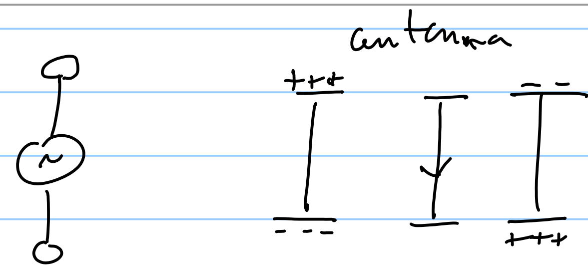
$t_r = t - \frac{r}{c}$ source & rec. are fixed

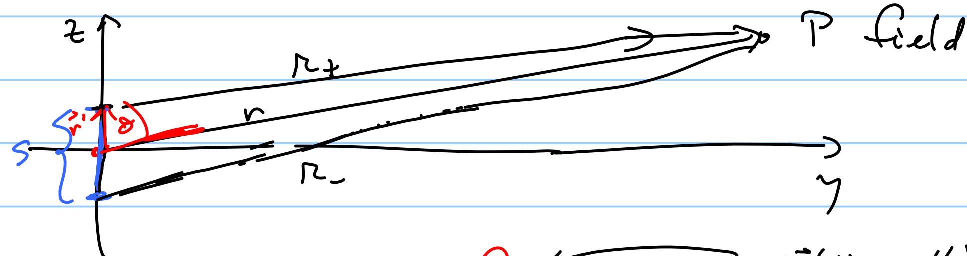
Note Title 7/3/2006

Ex:



$q(t) = q_0 \cos\omega t$

$I = \frac{dq}{dt}$



$$V(\vec{r},t) = \frac{1}{4\pi\epsilon_0}\int \frac{\rho(\vec{r}\,',t_r)}{r}\,d\tau'$$

$$\rho(\vec{r}\,',t) = q(t)\,\delta\!\left(\vec{r}\,' - \frac{s}{2}\hat{z}\right) - q(t)\,\delta\!\left(\vec{r}\,' + \frac{s}{2}\hat{z}\right)$$

$r \to r_+$ or r_-

$$V(\vec{r},t) = \frac{1}{4\pi\epsilon_0}\left[q_0 \frac{\cos\left[\omega\left(t - \frac{r_+}{c}\right)\right]}{r_+} - q_0 \frac{\cos\left[\omega\left(t - \frac{r_-}{c}\right)\right]}{r_-} \right]$$

approx

Approx: far away from dipole $s \ll r$

$\lambda \ll r$ far field approx

$$\pi_+^2 = \vec{\pi}_+ \cdot \vec{\pi}_+ = r^2 + r'^2 - 2\,\underline{\vec{r}\cdot\vec{r}\,'} \qquad \vec{r}\,' = \frac{s}{2}\hat{J}$$

$$|\vec{\pi}_+| \simeq r\left(\underline{1} - \frac{s}{2r}\cos\theta\right)$$: keep only terms 1st order in $\frac{s}{r}$

$\omega\left(t - \frac{\pi_+}{c}\right)$ $\left(1 - \frac{s}{2r}\frac{\cos\theta}{c}\right)\omega$

$\lambda\nu = c$

$\frac{\omega}{c} = \frac{2\pi}{\lambda}$

$$V(r,\theta,t) = -\frac{P_0\,\omega}{4\pi\epsilon_0 c}\,\frac{\cos\theta}{r}\,\sin\omega\left(t - \frac{r}{c}\right)$$

$\frac{s}{r}$

P_0 is dipole moment $= q_0 s$ $\qquad -q_0\,\omega\sin(\omega t)\,\hat{z}\,\times\delta(x')\,\delta(y')$ ''

Vector potential $\quad \vec{A}(\vec{r},t) = \frac{\mu_0}{4\pi}\int \frac{I(\vec{r}\,',t_r)\,d\tau'}{\pi}$

$$= \frac{\mu_0}{4\pi}\int \frac{-q_0\,\omega\sin\left[\omega(t - \pi/c)\right]\hat{z}}{\pi}\,dz' \qquad \int\delta(x')\,dx' = 1$$

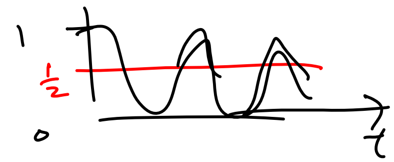
to 1st order in $\frac{s}{r}$ $\quad \vec{A}(\vec{r},t) = \frac{\mu_0}{4\pi}\,-q_0\,\omega\,\frac{\sin\omega\left(t - \frac{r}{c}\right)}{r}\int_{-s/2}^{s/2} dz'\,\hat{z}$

In far field this appears to be a spherical wave

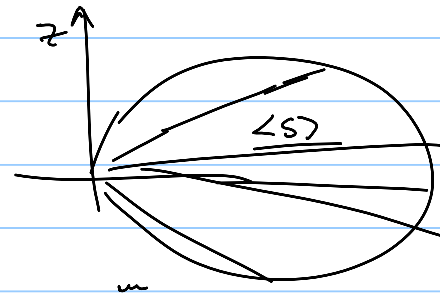
$\hat{k} = \cos\theta\,\hat{r} - \sin\theta\,\hat{\theta}$ & find $\vec{E}$ & $\vec{B} = \vec{\nabla}\times\vec{A}$

$\vec{E} = -\vec{\nabla}V - \frac{\partial\vec{A}}{\partial t}$

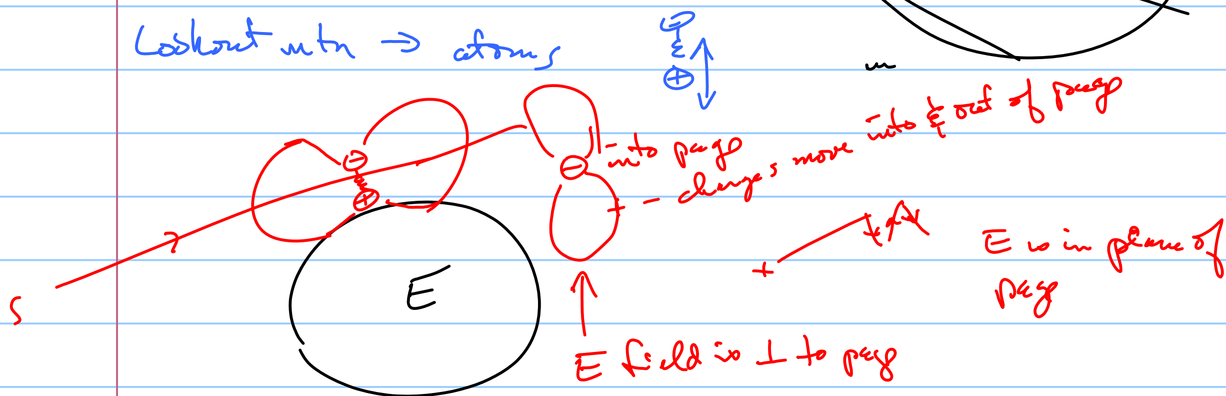
Find $\left\langle \frac{\vec{E} \times \vec{B}}{\mu_0} \right\rangle$ $\qquad \cos^2(\omega t \cdots)$



$$\langle S \rangle = \frac{\mu_0 P_0^2 \omega^4}{32 \pi^2 c} \frac{\sin^2 \theta}{r^2} \hat{r}$$



Look out wdw → atoms



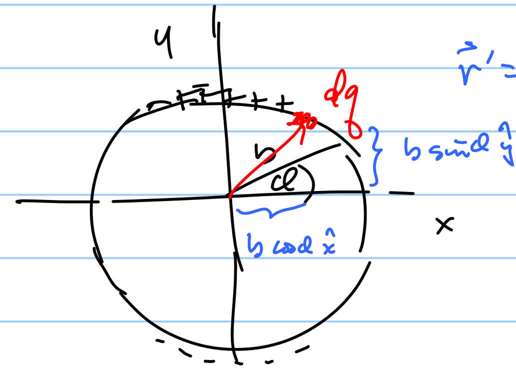
Lamor formula for power radiated

$$P = \int \vec{S} \cdot d\vec{a} = \frac{\mu_0 \ddot{p}^2}{6 \pi c}$$

p is dipole moment

$\vec{P} = q\vec{s}$ for two charges $\qquad \vec{p} = \int \underset{\rho d\tau'}{\underset{\shortparallel}{dq}}\, \vec{r}\,' = \int \rho\, d\tau'\, \vec{r}\,'$

1-D $\quad \vec{p} = \int \lambda\, dl'\, \vec{r}\,'$



$\vec{r}\,' = b\cos\varphi\,\hat{x} + b\sin\varphi\,\hat{y}$

$\lambda = \lambda_0 \sin\varphi$

$dl' = b\, d\varphi$

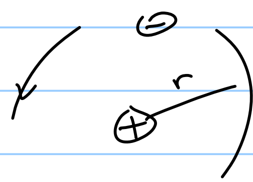
$\vec{r}\,' = b\,\hat{r}$

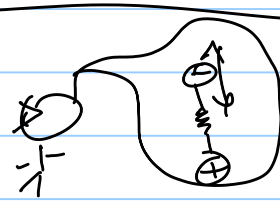
$$\int_0^{2\pi} \lambda_0 \sin\varphi\, b\, d\varphi\, b\, \hat{r}$$

cannot come outside integral because it depends on φ

$$\int_0^{2\pi} \lambda_0 \sin\phi\, b\, d\phi \left[b\cos\varphi\,\hat{x} + b\sin\varphi\,\hat{y} \right] = \vec{p}$$

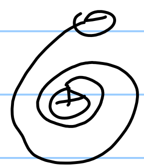
$\varphi(t)$





$$P_{rad} = \frac{a_1}{r^4}$$

$$U_{\cancel{\text{atom}}\ \text{electron}} = U_{\text{kin}} + U_{\text{potential energy}} = -\frac{a_2}{r(t)}$$



$r(t)$

$$-\frac{dU_{tot}}{dt} = -\frac{dU}{dr}\frac{dr}{dt} = P_{\text{radiation}}$$

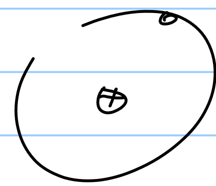
Larmor for

loss of energy

$\ddot{P}$

circular motion

$$\text{accel} = \frac{v^2}{r}$$



$$F = ma = m\frac{v^2}{r}$$

$\parallel$

Coulomb