一、 **單選題(1-30)，每小題 2.5 分，倒扣分數為 0.5 分，倒扣至本大題 (即單選題) 0 分為止。**

1. Two laser beams, one green (500 nm) and one infrared (wavelength = 1 μm), point at the same ideal photo detector (PD). When the green laser is on, the reading on the PD is 100 μW. When the infrared beam is on, the reading on the PD is 150 μW. Assuming the photon influx (number of photons per second) from the green laser reach photodetector is F_0, what is the total photon influx from both lasers when they both turn on?
   A. F_0
   B. $2.5 \times F_0$
   C. $3 \times F_0$
   D. $4 \times F_0$

2. In Bohr's model of a hydrogen atom (with one proton in its nucleus), the radius of the atom is R_H and its potential energy is U_H. Calculate the radius (R_{He+}) and the potential energy (U_{He+}) of a Helium He^+ atom (with two protons in its nucleus).
   A. $R_{He+} = 2 \times R_H$ and $U_{He+} = 0.5 \times U_H$
   B. $R_{He+} = 0.5 \times R_H$ and $U_{He+} = 1 \times U_H$
   C. $R_{He+} = 2 \times R_H$ and $U_{He+} = 2 \times U_H$
   D. $R_{He+} = 0.5 \times R_H$ and $U_{He+} = 4 \times U_H$

3. Consider bulk metal and their electron density listed on the right, which metal has the longest Fermi wavelength, $\lambda_F = h/p_F$? (Hint: p_F is the Fermi momentum of the particle and the Fermi energy, $E_F \sim n^{2/3}$, n is the electron density)
   A. Cu
   B. Au
   C. Fe
   D. Al

Element	Electron Density (10^{28} m^{-3})
Cu	8.47
Au	5.8
Fe	17.9
Al	18.1

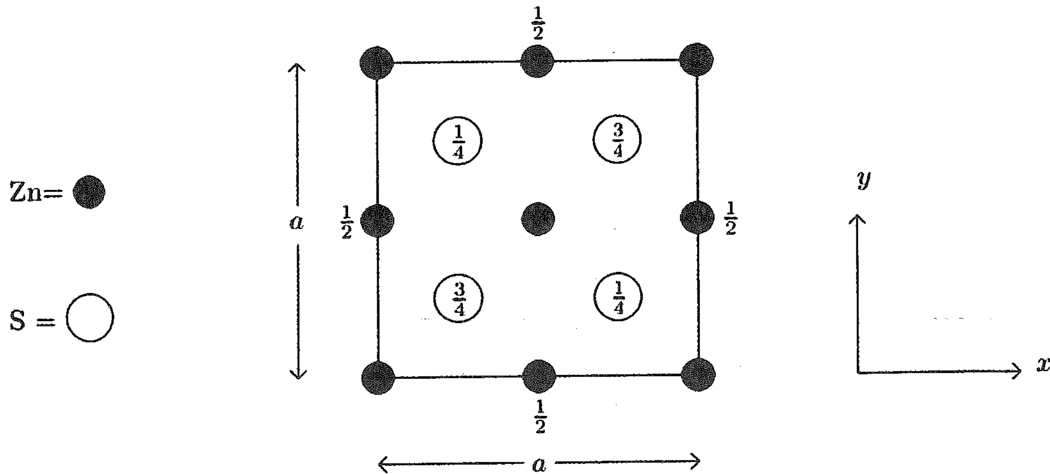
4. Based on the ionization energy and electron affinity listed on the table below, which Sodium based compound has the **highest** melting point?
   A. NaF
   B. NaCl
   C. NaBr
   D. NaI

Element	Electron Affinity (eV)	Ionization Energy (eV)
F	3.34	17.42
Cl	3.62	12.97
Br	3.37	11.81
I	3.06	10.45

5. The electron in Si has an effective mass is $m^*_{e,Si} = 0.2 \times m_0$ and the mobility being 1400 cm^2 V^{-1} s^{-1}. Estimate the mean free time in scattering of electrons. [Hint: electron charge: 1.6 x 10^{-16} C; electron mass, m_0 = 9.1 x 10^{-31} kg]
   A. 51 fs
   B. 141 fs
   C. 361 fs
   D. 810 fs

注意：背面有試題

For **Question 6-7**, provided diagram below offers an overhead perspective of a cubic ZnS (zinc blende) structure when observed along the z-axis. The numeric labels associated with certain atoms indicate their elevations above the z = 0 plane, expressed as a fraction of the cube edge 'a'.



6. Given that a = 5.4 Å, estimate the distance of nearest-neighbor (Zn-S)
[Hint: $1/\sqrt{2} = 0.7$; $\sqrt{3}/4 = 0.43$; $\sqrt{5} = 2.2$]

A. 5.4 Å
B. 2.3 Å
C. 10.2 Å
D. 3.8 Å

7. Estimate the distance between neighboring (110) planes for the same ZnS crystal.
[Hint: $1/\sqrt{2} = 0.7$; $\sqrt{3}/4 = 0.43$; $\sqrt{5} = 2.2$]

A. 5.4 Å
B. 2.3 Å
C. 10.2 Å
D. 3.8 Å

8. Consider a single phosphor atom as a single ionized atom in Si crystal, similar to the nucleus of a hydrogen atom. Estimate the binding energy of an electron attached to this atom of prosperity. (In silicon, effective mass of electron, $m^*_{e,Si} = 0.2 \times m_0$, where $m_0 = 9.1 \times 10^{-31}$ kg is the mass of an electron. Si also has the relative dielectric constant of is 11.7; binding energy for hydrogen atom is 13.6 eV)

A. 3.9 meV
B. 46.5 meV
C. 1.2 eV
D. 13.6 eV

注意：背面有試題

For **Question 9-13**, consider four pn diodes of an unknown semiconductor with a uniform doping concentration on both sides of the junction:

A. N_D=1x10^{18} cm^{-3} and N_A=1x10^{18} cm^{-3},
B. N_D=1x10^{18} cm^{-3} and N_A=1x10^{17} cm^{-3},
C. N_D=1x10^{17} cm^{-3} and N_A=1x10^{18} cm^{-3},
D. N_D=1x10^{16} cm^{-3} and N_A=1x10^{17} cm^{-3}.

The depletion width in the n-type and the p-type regions is denoted as x_n and x_p, respectively. The bandgap is 0.6 eV.

9. Which diode has the smallest V_{bi}?

10. Which diode has a ratio of x_p/x_n closest to 10 at zero bias?

11. Which diode is most likely to observe Zener tunneling in its current conduction?

12. For a given forward bias, which diode is most likely to have a high-level injection on either the n-side or p-side of the junction?

13. If you plot $1/C^2$ versus V_A for these four diodes, where C is the junction capacitance and V_A is applied reverse voltage, which diode has the smallest slope?

For **Question 14-17**, the work function of tungsten (W), nickel (Ni), platinum (Pt), and titanium (Ti) is 4.55, 5.15, 5.65, and 4.33 eV respectively. The electron affinity of silicon is 4.05 eV. Consider an n-type silicon with a uniform doping density of 1x10^{17} cm^{-3}. Assume that thermionic emission dominates current conduction.

14. If you need an M-S junction with the largest barrier height ϕ_{bn}, which metal would you choose?

A. W
B. Ni
C. Pt
D. Ti

15. If you need an M-S junction with the lowest reverse current, which metal would you choose?

A. W
B. Ni
C. Pt
D. Ti

16. If you need an M-S junction with the largest junction capacitance at zero bias, which metal would you choose?

A. W
B. Ni
C. Pt
D. Ti

17. If you simply increase the doping density of silicon, which of the following statements is true?

A. Forward current is unchanged.
B. Reverse current is unchanged.
C. Junction capacitance is unchanged.
D. Maximum breakdown voltage is unchanged

For **Question 18-22**, consider four Si npn BJTs with the following structures:

A. N_E=1x10^{18} cm^{-3}, N_B=1x10^{17} cm^{-3}, N_C=1x10^{16} cm^{-3}, W_B=1 μm

B. N_E=5x10^{18} cm^{-3}, N_B=1x10^{17} cm^{-3}, N_C=2x10^{16} cm^{-3}, W_B=1 μm

C. N_E=5x10^{17} cm^{-3}, N_B=5x10^{17} cm^{-3}, N_C=5x10^{16} cm^{-3}, W_B=0.5 μm

D. N_E=1x10^{18} cm^{-3}, N_B=1x10^{18} cm^{-3}, N_C=5x10^{15} cm^{-3}, W_B=0.5 μm

N_E, N_B, and N_C are the doping densities in the emitter, base, and collector respectively. W_B is the base width. Assume that the emitter width W_E and the collector width W_C are the same and wide enough to support the depletion regions in all cases. Ignore the carrier recombination in the base.

18. Which BJT has the largest common emitter current gain β?

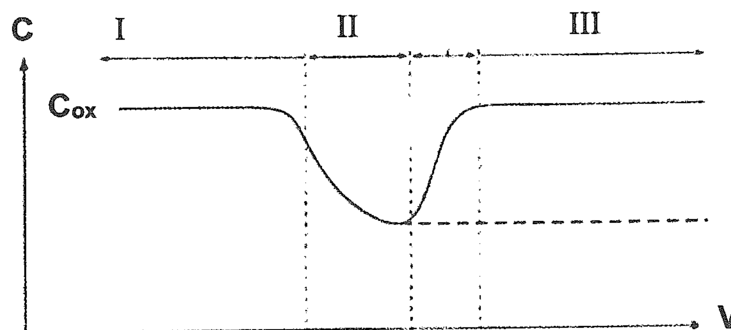
19. Which BJT has the largest common base current gain α?

20. Which BJT has the lowest Kirk current density?

21. Which BJT can support the largest V_{CE}?

22. For a V_{BE} of 0.6 V, which BJT has the largest base current I_B?

For **Question 23-24**, consider the measured C-V curves of a MOS-C shown below.



23. Which statement is true?

A. Region I is depletion, dash line is high-frequency CV

B. Region II is depletion, dash line is low-frequency CV

C. Region III is inversion, dash line is high-frequency CV

D. Region I is accumulation, sold line is high-frequency CV

24. The capacitance lowered as a MOS-C enters region II, because of which of the following?

A. inversion charge decreases

B. more free carriers accumulate at Si/SiO_2

C. depletion region widens

D. depletion charge reduces

25. In a MOS-Capacitor, its gate is connected to a sweeping voltage; its n-type Si substrate is grounded. Which of the following statement is true?

A. Inversion charge consists of electrons and does respond to fast signal

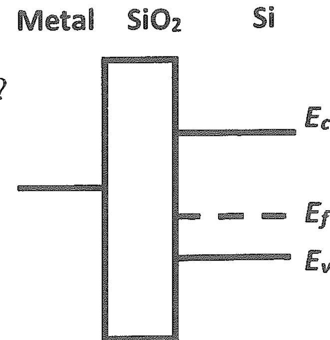
B. Depletion charge is negative and cannot respond to fast signal

C. Accumulation charge consist of holes and cannot respond to fast signal

D. Depletion charge is positive and does respond to fast signal

注意：背面有試題

26. The energy band of the MOS structure is shown on the right, the device is in which region?
   A. Inversion
   B. Depletion
   C. Accumulation
   D. Flat-Band



27. Which is the correct in describing the channel current of a nMOSFET operating in the linear region?
   A. Diffusion current dominates.
   B. Channel is pinched off at the drain side.
   C. Drift current dominates.
   D. Channel is pinched off at the source side.

28. For a pMOSFET in strong inversion, which of the following is true?
   A. Inversion charge in channel consists of holes
   B. Depletion charge is zero
   C. Electrons accumulate at the SiO_2/Si interface
   D. Carriers transport from source to drain by diffusion

29. Which of the following statement of a nMOSFET is correct?
   A. Threshold voltage is defined as the gate voltage applied when the hole concentration exceeds the depletion charge level.
   B. Higher channel doping level is expected to increase its threshold voltage.
   C. In inversion, its drain current can always be raised by increased drain voltage.
   D. In saturation region, its channel is continuous from source to drain.

30. Consider a long channel nMOSFET with source and body grounded, which of the following statement is correct in describing the electric field in the middle of the channel?
   A. In sub-threshold region, its vertical electric field rises with increasing V_G.
   B. In linear region, its lateral electric field is independent of V_D.
   C. In saturation, its lateral electric field is proportional to V_D.
   D. In saturation, its vertical electric field is proportional to V_G.

二、 **多選題(31-40)，每小題 2.5 分**，每題每一選項(ABCDE)單獨計分，每一選項個別分數為0.5分，**答錯一選項倒扣分數為 0.5 分，倒扣至本大題 (即多選題) 0 分為止。**

31. Which of the following particle(s) should be treated using Bose-Einstein statistics?
A. Electron
B. Photon
C. Heavy hole
D. Phonon
E. Light hole

32. When considering heat capacity at low temperatures, the internal energy of metal is made up of various types of energies, such as
A. mechanical energy of atoms
B. potential energy of nucleus
C. electrical energy of excitons
D. magnetic energy of spins
E. kinetic energy of electrons

33. A piece of semiconductor sample operating under normal operation. Which of the following statements accurately describe either drift or diffusion current?
A. Mobility characterize how fast an electron or hole can flow through the sample in the presence of an electric field
B. For electrons, the diffusion current flows from region of higher electron concentration to region of lower electron concentration
C. Drift current is always in the direction of the electric field
D. The diffusion coefficient and mobility (of electrons or holes) are described by the Einstein Relationship (of electrons holes)
E. The ratio between diffusion coefficient and mobility is quadratic proportional to the ambient temperature

34. In a semiconductor, which of the following statements accurately describes the relationship between the conduction band and the valence band?
A. We can use Boltzmann statistics for electrons in the conduction band
B. Electrons in the conduction band have higher energy than electrons in the valence band.
C. The effective mass of electron (hole) is determined from the slope of the conduction (valance) band
D. Holes loses energy when pushed away (down) from the band maximum
E. The valence band is associated with the movement of holes, while the conduction band is for electrons

注意：背面有試題

35. With which one of the following elements silicon should be doped so as to give p-type of semiconductor?

A. Gallium

B. Arsenic

C. Boron

D. Selenium

E. BF_2

36. Which statements are true for intrinsic and extrinsic semiconductors?

A. When there is no current flow (equilibrium), the Fermi level is constant

B. P-type semiconductor host more positive carriers (holes) and therefore its Fermi level increases

C. The multiplication of the positive and negative carrier density decrease as temperature decreases

D. In a pn-junction, the electric field points from the N-typed material toward the P-type material

E. The conductivity increase with increasing temperature is due to enhancement of mobility

37. For a n-channel enhancement-mode MOSFET, its gate dielectric thickness increases as other structural parameters remains unchanged. Which of the following is expected to happen?

A. Its threshold voltage increases.

B. Its body effect will be more significant.

C. Its gate tunneling current will increase.

D. Its sub-threshold swing increases.

E. Its channel length modulation coefficient increases.

38. Which of the following statements in a short-channel nMOSFET are correct?

A. When operating under velocity saturation region, its transconductance becomes independent of gate bias voltage.

B. Off-state drain leakage current decrease on shorter channel length devices.

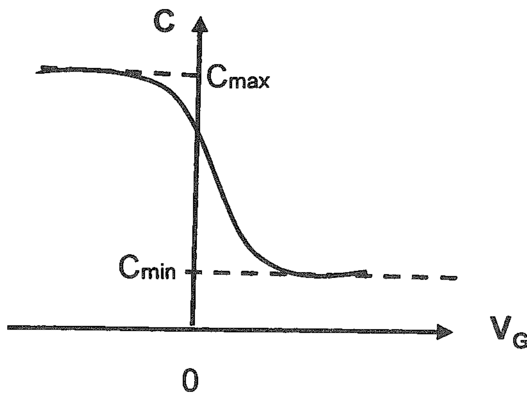
C. Lower threshold voltage is found on shorter channel length devices.

D. Increase source/drain junction depth can reduced Drain Induced Barrier Lowing (DIBL) effect.

E. Its threshold voltage becomes independent of the flat-band voltage

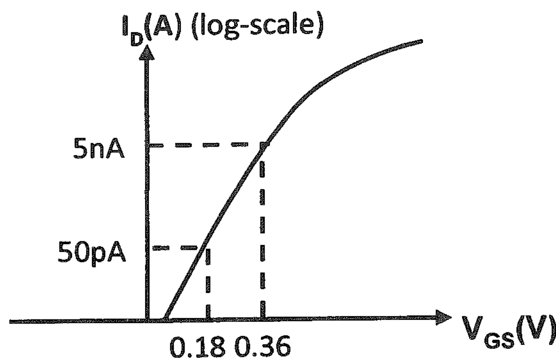
39. Based on the measured CV curve below on a MOS-C with gate oxide thickness of T_{ox}, where C_{max} =4XC_{min}. Its substrate is grounded and V_G is the gate voltage. Which of the following statements are true?

A. This MOS-C is on a p-type substrate
B. It is measured by the charging current in response to slow DC sweeps
C. The depletion capacitance at threshold is 4X smaller than the gate oxide capacitance
D. Its threshold voltage is positive
E. At strong inversion, the maximum depletion width = T_{ox}.



40. I_D-V_{GS} characteristic of a MOSFET with W/L=100 measured at 300°K is shown below. Assume its subthreshold swing is constant between 0~0.5V. Which of the following statements are true?

A. The off-state drain leakage current (at V_{GS}=0) is lower than 100fA.
B. At V_{GS}=0.27V, I_D =500pA.
C. At V_{GS}=0.45V, its drain current is higher than 100nA..
D. Its subthreshold swing is below 100mV/decade.
E. Its sub-threshold swing decreases at lower temperature.



注意：背面有試題