Circle the best answer.

1. An electromagnetic wave in free space with frequency = 600MHz is normally incident on a perfectly conducting planar surface. At what distance, z (with z > 0), from the surface is the first null? (4 points)

\[ s \text{ null } @ k z = -\pi \Rightarrow z = \left| \frac{-\pi}{2\pi} \lambda \right| = \frac{\lambda}{2} = \frac{1/2 m}{2} = 0.25 m \]

(a) 0.25m  
(b) 0.5m  
(c) 1.0m  
(d) 2m  
(e) none of the above

2. Given an interface with unit normal \( \hat{z} \) and \( \vec{D}_2 = 4\hat{x} + \hat{z} \left[ \text{Coul/m}^2 \right] \) for \( z < 0 \) and \( \vec{D}_1 = 2\hat{x} + \hat{z} \left[ \text{Coul/m}^2 \right] \) for \( z > 0 \), circle the answer below that best describes this situation: (4 points)

\[ \begin{align*}
\vec{D}_{n1} &= \vec{D}_{n2} \\
\vec{D}_{t1} &= \vec{D}_{t2} = \vec{E}_{t1} = \vec{E}_{t2} \\
\vec{E}_{n1} &= \vec{E}_{n2} = \frac{\epsilon_1 E_{t1}}{\epsilon_1} \Rightarrow \vec{z} = \frac{E_{t1}}{\epsilon_1} \Rightarrow \epsilon_2 = 2 \epsilon_1
\end{align*} \]

(a) medium 1 and medium 2 are dielectrics with \( \epsilon_1 > \epsilon_2 \)  
(b) medium 1 and medium 2 are dielectrics with \( \epsilon_1 < \epsilon_2 \)  
(c) there is positive surface charge on the boundary between two dielectrics  
(d) medium 2 is a perfect conductor  
(e) impossible

3. In a source-free region of free space, find the magnetic field (in [A/m]) if the electric field is known to be: \( \vec{E} = \hat{y} e^{-jkz} [\text{V/m}] \) (4 points)

\[ \begin{align*}
\nabla \times \vec{E} &= -j \omega \mu \vec{H} = \begin{vmatrix}
\hat{x} & \hat{y} & \hat{z} \\
\frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\
0 & 0 & 0
\end{vmatrix} = -j \hat{y} (\hat{x} e^{-jkz}) e^{-jkz} \\

\Rightarrow \vec{H} &= \hat{y} \frac{k}{\omega \mu} e^{-jkz} = \frac{\omega \mu \kappa_0}{\omega \mu \kappa_0} e^{-jkz} = (\hat{x} e^{-jkz}) / 377
\end{align*} \]

(a) \( \hat{x} e^{-jkz} \)  
(b) \( \hat{x} 377 e^{-jkz} \)  
(c) \( \hat{y}/377 \)  
(d) \( -\hat{x} e^{-jkz} / 377 \)  
(e) none of the above
4. A wave with frequency 100 MHz and polarization parallel to the plane of incidence impinges on an interface at an angle of 30° relative to the normal. Given \( k_1 = 6k_o \) (where \( k_o = \omega \sqrt{\mu_0 \varepsilon_o} \)) in region 1, if region 2 has \( \theta_t = 45° \) (the angle between the transmitted wave and the normal), find the permittivity in region 2, \( \varepsilon_2 \). (4 points)

\[
\begin{align*}
K_x &= k_1 \sin 30° = 6k_o \left( \frac{1}{k_t} \right) = 3k_o = k_x' = k_2 \sin 45° \\
&= k_o \sqrt{\varepsilon_2} \left( \frac{1}{\sqrt{2}} \right)
\end{align*}
\]

\( \varepsilon_2 = 18 \Rightarrow \varepsilon_2 = 18 \varepsilon_o \)

5. Ice has a conductivity of roughly \( \sigma = 10^{-6} \text{mho/m} \) and \( \varepsilon = 3.2 \varepsilon_o \). If an electromagnetic wave with frequency \( f=100\text{MHz} \) impinges at normal incidence to a block of ice, how far from the surface must one go (in meters) for the field to reach \( 1/e \) (or 37%) of the value at the surface? (4 points)

\[
d_p = \frac{2}{\sigma} \sqrt{\frac{\varepsilon}{\mu}} = c_1 \gamma \sqrt{\varepsilon} - q_1 \sqrt{\mu}
\]

a) \( 1.05 \times 10^{-4} \)  b) 9.500  c) 10.5  d) 0.368  e) none of the above

6. A perpendicularly-polarized wave has a \( z \)-component of the incident wave \( k_z = k_o \) and of transmit wave \( k_{z} = -j \sqrt{2}k_o \). What is the magnitude of the reflection coefficient \( |R_1| \)? (4 points)

\[
R_1 = \frac{k_z - k_{z}'}{k_z + k_{z}'} = \frac{1 - j\sqrt{2}}{1 - j\sqrt{2}} \Rightarrow |R_1| = 1
\]

a) 1  b) 0  c) 1/2  d) \( \sqrt{2} \)  e) none of the above