

## Secondary Quantization

### Problem 2-1

Find commutation relations for operators representing the Hermitian and anti-Hermitian parts of the creation and annihilation operators.

### Problem 2-2

Construct operators  $\hat{a}$  and  $\hat{a}^+$  from the coordinate  $\hat{x}$  and momentum  $\hat{p}$  operators of the particle, which have the properties of Bose creation and annihilation operators. Find the wave function of the particle state, which is vacuum in terms of fictitious particles, the creation and annihilation operators of which are the constructed  $\hat{a}$  and  $\hat{a}^+$ .

### Problem 2-3

Calculate the average of the product of four Fermi operators  $\langle \hat{a}_k^+ \hat{a}_p^+ \hat{a}_u \hat{a}_v \rangle$ , where  $\langle \dots \rangle$  means averaging over the state of non-interacting particles with a given temperature and chemical potential.

### Problem 2-4

For a system of N fermions (bosons), in the representation of secondary quantization, find the form of the operators of the total momentum  $\hat{\mathbf{P}}$ , radius vector of the center of inertia  $\hat{\mathbf{R}}$ , and velocity of the center of inertia  $\hat{\mathbf{V}}$ .

### Problem 2-5

For a system of identical particles, find the particle density operator  $\hat{n}(\mathbf{r})$  (at point  $\mathbf{r}$  of a space) in the secondary quantization representation, and a number of particles  $\hat{N}(\mathbf{v})$  in some volume  $v$ .