1. Two point charges Q_1 and Q_2 are placed in free space at points A and B as shown in Fig.1. How much energy is required to move two point charges Q_3 and Q_4 from infinite to the points C and D respectively. Assume $Q_1=Q_2=Q$, $Q_3=2Q$, $Q_4=4Q$. (7%)
2. Try to draw roughly the electric field lines of the different cases shown in Fig.2. (8%)
3. A voltage $V\sin\omega t$ is applied to the two parallel plates as shown in Fig.3. Find (a) the electric field intensity E_1 due to the applied voltage, (b) the induced magnetic field intensity H_1 due to the electric field intensity E_1, (c) the electric field intensity E_2 due to the magnetic field intensity H_1. Assume fringing effect is neglected. (15%)
4. Write the following equations: (a) wave equation, (b) Laplace equation, (c) diffusion equation, (d) the four Maxwell equations.
   Try to derive wave equation from Maxwell equations for source-free, lossless medium. You may take either electric field E or magnetic field H as wave function. (10%)
5. A conducting sliding bar oscillates over two parallel conducting rails in a sinusoidally varying magnetic field
   $$B=\hat{a}_z K\cos\omega t$$
   as shown Fig.4. The position of the sliding bar is given by $x=0.5(1-\cos\omega t)$, and the rails are terminated in a resistance R. Find the current i. (10%)

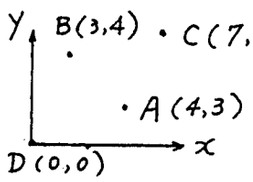


Fig.1

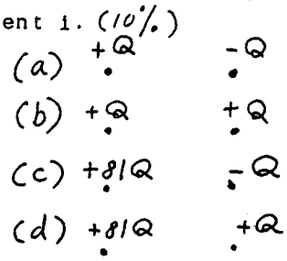


Fig.2

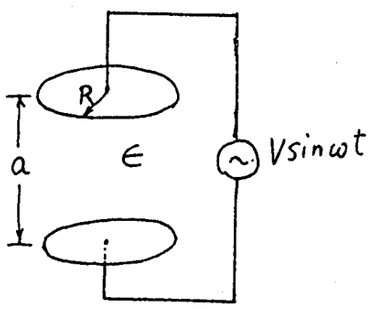
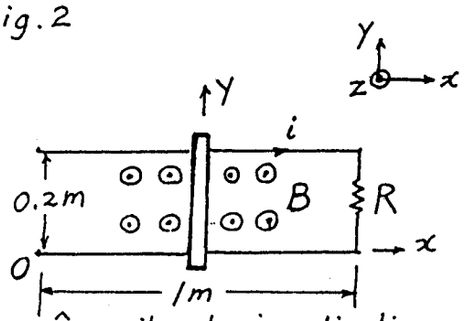


Fig.3



$\hat{a}_z$: unit vector in z-direction
Fig.4

6. For an exponentially graded base drift transistor, the base donor concentration is given by
$N_D(x) = N_{D0}e^{-n(x/w)}cm^{-3}$ (1)
where w is the base width. It can be shown that the injected hole distribution with a total current of I_p is
$\delta P(x) = \frac{I_p w}{qAD_p}\frac{1-e^{-n(1-x/w)}}{n}$ (2)
where A is the base area, D_p is the average diffusion constant in the base.
(a) Find the expression of the built-in electric field and indicate the corresponding direction.(4%)
(b) Find the position ($0 < x < w$) where the drift current equals the diffusion current (assume n=3) (5%)
(c)Derive Eq.2.(5%)

7. (a) Construct the energy-band diagram and charge distribution for the strong inversion mode from an ideal MOS capacitor on p-type substrate. Draw the C-V profile and indicate the positions of accumulation, depletion and inversion. Derive the minimum capacitance C_{min}. (8%)
(b) An n-channel GaAs MESFET with barrier height $\phi_{bn} = 0.9V$ $N_D = 10^{17}cm^{-3}$ and effective density of states $N_C = 4.7x10^{17}cm^{-3}$. $n_i = 2x10^{6}cm^{-3}$. $\epsilon_s = 13.1x8.854x10^{-14}F/cm$. μ_n=5000cm^2/$V.sec$ Active region is 0.1μm thick. Is this an enhancement or depletion mode device? Calculate the threshold voltage. (6%)

8. If the ionization rates in GaAs are α_n=α_p=$10^4(E/4x10^5)^6cm^{-1}$, where E is in V/cm, find the breakdown voltage of a $p-i-n$ diode with an intrinsic layer width of 5μm. $\epsilon_r = 13.1$. (5%)

9. (a)Describe the basic operation principle of the semiconductor lasers.(5%)
(b)Derive the threshold gain, assume that the volume loss is γ, the cavity length is L. The reflectivities for the mirrors are R_1 and R_2, respectively.(5%)

10. An $n^+-p-i-p^+$ Si IMPATT diode has a drift length of 1μm,
(a) Determine the operating frequency. Assume the drift velocity is 10^7 cm/sec. (2%)
(b) Describe briefly the operating principle of IMPATT diode to generate microwave power. (5%)