Promising Practices from the Woodrow Wilson Early College Network

Increasing Curriculum Intensity
Engage students in rigorous learning early on and move them to higher learning
University High School of Science and Engineering – University of Hartford
Hartford, CT

Goal: Build a curriculum to prepare students for college science and engineering

> *The need for a thorough grounding in concepts was ingrained in me years ago when I was teaching a course in atomic and nuclear physics to a class populated by senior electrical engineering majors at another university. These were students who could do some fairly sophisticated circuitry problems. One day, a problem in unit analysis arose and I tried to take them back to first principles, so I asked them what a volt was. Not a single person could tell me that a volt was a joule per coulomb. That in and of itself was not surprising, since they did not need that in typical circuit analysis. But more disturbing was the fact that when I asked them what a volt represented conceptually, again no one could tell me that it was potential energy per unit charge. That was of concern to me, because it indicated that we were all too often emphasizing repetitive patterns of problems, and forgetting the underlying concepts. In conversations with other faculty from around the country, I have heard similar stories, so I do not believe my experience was unique.*
> --University of Hartford Professor

The principle underscored by this story is that straightforward. Grounding students in the underlying concepts of any discipline is essential to developing their deep understanding of that discipline, and hence increasing their chances for success in college and beyond. Experts have noted that *"The content knowledge of discipline experts is organized around key concepts in ways that reflect a deep understanding of the subject matter."*[1] This simple fact would guide the founders of University High School of Science and Engineering (UHSSE).

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[1] Hanson, David. Stony Brook University

Developing a solid foundation in 9th and 10th grade

During the development of UHSSE's curriculum scope and sequence, teachers and college faculty reflected about what conceptual knowledge was requisite to succeed in college courses. Teachers and college faculty (see passage below) reflected on the efficacy of the traditional curriculum. After careful consideration, they decided on a new approach for science courses in years one and two (see Table A). They agreed that the traditional curriculum was based on a belief that biology was the most appropriate for the early high school years because it was the most descriptive and the least mathematical.

> *Historically, traditionally, science curricula at many high schools followed a pattern of biology first, chemistry second, and physics third. In some cases, this sequence began in the sophomore year, with earth science or "general science" being taught in the freshman year. In other situations, earth science was taught in middle school, and the biology was commenced at the freshman level. The latter arrangement allowed the student to take an AP course in one of the three subjects in the senior year.*
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> *The order of presentation was based upon the premise that biology was the most descriptive and least mathematical of the three sciences, with physics being the most mathematical. This in turn allowed the mathematics instruction to "catch up" with the science that would be taught concurrently. By the time a student reached the junior or senior year, s/he would have completed at the very least two years of algebra and one of geometry, and would be taking trigonometry or calculus concurrently with physics.*
>
> --University of Hartford professor

Their review of practice revealed that the field of biology had evolved. Over the last few decades, biology courses have become less"descriptive" and progressively more based on biochemistry. The teaching of physics has also evolved. These changes are significant and have important implications for UHSSE's curriculum work.

> *However, over time, educational philosophies changed as new knowledge came to light, particularly in biology. The elucidation of the structure of deoxyribonucleic acid (DNA) in 1953 (for which James Watson and Francis Crick later won the Nobel Prize) was a seminal event, in that biology courses came to be less and less "descriptive" (i.e., less traditional botany, zoology, and classification of species), and based more on biochemistry and activities at the cell and molecular levels.*
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> *In like manner, physics teaching also evolved, with the development of courses at the collegiate level, often entitled "Physics for Poets", or similar euphemism. Such courses were non-mathematical and conceptual in nature, but Paul Hewitt of San Francisco City College (he was a true flower child of the sixties, but nevertheless an enormously creative physics professor) showed that such courses need not be trivial. His book "Conceptual Physics", first published in the 1970's, is still the standard text for such courses; I've lost count of which edition is now in print.*
>
> --University of Hartford professor

A new scope and sequence emerged from this effort. Physics now functions as the foundation for the high school's science curriculum. The founders agreed that if students were successful in 9th grade conceptual physics, they would better prepared for college courses.

But it became apparent to us that such a conceptually based course could be utilized at UHSSE at the freshman level…. It would allow us to present physical concepts that would be very useful in subsequent courses in biology and chemistry (and engineering), while not getting bogged down in mathematics for which they were not yet prepared. This is followed by a course in biology that, for the best students, is at the AP level - this in turn is because the AP exam is recognized nation-wide, and students can receive college credit if the get a 4 or a 5 (in some places, a 3 is accepted) on the AP exam. We are only in our second year, but we anticipate that the same philosophy can be extended to chemistry in the junior year. We also believe that these will also be excellent preparation for more advanced courses that the students can take here at U of H.

--University of Hartford professor.

Table A

Science Courses for Grades 9 & 10	**Curriculum Content**
Conceptual Physics (9)	-Measurement, distance, speed, and velocity -Acceleration both linear and centripetal -Momentum and Newton's Laws of Motion -Atomic Structure, Electron Shells, Organization of the Periodic Table -Compounds, Bonding, Molecular Structure, Moles, and pH -Work, Power, Energy and the Sources of Energy -Gravity, Projectile Motion, Centripetal Motion, and Kepler's Laws -Fluids, Pressure, Temperature, and Convection of Ocean Currents -Heat (Changes in Phase, Conduction, Convection, Radiation) -Electricity and Circuit Analysis -Magnetism and Electric Power Generation -Waves and Sound -Light and Electromagnetic Energy -Subatomic Particles, the Universe and other Strangeness
Engineering (9) **Engineering II-Statics (10)**	-Fundamental Concepts and Principles -Resultants of Coplanar Force Systems -Equilibrium Coplanar Force Systems -Analysis of Structures -Frictional Force Systems -Concurrent Spatial Force Systems -Center of Gravity and Centroids -Area moments of Inertia -Simple Stresses -Strains -Mechanical Properties of Materials -Torsion of Circular Shafts -Shear Forces and Bending Moments in Beams -Stresses in Beam
Biology & AP Biology (10)	-Evolution: Patterns and Products of Change -Genetic Continuity and Reproduction -Energy, Matter and Organization -Science, Technology and Society -Interaction and Interdependence -Growth, Development and Differentiation -Maintenance of Dynamic Equilibrium

"When you make the finding yourself - even if you're the last person on Earth to see the light - you'll never forget it."
--Carl Sagan

Flexible and adaptive inquiry-based teaching strategies

As evidenced by the course of study, students in UHSSE face a high bar for success. However, the school staff thought carefully about how to help students succeed, and implemented flexible and adaptive teaching strategies to respond to children's sporadic and often uneven academic learning paths. Students discover concepts for themselves. To engage students, theories are made visual. A teacher stated:

> *So one of the things I do is take two 500 gram masses and say, Ok this is matter and this is anti-matter. What'll happen if I put them together? And you know they get energy. Do you have any idea how much energy? Well it turns out it's a crater two miles wide and two miles deep, and it'll destroy everything between Boston and New York. One of* the teacher's *favorite things is to have students experiment with a shot put to teach momentum. They love crashing the shot put into the wall. Also using the Vandergraff generator. Students touch it and their hair stands straight up.*

The 9th grade physics course drew heavily from Dr. Hewitt's work.

> 9th Grade Conceptual Physics Course
> *We thought kids would be ready for conceptual physics. Now conceptual physics is based on Hewitt's book. We felt that the kids could do that (conceptual physics), and as their algebra skills improved, we could add more of the calculation parts of physics. We were also convinced that physics is the basis of all other sciences. So if students had a firm understanding of the concepts of physics, they would do better, whether it be biology, or chemistry, or physiology, or any other science they might chose to take later, as well as a better overview of where they might chose to specialize.*
> --High school teacher

In the second year, the 9th grade physics curriculum and the 10th grade engineering courses were revised in ways that responded to student needs. One 9th grade teacher used two text books-one with more advanced work. And, a 10th grade engineering course was retooled to build up student's algebra skills.

> 9th Grade Conceptual Physics Course
> *I found some of the kids were quite capable of going beyond Hewitt's book. I had already ordered some of the Connecticut State Advanced Placement Physics book (*Giancoli*), normally taken in senior year. And so as the kids demonstrated their ability to handle Hewitt, and do that well, I'd give them assignments in both textbooks… It is my belief that we have just begun to tap the abilities of students to handle the material and work at an appropriate level. It doesn't bother me at all to assign literally half all the problems in Hewitt, plus about a quarter of all problems in Giancoli.*
> --High school teacher

> 10th Grade Engineering Mechanics and Statics Course
> *We found a couple of books that were algebra-based, rather than a typical calculus-based statics, mechanics, dynamics work. What I've noted this year is that kid's abilities to use algebra were horrible. So I've been advocating the use of engineering statics, which is*

heavy algebra, a little trigonometry, a little geometry, as a way of improving their math skills. I think this is very important to ensure the success of our graduates going into college science and engineering curriculums. Statics has historically been a weeding-out course in engineering colleges.
--High school teacher

The Connecticut standards (see Connecticut science standards at the end of this brief) provide a framework and guidepost for teachers. However, they use it not as a straightjacket but to anchor their work. They are creative.

While we were investigating the caves and how they form, students had to make an illumination device using the circuitry from physics. They had to build a hands-free illumination device. We're taking the physics content and saying, "How do we apply it?" High school teacher.

Recognizing that some students need more algebra instruction, teachers carefully integrated algebra into the science program.

Starting out, I've got it (algebra) in there. I'll pull some things out when we do energy. But as far as simple algebra I feel it's a good idea to have them at least exposed to it. There's a group of 15 kids that are out there, they are ready for it, so I've got to challenge them.

Kids fall into three or four categories. The top category, they can do it and they know what it means. Then there are the one's who can do, but if I give them another problem they can do it. If there's any variation, they're going to struggle. Then there's the ones that no matter how much you try, they have trouble with manipulations.

Importantly, when students struggled with some basic math concepts they moved ahead with related science concepts. One teacher found that organizing instruction in two week units was an effective strategy to maintain flexibility. Another indicated that assignments were designed to respond to individual student needs. The classroom was organized to provide each student with assignments to reteach and review concepts or to accelerate when students were ready for the next level of work.

University of Hartford professors support the school's inquiry-based hands on curriculum.

Teaching engineering at the high school level is still a relatively new phenomenon in the United States. Project Lead the Way is perhaps the most well known of the initiatives, but it has still reached only a few schools. Our philosophy here has been to attempt to have the students ***"get their fingers dirty" as I like to express it, in other words, receive an experience in school similar to what earlier generations learned outside of school.*** *That is, I would like them to emerge from their high school engineering experience having built and repaired electronic devices, learned how to survey, used a strength of materials machine, a wind tunnel, a wave machine, etc., ad infinitum. I would also give them as broad a base of experience as humanly possible, with experience in electrical, mechanical, and civil engineering; at ages 14-18, they should not as yet be forced to specialize. The ultimate result would be that the* <u>*synthesis*</u> *of theoretical concepts learned in the science courses combined with the practica of the engineering courses will produce a graduate that is very well prepared to succeed in college, graduate school, the business world, or academia.*
--University of Hartford Professor

By employing pedagogies that "get their fingers dirty", teachers have employed a variety of inquiry-based teaching strategies that teach students how concepts are relevant to daily life. Examples are provided by high school freshmen engineering and physics teachers.

> *The freshman engineering students are building hands-free illumination devices. Most of them are building headlamps of one sort or another. The introduction we gave them is they're going spelunking[2] and they need to be able to climb over rocks and such. They need to be able to have enough illumination and minimize the use of their hands on the device, so their hands are free to climb.*

> *I am trying to make connections to something in the world that we can connect to. When the tsunami happened, we jumped into waves.*

Teachers, school administration, and college students are in agreement that the high school should emphasize the importance of keeping the science program "real" to the high school students.

> *I try to make it real for them. After a camping trip he noted. Instead of saying, "Here are the equations for heat. Here is how you use them." We said, "Okay, we're going to go camping and we've got these three fuels. We want to know which one to bring with us and you need to make a decision. Which one? We're going backpacking for four days. Which one do you want to bring, and you need to defend your answer." Then we came back around and said, "Okay, how do we measure how much heat they gave us? Okay we got the heat, how do we say how much?-what's another way, well energy per mass, or how fast? What's the power rating?" So we went through all these different things, and now instead of just being equations that they plugged in and used, it was, I got this fuel and mine is better than yours because X,Y, Z." …. I think in two years, it was my most successful unit as far as how to put it into context they could use. They could get their hands around it, and then tie it back into the energies we use. The main component of the freshman 9th grade curriculum is energy transformation.—the STS component being fossil fuels versus renewable resources.*

Conclusion

The University High School for Science and Engineering is well on its way to achieving its goal: giving students a leg up on college. Their new program is grounded in what is best for the kids. The curriculum and instruction are pitched to student needs and press them to work hard and achieve. The teachers are caring in their approach. Teaching practices are flexible in ways that adapt to varied levels of student development. And most importantly, the high school is continually examining what is working, and what new efforts they might undertake. Their efforts are a model for others in the Woodrow Wilson Early College network to explore.

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[2] Clay Perry — an American caver of the 1940s — wrote about a group of men and boys who explored and studied caves throughout New England. This group referred to themselves as ***spelunkers***. This is regarded as the first use of the word in the Americas. Throughout the 1950s, ***spelunking*** was the general term used for exploring caves in US English. It was used freely, without any positive or negative connotations, although only rarely outside the US.

<table>
<tr><th colspan="2">Grades 9-10 Core Scientific Inquiry, Literacy and Numeracy
How is scientific knowledge created and communicated?</th></tr>
<tr><th>Content Standards</th><th>Expected Performances</th></tr>
<tr><td>SCIENTIFIC INQUIRY
♦ Scientific inquiry is a thoughtful and coordinated attempt to search out, describe, explain and predict natural phenomena.
♦ Scientific inquiry progresses through a continuous process of questioning, data collection, analysis and interpretation.
♦ Scientific inquiry requires the sharing of findings and ideas for critical review by colleagues and other scientists.

SCIENTIFIC LITERACY
♦ Scientific literacy includes the ability to read, write, discuss and present coherent ideas about science.
♦ Scientific literacy also includes the ability to search for and assess the relevance and credibility of scientific information found in various print and electronic media.

SCIENTIFIC NUMERACY
♦ Scientific numeracy includes the ability to use mathematical operations and procedures to calculate, analyze and present scientific data and ideas.</td><td>D INQ.1 Identify questions that can be answered through scientific investigation.
D INQ.2 Read, interpret and examine the credibility and validity of scientific claims in different sources of information.
D INQ.3 Formulate a testable hypothesis and demonstrate logical connections between the scientific concepts guiding the hypothesis and the design of the experiment.
D INQ.4 Design and conduct appropriate types of scientific investigations to answer different questions.
D INQ.5 Identify independent and dependent variables, including those that are kept constant and those used as controls.
D INQ.6 Use appropriate tools and techniques to make observations and gather data.
D INQ.7 Assess the reliability of the data that was generated in the investigation.
D INQ.8 Use mathematical operations to analyze and interpret data, and present relationships between variables in appropriate forms.
D INQ.9 Articulate conclusions and explanations based on research data, and assess results based on the design of the investigation.
D INQ.10 Communicate about science in different formats, using relevant science vocabulary, supporting evidence and clear logic.</td></tr>
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<table>
<tr><th colspan="2">Grade 9
Core Themes, Content Standards and Expected Performances
Strand II: Chemical Structures and Properties</th></tr>
<tr><th>Content Standards</th><th>Expected Performances</th></tr>
<tr><td>Properties of Matter – How does the structure of matter affect the properties and uses of materials?
9.4 - Atoms react with one another to form new molecules.
♦ Atoms have a positively charged nucleus surrounded by negatively charged electrons.
♦ The configuration of atoms and molecules determines the properties of the materials.</td><td>D 1. Describe the general structure of the atom, and explain how the properties of the first 20 elements in the Periodic Table are related to their atomic structures.
D 2. Describe how atoms combine to form new substances by transferring electrons (ionic bonding) or sharing electrons (covalent bonding).
D 3. Explain the chemical composition of acids and bases, and explain the change of pH in neutralization reactions.</td></tr>
<tr><td>Properties of Matter – How does the structure of matter affect the properties and uses of materials?
9.5 – Due to its unique chemical structure, carbon forms many organic and inorganic compounds.
♦ Carbon atoms can bond to one another in chains, rings and branching networks to form a variety of structures, including fossil fuels, synthetic polymers and the large molecules of life.</td><td>D 4. Explain how the structure of the carbon atom affects the type of bonds it forms in organic and inorganic molecules.
D 5. Describe combustion reactions of hydrocarbons and their resulting by-products.
D 6. Explain the general formation and structure of carbon-based polymers, including synthetic polymers, such as polyethylene, and biopolymers, such as carbohydrate.</td></tr>
<tr><td>Science and Technology in Society – How do science and technology affect the quality of our lives?
9.6 - Chemical technologies present both risks and benefits to the health and well-being of humans, plants and animals.
♦ Materials produced from the cracking of petroleum are the starting points for the production of many synthetic compounds.
♦ The products of chemical technologies include synthetic fibers, pharmaceuticals, plastics and fuels.</td><td>D 7. Explain how simple chemical monomers can be combined to create linear, branched and/or cross-linked polymers.
D 8. Explain how the chemical structure of polymers affects their physical properties.
D 9. Explain the short- and long-term impacts of landfills and incineration of waste materials on the quality of the environment.</td></tr>
</table>

Grade 9

Core Themes, Content Standards and Expected Performances

Strand III: Global Interdependence

Content Standards	Expected Performances
The Changing Earth – How do materials cycle through the Earth's systems? **9.7 - Elements on Earth move among reservoirs in the solid earth, oceans, atmosphere and organisms as part of biogeochemical cycles.** ♦ Elements on Earth exist in essentially fixed amounts and are located in various chemical reservoirs. ♦ The cyclical movement of matter between reservoirs is driven by the Earth's internal and external sources of energy.	**D 10.** Explain how chemical and physical processes cause carbon to cycle through the major earth reservoirs. **D 11.** Explain how solar energy causes water to cycle through the major earth reservoirs. **D 12.** Explain how internal energy of the Earth causes matter to cycle through the magma and the solid earth.
Science and Technology in Society – How do science and technology affect the quality of our lives? **9.8 - The use of resources by human populations may affect the quality of the environment.** ♦ Emission of combustion by-products, such as SO_2, CO_2 and NOx by industries and vehicles is a major source of air pollution. ♦ Accumulation of metal and non-metal ions used to increase agricultural productivity is a major source of water pollution.	**D 13.** Explain how the release of sulfur dioxide (SO_2) into the atmosphere can form acid rain, and how acid rain affects water sources, organisms and human-made structures. **D 14.** Explain how the accumulation of carbon dioxide (CO_2) in the atmosphere increases Earth's "greenhouse" effect and may cause climate changes. **D 15.** Explain how the accumulation of mercury, phosphates and nitrates affects the quality of water and the organisms that live in rivers, lakes and oceans.
Science and Technology in Society – How do science and technology affect the quality of our lives? **9.9 - Some materials can be recycled, but others accumulate in the environment and may affect the balance of the Earth systems.** ♦ New technologies and changes in lifestyle can have positive and/or negative effects on the environment.	**D 16.** Explain how land development, transportation options and consumption of resources may affect the environment. **D 17.** Describe human efforts to reduce the consumption of raw materials and improve air and water quality.

<table>
<tr><th colspan="2">Grade 10
Core Themes, Content Standards and Expected Performances
Strand IV: Cell Chemistry and Biotechnology</th></tr>
<tr><th>Content Standards</th><th>Expected Performances</th></tr>
<tr><td>Structure and Function – How are organisms structured to ensure efficiency and survival?
10.1 - Fundamental life processes depend on the physical structure and the chemical activities of the cell.
♦ Most of the chemical activities of the cell are catalyzed by enzymes that function only in a narrow range of temperature and acidity conditions.
♦ The cellular processes of photosynthesis and respiration involve transformation of matter and energy.</td><td>D 18. Describe significant similarities and differences in the basic structure of plant and animal cells.
D 19. Describe the general role of DNA and RNA in protein synthesis.
D 20. Describe the general role of enzymes in metabolic cell processes.
D 21. Explain the role of the cell membrane in supporting cell functions.</td></tr>
<tr><td>Science and Technology in Society – How do science and technology affect the quality of our lives?
10.2 - Microorganisms have an essential role in life processes and cycles on Earth.
♦ Understanding the growth and spread patterns of viruses and bacteria enables the development of methods to prevent and treat infectious diseases.</td><td>D 22. Describe the similarities and differences between bacteria and viruses.
D 23. Describe how bacterial and viral infectious diseases are transmitted, and explain the roles of sanitation, vaccination and antibiotic medications in the prevention and treatment of infectious diseases.
D 24. Explain how bacteria and yeasts are used to produce foods for human consumption.</td></tr>
<tr><td>Science and Technology in Society – How do science and technology affect the quality of our lives?
10.3 - Similarities in the chemical and structural properties of DNA in all living organisms allow the transfer of genes from one organism to another.
♦ The principles of genetics and cellular chemistry can be used to produce new foods and medicines in biotechnological processes.</td><td>D 25. Describe, in general terms, how the genetic information of organisms can be altered to make them produce new materials.
D 26. Explain the risks and benefits of altering the genetic composition and cell products of existing organisms.</td></tr>
</table>

Grade 10 Core Themes, Content Standards and Expected Performances Strand V: Genetics, Evolution and Biodiversity	
Content Standards	**Expected Performances**
Heredity and Evolution – What processes are responsible for life's unity and diversity? **10.4. - In sexually reproducing organisms, each offspring contains a mix of characteristics inherited from both parents.** ♦ Genetic information is stored in genes that are located on chromosomes inside the cell nucleus. ♦ Most organisms have two genes for each trait, one on each of the homologous chromosomes in the cell nucleus.	**D 27.** Explain how meiosis contributes to the genetic variability of organisms. **D 28.** Use the Punnet Square technique to predict the distribution of traits in mono- and di-hybrid crossings. **D 29.** Deduce the probable mode of inheritance of traits (e.g., recessive/dominant, sex-linked) from pedigree diagrams showing phenotypes. **D 30.** Describe the difference between genetic disorders and infectious diseases.
Heredity and Evolution – What processes are responsible for life's unity and diversity? **10.5 - Evolution and biodiversity are the result of genetic changes that occur over time in constantly changing environments.** ♦ Mutations and recombination of genes create genetic variability in populations. ♦ Changes in the environment may result in the selection of organisms that are better able to survive and reproduce.	**D 31.** Explain how the processes of genetic mutation and natural selection are related to the evolution of species. **D 32.** Explain how the current theory of evolution provides a scientific explanation for fossil records of ancient life forms. **D 33.** Describe how structural and behavioral adaptations increase the chances for organisms to survive in their environments.

Science and Technology in Society – How do science and technology affect the quality of our lives? **10.6 - Living organisms have the capability of producing populations of unlimited size, but the environment can support only a limited number of individuals from each species.** ♦ Human populations grow due to advances in agriculture, medicine, construction and the use of energy. ♦ Humans modify ecosystems as a result of rapid population growth, use of technology and consumption of resources.	**D 34.** Describe the factors that affect the carrying capacity of the environment. **D 35.** Explain how change in population density is affected by emigration, immigration, birth rate and death rate, and relate these factors to the exponential growth of human populations. **D 36.** Explain how technological advances have affected the size and growth rate of human populations throughout history.

High School Physics	
Content Standards	**Supportive Concepts**
Motion and Forces Newton's laws predict the motion of most objects.	▪ When forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest. ▪ The law $F = ma$ is used to solve motion problems that involve constant forces. ▪ When one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction. ▪ Applying a force to an object perpendicular to the direction of its motion causes the object to change direction. ▪ Circular motion requires the application of a constant force directed toward the center of the circle. ▪ Newton's laws are not exact, but provide very good approximations unless an object is small enough that quantum effects become important.
Conservation of Energy and Momentum The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects.	▪ Kinetic energy can be calculated by using the formula E = (1/2)mv2. ▪ Changes in gravitational potential energy near Earth can be calculated by using the formula (change in potential energy) = *mgh.* ▪ Momentum is calculated as the product *mv*. ▪ Momentum is a separately conserved quantity different from energy. ▪ An unbalanced force on an object produces a change in its momentum. ▪ The principles of conservation of momentum and energy can be used to solve problems involving elastic and inelastic collisions.
Heat and Thermodynamics Energy cannot be created or destroyed although, in many processes, energy is transferred to the environment as heat.	▪ Heat flow and work are two forms of energy transfer between systems. ▪ The work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature. ▪ The internal energy of an object includes the energy of random motion of the object's atoms and molecules. The greater the temperature of the object, the greater the energy of motion of the atoms and molecules that make up the object. ▪ Most processes tend to decrease the order of a system over time, so that energy levels eventually are distributed more uniformly.

Waves Waves have characteristic properties that do not depend on the type of wave.	▪ Waves carry energy from one place to another. ▪ Transverse and longitudinal waves exist in mechanical media, such as springs and ropes, and in the Earth as seismic waves. ▪ Wavelength, frequency and wave speed are related. ▪ Sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates. ▪ Radio waves, light and X-rays are different wavelength bands in the spectrum of electromagnetic waves, the speed of which in a vacuum is approximately 3×10^8m/s, and less when passing through other media. ▪ Waves have characteristic behaviors, such as interference, diffraction, refraction and polarization. ▪ Beats and the Doppler Effect result from the characteristic behavior of waves.
Electric and Magnetic Phenomena Electric and magnetic phenomena are related and have many practical applications.	▪ The voltage or current in simple direct current (DC) electric circuits constructed from batteries, wires, resistors and capacitors can be predicted using Ohm's law. ▪ Any resistive element in a DC circuit dissipates energy, which heats the resistor. ▪ The power in any resistive circuit element can be calculated by using the formula Power = 1^2R. ▪ Charged particles are sources of electric fields and are subject to the forces of the electric fields from other charges. ▪ Magnetic materials and electric currents (moving electric charges) are sources of magnetic fields and are subject to forces arising from the magnetic fields of other sources. ▪ Changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors. ▪ Plasmas, the fourth state of matter, contain ions, or free electrons or both and conduct electricity.