Physics Equations

1 Mechanics

1.1 Dimensional motion

$$\vec{v} = \vec{v}_o + \vec{a}t$$
$$x = x_o + \frac{1}{2}(\vec{v} + \vec{v}_o)t$$
$$x = x_o + \vec{v}_o t + \frac{1}{2}\vec{a}t^2$$
$$x = x_o + \vec{v}t - \frac{1}{2}\vec{a}t^2$$
$$\vec{v}^2 = \vec{v}_o^2 + 2\vec{a}(x - x_o)$$
$$\vec{r}_{AB} = \vec{r}_A - \vec{r}_B$$

x : Distance, m
x_o : Initial distance, starting point, m
$\vec{v}$: Velocity, ms^{-1}
$\vec{v}_o$: Initial velocity, ms^{-1}
t : Time, s
$\vec{a}$: Acceleration, ms^{-2}
$\vec{r}_{AB}$: Position of $\vec{A}$ relative to $\vec{B}$
$\vec{r}_V$: Position of $\vec{V}$ realtive to origin

1.2 Conversions

$km \cdot h^{-1} \longrightarrow m \cdot s^{-1}$
Multiply by $^5/_{18}$

$m \cdot s^{-1} \longrightarrow km \cdot h^{-1}$
Multiply by $^{18}/_5$

1.3 Projectile motion

$$v_y = v_{y_o} - gt$$
$$x = x_o + v_{x_o}t$$
$$y = y_o + v_{y_o}t - \frac{1}{2}gt^2$$
$$y = x\tan\theta - \frac{g}{2}\left(\frac{x}{v_o\cos\theta}\right)^2$$
$$y_{max} = \frac{v_o^2\sin^2\theta}{2g}$$
$$x_{max} = \frac{v_o^2\sin 2\theta}{g}$$
$$t_{max} = \frac{2v_o\sin\theta}{g}$$

y : Graph of the trajectory
t : Time
y_{max} : Maximum y-coord reached by projectile
x_{max} : Maximum x-coord reached by projectile
t_{max} : Time for which projectile airborne

1.4 Circular motion

$$\vec{a}_c = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$$
$$T = \frac{2\pi r}{v} = \frac{1}{f}$$

$\vec{a}_c$: Cetripetal acceleration
T : Period of uniform circular motion
f : Frequency, number of revolutions per unit time
r : Radius of circle

2 Forces

$$\vec{P} = m\vec{v}$$
$$\vec{F} = m\vec{a}$$
$$\vec{F}_g = m\vec{g}$$
$$\vec{F}_{sp} = -kx$$
$$\Delta\vec{P} = \vec{F}\Delta t = m\Delta\vec{v} = J$$

$\vec{F}$: Force, $N = kg \cdot ms^{-1}$
$\vec{F}_g$: Gravitational force, $kg \cdot m^2 s^{-2}$
m : Mass, kg
$\vec{g}$: Gravity, $-9.81 \cdot kg \cdot ms^{-2}$
$\vec{F}_{sp}$: Spring force, N
k : Spring constant, $Nm^{-1} = kg \cdot m^{-2} s^{-2}$
$\vec{P}$: Momentum, $kg \cdot ms^{-1}$
J : Impulse

2.1 Friction

$$f_s \leqslant \mu_s \vec{F}_N$$
$$f_k = \mu_k \vec{F}_N$$

f_i : Force of static ($i = s$) or kinetic ($i = k$) friction
μ_i : Coefficient of static ($i = s$) or kinetic ($i = k$) friction
$\vec{F}_N$: Normal force

3 Energy

$$E_k = \frac{1}{2}mv^2$$
$$E_{GP} = mg\Delta h$$
$$E_{EP} = \frac{1}{2}kx^2$$

E_k : Kinetic energy
E_{GP} : Gravitational potential energy
E_{EP} : Elastic potential energy

3.1 Work and Power

$$\vec{A} \bullet \vec{B} = \cos\theta |A||B| = \vec{A}_x \vec{B}_x + \vec{A}_y \vec{B}_y$$
$$W = \vec{F} \bullet \Delta\vec{r}$$
$$W = \int_{x_1}^{x_2} f(x)dx$$
$$W = \int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \bullet \Delta\vec{r} \qquad \text{(line integral)}$$
$$\Delta E_k = W_{net}$$
$$P = \frac{\Delta W}{\Delta t}$$
$$P = \vec{F} \bullet \vec{v}$$
$$\Delta E_{GP_{ab}} = -\int_a^b \vec{F} \bullet \Delta\vec{r}$$

$\vec{A} \bullet \vec{B}$: Dot product of vectors $\vec{A}$ and $\vec{B}$
$|A|$: Magnitude, length of vector $\vec{A}$
$\vec{A}_x$: x-parameter of vector $\vec{A}$
W : Work, $J = kg \cdot m^2 s^{-1}$
P : Power, $W = kg \cdot m^2 s^{-2}$

3.2 Torque

$$\tau = r\vec{F}\sin\theta$$
$$\vec{\tau} = \vec{r} \times \vec{F}$$
$$\tau = I\alpha$$

τ : Torque, Nm
I : Rotational inertia
α : Angular acceleration

3.3 Gravity

$$F = \frac{GMm}{r^2}$$
$$v_{orb} = \sqrt{\frac{GM}{r}} \qquad \text{(circular orbit)}$$
$$T^2 = \frac{4\pi^2 r^3}{GM} \qquad \text{(circular orbit)}$$
$$\Delta E_{GP} = GMm\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$
$$v_{esc} = \sqrt{\frac{2GM}{r}}$$
$$g_f = -\frac{GM}{r^2}$$

G : Universal gravitational constant
M : Larger mass (being orbited)
m : Smaller mass (in orbit)
r : Distance form M to m
v_{orb} : Orbital speed
v_{esc} : Escape velocity
g_f : Gravitational field

4 Systems of Particles

$$\vec{r}_{cm} = \frac{\sum m_i \vec{r}_i}{M}$$
$$x_{cm} = \frac{m_1 x_1 + m_2 x_2 + \ldots m_i x_i}{m_1 + m_2 + \ldots m_i}$$
$$E_{k_{sys}} = E_{k_{cm}} + E_{k_{int}}$$

$\vec{r}_{cm}$: Vector position of center of mass
x_{cm} : Coordinate position of center of mass
m_i : ith particle composing larger mass M

5 Rotational Motion

$$v = \omega r$$
$$a_t = \alpha r$$
$$a_r = \omega^2 r$$
$$E_k = \frac{1}{2} I \omega^2$$
$$I = \sum m_i r_i^2 = \int r^2 dm$$
$$\vec{L} = I\omega = \vec{r} \times \vec{p}$$

ω : Angular velocity
r : Radius of object
a_r : Radial acceleration
a_t : Tangential acceleration
I : Rotational inertia
$\vec{L}$: Angular momentum

Linear	Angular
x	θ
$v = \frac{dx}{dt}$	$\omega = \frac{d\theta}{dt}$
$a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$	$\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$
$v = v_o + at$	$\omega = \omega_o + \alpha t$
$x = x_o + v_o t + \frac{1}{2}at^2$	$\theta = \theta_o + \omega_o t + \frac{1}{2}\alpha t^2$
$v^2 = v_0^2 + 2ax$	$\omega^2 = \omega_o^2 + 2\alpha\theta$

6 Miscellaneous

Unit	Area under
Distance	Velocity v Time
Impulse	Force v Time

$$J = \Delta p = F\Delta t = m\Delta v$$