



**Physics & Astronomy  
Speaker Series**

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**"Biophysical Characterization and  
Developability of Early-Stage  
Biologics"**



Today from 12:00–12:50 pm in Olin 268

## Lecture 18 — Concept Test 1

Two particles are in an infinite square well.

**(a)** Which of these states below could describe a pair of identical bosons?

1.  $|E_1 \uparrow \ E_2 \uparrow\rangle$

4.  $\frac{1}{\sqrt{2}} |E_1 \uparrow \ E_2 \uparrow\rangle + \frac{1}{\sqrt{2}} |E_2 \uparrow \ E_1 \uparrow\rangle$

2.  $|E_1 \uparrow \ E_1 \uparrow\rangle$

5.  $\frac{1}{\sqrt{2}} |E_1 \uparrow \ E_2 \uparrow\rangle - \frac{1}{\sqrt{2}} |E_2 \uparrow \ E_1 \uparrow\rangle$

3.  $|E_1 \uparrow \ E_1 \downarrow\rangle$

6.  $\frac{1}{\sqrt{2}} |E_1 \uparrow \ E_2 \uparrow\rangle - \frac{1}{\sqrt{2}} |E_1 \uparrow \ E_1 \uparrow\rangle$

**(b)** Which of these states above could describe a pair of identical fermions?

## Lecture 18 — Concept Test 2

6 electrons (with spin  $s = 1/2$ ) are in a 1-dimensional system with energy levels given by  $E_n = n(2 \text{ eV})$ . That is

$$E_1 = 2 \text{ eV} \quad E_2 = 4 \text{ eV}, \quad E_3 = 6 \text{ eV}, \quad E_4 = 8 \text{ eV}, \quad \dots$$

The system has its lowest possible total energy. What is the energy of the most energetic electron in the system?

1. 2 eV

3. 4 eV

5. 9 eV

2. 3 eV

4. 6 eV

6. 12 eV

## Distinguishable (●●●●)

	$ \alpha\rangle$	$ \beta\rangle$
1	●●●●	
2	●●●	●
3	●●●	●
4	●●●	●
5	●●●	●
6	●●●	●●
7	●●●	●●
8	●●●	●●
9	●●●	●●
10	●●●	●●
11	●●●	●●
12	●●●	●●●
13	●●●	●●●
14	●●●	●●●
15	●●●	●●●
16	●●●	●●●

## Lecture 18 — Concept Test 3

How many different ways can you put four identical bosons (●●●●) into the two states  $|\alpha\rangle$  and  $|\beta\rangle$ ?

Hold up a card indicating the number of ways. If your answer is zero, hold up the back of a card.

*Hint:* make a list.

## Indistinguishable (●●●●)

	$ \alpha\rangle$	$ \beta\rangle$
1	●●●●	
2	●●●	●
3	●●	●●
4	●	●●●
5		●●●●

## Lecture 18 — Concept Test 4

How many different ways can you put four identical fermions into the two states  $|\alpha\rangle$  and  $|\beta\rangle$ ?

1. 1

3. 3

5. 16

2. 2

4. 5

6. 0