Motion in One Dimension.

I. Average Speed = $\frac{s}{t}$

II. Average Velocity: $\bar{\mathbf{v}} = \frac{\Delta \mathbf{s}}{\Delta t}$ where **s** is the position vector. It could be x,y, or z.

III. Instantaneous Velocity: $\mathbf{v} = \lim_{\Delta t \to \infty} \frac{\Delta \mathbf{s}}{\Delta t}$

IV. Average Acceleration: $\bar{\mathbf{a}} = \frac{\Delta \mathbf{v}}{\Delta t}$

V. Instantaneous Acceleration: $\mathbf{a} = \lim_{\Delta t \to \infty} \frac{\Delta \mathbf{v}}{\Delta t}$

IF a is constant:

VI. $\bar{\mathbf{v}} = \frac{v_f + v_i}{2}$ VII. $v = v_o + at$ VIII. $s = \frac{1}{2}at^2 + v_ot + s_o$ IX. $v^2 = 2as + v_o^2$

Motion in Two Dimensions.

Vector Mathematics: The addition of vectors and the resolution of vectors into components.

Projectile Motion: The equations of motion in one dimension applied to horizontal and vertical components.

Force and Motion.

Newton's Laws of Motion: I. $\Sigma \mathbf{F} = 0 \times \mathbf{a} = 0$ The condition for static translational equilibrium. This can be broken down into components…

$\Sigma \mathbf{F}_x = 0, \Sigma \mathbf{F}_y = 0, \Sigma \mathbf{F}_z = 0$

II. $\mathbf{F} = m\mathbf{a}$ From this we have that weight = mg

III. $\mathbf{F}_{A,B} = - \mathbf{F}_{B,A}$

Friction: IV. $f \leq \mu_s N$; static friction opposes motion with a force up to $\mu_s N$

V. $f = \mu_k N$

Uniform Circular Motion and Gravitation.

Kepler's Laws of Planetary Motion:

1. The orbit of each planet is an ellipse and the sun is at one of the foci.
2. An imaginary line from the sun to a moving planet sweeps out equal areas in equal intervals of time.
3. $\frac{T^2}{R^3} = k$, where T is the time for one complete orbit, R is the average distance of the planet from the sun, and k is a constant that is the same for all planets.

I. $a_c = \frac{v^2}{r}$ directed *toward the center of the circle.* $\therefore F_c = ma_c = \frac{mv^2}{r}$

II. $f = \frac{1}{T}$

III. The law of Universal Gravitation $F = G\frac{m_1 m_2}{r^2}$

This applies directly to "point" masses and in the region outside of spherical masses. Calculus must be used to sum up the gravitation forces due to masses of other shapes.

Work and Energy.

I. $W = F_x x = Fx\cos\theta$ or with the dot product $W = \mathbf{F}\cdot d\mathbf{s}$

II. $\mathbf{F} = -k\mathbf{x}$, Hooke's law.

III. The work done by a spring $W = \frac{1}{2}kx^2$

IV. $K = \frac{1}{2}mv^2$ The definition of kinetic energy.

V. The **Work-Energy Theorem:** The Work of the resultant force is equal to the change in kinetic energy. $W_R = \Delta K$

VI. $U = mgh$, the gravitational potential energy *near* the surface of the earth.

VII. $U = -G\frac{mM}{r}$, the potential energy "stored" in a two mass system due to their gravitational attraction. Masses must be points or spherical. The negative sign comes from assigning the value of potential energy at infinity as zero.

VIII. The principle of Conservation of Mechanical Energy.
In a system in which there are no dissipative forces energy is conserved: $U_i + K_i = U_f + K_f$.

IX. Escape Velocity: $v_{esc} = \sqrt{\frac{2GM}{R}}$ where M and R are the mass and the radius of the planet in question.

X. $P = \frac{\Delta W}{\Delta t} = \mathbf{F}\cdot\mathbf{v}$

Linear Momentum.

I. $\mathbf{p} = m\mathbf{v}$

II. $\mathbf{F}\Delta t = \Delta\mathbf{p}$ the product of force and time is called <u>impulse</u> and is always equal to the change in momentum.

III. The principle of **<u>Conservation of Momentum</u>**. If no external forces act on a system there can be no change in its momentum. Applied to collisions this means the total momentum before the collision is equal to the total momentum after the collision. $\Sigma\mathbf{p}_i = \Sigma\mathbf{p}_f$

IV. **Elastic** Collisions: $\Delta K = 0$

Rigid Bodies and Rotational Motion.

I. $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$

II. Rotational Equilibrium $\sum_{i=1}^{N}\boldsymbol{\tau}_i = 0 \times \alpha = 0$

III Angular Momentum $L = rmv$

IV. $\tau = \frac{\Delta L}{\Delta t}$ analogous to the Newton's Second Law relationship between force and Linear Momentum.

V. The principle of **<u>Conservation of Angular Momentum</u>**. If no external torques act on a system there can be no change in its angular momentum. Applied to systems which change configuration this means the total angular momentum is the same before and after the change.

Fluids &Thermal Physics.

I. $p = \frac{F}{A}$ definition of pressure

II. $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

III. $pV = nRT$

IV. $K_{avg} = \frac{3}{2}k_BT$ where k_B Boltzman's Constant $1.3807\text{X}10^{-23}$ J/K and T must be in **Kelvins**

V. $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_BT}{\mu}}$ where M is the molar mass and μ is the mass of a molecule

VI. $p = p_o + \rho gh$ where ρ is the mass density of the fluid

VII. $F_{buoy} = \rho Vg$ the buoyant force on an object displacing a volume V of the fluid

VIII. $A_1v_1 = A_2v_2$ where A is the cross sectional area of a tube and v is the velocity of the incompressible fluid at that point.

IX. $p + \rho gy + \frac{1}{2}\rho v^2 = \text{constant}$ Bernoulli's equation

X. Thermal Expansion: $\Delta L = L_o\alpha\Delta T$ or $L = L_o [\, 1 + \alpha(T - T_o)]$

XI. $Q = \frac{kA\Delta Tt}{L}$ the heat conducted during a time t through a bar of length L and cross sectional area A where ΔT is the temperature difference between the ends of the rod and k is the thermal conductivity of the material.

XII. $W = -P\Delta V$ where W is the work done on the gas.

XIII. $\Delta U = Q + W$ The First Law of Thermodynamics. Here ΔU is the change in the internal energy of a system, Q is the energy added by heating and W is the work done on the system. Actually this is an expression of the conservation of energy.

XIV. P *vs*. V diagrams. Area under the curve of reversible processes is equal to the work done on (if -) or by (if +) the system. (Only responsible for processes in which the area can be easily figured using algebra.)

XV. Definitions:

i) Adiabatic No energy is transfered to the system through heating. Q = 0

ii) Isothermal There is not change in the internal energy of the system. $\Delta U = 0$ For ideal gases this means there is no change in the temperature.

iii) Isochoric There is no change in volume for the gas, therefore no work is done on or by the system, therefore W = 0.

iv) Isobaric There is no change in pressure. $\Delta P = 0$.

Know how these would appear on a P vs. V diagram.

XVI. Thermal Efficiency for a Heat Engine: $\text{thermal efficiency} = \frac{W}{Q_H}$ where W is the work done by the engine and Q_H is the energy supplied to the engine as a heating process.

XVII. Ideal Thermal Efficiency for a Heat Engine: $\text{thermal efficiency} = 1 - \frac{T_C}{T_H}$ Where the **temperature** must be **in Kelvins.**

XVII. $\Delta S = \frac{Q}{T}$ the change in entropy of a system. **T** must be **in Kelvins**.

Periodic Motion.

I. $\mathbf{F} = -k\mathbf{x}$ Hooke's Law II. $T = \frac{2\pi}{|\omega|}$ III. $f = \frac{1}{T}$

IV. $x = x_o \sin(\omega t + \delta)$ V. $v = v_o \cos(\omega t + \delta)$ VI. $a = -a_o \sin(\omega t + \delta)$

VII. $U = \frac{1}{2} kx^2$

VIII. $T = 2\pi\sqrt{\frac{m}{k}}$ for a mass on a spring IX. $T = 2\pi\sqrt{\frac{L}{g}}$ for a simple pendulum of length L

Wave Motion.

I. $y(x,t) = y_o \sin 2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)$ II. $f\lambda = v$

The Doppler Effect:

III. source moving with a speed v_s $f' = \dfrac{f}{1 \mp \frac{v_s}{v}}$ the **upper sign for approaching** the listener.

V. listener moving with a velocity v_o $f' = f\left(1 \pm \frac{v_o}{v}\right)$ the **upper sign for approaching** the source.

VI. Waves in a string $f_n = \frac{n}{2L}\sqrt{\frac{T}{m/L}}$ where n is an integer, L is the length of the string, m is its mass, and T is the tension in the string. The part of the expression $\sqrt{\frac{T}{m/L}}$ is the velocity of the wave on the string.

VII. Beats $|f_1 - f_2| = f_{beat}$

Electric Charge and Electric Field.

I. $F = k\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}$ for *point* charges and outside of a spherical charge distribution.

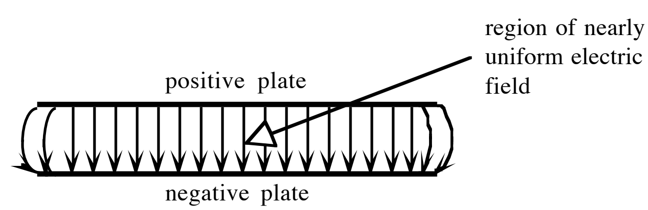
II. $\mathbf{E} = \frac{\mathbf{F}}{q_o}$ where q_o is is small test charge.

Electric Potential and Capacitance.

I. Electrical Potential Energy : $U = k\frac{Qq_o}{r}$ Applies to two point charges a distance r apart or two uniform spherical charges distributions a distance apart r from center to center.Where the electrical potential energy is taken as zero at infinity. N.B. the similarity and differences to the equation for Gravitational Potential Energy Chapter 6, Eq.VII above.

II. Definition of Potential: $V = \frac{U}{q_o}$ where q_o is is small test charge. Potential unit $\frac{J}{C}$ = volt [V]

III. $E = -\frac{\Delta V}{\Delta s}$ for a uniform field then, $\Delta V = Ed$



IV. Definition of Capacitance: $C = \frac{q}{V}$ Capacitance unit $\frac{C}{V}$ = farad [F]

V. Capacitance of a parallel plate capacitor: $C = \frac{\kappa \varepsilon_0 A}{d}$ where κ is the dielectric constant for the material between the plates. [κ = 1 for a vacuum and nearly 1 for air]

VI. Energy stored in a capacitor: $W = \frac{1}{2} CV^2$

Electric Current and Resistance.

I. Definition of Current: $I = \frac{\Delta q}{\Delta t}$ Current unit $\frac{C}{s}$ = ampere [A]

II. $V = IR$ where R is the resistance, defined by this equation. Resistance unit $\frac{V}{A}$ = ohms [Ω]
When R is a constant this is refered to as Ohm's Law.

III. Resistivity, ρ: $R = \rho \frac{L}{A}$

IV. $P = IV$

V. Definition of $\mathcal{E} = \frac{\Delta W}{\Delta t}$ This, the electromotive "force", is the energy per coulomb supplied to the circuit, whereas V the potential difference is the drop in energy per coulomb over a section of a circuit.

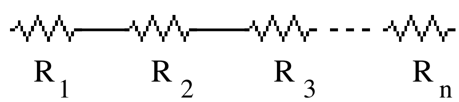
VI. $V = \mathcal{E} - Ir$ Where V is the terminal voltage, $\mathcal{E}$ is the emf, and r is the internal resistance of the source.

This could also be written as $\mathcal{E} = V + Ir = IR + ir$, where it is evident that the energy supplied per coulomb is equal to the sum of the energy losses per coulomb in the external and internal circuits.

VII. Kirchhoff's 1st Rule (**Junction Rule**): $\sum i_{in} = \sum i_{out}$ for any junction.

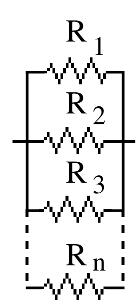
VIII. Kirchhoff's 2nd Rule (**Loop Rule**): $\sum \Delta V = 0$ around any closed loop.

IX. Resistances in Series: $R_{eq} = R_1 + R_2 + \cdots + R_n = \sum R_n$



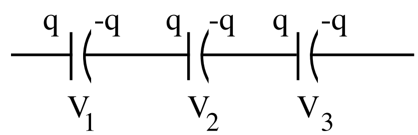
In this type of connection the *current is the same in all of the resistors*, and the **total potential difference** across the resistors is the **sum of the potential drops across each**.

X. Resistances in Parallel: $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n} = \sum_n \frac{1}{R_n}$



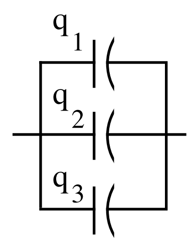
In this type of connection the *currents* in each branch *add up to the total current* through the circuit, and the **potential difference** across each resistor **is the same**.

XI. Capacitors in Series: $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n} = \sum_n \frac{1}{C_n}$



In this type connection, + to -, the *size of the charge* on all plates *is the same*, and the total **potential difference** is the **sum** of the individual potential differences.

XII. Capacitors in Parallel: $C_{eq} = C_1 + C_2 + \cdots + C_n = \sum C_n$



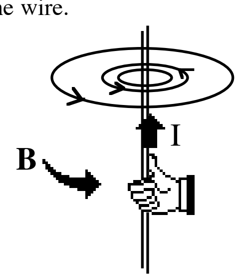
In this type connection, + to + and - to -, the *the sum of the charges* of each capacitor equals the *total stored charge*, and the **potential difference** across each capacitor **is the same**.

Magnetism.

I. $\mathbf{F} = I\mathbf{L}\infty\mathbf{B}$ Here **L** is a vector that points along the wire segment in the direction of conventional current. The SI unit for B is the Tesla [T]

II. $\mathbf{F} = q\mathbf{v}\infty\mathbf{B}$

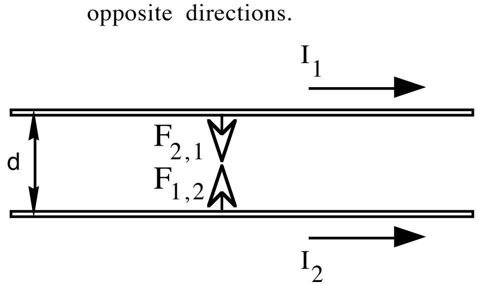
III. Magnetic Field about a long current carrying wire: $B = k'\frac{2I}{d}$ where $k' = \frac{\mu_o}{4\pi}$ and d is the distance from the wire.

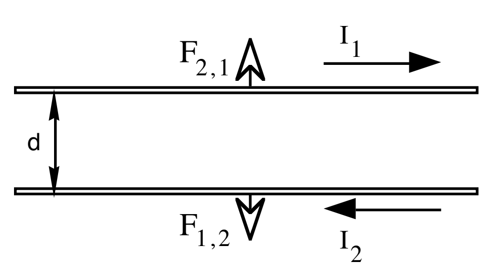


Using **right hand** with the thumb in the direction of the conventional current grasp the wire. The other fingers will encircle the wire in the direction of the magnetic field.

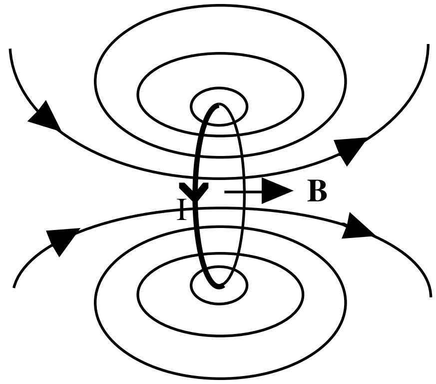
IV. The force between parallel current carrying wires: $\frac{F}{L} = \; = \frac{\mu_o I_1 I_2}{2\pi d} = k'\frac{2I_1I_2}{d}$

The force is attractive if the currents are in the same direction and repulsive if the currents are in opposite directions.





V. The magnetic field of a circular current loop. $B = \frac{\mu_o I}{2R}$



Electromagnetic Induction.

I. Magnetic Flux: $\Phi = BA$ unit of flux is $T \cdot m^2$ = weber [Wb]

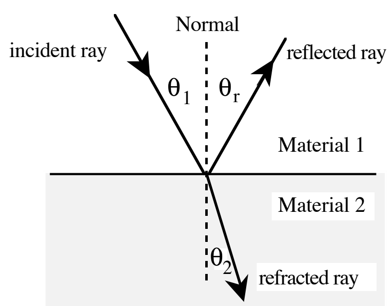
II. Faraday's Law: $\mathcal{E} = -\frac{\Delta\Phi}{\Delta t}$

III. $\mathcal{E} = vBL$

IV. Lenz's Law: A changing magnetic field through a conductor induces a current in such a direction as to oppose the change in magnetic flux.

Geometric Optics.

I. Law of Reflection: $\theta_i = \theta_{refl.}$ In Optics the *angles are always measured from a* ***normal*** drawn to the surface. The incident ray, the normal, and the reflected ray are in the same plane.



II. Snell's Law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

III. The index of refraction of a material is: $n = \frac{c}{v}$ where c is the speed of light in a vacuum.

IV. Critical Angle: $\sin\theta_c = \frac{n_1}{n_2}$

V. The Thin Lens Equation: $\frac{1}{i} + \frac{1}{o} = \frac{1}{f}$ Where $f > 0$ for a converging lens, and $f < 0$ for one that is diverging.

VI. Magnification: $m = -\frac{i}{o}$ the magnification will come out positive for an erect image and negative for an inverted image.

VII. Spherical Mirrors: $f = \frac{R}{2}$

VIII. Images for Mirrors: To locate the image and determine it size we use the same equations as we used for lenses, i.e. V and VI above.

Wave Optics. *Interference.*

Two Sources: I. $n\lambda = d\sin\theta$ for maxima. II. $(n+\frac{1}{2})\lambda = d\sin\theta$ $n = 0,1,2,3$ ... for minima.
Here d is the distance apart for the sources.

Thin Films: $\Delta L = 2nt$, where ΔL is the difference in path length and n is the index of refraction, and t is the thickness of the film. The index of refraction is here to adjust the geometric distance 2t for the fact that the light travels more slowly in the film.

The basic equation for construction is then: III. $m\lambda = 2nt$, where $m = 0,1,2,3\ldots$

and for destructive interference it is: IV. $(m + \frac{1}{2}) = 2nt$, where $m = 0,1,2,3\ldots$

When light reflects from a surface that has a higher index of refraction than the initial material the is a 180° phase shift and this must be taken into account. So you need to check the changes in n for each surface of reflection. For **each phase shift you must add an additional 1/2 to the m in the above two equations.**

Diffraction by a Single Slit: V. $n\lambda = b\sin\theta$ $n = 1,2,3,$ ...for minima. Here b is the width of the slit.

Diffraction Grating: Same equations as for two sources with d as the distance between adjacent openings. This quantity is usually refered to as the grating constant.

Atomic and Nuclear Physics.

I. Nuclear Reactions (Including conservation of mass number and charge.) Radioactive decays would be examples of this:

i. Alpha Decay: ${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + \alpha$ where α is a helium nucleus, ${}^{4}_{2}He$

ii. Beta Decay: ${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + \beta$ where β is an electron, e^-. The result of the reaction $n^o \rightarrow p^+ + e^- + \bar{\nu}$ in the nucleus.

iii. Gamma Decay: ${}^{A}_{Z}X^* \rightarrow {}^{A}_{Z}X + \gamma$ where γ is an electromagnetic wave. The * indicates an excited nucleus.

II. mass-energy equivalence (This is the only remnant of special relativity after the 1998 exam)

III. $E = hf$ where h is Planck's Constant

IV. Photoelectric Effect: $K_{max} = hf - \phi$ where ϕ is the minim energy needed to remove an electron from the surface. This is called the work function.

V. It follows from I and II that $\phi = hf_{th}$ where f_{th} is the threshold frequency

VI. $hf = E_2 - E_1$ for light emitted by electron transitions within the atom.

VII. Wave particle duality. The DeBroglie Wavelength: $\lambda = \frac{h}{p}$

History of Recent Changes; There were two changes in 2002. Fluids were added (now about 6% of the exam) and atomic an nuclear physics were reduced to a total of about 10%. In 2003 the subtopic "Specific and latent heat (including calorimetry)" was deleted.