Chapter 1. “Energy and Power” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) identify commonly used terms and abbreviations which are used as units of energy and power such as watt, kW, calories, Cal., horsepower, kilowatt-hour, BTU and joule.

2) be able to deal with large and small numerical quantities using scientific notation and the standard prefixes nano (n), micro (µ), milli (m), kilo (k), mega (M), and giga (G).

2) perform simple calculations involving energy, power and time.

3) use conversion tables to convert between different units of power and energy.

4) distinguish between phenomena involving large energy output and large power output.

5) distinguish between sources of energy and methods of energy transport.

6) discuss the characteristics of different sources of energy and energy transportation methods covered in the chapter. This should include how factors such as weight, volume, and cost govern their use in today’s society.

7) discuss why people worry about wasting energy even though physicists claim that energy is always conserved.

8) explain what we mean the following terms: hybrid car, electric car, incandescent light bulb, high efficiency light bulb, solar cell, hydrogen fuel cell...

9) make order-of-magnitude estimates for the power associated with a square meter of sunlight, a battery, a light bulb, and an automobile.

10) answer questions requiring approximate estimates for the efficiency of devices such as light bulbs, motors, and solar cells.
Chapter 2. “Atoms and Heat” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) make approximate conversions between Fahrenheit and Celsius scales. (Do this by memorizing the temperatures of freezing water and boiling water in both Fahrenheit and Celsius

2) convert temperatures measured in Celsius to the Kelvin scale. (Hint: Memorize the value of absolute zero on the Celsius scale.)

3) work with the extremely large and small numbers encountered in physics by using the standard prefixes to express common factors-of-ten multipliers. (Be sure to know the pronunciations and numeric multiplier values associated with the symbols n, µ, m, k, M, and G. Example, the symbol kW is pronounced “kilowatt” and means 1000 watts.)

4) give very rough order-of-magnitude estimates for the expansion of a solid when its temperature changes and the expansion of a substance when it undergoes a liquid to gas phase change.

5) use the ideal gas law to calculate the change in a pressure for a gas held at constant volume or the change volume for a gas held at constant pressure when the gas temperature changes. (Be sure to understand the importance of using the Kelvin temperature scale.)

6) explain the term “absolute zero” and its connection to the Kelvin scale.

7) discuss the first, second, and third laws of thermodynamics.

8) define what we mean by a “heat engine” and be able identify the source of heat and the method of heat dissipation for common heat engines.

9) apply the heat engine efficiency equation to calculate the fraction of heat energy that can be used to perform useful work.

10) discuss what we mean by “conduction, “convection” and “radiation”.

11) apply your knowledge to interpreting the information found in the news articles addressing energy issues.
Chapter 3. “Gravity, Force, and Space” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) understand that all objects feel an attractive force due to gravity.

2) discuss the meaning of Newton’s second and third laws and his law of gravity.

3) describe what a physicist means by term acceleration and explain its connection to Newton’s 2nd Law.

4) discuss the conditions under which an object can appear to be “weightless” even when it is near the Earth’s surface.

5) recognize scenarios, such as those sometimes found in movies or television, that clearly violate one or more of Newton’s laws.

6) define and discuss the following terms: “escape velocity”, “terminal velocity”, “geosynchronous orbit” and “g-factor”.

7) describe what is meant by terms Low-Earth-Orbit (LEO), Medium-Earth-Orbit (MEO), and High-Earth-Orbit (HEO) and gives examples of satellites which are in these orbits.

8) discuss why communication satellites are often put into geosynchronous orbits.

9) explain what is meant by the terms conservation of momentum and conservation of angular momentum and discuss situations in which these concepts can be used to understand motion.

10) discuss how airplanes, helicopters, helium balloons, and rockets can fly using appropriate physics principles such as force and momentum.

11) use the concepts of energy and momentum conservation to discuss issues relating to launching objects into space.
Chapter 4. “Nuclei and Radioactivity” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) define the term “radiation” and give several examples.

2) discuss several natural and man-made sources of radiation.

3) define the terms “ionizing radiation” and “non-ionizing radiation” and discuss why exposure to ionizing radiation can lead to adverse health effects.

4) explain what is meant by the terms “x-rays”, “gamma-rays”, “alpha particles”, and “beta rays”.

5) discuss the meaning of the term “isotopes”, and interpret the notation for specifying specific isotopes such as $^{12}\text{C}$, $^{13}\text{C}$, U-235, and U-238.

6) discuss the meaning of the terms “isotopes”, “enriched Uranium”, and “depleted Uranium”.

7) solve problems involving radiation exposures measured in the units “rem” and “mrem” including conversion between “rems” and “Sieverts”.

8) distinguish between short-term and long-term health effects of radiation exposure.

9) discuss the short-term health effects resulting from high levels of radiation exposure.

10) apply the “linear hypothesis” to estimate the number of excess occurrences of cancer in a population exposed to radiation. (Hint: memorize the radiation exposure that gives an estimated 1% probability of excess cancer occurrences.) Be able to compare this to typical cancer rates.

11) describe the difference between “fission” and “fusion”.

12) explain the concept of "half-life" and calculate the fraction of a radioactive substance which would remain after a given number of half-lives has passed.

13) explain the science of $^{14}\text{C}$ dating and discuss the types of objects and the range of ages for which it is useful.

14) list several methods of radiometric dating and their corresponding applications.

15) explain the meaning of the terms “dirty-bomb” and “ICBM”.

Chapter 5. “Chain Reactions, Nuclear Reactors, and Atomic Bombs” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) describe what is meant by a “chain reaction” and give several examples of phenomena which demonstrate chain reactions and exponential growth.

2) explain the meaning of the term “critical mass”.

3) define the terms “natural uranium”, “enriched uranium”, and “depleted uranium”.

4) discuss the purpose of a nuclear fuel processing plant.

5) discuss the meaning of the term “moderator” and explain why moderators are used in nuclear reactors.

6) describe the two types of atomic bombs exploded during World War II, including the types of fuel used and the technical difficulties associated with use of these fuels.

7) discuss the difference between reactor-grade uranium and bomb-grade uranium and explain why a nuclear reactor cannot blow up like an atomic bomb.

8) define the term “thermonuclear weapon” and discuss the difference between fission-based bombs and fusion-based bombs.

9) identify the approximate quantity of fuel required for an atomic bomb and for a nuclear reactor.

10) discuss the difficulties involved in handling and storing the wastes from nuclear power plants.

11) discuss the advantages and disadvantages of nuclear power compared to other energy sources.

12) discuss the potential advantages of a fusion-based reactor and the technical difficulties of constructing such a reactor.

16) give a concise description of what happened at Three Miles Island in 1979 and at Chernobyl in 1986, and discuss in what respect the events are similar and in what respect they are different. (Use material from both Chpts. 4 and 5.)

17) give a concise description of what happened at the Fukushima nuclear power plants following the earthquake and tsunami of March, 2011 and discuss the difficulties encountered with keeping the reactors cool even after the chain reactions had been shut down
Chapter 6. “Electricity and Magnetism” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) define the terms “charge”, “electric current”, “voltage”, “resistance”, and “high-tension”.
2) define the terms “AC current” and “DC current”.
3) discuss the sources of electrical forces and the sources of magnetic forces.
4) explain the role of an electrical generator in a power plant.
5) solve problems involving the relationship between “voltage”, “current”, and “resistance”.
6) solve problems involving the relationship between “power, “voltage”, and “current”.
7) perform calculations involving quantities which have units such as “watts” (W), “amps” (A), “coulombs” (C), “ohms” (Ω), “volts” (V), and “electron-volts” (eV).
8) discuss why electrical power is delivered to communities using high-tension power lines.
9) discuss the role of transformers and AC current in a power-distribution system.
10) solve problems requiring knowledge of the voltages and currents typical of household appliances.
11) describe the source of the Earth’s magnetic field.
12) discuss the path followed by the energy from a lump of coal or Uranium fuel to an electrified appliance in your house.
13) discuss the role of fuses, circuit breaks, and ground fault interrupters (GFIs) in a house.
14) describe what is meant by a “superconductor”.
15) Solve problems involving the relationships between power, voltage, current, and resistance.
Chapter 7. “Waves” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) define the terms “wavelength”, “frequency”, “period”, and “amplitude”.

2) give examples of waves that travel through air, liquid, and solid.

3) define the terms “transverse wave” and “longitudinal wave” and be able to use the terms appropriately when discussing examples of waves.

4) solve quantitative problems involving the relationships between “speed”, “wavelength”, “frequency”, and “period.”

5) solve qualitative problems involving the bending of waves as they propagate across a region of varying speed.

6) define the terms “constructive interference” and “destructive interference” and be able to give examples of these phenomena involving sound, water waves, and light.

7) define the term “Doppler shift” and give examples of applications of this phenomena.

8) discuss the relationship between the speed of sound and the temperature of the air.

9) discuss the physics and applications of the sound channel in the ocean and the sound channel in the atmosphere.

10) entertain your friends with explanations of how the Sofar spheres saved downed pilots, how Project Mogul led to the believe that flying saucers were found in Roswell New Mexico, and how Project SOSUS used the sound channel to track submarines.

11) discuss the type of waves generated by earthquakes and describe what they tell us about the interior of the Earth.

12) recall an approximate value of the speed of sound in air and be able to use this value in a calculation.

13) explain why wave amplitudes increase when a wave slows down.
Chapter 8. “Light” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) apply the first 7 student learning objectives listed for Chapter 7 to problems involving light waves.

2) discuss the experimental evidence supporting the model that light is a wave, including the details of Young’s 2-slit experiment.

3) give approximate values for the speed of light and the wavelengths corresponding to optical light.

4) make a sketch of an electromagnetic-wave which shows the direction of the electric and magnetic fields relative to the wave’s direction of propagation.

5) define the terms “spectral color”, “index of refraction”, “polarization”, and “polarizer”.

6) list the spectral colors in order of increasing wavelength.

7) discuss phenomena that separate white light into a spectrum, including examples involving refraction and examples of involving interference effects.

8) discuss what happens to an unpolarized beam of light when it is directed at two polarizers rotated at 90° relative to each other.

9) discuss how the human eye senses color and the limitations encountered because it has only three types of color-sensing cones.

10) discuss why the primary colors used for devices such as your computer screen are different than the primary colors used by an inkjet printer and give other examples of additive color-mixing and subtractive color-mixing.

11) make a sketch of an electromagnetic-wave which shows the direction of the electric and magnetic fields and the wave’s direction of propagation.

12) explain how pinhole cameras and cameras with a focusing lens work by making a sketch of several light-ray paths.

13) use the relationship between diffraction blurring, wavelength and aperture size to estimate the diffraction-limit of an imaging device’s resolution.
Chapter 9. “Invisible Light” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) identify terms describing radiation from different regions of the electromagnetic spectrum, including “gamma-rays”, “x-rays”, “ultra-violet”, “visible light”, “infra-red”, “micro-waves”, and “radio-waves” and give an estimate of the typical wavelengths associated with each type of radiation.

2) discuss how images of warm objects can be obtained even in the absence of visible light.

3) discuss the characteristics of thermal-radiation and be able to make a rough sketch illustrating the shape of the thermal radiation spectrum.

4) describe, qualitatively, how the color of the thermal radiation emitted from an object changes as the temperature of the object is increased and use the “color law” to relate the peak of the thermal radiation spectrum with an object’s temperature quantitatively.

5) describe the relation between the total thermal radiation energy emitted from and object and the object’s temperature.

6) give several examples of technologies that involve sensing infra-red radiation.

7) define the term “fluorescent”.

8) use the theory of photons to explain why there are materials that transform ultraviolet light to visible light but there are no materials that transform infrared light to visible light.

9) understand why some forms of radiation can cause cancer by breaking chemical bonds through ionization and others cannot.

10) define terms referring to various imaging techniques that utilize electromagnetic radiation such as “x-ray images”, “x-ray backscatter”, “MRI”, “CT scan”, “PET scan”,

11) define terms referring to imaging techniques that utilize sound, such as sonograms and sonar.

12) use the diffraction resolution equation introduced in Chapter 8 to work problems involving the diffraction resolution limit for various device apertures and electromagnetic wavelength.

13) discuss the connection between the ozone layer, UV light, and the motivation for banning the use of CFCs (chloro-fluoro-carbons) in the 1990’s.

14) discuss why a “CFL” is more efficient than a incandescent light bulb.
Chapter 10. “Climate Change” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) describe what is meant by “the Global Warming”.

2) discuss factors which determine the average temperature of the Earth.

3) define the terms “greenhouse effect”, and “green house gasses”.

4) differentiate between the concerns about the ozone-layer depletion, discussed in Chpt. 9, and the concerns about global warming and greenhouse gasses discussed in Chpt. 10.

5) give a reasonable estimate for the change in CO2 levels and in the average global temperature since the beginning of industrialization.

6) discuss what is known and/or speculated about how carbon-dioxide emissions might affect the Earth’s climate.

7) discuss what is known about temperature changes over the past 600,000 years.

8) discuss the IPCC and its findings, paying particular attention to statements regarding how the activities of humans may have affected the global temperature.

9) discuss the difference between a “causal relationship” between two phenomena and just a “correlation” between two phenomena.

10) define the terms “positive feedback” and “negative feedback”.

11) discuss why attempts to understand the effect of greenhouse gasses on the Earth’s global climate by performing simulations have had only limited success.

12) give examples of arguments given by both “pro climate-change” groups and “anti climate-change” groups that are incorrect or exaggerated.

13) give reasonable estimates for the amount of CO2 emitted by a single power plant and in the entire U.S.
(Chapter 11. “Quantum Mechanics” not covered)

Chapter 12. “Relativity” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) describe what is meant by a “frame of reference” and give some examples of physical properties or quantities that are “invariant” during a frame transformation and some examples of physical quantities whose values depend on the frame of reference.

2) discuss what is meant when we say that the speed of light is a constant.

3) describe what is meant by “the principle of relativity.”

4) sketch the Lorentz factor γ as a function of β which illustrates its behavior at low values of β (β near 0) and high values of β (β near 1).

5) define the terms “proper length” and “proper time”.

6) perform calculations involving time dilation and/or length contraction by identifying a proper length or proper time, determining the value of γ, and appropriately multiplying or dividing by γ to solve a frame transformation problem using the equations $L = L_0/\gamma$ and $t = \gamma t_0$.

7) discuss what is meant by the terms “general relativity” and “special relativity”
Chapter 13. “The Universe” Student Objectives

After mastering the concepts of this chapter, you should be able to:

1) define the term “Universe” and give three examples. (Just kidding… ignore this one.)

2) define the terms “galaxy”, “supernova”, and “Milky Way”.

3) answer questions requiring an estimate of the age of the solar system, the Earth, or the Universe.

4) sketch diagrams that illustrate the cause of lunar eclipses, solar eclipses, new moon, and full moon.

5) describe what astronomers mean by the expression “standard candle”.

6) discuss the scientific data used by Hubble to derive Hubble’s Law and be able to use Hubble’s law in a calculation.

7) discuss what is meant by “the Big Bang” theory and why Hubble’s law and the observation of the 3K cosmic microwave background support this theory.

8) discuss which elements found on Earth were formed just after the big bang, by fusion in stars, or during supernovas, and how (very roughly) this happen.

9) discuss how thermal energy is produced in stars.

10) discuss how cosmologists can observe events that took place billions of years back in time.

11) discuss the means by which astronomers can measure the distance to far stars or galaxies.

12) discuss what is meant by the terms “dark matter” and “dark energy”.