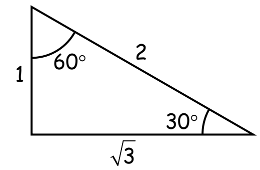
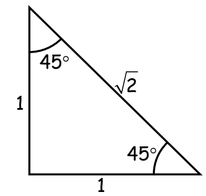
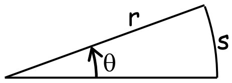
Essential Physics Knowledge ... a work in progress!

STUFF EVERY PHYSICIST SHOULD KNOW.





Basics

$s = r\theta$ 

$v = \frac{ds}{dt}$ $a = \frac{dv}{dt}$

- derivatives give v, ω, a, α and their relationships.

Trigonometry: $\sin^2\theta + \cos^2\theta = 1$, $\sin(90 - \theta) = \cos\theta$ (Unit Circle)

Notation: $\dot{y} = \frac{dy}{dt}$ and $y'(x) = \frac{dy}{dx}$

Wavelength and Wave Number: $k = \frac{2\pi}{\lambda}$

Magnitude of a complex number: |z| = z*z where z* is the complex conjugate of z

$\left|e^{i\phi}\right| = 1$

Vector dot product multiplies parallel components $\vec{a}\cdot\vec{b} = ab\cos\theta$ (scaler product)

Vector cross product multiplies perpendicular components $\left|\vec{a}\times\vec{b}\right| = ab\sin\theta$, dir. by RHR (vector product)

Momentum

Momentum: $\vec{p} = m\vec{v}$

De Broglie: $p = \frac{h}{\lambda} = \hbar k$

Angular Momentum: $\vec{L} = \vec{r}\times\vec{p} = rp\sin(\theta)$

- For r perpendicular to p (circular motion) $L = rp = r(mv) = mr(r\omega) = mr^2\omega \to I\omega$

Energy

Work: W = (force)(distance in direction of force), $W_{s_1 \text{ to } s_2} = \int_{s_1}^{s_2} \vec{F}\cdot d\vec{s}$

Kinetic Energy: $T = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

Potential Energy: $U_{s1 \text{ to } s2} = -W_{s1 \text{ to } s2}$ for conservative forces (W independent of path)

$$U_{s_1 \text{ to } s_2} = -\int_{s_1}^{s_2} \vec{F}_{conservative}\cdot d\vec{s} \quad \Rightarrow \quad \vec{F} = -\nabla U$$

$$U_G = \frac{GMm}{r} = mgh, \quad U_{Spring} = \frac{1}{2}kx^2, \quad U_E = \frac{kQq}{r} = \frac{Qq}{4\pi\epsilon_0 r}$$

Mechanical Energy: E = T + U

Work-Energy Theorem:

First form: $W_{total} = \Delta T$

Second form: $W_{non\text{-}conservative} = \Delta T + \Delta U$ or $T_{init} + U_{init} - W_{NC} = T_{final} + U_{final}$

Mechanics

Newton's Laws

1. Stuff coasts (it takes a force to change velocity magnitude or direction)
2. $\sum \vec{F}_{External} = m\vec{a}$ or $\Sigma\vec{\tau}_{External} = I\vec{\alpha}$

   ⇒ apply to each body in each coordinate direction using FBDs

   In static equilibrium the sums of the forces and torques are zero
3. Stuff pushes back (forces act on two bodies equally in opposite directions)

   - a normal force acts on *both bodies* in opposite directions
   - a frictional force acts on *both surfaces* in opposite directions

Forces

$F_{Gravity} = \dfrac{GMm}{r^2}$, Weight = $F_{Earth's\ Surface} = m\left(\dfrac{GM_{Earth}}{R^2_{Earth}}\right) = mg$

For two charges: $F_E = \dfrac{kQq}{r^2} = \dfrac{Qq}{4\pi\epsilon_0 r^2}$, Force on a charge in a uniform field: $F_{E\ Field} = qE$

$F_{Spring} = -kx$ (opposes displacement from equilibrium)

Friction

Static (surfaces not moving) $f_s \le \mu_S N$

Kinetic (surfaces in relative motion) $f_k = \mu_k N$

Normal Force: A reactive force between surfaces that resists deformation

Tension: A reactive force of a string that redirects force (no stretching or compression)

Kinematics (only when $\vec{a}_0 = \text{constant}$)

$v(t) = v_0 + a_0 t$ no x

$x(t) = x_0 + v_0 t + \frac{1}{2}a_0 t^2$ no v

} Derived from $\vec{a}_0 = \dfrac{d\vec{v}}{dt}$ and $\vec{v} = \dfrac{d\vec{x}}{dt}$

$v^2 = v_0^2 + 2a_0(x - x_0)$ no t

$x = x_0 + \left(\dfrac{v + v_0}{2}\right)t$ no a

} Derived from first two equations by eliminating t or a

For circular motion, $s = r\theta$, $v = r\omega$, $a = r\alpha$

$\omega(t) = \omega_0 + \alpha_0 t$ no θ

$\theta(t) = \theta_0 + \omega_0 t + \frac{1}{2}\alpha_0 t^2$ no ω

$\omega^2 = \omega_0^2 + 2\alpha_0(\theta - \theta_0)$ no t

$\theta = \theta_0 + \left(\dfrac{\omega + \omega_0}{2}\right)t$ no α

$$a_{centripetal} = \frac{v^2_{tangential}}{r} = r\omega^2$$