$$\vec{\nabla} f(\vec{r}) = \sum_i \hat{e}_i \frac{\partial f}{\partial x_i}$$

$$\vec{A} \cdot \vec{B} = \sum_i A_i B_i$$

$$(\vec{A} \times \vec{B})_i = \sum_{jk} \epsilon_{ijk} A_j B_k$$

$$\sum_i \epsilon_{ijk} \epsilon_{ilm} = \delta_{jl}\delta_{km} - \delta_{jm}\delta_{kl}$$

$$\vec{r}(t) = x(t)\hat{i} + y(t)\hat{j} + z(t)\hat{k}$$

$$\vec{v}(t) = \dot{\vec{r}}(t)$$

$$\vec{a}(t) = \dot{\vec{v}}(t) = \ddot{\vec{r}}(t)$$

$$\vec{F} = \frac{d\vec{p}}{dt} = m\vec{a}$$

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

$$\vec{L} = \vec{r} \times \vec{p}$$

$$T = \frac{1}{2} m v^2$$

$$\vec{F} = -\frac{GMm}{r^2} \hat{\mathbf{e}}_r$$

$$\vec{g} = -\frac{GM}{r^2} \hat{\mathbf{e}}_r$$

$$U = -\frac{GMm}{r}$$

$$\Phi = -\frac{GM}{r}$$

$$\vec{g} = -G \int \frac{dm}{r^2} \hat{\mathbf{e}}_r$$

$$\Phi = -G \int \frac{dm}{r}$$

$$\vec{F} = -\vec{\nabla} U$$

$$\vec{g} = -\vec{\nabla} \Phi$$

$$\mu = \frac{m_1 m_2}{m_1 + m_2}$$

$$l = \mu r^2 \dot{\theta}$$

$$\frac{dA}{dt} = \frac{l}{2\mu}$$

$$E = \frac{1}{2} \mu \dot{r}^2 + \frac{l^2}{2\mu r^2} + U(r)$$

$$E = \frac{1}{2} \mu \dot{r}^2 + U_{eff}(r)$$

$$U_{eff}(r) = \frac{l^2}{2\mu r^2} + U(r)$$

$$u = \frac{1}{r}$$

$$\frac{d^2 u}{d\theta^2} + u = -\frac{\mu}{l^2} \frac{1}{u^2} F(1/u)$$

$$U(r) = -\frac{k}{r}$$

$$\frac{\alpha}{r} = 1 + \varepsilon \cos\theta$$

$$\alpha = \frac{l^2}{\mu k}$$

$$\varepsilon = \sqrt{1 + \frac{2El^2}{\mu k^2}}$$

$$\tau^2 = \frac{4\pi^2 \mu}{k} a^3$$

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

$$a = \frac{\alpha}{1 - \varepsilon^2} = \frac{k}{2|E|}$$

$$b = \frac{\alpha}{\sqrt{1 - \varepsilon^2}} = \frac{l}{\sqrt{2\mu|E|}}$$