*** MIGHTY PHYSICS REVIEW NOTES ***

INERTIA-- The property of matter that opposes any change in its state of motion.
MASS-- the quantity of matter measured by its inertia.
MASS DENSITY-- mass per unit volume. D = M/V
ENERGY-- the capacity to do work.
POTENTIAL ENERGY-- stored energy.
KINETIC ENERGY-- energy in motion.
RELATIONSHIP BETWEEN MATTER AND ENERGY-- $E = mc^2$ where mis mass and c is the speed of light (300,000 km/sec).
ACCURACY-- compares well with accepted values.
PRECISION-- gives consistent results. (An instrument could be precisely inaccurate).
SIGNIFICANT DIGITS-- those digits in a number that are known with certainty plus the first digit that is uncertain.
ROUNDING OFF-- your answer must be rounded off to the least number of significant digits in the given data.
ORDERS OF MAGNITUDE-- powers of ten, each order of magnitude is a ten fold change in the value of a number.
INTERPOLATION-- using a graph to find values between the known points.
EXTRAPOLATION-- using a graph to find values beyond the last point.
VECTOR-- a line with an arrow head whose length represents magnitude and whose direction is indicated by the arrow.
SPEED-- a change in position with respect to time. v = d/t
VELOCITY-- a speed in a given direction. It's a vector quantity.
RESULTANT-- the vector which forms the diagonal of the parallelogram drawn with two vectors as sides. It can be solved graphically or by trigonometry.
EQUILIBRANT-- the vector which is equal and opposite to the resultant.
ACCELERATION -- a change in velocity with respect to time. a = v/t. It contains two units of time, v = d/t and a = v/t, so its unit may be meters per second per second (or m/s^2).
ACCELERATION EQUATIONS are to be found in the text or on our web page.

FREELY FALLING BODIES-- objects dropping with no friction (as in a vacuum).
ACCELERATION DUE TO GRAVITY-- $g = 9.8\ m/s^2$ for all freely falling bodies at sea level.
TERMINAL VELOCITY-- considering friction, wind friction increases with velocity until the force of friction equals an object's weight. For people it is about 170 km/hr. For a leaf it's a few cm/s. Cats survive great falls.
EQUATIONS FOR FREELY FALLING BODIES-- are the same as those for accelerated objects with "a" replaced with "g".
NEWTON'S LAWS OF MOTION:
1. The Law of INERTIA states that an object will either remain at rest or continue to move at constant velocity in a straight line unless acted upon by an external force.

2. The Law of ACCELERATION states that the acceleration of a body is directly proportional to the applied force and inversely proportional to its mass. a = f/m or f = ma
3. The Law of INTERACTION states that for every action there is an equal and opposite reaction. mV = Mv where m is mass of smaller body, V is velocity of smaller body, and M is mass of larger body, v is velocity of the larger body.
THE UNIT OF FORCE is the "newton", "n". One n of force will accelerate a one kilogram mass at the rate of one meter/second/second. f = ma, so 1n = (1Kg)(1m/s/s)
WEIGHT is the force of gravity, since f = ma, then wt = mg so a beefer whose mass is 80kg, will weigh 784n (wt = (80kg)(9.8m/s^2).
NEWTON'S LAW OF GRAVITATION: Every body attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers. $F = GMm/d^2$, where F is the force of attraction in n, M is the mass of the large object, m is the mass of the small object, d is the distance between their centers, and G is the gravitational constant (a constant to make the units work out).
For example, you on the Earth. F is your weight, M is the mass of the earth, m is your mass, and d is the distance to the center of the earth (6300 km = 6.3 X 10^6 meters). (G = 6.67 X 10^{-11} nm^2/kg^2).
RESOLUTION OF FORCES-- starting with the resultant, we find two components of it. The resultant is the diagonal of the parallelogram drawn with the two forces as sides. For example, a car on a slope has a gravity vector (its weight) acting straight toward the center of the earth. We will resolve this single force into the force acting to push the car down the slope and the force pressing the car into the roadway (the squish down force).
FRICTION-- a force that resists motion. For rough surfaces, it caused primarily by interlocking edges. For smooth surfaces, molecular attraction becomes important.
The coefficient of friction is the ratio of the force of friction (needed to keep the object moving) to the normal force (the vector component at right angles to the surface.
EQUILIBRIUM-- a state in which all force vectors are balanced. There will be no change in the motion of the object.
PARALLEL FORCES-- forces acting in the same or opposite directions at different points on an object.
CENTER OF MASS-- the point where all the mass appears to be concentrated. A spun object will spin around its center of mass. The Earth and Moon revolve about their common center of mass (which is located about 1000 Km inside the Earth). Double stars revolve about their common center of masses.
CENTER OF GRAVITY-- the point where the object's weight appears to be concentrated. It is the balance point. The center of mass and the center of gravity are at the same point.
TORQUE is force times its distance from the center of rotation.
EQUILIBRIUM is composed of two parts:
TRANSLATIONAL equilibrium-- from place to place. There will be no change in velocity along a line. The resultant is balanced by the equilibrant.
ROTATIONAL equilibrium-- no change in rotational velocity. The clockwise torque's are

balanced by the counterclockwise torque's.
SOLVING EQUILIBRIUM PROBLEMS:
TRANSLATIONAL-- the sum of the parallel forces in one direction must equal the sum of the parallel forces in the other direction (the ups = the downs).
ROTATIONAL-- the sum of the clockwise torque's must equal the sum of the counterclockwise torque's.
TRAJECTORY is the path taken by a thrown body. It is the result of the forward velocity and gravity. It forms a parabola.
CENTRIPETAL FORCE is the center seeking force, say gravity for a satellite or the tension on a string for an object spun around by a cord.
CENTRIFUGAL FORCE is the center fleeing force caused by the object's inertia trying to keep it going in a straight line.
$F = mv^2/r$ where f = centrifugal force, m is mass of object and r is the radius of curvature.
IN ORBIT the centrifugal acceleration is equal to the centripetal acceleration.
Critical velocity for an orbit, $v = (rg)^{1/2}$ (square root of rg) where r is radius of curvature and g is acceleration of gravity (9.8 m/s^2).
ROTARY MOTION is measure in revolutions/s, or radians/s. A radian is 57.3 degrees.
FORMULAS FOR ANGULAR VELOCITY are to be found in the text. Copy them and be familiar with them.
GYROSCOPES exhibit two forms of weird action:
... Gyroscopic inertia which resists change at right angles to the force.
... Gyroscopic precession which is circular motion caused by an unbalanced force on the gyroscope. The Earth precesses once every 26,000 years due to the unbalanced force of the Moon.
HARMONIC MOTION is motion that repeats in a regular pattern. Examples are pendula and bobbing masses on springs.
THE PENDULUM is a mass suspended such that it can swing to and fro.
... The period is the time for one complete swing (one cycle).
... Frequency is the number of swings per second.
THE LAWS OF THE PENDULUM.
... The period is independent of mass.
... The period is independent of displacement.
... The period is directly proportional to the square root of the length.
... The period is inversely proportional to the square root of gravity.

... The formula T = 2pi [sq rt of (l/g)], where T is the period, l is the length, and g is the acceleration of gravity (9.8 m/s^2)
WORK is force times distance, W = fd , the force is in newtons, the distance is in meters, and the work is (n)(m) which is called Joules.
One joule of work is done when a force of one newton acts through a distance of one meter. No matter how big the force is, if you don't move something, you do no work. (Physics only pays for that which is accomplished). When moving an object up an incline, the work is in two parts: that used to overcome friction plus that used to overcome gravity. The gravity vector acts straight

down and therefore the distance that the force of gravity moves is the height the object is lifted and not the length of the incline.
SIMPLE MACHINES:
...The lever and its three classes--
..... First class has the fulcrum between the load and the force. An example is the crow bar or see-saw.
..... Second class has the load between the force and the fulcrum. An example of this is the wheel barrow.
..... Third Class has the force between the load and the fulcrum. This gives a speed advantage as in the catapult, baseball bat, or shovel.
... The Wheel and Axle
... The Pulley
... The Inclined plane
... The Screw
... The Wedge
THEORETICAL MECHANICAL ADVANTAGE is determined by the ratio of distances. TMA = dist. moved by force/dist. moved by load
ACTUAL MECHANICAL ADVANTAGE is determined by the ratio of load to force. AMA = load/force
INPUT is the work put into a machine, that is the force X the dist. it moves, Input = $fd_{(in)}$
OUTPUT is the work delivered by the machine, that is the force X its distance. Output = $Fd_{(out)}$
EFFICIENCY is the ratio of AMA/TMA expressed in percent. A machine is never 100% efficient because of frictional losses of work.

EFFICIENCY can also be expressed by the ratio of output/input in percent.
POWER is the rate of doing work. That is work divided by time. P = W/t where P is the power in watts, W is the work in joules, and t is the time in seconds.
POTENTIAL ENERGY is energy that is stored, as in a raised blade of la Guillotine. Potential energy is weight X height. Remember that weight is in newtons and is found by Newton's Second Law, f = ma, where m is in kg and a will be for gravity. That is wt = mg. So PE = mgh
KINETIC ENERGY is energy in motion. Like that of a speeding steam locomotive. KE = $1/2\ mv^2$
LAW OF CONSERVATION OF MECHANICAL ENERGY-- the sum of the potential and kinetic energy in a system is constant. That is KE = PE so $mgh = 1/2\ mv^2$
MOMENTUM is the product of mass times velocity. p = mv
IMPULSE is the product of force times time and is equal to the change in momentum Ft = mv
CONSERVATION OF MOMENTUM-- the total momentum of a system remains constant.
COLLISION ACTION (crash)--Inelastic collisions (bump-stick): The momentum of the crasher + the momentum of the crashee = 0. Mv + mV = 0
Elastic collisions (bump-bounce):
The vector sums of momentum are equal (see a text for gory details).
ANGULAR MOMENTUM is also conserved as in the ice skater spin.

PROPERTIES OF MATTER:
ELEMENT is a form of matter that cannot be simplified by chemical means. A basic substance.
COMPOUND is a substance composed of two or more elements chemically combined.
ATOM is the smallest particle of an element.
MOLECULE is the smallest particle of a compound.
PROTON is a basic particle whose mass is 1 g/mol, and whose charge is +1.
ELECTRON is a basic particle whose mass is 1/1837 g/mol and whose charge is -1
NEUTRON is a basic particle whose mass is 1 g/mol and whose charge is 0.
ATOMIC NUMBER the whole number on the Periodic Chart, is the number of protons in the nucleus, and also the number of electrons around the nucleus (provided that the atom is not ionized).
MASS NUMBER is the sum of protons and neutrons in a nucleus (because each of these particles has a mass of 1 g/mol). This is not found on the Periodic Chart.
ISOTOPE is a different mass for the same element caused by a different number of neutrons in the nucleus.
ATOMIC WEIGHT, the decimal numbers on the Periodic Chart, is the average of the mass numbers of the isotopes of an element.
PHASES OF MATTER:
SOLID-- the molecules are packed tightly together vibrating in position in their regular crystalline array. It has a definite shape and volume.
LIQUID-- the molecules are close but loose and are able to tumble over one another. It has a definite volume but assumes the shape or its container.
GAS-- the molecules are relatively far apart (average distance at room temperature is 300 diameters). It has no definite shape and it expands to fill its container.
THE KINETIC THEORY: Atoms and molecules are in motion. The warmer they are the faster they move.
EVIDENCES SUPPORTING THE KINETIC THEORY--
Expansion upon heating. Hot molecules move faster and bump their neighbors harder therefore pushing them further apart. (Note that the molecules themselves do not expand).
Gas pressure. Molecular collisions impart force.
Vapor pressure. Molecules escaping a liquid exert force (an example is steam power).
Diffusion of molecules is the intermingling of particles due to molecular motion. It's faster at higher temperatures.
Osmosis is diffusion through a porous membrane. Heavier molecules diffuse more slowly as a function of the square root of their molecular masses (Graham's Law). Brownian Motion is the vibrations of microscopic particles as they are struck by moving molecules. It's faster at higher temperatures.
VAN DER WAALS FORCES are the weak attractions between molecules caused by the electrons of one molecule attracting the protons of another molecule. These are what causes molecular solids to form. Molecular solids are non-crystalline, like butter or wax.
CRYSTALLINE SOLIDS are formed by ionic or covalent bonding wherein electrons are transferred or shared. (The molecular solid, with its van der waals forces, is not considered to be

bonded).

PROPERTIES OF SOLIDS:

Adhesion is the attraction of unlike molecules like water and skin.

Cohesion is the attraction of like molecules like mercury.

Tensile strength is the force per unit area needed to break a substance measured in n/m^2.

Ductility is the ability for a solid to be drawn into wire.

Malleability is the ability of a metal to be hammered or rolled into sheets.

The metallic bond is caused by free electrons roaming through the atoms without being associated with particular atoms (delocalized). Because of this, metals are flexible, ductile, and malleable.

Elasticity is the ability of a solid to return to its original shape or size after having been distorted. If the solid is stressed too far, it will have reached its Elastic Limit.

Stress is the ratio of force to area, stress = F/A.

Strain is the ratio of the change of length to the original length.

Hooke's Law states that strain is directly proportional to stress.

Young's Modulus, the numerical value of Hooke's Law, is the ratio of stress to strain. Y = stress/strain.

LIQUIDS:

In a liquid the molecules are close together but loose so that they are free to tumble over one another.

Viscosity is the resistance to flow. A viscous liquid flows slowly (i.e.. molasses).

Volatility means easily vaporized. Alcohol and water are volatile.

Surface tension is a film-like layer on a liquid due to the inward attraction of the molecules (cohesion) not being balanced by an outward attraction. This causes droplets to form spheres, and allows small objects to stand on the surface (like water skeeters, razor blades and the like).

The meniscus is the curved surface of a liquid in a container due to surface tension. For water it curves upward at the edges.

Capillarity is the rising or depressing of liquid levels in tubes of small diameter. It is the result of the adhesion of the liquid to the tube and the surface tension. Mercury is depressed in a tube with a positive meniscus because its cohesion for itself is stronger than its adhesion for the glass tube. Liquids rise if they wet the tube.

Expansion on freezing of water occurs because water molecules form a ring structure with a hole in the center. This causes water to expand by ten percent as it freezes. This expansion exerts enormous force (80,000 n/cm^2) which breaks rocks as the first step in the production of soil.

Ice floats because of this expansion which gives it a density of 0.9 g/cm^3 vs. g/cm^3 for liquid water. Hence ice bergs float with 90% of the ice below water level.

Regelation is the melting of a ice by pressure and its re-freezing when the pressure is released. Examples are glacier movements and ice skating wherein the pressure of the blades melts the ice and the melt water refreezes immediately.

Vapor pressure is the force per unit area exerted by evaporating molecules escaping through the surface tension. An example is a boiler explosion.

Boiling Point is the temperature at which the vapor pressure equals the atmospheric pressure. Boiling can be accomplished by two methods: 1. Raise the vapor pressure to atmospheric by heating (molecules move faster and have higher energy to break the surface tension). 2. Lower the atmospheric pressure to the vapor pressure (by a pump or by condensing steam in a closed flask).
Pressure is the force per unit area.
Pascal's Principle states that the pressure in a confined fluid is transmitted undiminished in all directions. This is the principle of hydraulics wherein enormous forces can be produced by transmitting the pressure over very large areas. P = F/A, so F = PA.
Archimedes Principle states that an immersed body is buoyed up by a force equal to the weight of the displaced fluid. This is the principle that describes why ships float in water and lighter-than-air craft will rise.
Bernoulli's Principle states that for fluids in motion, the faster the forward velocity, the less pressure is exerted sideways. (The molecules are striking objects at the side with glancing blows). This is the principle of airplane lift, curving baseballs, bulging convertible tops, the carburetor, and the Brass Aspirator.
Torricelli's Principle is that air has weight and therefore exerts pressure. Atmospheric pressure is measured with Torricelli's invention, the Barometer. The density of air is 1 gram per liter (at room conditions).

Vacuum is the absence of matter (low pressure). Air is removed, vacuums are not added. Suction is the process of the atmosphere PUSHING, vacuums cannot pull.
Atmospheric Pressure, sea level average:
One Atmosphere.
Ten meters of water. (The average height that water can be pushed up at sea level by the atmosphere.
760 millimeters of mercury on the barometer.
One kilogram of mass per square centimeter (9.8 n of force).
THE HEAT IS ON:
Thermal energy is the total potential and kinetic energy involved with molecular motion.
Temperature is a function of the average rate of molecular motion.
Heat is thermal energy that is absorbed, given up, or transferred form one body to another.
The Celsius scale defines 0 as the temp of melting ice and 100 as the boiling point of water at one atmosphere of pressure (760mm on barometer).
Common temperatures: Melting ice = 0 C, Room Temp = 20 C, Body temp = 37 C, Boiling water (at 1 atm) = 100 C, Red Hot = 800 C.
The Kelvin scale (absolute scale) is the Celsius scale starting at absolute zero which is -273 C. K = C + 273.
Absolute zero is the lowest temperature. The molecules have minimum energy and very little motion. There is no such thing as "cold". Cold means less heat.
The calorie is the quantity of heat which will warm 1 g of water 1 deg C.
Specific Heat is the number of calories which will warm 1 g of substance by 1 deg C. Most substances take less heat than water. For water it is 1 cal/gC^{o}, (the definition of the calorie).

The formula is Q = mc(delta)t where Q is calories, m is mass in grams, and (delta)t is the temperature change in deg C.
Thermal Expansion is caused by molecules bombarding each other and pushing each other farther apart. The molecules themselves do not expand.
Charles's Law states that the volume of a gas varies directly as the absolute (Kelvin) temperature. Higher temp gives higher volume.
Boyle's Law states that the volume of a gas varies inversely as the pressure. Higher press gives smaller volume. (The Squeeze is ON).
FORMULAS:
PV = k where P is pressure, V is volume, k is the gas constant
PV/T = P'V'/T' where P,V,T are first press, vol, temp,
and P',V',T' are the new press, vol, and temp.
PV = nRT where n is the number of moles of gas, and R is the "universal gas constant" (8.21 X 10^{-2} liter atmos/mol. K)
NOTE: The temperatures must be in K (absolute units). K = C + 273.
STANDARD TEMPERATURE and PRESSURE, STP is 273 K, (0 C), and 1 atmos (760mm of Hg) pressure.
Law of Heat Exchange states that Heat lost = Heat gained, $Q_l = Q_g$.
CHANGE OF PHASE require energy to rearrange molecules.
Heat of fusion (melting) breaks the crystalline bonds in the solid to form a liquid.
For water it is 80 cal/g
Heat of vaporization (to evaporate) separates the loose molecules in a liquid to form a gas in which the molecules are very far apart (av. dist. at room temp and press is 300 diameters).
For water it is 538 cal/g.
HEAT PROBLEMS-- See the text p 190.
Critical Temperature is the maximum temp above which a gas cannot be liquefied (no matter how high the pressure).
Critical Pressure is the minimum press below which a gas cannot be liquefied (no matter how low the temp).
HEAT AND WORK:
The First Law of Thermodynamics is the Law of Conservation of Energy. Energy cannot be created nor destroyed, but only changed in form.
The Second Law of Thermodynamics is the Law of Entropy. It states that energy tends to run down hill (hot to cold) and that matter tends to become less organized. That is ENTROPY is the tendency to acquire MINIMUM ENERGY AND MAXIMUM RANDOMNESS.
Adiabatic temperature changes are those caused by expansion or contraction of gases. Gases are heated adiabatically by compression as in Charles' Law. An example is in the diesel engine which ignites the fuel by the temperature of the adiabatic compression of air. Another example is in the formation of upslope fog in which the air is cooled by adiabatic expansion as it is blown uphill.
WAVES ACTION:
WAVE-- a disturbance that propagates through a medium or space. It is in simple harmonic motion.

TRANSVERSE WAVES vibrate at right angles to the direction of propagation. They are composed of two parts, CRESTS and TROUGHS.
LONGITUDINAL WAVES vibrate along the direction of travel. They are composed of COMPRESSIONS and RAREFACTIONS.
CHARACTERISTICS of WAVES:
Wave length is the distance from one part to where that part repeats. For example from crest to crest or compression to compression.
One Cycle is a complete vibration, i.e. crest through trough. Its distance is the wave length.
The Frequency is the number of cycles per second, called Hz (hertz after Heinrich Hertz, discoverer of radio waves).
f = cycles/sec
The Period is the time for one cycle to pass a point.
T = 1/F
The Amplitude is the maximum displacement of a wave, i.e. the height of a crest.
Amplitude Modulation (as in AM radio) is controlling the magnitude of the wave.
Frequency Modulation (as in FM radio) is controlling the rate of vibration of a wave.
The Power transmitted by a wave is proportional to both the amplitude and to the frequency squared. So if we double both the amplitude and the frequency of a wave, its power increases sixteen times!
The Wave Equation relating velocity, frequency and wavelength is
v = fl l is the Greek letter, Lambda.
PROPERTIES OF WAVES:
Rectilinear Propagation-- the wave front travels in straight lines from the point of origin.
Reflection is the bouncing of a wave off a barrier.
The Law of Reflection states that the angle of incidence is equal to the angle of reflection, i = r.
Impedance is the resistance to motion of a wave.
Impedance = wave producing force/resulting velocity
Refraction is the bending of a wave as it passes from one medium into another. It is caused by a change in velocity.
Diffraction is the spreading out of a wave as it passes a barrier.
Superposition of waves is the resultant vector addition of two or more waves passing through the same medium together.
Interference is the result of superposition.
Constructive interference is the adding of two waves to give a stronger wave. This occurs when the crest of one meets the crest of another (or a compression meet a compression).
Destructive interference is the cancellation of waves when the crest from one meets the trough from another (or a compression meets a rarefaction.
Standing waves are the result of the interference of two waves of the same amplitude and wavelength traveling in opposite directions.
Nodes are the dead spots in standing waves. There is no vibration in a node.
Antinodes (or loops) are the positions of maximum vibration in a standing wave.

SOUND:
Sound in physics is defined as compression/rarefaction waves in matter.
Audible range for people varies between 20 Hz to 20,000 Hz.
Infrasonic range are vibrations whose frequency is below the audible.
Ultrasonic range are vibrations whose frequency is above the audible.
Production of sound is accomplished by setting up vibrations in matter. This can be done by vibrating solids, liquids, or gases.
Sound waves are longitudinal (light waves are transverse).
Sound needs a medium to carry it. It doesn't travel through a vacuum.
The speed of sound depends upon the medium and the temperature. In air it travels at 331 m/s at 0 C and its speed increases by 0.6 m/s for each degree C the temp goes up. V = 331 m/s + 0.6(t C). It travels 4 times faster in water and 15 times faster in steel.
PROPERTIES OF SOUND:
Intensity is the ratio of power to area I = P/A (watts/cm^2).
Intensity is proportional to the square of the amplitude.
Loudness obeys the inverse square law if it is a point source. Twice as far away, the intensity is only 1/4 as great.
Loudness depends on an auditory sensation in the consciousness of a listener. It is a subjective property.
Relative intensity measurements are done on a logarithmic scale called the DECIBEL SCALE. On this scale the threshold of hearing is 0, whispers are 15, conversation is 60, thunder is 110, the threshold of pain is 120, jet engine is 170, rock band 180 (just kidding).
PITCH is the highness or lowness of a tone and it depends uponf requency (the number of cycles/sec). The higher the frequency, the higher the pitch.
THE DOPPLER EFFECT is the change in pitch due to relative motion between the source and the listener. When the listener approaches the sound source, she runs into more waves/sec, and hence the pitch is increased, when the source approaches the listener, waves are crowded together so the pitch is increased. Likewise, when the distance between source and listener is increased, the pitch drops. A typical example is the passing of a car... EEEEEEEAAAAaaooow.
CHARACTERISTICS OF SOUND WAVES--
Standing waves are resonant waves with nodes and antinodes.
The fundamental or first harmonic consists of one antinode with a node at each end. The second harmonic has two antinodes, etc. See p 266 in the text for diagrams.
Harmonics may be superimposed upon other harmonics to produce musical tones.
The Quality of sound is that which differentiates the sound of one instrument from another even when they are playing the same pitch. A tone is determined by the number and strengths of the harmonics. See text for illustrations.
The Beat Frequency is the pitch caused by the interference of two sound waves of different frequencies undergoing constructive and destructive interference. It varies in loudness so that it is a throbbing sound. When two tones are in tune, there will be no beats. See p 276 for diagram.
The Laws of Strings--
Law of Lengths states that the frequency is inversely proportional the length. The longer string has

a lower pitch.
Law of Diameters is that frequency is inversely proportional to the diameter. The larger the diameter, the lower the pitch.
Law of Tensions states that the frequency is directly proportional to the square root of the tension. The higher the tension, the higher the pitch.
Law of Densities is that the frequency is inversely proportional to the square root of the density. The greater the density, the lower the pitch.
RESONANCE is the reinforcing of waves of the same frequency which are in phase. Standing waves are produced. A fun example (when no one is around) is to step on the damper pedal of a piano and scream into the thing. It screams back in resonance. See text for diagrams.
An open tube resonator (open organ pipe) has an antinode at each end. The result is that it resonates the even numbered harmonics.
A closed tube resonator (closed organ pipe) has a node at one and an antinode at the other. It resonates odd numbered harmonics. See diagrams in the text.
Formulas for resonant pipes are in the text .
LIGHT:
The corpuscular (particle) theory of Newton states that light is composed of particles.
The wave theory of Huygens states that light is composed of waves. Light waves are transverse waves composed of crests and troughs. (Sound waves are longitudinal).
We need both theories to explain all the phenomenon of light. Whenever a tiny particle moves at high speed, it assumes wave properties.
Photons are the particles (with wave properties) of light. Each photon is a quantum of energy.
The electromagnetic theory states that light photons are waves with two components at right angles to each other. The electric field and the magnetic field are the components.
PROPERTIES OF LIGHT:
RECTILINEAR PROPAGATION. Like all waves, the wave front spreads out in straight lines from the origin.
REFLECTION. The angle of incidence equals the angle of reflection. The angles are measured from the NORMAL to the surface.
REFRACTION is the bending of light as it changes media at an angle. It is due to the fact that light travels more slowly in denser media.
DIFFRACTION is the spreading out of light waves as they pass around objects.
THE PHOTOELECTRIC EFFECT. When light strikes a substances with sufficient energy, electrons are emitted by the substance. An example is the photoelectric cell or the "electric eye".
THE QUANTUM THEORY explains the photoelectric effect. The energy of the emitted electrons depends on the frequency of the light photon. The number of electrons emitted depends on the intensity of the light.
PLANK'S EQUATION is E = hf where E is the energy of the emitted electron, f is the frequency of the light waves, and h is Plank's Constant, 6 X 10^{-34} js (the quantum of energy).
THE QUANTIZED ATOM. The above quantum effects coupled with the discrete spectral lines emitted by stimulated atoms, led to the orbital model of the atom with electrons spreading out to fill quantum energy levels about the nucleus of the atom. Whenever an electron changes energy

levels (orbitals), photons of light are absorbed or emitted. This gives the special spectral lines associated with each element. See color plate VII about p 337.
THE LASER (Light Amplification by Stimulated Emission of Radiation), is the result of raising electrons to higher energy levels by applying a burst of energy (say by intense light, electrical charge, or chemical reaction). The energetic electrons drop back to their lower energy levels simultaneously when stimulated by photons reflecting back and forth between mirrors. This gives a coherent burst of pure light (the waves are in phase to give massive constructive interference).
PRESSURE OF LIGHT. Light exerts a force per area which is equal to 4 X 10-11 atmospheres. It is sufficient to push forth the tails of comets (along with other solar radiation).
ILLUMINATION--
Luminous is the property of a substance to emit light by virtue of accelerated particles. Particles are accelerated by electric stimulation or by high temperature. Examples are stars, heated objects, and electric discharges.
Illumination is the receiving of light from another source. An object which can be both luminous and illuminated is a light bulb.
Intensity is the strength of light emitted. It is measured in candles, cd.
Illumination depends upon both intensity and distance (the inverse square law). Its unit is the lumen. One lumen is the amount of light received on the interior surface of sphere one meter in area at a distance of one meter from a one candle source. The formula for illumination is $E = I/r^2$ where is E is in lumens, I is in candles, and r is in meters. See sample probs. in text.
The Seasons on Earth are caused by the variation of the angle of incidence of the sun's rays due to the tilt of the earth's axis (23.5 deg). See diagrams in text.
The Speed of Light is 300,000 km/s, 3×10^8m/s. See text diagrams for the Michelson's method using a rotating mirror and the formula d = rt.
The Umbra is the total dark shadow of the earth and the moon.
The Moon is eclipsed when it is in the Earth's umbra.
The Sun is eclipsed when we are in the Moon's umbra.
The Penumbra is the partial shadow of the earth or the moon.
Partial eclipses involve the penumbra. See text for diagrams.
The Inverse Square Law applies to all forms of energy that radiate from a point source such as light, sound, gravity, magnetism, and electric fields. See text for diagram of the inverse square law.
REFLECTION:
Mirror reflection is caused by smooth surfaces so that the reflected rays are parallel.
Diffuse reflection is caused by irregular surfaces such that the reflected rays are not parallel.
Law of reflection-- The angle in incidence is equal to the angle of reflection. The angles are measured from the line drawn normal to the surface at the point of contact. These three parts are all in the same plane.
MIRRORS--
Plane mirrors are flat and images appear as far behind them as the objects are in front of them.
Concave curves inward. It is a converging reflector as parallel rays come to a focus.
Convex curves outward (like the middle of the Boom). It will cause parallel rays to diverge.

Mirror diagrams and formulas are found amongst the text. They're important so check 'em out.

REFRACTION:

Refraction is the bending of light as it passes from one medium into another due to its change in speed

The Index of Refraction is the ratio of the speed of light in vacuum to the speed of light in the medium.

Snell's Law states that the index of refraction is also equal to the ratio of the sine of the angle of incidence to the sine of the angle of refraction. The angles are measured from the normal drawn to the surface.

n = sin i/sin r where n is the index of refraction. See diagrams in text.

LENS OPTICS:

Converging lenses are thicker (avoid the term fatter) in the center. They cause parallel rays to pass through a focal point.

Diverging lenses are thinner in the middle. They cause parallel rays to spread out.

Rules and diagrams for constructing and calculating lens situations are important. See text.

DISPERSION:

Dispersion is the spreading of white light into its spectrum of colors. ROY G BIV. It is caused by the fact that light of different wave lengths is refracted by different amounts. The red end of the spectrum bends the least.

Primary Colors of Light are red, green, and blue. These three join to make white light. The primaries of light ADD to make resultant colors.

Complementary Colors are two colors that join to make white light. One of the complements already contains two primaries.

Primary Colors of Pigment (paint) are cyan, magenta, and yellow. They SUBTRACT light by absorption. The three primaries of pigment produce black when mixed as they absorb all the light. See the color plates beginning after p 336.

Chromatic Aberration is the distortion and separation of colors by the fact that different colors are refracted differently by uncorrected lenses. See p 360 for diagram and what to do about it.

DIFFRACTION:

Diffraction is the spreading out of light as passes around sharp objects or through narrow slits. See diag. p 363.

Interference is the inter-reaction of light waves.

Constructive interference is the adding of light waves crest to crest and trough to trough.

Destructive interference is the adding of light waves crest to trough so that there is cancellation.

Two interacting light waves out of phase will give interference patterns. See Thin Film interference p 364 for explanation of soap bubble and oil slick colors. Also bird feathers are colored by this method.

The Diffraction Grating is a transparent surface having several thousand lines per centimeter etched thereon. It will produce spectra of white light or line spectra for stimulated gases. (The prism does this by refraction). Spectra are produced because different wavelengths are diffracted different amounts. See text.

THE DOPPLER EFFECT for light is the change in frequency (color) of light due to relative

motion between the source and observer. Approaching gives blue shifts, and receding gives redshifts. Remember that higher frequency is bluer light, and approaching sources crowd waves more closely together to increase the frequency.
The relative velocity of stars and galaxies can be determined by the blue or red shifts of their light. The shift is a comparison of spectral lines of the star to the lines of the same elements in the laboratory.
POLARIZATION is the process of the light waves vibrating in the same plane. This is accomplished by certain crystals or by reflection of light at certain angles. See text.
SCATTERING OF LIGHT is caused by small particles such as molecules or very tiny dust particles. The particles are a size about the same as the wavelength of the light being scattered.
BLUE SKY AND DEEP WATER are colored by the scattering of the blue light which has a short wave length. The longer red waves diffract around the particles in the atmosphere and travel a long distance. Hence, during the day when the sun is high in the sky, the rays travel a short distance down through the atmosphere (a few
hundred kilometers) and so not much blue light is scattered out.
RED SUNSETS AND SUNRISES are caused by the scattering of the short wave length blue light. This leaves the longer red waves to traverse the atmosphere to the observer over the horizon. Hence, at sunrise and sunset, the rays are traveling a
great distance through the atmosphere (thousands of kilometers) so most of the blue is scattered out and mainly the red remains. See Text diagrams.

ELECTRICAL ACTION:

ELECTRICAL TERMS:
Negative charge-- An excess of electrons.
Positive charge-- A deficiency of electrons.
Neutral charge-- The number of electrons equals the number of protons.
Electroscope-- A device for detecting electric charge. It has a pair of metal foil leaves that are pushed apart by electric force fields.
Coulomb's Law-- The force between charges varies directly as the product of the charges and inversely as square of the distance between the charges.
$F = k (Q Q)/d^2$.
DC-- Direct current. The electrons flow in one direction only. Negative to positive.
AC-- Alternating current. The flow of electrons reverses at a steady rate. (i.e. 60 cycles/sec).
Conductor-- A substance (usually metal) that has loose electrons (partially filled orbitals).
Insulator-- A substance (usually a non-metal) that has no free electrons.
Ohm's Law-- The current (amps) is directly proportional to the emf (volts) and inversely proportional to the resistance (ohms). $I = V/R$.
Solenoid-- A coil of wire for concentrating magnetic field. With a moveable permeable core, it can operate mechanical devices.
Capacitor-- A device for storing electric charges. Two conductors separated by an insulator (the dielectric).

Induction-- The process of producing a current in a conductor by moving it through a magnetic field. The field must be cut.
Inductor-- A coil of wire whose purpose is to cause an impedance (inductive reactance) to alternating current flow.
Inductive Reactance-- The opposition to current flow caused by the self-induction of opposing currents in coils. Coils oppose high frequency AC and have low reactance to DC.
Lenz' Law-- An induced current has such a direction that its magnetic field opposes the field which induced it.
Choke coil-- An inductor. It resists AC while passing DC.
Capacitive reactance-- The opposition to current flow caused by a capacitor. Capacitors are open circuits to DC. High frequency AC appears to pass through a capacitor.
Impedance-- The combined opposition to current flow due to resistance, inductive reactance, and capacitive reactance. It is a vector sum wherein the inductive reactance acts upward, the capacitive reactance acts downward, and the resistance acts sideways.
Angle of lag or lead- The angle caused by the impedance vector
measured from the resistance vector. It shows the phase relationship in an AC circuit.
Power factor-- The cosine of the angle of lag or lead.
Ohm's Law for AC circuits-- Current = volts/impedance. $I = V/Z$.
Power in AC circuits-- Power = (volts)(amps)(power factor).
Resonance-- The resonant frequency of an AC circuit is the frequency at which the inductive reactance equals the capacitive reactance.
At this frequency the two reactances cancel and the circuit acts as though it contains resistance only. This enables us to select certain frequencies. (i.e. to tune radio and television stations).
Electrolyte-- A solution that conducts electricity. It contains ions. (Acids, bases, salts).
Cell-- Two unlike conductors in an electrolyte, produces an emf (voltage).
Battery-- A group of cells connected together change voltage or current capacity.
Commutator-- A split ring on the shaft of a motor or a generator that mechanically reverses the wires as the rotor turns. It keeps a motor turning and will change a generator's AC to DC.
Slip rings-- The rotating connection on the shaft of a generator that contacts the brushes to remove the current from the rotor.
Series circuit-- Components connected such that tall of the current must pass through each component.
Parallel circuit-- Components are connected such that the current will divide between them.
Thermocouple-- Two unlike metals joined. When the junction is heated, an emf is produced.
Electrode-- A conductor placed into a solution or a vacuum tube. (or Frankenstein's temples).
Anode-- Usually the positive electrode.
Cathode-- Usually the negative electrode.
Thermionic emission-- A heated cathode boils off electrons. Source of electrons in vacuum tubes.
D'Arsenval meter movement-- The mechanism of springs, magnets and coils that operate electric meters.
Galvanometer-- A meter for measuring very small currents.
Voltmeter-- A high resistance galvanometer for measuring emf. It's connected in parallel with the

load.
Ammeter-- A low resistance galvanometer for measuring current flow. It's connected in series with the load.
Watt meter-- A combination volt and ammeter for measuring electric power.
Watt hour meter-- A recording meter for keeping a record of electrical energy consumed. (Found on houses).
Resistance-- The friction to electron flow in a conductor.
Resistor-- A device for limiting electron flow.
Rheostat-- A variable resistor.
Potentiometer-- A variable resistor that can reverse current direction as well as very the resistance.
Wheatstone Bridge-- A device for accurately measuring resistance.
Electrolysis-- The decomposition of substances by passing an electric current through their melts or solutions.
Permeability-- The ability to conduct a magnetic field. Iron is very permeable.
Electromagnet-- A coil of current-carrying wire wrapped around a permeable core.
Magnetic domains-- Groups of atoms adding their magnetic fields. Lining up the domains magnetizes a piece of metal.
ELECTRICAL UNITS:
Coulomb-- Unit of electric charge. Is equal to 6 X 10^{18} electrons.
Ampere-- Rate of current flow. Is equal to 1 coulomb per second.
Volt-- Unit of electrical pressure (potential difference) Will do a joule of work per coulomb of charge, V = J/c. Emf (electromotive force) is volts.
Ohm-- Unit of electrical resistance. Is equal to the resistance of a 1 meter column of mercury, 1 mm cross-sectional area at 0 deg C. Or one volt per ampere.
Mho-- Unit of conductance. The reciprocal of the resistance.
Watt-- Unit of power. Equal to one joule/sec or volts X amps. P = VI.
Farad-- Unit of capacity of a capacitor. Will take a charge of one coulomb per one volt of emf. C = Q/V where C is the capacitance in farads, Q is the charge in coulombs, and V is the emf in volts.
Henry-- Unit of inductance. A coil has an inductance of 1 h when a current changing at the rate of one ampere per second induces a back emf of one volt.

ATOMIC STRUCTURE and The Discovery of Sub-Atomic Particles

ATOMIC THEORIES:
Democritus (Ancient)
Dalton (Modern)
LAW OF CONSERVATION OF MASS: The Total Mass Entering a chemical reaction = the total mass leaving the reaction.
LAW OF DEFINITE PROPORTIONS (Dalton's Law): Every compound has a definite ratio of elements by mass. (Ah... Formulae!)
LAW OF MULTIPLE PROPORTIONS: Some compounds exhibit whole number ratios of elements.
H O, H O , NO, N O, N O , N O , FeO, Fe O , Fe O

2 2 2 2 2 3 3 4 2 3 3 4
THE LAW OF GAY LUSSAC: The combining ratios in reactions are of small whole numbers. The Above Laws indicate that there are basic particles (atoms) that make up matter.
FARADAY'S DISCOVERY: Electricity decomposes compounds into elements. On re-forming, electricity is re-generated. This shows that the binding force between atoms in a compound is electrical.
THE DISCOVERY OF PARTS OF THE ATOM (Late 19th and early 20th century action)--
The high voltage Induction Coil, "Sparky" gave the energy needed to probe the atom.
Discharge Tubes-- lowering air pressure in a tube allowed the "Cathode Rays" to travel great distances (many meters).
THE DISCOVERY OF THE ELECTRON: The Tube of Sir William Crookes--
The Rays-- travel from Cathode (negative) to Anode (positive), hence they are NEGATIVE. The Rays are easily stopped by thin metal obstacles (the Iron Cross).
The Rays travel in Rectilinear Propagation because the shadow of the cross is sharp.
The Rays are attracted to positive electric charges and repelled by negative charges placed beside the tube. The Rays are bent at right angles by magnet fields.
The Rays cause fluorescence on the glass and upon certain minerals.
THE DISCOVERY OF THE MOMENTUM OF THE RAYS--
The Paddle Wheel Tube (the tube of Jean Perrin) showed that the Cathode Rays have mass and velocity (momentum) because they push the paddles.
Great fluorescent colors are demonstrated by paint on the paddles.
The rays therefore must be particles and were named "Electrons".
THE MEASUREMENT OF THE CHARGE TO MASS RATIO OFELECTRONS:
The Tube of Sir JJ Thompson--
The candy cane-shaped tube bent the cathode rays in a magnetic field and showed their path on a fluorescent screen. This enabled the calculation of the Charge to Mass Ratio. Higher charge would bend the beam more, higher mass would bend the beam less. e/m = ratio = 1.8 X 10^{8} coulomb/ gram.
THE DETERMINATION OF THE CHARGE OF THE ELECTRON:
Millikan Oil Drop Experiment to measure the actual charge on an electron. X-Rays would add or subtract electrons to the microscopic droplets. By varying the electric charge needed to balance the weight of the droplet, three biggies were discovered:
1. All electrons are identical.
2. The electron is a basic particle of electricity.
3. The charge of the electron, e = 1.6 X 10^{-19} coulomb (c) of charge.

THE CALCULATION OF THE MASS OF THE ELECTRON:
The Mass of the electron is determined from e/m ratio and the charge:
e/m = ratio , so m = e/ratio , hence: m = 1.6 X 10^{-19}c /1.8 X 10^{8} c/g. So m = 9.11 X 10^{-29} gram/ electron WOW! That's tiny!
THE DISCOVERY OF IONS AND THE PROTON:
The Canal Ray tube was built to see if there are rays from the anode. There were positive rays, but not from the anode. They were produced by the impact of electrons with atoms of gas in the tube.

The Canal Ray Tube. The collisions knocked electrons off the atoms creating positive IONS. The e/m ratios of the ions (in a JJ tube) depended on which gas was used. When using the simplest gas, Hydrogen, we found the simplest ion, the Hydrogen nucleus called the "PROTON".

THE DISCOVERY OF ISOTOPES:

The Mass Spectroscope is a refined Sir JJ tube built for accurate measurements. When ions were sent through it, they separated into several beams according to different masses (their charges were the same). These different masses for the same element were called "ISOTOPES" (in the same place on the periodic table).

THE DISCOVERY OF THE NEUTRON:

To explain ISOTOPES we postulated a NEUTRAL particle whose mass was equal to that of the Proton. This way we could account for a change in mass without changing which element was present.

The Neutron was discovered in 1932 by Chadwick using a piece of jam jar paraffin to react with radiation.

THE DISCOVERY OF X-RAYS:

Roentgen was experimenting with discharge tubes and found fluorescent substances were glowing around in his lab including places behind barriers. Powerful! They are created when electrons strike a metal target. X-rays are electromagnetic waves above the Ultra-Violet on the spectrum.

X-rays are used to determine: The Atomic Number (the number of protons in the nucleus. The wave length of X-rays depends on number of protons), and the Structure of crystals (X-ray diffraction studies).

THE DISCOVERY OF RADIOACTIVITY AND ITS THREE RAYS:

Becquerel, experimenting with fluorescent minerals, found that Uranium ore on his desktop exposed film in the drawers below with the shadow of a key thereon.

Marie Curie analyzed Uranium ore and discovered new radioactive elements including Radium.

Lord Rutherford, using Marie's Radium, found three rays coming therefrom:

Alpha rays-- Positive Helium ions. Small deflection due to high mass.

Beta rays-- Electrons. Large deflection due to very low mass.

Gamma rays-- Electromagnetic waves of very high energy ... WOW!

Properties of Radioactivity: Cause ionization. Discharge electroscope. Cause fluorescence, expose photographic film, destroy cells. promote nuclear reactions.

THE SIZE OF THE ATOM: For Copper, weigh out 1 mole-- 63.5 g/mol. Make it into a cube. Ah, it's 2 cm per side. This cube contains 6 X 10^{23} atoms (1 mol). To find the number of atoms per side of the cube, take the cube root of 6 X 10^{23}. It's about 10^{8} atoms per side. Now divide the 2 cm per side by the 10^{8} atoms per side, and you get about 10^{-8} cm per atom. This is called the Angstrom unit (the size of an atom).

THE SIZE OF THE NUCLEUS:

Lord Rutherford shoots Alpha Particles (Helium nuclei) through a thin piece of gold foil. SHOCK! most Alphas go right on through. Hence the atom must be mostly empty space! A very few Alphas are deflected however. From the statistics of the deflection patterns, the size of the nucleus is calculated. About 10^{-13} cm diameter!

Compared to the size of the atom (10 cm), the nucleus is "The flea in Yankee Stadium".

DISCOVERY OF THE ORBITALS OF THE ELECTRONS:

Spectroscopy

When electrical discharge is sent through gases in a tube, and the light emitted passed through a prism, we get a spectrum of bright lines. These lines are the spectral "finger prints of the atom" From the line spectra we learn which elements are present (like in the stars), and the arrangement of electrons around the nucleus, called the Electronic Configuration.

NUCLEAR REACTIONS: Top numbers are the mass numbers (protons + neutrons). Bottom numbers are the charge numbers (atomic numbers). The sum of the numbers on the right must equal the sum of the numbers on the left.

$_{2}He^{4} + _{4}Be^{9} \rightarrow _{6}C^{12} + _{0}n_{1}$

TRANSMUTATION--

$_{0}n^{1} + _{92}U^{238} \rightarrow _{93}Np^{239} + _{-1}e^{0}$

NUCLEAR FISSION & THE CHAIN REACTION--

$_{92}U^{235} + _{0}n^{1} \rightarrow _{56}Ba^{141} + 3_{6}Kr^{92} + 3\ _{0}n^{1}$ + ENERGY!!

*** HERE ENDETH THE NOTES ***