科目：近代物理(300G)　　校系所組：交通大學電子研究所（甲組）
交通大學電信工程研究所（乙B組）
清華大學光電工程研究所
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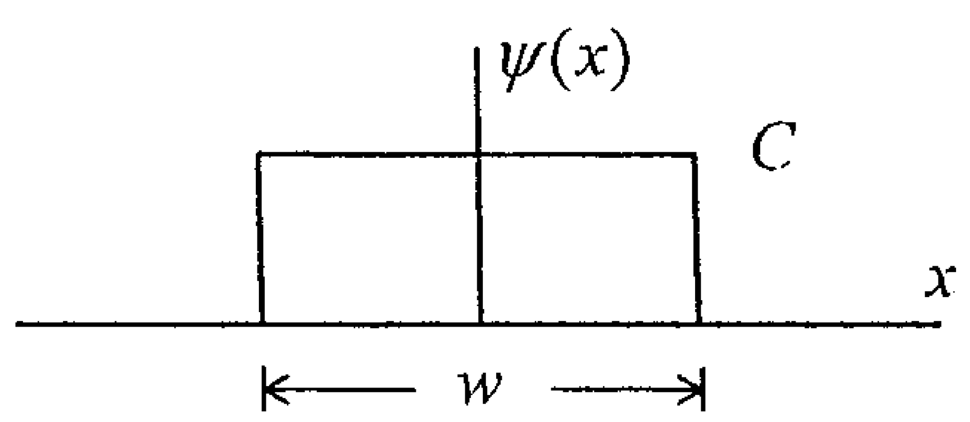
參考用

一、非選擇題(共計3大題)

1. An electron beam strikes a barrier with a single narrow slit, and the electron flux – number of electrons per unit time per unit area – detected at the very center of the resulting intensity pattern is F_1. Assume that the slit is along the x direction, that is of width w, and that as far as that direction alone goes, the probability amplitude $\psi(x)$ is just a constant C ending at the slit's edge, giving the simple function shown in the Figure. Next, two identical slits which are equidistant on either side of the central slit are opened and equally "illuminated" by the same beam.

(a) What is the amplitude $A(k)$ of the plane wave if all slits are opened? (5 points)

(b) What will be the flux at the very center now if all slits are opened? (5 points)



2. A helium nucleus is two protons and two neutrons bound together. Suppose that a very energetic photon strikes a helium nucleus and breaks it into two deuterons which are particles containing one neutron and one proton. Each deuteron travels with a speed of $0.6c$. The photon vanishes in the collision process.

(a) What was the energy of the photon? (5 points)

(b) What is the angle between the directions that deuterons travel? (5 points)

[Hint: The speed of light $c = 3\times10^8$ m/s. The mass of a deuterons is 2.0u, with 1u = 1.66×10^{-27} kg.]

θ	10°	20°	30°	40°	50°	60°	70°	80°	90°
10^3xSin θ	174	342	500	643	766	866	940	985	1000

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3.Useful formulas:

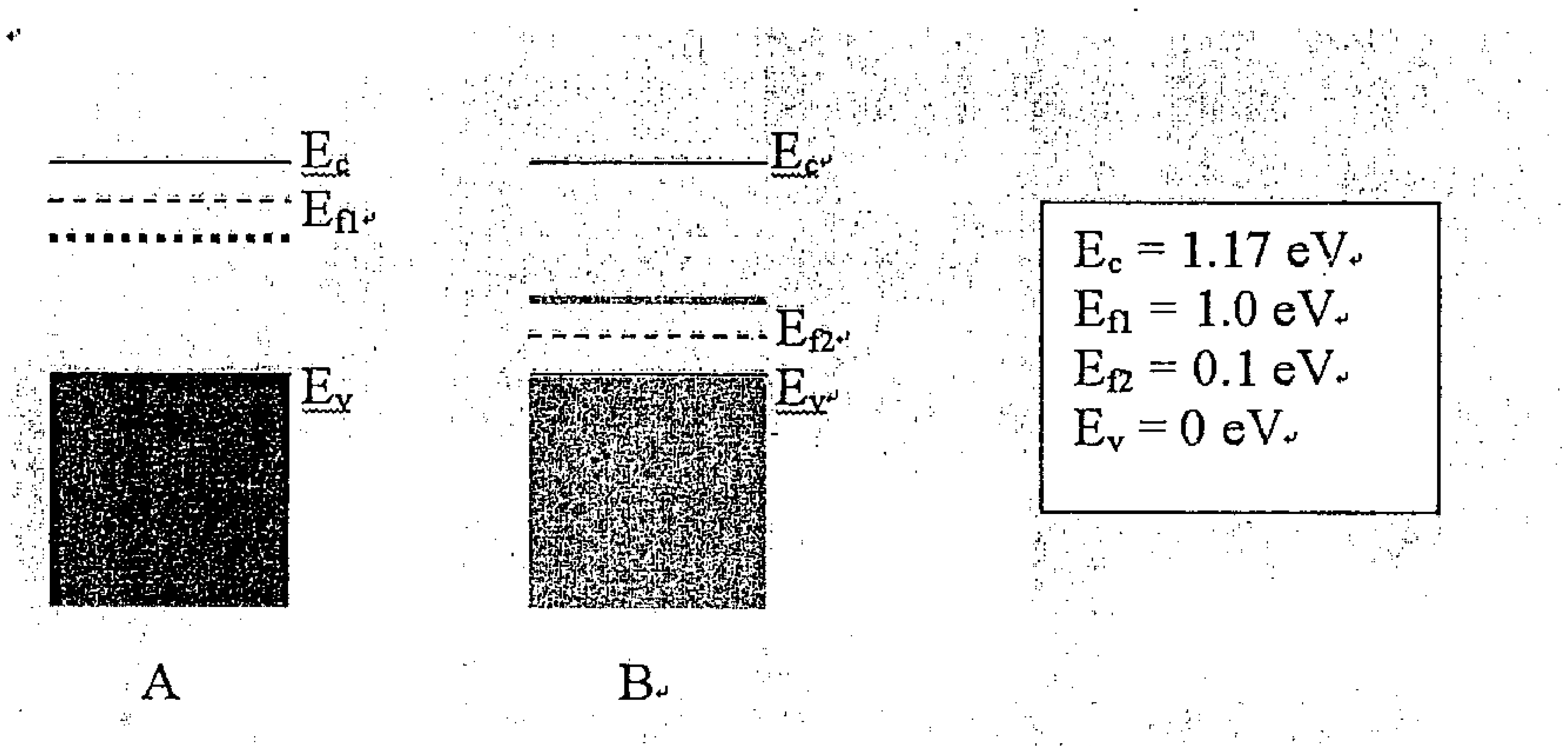
$$\int_0^{\infty} x^m e^{-bx} dx = \frac{m!}{b^{m+1}}$$

（1）A particle of mass m is described by the wave function:

$$\psi(x) = 4\sqrt{2}xe^{-2x} \qquad x > 0$$
$$\psi(x) = 0, \qquad x < 0$$

(a) Determine the most probable position of the particle. (2 points)
(b) Determine the expectation value of the position of the particle. (2 points)
(c) The expectation value of the particle's momentum is 0.What is the uncertainty of its momentum. (3 points)
(d) Calculate the value of the product ΔxΔp, where Δx and Δp are the uncertainty in position and momentum of the particle. (3 points)

（2）



The above diagrams are the energy band diagrams for two semiconductor materials A and B. E_c is the bottom energy of the conduction band, E_f is the Fermi energy, E_v is the energy of the top of the valence band.

(a) Indicate which of the two energy band diagrams belongs to a p-type semiconductor and which belongs to a n-type semiconductor. (2 points)
(b) Draw the energy band diagram of a p-n junction composed from these two materials. (2 points)
(c) What is the built-in voltage potential for the junction? (2 points)

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(3) (a) An exciton is an electron and a hole bound together by electrostatic Coulomb force. Is the exciton a boson or a fermion? Why? (2 points)

(b) Show that the probability distribution of occupying a state at energy E is larger at any temperature for excitons than for electrons. (2 points)

二、單選題(共計 6 題,每題 5 分,答錯 1 題倒扣 1.25 分)

*選擇題部分請務必使用答案卡作答，並從序號1開始劃記，若不依規定作答致光學閱讀機無法辨識答案而影響計分情形者，其後果由考生自行負責

1. The electron total angular momentum is **J**, and angle between the directions of electron orbital angular momentum **L** and spin angular momentum **S** is θ. The **cosθ** is

(A) $\dfrac{j(j+1)-l(l+1)-s(s+1)}{2\sqrt{l(l+1)\cdot s(s+1)}}$, (B) $\dfrac{j(j-1)-l(l-1)-s(s-1)}{\sqrt{l(l+1)\cdot s(s+1)}}$, (C) $\dfrac{j(j+1)+l(l+1)+s(s+1)}{2\sqrt{l(l+1)\cdot s(s+1)}}$, (D) $\dfrac{j(j+1)-l(l+1)-s(s+1)}{\sqrt{l(l+1)\cdot s(s+1)}}$,
(E) $\dfrac{s(s+1)+l(l+1)-j(j+1)}{\sqrt{l(l+1)\cdot s(s+1)}}$

2. In Planck radiation law, the average energy per oscillator (per standing wave in the cavity) is
(A) $\dfrac{hv}{\exp(hv/kT)}-1$, (B) $\dfrac{1}{\exp(hv/kT)}$, (C), $\dfrac{(3/2)hv}{\exp(hv/kT)}$ (D) $\dfrac{hv}{\exp(hv/kT)+1}$,(E) $\dfrac{hv}{\exp(hv/kT)-1}$,

3. The ground state energy of the hydrogen atom is −13.6 eV and that the π^- is a particle with charge −1, spin 0 and mass 270m_e. If all the electrons in the Carbon atom were replaced by π^- particles, the total ground state energy of the system obtained is (A) 3628 eV, (B) 21766 eV, (C) 605 eV, (D) 267 eV (E) 1602 eV.

4. To excite the mercury line 5461 Å, an excitation potential of 7.69 V is required. If the deepest term in the mercury spectrum lies at 84181 cm^{-1}, the two energy levels involved in the emission of 5461 Å are (A) 18.15 eV and 10.46 eV, (B) 15.88 eV and 7.69 eV, (C) 10.46 eV and 2.27 eV, (D) 7.69 eV and 2.27eV. (E) 18.15 eV and 15.88 eV.

5.The speed of a proton is increased from 0.6c to 0.8c. What are the rest energy E_0 in the unit of eV, the total energies in the unit of rest energy E_0, the kinetic energies in the unit of rest energy. E_1 and KE_1 for speed=0.6c. E_2 and KE_2 for speed=0.8c.
(A) E_0 =638 Mev, E_1 =1.33E_0, E_2=1.67 E_0, KE_1=0.33 E_0, KE_2=0.67E_0
(B) E_0 =938 Mev, E_1 =1.33E_0, E_2=1.67 E_0, KE_1=0.33 E_0 , KE_2=0.67E_0
(C) E_0 =638 Mev, E_1 =1.25E_0, E_2=1.33 E_0, KE_1=0.25 E_0 , KE_2=0.33E_0
(D) E_0 =938 Mev, E_1 =1.25E_0, E_2=1.67 E_0, KE_1=0.25 E_0 , KE_2=0.67E_0
(E) E_0 =638 Mev, E_1 =1.25E_0, E_2=1.67 E_0, KE_1=0.25 E_0 , KE_2=0.67E_0

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6.The sun's radius is given by R_s and the average Earth-Sun distance is R. The power per unit area from the Sun is measured at the Earth for all frequencies to be e. The Stefan-Boltzmann constant is given to be σ. Which in the following data is the surface temperature of the Sun as assume that the Sun is a blackbody.

(A) $\left[\dfrac{eR^2}{\sigma^2 R_s}\right]^{\frac{1}{3}}$,(B) $\left[\dfrac{eR^2}{\sigma R_S^2}\right]^{\frac{1}{3}}$,(C) $\left[\dfrac{eR}{\sigma R_S^2}\right]^{\frac{1}{4}}$,(D) $\left[\dfrac{eR^2}{\sigma R_S^2}\right]^{\frac{1}{4}}$,(E) $\left[\dfrac{eR}{\sigma R_S}\right]^{\frac{1}{2}}$

三、複選題(共計 6 題,每題 5 分,答錯 1 題倒扣 1 分)

7. For molecular energies in an **ideal gas**, which of following statements are **"true"**?
(N is the number of molecular, k is Boltzmann constant, T is absolute temperature)

(A) Average molecular energy is $\langle E\rangle = 3kT/(2N)$.
(B) Average molecular energy is $\langle E\rangle = 3kT/2$.
(C) Average molecular energy is $\langle E\rangle = kT/2$.
(D) Each molecular is distinguishable.
(E) Molecular energy distribution $n(E)dE$ is proportional to $\sqrt{E}\cdot\exp(-E/_{kT})dE$

8. For an **ionic crystal**, the total potential energy of each ion is $U_{tot} = -\dfrac{\alpha e^2}{4\pi\varepsilon_0 r} + \dfrac{B}{r^n}$, and its equilibrium separation distance is r_0.
The total potential of each ion at the equilibrium separation is U_0.
Which of the following statements are **"true"**?

(A) Graphite is the ionic crystal.
(B) $B = \dfrac{\alpha e^2}{4\pi\varepsilon_0 n}\cdot r_0^{\,n-1}$
(C) $B = \dfrac{\alpha e^2}{2\pi\varepsilon_0 n}\cdot r_0^{\,n-1}$
(D) $U_0 = -\dfrac{\alpha e^2}{4\pi\varepsilon_0 r_0}(1-\dfrac{1}{n})$
(E) $U_0 = -\dfrac{\alpha e^2}{4\pi\varepsilon_0 r_0}(1-\dfrac{1}{n^2})$

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9. The wave function for a particle moving in a one dimensional potential well $V(x)$ is given by $\psi(x)=\exp(-\frac{ax^2}{2})$. Which of the following statements are correct?

(A) $V(x)=E+(\frac{\hbar^2}{2m})(a^2x^2-a)$.

(B) Minimum value of $V(x)$ at $x=\frac{1}{a^3}$.

(C) Eigen value $E=\frac{a\hbar^2}{2m}$.

(D) $V(x)=\frac{a^2\hbar^2x^2}{2m}$.

(E) $V(x)=\frac{a\hbar^2}{2m}$.

10. Consider hydrogen atom with proton of finite size sphere with uniform charge distribution and radius R. The potential is $V(r)=\begin{cases}-\frac{3e^2}{2R^3}(R^2-\frac{r^2}{3}) & \text{for } r<R \\ -\frac{e^2}{r} & \text{for } r>R\end{cases}$; for the calculations of correction to first order for $n=1$ and $n=2$ with $l=0$ states, which of the following statements are correct?

(A) For $n=1$ state, $\Delta E=\frac{2e^2}{a_0^3}\int_0^R \exp(-\frac{2r}{a_0})(\frac{3r^2}{R}+\frac{r^4}{R^3})dr$

(B) For $n=1$ state, if $R<<a_0$, $\Delta E=3.87\times10^{-9}$ eV.

(C) For $n=2$ state, $\psi_{200}=\sqrt{8\pi a_0^3}(2-\frac{r}{a_0})\exp(-\frac{r}{2a_0})$.

(D) For $n=2$ state, $\Delta E=\frac{e^2}{8\pi a_0^3}\int_0^R \exp(-\frac{r}{a_0})(2-\frac{r}{a_0})^2(\frac{1}{r}-\frac{3}{2R}+\frac{r^2}{2R^3})4\pi r^2dr$

(E) For $n=2$ state, if $R<<a_0$, $\Delta E=1.93\times10^{-9}$ eV.

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11. What is the correct formula for calculating observed frequency ν_{obs} relative to the source frequency ν_{source} when the observer moves away from the source with a velocity of υ. If an observer is moving away from an yellow light with frequency $\nu_s = 5x10^{14}Hz$, what is the velocity υ of the observer if he sensed the light as red one with frequency $\nu_{obs} = 4x10^{14}Hz$.

(A) $\nu_{obs} = \frac{\sqrt{(1+\upsilon/c)}}{\sqrt{(1-\upsilon/c)}}\nu_s$ (B) $\nu_{obs} = \frac{\sqrt{(1-\upsilon/c)}}{\sqrt{(1+\upsilon/c)}}\nu_s$ (C) $\nu_{obs} = \frac{(1-\upsilon/c)}{(1+\upsilon/c)}\nu_s$ (D) $\upsilon = 5.2\times10^7 m/s$ (E) $\upsilon = 6.58\times10^7 m/s$

12. The maximum wavelength for photoelectric emission in a certain metal is 496nm. What is the work function of the metal. What is the wavelength of light required for electron emission with a maximum energy of 1.5eV.

(A) $\phi_0 = 3.1\, eV$
(B) $\phi_0 = 3.5\, eV$
(C) $\phi_0 = 2.5\, eV$
(D) $\lambda = 310nm$
(E) $\lambda = 248nm$