類組：電機類　科目：近代物理(300F)　※選擇題請在答案卡內作答，非選擇題請在答案卷內作答

一. 單選題 (共計 8 題, 每題 5 分, 答錯一題倒扣 1.25 分)

1. A cosmic ray photon is bombarding a massive object to pieces. The detectors indicate that two fragments, each of mass m_0, depart due to such a collision each moving at the speed of $0.6c$ at the angle of 60° relative to the photon's original direction of motion. What is the energy of the cosmic ray photon in terms m_0 of and c?
(A) 1/4 m_0c^2 (B) 1/2 m_0c^2 (C) 3/4 m_0c^2 (D) m_0c^2 (E) 3/2m_0c^2 .

2. Which of the following is not true of Blackbody Radiation?
   (A) The radiated power decreases as the wavelengths become very short for fixed T.
   (B) The maximum power occurs at a shorter wavelength for rising T.
   (C) The power spectrum demonstrates the existence of quanta of energy with E=hf.
   (D) The power spectrum demonstrates the ultraviolet catastrophe.
   (E) The Classical (Stefan) law that radiated power $\propto T^4$ applies.

3. In a semiconductor device, electrons are accelerated through a potential difference of 5 V. Then the electrons attempt to tunnel through a potential barrier of width = 0.8 nm and a height = 10 V. If the potential energy is zero outside the barrier, what is the probability that the electrons will tunnel through the barrier? (A) 1.02×10^{-2}, (B), 1.03×10^{-4} (C) 1.07×10^{-8}, (D) 1.15×10^{-16}, (E) none of the above.

4. Which of the following was a fundamental problem for the Rutherford model of the atom?
   (A) The atom was too large.
   (B) Electron orbits were unstable.
   (C) The atom was too small.
   (D) The distribution of charge was wrong.
   (E) none of the above.

5. Which one of the following distribution laws describes particles according to the Pauli exclusion principle?
   (A) The Bose-Einstein distribution
   (B) The Planck distribution
   (C) The Fermi-Dirac distribution
   (D) The Maxwell-Boltzmann distribution
   (E) None of the above.

6. We consider the free electron gas model in 2D. Take the system to be a square L x L, where L = side length. Please evaluate its density of states taking into account the two fold spin degeneracy. Which of the following expressions is the correct density of states,

   (A) $mL^2/(h^2\pi)$, (B) $m^2L^2/(2h^2\pi)$, (C) $mL^2/(2h\pi)$, (D) $mL^2/(2h^2\pi)$, (E) None of the above.

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7. The electrons emitted from the clean metal which is irradiated using the ultraviolet light with the frequency f and intensity I will possess the maximum kinetic energy K_{max}. Please choose the correct statement.
   (A) K_{max} is dependent on I and f.
   (B) K_{max} is dependent on I only.
   (C) K_{max} is dependent on f only.
   (D) K_{max} is independent of I and f.
   (E) The electrons emitted from the metal need a time as long as micro seconds.

8. In the Compton's effect, an X-ray with the wavelength λ_0 is utilized as the incident radiation on the graphite target. It results in a scattered X-ray with the scattered angle θ and the wavelength λ'. If m_e is the electron mass, the $\lambda' - \lambda_0$ is
   (A) $\frac{h}{m_e c}$.
   (B) $\frac{h}{m_e c}\cos\theta$.
   (C) $\frac{h}{m_e c^2}(1-\cos\theta)$.
   (D) $\frac{h}{m_e c}(1-\cos\theta)^2$.
   (E) $\frac{h}{m_e c}(1-\cos\theta)$.

二. 複選題 (共計 8 題，每題 5 分，答錯一題倒扣 1 分)

9. Two spacecrafts are each traveling past us at high velocity towards the right. Spaceship A is carrying a standard meter stick appearing to us to be only 80 cm long. Spacecraft B is carrying a standard clock and as our clock advances by one minute, it appears to us that spacecraft B'sclock only advances by 36 seconds. Which of the following statements are true:
   (A) Spacecraft A moves at a speed of 0.8c.
   (B) Spacecraft A moves at a speed of 0.6c.
   (C) Spacecraft B moves at a speed of 0.8c.
   (D) Spacecraft B moves at a speed of 0.6c.
   (E) According to spacecraft A, spacecraft B moves at a speed of 0.385c.

10. An atom with unknown atomic number Z has a single electron in the orbit n = 5. The electron then falls down by the smallest possible amount to the next level. The photon released from this transition is found to have an energy of 2.75 eV. Which of the following statements are true:

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(A) The transition energy can be expressed as $0.206Z^2$ eV

(B) $Z = 5$.

(C) We are working with a lithium atom

(D) If the atom is returned to the $n = 5$ state, and we wish to increase its energy by the smallest possible amount, so it goes up one level. The energy difference is 1.7eV

(E) The wavelength of light you you bathe the atom in if you want it to increase its level as described in part (D) is 827 nm.

11. Which of the following statements are correct?

A) An electron is accelerated through a potential difference of 25 V; the de Broglie wavelength of the electron is 0.24 nm.

B) An electron is sitting on a pinpoint having a diameter of 2.5 m; the minimum uncertainty in the speed of the electron is 92 m/s.

C) An electron is trapped in an infinite one-dimensional well of width = L, where the ground state energy for this electron is 4.4 eV. Energy of 13.2 eV must be added to the ground-state electron for it to reach the first excited state.

D) Suppose a tunneling current in an electronic device goes through a potential-energy barrier. The tunneling current is small because the width of the barrier is large and the barrier is high. To increase the current most effectively, we should reduce the height of the barrier.

E) Only (B) and (C) above.

12. The wave function of a particle is given by $\Psi(x) = \begin{cases} N\sqrt{a^2x - x^3} & \textbf{for } 0 < x < a, \\ 0 & \textbf{otherwise,} \end{cases}$ where N and a are positive constants. Which of the following statements are correct?

(A) The most likely place to find the particle is $x = 0.5a$.

(B) The normalization constant $N = 2/a^2$.

(C) If the particle's position is measured, the probability that it will be found to be in the range $0 < x < 0.5a$ is 43.75%.

(D) The expectation values $< x >$ and $< x^2 >$ for this wave function are $0.53a$ and $0.33a^2$, and the uncertainty Δx in the position of this particle is $0.22a$.

(E) If we measured the momentum of the particle, the average value $< P >$ that we would get is zero.

13. Which of the following statements are true in regard to the spin-orbit coupling (or L-S coupling) in an atomic orbital?

A) The coupling is a relativistic effect.

B) The heavier the atom, the weaker the coupling.

C) Let L = orbital angular momentum quantum number, Lz = the projection of L onto the z-axis. Then Lz

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is still a good quantum number, in the presence of the coupling.

D) Let S = spin angular momentum quantum number, Sz = the projection of S onto the z-axis. Then Sz is not a good quantum number, in the presence of the coupling.

E) None of the above.

14. Which of the following statements in regard to solids are true?

A) The free electron gas model is a reasonable approximate model for insulators.

B) The existence of an energy gap in the semiconductor is purely a quantum mechanical effect.

C) Undoped semiconductors can never conduct any electricity at all temperatures.

D) Doped semiconductors contain impurities and thus generally have higher resistance than undoped semiconductors.

E) None of the above.

15. A particle has the rest mass m_0 and the velocity u. The speed of light is c. Please indicate the correct statements in the following.

(A) The relativistic momentum is $\frac{m_0 u}{\sqrt{1-\frac{u^2}{c^2}}}$.

(B) The relativistic kinetic energy K is $\frac{m_0 c^2}{\sqrt{1-\frac{u^2}{c^2}}} - m_0 u^2$.

(C) The kinetic energy is K and the velocity can be defined as $c \cdot [1-(\frac{K}{m_0 c^2}+1)^{-2}]^{\frac{1}{2}}$ for the relativistic case.

(D) The non-relativistic (classical) case can be expressed as the limiting case of $u \ll c$ for the relativistic one.

(E) The relativistic total energy is $\frac{m_0 c^2}{\sqrt{1-\frac{u^2}{c^2}}}$.

16. Please indicate the correct statements in the following descriptions.

(A) The power per unit area emitted by the blackbody with the absolute temperature T is σT^3 and σ is called as Stefan-Boltzmann constant.

(B) The temperature of the Sun can be estimated by the Wien's displacement law.

(C) The spectral energy density $u(f,T)$ can be expressed as $\frac{8\pi f^2}{c^3} k_B T$ according to the Rayleigh-Jeans Law, where c is the speed of light, k_B is the Boltzmann constant, and f is frequency of the spectrum emitted from the blackbody with the temperature T.

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(D) The spectral energy density u(f,T) can be expressed as $\frac{8\pi hf^2}{c^3}\left(e^{\frac{hf}{k_BT}}-1\right)^{-1}$ based on the Planck's law, where c is the speed of light, k_B is the Boltzmann constant, and f is frequency of the spectrum emitted from the blackbody with the temperature T.

(E) The Planck's law can completely fit the spectral energy density of the blackbody radiation.

三. 非選擇題 (共計 2 題)

17. (10%) Schrödinger equation for a particle in a box.

(A). (5%) For a particle in one dimension (1D) potential well (length = a) with infinity potential barrier at each end, shown in Fig. (a). Please derive the wave functions and energy levels (eigenvalues)

(B). (5%) From (a) for a particle in two dimension (2D) potential well (length = a, width = b) with infinity potential barrier at each end, shown in Fig. (b). Please derive the wave functions and energy levels (eigenvalues)

Fig. (a)

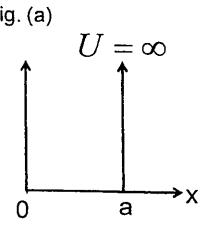
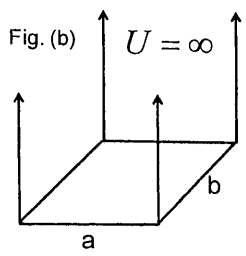


Fig. (b)



18. (10%) For semiconductor, use conduction band (E_c), valence band (E_v), energy band gap (E_g) electron, hole, photon energy and energy conversation law to

(A). (5%) Illustrate (畫圖說明) the operation principle of light-emitter diode (LED).

(B). (5%) Illustrate (畫圖說明) the operation principle of solar cell (SC).