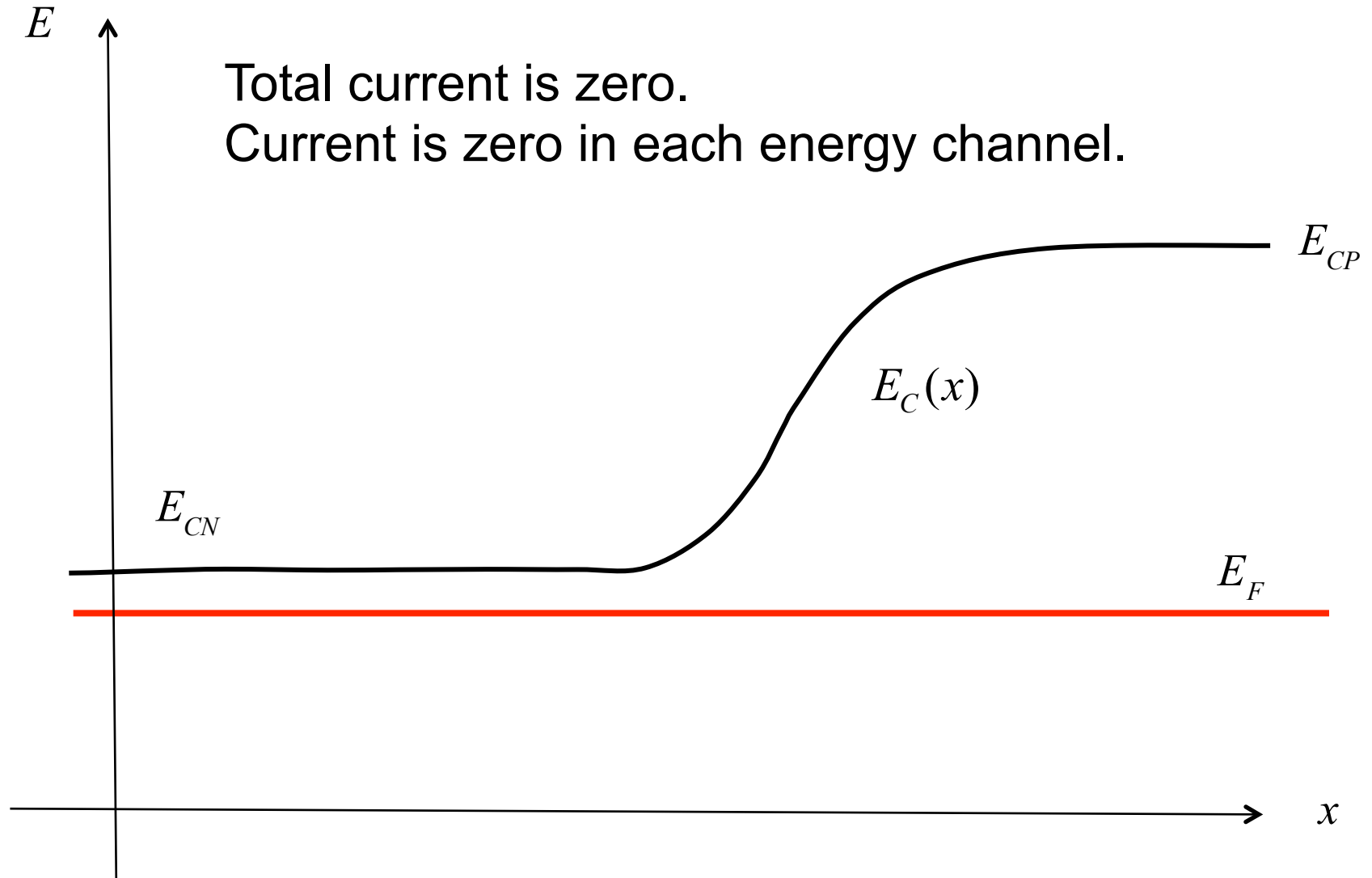# Interesting Question

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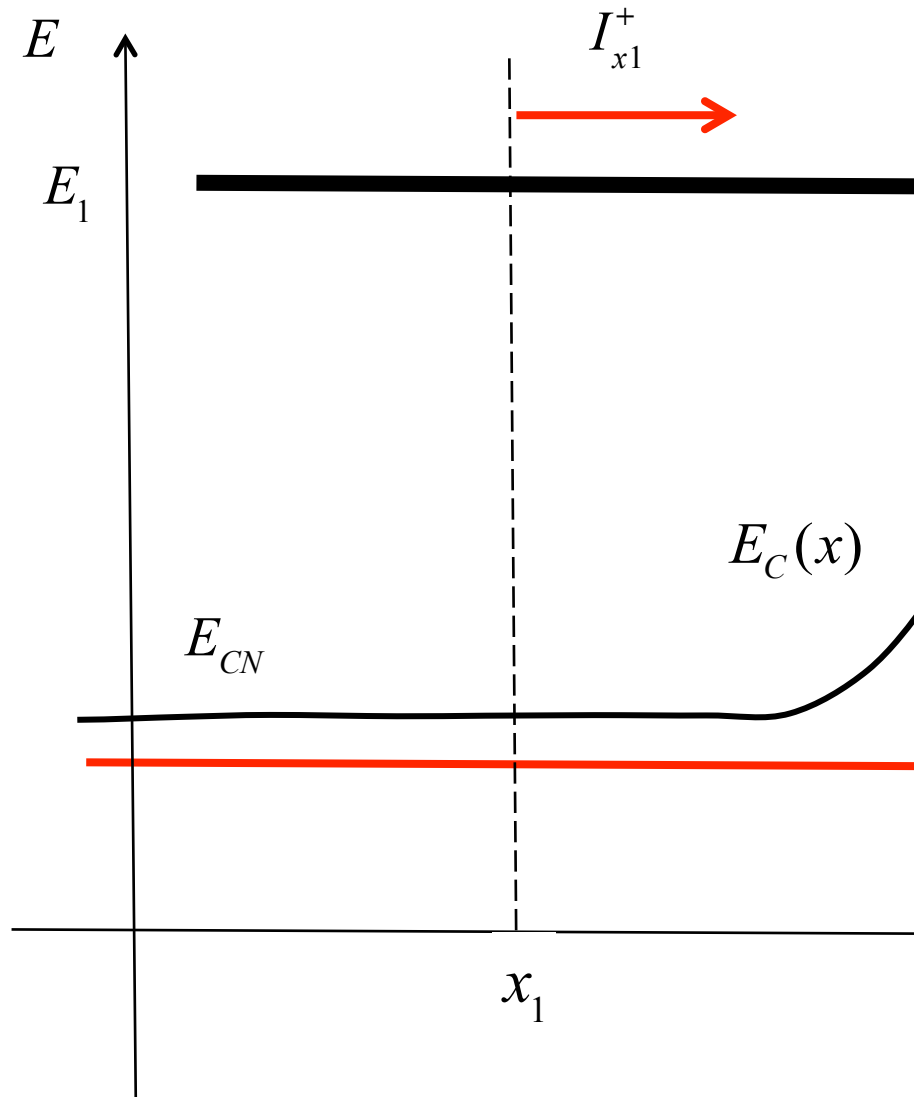
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11/29/17

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PN Junction in equilibrium

Total current is zero.
Current is zero in each energy channel.

E

E_{CP}

$E_C(x)$

E_{CN}

E_F

x

Consider 1 specific energy channel

$$I^+_{x1}$$

$$I^+_{x1} = \frac{D(x_1, E_1) dE}{2} f_o(E_1) v^+(x_1, E_1)$$

$$E_C(x)$$
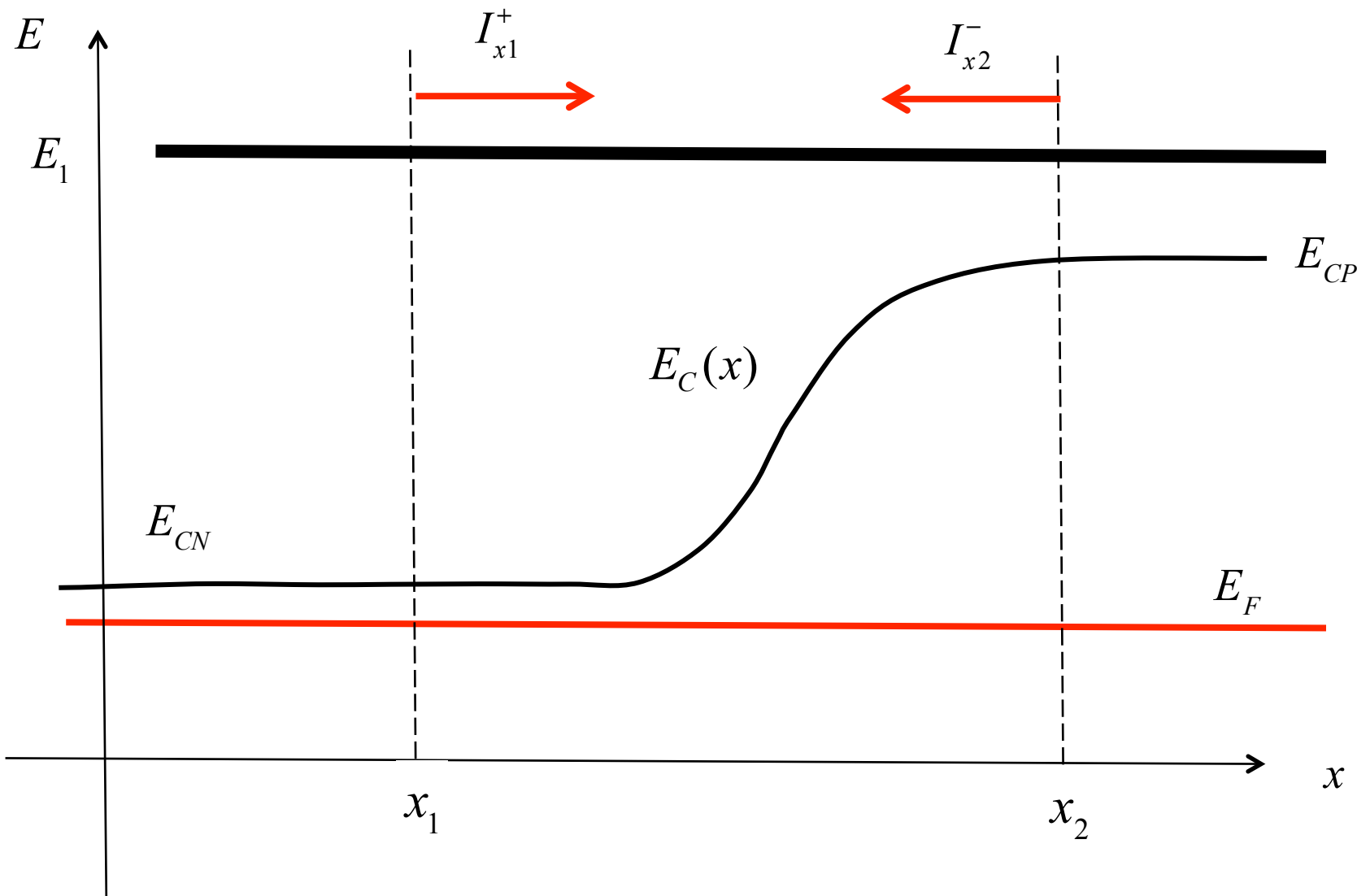
$$I^+_{x1} = \frac{D(x_1, E_1) dE}{2} f_o(E_1) \frac{v(x_1, E_1)}{2}$$

$$E_{CN}$$

$$I^+_{x1} \propto \sqrt{E_1 - E_{CN}} \, f_o(E_1) \sqrt{E_1 - E_{CN}}$$

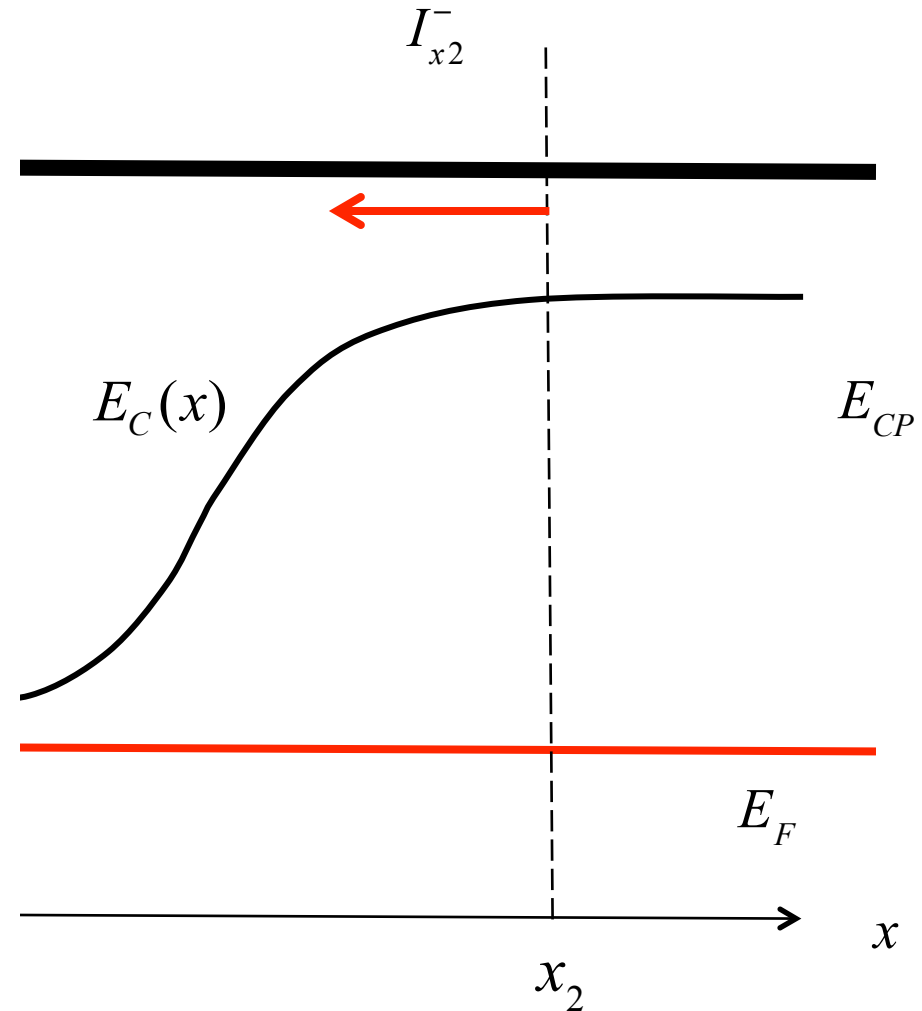$$I^+_{x1} \propto (E_1 - E_{CN}) f_o(E_1)$$

E

E_1

x_1

On the p-side

$$I_{x2}^- = \frac{D(x_2, E_1)dE}{2} f_o(E_1) v^1(x_2, E_1)$$

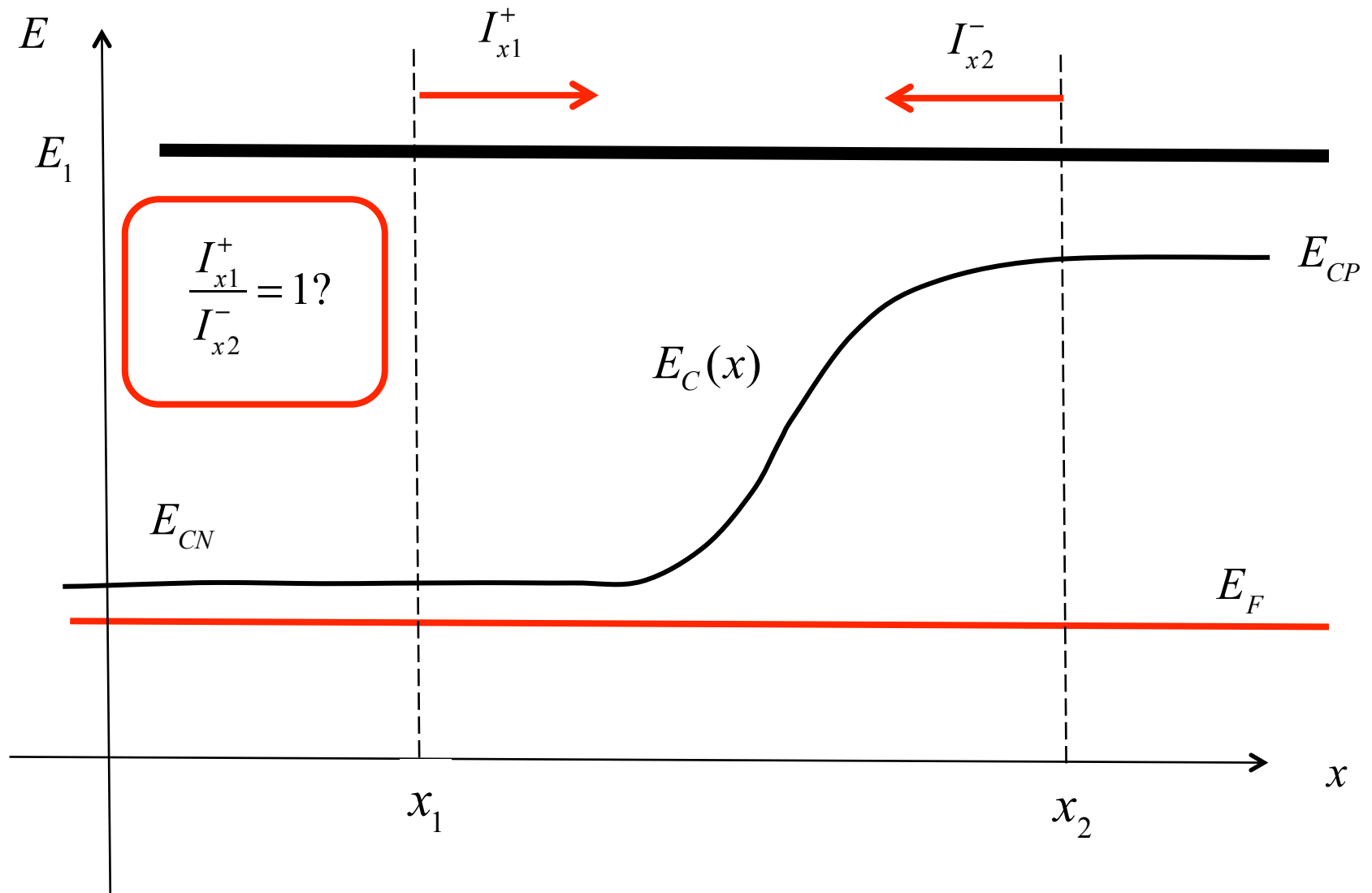$$I_{x2}^- = \frac{D(x_2, E_1)dE}{2} f_o(E_1) \frac{v(x_2, E_1)}{2}$$

$$I_{x2}^- \propto \sqrt{E_1 - E_{CP}} f_o(E_1) \sqrt{E_1 - E_{CP}}$$

$$I_{x2}^- \propto (E_1 - E_{CP}) f_o(E_1)$$

I_{x2}^-

$E_C(x)$

E_{CP}

E_F

x_2

x

Are these two currents equal?

Ratio of currents

$$I_{x1}^{+} \propto \left(E_1 - E_{CN} \right) f_o \left(E_1 \right)$$

$$I_{x2}^{-} \propto \left(E_1 - E_{CP} \right) f_o \left(E_1 \right)$$

Why is the current ratio > 1?

$$\frac{I_{x1}^{+}}{I_{x2}^{-}} \propto \frac{\left(E_1 - E_{CN} \right) f_o \left(E_1 \right)}{\left(E_1 - E_{CP} \right) f_o \left(E_1 \right)} = \frac{\left(E_1 - E_{CN} \right)}{\left(E_1 - E_{CP} \right)}$$

$$\frac{I_{x1}^{+}}{I_{x2}^{-}} \propto \frac{\left(E_1 - E_{CN} \right)}{\left(E_1 - E_{CN} - qV_{bi} \right)} > 1$$

How can the current be zero?

Question

But we know that the current in the channel at energy, E1, must be zero.

What is wrong with our argument?

How do we explain current = 0?