Classical Mechanics

Translation
The motion of objects as a whole

Kinematics

Laws: none

Definitions:

Position $\vec{r}$

Displacement $d\vec{r}$

Velocity $\vec{v} \equiv \frac{d\vec{r}}{dt}$

Acceleration $\vec{a} \equiv \frac{d\vec{v}}{dt}$

Useful Relations:

Kinematic Equations

$x = x_o + v_o t + \frac{1}{2} a t^2$

$v = v_o + at$

$v^2 = v_o^2 + 2a(x - x_o)$

$x - x_o = \frac{1}{2}(v + v_o)t$

Tangential Velocity $v_t = \frac{2\pi r}{T}$

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

SHM Equations of Motion

$x = A\cos(\omega t + \delta)$

$v = -\omega A \sin(\omega t + \delta)$

$a = -\omega^2 A \cos(\omega t + \delta)$

$v^2 = \omega^2 (A^2 - x^2)$

$a = -\omega^2 x$

Force

Laws:

Newton's Laws

1. Law of Inertia
2. $\Sigma \vec{F} = m\vec{a}$
3. Action/Reaction

Definitions:

Coefficient of Friction $\mu \equiv \frac{F_{fr}}{F_n}$

Useful Relations:

Mass/weight Rule $F_g = mg$

Air Resistance $F_d = bv$

Hooke's Rule $F_s = kx$

Law of Gravitation $F_g = G\frac{m_1 m_2}{r^2}$

Terminal Speed $v_t = \frac{mg}{b}$

Spring $\omega = \sqrt{\frac{k}{m}}$

Simple Pendulum $\omega = \sqrt{\frac{g}{l}}$

Physical Pendulum $\omega = \sqrt{\frac{mgr}{I_p}}$

Torsional Pendulum $\omega = \sqrt{\frac{\kappa}{I_p}}$

Momentum

Laws:

Conservation of Linear Momentum

Definitions:

Linear Momentum $\vec{p} \equiv m\vec{v}$

Impulse $\vec{J} \equiv \int_0^t \vec{F} dt$

Center of Mass $\vec{r}_{cm} \equiv \frac{1}{M}\int \vec{r} dm$

Useful Relations:

Original 2nd Law $\Sigma \vec{F} = \frac{d\vec{p}}{dt}$

Impulse/Momentum Theorem $\Delta \vec{p} = \vec{J}$

Energy

Laws:

Conservation of Energy $\Delta K + \Delta U = W_{nc}$

Definitions:

Work $W \equiv \int \vec{F} \bullet d\vec{s}$

Power $P \equiv \frac{dW}{dt}$

Kinetic Energy $K \equiv \frac{1}{2} m v^2$

Potential Energy $\Delta U \equiv -W_c$

Useful Relations:

Work-Energy Theorem $W_{net} = \Delta K$

Gravitational Potential Energy $U_g = mgy$ or $U_g = -G\frac{m_1 m_2}{r}$

Spring Potential Energy $U_s = \frac{1}{2} k x^2$

Rotation
The spinning motion of objects

Kinematics

Laws:

none

Definitions:

Angle θ

Angular Disp. dθ

Angular Velocity $\omega \equiv \frac{d\theta}{dt}$

Angular Acc $\alpha \equiv \frac{d\omega}{dt}$

Useful Relations:

Kinematic Equations (same)

Angular/Linear Rules

$s = r\theta$

$v_t = r\omega$

$a_t = r\alpha$

$a_c = \omega^2 r$

Torque

Laws:

1. Law of Rotational Inertia
2. $\Sigma \vec{\tau} = I\vec{\alpha}$
3. Action/Reaction

Definitions:

Torque $\vec{\tau} \equiv \vec{r} \times \vec{F}$

Rotational Inertia $I \equiv \int r^2 dm$

Useful Relations:

Rotational Inertia (about cm)

hoop mr^2

disk $\frac{1}{2} mr^2$

solid sphere $\frac{2}{5} mr^2$

hollow sphere $\frac{2}{3} mr^2$

rod $\frac{1}{12} m\ell^2$

rectangular plate $\frac{1}{12} m(a^2 + b^2)$

Angular Momentum

Laws:

Conservation of Angular Momentum

Definitions:

Angular Momentum $\vec{L} \equiv \vec{r} \times \vec{p}$

Useful Relations:

Angular Momentum Distributed Object $\vec{L} = I\vec{\omega}$

Second Law for Rotation $\Sigma \vec{\tau} = \frac{d\vec{L}}{dt}$

Energy

Laws:

Conservation of Energy (include rotational kinetic) $\Delta K + \Delta U = W_{nc}$

Useful Relations:

Rotational Kinetic Energy $K = \frac{1}{2} I\omega^2$

Dot Product

$\vec{A} \bullet \vec{B} \equiv AB\cos\theta = A_x B_x + A_y B_y + A_z B_z$

Cross Product $\vec{A} \times \vec{B} \equiv AB\sin\theta \hat{n}$

$\vec{A} \times \vec{B} = (A_y B_z - A_z B_y)\hat{i} + (A_z B_x - A_x B_z)\hat{j} + (A_x B_y - A_y B_x)\hat{k}$

Acceleration due to gravity

$g = 9.80$ m/s^2

$G = 6.67 x 10^{-11} \frac{N \cdot m^2}{kg^2}$

Moon - mass: 7.36×10^{22} kg

radius: 1.74×10^6 m

Earth - mass: 5.98×10^{24} kg

radius: 6.38×10^6 m

Earth - moon distance: 3.82×10^8 m

Sun - mass: 1.99×10^{30} kg

radius: 6.96×10^8 m

Sun - Earth distance: 1.50×10^{11} m