Ms 5103/2. Eötvös Loránd mágnesességi mérései

Mágnességi mérések

Variációs-eszköz.

negatív pólus van minden negatív együttható

Ösmer~~[illegible]~~ kendelfunctio[illegible] $\cancel{\xi \eta \zeta = 0}$

$$\cancel{\frac{\partial X}{\partial x} = \frac{1}{r^3} - 3\frac{x^2}{r^5}} \qquad x\ y\ z = 0$$

$$\cancel{\frac{\partial Y}{\partial y} = \frac{1}{r^3} - 3\frac{y^2}{r^5}}$$

$$\frac{\partial X}{\partial x} = \left(\frac{1}{r^3} - 3\frac{\xi^2}{r^5}\right) m$$

$$\frac{\partial Y}{\partial y} = \left(\frac{1}{r^3} - 3\frac{\eta^2}{r^5}\right) m$$

$$\frac{\partial Z}{\partial z} = \left(\frac{1}{r^3} - 3\frac{\zeta^2}{r^5}\right) m$$

$l\cos\delta$

$$\frac{\partial X}{\partial y} = \frac{\partial Y}{\partial x} = -3\frac{\xi\eta}{r^5} m$$

$$\frac{\partial X}{\partial z} = \frac{\partial Z}{\partial x} = -3\frac{\xi\zeta}{r^5} m$$

$$\frac{\partial Y}{\partial z} = \frac{\partial Z}{\partial y} = -3\frac{\eta\zeta}{r^5} m$$

Számításra nézve délibb pólusnál minden negatív

ξ helyébe $\xi'\ \eta'\ \zeta'$

Y föld declinatio δ inclinatio i,

$$\xi' = \xi - l\cos\delta\cos i$$

$$\eta' = -\eta$$

$$\zeta' = \zeta - l\cos\delta\sin i \qquad l\cos\delta\sin i \text{ hiány } \xi^2+\eta^2+\zeta^2 \text{ hoz képest}$$

$$\frac{1}{r'^3} = \frac{1}{\cancel{(\xi^2+\eta^2+\zeta^2-2\xi l\cos\delta\sin i)}^{\frac{3}{2}}} = \frac{1}{(\xi^2+\eta^2+\zeta^2-2l\xi\cos\delta\cos i-2l\zeta\cos\delta\sin i)^{\frac{3}{2}}}$$

$$\frac{1}{r'^5} = \frac{1}{\cancel{\xi^2+\eta^2+\zeta^2}} = \frac{1}{(\xi^2+\eta^2+\zeta^2-2l\xi\cos\delta\cos i-2l\zeta\cos\delta\sin i)^{\frac{5}{2}}}$$

$$\frac{1}{r'^3} = \frac{1}{r^3}\frac{1}{\left(1-\frac{2l\xi\cos\delta\cos i+2l\zeta\cos\delta\sin i}{r^2}\right)^{\frac{3}{2}}} = \cancel{\frac{1}{r^3}\left(1+\frac{2l\xi\cos\delta\cos i+2l\zeta\cos\delta\sin i}{r^2}\right)}$$

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

$$\frac{1}{r'^3} = \frac{1}{r^3}\left(1+\frac{3}{2}\frac{2l\xi\cos\delta\cos i+2l\zeta\cos\delta\sin i}{r^2}\right)$$

$$\frac{1}{r'^5} = \frac{1}{r^5}\left(1+\frac{5}{2}\frac{2l\xi\cos\delta\cos i+2l\zeta\cos\delta\sin i}{r^2}\right)$$

Kedves Tangl úr! Datum?

A ^mágneses^ variátió eszközre külső mágnes hatásának megitélhetése végett ide jegyzem a formulákat, melyek a mágnes Potentialjának második differentiál hányadosát adják.

Coordinátarendszer: A kezdőpont a felfüggesztett tehát azon mágnes tengelyének közepe, melyre a translatorikus erő kerestetik.

Az X Z sík ezen a kezdőponton és a külső mágnes középpontján keresztül fektetett függőleges sík, abban Z lefelé.

Külső mágnesre vonatkozók. —

Momentuma $\mathfrak{M}$

~~A~~ E mágnes ~~Északi pole~~ XZ síkra vetett vetületének Déli pólusától az északi pólus felé haladó egyenes és az X tengely pozitiv iránya által képezett inclinatio szöglet $= \underline{i}$

E mágnes vízszintes vetületének déli polusától az északi húzott egyenes és az X tengely által, ~~az~~ a pozitiv X-től a pozitiv Y felé számított Declinatio szöglet $\underline{\delta}$

$$a^2+b^2+c^2=r^2$$

A mágnes középpontjának összrendezői a, b, c ~~ok~~

akkor.

$$\frac{\partial^2 V}{\partial x^2} = \frac{\partial X}{\partial x} = \frac{3M\cos\delta}{r^5}\left(-3a\cos i - c\sin i + \frac{5a^2}{r^2}(a\cos i + c\sin i)\right)$$

$$\frac{\partial^2 V}{\partial y^2} = \frac{\partial Y}{\partial y} = \frac{3M\cos\delta}{r^5}\left(-a\cos i - c\sin i + \frac{5b^2}{r^2}(a\cos i + c\sin i)\right)$$

$$\frac{\partial^2 V}{\partial z^2} = \frac{\partial Z}{\partial z} = \frac{3M\cos\delta}{r^5}\left(-a\cos i - 3c\sin i + \frac{5c^2}{r^2}(a\cos i + c\sin i)\right)$$

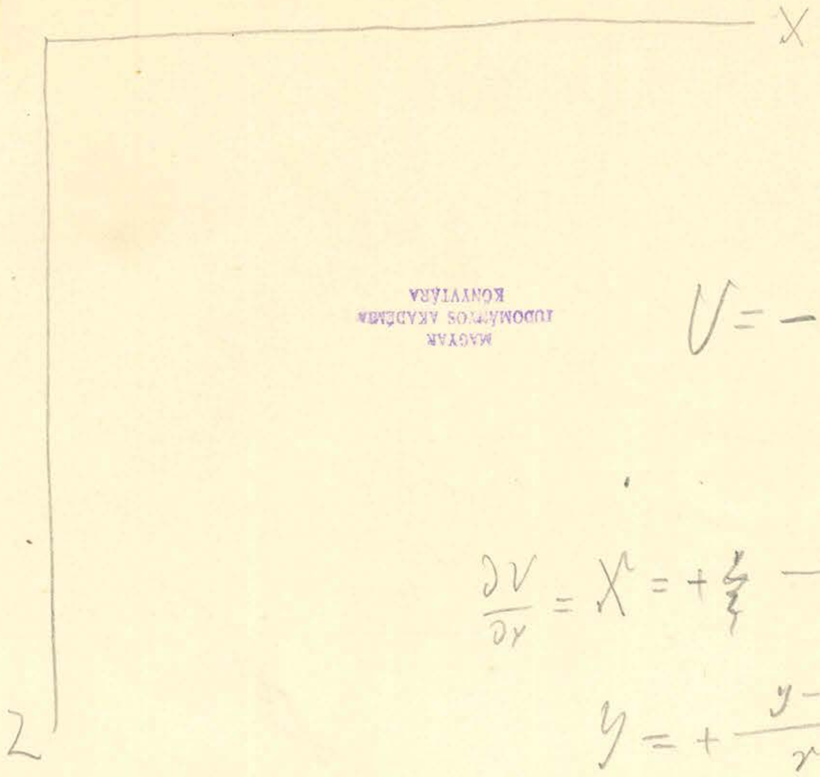
$$\Delta V = 0$$

$$\frac{\partial^2 V}{\partial x\partial y} = \frac{\partial X}{\partial y} = \frac{\partial Y}{\partial x} = 0$$

$$\frac{\partial^2 V}{\partial x\partial z} = \frac{\partial X}{\partial z} = \frac{\partial Z}{\partial x} = \frac{3M\cos\delta}{r^5}\left(-a\sin i - c\cos i + \frac{5ac}{r^2}(a\cos i + c\sin i)\right)$$

$$\frac{\partial^2 V}{\partial y\partial z} = \frac{\partial Y}{\partial z} = \frac{\partial Z}{\partial y} = 0$$

Ezekben a kifejezésekben el vannak hanyagolva az $\frac{l}{r}$ nek magasabb hatványai, a hol l a mágnes tengelyének félhossza.



$$V = -\frac{m}{\sqrt{(x-\xi)^2+(y-\eta)^2+(z-\zeta)^2}}$$

$$\frac{\partial V}{\partial x} = X = +\cancel{\xi}\,\frac{(x-\xi)}{r^3}$$

$$Y = +\frac{y-\eta}{r^3}$$

$$Z = +\frac{z-\zeta}{r^3}$$

[illegible]

$$\frac{\partial^2 V}{\partial x^2} = \frac{\partial X}{\partial x} = \frac{1}{r^3} - 3\,\frac{(x-\xi)^2}{r^5}$$

$$\frac{\partial^2 V}{\partial y^2} = \frac{\partial Y}{\partial y} = \frac{1}{r^3} - 3\,\frac{(y-\eta)^2}{r^5}$$

$$\frac{\partial^2 V}{\partial z^2} = \frac{\partial Z}{\partial z} = \frac{1}{r^3} - 3\,\frac{z-\zeta}{r^5}$$

$$\frac{\partial^2 V}{\partial x \partial y} = \frac{\partial X}{\partial y} = \frac{\partial Y}{\partial x} = -3\,\frac{(x-\xi)(y-\eta)}{r^5}$$

$$\frac{\partial^2 V}{\partial x \partial z} = \frac{\partial X}{\partial z} = \frac{\partial Z}{\partial x} = -3\,\frac{(x-\xi)(z-\zeta)}{r^5}$$

$$\frac{\partial^2 V}{\partial y \partial z} = \frac{\partial Y}{\partial z} = \frac{\partial Z}{\partial y} = -3\,\frac{(y-\eta)(z-\zeta)}{r^5}$$

$$\frac{1}{\varrho} = \frac{1}{r}\left(1 - \frac{f}{r^2}\right) \qquad \frac{1}{\varrho'} = \frac{1}{r}\left(1 + \frac{f}{r^2}\right)$$

$$V = -\mu\left(\frac{1}{\varrho} - \frac{1}{\varrho'}\right)$$

$$\frac{2f}{r^0}$$

$$V = \mu\left(\frac{1}{\varrho'} - \frac{1}{\varrho}\right)$$

$$f = \frac{1}{2}(a\,l\cos i\cos\delta + b\,l\cos i\sin\delta + c\,l\sin i)$$

$$V = \mu$$

$$\boxed{\begin{gathered} \cancel{-3\mu}\quad \frac{l}{2}\cos i\cos\delta = \alpha \qquad \frac{l}{2}\cos i\sin\delta = \beta \\ -3\mu\frac{(a+\alpha)(b+\beta)}{r^5}\left(1 - 5\frac{f}{r^2}\right) + 3\mu\frac{(a-\alpha)(b-\beta)}{r^5}\left(1 + 5\frac{f}{r^2}\right) \\ -\frac{6\mu}{r^5}(a\beta + \alpha b) + \frac{30\mu ab f}{r^7}. \end{gathered}}$$

$$\varrho = r\left\{1 + \frac{1}{2}\frac{a\,l\cos i\cos\delta + b\,l\cos i\sin\delta + c\,l\sin i}{r^2}\right)$$

$$\frac{1}{\varrho} = \frac{1}{r}\left(1 - \frac{1}{2}\right.$$

$$\frac{6\mu a f}{r^5} - \frac{\mu\,l\cos i\cos\delta}{r^3}$$

$$\frac{\mu}{r^3}\left(1 - 3\frac{f}{r^2}\right) - \frac{\mu(3a^2 + 3a\,l\cos i\cos\delta)}{r^5}\left(1 - 5\frac{f}{r^2}\right)$$

$$\cancel{\mu}\frac{\mu\left(a - \frac{l}{2}\cos i\cos\delta\right)}{r^3}\left(1 + 3\frac{f}{r^2}\right) \quad 3\frac{\mu a f}{r^5}$$

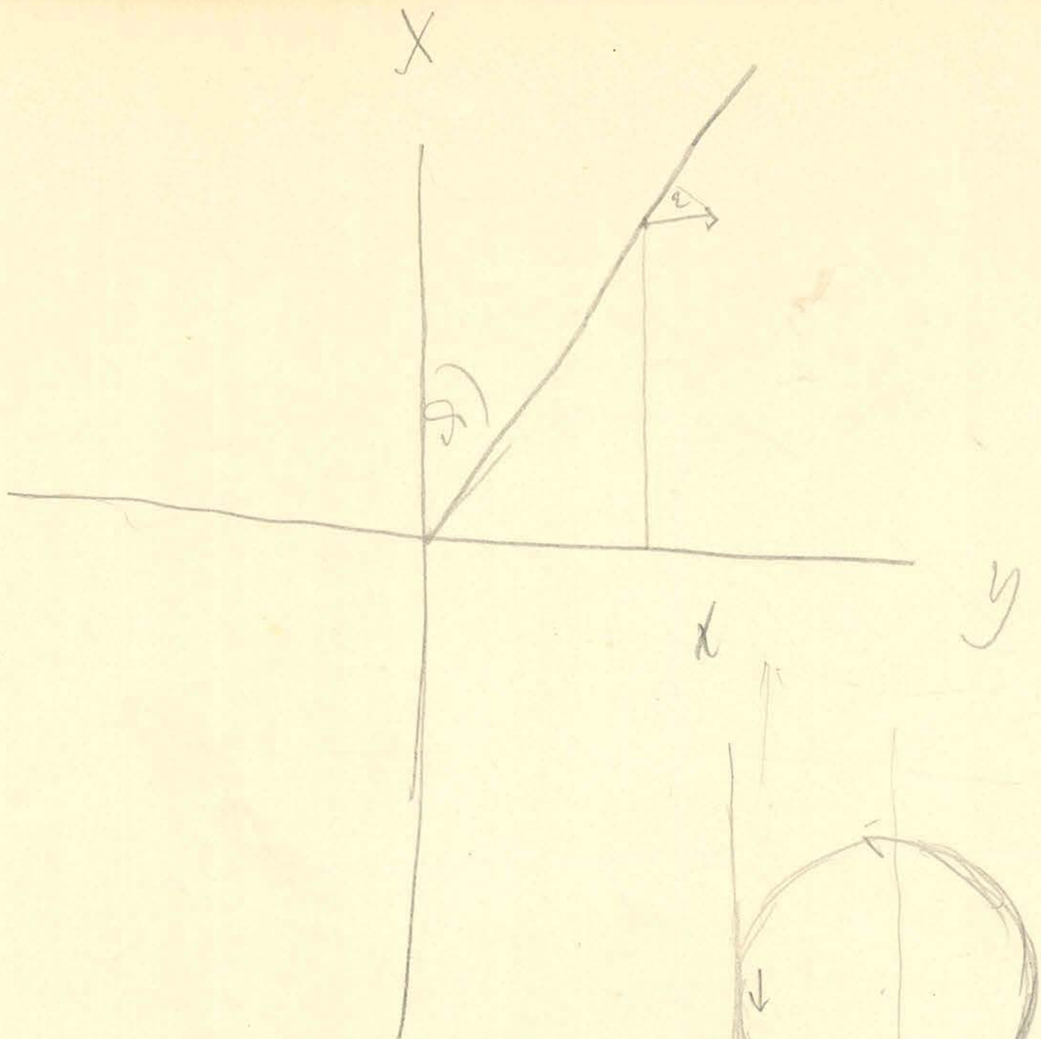
$$-\frac{\mu}{r^3}\left(1 + 3\frac{f}{r^2}\right) + \mu\frac{(3a^2 - 3a\,l\cos i\cos\delta)}{r^5}\left(1 + 5\frac{f}{r^2}\right)$$

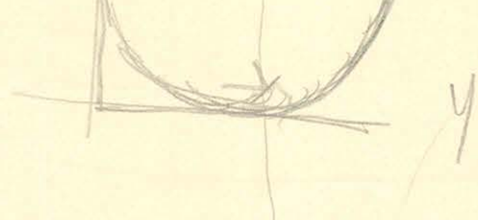
$$-\mu\frac{a + \frac{l}{2}\cos i\cos\delta}{r^3}\left(1 - 3\frac{f}{r^2}\right)$$

$$\frac{\mu}{r^3}.$$

$$-\frac{6\mu f}{r^5} + \frac{30\mu a^2 f}{r^7} - \frac{6a\mu l\cos i\cos\delta}{r^5}$$

$$\cancel{-6\mu} \quad -\frac{3\mu}{r^5}(3a\cos i\cos\delta + b\cos i\sin\delta + c\sin i) + \frac{15\mu a^2}{r^7}(a\cos i\cos\delta + b\cos i\sin\delta + c\sin i)$$


X
x
y


y

$$F = M\cos\gamma\, y_0 - M\sin\gamma\, X_0 + Ml\sin 2\gamma\left(\frac{\partial Y}{\partial y} - \frac{\partial X}{\partial x}\right) + 2Ml\cos 2\gamma\,\frac{\partial X}{\partial y}$$

$$F = 2Ml\sin 2\gamma\left(\frac{\partial Y}{\partial y} - \frac{\partial X}{\partial x}\right) + 4Ml\cos 2\gamma\,\frac{\partial X}{\partial y}$$

$$\Lambda = \{m_\xi\}$$

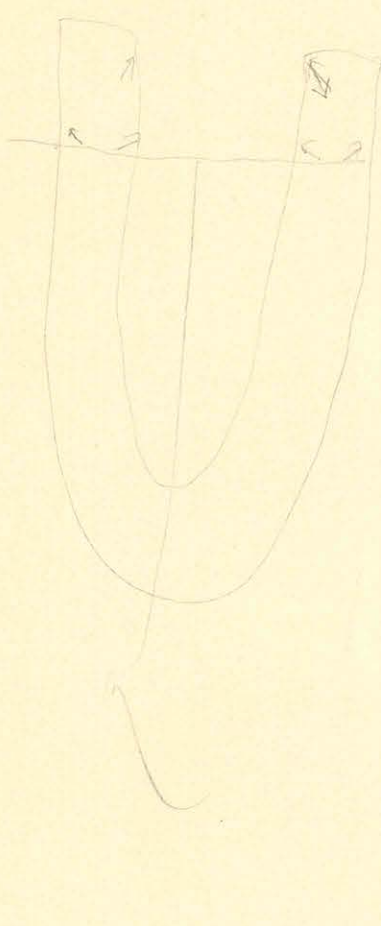
$$F = \sin 2\gamma\,\{m_\xi\}\left(\frac{\partial Y}{\partial y} - \frac{\partial X}{\partial x}\right) + 2\cos 2\gamma\,\{m_\xi\}\,\frac{\partial X}{\partial y}.$$

$$\{m_\xi\} = 2Ml.$$

$\{m_\xi\} = a$

$\{m_\eta\} = 0$

$\{\xi_\xi\} = 0$



$$\Big|_{l-\frac{\lambda}{2}}^{l+\frac{\lambda}{2}} \frac{l^3}{3}$$

$a+b$ $\quad a^2+b^2+2ab$ $\quad a^3+b^3+3ab^2+3a^2b.$

$a^3+ab^2+2a^2b$

$a^2b+b^3+2ab^2$

$$l^3+\frac{\lambda^3}{8}+\frac{3}{4}l\lambda^2+\frac{3}{2}l^2\lambda$$

$$l^3-\frac{\lambda^3}{8}+\frac{3}{4}l\lambda^2-\frac{3}{2}l^2\lambda$$

$$\frac{\lambda^3}{4}: \quad \frac{\lambda^3}{12}+l^2\lambda$$

$$\frac{\partial X}{\partial x}=\frac{6}{r^4}M \qquad \frac{\partial^2 X}{\partial x^2}=-24\frac{1}{r^5}$$

$$\frac{\partial Y}{\partial y}=-\frac{3}{r^4}M \qquad \cancel{\frac{\partial^2 Y}{\partial y^2}=+12\frac{1}{r^5}} \quad 0.$$

$$\frac{\partial Y}{\partial x}=0$$

$$\cancel{18}\left(\frac{m\lambda^2}{12}+ml^2\right)\frac{M}{r^5}$$

$$-\frac{2mM\sin\vartheta}{r^3}$$

$\sum \xi m_\xi - \sum \eta m_\eta =$

$$m_y x + m_x y = (a \sin \gamma + b \cos \gamma)\, m \cos i$$

$$m_x x - m_y y = (a \cos \gamma - b \sin \gamma)\, m \cos i$$

$$m_z x + m_x z = a\, m \sin i$$

$$m_z y + m_y z = b\, m \sin i$$

[illegible] a [illegible] [illegible] · és [illegible]

$$\cancel{m_x = m \cos i \cos(\gamma+\alpha)} \quad m_x = h \cos(\gamma+\alpha)$$

$$\cancel{m_y = m \cos i \sin \gamma + \alpha} \quad m_y$$

$$m_x = h \cos(\gamma+\alpha) = \cos \gamma\, m_\xi - \sin \gamma\, m_\eta = \cos \gamma\, m \cos i = h \cos \gamma$$

$$m_y = h \sin(\gamma+\alpha) = \sin \gamma\, m_\xi + \cos \gamma\, m_\eta = \sin \gamma\, m \cos i = h \sin \gamma$$

$$m \cos i = \underline{h}$$

$$m \sin i = \underline{v}$$

a [illegible] [illegible] ·

$$F = h \cos \gamma\, Y_0 - h \sin \gamma\, X_0 + h(a \sin \gamma + b \cos \gamma)\left(\frac{\partial Y}{\partial y} - \frac{\partial X}{\partial x}\right) + 2h(a \cos \gamma - b \sin \gamma)\frac{\partial X}{\partial y}$$

$$+ a v \frac{\partial Y}{\partial z} - b v \frac{\partial X}{\partial z}$$

[illegible] [illegible] $a = l \cos \delta \quad b = l \sin \delta$

$$F = h \cos \gamma\, Y_0 - h \sin \gamma\, X_0 + h l \sin(\delta+\gamma)\left(\frac{\partial Y}{\partial y} - \frac{\partial X}{\partial x}\right) + 2 h l \cos(\delta+\gamma)\frac{\partial X}{\partial y}$$

$$+ v l \cos \gamma \frac{\partial Y}{\partial z} - v l \sin \gamma \frac{\partial X}{\partial z}$$

[illegible] [illegible] γ [illegible] $\underline{\delta + \varepsilon}$ a hol ε a [illegible] [illegible] a

[illegible] [illegible] az 1-el [illegible] .

$M_x = 0 \qquad M_y = M \qquad M_z = 0 \qquad x = r \qquad y = 0 \qquad z = 0$

$$\frac{\partial^2 X}{\partial x^2} = 0$$

$$\frac{\partial^2 Y}{\partial y^2} = +\frac{9}{r^5} M$$

$$\frac{\partial^2 Y}{\partial x^2} = -\frac{3}{r^5} M + \frac{3M}{r^5} = 0$$

$$\frac{\partial^2 X}{\partial y^2} = 0$$

$$-\frac{36}{6}\frac{M}{r^5}$$

$$-\frac{36}{6} \qquad -6\frac{M}{r^5}\frac{m}{4}\lambda'^2$$

$$-\frac{3}{2}\frac{Mm}{r^3}\frac{\lambda'^2}{r^5}$$

$$\frac{2Mm}{r^3}\cdot\frac{\lambda'^2}{r^2} \qquad \frac{\lambda'^2}{r^2}$$

6,5334750	6,9069927	6,1741286	6,5650977
8 3311217	7 9597487	87960	84076
14,8646067	14,8667414	14,9701	14,9696

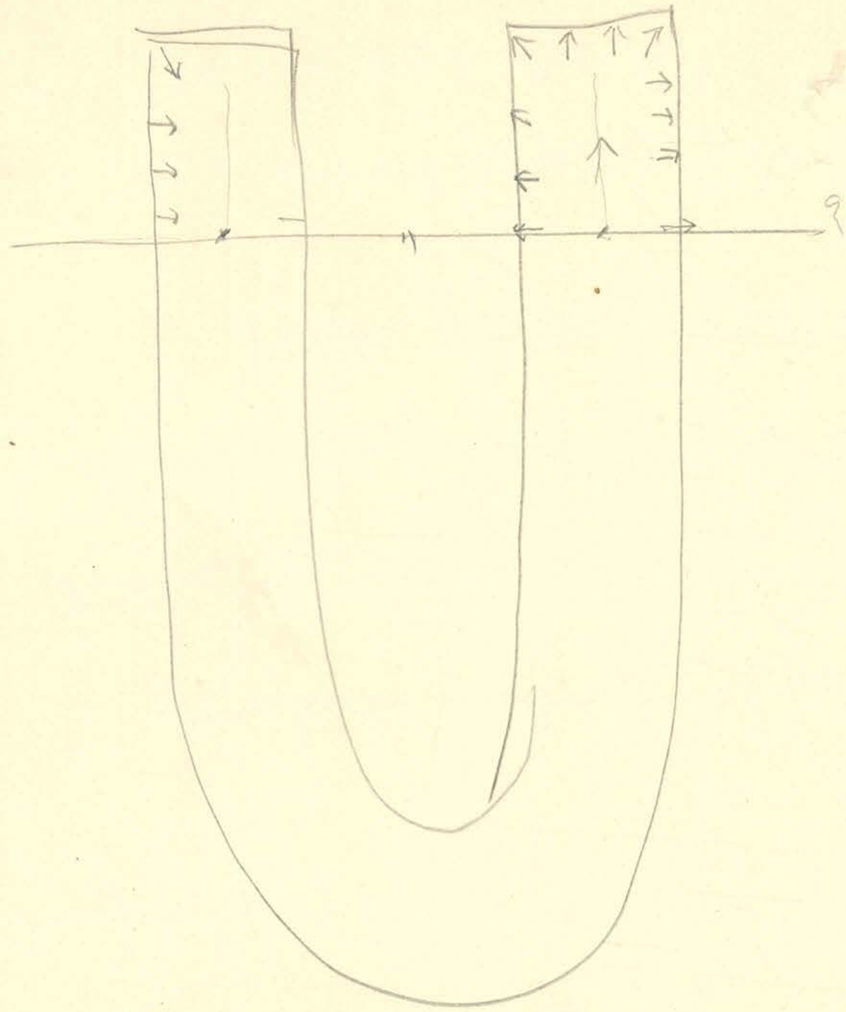
~~a M cos i~~

$a M \sin i + c M \cos i \cos\gamma \frac{\partial Y}{\partial z}$

$- b M \sin i - c M \cos i \sin\gamma \frac{\partial X}{\partial z}$

$+ c M \cos i \left(\cos\gamma \frac{\partial Y}{\partial z} - \sin\gamma \frac{\partial X}{\partial z}\right)$

$+ M \sin i \, l \left(\cos\delta \frac{\partial Y}{\partial z} - \sin\delta \frac{\partial X}{\partial z}\right)$



$\sum \xi m_\xi = 0$

$\sum \eta m_\eta = 0$

$\sum \xi m_\zeta = 0$

$\sum \eta m_\xi =$

$\sum \xi m_\eta =$ ez a [illegible]

$\sum \xi m_\xi = 0$

$$m_x X - m_y Y = a m_\xi \cos i \cos\gamma - a m_\zeta \sin i \cos\gamma - a m_\eta \sin\gamma$$

$$\xi m_\xi \cos^2 i \cos^2\gamma - \xi m_\zeta \sin i \cos i \cos^2\gamma - \xi m_\eta \cos i \sin\gamma \cos\gamma$$

$$- \zeta m_\xi \sin i \cos i \cos^2\gamma + \zeta m_\zeta \sin^2 i \cos^2\gamma + \zeta m_\eta \sin i \sin\gamma \cos\gamma$$

$$- \eta m_\xi \cos i \sin\gamma \cos\gamma + \eta m_\zeta \sin i \sin\gamma \cos\gamma + \eta m_\eta \sin^2\gamma$$

$$- \quad b m_\xi \cos i \sin\gamma - b m_\zeta \sin i \sin\gamma + b m_\eta \cos\gamma$$

$$+ \xi m_\xi \cos^2 i \sin^2\gamma - \xi m_\zeta \sin i \cos i \sin^2\gamma + \xi m_\eta \cos i \sin\gamma \cos\gamma$$

$$- \zeta m_\xi \sin i \cos i \sin^2\gamma + \zeta m_\zeta \sin^2 i \sin^2\gamma - \zeta m_\eta \sin i \sin\gamma \cos\gamma$$

$$+ \eta m_\xi \cos i \sin\gamma \cos\gamma - \eta m_\zeta \sin i \sin\gamma \cos\gamma + \eta m_\eta \cos^2\gamma$$

$$m_\xi \cos i (a\cos\gamma - b\sin\gamma) + m_\eta (b\cos\gamma + a\sin\gamma) + m_\zeta \sin i (b\sin\gamma - a\cos\gamma)$$

$$+ m_\xi \xi \cos^2 i \cos 2\gamma - m_\eta \eta \cos 2\gamma + m_\zeta \zeta \overset{\sin^2 i}{\cos 2\gamma}$$

$$- \xi m_\eta \sin 2\gamma \cos i - \eta m_\xi \cos i \sin 2\gamma$$

$$+ \eta m_\zeta \sin i \sin 2\gamma + \zeta m_\eta \sin i \sin 2\gamma$$

$$- \zeta m_\xi \sin i \cos i \cos 2\gamma - \xi m_\zeta \sin i \cos i \cos 2\gamma$$

$$\sin 2\gamma \left\{ \sin i (\eta m_\zeta + \zeta m_\eta) - \cos i (\xi m_\eta + \eta m_\xi) \right\}$$

$$+ \cos 2\gamma \left\{ m_\xi \xi \cos^2 i - m_\eta \eta + m_\zeta \zeta \sin^2 i \right.$$

$$\left. - (m_\zeta \xi + m_\xi \zeta) \sin i \cos i \right\}.$$

$$m_z X + m_x Z = a m_\zeta \cos i + a m_\xi \sin i$$

$$m_\zeta \xi \cos^2 i \cos\gamma + m_\zeta \zeta \sin i \cos i \cos\gamma + m_\xi \zeta \cos^2 i \cos\gamma + m_\xi \xi \sin i \cos i \cos\gamma$$

$$- m_\zeta \xi \sin i \cos i \cos\gamma - m_\xi \zeta \sin^2 i \cos\gamma - m_\zeta \zeta \sin i \cos i \cos\gamma - m_\zeta \xi \sin^2 i \cos\gamma$$

$$- m_\zeta \eta \cos i \sin\gamma - m_\xi \eta \sin i \sin\gamma - m_\eta \zeta \cos i \sin\gamma - m_\eta \xi \sin i \sin\gamma$$

$$= a(m_\zeta \cos i + m_\xi \sin i) + \cos\gamma \left\{ m_\zeta \xi \sin 2i - m_\xi \zeta \sin 2i + (m_\zeta \xi + m_\xi \zeta) \cos 2i \right\}$$

$$- \sin\gamma \left(\sin i (m_\xi \eta + m_\eta \xi) + \cos i (m_\zeta \eta + m_\eta \zeta) \right)$$

$$+ c \cos\gamma (m_\xi \cos i - m_\zeta \sin i) - c\, m_\eta \sin\gamma$$

$\underline{m_\zeta y + m_\eta z} =$

$b\, m_\zeta \cos i + b\, m_\xi \sin i \qquad \qquad c\sin\gamma\,(m_\xi \cos i - m_\zeta \sin i) + c\, m_\eta \cos\gamma$

$\cancel{\xi m_\zeta \cos^2 i \sin\gamma + \xi m_\xi \sin i \cos i \sin\gamma} \qquad + \cancel{\zeta m_\xi \cos^2 i \sin\gamma + \xi m_\zeta \sin i \cos i \sin\gamma}$

$\cancel{-\zeta m_\zeta \sin i \cos i \sin\gamma - \zeta m_\xi \sin^2 i \sin\gamma} \qquad \cancel{-\xi m_\zeta \sin i \cos i \sin\gamma - \xi m_\zeta \sin^2 i \sin\gamma}$

$\cancel{+\eta m_\zeta \cos i \cos\gamma + \eta m_\xi \sin i \cos\gamma} \qquad \cancel{+\zeta m_\eta \cos i \cos\gamma + \xi m_\eta \sin i \cos\gamma}$

$$= b\,(m_\zeta \cos i + m_\xi \sin i) + \sin\gamma \left\{ \xi m_\zeta \sin 2i - \zeta m_\zeta \sin 2i + (m_\zeta \xi + m_\xi \zeta)\cos 2i \right\}$$

$$+ \cos\gamma \left\{ \sin i\,(\eta m_\xi + \xi m_\eta) + \cos i\,(\eta m_\zeta + m_\eta \zeta) \right\}$$

$$+ c\sin\gamma\,(m_\xi \cos i - m_\zeta \sin i) + c\, m_\eta \cos\gamma$$

$$F = \left\{ \cos\gamma\,(m_\xi \cos i - m_\zeta \sin i) - m_\eta \sin\gamma \right\} Y_0 - \left\{ \sin\gamma\,(m_\xi \cos i - m_\zeta \sin i) + m_\eta \cos\gamma \right\} X_0$$

$$+ \left\{ m_\xi \cos i\,(a\sin\gamma + b\cos\gamma) + m_\eta\,(a\cos\gamma - b\sin\gamma) - m_\zeta \sin i\,(a\sin\gamma + b\cos\gamma) \right\} \left(\frac{dY}{dy} - \frac{\partial X}{\partial x} \right)$$

$$+ 2\left\{ m_\xi \cos i\,(a\cos\gamma - b\sin\gamma) - m_\eta\,(a\sin\gamma + b\cos\gamma) + m_\zeta \sin i\,(b\sin\gamma - a\cos\gamma) \right\} \frac{\partial X}{\partial y}$$

$$+ \left\{ a\,(m_\zeta \cos i + m_\xi \sin i) + c\cos\gamma\,(m_\xi \cos i - m_\zeta \sin i) - c\, m_\eta \sin\gamma \right\} \frac{\partial Y}{\partial z}$$

$$- \left\{ b\,(m_\zeta \cos i + m_\xi \sin i) + c\sin\gamma\,(m_\xi \cos i - m_\zeta \sin i) + c\, m_\eta \cos\gamma \right\} \frac{\partial X}{\partial z}$$

$$+ \Big[\sin 2\gamma \left\{ m_\xi \xi \cos^2 i - m_\eta \eta + m_\zeta \zeta \sin^2 i - (m_\zeta \xi + m_\xi \zeta) \sin i \cos i \right\} +$$

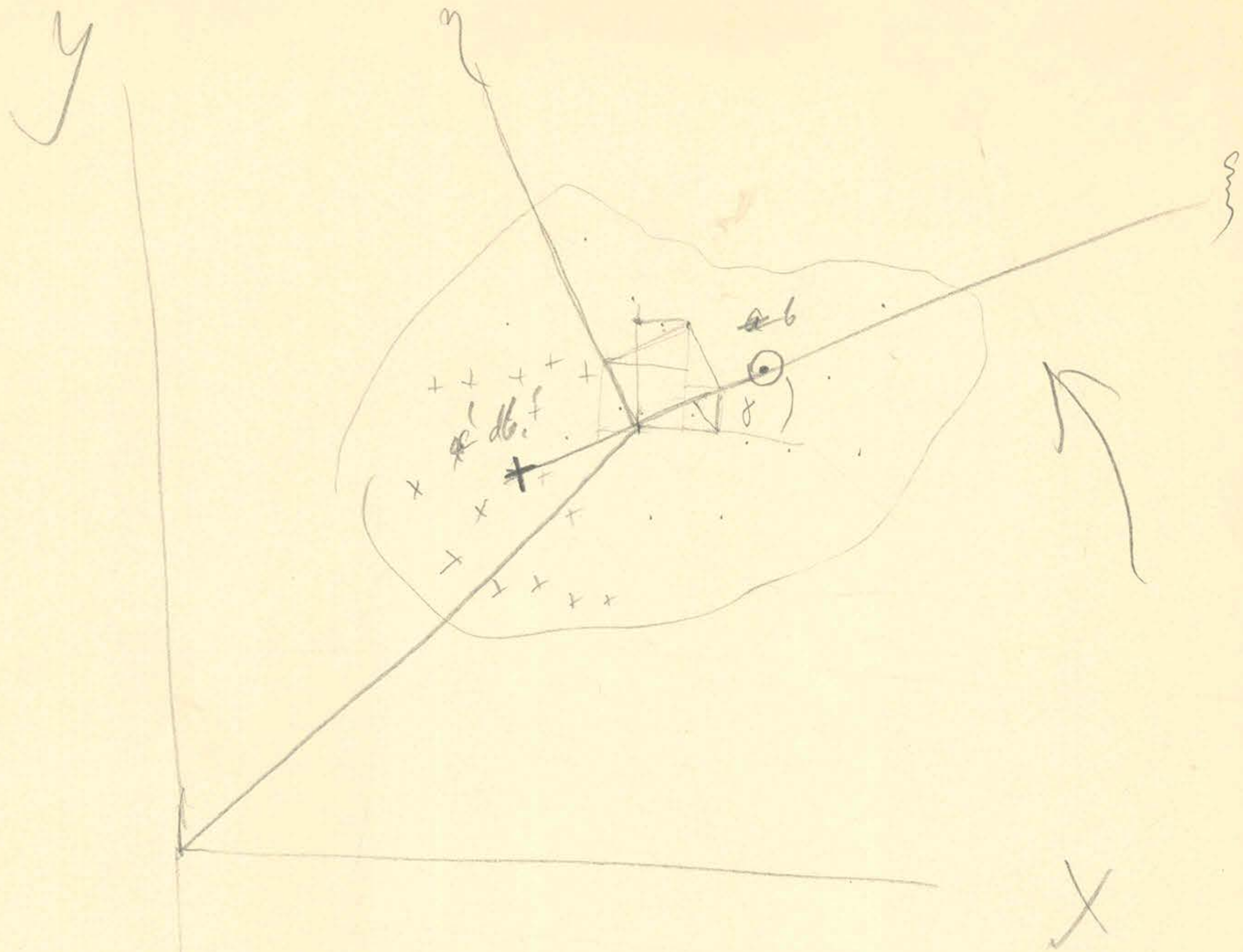
$$\cos 2\gamma \left\{ \cos i\,(m_\xi \eta + m_\eta \xi) - \sin i\,(m_\eta \zeta + m_\zeta \eta) \right\} \Big] \left(\frac{\partial Y}{\partial y} - \frac{\partial X}{\partial x} \right)$$

$$+ \Big[\sin 2\gamma \left\{ \sin i\,(m_\eta \zeta + m_\zeta \eta) - \cos i\,(m_\xi \eta + m_\eta \xi) \right\} +$$

$$+ \cos 2\gamma \left\{ m_\xi \xi \cos^2 i - m_\eta \eta + m_\zeta \zeta \sin^2 i) - (m_\zeta \xi + m_\xi \zeta) \sin i \cos i \right\} \Big] \frac{\partial X}{\partial y}$$

$$+ \Big[\cos\gamma \left\{ m_\xi \xi \sin 2i - m_\zeta \zeta \sin 2i + (m_\zeta \xi + m_\xi \zeta) \cos 2i \right\} - \sin\gamma \left\{ \sin i\,(m_\xi \eta + m_\eta \xi) + \cos i\,(m_\zeta \eta + m_\eta \zeta) \right\} \Big] \frac{\partial Y}{\partial z}$$

$$+ \Big[\cos\gamma \left\{ \sin i\,(m_\xi \eta + m_\eta \xi) + \cos i\,(m_\zeta \eta + m_\eta \zeta) \right\} + \sin\gamma \left\{ m_\xi \xi \sin 2i - m_\zeta \zeta \sin 2i + (m_\zeta \xi + m_\xi \zeta) \cos i \right\} \Big] \frac{\partial X}{\partial z}$$



$$F\Big(\sum m x y \; - F \sum \mu x y + y_0 a \sum m - X_0 b \sum \mu$$
$$+ y_0 a' \sum \mu + X_0 b' \sum \mu .$$

F

$$\cancel{F \sum m(a+\xi)(b+\eta)}$$

$$F a b \sum m + F \sum \xi \eta m + F a \sum$$

$$\xi = \sum (x-a)\cos\gamma$$

$$(x-a) = \xi\cos\gamma - \eta\sin\gamma$$

$$(y-b) = \eta\cos\gamma + \xi\sin\gamma .$$

$$x = a + \xi\cos\gamma - \eta\sin\gamma$$

$$y = b + \eta\cos\gamma + \xi\sin\gamma$$

$$\left(a \sum m z\right) \frac{\partial y}{\partial z} .$$

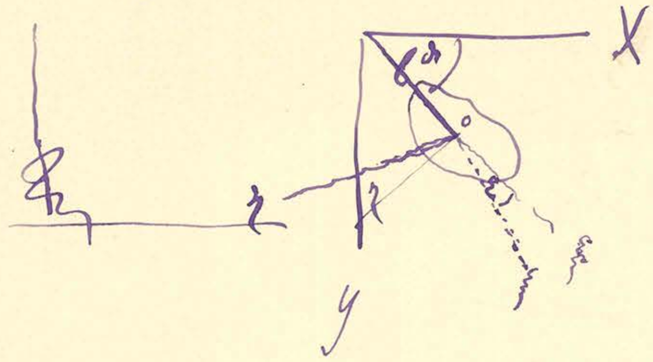
$$c + \xi$$

$$a \sum$$

Egy mágnes elemi mágnesnek hatása.

Ξ sarnak egyben összegek teendők.

~~Legyenek~~



~~Legyenek~~

Tekintsük be a mágnesnek egy összefüggő kezdőpontját a ξ tengely Ξ szögletét képezzen az l-el. $l^2 = a^2 + b^2$

Az egyes mágnes γ szögletet képezzen az X tengellyel

akkor.

$$\xi = \quad x = a + \xi\cos\gamma - \eta\sin\gamma$$
$$y = b + \eta\cos\gamma + \xi\sin\gamma$$

továbbá

$$m_{\mu}^2 = h^2 + v^2 \qquad h \text{ a } \ldots \qquad v = z \text{ komponens } \ldots$$

$$m_x = h\cos(\gamma+\alpha) \qquad m_y = h\sin(\gamma+\alpha) \qquad m_z = v$$

akkor.

$$m_y x + m_x y = ah\sin\gamma + bh\cos\gamma + \xi h\sin 2\gamma + \eta h\cos 2\gamma$$
$$m_x x - m_y y = ah\cos\gamma - bh\sin\gamma + \xi h\cos 2\gamma - \eta h\sin 2\gamma$$
$$m_z x + m_x z = av + \xi v\cos\gamma - \eta v\sin\gamma + hz\cos\gamma$$
$$m_z y + m_y z = bv + \eta v\cos\gamma + \xi v\sin\gamma + hz\sin\gamma$$

Jegyezzük

$$\cancel{\xi m_\xi \cos\alpha - \xi m_\eta \sin\alpha}$$
$$\cancel{- \eta m_\xi \cos\alpha - \eta m_\eta \sin\alpha}$$

$$\cancel{\frac{\xi m_\xi^2}{h} - \frac{\xi m_\eta^2}{h}}$$
$$\cancel{- \frac{\eta m_\xi m_\eta}{h} - \frac{\eta m_\xi m_\eta}{h}}$$

$$\frac{1}{h}\left(\xi m_\xi^2 - \xi m_\eta^2 - 2\eta m_\eta m_\xi\right)$$

Σm

$\sqrt{m_\xi^2 + m_\eta^2}$ $\quad m_\xi + m$

$$\xi h\cos 2\alpha - \eta h\sin 2\alpha$$
$$h(\xi\cos 2\alpha - \eta\sin 2\alpha)$$

$y_0 \int dv J\lambda \quad = \quad \iint J dv (\mu x + \lambda y)$

$J dv = m$

$\cancel{dy}$

$\cancel{\iint dv}$

$\int$

$x = a + \xi \cos\gamma - \eta \sin\gamma$

$y = b + \eta \cos\gamma + \xi \sin\gamma$

$m_x = h \cos\gamma = h \cos(\vartheta + \varepsilon) = h \cos\varepsilon \cos\vartheta - h \sin\varepsilon \sin\vartheta$

$m_y = h \sin\gamma = h \sin(\vartheta + \varepsilon) = \underline{h \cos\varepsilon \sin\vartheta + h \sin\varepsilon \cos\vartheta}$

$m_x = m_\xi \cos\vartheta - m_\eta \sin\vartheta$

$m_y = m_\xi \sin\vartheta + m_\eta \cos\vartheta$

$a\, m_\xi \sin\vartheta + a\, m_\eta \cos\vartheta + \underline{\sin\vartheta \cos\gamma\, m_\xi \xi} + \overset{\cos\vartheta \cos\gamma\, m_\eta \xi}{\cancel{\sin\vartheta \sin\gamma\, m_\eta \eta}}$

$\underline{- \sin\vartheta \sin\gamma\, m_\xi \eta} - \underline{\sin\gamma \cos\vartheta\, m_\eta \eta}$

$+ b\, m_\xi \cos\vartheta - b\, m_\eta \sin\vartheta + \underline{\cos\vartheta \cos\gamma\, m_\xi \eta} \quad \overset{- \sin\vartheta \cos\gamma\, m_\eta \eta}{\cancel{+ \sin\gamma \cos\vartheta\, m_\xi \xi}}$

$+ \underline{\sin\gamma \cos\vartheta\, m_\xi \xi} - \underline{\sin\gamma \sin\vartheta\, m_\eta \xi}$

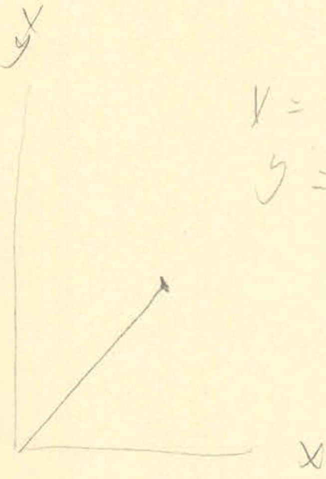
$m_\xi (a \sin\vartheta + b \cos\vartheta) + m_\eta (a \cos\vartheta - b \sin\vartheta)$

$\frac{1}{2} m \xi \sin 2\vartheta + m$

$\frac{m_\xi}{2} l \sin 2\vartheta + m \eta\, l \cos 2\vartheta + \sin(\vartheta + \gamma)(m_\xi \xi - m_\eta \eta) + \cos(\vartheta+\gamma)(m_\xi \eta + m_\eta \xi) = (m_y x + m_x y)$

$$\left(\frac{\partial X}{\partial x} - \frac{\partial Y}{\partial y}\right) Mr \sin(2\vartheta + \varepsilon) + r\frac{\partial Y}{\partial z} M_2 \cos\vartheta - Vr\frac{\partial X}{\partial z}\sin\vartheta$$

$$+ M Y_0 \cos\gamma - M X_0 \sin\gamma .$$



$$X = X_0 + x\frac{\partial X}{\partial x} = X_0 \cancel{r\sin\vartheta} + \frac{\partial X}{\partial x} r \cos\vartheta$$

$$Y = Y_0 + y\frac{\partial Y}{\partial y} = Y_0 \cancel{r\cos\vartheta}\, Y_0 + \frac{\partial Y}{\partial y} r \sin\vartheta$$

$$M Y_0 \cos\gamma + Mr\frac{\partial Y}{\partial y}\sin\vartheta\cos\gamma .$$

$$- M X_0 \sin\gamma - Mr\frac{\partial X}{\partial x}\cos\vartheta\sin\gamma .$$

$$\frac{\partial X}{\partial x} Mr\sin\vartheta\cos\gamma + \frac{\partial X}{\partial x} \cancel{Mr}\cos\vartheta\sin\gamma$$

$$- \frac{\partial Y}{\partial y} \cancel{Mr\sin\vartheta\cos\gamma} - \frac{\partial Y}{\partial y} Mr\cos\vartheta\sin\vartheta .$$

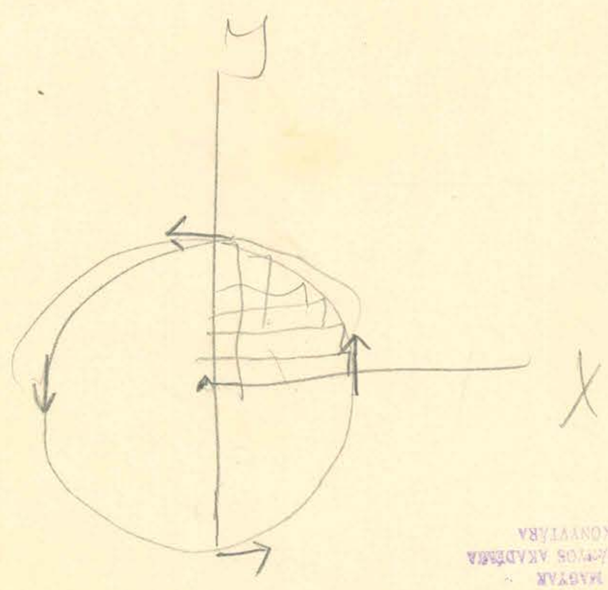
$$\frac{\partial X}{\partial x} Mr\sin\vartheta\cos\gamma - \frac{\partial Y}{\partial y} Mr\cos\vartheta\sin\gamma$$

$$0$$

$$x\,dx\cancel{\frac{\partial Y}{\partial x}} + x\,dy\frac{\partial Y}{\partial y} + x\,dz\frac{\partial Y}{\partial z}$$

$$-y\,dx\frac{\partial X}{\partial x} - y\,dy\cancel{\frac{\partial X}{\partial y}} - y\,dz\frac{\partial X}{\partial z} - x\,dy$$

$$0$$



$\{m_y x + m_x y)$

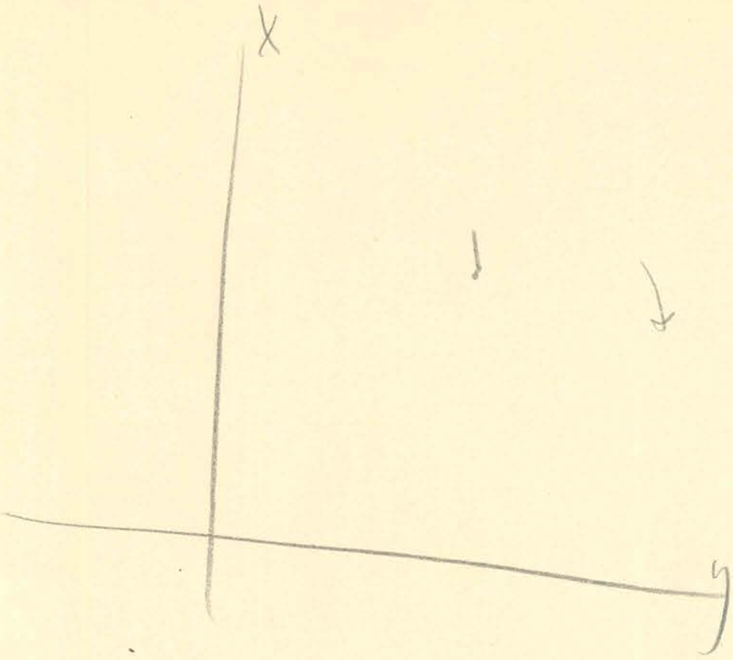
$(\cancel{m_x\cos\alpha + m_y\cos\beta + m_z\cos\gamma})($

$(m_x\cos\beta + m_y\cos\beta' + m_z\cos\beta'')(x\cos\alpha + y\cos\alpha' + z\cos\alpha'')$

$+ m_x\cos\alpha + m_y\cos\alpha' + m_z\cos\alpha'')(x\cos\beta + y\cos\beta' + z\cos\beta'')$

$m_x x\cos\alpha\cos\beta + m_x y\cos\beta\cos\alpha' + m_x z\cos\beta\cos\alpha''$

$m_y x\cos\alpha'\cos\beta'$



$$P_y x - P_x y$$

$$+ m_x Y_0 + m_x x \frac{\partial Y}{\partial x} + m_x y \frac{\partial Y}{\partial y} + m_x z \frac{\partial Y}{\partial z}$$

$$- m_y X_0 + m_y x \frac{\partial X}{\partial x} + m_y y \frac{\partial X}{\partial y} + m_y z \frac{\partial X}{\partial z}$$

3 a

$$\cancel{m_x x \frac{\partial X}{\partial x}}$$

$$\cancel{m_x x \frac{\partial Y}{\partial x}} + \boxed{\cancel{m_y x \frac{\partial Y}{\partial y}}} + \boxed{m_z x \frac{\partial Y}{\partial z}}$$

$$\boxed{\cancel{- m_x y \frac{\partial X}{\partial x}}} - \cancel{m_y y \frac{\partial X}{\partial y}} - \boxed{m_z y \frac{\partial X}{\partial z}}$$

$$+ m_x x \frac{\partial Y}{\partial x} + \boxed{\cancel{m_x y \frac{\partial Y}{\partial y}}} + \boxed{m_x z \frac{\partial Y}{\partial z}}$$

$$\boxed{\cancel{- m_y x \frac{\partial X}{\partial x}}} - \cancel{m_y y \frac{\partial X}{\partial y}} - \boxed{m_y z \frac{\partial X}{\partial z}}$$

$$- m_y X_0 + m_x Y_0$$

$$(m_y x + m_x y)\left(\frac{\partial Y}{\partial y} - \frac{\partial X}{\partial x}\right)$$

$$(m_z x + m_x z) \frac{\partial Y}{\partial z}$$

$$(m_z y + m_y z) \frac{\partial X}{\partial z}.$$

$$r \quad M \frac{3a}{r^4} \cos \varepsilon - \frac{M \cos \alpha}{r^3}$$

$$ds$$

$$\cancel{r \cos \alpha} \quad 3a \cos \varepsilon - r \cos \alpha$$

$$M \frac{3}{r^3} \cos$$

$$\frac{M}{r^3}\left(\frac{3a}{r} \cos \varepsilon - \cos \alpha\right)$$

$$\cos \alpha = \cos x \cos \varepsilon - \sin x \sin \varepsilon$$

$$\cos \alpha = \frac{a}{r} \cos \varepsilon$$

$$m_z x + m_x z = a\,m_\xi + \xi m_z \cos\gamma - \eta m_z \sin\gamma + h z \cos(\gamma+\alpha)$$
$$+ z \cos\gamma\, m_\xi - z \sin\gamma\, m_\eta$$

$$a\,m_\xi + \cos\gamma(\xi m_\xi + \zeta m_\xi) - \sin\gamma(\eta m_\xi + \zeta m_\eta$$

$$b\,m_z + \eta m_z \cos\gamma + \xi m_z \sin\gamma + h z \sin(\gamma+\alpha)$$

$$z \sin\gamma\, m_\xi + z \cos\gamma\, m_\eta$$

$$b\,m_\zeta + \cos\gamma(\eta m_z + z m_\eta) + \sin\gamma(\xi m_z + z m_\xi)$$

$\mu(\xi + \frac{d}{2})^2 - \mu(\xi - \frac{d}{2})^2$

$\int \mu \xi d$

m_ξ

$\underline{\xi \cos 2\alpha - \eta \sin 2\alpha}$

ξ^2

ξm_ξ

ξ

$m_\xi + m$

$\frac{1}{h}\left(\xi m_\xi^2 - \xi m_\eta^2 - 2\eta m_\eta m_\xi\right) = (\xi m_\xi - \eta m_\eta) m_\xi + m_\eta$

$\xi m_\xi^2 - \eta m_\eta m_\xi$

$\underline{-\eta m_\eta^2} \quad + \xi m_\xi m_\eta$

$\cancel{\xi m_\xi}$

$\frac{1}{h}\left(\xi(\cancel{m_\xi^2} - \right.$

$\frac{1}{h}\left(\xi(2m_\xi^2 - h^2)\right)$

$\cancel{\xi m_\xi}$

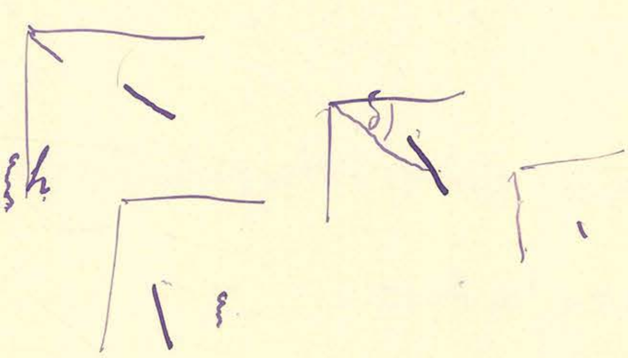
$\xi m_\xi^2 - \eta m_\eta m_\xi$

$+ \xi m_\xi m_\eta - \eta m_\eta^2$

$\cancel{h \xi} \; h\varrho(\cos\delta \cos 2\alpha - \sin\delta \sin 2\alpha$

$h\varrho(\cos(\delta + 2\alpha)$

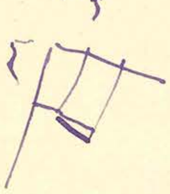
ξh



$\cos\alpha - \sin\alpha \left(\frac{a \sin\alpha + b \cos\alpha}{a \cos\alpha - b \sin\alpha}\right.$

$\frac{a \cos^2\alpha - b \sin\alpha \cos\alpha - a \sin^2\alpha - b \sin\alpha \cos\alpha}{a \cos\alpha - b \sin\alpha}$

$m_\xi \xi - m_\xi \eta = \xi h$



$\xi \cos 2\alpha - \eta \sin 2\alpha.$

$a m_y + \xi m_y \cos\gamma - \eta m_y \sin\gamma$

$+ b m_x + \underbrace{\eta m_x \cos\gamma} + \underbrace{\xi m_x \sin\gamma}$

$l \cos\delta \cos 2\alpha - l \sin\delta \sin 2\alpha.$

$\cancel{l \cos(2\alpha + \delta)}$

$\underline{h\xi \cos\alpha} - \underline{h\eta \sin\alpha}.$

$a \cos\alpha - b \sin\alpha$

$- b \sin\alpha . 2\cos\alpha$

$h\xi \cos 2\alpha - h\eta \sin 2\alpha.$

$a \cos 2\alpha - b \sin 2\alpha$

$\underline{a \cos\alpha . \cos\alpha} - a \sin\alpha \sin\alpha - \underbrace{b \sin\alpha \cos\alpha} - b \sin\alpha \cos\alpha$

$\gamma = (\vartheta + \varepsilon)$

$m_y x + m x y = a h \sin(\gamma+\alpha) + \xi h \sin(\gamma+\alpha)\cos\gamma - \eta h \sin(\gamma+\alpha)\sin\gamma$

$+ bh \cos(\gamma+\alpha) + \eta h \cos(\gamma+\alpha)\cos\gamma + \xi h \cos(\gamma+\alpha)\sin\gamma$

$a m_\xi \sin\gamma + a m_\eta \cos\gamma + b m_\xi \cos\gamma - b m_\eta \sin\gamma$

$+ \xi m_\xi \sin\gamma\cos\gamma + \xi m_\eta \cos^2\gamma - \eta m_\xi \sin^2\gamma - \eta m_\eta \sin\gamma\cos\gamma$

$+ \eta m_\xi \cos^2\gamma - \eta m_\eta \sin\gamma\cos\gamma + \xi m_\xi \sin\gamma\cos\gamma - \xi m_\eta \sin^2\gamma$

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ebből

$a m_\xi \sin\gamma + a m_\eta \cos\gamma + b m_\xi \cos\gamma - b m_\eta \sin\gamma$

$+ \xi m_\xi \sin 2\gamma - \eta m_\eta \sin 2\gamma + \xi m_\eta \cos 2\gamma + \eta m_\xi \cos 2\gamma$

$(a \sin\gamma + b\cos\gamma)\Sigma m\xi + (a\cos\gamma - b\sin\gamma)\Sigma m\eta$

$\Sigma m \xi = M \qquad \Sigma m\eta = 0.$

$\gamma = \vartheta + \varepsilon$

$M\, l \sin(2\vartheta + \varepsilon)$

~~l sin~~

$l(\sin\vartheta+\gamma) M\cos\gamma + l\cos(\vartheta+\gamma) M \sin\vartheta$

$a h \cos(\gamma+\alpha) + h\xi \cos\gamma\cos(\gamma+\alpha) - \eta h \sin\gamma \cos(\gamma+\alpha)$

$hb \sin(\gamma+\alpha) + h\eta\cos\gamma\sin(\gamma+\alpha) + h\xi\sin\gamma\sin(\gamma+\alpha)$

$a m_\xi \cos\gamma - a m_\eta \sin\gamma + b m_\xi \sin\gamma + b m_\eta \cos\gamma$

$\xi m_\xi \cos^2\gamma - \xi m_\eta \sin\gamma\cos\gamma - \eta m_\xi \sin\gamma\cos\gamma + \eta m_\eta \sin^2\gamma$

$- \eta m_\xi \sin\gamma\cos\gamma - \eta m_\eta \cos^2\gamma - \xi m_\xi \sin^2\gamma - \xi m_\eta \sin\gamma\cos\gamma$

$\Sigma m\xi \cos 2\gamma - \xi m_\eta \frac{\sin 2\gamma}{2}$

$(a\cos\gamma - b\sin\gamma) m_\xi - (a\sin\gamma + b\cos\gamma) m_\eta$

$- \sin 2\gamma (\xi m_\eta + \eta m_\xi)$

$+ \cos 2\gamma (\xi m\xi - \eta m\eta)$

$\cancel{ab\sum m}$ $\cancel{+ b\cos\gamma \sum m\xi}$ $\cancel{- b\sin\gamma \sum m\eta}$

$\cancel{+ a\cos\gamma \sum m\eta}$

$+ a\sin\gamma \sum m\xi$

$+ \cos^2\gamma \sum m\xi\eta - \sin\gamma\cos\gamma \sum m\eta^2$

$+ \sin^2\gamma \sum m\xi\eta + \sin\gamma\cos\gamma \sum m\xi^2$

$\cancel{-ab\sum \mu}$ $- b\cos\gamma \sum \mu\xi$ $+ \cancel{b\sin\gamma \sum \mu\eta}$

$\cancel{- a\cos\gamma \sum \mu\eta}$

$- a\sin\gamma \sum m\xi$

$- \cos^2\gamma \sum \mu\xi\eta + \sin\gamma\cos\gamma \sum \mu\eta^2$

$+ \sin^2\gamma \sum \mu\xi\eta - \sin\gamma\cos\gamma \sum \mu\xi^2$

$\sum m - \sum \mu = 0 \qquad \sum m\eta = 0 \quad \sum \mu\eta = 0$

$\sum m\xi - \sum \mu\xi = M$ (magneses moment)

c szerint az egész:

$$F.\left(M b\cos\gamma + M a\sin\gamma + \cos 2\gamma \sum m\xi\eta + \tfrac{1}{2}\sin 2\gamma\left(\sum m\xi^2 - \sum m\eta^2\right)\right)$$

$a = r\cos\vartheta \qquad b = r\sin\vartheta$

$\gamma = \vartheta + \varepsilon.$

$$\left(\frac{\partial X}{\partial x} - \frac{\partial Y}{\partial y}\right) F\left\{ M r\sin(2\vartheta+\varepsilon) + \cos(2\vartheta+2\varepsilon)\sum m\xi\eta + \frac{1}{2}\sin(2\vartheta+2\varepsilon)\left(\sum m\xi^2 - \sum m\eta^2\right)\right\}$$

$$+ \frac{\partial Y}{\partial z} r\cos\vartheta\, M_z - \frac{\partial X}{\partial z} r\sin\vartheta\, M_z$$

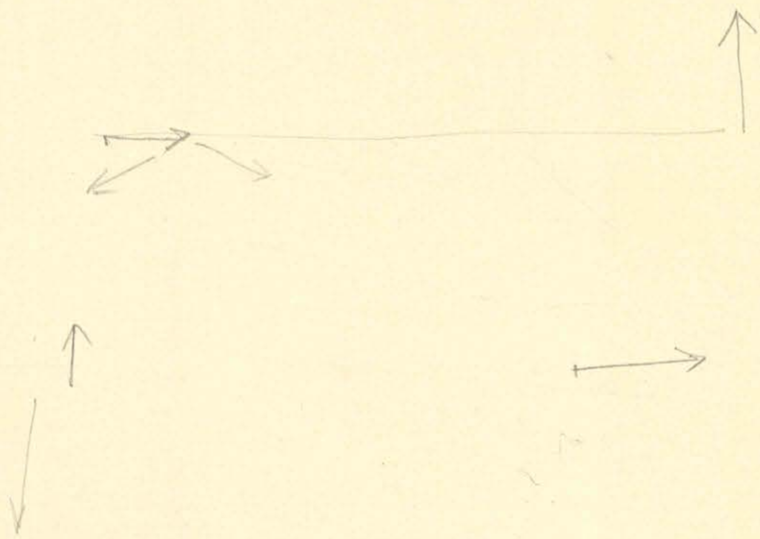
$(\xi + \frac{1}{2})(\eta + \frac{1'}{2}) \qquad \xi\frac{1}{2} + \eta\frac{1}{2}$

$-(\xi - \frac{1}{2})(\eta - \frac{1'}{2}) \qquad + \xi\frac{1'}{2} + \eta\frac{1}{2}$

$\xi\lambda\mu \quad \eta\lambda$

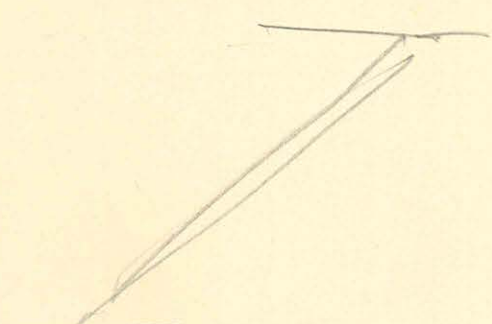
μdl. $h_x = \mu da$ $h_y = \mu db$. h_z μdi

$$P_y = -\frac{3 h_y m_x}{a^4}.$$



vonzó erő, ha egyféle tömeg és [illegible]

a két mágneses tömeg és [illegible]. stb. erő)



$$\frac{6m^2}{a^4} - \frac{3m^2}{a^4}.$$

$$\frac{3m^2}{a^4}$$

1

$$\begin{cases} x = a + \xi\cos i\cos\gamma - \zeta\sin i\cos\gamma - \eta\sin\gamma \\ y = b + \xi\cos i\sin\gamma - \zeta\sin i\sin\gamma + \eta\cos\gamma \end{cases}$$

C+ $z = \zeta\cos i + \xi\sin i$

$m_x = \cos\gamma\, h\cos\alpha - \sin\gamma\, h\sin\alpha$

$m_z = m_\zeta\cos i + m_\xi\sin i$

$m_y = \sin\gamma\, h\cos\alpha + \cos\gamma\, h\sin\alpha$

$h\sin\alpha = m_\eta \qquad h\cos\alpha = m_\xi\cos i - m_\zeta\sin i$

$$\begin{cases} m_x = m_\xi\cos i\cos\gamma - m_\zeta\sin i\cos\gamma - m_\eta\sin\gamma \\ m_y = m_\xi\cos i\sin\gamma - m_\zeta\sin i\sin\gamma + m_\eta\cos\gamma \\ m_z = m_\zeta\cos i + m_\xi\sin i \end{cases}$$

$m_y x + m_x y = \cancel{a m_\xi\cos i\sin\gamma} - \cancel{a m_\zeta\sin i\sin\gamma} + \cancel{a m_\eta\cos\gamma}$

$\cancel{+ m_\xi\xi\cos^2 i\sin\gamma\cos\gamma} - m_\zeta\xi\sin i\cos i\sin\gamma\cos\gamma + m_\eta\xi\cos i\cos^2\gamma$

$- m_\xi\zeta\sin i\cos i\sin\gamma\cos\gamma + \cancel{m_\zeta\zeta\sin^2 i\sin\gamma\cos\gamma}$ $\cancel{- m_\eta\zeta\sin i\cos^2\gamma}$

$\cancel{- m_\xi\eta\cos i\sin^2\gamma} + \cancel{m_\zeta\eta\sin^2\gamma\sin i} - \cancel{m_\eta\eta\sin\gamma\cos\gamma}$

$+ \cancel{b m_\xi\cos i\cos\gamma} - \cancel{b m_\zeta\sin i\cos\gamma} - \cancel{b m_\eta\sin\gamma}$

$+ m_\xi\xi\cos^2 i\sin\gamma\cos\gamma - \cancel{m_\zeta\xi\sin i\cos i\sin\gamma\cos\gamma} - m_\eta\xi\cos i\cancel{\sin^2\gamma}$

$- m_\xi\zeta\sin i\cos i\sin\gamma\cos\gamma + \cancel{m_\zeta\zeta\sin^2 i\sin\gamma\cos\gamma} + \cancel{m_\eta\zeta\sin i\sin^2\gamma}$

$\cancel{+ m_\xi\eta\cos i\cos^2\gamma} - \cancel{m_\zeta\eta\sin i\cos^2\gamma} - \cancel{m_\eta\eta\sin\gamma\cos\gamma}$

$= m_\xi\cos i(a\sin\gamma + b\cos\gamma) + m_\eta(a\cos\gamma - b\sin\gamma) - m_\zeta\sin i(a\sin\gamma + b\cos\gamma)$

$+ m_\xi\xi\cos^2 i\sin 2\gamma - m_\eta\eta\sin 2\gamma + m_\zeta\zeta\sin^2 i\sin 2\gamma$

$+ m_\xi\eta\cos i\cos 2\gamma + m_\eta\xi\cos i\cos 2\gamma$

$- m_\eta\zeta\sin i\cos 2\gamma - m_\zeta\eta\sin i\cos 2\gamma$

$- m_\zeta\xi\sin i\cos i\sin 2\gamma - m_\xi\zeta\sin i\cos i\sin 2\gamma$

$\sin 2\gamma\{m_\xi\xi\cos^2 i - m_\eta\eta + m_\zeta\zeta\sin^2 i - (m_\zeta\xi + m_\xi\zeta)\sin i\cos i\}$

$+ \cos 2\gamma\{\cos i(m_\xi\eta + m_\eta\xi) - \sin i(m_\eta\zeta + m_\zeta\eta)\}$

$$\frac{\sum\left(m_x x' \frac{\partial y}{\partial x} + m_y x \frac{\partial y}{\partial y} + m_z x' \frac{\partial y}{\partial z}\right)}{\sum\left(m_x \frac{\partial y}{\partial x} + m_y \frac{\partial y}{\partial y} + m_z \frac{\partial y}{\partial z}\right)}$$

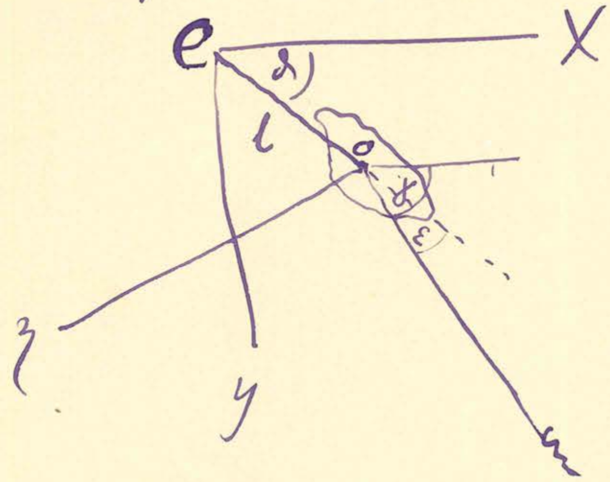
$$\delta_x = \left(a m_\xi \cos i \cos \gamma - a m_\zeta \sin i \cos \gamma - a m_\eta \sin \gamma\right)\frac{\partial y}{\partial x}$$
$$+\left(a m_\xi \cos i \sin \gamma - a m_\zeta \sin i \sin \gamma + a m_\eta \cos \gamma\right)\frac{\partial y}{\partial y}$$
$$+\left(a m_\xi \cos i + a m_\zeta \sin i\right)\frac{\partial y}{\partial z}$$

Nev. $= m_\xi \cos i \cos \gamma - m_\zeta \sin i \cos \gamma - m_\eta \sin \gamma$

$\underline{a}$ $\underline{b}$

Egész mágnes elemi mágnesek halmaza.

E pont O-ban összegek tengelye



$\gamma = \vartheta + \varepsilon$ = a mágnesben való

ξ tengely és x által képezett szöglet.

ebben ~~ε [illegible]~~

l a CO vezető egyenes.

$l^2 = a^2 + b^2$

Coordinaták transformatiója.

$$x = a + \xi\cos\gamma - \eta\sin\gamma$$

$$y = b + \eta\cos\gamma + \xi\sin\gamma.$$

x, y és ξ, η a mágnes egyes elemeinek összetevői.

ha már most tesszük előre.

$m^2 = h^2 + v^2$ a hol $\underline{m}$ az egyes elem mágneses momentuma

h ennek az xy síkba eső

v a Z irányába eső összetevője.

α a szöglet melyet a mágneses elem a $\underline{\xi}$ tengellyel képez

akkor

$$m_x = h\cos(\gamma+\alpha) \qquad m_y = h\sin(\gamma+\alpha) \qquad m_z = v$$

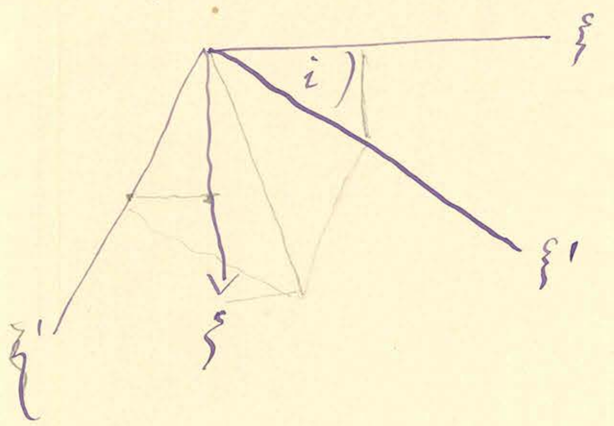
és a forgatónyomatékok kifejezései tehát $h\cos\alpha = m_\xi = h_\xi$ $\quad h\sin\alpha = m_\eta = h_\eta$

$$m_y x + m_x y = (a\sin\gamma + b\cos\gamma)\, h_\xi + (a\cos\gamma - b\sin\gamma)\, h_\eta$$
$$+ \sin 2\gamma(\xi m_\xi - \eta m_\eta) + \cos 2\gamma(\xi m_\eta + \eta m_\xi)$$

$$m_x x - m_y y = (a\cos\gamma - b\sin\gamma)\, m_\xi - (a\sin\gamma + b\cos\gamma)\, m_\eta$$
$$- \sin 2\gamma(\xi m_\eta + \eta m_\xi) + \cos 2\gamma(\xi m_\xi - \eta m_\eta)$$

$$m_z x + m_x z = a\, m_\zeta + \cos\gamma(\xi m_\zeta + \zeta m_\xi) - \sin\gamma(\eta m_\zeta + \zeta m_\eta)$$

$$(m_z y + m_y z) = b\, m_\zeta + \cos\gamma(\eta m_\zeta + \zeta m_\eta) + \sin\gamma(\xi m_\zeta + \zeta m_\xi)$$



$$\eta = \eta'$$
$$\xi = \xi' \cos i - \zeta' \sin i$$
$$\zeta = \zeta' \cos i + \xi' \sin i$$

$$m_\xi = m'_\xi \cos i - m_{\zeta'} \sin i$$
$$m_\zeta = m'_\zeta \cos i + m'_\xi \sin i$$

$$\xi m_\xi - \eta m_\eta = \xi' m'_\xi \cos^2 i - \xi' m'_\zeta \sin i \cos i - \zeta' m_{\xi'} \sin i \cos i + \zeta' m'_\zeta \sin^2 i - \eta' m_{\eta'}$$

$$\xi m_\eta + \eta m_\xi = \xi' m'_\eta \cos i - \zeta' m'_\eta \sin i + \eta' m'_\xi \cos i - \eta' m_{\zeta'} \sin i$$
$$= \cos i (\xi' m'_\eta + \eta' m'_\xi) - \sin i (\zeta' m'_\eta + \eta' m'_\zeta)$$

$$\xi m_\zeta + \zeta m_\xi = \xi' m'_\zeta \cos^2 i - \zeta' m'_\zeta \sin i \cos i + \xi' m'_\xi \sin i \cos i - \zeta' m'_\xi \sin^2 i$$
$$+ \zeta' m'_\xi \cos^2 i + \xi' m'_\xi \sin i \cos i - \zeta' m'_\zeta \sin i \cos i - \xi' m'_\zeta \sin^2 i$$
$$= \cos^2 i (\xi' m'_\zeta + \zeta' m'_\xi) - \sin^2 i (\zeta' m'_\xi + \xi' m'_\zeta) + \sin 2i (\xi' m'_\xi - \zeta' m'_\zeta)$$

$$(\eta m_\zeta + \zeta m_\eta) = \eta' m'_\zeta \cos i + \eta' m'_\xi \sin i + \zeta' m_\eta \cos i + \xi' m_\eta \sin i$$
$$= \cos i (\zeta' m'_\eta + \eta' m'_\zeta) + \sin i (\xi' m'_\eta + \eta' m'_\xi)$$

Ha egész mágnest veszünk, a mágneses tengelyét válasszuk ξ' tengelynek akkor.

$$m_\xi = M \cos i = \cos i \sum m'_\xi - \sin i \sum m_{\zeta'}$$
$$m_\zeta = M \sin i = \cos i \sum m_{\zeta'} + \sin \sum m'_\xi$$

$$\xi m_\xi - \eta m_\eta = \cos^2 i \sum \xi' m'_\xi + \sin^2 i \sum \zeta' m'_\zeta - \tfrac{1}{2} \sin 2i \left(\sum \zeta' m'_\xi - \sum \xi' m'_\zeta \right)$$

$$\xi m_\eta + \eta m_\xi =$$

$$\sum m_\xi = M \qquad \sum m_\eta = 0 \qquad \sum m_\zeta = 0$$

Symmetrikus mágnes.

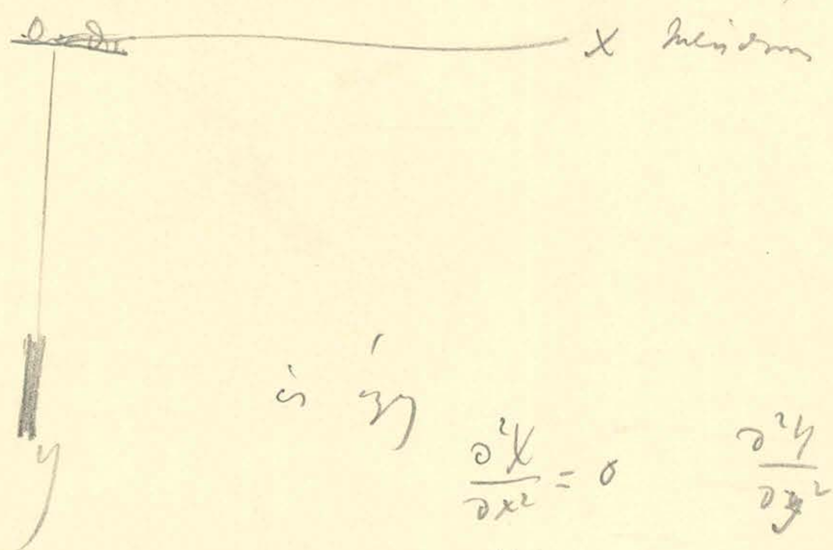
$$\sum \xi m_\xi = 0 \qquad \sum \eta m_\eta = 0 \qquad \sum \zeta m_\zeta$$
$$\sum \xi m_\eta = 0 \qquad \sum \eta m_\zeta = 0 \qquad \sum \zeta m_\eta = 0 \qquad \sum \eta m_\xi = 0$$
$$\sum \xi m_\zeta = 0 \qquad \sum \zeta m_\xi = 0 \quad \text{és így :}$$

$a = a_0 + \xi \qquad \int a M_x = a_0 \int M - \int \xi M_x$

az $\int \xi M_z\, dx$ ... ha egy mágnesről 0 lesz

a b) kiegészítés egy mágnesre is áll.

Első főhelyzet.



$a = 0$

$b = r$

$c = 0$

$M_x = 0$

$M_y = M$

$M_z = 0$.

és így

$$\frac{\partial^2 X}{\partial x^2} = 0 \qquad \frac{\partial^2 Y}{\partial y^2} = -\frac{45}{r^5} M_y + \frac{9}{r^5} M_y + \frac{105}{r^5} M_y - \frac{30 M_y}{r^5}$$

$$\frac{\partial^2 Y}{\partial y^2} = + \frac{39}{r^5} M$$

$$\frac{\partial^2 Y}{\partial x^2} = - \frac{12 M}{r^5} \qquad \frac{\partial^2 Y}{\partial x^2} = \frac{3 M}{r^5} - \frac{15 M_y}{r^5} = - \frac{12 M_y}{r^5}$$

$$\frac{\partial^2 X}{\partial y^2} = 0$$

Egy mágnesre. $M = \mu\, dr$ $\qquad \int \frac{M}{r^5} = \mu \int \frac{dr}{r^5} = - \frac{\mu}{4} \Big| \frac{1}{r^4} = - \frac{\mu}{4} \left(\frac{1}{(r + \frac{\lambda}{2})^4} - \frac{1}{(r - \frac{\lambda}{2})^4} \right)$

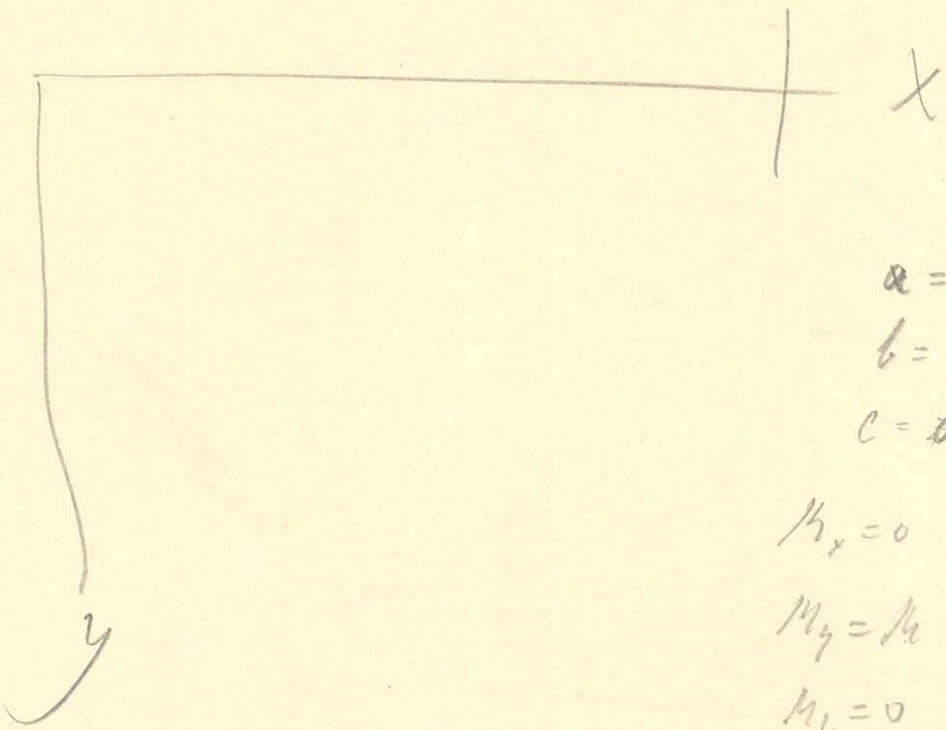
$$= - \frac{\mu}{4} r^4 \frac{(1 - \frac{\lambda}{2r})^4 - (1 + \frac{\lambda}{2r})^4}{r^8 (1 - \frac{\lambda^2}{4r^2})^4}$$

$+ \cos^2 \vartheta \frac{12 M}{r^5}$.

$$\Phi = \cos^2 \vartheta\, \frac{12 M}{r^5 \cdot 8} \cdot 3\, m \left(\lambda^2 + 6 l^2 \right) \qquad + \frac{\mu \lambda}{r^5} = \frac{M}{r^5}$$

$$= - \frac{9}{2} \frac{M m}{r^3} \left(\frac{\lambda^2}{r^2} + \frac{6 l^2}{r^2} \right)$$

Φ. második fő állás



$a = r$

$b = 0$

$c = 0$

$M_x = 0$

$M_y = M$

$M_z = 0$

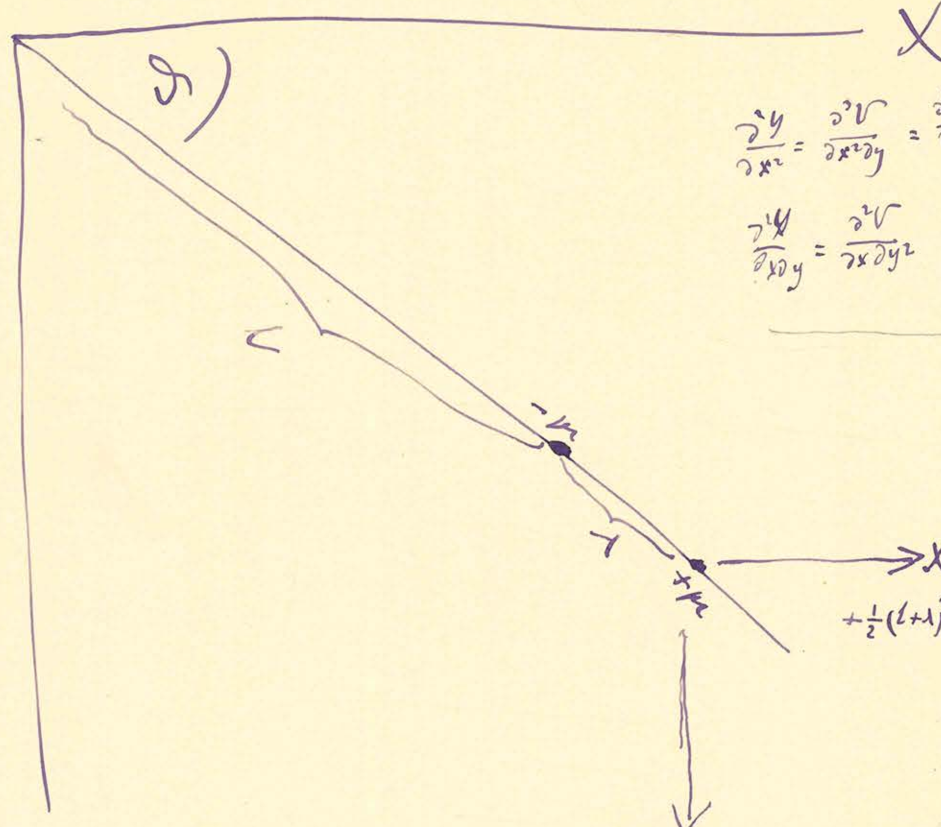
$$\frac{\partial^2 X}{\partial x^2} = 0 \qquad \frac{\partial^2 Y}{\partial y^2} = \frac{9}{r^5} M$$

$$\frac{\partial^2 Y}{\partial x^2} = -\frac{3}{r^5} M + \frac{3M}{r^5} = 0$$

$$\frac{\partial^2 X}{\partial y^2} =$$

$$\Phi = \frac{27}{16} \frac{mM}{r^5} (\lambda^2 + 6\lambda^2)$$ [illegible].

$$\frac{\partial^2 V'}{\partial x} = \frac{6a^2}{r^4}$$



$$\frac{\partial^2 Y}{\partial x^2} = \frac{\partial^3 V}{\partial x^2 \partial y} = \frac{\partial^2 Y}{\partial x^2} \qquad \frac{\partial^2 X}{\partial y^2} = \frac{\partial^3 V}{\partial x \partial y^2}$$

$$\frac{\partial^2 Y}{\partial x \partial y} = \frac{\partial^3 V}{\partial x \partial y^2} \qquad \frac{\partial^2 X}{\partial x \partial y} = \frac{\partial^3 V}{\partial x^2 \partial y}$$

$$X_0 + (l+\lambda)\cos\vartheta \frac{\partial X}{\partial x} + (l+\lambda)\sin\vartheta \frac{\partial X}{\partial y} + \frac{1}{2}(l+\lambda)^2\cos^2\vartheta \frac{\partial^2 X}{\partial x^2} + \frac{1}{2}(l+\lambda)^2\sin^2\vartheta \frac{\partial^2 X}{\partial y^2} + (l+\lambda)^2\sin\vartheta\cos\vartheta \frac{\partial^2 X}{\partial x \partial y}$$

$$Y_0 + (l+\lambda)\sin\vartheta \frac{\partial Y}{\partial y} + (l+\lambda)\cos\vartheta \frac{\partial Y}{\partial x} + \frac{1}{2}(l+\lambda)^2\sin^2\vartheta \frac{\partial^2 Y}{\partial y^2} + \frac{1}{2}(l+\lambda)^2\cos^2\vartheta \frac{\partial Y^2}{\partial x^2} + (l+\lambda)^2\sin\vartheta\cos\vartheta \frac{\partial^2 Y}{\partial x \partial y}$$

$l^2 + \lambda^2 + 2l\lambda$

$l^2 + 2l\lambda$

$l^3 + 2l^2\lambda + l^2\lambda$

$$Y_x - X_y = \underline{Y(l+\lambda)\cos\vartheta} - X(l+\lambda)\sin\vartheta$$

$$Y_x = Y_0\lambda\cos\vartheta + 2\sin\vartheta\cos\vartheta\,\lambda\frac{\partial Y}{\partial y} + 2\lambda\cos^2\vartheta\frac{\partial Y}{\partial x} + \frac{3}{2}l^2\lambda\sin^2\vartheta\cos\vartheta\frac{\partial^2 Y}{\partial y^2} + \frac{3}{2}l^2\lambda\cos^3\vartheta\frac{\partial^2 Y}{\partial x^2} + 3l^2\lambda\cos^2\vartheta\sin\vartheta\frac{\partial^2 Y}{\partial x \partial y}$$

$$X_y = -X_0\lambda\sin\vartheta - 2\sin\vartheta\cos\vartheta\,\lambda\frac{\partial X}{\partial x} + 2\lambda\sin^2\vartheta\frac{\partial Y}{\partial x} - \frac{3}{2}l^2\lambda\cos^2\vartheta\sin\vartheta\frac{\partial^2 X}{\partial x^2} - \frac{3}{2}l^2\lambda\sin^3\vartheta\frac{\partial^2 X}{\partial y^2} - 3l^2\lambda\sin^2\vartheta\cos\vartheta\frac{\partial^2 X}{\partial x \partial y}$$

$$\cancel{F} = Y_0\lambda\cos\vartheta - X_0\lambda\sin\vartheta$$

$$\sin 2\vartheta\,\lambda\left(\frac{\partial Y}{\partial y} - \frac{\partial X}{\partial x}\right) + 2\cos 2\vartheta\,\lambda\frac{\partial Y}{\partial x} \quad \cancel{+\frac{3}{2}l^2\lambda\sin\vartheta\cos\vartheta}$$

$$+\frac{3}{4}l^2\lambda\sin 2\vartheta\left(\frac{\partial^2 Y}{\partial y^2}\sin\vartheta - \frac{\partial^2 X}{\partial x^2}\cos\vartheta\right) + \frac{3}{2}l^2\lambda\left(\cos^3\vartheta\frac{\partial^2 Y}{\partial x^2} - \sin^3\vartheta\frac{\partial^2 X}{\partial y^2}\right)$$

$$+3l^2\lambda\left(\cos^2\vartheta\sin\vartheta\frac{\partial^2 X}{\partial y^2} - \sin^2\vartheta\cos\vartheta\frac{\partial^2 Y}{\partial x^2}\right)$$

$$+\frac{3}{2}l^2\lambda\sin 2\vartheta\left(\cos\vartheta\frac{\partial^2 X}{\partial y^2} - \sin\vartheta\frac{\partial^2 Y}{\partial x^2}\right)$$

$$\frac{3}{2}l^2\lambda\left\{\left(\sin 2\vartheta\cos\vartheta - \sin^3\vartheta\right)\frac{\partial^2 X}{\partial y^2} - \left(\sin 2\vartheta\sin\vartheta - \cos^3\vartheta\right)\frac{\partial^2 Y}{\partial x^2}\right\}$$

$2\cos^2\vartheta - \sin^2\vartheta$

$2\sin^2\vartheta - \cos^2\vartheta$

$\cos 2\vartheta + \sin^2\vartheta$

$\cos 2\vartheta + \sin^2\vartheta$

$$\frac{3}{2}l^2\lambda\left\{\cos^2\vartheta\frac{\partial^2 Y}{\partial x^2} + 2\cos^2\vartheta\sin\vartheta\frac{\partial^2 X}{\partial y^2} - \sin^2\vartheta\frac{\partial^2 X}{\partial y^2} - 2\sin^2\vartheta\cos\vartheta\frac{\partial^2 Y}{\partial x^2}\right)$$

$$\int \mu l^2\,dl = \left|\frac{\mu l^3}{3}\right|_{l-\frac{\lambda}{2}}^{l+\frac{\lambda}{2}} = \frac{\mu}{3}\left(\left(l+\frac{\lambda}{2}\right)^3-\left(l-\frac{\lambda}{2}\right)^3\right) = \frac{\lambda^3}{4}+\frac{3}{2}l^2\lambda\mu$$

$$(a+b)^3 = a^3+b^3+3ab^2+3a^2b$$

egy m momentumú fogó mágnesre.

$$F = mY_0\cos\vartheta - mX_0\sin\vartheta + ml\sin 2\vartheta\left(\frac{\partial Y}{\partial y}-\frac{\partial X}{\partial x}\right) + ml\cos 2\vartheta\frac{\partial Y}{\partial x}$$

$$\Phi = \begin{cases} +\frac{3}{16}m(\lambda^2+6l^2)\sin 2\vartheta\left(\frac{\partial^2 Y}{\partial y^2}\sin\vartheta - \frac{\partial^2 X}{\partial x^2}\cos\vartheta\right) + \cancel{\frac{3}{8}m(\lambda^2+6l^2)} \\ +\frac{3}{8}m(\lambda^2+6l^2)\left\{(\sin 2\vartheta\cos\vartheta - \sin^2\vartheta)\frac{\partial^2 X}{\partial y^2} - (\sin 2\vartheta\sin\vartheta - \cos^2\vartheta)\frac{\partial^2 Y}{\partial x^2}\right\}\end{cases}$$

Ez Lató mágnesre igen nagy momentuma M_x M_y M_z. C szerint

$$\cancel{\left(\frac{\partial^2 X}{\partial x^2}\right)_0 = -\frac{15}{r^7}(a-x)\{3(a-x)M_x + b}$$

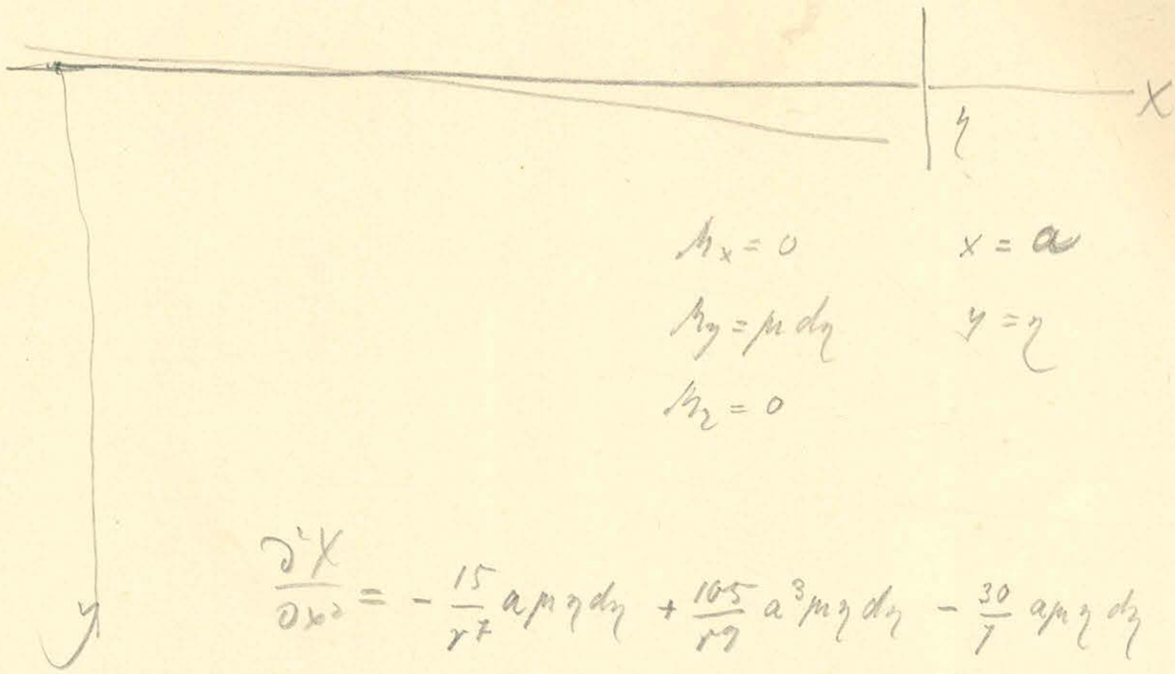
$$\frac{\partial^2 X}{\partial x^2} = -\frac{15}{r^7}a\{3aM_x+bM_y+cM_z\} + \frac{9}{r^5}M_x + \frac{105a^3}{r^9}\{aM_x+bM_y+cM_z\} - \frac{30a}{r^7}(aM_x+bM_y+cM_z)$$

$$\frac{\partial^2 Y}{\partial y^2} = -\frac{15}{r^7}b\{aM_x+3bM_y+cM_z\} + \frac{9}{r^5}M_y + \frac{105b^3}{r^9}\{aM_x+bM_y+cM_z\} - \frac{30b}{r^7}(aM_x+bM_y+cM_z)$$

$$\frac{\partial^2 Y}{\partial x^2} = -\frac{3a}{r^7}(aM_y+bM_x) + \frac{3M_y}{r^5} + \frac{105a^2b}{r^9}(aM_x+bM_y+cM_z) - \frac{15b}{r^7}(2aM_x+bM_y+cM_z)$$

$$\frac{\partial^2 X}{\partial y^2} = -\frac{3b}{r^7}(aM_y+bM_x) + \frac{3M_x}{r^5} + \frac{105ab^2}{r^9}(aM_x+bM_y+cM_z) - \frac{15a}{r^7}(aM_x+2bM_y+cM_z)$$

Számítás folytatás



$M_x = 0 \qquad x = a$

$M_y = \mu\, d\eta \qquad y = \eta$

$M_z = 0$

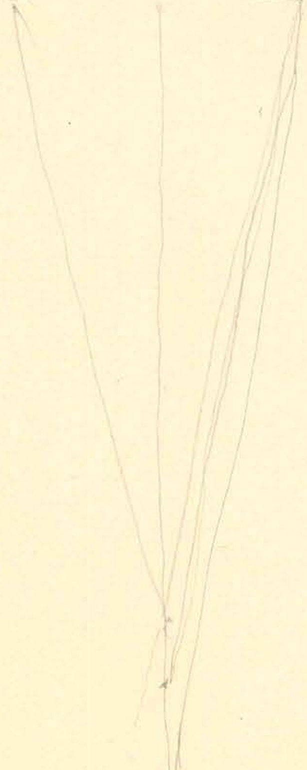
$$\frac{\partial^2 X}{\partial x^2} = -\frac{15}{r^7} a\mu\eta\, d\eta + \frac{105}{r^9} a^3 \mu\eta\, d\eta - \frac{30}{7} a\mu\eta\, d\eta$$

$$= -\frac{45}{r^7} a\mu\eta\, d\eta + \frac{105}{r^9} a^3 \mu\eta\, d\eta$$

$$\frac{\partial^2 Y}{\partial y^2} = -\frac{\cancel{7}5}{r^7} \mu\eta^2 d\eta + \frac{9}{r^5} \mu\, d\eta + \frac{105}{r^9} \mu\eta^4 d\eta$$

$$\frac{\partial^2 Y}{\partial x^2} = -\frac{3a^2}{r^7} \mu\, d\eta + \frac{3\mu\, d\eta}{r^5} + \frac{105}{r^9} a^2 \mu\eta^2 d\eta - \frac{15}{r^7} \mu\eta^2 d\eta$$

$$\frac{\partial^2 X}{\partial y^2} = -\frac{3a}{r^7} \mu\eta\, d\eta + \frac{105}{r^9} a\mu\eta^3 d\eta - \frac{30a}{r^7} \mu\eta\, d\eta$$



$$\frac{M}{r^3}$$

$$\frac{\mu}{\left(a - \frac{\lambda}{2}\right)^2 + 1}$$

$$\frac{\mu\lambda}{\left((a-\lambda)^2 + l^2\right)^{\frac{3}{2}}} + \frac{\mu\lambda}{\left((a+\lambda)^2 + l^2\right)^{\frac{3}{2}}}$$

$$\frac{mM}{a^3}\left\{ \frac{1}{\left(\left(1 - \frac{\lambda}{a}\right)^2 + \frac{l^2}{a^2}\right)^{\frac{3}{2}}} + \frac{1}{\left(\left(1 + \frac{\lambda}{a}\right)^2 + \frac{l^2}{a^2}\right)^{\frac{3}{2}}} \right.$$

$$1 - \frac{3}{2}\left(-\frac{2\lambda}{a} + \frac{\lambda^2}{a^2} + \frac{l^2}{a^2}\right) + \ldots$$

$$\frac{\partial r}{\partial x} = \frac{\partial}{\partial x}\sqrt{(a-x)^2+\cdots} = -\frac{a-x}{r}$$

C

$$\frac{\partial X}{\partial x} = -\frac{3}{r^5}\left(3(a-x)+(b-y)+(c-z)\right) + \frac{15(a-x)^2}{r^7}\left((a-x)M_x+(b-y)M_y+(c-z)M_z\right)$$

$$\frac{\partial^2 X}{\partial x^2} = -\frac{15}{r^7}(a-x)\left\{3(a-x)M_x+(b-y)M_y+(c-z)M_z\right\} + \frac{9}{r^5}M_x$$
$$+\frac{105(a-x)^3}{r^9}\left\{(a-x)M_x+(b-y)M_y+(c-z)M_z\right\} - \frac{30(a-x)}{r^7}\left\{(a-x)M_x+(b-y)M_y+(c-z)M_z\right\}$$

$$\frac{\partial^2 Y}{\partial y^2} = -\frac{15}{r^7}(b-y)\left\{(a-x)M_x+3(b-y)M_y+(c-z)M_z\right\} + \frac{9}{r^5}M_y$$
$$+\frac{105(b-y)^3}{r^9}\left\{(a-x)M_x+(b-y)M_y+(c-z)M_z\right\} - \frac{30(b-y)}{r^7}\left\{(a-x)M_x+\cdots\right\}$$

$M_x=0$ $\quad (a-x)=0 \quad b-y=\cancel{\ } \quad (c-z)=0$

$M_y=6 \quad\quad y=0 \quad b=r$

$M_z=0$

$$\frac{\partial^2 X}{\partial x^2}=0 \qquad \frac{\partial^2 Y}{\partial y^2} = -\frac{36M}{r^5}+\frac{105M}{r^5}-\frac{30M}{r^5} = +\frac{39}{r^5}M$$

$$\frac{\partial^2 Y}{\partial y^2} = \frac{39}{r^5}M.$$

$$\frac{\partial^2 Y}{\partial x^2} = -\frac{3(a-x)}{r^7}\left((a-x)M_y+(b-y)M_x\right) + \frac{3M_y}{r^5}$$
$$+\frac{105(a-x)^2(b-y)}{r^9}\left((a-x)M_x+(b-y)M_y+(c-z)M_z\right) - \frac{15(b-y)}{r^7}\left(aM_x+bM_y+cM_z\right)$$

$$-\frac{15(a-x)(b-y)}{r^7}M_x$$

$$\frac{\partial^2 X}{\partial y^2} = -\frac{3(b-y)}{r^7}\left((a-x)M_y+(b-y)M_x\right) + \frac{3M_x}{r^5}$$
$$+\frac{105(a-x)(b-y)^2}{r^9}\left((a-x)M_x+(b-y)M_y+(c-z)M_z\right) - \frac{15(a-x)}{r^7}\left(aM_x+2bM_y+cM_z\right)$$

$$\frac{\partial^2 Y}{\partial x^2} = -\frac{12M}{r^5} \qquad \frac{\partial^2 X}{\partial y^2} = 0 \qquad \Big/ \frac{l^3}{3}$$

$$-\frac{3}{2}l^2 l \cdot \frac{12\,\mu\,dl}{r^5} \qquad -\frac{3}{2}\int l^2 l \cdot \Big/_{r-\frac{l}{2}}^{r+\frac{l}{2}} \frac{12}{4}\mu\frac{1}{r^4} \qquad -\frac{9}{6}\left(\frac{1}{(r+\frac{l}{2})^4}-\frac{1}{(r-\frac{l}{2})^4}\right)\left((l+\tfrac{l}{2})^3-(l-\tfrac{l}{2})^3\right)$$