3.1. \( E = 3.8^2 y \cos (10^8 t) \) in media with \( \varepsilon_r = 2.56 \)

a) assuming linear, isotropic media \( \mathbf{P} = \varepsilon_0 \mathbf{E} \) where \( 1 + \varepsilon_0 = \varepsilon_r \)
\[ \mathbf{E} = 2.56 \mathbf{E} \] \[ \mathbf{P} = 6 \mathbf{E} \]
\[ \mathbf{P} = 6(1.56) \mathbf{E} \]
\[ \mathbf{P} = 4.68 \mathbf{E} \]

b) \( \mathbf{V} \cdot \mathbf{P} = -\mathbf{P} \cdot \frac{\partial \mathbf{E}}{\partial x} = 0 \) since \( \mathbf{P} \) is not a function of \( x \), i.e., \( \mathbf{P} \) is constant for given \( y, z \) value \( \Rightarrow \) flow in = flow out in \( x \) direction

\[ \mathbf{J}_p = (4.68 \mathbf{E}) \mathbf{y} \cos (10^8 t) \]
\[ \mathbf{J}_p = 4.68 \mathbf{E} \]

3.1.2. in sea water: \( \sigma = 4.5 \text{ S/m}, \mu = 1, \varepsilon_r = 81 \), find \( f \) s.t. \( \left| \frac{\mathbf{J}_p}{\mathbf{D}} \right| \geq 100 \)

\[ \mathbf{J}_c = \sigma \mathbf{E} \] and \( \mathbf{J}_b = \frac{\partial \mathbf{E}}{\partial t} = \frac{\partial}{\partial t} (\mathbf{E}) = \frac{\partial}{\partial t} (\varepsilon_r \varepsilon_0 \mathbf{E}) = \varepsilon_r \varepsilon_0 \frac{\partial}{\partial t} \mathbf{E} \]

now use phasors for assumed sinusoidal steady state (time-harmonic)

solution with implied \( e^{j\omega t} \) time dependence, i.e.,

\[ \mathbf{J}_c = \sigma \mathbf{E} \]
\[ \mathbf{J}_b = \varepsilon_r \varepsilon_0 \mathbf{E} \]

\[ \left| \frac{\mathbf{J}_c}{\mathbf{D}} \right| = \left| \frac{\sigma (\mathbf{E})}{\varepsilon_r \varepsilon_0 (\mathbf{E})} \right| = \left| \frac{\sigma (\mathbf{E})}{\varepsilon_r \varepsilon_0 (\mathbf{E})} \right| \]

\[ \left| \frac{\mathbf{J}_c}{\mathbf{D}} \right| = \frac{\sigma (\mathbf{E})}{\varepsilon_r \varepsilon_0 (\mathbf{E})} \]

\[ \Rightarrow \; f \leq \frac{\sigma (\mathbf{E})}{\varepsilon_r \varepsilon_0 (\mathbf{E})} \]

\[ \Rightarrow \; f \leq \frac{4}{100 \times 3 \times 10^{-9}} = 8.89 \text{ MHz} \]