國立雲林科技大學
九十三學年度碩士班入學招生考試試題

系所：電子系、光電所
科目：半導體元件

1. A silicon pn junction diode is doped with $N_d = N_a = 10^{18}\ \text{cm}^{-3}$, Zener breakdown occurs when the peak electric field reaches 10^6 V/cm. Determine the reverse-bias breakdown voltage. (20%)

2. To calculate the theoretical barrier height, built-in potential barrier, and maximum electric field in a metal-semiconductor diode for zero applied bias. Consider a contact between tungsten and n-type silicon doped to $N_d = 10^{16}\ \text{cm}^{-3}$ at $T = 300$ K. (The metal work function for tungsten is 4.55 volts and the electron affinity for silicon is 4.01 volts.). (20%)

3. The following currents are measured in a uniformly doped npn bipolar transistor:

$I_{nE} = 1.20$ mA $I_{pE} = 0.01$ mA $I_{nC} = 1.18$ mA

$I_R = 0.005$ mA $I_G = 0.001$ mA $I_{pc0} = 0.001$ mA

Assume that the active cross-sectional area is the same for the collector and emitter.

(a) Determine the emitter injection efficiency factor γ. (5%)

(b) Determine the base transport factor α_T. (5%)

(c) Determine the recombination factor δ. (5%)

(d) Determine small-signal common emitter current gain β. (5%)

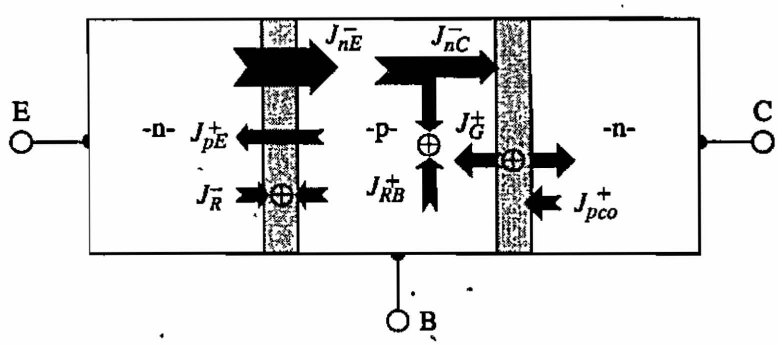

Figure for question 3: Particle current density in an npn bipolar transistor operating in the forward-active mode.

4. Consider an MOS system formed by an n^+ polysilicon gate and a p–type silicon substrate doped to $N_a = 5 \times 10^{16}\ \text{cm}^{-3}$. Assuming $Q'_{ss} = 10^{11}\ \text{cm}^{-3}$ and the work function difference is -1.12V. Determine the oxide thickness such that $V_{TN} = +0.63$ V. $T = 300$ K. (20%).

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5. For an n-channel MOSFET:
   (a) What is subthreshold conduction? What is the current-voltage relation of this effect? (7%)
   (b) What is short-channel effect? How does the channel length affect the transistor? (7%)
   (c) Explain the substrate bias effect. (6%)

Table B.4 | Silicon, gallium arsenide, and germanium properties ($T = 300$ K)

Property	Si	GaAs	Ge
Atoms (cm^{-3})	5.0×10^{22}	4.42×10^{22}	4.42×10^{22}
Atomic weight	28.09	144.63	72.60
Crystal structure	Diamond	Zincblende	Diamond
Density (g/cm^{-3})	2.33	5.32	5.33
Lattice constant (Å)	5.43	5.65	5.65
Melting point (°C)	1415	1238	937
Dielectric constant	11.7	13.1	16.0
Bandgap energy (eV)	1.12	1.42	0.66
Electron affinity, χ (volts)	4.01	4.07	4.13
Effective density of states in conduction band, N_c (cm^{-3})	2.8×10^{19}	4.7×10^{17}	1.04×10^{19}
Effective density of states in valence band, N_v (cm^{-3})	1.04×10^{19}	7.0×10^{18}	6.0×10^{18}
Intrinsic carrier concentration (cm^{-3})	1.5×10^{10}	1.8×10^{6}	2.4×10^{13}
Mobility (cm^2/V-s)			
Electron, μ_n	1350	8500	3900
Hole, μ_p	480	400	1900
Effective mass $\left(\frac{m^*}{m_0}\right)$			
Electrons	$m_l^* = 0.98$	0.067	1.64
	$m_t^* = 0.19$		0.082
Holes	$m_{lh}^* = 0.16$	0.082	0.044
	$m_{hh}^* = 0.49$	0.45	0.28
Effective mass (density of states)			
Electrons $\left(\frac{m_n^*}{m_0}\right)$	1.08	0.067	0.55
Holes $\left(\frac{m_p^*}{m_0}\right)$	0.56	0.48	0.37

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Table B.3 | Physical constants

Avogadro's number	$N_A = 6.02 \times 10^{+23}$ atoms per gram molecular weight
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ J/K $= 8.62 \times 10^{-5}$ eV/K
Electronic charge (magnitude)	$e = 1.60 \times 10^{-19}$ C
Free electron rest mass	$m_0 = 9.11 \times 10^{-31}$ kg
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H/m
Permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-14}$ F/cm $= 8.85 \times 10^{-12}$ F/m
Planck's constant	$h = 6.625 \times 10^{-34}$ J-s $= 4.135 \times 10^{-15}$ eV-s $\frac{h}{2\pi} = \hbar = 1.054 \times 10^{-34}$ J-s
Proton rest mass	$M = 1.67 \times 10^{-27}$ kg
Speed of light in vacuum	$c = 2.998 \times 10^{10}$ cm/s
Thermal voltage ($T = 300$ K)	$V_t = \frac{kT}{e} = 0.0259$ volt $kT = 0.0259$ eV

Table B.6 | Properties of SiO_2 and Si_3N_4 ($T = 300$ K)

Property	SiO_2	Si_3N_4
Crystal structure	[Amorphous for most integrated circuit applications]	
Atomic or molecular density (cm^{-3})	2.2×10^{22}	1.48×10^{22}
Density ($g\text{-}cm^{-3}$)	2.2	3.4
Energy gap	≈9 eV	4.7 eV
Dielectric constant	3.9	7.5
Melting point (°C)	≈1700	≈1900

國立雲林科技大學
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系所：光電所
科目：電磁學

說明：本試卷共六大題，總分共計１００分。

1. Assume that two homogeneous isotropic dielectric media with dielectric constants $\varepsilon_{r1} = 1.5$ and $\varepsilon_{r2} = 2$ are separated by the *xy*-plane. At a common point, $\mathbf{E}_1 = \mathbf{a}_x 2 - \mathbf{a}_y 3 - \mathbf{a}_z 4$. Find $\mathbf{E}_2$, $\mathbf{D}_2$, and the angle α_2 between $\mathbf{E}_2$ and the normal. (15%)

2. Calculate the energy expended in moving a point charge 100 (pC) from $P_1(4, \pi/3, -1)$ to $P_2(2, -\pi/3, -1)$ in an electric field $\mathbf{E} = \mathbf{a}_r\, 6r \sin\phi + \mathbf{a}_\phi\, 3r \cos\phi$ (*V*/m). (15%)

3. For a positive point charge *Q* located at a distance *d* from each of two grounded perpendicular conducting half-planes shown in the figure 1, find the expressions for the potential and the electric field intensity at an arbitrary point $P(x, y)$. (20%)

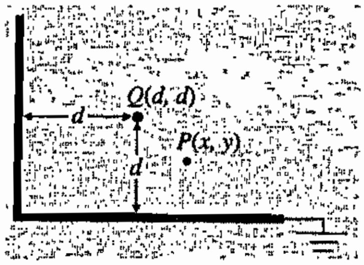

Fig.1.

4. A very large slab of material of thickness d lies perpendicularly to a uniform magnetic field of intensity $\mathbf{H}_0 = \mathbf{a}_z H_0$. Determine the magnetic field intensity in the slab. If the slab is permanent magnet having a magnetization vector $\mathbf{M}_i = \mathbf{a}_z M_i$ (15%)

5. Obtain the wave equations governing the **E** and **H** fields in a source-free conducting medium with constitutive parameters ε, μ, and σ, where ε is the permittivity, μ is the permeability, and σ is the conductivity of the medium. (15%)

6. As shown in Figure 2 for a d-c motor, a current I is sent through the loop in a magnetic field **B** produces a torque that makes the loop rotate. As the loop rotates, the amount of the magnetic flux linking with the loop changes, giving rise to an induced emf. Energy must be expended by an external electric source to counter this emf and establish the current in the loop. Prove that this electric energy is equal to the mechanical work done by the rotating loop. (20%)

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系所：光電所
科目：電磁學

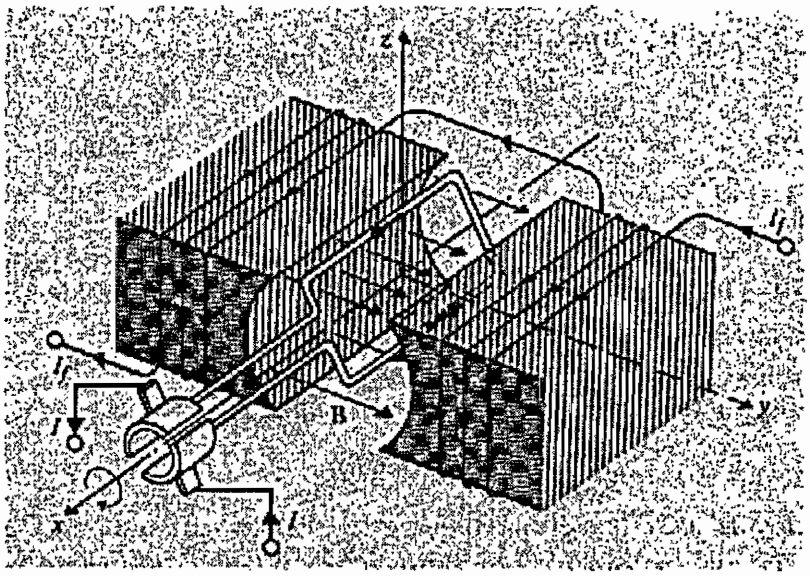

Fig. 2.

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系所：光電所
科目：物理

1. White light is incident normally on a soap film with a thickness of 225 nm that is surrounded by air. What wavelength is missing from the reflected light? (15%)

2. White light is incident on a grating with 5000 lines/cm. At what angle are the first- and second-order red lines for a source wavelength of 650 nm found? (20%)

3. The bandgap energies for Si and Ge are 1.12 eV and 0.66 eV, respectively. Explain why Si photodiodes cannot be used in optical communications at 1.3 and 1.55 μm whereas Ge photodiodes are commercially available for use at these wavelengths. (15%)

4. Two waves of the same frequency have amplitudes 1.00 and 2.00. They interfere at a point where their phase difference is 60.0°. What is the resultant amplitude? (15%)

5. Seven electrons are trapped in a one-dimensional infinite potential well of width L. As a multiple of $h^2/8mL^2$, what is the energy of the ground state of the system of seven electrons? Assume that the electrons do not interact with one another, and do not neglect spin. (20%)

6. Find the maximum kinetic energy of electrons ejected from a certain material if the material's work function is 2.3 eV and the frequency of the incident radiation is 3.0×10^{15} Hz.($h=6.63\times10^{-34}$J · s $=4.14\times10^{-15}$eV · s) (15%)