A First Course in Engineering Design Based on an Energy-Centered Thematic Approach

Yiannis A. Levendis

Christos Zahopoulos

Northeastern University

Boston

STEPs to Success in STEM Conference

April 12, 2013

Mass Bay Community College

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First Year ENGINEERING COURSE DESCRIPTION AND OBJECTIVES

The course introduces Community College students to the principles of engineering design and to the scientific foundations of engineering in applied sciences and mathematics.

The Engineering Design Process (EDP) is outlined, input factors are examined and implementation takes place using case studies.

The participants use the EDP, which incorporates the following elements:

1. Information gathering

2. Design methodology

3. Technical analysis based on the laws of science and mathematics

4. Implementation of the solution.

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Overall course objective:

Introduce students to the engineering design process (EDP) by engaging them in cost-effective team projects.

The participants learn to:

1. Address practical problems.
2. Integrate previously learned skills.
3. Use design methodologies and scientific/mathematical analysis to implement working solutions.
4. Use project management techniques.
5. Address intellectual property concerns.
6. Communicate ideas effectively in both written and oral formats.
7. Work effectively in a team.
8. Integrate ethical, social, safety, cost, environmental concerns and aesthetics in the design process.

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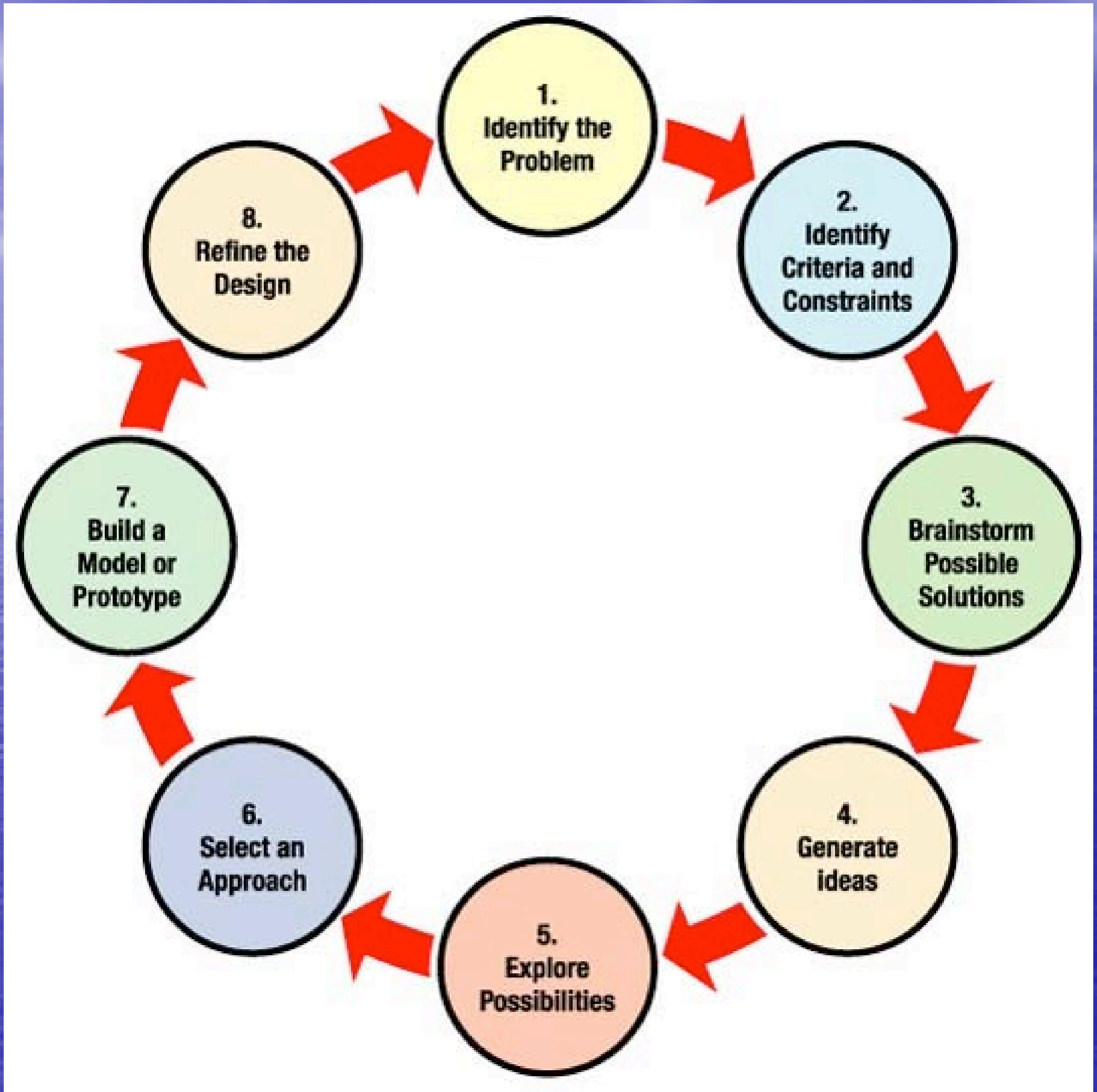
The ENGINEERING DESIGN PROCESS



Activities

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Activities

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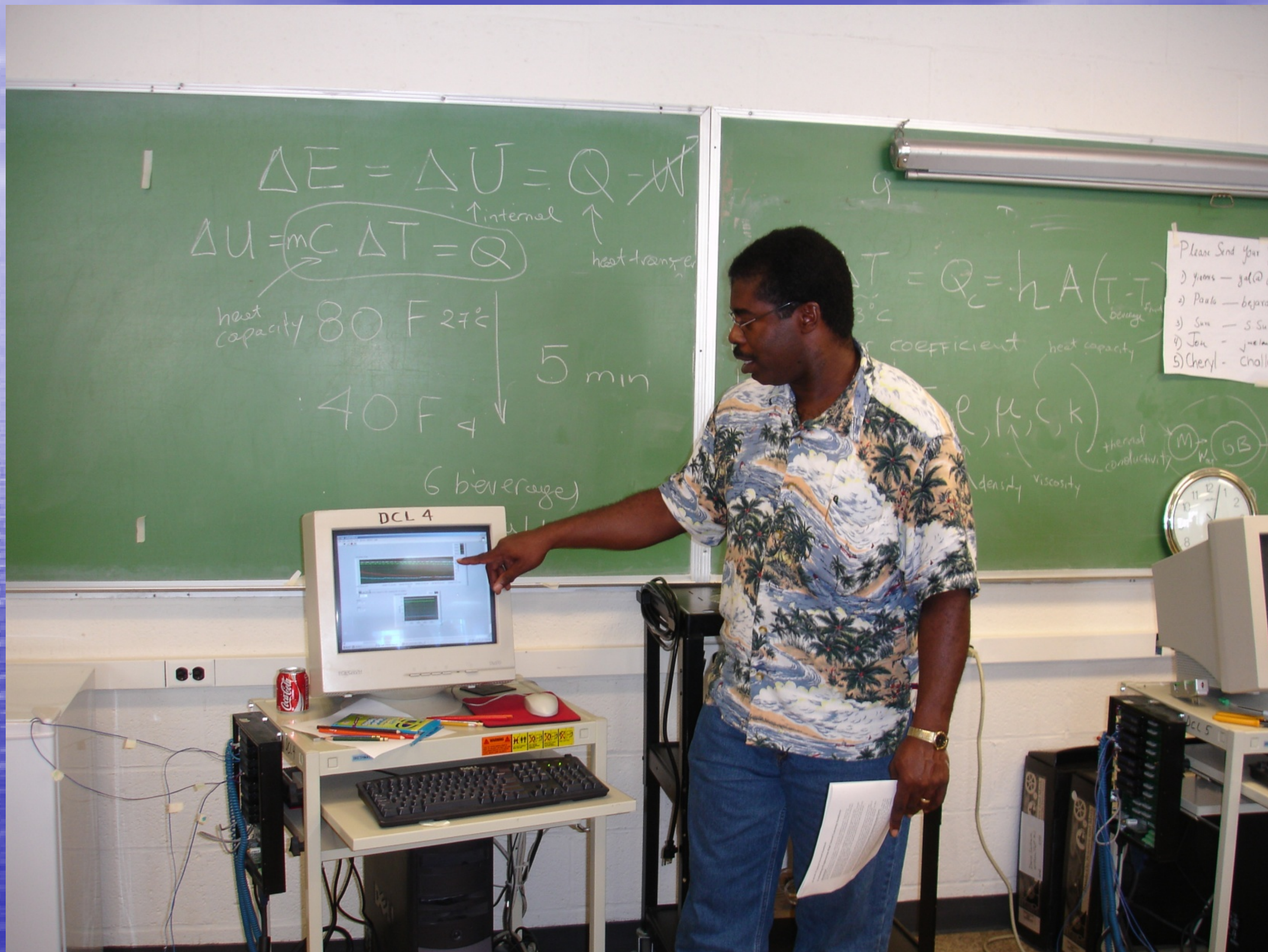

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Activities

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Example 1. The Putt-Putt Boat

Kenneth Cray
and
Gar-Hay Yee

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What Do You Think?

Boats come in all shapes and sizes. What do these boats all have in common?

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Engineering Design Process

- Define the problem
- Research the problem
- Propose creative solutions
- Choose the best solution
- Build a prototype
- Test the prototype
- Communicate the solution
- Redesign

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Define the Problem

- To improve some aspect of the putt-putt boat

  But first, you have to...

  – Determine what makes the putt-putt boat move, and

  – Determine what makes the putt-putt sound

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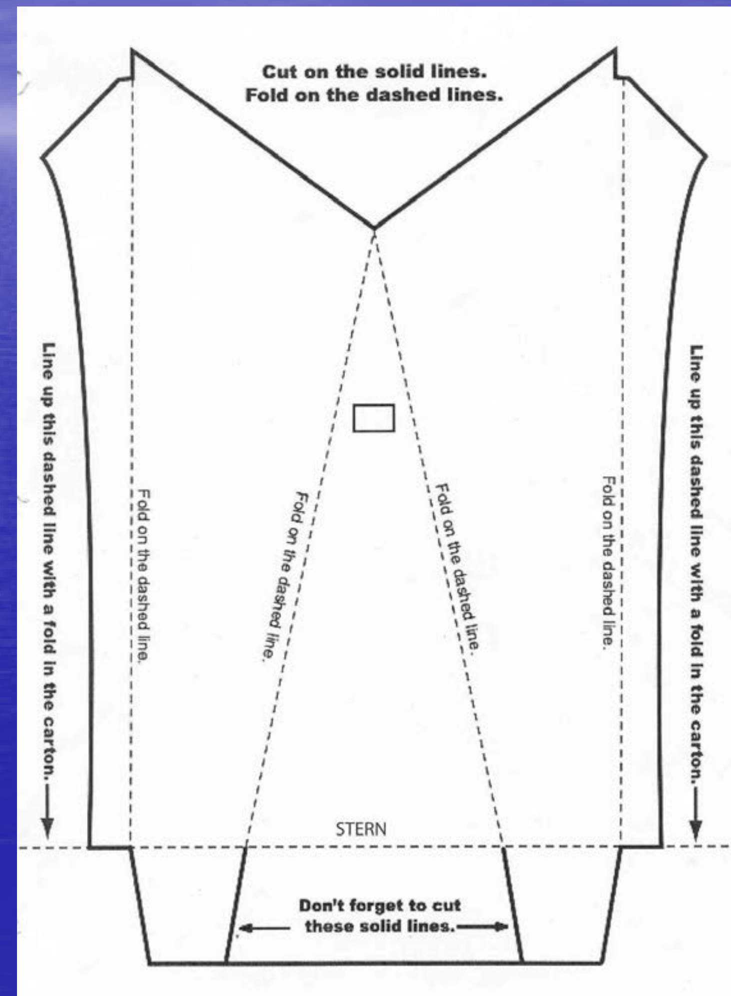
Existing Design (Boston Museum of Science)



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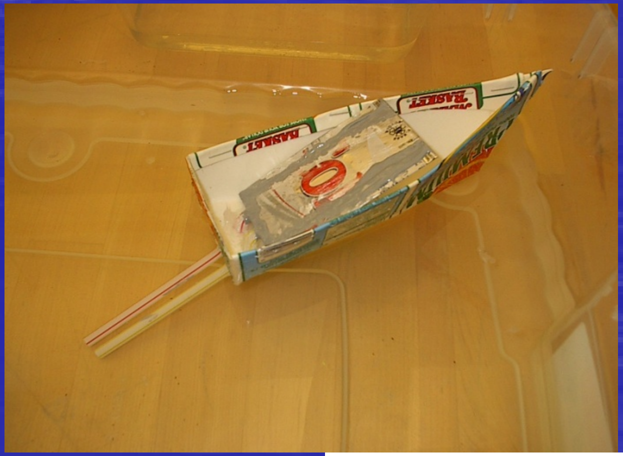
Research the problem

- Our initial research consisted of first building a boiler or steam engine and mounting it in a model boat constructed from a waxed carton and conducting a variety of experiments with it.

- Additional research included readings from the Boston Museum of Science's *Engineering the Future* curriculum, and an article, "How Things Work, The Pop-Pop Boat" from http://www.nmia.com/~vrbass/pop-pop/aapt/crane.htm .



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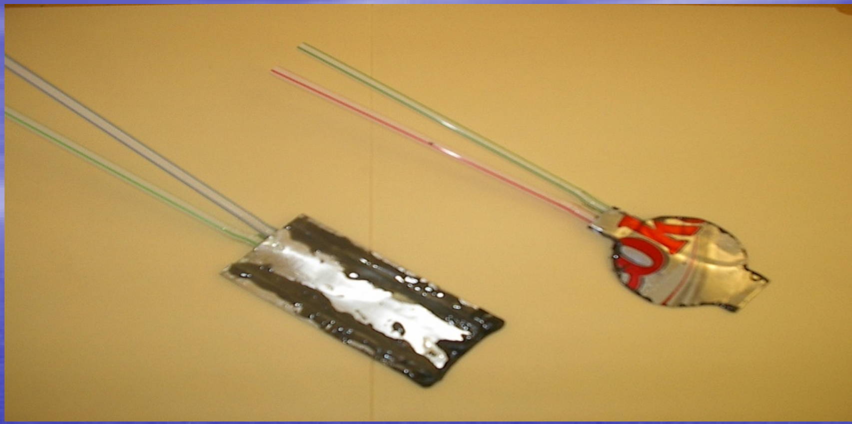
Propose creative solutions

- Solutions considered:
  - Change the boiler
  - Change the hull shape
  - Change the exhaust system
  - Use a combination of the above



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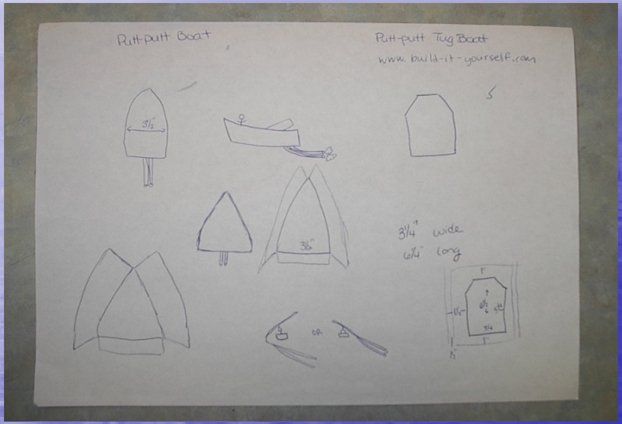
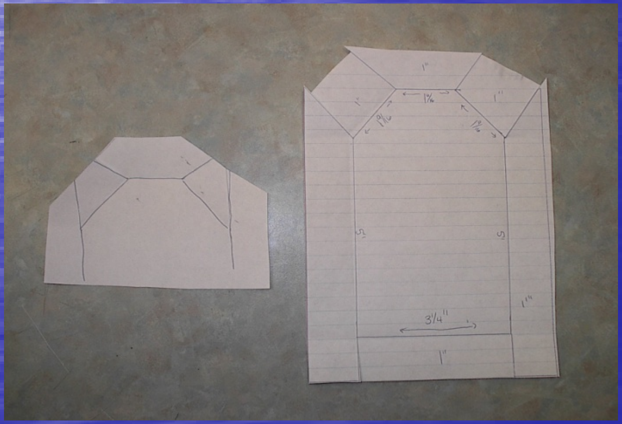
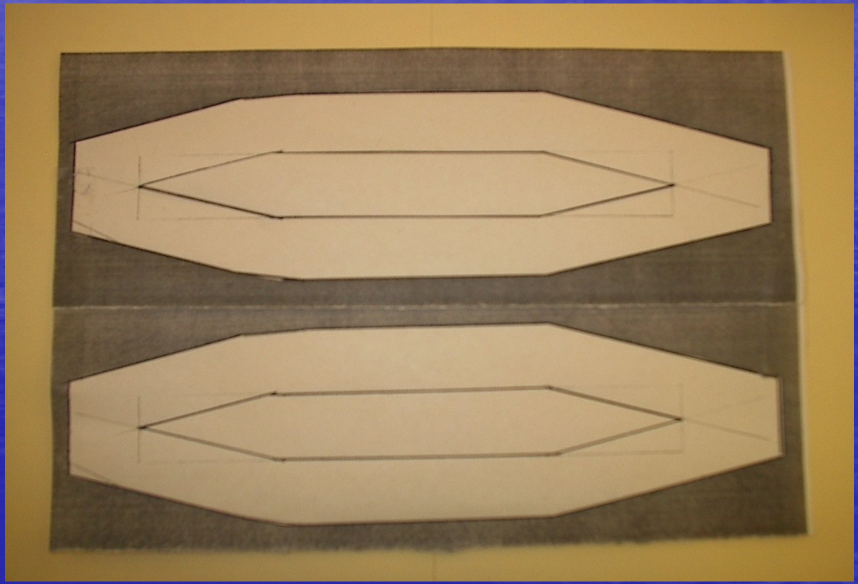
Choose the best solution







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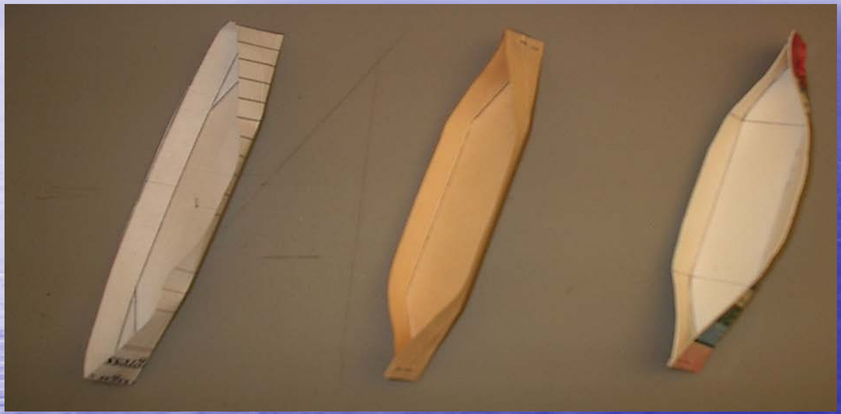
Build prototypes



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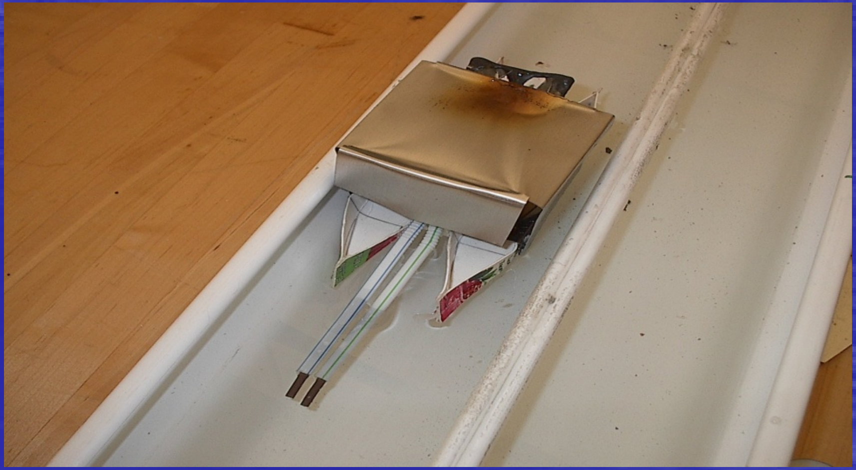
Test the prototypes



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Collect Test Data

	Catamaran One Foot	Catamaran Five Feet	Tug Boat One Foot	Tug Boat Five Feet
Time (sec)	5.76	34.33	4.48	22.96
Time (sec)	7.01	52.96	5.46	23.20
Time (sec)	6.15	41.35	4.91	25.14
Time (sec)	n/a	n/a	3.75	20.79

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Tug Boat
Test Data of Average Times

Weight (g)	One Foot (sec)	Five Feet (sec)
10	6.26	36.60
20	4.80	22.66
50	5.59	28.77
70	7.59	37.62
90	6.10	33.93
130	7.11	35.79
150	8.16 (1)	39.14 (1)

Communicate the solution

- So, what do you think we're doing right now, Sherlock?
- Creating a wider hull allows for a wider boiler, which can then be heated by two heat sources, resulting in greater speed.
- Are there are other possible design variations?

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Redesign

- Further investigations could include additional variations of the boiler, hull, and even the exhaust system.

Now Don't Forget The 7-E Model

- **Elicit** (prior understandings)
  - Aids the transfer of learning from a past association to a current one; "What do you think?"
- **Engage**
  - Gets students' attention and stimulates thinking; raises questions in their minds;
  - Accesses prior knowledge & excites students;
  - Use a demonstration
- **Explore**
  - Students observe, record data, isolate variables, design and plan experiments, create graphs, interpret results, develop hypotheses, and organize their findings; teachers make suggestions and provide feedback

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The 7-E Model

- **Explain**
  - Concepts precede terminology; teachers introduce models, laws and/or theories which the students should summarize results of their explorations in terms of new information
- **Elaborate**
  - Students apply their knowledge to new areas which may raise new questions or hypotheses; involves the transfer of learning from one situation to another
- **Evaluate**
  - Tests, quizzes, homework assignments should include questions from the investigations performed in class; ask students to interpret new data related to the investigations; and students should be asked to design a new investigation
- **Extend**
  - Allows students to demonstrate knowledge applied in a new situation

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Integrating the Putt-Putt Boat into the Existing Curriculum

Having done this project, and having been provided with a copy of the *Engineering the Future's* chapter on fluid and thermal systems makes it possible to introduce this boat-building activity in class.

This project will be introduced into our curriculum, either in addition to, or in place of, some other activity in the current curriculum.

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References

Museum of Science, "Project 3.0 Improve a Patented Boat Design." Engineering the Future September, 2005: 138-236.

- http://www.grsites.com/sounds/nautical001.shtml
- http://www.blogwaybaby.com/Unhappy%20Face.JPG
- http://www.nmia.com/~vrbass/pop-pop/aapt/crane.htm
- http://citationmachine.net/index.php?source=10#here

The

End!

- Example 2: A simple **Wind Turbine** project:

With this **GREEN** **Technology** as an example, the students will make the Connection between **Science** and **Engineering**.

To demonstrate the connection one can ask a few simple questions:

- What powers the wind turbine?
- If you double the speed of the wind by how much does the power output of the turbine change?

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A simple **Wind Turbine** project

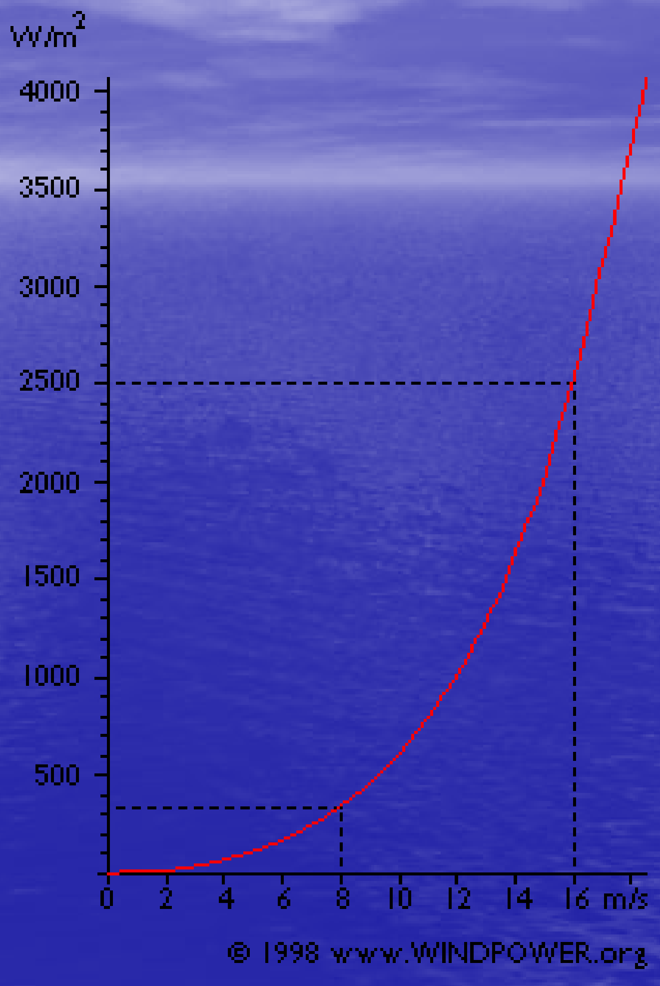
Kinetic energy of the wind passing through the cross sectional area of a turbine. Power is the rate of energy, thus:

$$\Delta KE / \Delta t = ½\, m/t\ (V_{in}^2 - V_{out}^2)$$

$$= ½\, \rho A V\ (V_{in}^2 - V_{out}^2)$$

thus $P_{turbine} = f(V^3)$

Finally, to find the energy utilized by the turbine multiply by experimentally determined efficiency factors.



A simple **Wind Turbine** project

The students can experiment with a scientific toy made by *Tamiya*, where wind energy is harnessed by a windmill and it is then transferred to and stored in a capacitor located in a little electric vehicle. It can be later used to move the vehicle.

This educational kit lets a student explore the mechanisms involved in harnessing the alternative energy of wind power.

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A simple **Wind Turbine** project

The efficiency of the wind turbine, η, is defined as

η= desired output/required input=P_{out}/ P_{in} ×100%.

Where P_{out} is the power output from the turbine to the capacitor, and P_{in} is the power input of the turbine, which comes from the power of the wind.

$$P_{in} = \rho \times A_{propeller} \times V_{average} \times (V_{in}^2 - V_{out}^2)/2,$$

$$V_{average} = (V_{in} + V_{out})/2;$$

ρ represents the density, here the density of air is $\rho = 1.2 kg/m^3$, at STP (25°C, 1 atm);

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A simple **Wind Turbine** project

The participating students will learn:

About the individual components of the wind turbine

- How to collect data,
- How to plot the data, and
- How to calculate power output and efficiency
- Energy harnessing, renewable energy, energy storage, electric vehicles, etc.

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A simple **Wind Turbine** project

$A_{propeller}$ is the area of the turbine envelope, which equals to $\pi \times R^2$.

If V_{in} is the velocity of air right before the turbine, V_{out} is the one measured right after and V_{ave} is the averaged velocity of the wind passing through the wind turbine, then,

$$P_{in}=1.2\ [kg/m^3] \times 3.14*0.09^2\ [m^2] \times (V_{in}+V_{out})/2\ [m/s] \times (V_{in}^2-V_{out}^2)/2\ [m^2/s^2]$$

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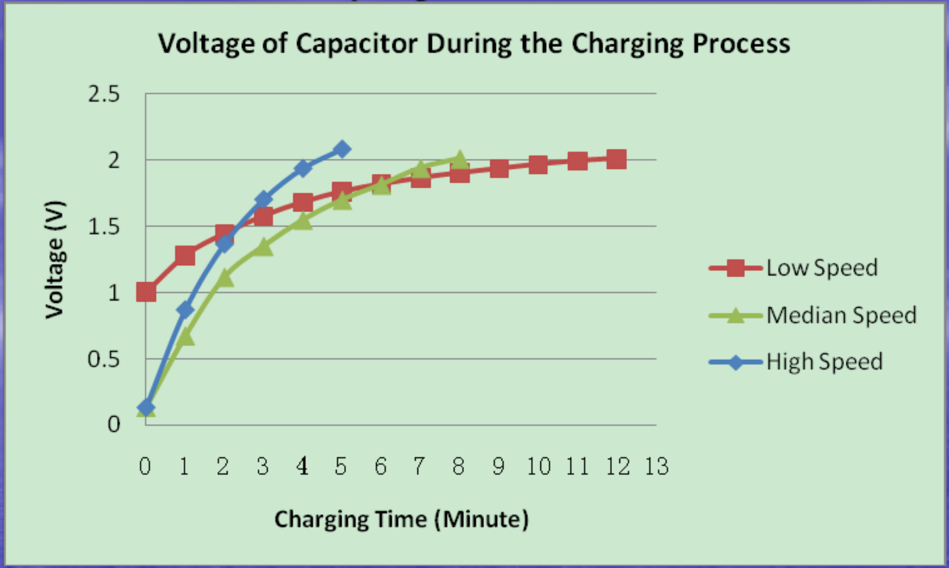
A simple **Wind Turbine** project



The power output of the wind turbine ($P_{out,\ w}$) = the power input of the capacitor ($P_{in,C}$), (Assumption: no energy loss during the transmission process.)

The relationship between $P_{in,\ c}$ and the energy stored in the capacitor, E_c, is:
$E_c = P_{in,\ c} \times \Delta t$, where Δt is the charging time for the capacitor.

The energy stored in the capacitor: $E_c = C \times V^2/2$,
(C is the capacitance constant, which is 3.3Farads for the particular capacitor in this kit and V and the voltage of the capacitor when it is completely charged.)

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A simple **Wind Turbine** project

Wind Speed (m/s)	Low Speed	Median Speed	High Speed
Before the propeller (V_{in})	3	3.4	3.9

	Low Speed	Median Speed	High Speed
Time of charging (min)	12	8	6
$P_{out, t}$(W)	0.00695772	0.013887844	0.019829333
$P_{in, t}$ (W)	0.23176733	0.300057615	0.376771646
Efficiency, η	3.0%	4.6%	5.3%

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A simple **Wind Turbine** project

This project can be easily extended into an Engineering Design project by concentrating in one element of this work.

For instance, the students can be asked to design and construct their own blades with the purpose of maximizing the efficiency of this machine.

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Example 3: Gear Box

Understanding the Gear Ratio and Torque

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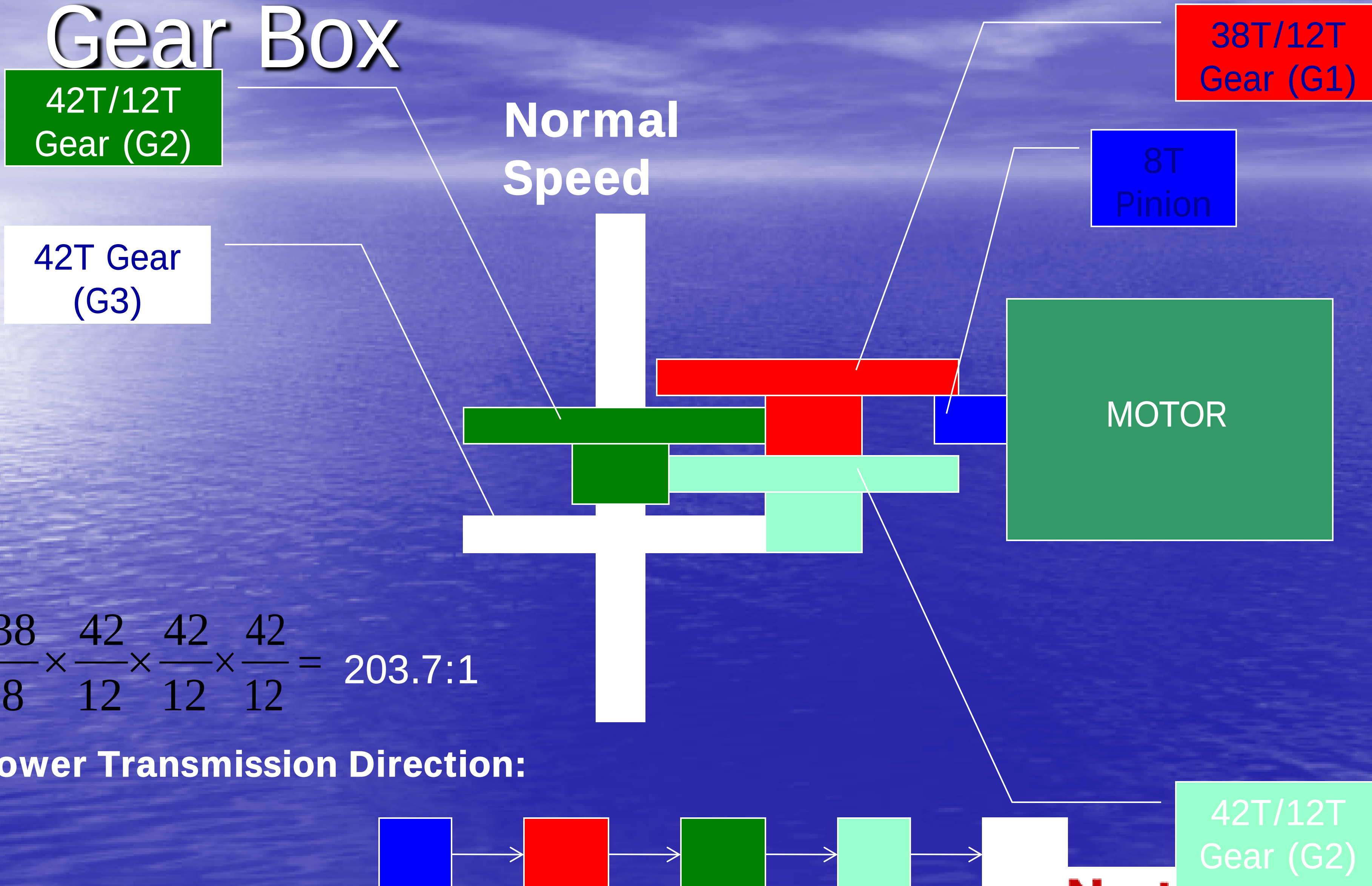
Power =Torque X Speed

For same Power:

- Less speed → More Torque
- More speed → Less Torque

Gear Box



$$\frac{38}{8}\times\frac{42}{12}\times\frac{42}{12}\times\frac{42}{12} = 203.7:1$$

Power Transmission Direction:

MOUNTAIN LIFT

CRAIN

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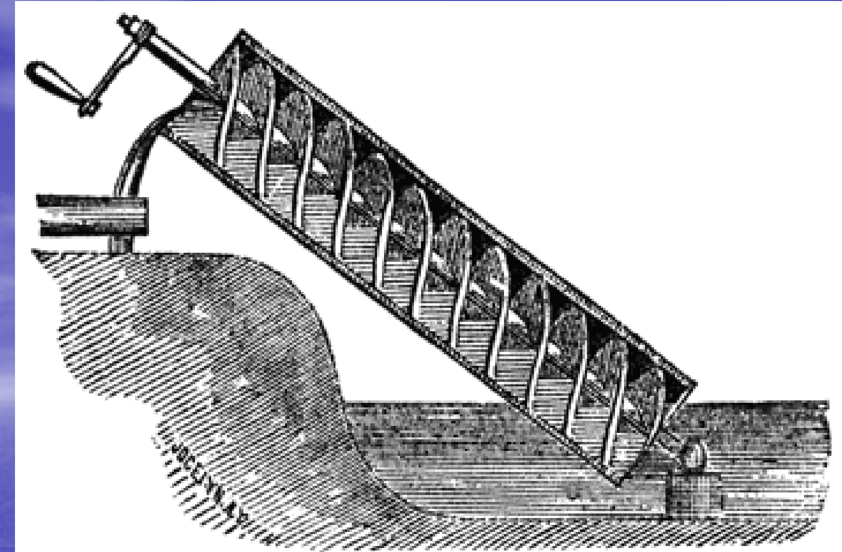
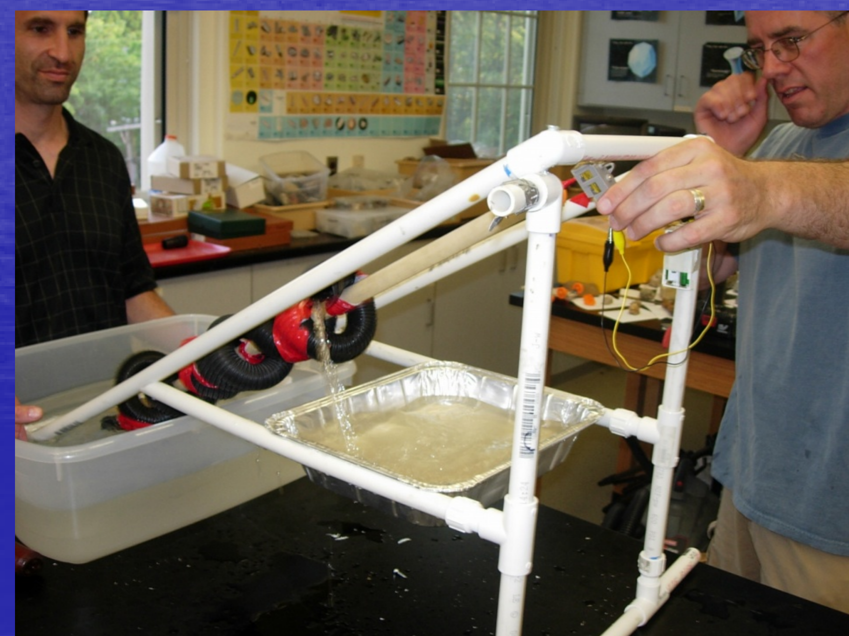
ARCHIMEDEAN SCREW PUMP





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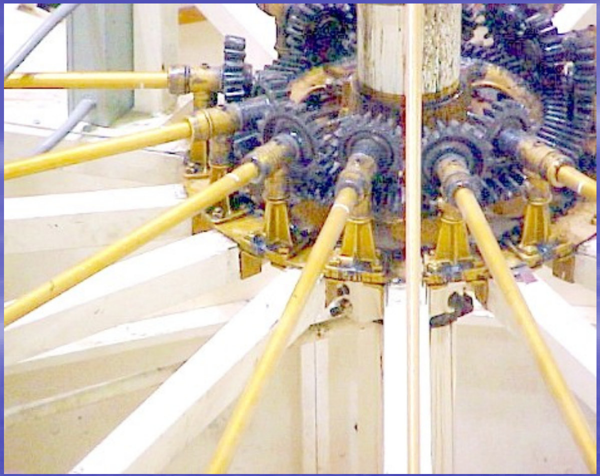
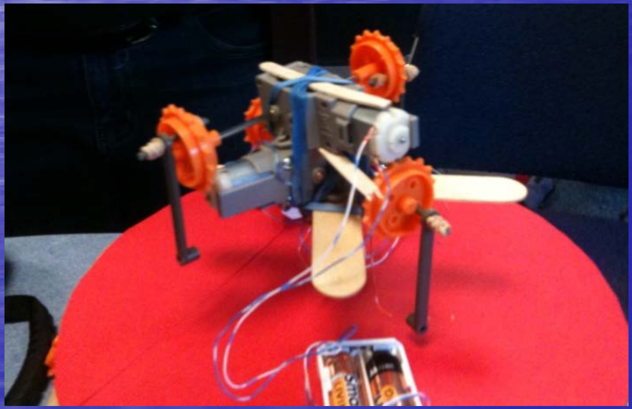
CAROUSEL





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ELEVATOR

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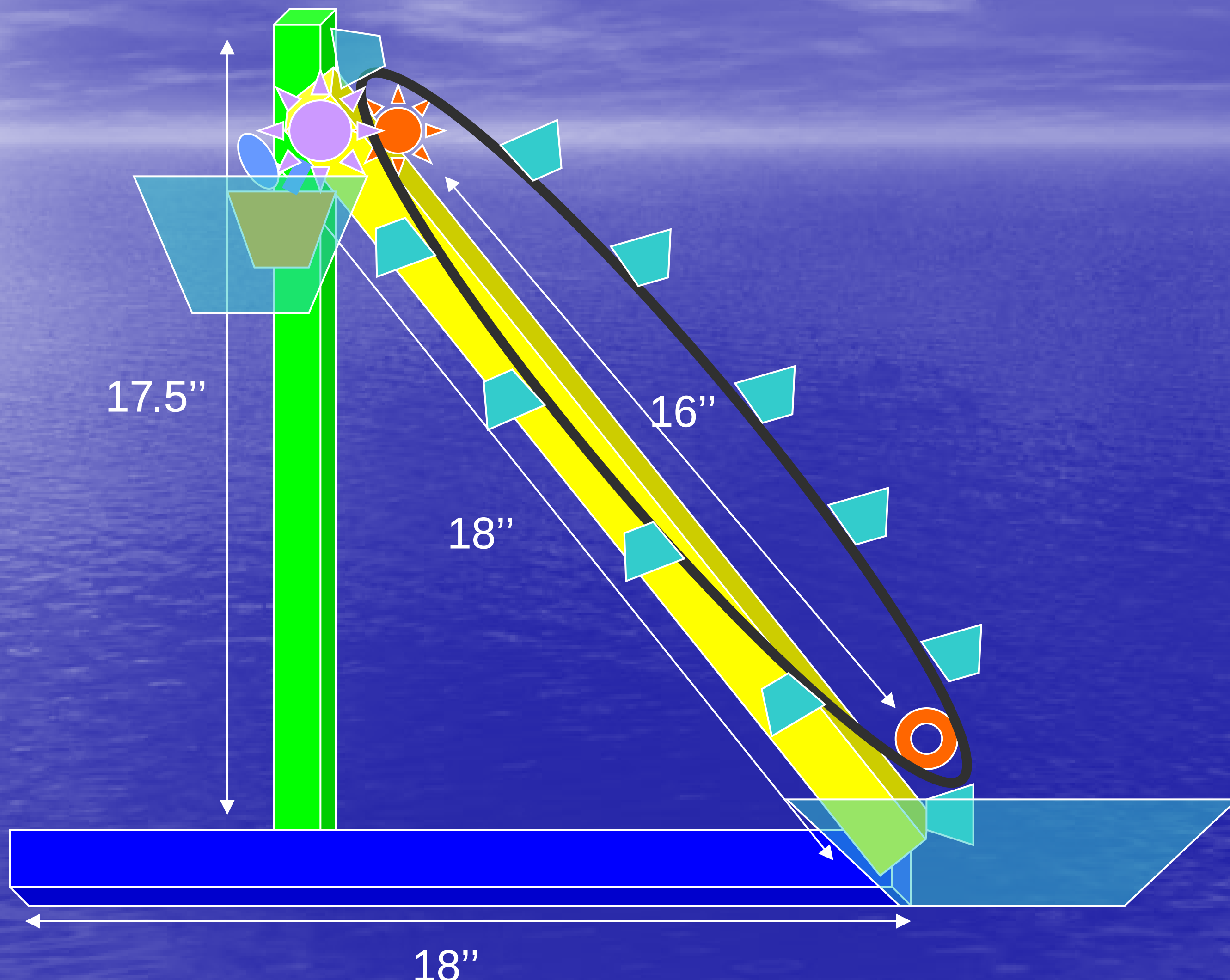
WATER PUMP



*Note: Imp… have a stro… of what you want when you go into the sho…

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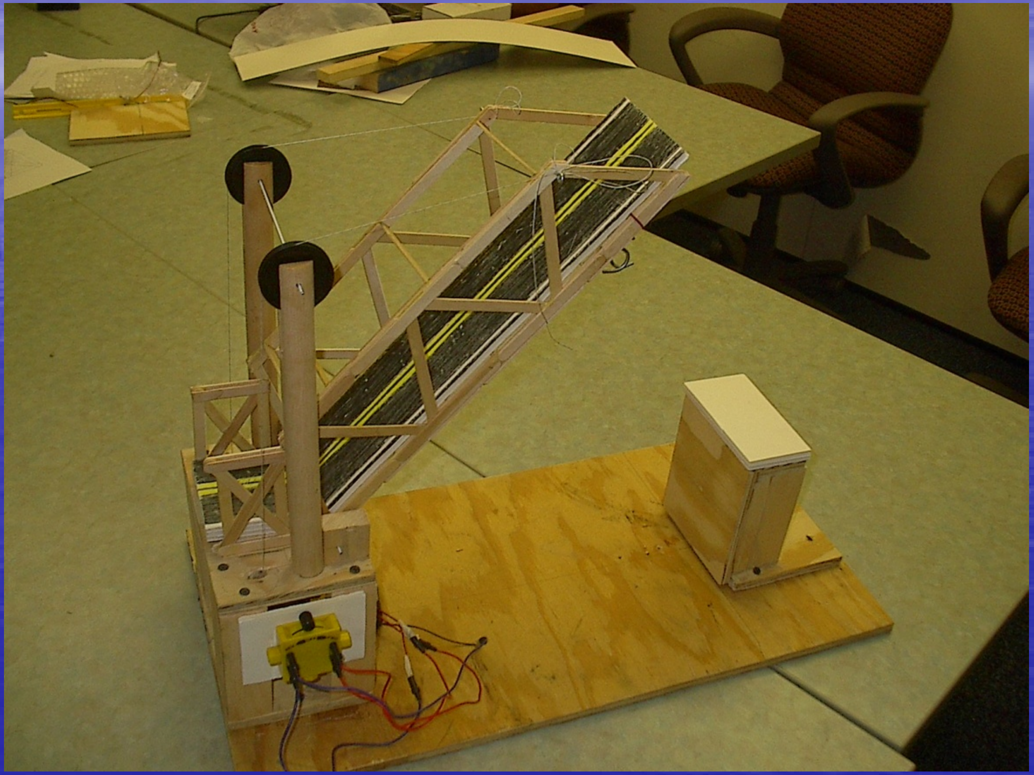
WATER PUMP

Drawbridge with Gearbox



THANK YOU FOR YOUR ATTENTION

Let's go Fishing in the Deep Blue Waters!!!

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