Formula sheet

Unit vector $\hat{a} = \dfrac{\vec{a}}{|\vec{a}|}$ Displacement $\vec{r}_f - \vec{r}_i = \Delta\vec{r}$ Velocity $\vec{v} = \dfrac{\vec{r}_f - \vec{r}_i}{t_f - t_i} = \dfrac{\Delta\vec{r}}{\Delta t}$

For motion along a curved path,

$$\left|\frac{d\vec{p}}{dt}\right|\hat{p} = \vec{F}_{\parallel} \text{ and } |\vec{p}|\frac{d\hat{p}}{dt} = |\vec{p}|\frac{|\vec{v}|}{R}\hat{n} = \vec{F}_{\perp} \text{ or } p\frac{v}{R} = F_{\perp}$$

where R is the radius of the "kissing circle" and $\hat{n}$ points in the direction of $\vec{F}_{\perp}$ (toward center of circle).

Speed of light $c = 3\times10^8\text{m/s}$ $G = 6.7\times10^{-11}\dfrac{\text{N}\cdot\text{m}^2}{\text{kg}^2}$ $\dfrac{1}{4\pi\epsilon_0} = 9\times10^9\dfrac{\text{N}\cdot\text{m}^2}{\text{C}^2}$ $0^\circ\text{ C} = 273\text{ K}$

Magnitude of gravitational force $\left|\vec{F}_{\text{gr}}\right| = G\dfrac{Mm}{|\vec{r}|^2}$ Gravitational potential energy $U_{\text{gr}} = -\dfrac{GMm}{|\vec{r}|}$

Near the Earth's surface $\left|\vec{F}_{\text{gr}}\right| \approx mg$ and $\Delta U_{\text{gr}} \approx \Delta(mgy)$ $g = +9.8\dfrac{\text{N}}{\text{kg}}$

Magnitude of electric force $\left|\vec{F}_{\text{el}}\right| = \dfrac{1}{4\pi\epsilon_0}\dfrac{|Qq|}{|\vec{r}|^2}$ Electric potential energy $U_{\text{el}} = \dfrac{1}{4\pi\epsilon_0}\dfrac{Qq}{|\vec{r}|}$

Magnitude of spring force $\left|\vec{F}_{\text{spring}}\right| = k_s|s|$ Spring potential energy $U_{\text{spring}} = \dfrac{1}{2}k_s s^2 + U_0$

where a negative U_0 makes $U_{\text{spring}} < 0$. It is the same value for initial and final states, so it cancels from the energy principle formula.

Idealized mass-spring oscillator $x = A\cos\omega t = A\cos\left(\sqrt{\dfrac{k_s}{m}}t\right)$, $f = \dfrac{1}{T} = \dfrac{\omega}{2\pi}$

$Y = \dfrac{\text{stress}}{\text{strain}} = \dfrac{F/A}{\Delta L/L} = \dfrac{k_{s,i}}{d}$ (in terms of atomic quantities) $v_{\text{sound}} = d\sqrt{\dfrac{k_{s,i}}{m}}$

Kinetic energy, valid at any speed less than c $K = E - mc^2$

Kinetic energy, valid at speeds much less than c $K \approx \dfrac{1}{2}m|\vec{v}|^2$

Relationship between relativistic energy and momentum of a particle $E^2 - (pc)^2 = (mc^2)^2$

More equations on next page

$$\vec{L}_A = \langle (yp_z - zp_y), (zp_x - xp_z), (xp_y - yp_x) \rangle \qquad \vec{\tau}_A = \vec{r}_A \times \vec{F} \qquad K_{\text{rot}} = \frac{1}{2} I\omega^2 = \frac{L_{\text{rot}}^2}{2I}$$

$$I = \sum_i m_i r_i^2 = m_1 r_1^2 + m_2 r_2^2 + \cdots$$

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ways to arrange q quanta of energy among N one-dimensional oscillators

$$\Omega = \frac{(q+N-1)!}{q!(N-1)!}$$

Entropy $S = k \ln \Omega$ where $k = 1.38 \times 10^{-23}$ J/K

Temperature : $\quad \dfrac{1}{T} = \dfrac{\Delta S}{\Delta E}$ Specific heat capacity *per atom* : $\quad C = \dfrac{\Delta E_{\text{atom}}}{\Delta T}$

Probability of finding energy E in small system in contact with large reservoir is proportional to $\Omega(E) e^{-E/kT}$