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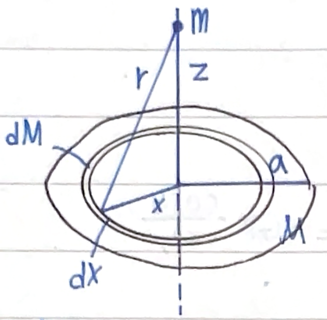

① $d\Phi = -G\dfrac{dM}{r}$ $\qquad dM = \rho\, dA = \rho\, 2\pi x\, dx$

$= -2\pi\rho G\dfrac{x\,dx}{r}$

$= -2\pi\rho G\dfrac{x\,dx}{\sqrt{x^2+z^2}}$

$$\Phi(z) = -\pi\rho G\int_0^a \frac{2x\,dx}{\sqrt{x^2+z^2}} = -2\pi\rho G\sqrt{x^2+z^2}\,\Big|_0^a$$

$= -2\pi\rho G\left(\sqrt{a^2+z^2}-z\right)$

$\vec F = -\nabla U = -m\nabla\Phi$

$F_z = -m\dfrac{\partial\Phi(z)}{\partial z} = 2\pi m\rho G\left(\dfrac{z}{\sqrt{a^2+z^2}}-1\right)$

② $d\vec F = -Gm\dfrac{dM'}{r^2}\vec e_r$

$d\vec{F_z} = \cos\theta\,|d\vec F| = -mG\dfrac{\cos\theta\, dM'}{r^2}$ $\qquad \because \cos\theta = \dfrac{z}{r}$

$= -mG\dfrac{z\,dM'}{r^3}$ $\qquad dM' = 2\pi x\rho\, dx$

$= -mG\dfrac{2\pi x z\, dx}{r^3}$

$$F_z = -\pi m\rho G z\int_0^a \frac{2x\,dx}{(x^2+z^2)^{3/2}}$$

$= -\pi m\rho G z\, \dfrac{-2}{\sqrt{x^2+z^2}}\Big|_0^a$

$= 2\pi m\rho G\left(\dfrac{z}{\sqrt{a^2+z^2}}-1\right)$

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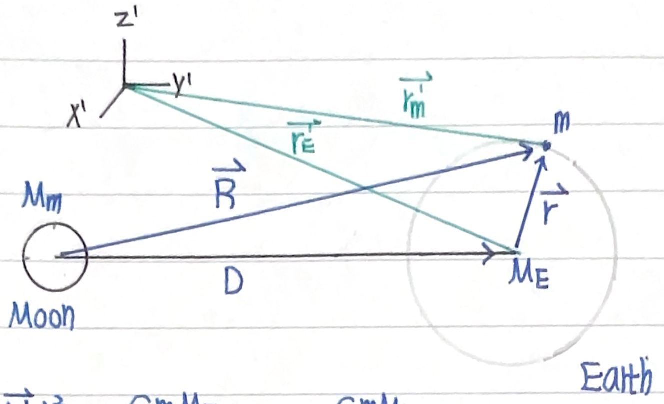
Ocean Tides



assume Earth's surface is completely covered with water

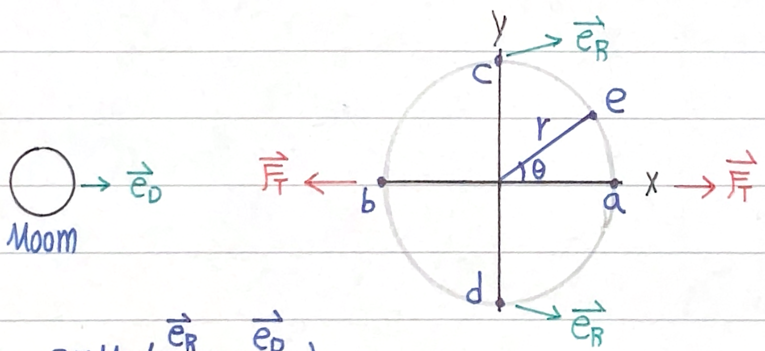
$$m\frac{d^2\vec{r_m'}}{dt^2} = -\frac{GmM_E}{r^2}\vec{e_r} - \frac{GmM_m}{R^2}\vec{e_R}$$

$$M_E\frac{d^2\vec{r_E'}}{dt^2} = -\frac{GM_EM_m}{D^2}\vec{e_D}$$

$$\frac{d^2\vec{r}}{dt^2} = \frac{d^2\vec{r_m'}}{dt^2} - \frac{d^2\vec{r_E'}}{dt^2} = \frac{m\ddot{\vec{r}}_m'}{m} - \frac{M_E\ddot{\vec{r}}_E'}{M_E}$$

$$= -\frac{GM_E}{r^2}\vec{e_r} - \frac{GM_m}{R^2}\vec{e_R} + \frac{GM_m}{D^2}\vec{e_D}$$

$$= -\frac{GM_E}{r^2}\vec{e_r} - GM_m\left(\frac{\vec{e_R}}{R^2} - \frac{\vec{e_D}}{D^2}\right)$$



$$\vec{F_T} = -GmM_m\left(\frac{\vec{e_R}}{R^2} - \frac{\vec{e_D}}{D^2}\right)$$

$$F_{Tx} = -GmM_m\left(\frac{1}{R^2} - \frac{1}{D^2}\right) = -GmM_m\left(\frac{1}{(D+r)^2} - \frac{1}{D^2}\right) = -\frac{GmM_m}{D^2}\left[\frac{1}{(1+\frac{r}{D})^2} - 1\right]$$

$$= -\frac{GmM_m}{D^2}\left[1 - 2\frac{r}{D} + 3\left(\frac{r}{D}\right)^2 - \cdots - 1\right] \quad \text{and} \quad \frac{r}{D} = 0.02$$

$$= \frac{2GmM_m r}{D^3}$$

$$F_{Ty} = -GmM_m\left(\frac{1}{D^2}\right)\frac{r}{D} = -\frac{GmM_m r}{D^3}$$

$x = r\cos\theta$ $\quad F_{Tx} = \frac{2GmM_m r\cos\theta}{D^3}$ $\quad F_{Ty} = -\frac{GmM_m r\sin\theta}{D^3}$

$y = r\sin\theta$