A COLLECTION OF ENGINEERING DESIGN PROBLEMS
[2009 Edition]

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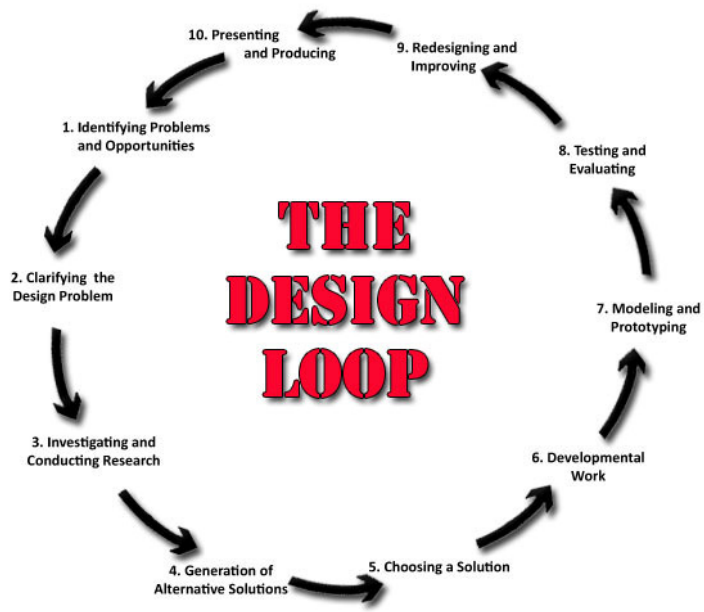
THE DESIGN LOOP

The design loop is a guide that helps make engineering design problems a more effective learning tool for students. It is a structure for thinking and doing—the essence of design and problem solving. Designing is not a linear process. When you design and make something, you do not think and act in separate, sequential steps. Rather, you complete activities that logically lead to additional activities--sometimes they occur in the order outlined below and sometimes they occur more randomly, but in almost all cases all of the activities outlined below occur during the engineering design process. It is a good teaching tool to require students to document their passage through all phases of engineering design. Below is an illustration and description of each phase of the design loop.



1. Identifying Problems and Opportunities:
Central to the process of designing is the identification of a problem in need of a solution. On the surface, this appears to be a simple task, but it requires careful observation and a critical eye.

2. Clarifying the Design Problem:
The student designer will attempt to clarify, understand the specifications, and detail exactly what it is that they intend to do. At this point, the student begins to ask a number of questions (i.e., What are my limits? How much time do I have? To what materials do I have access?).

3. Investigating and Conducting Research:
In order to solve problems, all pertinent information must be gathered and documented for possible future reference. The importance of investigation and research cannot be overemphasized. Few solutions are new. Most new inventions involve many previously known principles and concepts.

4. Generation of Alternative Solutions:
Generating a number of alternative solutions is one of the most important steps and often the most difficult to do. Although it seems to be human nature to latch on to your first idea and try and make it work. More ideas equal better solutions. Techniques: Brainstorming, sketching, doodling, attribute listing, and forced connection.

5. Choosing a Solution:
Choosing the best among a number of ideas is less straightforward than it may appear. Two strategies: (1) Listing the attributes (good and bad points) of the ideas and comparing them; and (2) Developing a decision matrix that compares attributes to design criteria. The evaluation process may indicate a way to combine features of several solutions into an optimum solution.

6. Developmental Work:
The student designer begins working on the myriad of sub-problems that need solutions. This involves modeling, experimentation with different materials, and fastening techniques, shapes, and other things that need to be done before actual construction of the final design is undertaken.

7. Modeling and Prototyping:
At this point the student designer begins to develop models and prototypes that represent their idea. Two-dimensional and Three-dimensional models, computer models, and mathematical models are commonly used.

8. Testing and Evaluating:
This may be as simple as applying the specifications to the end product to see if it does all the things that it is supposed to do. But more often it is performance testing, as in the case of a practical device.

9. Re-designing and Improving:
After evaluating the design, student designers begin implementing what they have learned from the evaluation—an effort to improve the product.

10. Presenting & Producing:
All design problems should end with a culminating event. This could be a formal presentation of the production of the product or system.

THE STUDENT SHUTTLE (4 DAYS)

Introduction

While completing this activity, students will begin to experience two concepts related to transportation. These concepts include propulsion (moving a vehicle forward) and guidance systems (directional control). Students will also have the opportunity to work cooperatively to solve a technical problem (creating an experimental vehicle out of miscellaneous materials). You will need to gather the materials listed below for each team of students. Additionally, you will want to gather hand and power tools that are acceptable for use with this activity, and develop a space to test the vehicles. Separate the students into small cooperative groups and then provide them with the (1) Scenario; (2) Parameters; (3) Materials and supplies; (4) Procedures; (5) Evaluation sheets; and, (6) Summary questions. This activity should take approximately four class periods.

Scenario

Assume the following: Because the high school that you attend is growing larger each year and students are habitually late for classes when they must move from one side of the campus to the other between classes, administrators have decided to develop a new transportation system to rapidly move students across campus between classes. Using the materials you were given, design and construct a scale model prototype vehicle that will travel under its own power or under a self-contained power source. The “student shuttle” vehicle must carry at least ten students (represented by dimes) a distance of twenty feet (in a relatively straight line from a starting point) in less than 20 seconds.

Parameters

You may use only the materials listed in the “materials and supplies” list below. Materials may be modified by combining, forming, or separating. Additionally, you may use any hand or power tools approved by your instructor. Success will be determined by the vehicle reaching its destination in less than twenty seconds while carrying the entire payload.

Materials and Supplies

2 soda straws	3 balloons	glue
2 straight pins	4 rubber bands	2 paper clips
12” of masking	20 feet fishing line	1 plastic bag to hold items listed
1 clothes pin	1 sheet 9 x 12” construction paper	10 coins used for cargo
1 styrofoam tray	4 jar lids	2 welding or 1/8” dowel rods
tape		

Procedures

When designing and constructing your student shuttle, you should consider each of the design procedures listed below.

1) Read the problem statement and formulate potential solutions.
2) Consider the steps in the problem solving process: **I**dentification of the problem, **D**evelop several alternative solutions, **E**valuate alternatives and decide on prototype, **A**pply and test your design (IDEA). There are many other models of problem solving but this one is short, contains the essential elements, and is easy to remember.
3) Be creative. You have been given general limited materials but you have been given unlimited possibilities to solve the problem.
4) Consider various ways to propel and guide your vehicle.
5) If at first you don't succeed, don't give up! Remember that almost all inventors experience some type of failure before they finally succeed.
6) Keep your ideas to yourself. You don't want to "leak" corporate secrets.
7) Be prepared to present and describe your solution in class.

Evaluation

Your success (or failure) in this activity will be evaluated according to the criteria listed below.

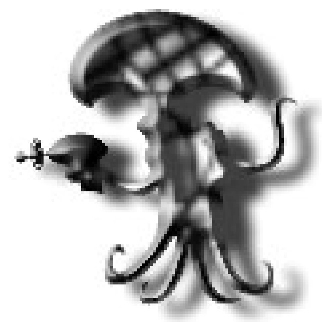
1. Operation: (15 points) Did the student shuttle travel the required distance?
2. Cooperation: (15 points) Did your team function as a cooperative unit?
3. Speed: (10 points) Did your student shuttle achieve an acceptable speed?
4. Aesthetics: (10 points) Was your student shuttle well designed and neat?
5. Planning: (30 points) You will be awarded 30 points for working drawings and a written description of your solution (these should be developed during the planning stages of the cooperative activity).
6. Summary Questions: (20 points) You will be awarded 20 additional points for successfully answering the summary questions listed below.

Summary Questions

Please provide answers to each of the questions listed below:

1. What two mechanical systems were considered in your solution to the problem?
2. What scientific principles are demonstrated in your solution?
3. Specifically identify the process you used to arrive at your solution?
4. How could you improve your solution to the problem if you had the opportunity to start over?
5. What ideas did other teams in your class use that could have been beneficial in your design?

AN ALIEN WITH AN ATTITUDE (3 DAYS)



Teacher Overview

This engineering design problem has been created to provide your students with the opportunity to construct, test, and demonstrate a catapult type device. The implementation of this activity should follow a unit of study on mechanical power—specifically, simple machines and mechanical advantage. Although it is not essential, students participating in this activity could be assisted by having some background information and knowledge of typical woodworking tools and equipment. You will need to construct a model that can be used to represent the gorge during the testing phase of the activity. This model could be constructed of taped lines on the laboratory floor or two tables placed 36 inches apart. This activity is designed for secondary students working in small teams or individually. You will also need to gather all materials listed below, hot glue guns, and woodworking equipment prior to the implementation of this activity. The activity should take approximately three-50 minute class periods to complete.

Design Rationale

People use mechanical power, simple machines, and mechanical advantages every day. Due to the availability of technology in our society, most people are unaware that they are using these machines or a mechanical advantage throughout their daily routines. For example, you use simple machines and mechanical advantage when you ride a bicycle, open a door, use a pencil sharpener, or open a can of soda. Today, you will have an opportunity to use your knowledge of simple machines and mechanical advantage (as well as your problem solving and creative thinking abilities) to build a device that just might save the human race!

Problem Scenario

You have been selected to champion your species in a duel with a vile, ugly, rude, arrogant, obnoxious, musty, and slightly overweight alien with mild acne and a really bad attitude. The loser, and the rest of his/her species, will be instantly obliterated—their planet completely pulverized. Since the alien is such a massive entity, it is imperative that you rely on your vast knowledge of physics, mathematics, and technology—more specifically, mechanical power, simple machines, and mechanical advantage to construct an “equalizer”. That is, a weapon that will allow you to defeat this hideous creature. In an effort to conserve natural resources, it was mutually decided to shrink both combatants to a more convenient size. You are now 3 inches tall, but the alien is still well over one foot tall! Fortunately, a bottomless gorge separates you from this hideous creature, but you will need help to deliver a projectile of sufficient mass to defeat this monster. You must create a mechanical device using the materials available that is capable of delivering a projectile (on target) from your side of the gorge to the alien side. For additional information about your assignment, read the "parameters" section of this activity sheet.

Activity Content

Mechanical energy is simply the energy of motion. For example, the mechanical energy of a moving hammer is used to drive a nail. Energy can be defined as the capacity to do work. Work, in turn, can be defined as useful motion, or motion that results in something useful being done. Work is a measurement of mechanical energy and can be calculated by multiplying weight times distance. Mechanical power is defined as energy per unit of time. Therefore, power is a measurement of work completed in a given period of time. Horsepower is the most common measurement of mechanical power. One horsepower is equal to the energy needed to lift 550 pounds 1 foot in 1 second.

There are many different devices used to modify mechanical power. These devices are called machines. There are basically six simple machines used to control and modify mechanical power. The simple machines are the lever, the wheel and axle, the pulley, the inclined plane, the wedge, and the screw. If you are not familiar with these machines, ask your instructor to show you some examples.

Another important form of measurement used in mechanical power is mechanical advantage. If you understand mechanical advantage, you can calculate exactly what you gain or lose when you use a machine. Mechanical advantage can be calculated using several different procedures. For this activity, we will calculate mechanical advantage by comparing output distance to input distance. To calculate the mechanical advantage for the device you build during this activity, simply measure the distance your machine moves (in order to catapult the load) with the distance the load is moved. Mechanical advantage is stated in a ratio. For example, your device might have a mechanical advantage of five to one or (5:1). After you have constructed your device, ask your instructor to help you calculate your mechanical advantage.

Parameters

You must create a mechanical device using the materials available that is capable of delivering a projectile (a golf ball) from your side of the gorge to the alien side (36 inches) and be on target (at least 2 hits during 5 rounds). You may only use the materials listed below, hot glue, and the equipment specified by your instructor. The target "alien" will be represented by a NERF type basketball.

Materials

In addition to the testing area and the Nerf ball that will be used as the target, teams may use any of the following materials to solve the design problem:

10 wooden toothpicks	2 metal paper clips	2 metal staples
4 wooden popsicle sticks	2 wood pieces ¼"x1"x3"	2 rubber bands
1 - 18" dowel rod ¼ inch diameter	6 small wire brads or nails	2 sewing spools
1 - wooden base block 1"x4"x4"	1 - plastic soda straw	1 - pencil
1 - 12"piece of cotton string	1 - hot glue gun & glue	Misc. tools/equip.

Evaluation

Your team will be evaluated on this project using the following criteria:

1. *Function*: (30 points) Does the prototype device perform the intended function of hurling a projectile?
2. *Accuracy*: (20 points) Does the machine control the direction and elevation of the projectile? (2 hits from a maximum of 5 rounds)
3. *Distance*: (20 points) Does the machine have sufficient power to propel the projectile a minimum of 36 inches?
4. *Questions*: (20 points) Did the team provide adequate responses to each of the questions outlined in the "summary" section below?
5. *Originality*: (10 points) Points will be awarded for design originality
6. *Extra credit*: (10 points) Points will be awarded for the efficiency of your work or "time on task".

Summary

During the completion of this activity, you had the opportunity to use all of your physics, mathematics, and technological knowledge to construct a launching device or catapult. You had to call upon your problem solving skills and your knowledge of simple machines and mechanical power to construct the device. Now that you have created and tested your device, please take a few minutes to provide clear and concise answers to each of the questions listed below. After you have completed each of the questions, please submit your device and your answers to your instructor for grading.

1. On a scale of 1 to 10, rate the performance of your device?
2. After witnessing the testing of all devices created in your class, rank the performance of your device? Was it the best device (number 1)? Was it the fifth best (number 5)?
3. How could you improve your design if you have the opportunity to start over?
4. After witnessing the designs of your classmates, which of their ideas could be used to improve your design?
5. If you were able to use an unlimited amount of supplies to produce you device, what additional materials would have been helpful? Why?
6. If the human species were dependent upon the performance of your device, would we continue to exist?
7. Please make a sketch of the device you created and use arrows to identify the simple machines included in your design.

8. Using the formula provided in your textbook, please calculate “work” and the “mechanical advantage” for your device.
9. What changes could be made in your design to increase the mechanical advantage of your device?

DON'T ROCK THE BOAT (2 DAYS)

Teacher Overview

This activity should follow a brief unit that researches Archimedes of Syracuse. Archimedes is known as the Father of Buoyancy. He developed the mathematical definitions explaining why things float or sink. This activity will assist in the discovery of density and effective density in relation to the buoyancy of an object. Students will be performing observations of two experiments. The first involves effective density and how the difference in buoyancy of four wood blocks of the same length, width and depth. The second is a lab that involves building two "boats" of aluminum foil of different shapes to see how much weight that they can hold. You will need to gather the materials listed below before implementing this activity in your classroom. The lab should take approximately two 50-minute class periods to complete.

Activity Rationale

People are dependent upon water transportation. It allows us to ship cargo all over the world, travel to exotic destinations, enjoy a weekend on the lake, and learn more about the world around us. Militaries would be nothing without ships and submarines and our world would be altogether different without the understanding of buoyancy. With this lab, you will have the opportunity to gain a better understanding of how humans have been using buoyancy to explore the world, ship cargo, and dive undersea for many centuries.

Problem Scenario

You have been chosen to research buoyancy in order to build a boat that will carry the most silver. If your boat carries more silver than any other boat you will be allowed to keep the silver for yourself. You will first explore the concept of density based on observation of buoyancy. Then you will be constructing two boats of different designs that will allow you to observe how much effective density is in place in the boats. It will then be up to you to design a third, new boat that will hold the most amount of "silver". You will be competing against the other teams in your class to find out whose boat can hold the most weight and thereby win the grand prize of all the silver in the boat.

Activity Content

In regard to Archimedes's theory of buoyancy, if the amount of water displaced by an object weighs more than the object itself, then the object will float. If the amount of water displaced by object weighs less than the object, then the object will sink.

Using this theory, Archimedes proved that the crown of King Hiero was made with something other than pure gold. He found out the volume of water that the crown displaced. Then he matched that volume of water with the same volume of gold that the crown was made of to find if the crown and the gold were the same weight. They did not weigh the same and the craftsman of the crown then confessed to defrauding the king.

With that same explanation, Archimedes showed how the weight of the water that is displaced by an object is the same as the weight of the object itself. Therefore an object with little density will float high on the surface of water whereas an object that has slightly less dense than water will float near the top of the surface of the water but most of the object will be submerged. An object denser than water will sink and the water will in a sense be floating on top of that object due to the relative densities.

We can transport large quantities of goods on boats by making the shape of the boat be able to displace a heavier amount of water than the overall weight of the ship and its cargo. Certain shapes will allow for a large amount of water displacement so that large quantities can be carried on board. Using some of the information gathered in the observations in this lab, create a boat that will carry a large amount of silver.

Parameters

You must complete the observations on density and buoyancy in order to gather data that will help you build a ship that will carry the greatest amount of washers (silver-treasure). Your ship will be made of a 10 cm by 10 cm piece of aluminum foil and tape. The washers will be added one at a time to your vessel until the boat sinks. The number of washers that your boat held prior to the washer that made it sink will be the total that your boat held.

Materials

The teams will need the following items to complete the observations and build the final boat to carry the "silver":

- 4 blocks of different densities provided by the instructor
- 1 gallon tub to perform the tests in
- Water (a source of water will be necessary)
- 3 pieces of 10 cm by 10 cm aluminum foil
- Scotch tape to waterproof the aluminum foil boat
- A wedge block and a pop can to mold the aluminum foil
- Random shape to mold the aluminum foil for the final design (not necessary)
- Small washers to act as silver to go on the boats

Evaluation

Your team will be evaluated on this project using the following criteria:

1. *Hypothesis*: Can you develop a rationale for why your design will hold the amount of silver that it does?
2. *Function*: Does the boat hold more washers than the test designs did?
3. *Originality*: Is the design original compared to the others in the class?
4. *Questions*: Did the team provide adequate answers to the questions on the handouts?
5. *Extra Credit*: Did the team build one more boat design that would hold more silver than their previous design?

Summary

During the completion of this activity, you should have learned about density and its relationship to buoyancy. Follow the directions on the handouts to complete the observations. Fill in the blanks to record your observations and answer the questions on the handouts. You will also need to write a paragraph on what other technologies are dependent upon buoyancy. You may use the library or the internet to gather information to write your paragraph. Once you have completed the lab, turn it in to the instructor with your boat(s), your handouts, and your paragraph on buoyancy in other technologies.

THE PACKAGING DILEMMA (2 DAYS)

The Problem:
Many retail stores sell products in vacuum sealed packaging. Although this type of packaging is strong, easy to set in a display, discourages theft, and allows the consumer to easily view the product there are a few problems. Many times it is very difficult to open these packages, and often the methods used can be dangerous. The packaging itself is very sharp and may cause injury to the consumer. It is also poses a threat to the environment as it is simply tossed in the trash and ends up in landfills.

The Challenge:
In groups of 3, students are to use the design process to design and model or prototype a pocket sized tool that anyone ages 7 to 100 could use to open vacuum sealed packaging OR redesign the packaging to make it easier to open and more environmentally pleasing without loosing the positive attributes the retailer enjoys as mentioned above.

Supplies
-Design portfolio
-Colored pencils
-Fasteners
-Tape
-Wire/string
-Wood
-Plexiglas
-Cardboard
-Clear plastic
-Razor blade

Tools/ Machinery
-Safety Glasses
-Any tools and machinery found in the lab may be used with teacher approval.
-Internet access

Limitations:
- The project must be completed in two class periods.
- All steps of the design process up to the model/ prototype stage must be represented in a mini portfolio.
- The model/ prototype must be well constructed and aesthetically pleasing.

Objectives:
After completing this assignment, students will have demonstrated their abilities to think critically, work in groups, and apply the design process.

Curricular Standards:
- Students will develop the ability to apply the design process.
- Students will develop the abilities to use and maintain technological products and systems.
- Students will develop the abilities to assess the impact of products and systems.

Project Assessment Rubric:

Ratings 5= Excellent, 4=Good, 3=Average, 2=Poor, 1= Very Poor, 0= Not Found

1. The project was completed in the two class period time limit	5 4 3 2 1
2. All steps of the design process were represented up to the model/ prototype stage.	5 4 3 2 1
3. The model/ prototype was well constructed	5 4 3 2 1
4. The model/ prototype was aesthetically pleasing	5 4 3 2 1
5. The design solved the problem	5 4 3 2 1
6. The design met all requirements outlined in the challenge.	5 4 3 2 1
	Total Score____/30

Post Activity Discussion Questions:

1. What steps did you take when designing your tool or packaging?

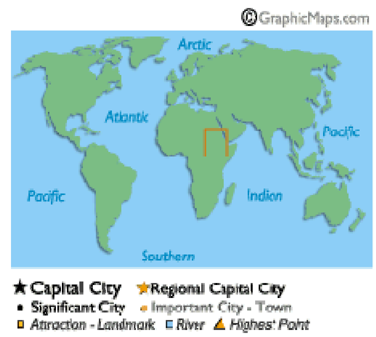
2. What considerations did you have to make when designing your tool or packaging?

3. How did you choose your particular design?

4. What about the challenge was the most difficult?

APPROPRIATE TECHNOLOGY CHALLENGE (4-5 DAYS)

Background information:
Sudan is an African country that has a major problem. Although several rivers including the Nile and the Blue Nile run through Sudan and it lies on the Red Sea there is a major shortage of fresh water. The people of this country are forced to leave their homes and live in camps in the desert by drilled water holes. Some of these camps are the size of small cities. Once the water runs out the people must move on to another camp site. Sudan is in need of finding a way to turn the water it does have into usable, drinkable water.



Design Challenge:
Sudan does have water sources that can be used to aid in the fresh water shortage. Using only the given materials create a solar water still to make the water from the Nile, Blue Nile, and Red Sea into drinkable water. In order to complete this assignment you must:

1. In teams, use the design process to research and design a solar water still that incorporates only the items on the list of materials.
2. Build a working prototype of your solar water still with appropriate level of craftsmanship.
3. Test the solar water still. To do this you must place your solar water still outside in the sun, fill it with the provided dirt and salt water mixture the teacher has provided, and allow it one day to distill the water. After one day measure how much water has been distilled. Be sure to record how much water you put into it the first day.
4. Record test information on the work sheet clearly describing how your solar water still worked.
5. In a five minute presentation tell the class about your design, why you chose it, and how well it worked.

List of materials :

Nails/ screws	Wood
Glass Jar	Reflective metal (sheet metal, aluminum foil, etc.)
Tin Can	Glass
Caulk	Clear Plastic
String	

Assessment rubric

1. The steps of the design process were used in the creation of the solar water still.	____/15 pts.
2. The working prototype was well constructed and aesthetically pleasing.	____/15 pts.
3. The solar water still was properly tested.	____/10 pts.
4. The solar water testing worksheet is complete and information is clear.	____/ 15 pts
5. The five minute presentation was well thought out, delivered, and described your design, why you chose it, and how well it worked	____/10 pts.
6. Teamwork was demonstrated- all members participated.	____/ 5 pts.
Total Score	**____/70 pts.**

Informative Websites

About Sudan's Water Shortage:

http://www.oxfam.org.uk/what_we_do/where_we_work/sudan/emergency/watershortage.htm

Sudan:

http://www.worldatlas.com/webimage/countrys/africa/sd.htm

Solar Water Stills:

http://www.energywhiz.com/3-5/EXPERIMENTS/solarstill.htm
http://www.solaqua.com/solstilbas.html
http://www.i4at.org/surv/sstill.htm
http://www.permapak.net/solarstill.htm
http://www.geda.org.in/solar/so_slr_still.htm

Testing Your Solar Still

Team Members

Names:____

Instructions:

1. Take your solar water still to the teacher designated area on the school lawn and set it up for testing.
2. Fill your solar water still with some of the dirt and salt water mixture provided by your instructor. Be sure to measure how much water you put in your solar water still.
3. Seal the water still and leave it for one day.
4. The next day open the water still and remove the container holding the distilled water.
5. Measure and record how much water was distilled in one day's time.
6. Calculate the percentage of water distilled compared to the amount of dirty water used.

Amount of water put into the solar water still = ________cups

Amount of water distilled=_________cups

Percentage of water distilled (Show calculation below)=_____%

Why do you think only that percentage of water was distilled? What factors should be considered?

Why would a solar water still be considered appropriate technology in Sudan?

A LONG SLOW DRINK

Scenario

Although many Americans take it for granted, a clean glass of water is rare in many developing countries around the globe; water supplies are threatened in most developing nations by ground water contaminants, chemical runoff, pollution, poor sanitation, and particulate contamination. Some suggest that adequate supplies of pure, clean and safe drinking water will become a worldwide problem in the next twenty years.

Task

Although the process of cleaning drinking water can be quite complex, sometimes it is just a matter of removing small particulates from the polluted water. However, the problem is compounded by the fact that most citizens in developing nations do not have adequate funds to purchase water cleaning systems or even purchase the materials needed to build a water filtration system. **Your task is to use recycled (free) materials to build a model water filtration system that could be used to remove particulates from polluted water in almost any developing nation.** While your model will not likely remove all chemicals from the polluted water, it should demonstrate how a device can be used to remove particulates from collected water.

Design Criteria

To adequately answer this design problem, your team will need to strictly adhere to the following design criteria:

- Design teams must use only materials and tools supplied at the beginning of the design challenge.
- The completed filtration system must filter at least 12 ounces of water and include a “catch basin” for the filtered water.
    - The catch basin must be removable so that the filtered water can be tested by the instructor.
- The filtration system must completely filter the 12 ounces of water in less than one (1) minute.

Testing

Each team will be provided with 12 ounces of contaminated water (one to test with and one to be evaluated with). The team will be required to filter the water and return the filtered water to the instructor. The instructor will evaluate the filtered water for impurities. The final score will consist of combined scores for product design, function, and the estimated number of impurities or particulates remaining in the water sample.

Materials

- Sand
- Miscellaneous plastic jugs
- Plastic straws
- Charcoal briquettes
- Cotton
- Paper and cardboard stock
- Masking tape
- Hot glue gun and glue
- Miscellaneous fabric
- Stop watch for product testing

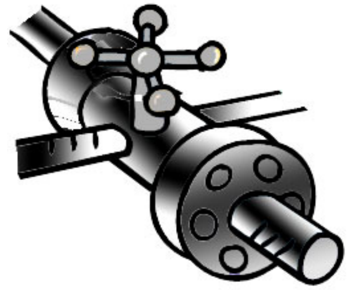
Evaluation

Team scores will be determined by high scores across the three (3) evaluation components listed below. The combined score will be recorded as the team score.

CRITERIA	30 points	20 points	15 points	10 points
Product Design	Clear evidence of extensive design, troubleshooting, testing, and refinements (used the design loop).	Clear evidence of design, troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence that the team used any features of the design loop.
Product Function	Product functions exceptionally well	Product functions well and did filter the water to some degree	Product operates, but does not function very well	Fatal flaws in product. Does not function properly or is unsafe
Particulates	Filtered water sample contained few remaining particulates	Filtered water sample contained some remaining particulates	Filtered water sample contained numerous remaining particulates	Water did not appear to have been filtered or had multiple remaining particulates.

Team Name: ____________________________________ Total Score: _________

PIPELINE TRANSPORTATION



Scenario

When asked to describe transportation, most people consider planes, trains and automobiles. However, stationary transportation systems are another vital segment of the transportation field. One of those stationary transportation systems is the pipeline. Pipelines move millions of gallons or cubic feet of fluids (gasoline, water, waste water, natural gas, etc) every day. Without pipelines, we might still be carrying our drinking water from the stream to the house in buckets. Worse yet, we might be removing waste water from our homes with buckets.

Task

Build a model pipeline system that will transfer water from one container to a second and then back to the first container. The two containers must be placed at least two (2) feet apart and the water must completely flow from one container to the other and then (on command) back again.

Design Criteria

To adequately answer this design problem, your team will need to strictly adhere to the following design criteria:

- Design teams must use only materials and tools supplied at the beginning of the design challenge.
- Although gravity flow may be used during one leg of the transfer, this technique may not be used on both legs to the water transfer.
- The pipeline system must be controlled (e.g., switching devices, flow gates, etc.)
- Design teams will only be allowed to remotely control (from a distance) the pipeline system after the initial flow has begun (no lifting or rearranging containers after the flow has begun).
- The pipeline system must not leak or spill water on the floor surface.
- The transfer from one container to another and back again must be completed in less than five (5) minutes.

Testing

After construction is completed, each team will be provided with 12 ounces of water. The team will be required to insert the water into one container, transfer that water to the second container, and then (on command) transfer the water back to the original container. The final score will consist of combined scores for product design and function.

Materials

- Clothes pins
- Various barbed fittings (centrally located for all competitors – pick any 2)
- Plastic hose
- Plastic straws
- Masking tape
- Hot glue gun and glue
- Two plastic bottles with caps
- Air pump (to be shared by all competitors)
- Miscellaneous cardboard

Evaluation

Team scores will be determined through the use of the scoring rubric below. The combined score across the two criteria will be recorded as the team score.

CRITERIA	50 points	40 points	30 points	10 points
Product Design	Clear evidence of extensive design, troubleshooting, testing, and refinements (used the design loop).	Clear evidence of design, troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence that the team used any features of the design loop.
Product Function	Product functions exceptionally well and transfers water in both directions	Product functions well and transfers water marginally well.	Product operates, but does not transfer the water in an efficient manner.	Fatal flaws in product. Does not function properly or is unsafe

Team Name: ___________________________________ Total Score: _________

BEWARE OF SLOW MOVING VEHICLES (3-4 DAYS)

Scenario

Most technology students have experienced the chance to build some sort of vehicle in technology education classes. These problem solving activities typically require the student to build a vehicle that will travel at the greatest rate of speed over some type of test track. This problem is going to require your team to consider gear ratios, distance and speed in a different way.

Task

Using the materials supplied, build a scale-model vehicle that will travel at the lowest rate of speed possible. When completed, your vehicle will be tested on an elevated platform. The successful vehicle will be the one that travels continuously for the greatest amount of time without falling from the elevated table surface. This will force you to consider gear ratios, distance, guidance, and speed.

Design Criteria

To adequately answer this design problem, your team will need to strictly adhere to the following design criteria:

- Design teams must use only materials and tools supplied at the beginning of the design challenge.
- The completed vehicle must operate freely (without human intervention) once movement has begun during testing.
- Teams may not alter the testing platform in any way (temporarily or permanently).
- The completed vehicle must remain in motion during the testing phase (if the vehicle fails to move in any direction for more than 1 second, testing will be considered complete and a final test time will be recorded)
- If a vehicle falls from the testing platform at any time during the testing phase of the contest, a final test score will be recorded.
- Teams will have three (3) trials on the testing platform. The highest score (time) will used as the final score for the team.
- Teams will not be allowed to make significant modifications to the vehicle during testing. Each team will have only three (3) minutes between trials on the testing platform.
- Teams will be required to submit vehicle sketches (labeled prominently with the team name) prior to testing.

Materials

- Miscellaneous wood
- Plastic straws
- Balloons
- Rubber bands
- Tongue depressors
- Wheels/axles
- Paper and cardboard stock
- Mousetraps
- Electric motors
- Assortment of gears
- Masking tape
- Hot glue gun and glue
- Battery
- Stop watch and table for vehicle testing

Evaluation

Team scores will be determined by high scores related to the amount of time that the vehicle remained in motion. Teams will have three trials. The highest score will be recorded as the team score.

A MOVING EXPERIENCE

Scenario

Almost every task performed by humans is accomplished by using various combinations of the six simple machines. The six simple machines include: The lever, pulley, wheel and axle, inclined plane, wedge, and screw. Recently, your technology teacher has mentioned that it is difficult to demonstrate these machines to students and you would like to help.

Task

Using as many of the six simple machines outlined above and described on the following page, build a device that will (using the least possible force) lift a 25 pound weight from the floor to a height of six inches. Additional points may be earned by the team for successfully lifting additional weight.

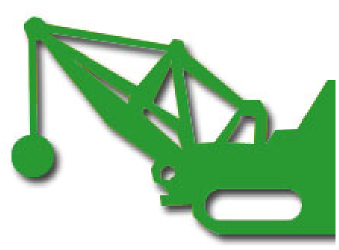
Design Criteria

To adequately answer this design problem, your team will need to strictly adhere to the following design criteria:

- Design teams must use only materials and tools supplied at the beginning of the design challenge.
- Completed prototypes must (at a minimum) use three simple machines.
- Completed prototypes must be submitted with a credible sketch of the device.
- Completed prototype must be safe during product testing.
- Completed prototype must be capable of lifting the weight to a height of six inches (from the floor) and hold for at least two (2) minutes
- Completed prototype must include labels for each of the simple machines (**note: simple machines may be used more than once**).
- Completed prototypes must utilize the least possible input force to accomplish the task.

Materials

- Miscellaneous wood
- Screws/nails
- Paper and cardboard stock
- String/Twine
- Pulleys
- Bolts/nuts
- Glue guns and glue



Simple Machines

The six simple machines are the primary machines that can be found in even the most complex machines. The 6 simple machines are:

- **Pulley:** This simple machine reverses the direction of a force, and when multiple pulleys are utilized in conjunction with each other, less force is required to lift an object. The one downside of using multiple pulleys is that the rope's end must move across a longer distance than the object being lifted.
- **Wheel and Axle**: Setup such that the axle is connected to the center of the wheel. This allows the wheel to be set in motion once the axle starts to turn.
- **Lever:** This machine is such that when downward motion is applied at one end, upward motion is created at the other end.
- **Inclined Plane:** This machine allows for an object to be moved vertically without being lifted.
- **Wedge:** This machine allows motion from objects such as hammers to be transferred into a breaking, cutting, or splitting motion.
- **Screw:** This simple machine is crafted in such a fashion to where a groove that wraps around a central material in the shape of a spiral. When placed into a slot that fits the screw's groove and shape, this allows for rotary motion.

Evaluation

CRITERIA	25 points	20 points	15 points	10 points
Input Force Required	The product required less than 25 pounds of input force to operate	The product required less than 50 pounds of input force to operate	The product required less than 75 pounds of input force to operate	The product required more than 75 pounds of input force to operate
Product Design	Clear evidence of extensive design, troubleshooting, testing, and refinements (used the design loop).	Clear evidence of design, troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence that the team used any features of the design loop.
Product Function	Product functions exceptionally well and achieves needed height	Product functions well and achieves needed height, but does not remain at height for two minutes	Product operates, but does not achieve needed height or meet time requirement	Fatal flaws in product. Does not function properly or is unsafe
Six Simple Machines (labeling, sketches)	Demonstrated a great deal of knowledge related to six simple machines	Demonstrated some knowledge of six simple machines	Exhibited only slight understanding of six simple machines	Clearly did not understand the basic principles of the six simple machines

DEVELOPING "TEACHER-MADE" ENGINEERING DESIGN PROBLEMS

Now that your students have completed some introductory engineering design problems, you may want to develop additional activities that encourage creativity, cooperation, and problem solving. One of the most difficult, yet important, skills that a teacher must master is the ability to be critical and fair with the work of others. Mediocrity flourishes when teachers are afraid of being critical. And, in truth, teachers are not fair to their students when they are unduly non-critical. The criteria listed below are designed to allow you to critically analyze problem solving activities designed for the technology education classroom. Use these criteria when evaluating commercially available problem solving activities, those developed by fellow teachers, or problem solving activities of your own creation. High-quality problem solving activities exhibit the following characteristics:

Rationale

All quality lessons contain a rationale. A rationale provides the student with a reason for completing the lesson. It also provides the student with the answer to the question: "Why do I need to know this?"

- Does the engineering design problem include a rationale?
- Could I defend this problem solving activity if a parent asked, "why is my child doing this activity?"
- How could the rationale, included with this problem solving activity, be improved?

Material Lists

All problem solving lessons should contain a list of materials available for the student. This list of materials should contain all materials that the students will be able to use in their solution to the given problem. By providing the list of materials necessary, both the teacher and the student can adequately prepare for the activity.

- Does this problem solving activity contain a list of materials?
- If so, does this list seem reasonable? (could the problem be solved using this list?)
- What materials could be added to the list to make the problem more reasonable?

Scenario

Problem solving lessons should contain some type of background information that puts the problem in context. This background information could be factual or it could be in the form of a fictionalized story or scenario. The background information portion of a problem is used to entice the student into the problem (to intrigue the student).

- Does this problem solving lesson include background information?
- Is this background information written in such a way as to entice the student into wanting to continue this activity?
- How could the background information be re-written to be more interesting for students?

Content

Many times, teachers develop problem solving lessons that are fun and interesting but, really don't have a point. In other words, the lesson is interesting but, students don't really learn what the teacher had intended. It is imperative that problem solving lessons cause students to learn new content, increase their knowledge of previously learned information and/or apply knowledge that they have previously learned.

- By solving this problem, will students have the opportunity to learn new information or build upon previously learned knowledge?
- How could the problem solving activity be re-written to include a greater emphasis on learning new knowledge or building upon existing knowledge?
- What do you think the students will learn by completing this problem solving activity?
- What do you think the teacher intended for the students to learn by completing this lesson?

Parameters

Problem solving activities should contain parameters that are included to make certain that students stay within the desired learning objectives. Parameters can include lists of acceptable materials, appropriate strategies, how large or small their solution may be, time limits, design restrictions, etc.. Parameters are a helpful way of keeping the problem to a manageable size.

- Does the given problem solving activity contain parameters for the student?
- Are these parameters appropriate and feasible?
- Are there additional parameters that should be added?

Evaluation

When students are asked to complete a problem solving activity, it is imperative that the know, in advance, how they will be evaluated. Problem solving activities usually include specific information about the procedures that will be used to determine whether the solutions developed by the students meet the desired outcome specifications.

- Does the given problem solving activity include an evaluation component?
- How could this evaluation component be re-written to more clearly reflect the purposes of the lesson?

Summary

Remember, one purpose of a problem solving activity in technology education is to allow students the opportunity to apply the content being delivered in the classroom. An additional purpose for using the problem solving method (or any other method) of instruction is to extend the knowledge and capabilities of the students involved. Problem solving activities should be summarized, evaluated, and synthesized by the student. This summarization allows the student the opportunity to reflect upon the activity and categorize this newly learned information. Quality problem solving activities contain ample opportunities for student or teacher summarization. This summarization may be accomplished by providing the teacher or student with a series of probing questions, like:

- What did you like the most about this lesson?
- How could've your solution to the given problem been improved?
- How could've you used solutions from classmates to improve your final solution?
- What additional materials would have been helpful in solving the given problem?

STARTERS: ENGINEERING DESIGN PROBLEM IDEAS

The following problem solving/cooperative learning activities are presented in draft form to serve as a launch point for continued development. Use the guidelines listed above to create well-designed problem solving activities that meet the needs of your students.

Force and Friction

Require students to design an object (that weighs at least 2 grams) that can travel 10 feet or more on a horizontal surface--without assistance from the builder. Students will be evaluated based on the idea and how far the object travels. This problem could also be designed to include a competition where students try to travel the distance at the greatest rate of speed.

Mechanical Trap

A northern Illinois city has become overpopulated with stray cats. The animals are becoming a nuisance to the people in the city and the population must be decreased. Since you are the President of the local animal rights group, you must find a human way to capture and relocate the animals. The city engineer has ask your team to design a trap that will capture as many cats as possible without causing physical harm. The traps must not be man or electric powered, but can and should be fully mechanical. Your trap will be evaluated trough the utilization of a mechanical wind-up toy. Note: The activity should provide a list of materials and parameters within which the students must work - i.e. size of trap.

Mechanical Conveyor

A major concrete company's main conveyor for transporting coarse aggregate to the weighing scales has broken down. It will take approximately two hours to be up and running again. Design a model of a device that can be used to transport the aggregate to the scales until the conveyor is repaired. You will only be allowed to use readily available materials to develop this device (see materials list).

Portable Bridge

A small island in the Caribbean has a great number of water ways carving the landscape. In fact, the island has so many water ways, it is impossible to travel around the island using a land vehicle alone. The local island government will not allow any bridges to be built on the island because they feel it will harm the beauty of the island and harm wildlife. Design a portable device that every person on the island can use in order to cross the water ways on their own. The devise should be simple enough so that the people of the island can build it themselves if needed. The devise should enable them to travel both on land and on water.

Extra Hands for Wheelchair Users

Individuals who use wheelchairs often have a difficult time reaching the door to retrieve items that may have been dropped. Design a device that will assist individuals who use wheelchairs, in picking up items dropped onto the floor. The cost of the finished product should not price itself out of the market and it should be light in weight so that it is easy to carry. Performance will be based on the ability to pick up a checkbook and a set of car keys.

Catch the Ball

The local fire chief has ask you to design a device that can be used to rescue large dogs and cats from multiple level buildings. He has requested that you develop a model of the device for a demonstration. Build a device that will capture a bowling ball after being dropped from the top of a ten foot step ladder. The device must catch the ball and prevent it from breaking. Due to weight and size limitations, your device must be no larger than 2 cubic feet and weigh no more than 8 pounds. The device must operate without the assistance of humans—in fact, no human can be within ten feet of the device during testing.

The Morning Paper

Mr. Jones is self-employed and relies heavily on stocks and bonds information from the morning paper. There are no mail boxes on this street since a recent rash of mail box bombing incidents-- the paper boy simply throws the paper on the front porch. Before Mr. Jones can get to his morning paper, Mr. Smith's dog carries it off and shreds the paper to pieces. Since the paper boy has such a long route, there is no possible way he has enough time to put the morning paper inside the screen door. Develop a device to keep Mr. Smith's dog off the front porch of Mr. Jones.

You cannot build a mailbox for the paper. The student must develop a device to keep the dog off of the front porch. The device can be no larger than 2 cubic feet and cannot cost more than $2 for materials.

Ball Elevator

Build a device that will hold a golf ball as high off of a desk as possible. The ball has to be hanging over the edge of the desk so it can be measured from the ground up. It must remain in position for at least one minute.

Send a Message

Students need to learn to transfer messages from one person to another. Messages are not always transferred orally or in writing. Design a device that can relay a message to a student in another room and back. You will be provided with two light bulbs with sockets, one hundred feet of wire, two on/off switches, a battery, and a piece of paper and pencil. You will be provided with five minutes together to decide on the codes necessary for sending and deciphering messages.

Mars Colony

The year is 2050 and the first colony is being started on the planet of Mars. You're an engineer for a company that is bidding for the contracting job on the Mars 2060 Project. You have been asked to design a model of a family dwelling that will house at least two adults and two children. A three dimensional model of your creation will illustrate an environmentally self-supporting habitat, with the exception of food manufacture. For example, your design must illustrate how the family unit will be heated or cooled, ho power will be generated, how waste will be managed, etc. You are expected to create a model and prepare an oral presentation for the U.S. Space Station Board of Directors. You will need to investigate various forms of alternative power sources, including: Solar, thermal, water, natural gas. Students will also need to investigate appropriate waste management systems and water treatment processes.

Ergonomics

Recent research has indicated that long-term computer usage can be physically disabling. Long-term computer users can develop a wrist condition called Carpal Tunnel Syndrome. Design a device than can be attached to a keyboard that eases the stress on the wrists. The device cannot be any larger than two cubic feet, cost no more than $2.00, and must be constructed of commonly available materials.

Ship Wreck

After a massive ship wreck, you have become stranded on a deserted island with 24 other people. As a natural leader, you immediately take charge. You decide that a boat must be built. There are only a few materials that are available for your team to construct a floatation type of vehicle. Although you have great confidence in your abilities, a number of the other people do not. They request that you construct a model of the boat and test it prior to the construction of the full-scale vessel. Create a boat that will carry a payload of 24 golf balls for a distance of five feet in less than two minutes.