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1. (a) Draw a diagram to explain the Fermi level in silicon as a function of temperature for various impurity concentrations.
   (b) Draw a diagram to explain the electron density as a function of temperature in n-type silicon. (10%)

2. A silicon p-n junction diode has the following parameters, $N_d = 10^{16}\ cm^{-3}$ ($\mu_n = 1{,}100\ cm^2/V \cdot s$), $N_a = 5 \times 10^{18}\ cm^{-3}$ ($\mu_p = 120\ cm^2/V \cdot s$), $\tau_n = \tau_p = 1\ \mu sec$, $A = 0.01\ cm^2$. Assume that the width of two sides of the junction are much greater than the respective minority-carrier diffusion length. Obtain the applied voltage at a forward current of 1mA at 300°K. (10%)
   (Hint: the intrinsic carrier concentration, $n_i = 1.5 \times 10^{10}\ cm^{-3}$)

3. (a) Explain basic operation principle for double heterojunction laser.
   (b) In a solar cell, obtain the expression for maximum output power, P_m; conversion efficiency η and fill factor FF. (15%)
   (c) Draw a diagram to explain current-versus-electric field of a two valley semiconductor.

4. (a) Draw an energy diagram and charge distribution of $Al/SiO_2/P\text{-}Si$ (MOS structure) under negative V_G, small positive V_G and large positive V_G.
   (b) Draw and explain capacitance-voltage diagram at high and low frequencies for $Al/SiO_2/P\text{-}Si$ MOS capacitor. (15%)
   (c) Explain the operation principle for Tunnel diode.

5. A point charge Q is at a distance d from the center of a grounded conducting sphere a (a < d). Determine (a) the charge induced on the surface of a sphere, and (b) the total charge induced on the sphere, (c) If the conducting sphere is not grounded, determine the force at point charge Q. (10%)

6. (a) What is meant by loss tangent
   (b) In a time-varying solution, how do define a good conductor?
   (c) Explain displacement current.
   (d) Explain the principle of virtual work. (15%)

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7. (a) A thin conducting wire is bent into the shape of a regular polygon on N sides. A current flows I flows in the wire. Show that the magnetic flux at the center is

$$\vec{B} = \hat{a}_n \frac{\mu_0 N I}{2\pi b} \tan\frac{\pi}{N} \qquad (10\%)$$

where b is the radius of the circle circumscribing the polygon and $\hat{a}_n$ a unit vector normal to the plane of the polygon. If $N \to \infty$, derive the magnetic flux at the center.

Find the mutual inductance between two coplanar rectangular loops with parallel sides as shown in Fig. 1. Assume $h_1 >> h_2$, and $h_2 > w_2 > d$

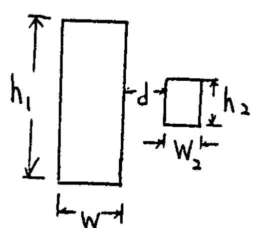

Fig. 1

8. A uniform plane wave with $E_i(z) = \hat{a}_x E_{i0} e^{-j\beta_0 z}$ in air propagates normally through a thin copper sheet of thickness d, as shown in Fig. 2. Neglecting multiple reflections within the copper sheet, find (a) E_2^+, H_2^+ (in copper sheet), (b) H_2^-, E_2^-, (c) E_{30}, H_{30} (d) $(P_{av})_3/(P_{av})_i$. Calculate $(P_{av})_3/(P_{av})_i$ for a thickness d that equals one skin depth at 10 (MHz) (Note that this pertains to the shielding effective of the thin copper sheet (parameters in copper sheet: $\epsilon = \epsilon_0 = 8.85 \times 10^{-12}$ F/m, $\mu = \mu_0 = 4\pi \times 10^{-7}$ h/m, $\sigma = 5.8 \times 10^7$ S/m)

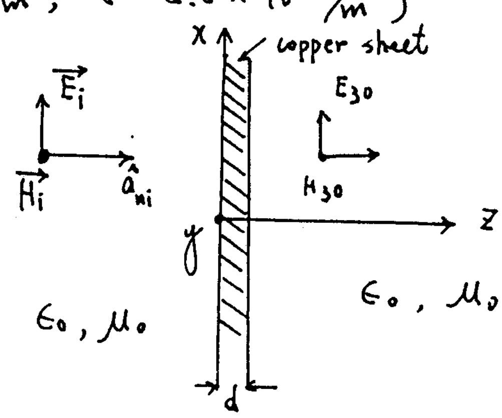

Fig. 2 (15%)