$$\therefore\ k^2 = \mu\epsilon\omega^2 + i\mu\sigma\omega$$

Hence, k, the wave number is complex and be expressed as

$$k = \alpha + i\beta = (\mu\epsilon\omega^2 + i\mu\sigma\omega)^{1/2}$$

Therefore, we get $\alpha^2 - \beta^2 = \mu\epsilon\omega^2$; $2\alpha\beta = \sigma\mu\omega$

Solving these ~~of~~ equations we get

$$\alpha = \omega\sqrt{\frac{\epsilon\mu}{2}\left[\sqrt{1+\left(\frac{\sigma}{\epsilon\omega}\right)^2}+1\right]}$$

$$\beta = \omega\sqrt{\frac{\epsilon\mu}{2}\left[\sqrt{1+\left(\frac{\sigma}{\epsilon\omega}\right)^2}-1\right]}$$

For good conductor $\sigma \gg \epsilon\omega$ then

$\alpha = \beta = \sqrt{\frac{\omega\sigma\mu}{2}}$, since, $k = \alpha + i\beta$, then electric field $\bar{E}$ and magnetic field $\bar{B}$ can be written as

$$\bar{E} = \bar{E}_0 e^{-\beta x} e^{i(\alpha x - \omega t)} \quad ; \quad \bar{B} = \bar{B}_0 e^{-\beta x} e^{i(\alpha x - \omega t)}$$

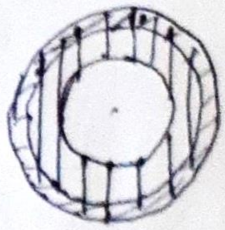
The above equations indicate that the imaginary part of k results in an attenuation of the amplitude of electromagnetic wave with increasing x.

The distance it takes to reduce the amplitude by a factor of $1/e$ is called <u>skin depth</u>

Therefore, skin depth of a conductor is

$$\boxed{d = \frac{1}{\beta} = \sqrt{\frac{2}{\omega\sigma\mu}}}$$

For a poor conductor $\sigma << \omega\epsilon$. In this case $\beta = \frac{\sigma}{2}\sqrt{\frac{\mu}{\epsilon}}$ Hence, the skin depth of a poor conductor is



$$d = \frac{2}{\sigma}\sqrt{\frac{\epsilon}{\mu}}$$

<u>Physical significance of skin depth</u>

Skin effect is the tendency of an alternative alternative current to become distributed with in a conductor such that current density is large near the surface of the conductor, and decreses with greater depths in the conductor due to the attennation of electromagnetic waves in the greater depths. The electric current flows mainly at the skin of the conductor, between outer surface a inner level ~~clas~~ called the skin depth. The skin

This effect causes the effective resistance of the conductor to increase at higher frequencies where the skin depth is smaller, thus reducing the effective cross-section of the conductor. Because the interior of a large conductor carries so little of the current, tubular conductor such as pipe can be used to save weight and cost. The penetration depth of 1 MHz A/c in copper is about 0.0667 mm, where as it is 9.49 mm at 60 Hz. Thus, the higher will be the frequency, the more will be the effective resistance of the wire, hence losses will be more. Therefore, to keep transmission losses of alternating current to a lower limit, we have chosen 50/60 Hz is an optimum frequency. It is to note that producing alternating current at lower frequencies would cause size, weight and hence cost of the generation of power.