Earth tides

MMNS PGG 2002.01.13

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Lord Kelvin, 1882

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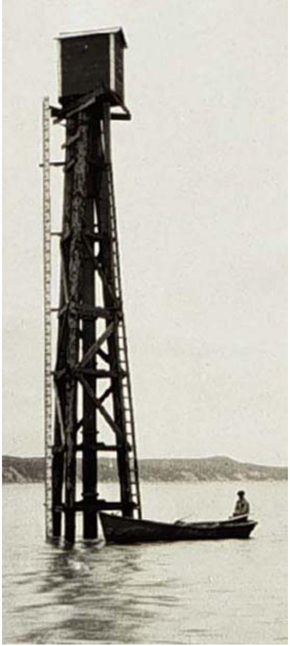
- ~~All phenomena caused by external bodies~~
- ~~Phenomena caused by mass of external bodies~~
- ~~Deformations caused by external bodies~~
- Effects caused by differential gravitational forces exerted by external bodies

Earth breathing



oceanservice.noaa.gov

homepage.oma.be/mvc

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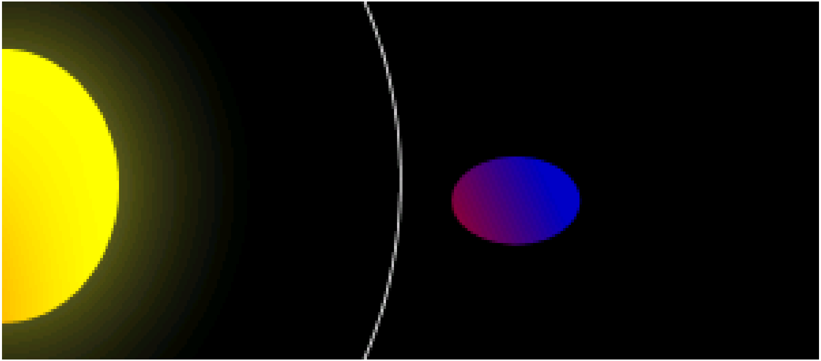
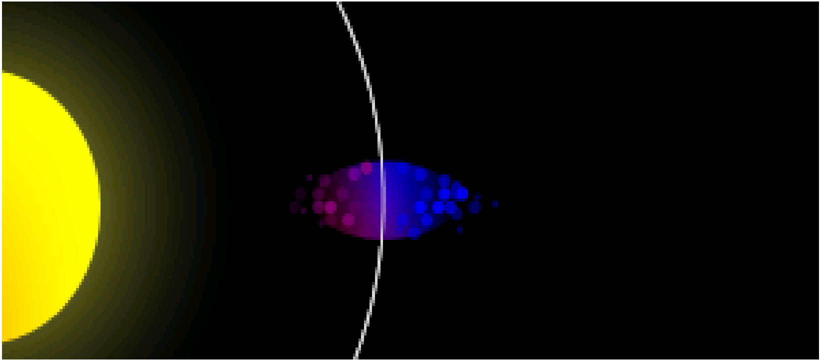


pl.wikipedia.org



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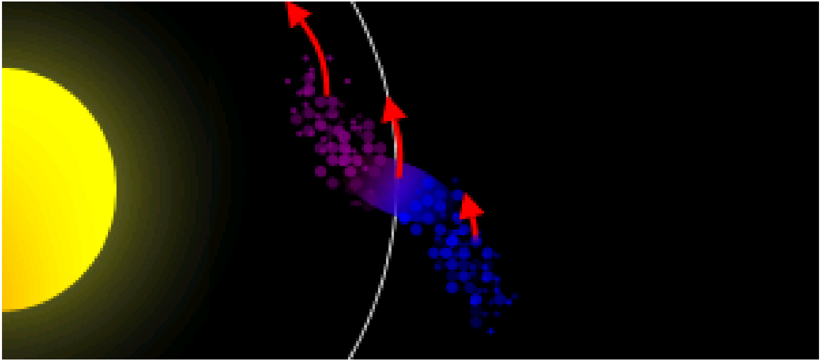

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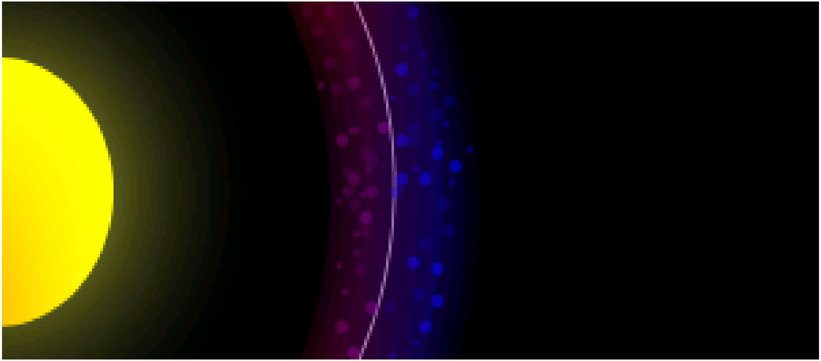

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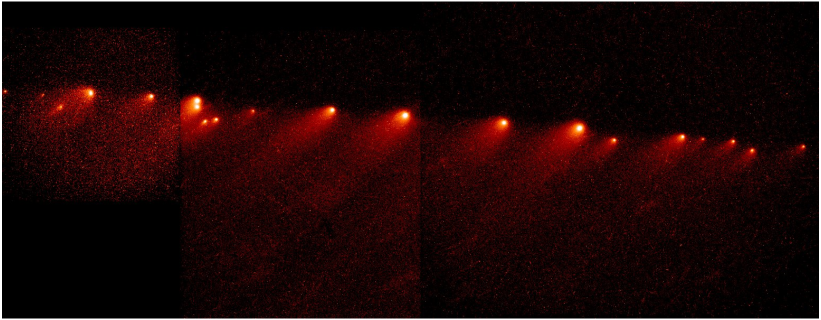

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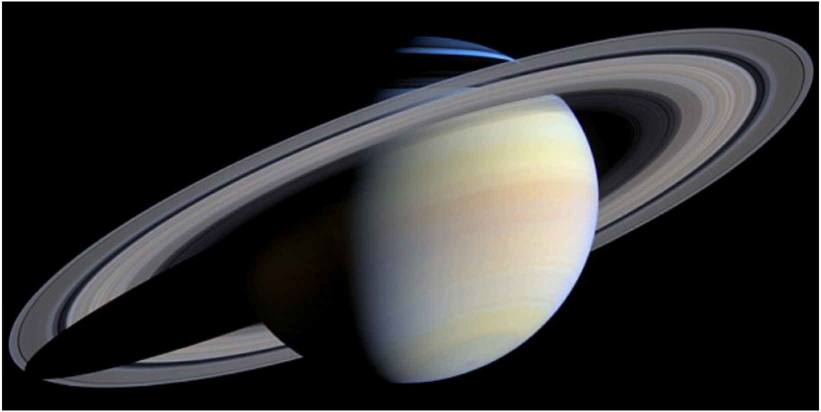

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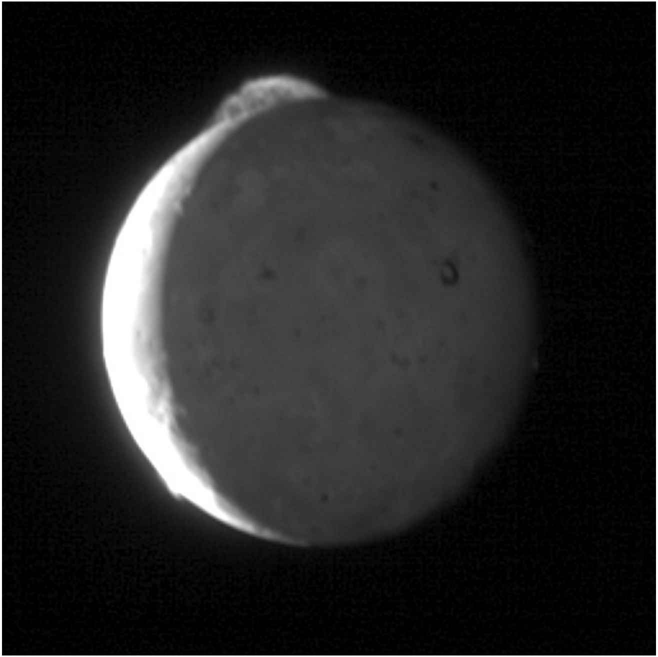

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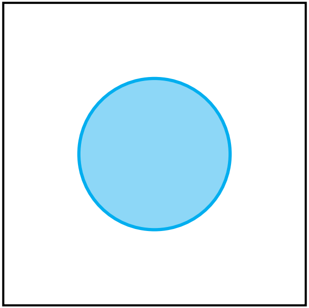
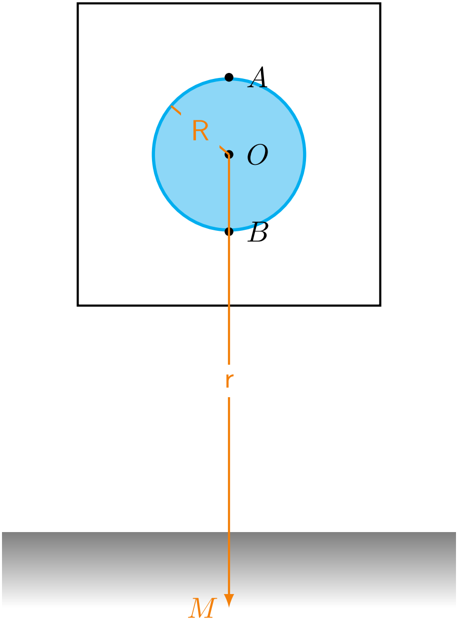
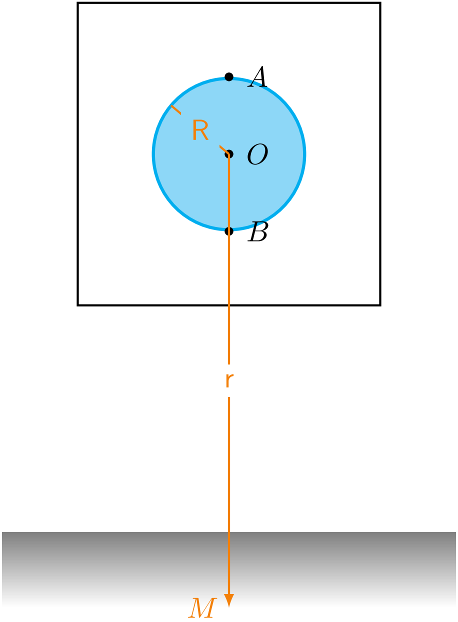
Less spectacular, but important and interesting:

- earth tides,
  - tidal heights changes
  - tidal gravity changes
  - plumb line variation
- atmospheric tides
- tidal variations in Earth rotation
- tidal variations of Earth axis orientation
- satellites perturbations
- „dark side of the moon” and its drifting apart
- indirect effects of ocean tides and atmospheric tides,
- earthquakes
- . . .



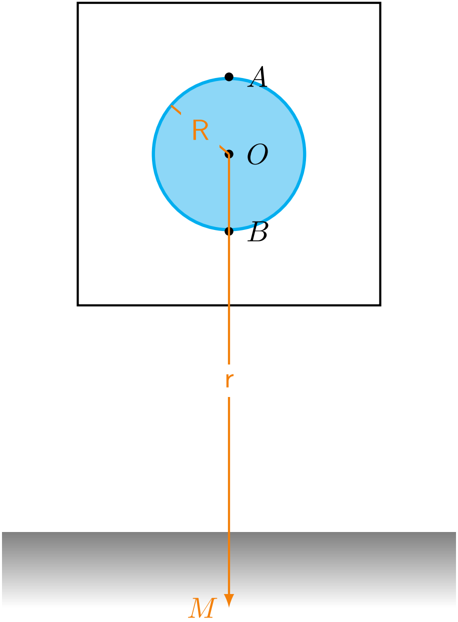

A
R
O
B
r
M



$$\gamma_O = \frac{GM}{r^2}$$

$$\gamma_A = \frac{GM}{(r+R)^2}$$

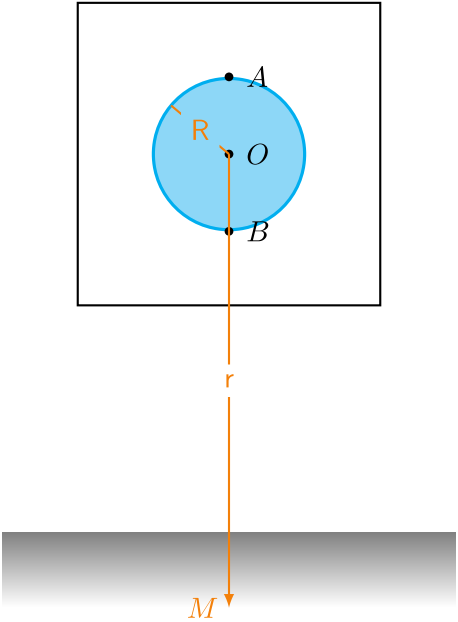
$$\gamma_B = \frac{GM}{(r-R)^2}$$



$$\gamma_O = \frac{GM}{r^2}$$

$$\gamma_A \simeq \gamma_O - \gamma_O \cdot \frac{2R}{r}$$

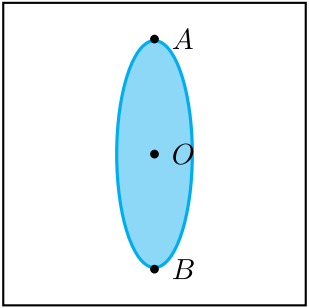
$$\gamma_B \simeq \gamma_O + \gamma_O \cdot \frac{2R}{r}$$



$$\gamma_O = \frac{GM}{r^2}$$

$$\gamma_A \simeq \gamma_O - \boxed{\gamma_O \cdot \frac{2R}{r}} \sim \frac{M \cdot R}{r^3}$$

$$\gamma_B \simeq \gamma_O + \boxed{\gamma_O \cdot \frac{2R}{r}}$$



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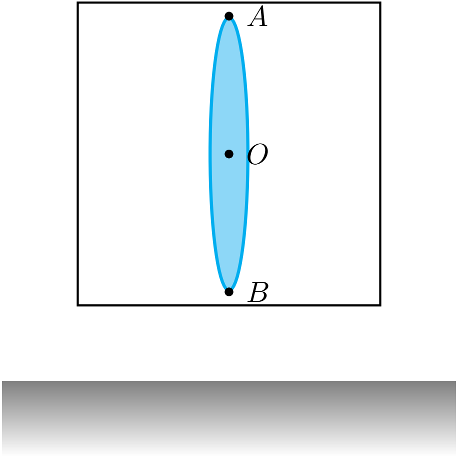

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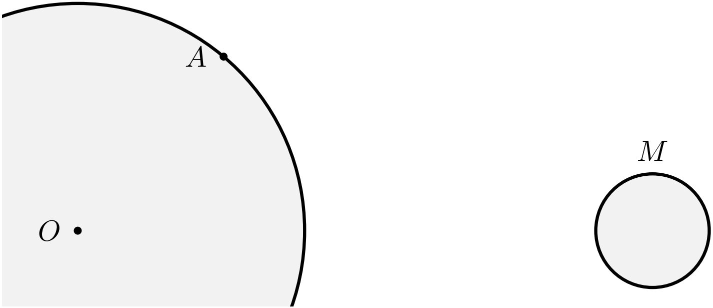
More general derivation

geocentric (z), topocentric (z') zenith angle, earth is sphere with radius of R, distance to external body is r and mass is M, and radius R'



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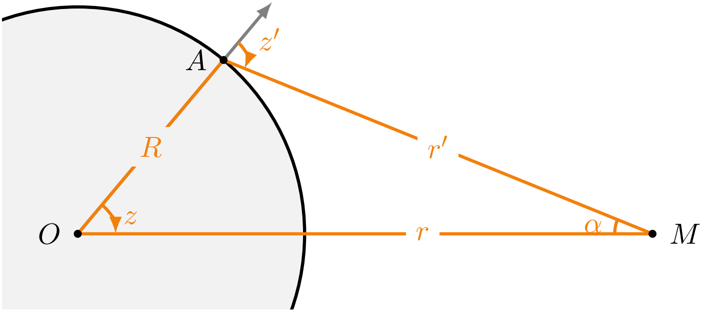
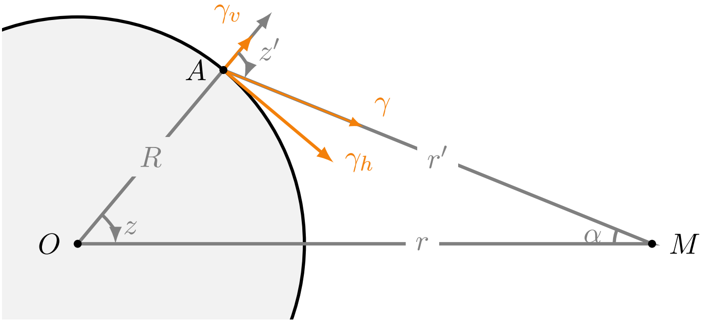
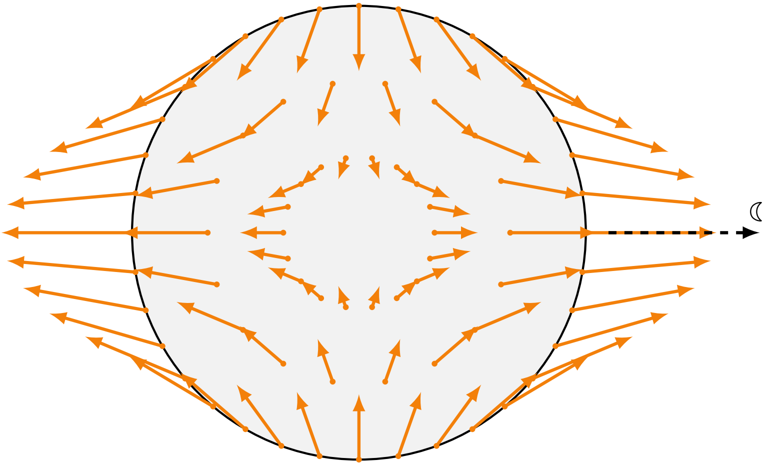


$$\gamma_v = \boxed{\frac{GM}{r^2}} \cdot \left(\boxed{\cos z} + \frac{R}{r}(3\cos^2 z - 1) \right)$$

$$\gamma_h = \boxed{\frac{GM}{r^2}} \cdot \left(\boxed{\sin z} + \frac{R}{r}(\frac{3}{2}\sin 2z) \right)$$



net force — γ



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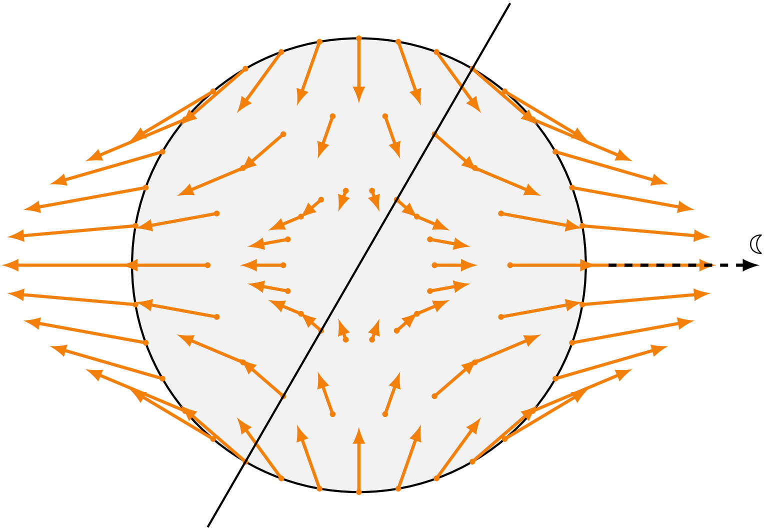


$$Vp = V_{☾} + V_{\odot} + V_{♀} + V_{♃} + V_{♂} + \ldots$$

☾	1
$\odot$	0,46
♀	0,00005
♃	0,000006
♂	0,000001

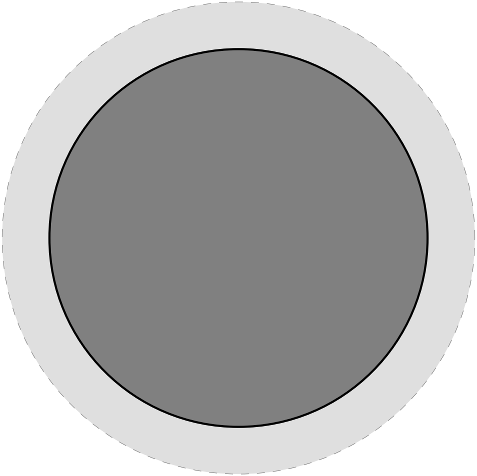
$$\begin{cases} V_2 = \frac{GmR^2}{r^3}(\frac{3}{2}\cos^2 z - \frac{1}{2}) \\ \cos z = \sin\varphi \sin\delta + \cos\varphi \cos\delta \cos(t) \end{cases}$$

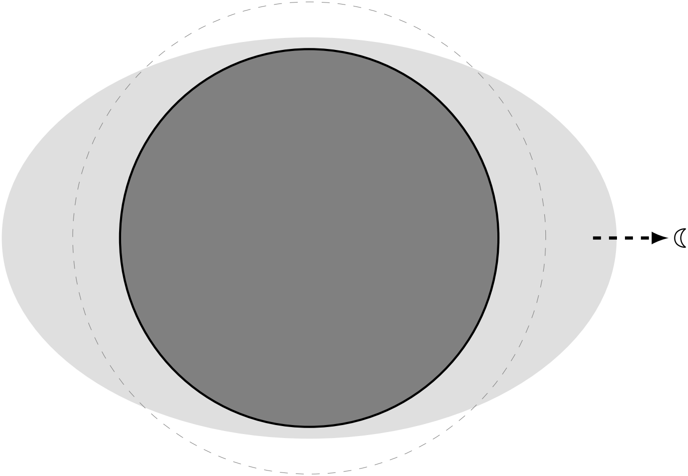
$$V_2 = \frac{3}{4}\frac{GmR^2}{r^3} \cdot \begin{cases} 3(\sin^2\varphi - \frac{1}{3})(\sin^2\delta - \frac{1}{3}) \\ + \sin 2\varphi \sin 2\delta \cos t \\ + \cos^2\varphi \cos^2\delta \cos 2t \end{cases}$$

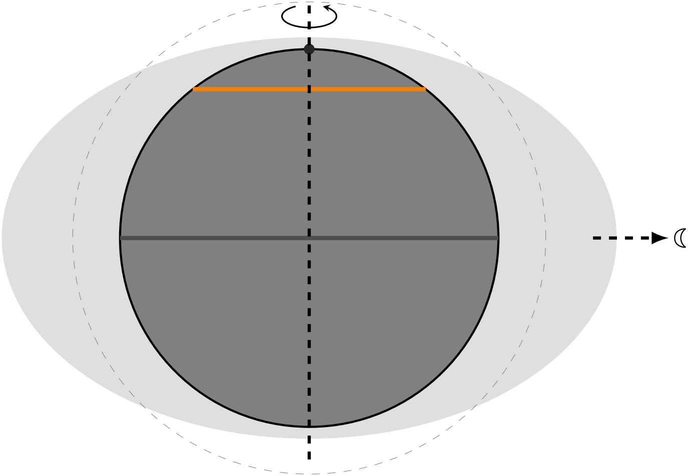
zonal term
long-term tides

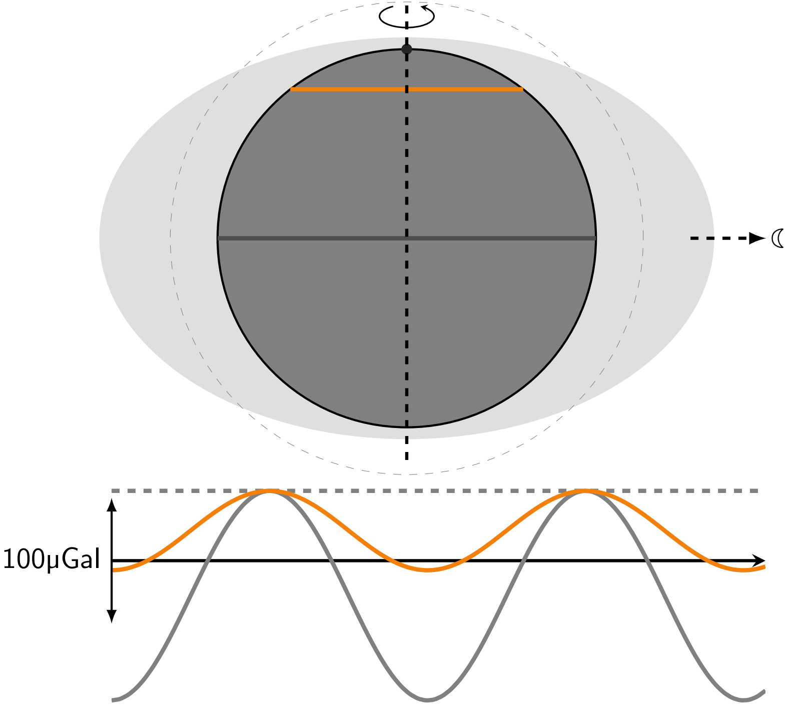
mosaic term
diurnal tides

sectoral term
semi-diurnal tides

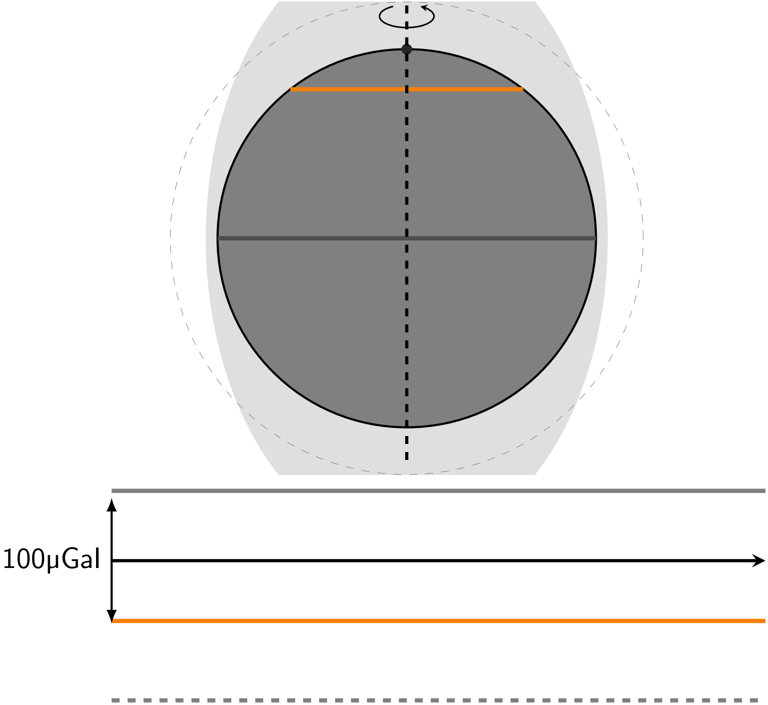


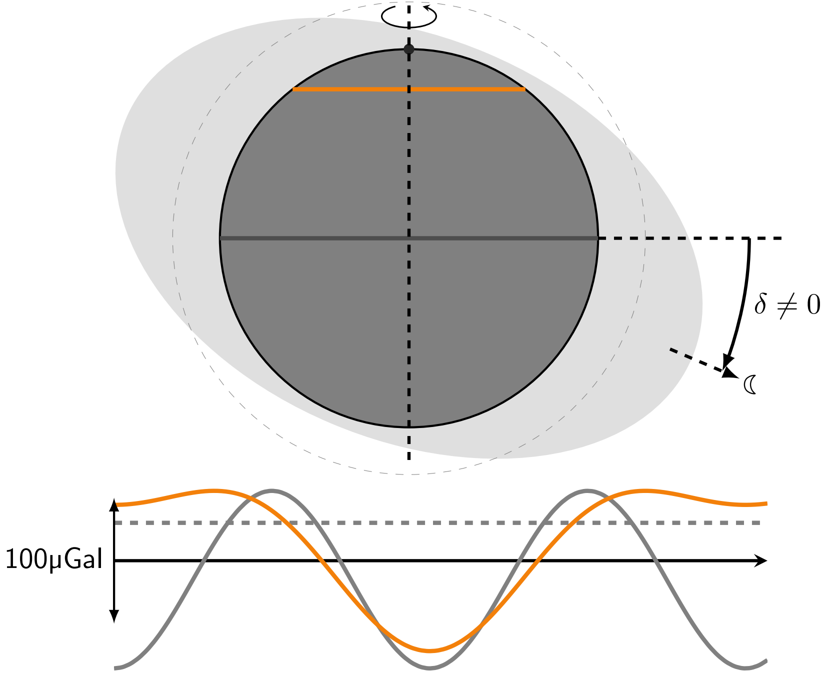




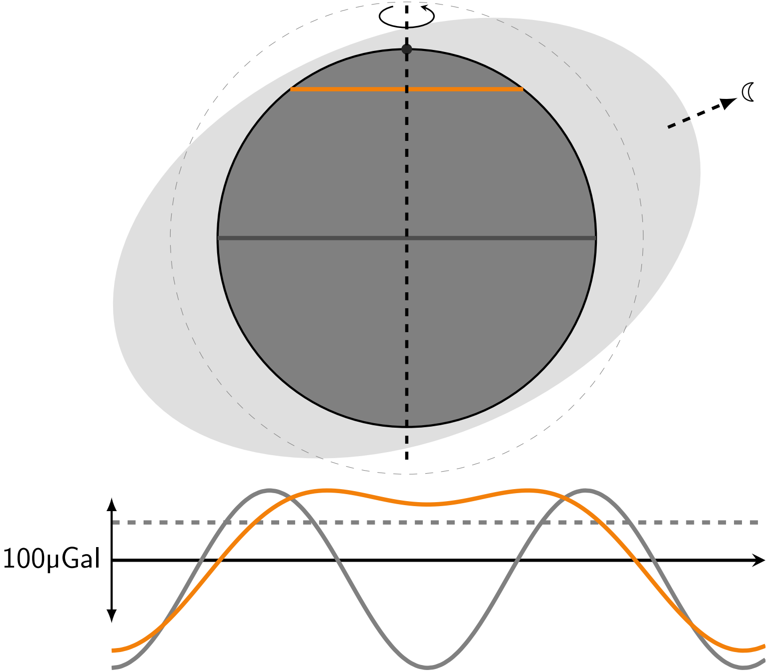


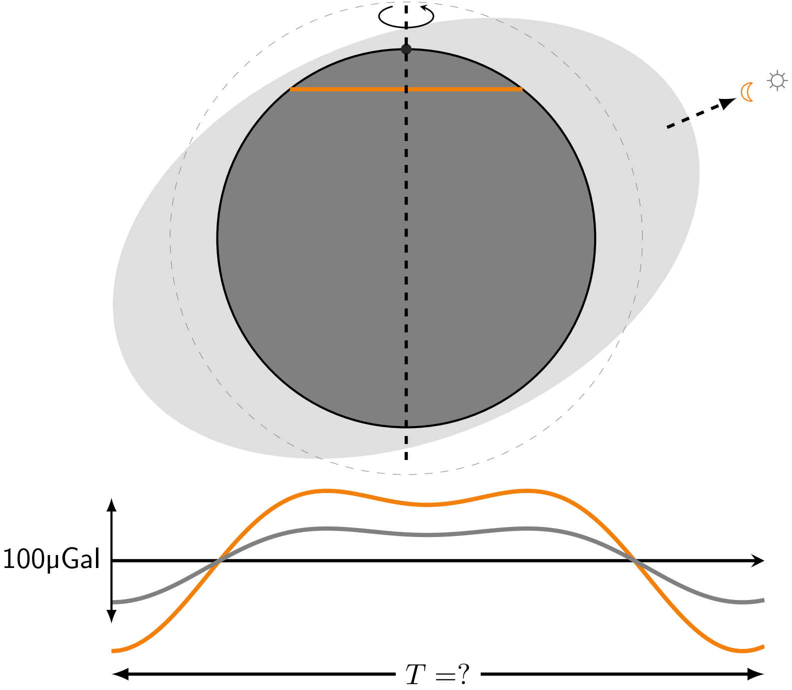
100μGal

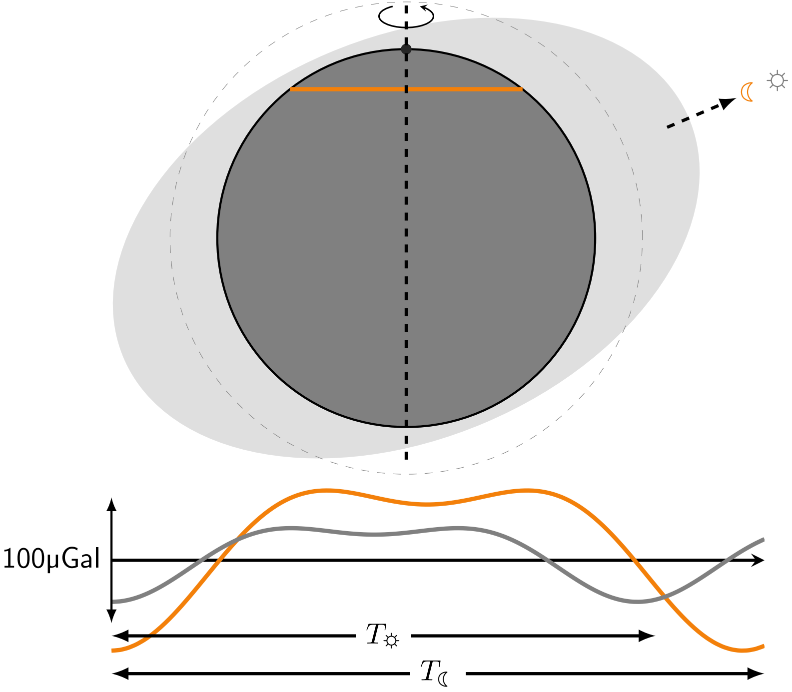

100μGal

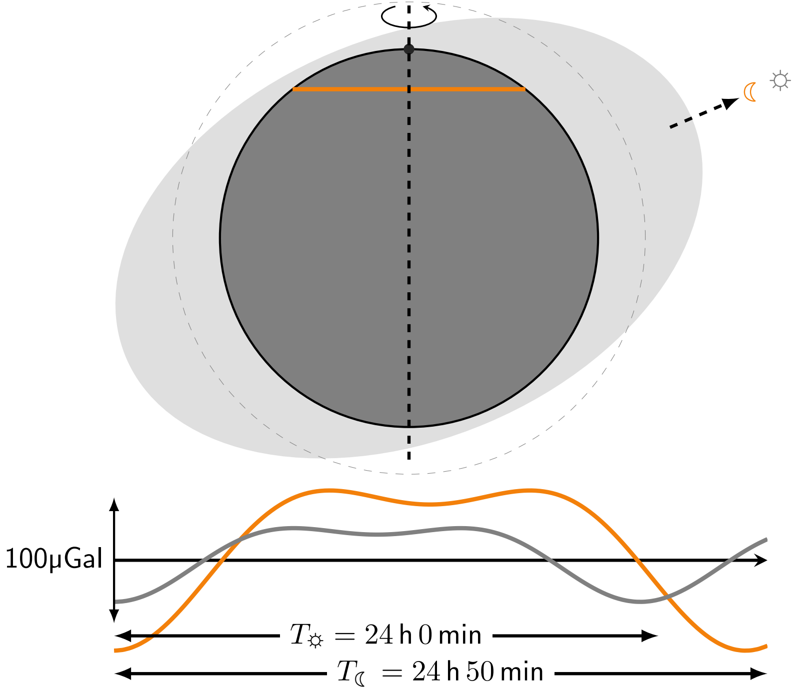


$\delta \neq 0$
☾
100μGal


100μGal


100µGal
$T = ?$


100µGal
$T_{☼}$
$T_{☾}$



100μGal
$T_{☼} = 24\,\mathrm{h}\,0\,\mathrm{min}$
$T_{☾} = 24\,\mathrm{h}\,50\,\mathrm{min}$