1. A silicon ingot is doped with 10^{16} arsenic atoms/cm^3. Find the carrier concentrations and the Fermi level at room temperature(300K). (10%)

2. Given a silicon sample of unknown doping. Hall measurement has been made and the following information obtained: W=0.05cm, A=1.6×10^{-3} cm^2 (refer to Fig.1), I=2.5mA, and the magnetic field is 30nT(1T=10^{-4}Wb/cm^2). If a Hall voltage of +10mV is measured, find the Hall coefficient, conductivity type, majority carrier concentration, resistivity, and mobility of the semiconductor sample. (14%)

3. For an ideal silicon p-n abrupt junction with $N_A = 10^{17}$ cm^{-3} and $N_D = 10^{15}$ cm^{-3}, (a)calculate V_{bi} at 250, 300, 350, 400, 450 and 500 K and plot V_{bi} versus T. (Hint: use Fig.2). (b) Comment on your result in terms of energy band diagram. (c) Find the depletion layer width and the maximum field at zero bias for T = 300 K. (12%)

4. If a silicon layer of thickness x is grown from thermal oxidation, what is the thickness of silicon being consumed? (The density is 2.33g/cm^3 for Si and 2.21g/cm^3 for SiO_2 .)　(10%)

5. Sketch and explain the output and transfer characteristics of an NMOS enhancement transistor. (10%)

6. Describe the operation principles of the following devices, (a)LED, (b)semiconductor laser, (c)solar cell, (d)tunnel diode. (16%)

7. (a) What resist would you use for high resolution? Why? (b) What are the advantages of e-beam lithography? (c) State two ways by which the exposure time can be reduced in an e-beam system. (12%)

8. Describe the following technologies of IC fabrication: (a) the Czochralski Technique, (b) the float zone process, (c) Vapor-phase Epitaxy ,(d) Physical Vapor Deposition. (16%)

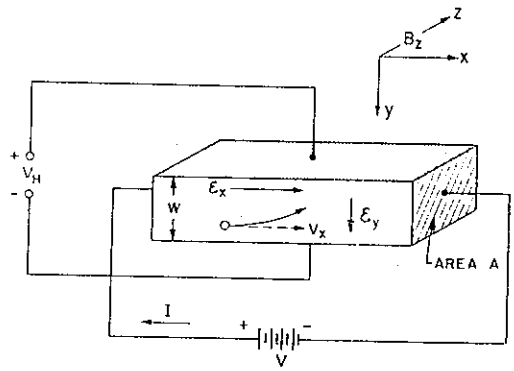


Fig. 1 Basic setup to measure carrier concentration using the Hall effect.

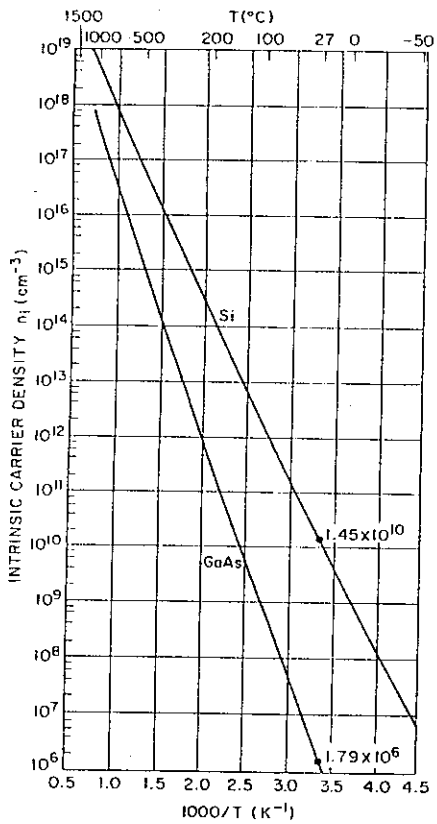


Fig. 2 Intrinsic carrier densities in Si and GaAs as a function of the reciprocal of temperature.

● **There are 4 problems, each counts 25 points.**

Problem #1

Please answer following questions, in English, clearly.

(a) Why use the *Laplace transformation* in control systems study?

(b) What use the *feedback* in control systems design, e.g. the benefits or disadvantages?

(c) What are the concepts of *controllability* and *observability*?

(d) What is the *Lyapunov stability theorem* saying?

Problem #2

Consider two plants described by

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & -1 \end{bmatrix} x + bu \; ; \quad y = \begin{bmatrix} 1 & 0 \end{bmatrix} x$$

where for plant #1, $b = \begin{bmatrix} 1 & 0 \end{bmatrix}^T$ and for plant #2, $b = \begin{bmatrix} 0 & 1 \end{bmatrix}^T$. Suppose all states are measurable. Now we want to use state feedback $u = -Kx$ to design a control system having damping ratio $\zeta = 0.707$ and undamped natural frequency $\omega_n = 2$.

(a) Which one or both plants can be used to achieve the design? Explain your answer in details.

(b) What is (or are) the corresponding state feedback gain(s) K?

Problem #3

For any matrix $A \in \mathbf{R}^{m \times n}$, the induced norm of it is defined as

$$\|A\| := \sup_{\|x\|=1} \|Ax\|.$$

Show that

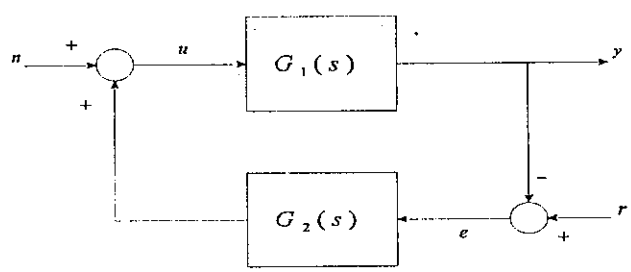
(a) $\|Ax\| \le \|A\| \cdot \|x\|$, for any $x \in \mathbf{R}^n$.

(b) $\|A + B\| \le \|A\| + \|B\|$, for any A, B in $\mathbf{R}^{m \times n}$.

(c) $\|AB\| \le \|A\| \cdot \|B\|$, for any compatible A and B.

Problem #4

Consider the closed-loop system below, where $G_1(s)$ and $G_2(s)$ are $p \times l$ and $l \times p$ proper transfer matrices, respectively.



(a) What is the necessary and sufficient condition for $(I_p + G_1(s)G_2(s))^{-1}$ being proper? Prove your answer clearly.

(b) Suppose $p = 1$, i.e. the system is SISO. Show that : If (i) $G_1(s)$ and $G_2(s)$ are proper, and (ii) $G_1(\infty)G_2(\infty) \neq -1$, then the system is well-posed.

1. (20%) In a complete binary tree of depth d, how many number of rooted subtrees do exist in it? (Hint: use recursive equation to derive the answer.)

2. (20%) Write a subroutine **insert(head,new_key,new_data)** to perform the insertion of a keyed element (**new_key,new_data**) into a linear linked list.

   - The data structure of the linked list element consists of three fields: **key, data, next**.
   - A **head** variable points to the linked list.
   - When the **new_key** matches **key** field of any element in the linked list, it outputs an error message. Otherwise, it inserts the new element at the end of the linked list.

3. (20%) Design an algorithm to evaluate the postfix expression with numbers and operators { +, -, *, / } .
   (e.g. input postfix expression: 1 4 5 * + 8 2 / -, evaluated result = 17)

4. (20%) Design a string detector which recognizes "**bar**" and "**are**" on the input character stream I. Draw its state transition diagram.

   - When the pattern "**bar**" is recognized, it produces '1' on output **B**. Otherwise, it produces '0' on output **B**.
   - When the pattern "**are**" is recognized, it produces '1' on output **A**. Otherwise, it produces '0' on output **A**.
   - for example,

Input I	c	b	a	b	a	r	d	a	r	e	f	b	a	r	e	g
Output B	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Output A	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0

5. (20%) Given a multiply pipeline with 3 stages, in order to compute the product $\Pi_{i=1}^{100} A_i$, where all A_i's are in a vector register, what is the minimum time to compute the product? How do you perform it?

1. In using Newton-Raphson method for solving power flow problem, a Jacobian J is usually introduced, specify the definition of this matrix J (20%). Also, to simplify the complexity of J for large coupled system, it is generally preferred to incorporate the characteristics of real and reactive powers with respect to the power angles and voltage magnitudes in formulating the Jacobian, discuss these relationships and the possible form of J (20%).

2. To enhance the overall power system stability and increase the transmission capability, the idea of constructing flexible ac transmission system (FACTS) has been introduced recently, discuss some of the features and structures of FACTS (20%)?

3. It is generally advised that some matrix manipulations are required to simplify the dynamic and transient analyses of synchronous machines, by introducing appropriate reference frame transformation techniques, what advantages can be obtained by such steps (20%)?

4. The ac/dc (and dc/ac) power converters have now been widely used in various industrial applications, for example, the un-interruptible power supply (UPS) systems generally require such devices to convert the input ac line voltages to adequate ac forms. Discuss the overall structure and draw a feasible circuit of a single phase UPS (20%).

光電工程導論及電磁波各佔 100%，請擇一做答

第一部份： 光電工程導論

1. Derive the scalar Helmholtz equation. (20%)
2. Describe the Fresnel and Fraunhofer approximation. (20%)
3. Show how a linearly polarized wave may be characterized as two circularly polarized wave of equal amplitude, one of which is left-handed and the other right-handed. (20%)
4. Explain in you own words why quantum detectors are narrowband detectors. That is, why do they typically have a response that drops off rapidly above some maximum wavelength and below some minimum wavelength? (20%)
5. What are modal dispersion, waveguide dispersion and material dispersion? (20%)

第二部份：**Electromagnetics**

1. (10%) Write the differential and integral forms of Maxwell's equations.
2. (10%) What is meant by the skin depth of a conductor? How is it related to the attenuation constant? How does it depend on σ? On f?
3. (10%) State Poynting's theorem.
4. (10%) What is a standing wave? Define standing-wave ratio.
5. (10%) Write the general transmission-line equations.
6. (10%) The following characteristics have been measured on a lossy transmission line at 100 MHz: $Z_0 = 50 + j0$ (Ω), $\alpha = 0.01$ (dB/m), $\beta = 0.8\pi$ (rad/m). Determine R,L, G, and C for the line.
7. (10%) The open-circuit and short-circuit impedances measured at the input terminals of an air-spaced transmission line 4 (m) long are $250\angle -50^{\circ}(\Omega)$ and $360\angle 20°(\Omega)$, respectively. Determine Z_0, α, and β of the line.
8. (10%) What is a Smith chart and why is it useful in making transmission-line calculations?
9. (10%) What is the cutoff wavelength of the TE_{10} mode in a rectangular waveguide?
10. (10%) Standard air-filled waveguides have been designed for X-band applications. Its dimensions are: a = 2.29 cm and b = 1.02 cm. If it is desired that such a waveguide operate only in the dominant TE_{10} mode and that the operating frequency be at least 25% above the cutoff frequency of the TE_{10} mode but no higher than 95% of the next higher cutoff frequency, what is the allowable operating frequency range?

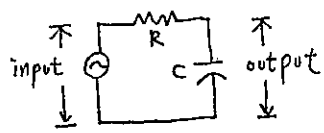
All problems are equally counted.

1. A linear system must satisfy additivity and Homogeneity. They seem similar.
   (a) In what case and how there is redundancy between them?
   (b) In what case and how there is no redundancy between them?

2. A system is described by the following equation:
   $y(t) = f(2t)$
   where y(t) and f(t) are the output and the input.
   Is this system (a) linear (b) time-invariant (c) causal?

3 Please sketch the Fourier spectrum for the signal $f(t) = A \cos(wct + b)$. The involved important values must presented.

4. What are the eigenvalues for the following system?



5. Which of the following system can be written as the following relation?
   $y(t) = \int_0^t f(t')h(t-t')dt'$
   where y(t) and f(t) are the output and the input.
   (a) a linear time-varying causal system.
   (b) A linear time-invariant noncausal system.
   Please give your explanation.

6. Please prove the convolution in time domain is equivalent to the multiplication in frequency domain.

7. Please prove the initial value theorem in Laplace transformation.