## (1) MECHANICS

$$v = \frac{\mathrm{d}x}{\mathrm{d}t}$$
$$a = \frac{\mathrm{d}v}{\mathrm{d}t}$$

Where $\bar{v}$ is the average velocity:

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

In a constant acceleration:

$$v = v_0 + at$$
$$x = x_0 + v_0 t + \frac{1}{2}at^2$$
$$x = x_0 + \frac{v_0 + v}{2}t$$
$$||v|| = \sqrt{v_0^2 + 2a(x - x_0)}$$

## (2) FORCES

$$F_g = mg$$
$$F_{sp} = k\,\Delta\ell$$
$$f_s \leq \mu_s N$$
$$f_k = \mu_k N$$

**Newton's laws:**

1. A body remains at rest, or in motion at a constant speed in a straight line, unless it is acted upon by a force.
2. $$\sum \vec{F} = m\vec{a}$$
3. If two bodies exert forces $\vec{F}_1, \vec{F}_2$ on each other, then $\vec{F}_1 = -\vec{F}_2$.

## (3) ENERGY

$$W = \int \vec{F}(s)\,\mathrm{d}s$$

$$(\exists c, \theta\, \forall t\colon |F(t)| = c,\ \measuredangle F(t) = \theta)$$
$$\implies W = F_x \cdot \Delta x = F\cos\theta \Delta s$$

$$E_k = \frac{1}{2}m\,||v||^2$$
$$U_g = mgh$$
$$U_{sp} = \frac{1}{2}k(\Delta\ell)^2$$
$$E_{k1} + U_{g1} = E_{k2} + U_{g2}$$
$$\forall i, j\colon\ \left(\sum E\right)_i = \left(\sum E\right)_j$$
$$W_F = \Delta E = E_{\text{final}} - E_{\text{begining}}$$

## (4) ROTATIONAL MOVEMENT

$$f = \frac{1}{T} \quad [\text{Hz}]$$
$$L = r\psi_{\text{rad}}$$
$$\omega = 2\pi f = \frac{2\pi}{T}$$
$$v \overset{*}{=} \frac{2\pi r}{T}$$
$$\bar{\omega} = \frac{\Delta\theta}{\Delta t}$$
$$v = \omega r$$
$$a_R = \frac{v^2}{r} = \omega^2 r$$
$$P = 2\pi r$$

Critical Velocity at max.:

$$N = 0 \iff v = \sqrt{gr}$$

$$a_T = -g\sin\alpha$$
$$\vec{a} = \vec{a}_T + \vec{a}_r$$
$$|a| = \sqrt{a_T^2 + a_R^2}$$
$$\tan\theta = \frac{|a_T|}{|a_R|}$$

## (5) GRAVITY

$$\left(\frac{\bar{r}_1}{\bar{r}_2}\right)^3 = \left(\frac{T_1}{T_2}\right)^2$$
$$F_g = G\,\frac{Mm}{r^2}$$
$$U_G = -\frac{GMm}{r}$$
$$(W_g)_{A\to B} \overset{*}{=} GMm\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$$
$$\rho = \frac{m}{v}$$

In a circular motion:

$$E_k = \frac{GMm}{2r} = -\frac{U_G}{2}$$

$$\begin{aligned}\sum E_{\text{mechanic}} &= E_k + U_G \\ &= -\frac{GMm}{2r} = -E_k\end{aligned}$$

$$T \overset{*}{=} \frac{2\pi r}{v} \overset{*}{=} 2\pi\sqrt{\frac{r^3}{GM}}$$

**Kepler's laws of planetary motion:**

1. The orbit of a planet is an ellipse
2. A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. For a given gravitational system:

$$\exists c\, \forall i\colon \frac{T_i^2}{r_i^3} = c \overset{*}{=} \frac{4\pi^2}{GM}$$

## (6) MOMENTUM

$$\vec{p} = m\vec{v} \quad [N\,\text{sec}] \sim \left[\frac{\text{kg}\,m}{\text{sec}}\right]$$

$$\vec{J} = \int F\,\mathrm{d}t \overset{!}{=} \vec{F}\cdot\Delta\vec{t} = \left|\vec{F}\right|\left|\Delta\vec{t}\right|\cos\theta$$

$$\vec{J}_{\Sigma F} = \sum_{i=1}^{n}\vec{J}_{F_i} = \Delta\vec{p}$$

$$\forall t_1, t_2 \in \mathbb{R}\colon \sum_{i=1}^{n}\vec{p}_i(t_1) = \sum_{i=1}^{n}\vec{p}_i(t_2)$$

In an inelastic collision:

$$Q = \Delta E_k$$

In an elastic collision, where $v_i$ before collision and $u_i$ after it:

$$\vec{v}_1 - \vec{v}_2 = -(\vec{u}_1 - \vec{u}_2)$$

Elastic Collision iff no loss of kinetic energy, Inelastic iff not ecstatic.

## (7) CONSTANTS

| $M\,[kg]$ | $R\,[m]$ | Obj |
|---|---|---|
| $5.974\cdot10^{24}$ | $6.38\cdot10^{6}$ | Earth |
| $1.99\cdot10^{30}$ | $6.96\cdot10^{8}$ | Sun |
| $7.35\cdot10^{22}$ | $1.74\cdot10^{6}$ | Moon |

$$G = 6.67\cdot10^{-11}\,\frac{\text{N}m^2}{\text{kg}}$$

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