1) A neodymium-glass laser emits short pulses of high-intensity electromagnetic waves. The electric field has an rms value of \( E_{\text{rms}} = 2.0 \times 10^9 \text{ N/C} \).

a) Find the average power of each pulse that passes through a \( 1.6 \times 10^{-6} \text{ m}^2 \) surface that is perpendicular to the laser beam. (2 pts; \( c = 3 \times 10^8 \text{ m/s}, \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2 \)).

\[
\begin{align*}
\mathcal{S}_0 &= e \epsilon_0 E_{\text{rms}}^2 = 1.06 \times 10^{16} \text{ W/m}^2 \\
\mathcal{P} &= \mathcal{S}_0 A = 1.7 \times 10^{11} \text{ W}
\end{align*}
\]

b) What is the rms value of the magnetic field in a pulse? (1 pt)

\[
B_{\text{rms}} = \frac{\mathcal{E}_{\text{rms}}}{c} = 6.7 \text{ T}
\]

c) In a right-handed Cartesian coordinate system, the laser light propagates in the \( x \)-direction and the electric field points in the \( y \)-direction. If a polarizer, \( P_1 \), is placed in front of the laser with the transmission axis parallel to the \( z \)-axis, what is the average intensity (not power) in a pulse after going through \( P_1 \)? (1 pt)

\[
\text{INCIDENT LIGHT IS POLARIZED ALONG } Y \text{ AXIS} \Rightarrow \text{ INTENSITY OF TRANSMITTED LIGHT } = 0 \text{ (AXIS OF } P_1 \text{ ALONG } \frac{\pi}{2} )
\]

d) A second polarizer, \( P_2 \), is placed between the laser and the \( z \)-polarizer (\( P_1 \) above) at an angle of 45 deg with respect to the \( z \)-axis. Now what is the average intensity in a pulse after going through \( P_1 \)? (2 pts)

\[
\begin{align*}
\mathcal{S}_2 &= \mathcal{S}_0 \cos^2 45^\circ = 2.7 \times 10^{15} \text{ W/m}^2
\end{align*}
\]

(CONTINUED ON OTHER SIDE)

Rewrite and sign the honor pledge: "I pledge my honor that I have not violated the Honor Code during this examination."

______________________________
Signature
2) A 10-cm-high object is situated 25 cm in front of a convex mirror with a radius of curvature of 100 cm.
   a) Draw the object and trace three rays on the diagram below (1 pt)

   \[ f = -\frac{1}{2} \frac{R}{R} \quad \text{(CONVEX MIRROR)} \]

   \[ f = -50 \text{ cm} \]

   b) Where is the image formed? (1 pt)

   \[ \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \quad \Rightarrow \quad \frac{1}{50} = \frac{1}{25} + \frac{1}{d_i} \]

   \[ \Rightarrow \quad \frac{1}{d_i} = -\frac{3}{50} \quad \text{or} \quad d_i = -\frac{50}{3} = -16.7 \text{ cm} \]

3) A dentist's mirror is placed 2.0 cm from a tooth. The enlarged image is located 5.6 cm behind the mirror.
   a) What kind of mirror (planar, convex, concave) is being used? (1 pt)

   [VIRTUAL, ENLARGED IMAGE]

   \[ \Rightarrow \quad \text{CONCAVE MIRROR, WITH OBJECT PLACED BETWEEN F AND MIRROR} \]

   b) What is the focal length of the mirror? (1 pt)

   \[ \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \]

   \[ = \frac{1}{2} - \frac{1}{5.6} \quad (d_i < 0 \quad \Rightarrow \quad \text{IMAGE BEHIND MIRROR}) \]

   \[ = \frac{1.8}{5.6} \quad f = \frac{5.6}{1.8} = 3.1 \text{ cm} \]