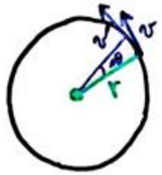
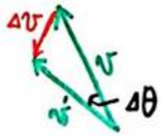
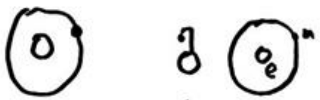
원운동 → 뉴턴 3법칙 → 만유인력 → 포아송 → 중력장 방정식

→ 비리알 → 진즈 M_J

$$T^2 = KR^3$$







$F = 4\pi^2 K_s \frac{m}{r^2}$ ↑ $F = 4\pi^2 K_e \frac{m}{r_m^2}$

$F = 4\pi^2 K_e \frac{m}{r_e^2}$

$$U = \int \vec{F} \cdot d\vec{r}$$

$a_{사과} = 4\pi$

$a_{달} = 4\pi^2$

$F = ma \quad a = \frac{F}{m} \quad g = \cdot$

$$\Delta v = v\Delta\theta = v\Delta(\omega t) = v\omega\Delta t$$

$$P = mv \qquad l = l_0\sqrt{1-\left(\frac{v}{c}\right)^2}$$

$$a = \frac{\Delta v}{\Delta t} = v\omega = v\,\frac{2\pi}{T} = v\,\frac{2\pi}{\frac{2\pi r}{v}} = \frac{v^2}{r}$$

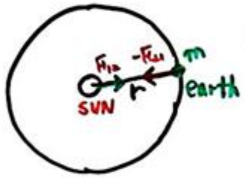
$$\int \vec{g} \cdot d\vec{a} = \int_V \nabla \cdot \vec{g}\, dv$$

$$F = ma = \frac{dP}{dt} \qquad m = \frac{m_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

$$F = ma = m\frac{v^2}{r} = m\frac{\left(\frac{2\pi r}{T}\right)^2}{r} = m\frac{4\pi^2 r}{T^2}$$

$$F = \frac{4\pi^2 m r}{\left(\frac{r^3}{K}\right)} = \frac{4\pi^2 K m}{r^2}$$

$$F_{12} = -F_{21} \qquad t = \frac{t_0}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$



$$F = 4\pi^2 K \frac{m}{r^2}$$

$$E = mc^2$$

$$4\pi^2 K_e = G m_e \qquad 4\pi^2 K_e \frac{m_s}{r^2} = G\frac{m_e m_s}{r^2}$$

$$4\pi^2 K_s = G m_s \qquad 4\pi^2 K_s \frac{m_e}{r^2} = G\frac{m_s m_e}{r^2}$$

$$\int \vec{g} \cdot d\vec{a} = -G$$

$$= -GM$$

$$F = \frac{GMm}{r^2} \qquad \frac{du^\mu}{ds} - \Gamma^\mu_{\alpha\beta} u^\alpha u^\beta = 0$$

$$F = \frac{GMm}{r^2}$$

$$\nabla^2\phi = 4\pi G\rho \qquad R^{\mu\nu} - \frac{1}{2}g^{\mu\nu}R = \frac{8\pi G}{c^4}T^{\mu\nu}$$

$$a_{달} = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2 (3.8\times10^8\,\mathrm{m})}{(27.3\ \mathrm{day})^2} \qquad = -4\pi$$

$$= 2.7\times10^{-3}\ \mathrm{m/sec^2}$$

$\vec{r}$

$a_{사과} = 4\pi^2 k_e \frac{1}{r_e^3}$

$a_{달} = 4\pi^2 k_e \frac{1}{r_m^2}$

$\frac{a_{달}}{a_{사과}} = \left(\frac{r_e}{r_m}\right)^2 = \left(\frac{1}{60}\right)^2$

$$\int \vec{g} \cdot d\vec{a} = -4\pi G M = -4\pi G \int_v \rho \, dv = \int_v \nabla \cdot \vec{g} \, dv$$

$a = \frac{F}{m}$ $\quad g = -\frac{GM}{r^2}\hat{r}$

$a_{달} = g\left(\frac{1}{60}\right)^2 = 9.8\,m/sec^2 \left(\frac{1}{60}\right)^2 = 2.7\times10^{-3}\,m/sec^2$

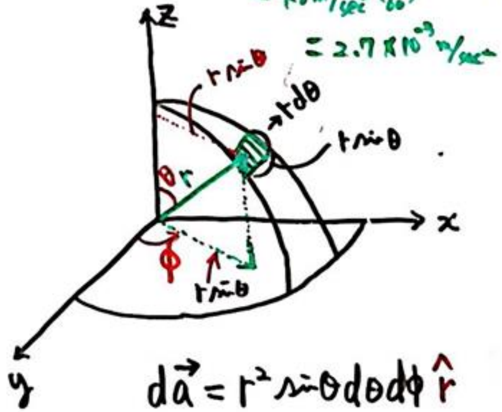
$$-4\pi G\rho = \nabla \cdot \vec{g} \qquad \vec{g} = -\nabla\phi$$

$d\vec{a} = \int_v \nabla \cdot \vec{g} \, dv$

$$\nabla \cdot (-\nabla\phi) = -4\pi G\rho$$

$$\nabla^2 \phi = 4\pi G \rho$$

$\pi^2 K \frac{m}{r^2}$



$$d\vec{a} = r^2 \sin\theta \, d\theta \, d\phi \, \hat{r}$$

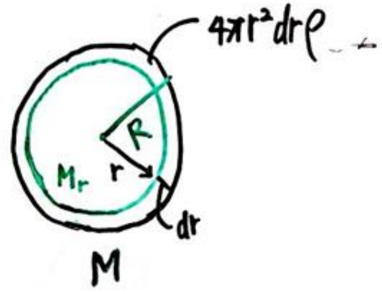
$$\int \vec{g} \cdot d\vec{a} = -GM \int \frac{\hat{r}}{r^2} \cdot r^2 \sin\theta \, d\theta \, d\phi \, \hat{r}$$

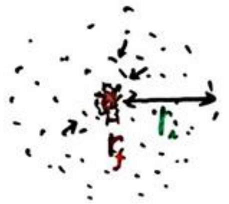
$$= -GM \underbrace{\int_0^{2\pi} d\phi}_{2\pi} \underbrace{\int_0^{\pi} \sin\theta \, d\theta}_{-\cos\theta|_0^{\pi} = -(-1-1) = 2}$$

$$= -4\pi G M$$

$\frac{4\pi^2 (3.8\times10^8\,m)}{(27.3\ day)^2}$

$7\times10^{-3}\,m/sec^2$





$$dF = \frac{G M_r \, 4\pi r^2 dr \rho}{r^2}$$

$$U = 4\pi G \int M_r \rho \, r \, dr$$

$\rho \sim \bar{\rho}$

$M = \frac{4\pi}{3} R^3 \bar{\rho}$

$$U = 4\pi G \int \frac{4\pi r^3}{3} \bar{\rho}\bar{\rho}\, r\, dr$$

$$= \frac{16\pi^2 G}{3} \bar{\rho}^2 \int_0^R r^4 dr \quad \hookrightarrow \frac{1}{5} r^5 \Big|_0^R = \frac{R^5}{5}$$

$$= \frac{16\pi^2 G}{15} \bar{\rho}^2 R^5$$

$$U = \frac{16\pi^2 G}{15} \left(\frac{3M}{4\pi R^3}\right)^2 R^5 = \frac{-3}{5}\frac{GM^2}{R}$$

↑ 중력 위치에너지

$2K + U = 0$

비리얼 정리

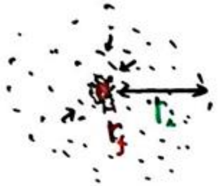
$2K < |U|$

$K = \frac{1}{2} U =$

$\Delta E = -(E_f -$

$\Delta E = \frac{}{10}$

$$t_{KH} = \frac{\Delta E}{L_\odot}$$



$2K + U = 0$

비리얼 정리

$2K < |U|$

$K = \frac{1}{2}U = \frac{3}{10}\frac{GM^2}{R}$

$\frac{\pi r^3}{3}\bar{\rho}\,\rho\, r dr$

$\Delta E = -(E_f - E_i) = -E_f$

$\bar{\rho}^2 \int_0^R r^4 dr \rightarrow \frac{1}{5}r^5\Big|_0^R = \frac{R^5}{5}$

$\bar{\rho}^2 R^5$

$\Delta E = \frac{3}{10}\frac{GM_\odot^2}{R_\odot} = 1.1\times10^{41}\,J$

$\frac{3}{5}\frac{GM^2}{R}$

$t_{KH} = \frac{\Delta E}{L_\odot} \approx 10^7$ years

$\vec{x} = (ct, x)$

$\sqrt{\vec{x}\cdot\vec{x}} = \sqrt{(ct)^2 - x^2}$

$\vec{U} = \frac{d\vec{x}}{d\tau} = \left(\frac{dct}{d\tau}, \frac{dx}{d\tau}\right) = \Big(c\underbrace{\frac{dt}{d\tau}}_{\gamma}, \frac{dt}{d\tau}\underbrace{\frac{dx}{dt}}_{v}\Big)$

$= (c\gamma, v\gamma)$

$\sqrt{\vec{U}\cdot\vec{U}} = \sqrt{(c\gamma)^2 - (v\gamma)^2} = \gamma\sqrt{c^2 - v^2}$

$= \gamma c\sqrt{1 - (\frac{v}{c})^2} = \gamma\cdot\frac{1}{\gamma}c = c$

$\vec{P} = m_0 U = (cm_0\gamma, vm_0\gamma)$

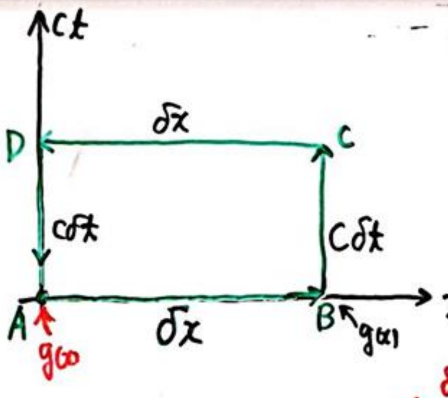
$= (mc, mv) = \left(\frac{mc^2}{c}, mv\right)$

$= \left(\frac{E}{c}, P\right)$

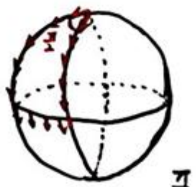
$\sqrt{\vec{P}\cdot\vec{P}} = \sqrt{(\frac{E}{c})^2 - P^2}$

$\vec{P}\cdot\vec{P} = m_0\vec{U}\cdot m_0\vec{U} = m_0^2\,\vec{U}\cdot\vec{U} = m_0^2c^2$

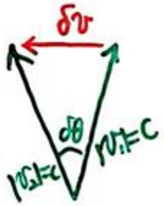
$(\frac{E}{c})^2 - P^2 = m_0^2c^2 \quad E^2 = (pc)^2 + (m_0c^2)^2$



구의 곡률 $\equiv \frac{\delta\theta}{\delta A}$



구의 곡률 $= \frac{\frac{\pi}{2}}{4\pi R^2\times\frac{1}{8}} = \frac{1}{R^2}$

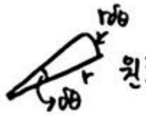


$A\rightarrow B \quad t=0$

$B\rightarrow C \quad \rightarrow \delta v_1 = g(x+\delta x)\delta t$

$C\rightarrow D \quad t=0$

$D\rightarrow A \quad \rightarrow \delta v_2 = g(x)(-\delta t) \qquad \delta v = c\delta\theta$



원의 곡률 $= \frac{\delta\theta}{\delta x} = \frac{\delta\theta}{r\delta\theta} = \frac{1}{r}$

$\delta v = \delta v_1 + \delta v_2 = [g(x+\delta x) - g(x)]\delta t \qquad \lim_{\delta x\to0}\frac{g(x+\delta x) - g(x)}{\delta x} \equiv \frac{dg(x)}{dx}$

$= \frac{dg(x)}{dx}\delta x\delta t = \frac{d}{dx}\left(\frac{-GM}{x^2}\right)\delta x\delta t = \frac{2GM}{x^3}\delta x\delta t$

$\delta\theta = \frac{\delta v}{c} = \frac{2GM}{cx^3}\delta x\delta t$

지구 시공곡률 $= \frac{\delta\theta}{\delta A} = \frac{\frac{2GM}{cx^3}\delta x\delta t}{\delta x\cdot c\delta t}$

$= \frac{2GM}{c^2x^3} = \frac{1}{R^2}$

$R = \sqrt{\frac{c^2x^3}{2GM}} = \sqrt{\frac{c^2x}{2\frac{GM}{x^2}}} = \sqrt{\frac{c^2x}{2g}} = \sqrt{\frac{(3\times10^8)^2\,6.4\times10^6}{2\times9.8\,m/sec^2}}$

$= 1.7\times10^{11}m = 27000\,R_{earth}$