Lecture 37

Application of E-radiation formula due to acceleration of a point charge:

\[ \vec{E}_P = \frac{kq}{c^2r} (-\vec{a}) \]

For 1D-plane wave case – simple case:  (Assume \( q > 0 \))

At \( P \), \( \vec{E} \) ↓

(Source is a current sheet)

For point charge case, notice only \( a \)-perp contributes.
As is convenient, do the vector decompositions as indicated.
At \( P \) the direction of E-rad detected is indicated by the dashed vector.
EM Waves

EM waves in a vacuum are specified by one thing:

$$\lambda \ or \ f$$

EM wave spectrum:

Radio Station KLBJ

$$590 \ kHz \approx 600 \times 10^3 \frac{1}{sec} \quad \lambda = \frac{c}{f} = \frac{3 \times 10^8}{6 \times 10^5} \approx 500 \ m$$

Example of EM waves:

<table>
<thead>
<tr>
<th>Wave Type</th>
<th>Description</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio AM</td>
<td>Stadium</td>
<td>$10^3$ m</td>
</tr>
<tr>
<td>Microwaves</td>
<td>Bean size</td>
<td>$10^2$ m</td>
</tr>
<tr>
<td>Visible Light</td>
<td>Micrometer</td>
<td>600 nm</td>
</tr>
<tr>
<td>X-Ray</td>
<td>Atomi size</td>
<td>$10^{-10}$ m</td>
</tr>
</tbody>
</table>
Q23.5a

A narrow collimated pulse of radiation propagates in the –y direction. There is a proton at location B. What is the direction of the radiative electric field detected at location A?
\[ E_y \approx \sin(\omega t_0 - kx + \phi) \]

Sinusoidal in x:

\[ k\lambda = 2\pi, \quad k = \frac{2\pi}{\lambda} \]

\( \lambda \) is a conversion factor from x-scale to angle-scale

Period:
\[ \omega T = 2\pi, \quad \omega = \frac{2\pi}{T} = 2\pi f \]

Fix phase: Defines the speed the fixed shape travels

\[ v = \left. \frac{dx}{dt} \right|_{fixed \ phase} \]

\[ \omega t - kx + \phi = \text{const.} \]

\( kx = \omega t + \phi - \text{const.} \)

\[ \therefore \frac{dx}{dt} = \frac{\omega}{k} = \left( \frac{2\pi}{T} \right) / \left( \frac{2\pi}{\lambda} \right) = \frac{\lambda}{T} = \lambda f = c \]
Radiation Field Due to Sinusoidal Oscillation of a Point Charge

\[ y = y_{\text{max}} \sin \omega t \]
\[ \frac{dy}{dt} = y_{\text{max}} \omega \cos \omega t \]
\[ \frac{d^2y}{dt^2} = y_{\text{max}} \omega^2 (-\sin \omega t) = -\omega^2 t \]

\[ E_y = \frac{kq}{c^2 r} (-a_\perp) = \frac{kq}{c^2 r} y_{\text{max}} \omega^2 \sin \omega t = E_{y,\text{max}} \sin \omega t \]

Along x (or more generally, along r):
\[ E_y = E_{y,\text{max}} \sin(\omega t - kx + \phi) \]

Fix \( t = t_0 \):
\[ E_y \approx \sin(\omega t_0 - kx + \phi) \]

\( \Phi \) is the initial phase angle of the oscillation.
Q23.3d

A proton is accelerated in the direction shown.

What is the direction of propagation of radiation reaching location S?
Q23.3a

A proton is accelerated in the direction shown.

What is the direction of propagation of radiation reaching observation location P?