Assume single particle states $\varphi_k(x)$. Identify the correct first quantized representation of the Fock state $|101\rangle$ for $\mathbf{Fermions}$.

$$\varphi_1(x_1)\,\varphi_0(x_2)\,\varphi_3(x_3)$$

$$\frac{1}{\sqrt{2}}\left(\varphi_1(x_1)\,\varphi_2(x_2)-\varphi_1(x_2)\,\varphi_2(x_1)\right)$$

$$\varphi_1(x_1)\,\varphi_3(x_2)$$

$$\frac{1}{\sqrt{2}}\left(\varphi_1(x_1)\,\varphi_3(x_2)-\varphi_1(x_2)\,\varphi_3(x_1)\right)$$

Correct Answer

Score: 1

Correct Answer:

$$\frac{1}{\sqrt{2}}\left(\varphi_1(x_1)\,\varphi_3(x_2)-\varphi_1(x_2)\,\varphi_3(x_1)\right)$$

Which of the following describes two distinguishable particles, one in harmonic oscillator state with quantum number 7 , the other in 6 . Harmonic oscillator states are denoted by $\varphi_n(x)$.

- $\Psi(x,y) = \varphi_6(x-y)\varphi_7(x+y)$
- $\Psi(x,y) = \varphi_{7+6}(x)$
- $\Psi(x,y) = \varphi_6(y)\varphi_7(x)$
- $\Psi(x,y) = \varphi_6(\mathrm{xy})\varphi_7(\mathrm{xy})$

Correct Answer

Score: 1

Correct Answer: $\Psi(x,y) = \varphi_6(y)\varphi_7(x)$

Bring the product of **Bosonic** field operators below into normal ordered form. " Here, normal ordered" means that all field operators with † (adjoints) are on the left of all field operators without adjoint. You should get the normal ordered form plus some extra terms.

$$\widehat{\Psi}^\dagger(c)\,\widehat{\Psi}(a)\,\widehat{\Psi}^\dagger(b)$$

In this reordering, you get:

- $\widehat{\Psi}^\dagger(b)\,\widehat{\Psi}^\dagger(c)\,\widehat{\Psi}(a)+\widehat{\Psi}(a)\,\delta(b-c)$
- $\widehat{\Psi}^\dagger(b)\,\widehat{\Psi}^\dagger(c)\,\widehat{\Psi}(a)+\widehat{\Psi}^\dagger(c)\,\delta(b-a)$
- $\widehat{\Psi}^\dagger(b)\,\widehat{\Psi}^\dagger(c)\,\widehat{\Psi}(a)+\widehat{\Psi}^\dagger(c)\,\delta(b-a)+\widehat{\Psi}^\dagger(b)\,\delta(c-a)$
- $\widehat{\Psi}^\dagger(c)\,\widehat{\Psi}^\dagger(b)\,\widehat{\Psi}(a)+\widehat{\Psi}^\dagger(b)\,\delta(a-c)$

Correct Answer

Score: 1

Correct Answer: $\widehat{\Psi}^\dagger(b)\,\widehat{\Psi}^\dagger(c)\,\widehat{\Psi}(a)+\widehat{\Psi}^\dagger(c)\,\delta(b-a)$

Bring the product of **Fermionic** field operators below into normal ordered form. " Here, normal ordered" means that all field operators with † (adjoints) are on the left of all field operators without adjoint. You should get the normal ordered form plus some extra terms.

$$\widehat{\Psi}\left(x\right)\widehat{\Psi}^\dagger\left(y\right)\widehat{\Psi}\left(z\right)$$

In this reordering, you get:

- $\widehat{\Psi}^\dagger\left(y\right)\widehat{\Psi}\left(x\right)\widehat{\Psi}\left(z\right)+\widehat{\Psi}\left(x\right)\delta\left(y-z\right)+\widehat{\Psi}\left(z\right)\delta\left(x-y\right)$
- $\widehat{\Psi}^\dagger\left(y\right)\widehat{\Psi}\left(z\right)\widehat{\Psi}\left(x\right)+\widehat{\Psi}\left(z\right)\delta\left(x-y\right)$
- $-\widehat{\Psi}^\dagger\left(y\right)\widehat{\Psi}\left(x\right)\widehat{\Psi}\left(z\right)+\widehat{\Psi}\left(x\right)\delta\left(y-z\right)+\widehat{\Psi}^\dagger\left(y\right)\delta\left(x-z\right)$
- $\widehat{\Psi}^\dagger\left(y\right)\widehat{\Psi}\left(x\right)\widehat{\Psi}\left(z\right)+\widehat{\Psi}\left(x\right)\delta\left(y-z\right)$

Correct Answer

Score: 1

Correct Answer: $\widehat{\Psi}^\dagger\left(y\right)\widehat{\Psi}\left(z\right)\widehat{\Psi}\left(x\right)+\widehat{\Psi}\left(z\right)\delta\left(x-y\right)$

Select the correct statement from the following:

All information of a physical system can be extracted from expectation values of products of field operators, given a certain specified quantum many-body state.

The field operator contains the same information as a quantum many-body state.

All information of a physical system can be extracted from expectation values of products of field operators, we no longer need to know a quantum many-body state.

The expectation values of the field operator gives all information of a physical system, given a certain specified quantum many-body state.

Correct Answer

Score: 1

Correct Answer: All information of a physical system can be extracted from expectation values of products of field operators, given a certain specified quantum many-body state.

Fill in the blank and click lock.

Let $\widehat{O}$ be a normal ordered product of field operators (such as, but not limited to, $\widehat{O} = \widehat{\Psi}^\dagger(x)\,\widehat{\Psi}(y)$, $\widehat{A}$ an anti-normal ordered one (e.g. $\widehat{A} = \widehat{\Psi}(x)\,\widehat{\Psi}^\dagger(y)$, and $\widehat{C}$ an arbitrarily ordered product containing at leat one field operator and one adjoint. Let $|\,0\rangle$ be the vacuum state and $|\,1\rangle$ be the state with one particle **in each** single particle state. Finally let $|\,\Psi\rangle$ be a general quantum state.

Which of the following statements is true (give 0 for false, 1 for true).

$\langle 1 \mid \widehat{O} \mid 1\rangle = 0$ 0

$\langle \Psi \mid \widehat{O} \mid \Psi\rangle$ is a function of positions $x\,y$ 1

$\langle 0 \mid \widehat{C} \mid 0\rangle = 0$ regardless of ordering 0

$\langle \Psi \mid \widehat{O} \mid \Psi\rangle$ is a single complex number 0

Correct Answer

Score: 1

Correct Answer: Answers in order of appearance of blanks:

0
1
0
0