Formula Sheet for Physics 131

General Kinematics Definitions

Δ always signifies the change in a quantity, i.e the difference between the final and the initial value; e.g. time interval $\Delta t = t_f - t_i$ and displacement $\Delta\vec{r} = \vec{r}_f - \vec{r}_i$

average speed = distance traveled / time interval spent traveling

average velocity $\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t}$ instantaneous velocity $\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt}$

instantaneous speed is the magnitude of the instantaneous velocity

average acceleration $\vec{a}_{avg} = \frac{\Delta\vec{v}}{\Delta t}$ instantaneous acceleration $\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta\vec{v}}{\Delta t} = \frac{d\vec{v}}{dt}$

Motion in a straight line

The direction of motion is generically called s; it can be replaced with x or y when appropriate.

instantaneous velocity: $v_s = \frac{ds}{dt}$ = slope of position vs time graph

instantaneous acceleration: $a_s = \frac{dv_s}{dt}$ = slope of velocity vs time graph

final position $s_f = s_i + \int_{t_i}^{t_f} v_s dt = s_i +$ area under the velocity curve from t_i to t_f

final velocity $v_{fs} = v_{is} + \int_{t_i}^{t_f} a_s dt = v_{is} +$ area under the velocity curve from t_i to t_f

Equations for **constant acceleration** in one dimension:

$$v_{fs} = v_{is} + a_s\Delta t \qquad s_f = s_i + v_{is}\Delta t + \frac{1}{2}a_s(\Delta t)^2 \qquad v_{fs}^2 = v_{is}^2 + 2a_s\Delta s$$

magnitude of the **acceleration due to gravity at Earth's surface:** $g = 9.8 m/s^2$

Dynamics

Newton's Second Law: $\sum \vec{F} = m\vec{a}$

Newton's Third Law: $\vec{F}_{\text{A on B}} = -\vec{F}_{\text{B on A}}$

force of **gravity** on earth's surface: $|\vec{F}_g| = mg$, $g = 9.8\frac{m}{s^2}$, $|\vec{F}_g|$ is also called weight

Friction: static friction: $f_{s,max} = \mu_s \cdot n$, kinetic friction: $f_k = \mu_k \cdot n$

uniform circular motion - centripetal acceleration: $a = \frac{v^2}{r}$

angular position $\theta = \frac{s}{r}$, measured in *radians* angular velocity $\omega = \frac{d\theta}{dt}$ $v_t = \omega r$

angular acceleration $\alpha = \frac{d\omega}{dt}$ $a_t = r\alpha$

period: $T = \frac{2\pi r}{v} = \frac{2\pi}{\omega}$

Non-uniform circular motion: $\theta_f = \theta_i + \omega_i \Delta t + \frac{1}{2}\alpha(\Delta t)^2 \qquad \omega_f = \omega_i + \alpha \Delta t$

impulse $\vec{J} = \int_{t_i}^{t_f} \vec{F} dt$

momentum $\vec{p} = m\vec{v}$ impulse - momentum theorem: $\vec{J} = \Delta\vec{p}$

kinetic energy $K = \frac{1}{2}mv^2$ gravitational potential energy $U_g = mgy$

elastic potential energy $U_s = \frac{1}{2}k(\Delta s)^2$ Hooke's Law $(F_{sp})_s = -k\Delta s$

perfectly elastic collision, ball 2 initially at rest: $(v_{fx})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{ix})_1$ $(v_{fx})_2 = \frac{2m_1}{m_1 + m_2)}(v_{ix})_1$

work: $W = \int_{s_i}^{s_f} F_s ds$, for a constant force $W = \vec{F} \cdot \Delta\vec{r}$

work - kinetic energy theorem: $\Delta K = W_{net} = W_c + W_{diss} + W_{ext}$

$\Delta E_{th} = -W_{diss}$

energy equation: $\Delta K + \Delta U + \Delta E_{th} = \Delta E_{sys} = W_{ext}$

power $P = \frac{dE_{sys}}{dt}$

Gravitational force between two masses: $F = G\frac{m\,M}{r^2}$, $G = 6.67 \cdot 10^{-11} \frac{Nm^2}{kg^2}$

gravitational potential energy (general form): $U_g = -\frac{GmM}{r}$

location of the center of mass (CM): $x_{cm} = \frac{m_1x_1 + m_2x_2 + \ldots m_nx_n}{m_1 + m_2 + \ldots m_n}$

torque $\tau = rF\sin\phi$

Newton's Second Law for rotational motion: $\alpha = \frac{\tau}{I}$

Geometry: area of a circle of radius r: $A = \pi r^2$ circumference of a circle of radius r: $C = 2\pi r$

surface area of a sphere of radius r: $S = 4\pi r^2$ volume of a sphere of radius r: $V = \frac{4}{3}\pi r^3$

Quadratic equation: $ax^2 + bx + c = 0$, $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Unit vectors: $\hat{i}$ in x-direction $\hat{j}$ in y-direction $\hat{k}$ in z-direction

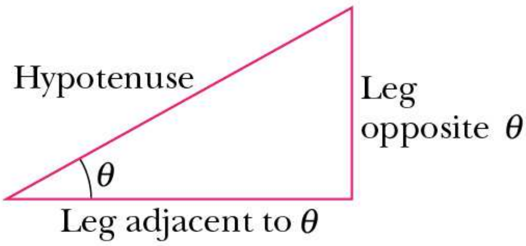
Dot Product (or Scalar Product) of two vectors: $\vec{a} \cdot \vec{b} = a_xb_x + a_yb_y + a_zb_z = ab\cos\theta$, θ angle between the two vectors

Trig and right triangle:

$$\sin \theta = \frac{\text{leg opposite } \theta}{\text{hypotenuse}}$$

$$\cos \theta = \frac{\text{leg adjacent to } \theta}{\text{hypotenuse}}$$

$$\tan \theta = \frac{\text{leg opposite } \theta}{\text{leg adjacent to } \theta}$$



Theorem of **Pythagoras**: $(\text{leg adjacent})^2 + (\text{leg opposite})^2 = (\text{hypotenuse})^2$

physical quantity	symbol	SI unit	abbreviation for unit
displacement, distance	$\vec{r}, x, y, ...$	meter	m
velocity	$\vec{v}$, v_s	meter/second	$\frac{m}{s}$
acceleration	$\vec{a}, a_s$	meter/second/second	$\frac{m}{s^2}$
mass	m	kilogram	kg
force	F	Newton	$N = \frac{kgm}{s^2}$
angular displacement	θ	radians	rad
angular velocity	ω "omega"	radians/second	$\frac{rad}{s}$
angular acceleration	α "alpha"	radians/ second /second	$\frac{rad}{s^2}$
momentum	p	kilogram meter/second	$kg\frac{m}{s}$
energy, work	E, U, K, W	Joule	$J = Nm$
power	P	Watt	$W = \frac{J}{s}$