Grades 9-12   Physics

Motion

1. The motion of objects is described by velocity, acceleration, and force vectors. As a basis for understanding this concept, students know:

    a.   how to solve problems involving constant speed and average speed.

    b.   velocity is the rate of change of position in a particular direction.

    c.   acceleration is the rate of change of velocity.

    d.   force is a push or pull that causes changes in motion.

    e.   when forces are balanced no acceleration occurs, and thus an object continues to move at a constant speed or stays at rest (Newton's First Law).

    f.   motion in a circle requires force that is always directed toward the center of the circle.

    g.   when any pair of objects interact, the forces on each due to the other are equal in magnitude and opposite in direction (Newton's Third Law).

    h.   the relationship between the universal law of gravitation and the force of gravity on an object at the surface of the Earth.

    i.   force perpendicular to the direction of motion causes a change in direction.

    j.   motion in a circle requires force that is always directed toward the center of the circle.

  * k.   Newton's Laws are not exact but they provide very good approximations unless an object is moving close to the speed of light or is small enough that the quantum effects are important.

  * l.   how to solve two-dimensional static and trajectory problems.

    m.   how to resolve two-dimensional vectors into their components and calculate the magnitude and direction of a vector from its components.

    n.   how to build a foot-long balsa wood bridge illustrating the strength of static equilibrium.

    o.   how to solve problems in circular motion, using the formula for centripetal acceleration in the following form: $a=v^2/r$.

    p.   how to solve problems involving the forces between two electric charges at a distance (Coulomb's Law) or the forces between two masses at a distance (Universal gravitation).

    q.   how to compute a value for g using the motion of an object on an incline plane or a pendulum.

Conservation of Energy and Momentum

2. The laws of conservation of energy and momentum provide a way to predict and describe the movement of objects. As a basis for understanding this concept, students know:

    a.   how to calculate kinetic energy using the formula $KE=(1/2)mv^2$ and gravitational potential energy near the Earth using the formula $PE=mgh$.

    b.   how to solve problems involving conservation of energy in simple frictionless systems such as falling objects in a vacuum.

    c.   how to calculate momentum as product mv and that momentum is a separately conserved quantity in every collision in the universe, which is different from energy.

    d.   an unbalanced force on an object produces a change in its momentum.

    e.   how to solve problems involving elastic collisions in one dimension using the principles of conservation of momentum and energy.

  * f.   how to solve problems involving conservation of energy in simple systems incorporating a variety of sources of potential energy, such as capacitors and springs.

    g.   how to solve problems involving inelastic collisions in one dimension.

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Work, Power, and Simple Machines
3. <u>Machines do work and develop power with different efficiencies</u>. As a basis for understanding this concept, students know:
    a.   work done is the dot product of force applied and displacement as well as the change in energy produced.
    b.   power is the rate of doing work.
    c.   there are six simple machines each with an efficiency of work output / work input as well as IMA / AMA.
    d.   how to determine the power needed to perform a given work in a given time.

Basic Astronomy
4. <u>The study of the motions observed in the heavens has a rich history linked to natural philosophy or physics</u>. As a basis for understanding this concept, students know:
    a.   the recurring motions of the sun, moon, stars, and planets.
    b.   the basic astronomical contributions of Aristarchus, Ptolemy, Eratosthenes, Galileo, Kepler, and Newton.
    c.   how to plot to scale the orbit of the Earth, Mars, and Mercury.
    d.   how to use Kepler's Laws to determine the eccentricity, period and radius of a satellite's orbit.
    e.   a dozen of the brightest stars and constellations in the San Marino winter sky.

Heat and Thermodynamics
5. <u>Energy cannot be created or destroyed, however in many processes energy is lost to the environment as heat, that is as disordered motion of atoms</u>. As a basis for understanding this concept students know:
    a.   heat flow and work are two forms of energy transfer between systems.
    b.   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 (First Law of Thermodynamics) and that this is an example of the law of conservation of energy.
    c.   heat consists of random motion and the vibrations of atoms and molecules. The higher the temperature, the greater the atomic or molecular motion.
    d.   everything tends to become less organized and less orderly over time. Thus, in all energy transfers, the overall effect is that the energy is spread out uniformly.
    e.   entropy is a quantity that measures the order or disorder of a system, and is larger for a more disordered system.
    f.   the statement "entropy tends to increase" is a law of statistical probability that governs all closed systems (Second Law of Thermodynamics).
    g.   how to solve problems involving heat flow, work, and efficiency in a heat engine and know that all real engines have some heat flow out.
    h.   how to determine the total energy needed to change the temperature of a given amount of substance, with a change of phase occurring in between the initial and final temperatures.
    i.   how to predict the final temperature of a given mixture of hot and cold substances.

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Fluids
6. <u>Archimedes', Pascal's, and Bernoulli's principles are very useful in understanding the motion of objects in fluids</u>. As a basis for understanding this concept students know:
    a.   how to use Archimedes' principle to determine the density of a liquid.
    b.   the pressure in a confined fluid is the same in all directions.
    c.   the faster a fluid moves next to a surface the less the pressure it exerts against the surface.
    d.   how to determine the fraction of an object that will be submerged in a liquid given their densities.
    e.   why a moving ball curves downward when given top spin.

Water, Sound and Light Waves
7. <u>Waves have characteristic properties that do not depend on the type of wave</u>. As a basis for understanding this concept, students know:
    a.   waves carry energy from one place to another proportional to its amplitude squared.
    b.   how to identify transverse and longitudinal waves in mechanical media such as springs, ropes, and the Earth (seismic waves).
    c.   how to solve problems involving wavelength, frequency, and wave speed.
    d.   sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates.
    e.   radio waves, light and X-rays are electromagnetic waves whose speed in vacuum is 3×10^8 m/s (186,000 miles/second).
    f.   how to identify the phenomena of interference (beats), diffraction, refraction, Doppler effect, and polarization and know that these are distinctive wave properties.
    g.   how to calculate the standing wave frequency created by a cardboard pipe resonating over a Bunsen burner.

Electric and Magnetic Phenomena
8. <u>Electric and magnetic phenomena are related and have many practical applications</u>. As a basis for understanding this concept, students know:
    a.   how to predict the voltage or current in simple electric circuits constructed from batteries, wires, resistors, and capacitors.
    b.   how to solve problems involving Ohm's law.
    c.   how to calculate the power (energy per unit time) dissipated in any circuit element by using the formula that Power $= I^2R$.
    d.   the properties of transistors and their role in electric circuits.
    e.   that electric and magnetic fields contain energy and act on charged particles or currents.
    f.   how to determine the orientation of a magnetic field produced by a current flowing in a straight wire and a coil.
    g.   changing magnetic fields produce electric fields, thereby inducing currents in nearby conductors.
    h.   that plasmas, the fourth state of matter, contain ions and/or free electrons and conduct electricity.
    i.   that electric and magnetic fields contain energy and act as vector force fields.
    j.   the force on a charged particle in an electric field is qE, where E is the electric field at the position of the particle and q is the charge of the particle.

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Electric and Magnetic Phenomena (8. continued)
- k.   how to calculate the electric field due to a point charge and recognize that static electric fields have as their source some arrangement of electric charges.
- l.   the force on a moving particle (with charge q) in a magnetic field is qvB sin(a) where a is the angle between v and B (v and B are the magnitudes of vectors v and B, respectively), and students use the right-hand rule to find the direction of this force.
- * m.   how to apply the concepts of electrical and gravitational potential energy in solving problems involving conservation of energy.
- n.   how to determine the magnetic field of the Earth using a compass and a current carrying loop of wire.
- o.   how to calculate the coil ratio required in a transformer given the primary and secondary voltages.

Geometrical Optics
9. <u>Simple mirrors and lenses singly and in combination form a variety of real and virtual images.</u> As a basis for understanding this concept, students know:
- a.   how a simple magnifier works.
- b.   resolution in terms of Rayleigh's Criterion.
- c.   for a mirror or lens, given two of the three following quantities: focal length, object and image distance, how to find the unknown and the image size by three different methods: 1) algebraic formulas 2) experimental procedure (optical bench) 3) ray diagram.
- d.   the difference between a Galilean, Newtonian, and Cassegrain telescope design.
- e.   lens and mirror aberrations can be determined experimentally.
- f.   the color observed by the human eye is the result of either additive or subtractive mixing.

Special Theory of Relativity
10. <u>Einstein's paper in 1905 on Special Theory of Relativity explains what happens to objects observed to be moving in a straightline within one-tenth the speed of light in a vacuum.</u> As a basis for understanding this concept, students know
- a.   how to apply the formulas for length contraction, time dilation, and velocity addition.
- b.   that moving unstable particles verify Einstein's theory that moving clocks slow down.
- c.   what the Michelson-Morley experiment proved.

Atomic Physics
11. <u>The electrons moving within atoms have energies that are quantized.</u> As a basis for understanding this concept, students know:
- a.   how to analyze quantitatively the spectrum of a hot body in light of Planck's theory.
- b.   how to solve for the cutoff frequency and the work function in the Photoelectric Effect.
- c.   how to determine the change of wavelength in a Compton Scattering Experiment.
- d.   how to calculate the wavelength of everyday moving objects as well as that of electrons and protons within the atom.

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Atomic Physics (11. continued)
  e.   the duality of both waves and particles with the impact of the Heisenberg Uncertainty Principle.
  f.   how disctinction between emission and absorption spectra as well as between continuous and line spectra.
  g.   Bohr's assumptions and the connection between photon energy and the electron energy levels in an atom.
  h.   the limitations of the Bohr Theory.
  i.   the fundamental operation of a simple He-Ne laser at 6328 Angstroms.
  j.   how to calculate the wavelengths of the visible lines in the hydrogen spectrum given the quantized energy levels involved.
  k.   the similarities and differences between n-type and p-type materials.
  l.   the fundamental operation of a diode, transistor, and integrated circuit.
  m.   the fundamentals of the band theory of solids and the difference between electron movement and the speed of the electrical signal.

Nuclear Physics
12. <u>The force binding the nucleus together is very strong and short ranged</u>. As a basis for under-standing this concept, students know:
  a.   the neutrons and protons are themselves made up of smaller particles called quarks.
  b.   the basic properties of neutrons and protons.
  c.   nuclear stability can be discussed in terms of radioactivity, electron capture, and artificial transmutation.
  d.   the mean life is different than the half-life in light of the decay constant.
  e.   the glue of the nucleus involves mesons.
  f.   the role of antimatter is analyzed in decay and cosmic ray events.
  g.   the differences between baryons and leptons.
  h.   the binding energy of the nucleons is large compared to typical chemical reactions and it is quantifiable in fission and fusion reactions as well using Einstein's relation $E = mc^2$.

Investigation and Experimentation
13. In the context of investigations designed to develop understanding of the content of the other strands students will:
  a.   select and use appropriate tools and technology (such as computer linked probes, spread sheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
  b.   identify and communicate the sources of error inherent in experimental design.
  c.   identify discrepant results and identify possible sources of error or uncontrolled conditions.
  d.   formulate and revise explanations using logic and evidence.
  e.   apply mathematical relationships involving quadratic equations, simple trigonometric relationships, exponential growth and decay laws, and logarithmic relationships to scientific situations.
  f.   distinguish between a guess, a hypothesis and a theory as these terms are used in science.

Investigation and Experimentation (13. continued)

g. recognize the use and limitations of models and theories as scientific representations of reality.
h. read and interpret a topographic map, and a geologic map for evidence.
i. identify natural events by sequence and time from natural phenomena (e.g., relative ages of rocks and intrusions).
j. recognize the issues of statistical variability and the need for controlled tests.
k. recognize the cumulative nature of scientific evidence.
l. analyze situations and solve problems that require combining concepts from more than one topic area of science and applying these concepts to real world situations.
m. investigate a science-based societal issue by researching the literature, analyzing data where appropriate and communicating their findings. Examples include irradiation of food, cloning of animals by somatic cell nuclear transfer, choice of energy sources, and land and water use decisions (including California).