Physics 51/53 Equivalency Exam
Equation Sheet

Kinematics

\[ \mathbf{v} = \mathbf{v}_0 + a t, \]
\[ \mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + \frac{1}{2} a t^2. \]
\[ v^2 = v_0^2 + 2a \cdot (r - r_0). \]
\[ a_r = \omega^2 r = \frac{v^2}{R}. \]
\[ \mathbf{v}_{PA} = \mathbf{v}_{PB} + \mathbf{v}_B/A. \]

Dynamics

\[ \mathbf{F}_{\text{grav}} = mg \]
\[ g_{\text{eff}} = g - a_0. \]
\[ F = -kx \]
\[ f_s \leq \mu_s N, \ f_k = \mu_k N \]

Potential Energy

\[ U(y) = mgy \]
\[ U(x) = \frac{1}{2} k x^2 \]

Rotational Motion

\[ \mathbf{v} = \omega \times \mathbf{r} \]
\[ a_r = -\omega^2 \mathbf{r} \]
\[ a_t = \alpha \times \mathbf{r} \]

Rigid Bodies

\[ K_{\text{rot}} = \frac{1}{2} I \omega^2 \]
\[ \tau = I \alpha \]
\[ L = I \omega \]
\[ v_{CM} = R \omega \]
\[ K = \frac{1}{2} m v_{CM}^2 + \frac{1}{2} I \omega^2 \]

Oscillations

\[ x(t) = A \cos(\omega t + \delta) \]
\[ E = \frac{1}{2} m \omega^2 A^2 \]
\[ \omega = \sqrt{k/m} \]

Gravity and Planetary Motion

Potential energy of point mass \( m \) at distance \( r \) from center of thin spherical shell of radius \( R \) and mass \( M \):

\[ U(r) = \begin{cases} 
-\frac{GMm}{r} & \text{for } r > R \\
-\frac{GMm}{R} & \text{for } r \leq R 
\end{cases} \]

Potential energy of spherically symmetric mass \( M \) and point mass \( m \), for distance \( r \) from the center of \( M \) greater than the radius of \( M \):

\[ U(r) = -\frac{GMm}{r} \]

Total energy of orbit for satellite of mass \( m \) around object of mass \( M \); semi-major axis of orbit is \( a \):

\[ E = -\frac{GMm}{2a} \]

Wave motion

\[ y(x, t) = A \cos(kx - \omega t + \delta) \]
\[ k = 2\pi/\lambda, \quad \omega = 2\pi f, \quad v = f\lambda = \omega/k \]
\[ \beta = 10 \log_{10}(I/I_0) \]
\[ I = 4I_0 \cos^2(\delta/2) = 2I_0(1 + \cos \delta) \]

Phase difference due to path difference only:

\[ \delta = k\Delta x \]

Doppler effect:

\[ f = f_0 \frac{v - v_R}{v - v_S} \quad \text{(source chasing receiver)} \]

Standing waves in string fixed at both ends:

\[ f_n = n f_1 = n(v/2L), \quad n = 1, 2, 3, \ldots \]
Thermal Physics

\[ dE_{\text{int}} = n c vdT \]

\[ PV' = \text{const.} \]

\[ \frac{\Delta L}{L} = \alpha \Delta T \]

\[ \frac{dQ}{dt} = -kA \frac{dT}{dx} \]

\[ Q_H / T_H = Q_C / T_C \]