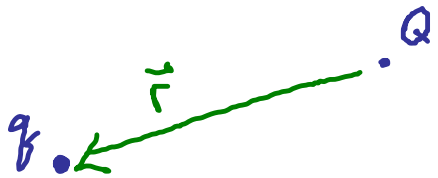
Physics 142 - Sept. 9, 2014

- SPS POA library help hours
- Inga Koch office hour Wed 2-3 pm B+L 477
  hope to have another hour scheduled by Mehr soon
- Course issues ?

Coulomb's Law

Single discrete charge



$\vec{F}$ of Q on q

$$\vec{F} = \frac{k q Q \hat{r}}{r^2}$$

same as $|\vec{r}|^2$

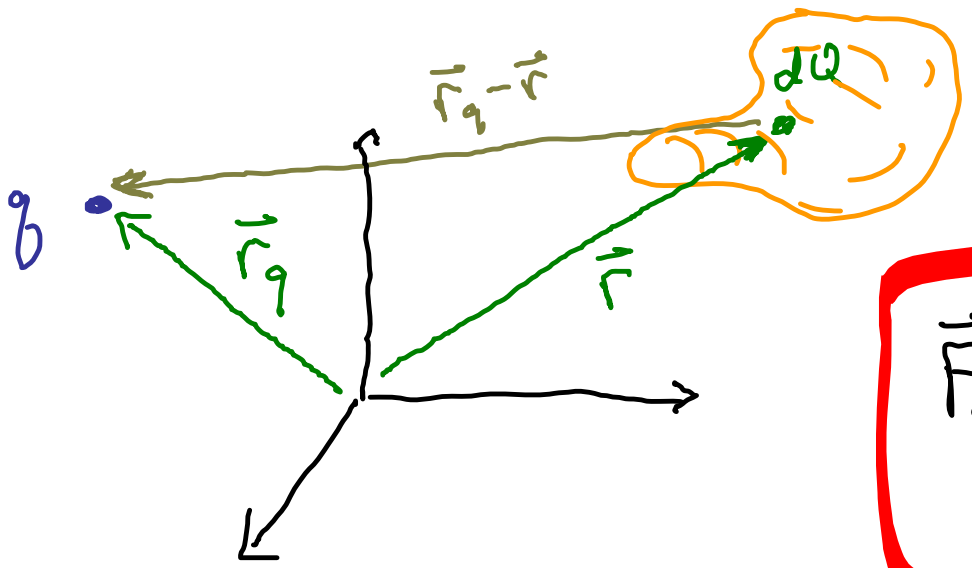
Multiple charges

vector superposition

$$\vec{F}_{\text{on } q} = \vec{F}_{Q_1 \text{ on } q} + \vec{F}_{Q_2 \text{ on } q} + \cdots + \vec{F}_{Q_N \text{ on } q}$$

$$\vec{F}_{\text{on } q} = \sum \frac{k q Q_i}{r_i^2} \hat{r}_i$$

F on q from continuous charge distribution



$$\vec{F}_{\text{on } q \text{ from } dQ} = d\vec{F} = \frac{k\,q\,dQ\,(\vec{r}_q - \vec{r})\hat{}}{|\vec{r}_q - \vec{r}|^2}$$

$$\vec{F}_{\text{on } q} = \int_{\text{vol}} d\vec{F} = \int_{\text{vol}} \frac{k\,q\,dQ\,(\vec{r}_q - \vec{r})\hat{}}{|\vec{r}_q - \vec{r}|^2}$$

3d volume $dQ = \rho(\vec{r})\, dV$

ρ: 3 dimensional charge density

Coul/m^3

2d surface $dQ = \sigma(\vec{r})\, dA$

C/m^2

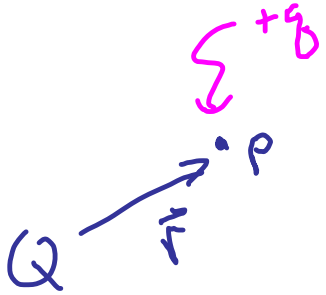
line charge distr. $dQ = \lambda(\vec{r})\, ds$

C/m

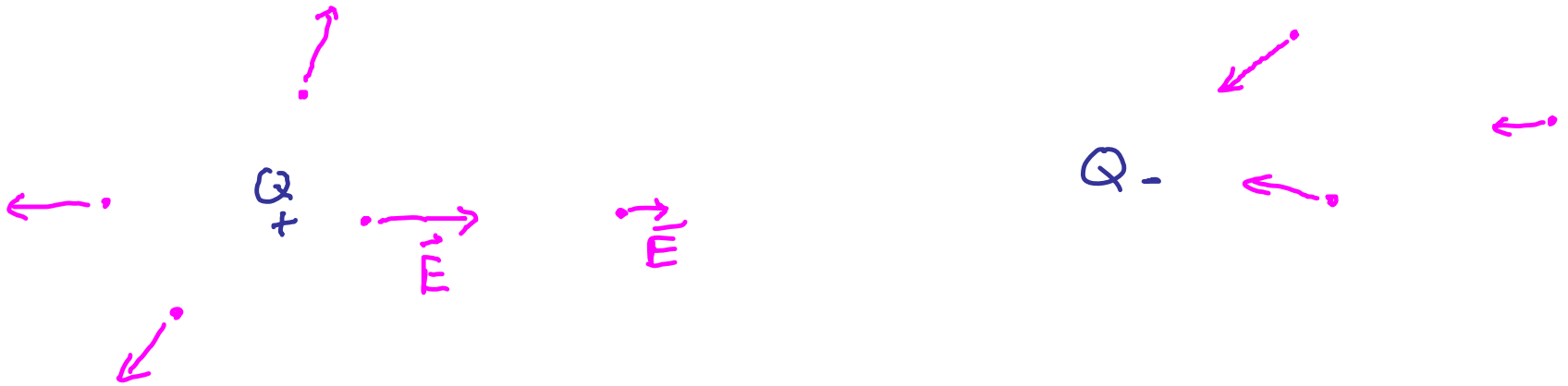
what causes the force

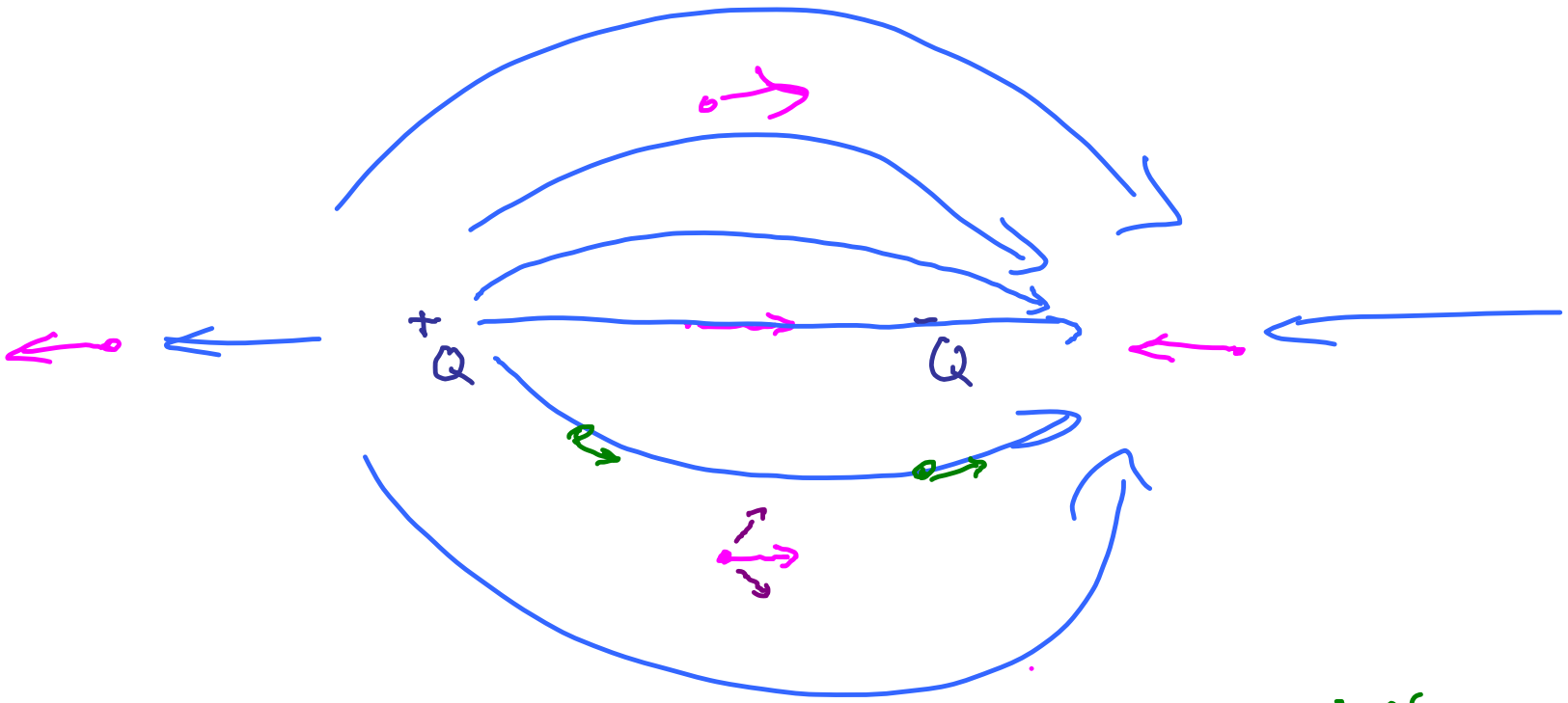
Electric field

$$\vec{E} = \frac{\vec{F}}{q}$$

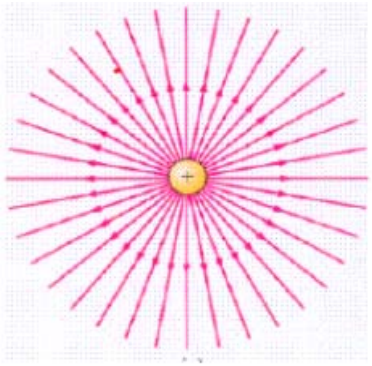


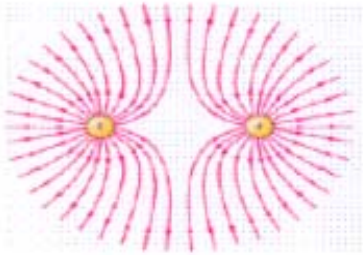
$$\vec{E}_P = \frac{\frac{kQq}{r^2}\hat{r}}{q} = \frac{kQ}{r^2}\hat{r}$$

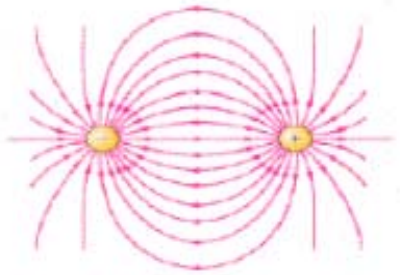

Q+
E
E
Q-



lines of force.



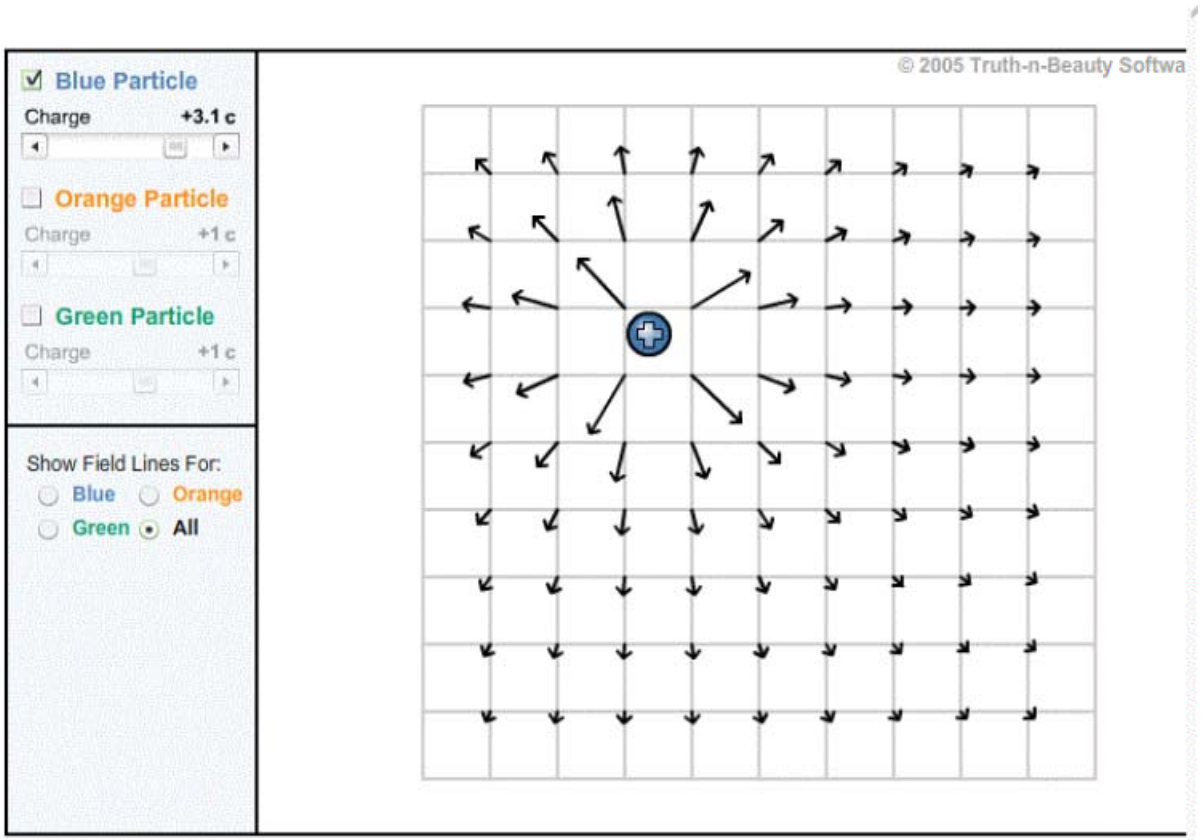


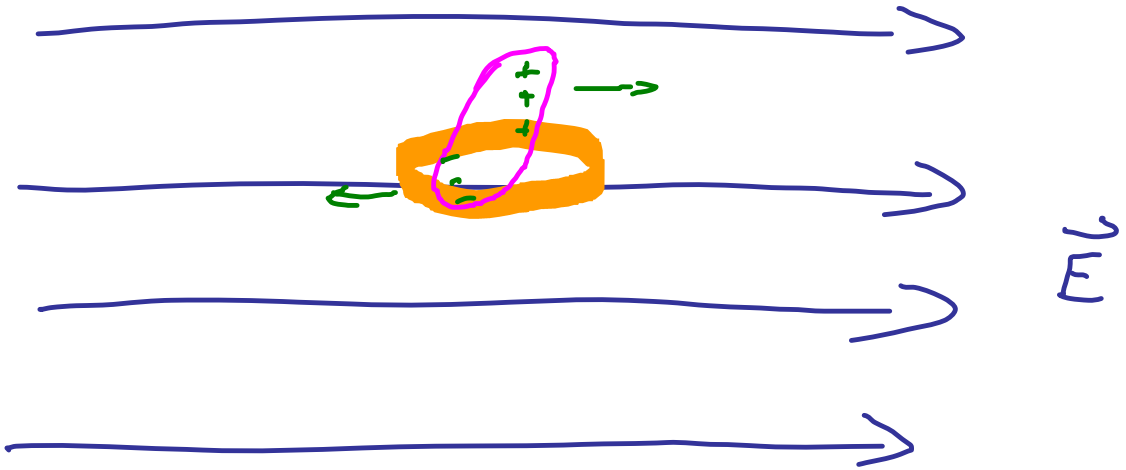


lines of force

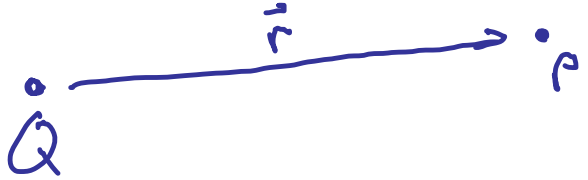
- go from $\oplus$ to $\ominus$
- lines Never cross
- density $\propto |\vec{E}|$
- $\vec{F}, \vec{E}$ always Tangent to line of force

Check out electric field java applet … link is on class website




E

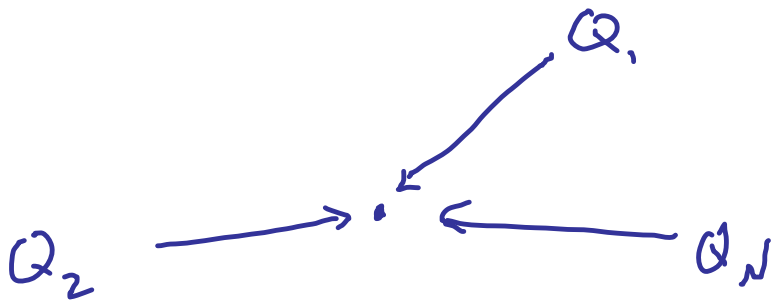
Electric field discrete charge



$$\vec{F}_{\substack{q \text{ at } P \\ \text{on} \\ \text{test chg}}} = \frac{kQq}{r^2}\hat{r}$$

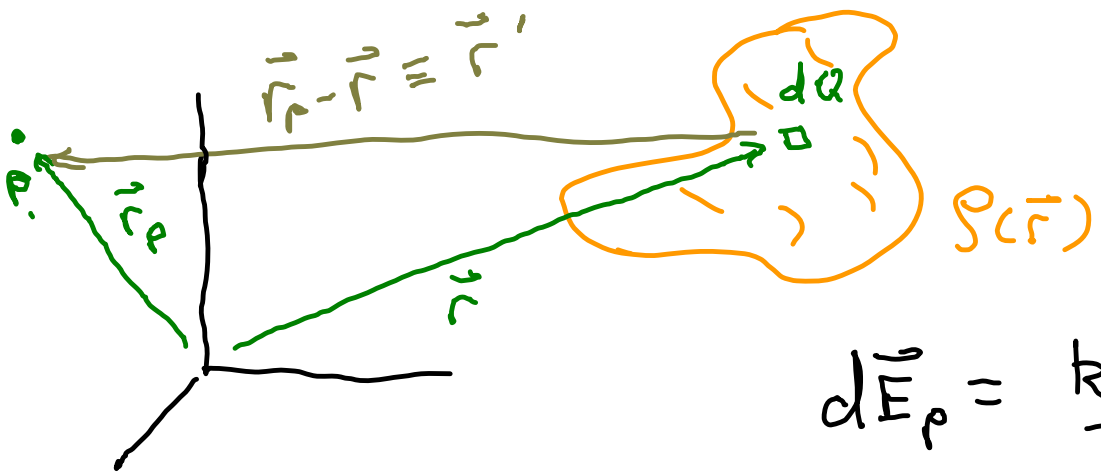
$$\vec{E}_{\substack{\text{due to } Q \\ \text{at } P}} = \frac{kQ}{r^2}\hat{r}$$

System of discrete charges



$$\vec{F}_{P \text{ on } q} = \sum \frac{kQ_i q \hat{r}_i}{r_i^2}$$

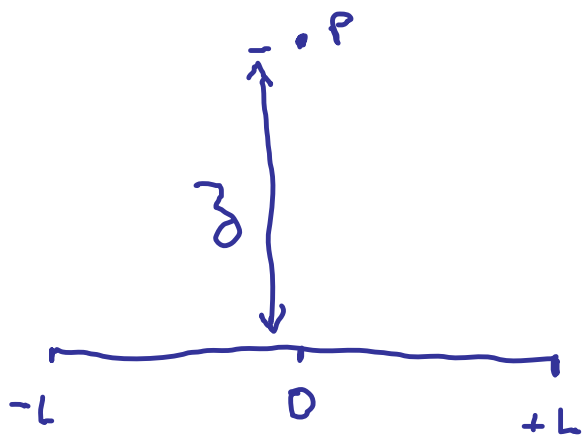
$$\vec{E}_{\substack{\text{at } P \\ \text{due to N Q's}}} = \sum \frac{kQ_i \hat{r}_i}{r_i^2}$$



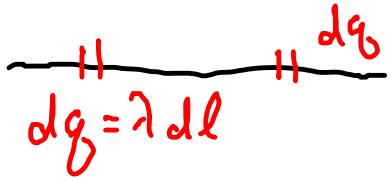
$$d\vec{E}_p = \frac{k\, dQ\, \hat{r}'}{r'^2}$$

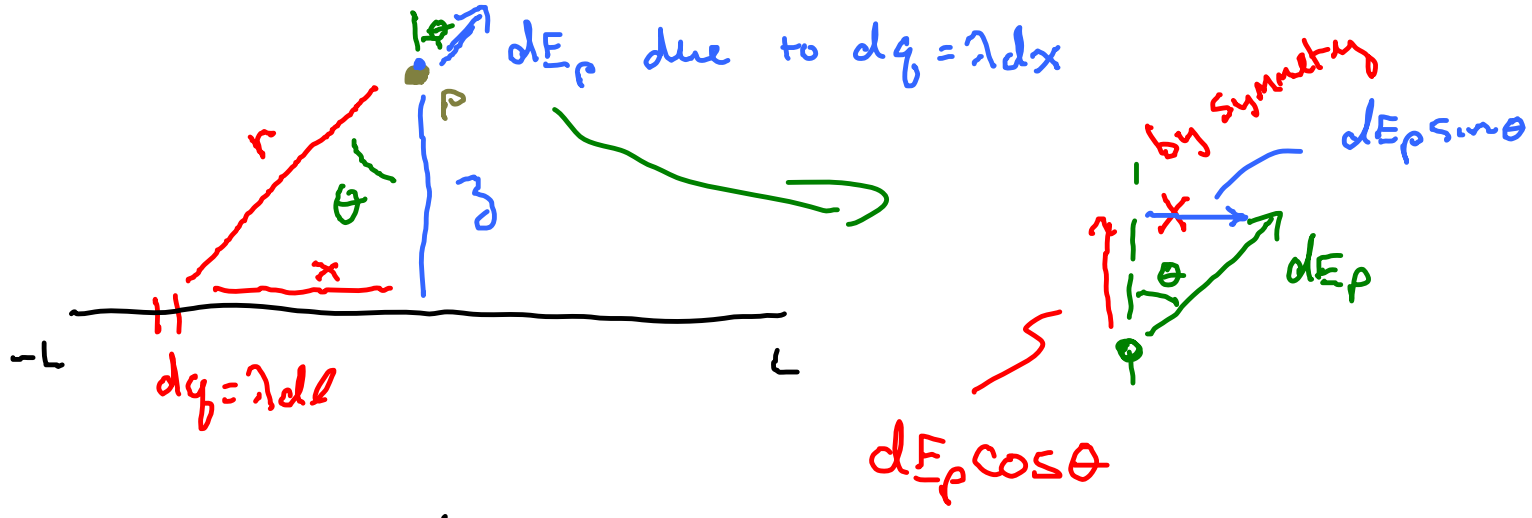
$$\vec{E}_p = \int_{\text{charge dist}} \frac{k\, dQ\, \hat{r}'}{r'^2} = \int_{\text{charg}} \frac{k\, \rho(r')\, dv\, \hat{r}'}{r'^2}$$

Example



Find $\vec{E}$ at a point P a distance z above the midpoint of a line segment of length 2L which carries a uniform line charge of λ.





$$\vec{E}_P = \int \frac{k\,dq}{r^2}\,\hat{r} = 2\int_0^L \frac{k\lambda dx}{r^2}\cos\theta\;\hat{z} \qquad r = (x^2+z^2)^{1/2}$$

$$\cos\theta = z/(x^2+z^2)^{1/2}$$

$$= 2k\lambda \int_0^L \frac{z}{(x^2+z^2)^{1/2}}\frac{dx\;\hat{z}}{(x^2+z^2)} = 2k\lambda\int_0^L \frac{z\,dx\;\hat{z}}{(x^2+z^2)^{3/2}}$$

$$\vec{E}_p = \left[\frac{x}{z^2 (x^2 + z^2)^{1/2}} \right]_0^L \hat{z}$$

$$\vec{E}_p = \frac{2k\lambda z L}{z^2 (L^2 + z^2)^{1/2}} \hat{z}$$