類組：電機類　　科目：近代物理(300F)　　第 1 頁 共 6 頁

※選擇題請填於答案卡，非選擇題請在答案卷內作答

(一) 單選題：共 10 題，每題 4 分，答錯者每題倒扣 1 分，倒扣率即為 1/4，倒扣至本大題(即單選題) 0 分為止。

1. For a particle with an energy of E tunneling through a finite barrier height of U and width of δ solve the Schrodinger wave equation to calculate the tunneling probability and select the correct answer corresponding to various E, U, and δ for different particles.

(A) For a neutron with E = 50 meV incident on a barrier of U = 250 meV and δ = 0.16 nm, the tunneling probability is 4.45×10^{-11} = 0.0445 ppb

(B) For a neutron with E = 50 meV incident on a barrier of U = 250 meV and δ = 0.1 nm, the tunneling probability is 5.86×10^{-10} = 0.586 ppb

(C) For an electron with E = 1.0 eV incident on a barrier with U = 5.0 eV and δ = 0.5 nm, the tunneling probability is 7.1×10^{-7} = 0.71 ppm

(D) For an electron with E = 1.0 eV incident on a barrier with U = 5.0 eV and δ = 1.0 nm, the tunneling probability is 2.52×10^{-9} = 2.52 ppb

(E) For an electron with E = 1.0 eV incident on a barrier with U = 5.0 eV and δ = 1.25 nm, the tunneling probability is 1.5×10^{-10} = 0.15 ppb

2. For a nuclear magnetic dipole of Hydrogen placed in a magnetic field B (T: Tesla), calculate the Zeeman effect to be observed in a spectral line of various wavelengths λ and the resolution $\Delta\lambda$ select the correct solution (T = kg/C · s)

(A) B = 0.3 T, λ = 450 nm, $\Delta\lambda$ = 1.5425×10^{-11} m = 1.5425 pm

(B) B = 2.0 T, λ = 450 nm, $\Delta\lambda$ = 2.314×10^{-14} m = 23.14 fm

(C) B = 7.5 T, λ = 360 nm, $\Delta\lambda$ = 2.468×10^{-14} m = 24.68 fm

(D) B = 2.0 T, λ = 675 nm, $\Delta\lambda$ = 2.468×10^{-14} m = 24.68 fm

(E) B = 7.5 T, λ = 450 nm, $\Delta\lambda$ = 2.314×10^{-14} m = 23.14 fm

3. Consider a *p-n* junction diode. Which of the following statements is *wrong*?

(A) In the absence of any bias, there is no drift current in the junction.

(B) A forward bias will result in a rapid increase in the current.

(C) A reverse bias will turn off the diode.

(D) A diffusion current exists in both forward and reverse bias.

(E) The current-voltage curve is temperature sensitive.

注意:背面有試題

※選擇題請填於答案卡，非選擇題請在答案卷內作答

4. The atomic radii r in terms of the lattice constant a, for the structure of

(A) simple cubic is $a/2$, face-centered cubic is $\sqrt{2}a/4$, body-centered cubic is $\sqrt{3}a/4$, and diamond is $\sqrt{3}a/8$, respectively.

(B) simple cubic is $a/2$, face-centered cubic is $\sqrt{3}a/4$, body-centered cubic is $\sqrt{2}a/4$, and diamond is $\sqrt{3}a/8$, respectively.

(C) simple cubic is $a/2$, face-centered cubic is $\sqrt{3}a/8$, body-centered cubic is $\sqrt{3}a/4$, and diamond is $\sqrt{2}a/4$, respectively.

(D) simple cubic is $a/2$, face-centered cubic is $\sqrt{2}a/4$, body-centered cubic is $\sqrt{3}a/8$, and diamond is $\sqrt{3}a/4$, respectively.

(E) simple cubic is a, face-centered cubic is $\sqrt{3}a/8$, body-centered cubic is $\sqrt{2}a/4$, and diamond is $\sqrt{3}a/4$, respectively.

5. Which of the following statements is correct?

(A) An LED is constructed from a *p-n* junction based on a certain semi-conducting material with energy gap of 1.55 eV. The wavelength of the emitted light is 80 nm.

(B) $\pi/6$ of the available volume is occupied by hard spheres in contact in a simple cubic arrangement.

(C) If the Debye temperature for iron is known to be 360 K, the maximum frequency is 75 THz.

(D) The Fermi energy in gold is 5.54 eV. The average energy of the free electrons in gold at 0 K is right the Fermi energy and the corresponding speed of free electrons is 9.9×10^5 m/s.

(E) The density of states function for electrons in a metal is given by $Z(E)dE = 13.6\times10^{27}\sqrt{E}dE$. The Fermi level at a temperature few degrees above absolute zero for copper which has 8.5×10^{28} electrons per cubic meter is about 9.35 eV.

6. Which of the following principles of classical physics is violated in the *Bohr model*?

(A) Newton's $F = m \cdot a$

(B) Coulomb's law

(C) Accelerating charges radiate energy

(D) Particles always have a well-defined position and momentum

(E) More than one of the above

7. Consider a particle in the relativistic regime, with the energy given by the expression $E^2 = (c^2p^2 + m^2c^4)$ (E = energy, p = momentum, m = mass, c = light speed). What is the leading-order relativistic correction to the kinetic energy?

(A) $p^2/(16m)$

(B) $-p^4/(8m^3c^2)$

(C) $-p^6/(16m^5c^4)$

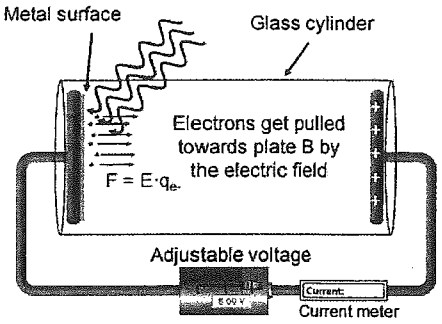
(D) $p^6/(16m^5c^4)$

(E) None of the above

注意:背面有試題

※選擇題請填於答案卡，非選擇題請在答案卷內作答

8. You found an interesting looking piece of metal. You want to find out what kind of metal that is and so you decide to replace the cathode in your photoelectric effect apparatus with that metal piece. You still have the laser diode from the blue-ray player (405 nm wavelength). In this setup you find a stopping potential of 0.16 eV. What kind of metal is it?



(A) Sodium (work function $\Phi \approx 2.3$ eV)
(B) Calcium (work function $\Phi \approx 2.9$ eV)
(C) Silver (work function $\Phi \approx 4.7$ eV)
(D) Lead (work function $\Phi \approx 4.1$ eV)
(E) Some other material

9. A radio transmitter of 1 kW operates at a frequency of 880 kHz. How many photons per second does it emit?

(A) 0.88×10^{30} photons/s
(B) 1.13×10^{30} photons/s
(C) 4.42×10^{30} photons/s
(D) 1.72×10^{30} photons/s
(E) None of the above

10. A galaxy in the constellation Ursa Major is receding from the earth at 15,000 km/s. If one of the characteristic wavelengths of the light the galaxy emits is 550 nm, what is the corresponding wavelength measured by astronomers on the earth?

(A) 578 nm
(B) 940 nm
(C) 340 nm
(D) 1.15 μm
(E) 405 nm

(二) 複選題：共 10 題，每題 4 分，答錯倒扣 0.8 分，倒扣率即為 1/5，倒扣至本大題(即複選題) 0 分為止

11. Consider the conduction band in the Na metal at T = 0 K (T = temperature). Which of the following statements are *correct*?

(A) The band derives primarily from the 3s orbital of Na atom.
(B) The band is completely filled.
(C) The Fermi energy lies inside the conduction band.
(D) Since conduction band electrons move quite freely in the metal, they do not bind the atoms together at all.
(E) All of the above.

注意:背面有試題

※選擇題請填於答案卡，非選擇題請在答案卷內作答

12. Let 'v' and 's' both be binary electron degrees of freedom, with v = K or K', and s = U or D. Below, we will use the following convention: a) A notation such as $|K,U\rangle$ represents an one-electron state with v = K, and s = U; b) A product such as $|K,U\rangle|K',D\rangle$ denotes a two-electron state with the 1st electron in the state $|K,U\rangle$ and the 2nd in $|K',D\rangle$. Which of the following states are consistent with the Pauli exclusion principle?

(A) $|K,U\rangle|K',D\rangle - |K',U\rangle|K,D\rangle$

(B) $|K,U\rangle|K',U\rangle - |K',U\rangle|K,U\rangle$

(C) $|K,U\rangle|K',U\rangle - |K',D\rangle|K,D\rangle$

(D) $|K,U\rangle|K',D\rangle - |K',D\rangle|K,U\rangle$

(E) None of the above

13. $\psi_1(x)$ and $\psi_2(x)$ are both non-trivial solutions (i.e., $\psi_{1,2}$ are not zero everywhere) of the time-independent 1D Schrodinger equation. Which of the following is **not** a solution to that Schrodinger equation? (Note: A, B, and α are arbitrary, non-zero constants. This question only asks for 'mathematical solution' to the Schrodinger equation. You don't need to normalize the wave functions nor fulfill any boundary conditions.)

(A) $A\psi_1(x)$

(B) $A\psi_1(x) + B\psi_2(x)$

(C) $(A+B)\cdot(\psi_1(x)+\psi_2(x))$

(D) $\psi_1(x)\cdot e^{\alpha} + \psi_2(x)\cdot e^{-\alpha}$

(E) None of the above is solution to that Schrodinger equation.

14. Assuming there are particles, whose de Broglie waves shown in the figure below. (A: amplitude of the de Broglie waves, λ: wavelength of the de Broglie waves. All three particles have the same mass.) Which of the following relations about the velocity of particles are correct?

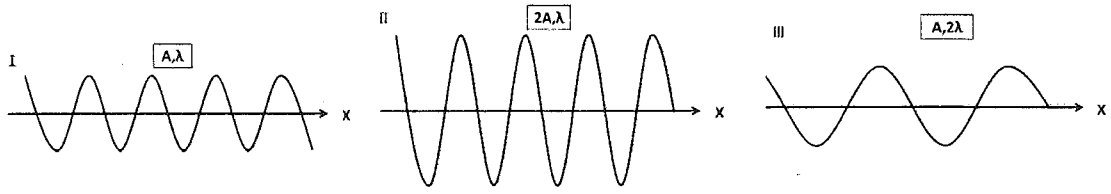
(A) I > III

(B) II = I

(C) II > I

(D) III > II

(E) III = I



15. An electron has a matter wavelength of 2×10^{-12} m and the rest energy E_0 = 511 keV, which of the following answers is correct?

(A) The electron energy is 620 keV.

(B) The kinetic energy (KE) of the electron is 292 keV

(C) The electron velocity is about 0.77 c.

(D) The group velocity v_g is about 0.77 c.

(E) The phase velocity v_p is about 1.3 c.

注意:背面有試題

※選擇題請填於答案卡，非選擇題請在答案卷內作答

16. Assume the Fermi energy of silver is 5.52 eV and the number of conduction electrons is $5.86\times10^{28}\text{m}^{-3}$. Which of the following statements are correct?

(A) The corresponding velocity of conduction electron is 1.39×10^{6} m/s.

(B) If the resistivity of silver at room temperature is 1.62×10^{-8} Ωm, the average time between collisions is 3.7×10^{-14} s.

(C) The mean free path is 51.4 nm.

(D) The corresponding velocity of conduction electron is 9.85×10^{5} m/s.

(E) The mean free path is 36 nm.

17. Which of the following statements are correct?

(A) The splitting of spectrum lines in a magnetic field is known as Zeeman effect.

(B) The energy spacing between the components of the ground state energy level of hydrogen when split by a magnetic field of 1.0 T is 9.27×10^{-24} J.

(C) The energy spacing between the components of the ground state energy level of hydrogen when split by a magnetic field of 1.0 T is 1.16×10^{-4} eV.

(D) Splitting levels by equal amount in the presence of magnetic field is called normal Zeeman effect.

(E) Splitting levels by equal amount in the presence of magnetic field is called anomalous Zeeman effect.

18. For an electron trapped in a quantum well with infinitely high barrier $U(x)\rightarrow\infty$ at the boundaries, $x = 0$ and $2L$. Derive the wave function Ψ and calculate the expectation values of specified terms. Herein p is the linear momentum operator given by $\mathrm{p} = \frac{\hbar}{i}\frac{d}{dx}$

(A) $\Psi(x) = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}, \langle x^3\rangle - \langle x\rangle^3 = \frac{L^3}{8}$

(B) $\Psi(x) = \sqrt{\frac{1}{L}}\sin\frac{n\pi x}{2L}, \langle x^3\rangle - \langle x\rangle\langle x^2\rangle = \frac{2L^3}{3}\left(1-\frac{6}{(n\pi)^2}\right)$

(C) $\Psi(x) = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}, \langle x^3\rangle - \langle x\rangle\langle x^2\rangle = \frac{L^3}{12}\left(1-\frac{6}{(n\pi)^2}\right)$

(D) $\Psi(x) = \sqrt{\frac{2}{L}}\sin\frac{n\pi x}{L}, \langle px^3\rangle - \langle x^3p\rangle = \frac{\hbar}{i}L^2\left(1-\frac{3}{2(n\pi)^2}\right)$

(E) $\Psi(x) = \sqrt{\frac{1}{L}}\sin\frac{n\pi x}{2L}, \langle px^3\rangle - \langle x^3p\rangle = \frac{\hbar}{i}4L^2\left(1-\frac{3}{2(n\pi)^2}\right)$

19. Which of the following statements are correct?

(A) All motion is relative and the speed of light in free space is the same for all observers.

(B) Although they lack rest mass, photons behave as though they have gravitational mass.

(C) The de Broglie wave group associated with a moving body travels with the same velocity as the body.

(D) The energies of electrons liberated by light depend on the frequency of the light.

(E) Only the quantum theory of light can explain the origin of blackbody radiation.

注意:背面有試題

※選擇題請填於答案卡，非選擇題請在答案卷內作答

20. Select the correct electron configures and quantum numbers of the electrons considering LS coupling effect for various atoms

(A) *Ca*: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$; $3d^1$: $n=3$, $\ell=2$, $m_\ell=0, \pm1, \pm2$

(B) *Cu*: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^9$; $3d^9$: $n=3$, $\ell=2$, $m_\ell=0, \pm1, \pm2$

(C) *Cr*: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$; $3d^5$: $n=3$, $\ell=2$, $m_\ell=0, \pm1, \pm2$, $m_s=+\frac{1}{2}$ or $-\frac{1}{2}$

(D) *Ca*: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$; $3d^5$: $n=3$, $\ell=2$, $m_\ell=0, \pm1, \pm2$, $m_s=+\frac{1}{2}$ or $-\frac{1}{2}$

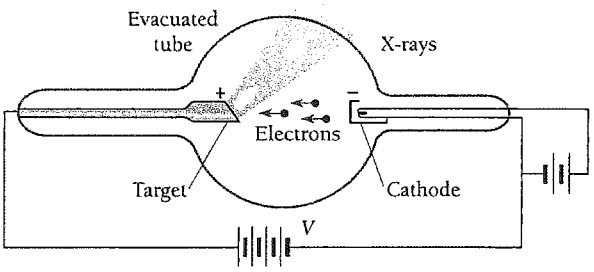
(E) *K*: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$; $4s^1$: $n=4$, $\ell=0$, $m_\ell=0$, $m_s=+\frac{1}{2}$ or $-\frac{1}{2}$, $m_j=\pm\frac{1}{2}$

(三) 非選擇題：共 2 題，每題 10 分

21. (10%) Right figure is an x-ray tube.

(a) (5%) Describe the generation of x-ray.

(b) (5%) Determine the minimum wavelength λ_{min}, when voltage V is 50,000 V.

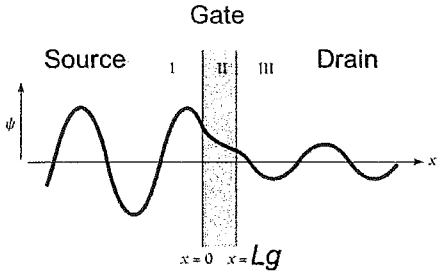


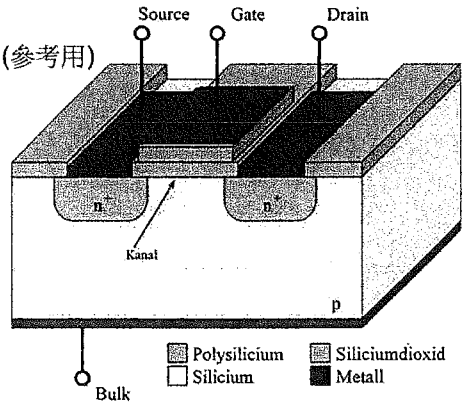
22. (10%) Modern Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET), its device structure is as following figure.

(a) (5%) Determine electron matter wavelength λ, when electron with velocity v = 10^5 m/s and mass m_e = 9.1095×10^{-31} kg.

(b) (3%) Electron transport from source (I) to drain (III), electron will meet a potential barrier (II), which established by gate. Explain electron tunneling effect briefly.

(c) (2%) Give a reasonable minimum gate length (*Lg*) of MOSFET from the answer (a). (Hint: use tunneling effect.)





Electron rest mass: $m_e = 9.1095\times10^{-31}$ kg

Light velocity: $c = 2.998\times10^8$ m/s

Proton rest mass: $m_p = 1.6726\times10^{-27}$ kg

Electron charge: $e = 1.602\times10^{-19}$ C

Neutron rest mass: $m_n = 1.6750\times10^{-27}$ kg

Planck's constant: $h = 6.626\times10^{-34}$ *Js*

Hydrogen atomic mass: $M_H = 1.6736\times10^{-27}$ kg

Permittivity of free space: $\varepsilon_0 = 8.854\times10^{-12}$ F/m

注意：背面有試題