科目：近代物理(300I)

校系所組：中央大學系統生物與生物資訊研究所
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(一)單選題:1~8 題 每題 5 分 答錯倒扣 1.25 分
(二)複選題:9~16 題 每題 5 分 答錯倒扣 1 分
(三)非選擇題:17~18 題 每題 10 分

(一)　單選題:1~8 題 每題 5 分 答錯倒扣 1.25 分

1. An electron is trapped in an infinite potential well. The minimum value of its energy is 5.00 eV. What is its energy in the $n = 4$ quantum state?
   (A) 5.00 eV
   (B) 10.0 eV
   (C) 20.0 eV
   (D) 80.0 eV

2. What is the probability that a particle whose wave function $\psi(x) = A(x\text{-}2)^2$ for x between 0 and 1, and otherwise, $\psi(x) = 0$, is found at $x > 0.5$?
   (A) 21.3%
   (B) 26.0%
   (C) 33.9%
   (D) 48.6%
   (E) 50.0%

3. If the X-rays of wavelength $\lambda = 0.200$ nm are aimed at a block of carbon and the scattered X-rays are observed at an angle of 45° to the incident beam, please indicate the wavelength of the scattered X-ray at this angle as the Planck constant h is 6.63×10^{-34} J·s, the mass of electron m_e is 9.11×10^{-31} kg, and the speed of light c is 3×10^{8} m/s.
   (A) 0.00711 nm.
   (B) 0.000711 nm.
   (C) 0.200711 nm.
   (D) 0.20711 nm.

4. The Sun's radius is given by R_s. The average Earth-Sun distance is D. The power per unit area (at all frequencies) from the Sun is measured at the Earth to be e. Please indicate the surface temperature of the Sun provided that the Sun is a blackbody.
   (A) $\left[\frac{e\times D^2}{\sigma\times R_s^2}\right]^{1/2}$,
   (B) $\left[\frac{e\times R_s^2}{\sigma\times D^2}\right]^{1/4}$,
   (C) $\left[\frac{e\times D^4}{\sigma\times R_s^4}\right]^{1/2}$,
   (D) $\left[\frac{e\times D^2}{\sigma\times R_s^2}\right]^{1/4}$,
   where σ is the Stefan-Boltzmann constant.

注意：背面有試題

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5. Consider the X-ray diffraction from a crystal. Let λ = X-ray wave length. A diffraction peak is observed at diffraction angle θ = 30°. What are the possible values of "d" (i.e., the interplanar spacing of the crystal planes which result in the corresponding diffraction) in terms of λ?
   (A) λ, 1.5λ, 2λ, …
   (B) 0.5λ, 1.5λ, 2.5λ, …
   (C) λ, 2λ, 3λ, …
   (D) 0.5λ, λ, 1.5λ, …
   (E) none of the above.

6. Consider the specific heat C(T) of a crystalline insulator at the temperature T. Which of the following statements is wrong?
   (A) C(T) approaches zero at T = 0.
   (B) C(T) approaches a constant independent of T at high temperatures.
   (C) Quantization of energy is important for the behavior of C(T) at low temperatures.
   (D) The average energy associated with each degree of freedom is always $k_B T/2$.
   (E) C(T) in a 2D system differs from that in a 3D system.

7. When the freedom of the system is f, the specific heat is $\frac{f}{2}k_B$, where k_B is Boltzmann's constant and T is the absolute temperature. This is called:
   (A) Law of Great Number
   (B) Boltzmann's Rule
   (C) Moore's Rule
   (D) Energy Equipartition Rule
   (E) Uncertainty Principle

參考用

8. Calculate the specific heat of the system described by the following Hamiltonian:

$$\hat{H} = \sum_{i=1}^{N} \frac{m}{2} v_i^2 + \frac{1}{2I}\left(p_{i\theta}^2 + \frac{1}{\sin^2\theta} p_{i\varphi}^2\right),$$

where v_i is the absolute value of the velocity of the i-th particle, I is the moment of inertia, and $p_{i\theta}$ and $p_{i\varphi}$ are the components of the angular moment of the i-th particle. The space is three-dimensional.
   (A) $\frac{5}{2}Nk_B$
   (B) $3Nk_B$
   (C) $\frac{2}{3}Nk_BT$
   (D) $4Nk_B$
   (E) $\frac{3}{2}k_BT$

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（二）　複選題:9~16題 每題5分 答錯倒扣1分

9. Which of the following statements are true:
   (A) Group velocity of a signal is always less than phase velocity.
   (B) In vacuum, EM wave travels at the speed of light and group velocity is equal to phase velocity.
   (C) Group velocity of a signal is always less than the speed of light in normally dispersive media.
   (D) A monochromatic wave can have a speed in excess of the speed of light, it cannot convey information.

10. Please select the correct items from the following statements.
    Pauli exclusion principle states that which two particles cannot occupy the same quantum state at the same time and at the same location?
   (A) fermions
   (B) neutrons
   (C) protons
   (D) electrons
   (E) photons

11. Which of the following statements are true:
   (A) Muons which have an average lifetime 2.2 μs with respect to them will travel a distance 650 m with respect to the Earth reference frame provided that Muons have the speed of 0.99c, where c is the speed of light.
   (B) A stick which has a length L measured in a stationary situation will become shorter for the observer at rest as the stick moves with a speed v parallel to the direction of its length.
   (C) The classical Galilean coordinate transformation is the limitation case of the Lorentz transformation for the relative speed of the observers' reference frames to be remarkably less than the speed of light.
   (D) The frequency of the light for the receiver will become higher than the frequency of the light-source emitter as the receiver is approaching to the emitter.

12. Please select the correct items from the following statements.
   (A) The relativistic acceleration is proportional to the $\left(1-\frac{u^2}{c^2}\right)^{3/2}$, where u is the speed of the particle and c is the speed of light.
   (B) The relativistic speed of particle is proportional to the $\left[1-\left(\frac{K}{mc^2}+1\right)^{-2}\right]$, where K is the relativistic kinetic energy and m is the rest mass of the particle.
   (C) The rest energy of the electron is 8.2×10^{-14} J as the mass of electron is 9.11×10^{-31} kg and the speed of light c is 3×10^{8} m/s.
   (D) If a nucleus of mass M undergoes fission into the particles with masses M_1, M_2, and M_3 ,and having speeds u_1, u_2, and u_3, respectively, the conservation of total relativistic energy means

$$Mc^2=\frac{M_1c^2}{\sqrt{1-\frac{u_1^2}{c^2}}}+\frac{M_2c^2}{\sqrt{1-\frac{u_2^2}{c^2}}}+\frac{M_3c^2}{\sqrt{1-\frac{u_3^2}{c^2}}}.$$

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13. Which statements are true about the Bohr atomic model?
(A) Electrons in an atom are guided by stationary waves.
(B) The Bohr model can be used to explain the line spectrum in a hydrogen atom.
(C) The Bohr model is an exact description of the hydrogen atom.
(D) The Bohr model can be applied to derive the probability distribution of 2p state which is dumb bell like.
(E) The Bohr model can explain the forbidden transition 1s → 2s in an hydrogen atom.

14. Which statements are wrong about the Planck quantization of energy?
(A) The Planck distribution is given by $\exp(-h\nu/k_BT)/[1-\exp(-h\nu/k_BT)]$.
(B) The Planck distribution equals the average energy of a photon at temperature T.
(C) The Planck distribution is derived by assuming the energy $E_n = (2n+1)\,h\nu$ for an EM wave mode.
(D) At high temperatures (e.g., $h\nu \ll k_BT$), the result of Planck distribution reduces to $k_BT/h\nu$.
(E) The Planck distribution does not apply to EM waves in a liquid in thermal equilibrium.

15. $\langle n_i \rangle$ is the average number of particles existing in the i-th eigenstate. Select the equations which correctlydescribe the quantum fluctuation from the following options.

(A) $\sqrt{\frac{\langle n_i^2\rangle-\langle n_i\rangle^2}{\langle n_i\rangle^2}} = \sqrt{\frac{1}{\langle n_i\rangle}-1}$

(B) $\sqrt{\frac{\langle n_i^2\rangle-\langle n_i\rangle^2}{\langle n_i\rangle^2}} = \sqrt{\frac{1}{\langle n_i\rangle}}$

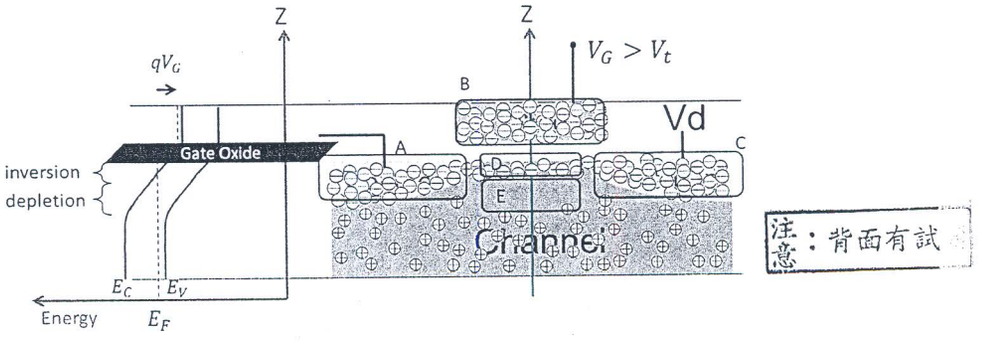
(C) $\sqrt{\frac{\langle n_i^2\rangle-\langle n_i\rangle^2}{\langle n_i\rangle^2}} = \sqrt{\frac{1}{\langle n_i\rangle}+1}$

(D) $\sqrt{\frac{\langle n_i^2\rangle+\langle n_i\rangle^2}{\langle n_i\rangle^2}} = \sqrt{\frac{1}{\langle n_i\rangle}-1}$

(E) $\sqrt{\frac{\langle n_i^2\rangle+\langle n_i\rangle^2}{\langle n_i\rangle^2}} = \sqrt{\frac{1}{\langle n_i\rangle}+1}$

參考用

16. The following figure illustrates the cross-sectional view of n-type MOSFET and the corresponding band diagram along the Z-axis. The gate voltage (V_G) is higher than the threshold voltage (V_t). The region A, B, and C are the source, the gate, and the drain, respectively. The drain voltage (V_D) is applied. The E_C and E_V are the conduction band edge and the valence band edge, respectively. The q is the elementary charge. The E_F is the Fermi level.



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Select the correct sentences concerning this figure from the following options.

(A) The leakage current can flow mainly in the region D if V_G becomes smaller than V_t.

(B) The leakage current can flow mainly in the region E if V_G becomes smaller than V_t.

(C) The current flowing through the region D can be described by the Boltzmann's model.

(D) The current flowing through the region D can be described by the drift-diffusion model.

(E) The current flowing through the region D can be described by the Einstein model.

(三)　非選擇題:17~18 題 每題 10 分

17. Please illustrate the **Stern-Gerlach** experiment and state the important discovery of this experiment in modern physics. You must draw a proper experiment diagram to support your answer.

18. **If the total number of molecules of ideal molecular gas is N, please answer the following questions.**

(a). The number of molecular with energies between ε and dε is $n(\varepsilon)d\varepsilon = C\sqrt{\varepsilon}\cdot e^{-\varepsilon/kT}d\varepsilon$.

Please determine the value of C.

(b). Prove the average molecular energy is $<\varepsilon>=\frac{3}{2}kT$

Useful formula: $\int_0^\infty \sqrt{x}\cdot e^{-ax}dx = \frac{1}{2a}\sqrt{\frac{\pi}{a}}$　　$\int_0^\infty x^{3/2}\cdot e^{-ax}dx = \frac{3}{4a^2}\sqrt{\frac{\pi}{a}}$