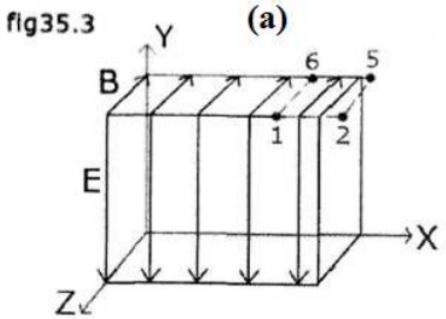
# Lecture 36

Propagation of EM waves:

1. $E \perp B$, $E \times B$ gives the direction of propagation $E = vB$
2. Universal Speed $v = \dfrac{1}{\sqrt{\mu_0 \epsilon_0}}$ (in a vacuum)

   All light is an EM wave, and travels with the same speed
3. $E = cB$

Reflection: c is the speed of the "wavefront"

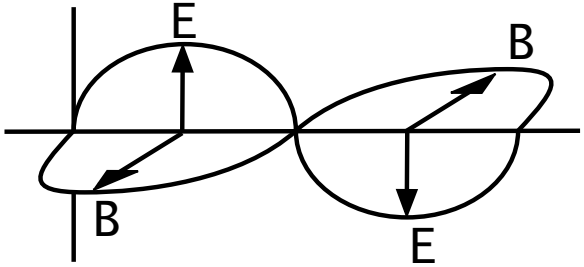



Field has a boundary. This boundary travels with v = c in vacuum.

The wave shape is initiated by the t-dependence of the source.

For sinusoidal current:

The squares are rounded off



EM Pulse due to a acceleration of point charge

Fields generated by point charge:

$$q \Rightarrow \vec{E} = \frac{kq}{r^2}\hat{r}$$

$$qv \Rightarrow \vec{B} = \frac{\mu_0}{4\pi}\frac{q\vec{v} \times \hat{r}}{r^2}$$

$$q\vec{a} \Rightarrow EM\ radiation\ field\ E_{rad} = \frac{kq(-\vec{a}_\perp)}{c^2 r}$$

$$|B_{rad}| = \frac{E_{rad}}{c}$$

$< \vec{E}_{rad} \times \vec{B}_{rad} >$ Is direction of travel

**Consider a stationary charge is accelerated (knocked) in a short time. The stationary field pattern is isotropic. A short knock leads to a field pattern with a kink. This kink is traveling radially outward with speed of light.**

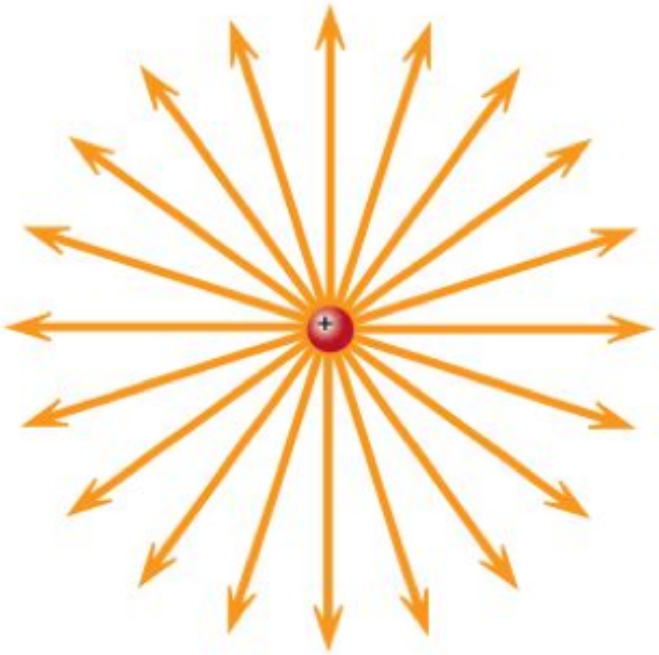


***Figure 24.16*** Directions of electric field surrounding a stationary positive charge.

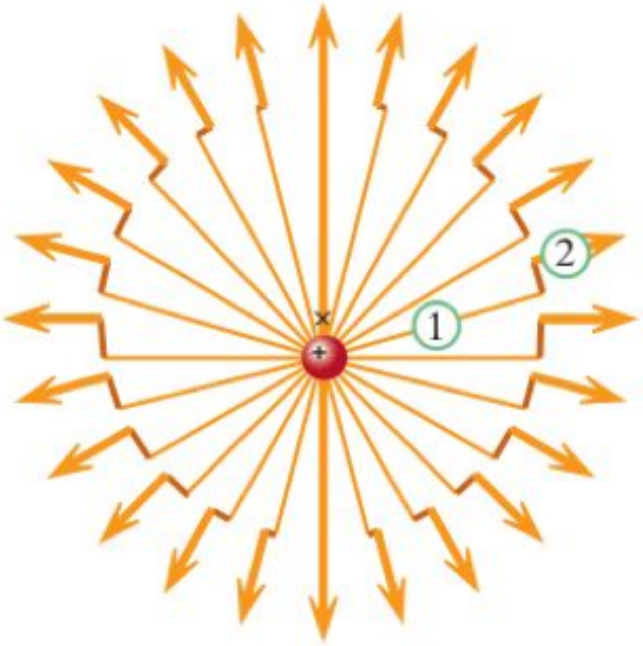
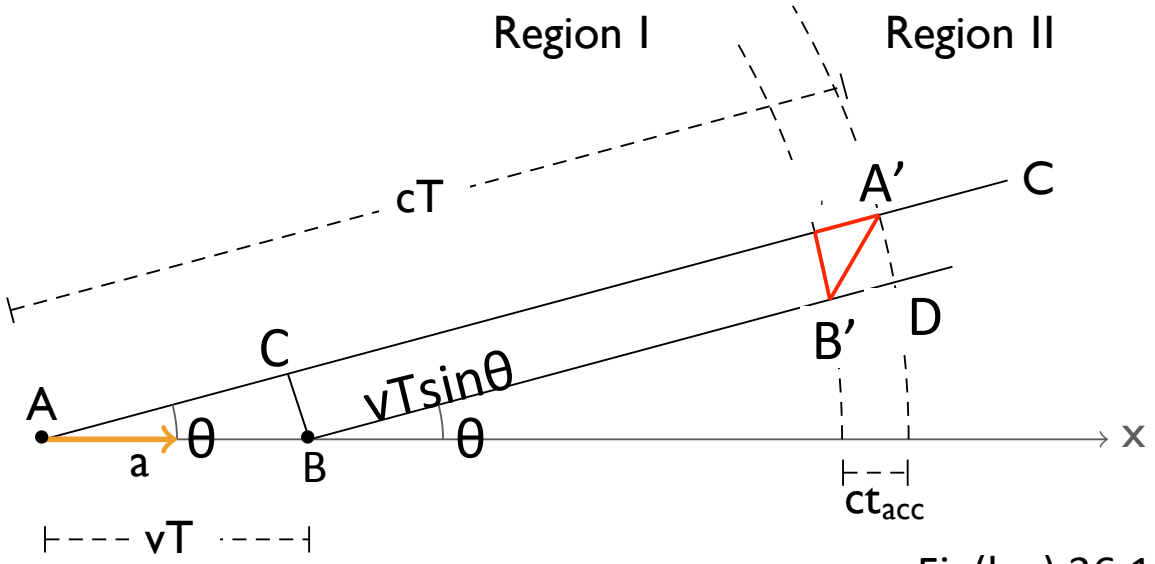



***Figure 24.17*** Directions of electric field shortly after the charge was kicked. The × marks the original location of the charge.

In section 24.11 in the textbook the derivation of field due to acceleration of point charged particle is discussed. We will cover selected features in this derivation.




Fig(lec) 36.1

1. The figure above illustrates the setup
   - A positively charged particle was at rest at location A. At t = 0, it experiences a brief acceleration "a" to the right to arrive at a low speed, $v = a\, t_{acc}$ after a short time interval acceleration.
   - At large time t = T, the light signal from A reaches A' at distance r and angle θ. AA' = r = cT
   - Along x-axis, A coasts to B along x-axis at AB = vT.
   - The light signal from B reaches B' at angle θ, and at r.

The acceleration zone is bordered by the pair of two circular arcs through the points A' and B'. The thickness of this radiation zone is $ct_{acc}$.

2. From Gauss Law argument, the text shows that in the acceleration zone region there is a similar triangular relationship.

$$\tan\alpha = \frac{A'D}{B'D} = \frac{E_{rad}}{E_{coul}}$$

Thus $E_{rad} = \tan\alpha E_{coul}$

Here tanα can be obtained from geometry and coulomb field is known, i.e. $E_{coul} = \frac{kq}{r^2}$. So $E_{rad}$ can be determined.

3. Evaluate the geometric factor. $\tan\alpha = \frac{A'D}{B'D}$. From geometry

$$A'D = BC = vT\sin\theta$$

$$B'D = ct_{acc}$$

Using the relations: $\frac{v}{t_{acc}} = a$ and $r = cT$, one arrives at

$$\tan\alpha = a\frac{r}{c^2}\sin\theta \quad (2)$$

$$= \frac{a_\perp r}{c^2}$$

Sub. gives: $E_{rad} = \left(\frac{kq}{r^2}\right)\frac{a_\perp r}{c^2} = \frac{kqa_\perp}{c^2 r}$