SPECIAL PURPOSE DIODES

- Varactor Diode
- Zener Diode
- Tunnel Diode

Avalanche diode	p^-	n^-
pn Junction	p	n
Zener diode	p^+	n^+
Tunnel diode	p^{++}	n^{++}

Doping $\uparrow$

VARACTOR DIODE

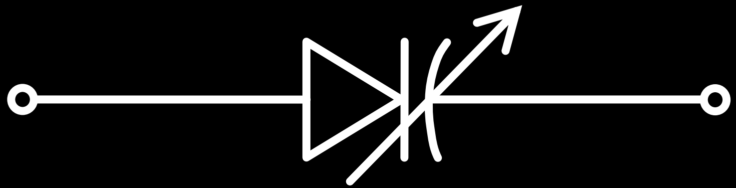
- Variable reactor $\Rightarrow$ Varactor
- Varicap
- Reverse bias

Depletion capacitance

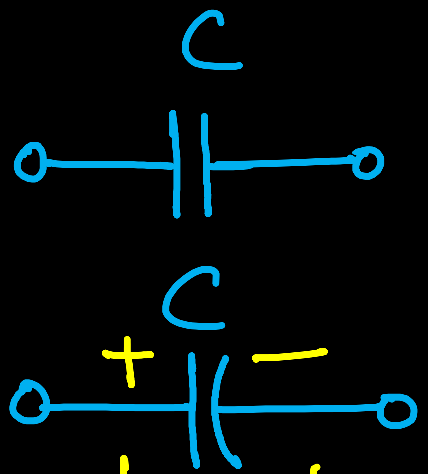
(or)

Transition capacitance

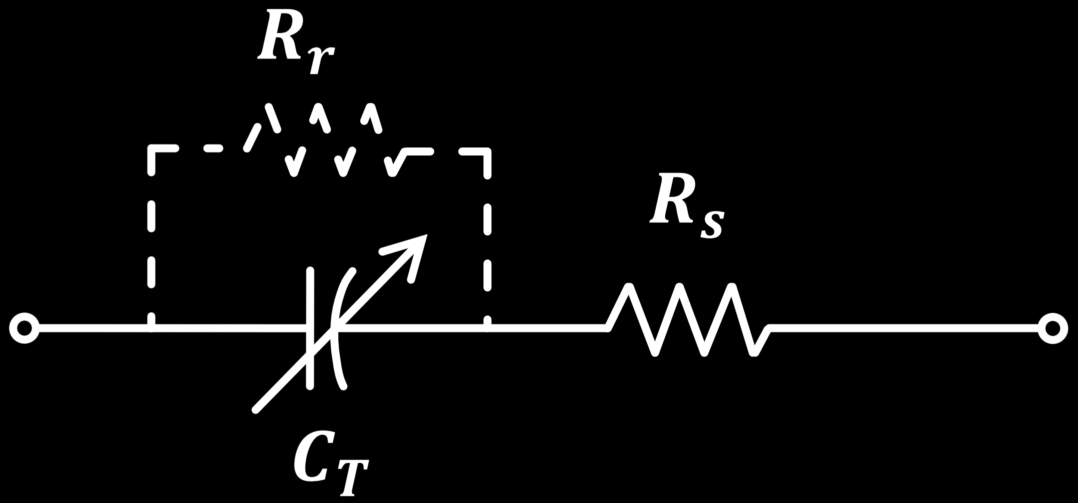
(C_T)



Circuit Symbol



Electrolytic Capacitor

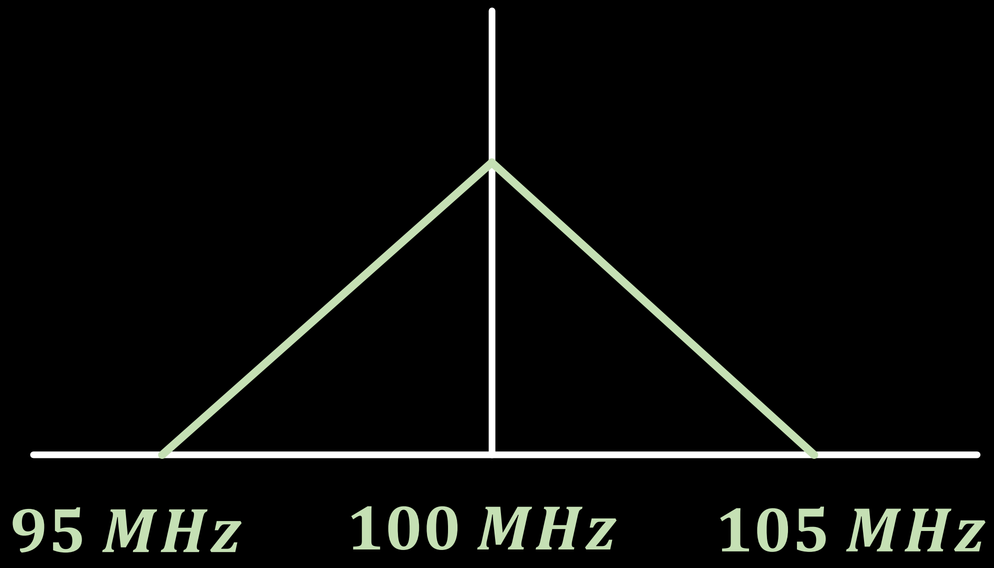


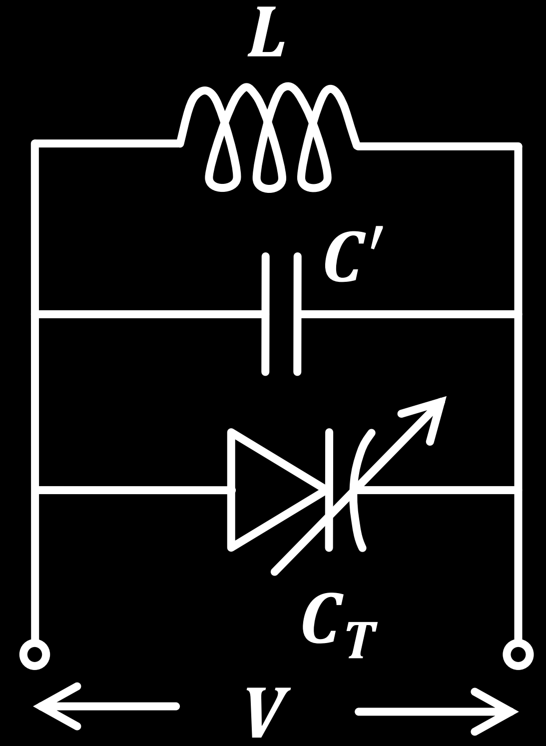
Equivalent Circuit

$$\boxed{C_T = \frac{C_{T0}}{\sqrt{\left(1 + \frac{V_R}{V_0}\right)}}}$$

Applications

- Tunning Circuits
- Harmonic Generation
- Microwave Frequency Multiplication
- Active Filters
- Self Balancing Bridges
- Parametric Amplifiers

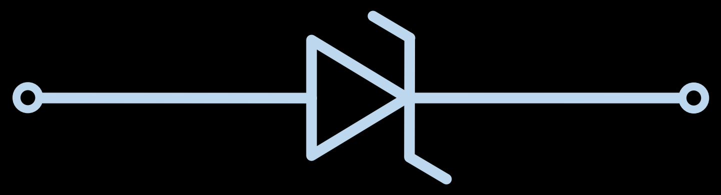




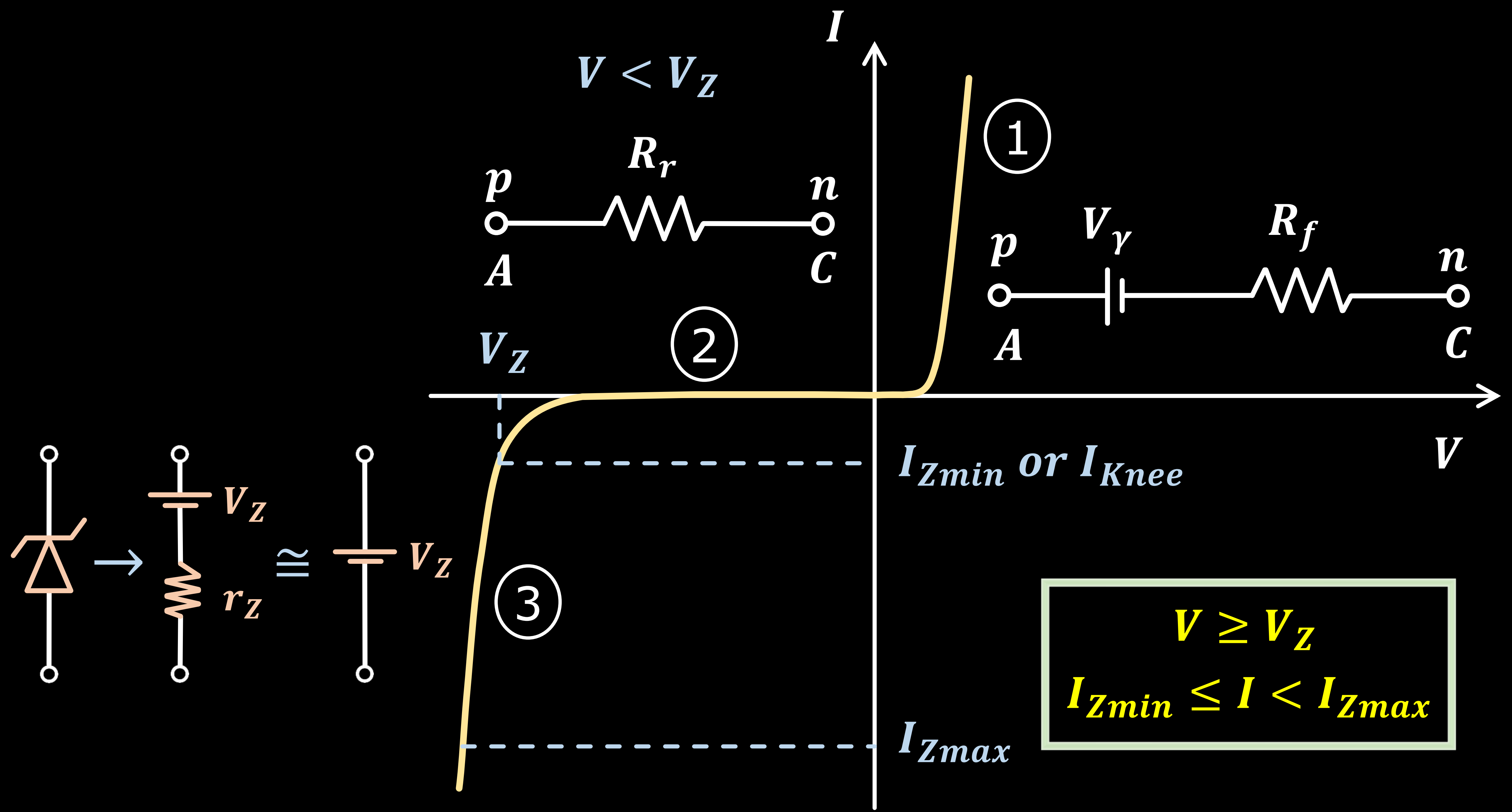
$$f = \frac{1}{2\pi\sqrt{LC}} \qquad C = C' + C_T$$

$$V\nearrow \longrightarrow C_T\nearrow \longrightarrow C\nearrow \longrightarrow f\nearrow$$

ZENER DIODE

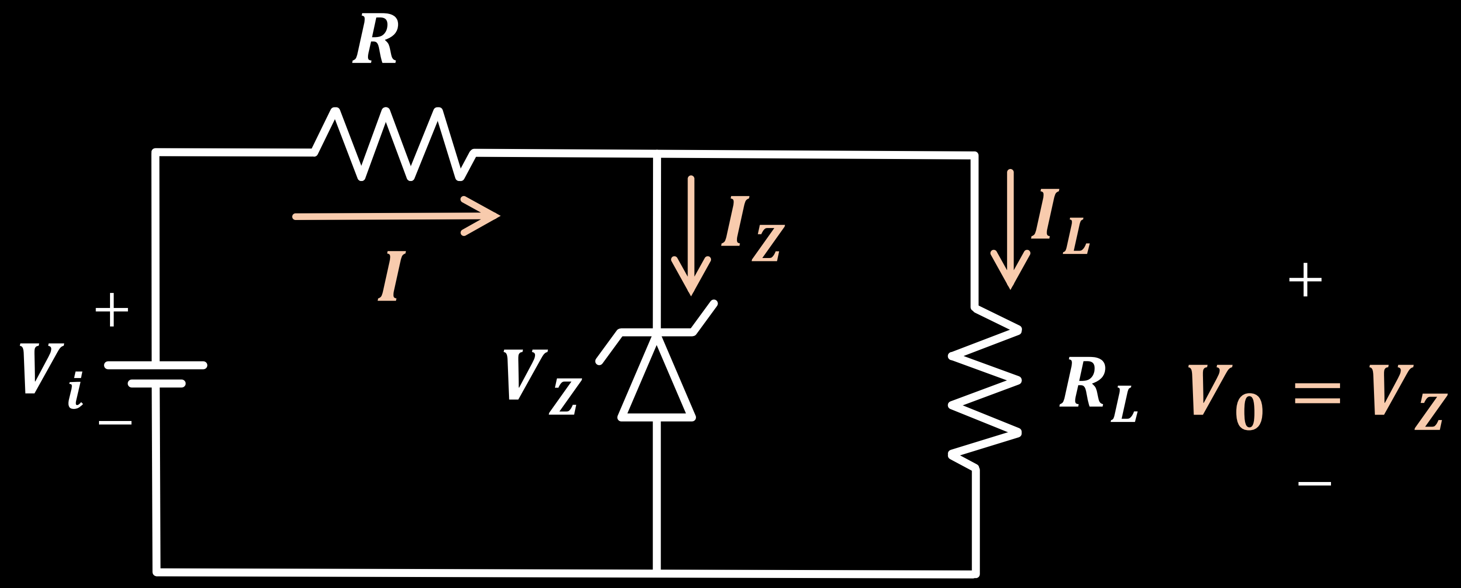


Circuit Symbol


I
V
$V < V_Z$
R_r
p
n
A
C
1
2
3
V_γ
R_f
p
n
A
C
V_Z
I_{Zmin} or I_{Knee}
I_{Zmax}
V_Z
r_Z
≅
V_Z
$V \geq V_Z$
$I_{Zmin} \leq I < I_{Zmax}$

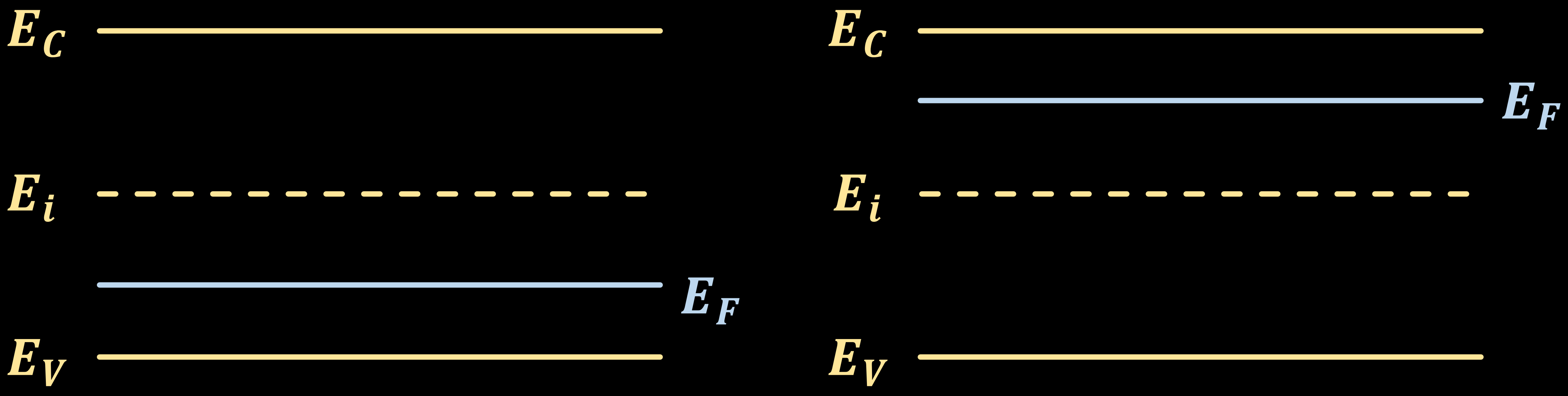
Zener diode as voltage regulator

Voltage regulation is the process of generating constant output voltage w.r.t variations present at the input (line) and the load.



$I = I_Z + I_L \quad I_{Zmin} \leq I_Z < I_{Zmax} \quad V_i = IR + V_Z$

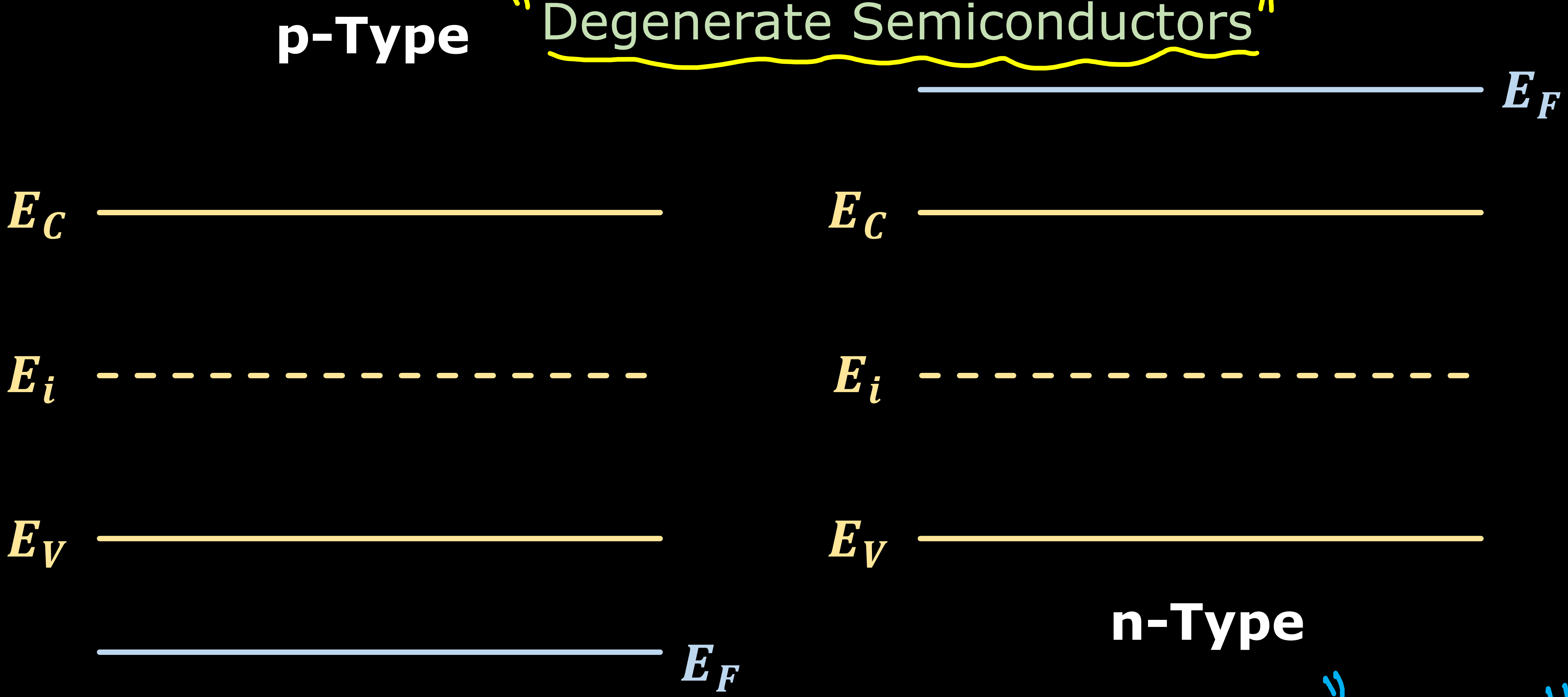
TUNNEL DIODE (ESAKI DIODE)



p-Type **n-Type**

In pn junction the doping ratio is "1 in 10^8". This results in width of the depletion region in the order of "micrometres (microns)".

"Degenerate Semiconductors"



In Tunnel diode the doping ratio is "1 in 10^3". This results in width of the depletion region in the order of Å.

p-type

$$E_F = E_V + kT\ln\left(\frac{N_V}{N_A}\right)$$

n-type

$$E_F = E_C - kT\ln\left(\frac{N_C}{N_D}\right)$$

pn junction $\rightarrow N_A < N_V$ and $N_D < N_C$

If doping concentration is increased

$$\boxed{N_A > N_V}$$

$$\boxed{N_D > N_C}$$

Tunnel diode is junction between degenerate p-type and degenerate n-type semiconductor.

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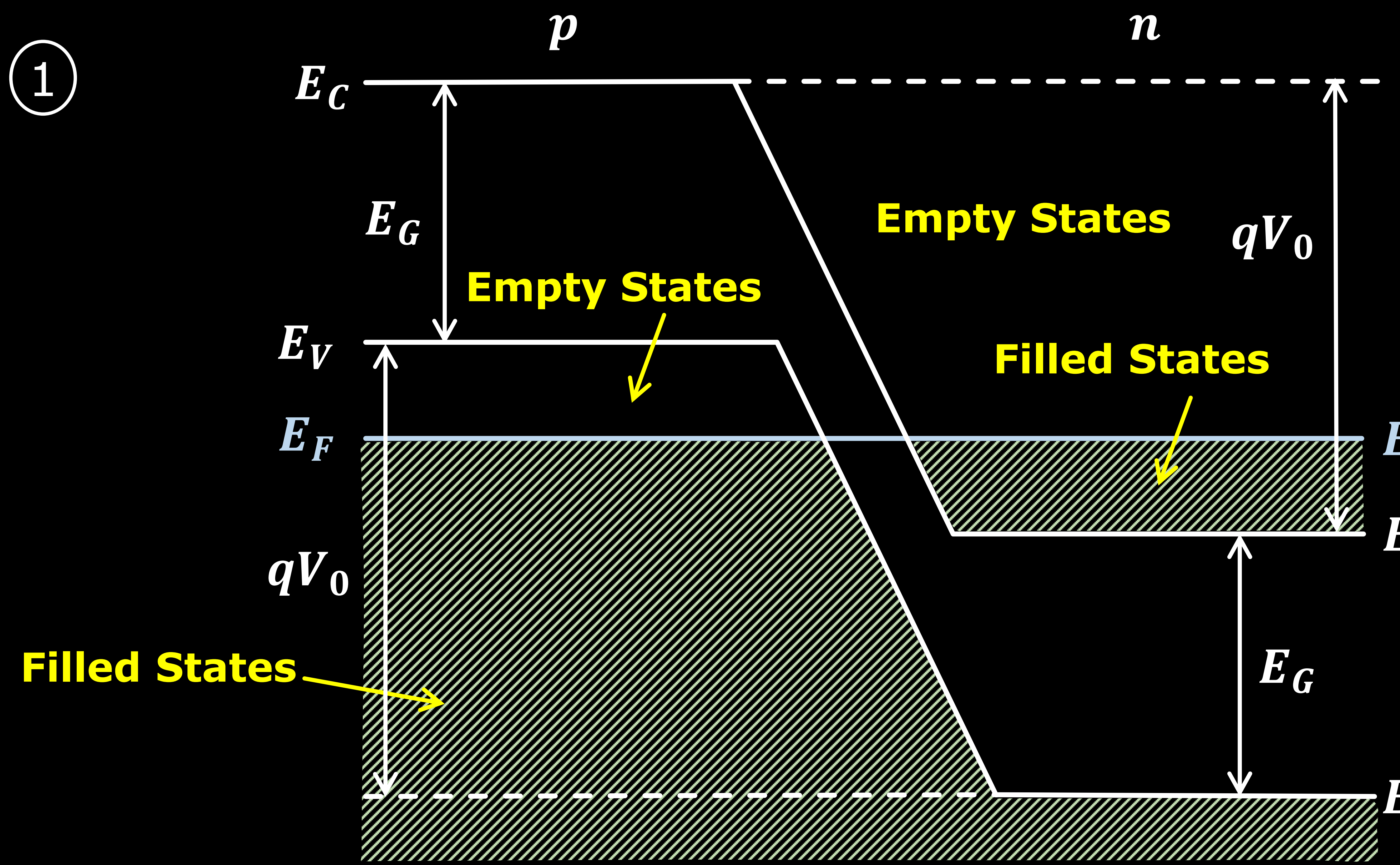
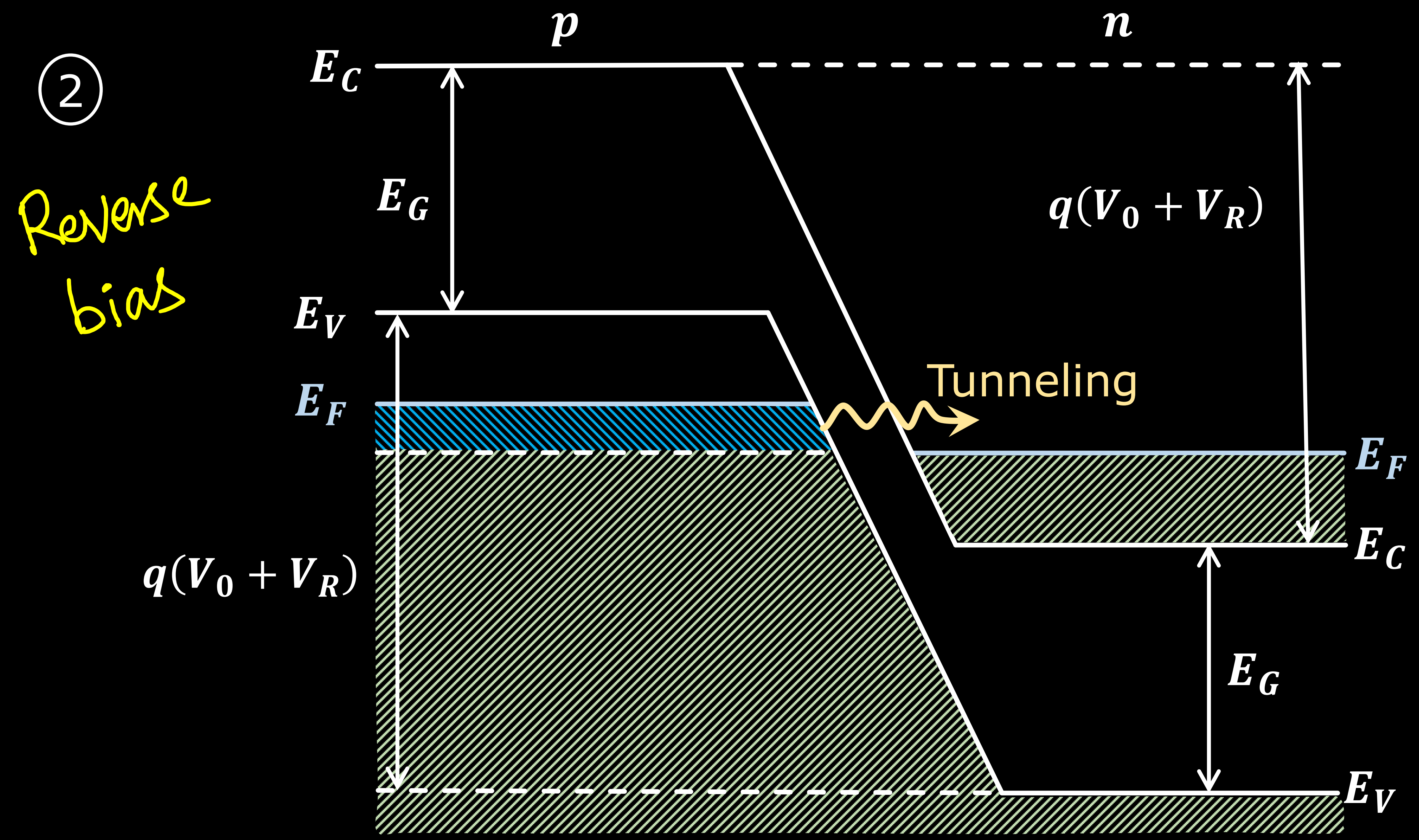
Tunnelling can happen only if there are corresponding filled and empty states on either side (p and n) of the junction.

Open Circuit (Equilibrium)

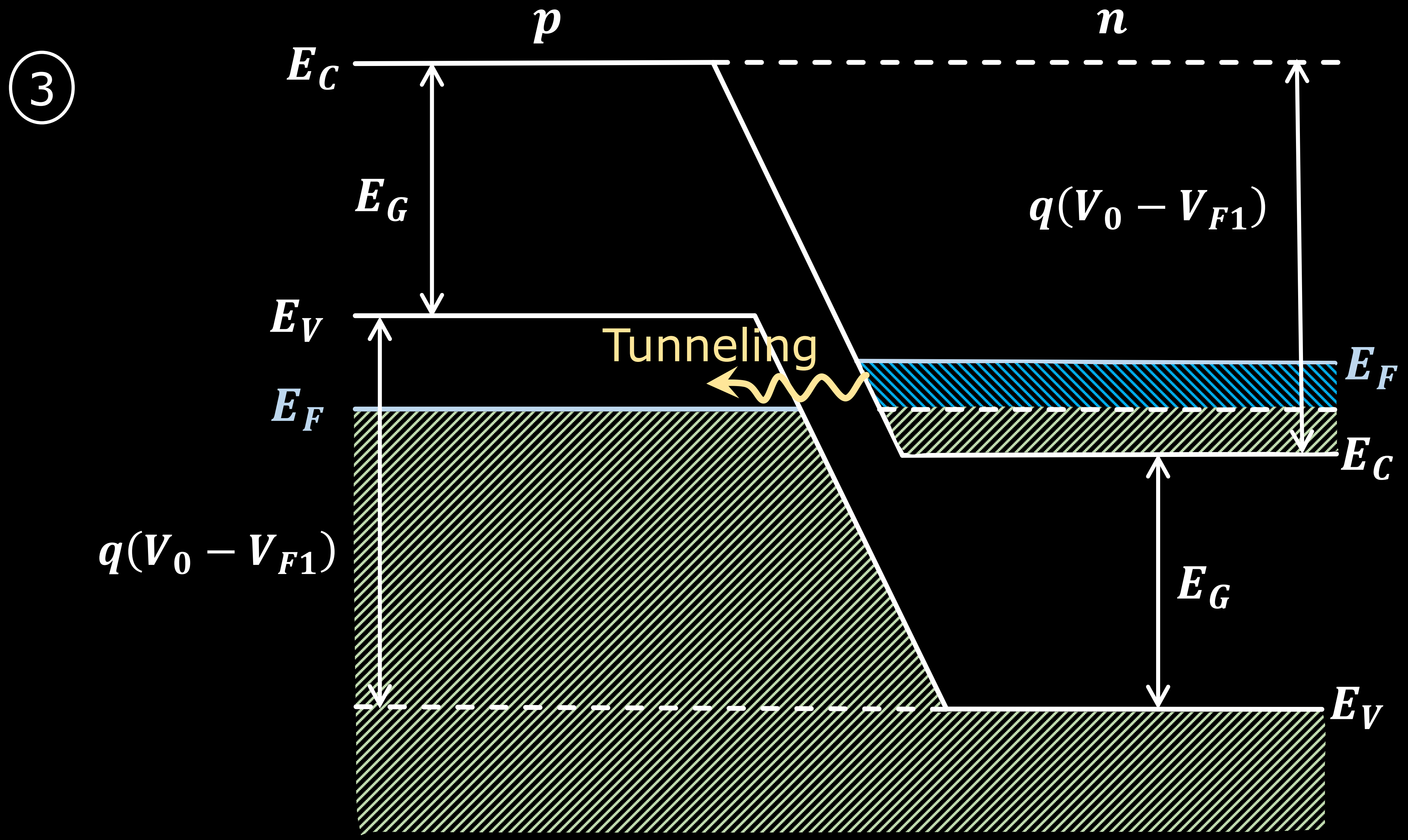
Under equilibrium

$$\boxed{\frac{\partial E_F}{\partial x} = 0}$$

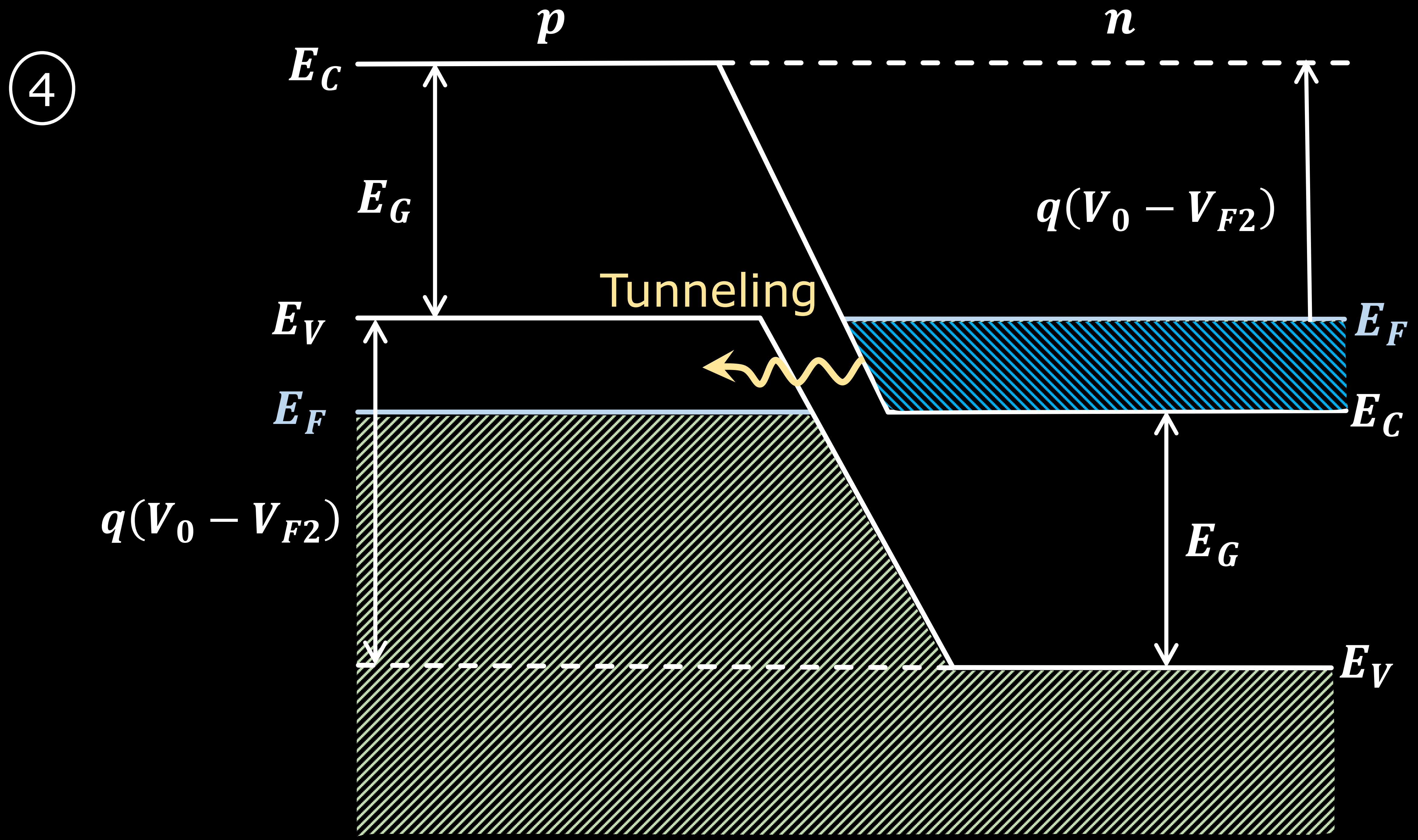

1
p
n
E_C
E_G
Empty States
E_V
E_F
qV_0
Filled States
Empty States
qV_0
Filled States
E_F
E_C
E_G
E_V



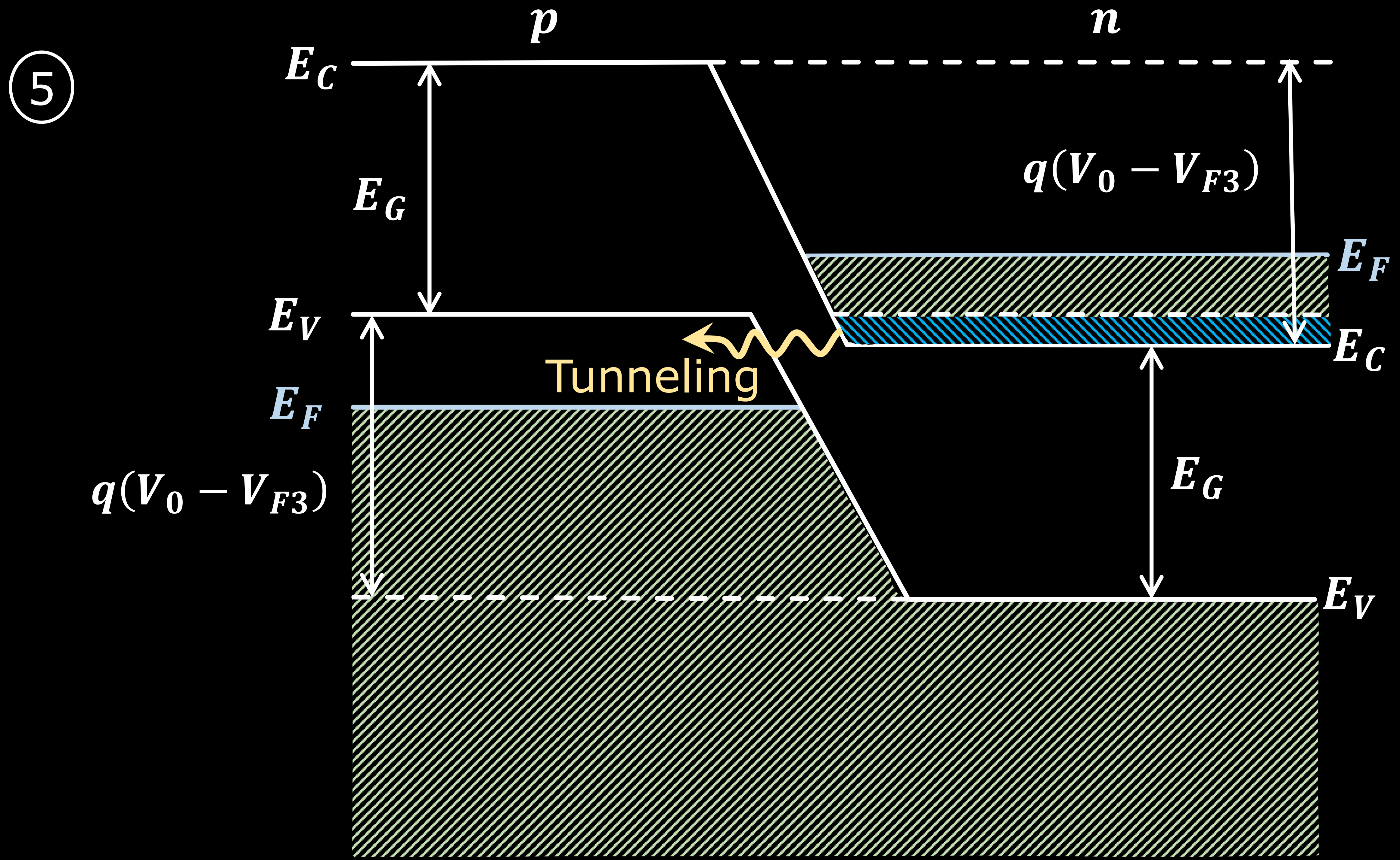
2
Reverse bias
p
n
E_C
E_G
E_V
E_F
$q(V_0 + V_R)$
Tunneling
E_F
E_C
$q(V_0 + V_R)$
E_G
E_V



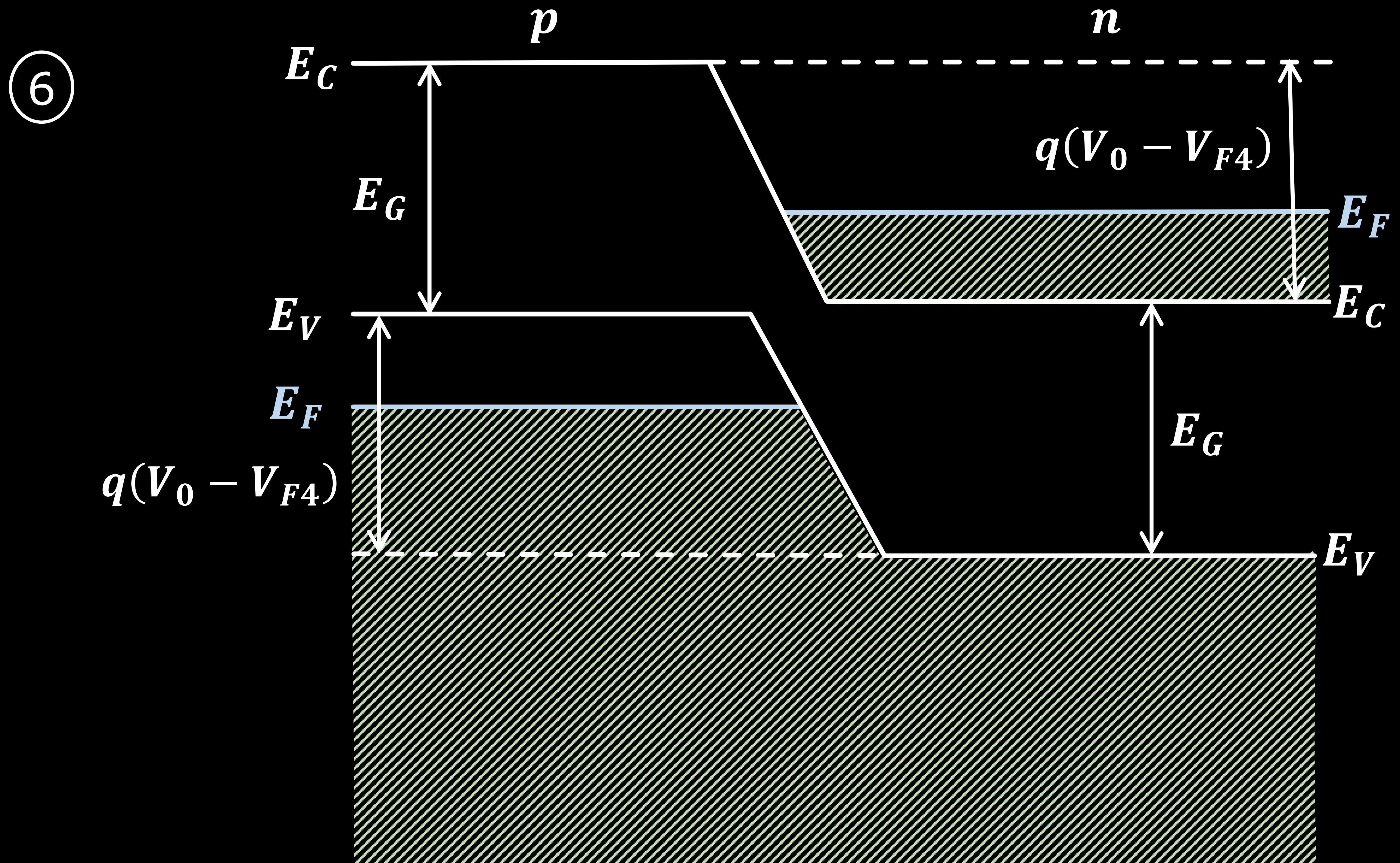
3
p
n
E_C
E_G
E_V
Tunneling
E_F
$q(V_0 - V_{F1})$
E_F
E_C
$q(V_0 - V_{F1})$
E_G
E_V

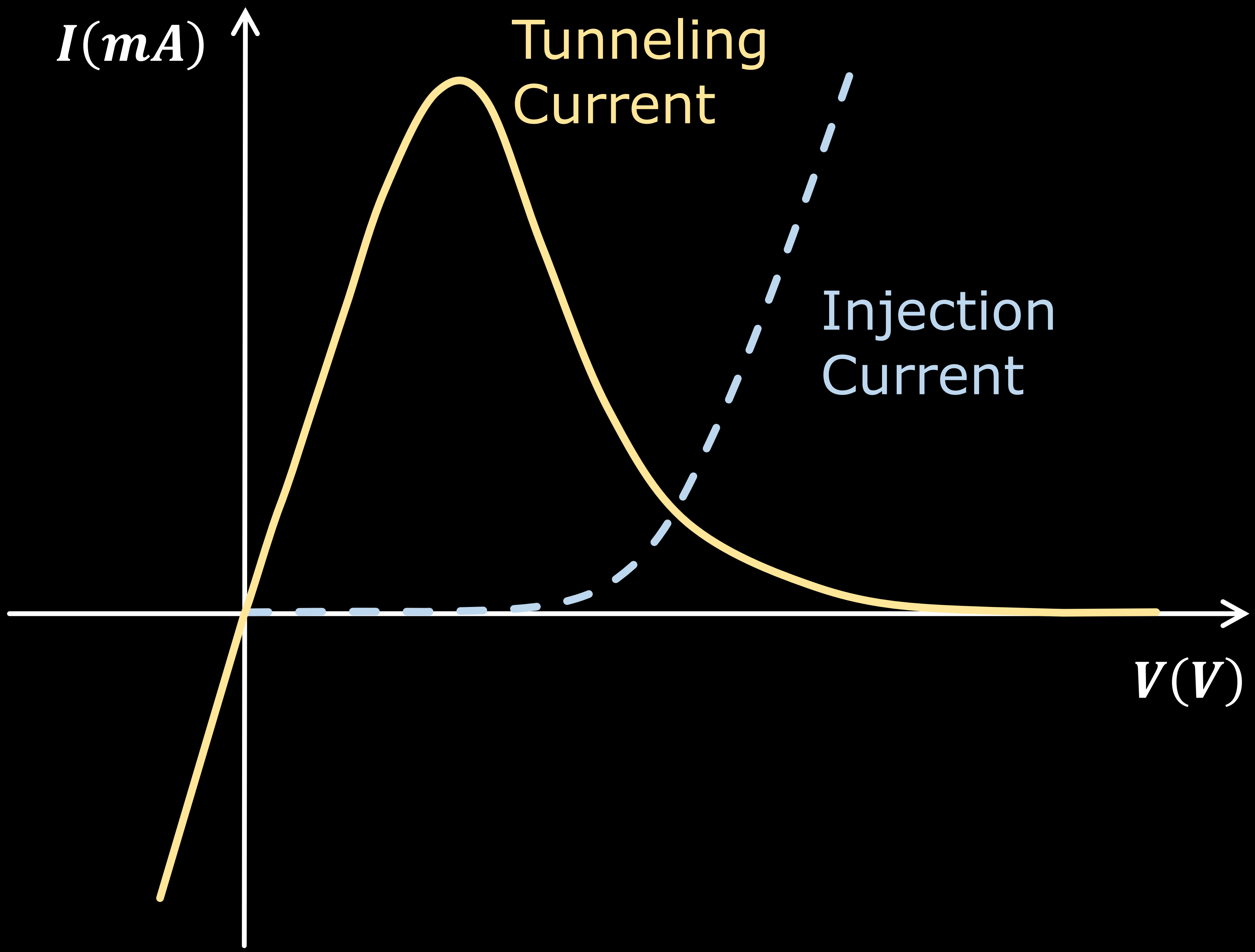


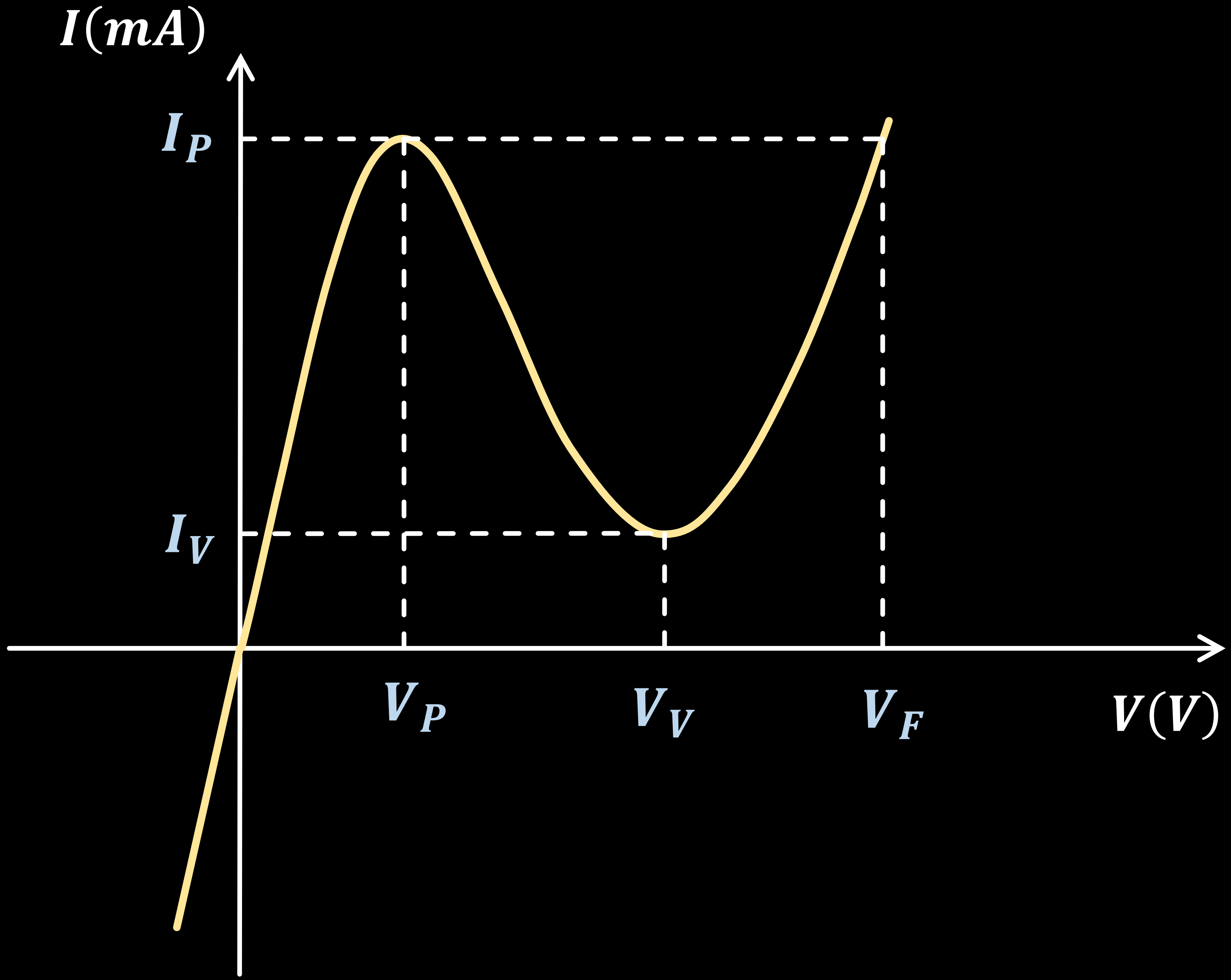
4
p
n
E_C
E_G
E_V
E_F
$q(V_0 - V_{F2})$
Tunneling
E_F
E_C
$q(V_0 - V_{F2})$
E_G
E_V



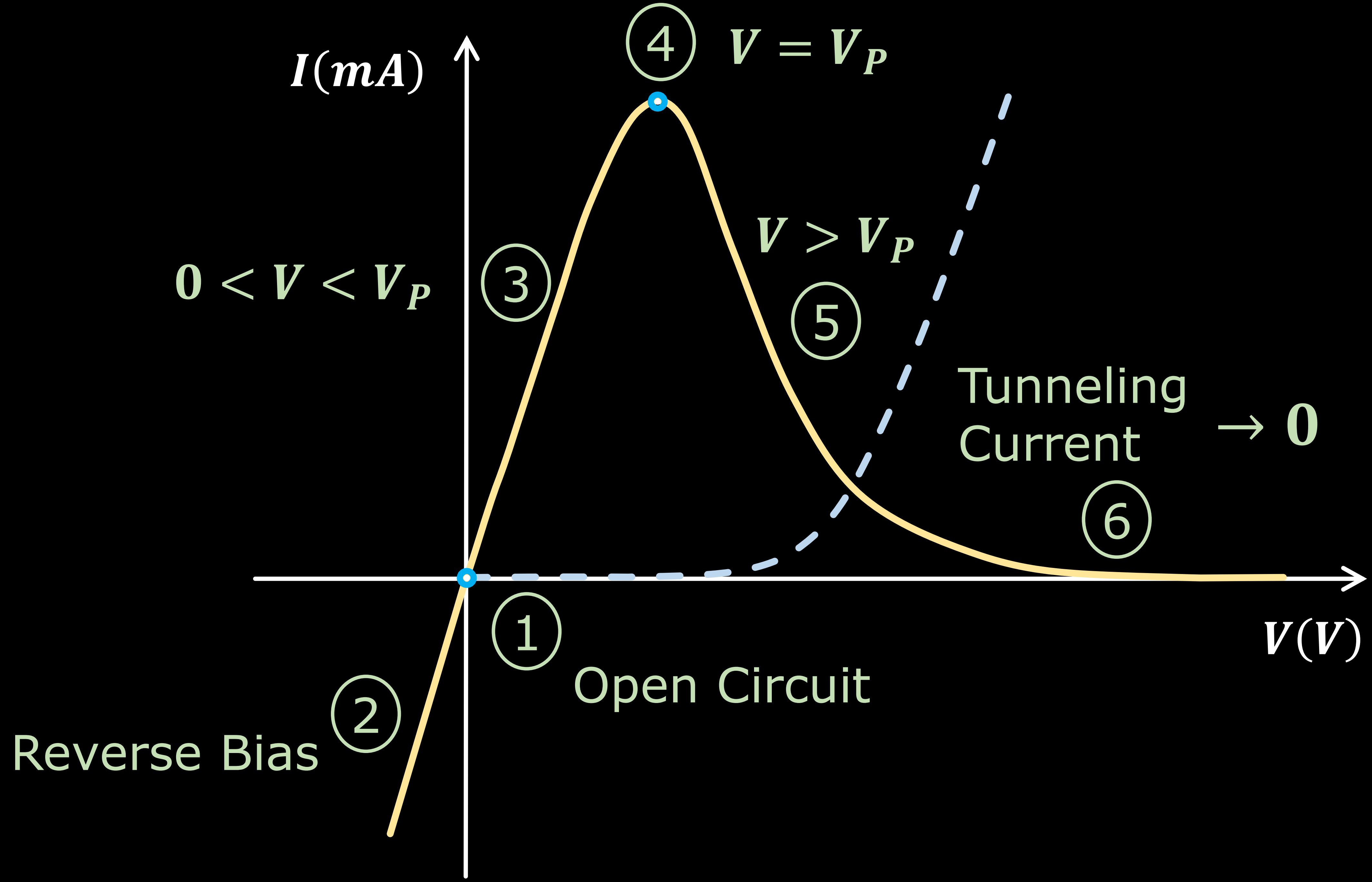
5
p
n
E_C
E_G
E_V
E_F
$q(V_0 - V_{F3})$
Tunneling
$q(V_0 - V_{F3})$
E_F
E_C
E_G
E_V


⑥
p
n
E_C
E_G
E_V
E_F
$q(V_0 - V_{F4})$
$q(V_0 - V_{F4})$
E_F
E_C
E_G
E_V

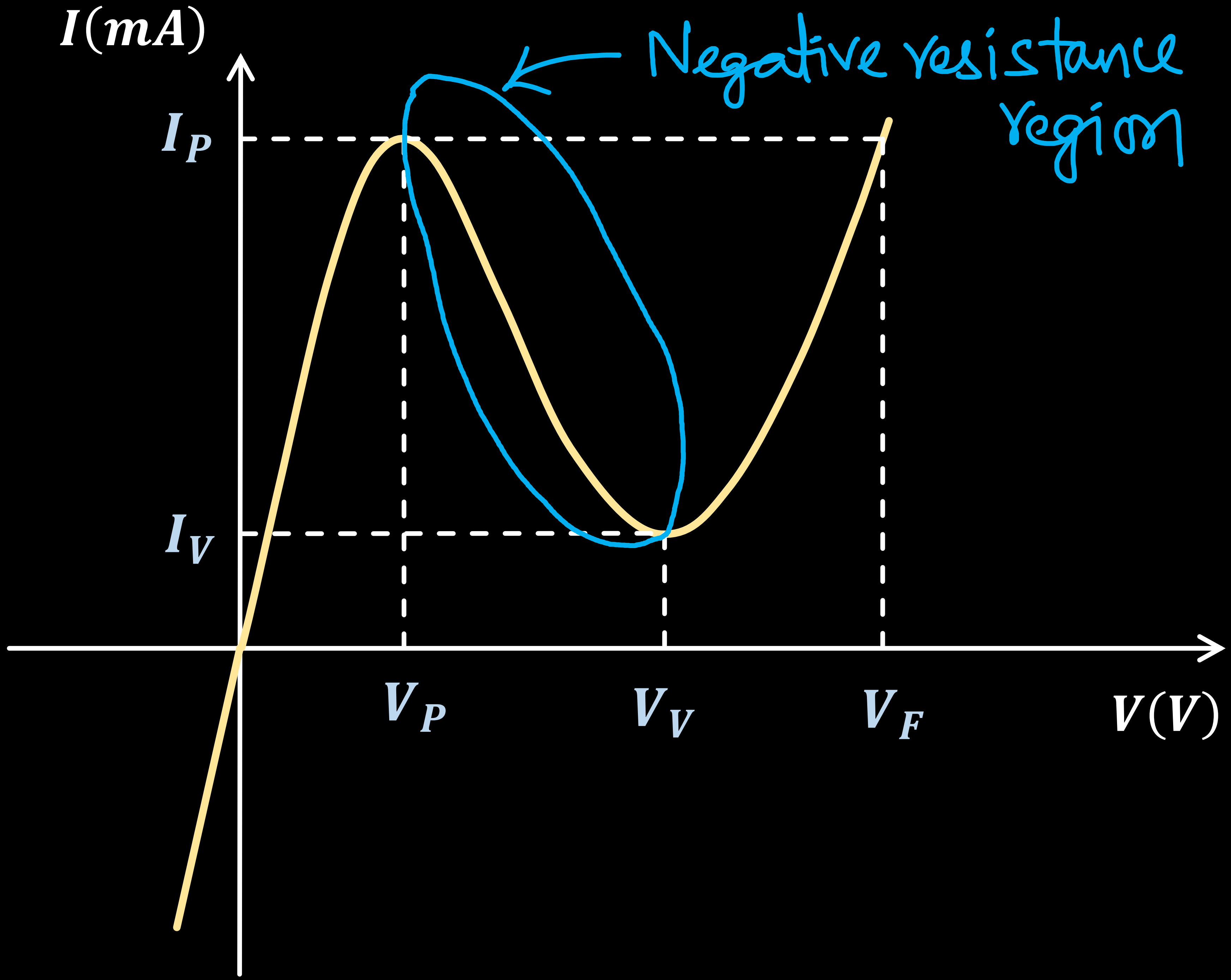

$I(mA)$
Tunneling
Current
Injection
Current
$V(V)$



I(mA)
I_P
I_V
V_P
V_V
V_F
V(V)



$I(mA)$
4
$V = V_P$
$V > V_P$
3
$0 < V < V_P$
5
Tunneling
Current
$\rightarrow 0$
6
1
$V(V)$
Open Circuit
2
Reverse Bias

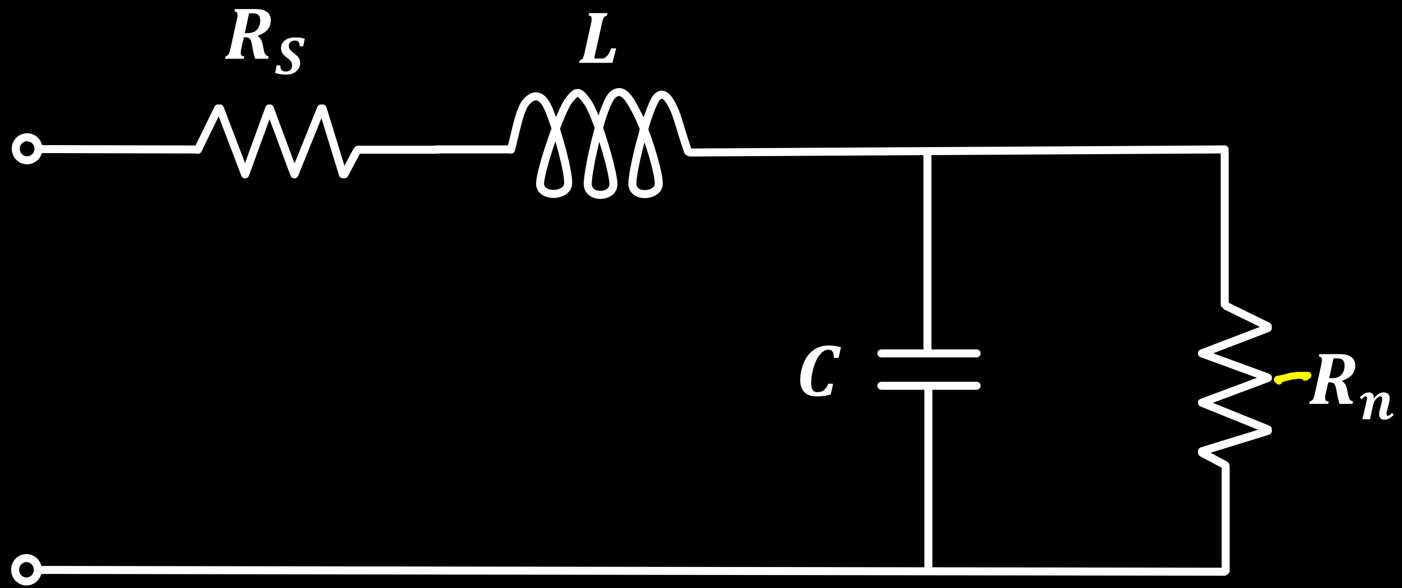


I(mA)
I_P
I_V
V_P
V_V
V_F
V(V)
Negative resistance region

	GaAs	Ge	Si
$\frac{I_P}{I_V}$	15	8	3.5
V_P	$0.15\ V$	$0.055\ V$	$0.065\ V$
V_V	$0.5\ V$	$0.35\ V$	$0.42\ V$
V_F	$1.1\ V$	$0.5\ V$	$0.7\ V$

$$\left(\frac{I_P}{I_V}\right)_{GaAS} > \left(\frac{I_P}{I_V}\right)_{Ge} > \left(\frac{I_P}{I_V}\right)_{Si}$$

Circuit Symbol



Equivalent Circuit

Applications

- High frequency oscillator
- Very high speed switch

A Zener diode when used in voltage stabilization circuits, is biased in

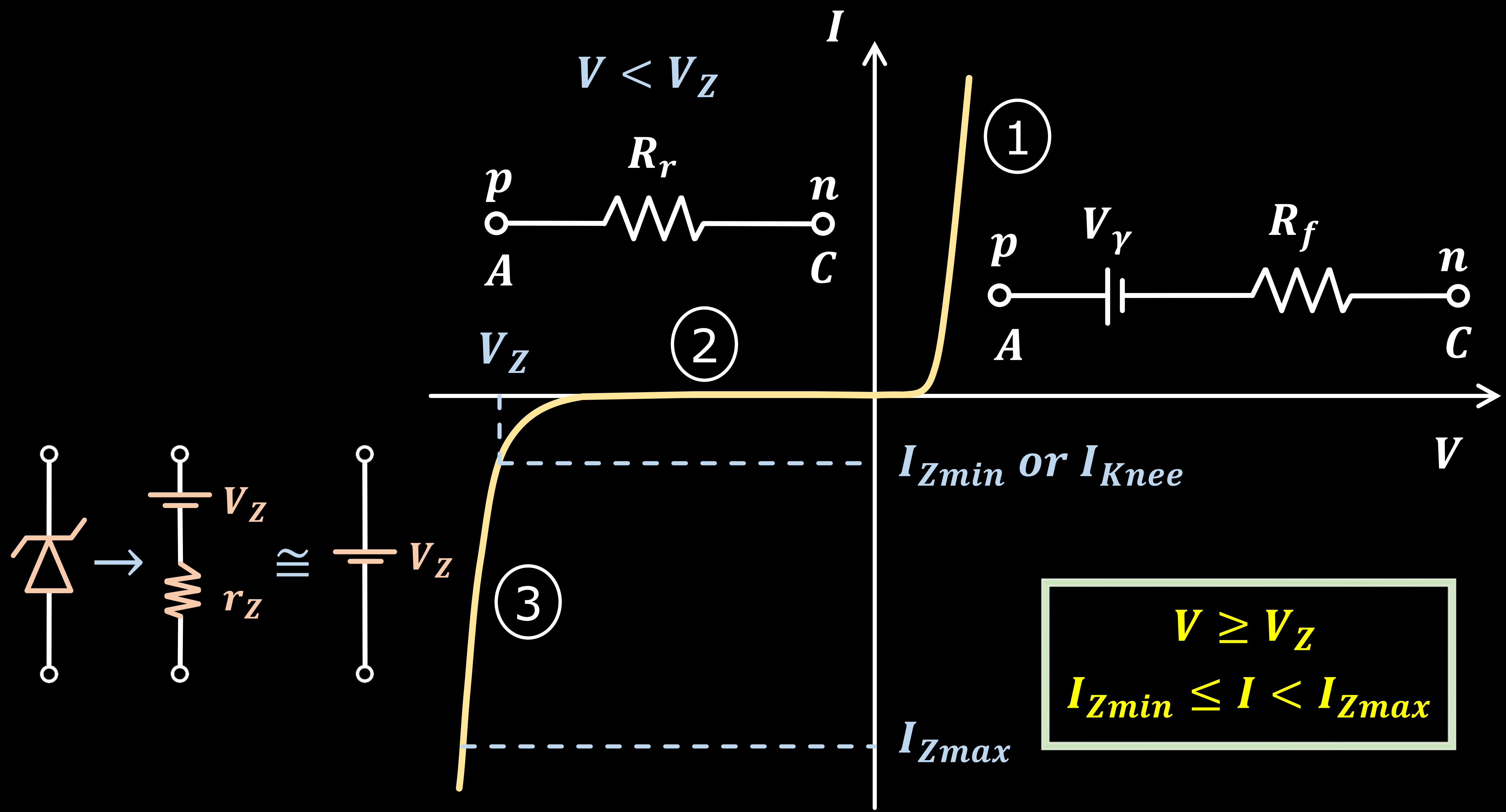
$V < V_Z$ (Reverse bias)

(a) reverse bias region below the breakdown voltage ✗

(b) reverse breakdown region ✓ $V \geq V_Z$

(c) forward bias region

(d) forward bias constant current mode



I
V
$V < V_Z$
R_r
p
n
A
C
1
V_γ
R_f
p
n
A
C
2
V_Z
I_{Zmin} or I_{Knee}
V_Z
r_Z
≅
V_Z
3
I_{Zmax}
$V \geq V_Z$
$I_{Zmin} \leq I < I_{Zmax}$

Consider the following statements pertaining to tunnel diodes

(1) Impurity concentration is high ✓

✗ (2) Carrier velocities are low high

✗ (3) They have current-controlled V-I characteristics

Voltage

Which of the statements given above are correct ?

(a) 1 only

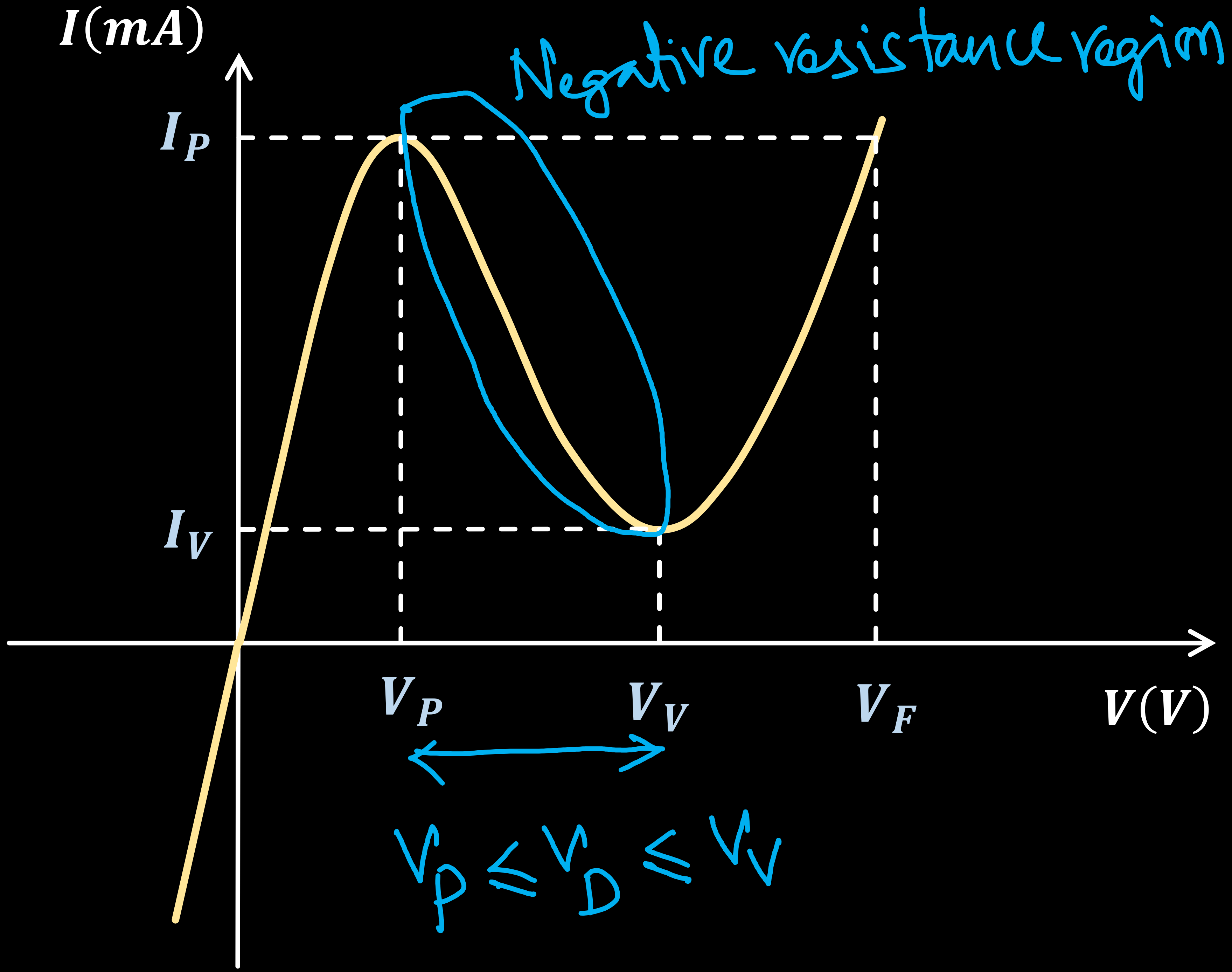
(b) 2 and 3 only

(c) 1 and 3 only

(d) 1 and 2 only

The values of voltage (V_D) across a tunnel diode corresponding to peak and valley currents are V_P and V_V respectively. The range of tunnel-diode voltage V_D for which the slope of $I - V_D$ characteristics is negative would be

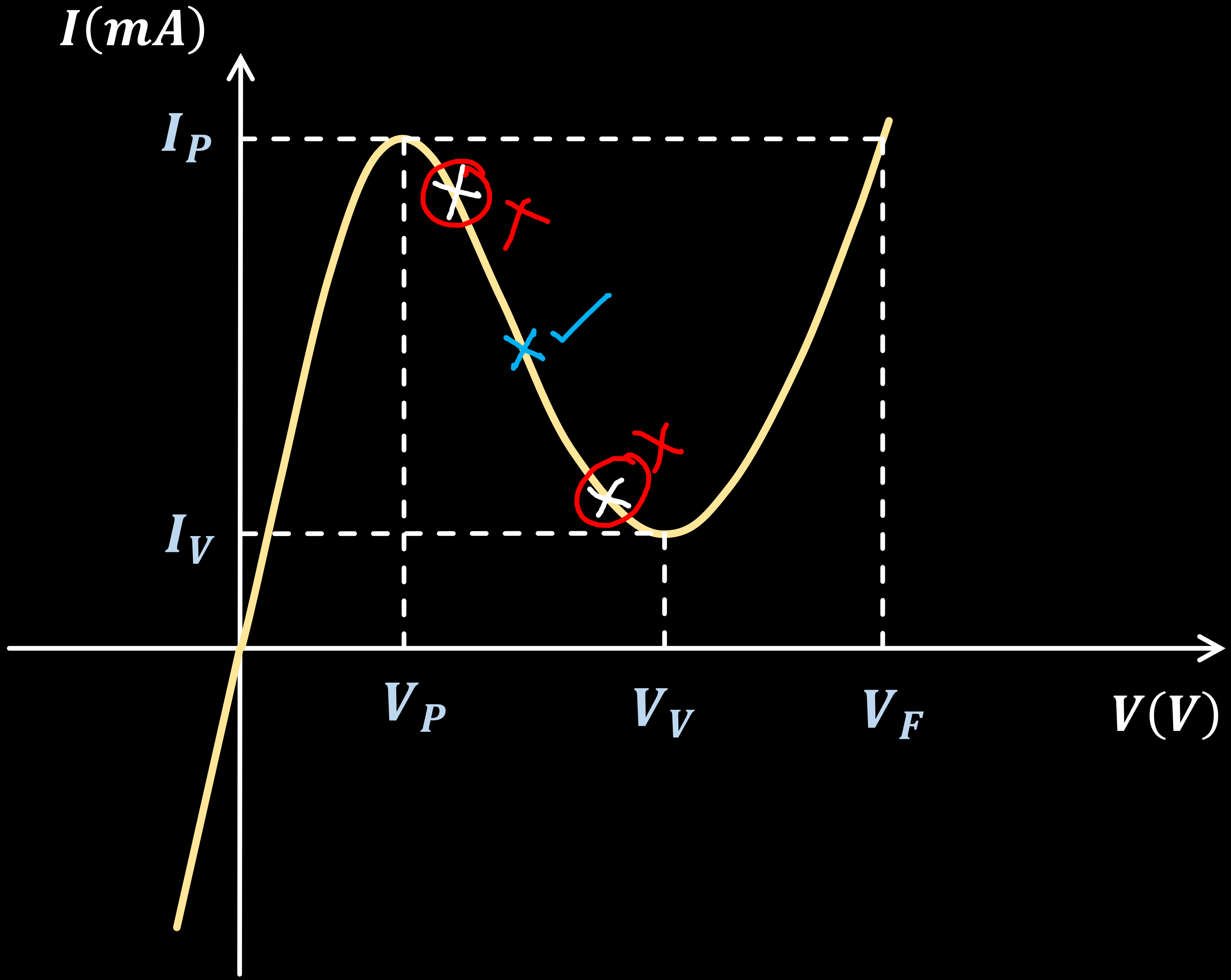
(a) $V_D < 0$
(b) $0 \leq V_D \leq V_P$
(c) $V_P \leq V_D \leq V_V$
(d) $V_D \geq V_V$



Negative resistance regim
$I(mA)$
I_P
I_V
V_P
V_V
V_F
$V(V)$
$V_P \leq V_D \leq V_V$

Which of the following statement is correct? A tunnel diode is always biased

(a) by a dc source
(b) in the middle of its negative resistance region
(c) in the positive resistance region nearest to zero
(d) in the reverse direction



$I(mA)$
I_P
I_V
V_P
V_V
V_F
$V(V)$

A tunnel diode is p^{++} and n^{++}

(a) High resistivity p-n junction diode ✗

✗ (b) A slow switching device Fast

(c) An amplifying device ✗ an oscillator

(d) A very heavily doped p-n junction diode ✓