9.19.

a. Suppose you imbedded some free charge in a piece of glass. About how long would it take for the charge to flow to the surface?

b. Silver is an excellent conductor, but it's expensive. Suppose you were designing a microwave experiment to operate at a frequency of 10^{10} Hz. How thick would you make the silver coatings?

c. Find the wavelength and propagation speed in copper for radio waves at 1 MHz. Compare the corresponding values for air (or vacuum).

$\tau = \epsilon/\sigma$ $\qquad \rho = \rho_0 e^{-t/\tau}$

$\rho =$ coul/m^3

$\nabla \cdot J = -\frac{\partial \rho}{\partial t}$

$\nabla \cdot \sigma E = -\frac{\partial \rho}{\partial t}$

$\nabla \cdot E = \rho/\epsilon$

$\frac{\sigma}{\epsilon}\rho = -\frac{\partial \rho}{\partial t}$

$\rho = \rho_0 e^{-\frac{\sigma}{\epsilon}t}$

$\epsilon = \epsilon_r \epsilon_0$

$\epsilon_r = n^2 = 1.5^2$ $\qquad \rho =$ OHM-Meter

$\epsilon = (1.5)^2\, 8.854 \times 10^{-12}$ $\qquad \rho \neq \rho$ 2 different ρs

$\sigma = \frac{1}{\rho} = 10^{-12}$

a) $\tau = \dfrac{(1.5)^2 * 8.854 \times 10^{-12}}{10^{-12}} = 19.9 \approx 20$ Sec

b) $d = \sqrt{\dfrac{2}{\omega\sigma\mu}} = \sqrt{\dfrac{2}{2\pi \times 10^{10}\, 6.25 \times 10^{7} * 4\pi \times 10^{-7}}}$

$d = 6.4 \times 10^{-7}$ m

Lead Thickness $= 10 \times 10^{-7}$ m $= 10^{-6} = .001$ mm

c) $E = e^{-\alpha z - j\beta z} e^{j\omega t}$

$\beta = \frac{2\pi}{\lambda}$ $\qquad \alpha = \beta = \sqrt{\dfrac{\omega\sigma\mu}{2}} = \dfrac{1}{\delta}$

$\lambda = 2\pi\sqrt{\dfrac{2}{\omega\sigma\mu}} = 2\pi\sqrt{\dfrac{2}{2\pi \times 10^{6} * 6 \times 10^{7} * 4\pi \times 10^{-7}}}$

$\lambda = 4 \times 10^{-4}$ m $= 0.4$ mm

$v = \dfrac{\omega}{\beta} = \dfrac{\omega\lambda}{2\pi} = \lambda f = 4 \times 10^{-4} \times 10^{6} = 400$ m/s

9.12 In the complex notation there is a clever device for finding the time average of a product. Suppose f(**r**, t) = A cos(**k**·**r** - ωt + δ_a) and g(**r**, t) = B cos(**k**·**r** - ωt + δ_b). Show that the average value of the product fg = (1/2) Re ($\tilde{f}\,\tilde{g}^*$ where the star denotes complex conjugation. [Note that this only works if the two waves have the same **k** and ω, but they need not have thesame amplitude or phase.] For example,

$$\langle u \rangle = \frac{1}{4}\,\mathrm{Re}\left(\epsilon_0 \tilde{E}\cdot\tilde{E}^* + \frac{1}{\mu_0}\tilde{B}\cdot\tilde{B}^*\right) \qquad \langle S \rangle = \frac{1}{2\mu_0}\,\mathrm{Re}\,(\tilde{\mathbf{E}} \times \tilde{\mathbf{B}}^*)$$

$$\tilde{f} = A e^{j(k\cdot r - wt + \delta_a)}$$

$$\tilde{g} = B e^{j(k\cdot r - wt + \delta_b)}$$

$$\tilde{g}^* = B e^{-j(k\cdot r - wt + \delta_b)}$$

$$\tilde{f}\tilde{g}^* = AB e^{j(\delta_a - \delta_b)}$$

$$\frac{1}{2}\,\mathrm{Re\,pt}\,(\tilde{f}\tilde{g}^*) = \frac{1}{2} AB\cos(\delta_a - \delta_b)$$

$$\langle fg \rangle = \frac{1}{T}\int_0^T AB\cos(k\cdot r - wt + \delta_a)\cos(k\cdot r - wt + \delta_b)\,dt$$

$$\cos A \cos B = \frac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$$

$$\langle fg \rangle = \frac{AB}{2T}\int_0^T \Big(\underbrace{\cos(2k\cdot r - 2wt + \delta_a + \delta_b)}_{\substack{2wT = 2\frac{2\pi}{T}T = 4\pi = 2\text{ periods} \\ \text{This integrates to zero}}} + \cos(\delta_a - \delta_b)\Big)\,dt$$

$$\langle fg \rangle = \frac{AB}{2T}\cos(\delta_a - \delta_b)\,T$$

$$= \frac{AB}{2}\cos(\delta_a - \delta_b)$$

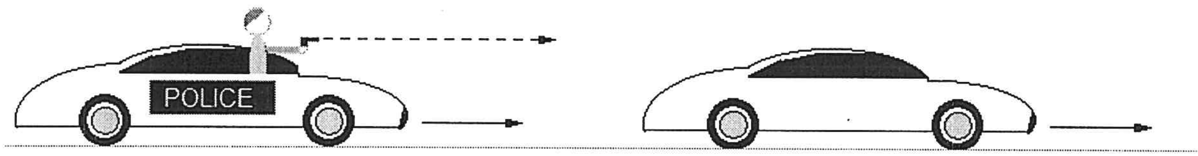

Figure 12.3

12.4 As the outlaws escape in their getaway car, which goes 0.75c, the police officer fires a bullet from the pursuit car, which only goes at 0.5c (Fig 12.3). the muzzle velocity of the bullet (relative to the gun) is c/3. Does the bullet reach its target (a) according to Galileo, (b) according to Einstein?

EQUation 12.20

$$u_2 = \frac{u_1 - v}{1 - u_1 v/c^2}$$

u_2 is the bullet Speed in the moving Reference Frame.
v is the velocity of the police.

We want the bullet velocity in the stationary Reference frame, i.e. u_1

$$u_2(1 - u_1 v/c^2) = u_1 - v$$

$$u_2 - u_1 u_2 v/c^2 = u_1 - v$$

$$u_1(-u_2 v/c^2 - 1) = -v - u_2$$

$$u_1 = \frac{v + u_2}{1 + u_2 v/c^2}$$

u_2 is the muzzle velocity of the bullet in the moving Reference FRAME $v = \frac{c}{2}$ $u_2 = c/3$

Bullet

$$u_1 = \frac{\frac{c}{2} + c/3}{1 + \frac{1}{2} * \frac{1}{3}} = \frac{\frac{5}{6}c}{\frac{7}{6}} = \frac{5}{7}c < \frac{3}{4}c$$

Bullet Velocity < CAR Veloc

12.4

Bullet velocity as Seen by a STATIONary observer

$$u_1 = \frac{5}{7}c = 0.714\ c$$

Getaway Car Velocity as Seen by a STATIONary Observer

$$v = \frac{3}{4}c = 0.75c$$

b) Einstein Says CAR is faster than the bullet
CAR Gets AWAY

a) Galileo   Bullet velocity = Police Velocity plus GUN muzzle Velocity

$$\text{Bullet Velocity} = \frac{c}{3} + \frac{c}{2} = \frac{5}{6}c = .833c$$

Get Away CAR Velocity $= 0.75c$

$$0.833c > 0.75c$$

Bullet reaches getaway CAR

9.Problem

Write Maxwell's equations in;

a. Differential form,

b. Integral form,

c. Words.

a) $\nabla \cdot E = \rho / \epsilon_0$ (i)

$\nabla \times E = -\frac{\partial B}{\partial t}$ (ii)

$\nabla \cdot B = 0$ (iii)

$\nabla \times B = \mu_0 J + \mu_0 \epsilon_0 \frac{\partial E}{\partial t}$ (iv)

b) $\oint \vec{E} \cdot \vec{da} = \frac{1}{\epsilon_0} \int_V \rho dv$ (i)

$\oint E \cdot dl = -\frac{\partial}{\partial t} \int \vec{B} \cdot \vec{da}$ (ii)

$\oint B \cdot da = 0$ (iii)

$\oint \vec{B} \cdot \vec{dl} = \mu_0 \int J \cdot da + \mu_0 \epsilon_0 \frac{\partial}{\partial t} \int \vec{E} \cdot \vec{da}$ (iv)

(i) Gauss' LAW: The total Electric flux Leaving a closed Surface is equal to the charge enclosed divided by ϵ_0.

(ii) FARADAY'S LAW: The integral of the electric field around a closed loop is equal to the negative rate of change of the magnetic flux passing through the loop.

9. problem CONTINUED.

(iii) the total magnetic flux leaving a closed surface is zero.

(iv) Amperes LAW: The line integral of the magnetic field around a closed loop is equal to the total current passing through the loop. MULTIPLIED by the magnetic permeability, μ_0.