

- (1.) (15%) Two particles, each of (rest) mass m , collide head-on at $0.8c$ (c : light velocity). They stick together. What is the mass of the composite object?
- (2.) (10%) Use the Bohr quantization rules to calculate the energy levels for a harmonic oscillator.
- (3.) (10%) Determine the expectation values for x (position) and p (momentum) of a particle in an infinity square well for the first excited state.
- (4.) (15%) Five identical noninteracting particles are placed in an infinity square well. Compute the lowest total energy for the system if the particles are (a) electrons (fermions) and (b) pions (bosons).
- (5) (15%) Consider a hydrogen atom in a non-zero magnetic field B .
- (a) Sketch the possible transitions between the $n=3, \ell=2$ and $n=2, \ell=1$ levels, where n and ℓ are the principal quantum number and angular-momentum quantum number respectively.
- (b) Which lines will *not* appear if the selection rules considered?
- (c) How many spectral lines with different frequencies will be seen in the spectrum?
- (d) What will the frequencies of these lines be? *Hint*: The ground state energy for hydrogen is -13.6 eV.
- (6) (15%) Neutrino are fermions just like electrons, except that their mass is zero or nearly so, and instead of having a two-valued "spin" label, the spin can only be in one state. Thus there can be only one neutrino in an energy state. The mass of the neutrino, if it has one, is so close to zero that we can take its total energy as $E=|p|c=pc$, where p is its momentum and c the speed of light in vacuum. Calculate the Fermi energy of a gas of N free neutrinos in a cube with sides of length L .
- (7) (10%) Which of the following atomic transition are allowed according to the selection rule for electric dipole transition? Why?
- (a) $^2S_{1/2} \rightarrow ^2P_{3/2}$
- (b) $^3D_2 \rightarrow ^1P_1$
- (c) $^3P_0 \rightarrow ^1S_0$

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第3節

第2頁，共2頁

- (8) (10%) (a) Consider the excited state of an atom. The lifetime is measured to be τ . Estimate the energy uncertainty ΔE of the state, and linewidth Γ of the spontaneously emitted photons. (b) Which of the following particles are *not* bosons?
(I) photon (II) proton (III) electron (IV) neutron (V) neutrino