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研究所招生考試

Physical constants:

Avogadro's number: $N_a=6.02 \times 10^{23}$ particles/mol

Boltzmann's constant: $k=1.38 \times 10^{-23}$ J/K

Coulomb constant: $k=8.987 \times 10^9$ N·m²/C²

Fundamental charge: $e=1.6 \times 10^{-19}$ C

Mass of electron: $m_e=9.1 \times 10^{-31}$ Kg

Mass of proton: $M_p=1.672623 \times 10^{-27}$ Kg = 938.3 MeV

Mass of neutron: $M_n=1.674929 \times 10^{-27}$ Kg = 939.6 MeV

Mass of pion: M_{π^-} = 139.6 MeV

Mass of unit: $u=1.66 \times 10^{-27}$ Kg

Planck's constant: $h=6.6 \times 10^{-34}$ J·s

Speed of light: $c=299792458$ m/s

Constant of gravitation: $G=6.67 \times 10^{-11}$ N·m²/Kg²

Fine structure constant: $\alpha= 7.297 \times 10^{-3}$

Gas constant: $R=8.3$ J/mol·K

Permeability of free space: $\mu_0=4\pi \times 10^{-7}$ N/A²

$\gamma = \dfrac{1}{\sqrt{1-\beta^2}} = 1.9596545$, for $\beta=0.86$

1. What are the **relativistic total energy** and **kinetic energy** of a proton moving at a speed of $u = 0.86c$? (Estimate to within 1%) **(15 points)**

2. The wave function solutions of a Hydrogen atom can be written as

$$\Psi_{n,l,m_l}(r,\theta,\psi) = R_{n,l}(r)\Theta_{l,m_l}(\theta)\Phi_{m_l}(\phi).$$

(a) Explain the physical meanings of the product of these wave functions. **(5 points)**
(b) What are the allowed values for each quantum number? **(5 points)**
(c) With electron spin wave function and Pauli exclusion principle included, try to construct the periodic table and write down the electronic configurations for the first 10 atoms. **(10 points)**

3. (a) Please scratch the experimental arrangement of the black body radiation experiment. **(5 points)**
  (b) Plot the experimental results of the measurement with two different temperatures ($T_1>T_2$). **(5 points)**
  (c) What did Max Planck suggest in his theory in order to explain the observation data? **(5 points)**

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4. A particle is confined to a three-dimensional cubic box with potential energy:

$$U(x, y, z) = \begin{cases} 0, & 0 \leq x, y, z \leq L \\ \infty, & \text{elsewhere} \end{cases}$$

   (a) Solve the Schrödinger equation for the normalized eigen functions $\Psi(x, y, z)$ and eigen energy E. **(10 points)**

   (b) Sketch an energy level diagram, showing the energy, quantum number, and the degeneracy for the lowest 5 energy levels. **(10 points)**

5. (a) What is the superconductor? Briefly describe the Meissner effect? **(5 points)**

   (b) State two physical properties of super fluid ^{4}He below the transition temperature 2.18K. **(5 points)**

   (c) Explain the Bose-Einstein statistics and Fermi-Dirac statistics. **(5 points)**

6. A stepped-index fiber has a core of index $n_f=1.500$ and cladding of index $n_c=1.485$.

   (a) What is the maximum incident angle of the light from air ($n_{air}=1.0$) into the fiber such that the total internal reflection will occur at an inner fiber wall? **(8 points)**

   (b) Determine the time delay (in ns/km) of the light traveling directly or with the maximum incident angle through the fiber? **(7 points)**