Title: Green Up and Go: The Physics of Clean Engineering

Length of Course: Full Year (2 semesters; 3 trimesters; 4 quarters)

Subject Area – Discipline: Laboratory Science ("d") – Physics

UC Honors designation: No

CTE Sector: Engineering and Architecture

CTE Pathway: Engineering Technology

Grade Level(s): 9-12

Prerequisite(s): Algebra 1 or IM 1

Course Overview:

Green Up and Go offers students a real world opportunity to discover and understand principles of physics, engineering, design and green-clean technologies. From electric cars to wind farms our world is driven by innovations that come to life through the marriage of science and engineering. How do we prepare students to successfully navigate these two worlds? *Green Up and Go* offers students a real world opportunity to discover and understand principles of physics, engineering, design and green-clean technologies. Students, working individually and in teams, participate in a series of hands-on experimental projects such as building wind generators and personal transportation devices to explore both alternative and traditional energy sources and transportation. The projects provide a foundation for data collection, analysis, reflection, presentations and technical writing skills. Through these experiences students hone critical thinking, communication, collaboration, creativity and Career Technical Education skills while learning key physics, engineering, and design concepts. Students will maintain an engineering journal throughout the year long course. It will contain lab write-ups, diagrams and all other assignments. This year long UC-approved D - lab science course combines elements of physics, engineering and green technology to prepare students for success in college science and engineering as well as careers that can contribute to a greener environment for us all.

Course Content:

Unit 1 - Engineering Engines: What They Are and How They Work

Essential Question: How do we build a greener engine?

Supporting Question(s):

What are the functional characteristics of a variety of currently existing engines?
How can energy be converted into motion?
Which characteristics of an engine can we modify to make it “greener”?

Physics Concepts Covered: The laws of Thermodynamics, efficiency, Charles’ Law, Boyle’s Law, Combined Gas Law, Pascal’s Principle, States of Matter.

This first unit is used as an introduction to the course by defining the critical steps of the scientific process and engineering design. Moreover, norms for team work, collegial cooperation, and professional communication are introduced. Through research and analysis, students, working in small teams, discover the many types of engines that exist, how they work, and how energy is used, through thermodynamics and the gas laws. Teams learn the history and design development of types of engines (devices that transmit motion), i.e., simple internal combustion, external combustion, turbine, and ones using alternative energy sources. Students present these findings to class. By manipulating variables such as volume, pressure and temperature in a virtual simulator, students collect and analyze data to describe the relationship between these variables as they relate to the motion of the gas particles in various engines. This connects the volume and pressure to thermodynamics. Students in their teams design 3-D models of their engines, report, through papers and oral presentations their engine research and any analysis of the continuing value of that type of engine. Students learn design and drafting techniques as they draw their 3-D models of their engines. Subsequently, teams are challenged to create their 3-Dimensional model using materials available in the classroom, and explore ways of using green technology to reduce environmental impact. Class discussion will cover the future of various types of engines, their continued evolution, and new concepts. Using teamwork, critical thinking, problem solving, imagination, and inquiry, teams analyze their 3-D model engine design to determine how the engine could be made to work, then write and present to the class a technical paper.

Note: In each unit, labs addressing research and construction of models emphasize the physics and CTE concepts involved, while alerting students to the environmental impact and possible solutions to green needs. Students maintain an Engineering Journal throughout the course to record all research, results, data acquired, team activities, and building projects.

Unit 1 - Key Assignments

1. Background Research on Engines
    a. Teams write a research paper including history, development, an introductory exploration of the physics involved in the operation of the engine and how it has evolved to the current design stage, reporting orally to the full class their findings.
    b. Students research types of machines (device that transmits or modifies force or motion): simple, internal combustion, external combustion, turbine, electronic, hydraulics, and ones using alternative energy sources).

   c. In teams of 4, students research and discuss in class specific details of assigned types of machines, including vocabulary and concepts learned in thermodynamics, force, motion, energy transformation, efficiency, work produced.
   d. Students begin maintaining an engineering journal, carried throughout all units to end of class.
   e. Based on previous assignment research, students work in teams of 2 to draft designs of an engine of their choice such as steam, internal combustion, etc.
2. Virtual Simulation of Gas Laws
   a. Using an online virtual simulator (see the resources section), students observe the relationship between an engine and the gas laws, thermodynamics, motion, force, energy, gas output, and power production.
   b. In the simulator, students manipulate variables such as volume, pressure and temperature, collect and analyze data to describe the relationship between these variables on the motion of the gas particles in the engine.
3. Creating a Model Engine
   a. Students, in teams of 4, design and build a 3-D representation of their specific type of engine. They will present their findings to class, emphasizing the use of gas laws, thermodynamics, pressure.
   b. Teams will do a 5 minute oral presentation of their engine using powerpoint or other visual aids and write a 2-3 page technical paper reviewing their engine, why it did or did not operate, including the engineering design, physics laws, and fuel types involved.
4. Lab Write-up
   a. Referencing the online virtual simulator, students reanalyze their engine in light of efficiency and suggest ways that the engine can be improved.
   b. Reflecting on their 3-D design and the virtual simulator data, students write-up an engine improvement proposal, emphasizing energy efficiency.
   c. The 2-3 page write up will be entered in the lab journal.

Unit 2 - Mousetrap Vehicle Performance Test

Essential Question: How do acceleration and velocity concepts interrelate with force and energy concepts to describe the motion of vehicles?

Supporting Question(s):

How can we design and build a prototype moving vehicle using a mousetrap?
How can we measure velocity, acceleration, force, torque, and work using our mousetrap vehicle?
What is needed to improve the performance of our mousetrap vehicle?

Physics concepts covered: distance, displacement, motion, velocity, acceleration, kinematics, forces and Newton's laws of motion, torque, mechanical advantage, efficiency, energy and work.

This unit builds on topics presented in unit 1 by reinforcing design and prototyping processes. Working in teams of two, students develop and test a mousetrap-powered vehicle that can push a recycled paper cup two meters forward, then back away from the cup for one meter. Student teams design, prototype and draw 2-d and 3-d plans for their vehicles. Teams measure velocity, acceleration, force, torque and directional stability and calculate mechanical advantage, energy and work. Teams document their work in the team members' Engineering journals, and a team report orally and with papers their results to their class and teacher.

Unit 2 - Key Assignments

1. Project Introduction -- Students are presented 2 standard mousetraps and learn that these mousetraps will be the engine of their vehicle.
2. Initial Design Planning -- In their engineering journal, students sketch a model vehicle that includes a plan for the vehicle chassis and a list of the necessary parts selected from the reusable/recycled materials.
3. Presentation of Design Analysis -- Each student presents his or her design to the group in a 2-3 minute presentation and records suggestions for design improvement from their peers in their engineering journal. Examples: Considerations of drag, mechanical advantage, torque, effects of wheel radius, etc.
4. Building and Drawing the Chassis
    a. Students are divided in small teams and select with their team members their ideal vehicle design.
    b. Teams build a mousetrap vehicle chassis--a frame, 4 wheels (using any material for wheels), and appropriate axles.
    c. Teams explore the directional stability of the vehicle and may modify their chassis. In their engineering journal, students explain their thoughts by drawing an orthographic projection (top and side views) of their mousetrap car chassis.
5. Experimentation with the Chassis
    a. Teams experiment with their vehicles to determine velocity and acceleration, by pushing the vehicle on a horizontal surface and down an inclined plane, by measuring time and distance. In their engineering journal, students explain, elaborate and evaluate design experimental procedures which controls variable, collect, process, and analyze data, and use that data to draw conclusions.
    b. Students calculate linear velocity, linear acceleration and the acceleration due to gravity on an inclined plane and report their results in a lab write-up.
6. Determining the Force
    a. Students measure and evaluate forces created by their vehicle using a spring scale.
    b. They measure the force exerted as the spring is stretched by different amounts.
    c. Students further explore Newton's laws of motion using spring scales and

are guided to identify how those laws apply to their vehicle.
    d. Students use spring scales to measure and calculate their vehicle's torque, making notes on their journal.
    e. Teams report their findings in a 3-5 page research paper.
7. Experimentation with Optimization
    a. Students brainstorm to develop strategies to solve the performance criteria in the overall assignment.
    b. Students measure the radius and circumference of their vehicle wheels and calculate the rotations needed to cover the required distances.
    c. Students develop prototypes, testing the placement of their mousetraps on the vehicle.
    d. Students create 2-d mechanical drawings to scale of the team's mousetrap vehicle.
    e. Students review and evaluate their test results and determine their final design.
    f. All work is recorded in their engineering journal.
8. Final performance testing
    a. Teams test their mousetrap vehicles based upon the performance criteria.
    b. Students calculate the potential and kinetic energies of their vehicles as they move through a trial run.
    c. Teams evaluate their vehicle's performances and report one step that could improve their vehicle's performance.
    d. Teams measure the distances their vehicles traveled and the time required, then calculate the acceleration, kinetic energy and total work of their vehicles.
    e. Teams present to the class an oral report evaluating the performances of the mousetrap vehicle.
    f. Teams submit a technical paper that details the design, development, experimentation and performance of their device.
9. Lab Write-up
    a. Students analyze their mousetrap car's performance, emphasizing comparisons between projected results and actual values, such as distance traveled, speed, force, efficiency.
    b. The 2-3 page write up will be entered in the lab journal.

Unit 3 - Wind Energy (Weightlifting/High Torque)

Essential Question: How can a wind-powered device lift a weight?

Supporting Question(s): What are the historical applications of wind turbines?

Physics Concepts Covered: Motion, force, rotational motion, torque, Ohm's Law, power and efficiency, simple machines

Students explore the relationship of wind to mechanical power, studying force to change direction, rotational dynamics, torque, the nature of gears and pulleys, friction, mechanical advantage and power. In teams, students investigate historical devices using wind and water to do work (grinding grain, cutting wood, pumping water) and describe the limitations and benefits of these energy sources as well as the impact on environmental sustainability and green energy. They will also determine whether windmills are still used today for any of these applications.

Unit 3 - Key Assignments

1. Research and exploration
    a. Small teams of students explore and research two historical devices where rotational motion is generated from natural sources of wind or water flow which are harnessed to accomplish work such as in a water mill or wind turbine.
    b. Teams define how historic innovations relate to contemporary efforts in promoting environmental sustainability in the area of renewable energy, using Green/Clean technology.
2. Research Application -- Teams identify how energy transfer produces rotational motion and describe the benefits and limitations of the two selected devices.
3. Findings -- Students present to the class their findings from this research in the form of a 2-3 page written technical paper and a 2-3 minute oral presentation.
4. Introduction to Materials
    a. Teacher introduces students to various types of turbines, discussing operation and functionality.
    b. Students are introduced to factors such as blade diameter and pitch and how they relate to efficiency.
5. Blade Design
    a. Teams use research and prior knowledge about motion and forces to engage in an analysis of blade design.
    b. Teams experiment with different blade variables (length, pitch, surface area, shape, etc.) and materials.
    c. Teams isolate one variable at a time, collect weightlifting performance data, and determine maximum output for that variable as a function of different wind speed. In order to maximize classroom time and ensure that all students have a basic understanding of how these variables affect torque, teams present their analysis to the class.
6. Gear and Pulley design
    a. Teams apply appropriate problem-solving strategies and critical thinking skills to work-related issues by designing an experiment involving pulleys and gears with different specifications.
    b. Teams address the effects of changing pulley radius ratios on the torque of the system and the magnitude of the force necessary to raise different masses using the wind turbine as primary power source.
    c. Teams draw conclusions regarding the relationship between these variables by collecting and analyzing data, representing data on appropriate graphs, and calculating the time necessary to raise the mass

under each experimental condition.

7. Windmill design and construction -- Students compete to construct a windmills that are either very strong (lifting the most weight), very powerful (lifting weight quickly), or very efficient (compared to the energy in the wind).
8. Lab Write-up
   a. Students analyze their results and compare their data to estimated values, then reflect on improvements to their device.
   b. The 2-3 page write-up will be entered in the lab journal

Unit 4 - Electric Motors & Generators

Essential Question: What is the relationship between electricity and magnetism in the functioning of electric motors and power generators?

Supporting Question(s):

What is the effect of a magnetic field on a current-carrying armature?
What are the basic principles of an electromagnetic generator?
What makes an electric motor and generator "greener"?

Physics Concepts Covered: Electricity, magnetism, electromagnetic induction, simple circuits, current, charge, Ohm's Law

Students analyze the relationship between electricity and magnetism, electromagnetic induction, and electrical circuits, energy transfer and efficiency as they relate to motors and generators in powering a vehicle in a greener form. By observation and analysis, teams record the applicable physics principles involved in their function in their engineering journal, including diagrams of electrical circuits showing relevant values such as power and torque. Working in teams, students deconstruct a motor and a generator. Students then construct a simple motor model and a simple generator model. In teams, students research similarities between motors and generators, study motor-generator systems and green alternatives, such as regenerative braking and hybrid power, recording their results and reporting to the class. Based on their research, teams design plans for a vehicle or other device powered by a motor-generator green power system. Teams describe their plans to the group for peer review and critique. Incorporating recommended changes, teams build a functioning vehicle or device, with emphasis on green energy aspects. Each teams tests their vehicle or device, making modifications as needed, until they are able to present the whole group with their final project. A final technical report, based on their engineering journals, kept throughout the process, is written and presented by the team along with the demonstration, emphasizing the physics concepts and CTE Engineering Design concepts learned and used in the project.

Unit 4 - Key Assignments

1. Deconstruct an Electric Motor
   a. Students disassemble a motor noting the applicable physics principles responsible for its function.

    b. Students document their observations in their engineering journal, researching and explaining their understanding of interactions between electricity and magnetism through a series of diagrams, including a circuit diagram with relevant values such as power and torque.
2. Building a simple motor
    a. Referencing the diagrams from Assignment 1, students build a simple electric motor using common household items. This simple motor should take no more than two hours to build.
    b. The students kinesthetically demonstrate understanding of electromagnetic phenomena. The end result is a functional motor.
    c. The construction process is documented in the engineering journal.
3. Deconstruct and Build an Electric Generator
    a. In groups, students research similarities between motors and generators, paying special attention to motor-generator systems and green alternatives such as regenerative braking and hybrid power.
    b. Students write a 2-3 page report on the history and implementation of motor-generator systems.
    c. Students disassemble a generator noting the applicable physics principles responsible for its function. Students then build a simple electric generator using common household items. This simple generator should take no more than two hours to build.
    d. The students kinesthetically demonstrate understanding of electromagnetic phenomena energy transport. The end result is a functional motor.
    e. The construction process is documented in the engineering journal.
4. Building a Motor-Generator Powered Model Vehicle or Device
    a. After investigating and documenting their understanding of hybrid power, dynamic braking and motor-generator systems, students develop and present plans to power the mouse trap car or other vehicle/device with a green energy motor-generator system.
    b. Students stress the importance of physics principles in their 2-3 minute presentation.
    c. Peers analyze and critique the project in a reflection period and the authoring team manipulates their designs based on that feedback.
    d. Using the plans developed for their presentations, students build a functional model vehicle/device which incorporates a motor-generator system.
    e. Students test the functionality of their vehicle/device with special emphasis on the green aspects, and reflect on possible improvements.
    f. Vehicle is run with and without regenerative braking. Battery charge is measured and a comparison is made with and without regenerative braking.
    g. Results are graphed as running time vs. residual charge. In this way students explore efficiency of their regenerative braking motor-generator system by applying energy conservation principles.

   h. In teams of 4, students design and build a functional model vehicle or device which will incorporate a motor-generator system.
5. Lab Write-up
   a. After testing the vehicle or device and analyzing improvement opportunities teams write a project report detailing the scope of the project, the graphing results and their possible green energy applications, focusing on the energy efficiency of the green energy motor- generator system and proposing possible improvements for future application.
   b. A 2-3 page lab write-up is entered in the journal.

Unit 5 - Wind Energy (Electricity Generator/High Speed)

Essential Question: How can a wind turbine convert mechanical energy into electrical energy?

Supporting Question(s):

How can we design a wind turbine that produces electricity?
How can we maximize the efficiency of the turbine?

Physics Concepts Covered: Motion, force, energy transfer, rotational motion, torque, Ohm's Law, electromagnetic induction, power and efficiency, simple machines

Based on past investigations of wind power and generators (motion, force, energy transfer, torque, Ohm's Law, electromagnetic induction, power and efficiency), students design and build a wind turbine. They produce experimental data isolating one design variable (length, pitch, surface area or shape) and analyze their results. Students investigate how gears can be used to change speed and torque. Based on these results, students compete to build the best wind powered generator judging performance based on both electrical energy output and efficiency.

Unit 5 - Key Assignments

1. Initial Research
   a. Teams research contemporary wind turbine design identifying the major components and their interactions as a complete electrical generation system. Research includes:
      i. Examination of major variables that include blade design, blade number and configuration, axis orientation and component dimensions and gearing and their impact on performance.
      ii. The role that wind turbines play in the emerging field of Green/ Clean technology.
      iii. The potential negative environmental impact of wind turbines.
   b. This research is presented to the class through a combination of written documents and visual media presentations.
   c. After the presentation, the class is introduced to the design challenge of building their own electricity generating turbine.

2. Blade Design
    a. Teams rely on their research and knowledge about motion, forces, and electricity (from previous units) to engage in an analysis of blade design.
    b. Teams experiment with different blade variables (length, pitch, surface area, shape, etc.) and materials.
    c. Teams isolate one variable at a time, collect performance data (output voltage), and determine maximum output for that variable as a function of different wind speed.
    d. Teams graph the data and present their analysis to the class.
3. Gear Design
    a. Teams rely on their research and their prior discoveries about motion and forces to engage in an analysis of gear design.
    b. Teams construct simple gear boxes to calculate gear ratios, examine different types of gears (spur gear, bevel gear, worm and compound gears) and compare input force to output force and the relationship between speed and torque.
    c. Data is recorded in a log. Teams analyze the data, compare these results with their findings in Unit 3 and present their analysis to the class.
4. Blade and Gear Design Analysis
    a. Teams come together to evaluate the results of their blade and gear analysis using a decision matrix that allows them to rank aspects of their designs in order to choose the design that best suits the challenge.
    b. Once teams select their design, they formalize a plan to build their design as a functioning prototype. This plan must include scale drawings and/or 3d computer models.
    c. Teams present the design in a 2-3 minute oral presentation.
    d. Data from all tests is presented in graph format and entered in the journal along with recommendations for potential improvements to the design.
    e. Teams evaluate their design and brainstorm improvements to maximize output.
5. Wind Turbine Prototyping, Testing, Data Collection/ Analysis
    a. Teams fabricate their prototype windmill (size limitations and component parameters are identified by the instructor in the design challenge specifications). Teams engage in a series of tests, data collection and data analysis.
    b. Teams evaluate performance under a variety of series and parallel electrical loads to understand the effect on force, torque, work, and energy necessary to power the load. Data is recorded in a log as well as conclusion statements.
    c. Teams measure energy output with turbine angled to the wind between 0 degrees and 90 degrees. Data is recorded in a log as well as conclusion statements.
    d. Teams design a vane that uses the force of the wind to align the turbine to achieve maximum energy output. Data is recorded in a log as well as conclusion statements.

6. Lab Write-up
    a. Students analyze their results and compare their data to estimated values, then reflect on improvements to their device.
    b. The 2-3 page write-up will be entered in the lab journal.

Unit 6 - Short range human/electric powered transportation solution

Essential Question: How can the integration of physics and the engineering design process be used to develop a short range personal transportation solution which is designed to: 1) help users make local trips, 2) be economically and mechanically viable, 3) be safe and user friendly 4) utilize both human and electro-mechanical power sources, 5) make a positive impact on the environment.

Supporting Question(s):

What are the benefits and drawback of the current forms of local, short-range transportation (in your specific geographic location)?

What factors relating to human needs, marketability, technology, and laws of physics influence the design of a solution which meets the design requirements listed above.

Physics Concepts Covered: Motion, force, energy transfer, rotational motion, torque, Ohm's Law, simple circuits, electromagnetic induction, power and efficiency, simple machines, stress and strain

This unit provides a capstone experience where students apply the conceptual understanding and skills related to physics and engineering acquired throughout the prior units in the context of a comprehensive Engineering Design project. Students develop a short range human/electric powered transportation solution to help reduce the dependence on fossil fuels for local transportation, engendering a positive environmental impact. Students investigate the needs of the end user and correspondingly develop a set of design requirements. Physics content will be reviewed and/or learned through a series of carefully orchestrated lab activities that address the information students need-to-know in order to complete the engineering design cycle for this project.

Physics content to be addressed in these lab activities includes:

- electro-mechanical energy systems (storage of electrical energy, circuitry, motors)
- Power and Efficiency
- work and energy transfer (potential, kinetic, electrical, thermal)
- forces (applied, frictional, rolling resistance)
- stress and strain
- torque

Engineering CTE concepts and skill acquisition will also be addressed during these lab activities, and will be applied to successfully execute this capstone project. These skills and concepts include:

- ➢ Understanding Engineering Design Process
- ➢ materials strength and selection considerations
- ➢ fastening systems
- ➢ visual communication - 2-D and 3-D drawing and modeling
- ➢ rapid prototyping technology and virtual testing
- ➢ electro-mechanical systems
- ➢ gear ratios, simple machines

For example, to design a functional and safe chassis for their vehicle, students will need to understand how the selection of materials and their fastening systems respond to applied forces. To gain an understanding of these relationships, students collect data during a series of lab activities involving the manipulation of variables that include material type, material dimensions, type and direction of forces applied. Students analyze this data to gain insight into the criteria needed for specifying appropriate material and fabrication methods for their proposed design.

Based on these investigations, students develop one or a combination of the following: physical, full size or scaled down electro-mechanical functioning test prototype with accompanying mechanical drawings and/or virtual prototypes utilizing computer modeling. Where available these can be supplemented by rapid prototyped components utilizing such technologies as 3D printing, CNC machining and laser cutting. Students collect and analyze data, and evaluate the efficiency and performance of their design. Results are presented and evaluated by peers, teacher, parents, and external individuals.

Unit 6 - Key Assignments

1. Student review past unit content and engage in experimentation, data collection, analysis of actual prototypes as needed for information about the following topics.
   a. Forces on an incline - students design an experiment, collect and analyze data to determine the amount of force necessary to move a load at a constant speed at a variety of inclines. They then scale this up to the expected loads for their design.
   b. Gears - torque and speed, work and distance - experimentation in unit 5
   c. Human power output capabilities - students design an experiment, collect, and analyze data to determine their own power output capabilities on a bicycle while varying exertion level, gear ratio, and speed.
   d. Materials Selection - student design and experiment, collect and analyze data to determine material strength capabilities while varying material type and dimensions.
   e. Electro-mechanical energy systems - Students experiment with a variety of batteries and motors to determine the torque, power output, and battery life, of different combinations of battery-motor systems.
2. Project Introduction After being presented with the overall challenge, students will be divided into small groups. Sample engineering design proposals are provided by the instructor as a reference and students work to develop their own written

design proposals. The proposal describes the scope of the project, the intended purpose(s) and user(s) and identifies the physics and CTE concepts and skills they may need to apply in developing a short range human/electric powered transportation solution. A minimum length of 2 pages is expected.

3. Exploration
    a. Working in small teams, students use their design proposal as a framework to brainstorm how to approach/tackle the challenge sharing their ideas with the class.
    b. With the input, the entire class produces a 2-3 page document summarizing current solutions, user needs, potential characteristics of a solution, and the physics concepts that will guide the development of a successful design.
4. Define
    a. Building upon the prior two key assignments, teams develop a detailed engineering design criteria matrix that clarifies end user needs and product performance specifications.
    b. Criteria for the matrices to include but not limited to the following variables:
        i. Intended users (demographics)
        ii. SafetyPerformance range- speed, battery re-charge time, weight and size limits
        iii. Functionality (what will they be carrying, how far, how long?, etc.)
        iv. Usability/comfortPrice/affordabilityAesthetic requirements
    c. Based on class and teacher feedback to the initial draft, teams produce their final design criteria matrix as either a carefully organized 1-2 page hand drawn or computer generated document.
5. Brainstorming
    a. Building upon the knowledge already acquired from earlier activities, students investigate possible solutions for the design challenge utilizing a variety of methods, including hand/computer generated drawings, virtual models and/or 2-D and 3-D physical models to conceptualize potential design solutions.
    b. Team concepts are presented to the class for feedback in a 2-3 minute presentation.
6. Prototype
    a. Teams select a specific design concept from their brainstorm stage.
    b. Fabricating a virtual prototype of the proposed engineering design solution. Students utilize CAD and/or parametric modeling software to visualize and virtually evaluate the feasibility of their proposed solution. Where feasible, students are encouraged to incorporate animation to better communicate and evaluate their solution.
    c. If resources are available, design and fabrication of rapid prototyped components to evaluate key components of the proposed engineering design solution using technologies such as 3D printing, CNC and laser cutting.
    d. Throughout the prototyping stage students are required to maintain an engineering log to record performance data evaluated relative the criteria

developed in key assignment 3.
    e. Fabricating a physical, full size or scaled down electro-mechanical functioning test prototype.
    f. Prior to fabrication students complete a set of mechanical drawings utilizing traditional hand or computer assisted drafting techniques. This type of prototype will be used to evaluate the electro-mechanical functional characteristics of the proposed design and does not address aesthetics.
7. Refine -- Students utilize continuous feedback from peers and teachers to evaluate and fine tune their proposed design. The refinements can be made to the physical electro-mechanical functioning test prototype and/or through virtual models.
8. Lab Write-up
    a. Students analyze their results and compare their data to estimated values, then reflect on improvements to their device.
    b. The 4-6 page write-up will be entered in the lab journal.
    c. Final analysis report will be included in the final presentation.
9. Presentation
    a. In this final stage, teams give a 3-5 minute presentation of their physical or virtual engineering prototypes. Presentations must address the following key points:
        i. Important features of the design with respect to the criteria established in key assignment.
        ii. An analysis of the performance data comparing the data derived from prototype testing to the criteria benchmarks defined in the design criteria matrix.
        iii. The key physics concepts embedded in the design solution.
        iv. The students' understanding of the engineering design process.

Course Materials:

Textbook:
Title: Any district adopted physics text
Usage: Primary Text

Title: CK-12 Engineering: An Introduction for High School
Edition: NA
Publication Date: 2009
Publisher: CK-12.org
Authors(s): D. Baker, T. Ganesh, A. Ganesh, S. Krause, C. Roberts, J. White-Taylor
URL Resource(s): http://www.ck12.org/flexbook/book/736
Usage: Supplemental Text (Engineering)

Supplemental Instructional Materials:

Unit 1 - Engineering Engines: What They Are and How They Work

Text books:

Moaveni, Saeed, Engineering Fundamentals: An Introduction to Engineering, 4th Ed., 2007, Thompson Engineering Co. (or district adopted text)

Eisenkraftt, Arthur, Active Physics: Transportation, AAPT/AIP, It's About Time, Inc. (or the district adopted text)

Duffy, James E., Modern Automotive Technology, 7th ed., 2009, Tinley Park, IL, Goodheart-Willcox Company, Inc.

Online Resources:

http://www.khanacademy.org/ (an excellent source of video tutorials related to the underlying math and physics principles related to this course.)

http://www.animatedengines.com/index.shtm (comprehensive list of engines, virtually animated)

http://phet.colorado.edu/en/simulation/gas-properties (online virtual simulator to explore thermodynamics and gas properties)

http://www.sciencetoymaker.org/boat/index.htm (instructions for how to build a steam-powered "put-put" boat)

Other Resources:

http://www.cert.ucr.edu - UCR Center for Environmental Research and Technology (model of a cutting-edge center for research partnership among industry, government, and academia)

Unit 2 - Mousetrap Vehicle Performance Test

Online Resources:

http://www.khanacademy.org/ (an excellent source of video tutorials related to the underlying math and physics principles related to this course.)

http://www.docfizzix.com/, http://shop.pitsco.com/, Example kits of materials at these sites among other places

http://www.google.com/search?client=safari&rls=en&q=mousetrap+vehicle&ie=UTF-8&oe=UTF-8#q=mousetrap+vehicle&hl=en&client=safari&rls=en&prmd=imvns&source=univ&t example videos on line

Suggested Build Materials:

spring scales, meter sticks, weights and stopwatch

wood, 2 mousetraps, string, paper cups, metal axles, paper clips

Unit 3 - Wind Energy - Weightlifting

Online resources:

http://www.khanacademy.org/ (an excellent source of video tutorials related to the underlying math and physics principles related to this course.)

www.ATETV.org--youtube video--showing how wind turbine technicians are trained
www.WindTechTV.org--videos showing how wind turbines work
www.KidWind.org--turbine kits, lessons and background information
WindWise (Lesson 6--"How Does a Windmill Work?")
www.ASE.com--federal energy efficiency website
http://www.cosi.org/files/Flash/simpMach/sm1.swf (simple machines)
http://www1.eere.energy.gov/education/lessonplans/default.aspx (lesson plans for wind energy)
http://www1.eere.energy.gov/education/lessonplans/plans.aspx?id=317 (wind energy exploration assignment 1)
http://nsf.gov/discoveries (research of wind turbines)
www1.eere.energy.gov/education/lessonplans/ (Energy Efficiency & Renewable Energy (U.S. Dept. of Energy)
www.k12science.org/currichome.html (Center for Innovation in Engineering and Science Education (CIESE))
www.edf.org/article.cfm?contentid=8466&redirect=cagreenjobs (Green Jobs Guidebook – Employment Opportunities in the New Clean Economy)
www.ellabakercenter.org/index.php?p=gcjc_teaching_tools (Green-Collar Jobs Campaign Teaching Tools)
skillsusa.org (career paths and competitions)
http://mesa.ucop.edu/ (career paths and competitions)

Suggested Build materials:
small electric fan
metal rod (16" long)
PEX tubing (10" long)
4"x6" index cards
skewers
¼" dowels
string
paper cups
plastic cups
corks
straight pins
tape
washers
straws
cardboard
balsa wood
corrugated plastic
hot glue gun

Unit 4 - Electric Motors and Generators

Text Book:

Duffy, James E., Modern Automotive Technology, 7th ed., 2009, Tinley Park, IL, Goodheart-Willcox Company, Inc.

Suggested Supplies:
Basic hand tools
Magnets, wire, cardstock, nails, etc
Electric motors
Electric generators
Batteries
Motor-generator
Multi-meters
Model vehicle/ device

Unit 5 - Wind Energy - Electricity Generation

Supplemental Texts:
Wind Energy Basics: A Guide to Home- and Community-Scale Wind Energy Systems, Paul Gipe (2009)
WindWise Education (www.WindWiseEducation.org)--Lesson 8, "Which Blades are Best?". Interdisciplinary wind energy curriculum with tools to teach wind concepts in grades 6-12.

Online Resources:
http://www.khanacademy.org/ (an excellent source of video tutorials related to the underlying math and physics principles related to this course.)
ATETV (videos showing how wind turbine technicians are trained)
www.WindTechTV.org (videos showing how wind turbines work)
www.awea.org--American Wind Energy Association (background info and resources)
www.doe.gov--U.S. Department of Energy (background info and statistics)
www.nrel.org--National Renewable Energy Laboratory (background info, resources, statistics, data on latest research)
www.kidwind.org (turbine kits, lessons, and background info)
www.vernier.com (probeware)
www.pasco.com (turbine kits, probeware)
www.kelvin.com (project motor)

Suggested Build Materials:
Tower--PVC pipe
Generator--project motor (www.kelvin.com or www.kidwind.org)
Hub--CDs or DVDs, foam, Tinker toys, turbine kit
Blades--balsa wood, card stock, cardboard, corrugated plastic
box fan
resistor--10-ohm, 1 watt
multimeter (for measuring voltage) or probeware (voltage and current for measuring power)--Vernier, Pasco. Probeware allows the user to graph power calculated from

voltage and current versus time. Integrating over time gives total energy in units similar to kW-h (mW-s)

Unit 6 - Human Transport Solution

Online Resources:
http://www.khanacademy.org/ (an excellent source of video tutorials related to the underlying math and physics principles related to this course.)

Software:
CAD software
3-D modeling software

Suggested Build Materials:
Used bikes and misc bike parts (gears, cable, chain, wheels, etc...)
Small DC motors (SIM motors used by the robotics team cost about $30 and should work well. treadmill motors can also work.)
Heavy gauge wire
Heavy duty potentiometers
Heavy duty switches
Lead-acid batteries
Scrap wood
Scrap metal
Steel tubing
Uni-strut or c-strut channel and matching nuts/bolts
Nuts and bolts

Tools:
Hand tools - wrenches, pliers, hacksaws, wood saws,
Power Tools - battery operated drill/screwdriver, drillpress
Welding equipment (optional)