With this in mind, we decided to add a flywheel to the system in hopes of leveling out the motion. The flywheel will help maintain the constant rpm required for an electric generator. The flywheel will be attached after the gear box, so that it will rotate at a higher speed. The concerns with adding a flywheel are cost and safety. The flywheel may break apart and rapidly release all of the stored energy, destroying the mechanism. A source for flywheels is Diamond Precision out of Wisconsin (http://www.diamondprecision.com/flywhl.htm). These are custom made flywheels and expensive. We have looked at Ebay.com for purchasing a used flywheel available for under $100. The other alternative is designing and machining our own flywheel.

2. Gearbox

Because wave motion is relatively slow we have recognized the need for a mechanism to increase the RPM for the electrical generator. We have looked into purchasing a gear box, but most gear boxes decrease RPM not increase. This problem, coupled with the expense factor, has forced us to look at a chain and sprocket design (bike parts).

3. Chain and Sprocket

Understanding the need for at least 300 RPM to run an electric generator, we looked into the feasibility of using bike chains and sprockets to increase the RPM. We calculated, using EES, the number and size of the sprockets needed to increase the RPM. We calculated that using 6 sprockets (3, 3inch radius and 3, 6inch radius sprockets) we could go from the 5 RPM input to 300+ RPM output. We talked to Dave Ryskamp about acquiring these gears. We determined that we could find these gears in the engineering building parts room or acquire them from unclaimed bikes on campus (these bikes are usually donated but could be given to us instead). This proved to be a cheap and relatively efficient means of ramping up the needed angular velocity (bike chains are about 90% efficient). The EES computation for this chain design can be found in Appendix 4.

Preliminary Evaluation of Feasibility

- Parts are all accessible and available. All parts of our system are currently produced and can be purchased. The majority of our project will entail assembling the different components of our design. Furthermore, we are able to find components that meet our specifications. Our plan is to use a generator to produce electricity.
- Wave energy has been harnessed. In his book, *Sustainability at the Cutting Edge*, Peter Smith describes an Inter-project Service Offshore Wave Energy Converter (OWEC) similar to our design solution that could generate 200 kW of electricity. The system is 30-35% efficient. Although that particular system operates at a different depth than we are considering, the study shows that it is possible to make use of water energy. According to the National Weather Service Forecast Office, waves in Lake Michigan range between one and four feet in height with a period of about three seconds. This will be enough to make the small scale power generator we seek to build.
- Based on our EES calculations in Appendix 3, it can be seen that the project will produce about 120 W, which will be enough to power to a light bulb.

However, these are our concerns:

- System would be destroyed during a storm
- Installing the system would be difficult
- Anchoring of the system would be problematic
- Wave height variation will be difficult to compensate for
- Usefulness of such a large device with small electrical output

Cessation of Wave Powered Electricity Generation

For the past few months, we the members of the Bobbers have looked into the feasibility of generating electricity using wave energy. We wanted to demonstrate that using simple components, we could make a device that generated electricity on a small scale. We were faced with a number of challenges and hurdles, but these did not discourage us. It was not until we received an outside view on our project, that we realized that we had overlooked an important area of project. We had been so focused on getting our device to function that we never thought about the conceived prototype's practicality. So it is in view of the internal difficulties within the project and the overall impracticality of the envisioned device that we have decided to end our initial project and pursue an alternative, yet similar project.

There were a number of internal barriers that we faced in this project that we are uncertain could have been resolved in the allotted timeframe. The first of these was the wave height at which our bobber could operate. The waves in Lake Michigan can vary from zero to nine feet in storm conditions. We were uncertain whether a device could be constructed to function during storms yet still be effective at the lower and more common wave heights. Another difficulty we encountered was stability of the entire system. Waves not only move vertically but horizontally in their circular motion. This horizontal motion, especially in more extreme conditions would probably topple or destroy our device. In order to ensure that our system was sturdy enough, the net weight of the device would be such that it would be very difficult to move, especially in deep water. This would violate DNR regulations and add additional costs, if a permit needed to be obtained. Furthermore, we were unsure whether the waves would be able to create the RPM required to run our generator. The vertical motion of the waves is slow relative to the speed at which we wanted to run our generator. We envisioned using a gearing system. This would result in further efficiency losses as our gearing system would probably be about 80% efficient. Even if all theses previously listed issues were resolved, our device fails to be economically practical. Our preliminary budget analysis showed us that we were almost over budget even without including unforeseen project costs and publication costs.

As can be seen, the aforementioned problems are not necessarily show stoppers but simply obstacles to be overcome. In discussing with our industrial consultant, we were made aware of another potential barrier to our project, namely economics. If we were able to get all aspects of our devices working, we estimate that we would be producing about 50 watts of electricity. This amounts to 7.2 cents of electricity a day or $15 a year. Accordingly the pay back period for this device would be about 33 years. Our device would not be designed to last that long. There is simply too much inefficiency in transferring the mechanical to electrical power.

Although our goal in this project was to demonstrate that a small scale wave electricity generator was possible, it would not show it economically feasible. We were more concerned with demonstrating the possibility not the practicality. From an economical standpoint, our project does not make sense. This would make it impractical and almost impossible to implement anywhere. Therefore, since we seek to create something that is useful and practical, we decided to forego this project and instead build a wave powered water pump.

New Project: Wave Powered Water Pump

Our new project uses the translational action provided by the waves to pump water out of the lake for purposes such as;

- To water lawns/gardens
- To fill water storage tanks
- To replenish water in a water fountain/pond

Objectives

The objectives of this project can be described as;

- To build a device that a homeowner can potentially use to pump freshwater for watering lawns, filling tanks or replenishing a water fountain
- This device will be cheap and will save the owner subsequent costs as he/she will not pay water bills
- To build a prototype test it

Components

Several critical components are necessary for this project and there are listed below;

- Pump
- Two-way valves
- Cable
- Floatation Device
- Anchoring Device
- Hose Attachment

Procedure

We have determined that the project is to proceed in this manner;

- Use the data of wave height and frequency to compute stroke and maximum pressure in attached hose
- Determine volume and pressure requirements necessary for application
- Build prototype, test it and measure the pressure generated

Task Specifications

Budget

- $500 from Calvin College

Phase I: Wave Research

Phase II: Requirements of System Components

- Pump
    - Sturdy – withstand constant water motion and particles in water

    - Weight – low weight requirement for ease of implementation
    - Pricing – need to keep cost low to provide a marketable product
- Two-way valves
    - Efficient – do not want to be using a lot of force to open and close the valves
- Cable
    - Corrosion – needs to resist a changing environment of wind, waves, sun
    - Nylon vs. Aircraft Cable
- Hose Attachments
    - Male Hose Fitting - ease of connection (e.g. a garden hose)
- Bobber
    - Styrofoam/Plastic Ball – need reasonable size for a person to carry with ease
    - Scale to size of feasible prototype
    - Durable - environment of wind, waves, sun

Phase III: Acquisition and Assemblage of System Components
- Overall design for prototype
- FMEA analysis of design
- Purchase all components
- Fabrication of necessary components
- Assembly of all components

Phase IV: Prototype Testing
- Simulate testing in Engineering Building – construction of wave machine
- Redesign/Rework prototype
- Get the prototype to testing site
- Anchor the prototype to lake bed
- Videotape the active prototype
- Take measurements of prototype output with various wave action

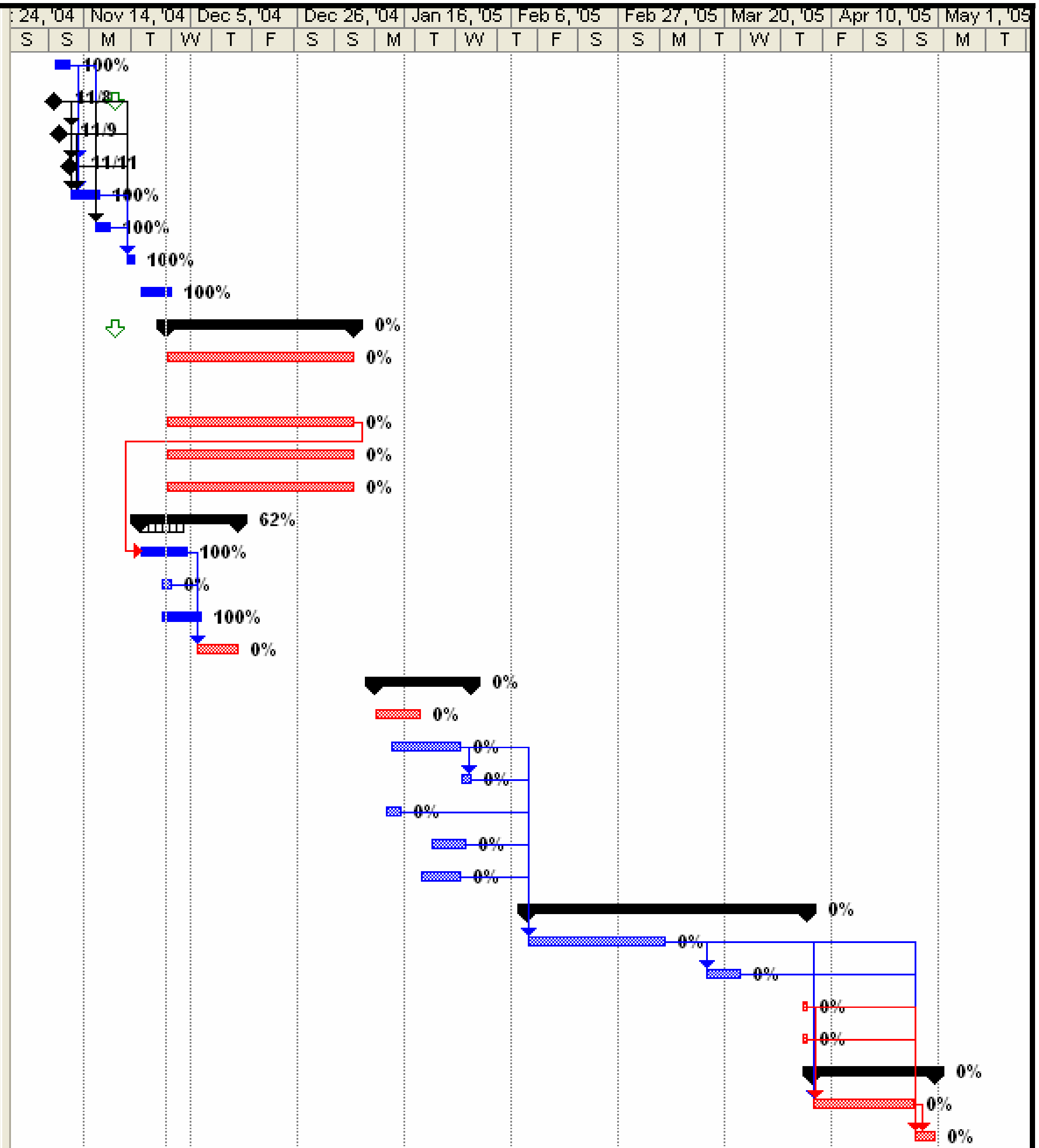
Method of Approach

The method of approach for this project is first of all to determine if we want a big system that will be anchored to the bottom of the Lake, versus the idea of a small portable system. The team has decided to go with the option of the small portable system because we believe it will be more marketable and appealing to the prospective consumer. We also decided to go with a small volume, large pressure system so that the water pumped can travel a longer distance (i.e. more head).

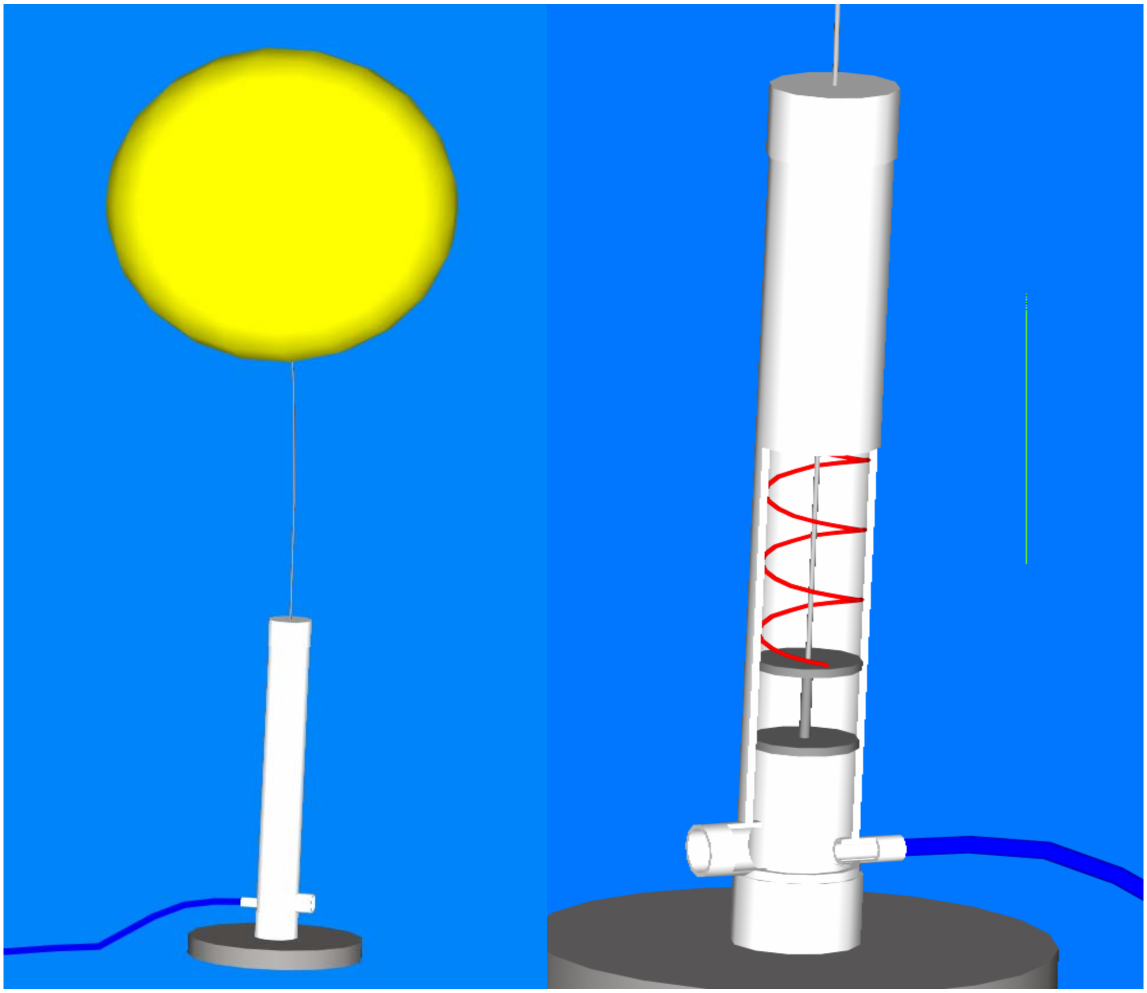
Now that we have our basic design idea, we will make a theoretical model of the prototype to determine the optimal size and output of the wave pump. Next we will gather materials and components and build our prototypes. These prototypes will be tested in the Engineering Building or swimming pool. Based on the performance of these prototypes we will redesign/rebuild our final prototype and test in Lake Michigan. We are behind schedule because of the failure of our first design to generate electricity. We need to push forward and stay on track with our new schedule to achieve our goals and deadlines. We are dividing up each task (e.g. pump, anchoring, and float) and have included interim in our schedule so that we might catch up.

New Project Timeline

ID	Indicators	Task Name
1	✓	Group Poster
2	✓	Call DNR
3	✓	Determine Regulations
4	✓	Subscribe to IAGLR.org
5	✓	Yearly Wave Info Database
6	✓	Determine Testing Feasibility
7	✓	Meeting with Ind. Consultant
8	✓	Monthly budget Report
9	!	**Analyze System Components**
10	calendar icon	Pump Research
11	calendar icon	Valve Research
12	calendar icon	Bobber Research
13	calendar icon	Cable Research
14	calendar icon	Anchoring Alteranatives
15		**Class Requirements**
16	✓	PPFS Draft
17	calendar icon	Oral Presentation PPT
18	✓	Website Design
19	calendar icon	PPFS
20		**Component Analysis**
21	calendar icon	AutoDESK Design
22	calendar icon	ALGOR Analysis
23	calendar icon	Determine Final Design
24	calendar icon	Review Design
25	calendar icon	Pump and Valves
26	calendar icon	Bobber, cable and anchoring
27		**Prototype Building**
28	calendar icon	Construct Prototype
29	calendar icon	Component Placement
30	calendar icon	Test Prototype
31	calendar icon	Videotape Simulation
32		**Class Submittals and Presentations**
33	calendar icon	Final Report
34		Senior Design Presentation



System Diagram



Christian Perspectives

A major component of our senior design project is the Christian Perspectives from which we operate. As soon-to-be engineers, there is the need to integrate our Christian calling with our profession and we feel the need integrate our calling as Christians with our project.

We are fully aware of the misuse and wastefulness of natural resources that are used to produce electricity, an example being coal and fossil fuels, and the dire consequences that may come to pass when future shortages occur. Based on this motivation, we decided to harness wave energy. Initially, our project was aimed at harnessing this energy and converting it into electrical energy, but due to the impracticality of the project, we decided to convert this harnessed energy to pump water. The Christian design norm that this project addresses is stewardship because we are using the natural resource of wave energy, to pump water without any pollution to the environment.

Another design norm that this project reflects is caring. We are caring for our environment when we use alternative means to power our pump instead of electricity. We must also care for the aquatic life and make sure that our project does not harm any aquatic animals.

APPENDICES

Appendix 1: Task Specifications for Old Project

Appendix 2: Budget for Old Project

Appendix 3: EES Computation for Power Generation

Appendix 4: EES Computation for Gearing

Appendix 5: Design Diagram for Old Project

Appendix 6: Project Timeline for Old Project

Appendix 1: Task Specifications for Old Project

Phase I: Wave Research

- The period of wave
- Height of wave
- Power of wave
- Depth of water at which wave occurs
- Geographical location of wave: location of testing site
- Ordinances/Regulations against deployment of system prototype
- Model of possible power output from a theoretical look at our prototype

Phase II: Requirements of System Components

All components must withstand the weather conditions and be within our budget

- Drum for Buoy
  - Large enough for power output
  - Small enough for feasible prototype
- Pulleys
  - Used underwater
  - Bearing specifications/loads
- Flywheels
  - Sizes Weight/Diameter
- Gear Box
  - Reduction Ratios
  - Water Proof?
- Ratcheting/Spring Mechanism
  - Bicycle parts
  - Strong enough to withstand stresses
- Generators and Alternators
  - Car alternator
  - DC motors
  - Speed vs. Power analysis for different models (low speed, high power)
- Cable
  - Braided stainless steel
  - Withstand stresses
  - Withstand wear
- Stand
  - Steel vs. Aluminum
  - Withstand stresses

Phase III: Acquisition and Assemblage of System Components

- Overall design for prototype
- ALGOR analysis
- Purchase all components
- Fabrication of necessary components
- Assembly of all components

Phase IV: Prototype Testing

- Simulate testing in Engineering Building

- Redesign/Rework prototype
- Get the prototype to testing site
- Anchor the prototype to sea/lake bed
- Videotape the active prototype

Appendix 2: Budget for Old Project

Component	**Estimated Price**
Drum for Buoy	Free
Pulleys (x4)	$ 8.00 per pulley
Flywheel	$ 100.00
Gear Box	$ 150.00 ~ est.
Ratcheting/Spring Mechanism	--*
Generator / Alternator	$ 99.50
Stand	--**
Cable	$ 20.00
Bearings (x4)	$ 8.95 per bearing
Wiring	$50.00
Total	$490.00

Appendix 3: EES Computation for Power Generation

Constants

$T1 = 70$ [F]

$P1 = 1$ [atm]

$gravity = 32.2$ [ft/s^2]

$\rho_{air} = \rho(\text{'Air'}, T=T1, P=P1)$

$\rho_{water} = \rho(\text{'Water'}, T=T1, P=P1)$

Volume of Cylinder

$Vol_{cyl,gal} = 55$ [gal]

$$Vol_{cyl} = Vol_{cyl,gal} \cdot \left| 0.133681 \cdot \frac{ft^3}{gal} \right|$$

Weight Force of Cylinder

$W_{shell} = 10$ [lbm]

$W_{air} = Vol_{cyl} \cdot \rho_{air}$

$$F_W = (W_{shell} + W_{air}) \cdot gravity \cdot \left| 0.031081 \cdot \frac{lbf}{lbm-ft/s^2} \right|$$

Wave Characteristics

$$\rho_{water,gal} = \rho_{water} \cdot \left| 0.133681 \cdot \frac{lbm/gal}{lbm/ft^3} \right|$$

Data from IAGRL

$k_{height} = 2.23$ [ft]

$k_{period} = 3.6$ [s]

$h_{wave} = k_{height}$

$period_{wave} = k_{period}$

Volume Displaced

$Displaced = 33$ [%] Percent of Bouy Underwater

$$Vol_{disp} = Displaced \cdot Vol_{cyl} \cdot \left| 0.01 \cdot \frac{ft^3}{\%*ft^3} \right|$$

Bouyancy Force

$$F_B = \rho_{water} \cdot Vol_{disp} \cdot gravity \cdot \left| 0.031081 \cdot \frac{lbf}{lbm-ft/s^2} \right|$$

$$F_T + F_W = F_B$$

Power Calculation

$$Power = F_T \cdot h_{wave}$$

$$Power_{watts} = \frac{Power}{period_{wave}} \cdot \left| 1.35582 \cdot \frac{W}{ft-lbf/s} \right|$$

Solution

Unit Settings: [F]/[atm]/[lbm]/[degrees]

Displaced = 33 [%]	F_B = 151.3 [lbf]
F_T = 140.7 [lbf]	F_W = 10.56 [lbf]
gravity = 32.2 [ft/s^2]	h_{wave} = 2.23 [ft]
k_{height} = 2.23 [ft]	k_{period} = 3.6 [s]
P1 = 1 [atm]	$period_{wave}$ = 3.6 [sec]
Power = 313.8 [ft-lbf]	$Power_{watts}$ = 118.2 [W]
ρ_{air} = 0.07489 [lb$_m$/ft^3]	ρ_{water} = 62.3 [lbm/ft^3]
$\rho_{water,gal}$ = 8.329 [lbm/gal]	T1 = 70 [F]
Vol_{cyl} = 7.352 [ft^3]	$Vol_{cyl,gal}$ = 55 [gal]
Vol_{disp} = 2.426 [ft^3]	W_{air} = 0.5506 [lbm]
W_{shell} = 10 [lbm]	

No unit problems were detected.

Calculation time = .0 sec

Appendix 4: EES Computation for Gearing

Gear Reduction

$$Turns_{Wheel} = \frac{height_{wave}}{Circumference_{Shaft}}$$

$$\omega_1 = \frac{Turns_{Wheel}}{Period_{wave}} \cdot \left| 9.5493 \cdot \frac{rpm}{rad/s} \right|$$

Radius Size

$Radius_{Shaft} = 2$ [in]

$Radius_1 = 6$ [in]

$Radius_2 = 1.5$ [in]

$Radius_3 = 6$ [in]

$Radius_4 = 1.5$ [in]

$Radius_5 = 6$ [in]

$Radius_6 = 1.5$ [in]

Efficiency

$\eta_{gear} = 0.8$

Omega Input

$height_{wave} = 2.3 \cdot 12$ [in]

$Period_{wave} = 3.6$ [s]

$Circumference_{Shaft} = 2 \cdot \pi \cdot Radius_{Shaft}$

$Circumference_1 = 2 \cdot \pi \cdot Radius_1$

$Circumference_2 = 2 \cdot \pi \cdot Radius_2$

$Circumference_3 = 2 \cdot \pi \cdot Radius_3$

$Circumference_4 = 2 \cdot \pi \cdot Radius_4$

$Circumference_5 = 2 \cdot \pi \cdot Radius_5$

$Circumference_6 = 2 \cdot \pi \cdot Radius_6$

Omega Ratio

$$\frac{\omega_1}{\omega_2} = \frac{Radius_2}{Radius_1}$$

$$\omega_3 = \omega_2$$

$$\frac{\omega_4}{\omega_3} = \frac{Radius_3}{Radius_4}$$

$$\omega_5 = \omega_4$$

$$\frac{\omega_6}{\omega_5} = \frac{Radius_5}{Radius_6}$$

Gear Ratio

$$Ratio_{Gear} = \frac{\omega_6}{\omega_1}$$

Solution

Unit Settings: [kJ]/[K]/[kPa]/[kmol]/[degrees]

$Circumference_{Shaft} = 12.57$ [in]

$\eta_{gear} = 0.8$

$height_{wave} = 27.6$ [in]

$Period_{wave} = 3.6$ [s]

$Radius_{Shaft} = 2$ [in]

$Ratio_{Gear} = 64$

$Turns_{Wheel} = 2.196$ [rad]

No unit problems were detected.

Calculation time = .0 sec

ID	Task Name
1	Group Poster
2	Call DNR
3	Determine Regulations
4	Subscribe to IAGLR.org
5	Yearly Wave Info Database
6	Determine Testing Feasibility
7	Meeting with Ind. Consultant
8	Monthly budget Report
9	**Analyze System Components**
10	Size Generator
11	Size Flywheel
12	Determine Gear Box Ratio
13	Determine Pulley Quantity
14	Determine Ratcheting System
15	Determine Cable Alternatives
16	Miscellaneous Components
17	**Class Requirements**
18	PPFS Draft
19	Oral Presentation PPT
20	Website Design
21	PPFS
22	**Component Analysis**
23	Design Base stand
24	ALGOR Analysis
25	Determine Final Design
26	Collect Drum and base stand Mat's
27	Generator and Flywheel
28	Pulleys and gearbox
29	Ratcheting and Cable
30	**Prototype Building**
31	Construct Prototype
32	Component Placement
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