WHY SHOULD I TAKE A BATH? I'M JUST GOING TO GET DIRTY AGAIN.

WHY SHOULD I BRUSH MY TEETH? I'M JUST GOING TO EAT AGAIN.

WHY SHOULD I COMB MY HAIR? IT'S JUST GOING TO GET MESSED UP AGAIN.

I'D RATHER BE EFFICIENT THAN HYGIENIC.

SO YOUR TEACHER DIDN'T KNOW YOU'D RIPPED YOUR PANTS, AND SHE MADE YOU DO A PROBLEM AT THE CHALK-BOARD?

THAT SUMS IT UP.

HOW AWFUL! WHAT DID YOU *DO*?!?

I DIDN'T HAVE A CHOICE. I MOONED THE WHOLE CLASS.

THAT'S WHY YOU'RE HOME EARLY?

THREE TEACHERS AND THE PRINCIPAL COULDN'T RESTORE ORDER.

4-11

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Question #9

There are 2 electrons in each primitive unit cell.

Which bands get filled if these are free electrons?

D) green states. E) red states

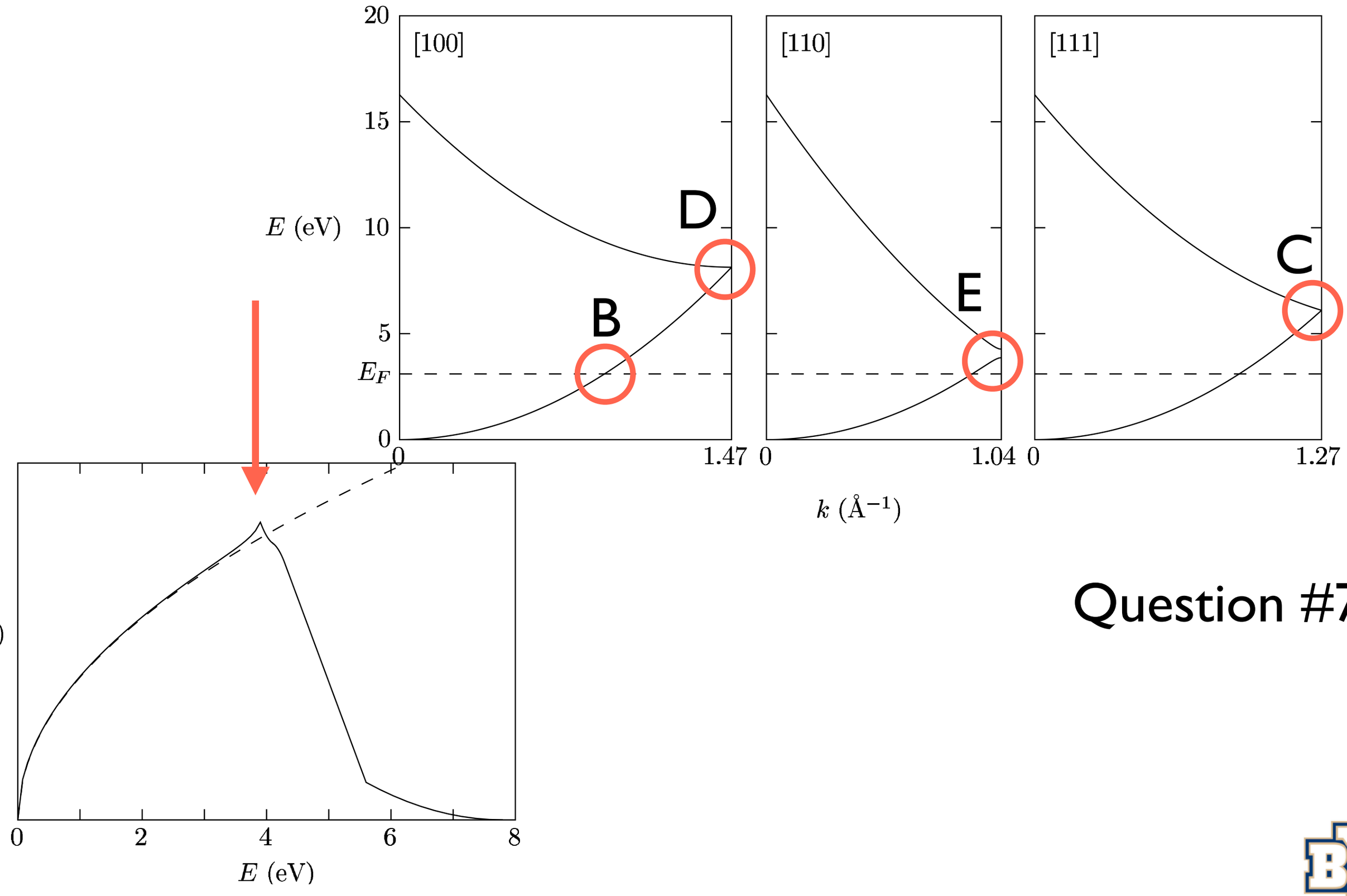
Question #10

There are 2 electrons in each primitive unit cell.

Which bands get filled if these are **not** free electrons?

D) green states. E) red states

Which part of the band diagram(upper) is responsible for the spike in the density of states (indicated with arrow)?



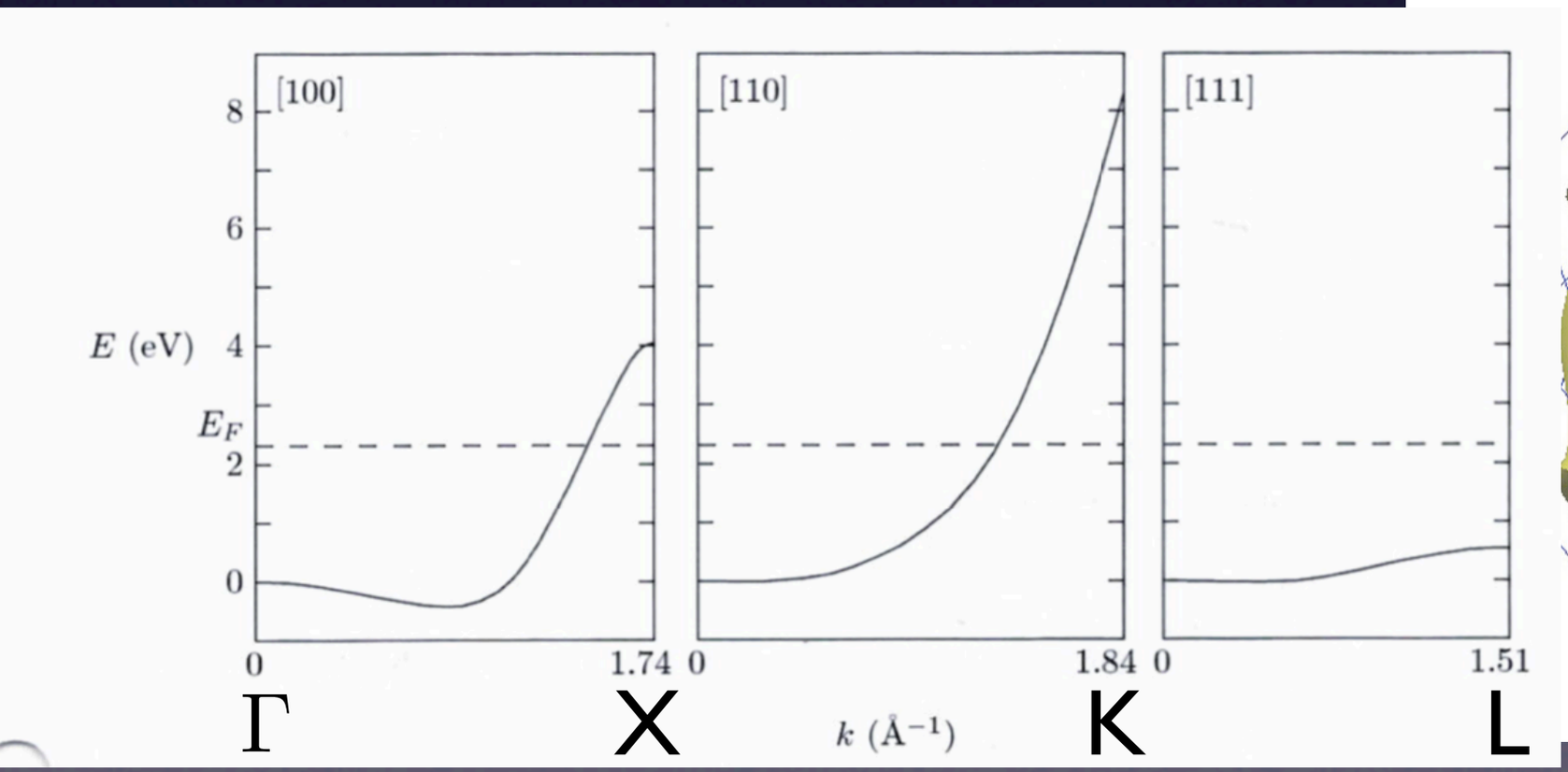
Question #7

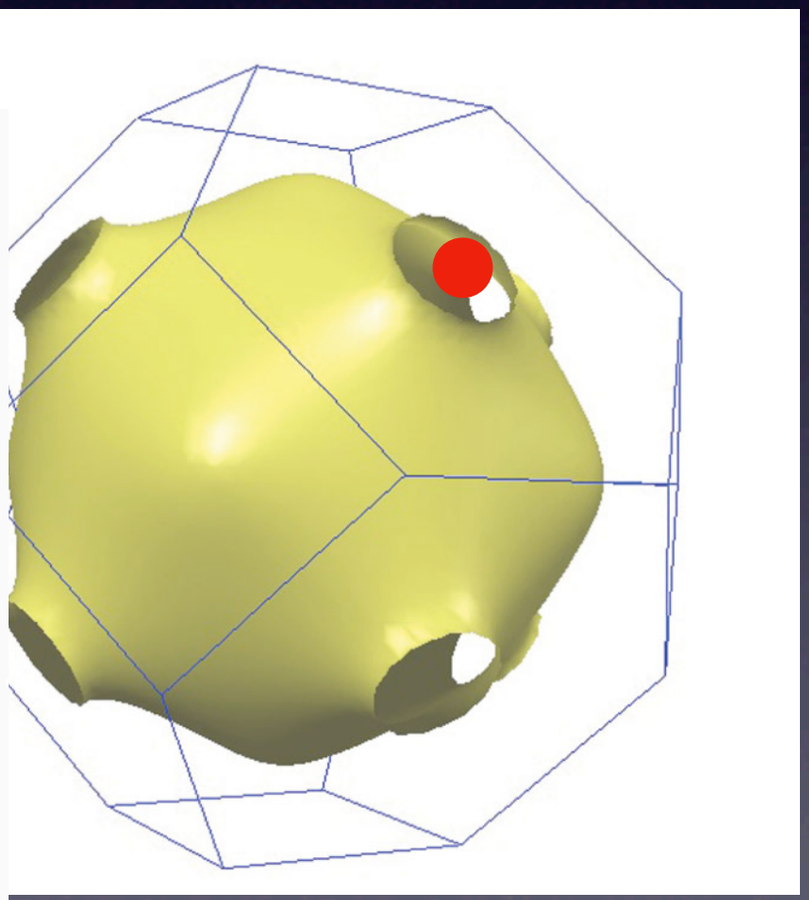
Question #8

Fermi Surfaces

By looking at the band structure diagram, can you determine the location of the red dot?

A) L B) X C) K





Question #8

Fermi Surfac

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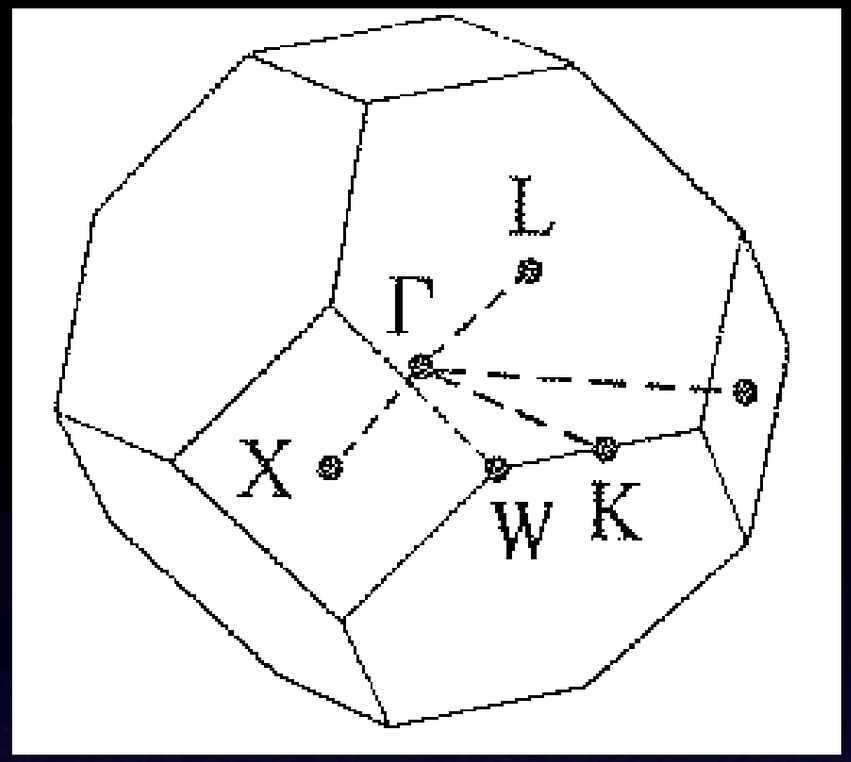
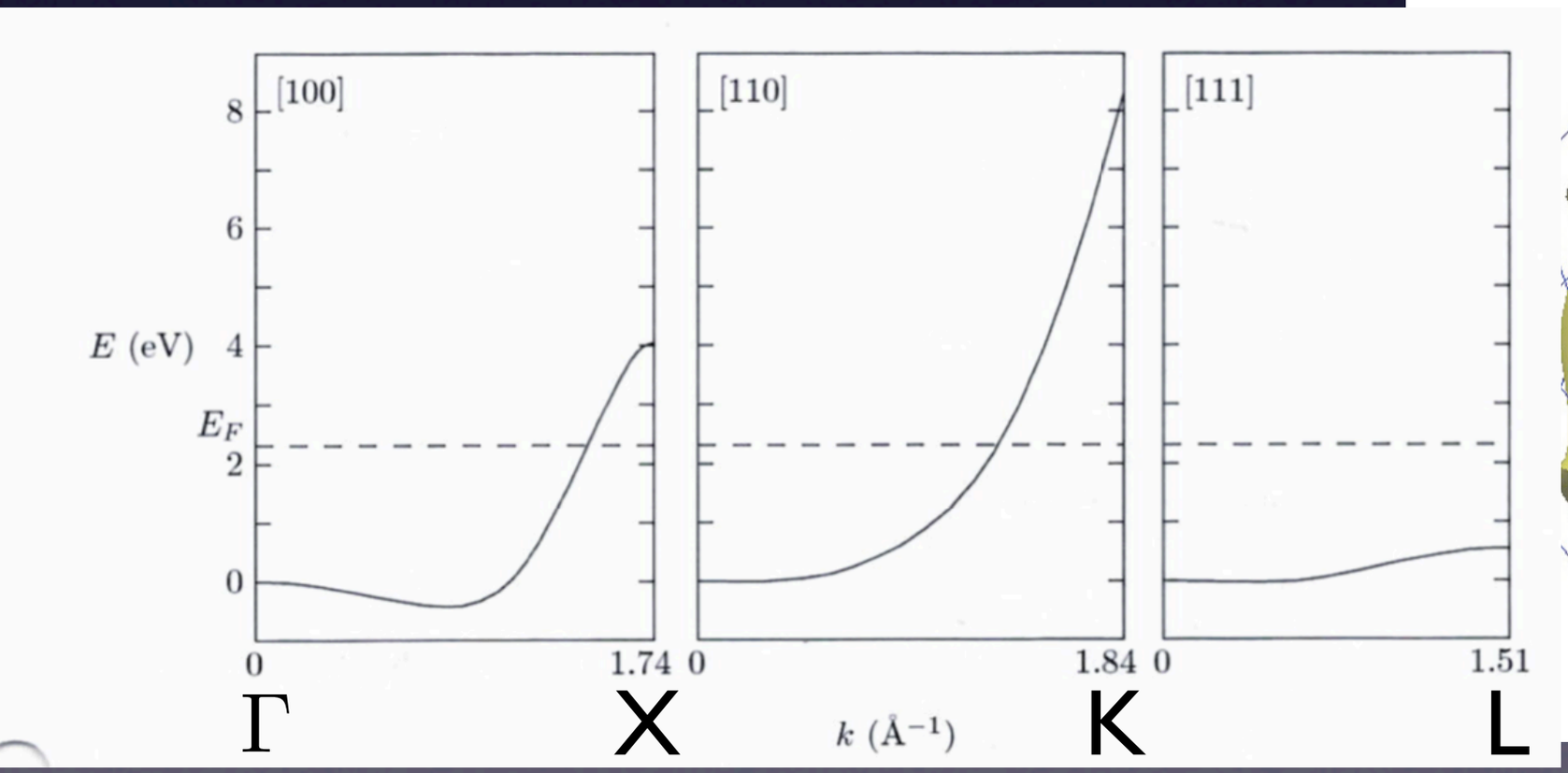
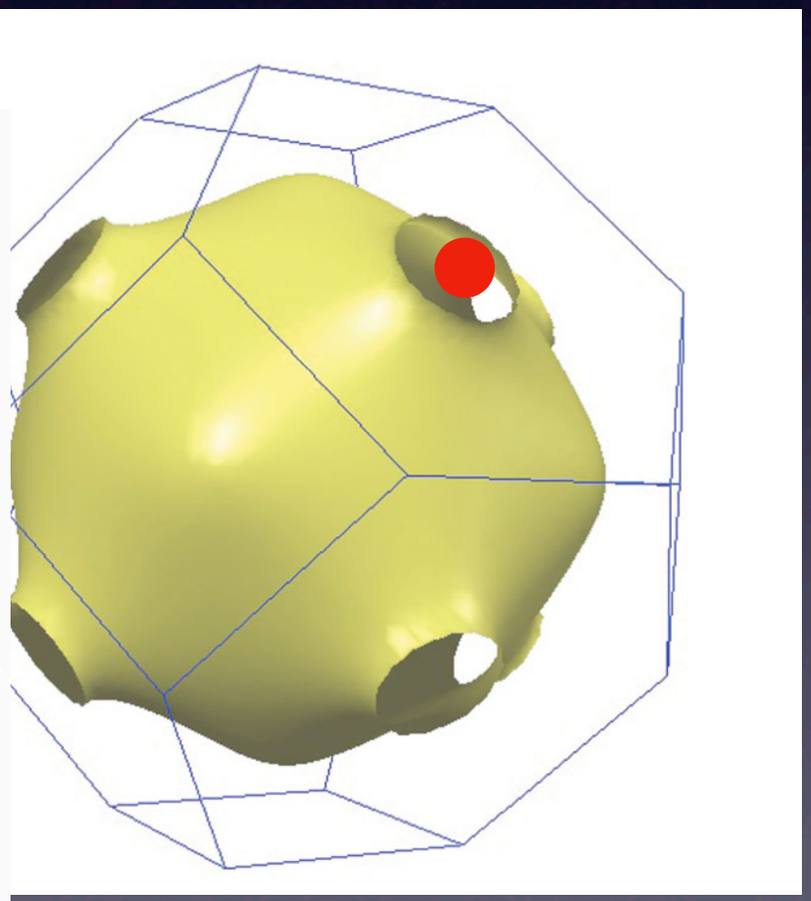
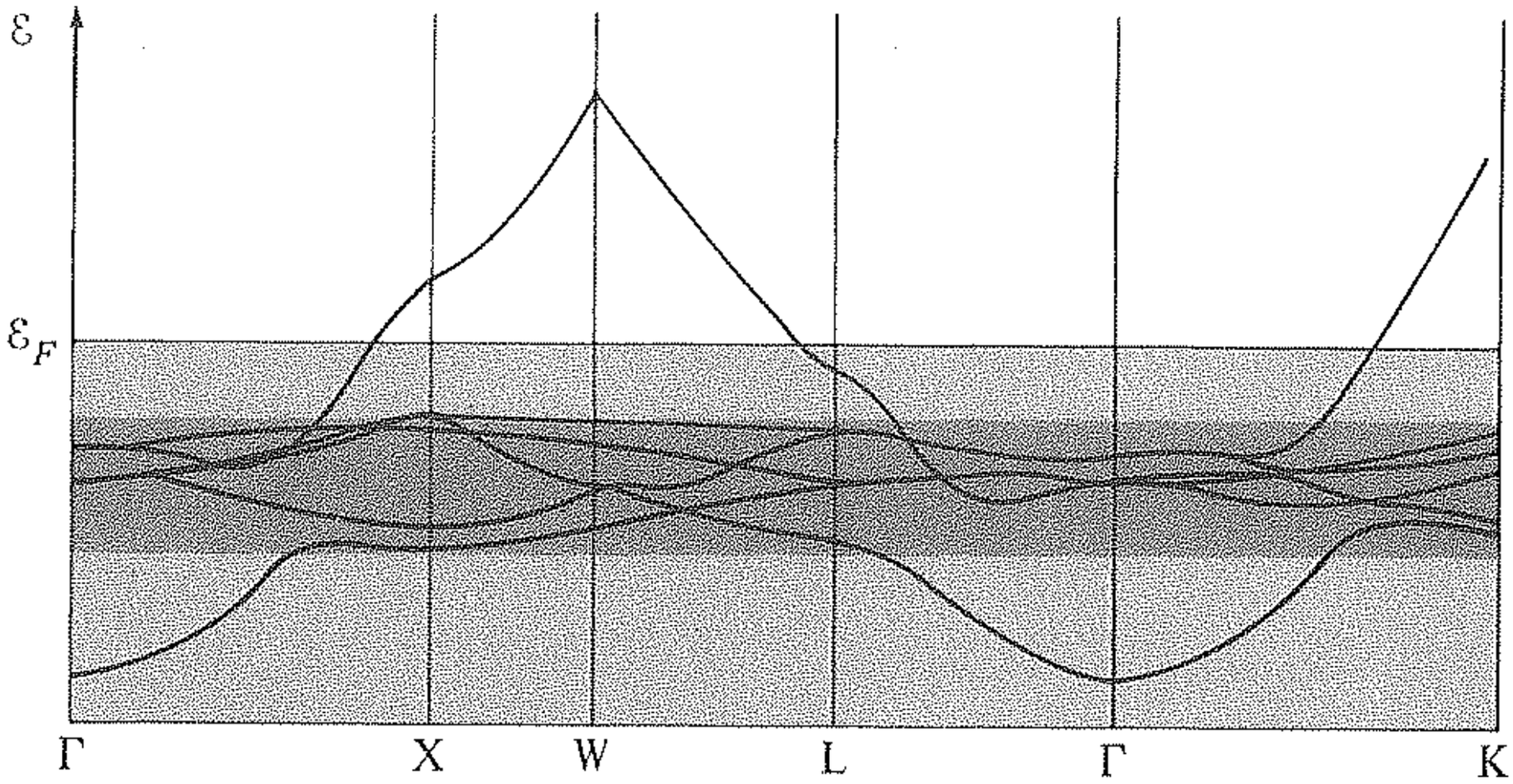
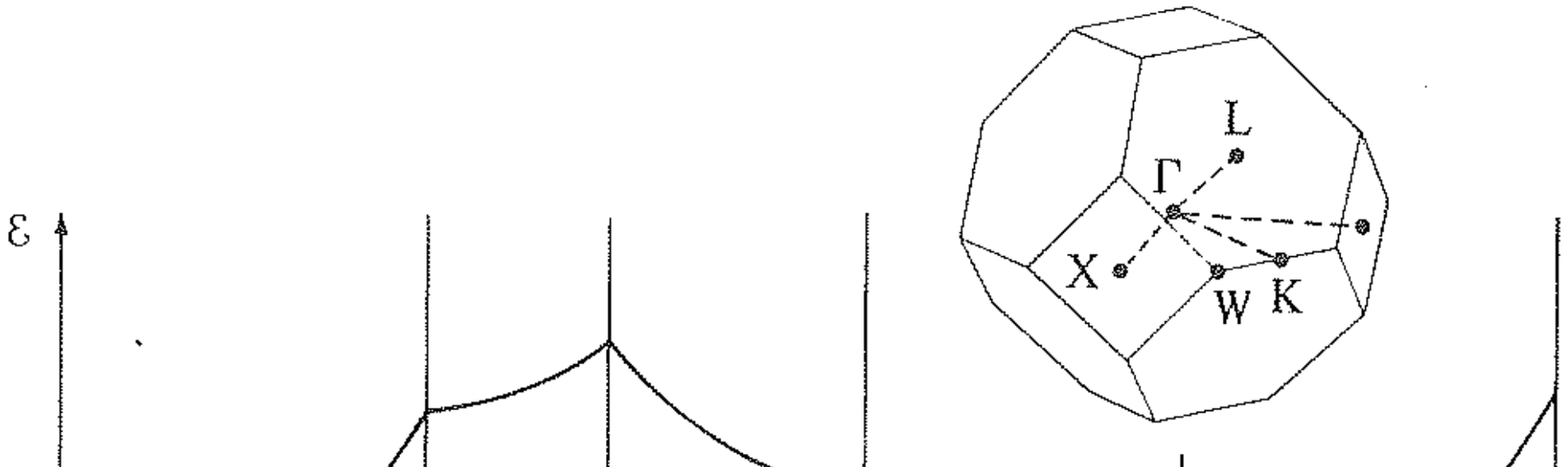




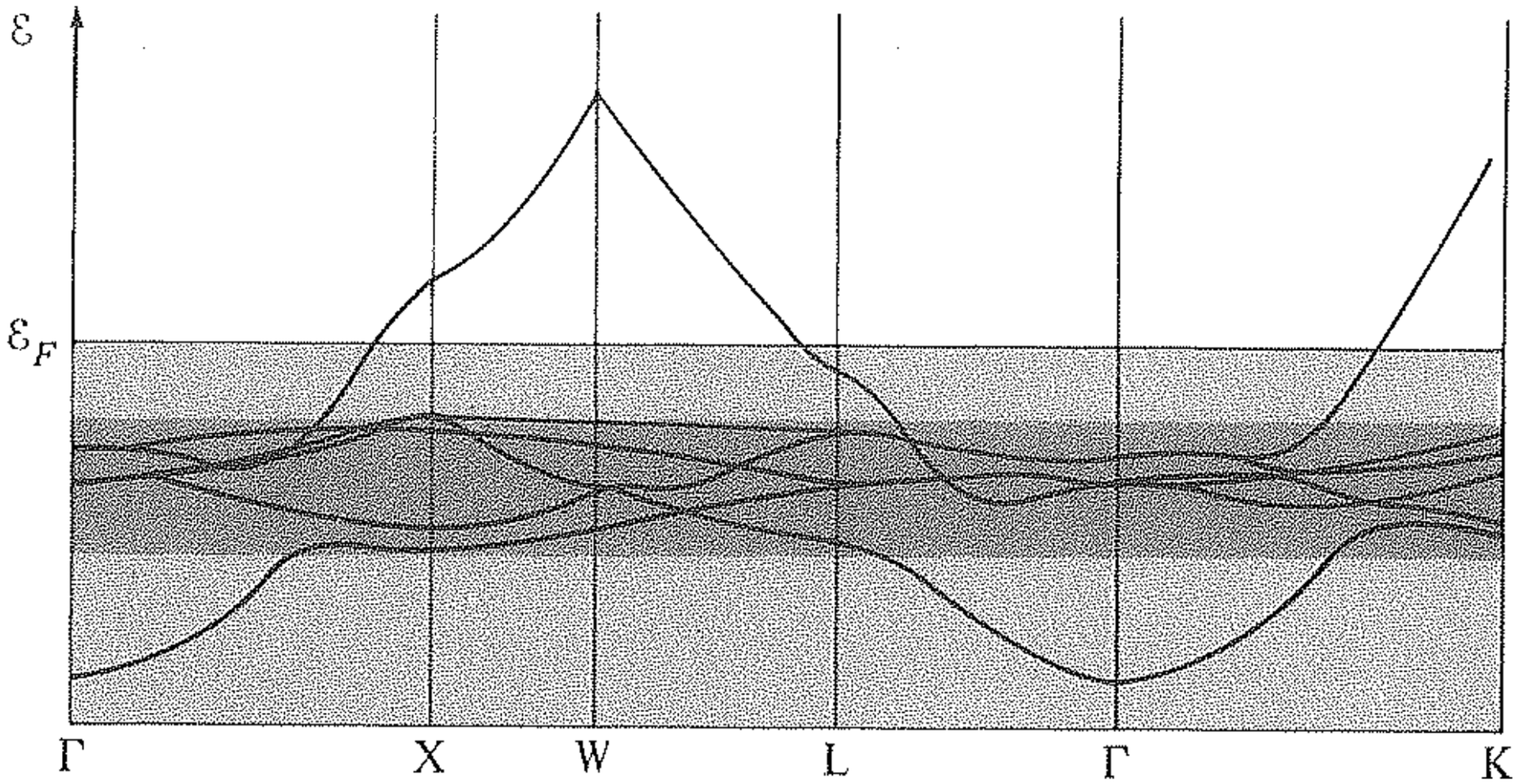




(a)



How many valence electrons in Cu?
How many bands can be full?



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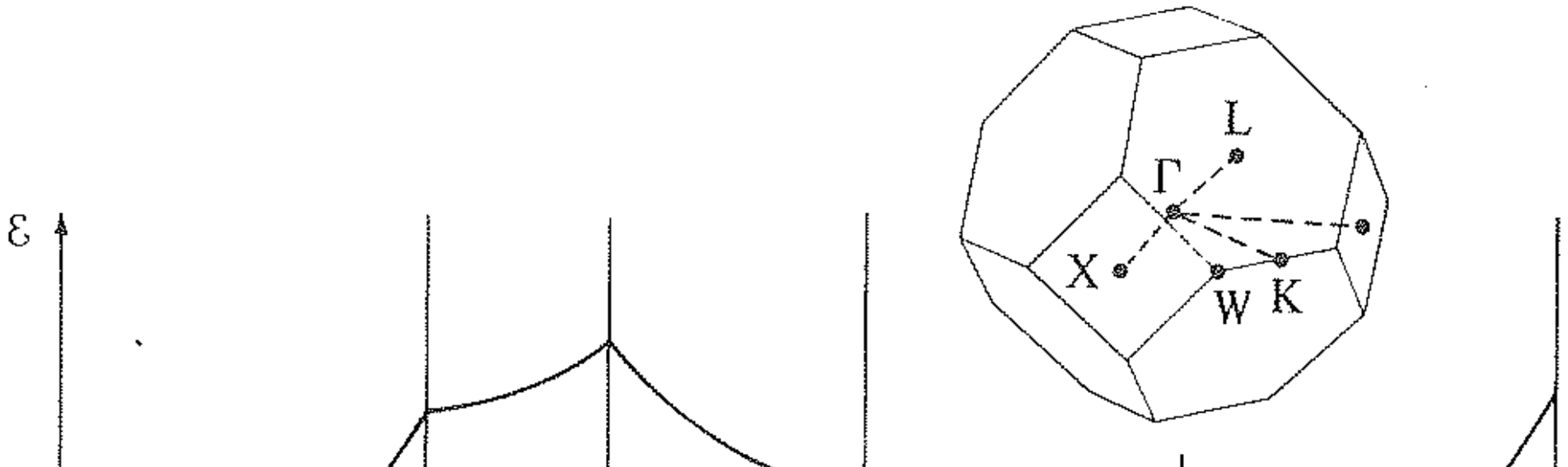
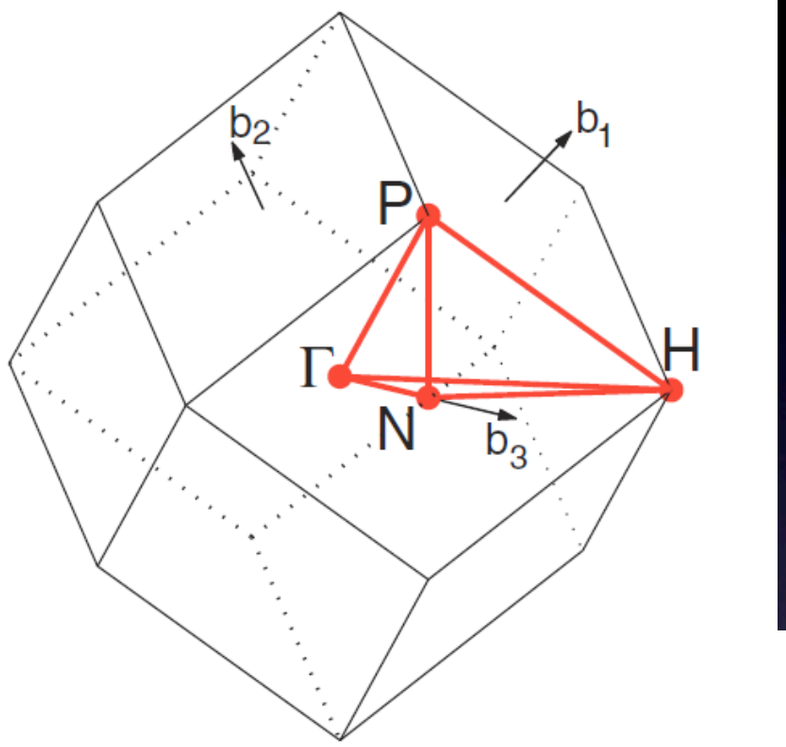
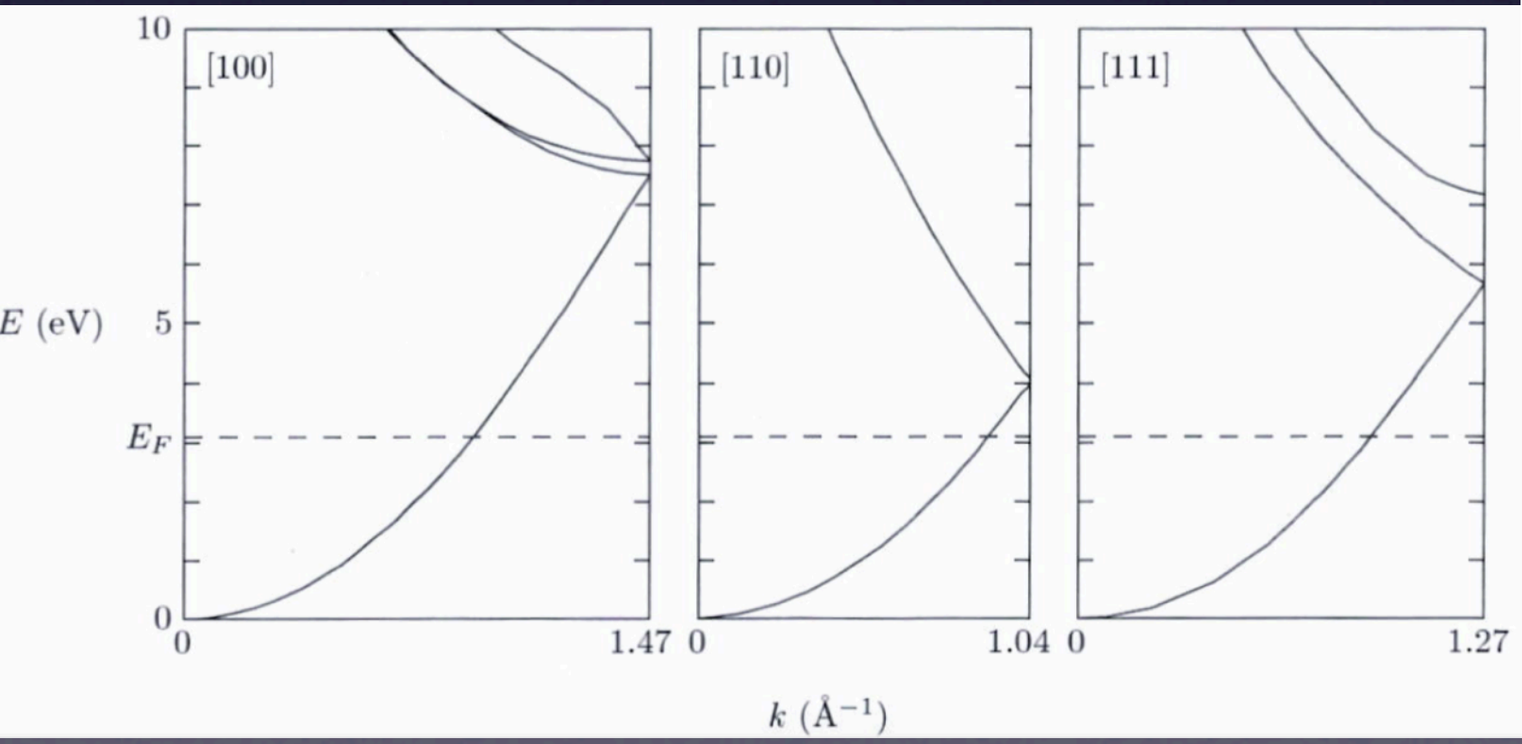
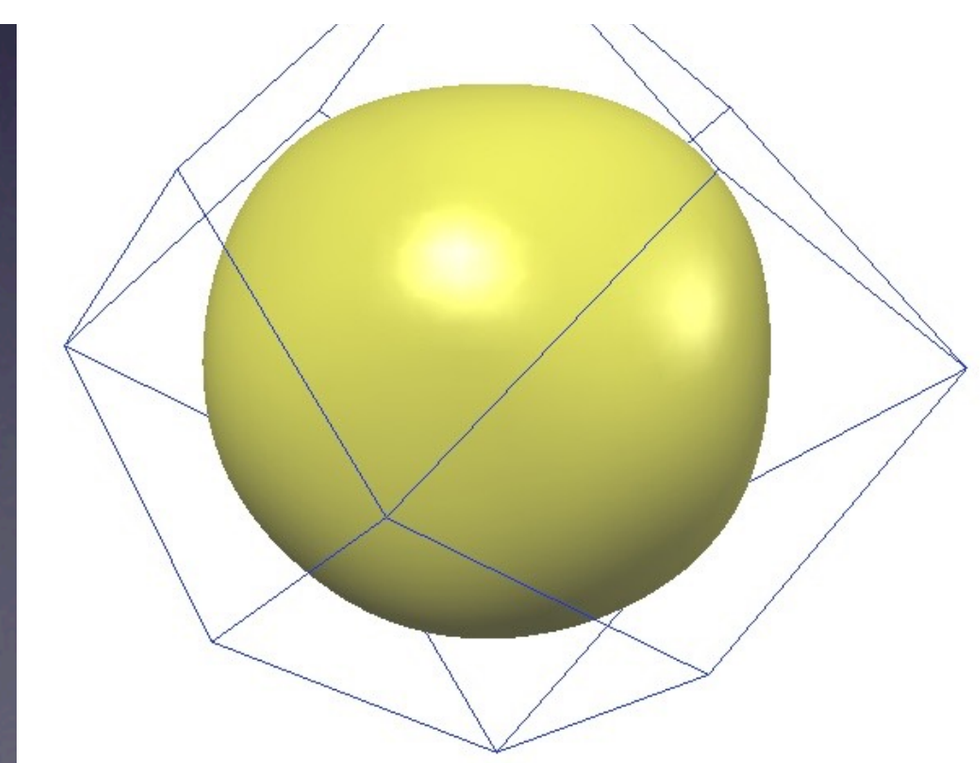


Fermi Surfaces

Can you explain why the Fermi surface for Na has no protrusions?





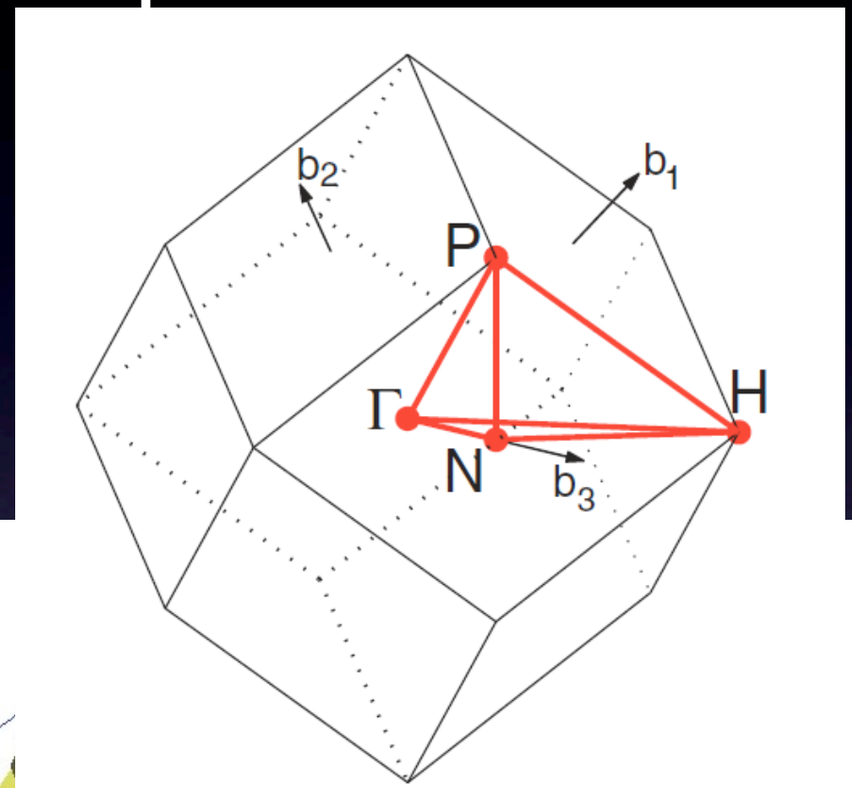


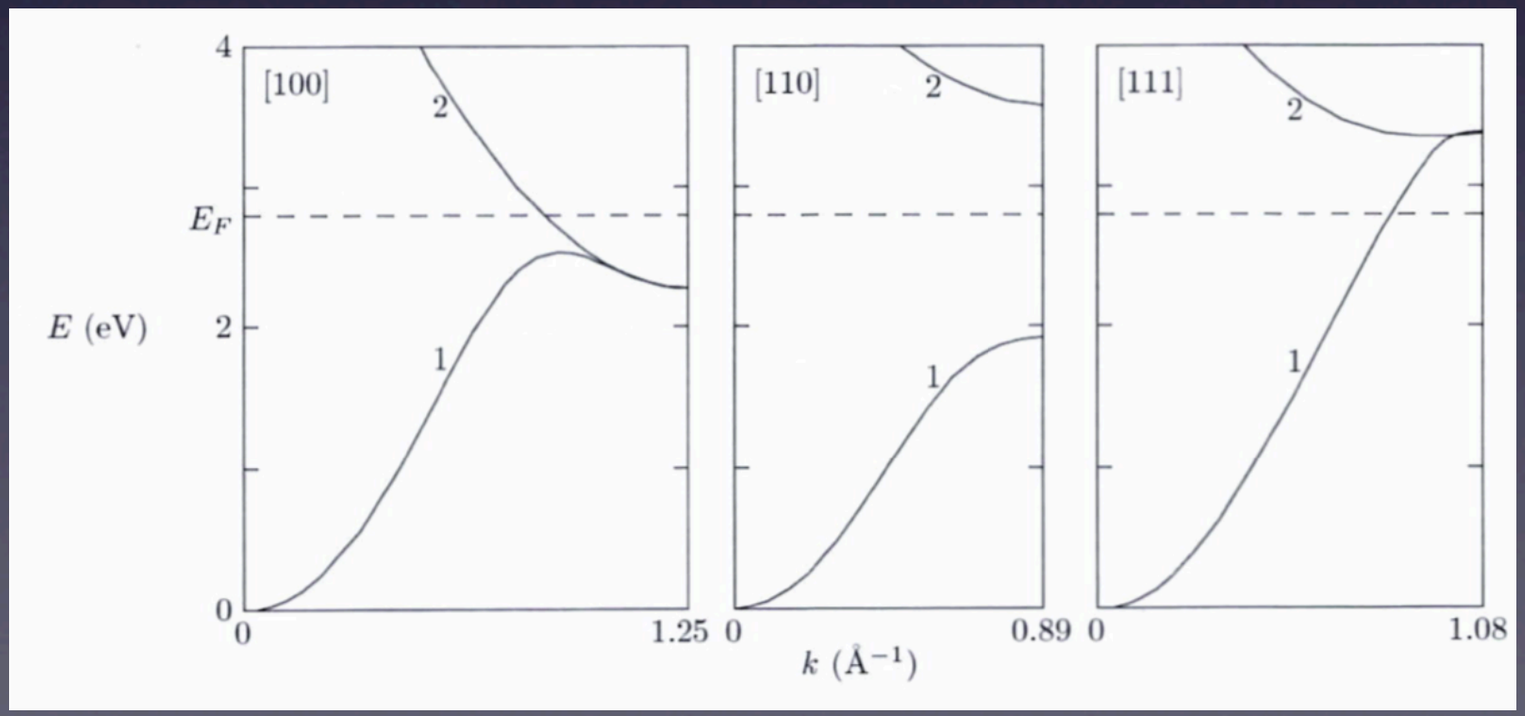
Question #9

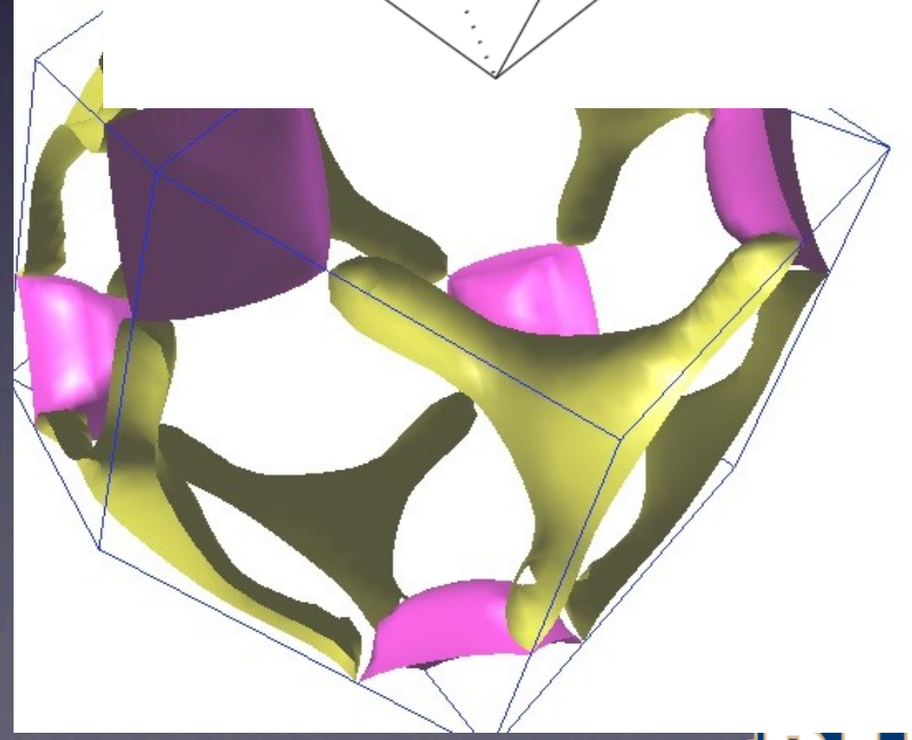
Fermi Surfaces

Judging from the band structure diagram how many electrons do you think are present in each primitive unit cell?

a) 1 b) 2







Conductivity and bands

$$v = \frac{d\omega}{dk}$$

$$E = \hbar\omega \Rightarrow v = \frac{1}{\hbar}\frac{dE}{dk}$$

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Free particle (no forces)

$$v = \frac{d\omega}{dk}$$

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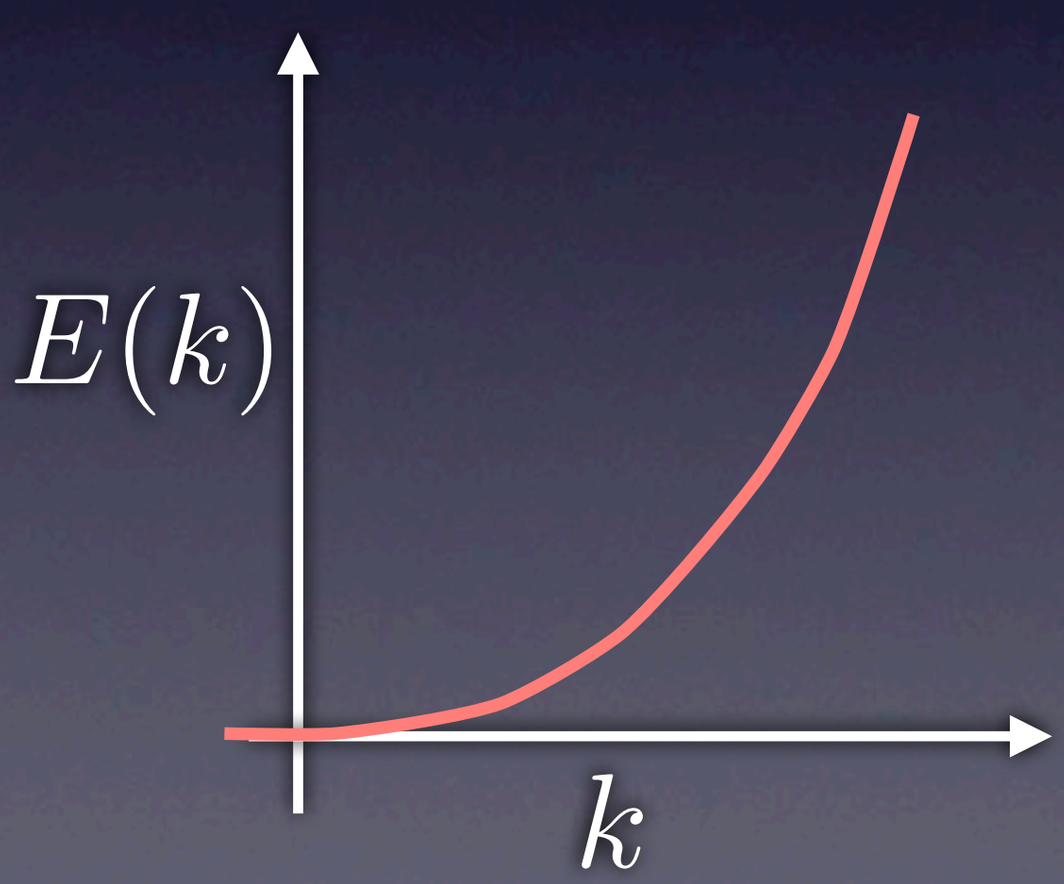

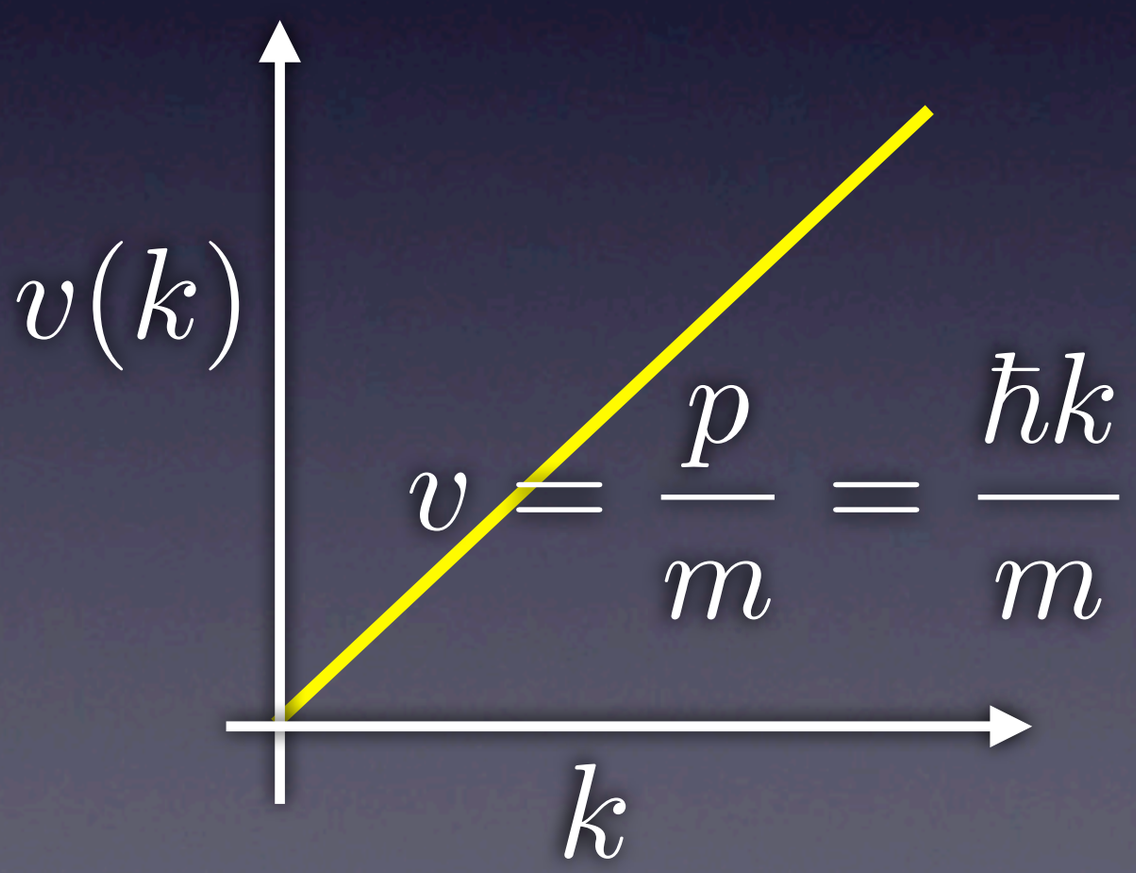

In a crystal...

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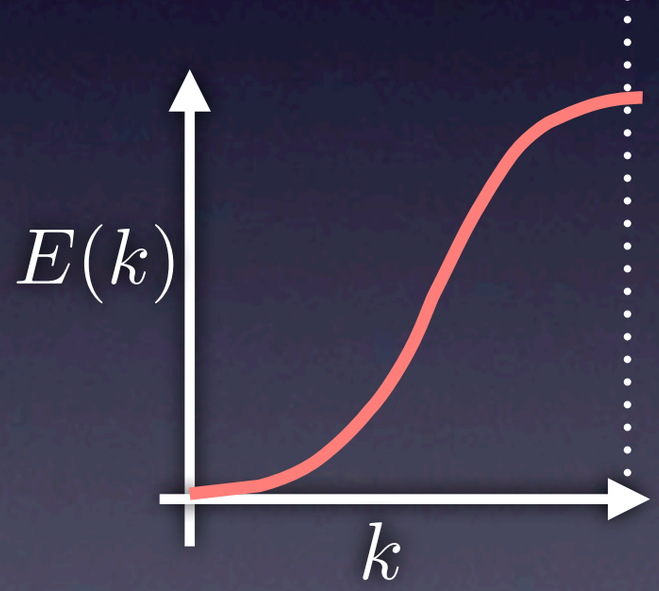

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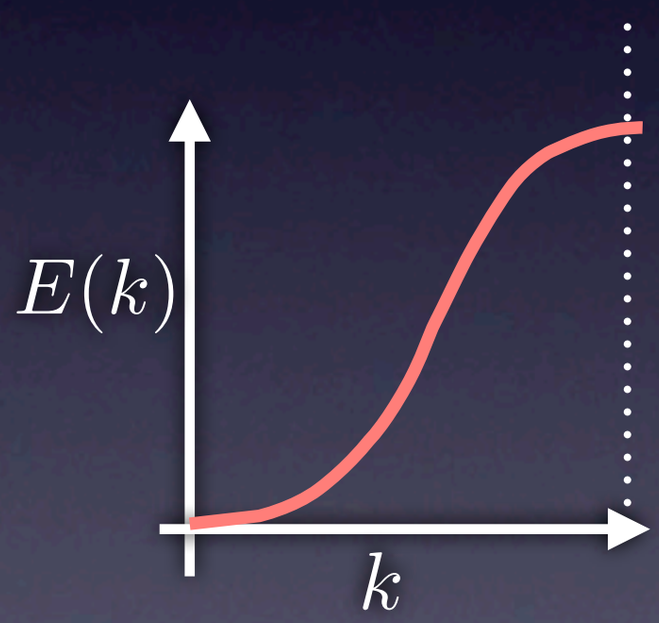


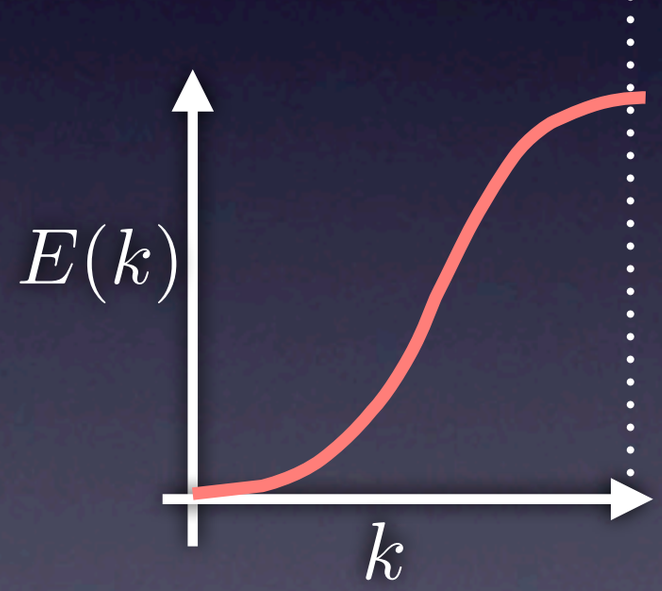
The velocity of the electrons with the greatest energy is
(B) zero, or
(C) not zero.

Question #10

In a crystal...

$$v = \frac{d\omega}{dk}$$

$$E = \hbar\omega \Rightarrow v = \frac{1}{\hbar}\frac{dE}{dk}$$



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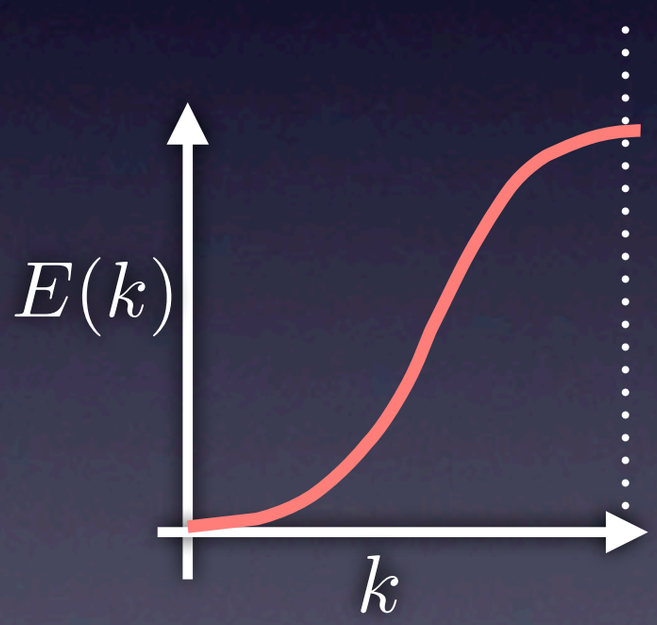
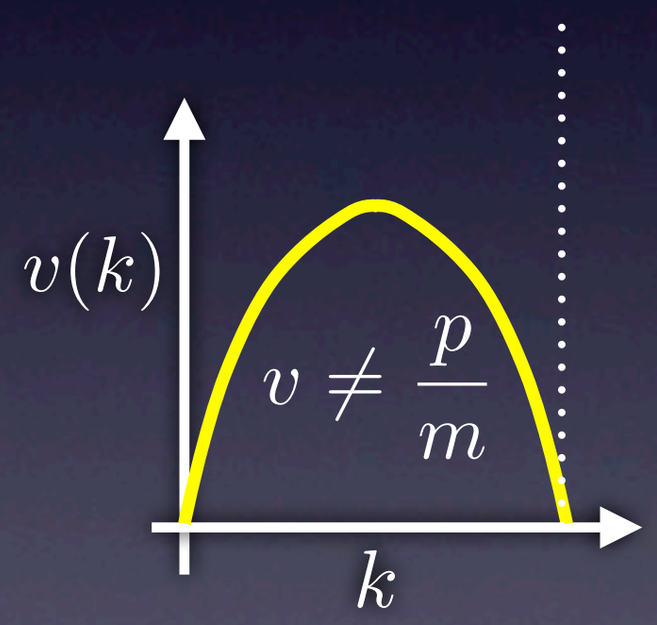




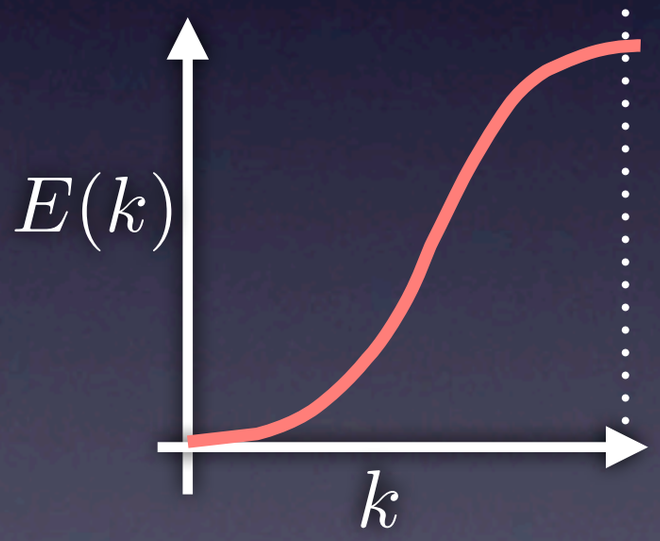
Question #10

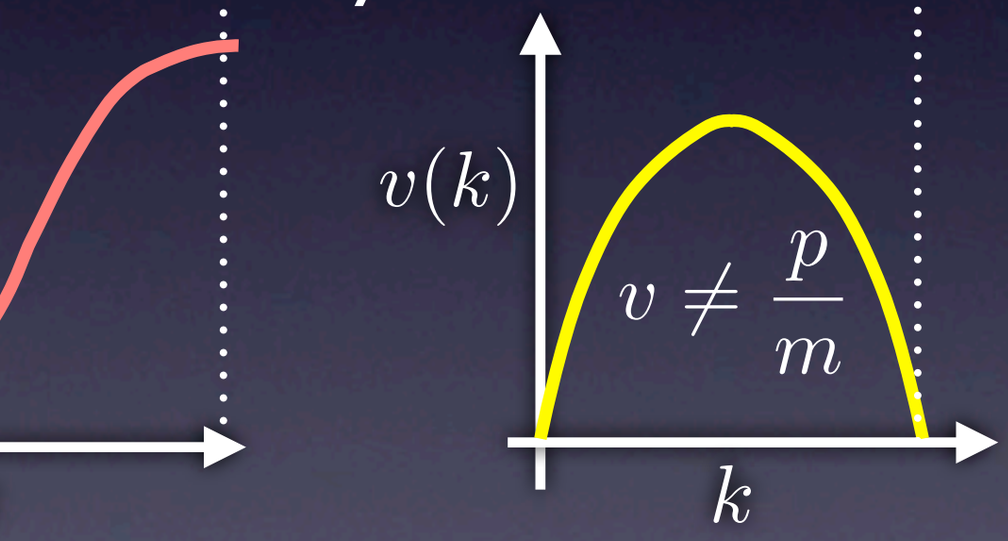
In a crystal...

$$v = \frac{d\omega}{dk}$$

$$E = \hbar\omega \Rightarrow v = \frac{1}{\hbar}\frac{dE}{dk}$$

How can the velocity be zero?





Question #10

Apply a force

$$F_{\text{ext}} = \hbar \frac{dk}{dt}$$

$$\text{free electron: } \hbar k = p \Rightarrow F_{\text{ext}} = \frac{dp}{dt} = m\frac{dv}{dt} = ma$$

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In a crystal...

Apply a force

$$F_{\text{ext}} = \hbar \frac{dk}{dt}$$

$$\text{free electron: } \hbar k = p \Rightarrow F_{\text{ext}} = \frac{dp}{dt} = m\frac{dv}{dt} = ma$$

In a crystal...

$\hbar k \neq$ momentum, F_{ext} is not total force

But applying an external force causes the k-vector to change with time. So the electron is "moving in k space."

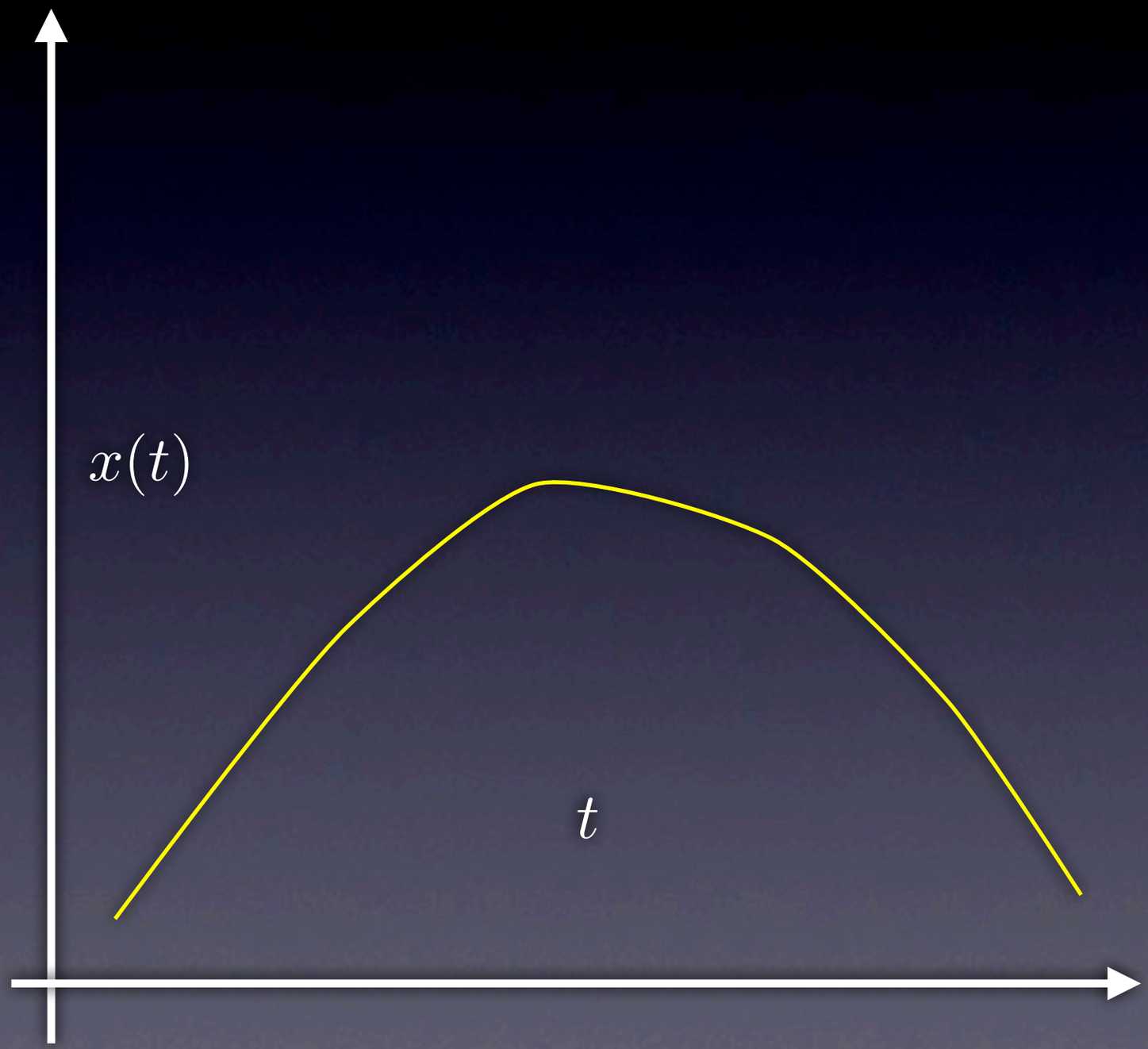
$$F_{\text{ext}} = \hbar \frac{dk}{dt}$$

What does it mean for an electron to "move in k-space"?

But applying an external force causes the k-vector to change with time. So the electron is "moving in k space."

$$F_{\text{ext}} = \hbar \frac{dk}{dt}$$

What does a graph represent?



Question #11

x represents the horizontal position of a car.
Which of the following is true?

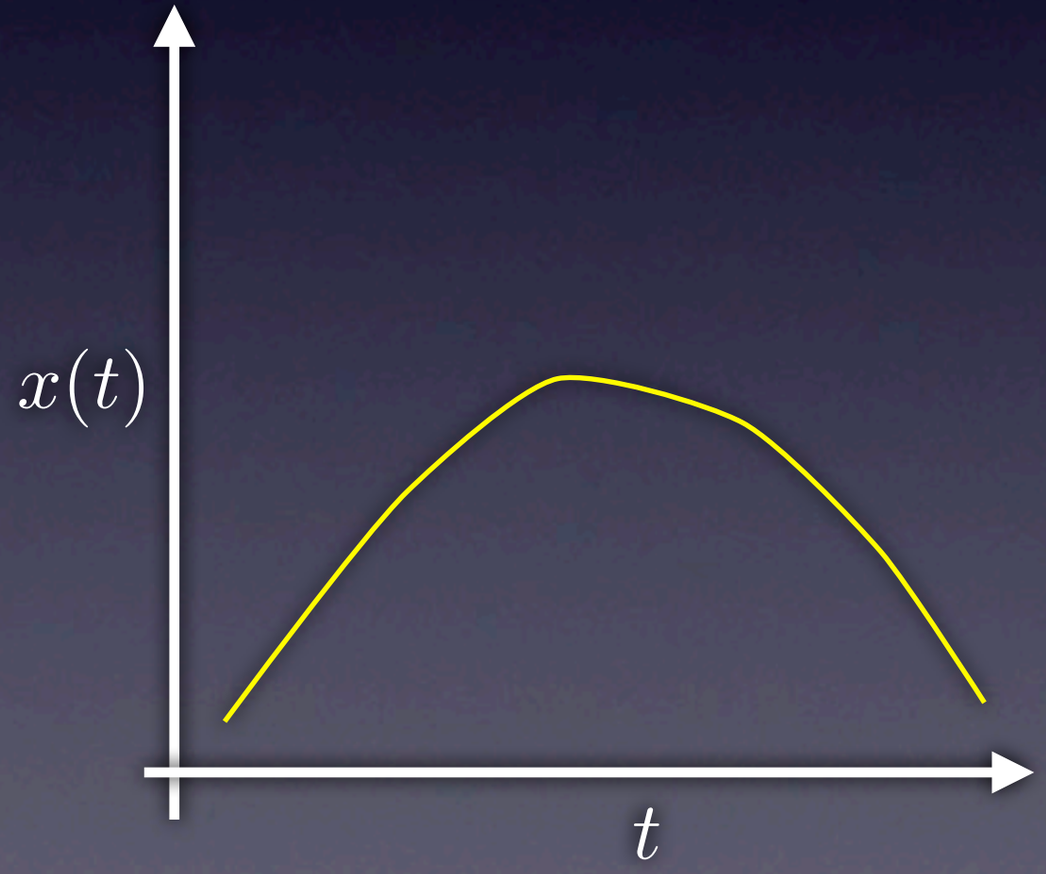
(A) The car went over a hill.

(B) The force on the car was zero during the entire interval.

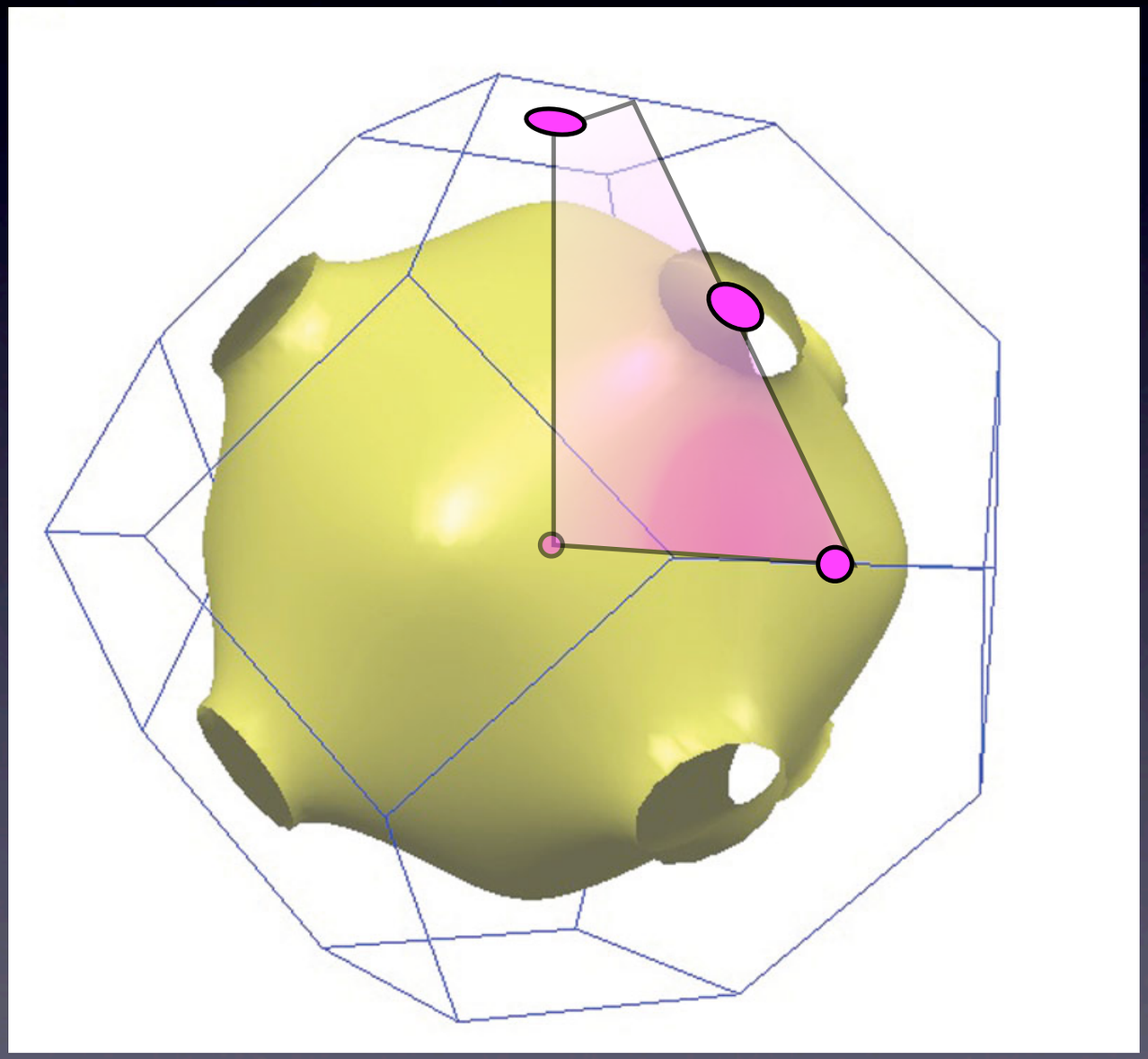
(C) The car was moving to the right the whole time but sped up and then slowed down.

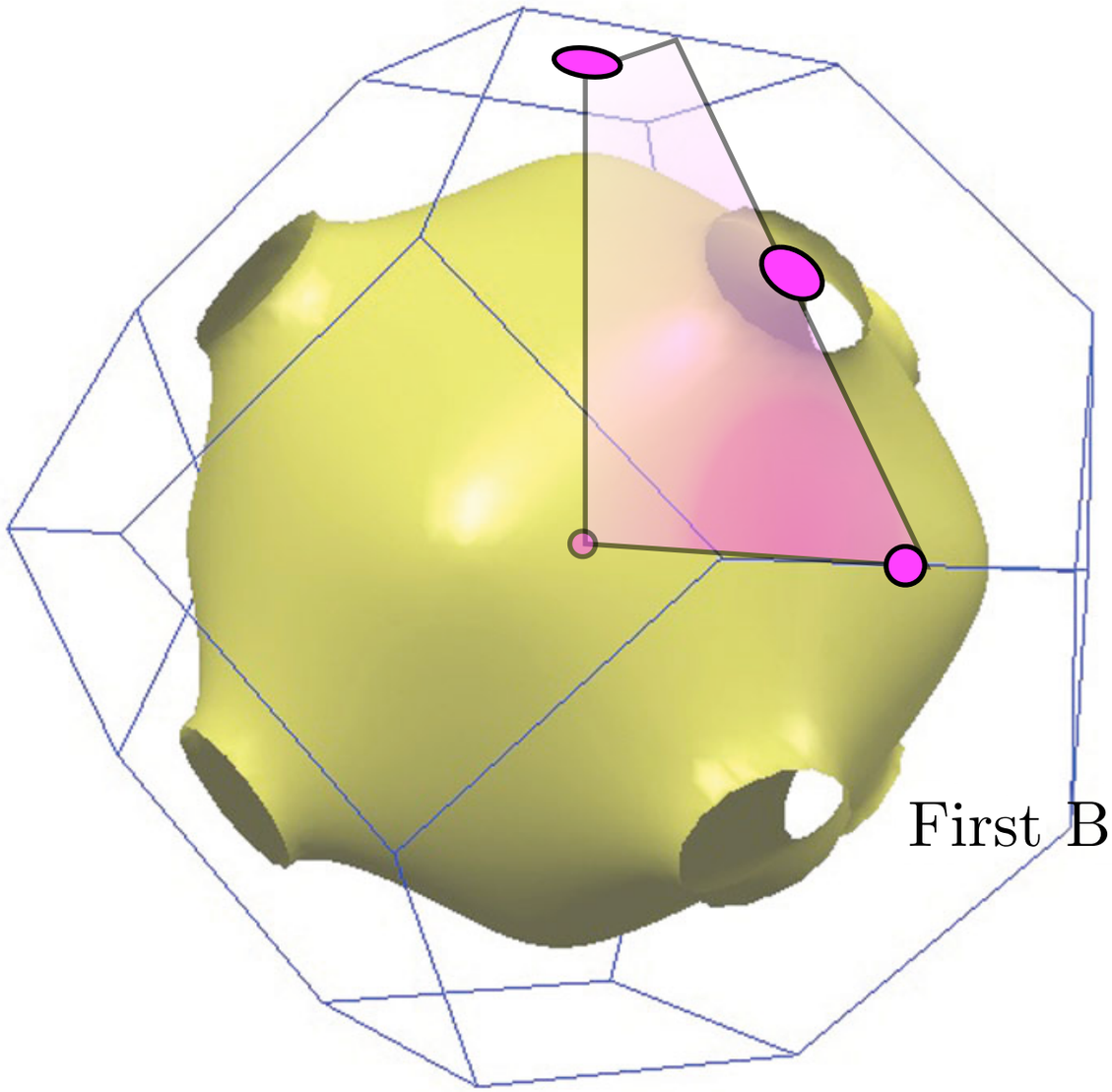
(D) The velocity of the car was positive during the whole interval.

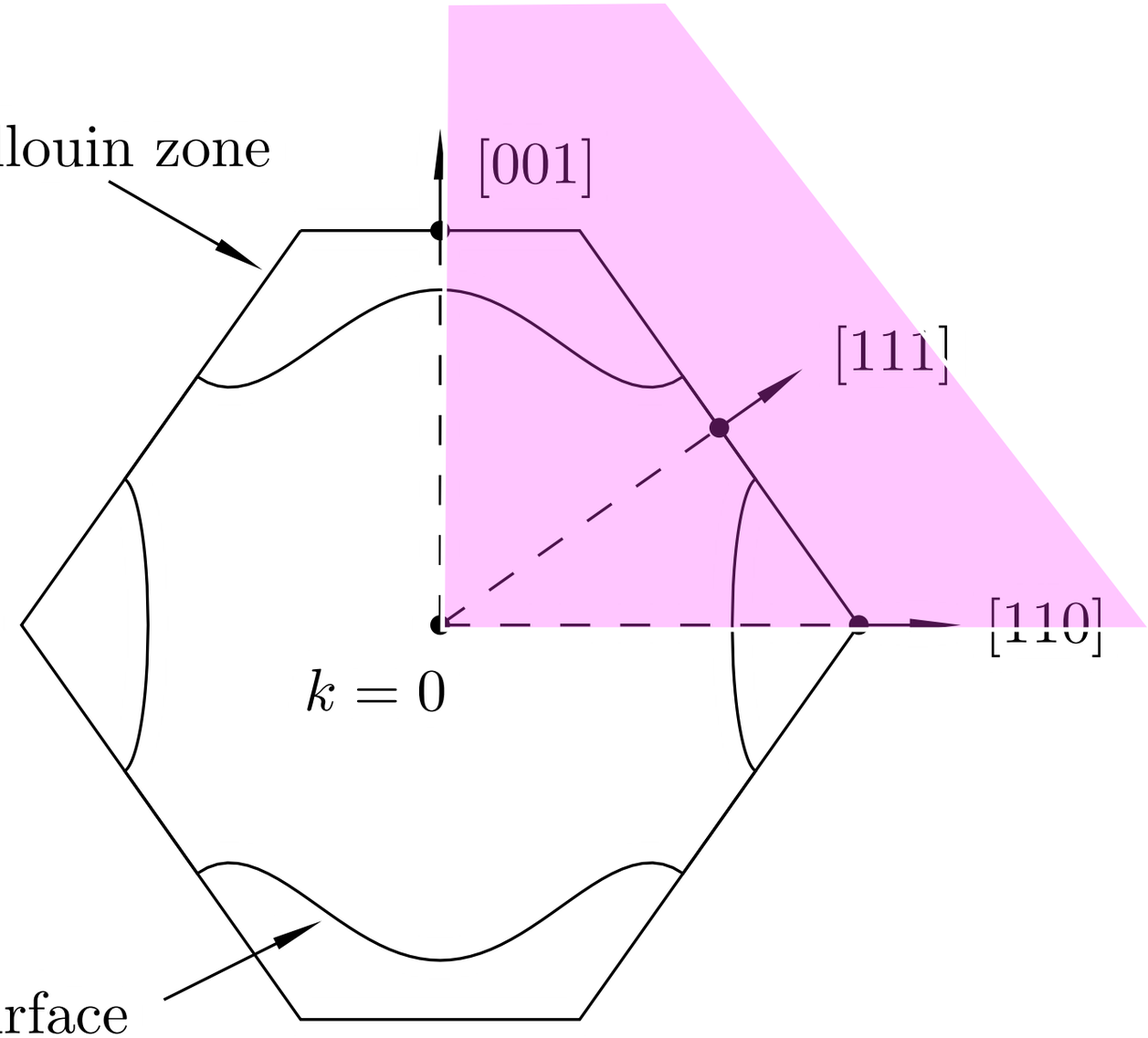
(E) The car moved to the right, then to the left.



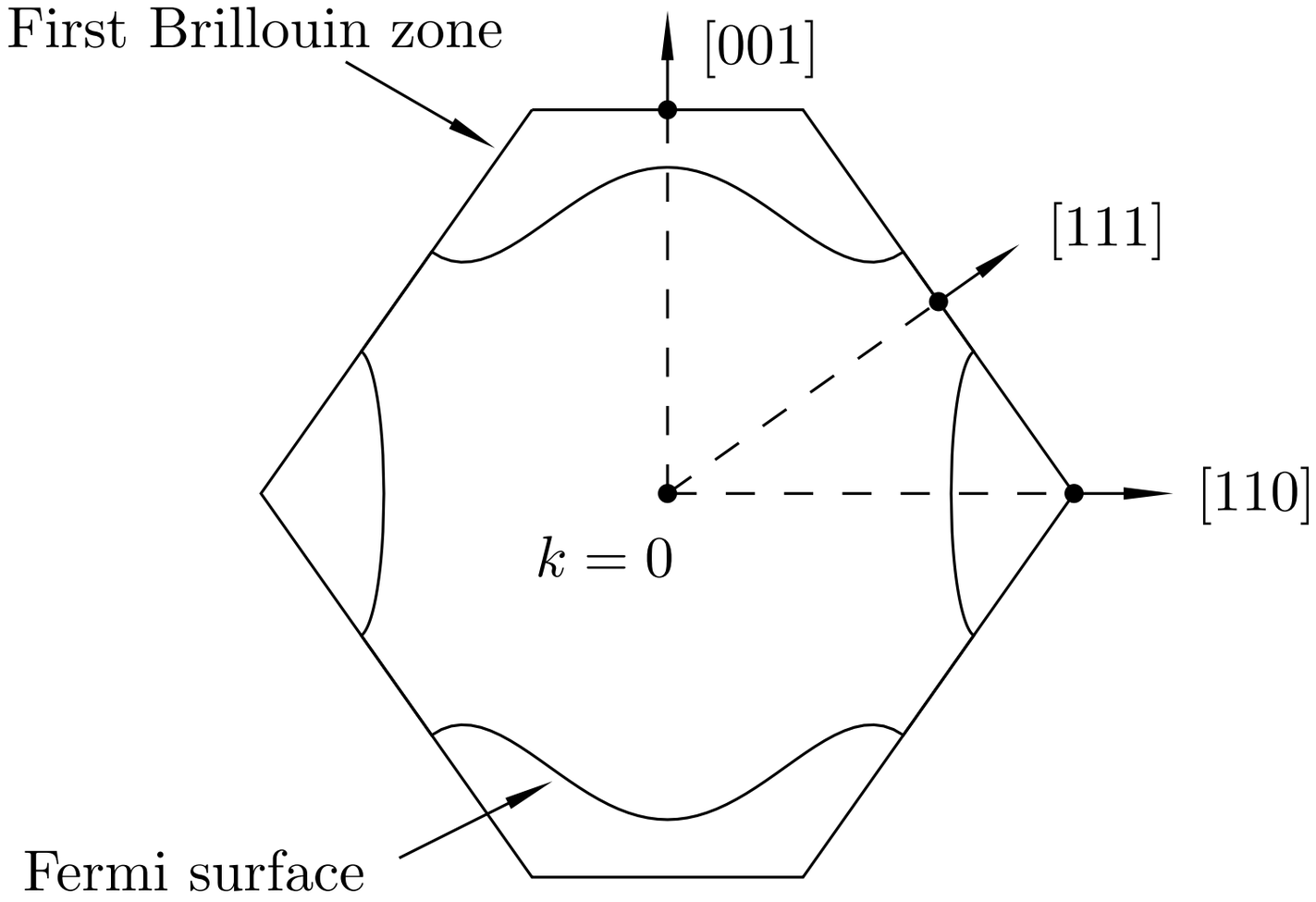
Fermi Surface of Cu






First Brillouin zone
[001]
[111]
[110]
$k = 0$
Fermi surface

What does it mean for an electron to "move in k-space"?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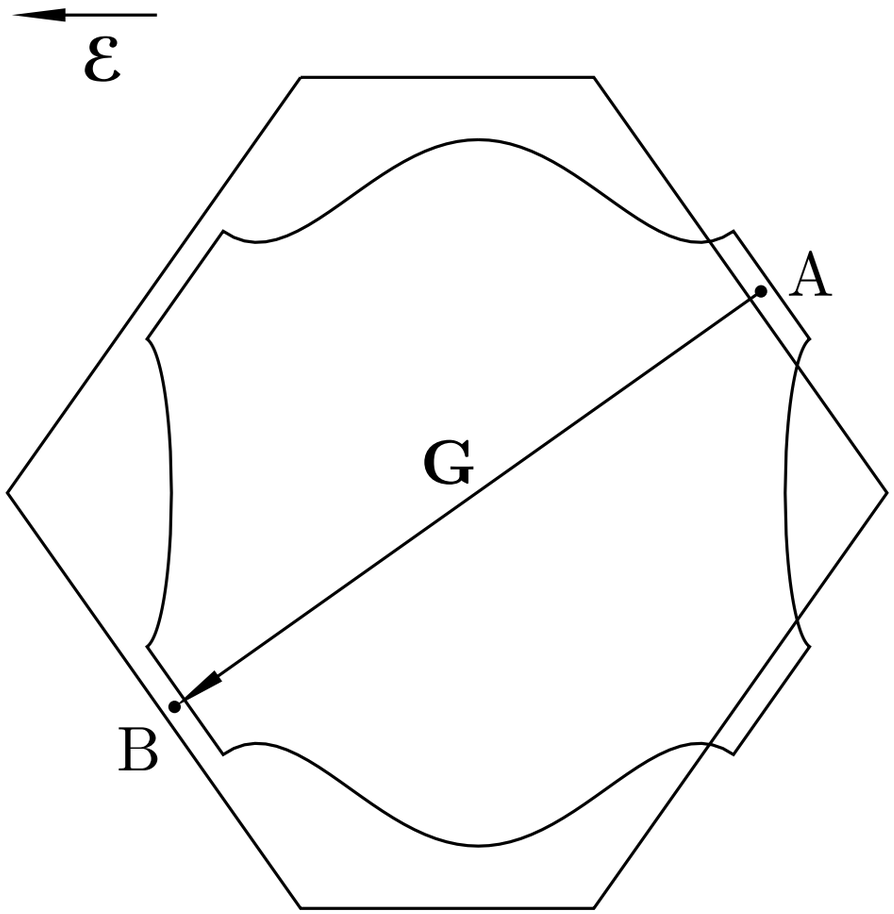
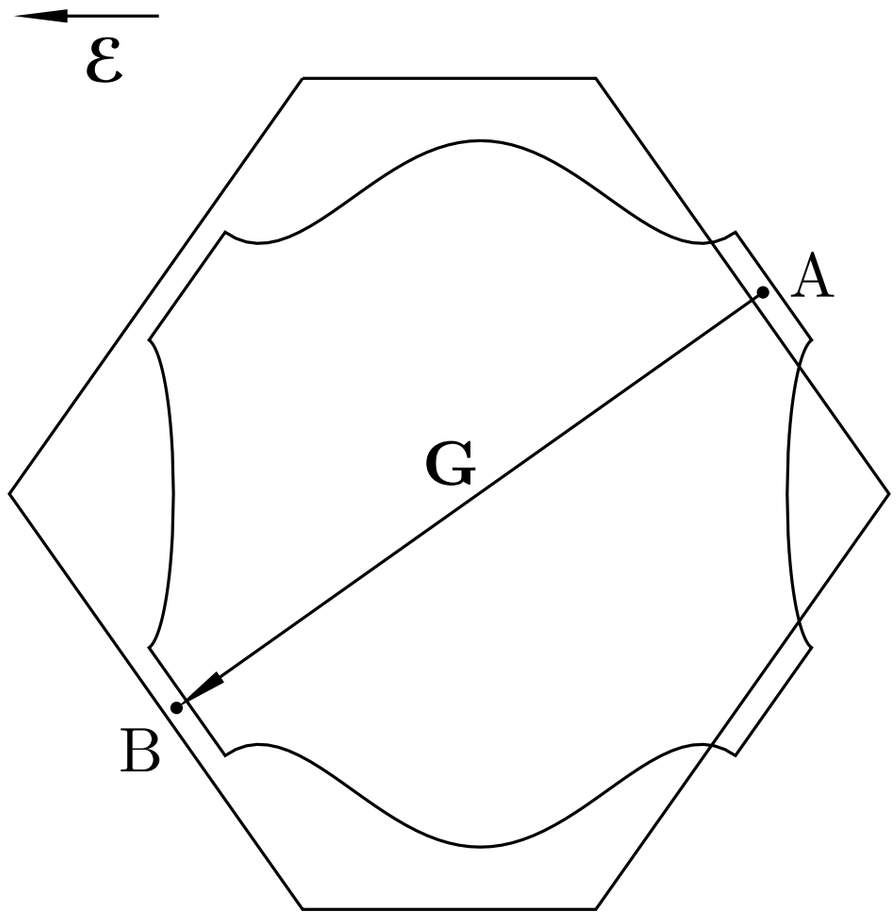
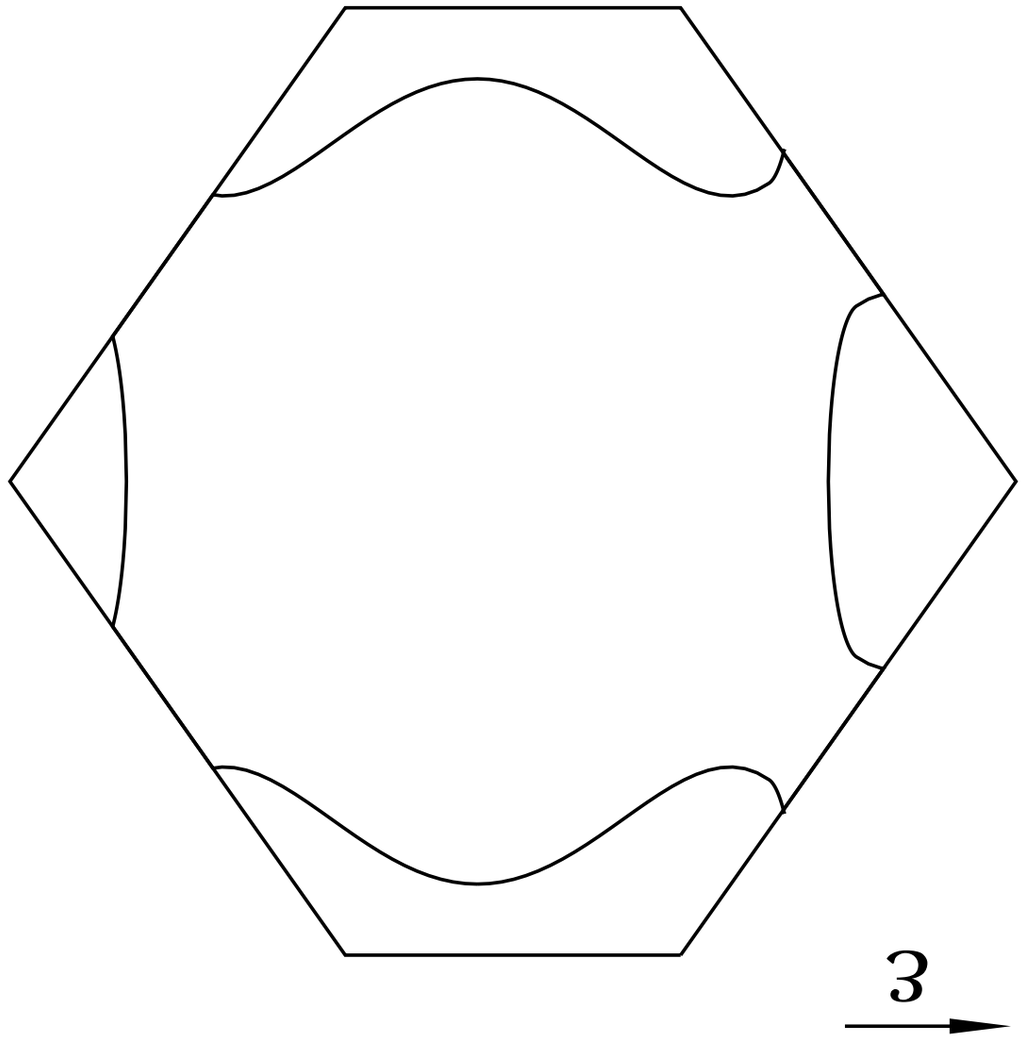

ε
A
G
B

What is happening to the electrons?

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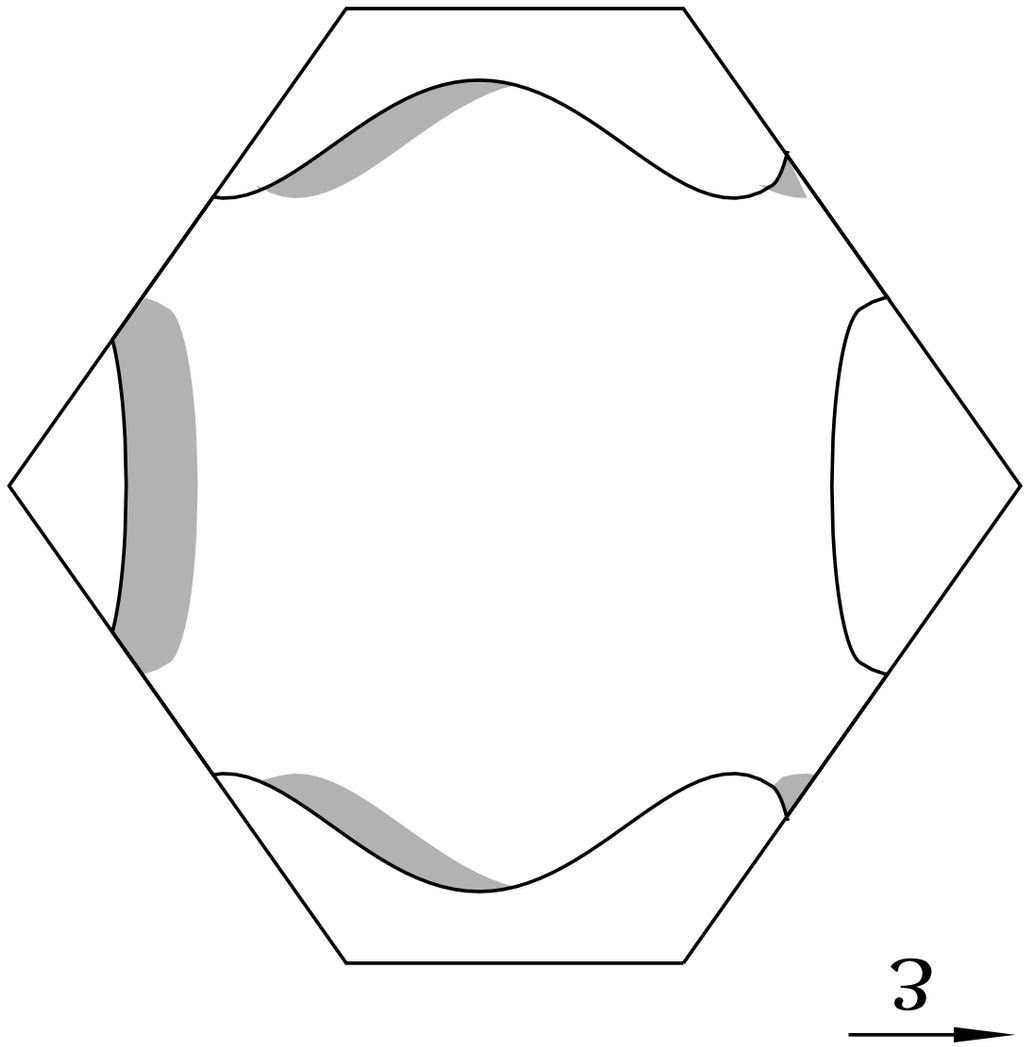
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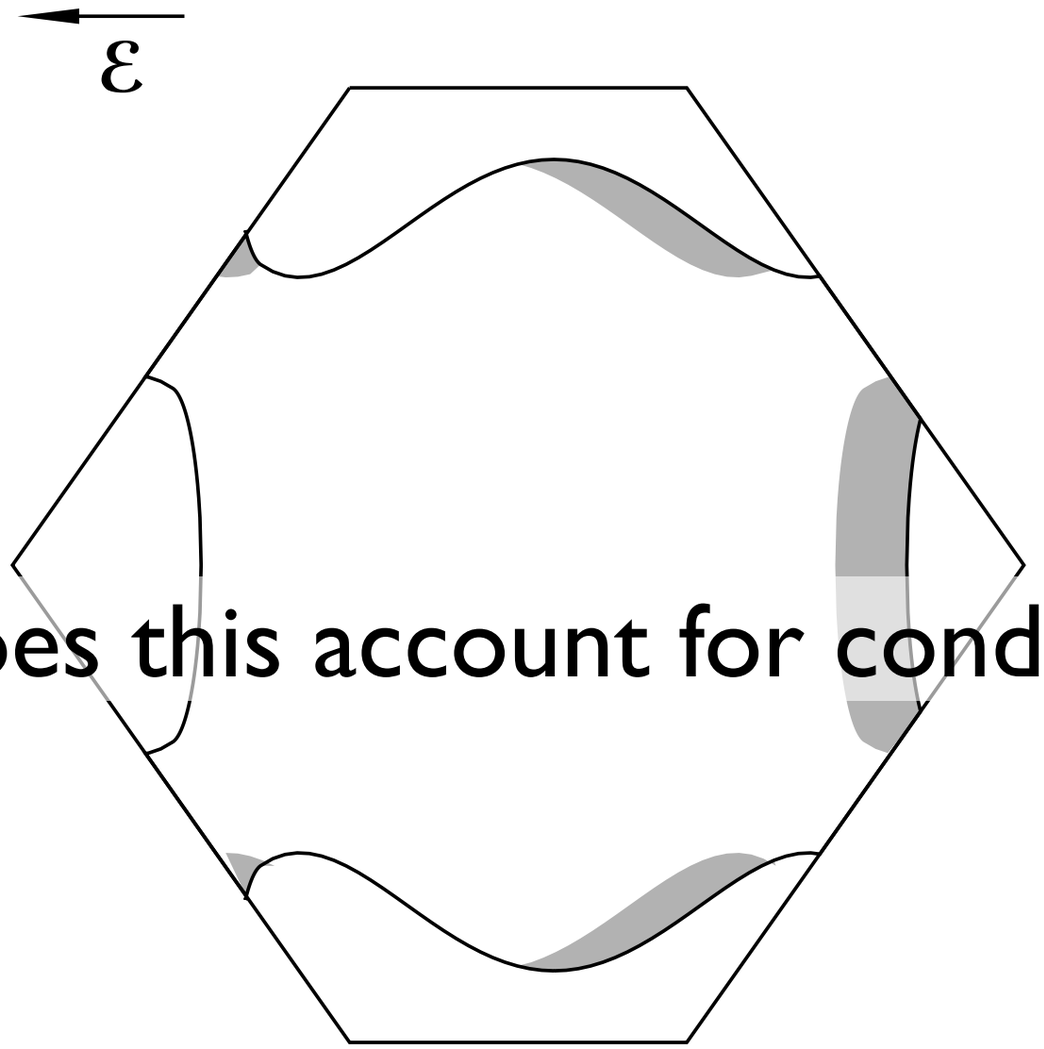
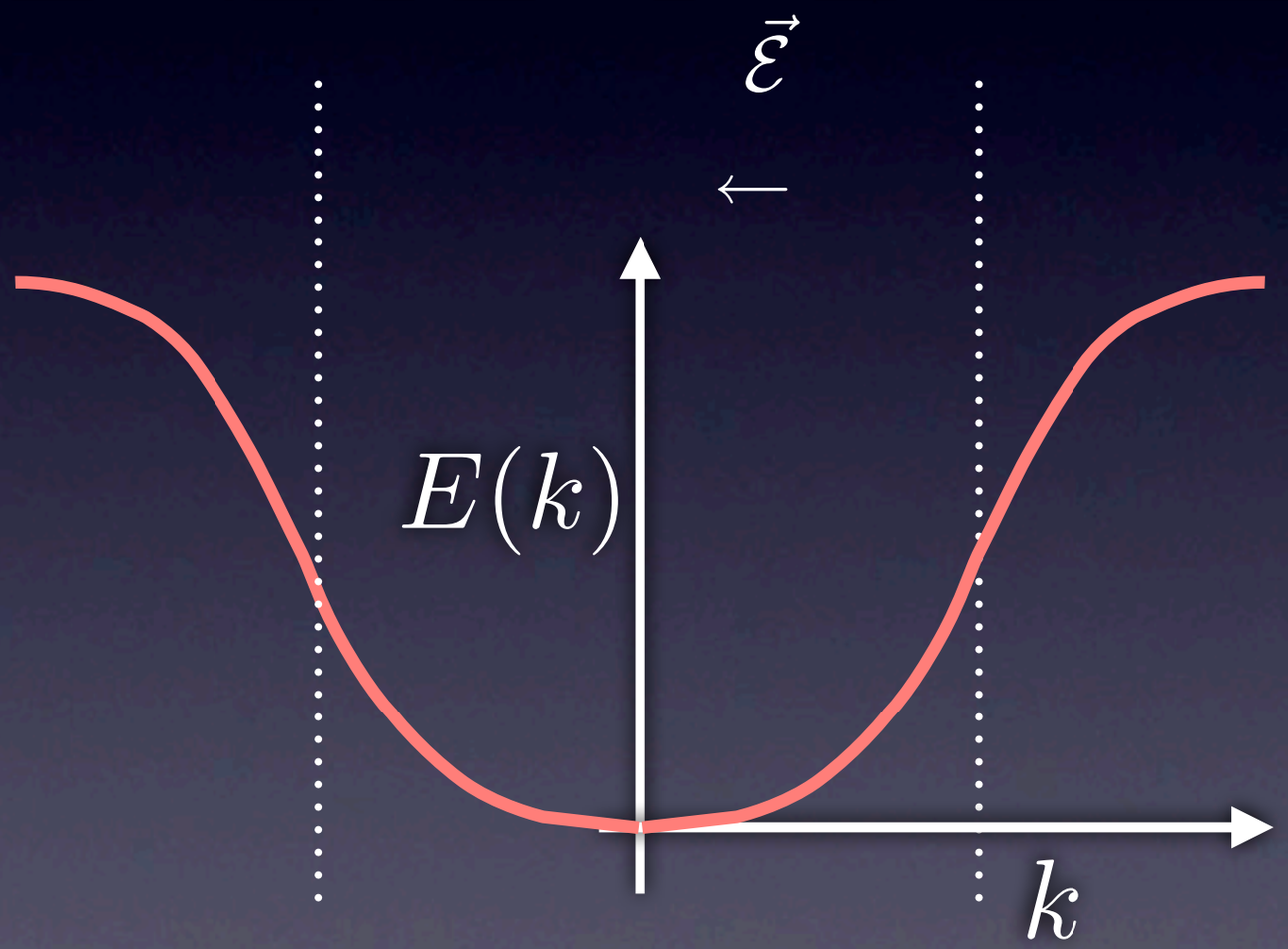


How does this account for conductivity?

What happens if a band is full?



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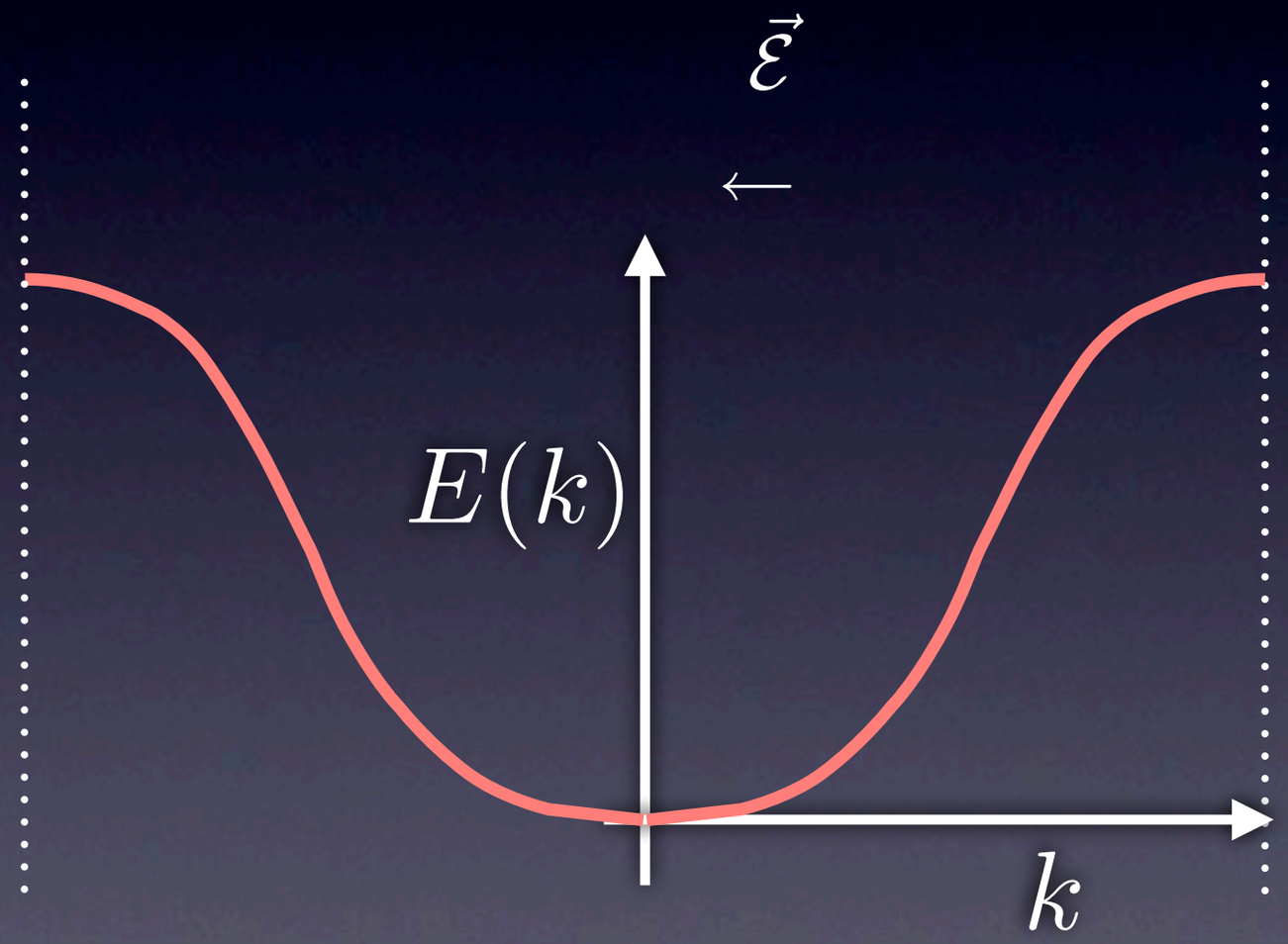

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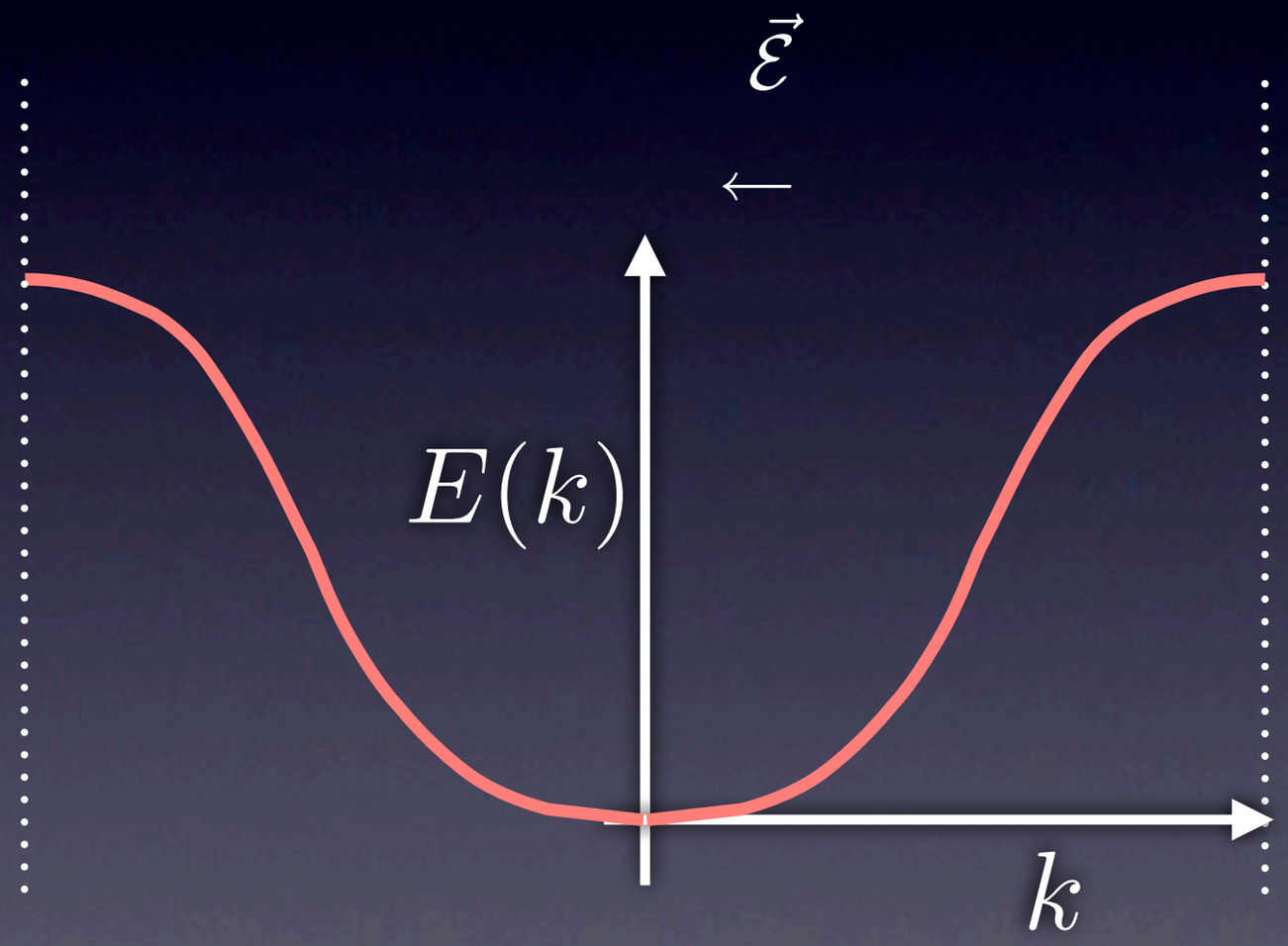
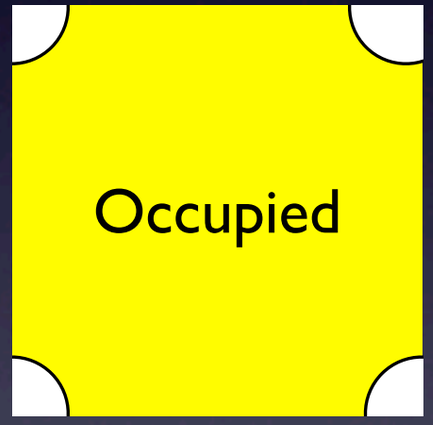


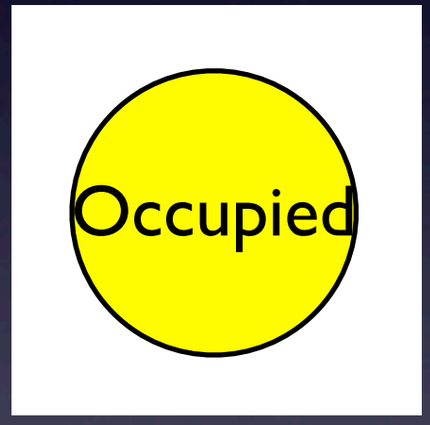
What happens to the conduction?

Consider the conduction bands below. Each square represents the first Brillouin zone. Which band contains the most electrons?

Question #12



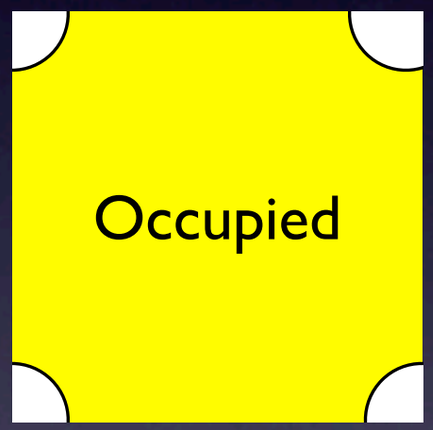
(A)



(B)

Question #13

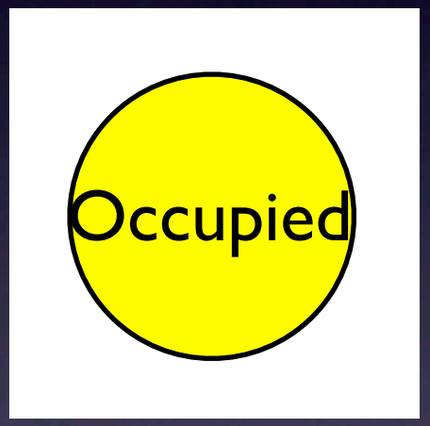
Consider the conduction bands below. Each square represents the first Brillouin zone. If we apply the same electric field to each band, which band will produce the most current?



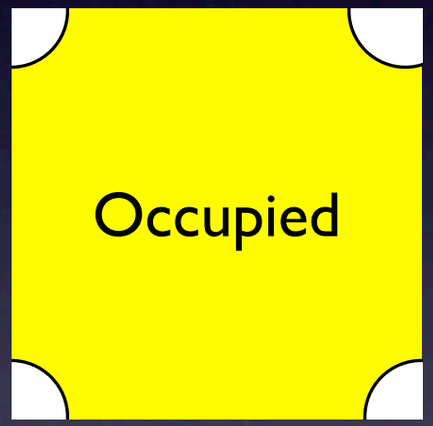
(D)

(E)

Two bands...



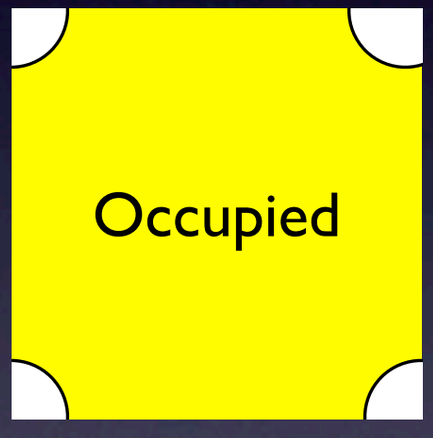
half full



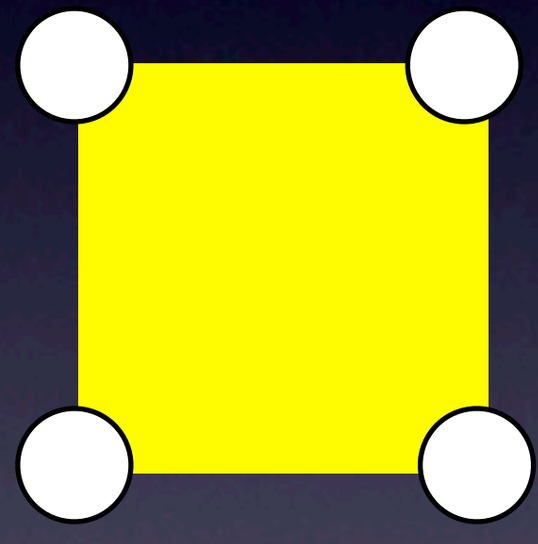
almost full

Two bands...

half full



almost full



Which of the following has the greatest influence on how much current will flow through a metal if an electric field is applied?

(A) the number of conduction electrons
(B) number of conduction electrons with energies close to the Fermi energy
(C) the volume of states enclosed by the Fermi surface

Classical vs. Quantum Model

Classical vs. Quantum Model

$$\sigma = \frac{ne^2\tau}{m}$$

Classical vs. Quantum Model

$$\sigma = \frac{ne^2\tau}{m}$$

$$\sigma \propto n$$

Classical vs. Quantum Model

$$\sigma = \frac{ne^2\tau}{m}$$

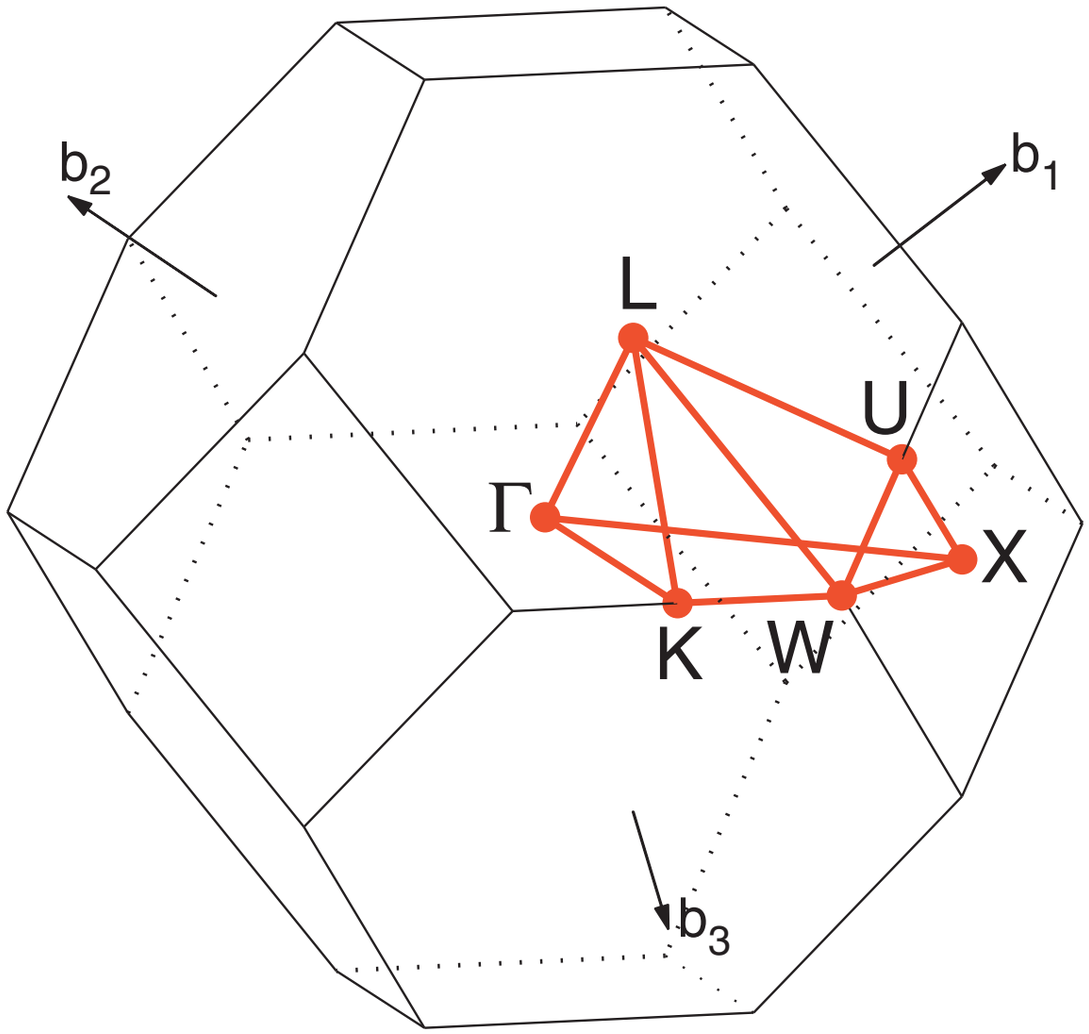
$$\sigma \not\propto n$$

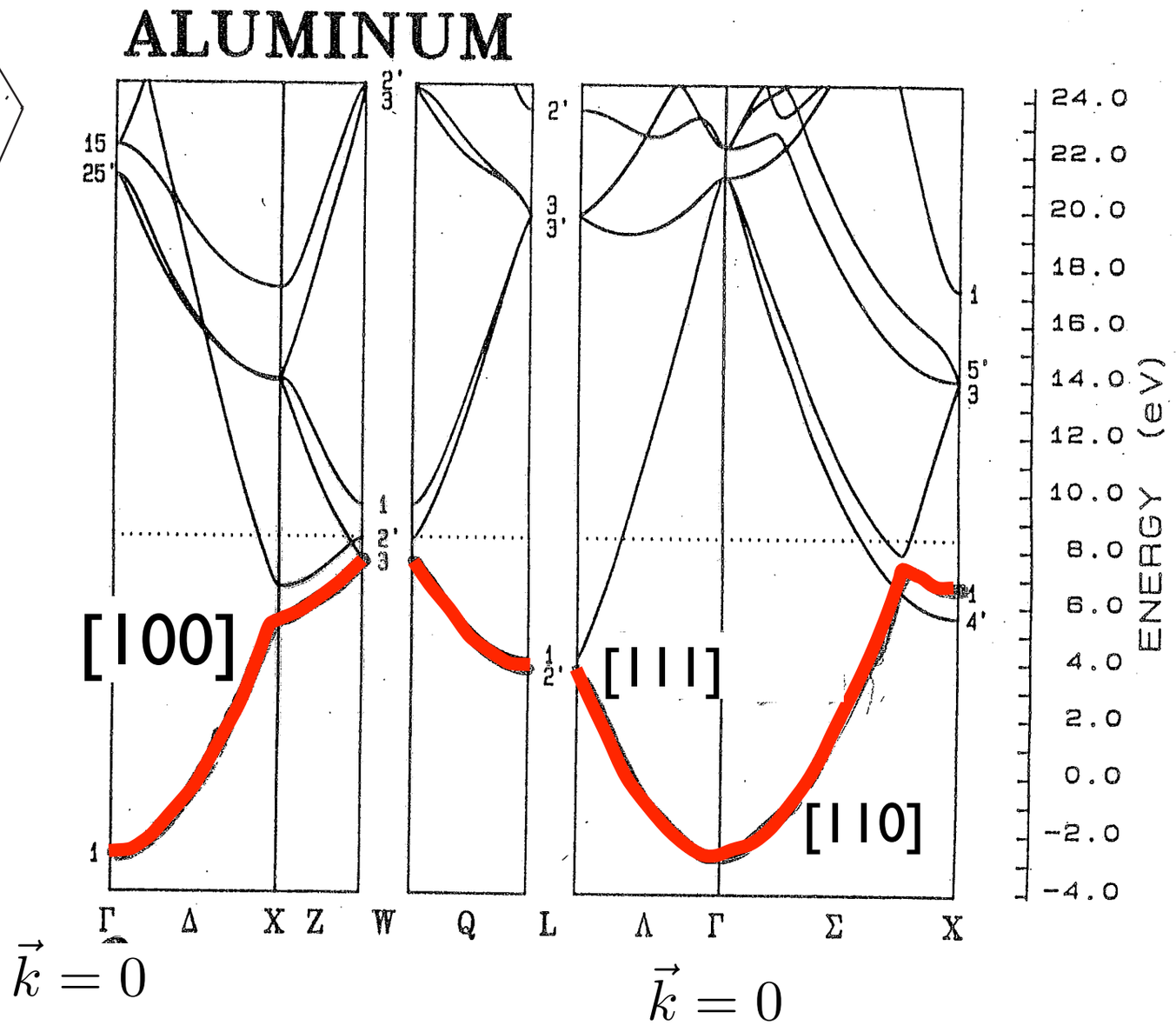
Classical vs. Quantum Model

$$\sigma = \frac{ne^2\tau}{m}$$

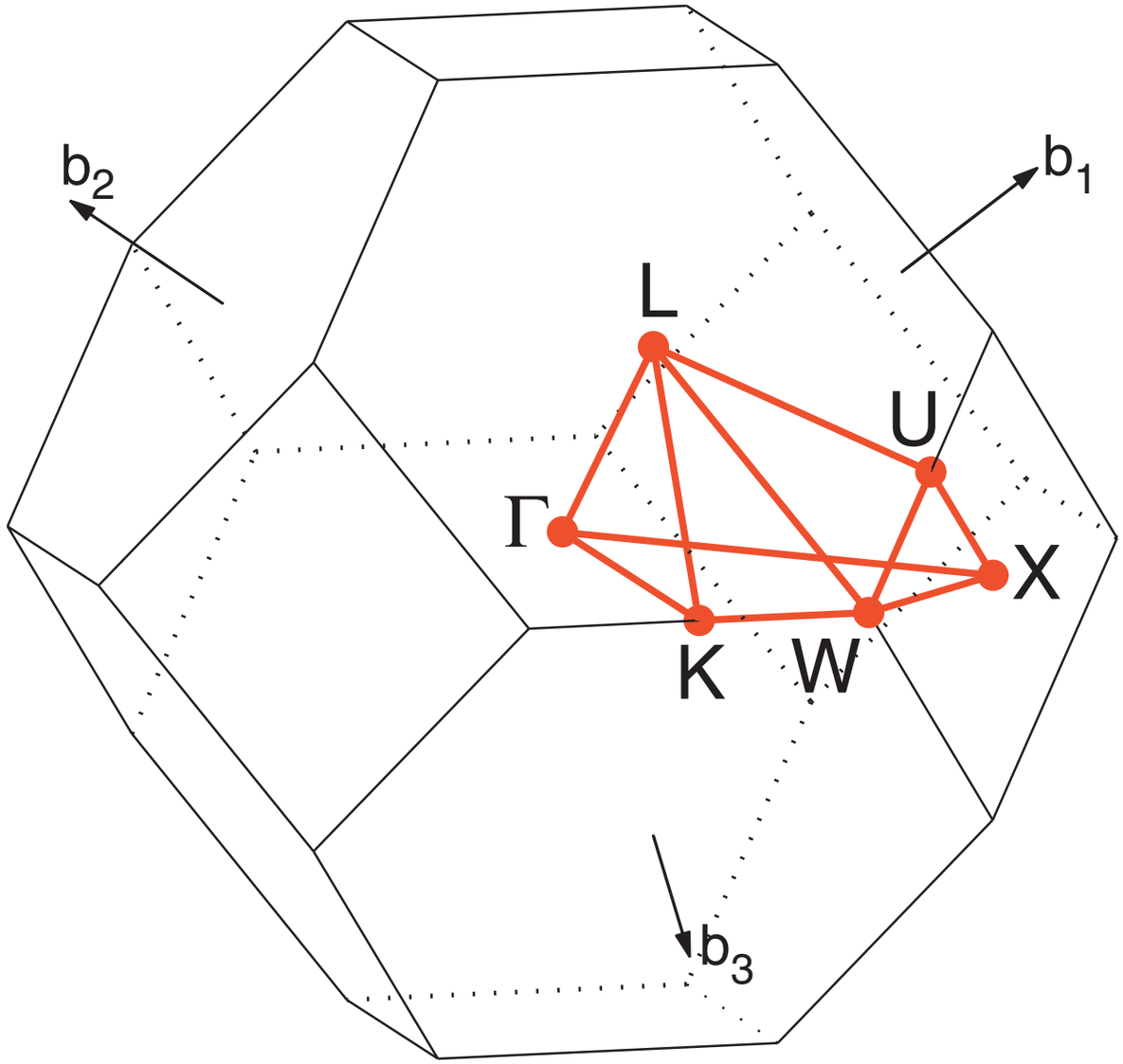
$$\sigma \not\propto n$$

$$\sigma \propto A_{\mathrm{FS}}$$

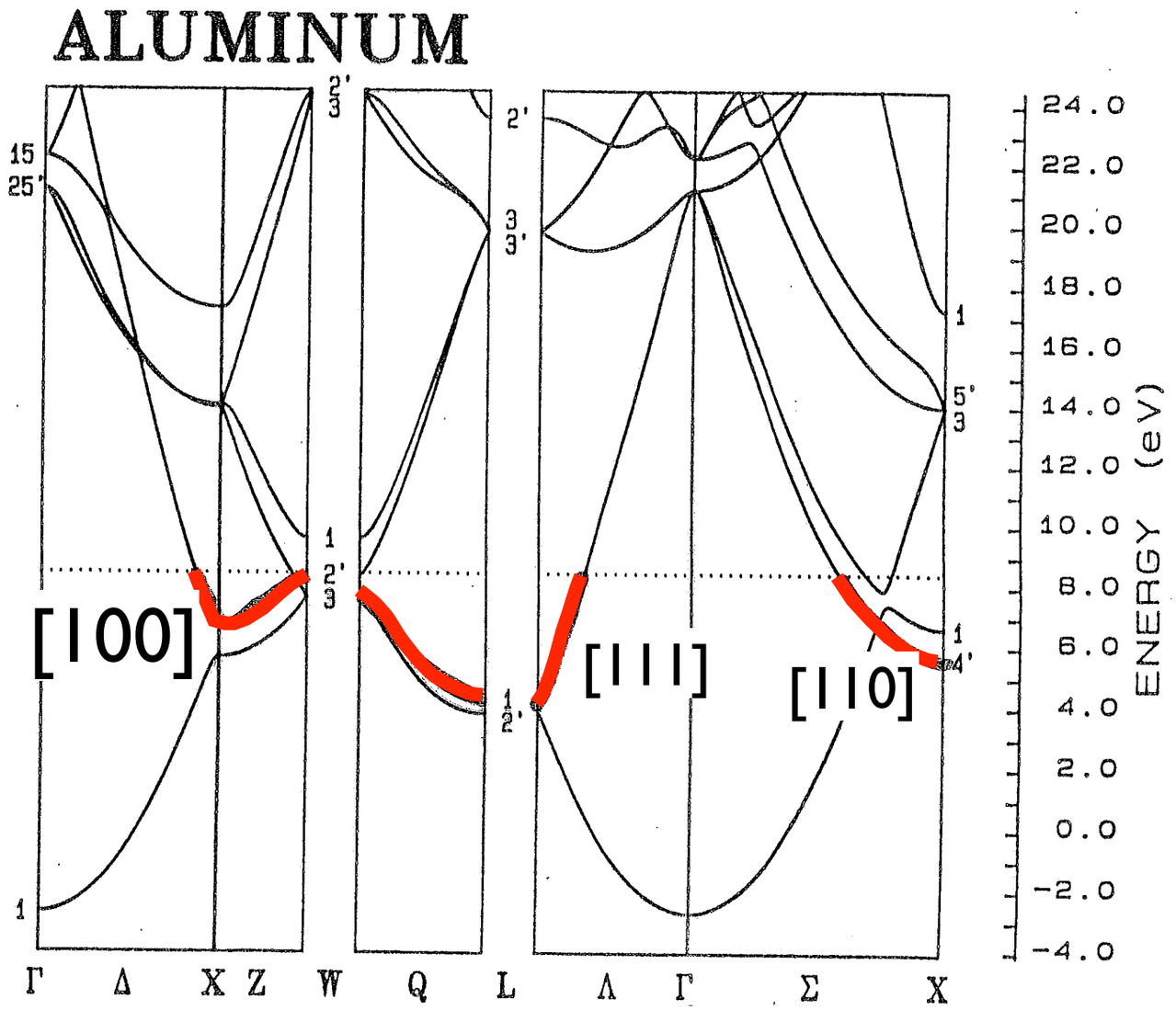

b2
b1
b3
L
U
Γ
X
K
W


ALUMINUM
[100]
[111]
[110]
Γ Δ X Z W Q L Λ Γ Σ X
ENERGY (eV)
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0

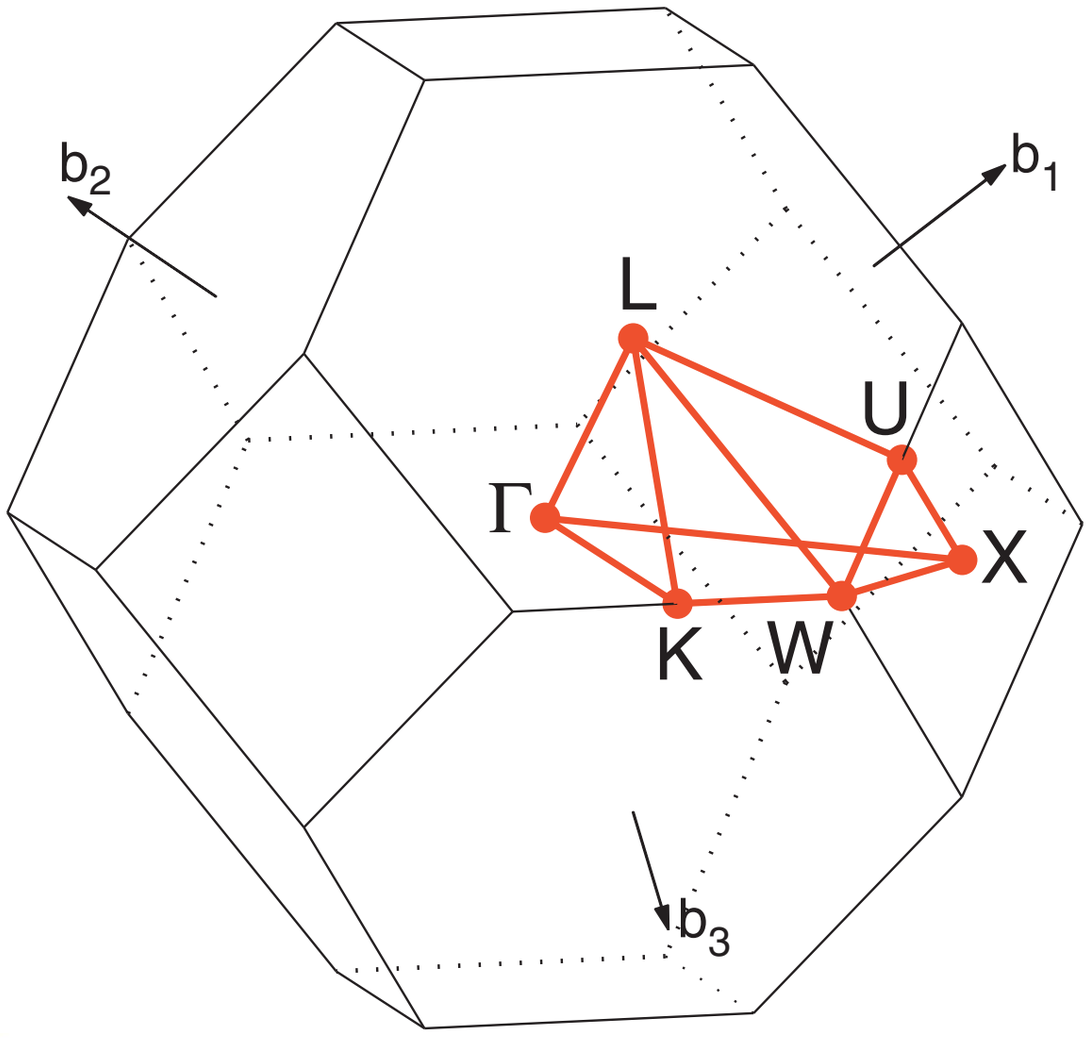
$\vec{k} = 0$ $\vec{k} = 0$


b2
b1
b3
L
U
Γ
X
K
W

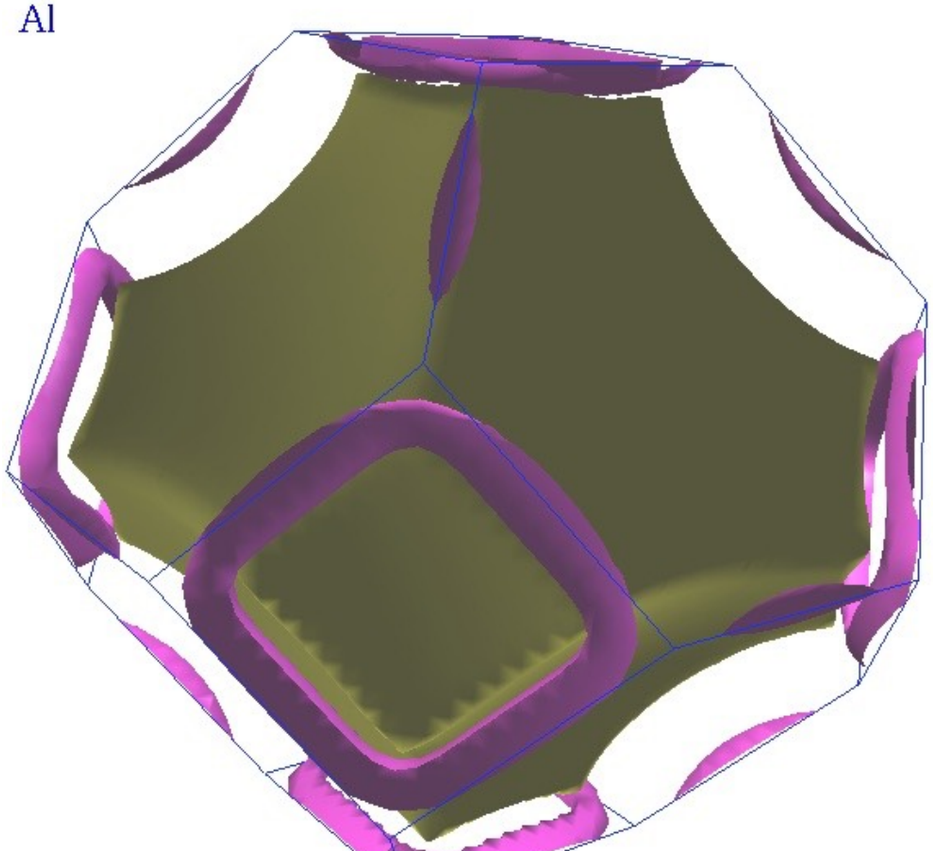
$\vec{k} = 0$

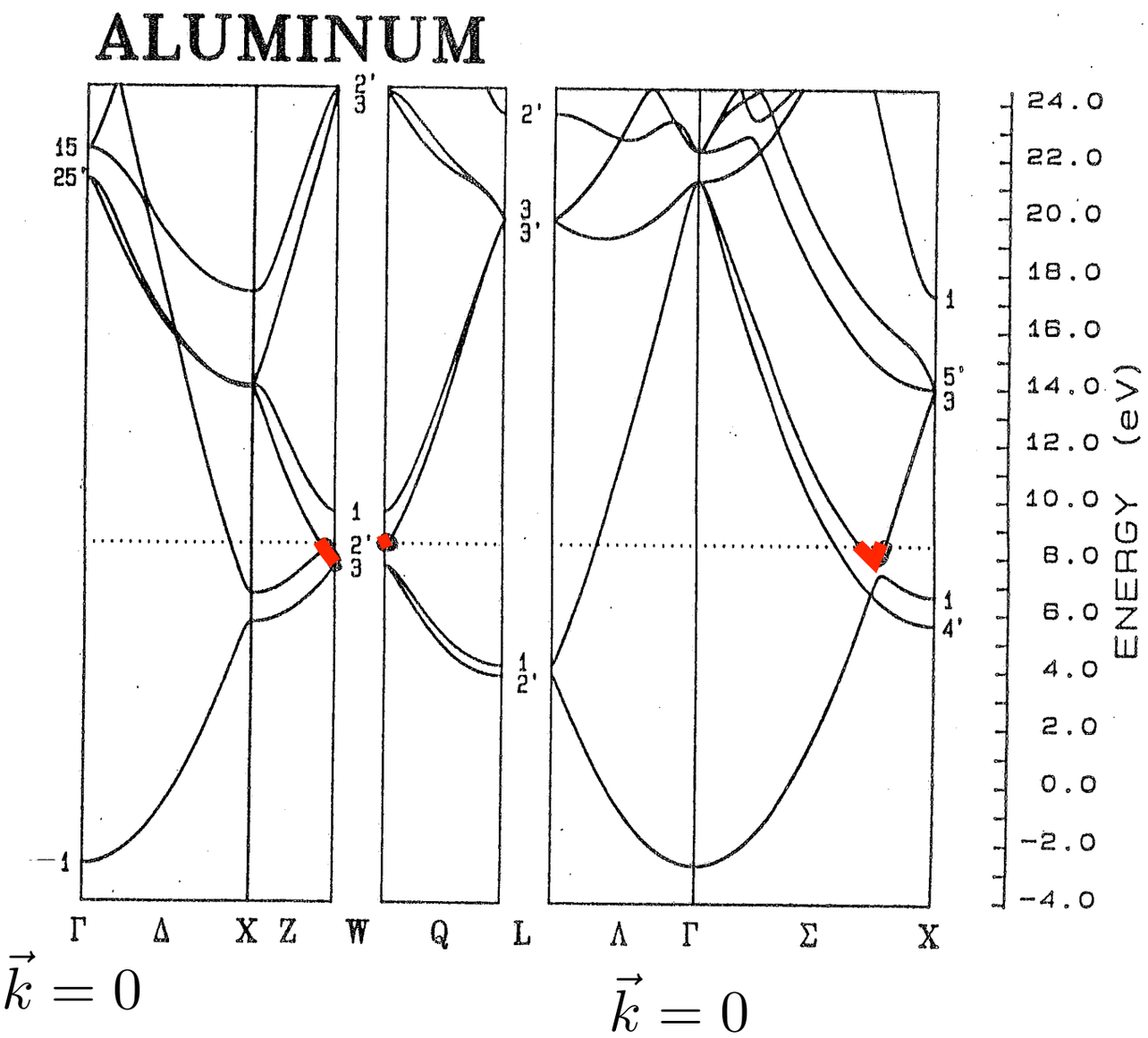

ALUMINUM
[100]
[111]
[110]
Γ Δ X Z W Q L Λ Γ Σ X
ENERGY (eV)
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0

$\vec{k} = 0$

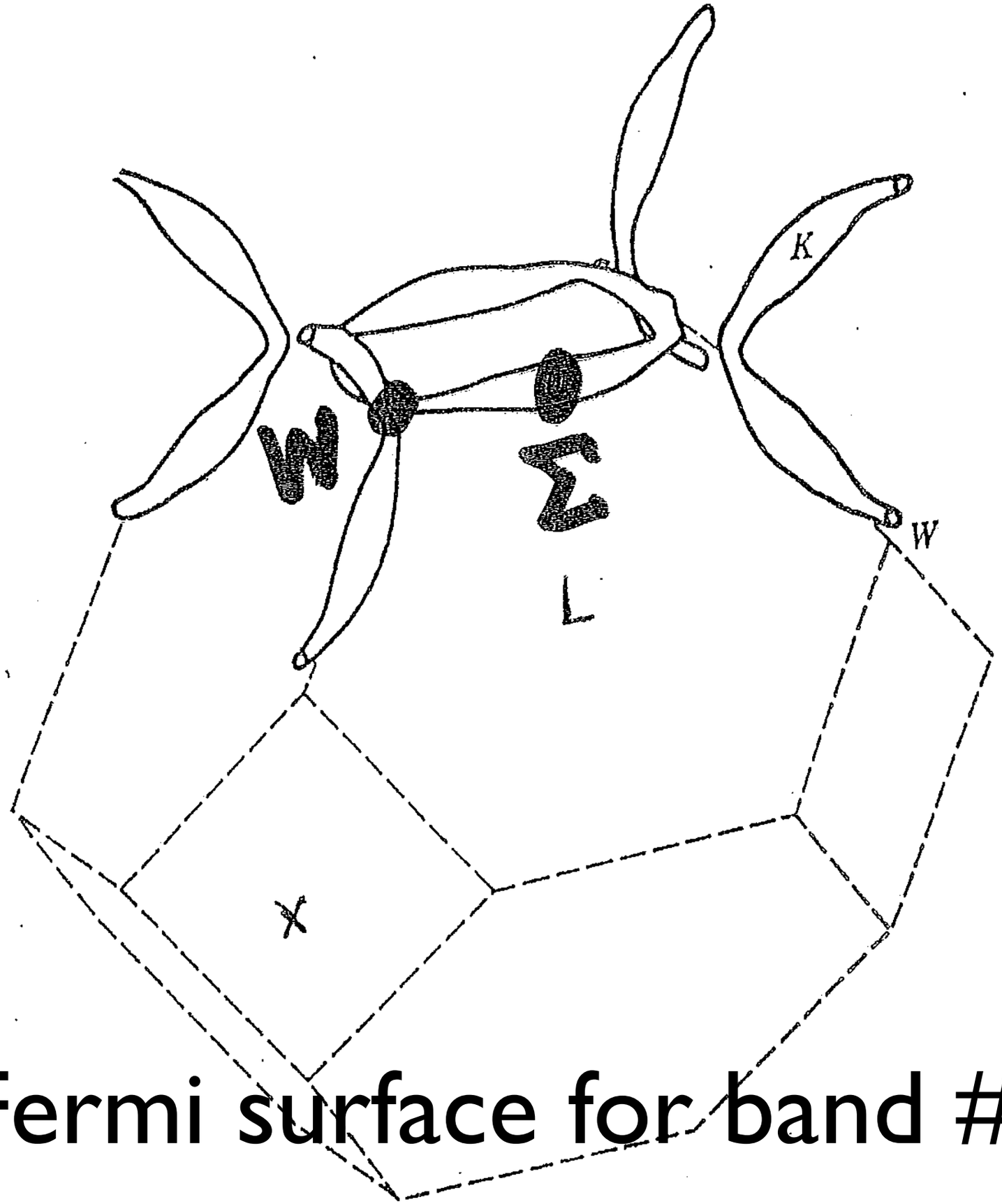


Al





$\vec{k} = 0$ $\vec{k} = 0$



Fermi surface for band #3

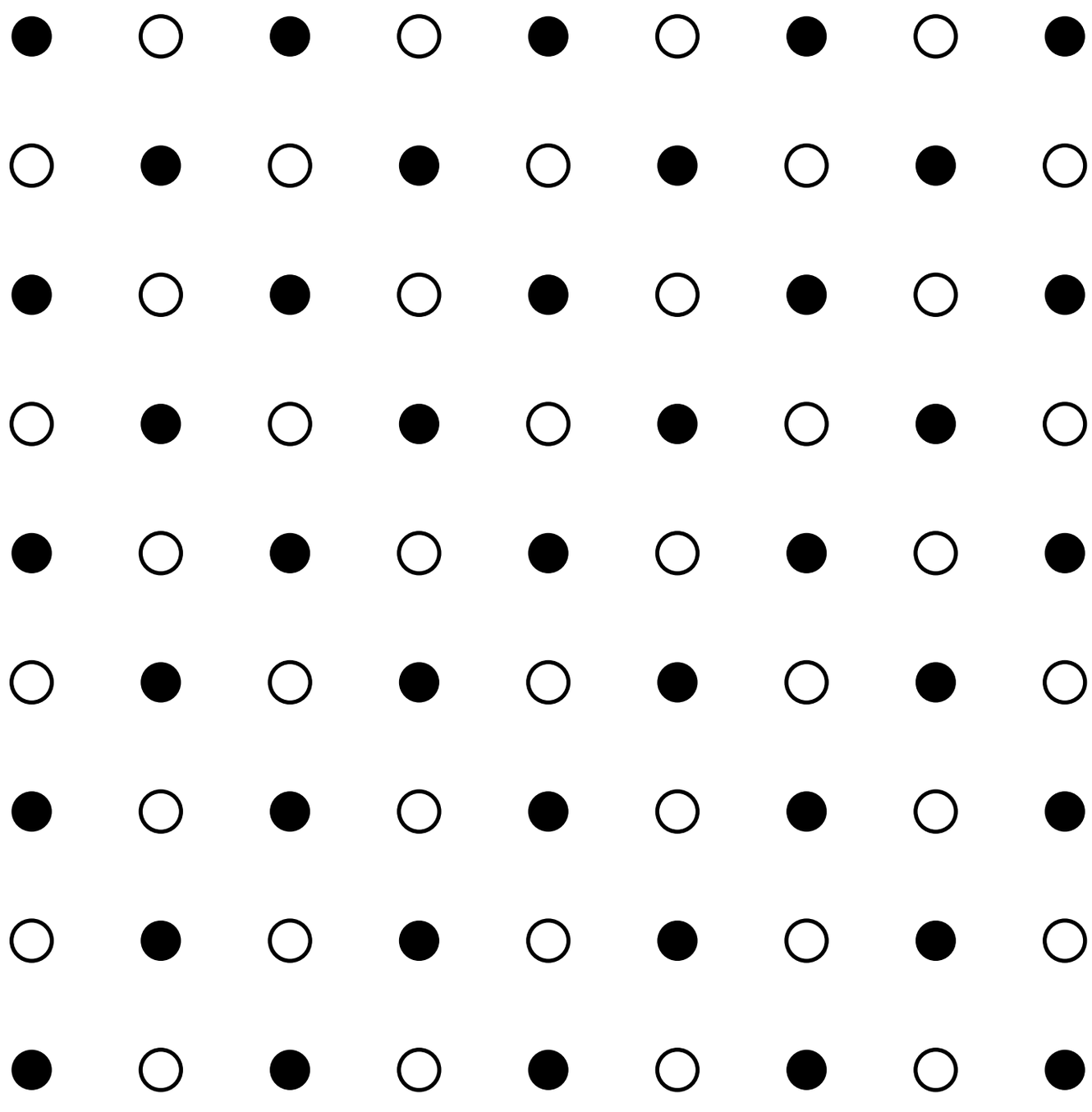
Question #15

This material:

b) must be an insulator

c) may be a metal

d) must be a metal



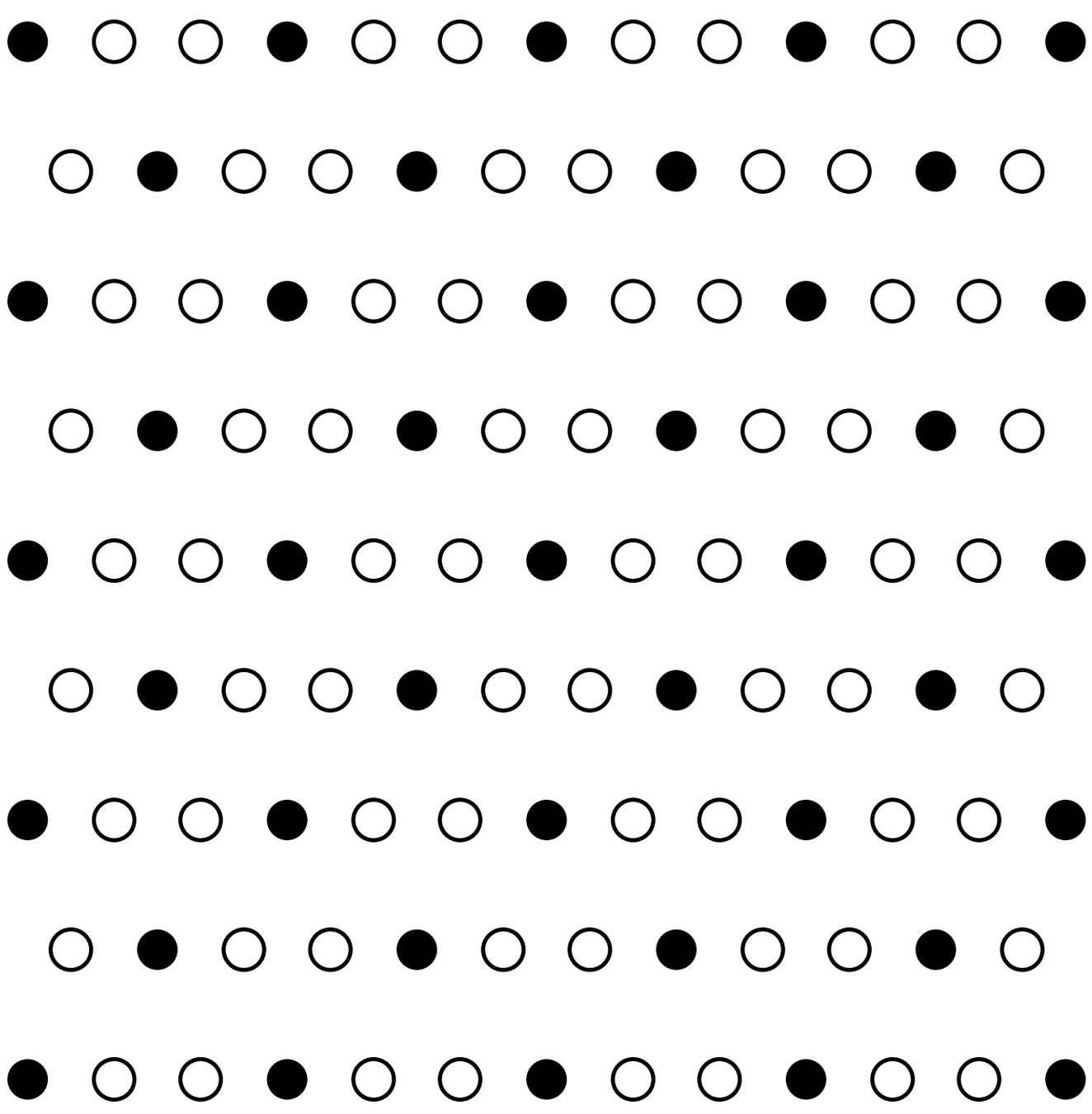
● 5 electrons

○ 12 electrons

Question #16

This material:

a) must be a metal
b) must be an insulator
c) may be a metal



● 5 electrons

○ 12 electrons

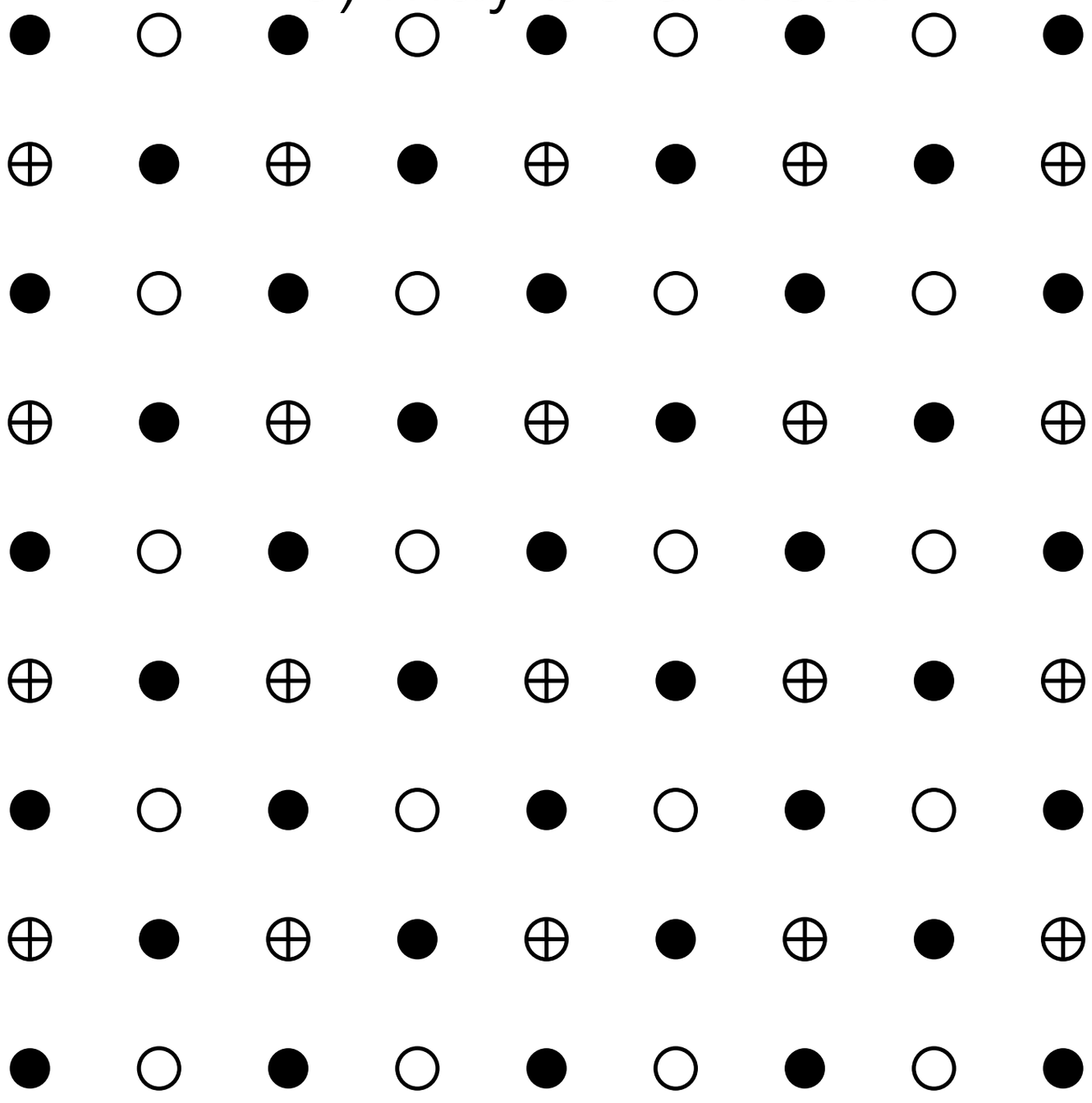
Question #17

This material:

a) must be a metal

b) must be an insulator

c) may be a metal



● 5 electrons

⊕ 12 electrons

○ 10 electrons