PHYSICS 113: Contemporary Physics – Final Exam Formula Sheet

Not every equation here will actually be needed on the exam, and some may be needed more than once. Process of elimination is not a terribly good strategy.

Physical Constants:

$$c = 3 \times 10^8 m/s$$

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

$$h = 6.626 \times 10^{-34} Js$$

$$\hbar = 1.05 \times 10^{-34} Js$$

Units:

$$1N = kg\ m/s^2$$

$$1J = 1Nm = 1kg\ m^2/s^2$$

$$1W = 1J/s$$

$$1eV = 1.6 \times 10^{-19} J$$

A Handy Math relation:

$$(1+x)^n \simeq 1 + nx$$

Fundamental Physical Definitions:

$$\vec{v} = \frac{d\vec{r}}{dt}$$

$$\vec{a} = \frac{d\vec{v}}{dt}$$

Projectile Motion

$$\vec{r} = \vec{r}_0 + \vec{v}_0 t + \frac{1}{2}\vec{a}t^2$$

$$\vec{v} = \vec{v}_0 + \vec{a}t$$

From Newton's Laws (in relativity):

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

$$\vec{p} = \frac{m\vec{v}}{\sqrt{1 - v^2/c^2}}$$

$$\vec{v} = \frac{\vec{p}/m}{\sqrt{1 + (\frac{p}{mc})^2}}$$

$$\vec{F}_{net} = \frac{d\vec{p}}{dt}$$

For a single timestep:

$$\Delta\vec{p} = \vec{F}_{net}\Delta t$$

$$\begin{aligned} \Delta\vec{r} &= \vec{v}\Delta t \\ &= \frac{\vec{p}/m}{\sqrt{1 + (\frac{p}{mc})^2}}\Delta t \\ &\simeq \frac{\vec{p}}{m}\Delta t \end{aligned}$$

Springs:

$$F = -kx$$

Which has the solution:

$$x(t) = x_0 \cos(\omega_0 t)$$

where

$$\omega_0 = \sqrt{k/m}$$

Young's Modulus:

$$\frac{F}{A} = Y \times \frac{\Delta L}{L}$$

Pendulums:

$$\omega_0 = \sqrt{g/l}$$

The Force of Gravity:

$$\vec{F}_{1,g} = \frac{Gm_1 m_2}{r^2}\hat{r}_{12}$$

Near the surface of the earth:

$$\vec{F}_g = -mg\hat{j}$$

Properties of a circular orbit:

$$\vec{a}_c = -\frac{v^2}{r}\hat{r}$$

$$v = \sqrt{\frac{GM}{r}}$$

Work:

$$W = \vec{F} \cdot \Delta\vec{r}$$

$$W_{ext} = \Delta E$$

$$P = \frac{W}{\Delta t} = \vec{F} \cdot \vec{v}$$

Energy:

$$\frac{dE}{dt} = \vec{v} \cdot \frac{d\vec{p}}{dt}$$

$$E = \frac{mc^2}{\sqrt{1 - v^2/c^2}}$$

$$E = mc^2 + K + U$$

$$E^2 = (mc^2)^2 + (pc)^2$$

$$K = mc^2(\gamma - 1)$$

$$K \simeq \frac{p^2}{2m}$$

Potential Energy:

$$\frac{dU}{dx} = -F_x$$

For a Mass on a Spring:

$$U_s = \frac{1}{2}kx^2$$

Gravitational Potential Energy:

$$U_g = -\frac{Gm_1m_2}{r}$$

Near the Surface of the earth:

$$U_g = mgy$$

Special Relativity:

$$\begin{aligned}
\Delta x' &= \gamma \Delta x - v\gamma \Delta t \\
\Delta t' &= \gamma \Delta t - \frac{v}{c^2}\gamma \Delta x \\
u' &= \frac{u - v}{1 - \frac{uv}{c^2}} \\
\Delta x &= \gamma \Delta x' + v\gamma \Delta t' \\
\Delta t &= \gamma \Delta t' + \frac{v}{c^2}\gamma \Delta x' \\
u &= \frac{u' + v}{1 + \frac{u'v}{c^2}}
\end{aligned}$$

Heat and Friction

Contact Friction:

$$F_r = \mu F_N$$

Viscous Friction:

$$F_v = -bv$$

Air Resistance

$$F_a = -\frac{1}{2}C\rho A v^2$$

$$v_t = \sqrt{\frac{2mg}{C\rho A}}$$

$$\Delta E = Q + W$$

$$Q = \Delta E_{thermal} = mC\Delta T$$

Quantized Energy:

$$E_\gamma = E_u - E_l = h\nu$$

Hydrogen:

$$E_n = -\frac{13.6eV}{n^2}$$

QHO:

$$E_n = (n + 1/2)\hbar\omega$$

Wave, Photons and Quantum Mechanics:

$$c = \lambda\nu$$

$$k \equiv \frac{2\pi}{\lambda}$$

$$p = \frac{h\nu}{c} = \frac{\hbar}{\lambda}$$

$$P(x)dx = |\psi(x)|^2 dx$$

Center of Mass:

$$\vec{r}_{com} = \frac{\sum_i m_i \vec{r}_i}{M_{tot}}$$

$$\vec{v}_{com} = \frac{\sum_i m_i \vec{v}_i}{M_{tot}}$$

$$\vec{P}_{tot} = M_{tot}\vec{v}_{com}$$

$$I = \sum_i m_i r_i^2$$

$$I_{disk} = \frac{1}{2}MR^2$$

$$I_{sphere} = \frac{2}{5}MR^2$$

$$E_{rot} = \frac{1}{2} I \omega^2$$

Collisions:

1-d elastic:

$$p_3 = p_1 \left(\frac{m_1 - m_2}{m_1 + m_2} \right) + p_2 \left(\frac{2m_1}{m_1 + m_2} \right)$$
$$p_4 = p_1 \left(\frac{2m_2}{m_1 + m_2} \right) + p_2 \left(\frac{m_2 - m_1}{m_2 + m_1} \right)$$

2-d elastic (ϕ is the scatter angle of the second particle which is initially stationary):

$$\cos\theta = \frac{m_1 + m_2 - 2m_2 \cos^2\phi}{\sqrt{m_1^2 + m_2^2 + 2m_1 m_2 - 4m_1 m_2 \cos^2\phi}}$$