Temperature $(x\,°F - 32°) * \frac{5}{9} = y\,°C$ $x\,°C + 273.15 = y\,°K$ $P = A + BT$[1] $P = P_0 + pgh$	*Ideal Gas Law* $PV = nRT$[2] $R = 8.314 \frac{J}{mol \cdot °K}$ or $\frac{m^3 \cdot Pa}{mol \cdot °K}$ $R = 0.0821 \frac{L \cdot Atm}{mol \cdot °K}$
Thermal Expansion $\Delta L = \alpha \Delta T L_i$[3] $[\Delta A = 2\alpha \Delta T A_i]$[4] $[\Delta V = \beta \Delta T V_i]$[5] $(\beta = 3\alpha)$	*Heat Capacity* $Q = mc\Delta T$[6] $\left(c_{water} = 4186 \frac{J}{kg \cdot °C}\right)$ $Q = Lm$[7] $\Delta E_{int} = Q + W$ $\frac{1\ cal}{g} = \frac{4186.8\ J}{kg}$
Work from Pressure $W_{work} = -\int_{Vi}^{Vf} PdV$ $W_{isothermal} = nRT * ln\left(\frac{V_i}{V_f}\right)$ $W_{isobaric} = -P\left(V_f - V_i\right)$ $Q_{isothermal} = nRT * ln\left(\frac{P_i}{P_f}\right)$	*Rate of Energy Transfer* $P = kA\left(\frac{T_h - T_c}{L}\right)$[8] $W_{watt} = 1\frac{J}{s}$ $E_{loss} = Q\Delta T$
Remember $K = \frac{1}{2}mv^2$ $U_{potential} = mgh$ $V_{sphere} = \frac{4}{3}\pi r^2, V_{cylinder} = \pi r^2 h$ $P = \frac{F}{A}$ $\rho_{density} = \frac{m}{V}$	• Isobaric: pressure is constant • Isovolumetric: volume is constant $\Delta E_{int} = Q$ W=0 • Isothermal: temperature is constant • Adiabatic: Q is 0 $W = \Delta E_{int}$

[1] A and B are constants
[2] pressure * volume = moles * molar gas constant R * temperature
[3] change in length = coeff. of linear expansion * change in temperature * initial length (α sourced from table)
[4] change in length = coeff. of linear expansion * change in temperature * initial length (α sourced from table)
[5] change in length = coeff. of linear expansion * change in temperature * initial length (α sourced from table)
[6] heat energy = mass* constant c * delta temperature (c is specific heat capacity, sourced from table)
[7] Latent heat during a state change
[8] heat transfer rate = thermal conductivity * surface area * (difference in temperature: hot - cold)/thickness (conductivity sourced from table)

$PV = NkT$[9]

$P = \frac{2}{3}\left(\frac{N}{V}\right)\left(\frac{1}{2}m_0\overline{v^2}\right)$

$T = \frac{2}{3k_B}\left(\frac{1}{2}m_0\overline{v^2}\right)$

$K_{avg} = \frac{3}{2}k_BT = \frac{1}{2}m_0\overline{v^2}$

$W_{on\ gas} = P\Delta V$

$F_{avg} = \frac{\Delta p}{\Delta t}$

$F_{avg} = \frac{-2\,N\cdot m\,V_x}{\Delta t}$

$\Delta E_{int} = nc\Delta T$[10]

$W_{Joules} = Fd$

$m = n_{moles} * n_{mass}$

$v_{rms} = \sqrt{\frac{3k_BT}{m}}$[11]

$v_{rms} = \sqrt{\frac{3RT}{M}}$[12]

$v_{avg} = \sqrt{\frac{8kT}{\pi\cdot m}}$

$P_f = P_i\left(\frac{V_i}{V_f}\right)^{\gamma}$

$T_f = T_i\left(\frac{V_i}{V_f}\right)^{\gamma-1}$

$c = \frac{1}{1-\gamma}R$

$S = k * ln(W)$

$\Delta S = \frac{\Delta Q}{T}$

Conversions & Constants

$1\,Joule = 1\frac{kg\cdot m^2}{s^2}$

$k = 1.38 * 10^{-23}\frac{J}{K}$[13]

$Avogadro's:\ 6.022 * 10^{23}\ \frac{molecules}{mole}$

$1\,Torr = 133\,Pa$

$1\,m^3 = 1000\,L$

$1\,Pa = 9.87 * 10^{-6}\,atm$

$1\,kg = 1\,L\,water$

$745.7\ W_{watt} = 1\,hp$

Energy Required for Phase Changes

$Ice \leftrightharpoons water:\ 334\ \frac{J}{g}$

$Water \leftrightharpoons steam:\ 540\ \frac{cal}{g}$

	Monatomic[14]	Diatomic ($\gamma = 1.4$)
C_v	$\frac{3}{2}R$	$\frac{5}{2}R$
C_P	$\frac{5}{2}R$	$\frac{7}{2}R$

$COP = \frac{|Q_h|}{W}$

$COP = \frac{Heat\ expelled}{Heat\ absorbed}$

$COP = \frac{heat\ out}{heat\ out - heat\ in}$

$W = |Q_h| - |Q_c|$

$E_{pre-loss} = \frac{Electricity\ generated}{Efficiency}$

$\eta = 1 - \frac{T_C}{T_H}$[15]

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[9] P is pressure, V is volume, N is number of molecules, k is the Boltzmann constant, and T is temperature
[10] where c is either Cv, Cp
[11] T is temperature (°K), m is molecular mass (Daltons)
[12] T is temperature (°K), M is the molar mass kg/mol
[13] Boltzmann constant
[14] Monatomic elements: He, Ne, Ar, Kr, Xe, Rn, H, F, Og, O, S
[15] Thermodynamic efficiency: 1 - (Cold temperature/Hot temperature)

Electric Forces[16]	Electric Flux	Conversions[24]
$F_e = k_e \frac{\lvert q_1 \rvert \lvert q_2 \rvert}{r^2}$[17]	$\Phi = EA$[21]	$\rho \equiv \frac{Q}{V} \mid \sigma \equiv \frac{Q}{A} \mid \lambda \equiv \frac{Q}{l}$
$F_e = k_e \frac{\lvert q_{source} \rvert}{r^2}$[18]	$\Phi = EA\cos(\theta)$	$dQ = \rho\, dV \mid dQ = \sigma\, dA \mid$
$\Delta E = k_e \frac{\Delta q}{r^2}$	$\Phi = \int_{surface} E \cdot dA$	$dQ = \lambda\, dl$
$F = \lvert q \rvert E\ (F = eE)$	$\Phi = \frac{Q}{\varepsilon_0}$[22]	**Capacitance**
$\lvert \Delta V \rvert = Ed$[19]	$\Phi = \frac{\rho_v V}{\varepsilon_0}$[23] as $Q = \rho_v V$	$Q = CV$[25]
Constants[20]	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ for $r > a$	$C = 2\pi\varepsilon_0 \frac{L}{ln\left(\frac{b}{a}\right)}$[26]
$k_e = 8.988 * 10^9\ \frac{N * m^2}{C^2}$	$E = k_e \frac{Q}{a^3} r$ for $r < a$	$Q = EA\varepsilon_0$
$e = 1.602 * 10^{-19}\ C$	**Electric Potential Energy**	$E = \frac{1}{2} C_{eq} V^2$
$\varepsilon_0 = 8.85 * 10^{-12}\ \frac{s^4 A^2}{m^3 kg}$	$V \equiv \frac{U_E}{q}$	$C_{eq\,parallel} = C_1 + C_2 + C_n$
$m_{proton} = 1.67 * 10^{-27}\ kg$	$\Delta V \equiv \frac{\Delta U_E}{q} \equiv V_B - V_A$	$\frac{1}{C_{eq\,series}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$
$m_{electron} = 9.11 * 10^{-31}\ kg$	$V = k_e \frac{q}{r}$	**Classic Equations**
Units	$W = q\Delta V$	$Volume = Area * height$
$Coulombs = A * s$	$K = \frac{1}{2} mv^2$	$number\ of\ electrons = \frac{C}{e}$
$Volts = \frac{kg * m^2}{A * s^3}, \frac{1\,Joule}{1\,C}$	$U_E = k_e \frac{q_1 q_2}{r_{1\&2}}$	$V_f = V_i + at$
$Joule = N * m$	$U_E = qV$	$\Delta x = V_i t + \frac{1}{2} at^2$
$\Phi_{flux} = V * m$	$\Delta K + \Delta U = 0$	$V_f^2 = V_i^2 + 2a\Delta x$
$\mu \gg 10^{-6}, n \gg 10^{-9}$		$\Delta x = \frac{1}{2}(V_i + V_f)t$
$mm = 10^{-6} \mid cm = 10^{-3}$		$F_{cent} = \frac{mv^2}{r} \mid \omega_{ang\,vel} = \frac{v}{r}$

[16] C (Coulombs), V (Volts), ϕ (Electric flux), Q (Particle charge), A (Ampere)
[17] k is Coulomb's constant, q are the magnitudes of particles' charges, and r is the distance between the particles
[18] k is Coulomb's constant, q is the magnitude of the source charge, and r is the distance from the source, use this equation for when the affected particle is uncharged.
[19] ΔV is the difference in voltage, E is the electric field strength, and d is the distance between the points
[20] e is the elementary charge of a proton and electron.
[21] The electric flux of a surface is the strength of the electric field passing through it times its area
[22] *Gauss' Law*: The total electric flux through a closed surface of a volume is given by dividing the total charge enclosed in the volume divided by the electric constant
[23] The total electric flux through the surface of a given object is equal to the object's density times the object's volume over the electric constant
[24] Charge per volume (volume charge density), charge per area (surface cd), charge per length (linear cd)
[25] Charge = Capacitance * Voltage
[26] Capacitance of a cylindrical capacitor

Current and Resistivity $\Delta V = IR \mid I = \frac{\Delta V}{R} \mid R = \frac{\Delta V}{I}$ $P_{watts} = \frac{V^2}{R}, P_{watts} = I^2 R$ $I = \frac{\Delta Q}{\Delta t} \quad P = I\Delta V$ $v_{drift} = \frac{I}{neA}$ where $n = \frac{6.022*10^{23} * \rho}{m_{atomic}}$ $Current = I = \frac{Q}{t}, I_{avg} = \frac{\Delta Q}{\Delta t}$ $R = R_0(1 + \alpha\Delta T)$ $R = \frac{\rho L}{A}$ $J = \frac{I}{A}$[27] $\Delta Q = (nA * \Delta x)q$[28] $\Delta Q = (nA * v_d * \Delta t)q$ *Conversions* $1\Omega = \frac{1V}{1A}$ *Rolling without slipping (only)* $v_{center\ of\ mass} = \sqrt{\frac{4a\Delta x}{3}}$ $F\Delta x = \frac{3}{4} m (v_{cm})^2$	*Biot-Savart Law* $B = \frac{\mu_0 I}{4\pi} \int \frac{ds \times r}{r^2}$[29] $\mu_0 = 4\pi * 10^{-7}$ $B = \frac{\mu_0 I}{2\pi a}$[30] Curved wire segments: $B = \frac{\mu_0 I}{4\pi a}\theta$ Circular current loops[31]: $B_x = \frac{\mu_0 I a^2}{2(a^2+x^2)^{3/2}}$ $\frac{F_B}{l} = \frac{\mu_0 I_1 I_2}{2\pi a}$[32] *Ampére's Law* $\oint B \cdot ds = \mu_0 I$ $B_{solenoid} = \mu_0 nI$[33] $n = \frac{N}{Helix\ length}; N_{turns/length} = \frac{Helix\ length}{2r_{wire}}$ $l_{wire} = N * 2\pi r_{helix}$ $\Phi_B = \int B \cdot dA$
$1\ Tesla = 1\frac{N}{C \cdot m/s} = 1\frac{N}{A \cdot m}$ $F_B = qv \times B$[34] $\lvert F_B \rvert = \lvert q \rvert vB\ sin(\theta)$ $F_L = qE + F_B$[35] $F_B = IL \times B$ $F_B = I\int ds \times B$[36]	*Faraday's Law* $\varepsilon = -\frac{d\Phi_B}{dt}$ $\varepsilon = -N\frac{d\Phi_B}{dt}$ $\varepsilon = -Bl\frac{dx}{dt} \gg \varepsilon = -Blv$ $v = \frac{E}{B}$

[27] Current density is charge over cross sectional area
[28] n is mobile charge carriers per unit volume, A dx is cross sectional area, q is charge
[29] The Biot-Savart Law finds the magnetic field created by the charges that make up a flowing current
[30] The magnetic field a distance a away from an infinite (or very long) wire
[31] *a* is the radius of the loop while *x* is the distance from the center the magnetic force is being solved for
[32] Magnetic force between two wires
[33] The magnetic field inside an ideal solenoid (a wire wound as a helix) where n is the number of turns/unit length
[34] The vector expression for magnetic force: q is charge, v is the velocity vector, B is the magnetic field vector
[35] The Lorentz Force is used when the particle is affected by both an electric field and a magnetic field
[36] The magnetic force on a length ∫ ds of wire