1. A small transmitter in a secret location broadcasts a signal uniformly in all directions with 1 W of power. If a receiving antenna can detect a minimum signal intensity of $10^{-8}$ W/m$^2$, what is the maximum distance in meters that the transmitter signal can be detected?

**Solution:** Since the transmitter broadcasts uniformly in all directions, the intensity $S$ at a distance $d$ is $S = P/(4\pi d^2)$, where $P = 1$ Watt is the radiated power. Using $S = 10^{-8}$ W/m$^2$ yields a maximum distance of 2820 meters.

2. A solenoid with radius $r$ and length $l$ is wound with copper wire having a resistance of 10 Ω/m. The number of turns of wire per unit length of solenoid is $n$. Similar wire with the same winding density $n$ is used to fabricate a second solenoid with twice the radius and four times the length of the first solenoid. The relaxation time of the second solenoid, $L/R$, is how much larger than the relaxation time of the first solenoid?

**Solution:** The inductance is proportional to $n^2Al$, where $n$ is the number of turns per meter, $A$ is the area and $l$ is the length of the solenoid. With $A$ and $l$ both 4 times bigger, $L$ is 16 times bigger for the second solenoid compared to the first. The resistance $R$ is 8 times larger (2 from radius and 4 for length), making $L/R$ 2 times larger.

3. A 10 µF capacitor is charged by a battery to a potential of 1.5 V. The battery is then disconnected and at time $t = 0$ the capacitor is connected across a 20 mH inductance. What is the earliest time when the instantaneous energy in the inductor is maximized?

**Solution:** When the capacitor is connected to the inductor, an LC circuit is created with an angular frequency of $1/\sqrt{LC}$. At $t = 0$, all the energy is in the capacitor. The energy in the inductor is maximized after 1/4 cycle or at $t = \pi \sqrt{LC}/2 = 7.0 \times 10^{-4}$ sec or 0.70 msec.

4. A woman is walking down the beach, where the light from the sun is partially polarized, with the horizontal component of the electric field 3.6 times the vertical component. The woman then puts on her sunglasses, which eliminate the horizontal component of the electric field. What percentage of the original intensity of the light reaches the woman’s eyes?

**Solution:** The total intensity is proportional to the square of the electric field, or $S \propto E_H^2 + E_V^2$, where $S$ is the intensity and $E_H$ and $E_V$ are the horizontal and vertical components of the electric field, respectively. If the horizontal component is eliminated,
then the new intensity is reduced to $E^2/V/(E^2_H + E^2_V) = 1/(3.6^2+1) = 0.072$ of the original intensity.

5. Consider a uniform externally-applied magnetic field $B_0$ which is applied in a region filled with sodium, a paramagnetic substance. Which statement correctly describes the magnitude of the total magnetic field in the region?

**Solution:** For any paramagnetic substance, the magnetic field in the region is slightly larger than the applied field.

6. A capacitor consists of parallel plates separated by vacuum. The plates are squares with side length 1 cm and separated by 2 mm. An electric field uniformly distributed over the plates has a strength (in V/m) given by $E(t) = 600t^3 - 6000t + 4000$. At time $t = 4$, what will be the displacement current in amperes between the plates?

**Solution:** The displacement current $i_D$ is given by $i_D = \epsilon_0 d\phi_E/dt$, where $\phi_E = EA$ (electric flux), $E$ is the magnitude of the electric field and $A$ is the area. Using $dE/dt = 1800t^2 - 6000$, and $A = 10^{-4}m^2$ we obtain, for $t = 4$, $i_D = 2.28\epsilon_0$.

7. A uniform time dependent magnetic field given by $B(t) = 0.3t^2$ is directed perpendicular to the plane of a square wire loop with sides of length 0.5 m. If the resistance of the square wire is 0.4 Ω, how much total energy (in Joules) is dissipated by heat in the wire during the interval from $t = 0$ to $t = 10$ seconds?

**Solution:** The power $P$ dissipated in the resistor is given by $E^2/R$, where $R$ is the resistance of the wire loop, $E = d\phi_B/dt$ is the induced EMF, $\phi_B = BA$ is the magnetic flux and $A$ is the area of the loop. Using $B = 0.3t^2$ and $A = 0.25m^2$, we obtain $E = 0.15t$ and $P = 0.05625t^2$. The total energy dissipated is obtained by integrating $\int_0^{10} Pdt = 18.8$ joules.

8. A series RLC circuit consisting of a resistor, an inductor and a capacitor is driven at an angular frequency $\omega_d$. As the driving frequency approaches the natural frequency of the system, what happens to the total impedance $Z$ and phase $\phi$ of the current (measured relative to the driving EMF)?

**Solution:** At resonance, the capacitative and inductive reactances cancel leading to a minimum $Z$ and $\phi = 0$.

9. Which of the following produce a changing electric field? (A) a charging capacitor, (B) a steadily changing B-field ($dB/dt = \text{const.}$) through a fixed area, (C) any object whose charge is changing

**Solution:** Only A and C lead to a changing electric field. A steadily changing $B$ field creates a constant $E$ field.

10. A rectangular block of heavy glass with index of refraction 1.7 is immersed in water ($n = 1.333$). A light beam strikes the inner surface of the glass at an angle $\theta$ from the...
normal and is totally internally reflected. What is the minimum value of $\theta$ for which this is possible?

**Solution:** The minimum angle is the critical angle, given by $\sin \theta_c = 1.333/1.7 = 0.78$, leading to an angle of 51.6°.