Wild about learning

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Hands-on Engineering

Intermediate workshop

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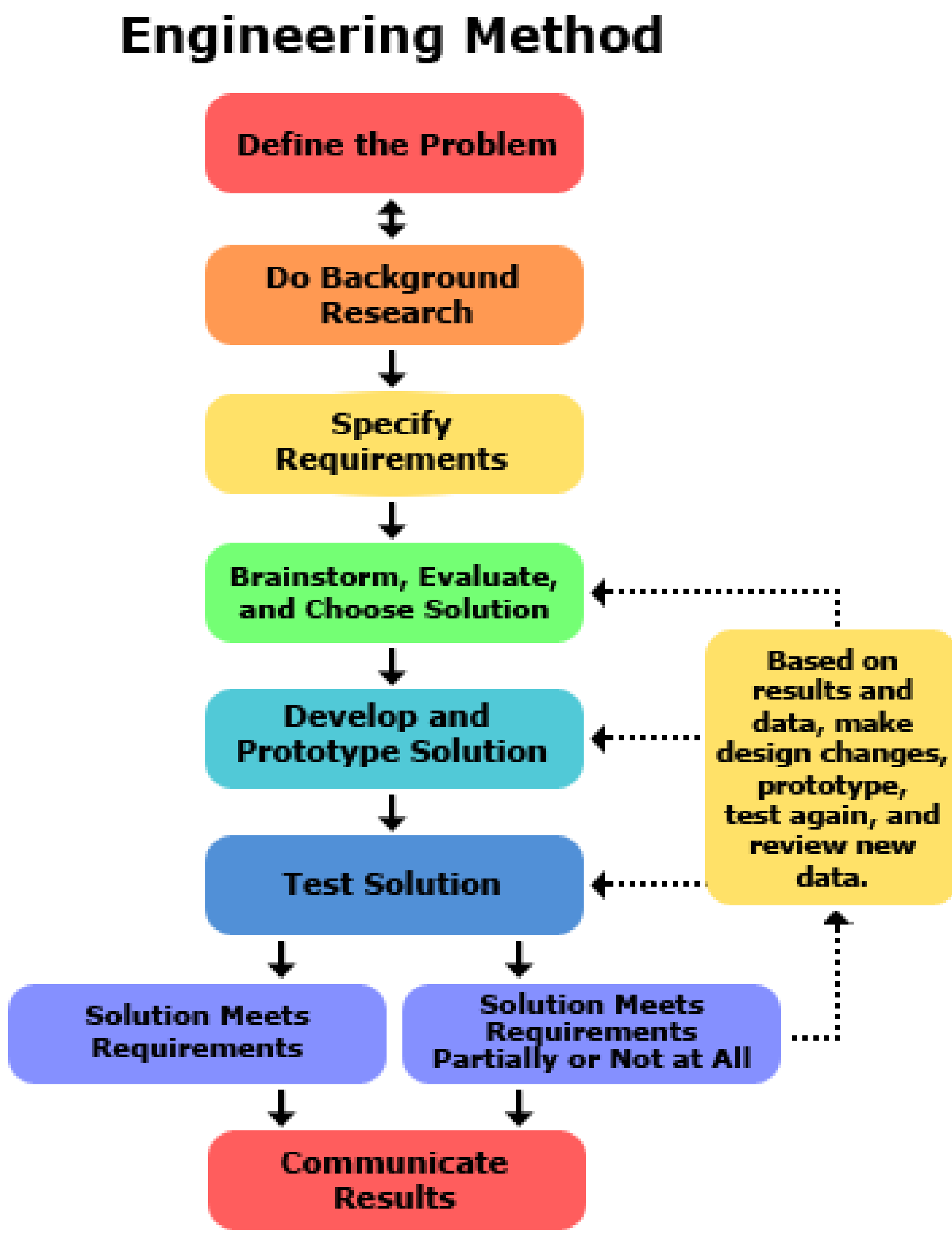
The engineering design process is a series of steps that engineers follow to come up with a solution to a problem. Many times the solution involves designing a product (like a machine or computer code) that meets certain criteria and/or accomplishes a certain task.

The steps of the engineering design process are to:

- **Define the Problem**
- **Do Background Research**
- **Specify Requirements**
- **Brainstorm Solutions**
- **Choose the Best Solution**
- **Do Development Work**
- **Build a Prototype**
- **Test and Redesign**



Engineers do not always follow the engineering design process steps in order, one after another. It is very common to design something, test it, find a problem, and then go back to an earlier step to make a modification or change to your design. This way of working is called iteration, and it is likely that your process will do the same!

Define the Problem: The engineering design process starts when you ask the following questions about problems that you observe:

Do Background Research: Learn from the experiences of others — this can help you find out about existing solutions to similar problems, and avoid mistakes that were made in the past. So, for an engineering design project, do background research in two major areas:

Specify Requirements: Design requirements state the important characteristics that your solution must meet to succeed. One of the best ways to identify the design requirements for your solution is to analyze the concrete example of a similar, existing product, noting each of its key features.

Brainstorm Solutions: There are always many good possibilities for solving design problems. If you focus on just one before looking at the alternatives, it is almost certain that you are overlooking a better solution. Good designers try to generate as many possible solutions as they can.

Choose the Best Solution: Look at whether each possible solution meets your design requirements. Some solutions probably meet more requirements than others. Reject solutions that do not meet the requirements.

Develop the Solution: Development involves the refinement and improvement of a solution, and it continues throughout the design process, often even after a product ships to customers.

Build a Prototype: A prototype is an operating version of a solution. Often it is made with different materials than the final version, and generally it is not as polished. Prototypes are a key step in the development of a final solution, allowing the designer to test how the solution will work.

Test and Redesign: The design process involves multiple iterations and redesigns of your final solution. You will likely test your solution, find new problems, make changes, and test new solutions before settling on a final design.

Communicate Results: To complete your project, communicate your results to others in a final report and/or a display board. Professional engineers always do the same, thoroughly documenting their solutions so that they can be manufactured and supported.

** Adapted from Science Buddies (http://www.sciencebuddies.org)*

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Careening Coaster Challenge

In this experiment, you will be challenging your students to construct the fastest roller coaster in class with one loop or spiral, one hill at least 5 cm high at the peak, and a 45-90 degree turn out of a handful of simple materials.

Materials:
6 feet of tubing
3 binding clips
2 paper clips
One BB
One ring stand
Timer/stopwatch
2 sheets of copy paper

Procedure:

1) Choose which path is best for your students to complete this challenge. It would be best to have them design a solution first and to explain this design to the group/class before running the experiment. For advanced students, restrict the testing of their rollercoaster until all student groups have collaborated, built, and drawn their design.
2) Regardless of how you approach this problem, all times collected from these experiments should be published for the class to observe along with the design ideas.
3) After communicating results, allow the students to choose the best design and rerun their experiment.
4) Rules for the students:
    - Roller coasters must be attached to the ring stand
    - Coaster must be self-starting (no initial pushing)
5) Have the students draw their best design to scale and include the following information:
    - Height of each hill (including the start and end points)
    - Maximum potential energy (PE)
    - Maximum kinetic energy (KE)
    - Areas of decreasing potential energy and increasing kinetic energy
    - Diameter of the loop or spiral
6) Instruct the students to calculate the mass of the BB, the potential energy of the BB at the two highest points on the coaster, its average run time after four trials, and the average velocity (speed) of the BB. The following worksheet may assist you.

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Names: ______________________________________ Date: ________________

Careening Coaster Student Worksheet

Draw your roller coaster to scale on a sheet of graph paper. Be certain to indicate your scale in the lower corner of the drawing. When you are finished it should have the following labels:

- Height of each hill (including the start and end points)
- Maximum potential energy (PE)
- Maximum kinetic energy (KE)
- Areas of decreasing potential energy and increasing kinetic energy
- Diameter of the loop or spiral

What is the mass of the BB?

Calculate the PE at the two highest points of the PE in the coaster. Remember: gravity=9.8 m/s^2

After four trials, what was your average time?

1st run ____________

2nd run ____________

3rd run ____________

4th run ____________

Average run time ________________

Calculate the average velocity (speed) of the ball. Be certain to include units.

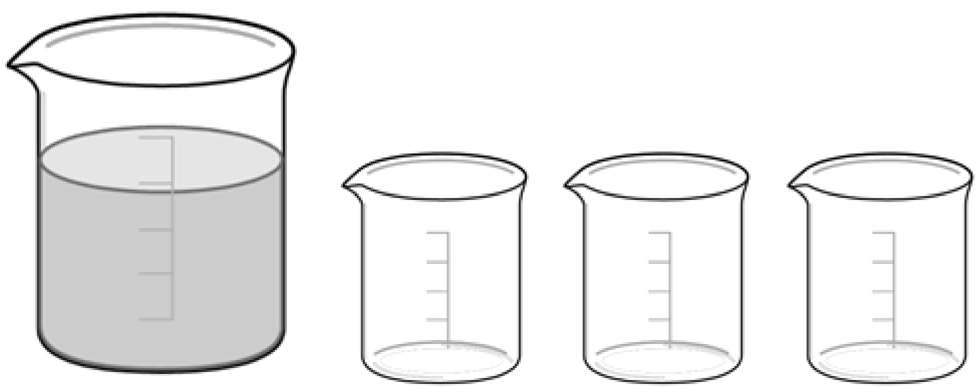
Reverse Engineering Challenge – Water to Juice and Back Again

In this experiment, you will demonstrate a specific series of chemical reactions in front of your students and will ask them to recreate your performance.

Materials:
2-3 gallons distilled water
One large clear pitcher or beaker
Three small clear glass/plastic containers
Ammonia
Vinegar
Phenolphthalein solution

For each group of students:
Four glass/plastic cups
Eyedroppers and containers for ammonia, vinegar, and phenolphthalein solution
Distilled water

Procedure:
The following image will help you prepare the solutions and run through the demonstration:



Cup 1 Cup 2 Cup 3 Cup 4

Preparation: (Do not allow the students to see you do this!)
Fill Cup 1 halfway with distilled water.
Add one capful of ammonia into the distilled water.
Add a little more vinegar in Cup 4 than the pitcher has ammonia.
Place 3-5 drops of phenolphthalein into Cup 3.

Demonstration:

1) Pour the contents of Cup 1 into Cup 2 (Cup 2 will remain clear).
2) Pour the remainder of Cup 1 into Cup 3 (Cup 3 will turn pink).
3) Pour Cup 2 back into Cup 1 (Cup 1 will remain clear).
4) Pour Cup 3 back into Cup 1 (Cup 1 will turn the same color of pink).

5) Pour Cup 1 into Cup 2 (Cup 2 will remain pink).
6) Pour Cup 1 into Cup 3 (Cup 3 will remain pink).
7) Pour Cup 1 into Cup 4 (Cup 4 will turn clear).
8) Pour Cup 2 back into Cup 1 (Cup 1 will remain pink).
9) Pour Cup 3 back into Cup 1 (Cup 1 will remain pink).
10) Pour Cup 4 back into Cup 1 slowly (Cup 1 will turn clear).

Student rules:

- Student groups are to be encouraged to take very good notes about what the demonstrator is doing.
- They will be asked to perform the same demonstration to the instructor.
- No more than three drops of any fluid can be placed within their cups.
- All cups must be rinsed with distilled water prior to every trial. Tap water will likely spoil the results.

Hints:

You may want to help the students by informing them that Cup 1 contains a solution of water and one of the three chemicals. Furthermore, you can also help them by asking how they could determine what chemical causes the phenolphthalein to turn pink and which one can make it turn back to clear.

Simulating the most frightening form of defense imaginable

Students will be challenged to create a model of phagocytosis among white blood cells.

Materials:
1 plastic shopping bag
1 pair of scissors
15 cm of string, large rubber band, or tape
4 pieces of wrapped candy, peanuts, raisins, or other item

Procedure:
With the materials in hand, the students are challenged to get the candy into their bag according to the following rules:

- The candy must enter through a solid part of the bag.
- The inside of the bag may not be directly open to the external environment (which means you cannot simply drop the candy into the bag.)
- The candies entering the bag must remain clustered together.
- You may work with your hands in the bag to act as the inside of a cell.
- All materials must be used

Explanation:
White blood cells are known as phagocytic cells due to their ability to consume foreign pathogens within the blood. Within the lymph nodes are specific types of phagocytes called **macrophages** which are very efficient at engulfing and destroying pathogens that find their way into the lymphatic system.

The main problem that one has to consider is how a cell such as a macrophage can ingest such large objects without the use of a mouth or other cavity to ingest such materials. Imagine having to ingest a beachball – how could it be done?
Macrophages utilize the process of **phagocytosis** in which the foreign object is engulfed entirely by the cellular membrane of the macrophage itself. This object is brought into the macrophage surrounded by a pinched-off area of its own cellular membrane. The macrophage's membrane is never opened up to the outside environment. If this were to occur, it would likely perish.

This activity is very similar to the actions of a macrophage within the lymph nodes of our bodies. The pictures below will help you solve the puzzle...

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