# 1 Kinematics

### Scalar Product

$$\vec{A} \cdot \vec{B} = AB\cos\theta$$
$$\vec{A} \cdot \vec{B} = A_xB_x + A_yB_y + A_zB_z$$

### Cross Product

$$\vec{A} \times \vec{B} = -\vec{B} \times \vec{A} = AB\sin\theta$$
$$\vec{A} \times \vec{B} = (A_yB_z - A_zB_y)\,\hat{\imath} + (A_zB_x - A_xB_z)\,\hat{\jmath} + (A_xB_y - A_yB_x)\,\hat{k}$$

Use right hand rule (point fingers along the first vector, curl hand in towards next vector).

### 1D/2D Kinematics

$$v_i = v_o + at$$
$$\Delta x = v_o t + \tfrac{1}{2}at^2$$
$$v_f^2 = v_o^2 + 2a\Delta x$$
$$\Delta x = \tfrac{1}{2}t\,(v_o + v_i)$$

#### Projectile Motion

$$t = \frac{2v_o\sin\theta}{-g}$$
$$\Delta x = \frac{v_o^2\sin(2\theta)}{-g} = \frac{2v_o^2\sin\theta\cos\theta}{-g}$$

### Relative Motion

$$v_{pw} = v_{pg} + v_{gw}$$

**DRAW VECTOR DIAGRAMS**

# 2 Newton's Laws of Motion

$$\vec{F} = m\vec{a}$$
$$F_g = mg = weight$$
$$F_g = \frac{GMm}{r^2}$$
$$g = \frac{GM}{r^2} = \frac{F_g}{m}$$
$$F_N = mg \quad \text{(horizontal surface)}$$
$$F_N = mg\cos\theta \quad \text{(angled surface)}$$
$$F_{f_s} = \mu_s F_N$$
$$F_{f_k} = \mu_k F_N$$
$$\mu_k < \mu_s \quad \text{(always)}$$
$$F_c = ma_c = \frac{mv^2}{r} = mr\omega^2$$
$$F_{drag} = \tfrac{1}{2}C\rho Av^2$$
$$\tan\theta = \frac{v^2}{rg} \quad \text{(banked curve)}$$
$$F_c = mg\tan\theta = F_{Nx} \quad \text{(banked curve)}$$

**FREE-BODY DIAGRAMS ONLY INCLUDE EXTERNAL FORCES**

# 3 Work Power Energy

### Energy

$$E_k = \tfrac{1}{2}mv^2 = \frac{p^2}{2m}$$
$$E_{pg} = mgh = \frac{-GMm}{r}$$
$$E_{ps} = \tfrac{1}{2}k\,(\Delta x)^2$$

### Work

$$\Delta\sum E = \Delta E_k + \Delta E_p = W$$
$$= Fd\cos\theta \quad \text{(Force parallel to direction of motion)}$$

### Power

$$P = \frac{W}{t} = Fv$$
$$h_{min} = \frac{5r}{2} \quad \text{(rollercoaster loop)}$$

# 4 Linear Momentum/Collisions

### Momentum

$$p = mv$$

### Impulse

$$J = \Delta p = Ft$$

### Conservation of Momentum

$$p_i = p_f$$
$$p_{i_x} = p_{f_x}$$
$$p_{i_y} = p_{f_y}$$

### Centre of Mass

$$R_{cm} = \frac{1}{M}\left(\sum r\right)$$
$$V_{cm} = \frac{1}{M}\left(\sum mv\right) = \frac{1}{M}\left(\sum p\right)$$
$$a_{cm} = \frac{1}{M}\left(\sum ma\right) = \frac{1}{M}\left(\sum F\right)$$

**LINEAR MOMENTUM MUST BE CONSERVED IN AT LEAST ONE DIRECTION**

# 5 Rotational Motion

## Rotational Kinematics

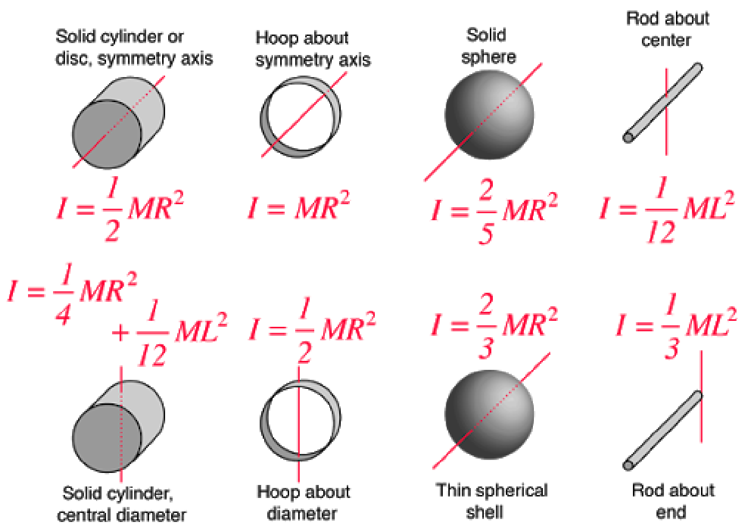
$$\begin{aligned}
r\theta &= s_t \\
r\omega &= v_t \\
r\alpha &= a_t \\
\theta_f &= \theta_i + \omega t \\
\omega_f &= \omega_i + \alpha t \\
\Delta\theta &= \omega_i t + \tfrac{1}{2}\alpha t^2 \\
\omega_f^2 &= \omega_i^2 + 2\alpha\Delta\theta
\end{aligned}$$

## Rotational Work Power Energy

$$\begin{aligned}
E_k &= \tfrac{1}{2} I\omega^2 \\
\tau &= I\alpha \\
\tau &= Fd_| = rF\sin\theta \\
W_\tau &= \Delta E_k = \tau\theta \\
P &= \tau\omega
\end{aligned}$$

## Inertia

$I$ changes depending on the system.




# 6 Angular Momentum

## Centre of Mass

$$\begin{aligned}
V_{cm} &= R\omega \\
a_{cm} &= R\alpha \\
d_{cm} &= R\theta \\
L &= I\omega \\
L &= mvr \quad \text{(for point object)} \\
\Delta L &= \tau\Delta t \\
T &= \frac{2\pi}{\omega} = \frac{1}{f}
\end{aligned}$$

**ANGULAR MOMENTUM MUST BE CONSERVED**

# Terms/Definitions

# Constants

# Conversions

# Orders of Magnitude

# Trigonometry

# Calculus