Physics 32 Equation Sheet

$F_g = G\frac{Mm}{r^2}$ $U_g = -G\frac{Mm}{r}$ potential $V = -\frac{GM}{r}$

$G = 6.67\times10^{-11}\ \frac{N\cdot m^2}{kg^2}$

Kepler's Laws

1. Law of orbits - Ellipses
2. Law of Areas - Equal times swept equal areas → L (angular momentum conserved)
3. Law of periods - $T^2 \propto R^3$

Oscillations

$F_k = -kx$

$U_s = \frac{1}{2}kx^2$ $I = \int r^2 dm$

$\frac{d^2x}{dt^2} = -\omega^2 x$, $T = \frac{2\pi}{\omega_0}$

$x(t) = A\cos(\omega t + \phi)$

spring → $T = 2\pi\sqrt{\frac{m}{k}}$

pendulum → $T = 2\pi\sqrt{\frac{l}{g}}$

$x(t) = x_{max}e^{-\frac{bt}{2m}}\cos(\omega' t + \phi)$

$\omega' = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$ dampened

Fluid Dynamics

$P = \frac{F}{A}$ [Pa]

$\frac{F}{A} = \frac{F'}{A'}$ ⇒ Pascal's principle

$P_2 - P_1 = \rho g(y_2 - y_1)$ ⟩ fluid pressure w/ depth

$dP = \rho g\, dy$

$\vec{F}_B = \rho_{fluid} V_{displaced}\, g$ (= $M_{water}\, g$) → archimedes principle

$A_1V_1 = A_2V_2 = \frac{V}{t}$ continuity

$P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$ = Bernoulli's $V\uparrow P\downarrow$, $V\downarrow \to P\uparrow$

- $1\,atm = 1.013\times10^5$ Pa

Waves

$v_{const} = \lambda f$ $T = \frac{1}{f}$

$v = \sqrt{\frac{F_T}{\mu}}$ F_T = tension, $\mu = \frac{m}{l}$

general

Fluid: $v = \sqrt{\frac{B}{\rho}}$ B = Bulk Modulus

Solid: $v = \sqrt{\frac{E}{\rho}}$ E = elastic modulus

$E_{wave\ generic} = 2\pi^2 f^2 \rho (v_1 t\,(Area)) A^2$ (A = x_{max})

$I_{ntensity} = \frac{Power}{Area}$

$y(x,t) = y_{max}\sin(kx \mp \omega t)$ (− : pos x dir, + = neg x dir.) Traveling wave (not SHM)

wave # → $k = \frac{2\pi}{\lambda}$ $\omega = \frac{2\pi}{T}$

$v = \frac{\lambda}{T} = \lambda f = \frac{\omega}{k}$ - select

wave equation: $\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\left(\frac{\partial^2 y}{\partial t^2}\right)$

Sound

$f_{Beat} = |f_1 - f_2|$

#dB → $\beta = 10\log\left(\frac{I}{I_0}\right)$, $I_0 = 10^{-12}\ \frac{W}{m^2}$

$\beta = 20\log\left(\frac{y_{max}}{I_0}\right)$ - select (terms of Amp)

Doppler Effect → $f_{obs} = f_{source}\left(\frac{v_{sound} \pm v_{obs}}{v_{sound} \mp v_{source}}\right)$ pos = towards, neg = away

Light

law of reflection: $\theta_i = \theta_R$ $n_0\sin\theta_0 = n_f\sin\theta_R$ (internal)

$n = \frac{c}{v}$ snell's law (refraction) (through)

($\tan\theta = \frac{y}{D}$) → y from centerline

$d\sin\theta = m\lambda$ - (bright)

$d\sin\theta = (m + \frac{1}{2})\lambda$ (dark) ⟩ interference double slit

$2d = (m + \frac{1}{2})\lambda' = (m + \frac{1}{2})\frac{\lambda}{n'}$ - Thin film interference

Thermodynamics

$PV = nRT$, $n = \frac{N}{N_a}$ (# of moles; N = # of molecules)

$N_A = 6.02\times10^{23}$ avagadro's number

$R = 8.31 \frac{Pa\cdot m^3}{mol\cdot K}$

$L = L_0(1+\alpha\Delta T)$ thermal expansion

$T(K) = T(C) + 273$

Kinetic Theory of Gasses

$K_{avg} = \frac{3}{2}K_B T = \frac{1}{2}mv_{RMS}^2$

$K_B = \frac{R}{N_A} = 1.38\times10^{-23}\frac{J}{K}$

$V_{RMS} = \sqrt{\frac{3RT}{MN_A}}$ $V_{RMS} = \sqrt{\overline{v^2}}$

Mean free path

$l_{MFP} = \frac{1}{\sqrt{2}\left(\frac{N}{V}\right)(4\pi r^2)}$

at STP: $\frac{N}{V} = \frac{6.02\times10^{23}\text{ molecules}}{22.4\times10^{-3}\text{ m}^3}$

$1L = 1\times10^{-3}\text{ m}^3$

$P(v) = 4\pi N\left(\frac{M}{2\pi K_B T}\right)^{3/2} v^2 e^{-\frac{1}{2}\frac{mv^2}{K_B T}}$ ← MB Dist.

First law of thermodynamics

$\Delta E = \Delta Q \pm \Delta W$

$\Delta E = (N)\frac{3}{2}K_B T = (n)\frac{3}{2}RT$ (# mols, separation (mols)); $\left(\frac{5}{2}\right)$ if diatomic

$\Delta Q = mc\Delta T$ ← temp. change, specific heat

$\Delta Q = mL \rightarrow L_{fusion}$, $L_{vaporization}$ (L_f, L_v)

$\Delta E = nC_v\Delta T$ for $\Delta Q = 0$, $\Delta E = \Delta W$

$\Delta W = \int P\,dV$ → PV Diagram work

$P_A V_A^\gamma = P_B V_B^\gamma$ – Adiabats — $\Delta E = nC_v\Delta T$, $\Delta E = \Delta Q + \Delta W$, $\Delta W = nC_v\Delta T$

$\gamma = \frac{C_p}{C_v}$ ← Pressure const., ← Vol const.

$C_p = C_v + R$ $\left(\frac{5}{2}\right)$ if diatomic

$C_p = \frac{5}{2}R$, $C_v = \frac{3}{2}R$ $C = M C_v$ (molar mass $\left(\frac{kg}{mol}\right)$)

Heat Transfer

$\frac{dQ}{dt} = \sigma\epsilon A(T^4 - T_0^4)$ – radiation

$\sigma_B = 5.67\times10^{-8}\frac{W}{m^2\cdot K^4}$

$\frac{\Delta Q}{\Delta t} = KA\frac{T_1 - T_2}{l}$ ← conduction, "conductivity"

$\frac{dQ}{dt} = KA\frac{dT}{dx}$

Multiple conductors: H [ ][ ][ ][ ] C

$\frac{dQ}{dt} = \frac{A(T_H - T_C)}{\sum_i \frac{L_i}{k_i}}$

Heat engine efficiency

$e = \frac{\Delta W_{out}}{\Delta W_{in}} = \frac{\Delta W_{net}}{\sum Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}} = \frac{T_H - T_C}{T_H}$ (carnot cycle only)

$\Delta E = \Delta Q + \Delta W$, engine = $\Delta E = 0$

$W_{net} = Q_H - Q_L$ (input, loss)

$\Delta S = \int\frac{1}{T}dQ$ – entropy

$COP = \frac{Q_C}{\Delta W_{in}}$ (refrigerator), $COP = \frac{Q_H}{\Delta W_{in}}$ (Heater (Heat Pump)) – coefficient of performance

Lenses

lens $P = \frac{1}{f}$ [D] (diopter) [m⁻¹] (f: focal length)

$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ converging

$\frac{1}{f} = \frac{1}{d_i} - \frac{1}{d_o}$ diverging

$m = \frac{h_i}{h_o} = (-)\frac{d_i}{d_o}$

$M_T = M_1\cdot M_2\cdot M_3\cdots$

$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$ – lensmaker's

Van Der Waal's:
1. Molecule size
2. Molecule attraction