

OPERATION CATAPULT
Session I, 2008

Group Projects

One of the goals of “Operation Catapult” is to provide an opportunity to investigate some physical phenomenon or opportunity about which you may not have much knowledge — an experience in applying the “scientific method” of investigation or the design process. Such a study may require you to learn some topic of mathematics you have not had. It may involve some fundamental physical principles of which you are not aware. It will require that you learn something “on your own” and arrive at meaningful questions to ask (of other students or staff members). Your project will almost certainly acquaint you with occasional feelings of (temporary) frustration which accompany research and design.

In order to derive the most benefit from this experience, you are strongly encouraged to choose a project which interests you but which is not the same as something you may have done before (either for a science fair or as a hobby). Groups of four are strongly recommended for all projects. There will be no groups of less than three or more than five. Please note that two students from the same school are not allowed to work on the same project.

The attached pages contain brief descriptions or questions concerning a number of physical phenomena, each of which is a broad topic that could lead to extensive investigation. These will be discussed on the first day of Catapult. You are asked to read these so that you can submit four topics (in order of preference) which would be most interesting to you. One topic (your first choice, we hope) will be assigned to you and three other students as a group project. You will also be asked to list the names of other students you would like in your group.

If you would like to pursue a project not on this list, discuss your idea with a faculty member. If it complies with the intent of the Catapult program, is feasible, fits the time available, if you can find a couple of other students who are also interested, and if you can find a faculty member to supervise the project, you may be permitted to work on that project. You are encouraged to choose your four projects from different areas. Project assignments will be made according to faculty availability as well as student interest. Therefore, you may not get your first choice if too many groups want to work in the same area.

The procedure to be followed in the investigation is:

1. Study the phenomenon or opportunity, including a discussion with others and a library search, to determine what you can learn about it.
2. Determine what properties and/or measurements you need to investigate.
3. Write a brief description of the problem and the proposed experiment, including an explanation of what you expect to do with the experimental results.
4. Explain your ideas to a faculty member and get her/his approval of the experiment and permission to proceed.
5. Do the described work, analyze results, and arrive at conclusions and ideas for further investigation.
6. Prepare a typed group report on your project using one of the word processors. (Instruction will be given on the proper format for the report and abstract.)
7. Each group will give a poster presentation on its project on the last day of Catapult. For this presentation, you may use charts, graphs, photographs, or other visual aids which you believe will add to the presentation in addition to the project itself. During the poster presentations, each student (not in the reporting group) will fill out an unsigned evaluation form on the content and presentation of the project. These evaluations will be available for review late in the afternoon on the last day.
8. Each student will receive a copy of the abstracts of all written reports. Since such a duplication job requires time, the abstracts must be submitted no later than the time stated in the Catapult schedule.

The following projects are being offered by faculty mentors this year:

1. ANALYSIS OF BEAMS

How much material can be removed (and where) from a rectangular-shaped beam without changing the strength of the beam by more than, say five percent? Why? What shape gives the strongest beam and why? What is meant by "strength"? This project provides an understanding of the factors which determine the design of beams and leads to determination of a formula for the deflection of beams of various shapes (I-beams, box-beams, etc.). (Algebra and elementary properties of logarithms are used for the mathematical analysis of the data.)

2. TRUSS ANALYSIS

The truss, a triangular arrangement of two force members, is one of the most versatile mechanical systems known to man. This project focuses on the design, construction, analyzing and testing (to failure) of lightweight balsa wood trusses. It provides an excellent introduction to engineering mechanics (statics) as well as the ground work for many subsequent design courses.

3. COMPUTER PROGRAMMING USING PYTHON

Python is a powerful programming language that is easy to learn, and it is rapidly growing in popularity both as a first language and as a language in which to accomplish complex tasks. We encourage two kinds of students to choose this project. First, if you have never programmed before, this introductory course is for you! We will spend the first few days doing classroom and lab instruction on the basics of Python programming, aimed at students with little or no programming experience. Second, if you already know another programming language, but your high school doesn't offer Python, this would be a great opportunity to learn this language; you may work at a faster pace than the beginning programmers if you wish. Any of the following programs are feasible to implement in Python, or you can propose your own.

If you sign up for the Python programming project, it is okay to delay the choice of the specific kind of program your team will write after you have learned more about Python's capabilities. You may even delay team selection if you wish. Once our project sessions begin and everyone is learning Python, you'll be able to team up with other students whose interests and programming experience (or lack of it) are similar to yours. Note that all of the software tools we will use are free, so it will be easy for you to take your project home and continue to enhance it after Catapult ends.

- Strategy Game — Build a computer program that allows users to play your favorite board game, such as Connect 4, Boggle, or Scrabble. Then add a computer player who is good enough to defeat most human players. Perhaps we can have multiple computer players battling each other.
- Action Game — This is the most common Catapult computer programming project. Build a computer program that implements a classic game like Asteroids, PacMan, Frogger, or Space Invaders. Or make up your own game! Students with prior programming experience may want to incorporate networking so that multiple players can participate remotely.
- Puzzle Solver — Write a program to aid someone playing a game or solving a common puzzle, such as Scrabble, Jumble, Sudoku, or Cryptquip.
- Search Engine — Explore the strategies that various web search engines use to index a large number of web pages so that rapid searches can be done. Write your search engine to incorporate one or more of these strategies.
- File Compression Techniques — When sending large amounts of information across the internet, it is crucial to be able to compress a file before sending it, and then to uncompress it at the other end. This project will explore file compression techniques and produce a computer program that implements one or more of these techniques.
- Simulation of Random Processes — Many processes in nature follow certain patterns, but with enough seemingly random elements so that the behavior is unpredictable while remaining within certain constraints. The Markov chain algorithm provides a fascinating simulation of this mechanism, allowing us to generate random sentences in the style of some work of literature.
- Auction Site — Write a client-server program that allows people to advertise items for sale, to bid on items, to provide feedback on good and bad transactions with other users, etc.
- Database Application — Learn to write a Python program to create and maintain a database. Examples might include cataloging your CD collection, organizing major league baseball statistics, managing your "little black book" of romantic interests or your school's grade information for current students, or perhaps simulating an "on-line store" or an on-line catalog of information about your favorite subject.
- Spelling Checker / Suggester — When your document contains a misspelled word, many spell checkers provide suggestions of alternate words. Do you ever get frustrated when your misspelling is very simple (you left out a letter, added an extra letter, or transposed two adjacent letters) but the computer's list of suggestions does not include the word that you meant to use? Perhaps your checker/suggester can do better!
- Make up your own program — Design and write an imaginative, exciting computer application that may dazzle your friends back home. It can fit one of the above categories, or be something entirely different that you'd like to explore.

4. WIND TUNNEL TESTING

Use a wind tunnel to measure the lift, drag, and pressure distribution on objects including aircraft, wings, spacecraft, automobiles, sports balls, etc. Use existing models or design and build your own.

5. SUBMARINE

Design, build, and test a model submarine. Can you make it travel forward & backward, turn, and change depth? With proper advance notice, the SRC pool is available for testing.

6. WASTE HEAT RECOVERY

Design, build, and test a system which can use the energy in a “used” fluid, such as hot soapy water leaving a dishwasher, to heat fresh water. Predict energy savings and financial feasibility.

7. SOLAR COOKER

Design, build, and test a solar cooker capable of heating 1 quart of cold water to 80 °C in 30 minutes. Investigate methods to build this device with materials commonly available in a third world country of your choice. Prepare instructions for building and using such a device.

8. ROCKET MOTORS

Use a strain gauge and high-speed data acquisition system to measure the variation of thrust with burn time for model rocket motors. Design and build a test stand to conduct these tests.

9. WIND TURBINE

Design, build, and test a small-scale wind turbine to generate electricity. Use a wind tunnel to investigate several wind turbine shapes and sizes. Document the power produced as a function of fan diameter and wind speed.

11. BICYCLE AERODYNAMICS

Find the aerodynamic drag, rolling resistance, & power required for various configurations of a person riding a bicycle. Report results relevant to a bicycle commuter and a bicycle racer. Optional: design, build, & test a fairing for the bicycle.

12. A BETTER BATTERY

Batteries are engineering marvels and represent the coupling of chemistry & engineering design. What are the components of a battery? Can a better battery be made using other materials such as aluminum and air? What about fuel cells?

13. RECOVERY AND RECYCLE OF MATERIALS

Our society needs to develop more concern for re using materials, as opposed to the current practice of “use it and toss it away.” There are several areas where we could study processes for the recovery and re use of key materials: (a) waste motor oil, (b) waste antifreeze, (c) used tires, (d) wood waste (sawdust, chips, bark), (e) gob piles (from surface mining), (f) fly ash, (g) municipal refuse, (h) household batteries (D cells, not auto batteries), (i) plastics. It will be important to determine the economic feasibility of the proposed process. (A course in chemistry is desirable.)

14. CHEMICAL SYNTHESIS

How is a particular substance prepared, characterized, and purified? Can a particular substance be prepared several different ways and can these ways be compared?

15. INVESTIGATING ENZYMES – BIOLOGICAL CATALYSTS

Enzymes are proteins which are selective in their speeding up of biochemical processes. What affects these materials?

16. POLYMER SYNTHESIS

How can useful polymers like plastic or nylon be made? What factors affect the polymer’s properties? What new property for a polymer might be developed?

17. FERROFLUIDS

Ferrofluids are liquids with magnetic properties. How can these materials be synthesized and used?

18. SUPERCONDUCTIVITY

When a material exhibits “resistanceless” current flow, it is considered to be a superconductor. These materials usually require very low temperatures (around 77 K which is the boiling point of liquid nitrogen) in order to exhibit superconductivity. How can these materials be made, and can variations on their synthesis lead to better superconductors?

19. MICRO-MANUFACTURING

With the current trends of miniaturizing electromechanical devices there is a great interest in investigating faster and cheaper ways of manufacturing the micro-components that are required. This project will investigate how the properties of a metal change with specimen size.

20. FRICTION FORCE MODEL

When studying mechanics we model friction as being related to the normal force between the two objects multiplied by a friction coefficient. The coefficient accounts for the types of materials in contact. Our model does not consider any effects due to surface roughness, contact area, relative velocity of the surfaces, etc. An interested group could design and conduct a series of experiments which test the validity of this model. If a correlation of the friction force with other parameters is noted, an alternate model for friction should be proposed.

21. COEFFICIENT OF RESTITUTION

Probably you are aware that work (or energy) is required to deform a material – squeeze a ball, deflect a diving board, stretch a spring, etc. But how much of this energy can be retrieved when the deformed object is released? The ratio (retrievable energy)/(input energy) is called the coefficient of restitution. Questions which may involve a study of this ratio include: (1) If this ratio is less than one, what happened to the remaining energy? (2) If a tennis ball when dropped onto concrete from shoulder height will bounce 4 ft. high, will a concrete ball dropped onto rubber also bounce as high? Why? (3) Can the quality of various brands of ping pong balls, golf balls, and handballs be determined by comparing their coefficients of restitution? How about bowling balls?

22. RAPID PROTOTYPING

Machines have been developed that can take a 3-D model from a Computer-Aided Drawing (CAD) program and produce it in plastic. The objective of this project is to explore the capability and characterize the performance of our rapid prototyping equipment. Students will learn to use Solid Edge to describe their objects. The actual production of parts will be limited.

23. HEAT TREATMENT OF STEELS

One reason steel is a popular structural material is that it can be heat-treated to obtain desired properties (e.g. hardness or strength). As part of this project you will study the heat treatment of steels. You will also design and perform an experiment to illustrate the changes in properties of steel caused by heat treatment.

24. WATERWHEELS AS A SOURCE OF POWER

Everyone (?) knows that waterwheels were widely used for powering grain mills, textile mills, and other industries. With the current energy situation, perhaps waterwheels could be used to generate electricity for private use (much the same as being proposed for the revival of windmills). This project involves investigating design criteria, constructing a working model, and testing the efficiency of several designs.

25. COMPARISON OF INSULATING MATERIALS

This project would be divided into two parts: (a) design and construct a system for the testing of insulating materials and (b) then use the system to compare various insulating materials.

26. HOVERCRAFT

Design, build, and test a small scale hovercraft. Its largest dimension should not exceed 24 inches. During operation, it should be capable of controlled motion (start, stop, turn) and of traversing a flat surface (a floor) on which are fixed some 1/4 inch objects. It shall be built using just one small electric motor. There must be a safety guard around the propeller(s).

27. FORENSIC ENGINEERING PROJECT

This project is a part of a program under way to educate engineering students and conduct research and actual studies in Forensic Engineering. Forensic Engineering is the engineering study and analysis of accidents or failures with the intent of understanding the cause, developing a repair, and devising means of avoiding or reducing similar failures in the future.

28. “GREEN” ENGINEERING MATERIALS

Engineering research on the behavior and performance of “green” engineering materials versus the materials they would replace is ongoing throughout the world. Projects in this category evaluate the engineering behavior of materials that are in use or being proposed for use in civil engineering applications.

29. FRISBEE™ THROWING DEVICE

You can play catch by yourself by simply throwing a ball against a wall or a flexible net. But if you want to play catch with a Frisbee, you need a partner or you'll spend a lot of time chasing after the Frisbee. The purpose of this project is to design a device to throw a Frisbee. The device should be able to throw the Frisbee consistently a certain distance (say, 15 m) in a certain direction. An optional feature would be to have the device "catch" a thrown Frisbee and then return it.

30. TREBUCHET

Design and construct a trebuchet to hurl a golf ball as far and as accurately as possible. The design must be small enough to sit comfortably on a table top. No dimension of the trebuchet can be greater than 3 feet.

31. EMBEDDED CONTROL PROJECTS

This project is actually MANY fun and challenging projects, but all of them share the common thread of programming a microprocessor which is popular in many current industrial and automotive embedded control applications. Approximately one week of preliminary classroom and hands-on instruction will be given in practical laboratory instrumentation (digital voltmeters, ohmmeters, function generators, dc power supplies, and oscilloscopes), analog and digital electronics, as well as elementary C programming before the project work begins. No prior experience in electronics is expected, although some prior programming experience in any high level language (C, Pascal, or Basic) certainly does not hurt!

- Smart car — A computerized toy electric car is controlled via a microprocessor board. Infrared, microswitch, and/or ultrasonic sensors are used to determine when the car is approaching an obstacle and the car must automatically take evasive action. Another possibility is to use two optical sensors underneath the car to enable it to follow a line drawn on the floor. It is up to each project team to decide what kind of "smarts" to program into their car! If there are multiple teams, a timed or head-to-head competition is possible!
- Inverted pendulum smart car — Design a microprocessor controlled car to balance a broomstick. Similar hardware to the smart car above, but now you must program the car to go back and forth to keep the broom stick from falling.
- Rail Runner — A microprocessor based rail runner that can beat Wily Coyote on the stair railing outside Room C-115. The device should be able to climb the stair rail, run around the horizontal rail at the top, and then descend without crashing. If more than one team designs such a beast, a timed contest is possible, perhaps with the award of a square donut to each member of the winning team.
- Virtual Harp — Create a virtual harp (or other musical instrument) that senses the location of the players fingers and responds with the appropriate sound. Infrared or ultrasonic sensors can be used and interfaced with the microcontroller.
- Ultrasonic ranging system (eye for the blind) — The system uses one or two ultrasonic transducers to measure distances between 1 and 10 feet using the principle of radar, or sonar. This is done by sending bursts of 40 kHz ultrasound and timing how long it takes to receive reflections from a nearby object. The proximity to a wall might be changed into an audible tone (the higher the frequency, the closer to the wall) in order to provide navigational information to a blind person. This challenging project will familiarize you with operational amplifiers and oscillator circuits as well as computer interfacing.
- Home security system — It is envisioned that this system will accept inputs from various kinds of intrusion detectors (magnetic reed switches, infrared light beams, infrared motion sensors, etc.) and smoke and CO detectors, and sound an alarm and / or dial a phone number to report the problem.
- Subliminal message wand (persistence of vision display) — Seven light-emitting diodes (LEDs) are placed close together on a stick. The LEDs are then turned on and off in such a way as to trace out a message when the stick is waved in a darkened room. Some provision for entering the desired message must be made. Also, some form of motorized stick waving system, that periodically refreshes the displayed message might be added if time permits.
- Hand held Game — Build a reaction time, memory, or "Simon Says" type game using sensors, switches and the microcontroller. Show your creativity and come up with a new and unique game!