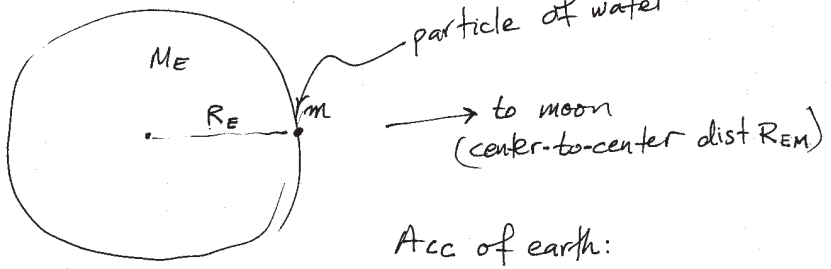
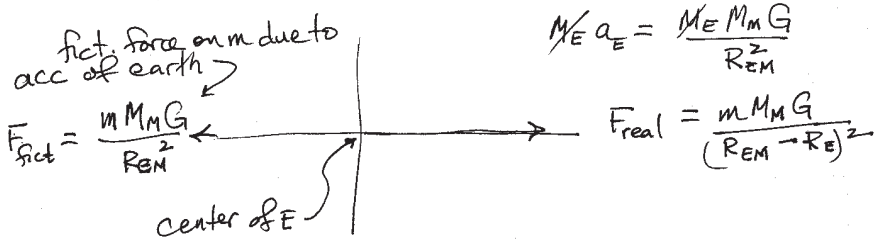
Tide effect of moon on earth



Acc of earth:

$$M_E a_E = \frac{M_E M_M G}{R_{EM}^2}$$



Adding the two forces:

$$F_{tot} = \frac{m M_M G}{(R_{EM} - R_E)^2} - \frac{m M_m G}{R_{EM}^2}$$

$$= \frac{m M_M G}{R_{EM}^2}\left[\frac{1}{\left(1 - \frac{R_E}{R_{EM}}\right)^2} - 1\right]$$

$$= \frac{m M_M G}{R_{EM}^2}\left[\left(1 - \frac{R_E}{R_{EM}}\right)^{-2} - 1\right]$$

Binomial Thm: $(1+a)^n = 1 + \frac{na}{1!} + \frac{n(n-1)a^2}{2!} + \cdots$

$$\Rightarrow F_{tot} = \frac{m M_M G}{R_{EM}^2}\left[1 - 2\left(\frac{-R_E}{R_{EM}}\right) + \frac{(-2)(-3)}{2}\left(\frac{-R_E}{R_{EM}}\right)^2 + \cdots\right]$$

small; very small

$$\therefore \quad F_{tot} \approx \frac{2 m M_M G R_E}{R_{EM}^3} \leftarrow \frac{1}{R_{EM}^3} \text{ dependence}$$

For a mass m on the far side of the earth,

$$F_{real} = \frac{m M_M G}{(R_{EM} + R_E)^2}$$

$\Rightarrow$ F_{tot} is approx the same magnitude but to the left.

For the tides due to the sun:

$$F_{sun} = \frac{2 m M_S G R_E}{R_{ES}^3}$$

Ratio

$$\frac{F_m}{F_{sun}} = \frac{\not{2} m M_M G R_E / R_{EM}^3}{\not{2} m M_S G R_E / R_{ES}^3}$$

$$= \frac{M_M}{M_S} \cdot \left(\frac{R_{ES}}{R_{EM}}\right)^3$$

$$= \frac{7.4 \times 10^{22}}{2.0 \times 10^{30}} \left(\frac{1.52 \times 10^{11}}{4.06 \times 10^{8}}\right)^3$$

$$= \boxed{1.94}$$