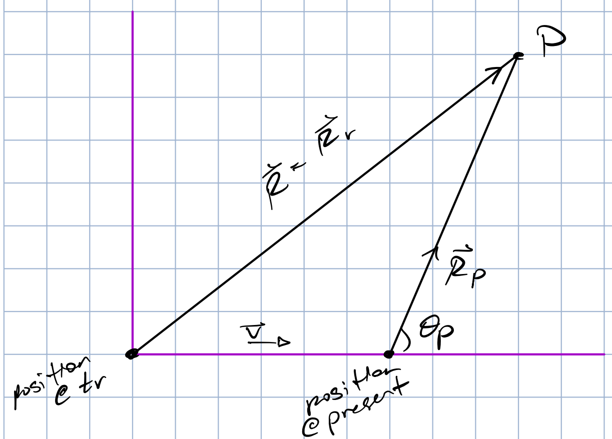
work out $\vec{S}$ for ① $v \neq 0, a = 0$ + ② $v \neq 0, a \neq 0$ $(\beta << 1)$

constant velocity $v \neq 0$, $a = 0$

$$\vec{E}_v(\vec{r}, t) = \frac{q}{4\pi\epsilon_0}\left(\frac{(\hat{R} - \vec{\beta})(1-\beta^2)}{k^3 R^2}\right)\Big]_{@t=t_r}$$

$$K = 1 - \vec{\beta}\cdot\hat{R}$$

$$t - t_r = R_r/c$$



$$\vec{R}_r = \vec{R}_p + \vec{v}(t - t_r)$$ position @ present + (velocity)·(time taken)

$$\vec{R}_p = \vec{R}_r - \vec{v}(t - t_r)$$

$$R_p^2 = R_r^2 - 2R_r(\vec{R}_r\cdot\vec{\beta}) + R_r^2\beta^2$$

$$k^2 R_r^2 = R_p^2\,(1 - \beta^2\sin^2\theta_p)$$

$$\vec{B}(\vec{r}, t) = \frac{1}{c}\,\vec{\beta}\times\vec{E}$$

$$\vec{E}_v(\vec{r}, t) = \frac{q}{4\pi\epsilon_0}\left(\frac{1-\beta^2}{R_p^2(1-\beta^2\sin^2\theta_p)^{3/2}}\right)\hat{R}_p$$

nonconstant velocity $v \neq 0$ $a \neq 0$ $(\beta << 1)$

$$\vec{E}_a(\vec{r}, t) = \left(\frac{q}{4\pi\epsilon_0}\right)\left(\left(\frac{1}{c^2 k^3 R}\right)\cdot \underbrace{\hat{R}\times\{(\hat{R} - \cancel{\vec{\beta}})\times\vec{a}\}}_{\hat{R}\times(\hat{R}\times\vec{a})}\right)\Big|_{t=t_r}$$

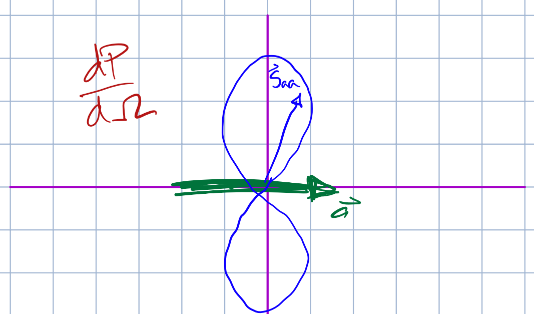
$$\left.\begin{array}{l} K = 1 - \cancel{\vec{\beta}}\cdot\hat{R} = 1 \\ \hat{R} = \dfrac{\vec{R}}{|\vec{R}|} \end{array}\right\} \quad S_{aa} = \frac{1}{\mu_0}(\vec{E}_{aa}\times\vec{B}_{aa}) = \frac{1}{\mu_0 c}\cdot(E_{aa})^2\,\hat{R}$$

$$E_a^2 = \left(\frac{q}{4\pi\epsilon_0}\right)^2\cdot\left(\frac{1}{c^2 R}\right)^2\left(\hat{R}\times(\hat{R}\times\vec{a})\right)^2$$

$$= \left(\frac{\mu_0 q}{4\pi R}\right)^2\cdot\left(a^2 - (\hat{R}\cdot\vec{a})^2\right)\hat{R}$$

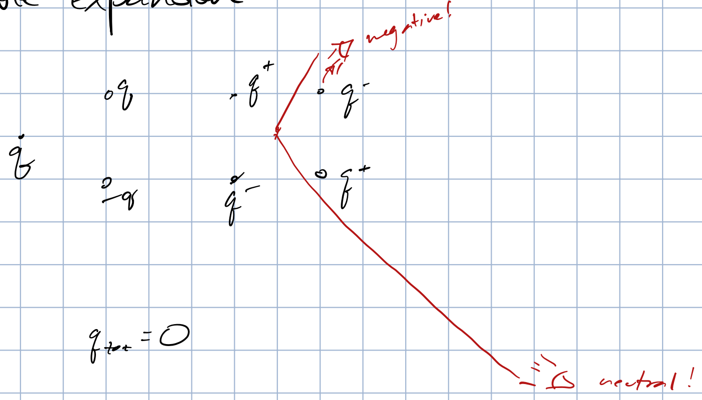
$$\vec{S}_{aa} = \left(\frac{\mu_0 q^2}{16\pi^2 c}\right)\cdot\left(\frac{a^2\sin^2\theta}{R^2}\right)\hat{R}$$

energy/(time · area)



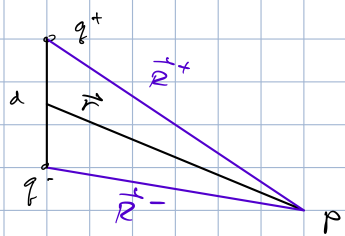
Power radiated: $P = \oint \vec{S}_{rad} \cdot d\vec{a} \rightarrow P = \frac{\mu_0 q^2}{6\pi c} \cdot a^2$ Larmor Radiation

Multipole expansion



$q_{tot} = 0$

dipole:



$\vec{p}_0 = p_0 \hat{z} = q_0 \cdot d \cdot \hat{z}$ $(+q = -(-q) = q_0)$

$\vec{p}(t) = p_0 e^{-i\omega t} \hat{z}$ oscillating dipole

$Re[\vec{p}(t)] = p_0 \cos(\omega t)$

assuming:
1. $d \ll r$ or $\frac{d}{r} \ll 1$
2. $d \ll \frac{c}{\omega} = \lambda$ 1 wavelength sees all dipole
3. $r >> \frac{c}{\omega} = \lambda$

$d \ll \lambda \ll r$