

# 1 Kinematics

## Scalar Product

$$\vec{A} \cdot \vec{B} = AB \cos \theta$$

$$\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$$

## Cross Product

$$\vec{A} \times \vec{B} = -\vec{B} \times \vec{A} = AB \sin \theta$$

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

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

## 1D/2D Kinematics

$$v_i = v_o + at$$

$$\Delta x = v_o t + \frac{1}{2} at^2$$

$$v_f^2 = v_o^2 + 2a\Delta x$$

$$\Delta x = \frac{1}{2} t (v_o + v_i)$$

## 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

$$\vec{F} = m\vec{a}$$

$$F_g = mg = \text{weight}$$

$$F_g = \frac{GMm}{r^2}$$

$$g = \frac{GM}{r^2} = \frac{F_g}{m}$$

$$F_N = mg \quad (\text{horizontal surface})$$

$$F_N = mg \cos \theta \quad (\text{angled surface})$$

$$F_{fs} = \mu_s F_N$$

$$F_{fk} = \mu_k F_N$$

$$\mu_k < \mu_s \quad (\text{always})$$

$$F_c = ma_c = \frac{mv^2}{r} = mr\omega^2$$

$$F_{drag} = \frac{1}{2} C \rho A v^2$$

$$\tan \theta = \frac{v^2}{rg} \quad (\text{banked curve})$$

$$F_c = mg \tan \theta = F_{Nx} \quad (\text{banked curve})$$

## FREE-BODY DIAGRAMS ONLY INCLUDE EXTERNAL FORCES

# 3 Work Power Energy

## Energy

$$E_k = \frac{1}{2} mv^2 = \frac{p^2}{2m}$$

$$E_{pg} = mgh = \frac{-GMm}{r}$$

$$E_{ps} = \frac{1}{2} k (\Delta x)^2$$

## 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

$$p_i = p_f$$

$$p_{ix} = p_{fx}$$

$$p_{iy} = p_{fy}$$

## Centre of Mass

$$R_{cm} = \frac{1}{M} (\sum r)$$

$$V_{cm} = \frac{1}{M} (\sum mv) = \frac{1}{M} (\sum p)$$

$$a_{cm} = \frac{1}{M} (\sum ma) = \frac{1}{M} (\sum F)$$

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

## 5 Rotational Motion

### Rotational Kinematics

$$r\theta = s_t$$

$$r\omega = v_t$$

$$r\alpha = a_t$$

$$\theta_f = \theta_i + \omega t$$

$$\omega_f = \omega_i + \alpha t$$

$$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$$

$$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$$

### Rotational Work Power Energy

$$E_k = \frac{1}{2}I\omega^2$$

$$\tau = I\alpha$$

$$\tau = Fd_{\perp} = rF\sin\theta$$

$$W_{\tau} = \Delta E_k = \tau\theta$$

$$P = \tau\omega$$

### Inertia

$I$  changes depending on the system.

## 6 Angular Momentum

### Centre of Mass

$$V_{cm} = R\omega$$

$$a_{cm} = R\alpha$$

$$d_{cm} = R\theta$$

$$L = I\omega$$

$$L = mvr \quad (\text{for point object})$$

$$\Delta L = \tau\Delta t$$

$$T = \frac{2\pi}{\omega} = \frac{1}{f}$$

### ANGULAR MOMENTUM MUST BE CONSERVED

#### A Terms/Definitions

#### B Constants

#### C Conversions

#### D Orders of Magnitude

#### E Trigonometry

#### F Calculus