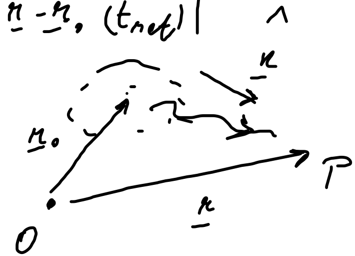
$$\phi(\mathbf{r},t) = \frac{q}{4\pi\varepsilon_0}\,\frac{1}{|\mathbf{r}-\mathbf{r}_0(t_{ret})|}\,\frac{1}{1-\dfrac{\mathbf{v}_0\cdot(\mathbf{r}-\mathbf{r}_0(t_{ret}))}{c\,|\mathbf{r}-\mathbf{r}_0(t_{ret})|}}$$

$$t_{ret} = t - \frac{|\mathbf{r}-\mathbf{r}_0(t_{ret})|}{c}$$

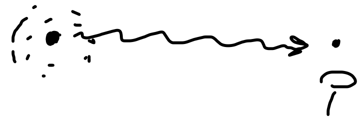


$$\mathbf{E} = -\nabla\phi - \frac{\partial}{\partial t}\mathbf{A}$$

$$\mathbf{A}(\mathbf{r},t) = \frac{\mu_0}{4\pi}\,\frac{\mathbf{v}_0(t_{ret})}{|\mathbf{r}-\mathbf{r}_0(t_{ret})|}\cdot\frac{q}{1-\dfrac{\mathbf{v}_0\cdot(\mathbf{r}-\mathbf{r}_0(t_{ret}))}{c\,|\mathbf{r}-\mathbf{r}_0(t_{ret})|}}$$

$$\mathbf{B} = \nabla\times\mathbf{A}$$

$$\hat{\underline{r}} = \frac{(\underline{r} - \underline{r}_0(t_r))}{|\underline{r} - \underline{r}_0(t_r)|}$$



$$\underline{S} = \underline{E} \times \underline{H} = \frac{1}{\mu_0} \underline{E} \times \underline{B}$$

$$P_{ower} = \int_{surface} \underline{S} \cdot d\underline{a} \qquad [S] = W/m^2$$

Area $\propto r^2$ $\qquad S \propto \frac{1}{r^2} \Rightarrow E \propto \frac{1}{r}$ $\qquad$ Radiative components

$B \propto \frac{1}{r}$

Intermediate results

$$t = t_r + \frac{1}{c}\sqrt{(x - x_0(t_r))^2 + (y - y_0(t_r))^2 + (z - z_0(t_r))^2}$$

$$\frac{\partial t}{\partial t_r} = $$

$$= 1 + \frac{1}{\cancel{2}c} \frac{-\cancel{2}(x - x_0(t_r)) \cdot v_{0x} - \cancel{2}(y - y_0(t_r))\, v_{0y} - \cancel{2}(z - z_0(t_r))\, v_{0z}}{(\quad)^{\frac{1}{2}}}$$

$$= 1 - \frac{v_r(t_r)}{c} \qquad v_r = \underline{v}_0 \cdot \hat{\underline{r}}$$

$$\simeq 1$$

$$v_r/c \ll 1$$

$$\underline{\nabla} t = ?$$

$$\frac{\partial t}{\partial x} = \frac{1}{\cancel{2}c} \frac{\cancel{2}(x - x_0(t_r))}{(\quad)^{\frac{1}{2}}} \qquad \frac{\partial t}{\partial y} = \frac{y - y_0(t_r)}{c(\quad)^{\frac{1}{2}}} \qquad t_r = t - \frac{1}{c}\sqrt{\ldots}$$

$$\underline{\nabla} t_r = -\hat{\underline{r}}/c$$

$$\frac{\partial t}{\partial z} = \frac{z - z_0(t_r)}{c(\quad)^{\frac{1}{2}}} \qquad \underline{\nabla} t = \frac{1}{c} \frac{\underline{r} - \underline{r}_0}{|\underline{r} - \underline{r}_0|} = \hat{\underline{r}}/c$$

$$\frac{\partial \underline{A}^{(R)}}{\partial t} =$$

$$\frac{\partial}{\partial t}\left(\frac{\mu_0}{4\pi}\frac{\underline{v}_0(t_R)}{|\underline{r}-\underline{r}_0(t_R)|}\cdot\frac{q}{\underbrace{1-\frac{v_r}{c}}_{\substack{12\\1}}}\right) = \frac{1}{|\underline{r}-\underline{r}_0(t_R)|}\frac{\mu_0 q}{4\pi}\frac{\partial \underline{v}_0}{\partial t_R}\cdot\underbrace{\frac{\partial t_R}{\partial t}}_{\substack{12\\1}} \simeq \frac{\mu_0 q}{4\pi|\underline{r}-\underline{r}_0(t_R)|}\cdot\dot{\underline{v}}_0$$

$$(\underline{\nabla}\times\underline{A})^{(R)} = \frac{\mu_0 q}{4\pi}\frac{1}{|\underline{r}-\underline{r}_0(t_R)|}\cdot\underline{\nabla}\times\underline{v}_0(t_R)$$

$$\underline{\nabla}\times\underline{v}_0(t_R) = \begin{pmatrix} \frac{\partial v_{0z}(t_R)}{\partial y} - \frac{\partial v_{0y}(t_R)}{\partial z} \\ \frac{\partial v_{0x}}{\partial z} - \frac{\partial v_{0z}}{\partial x} \\ \frac{\partial v_{0y}}{\partial x} - \frac{\partial v_{0x}}{\partial y} \end{pmatrix} = \begin{pmatrix} \underbrace{\frac{\partial v_{0z}}{\partial t_R}}_{(\dot{\underline{v}}_0)_z}\cdot\frac{\partial t_R}{\partial y} - \frac{\partial v_{0y}}{\partial t_R}\cdot\frac{\partial t_R}{\partial z} \\ - - - \,. \\ \_\_ \; - \, . \end{pmatrix} = \underline{\nabla} t_R \times \dot{\underline{v}}_0$$

$$= -\frac{\hat{\underline{n}}}{c}\times\dot{\underline{v}}_0$$

$$\left(\underline{\nabla}\times\underline{A}\right)^{(R)} \simeq -\frac{\mu_0 q}{4\pi c}\,\frac{q}{|\underline{r}-\underline{r}_0(t_R)|}\,\hat{\underline{n}}\times\underline{\dot{v}}_0$$

$$\underline{\nabla}\phi^{(R)} = \underline{\nabla}\left(\frac{q}{4\pi\varepsilon_0}\,\frac{1}{|\underline{r}-\underline{r}_0(t_R)|}\,\underbrace{\frac{1}{1-\frac{v_r}{c}}}_{\simeq 1}\right) \simeq \underline{\nabla}\left(\frac{q}{4\pi\varepsilon_0}\,\frac{1}{|\underline{r}-\underline{r}_0(t_R)|}\right)=0$$

$$\underline{\nabla}\phi^{(R)} = \frac{q}{4\pi\varepsilon_0}\,\frac{1}{|\underline{r}-\underline{r}_0(t_R)|}\,\underline{\nabla}\,\frac{1}{1-\frac{v_r}{c}} = \frac{q}{4\pi\varepsilon_0}\,\frac{1}{|\underline{r}-\underline{r}_0(t_R)|}\,+\frac{1}{\underbrace{\left(1-\frac{v_r}{c}\right)^2}_{\simeq 1}}\cdot\underline{\nabla}\left(+\frac{v_r}{c}\right)$$

$$\underline{\nabla}(v_r) = ?$$

$$\underline{\nabla}^{(R)} v_r = \underline{\nabla}\left(\underline{v}_0 \cdot \frac{(\underline{r}-\underline{r}_0(t_R))}{|\underline{r}-\underline{r}_0(t_R)|}\right) \approx \frac{1}{|\underline{r}-\underline{r}_0(t_R)|}\underline{\nabla}\left(\underline{v}_0 \cdot (\underline{r}-\underline{r}_0(t_R))\right)$$

$$\frac{\partial}{\partial x}\left(v_{0x} \cdot (x - x_0(t_R))\right) = \dot{v}_{0x}\frac{\partial t_r}{\partial x} \cdot (x - x_0(t_R)) + v_{0x} \cdot \left(1 - \frac{\partial x_0}{\partial t_r} \cdot \frac{\partial t_r}{\partial x}\right)$$

$$= -\frac{\dot{v}_{0x}(x - x_0(t_R))^2}{c\,|\underline{r}-\underline{r}_0(t_R)|} + v_{0x} \cdot \Bigg(1 - \underbrace{\frac{v_{0x}}{c}\frac{(x-x_0)}{|\underline{r}-\underline{r}_0|}}_{\ll 1}\Bigg)$$

$$\underline{\nabla}(v_r) \approx -(\dot{\underline{v}}_0 \cdot \hat{\underline{n}})\hat{\underline{n}}/c + \underline{v}_0/|\underline{r}-\underline{r}_0| \approx -(\dot{\underline{v}}_0 \cdot \hat{\underline{n}})\hat{\underline{n}}/c$$

$$\underline{\nabla}\phi^{(R)} \simeq \frac{-q}{4\pi\varepsilon_0 |\underline{r}-\underline{r}_0(t_R)|} \cdot \frac{(\dot{\underline{v}}_0 \cdot \hat{\underline{n}})\hat{\underline{n}}}{c^2} = -\frac{\mu_0 q}{4\pi |\underline{r}-\underline{r}_0(t_R)|} \cdot (\dot{\underline{v}}_0 \cdot \hat{\underline{n}})\hat{\underline{n}}$$

$$\frac{1}{c^2} = \varepsilon_0\mu_0$$

$$\underline{B}^{(R)} \simeq -\frac{\mu_0 q}{4\pi c |\underline{r}-\underline{r}_0(t_R)|} \hat{\underline{n}} \times \dot{\underline{v}}_0 = \frac{\mu_0 q}{4\pi c |\underline{r}-\underline{r}_0(t_R)|} \cdot (\dot{\underline{v}}_0 \times \hat{\underline{n}})$$

$$\underline{E}^{(R)} \simeq \frac{\mu_0 q}{4\pi |\underline{r}-\underline{r}_0(t_R)|} \cdot \left[(\dot{\underline{v}}_0 \cdot \hat{\underline{n}})\hat{\underline{n}} - \dot{\underline{v}}_0\right] \simeq \frac{\mu_0 q}{4\pi |\underline{r}-\underline{r}_0(t_R)|} \cdot (\dot{\underline{v}}_0 \times \hat{\underline{n}}) \times \hat{\underline{n}}$$

$$(\underline{C} \times \underline{B}) \times \underline{A} = (\underbrace{\underline{A}}_{\hat{\underline{n}}} \cdot \underbrace{\underline{C}}_{\dot{\underline{v}}_0})\underbrace{\underline{B}}_{\hat{\underline{n}}} - (\underline{A} \cdot \underline{B})\underline{C} = \frac{1}{c} \underline{B}^{(R)} \times \hat{\underline{n}}$$

$\underline{S} = ?$ $\quad P = ?$ $\quad \dfrac{dP}{d\Omega} = ?$