Lecture37 iq32

1D plane EM waves & Radiation from accelerating a charged particle

1. Ch24.h1: 15-16. 1D plane EM waves.
   - Switch on the current sheet at t=0.
   - B-flux passing through the front window 12341 and Faraday's law
   - E-flux passing through the top area 12561 and Ampere-Maxwell's law
   - v^2=1/(esp0 x mu0)
   - Measurement of esp0 and mu0 in static experiments.

   Faraday law and Ampere-Maxwell's law enable the propagation of EM waves in vacuum.
2. Properties of the EM waves.
3. Radiative E field due to acceleration of a point charge.
   - Stationary at A, there is an isotropic E-field pattern.
   - After a knock. A kink structure appears in the pattern. It expands outward with the speed of light.
   - A snapshot at T
     i. The acceleration zone
     ii. Determine the radiative field at theta, r
     iii. The direction of the total E field is along the segment 21. (See the proof in Sec24.11 is based on the Gauss's law.)
4. The key steps in the derivation.
   - tan (alpha)= $E_{perp}/E_{parall} = E_{radiative}/E_{coul}$
   - Geometry: tan (alpha)= vT sin(theta)/(c t_{acc}).
   - Complete the homework problem: ch24.h2 008-012

Announcement:

Please take a look at the updated lesson plan (see the top line on our homepage)

The lecture video in our homepage is now available for viewing. Keep in mind it is an experimental project. Your feedback is welcome.

Application of the LA position is now available. For those of you who do well in this course are encouraged to apply the LA job. LAs are playing an important part in helping students through their interaction with students. If you are interested in this job opportunity please contact Lisa Gentry*.

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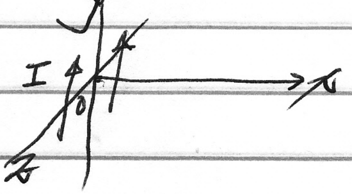
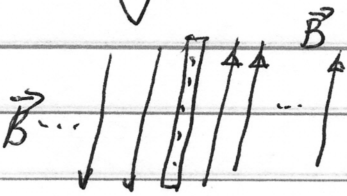
1. Properties of EM waves — Ch24. h1. 015, 016.

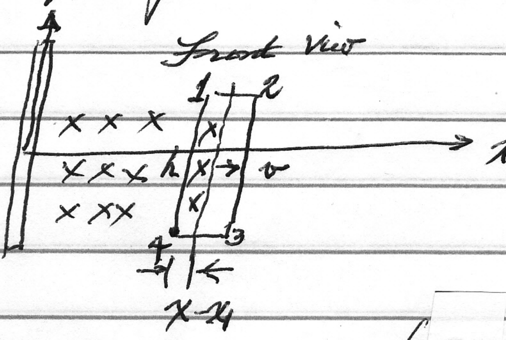
1d-plane wave —



If we have I along y, for this infinite current sheet (top view)



we would have B-pattern: to the right B points upward, to the left B points downward. This is the situation after I - turned on for a long time. Suppose I is turned on at $t=0$. For small t, B is established near $x=0$. It takes time to have B field spread out. Here is the situation



Within window |2341|,

At earlier time $\Phi_B = 0$

At $t=t_1$, $\Phi_B = Bh(x-x_1)$

Faraday L: $\oint E\cdot dl = -\frac{d\Phi_B}{dt}$. RHS: Φ_B increase

clicker Find: Dir of B in ⊙, E field ⊙

F.L. $|Eh| = |Bhv|$ $\therefore E = Bv$ (1)

Top loop: 12561 Amp-M Law —

$\oint B\cdot dl = \mu_0\epsilon_0 \frac{d\Phi_E}{dt}$ $\quad Bb = \mu_0\epsilon_0 Ebv$

$B = \mu_0\epsilon_0 Ev = \mu_0\epsilon_0 Bv^2$

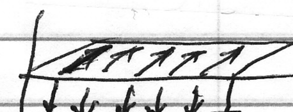
$\mu_0 \epsilon_0 v^2 = 1$

$v = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$. Nar. value of v.

$\mu_0 \epsilon_0 = \frac{\mu_0}{4\pi}(4\pi\epsilon_0) = 10^{-7} \times \frac{1}{9\times10^9}$

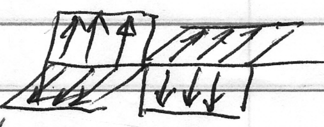
$\therefore \frac{1}{\mu_0\epsilon_0} = \frac{9\times10^9}{10^{-7}} = 9\times10^{16}$, $v = \frac{1}{\sqrt{\mu_0\epsilon_0}} = 3\times10^8\, m/s. = c$ speed of light

- Notice the rectangular loop 12341, can be stretched out to left. The E-B pattern continues to extend its length

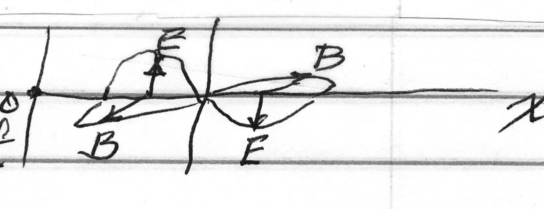


- When I switches the direction, the B-E fields change their direction

A new structure adds to the pattern



For sinusoidal current:
the squares will be rounded-off.



2. <u>Properties of EM waves:</u>

1. $E \perp B$, $E\times B$ direction of travel, $E = vB$

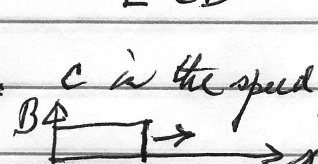
2. Universal speed: $v = \frac{1}{\sqrt{\mu_0\epsilon_0}}$ in vac

Since light is EM waves, it travels with the same speed,

3. $E = cB$

Reflection: c is the speed of the "wavefront"

(1)



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

Wave shape is imitated by the t-dependence of the source.

3. em pulse due to acceleration of point charge

fields generated by point charge —

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

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

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

$\langle \vec{E}_{rad} \times \vec{B}_{rad} \rangle$. is direction of travel.

Derivation of $\vec{E}_{rad}$ formula (see ch24.h2 _ 018 - 012), text sec 24.11,

also Slides 36.1, 36.2.

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.

Let us start from beginning. The charge is stationary at origin. The kock occurs at $t=0$, over very short time $\Delta t = t_{acc}$. After that the charge acquires a speed $v = a t_{acc}$. At $t = T$ (long time after the acc) here is the snapshot

- A has moved to B at $x = vT$.

Acceleration zone:

- Field due to A at $t=0$ has reach $r=cT$, which is the outer arc. In region $r>cT$, acceleration information has not arrived. It is region II
- For $r<(cT-ct_{acc})$, it is region I, where acceleration information is available, the new pattern is emitted by the source at

So the acceleration zone defined by the circular arc with $r\sim cT$ & thickness ct_{acc}.

We are interested in the field emitted during the knock, say at θ. Based on Gauss Law the text has shown that the E field vector is along the direction of the segment 21, i.e. $\vec{E}=\vec{E}_\perp+\vec{E}_\parallel$

$$\tan\alpha=\frac{E_\perp}{E_\parallel}=\frac{E_{radiation}}{E_{coulomb}} \quad (1)$$

From geometry, $\tan\alpha=\frac{\overline{13}}{\overline{23}}=\frac{vT\sin\theta}{c\,t_{acc}}$ (2). Your homework is based on: $\frac{v}{t_{acc}}=a$, $a\sin\theta=a_\perp$, $r=cT$, together with (1) + (2). Show that

$$\vec{E}_{rad}=\vec{E}_\perp=\frac{kq}{c^2r}(-\vec{a}_\perp).$$

Notice that the kink structure in Fig 14.17 corresponds to the line: B24C