Formula sheet (last updated: 9 dec 2012)

Constants and Factors

Speed of light: $c = 299,792,458$ m/s exactly (about 3×10^8 meters/sec)
$\epsilon_0 = 8.85 \times 10^{-12}$ F/m; $\mu_0 = 4\pi \times 10^{-7}$H/m; $c = 1/\sqrt{(\epsilon_0\mu_0)}$
Newton's constant $G = 6.67 \times 10^{-11}$ m^3/s^2 kg; Earth's surface $g = 9.8$m/s^2
Mass of proton and neutron about 1.67 $\times 10^{-27}$ kg
Mass of electron: $m_e = 9.11 \times 10^{-31}$kg
Standard air pressure: $P_0 = 1.01 \times 10^5$N/m^2 = 1 Atmosphere
Speed of sound: in Air: 343 m/s, in Water: 1500 m/s, in Steel: 5940 m/s
Density of air: 1.2 kg/m^3; of water: 1000 kg/m^3
Specific Heats (in kcal/(kg ^{0}C) or Btu/(lb ^{0}F)): water: 1, ice: 0.49, wood: 0.33, stone: 0.20, iron: 0.107, glass: 0.033
Energy Units: 1 kcal = 4184 Joule = 3.97 Btu; 1 kWh = 3.6×10^6J; 1 Btu/hr = 0.293 Watt
Boltzman constant $k = 1.38 \times 10^{-23}$J/K, Universal gas constant R=8.314 J/(K mol)
Avagadro's number $N_A = 6.022 \times 10^{23}$ molecules/mole
Heat of transformation for Water (kJ/kg): melting: 334, vaporization: 2257
Conversions: meter = 3.28 ft; meter^3 = 1000 liters
Index of refraction: air: 1.0003 (≈ 1.0), water: 1.333, ice: 1.309, glass: 1.5, diamond: 2.419

Formulas from Physics 2A

Velocity, position, acceleration: $\vec{v} = d\vec{r}/dt$, acceleration $\vec{a} = d\vec{v}/dt$; $\vec{v} = \vec{v}_0 + \vec{a}t$, and $\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$
Circular motion: $a = v^2/r$; Newton's acceleration law: $\vec{F} = d\vec{p}/dt = m\vec{a}$; Weight: $\vec{W} = m\vec{g}$

Formulas for Physics 2C

Wave velocity: $v = \lambda/T = f\lambda$, with wavelength λ; period T; frequency $f = 1/T$
Simple harmonic wave: $y(x,t) = A\cos(kx \pm \omega t)$, with displacement of the medium y; amplitude of wave A; wave number $k = 2\pi/\lambda$; angular frequency $\omega = 2\pi f$. Wave speed is $v = \omega/k$.
Small amplitude wave on a stretched spring has speed: $v = \sqrt{F/\mu}$ with F the string tension and μ the mass per unit length of the string.
Average wave power on a string: $\bar{P} = \frac{1}{2}\mu\omega^2 A^2 v = \frac{1}{2}F\omega k A^2$
Wave intensity is power per unit area carried by wave. For 3-D waves $I = P/(4\pi R^2)$, with P total power, and R distance from source of wave.
Linear wave equation: $\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\frac{\partial^2 y}{\partial t^2}$

Speed of sound in gas: $v = \sqrt{\gamma P_0/\rho}$, where P_0 is the gas pressure, ρ is the density, and $\gamma = 5/3$ in monatomic gases like Helium and $\gamma = 7/5$ in diatomic gases like air; speed of sound in air: 343 m/s
Speed of sound in solid: $v = \sqrt{B/\rho}$, where $B = -\Delta P/(\Delta V/V)$ is the bulk modulus of elasticity
Average intensity of sound: $\bar{I} = \frac{1}{2}\Delta P_0^2/(\rho v) = \frac{1}{2}\rho\omega^2 s_0^2 v$, where ΔP_0 is the pressure amplitude and s_0 is the displacement amplitude
Sound is sometimes measured in decibels: $\beta = 10\log\left(\frac{I}{I_0}\right)$, where $I_0 = 10^{-12}$W/m^2
Standing waves have formula: $y(x,t) = 2A\sin(kx)\sin(\omega t)$; for strings: ends clamped (ends nodes) $L = n\lambda/2$ with n and integer.
Doppler shift in sound from moving source: $f' = f/(1 \pm u/v)$ for source moving away (+) or towards (-) observer, where v is sound speed and u is source speed
For moving observer: $f' = f(1 \pm u/v)$ for observer moving towards(+) or away (-)

Hydrostatic equilibrium: no net force on any fluid element: pressure is $P = P_0 + \rho g h$, with P_0 surface pressure, ρ density, and h the depth in liquid.
Archimedes' principle: Buoyancy force is equal to the weight of the fluid displaced by the object
Continuity equation (conservation of mass): $\rho v A$ = constant along a flow tube (A area, v velocity)
Bernoulli's equation (conservation of energy): $P + \frac{1}{2}\rho v^2 + \rho g h$ = constant along a flow tube

Temperature scales: $T_{Celsius} = T_{Kelvin} - 273.15$ and $T_{Fahrenheit} = \frac{9}{5}T_{Celsius} + 32$
$\Delta Q = C\Delta T$, where ΔQ is heat transferred, ΔT is temperature change, and C is the heat capacity of the object.
Also $\Delta Q = cm\Delta T$, where c is the *specific* heat of the object, and m is the mass

Heat flow rate (in J/s): $H = -kA(\Delta T/\Delta x)$, k is thermal conductivity (in W/m K), A is area
Heat flow rate (in Btu/hr): $H = A\Delta T/R$, where R Factor: $R = \Delta x/k$ (in ft^{2}F^0 hr/Btu)
Stefan-Boltzmann radiation law: Power radiated is $P = e\sigma AT^4$, where e is emmisivity, $\sigma = 5.67 \times 10^{-8}$ W/m$^2 \cdot K^4$, T is temp in Kelvins, A surface area of object

Ideal gas law $PV = NkT$; $PV = nRT$, with N number of molecules and n number of moles.
Maxwell-Boltzmann distribution: $dN = (dN/dv)dv = 4\pi N(m/(2\pi kT))^{3/2}v^2 \exp[-mv^2/2kT]dv$
RMS speed of molecule in gas is given by: $\frac{1}{2}m\bar{v}^2 = \frac{3}{2}kT$
Thermal expansion coefficients: Linear $\Delta L = \alpha L\Delta T$, Volume $\Delta V = \beta V\Delta T$, where $\beta = 3\alpha$
Heat of transformation: $Q = Lm$, with L heat of fusion, vaporization, etc. and m mass

First law of thermodynamics: $\Delta U = Q - W$, ΔU is change of internal energy, Q is heat into system and work done by system is $W = \int_{V_1}^{V_2} PdV$; ideal gas: $U = nc_VT$
Processes: *Isothermal*: $Q = W$, $W = nRT\ln(V_2/V_1)$; $PV =$ constant
Constant volume: $Q = \Delta U$; $W = 0$; $Q = nc_V\Delta T$, C_V specific heat at constant volume
Isobaric: $W = P(V_2 - V_1)$; $Q = nC_P\Delta T$; C_P specific heat constant pressure; $C_P = C_V + R$;
Adiabatic: $Q = 0$; $(\Delta U = -W)$: $W = (P_1V_1 - P_2V_2)/(\gamma - 1)$; $PV^\gamma =$ constant; $\gamma = C_P/C_V$
Degrees-of-freedom (dof): Monatomic has 3, diatomic has 5, triatomic has 6; $C_V = (\text{dof})\frac{1}{2}R$

Heat engine working in cycle has efficiency $\epsilon = W/Q_h = 1 - Q_c/Q_h$; For reversible processes: $Q_c/Q_h = T_c/T_h$ and efficiency is called Carnot efficiency: $\epsilon \le \epsilon_{Carnot} = 1 - T_c/T_h$
A refrigerator (reverse heat engine) uses work W to extract heat Q_c from cold and deposit heat Q_h at hot temp. Coefficient of performance: $\text{COP} = Q_c/W \le \text{COP}_{Carnot} = T_c/(T_h - T_c)$
Entropy measures disorder in a system: $\Delta S = \int_1^2 (dQ/T)$; For adiabatic free expansion $\Delta S = nR\ln(V_2/V_1)$; for heating from T_1 to T_2, $\Delta S = mc\ln(T_2/T_1)$; for other processes (e.g. constant volume or pressure) use integral formula, with $Q \to dQ$ and $\Delta T \to dT$

Gauss law: $\oint \vec{E} \cdot d\vec{A} = q/\epsilon_0$; Faraday law: $\oint \vec{E} \cdot d\vec{l} = -d\phi_B/dt$; Ampere law: $\oint \vec{B} \cdot d\vec{l} = \mu_0 I + \mu_0\epsilon_0 d\phi_E/dt$; $\phi_E = \int \vec{E} \cdot d\vec{A}$; $\phi_B = \int \vec{B} \cdot d\vec{A}$; Displacement current: $\epsilon_0 d\phi_E/dt$
Electromagnetic plane wave in x direction: $E = \hat{j}E_0\sin(kx - \omega t)$; $B = \hat{k}B_0\sin(kx - \omega t)$;$c = \omega/k$; $E = cB$; Intensity (W/m^2): $\bar{S} = \bar{EB}/\mu_0 = E_pB_p/(2\mu_0)$; for spherical wave: $S = P/(4\pi r^2)$; for polarization at angle θ: $S = S_0\cos^2\theta$; Radiation pressure: $P_{rad} = \bar{S}/c$

Reflection: $\theta_{\text{incidence}} = \theta_{\text{reflection}}$
Refraction: Snell law: $n_1\sin\theta_1 = n_2\sin\theta_2$, n is index of refraction; $v_{\text{light}} = c/n$;
Total internal reflection critical angle: $\sin\theta_c = n_2/n_1$; Polarizing Brewster angle: $\tan\theta_p = n_2/n_1$

Lens/Mirror equation: $\frac{1}{l} + \frac{1}{l'} = \frac{1}{f}$, f is focal length; Magnification is $M = h'/h = -l'/l$; h' negative means inverted image; l' negative means virtual image; f negative means concave (dispersing).
Curved interface of radius R between materials with n_1 and n_2: $n_1/l + n_2/l' = (n_2 - n_1)/R$
Lensmaker formula: $\frac{1}{f} = (n-1)(\frac{1}{R_1} - \frac{1}{R_2})$; for spherical mirror: $f = R/2$

Double slit spectrograph: bright fringes $d\sin\theta = m\lambda$, dark fringes $d\sin\theta = (m + \frac{1}{2})\lambda$, $m = 0, 1, 2, \cdots$
$y_{bright} = m\lambda L/d$, $y_{dark} = (m + \frac{1}{2})\lambda L/d$
Multiple slit with N slits (diffraction grating): maxima: $d\sin\theta = m\lambda$, $m = 0, 1, 2, \cdots$
minima: $d\sin\theta = m\lambda/N$, $m = 1, 2, ..., N-1$
Thin film interference: 180^0 phase shift for reflection from lower n_1 off higher n_2; otherwise no phase shift. From air to material: constructive interference: $2nd = (m + \frac{1}{2})\lambda$; destructive: $2nd = m\lambda$