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HW 1: Method 1

$$E_{point} = \frac{kq}{r^2}$$

$$E_{quad} = kq\left[\frac{1}{(d+z)^2} - \frac{2}{z^2} + \frac{1}{(z-d)^2}\right]$$

$$= kq\left[\frac{z^2(z-d)^2 - 2(d-z)^2(d+z)^2 + z^2(d+z)^2}{(d+z)^2(z-d)^2z^2}\right]$$

$$= kq\left[\frac{z^2(\cancel{z^2}-2zd+d^2) - 2(d^4-2d^2z^2+\cancel{z^4}) + z^2(d^2+\cancel{2dz}+\cancel{z^2})}{(d+z)^2(d-z)^2z^2}\right]$$

$z >> d$

$$\approx kq\left[\frac{6z^2d^2 - \cancel{2d^4}_{0}}{z^6}\right] = \cancel{kqd^2[}$$

$$\approx \frac{6kqd^2}{z^4} = \frac{6kqd^2}{z^4}$$

$$Q = 2qd^2$$

$$E = \frac{3Q}{4\pi\varepsilon_0 z^4}$$

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Method 2

$$E_{quad} = E_{dipole}\left(z-\frac{d}{2}\right) - E_{dipole}\left(z+\frac{d}{2}\right)$$

$$E_{dipole} = \frac{2pk}{z^3}$$

$$E_{quad} = 2pk\left[\frac{1}{(z-\frac{d}{2})^3} - \frac{1}{(z+\frac{d}{2})^3}\right]$$

$$= \frac{2pk}{z^3}\left(\frac{1}{(1-\frac{d}{2z})^3} - \frac{1}{(1+\frac{d}{2z})^3}\right)$$

$z \gg d$ $$\approx \frac{2pk}{z^3}\left(\cancel{1}+\frac{3d}{2z} - \cancel{1}+\frac{3d}{2z}\right)$$

$$= \frac{\cancel{2}pk}{z^3}\left(\frac{3d}{\cancel{2}z}\right)^2$$

$p = qd$

$$= \frac{\cancel{2}qdk\,6d}{z^4} = \frac{3Q}{4\pi\varepsilon_0 z^4}$$

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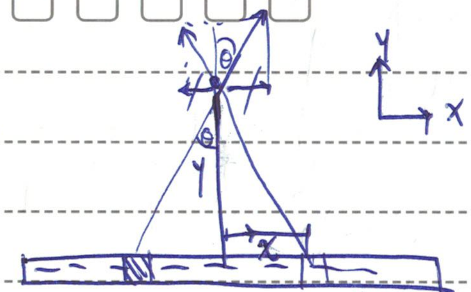
HW2



only y component survives the integral

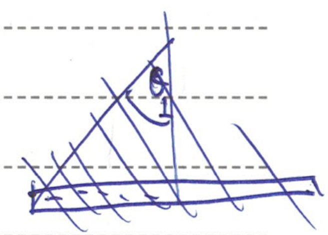
$$dE_y = \frac{k\lambda\, dx}{(x^2+y^2)} \frac{y}{(x^2+y^2)^{1/2}}$$

$$E_y = \int_{-z}^{z} \frac{k\lambda y\, dx}{(x^2+y^2)^{3/2}}$$

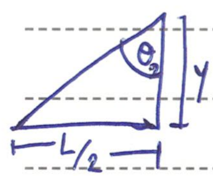
substitution

$$\frac{x}{y} = \tan\theta$$

$$dx = y\sec^2\theta\, d\theta$$



$$E_y = \int \frac{k\lambda y^2 \sec^2\theta\, d\theta}{y^3 \sec^3\theta}$$



$$= \frac{k\lambda}{y}\int \cos\theta\, d\theta = \frac{k\lambda}{y}\sin\theta \Big|_{\theta_1}^{\theta_2}$$

$$= \frac{k\lambda}{y}\left(\frac{L}{2}\right)\frac{1}{\sqrt{\left(\frac{L}{2}\right)^2 + y^2}}\,(\cancel{2}) \; -$$

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$$= \frac{2k\lambda L}{y\sqrt{L^2+4y^2}}$$

$$\lambda = \frac{q}{L}$$

$$= \frac{1}{2\pi\varepsilon_0}\frac{q}{y}\frac{1}{\sqrt{L^2+4y^2}}$$

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HW 3

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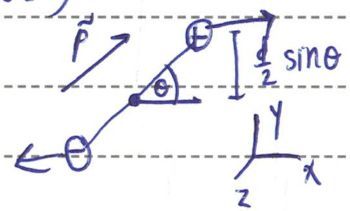
(a) $\Sigma F = qE - qE = 0$

(b)



$$\tau = pF\sin\theta$$
$$= -\left(\frac{d}{\cancel{2}}qE\sin\theta\right)\cancel{2}$$
$$= -pE\sin\theta$$

(c) $|\vec{p}\times\vec{E}| = +p|E|\sin\theta$

$\vec{p}\times\vec{E}$ is in negative z direction

therefor, torqe is negative

$\vec{\tau} = \vec{p}\times\vec{E}$

(d)

$$W = \int_{\frac{\pi}{2}}^{\theta} \tau \, d\theta$$
$$= \int_{\frac{\pi}{2}}^{\theta} -pE\sin\theta \, d\theta$$
$$= pE\cos\theta\Big|_{\frac{\pi}{2}}^{\theta} = pE\cos\theta$$

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$U = -W$

$= -pE\cos\theta$

$= -\vec{p}\cdot\vec{E}$

since $\vec{p}\cdot\vec{E} = pE\cos\theta$

(e) $\vec{U} = -\vec{p}\cdot\vec{E}$

minimize when $p \parallel E$ or $\theta = 0°, 360°, \ldots$

(f) $\tau = I\ddot{\theta}$

$-pE\sin\theta = I\ddot{\theta}$

if θ is small, $\sin\theta \approx \theta$ (from previous problem $\theta = 0°$ is equlibrium)

$\ddot{\theta} + \frac{pE\theta}{I} = 0$

Which is an equation for SHO

$\omega^2 = \frac{pE}{I}$

$\omega = 2\pi f$ $\quad f = \frac{1}{2\pi}\sqrt{\frac{pE}{I}}$

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