FORMULA SHEET

- Vectors:

$$\vec{A} \cdot \vec{B} = AB\cos\theta$$

$$\left|\vec{A} \times \vec{B}\right| = AB\sin\theta$$

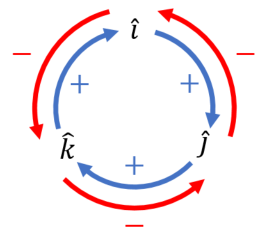

Figure 1: Cyclic permutations for cross product

- Kinematics:

$$g = 9.8\text{m/s}^2$$

$$\Delta x = v_0 t + \frac{1}{2}at^2$$

$$v = v_0 + at$$

$$v^2 = v_0^2 + 2a\Delta x$$

- Forces:

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

$$W = mg$$

$$f_{s,max} = \mu_s N$$

$$f_k = \mu_k N$$

- Circular Motion:

$$a_c = \frac{v^2}{r}$$

$$v = \frac{2\pi r}{T}$$

- Gravity:

$$G = 6.67 \times 10^{-11}\frac{\text{Nm}^2}{\text{kg}^2}$$

$$F_g = G\frac{mM}{r^2}$$

$$a_g = G\frac{M}{r^2}$$

$$T^2 = \frac{4\pi^2}{GM}a^3 \quad \text{(Kepler's third law)}$$

- Work & Energy:

$$K = \frac{1}{2}mv^2$$
$$U_g = mgy \text{ (near Earth's surface)}$$
$$U_g = -G\frac{mM}{r} \text{ (anywhere)}$$
$$W = F\Delta x \cos\theta$$
$$W_{tot} = \Delta K$$
$$W_{cons} = -\Delta U$$
$$W_{other} = \Delta E$$
$$K_i + U_i + W_{nc} = K_f + U_f$$
$$P = \frac{\Delta E}{\Delta t}$$
$$P = Fv \text{ (at constant velocity)}$$

- Linear Momentum:

$$\vec{p} = m\vec{v}$$
$$\sum \vec{F}_{ext,sys} = \frac{\Delta \vec{p}_{sys}}{\Delta t}$$
$$m_A\vec{v}_{Ai} + m_B\vec{v}_{Bi} = m_A\vec{v}_{Af} + m_B\vec{v}_{Bf}$$
$$v_{1i} - v_{2i} = v_{2f} - v_{1f} \text{ (elastic collisions)}$$
$$\vec{J} = \vec{F}_{av}\Delta t \text{ (impulse)}$$

- Rotational Motion:
  - Rotational Kinematics:

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

  - Rolling without slipping:

$$\Delta x = R\Delta\theta$$
$$v = R\omega$$
$$a = R\alpha$$

  - Rotational Dynamics:

$$\tau = rF\sin\theta$$
$$\Delta\tau = I\alpha = \frac{\Delta L}{\Delta t}$$
$$K_{rot} = \frac{1}{2}I\omega^2$$
$$L = I\omega = rp$$

- Rotational Motion (continued):
  - Moment of inertia:

$$I = mr^2 \text{ (point mass)}$$

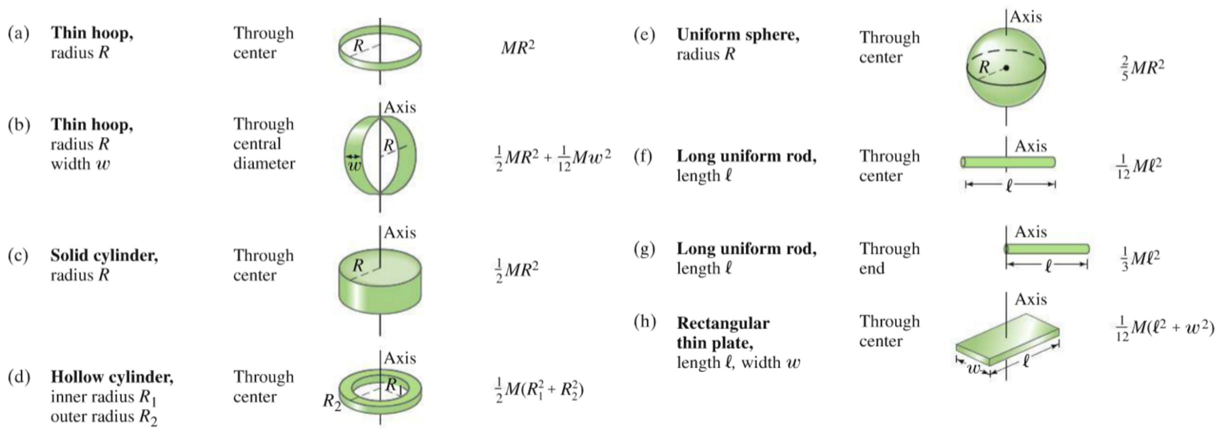

Figure 2: Moments of Inertia of Rigid Objects

- Fluids:

$$\rho_{H_2O} = 1000\frac{\text{kg}}{\text{m}^3}$$

$$P = \frac{F}{A}$$

$$P_f = \rho_f g D$$

$$B = \rho_f g V_{sub}$$

$$\frac{V_{sub}}{V_{obj}} = \frac{\rho_{obj}}{\rho_f}$$

$$A_1 v_1 = A_2 v_2$$

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

- Oscillations:

$$F_{sp} = -kx$$

$$U_{sp} = \frac{1}{2}kx^2$$

$$E = U_{max} = K_{max}$$

$$\omega = 2\pi f$$

$$\omega_{sp} = \sqrt{\frac{k}{m}}$$

$$\omega_{pend} = \sqrt{\frac{g}{l}}$$

- Waves & Sound:

$$v_{\text{sound}} = 350\text{m/s}$$

$$I_0 = 10^{-12}\frac{\text{W}}{\text{m}^2}$$

$$v = \lambda f$$

$$v = \sqrt{\frac{T}{m/L}} \;\; \text{(mechanical wave on a string)}$$

$$P \propto A^2 \;\; (\propto \text{ is “proportional to”})$$

$$\frac{I_1}{I_2} = \left(\frac{r_2}{r_1}\right)^2$$

$$\beta = (10\text{dB})\log\left(\frac{I}{I_0}\right)$$

$$\lambda_n = \frac{2L}{n},\; f_n = \frac{nv}{2L},\; n = 1, 2, 3, ... \;\; \text{(node-node)}$$

$$\lambda_n = \frac{4L}{n},\; f_n = \frac{nv}{4L},\; n = 1, 3, 5, ... \;\; \text{(node-antinode)}$$

$$f_{obs} = \frac{v \pm v_{obs}}{v \mp v_s} f_s \;\; \text{(”top is towards”)}$$

- Temperature & Heat:

$$k_B = 1.38 \times 10^{-23}\frac{\text{J}}{\text{K}}$$

$$N_A = 6.02 \times 10^{23}\;\frac{1}{\text{mol}}$$

$$R = 8.314\;\frac{\text{J}}{\text{mol K}}$$

$$\Delta l = l_0 \alpha \Delta T$$

$$PV = Nk_BT = nRT$$

$$Nk_B = nR$$

$$N = nN_A$$

$$K_{av} = \frac{3}{2}k_BT$$

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

- Thermodynamics:
  - Heat Transfer:

$$\sigma = 5.67 \times 10^{-8}\frac{\text{W}}{\text{m}^2\text{K}^4}$$

$$\frac{Q}{\Delta t} = kA\frac{\Delta T}{L} \;\; \text{(conduction)}$$

$$I = \epsilon \sigma T^4 \;\; \text{(radiation)}$$

- First Law of Thermodynamics:

$$\Delta U = Q + W$$

$$U = \frac{3}{2} N k_B T$$

$$W = -P\Delta V$$

- Second Law of Thermodynamics:

$$\Delta S_{tot} \geq 0$$

$$\Delta S \geq \frac{Q}{T} \text{ (constant } T)$$

- Heat Engines and Refrigerators

$$e = \frac{W}{Q_H}$$

$$e_{\text{Carnot}} = 1 - \frac{T_C}{T_H}$$

$$COP = \frac{Q_C}{W}$$

$$COP_{\text{Carnot}} = \frac{T_C}{T_H - T_C}$$

- Unit Conversions:

$$1 \ \frac{\text{km}}{\text{hr}} = 0.2778 \ \frac{\text{m}}{\text{s}}$$

$$1 \text{ rpm} = 0.1047 \ \frac{\text{rad}}{\text{s}}$$

$$1 \text{ atm} = 1 \times 10^5 \text{ Pa}$$

$$T_K = T_{^\circ C} + 273$$

$$T_{^\circ F} = \frac{9}{5} T_{^\circ C} + 32$$

$$1 \text{ cal} = 4.184 \text{ J}$$