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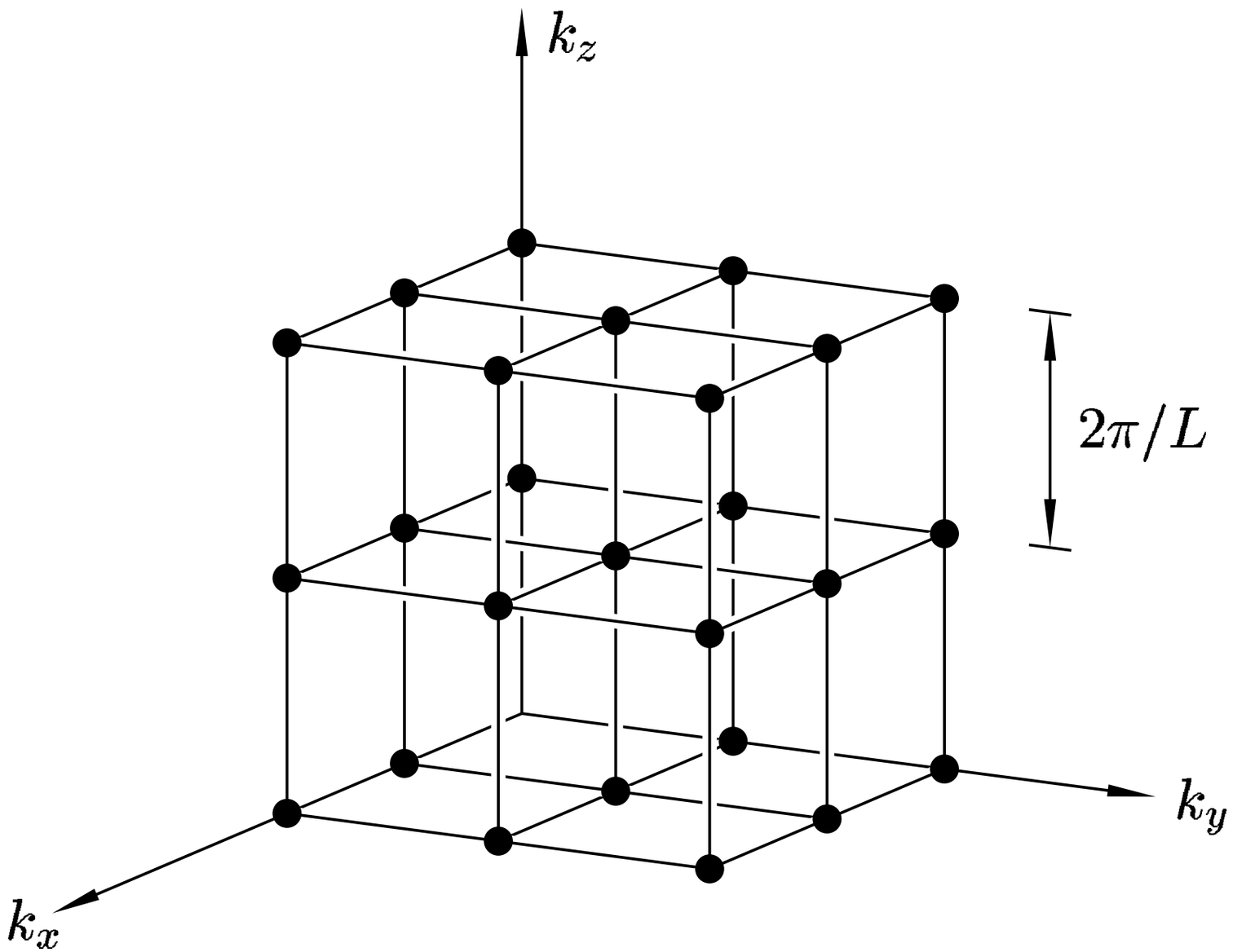
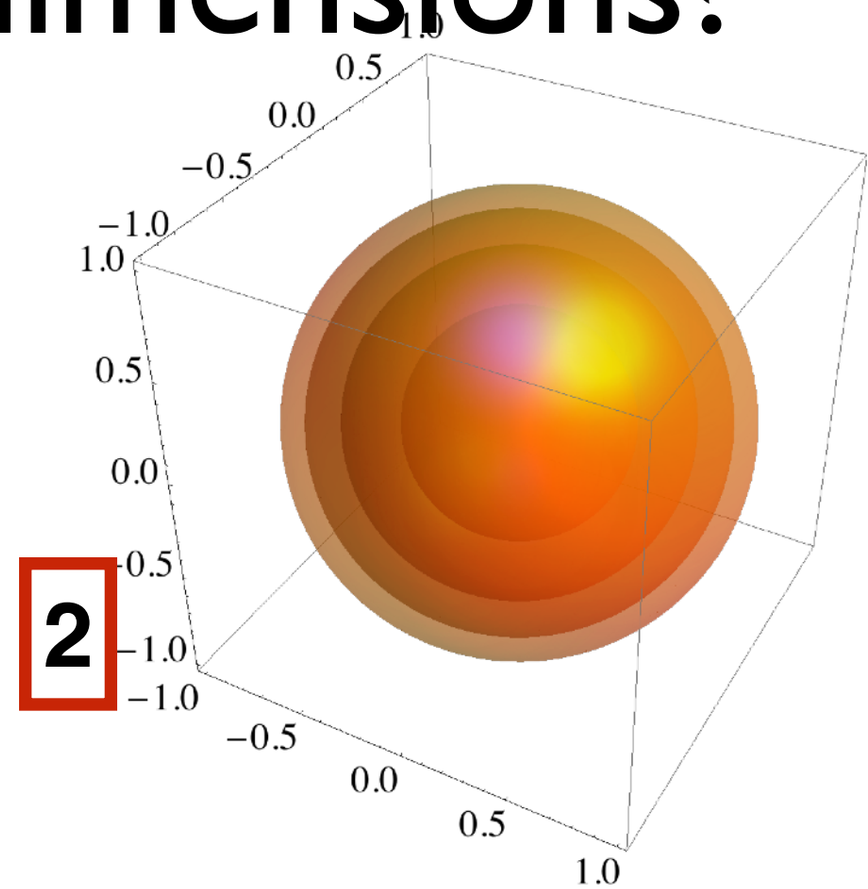
- Two particles, with the same spin, cannot have the same point in k-space (can't be in the same state)—Pauli exclusion principle
- Densities of states (as a function of energy) shows us which states are occupied and which electrons are "active"

$$\psi(x, y, z, t) = A \sin(k_x x) \sin(k_y y) \sin(k_z z) \exp(-i\omega t)$$



$$\mathbf{k} = (k_x, k_y, k_z) = 2\pi/L(n_x, n_y, n_z)$$

What is $g(E)$ in three dimensions?



1

2

3

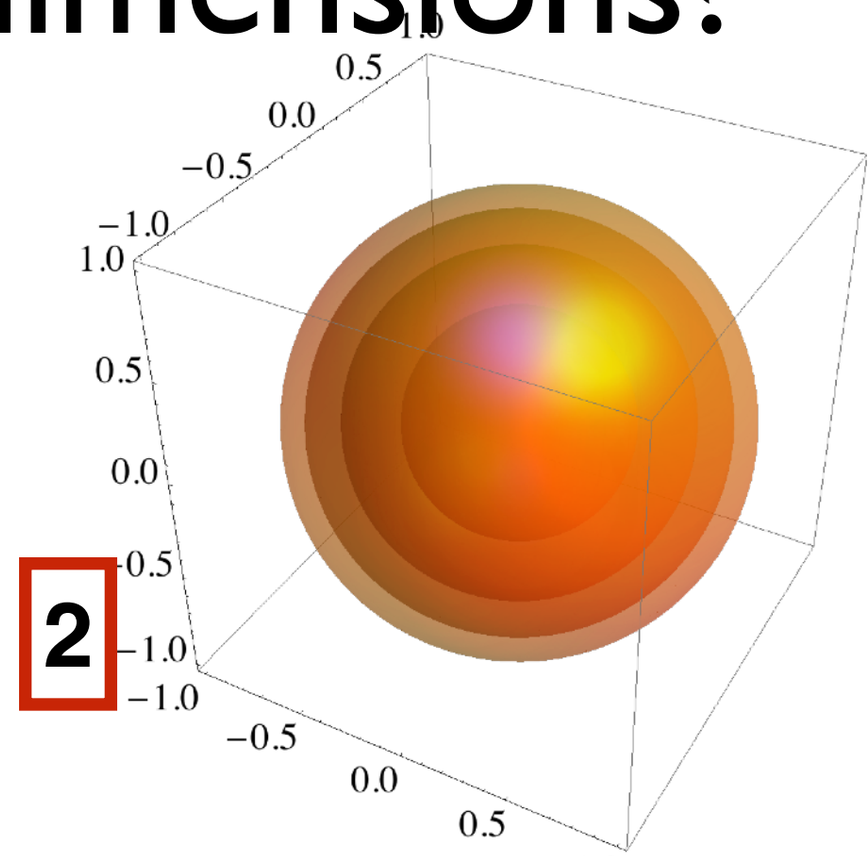
4

5

What is $g(E)$ in three dimensions?

$$E = \frac{\hbar^2 k^2}{2m} \Rightarrow k = \sqrt{\frac{2mE}{\hbar^2}}$$

1



2

3

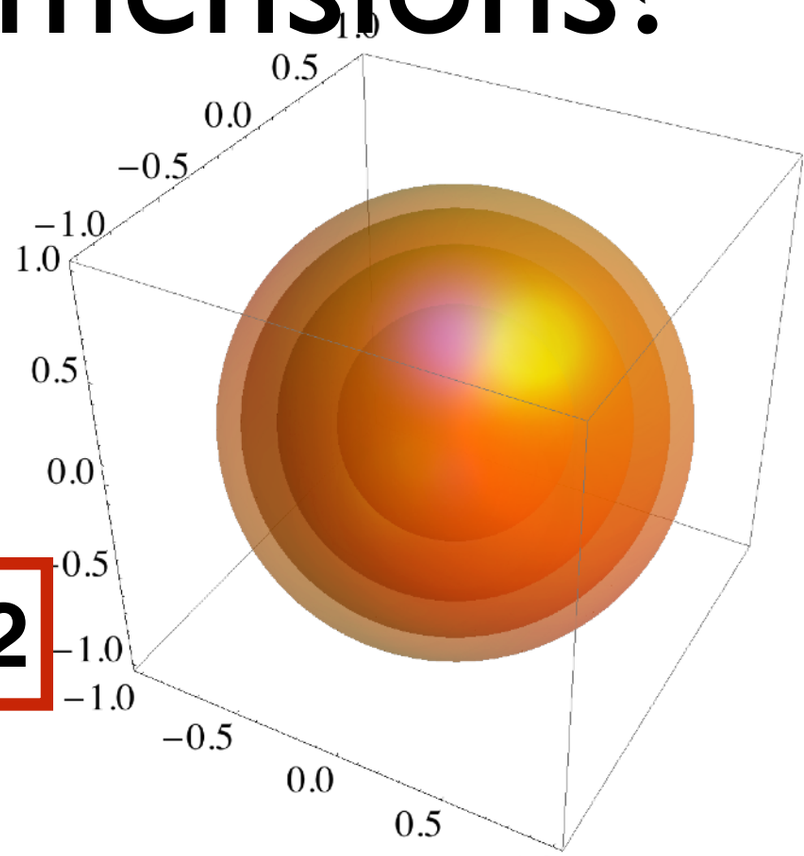
4

5

What is $g(E)$ in three dimensions?

$$E = \frac{\hbar^2 k^2}{2m} \Rightarrow k = \sqrt{\frac{2mE}{\hbar^2}}$$ 1

$$V_k = \frac{4}{3}\pi k^3 = \frac{4}{3}\pi (2mE/\hbar^2)^{3/2}$$ 2



3

4

5

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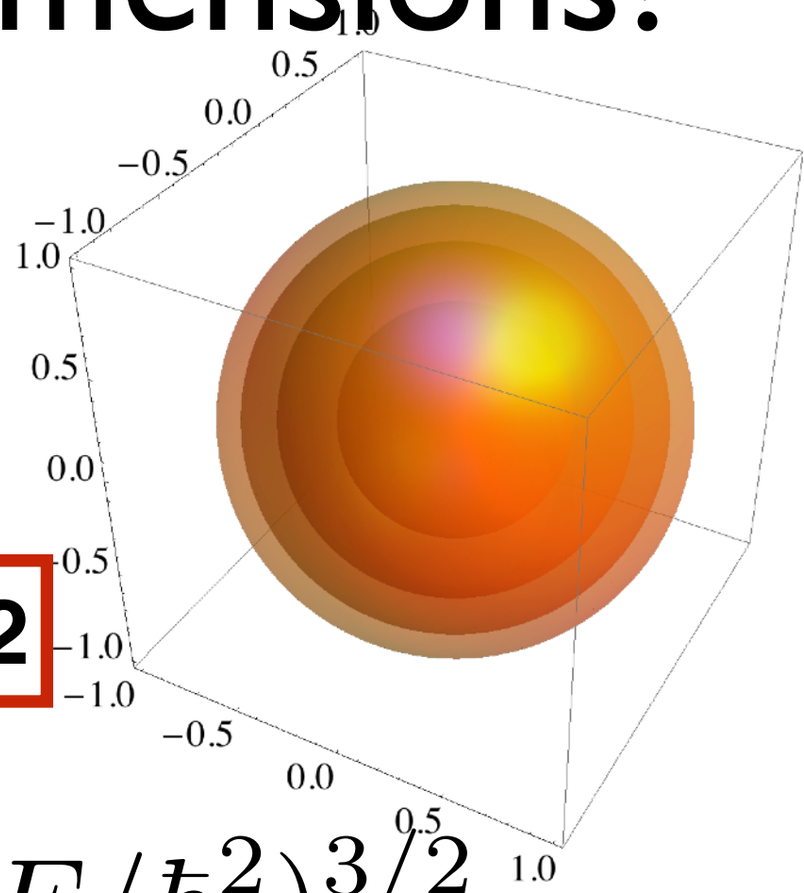


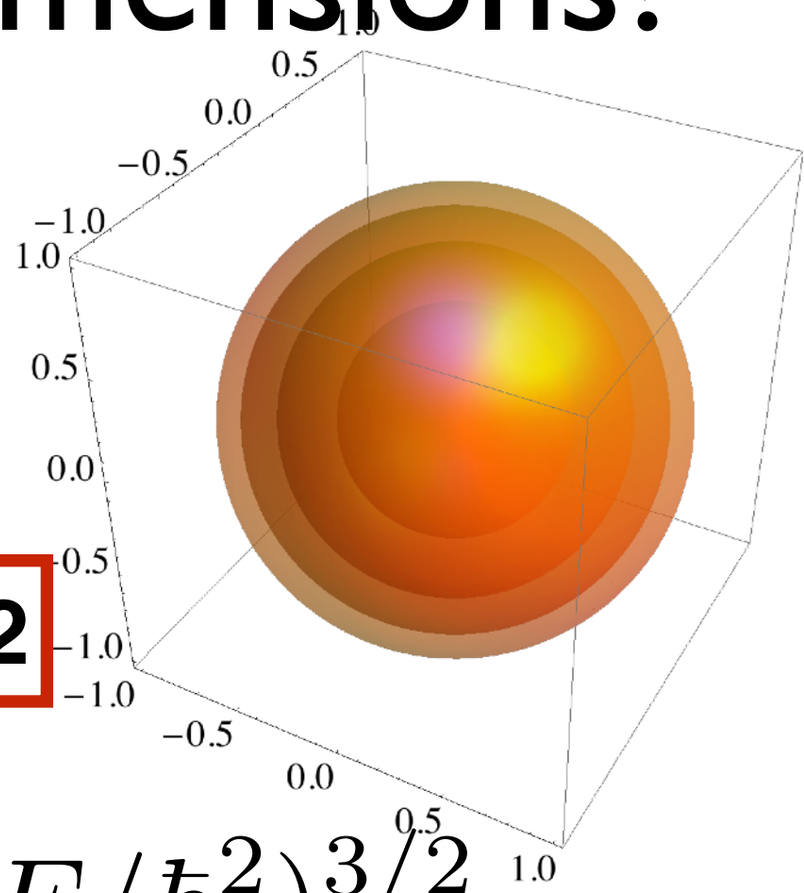
$$N(E) = V_k \; g(\vec{k}) = (V/3\pi^2)(2mE/\hbar^2)^{3/2}$$ 3

4

5

What is $g(E)$ in three dimensions?

$$E = \frac{\hbar^2 k^2}{2m} \Rightarrow k = \sqrt{\frac{2mE}{\hbar^2}}$$ **1**



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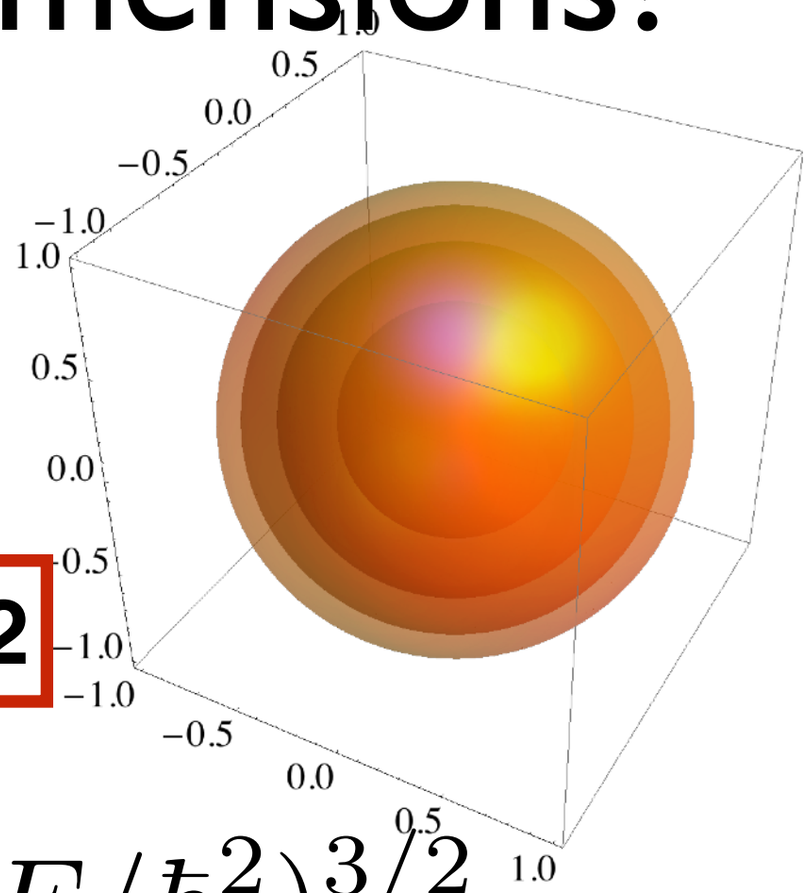
$$N(E) = V_k \; g(\vec{k}) = (V/3\pi^2)(2mE/\hbar^2)^{3/2}$$ **3**

$$N(E) = \int_0^E g(E)\; dE$$ **4**

5

What is $g(E)$ in three dimensions?

$$E = \frac{\hbar^2 k^2}{2m} \Rightarrow k = \sqrt{\frac{2mE}{\hbar^2}} \quad \boxed{1}$$



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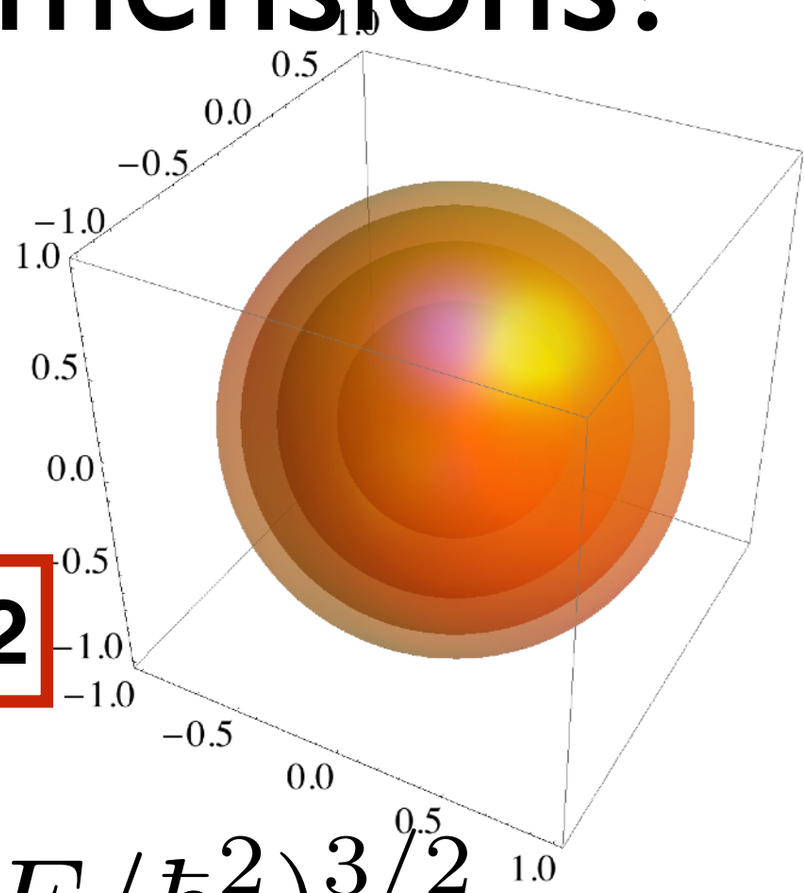
$$N(E) = V_k \; g(\vec{k}) = (V/3\pi^2)(2mE/\hbar^2)^{3/2} \quad \boxed{3}$$

$$N(E) = \int_0^E g(E)\, dE \quad \boxed{4}$$

$$g(E) = \frac{dN(E)}{dE} \quad \boxed{5}$$

What is $g(E)$ in three dimensions?

$$E = \frac{\hbar^2 k^2}{2m} \Rightarrow k = \sqrt{\frac{2mE}{\hbar^2}} \quad \boxed{1}$$



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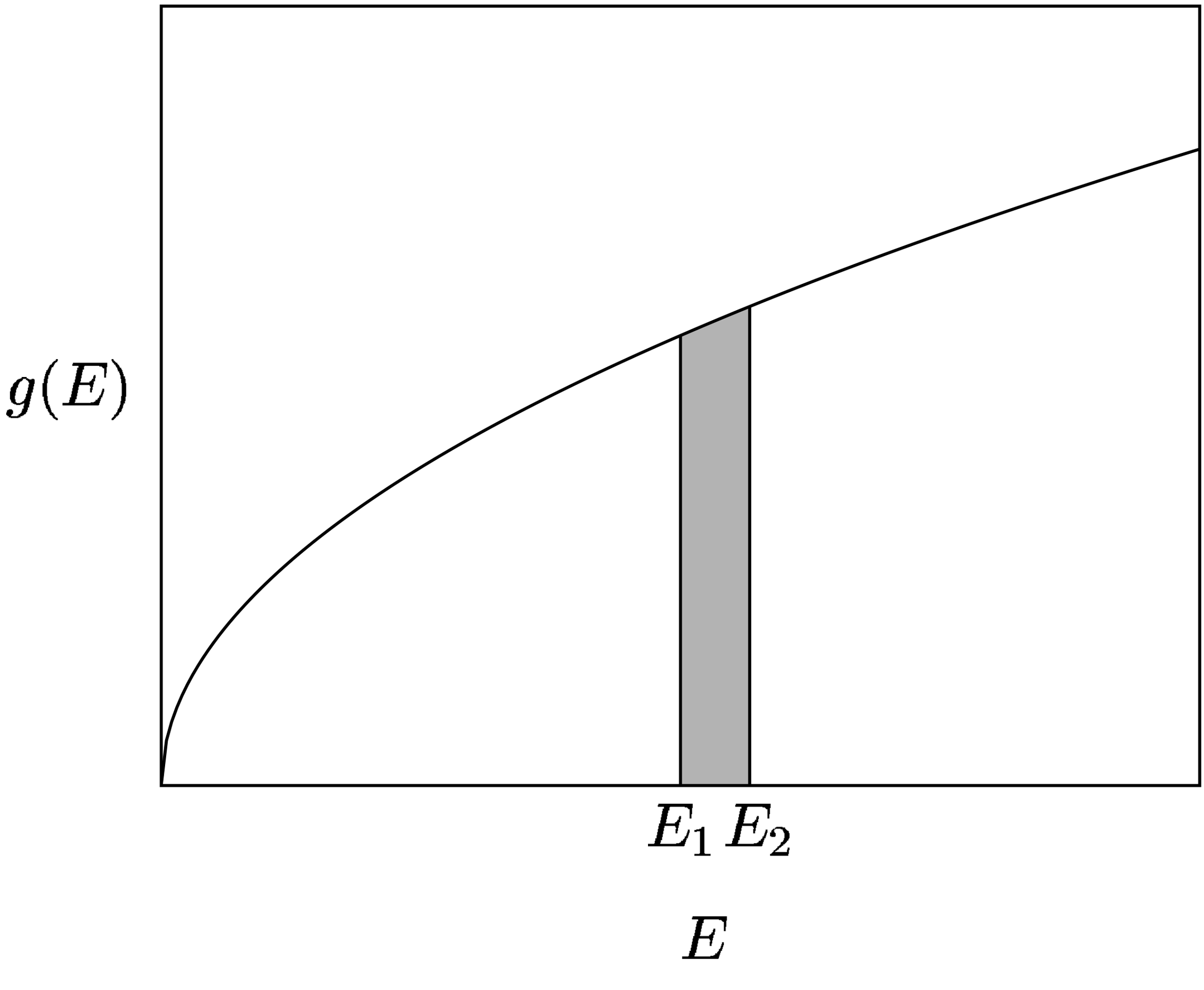
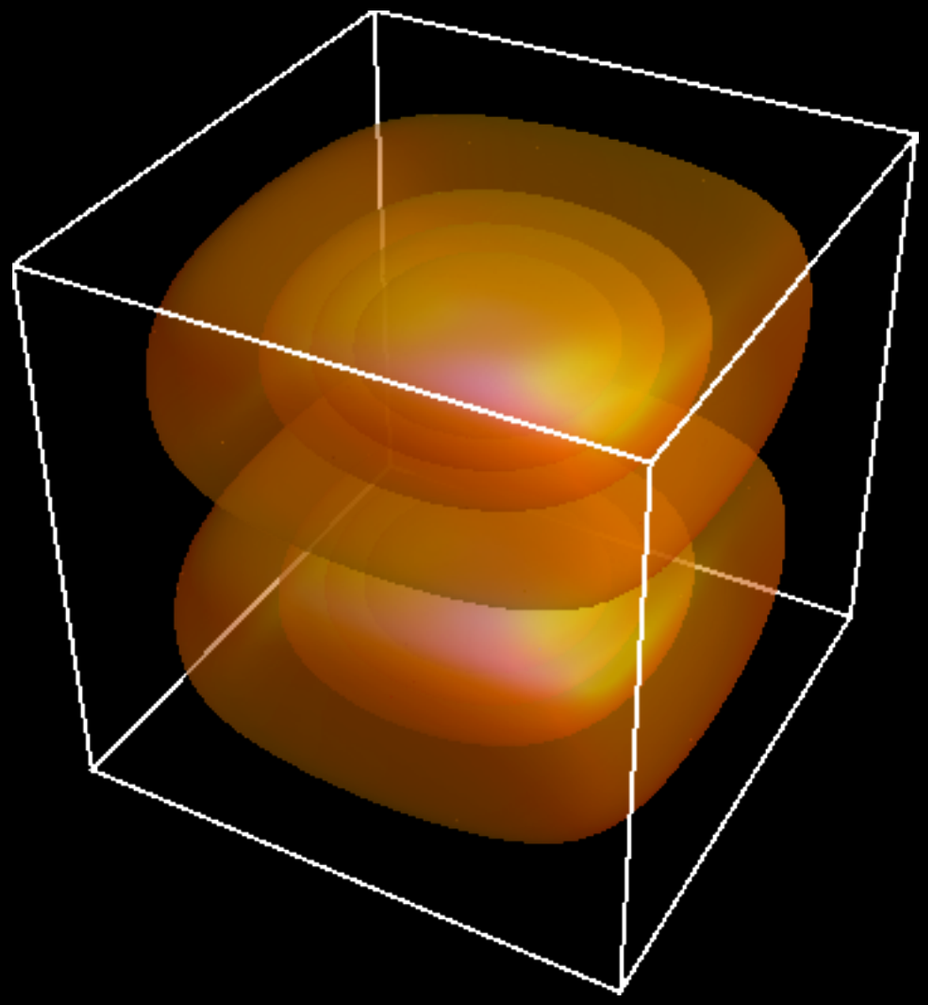
$$N(E) = \int_0^E g(E)\, dE \quad \boxed{4}$$

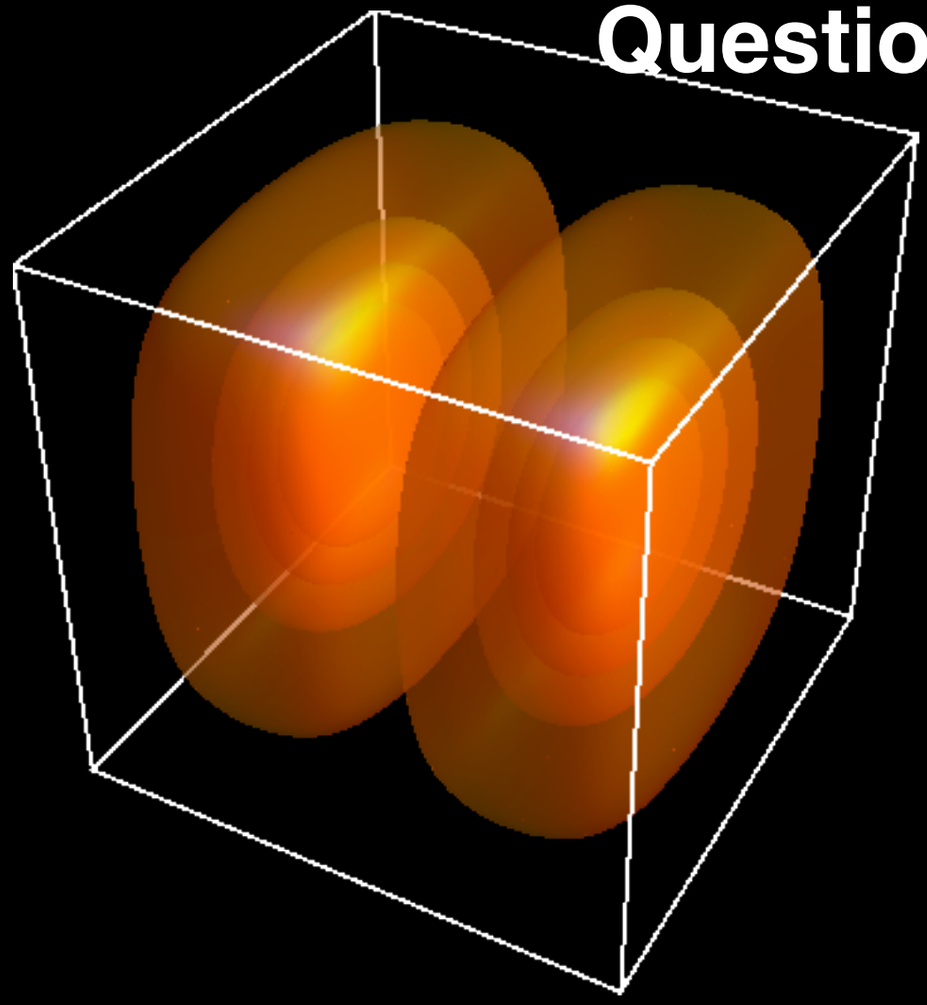
$$g(E) = \frac{dN(E)}{dE} = (V/2\pi^2)(2m/\hbar^2)^{3/2} E^{1/2} \quad \boxed{5}$$


$g(E)$
E_1 E_2
E

Question #12



$\mathbf{k} = (2\pi/L)(1, 1, 2)$



$\mathbf{k} = (2\pi/L)(2, 1, 1)$

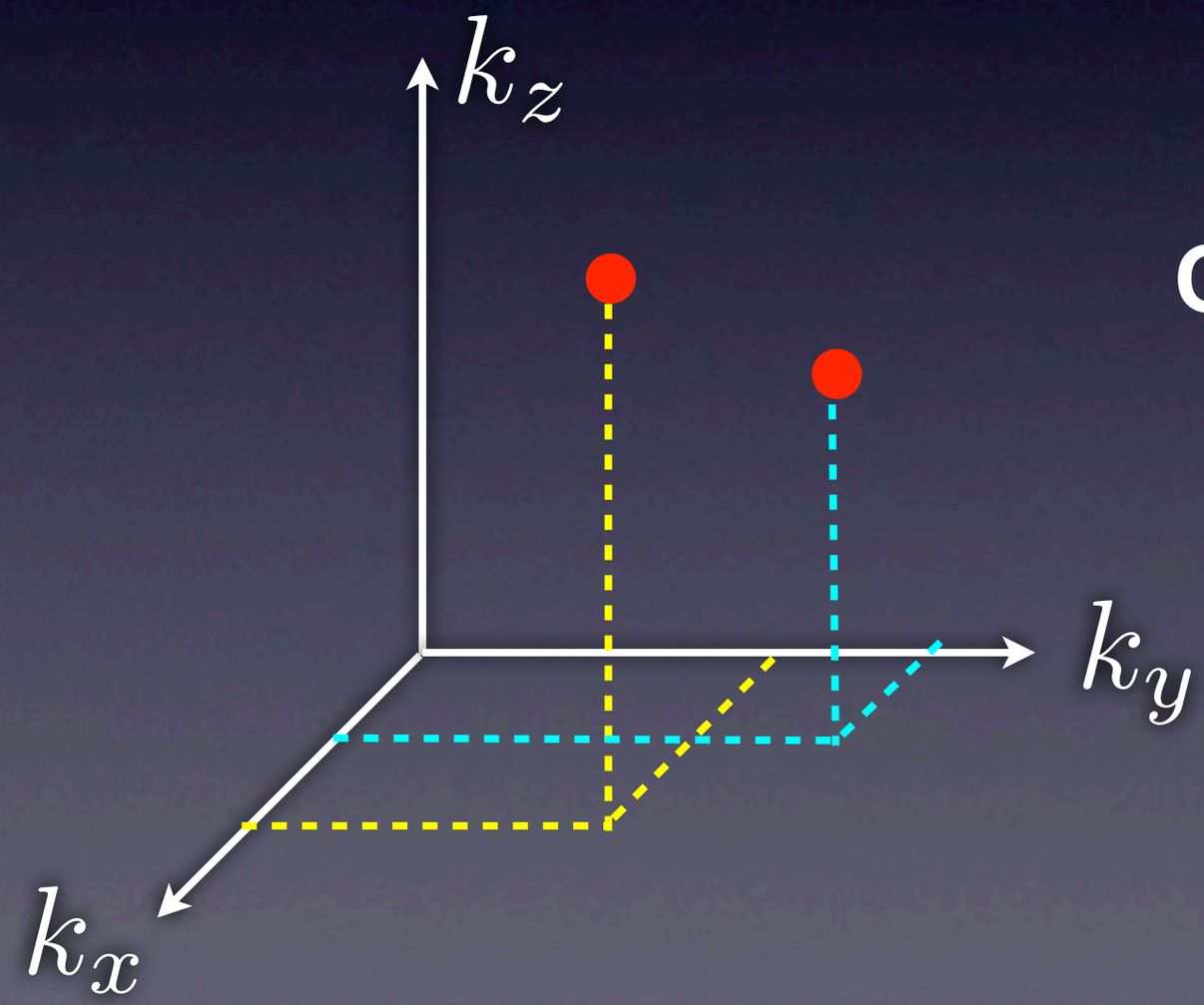
These two states are different energy states.

(D) True

(E) False

Consider 2 electrons with states in k space as shown below. Both states are the *same distance* from the origin. The two electrons

(A) have the same speed and are moving in the same direction,
(B) have the same speed and are moving in different directions,
(C)have different speeds and are moving in the same direction,
or
(D) have different speeds and are moving in different directions.

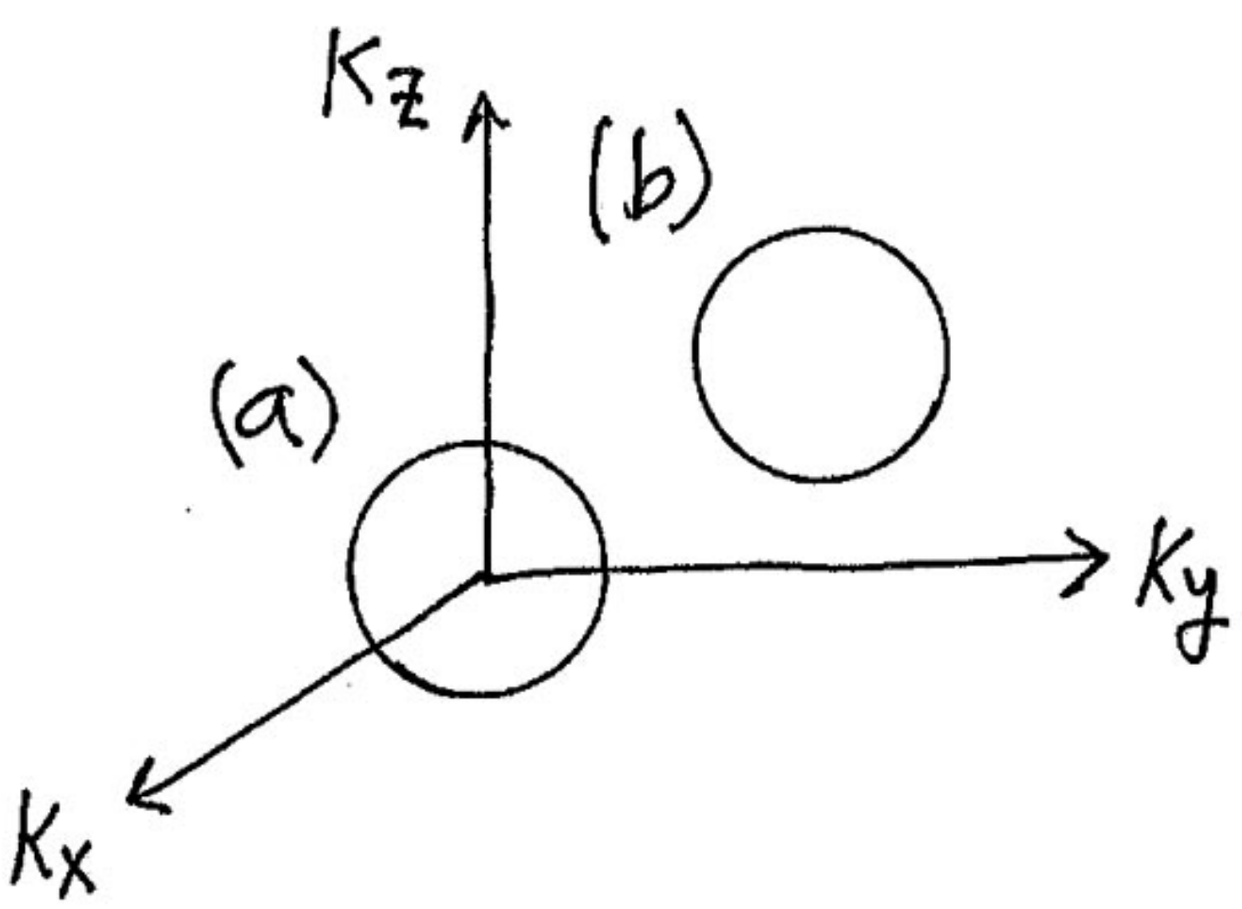


Question #13

Question #14

Consider two spheres in *k* space, as shown in the figure below. They each have the same volume. One is centered at the origin, and the other is not. Which sphere contains the most electron states?

(B) the sphere marked (a)
(C) the sphere marked (b)
(D) Each contains the same number of electron states



Question #15

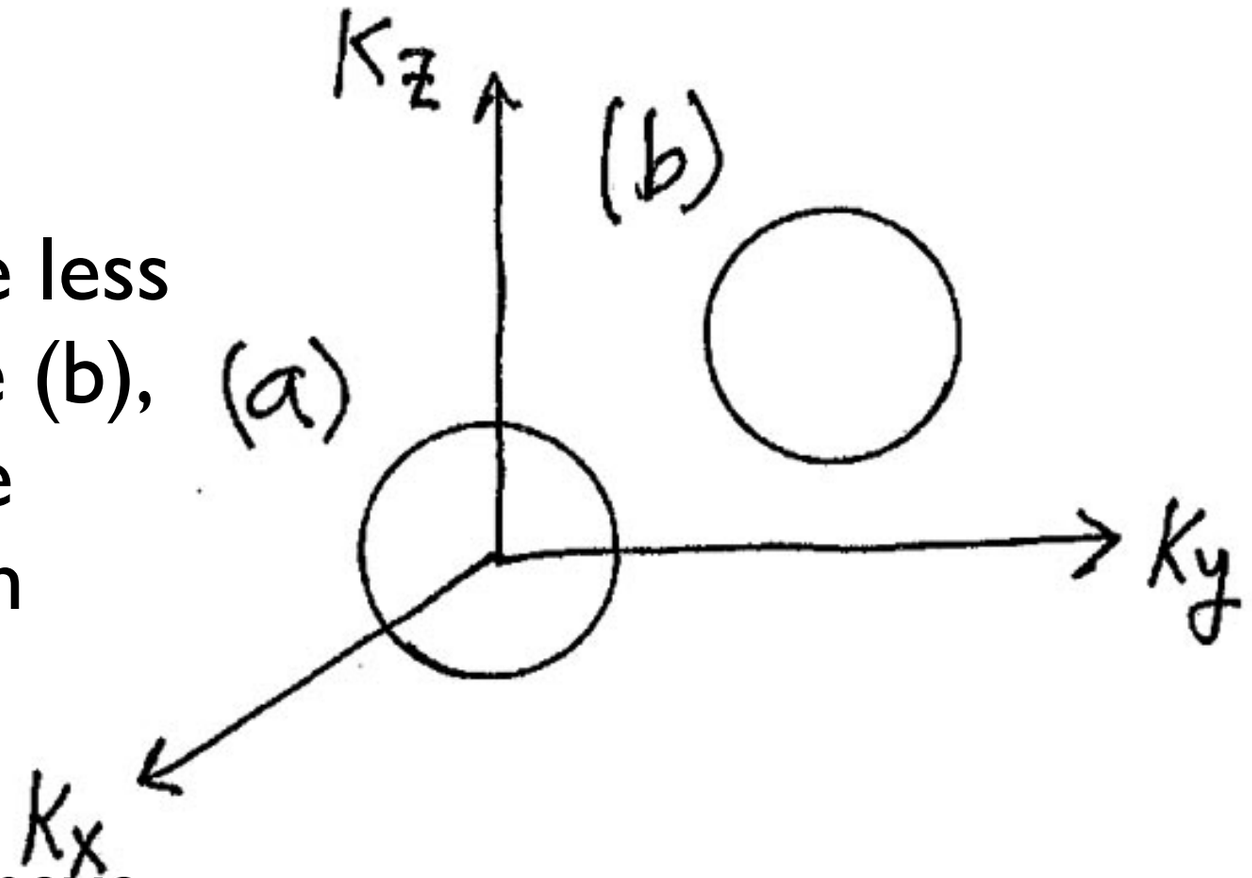
Which statement is true?

(A)All states in either sphere have the same energy.

(B) All of the states in sphere (a) have greater energy than any of the states in sphere (b).

(C) Some states in sphere (a) have less energy than some states in sphere (b), and some states in sphere (a) have greater energy than some states in sphere (b).

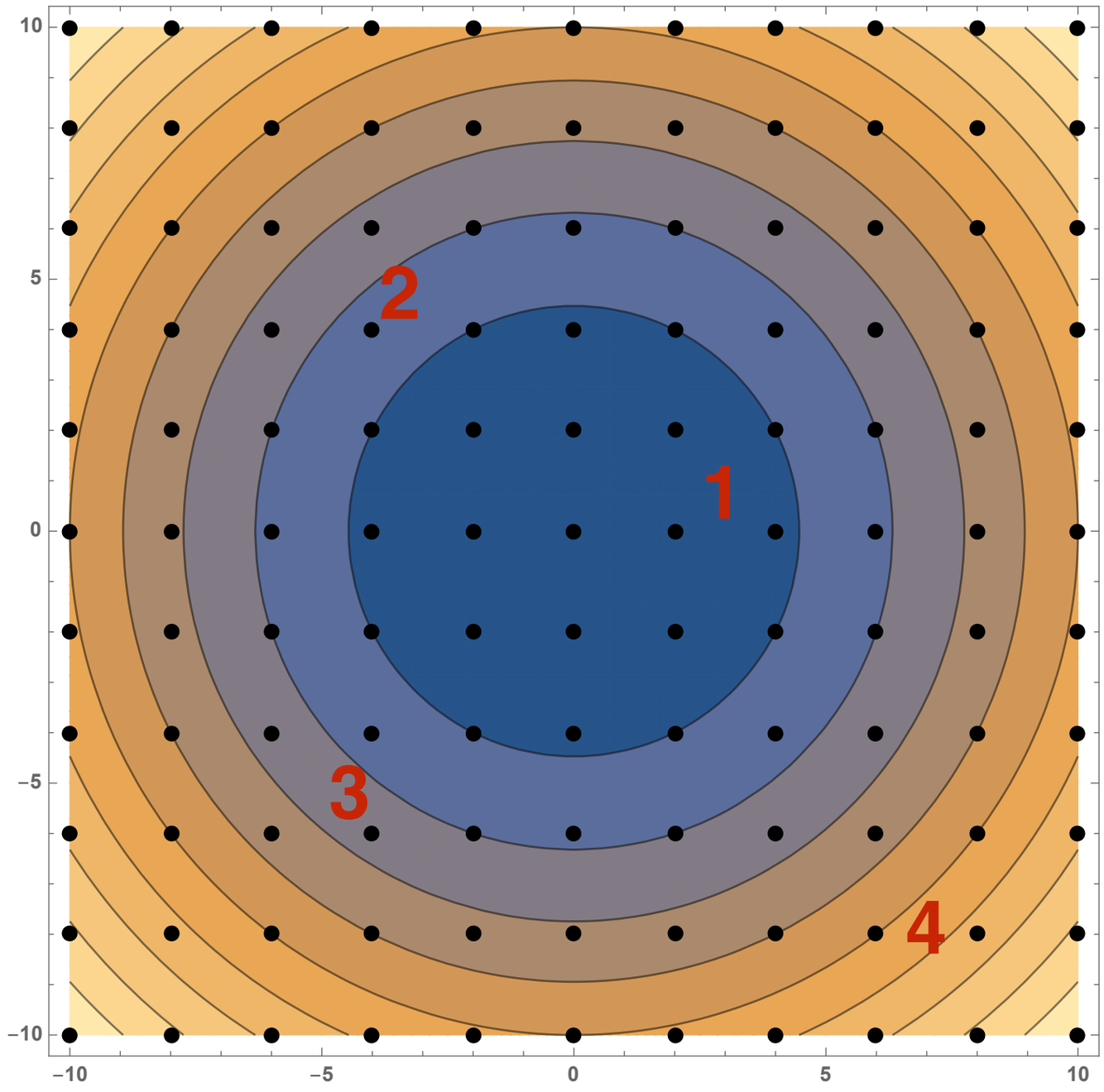
(D) All of the states in sphere (a) have less energy than any of the states in sphere (b).



Which electronic states will fill first?

Question #16

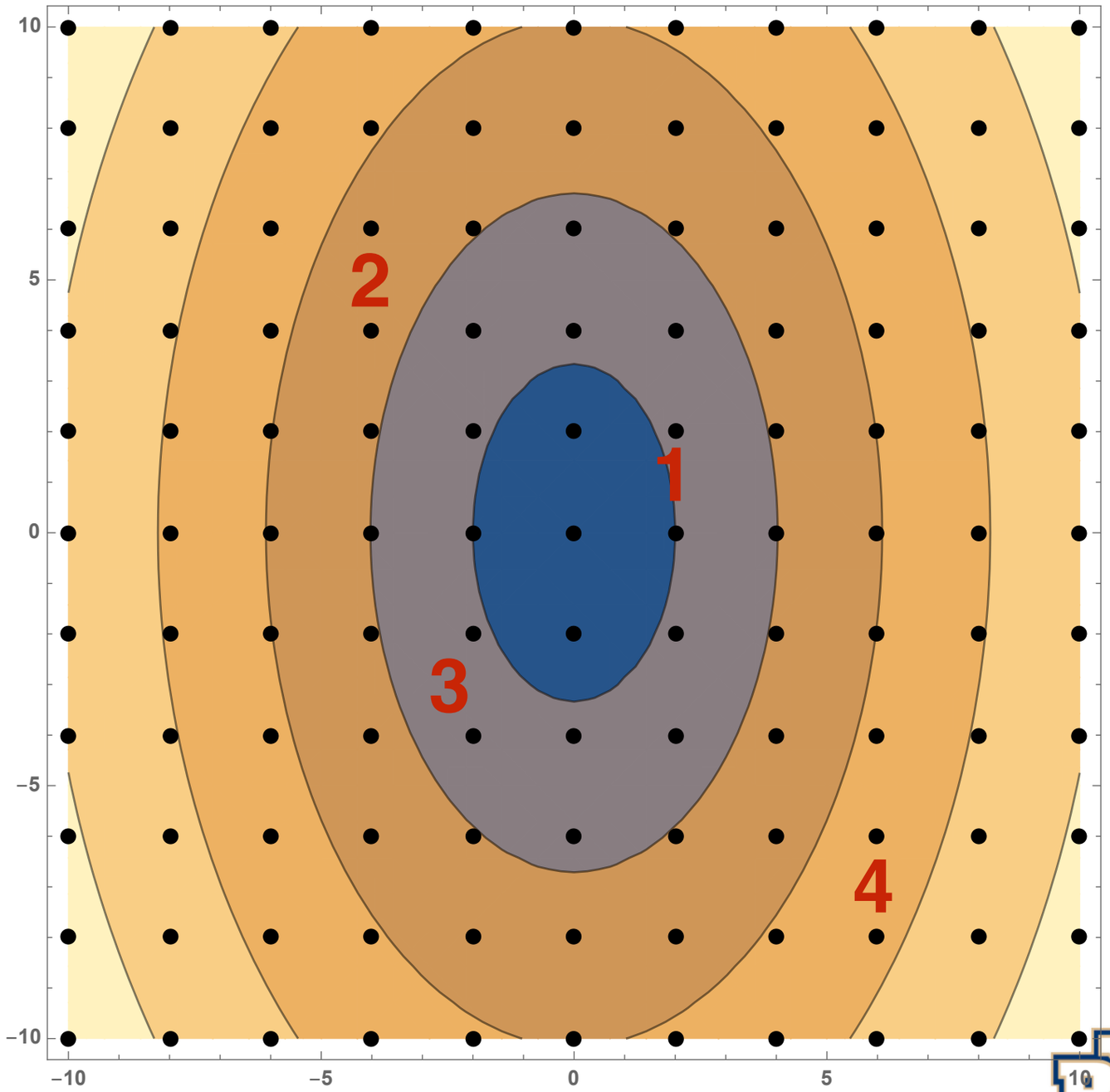
a) 4,1,2,3
b) 4, 3,2,1
c) 1, 2, 3, 4
d) 3,2,4,1

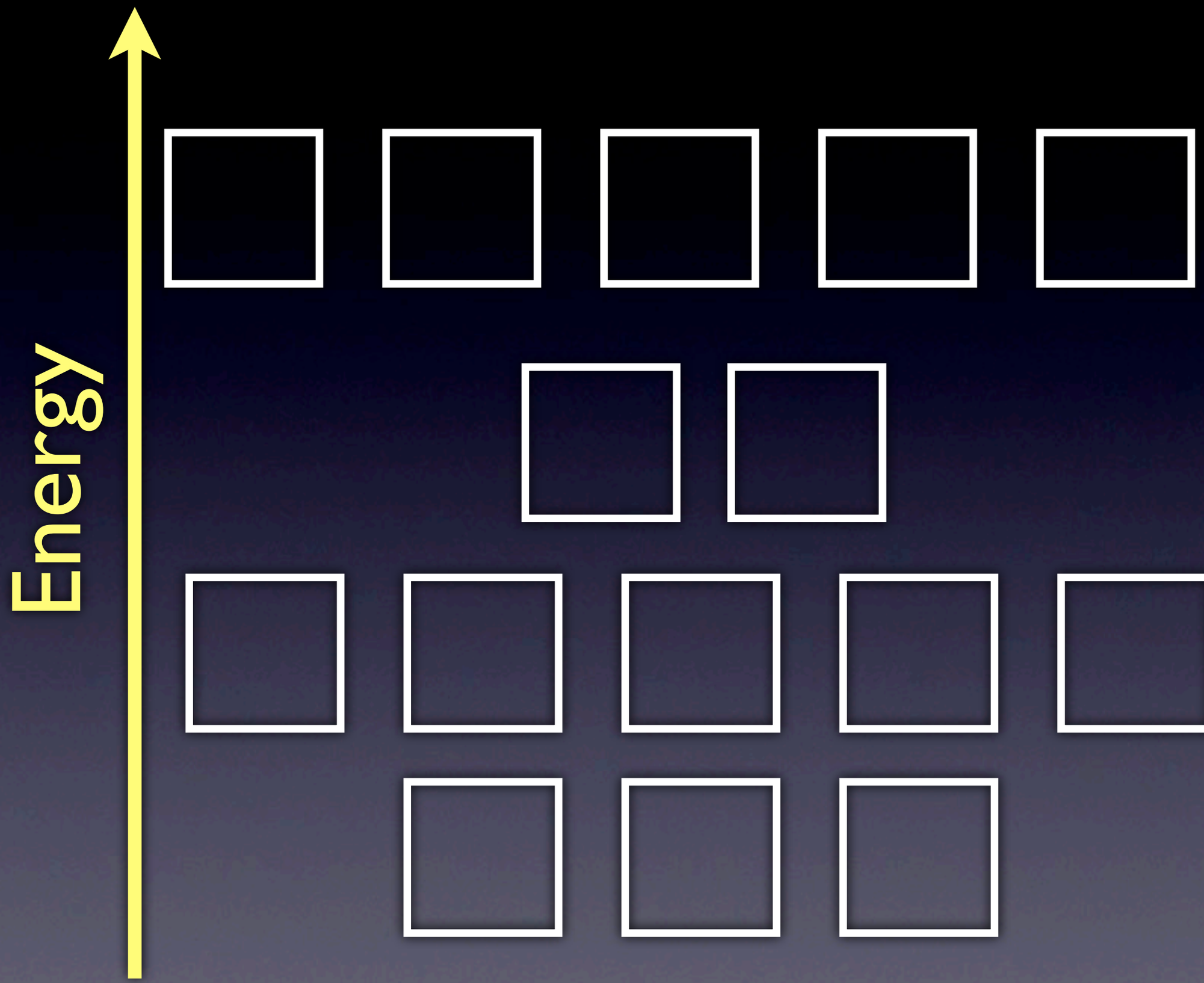


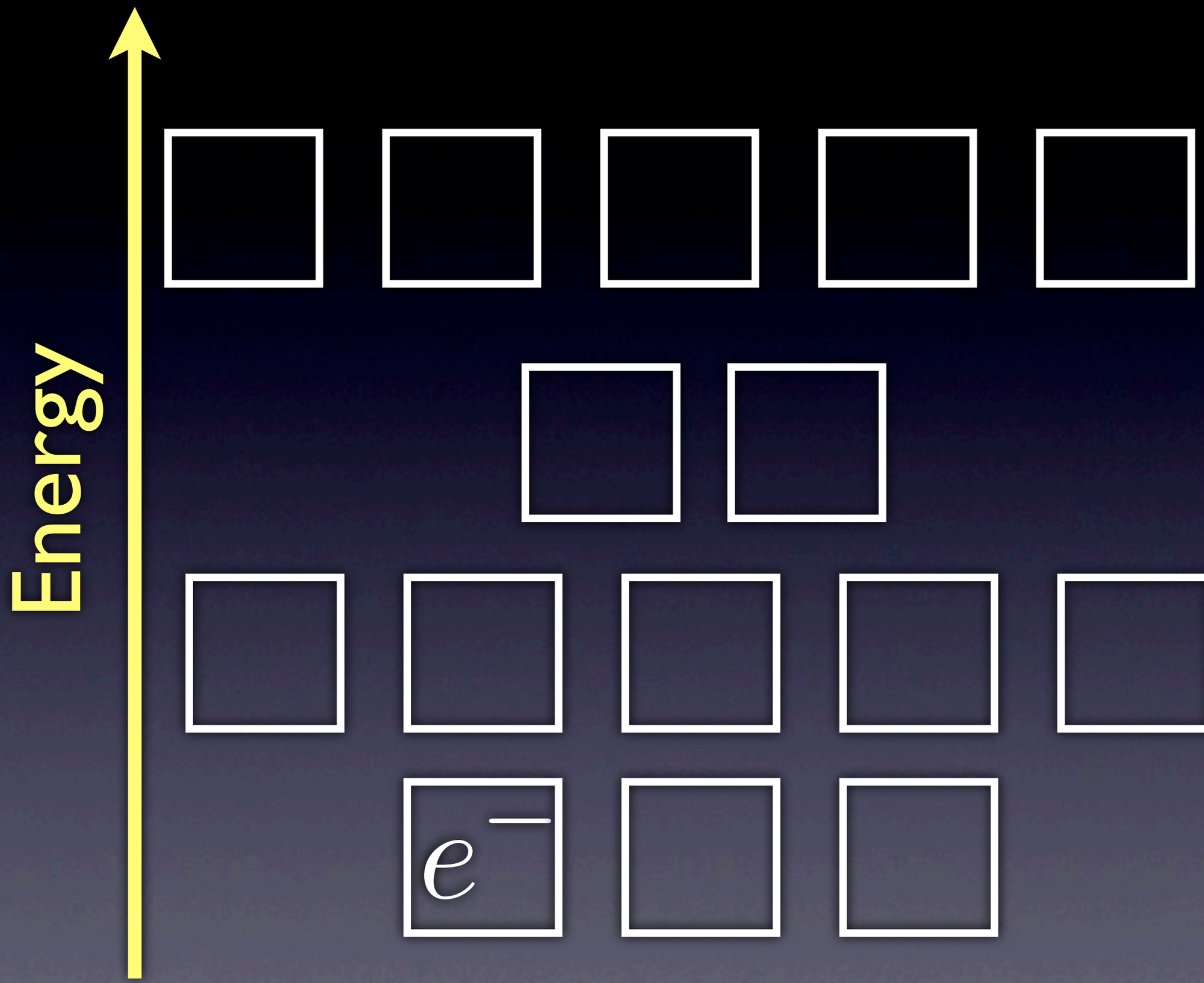
Which electronic states will fill first?

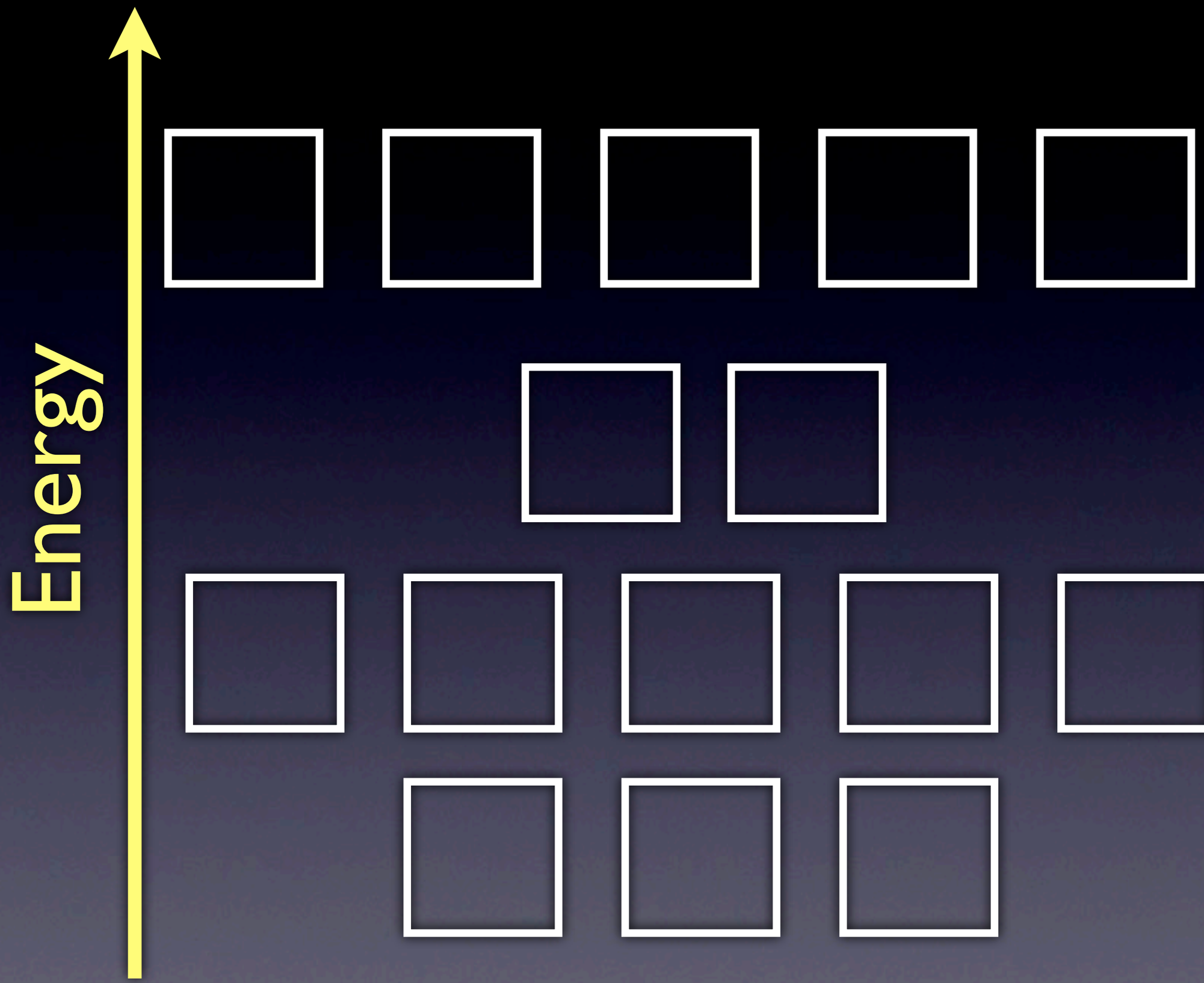
Question #17

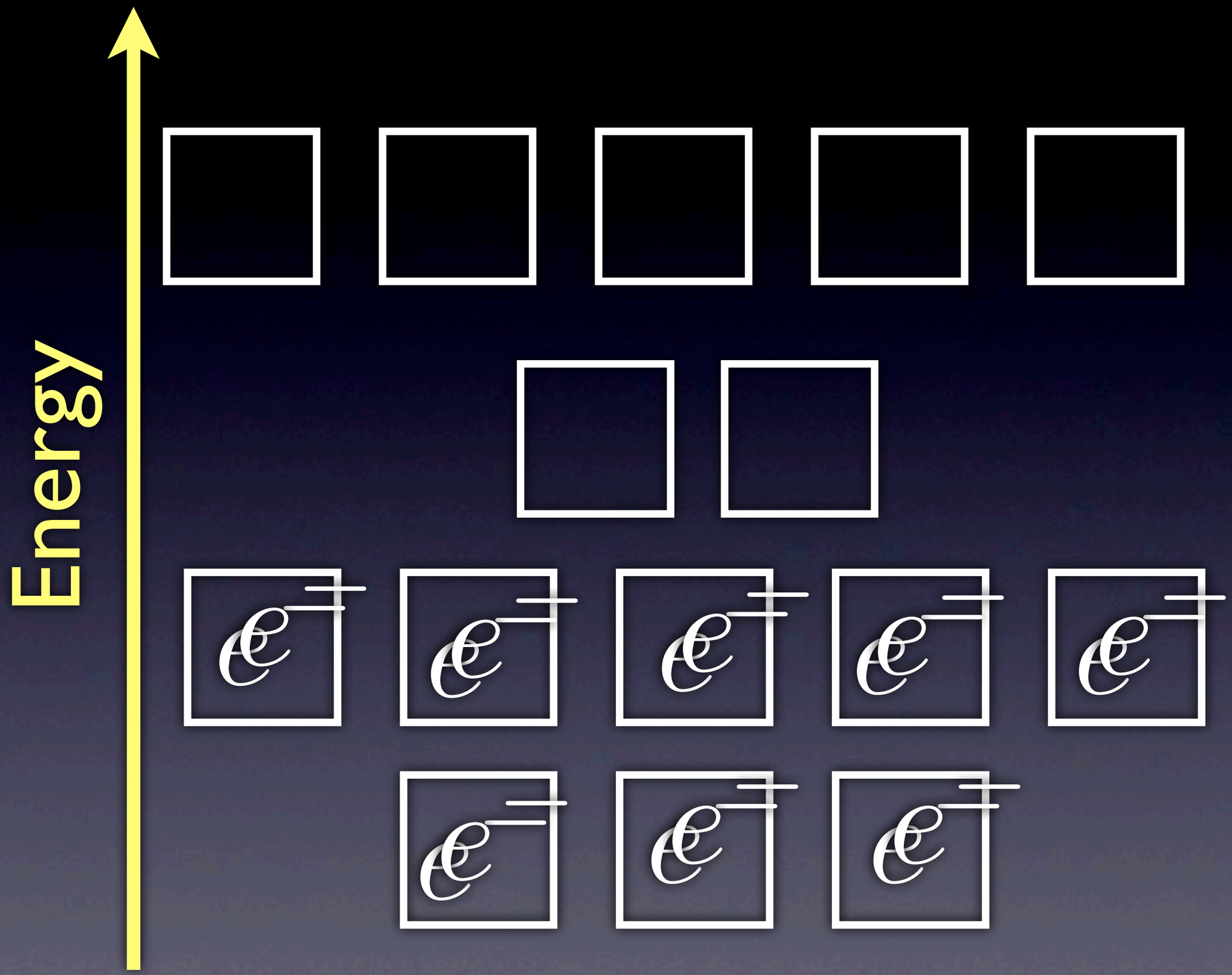
a) 1,3,2,4
b) 4, 3,2,1
c) 1, 2, 3, 4
d) 3,2,4,1

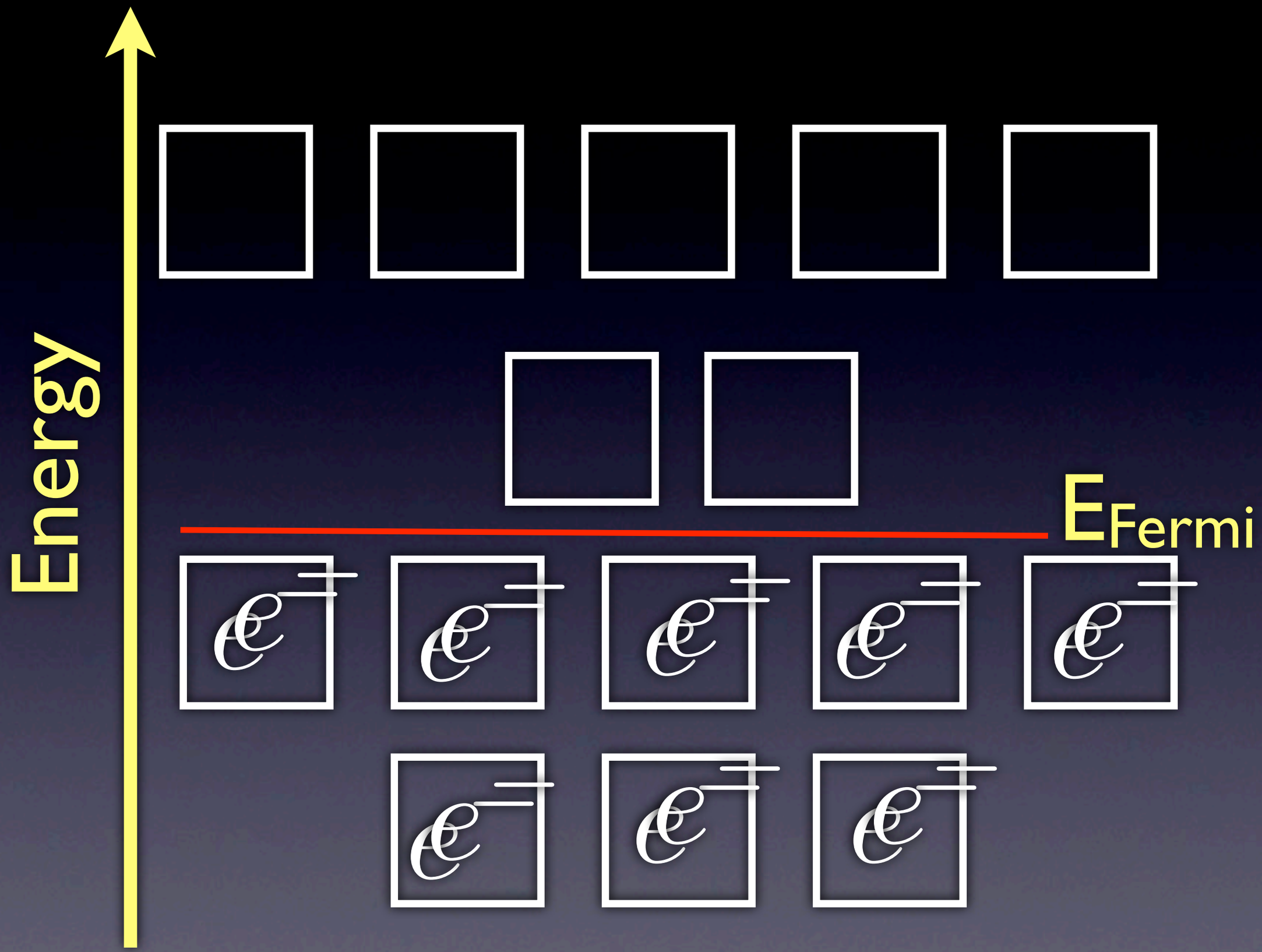



Energy

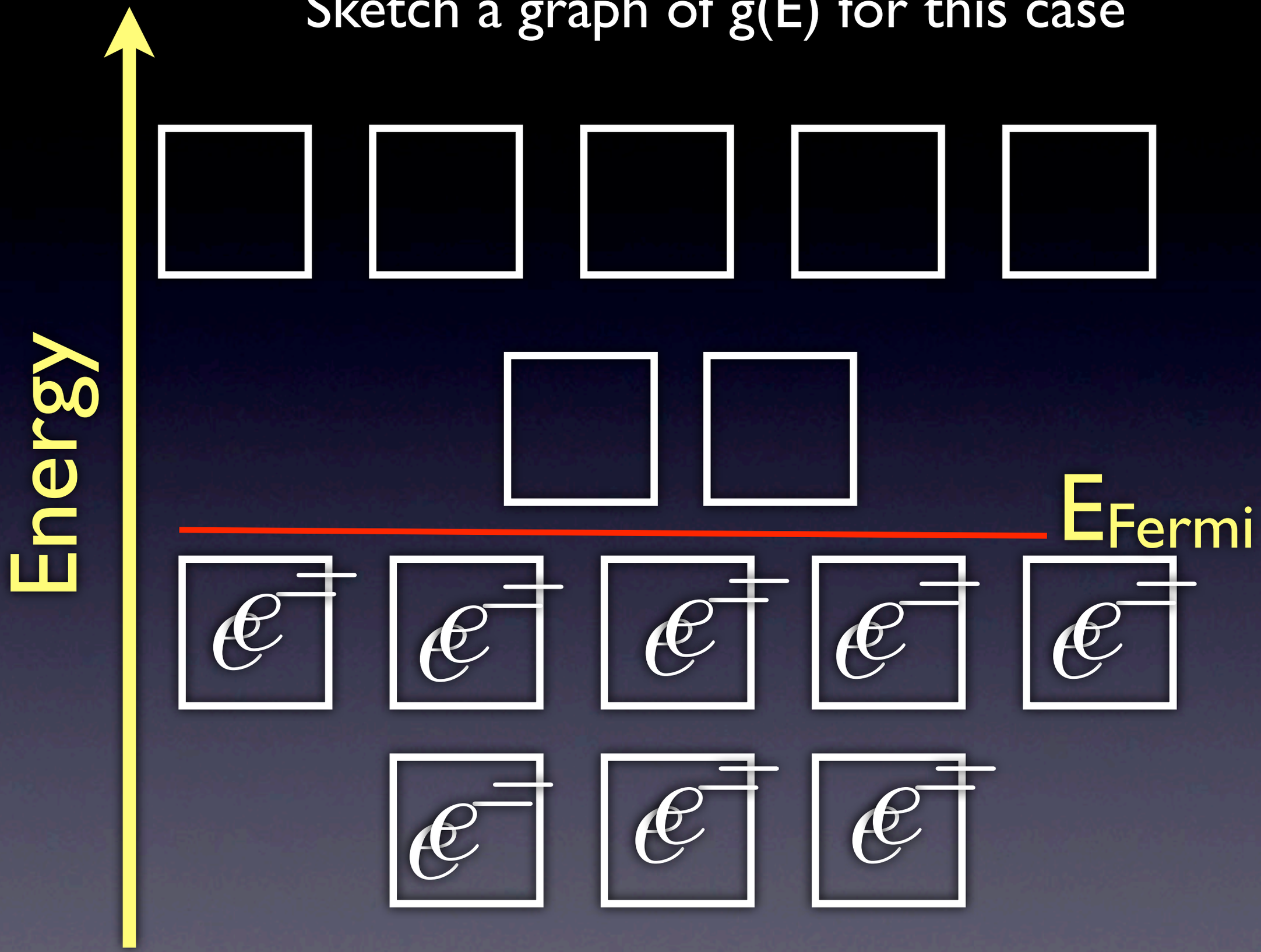

Energy
e^-


Energy


Energy


Energy
E_{Fermi}

Sketch a graph of g(E) for this case



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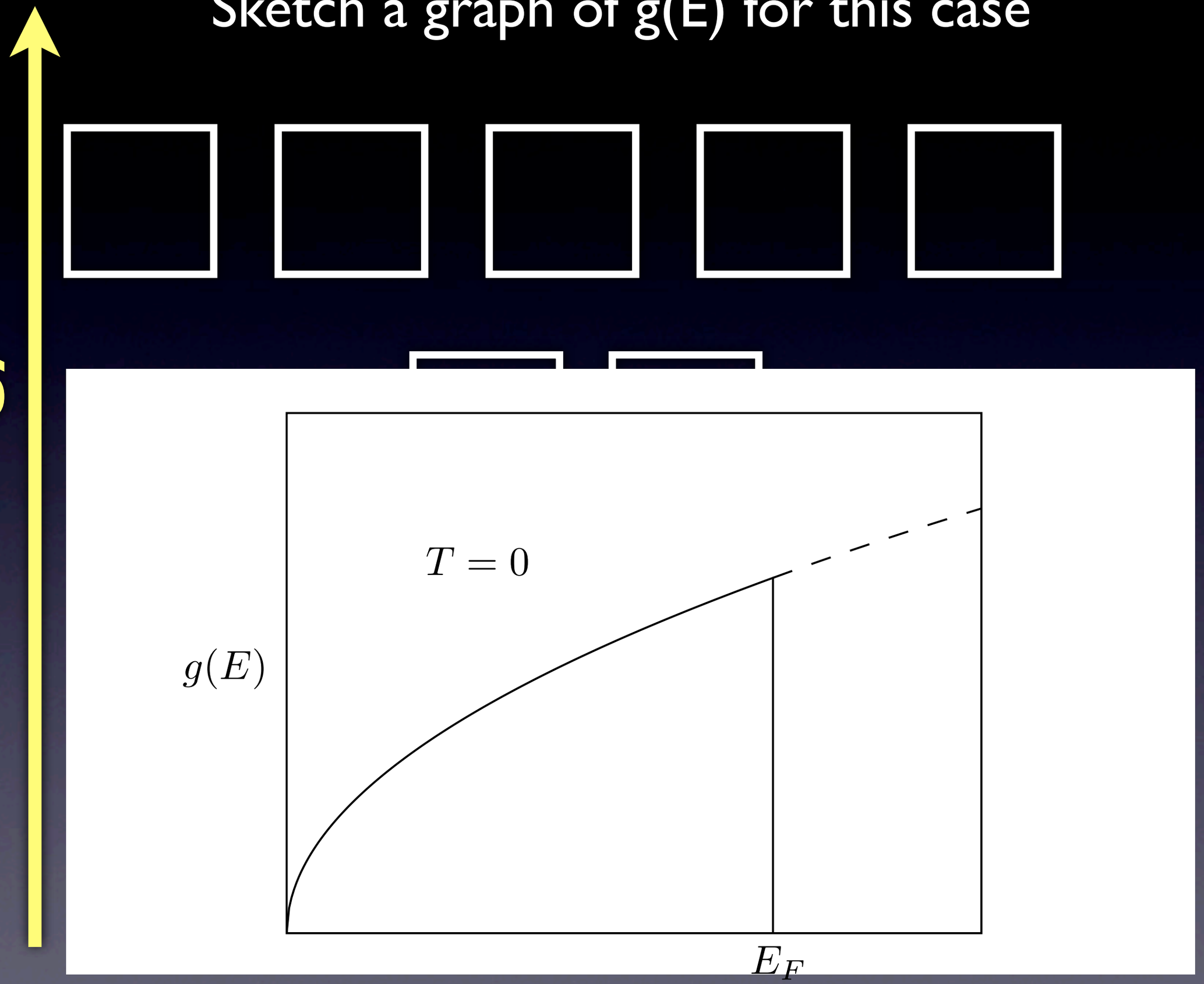

What is the Fermi energy for Na?
What is the speed of electrons with this energy?

Each Na atom has 1 valence electron.

Na forms on a bcc lattice with lattice parameter 4.30 Angstroms

$$N(E) = V_k \; g(\vec{k}) = (V/3\pi^2)(2mE/\hbar^2)^{3/2}$$

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$$E_F = 3.13 \text{ eV} \qquad v_F = 1.05 \times 10^6$$

Question #7

At T=0

a) .
b) all electrons have zero energy
c) Some electrons have zero energy and some don’t
d) All electrons have nonzero energy

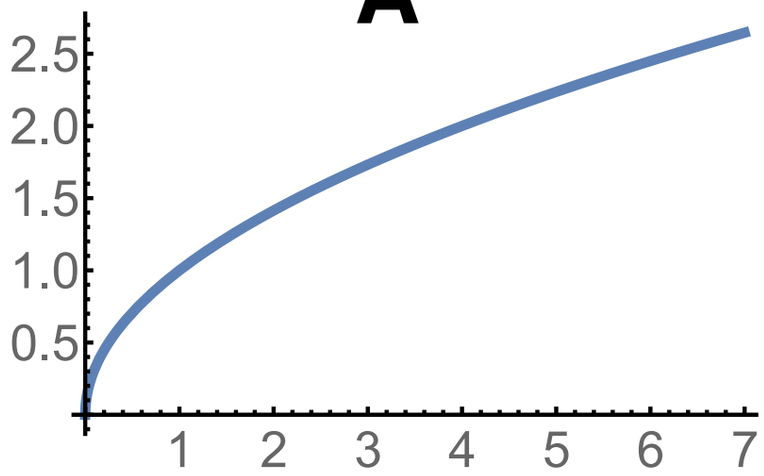
Question #8

At T > 0:

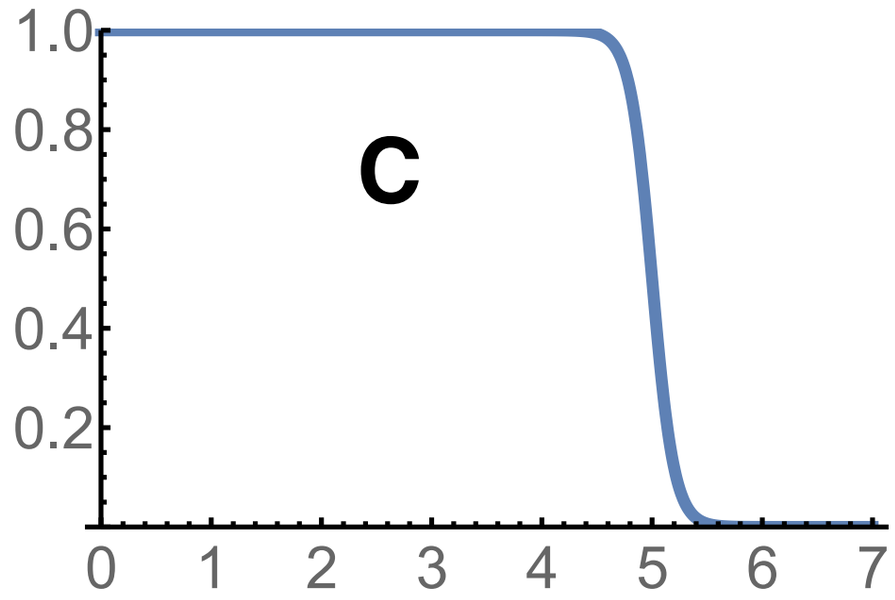
d) all electrons have more energy than they had at T= 0
e) Some electrons have more energy than they had at T= 0

Question #9

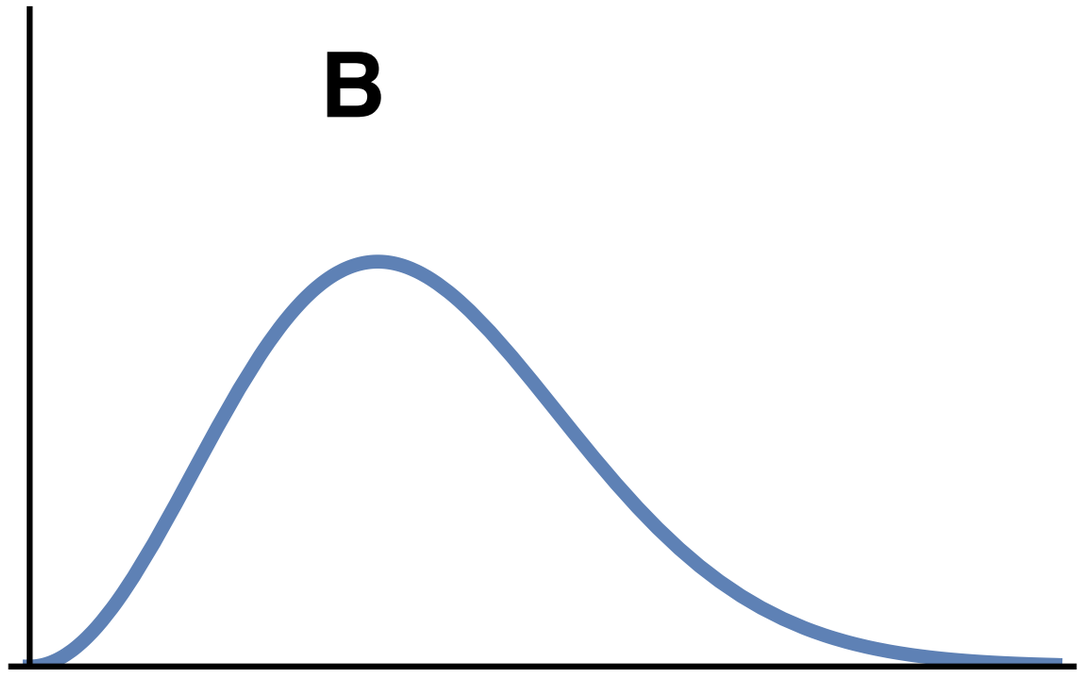
A



C

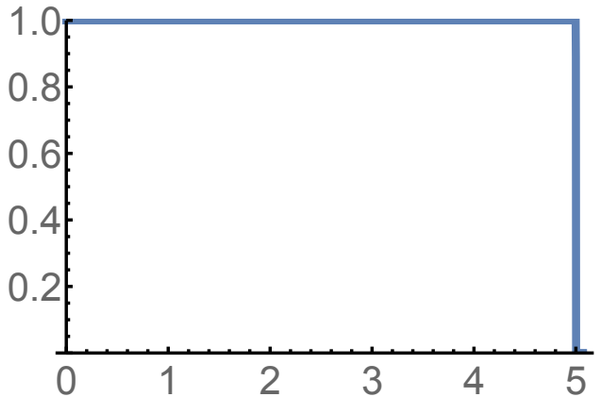


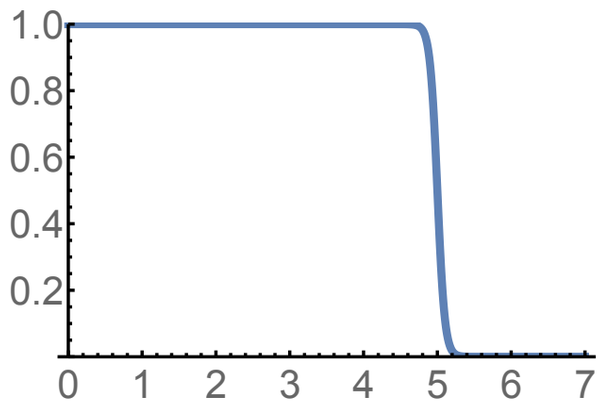
B

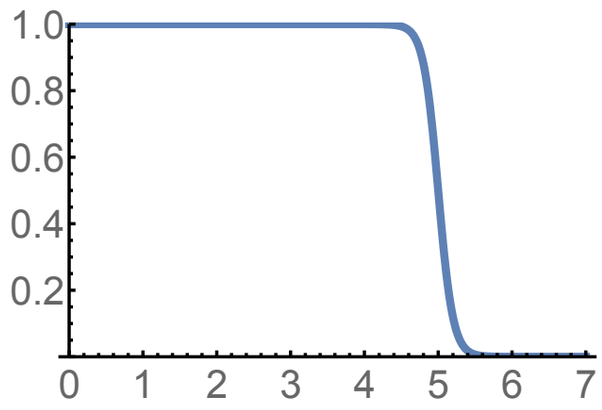


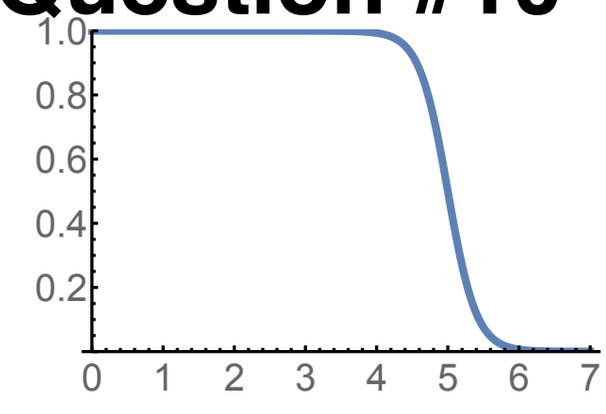
Which is the Fermi-Dirac distribution?

Question #10







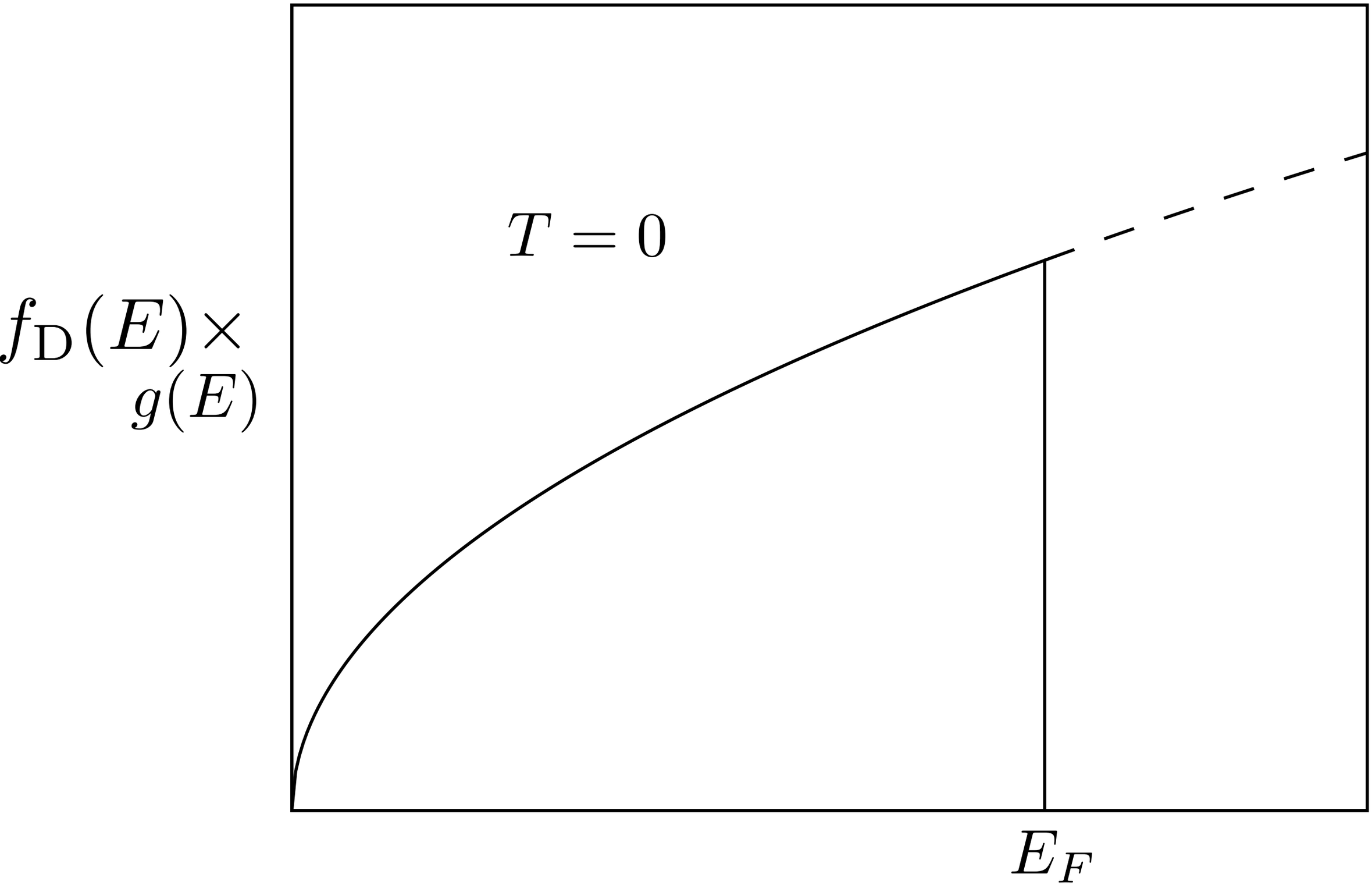


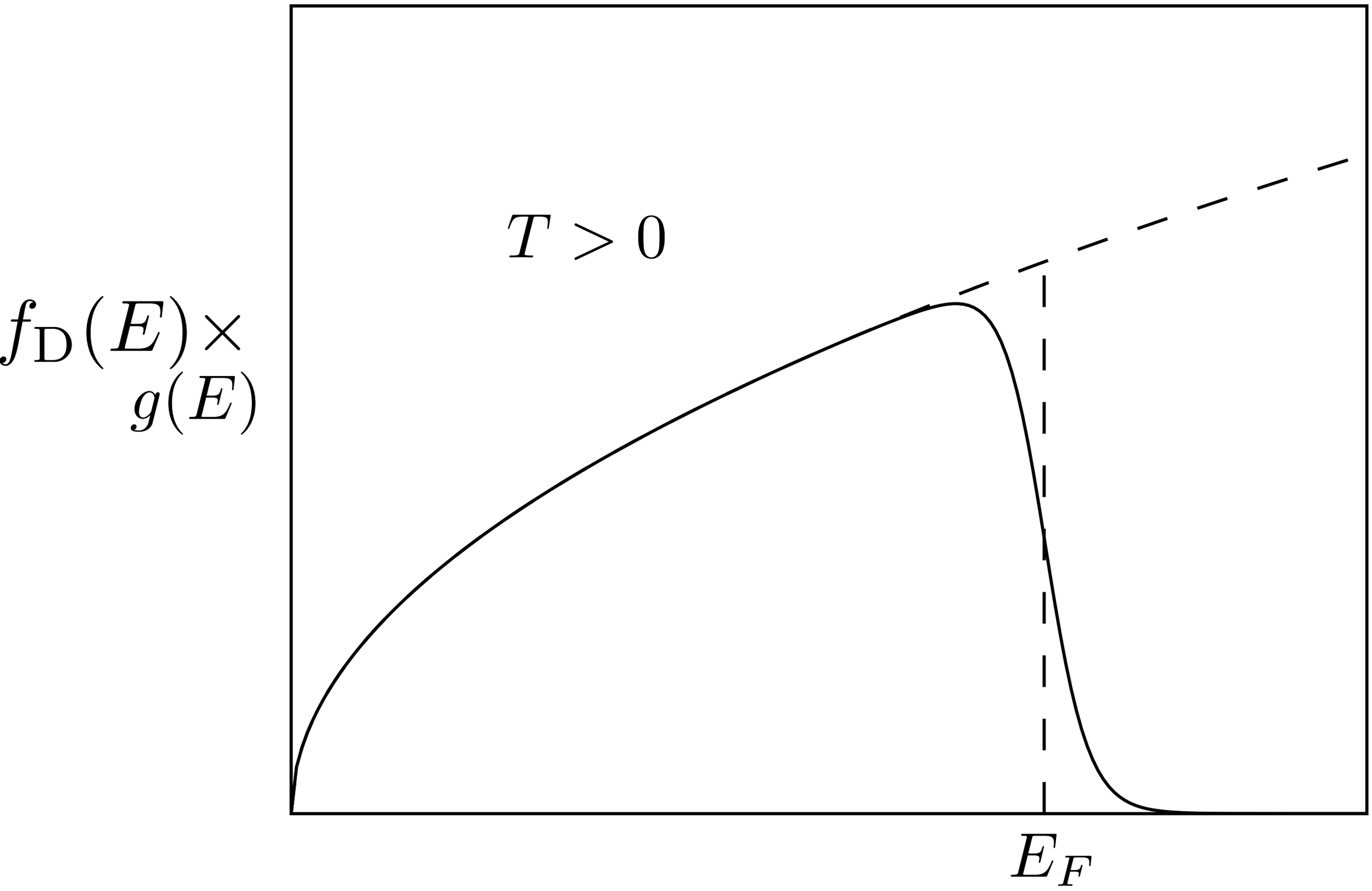
Which F.D function correspond to which temperatures?

a) Temperature is biggest for rightmost function and smallest for leftmost function

b) Temperature is biggest for leftmost function and smallest for rightmost function.

c) The temperature is the same for all of the functions.


$T = 0$
$f_{\mathrm{D}}(E) \times g(E)$
E_F
E


$T > 0$
$f_{\mathrm{D}}(E) \times g(E)$
E_F
E

Question #11

At room temperature, all of the occupied electron states are inside the Fermi sphere.

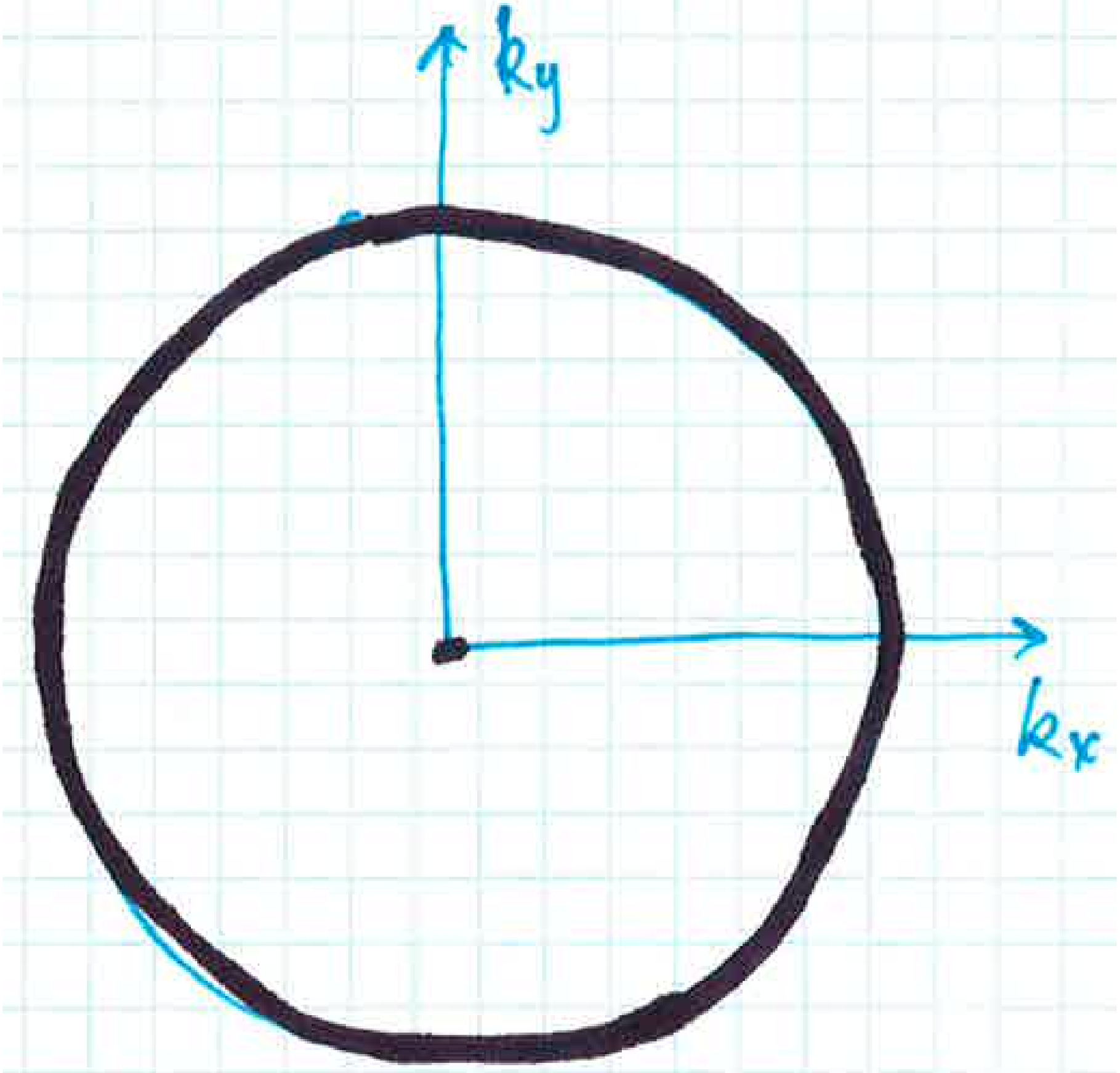
(A) True

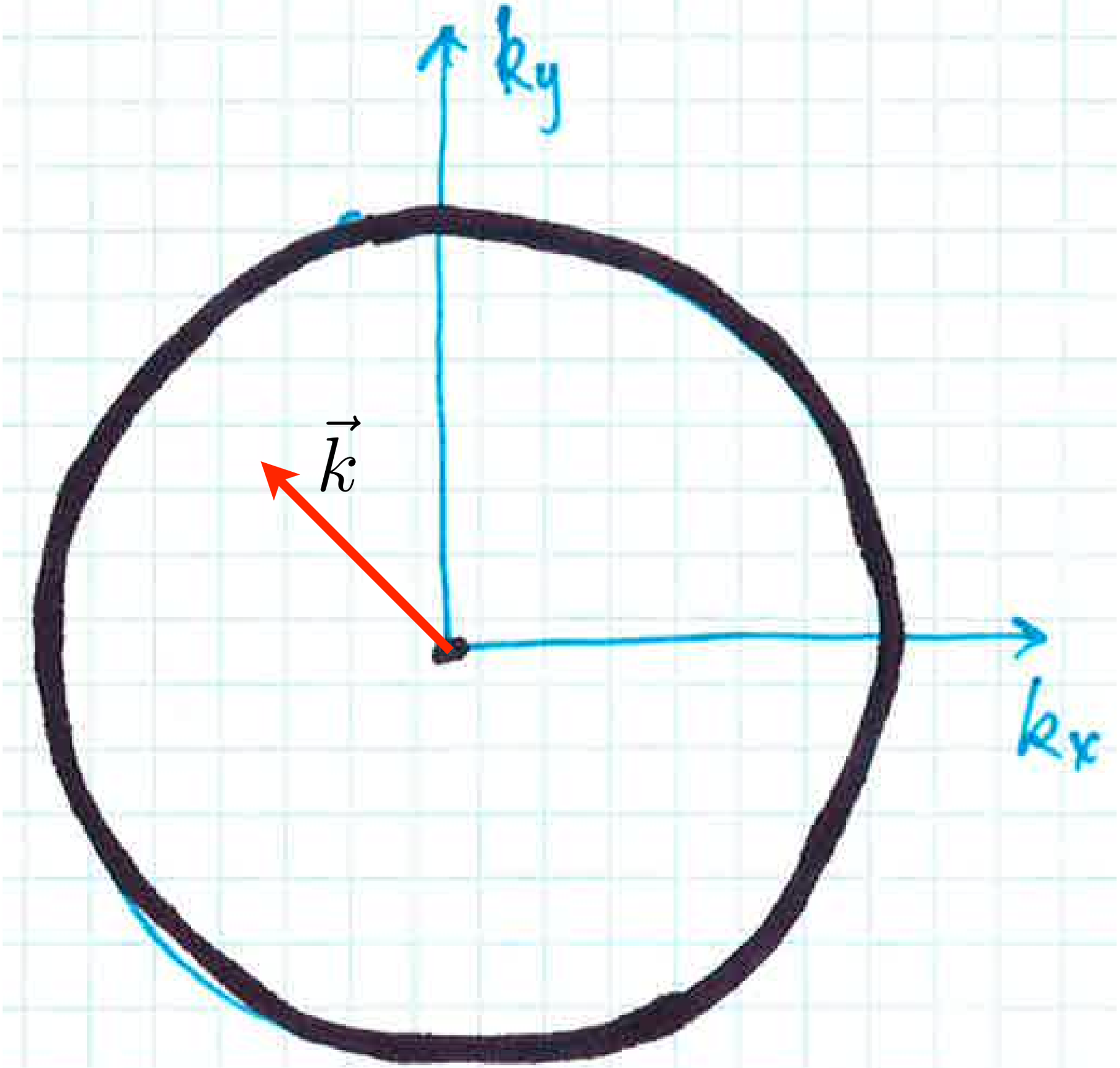
(B) False

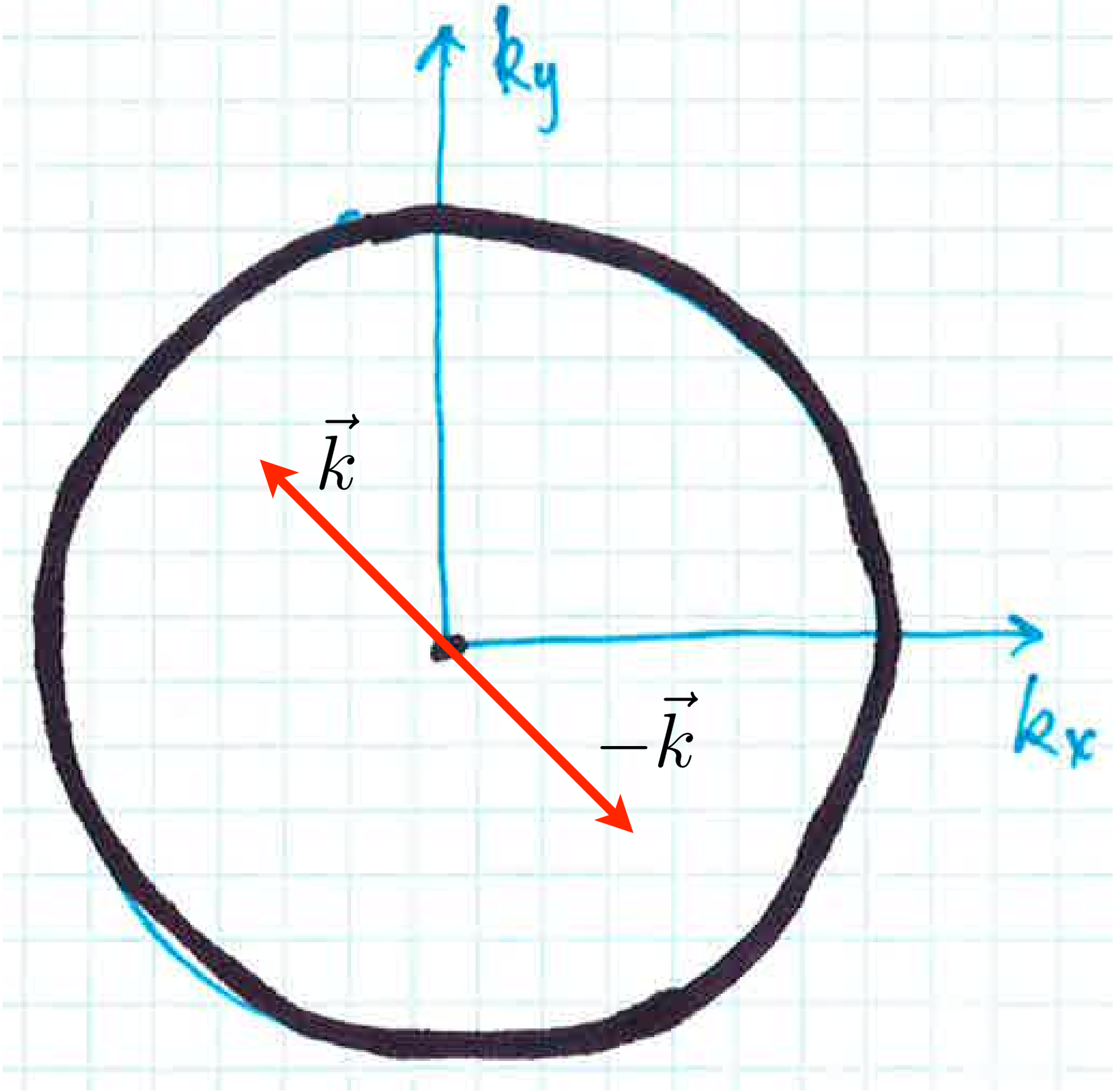
Question #12

In the free-electron quantum model of metals, which electrons are allowed to undergo collisions?

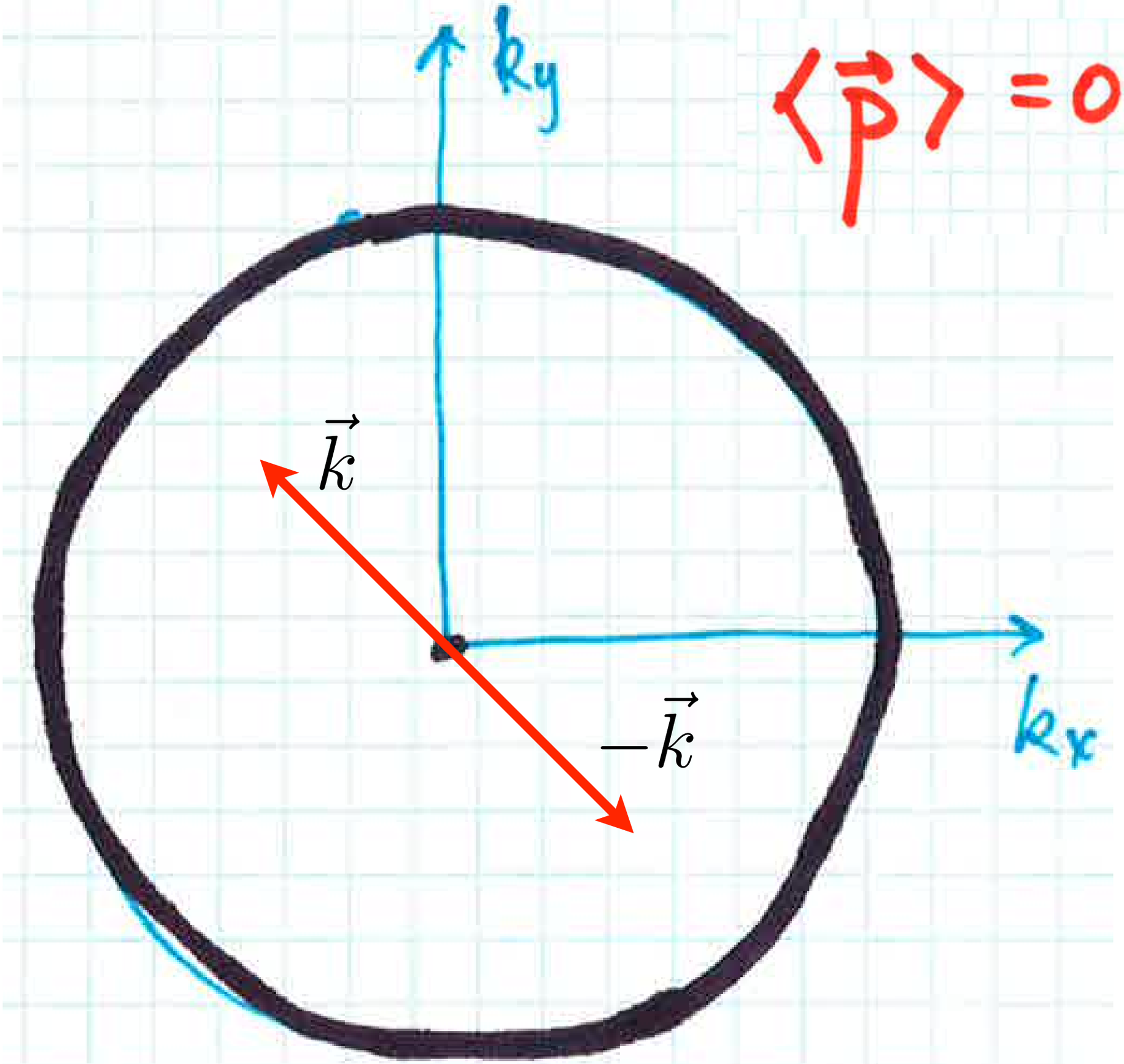
(A) only pairs with opposite velocity (or momentum)
(B) only those with low energies
(C) all of them
(D) only those with energies near the Fermi energy

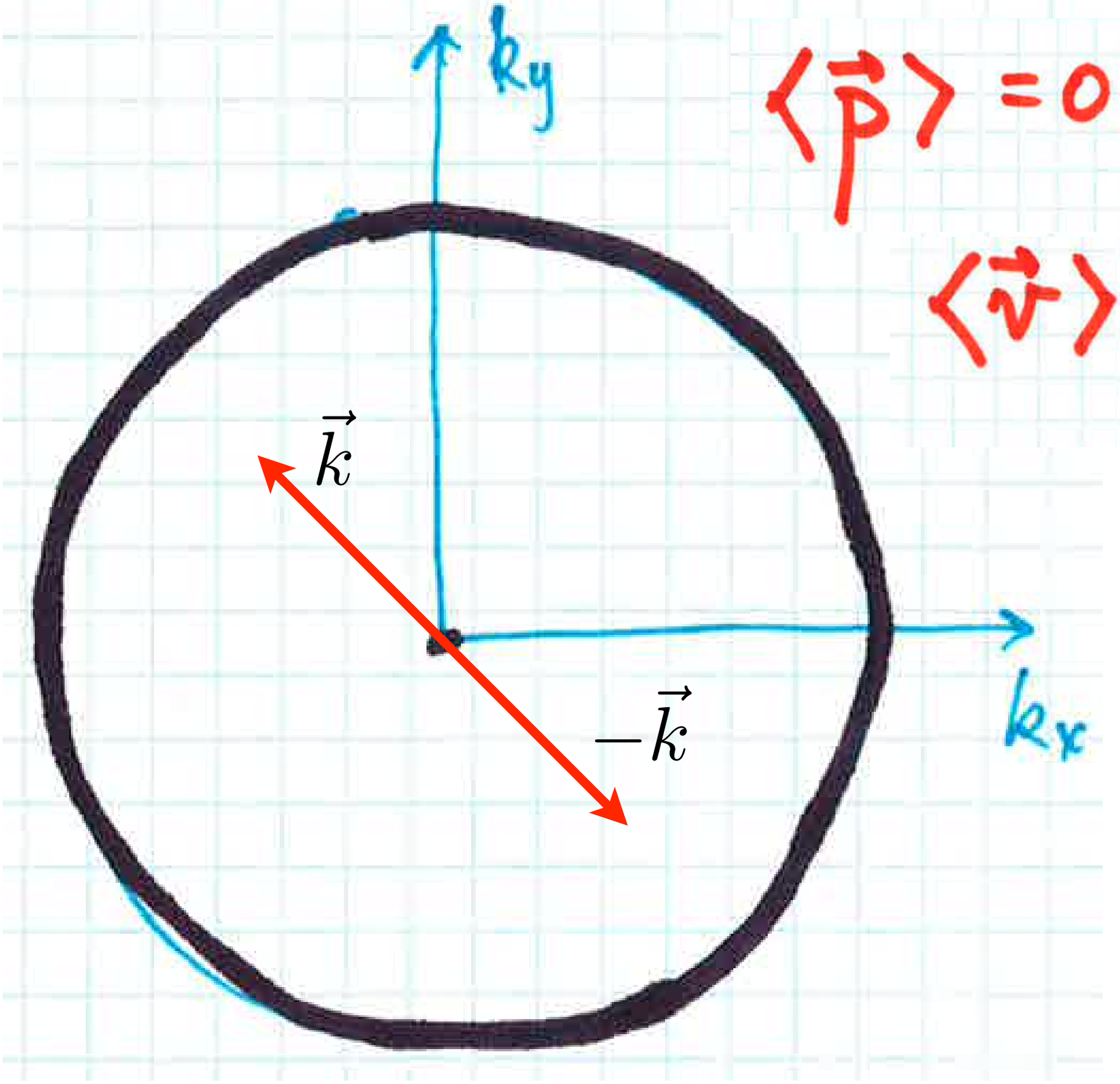

k_y
k_x


k_y
$\vec{k}$
k_x


k_y
$\vec{k}$
$-\vec{k}$
k_x

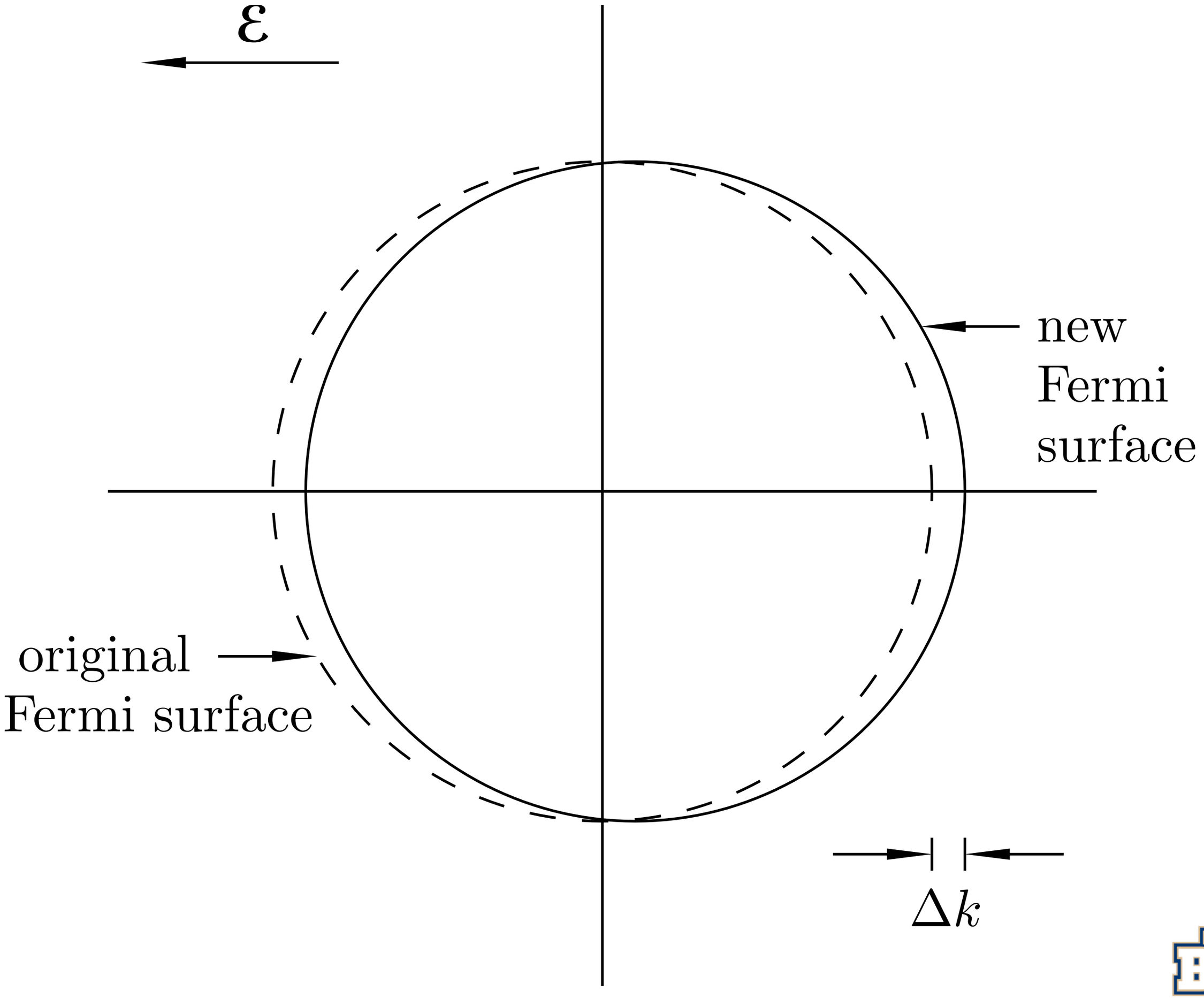
$\langle \vec{p} \rangle = 0$

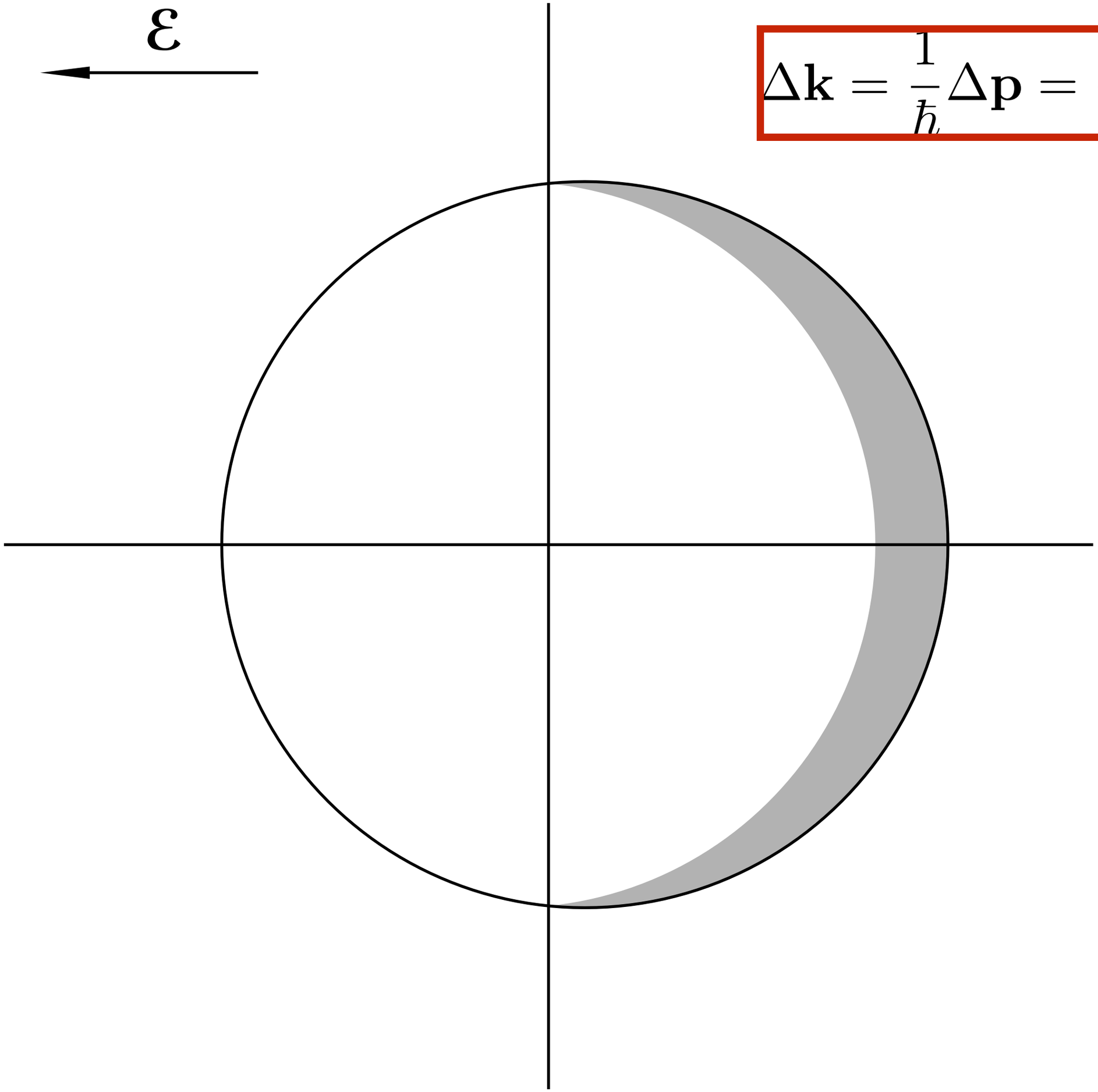




$\langle \vec{p} \rangle = 0$

$\langle \vec{v} \rangle = 0$


ε
new
Fermi
surface
original
Fermi surface
Δk


$\mathcal{E}$
$\Delta\mathbf{k} = \frac{1}{\hbar}\Delta\mathbf{p} = \frac{m}{\hbar}\mathbf{v}_d$

Question #13

For Na metal

$$E_F = 3.13 \text{ eV}$$

$$v_d = 5.90 \times 10^{-3} \text{ m/s}$$

$$E = \frac{\hbar^2 k^2}{2m}$$

$$\Delta \mathbf{k} = \frac{1}{\hbar}\Delta \mathbf{p} = \frac{m}{\hbar}\mathbf{v}_d$$

Which is the true statement? (Some simple calculations will be necessary)

A

$$\frac{\Delta k}{k} \ll 1$$

B

$$\frac{\Delta k}{k} \gg 1$$

C

$$\frac{\Delta k}{k} \approx 1$$

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Which is the true statement? (Some simple calculations will be necessary)

A

$$\frac{\Delta k}{k} \ll 1$$

$$|\mathbf{k}| = 9.07 \times 10^9 \text{m}^{-1}$$

B

$$\frac{\Delta k}{k} \gg 1$$

$$\Delta\mathbf{k} = 50.9 \text{ m}^{-1}$$

C

$$\frac{\Delta k}{k} \approx 1$$

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$$v_d = 5.90 \times 10^{-3} \text{ m/s}$$

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$$\Delta \mathbf{k} = \frac{1}{\hbar}\Delta \mathbf{p} = \frac{m}{\hbar}\mathbf{v}_d$$

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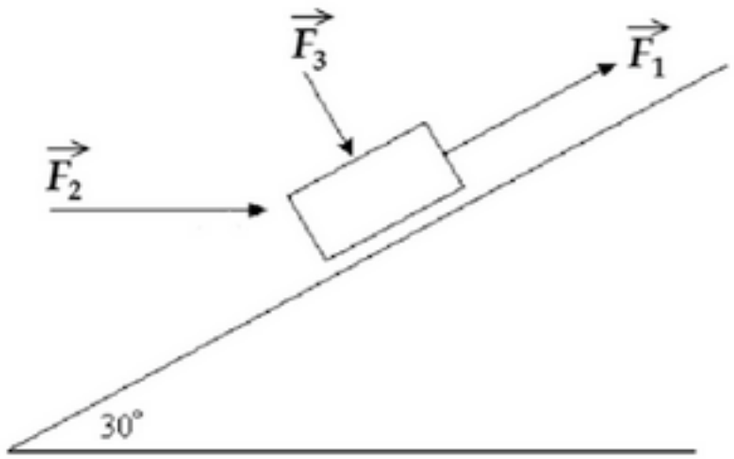

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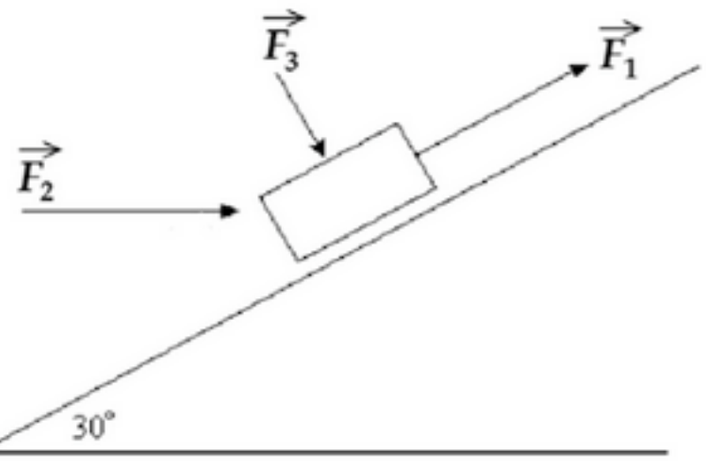

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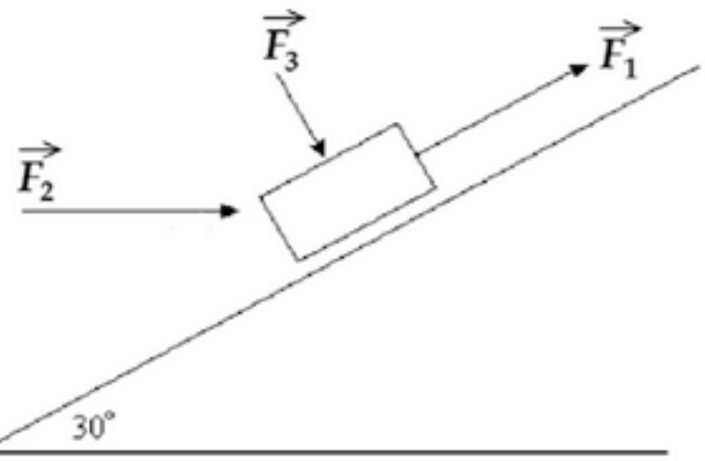

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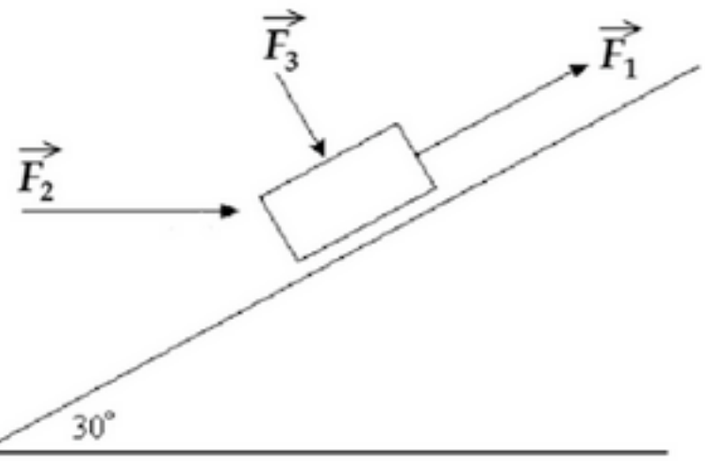

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