Academic Resource Sheet

PHYS 2350

Kinematics

$$\Delta s = v_{0s}t + \tfrac{1}{2}a_s t^2$$

$$v_s = v_{0s} + a_s t$$

$$v_s^2 = v_{0s}^2 + 2a_s \Delta s$$

$$\overline{v} = \frac{\Delta s}{\Delta t}$$

$$\overline{a} = \frac{\Delta v}{\Delta t}$$

$$\vec{u} = \vec{u}' + \vec{v}, \text{ relative velocities}$$

$$R = \frac{2v_0^2 \sin\theta \cos\theta}{g}$$

$$H = \frac{v_0^2 \sin^2\theta}{2g}$$

$$t_{\text{flight}} = \frac{2v_0 \sin\theta}{g}$$

Dynamics

$$\sum \vec{F} = m\vec{a}$$

$$\mathcal{F}_s \leq \mu_s N$$

$$\mathcal{F}_k = \mu_k N$$

$$w = mg, \quad g = 9.8\ m/s^2$$

Uniform Circular Motion

$$a_{\text{radial}} = -\frac{v_{\text{tangent}}^2}{r}$$

$$a_{\text{tangent}} = 0$$

$$v_{\text{radial}} = 0$$

$$v_{\text{tangent}} = \frac{2\pi r}{T}$$

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

Gravitation

$$F_g = \frac{GMm}{r^2}, \quad G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$$

$$\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{a_1}{a_2}\right)^3, \; a = \text{semimajor axis}$$

$$v^2 = \frac{GM}{r}, \text{ orbits}$$

Work and Energy

$$W_F = F\Delta s \cos\phi$$

$$\overline{P} = \frac{W}{t} = Fv\cos\phi$$

$$KE_T = \tfrac{1}{2}mv^2$$

$$U_g = \begin{cases} -\frac{GMm}{r} \\ mgy, \text{ if } r \approx R_e \end{cases}$$

$$F_x^{(\text{spring})} = -kx$$

$$U_s = \tfrac{1}{2}k\,(\Delta\ell)^2$$

$$KE_1 + U_{g1} + U_{s1} + W^* = KE_2 + U_{g2} + U_{s2}$$

$$W_g = -\Delta U_g$$

$$W_s = -\Delta U_s$$

$$v_{\text{esc}}^2 = \frac{2GM}{R}$$

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Linear Momentum

$\vec{p} = m\vec{v}$

$\vec{J} = \Delta\vec{p} = \left(\sum \vec{F}\right)\Delta t$

if $\sum_{\text{ext}} F = 0$, $p_{\text{initial}} = p_{\text{final}}$

if elastic collision, $KE_{\text{initial}} = KE_{\text{final}}$, $\varepsilon \equiv \frac{v_2 - v_1}{u_1 - u_2} = 1$ for 1-dim

$u_1 + v_1 = u_2 + v_2$, for 1-dim, 2-body, elastic collisions

$x_{\text{cm}} = \frac{\sum m_i x_i}{\sum m_i}$, $y_{\text{cm}} = \frac{\sum m_i y_i}{\sum m_i}$

if $\sum_{\text{ext}} F = 0$ & $p_{\text{system}} = 0$, then $\Delta x_{\text{cm}} = 0$ $\left(\sum m_i x_i = \sum m_i x_i'\right)$

Rotational Motion

$\overline{\omega} = \frac{\Delta\theta}{\Delta t}$

$\overline{\alpha} = \frac{\Delta\omega}{\Delta t}$

$\omega = 2\pi f$

$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

circular motion $\Rightarrow$

$a_{\text{radial}} = -r\omega^2$

$a_{\text{tangent}} = r\alpha$

$v_{\text{tangent}} = r\omega$

$\Delta s = r\Delta\theta$

$$\tau = \begin{cases} rF\sin\phi \\ rF_{\perp} \\ r_{\perp}F \end{cases}$$

$\sum \tau = \frac{\Delta L}{\Delta t}$

$L = rp\sin\phi = r_{\perp}p$

if $\sum_{\text{ext}} \tau = 0$, $L_{\text{initial}} = L_{\text{final}}$

rigid rotator about O', O' is stat. pt. or c.m. :

$\sum \tau = I_{O'}\alpha$

$L = I_{O'}\omega$

$W = W^{(\text{pseudo})}_{F \text{ on } O'} + W_{R \text{ about } O'}$

$KE = KE_{T \text{ of } O'} + KE_{R \text{ about } O'}$

$W_R = \tau\Delta\theta\cos\phi$

$P = \tau\omega\cos\phi$

$KE_R = \frac{1}{2}I\omega^2$

$I = \sum m r_{\perp}^2$

$I_{\parallel} = I_{\text{cm}} + md^2$

$I_{\text{center rod}} = \frac{1}{12}m\ell^2$

$I_{\text{loop}} = mr^2$

$I_{\text{cylinder}} = \frac{1}{2}mr^2$

$I_{\text{sphere}} = \frac{2}{5}mr^2$

rolling, no slipping $\Rightarrow$

$a_{\text{cm}} = r\alpha$

$v_{\text{cm}} = r\omega$

$\Delta s_{\text{cm}} = r\Delta\theta$

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Fluids

$\overline{\rho} = \frac{m}{V}$ | $\rho_{water} = 1000\ kg/m^3$ | $SG = \frac{\rho}{\rho_w}$ | $P = \frac{F_\perp}{A}$ | $\Delta P_{fluid} = \rho_{fluid} g \Delta y$

$P_{atm} = 1.013 \times 10^5\ Pa$ | $P^{(absolute)} = P_{atm} + \Delta P^{(gauge)}$ | $B = \rho_{fluid}\ g\ V_{displaced}$

$Q = \frac{\Delta V}{\Delta t} = A_1 v_1 = A_2 v_2$ | $P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

Vibration and Waves

$f = \frac{1}{T} = \frac{\omega}{2\pi}$

mass-spring:
$$E_{total} = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$$
$$v = \pm\omega\sqrt{A^2 - x^2} \quad , \omega = \sqrt{\frac{k}{m}}$$
$$a = -\omega^2 x$$

$$v_{max} = \omega A$$
$$a_{max} = \omega^2 A$$

mass-spring:
$$x(t) = A\sin(\omega t + \delta)$$
$$v(t) = \omega A\cos(\omega t + \delta) \quad , \tan\delta = \frac{\omega x_0}{v_0}$$
$$a(t) = -\omega^2 A\sin(\omega t + \delta)$$

simple pendulum: $T = 2\pi\sqrt{\frac{L}{g}}$

physical pendulum: $T = 2\pi\sqrt{\frac{I_O}{mgd}}$

$f\lambda = v$

string:
$$f_n = n\left(\frac{v}{2L}\right),\ n = 1, 2, 3, \ldots$$
$$v = \sqrt{\frac{T}{\mu}},\ \mu = \frac{m}{L}$$

$\overline{I} = \frac{P}{S}$ (if spherical wave, $S = 4\pi r^2$)

$I = 2\pi^2 v\rho f^2 A^2$

Sound

$v_{sound} = 331\sqrt{\frac{T_K}{273}}\ [m/s]$ | $\beta = 10\log\frac{I}{I_0},\ I_0 = 10^{-12}\ W/m^2,\ I = I_0 10^{\frac{\beta}{10}}$

pipes:
$$f_n = n\left(\frac{v}{2L}\right),\ n = 1, 2, 3, \ldots, \text{ open}$$
$$f_n = m\left(\frac{v}{4L}\right),\ m = 1, 3, 5, \ldots, \text{ closed}$$

$f_{beat} = |f_1 - f_2|$ | $\frac{f_L}{v + v_L} = \frac{f_S}{v + v_s},\ L \xrightarrow{+} S$

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Temperature and Kinetic Theory

$T_C = \frac{5}{9}(T_F - 32)$

$T_K = T_C + 273.15$

$\frac{P}{RT} = \frac{n}{V} = \frac{\rho}{\mathcal{M}}, \ R = 8.315 \ J/(mol \cdot K)$

$1 \ atm = 1.013 \times 10^5 \ Pa$

$n = \frac{N}{N_A} = \frac{M}{\mathcal{M}}$

$m = \frac{\mathcal{M}}{N_A}$

$\overline{KE}_{\text{gas molec}} = \frac{1}{2}m\overline{v^2} = \frac{3}{2}k_B T$

$v_{\text{rms}} = \sqrt{\frac{3RT}{\mathcal{M}}}$

$k_B = R/N_A, \ N_A = 6.022 \times 10^{23} \ mole^{-1}$

Heat

$(Q + W^{(\text{on})})_{\text{IS}} = 0$

$Q_{\text{temp change}} = mc\Delta T$

$Q_{\text{phase change}} = \pm m L_{S,F,V}$

$Q > 0$, absorbed

$Q < 0$, released

$\dot{Q}_{\text{conv}} = hA(T_\infty - T_{\text{surf}})$

$\dot{Q}_{\text{cond}} = -kA\frac{\Delta T}{\Delta s}$

$\dot{Q}_{\text{rad}} = e\sigma A(T_{\text{surr}}^4 - T_{\text{body surf}}^4)$

$1 \ cal = 4.186 \ J$

$\sigma = 5.67 \times 10^{-8} \ W/(m^2 \cdot K^4)$

$c_{\text{water}} \approx 2c_{\text{ice}} = 1 \ cal/(g \cdot C^0)$

$L_F^{(H_2O)} = 80 \ cal/g$

Thermodynamics

$\Delta U = Q - W^{(\text{by})}$, 1st law

$W =$ area under PV curve

$W_{\Delta P=0} = P\Delta V$

$W_{\Delta T=0} = nRT\ln\left(\frac{V_{fin}}{V_{ini}}\right)$, ideal gas

$W > 0$, done by

$W < 0$, done on

$Q_{\Delta V=0} = nC_V\Delta T$

$Q_{\Delta P=0} = nC_P\Delta T$

$\Delta U = nC_V\Delta T$, ideal gas

$C_V = \frac{3}{2}R$, monatomic

$C_P = C_V + R$

$PV^\gamma = const., \ \gamma = \frac{C_P}{C_V}$, adiabats

$\Delta S_{\text{q.s.}} = \sum\frac{\delta Q}{T} \approx \frac{Q}{T}$

$\Delta S_{\text{IS}} \geq 0$, 2nd law

$\Delta U_{\text{cycle}} = 0$

$W_{\text{cycle}} = Q_H + Q_L$

$\Delta S_{\text{cycle}} = 0$

$\varepsilon = \frac{W}{Q_H}$, heat engine

$\kappa = -\frac{Q_L}{W}$, refrigerator

Carnot cycle:

$-\frac{Q_L}{Q_H} = \frac{T_L}{T_H}$

$\varepsilon_{\text{Carnot}} = 1 - \frac{T_L}{T_H}$

$\kappa_{\text{Carnot}} = \frac{T_L}{T_H - T_L}$