$mzon := 1.98 \cdot 10^{30}$ $G := 6.67 \cdot 10^{-11}$ $c := 3 \cdot 10^{8}$ $rzon := 680 \cdot 10^{6}$

$$g(r) := \frac{mzon \cdot G}{r^2}$$

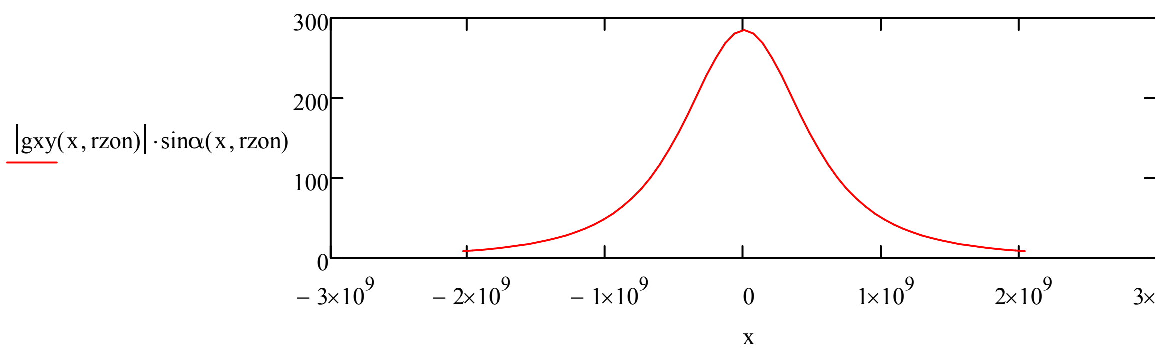
$$g(rzon) = 285.61$$

$$g\_alpha\_r(\alpha, rzon) := \begin{pmatrix} \frac{mzon \cdot G}{rzon^2} \cdot \sin(\alpha) \\ \frac{mzon \cdot G}{rzon^2} \cdot \cos(\alpha) \end{pmatrix}$$

$$\sin\alpha(x, rzon) := \sqrt{\frac{rzon^2}{x^2 + rzon^2}} \qquad \cos\alpha(x, rzon) := \sqrt{\frac{x^2}{x^2 + rzon^2}}$$

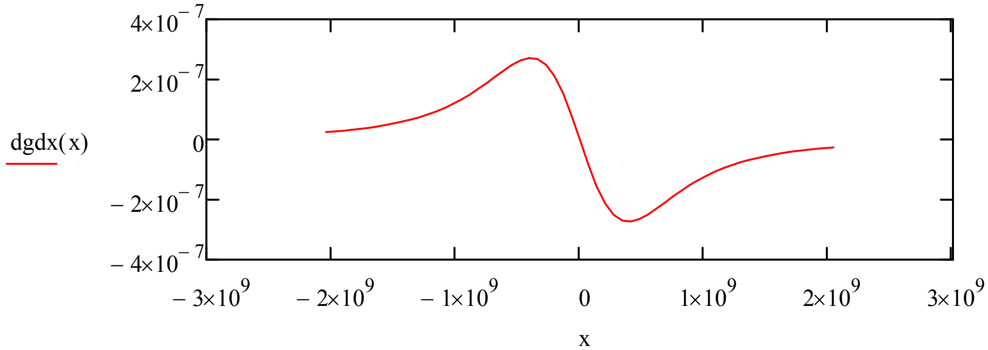
$$gxy(x, rzon) := \begin{bmatrix} \frac{mzon \cdot G}{x^2 + rzon^2} \cdot \sqrt{\frac{rzon^2}{\left(x^2 + rzon^2\right)}} \\ \frac{mzon \cdot G}{x^2 + rzon^2} \cdot \sqrt{\frac{x^2}{\left(x^2 + rzon^2\right)}} \end{bmatrix}$$

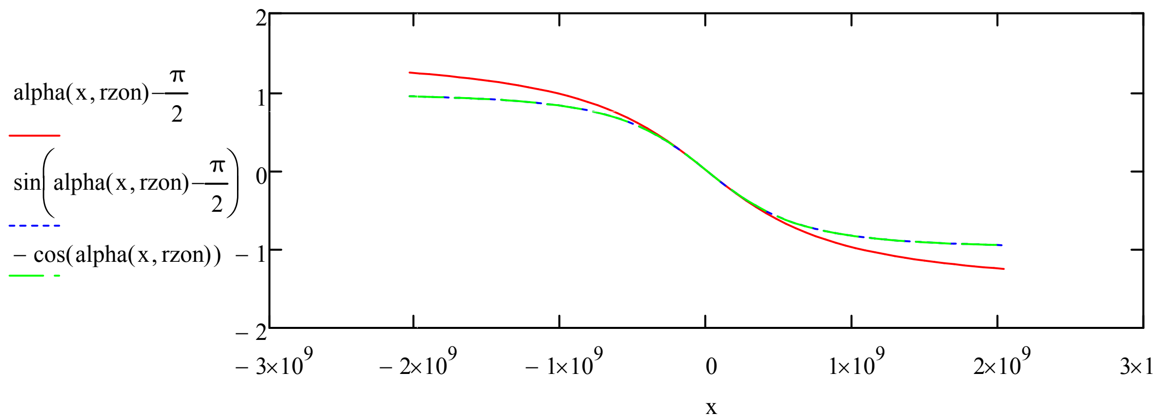
$x := -3 \cdot rzon, -2.9 \cdot rzon .. 3 \cdot rzon$



$$alpha(x, r) := \operatorname{acos}\left(\frac{x}{\sqrt{x^2 + rzon^2}}\right)$$

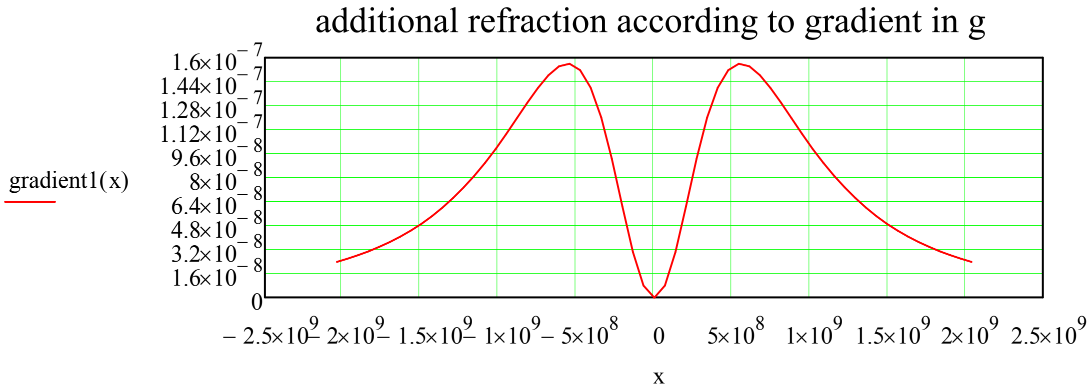
$$\mathrm{dgdx}(x) := \frac{d}{dx}\left|\mathrm{gxy}(x,\mathrm{rzon})\right|$$

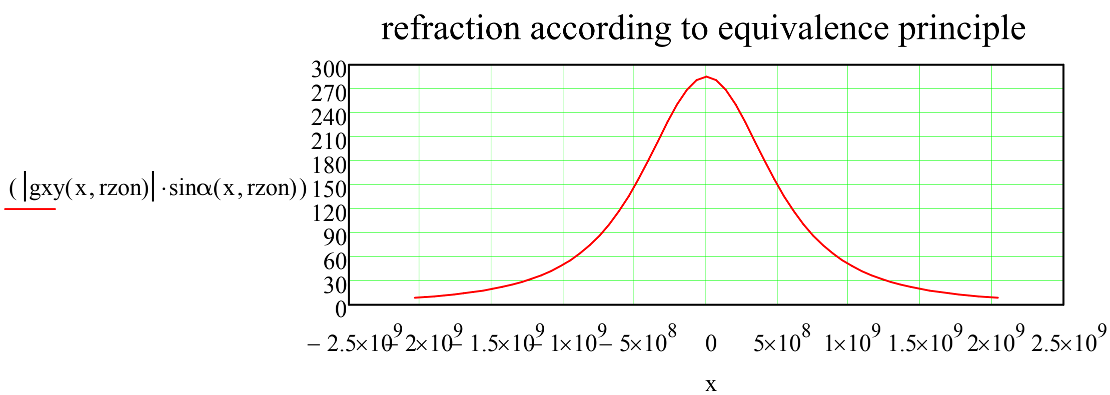




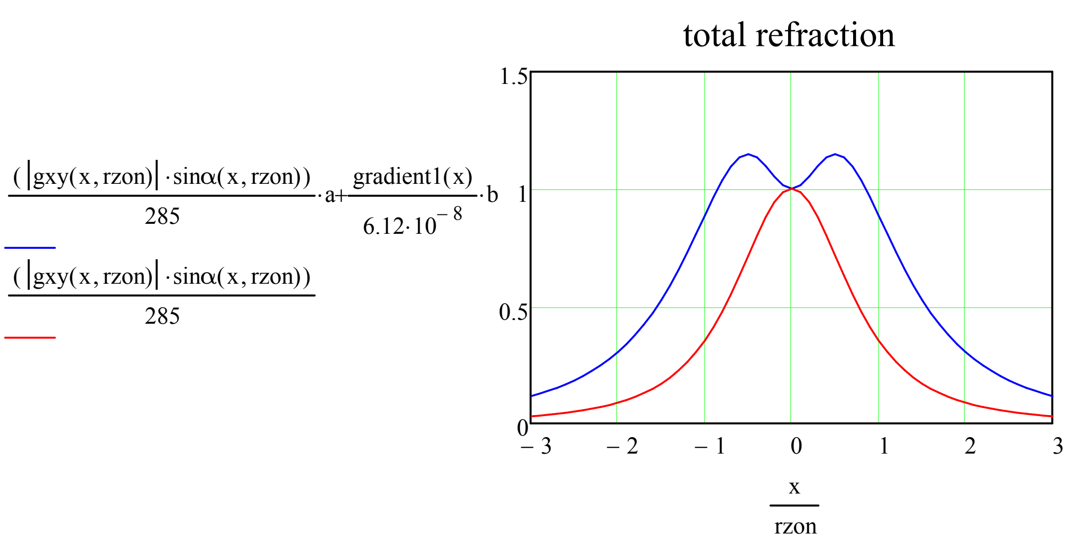
$$\frac{d}{dx}|g|\cdot\cos(\alpha) \qquad \mathrm{gradient} = \frac{d}{dx}|g|\cdot\cos(\alpha)$$

$$\mathrm{gradient1}(x) := \mathrm{dgdx}(x)\cdot-\cos(\mathrm{alpha}(x,\mathrm{rzon}))$$


additional refraction according to gradient in g
gradient1(x)
1.6×10^−7
1.44×10^−7
1.28×10^−7
1.12×10^−7
9.6×10^−8
8×10^−8
6.4×10^−8
4.8×10^−8
3.2×10^−8
1.6×10^−8
0
− 2.5×10^9 − 2×10^9 − 1.5×10^9 − 1×10^9 − 5×10^8 0 5×10^8 1×10^9 1.5×10^9 2×10^9 2.5×10^9
x


refraction according to equivalence principle
(|gxy(x, rzon)| · sinα(x, rzon))
300
270
240
210
180
150
120
90
60
30
0
− 2.5×10^9 − 2×10^9 − 1.5×10^9 − 1×10^9 − 5×10^8 0 5×10^8 1×10^9 1.5×10^9 2×10^9 2.5×10^9
x

a := 1   b := 0.22


total refraction
(|gxy(x, rzon)| · sinα(x, rzon)) / 285 · a + gradient1(x) / 6.12·10^−8 · b
(|gxy(x, rzon)| · sinα(x, rzon)) / 285
1.5
1
0.5
0
− 3 − 2 − 1 0 1 2 3
x / rzon

$$\frac{(|gxy(x, rzon)| \cdot sin\alpha(x, rzon))}{285} \cdot a + \frac{gradient1(x)}{6.12 \cdot 10^{-8}} \cdot b$$

$a = 1$ $\quad$ $b = 0.22$

$$\frac{\left[\left|\begin{bmatrix} \frac{mzon \cdot G}{x^2 + rzon^2} \cdot \sqrt{\frac{rzon^2}{\left(x^2 + rzon^2\right)}} \\ \frac{mzon \cdot G}{x^2 + rzon^2} \cdot \sqrt{\frac{x^2}{\left(x^2 + rzon^2\right)}} \end{bmatrix}\right| \cdot \sin(\alpha)\right]}{285} \cdot a + \frac{\left[\frac{d}{dx}\left|\begin{bmatrix} \frac{mzon \cdot G}{x^2 + rzon^2} \cdot \sqrt{\frac{rzon^2}{\left(x^2 + rzon^2\right)}} \\ \frac{mzon \cdot G}{x^2 + rzon^2} \cdot \sqrt{\frac{x^2}{\left(x^2 + rzon^2\right)}} \end{bmatrix}\right|\right] \cdot \left(\alpha - \frac{\pi}{2}\right)}{6.12 \cdot 10^{-8}} \cdot b$$

$$\frac{\left(\frac{d\phi}{dx}\right)}{\frac{m}{rzon^2}}$$


10^9

0^9