Einstein
Podolsky
Rosen

EPR argumentum

Bell egyenlőtlenségek

EPR/Bell paradoxon

EPR argumentum

Bell egyenlőtlenségek

EPR/Bell paradoxon

EPR argumentum

Bell egyenlőtlenségek

EPR/Bell paradoxon

EPR argumentum

Bell egyenlőtlenségek

EPR/Bell paradoxon

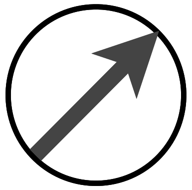
I. EPR-argumentum

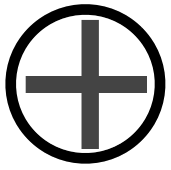
realitás kritérium

$$P(A \mid \psi) = 1 \longrightarrow A \text{ létezik}$$

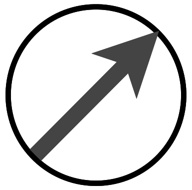
teljességi kritérium

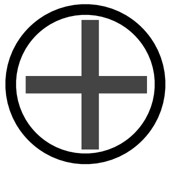
fizikai valóság





modell

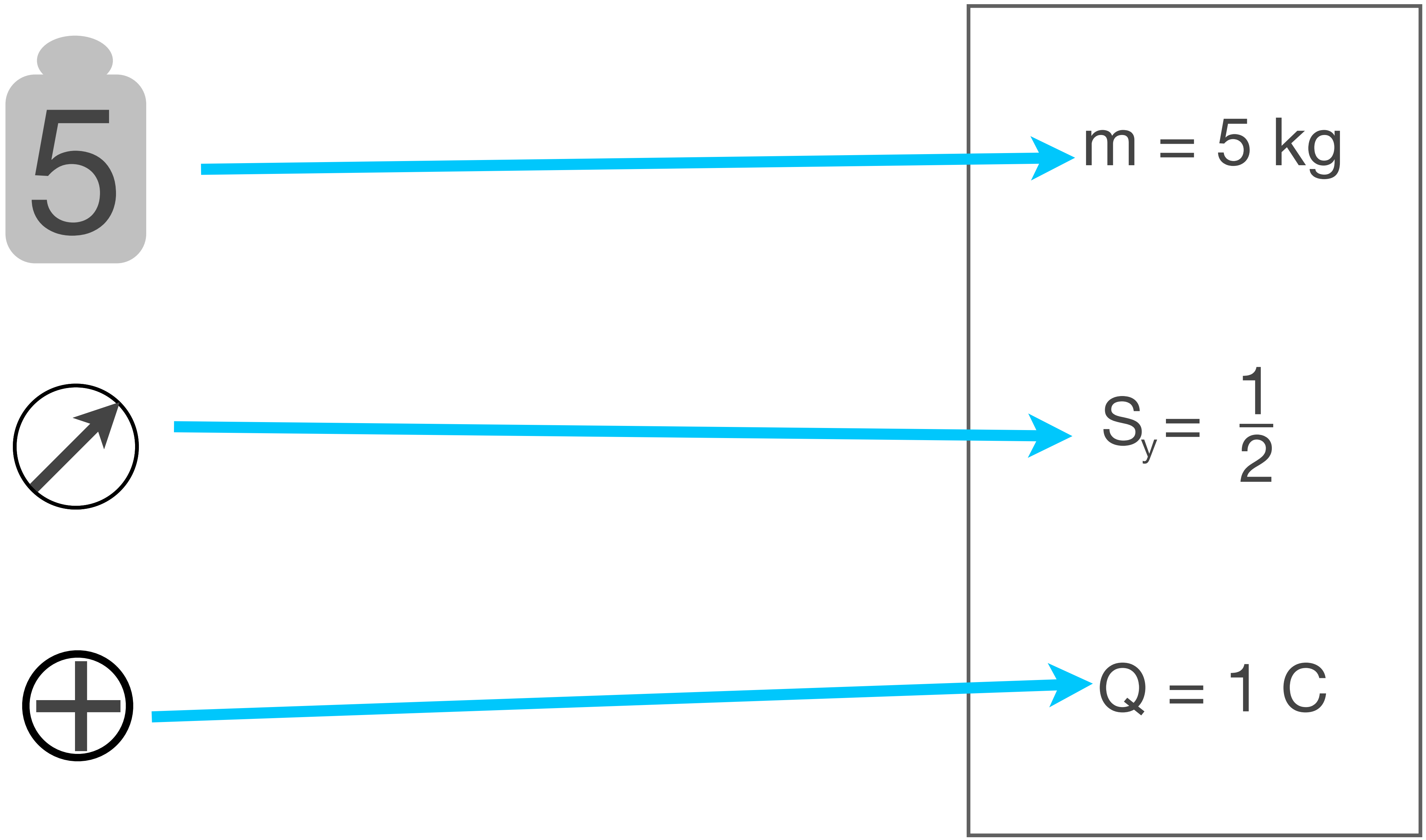




$m = 5\ \text{kg}$

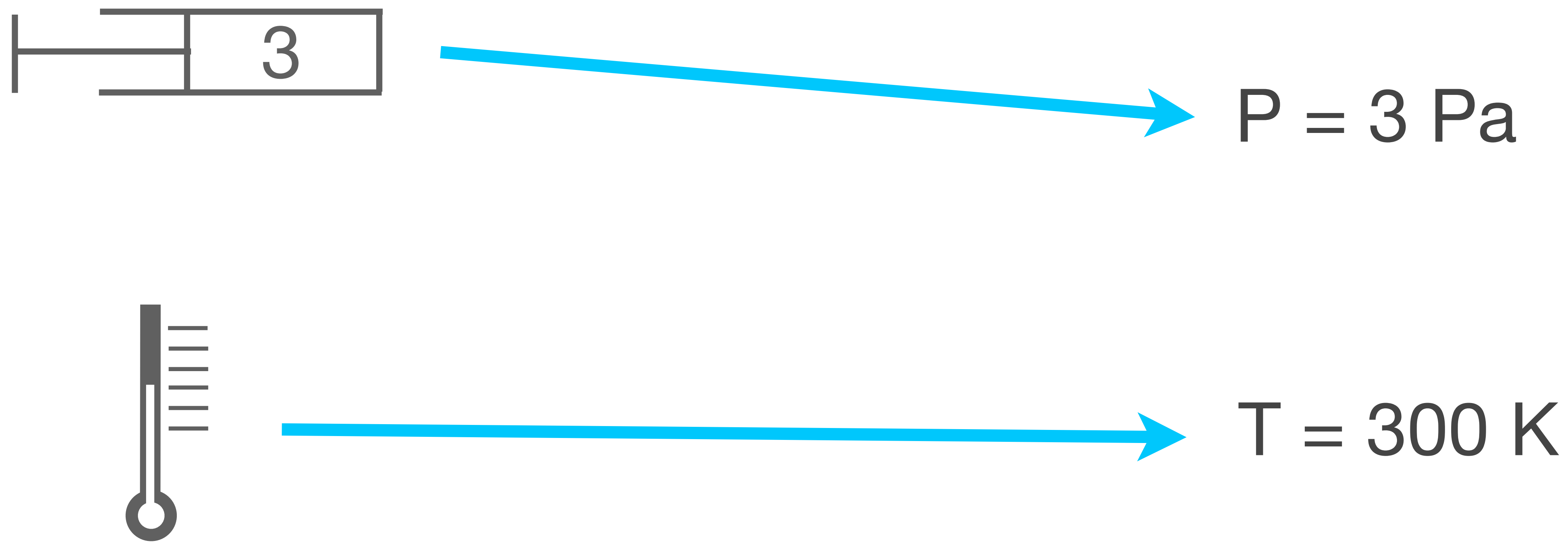
$S_y = \frac{1}{2}$

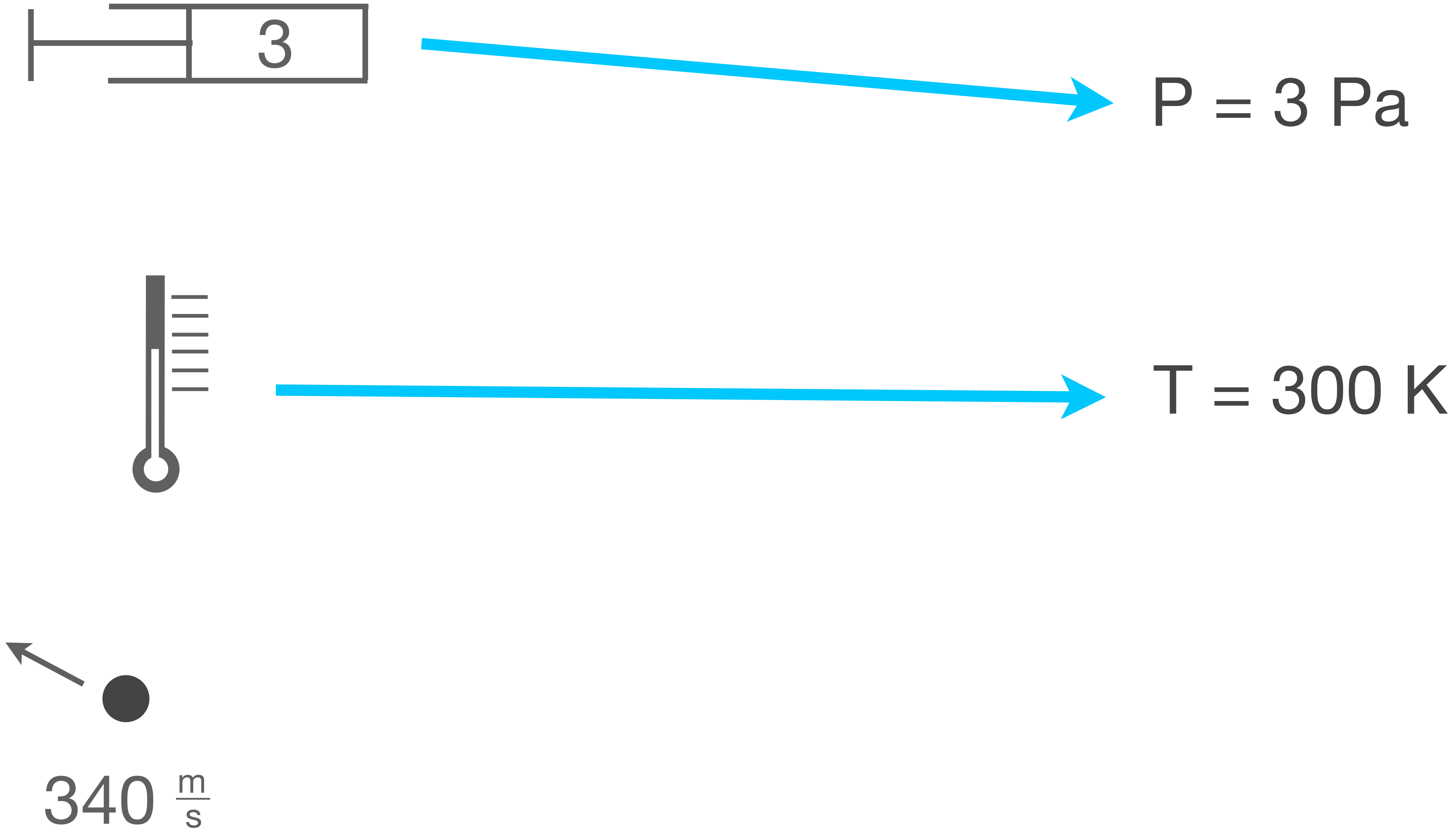
$Q = 1\ \text{C}$

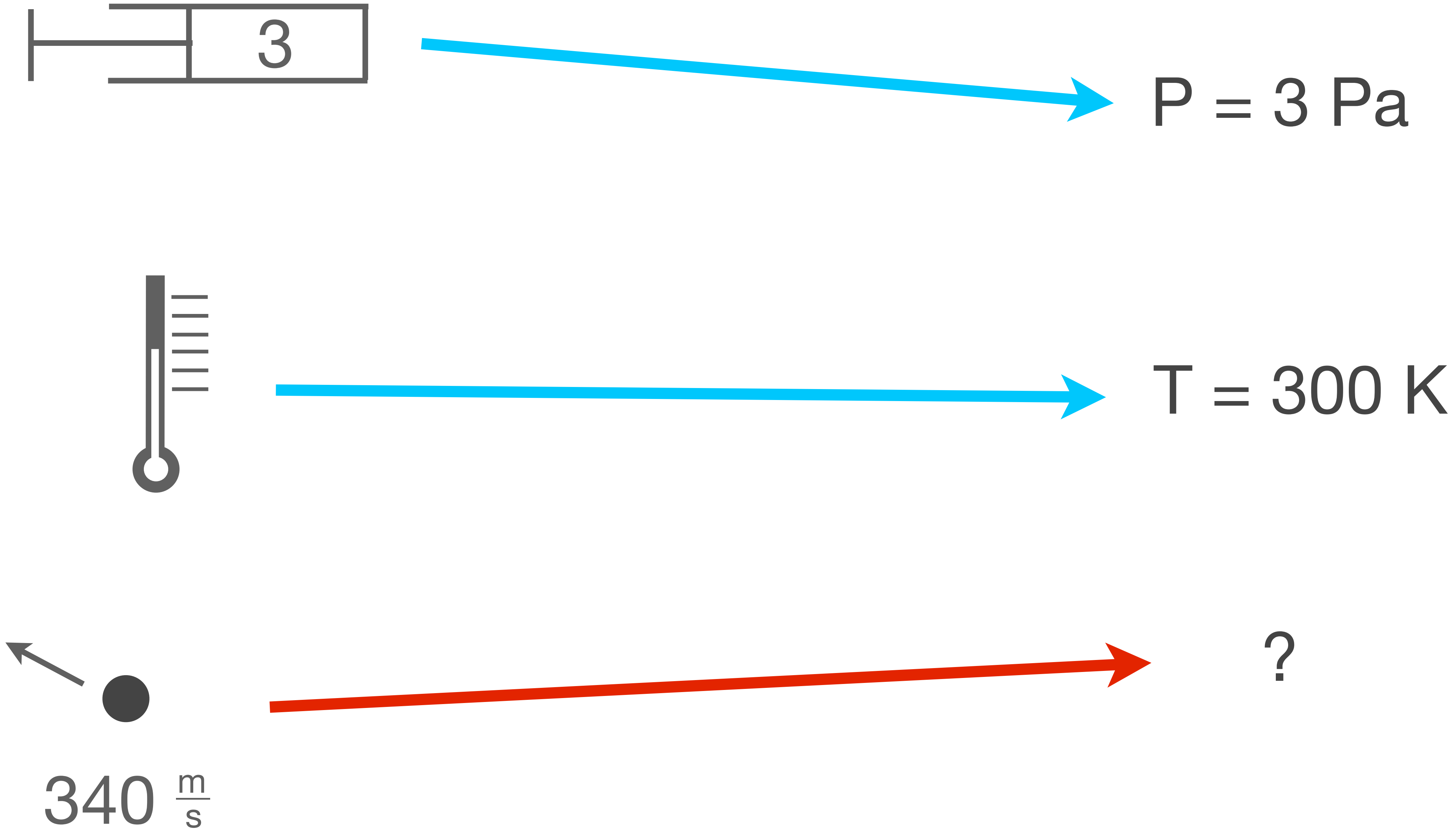

5
m = 5 kg
S_y = 1/2
Q = 1 C

példa : **termodinamika**

$P = 3$ Pa


3
P = 3 Pa
T = 300 K


3
P = 3 Pa
T = 300 K
340 m/s


3
P = 3 Pa
T = 300 K
?
340 m/s

EPR-argumentum

(1) QM nem teljes

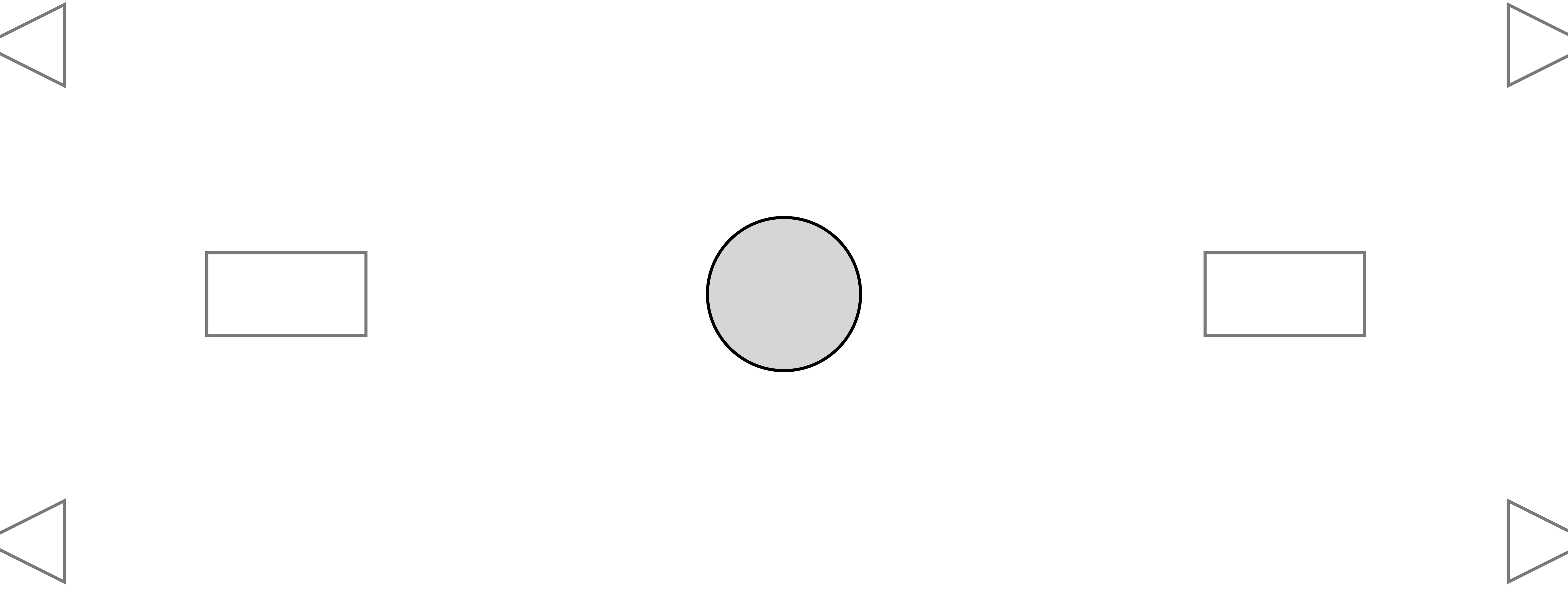
(2) $[A,B]=0 \rightarrow \nexists$ A és B egyszerre

$\neg(1)$

$$\neg(1) \longrightarrow \neg(2)$$

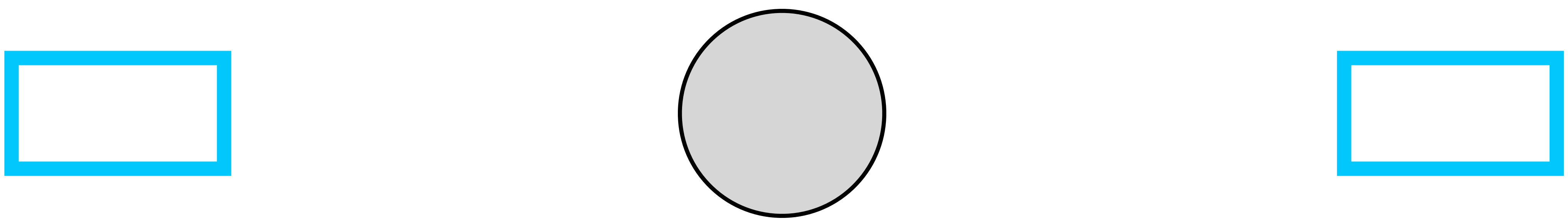
$$\neg(1) \longrightarrow \neg(2) \longrightarrow (1)$$

Bohm-Aharonov kísérlet

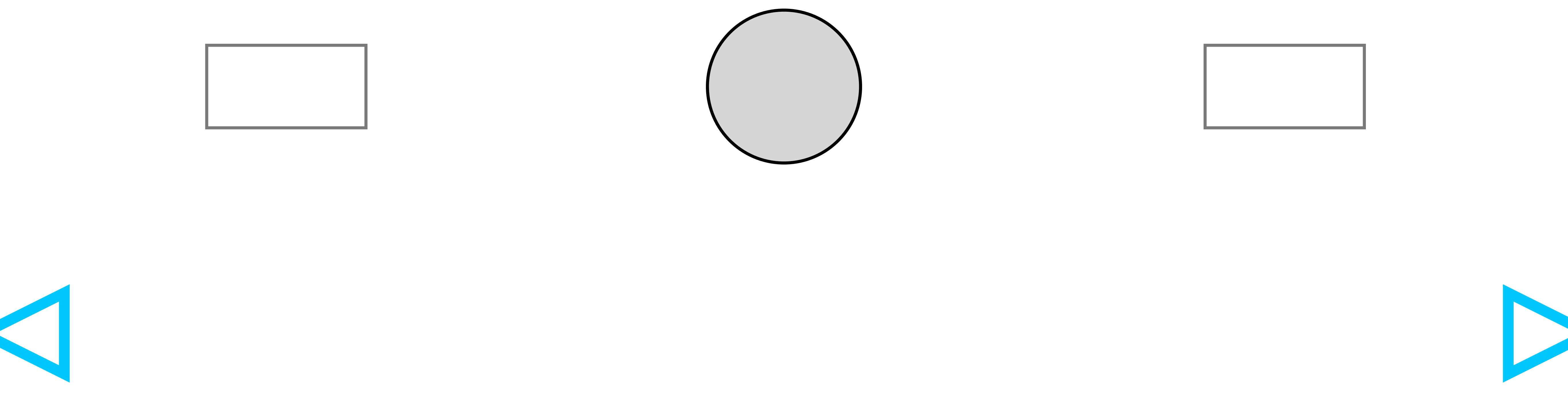


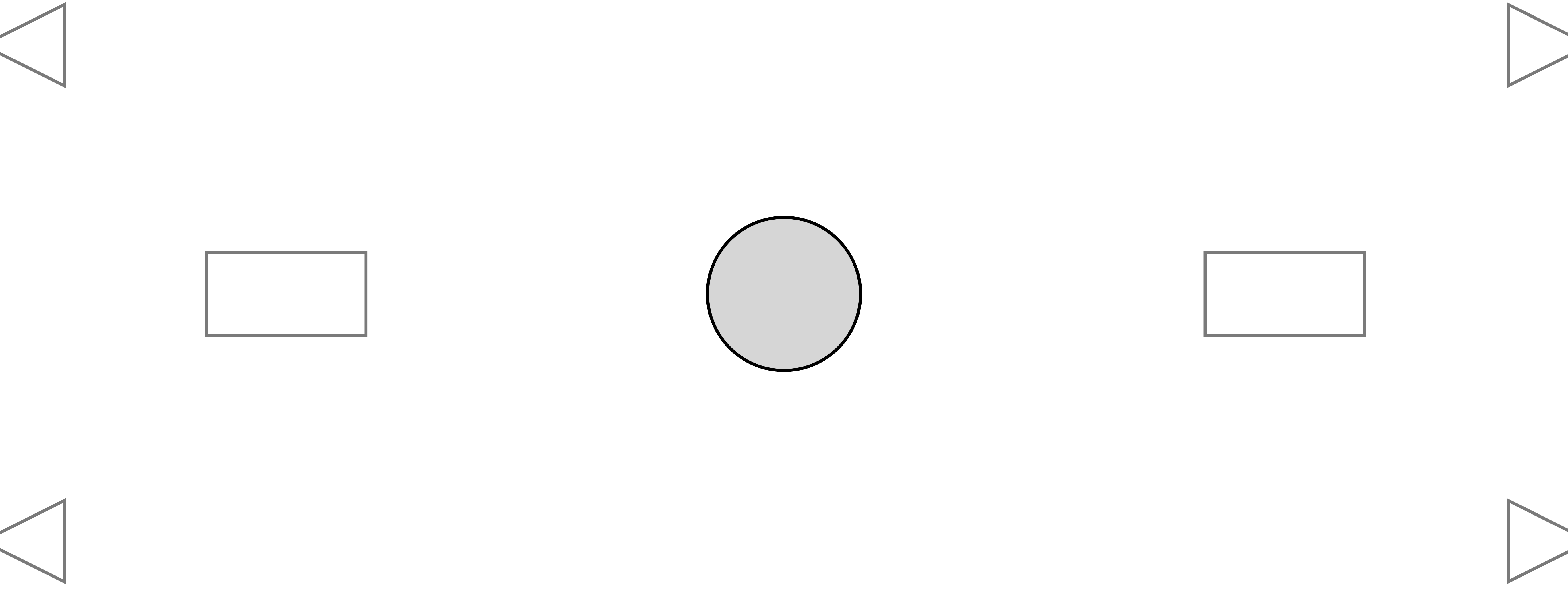

forrás

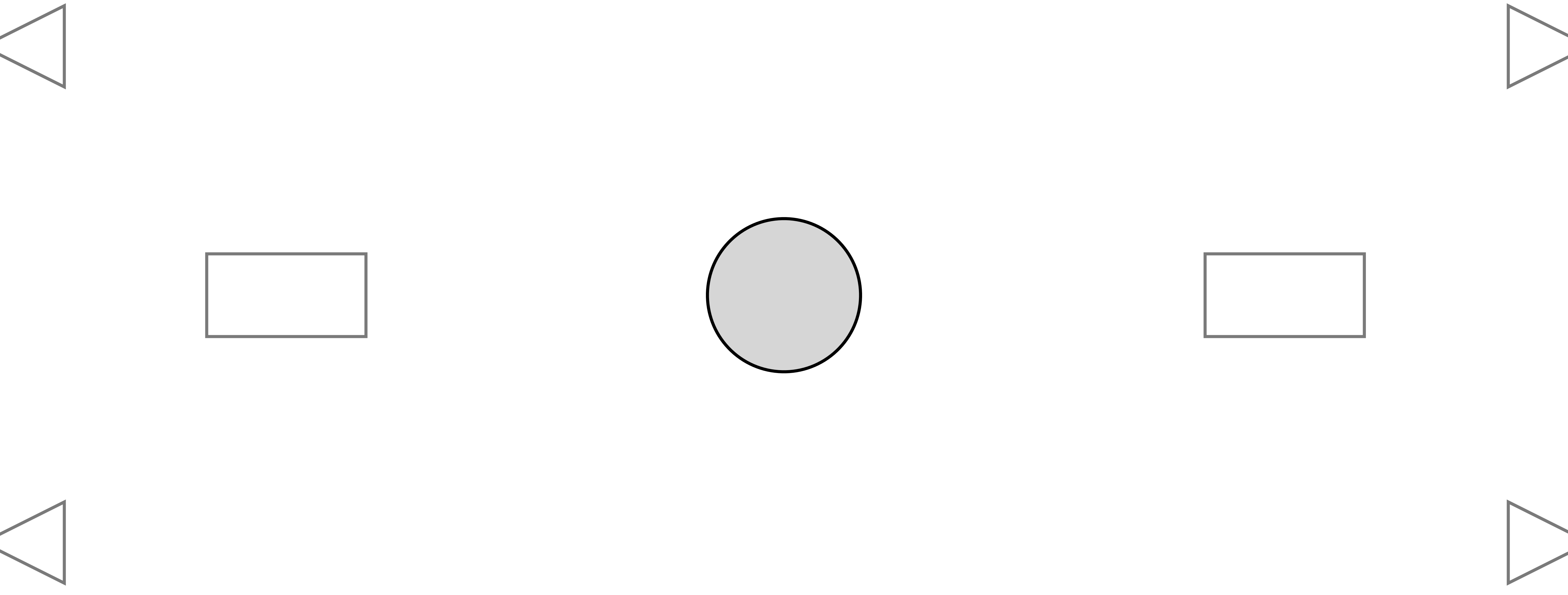
Stern-Gerlach mágnesek

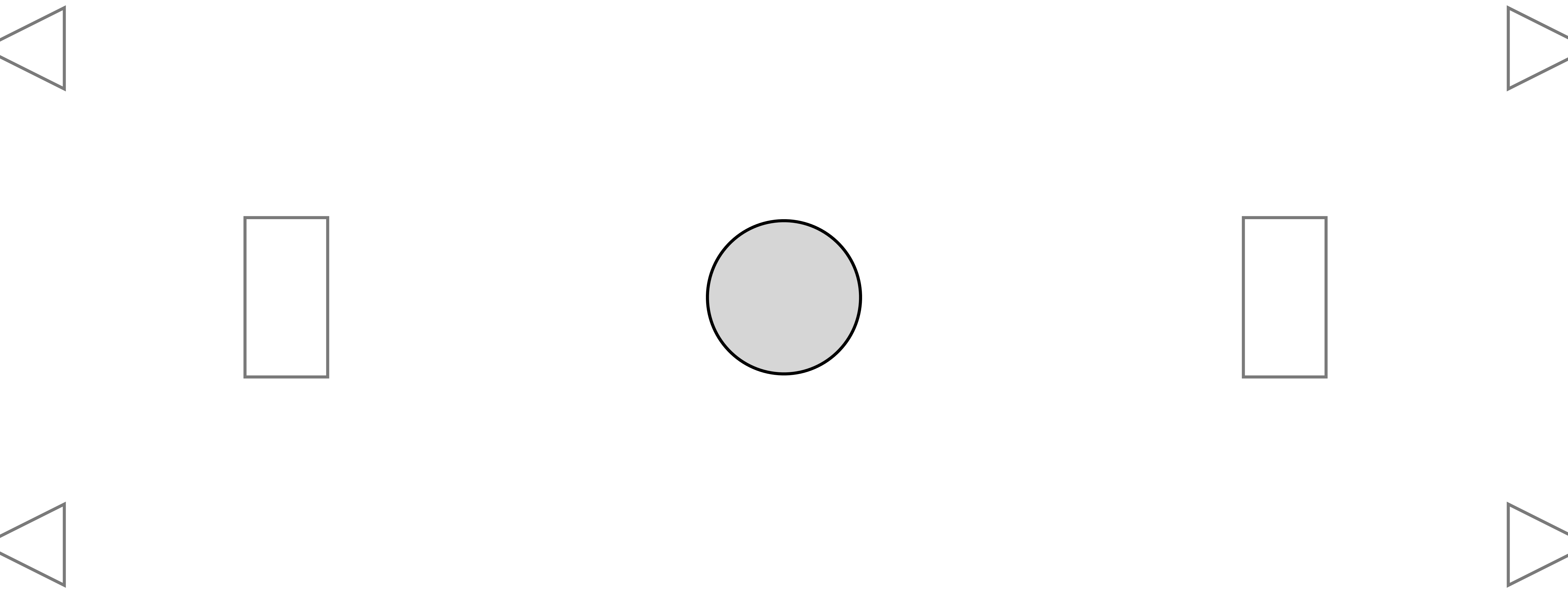


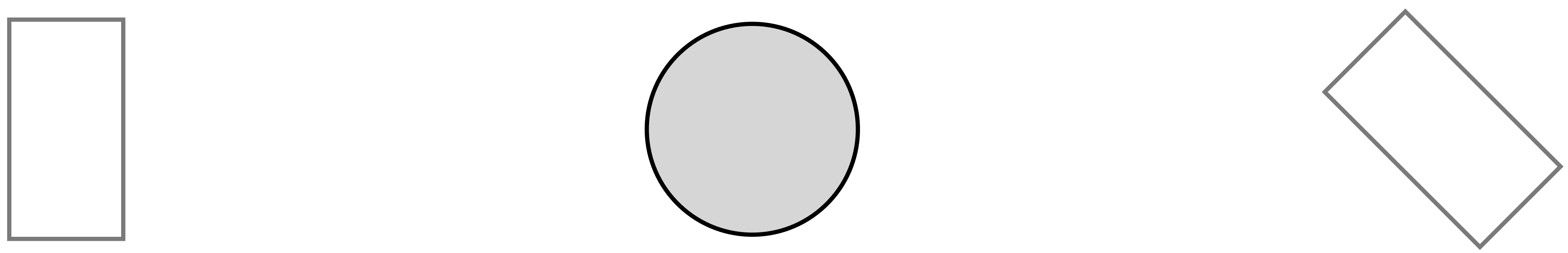
részecske detektorok

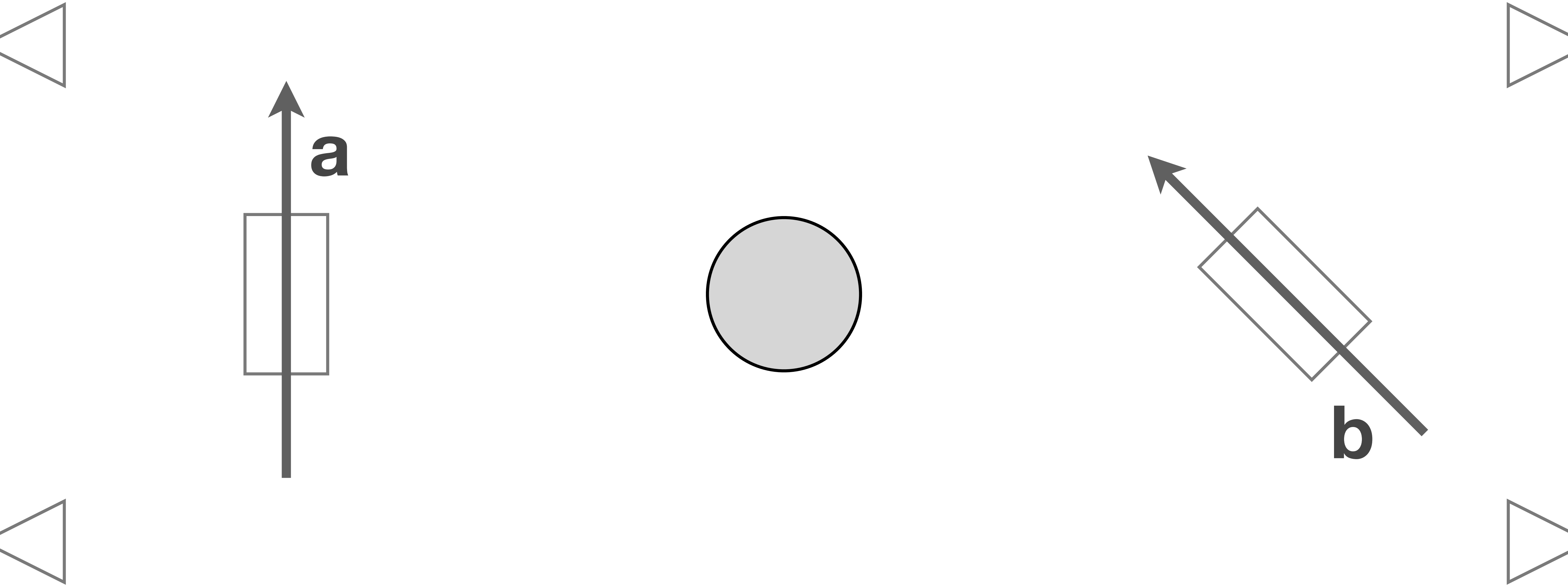






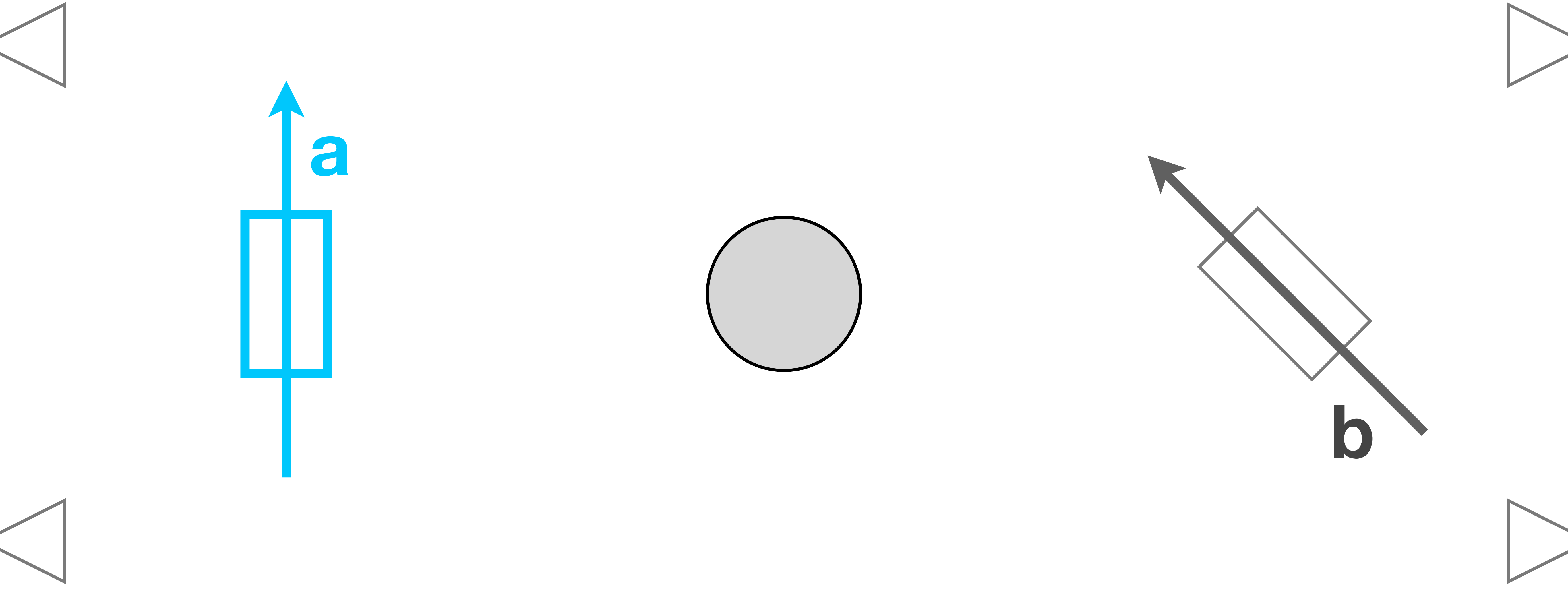


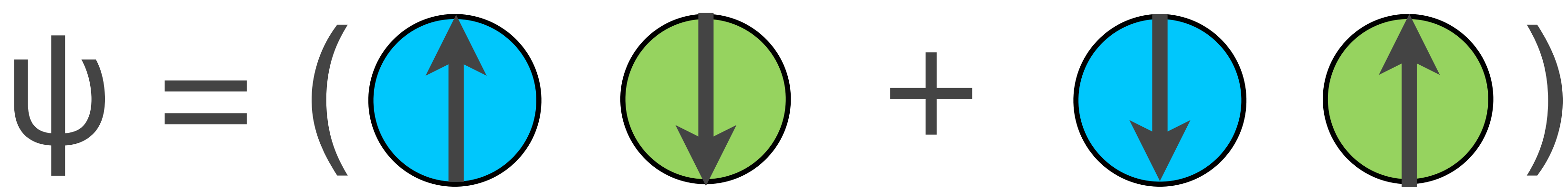


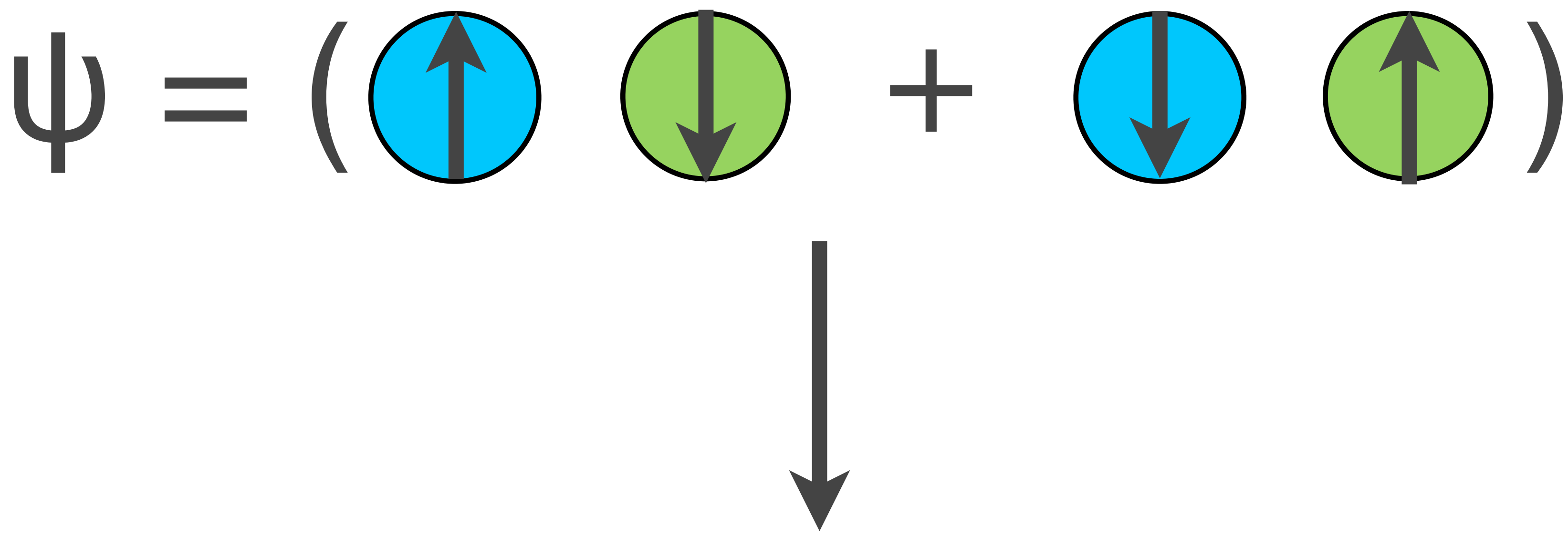

a
b

$$P(A|a) = \frac{1}{2}$$

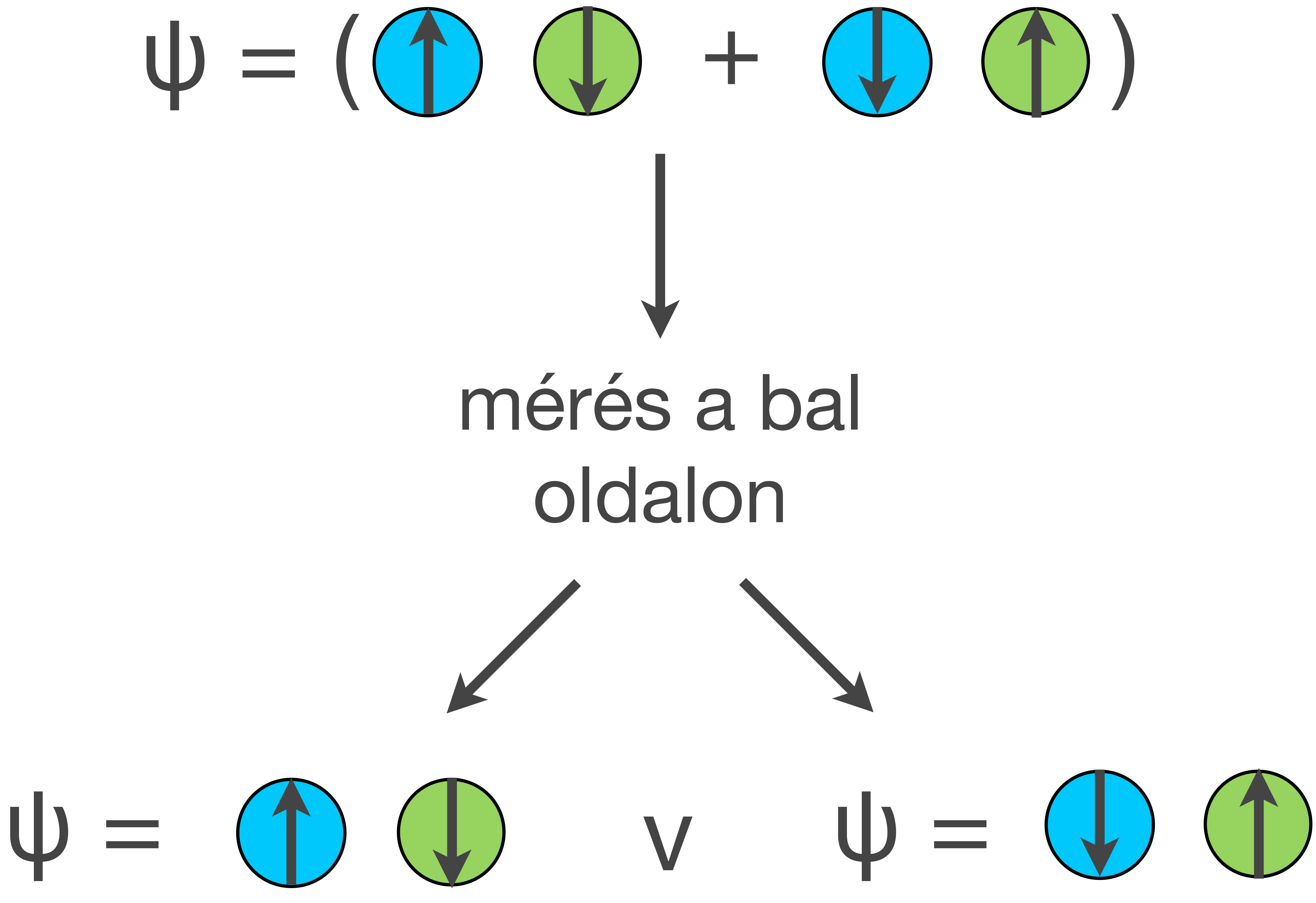
$$P(A\wedge B|a\wedge b) = \frac{1}{2}\sin^2\frac{\mathbf{ab}}{2ab}$$

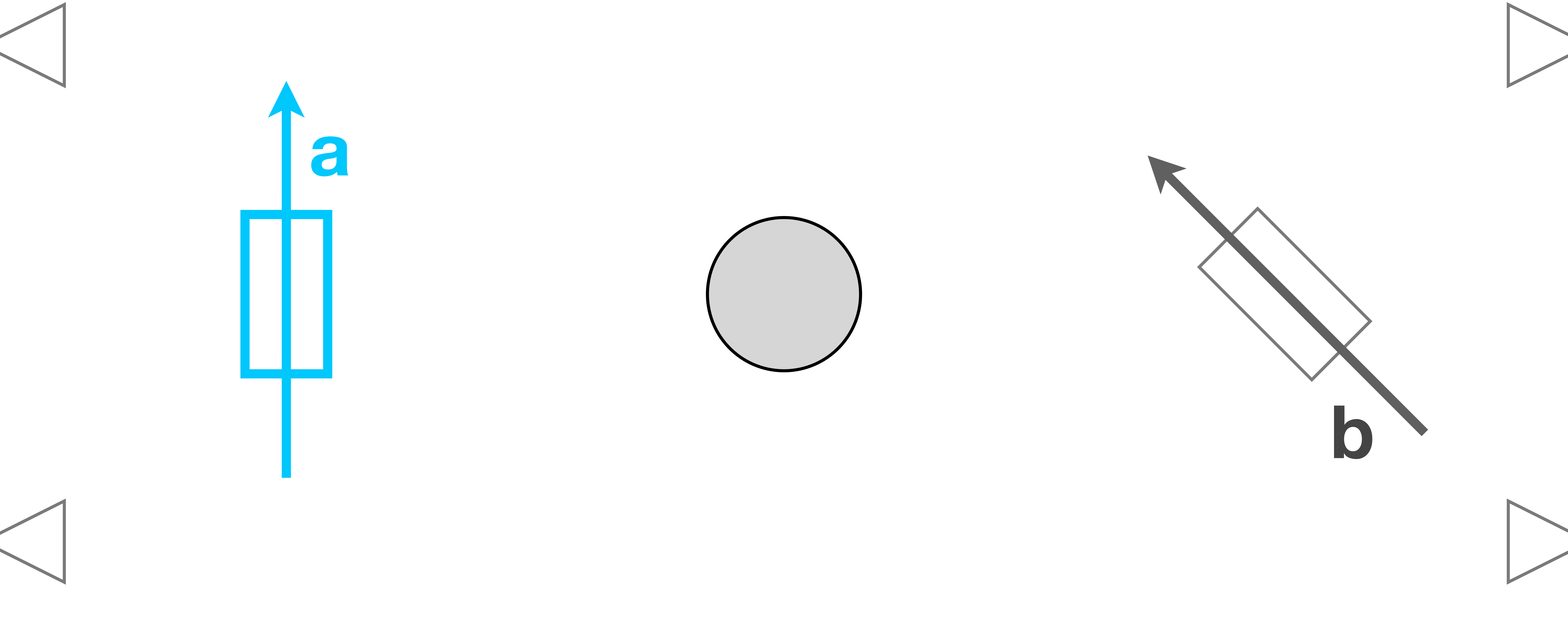

a
b

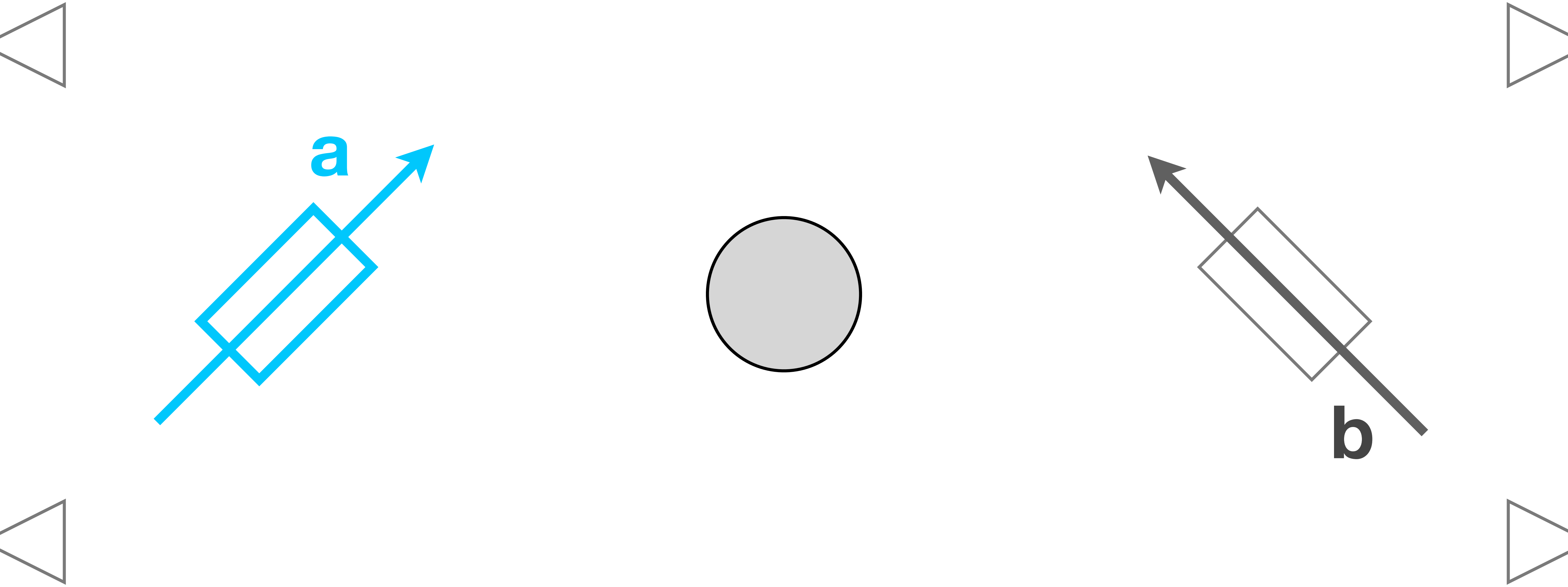

ψ = (+)

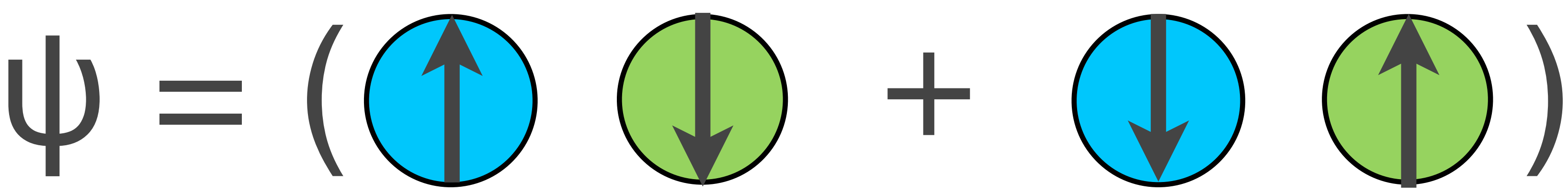


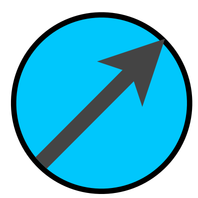
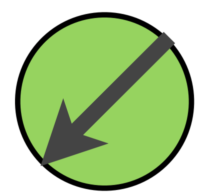
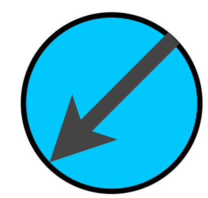
mérés a bal oldalon

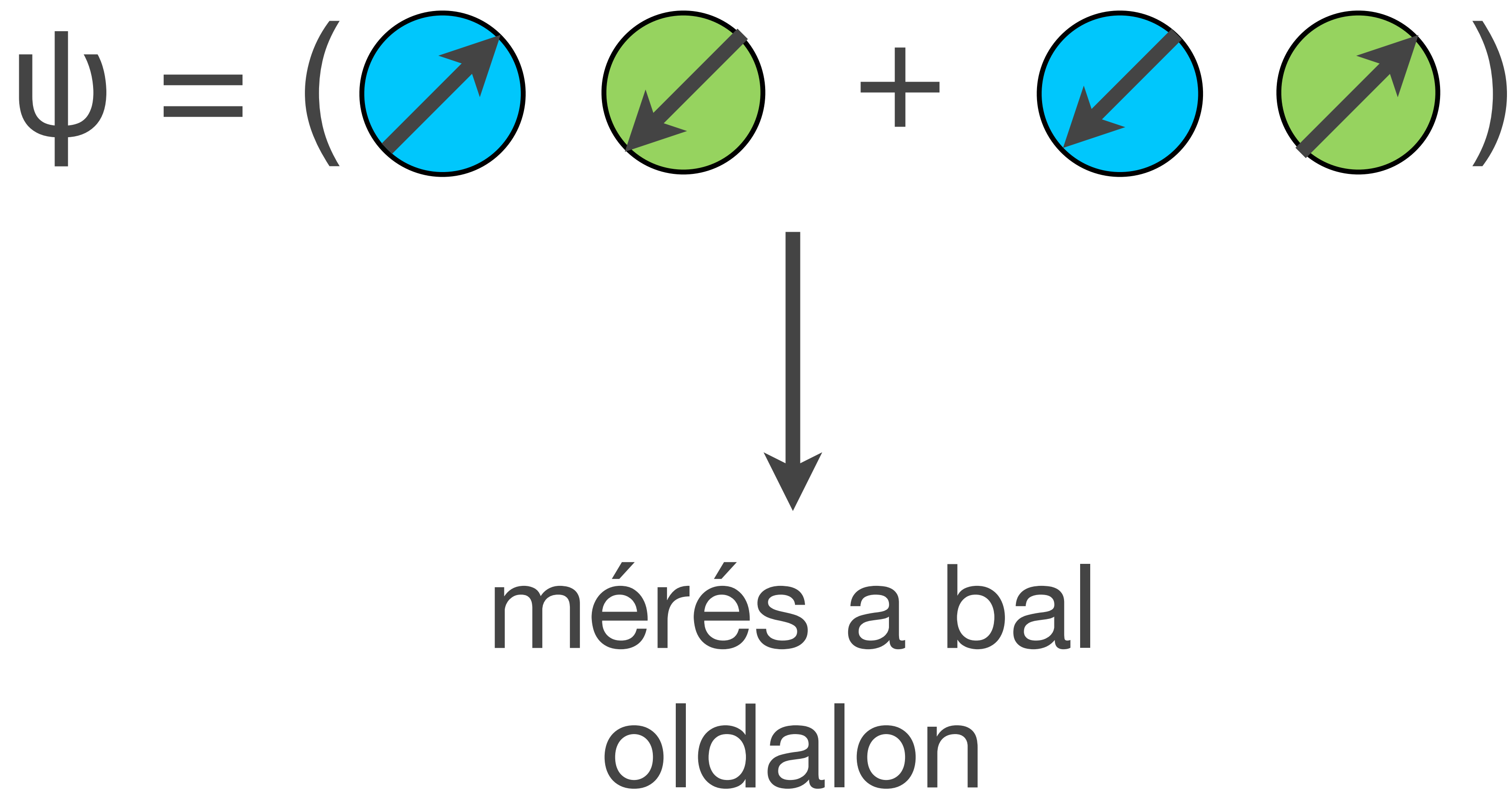

ψ = (
+
)
mérés a bal oldalon
ψ =
v
ψ =

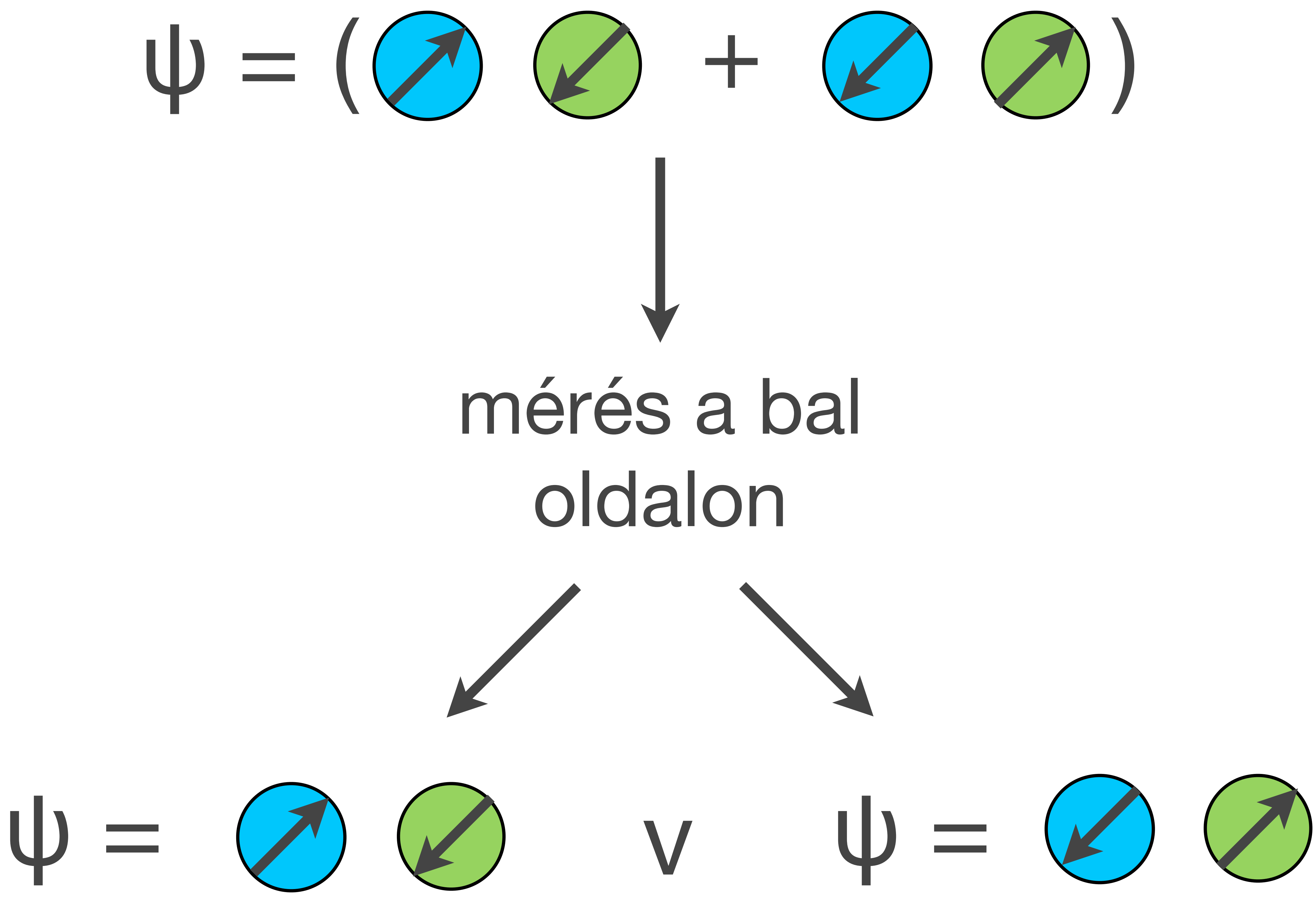

a
b

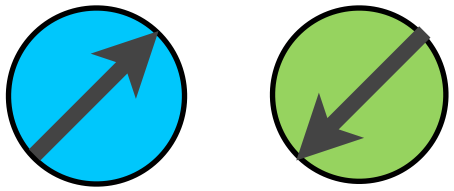

a
b

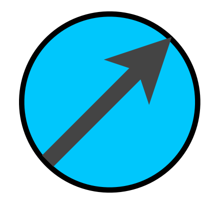

ψ = (+)

$\psi = ($   $+$   $)$


ψ =
+
mérés a bal oldalon


ψ = (
+
)
mérés a bal
oldalon
ψ =
v
ψ =

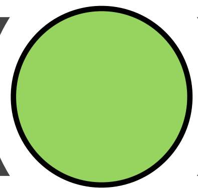
$\psi =$ 

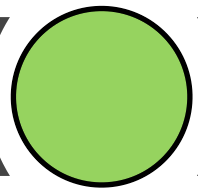
$\psi_{bal} =$ 

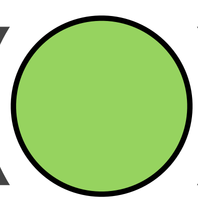
$\psi_{jobb} =$ 

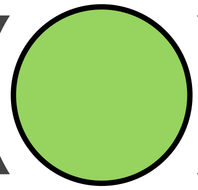
mérés a
baloldali
részecskén

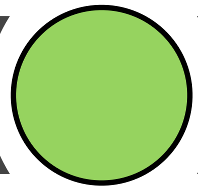
→ ψ_{jobb}

$\hat{S}_y$() a fizikai valóság eleme

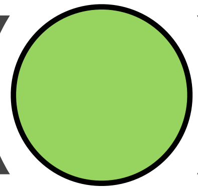
$\hat{S}_y$() a fizikai valóság eleme

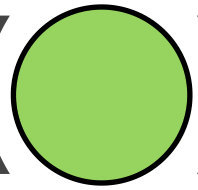
$\hat{S}_z$() a fizikai valóság eleme

$\hat{S}_y($$)$ a fizikai valóság eleme

$\hat{S}_z($$)$ a fizikai valóság eleme

$$[S_y, S_z] \neq 0$$

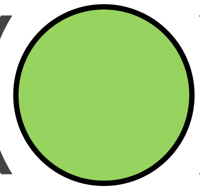
$\hat{S}_y($$)$ a fizikai valóság eleme

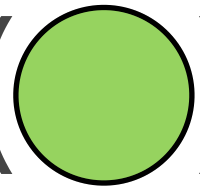
$\hat{S}_z($$)$ a fizikai valóság eleme

$$[S_y, S_z] \neq 0$$

↓

a QM-ban nincs megfelelőjük

$\hat{S}_y$() a fizikai valóság eleme

$\hat{S}_z$() a fizikai valóság eleme

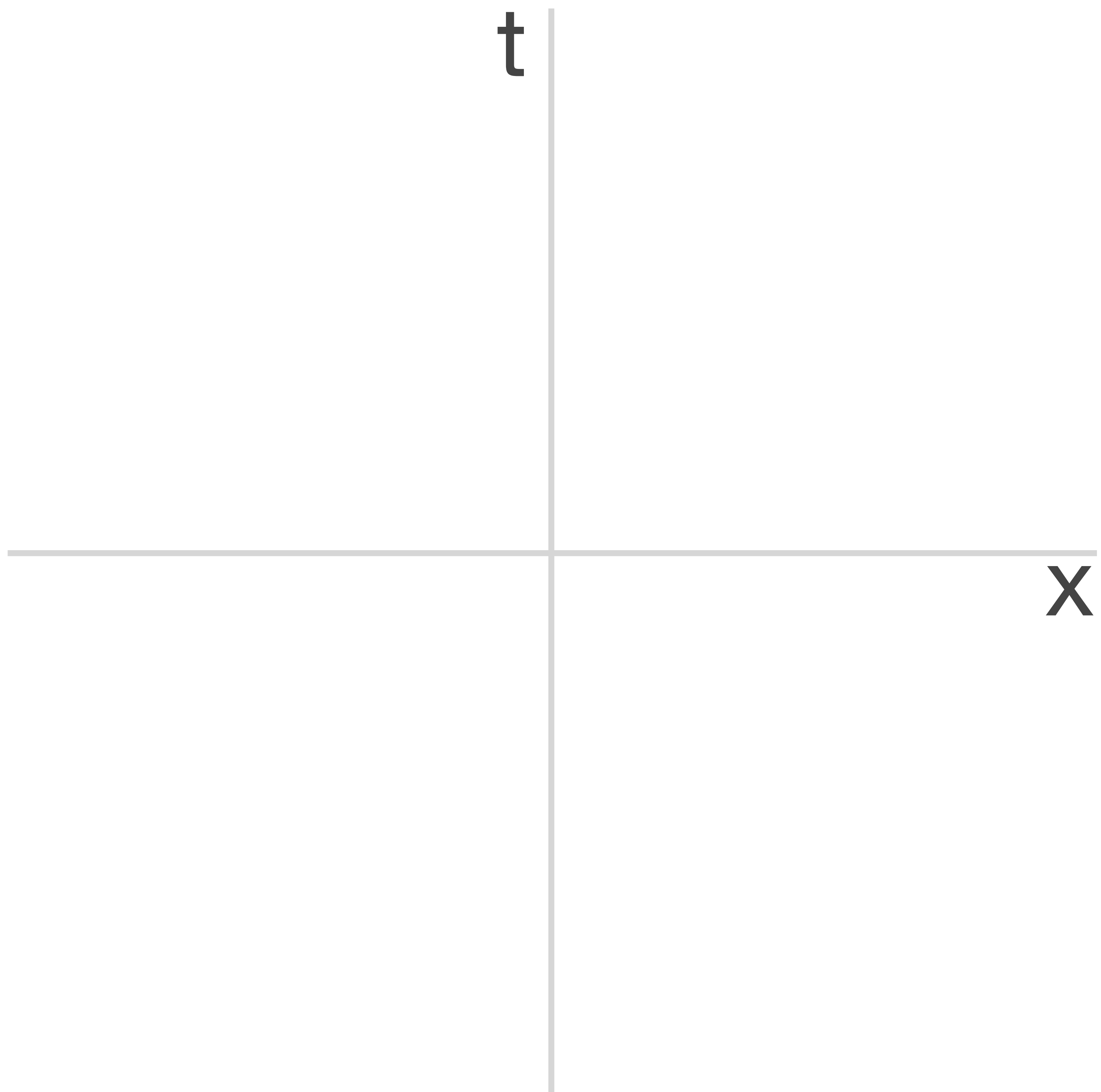
$$[S_y, S_z] \neq 0$$

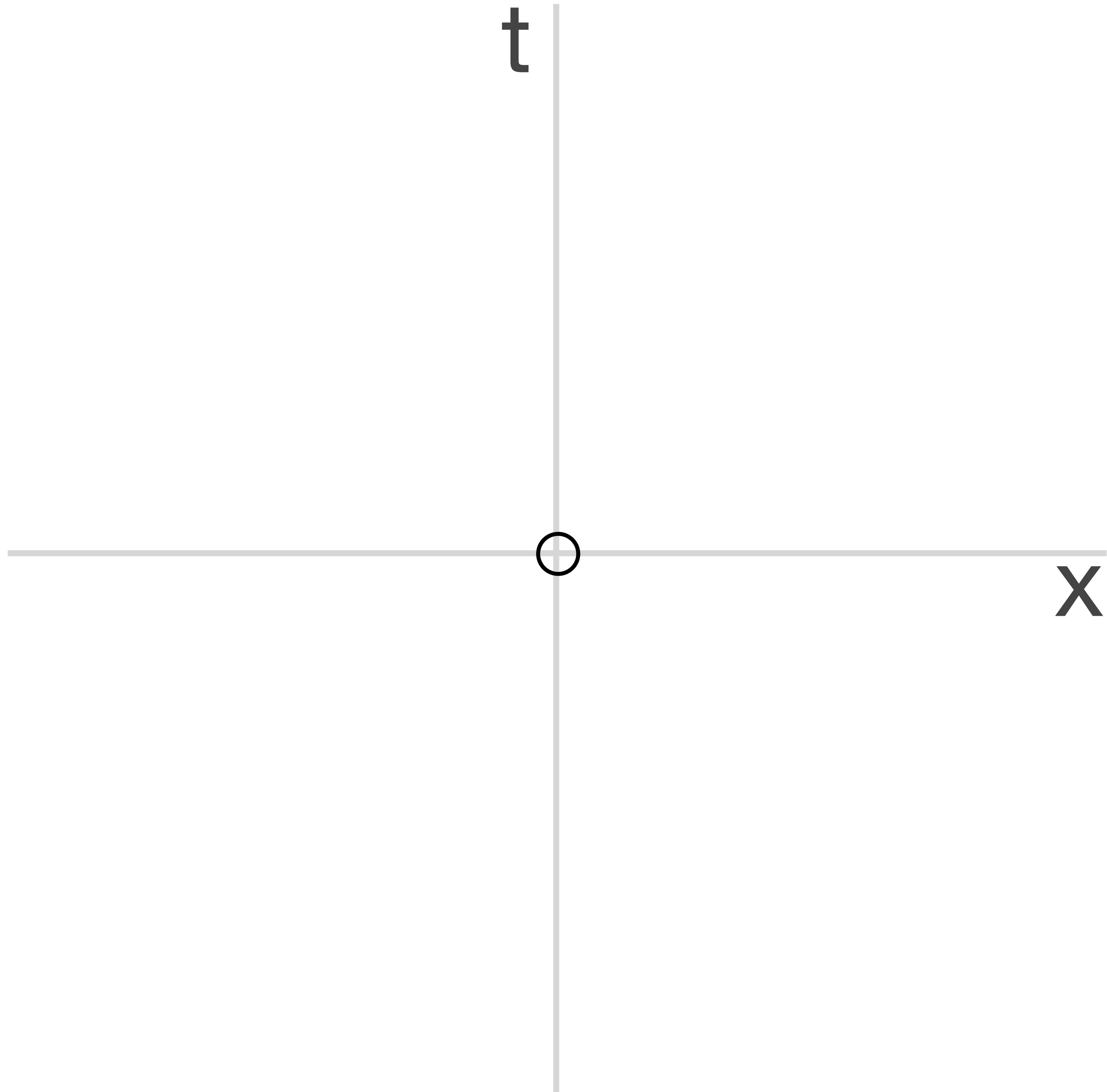
a QM-ban nincs megfelelőjük

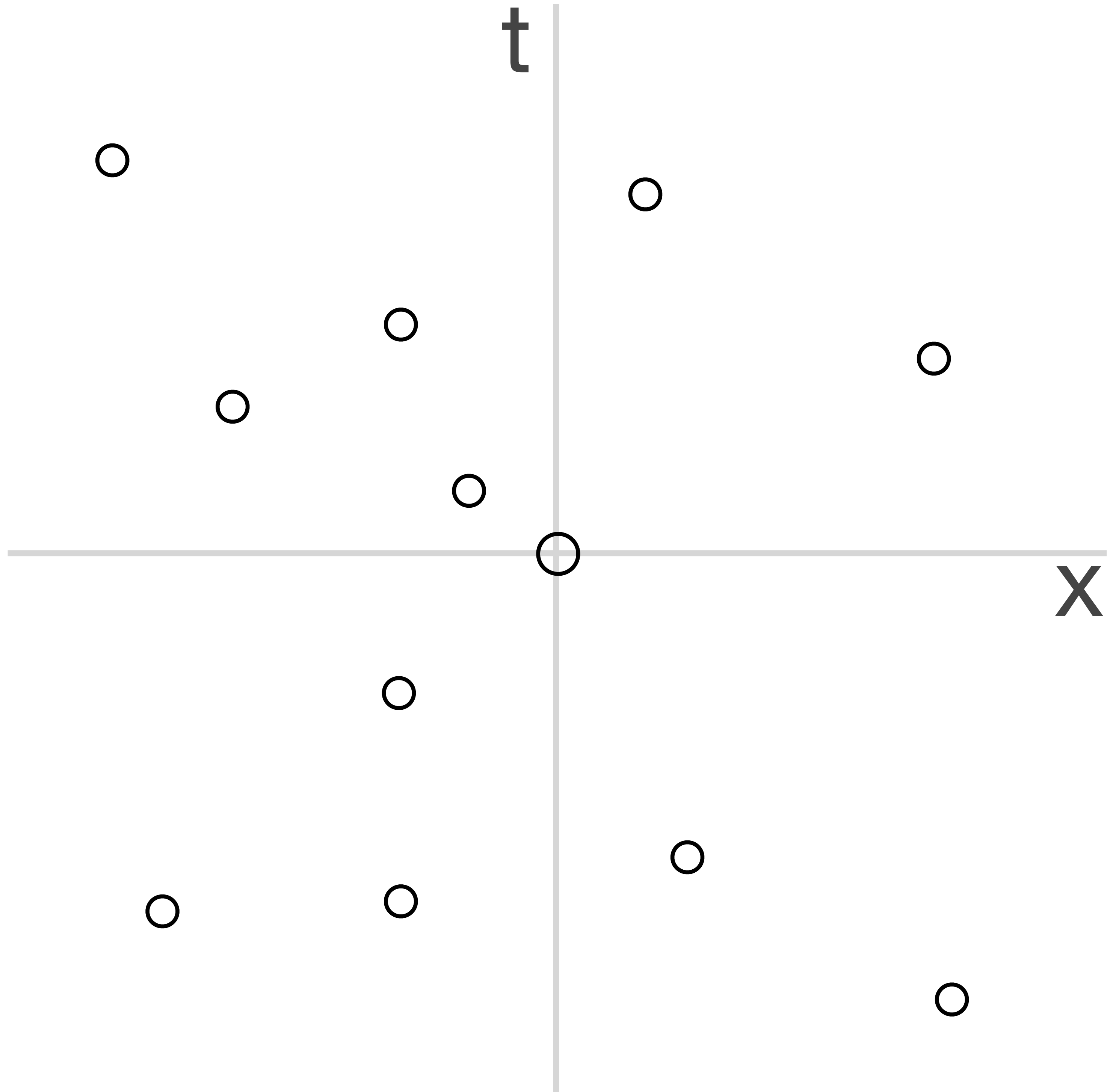
QM nem teljes

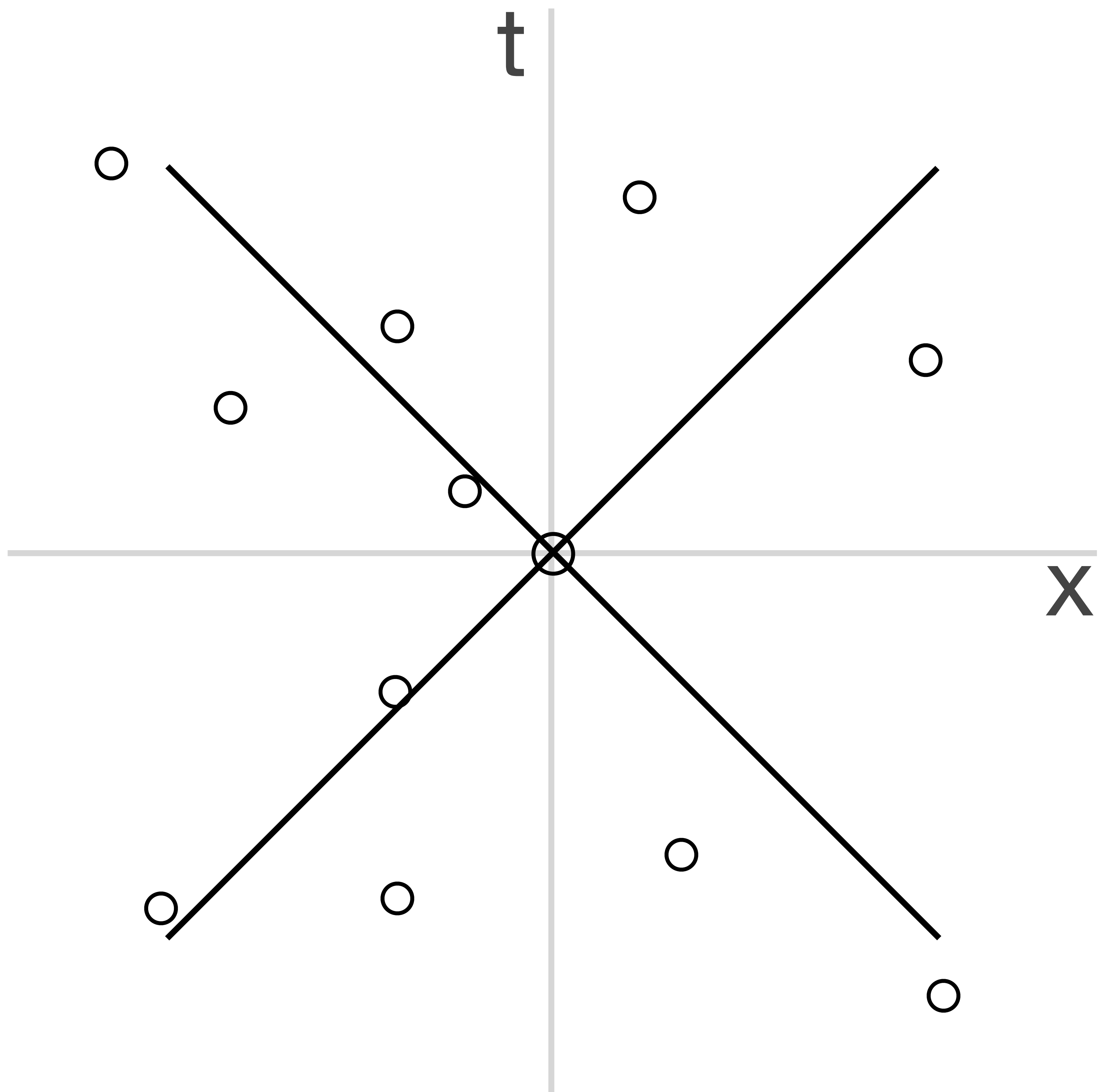
feltétel

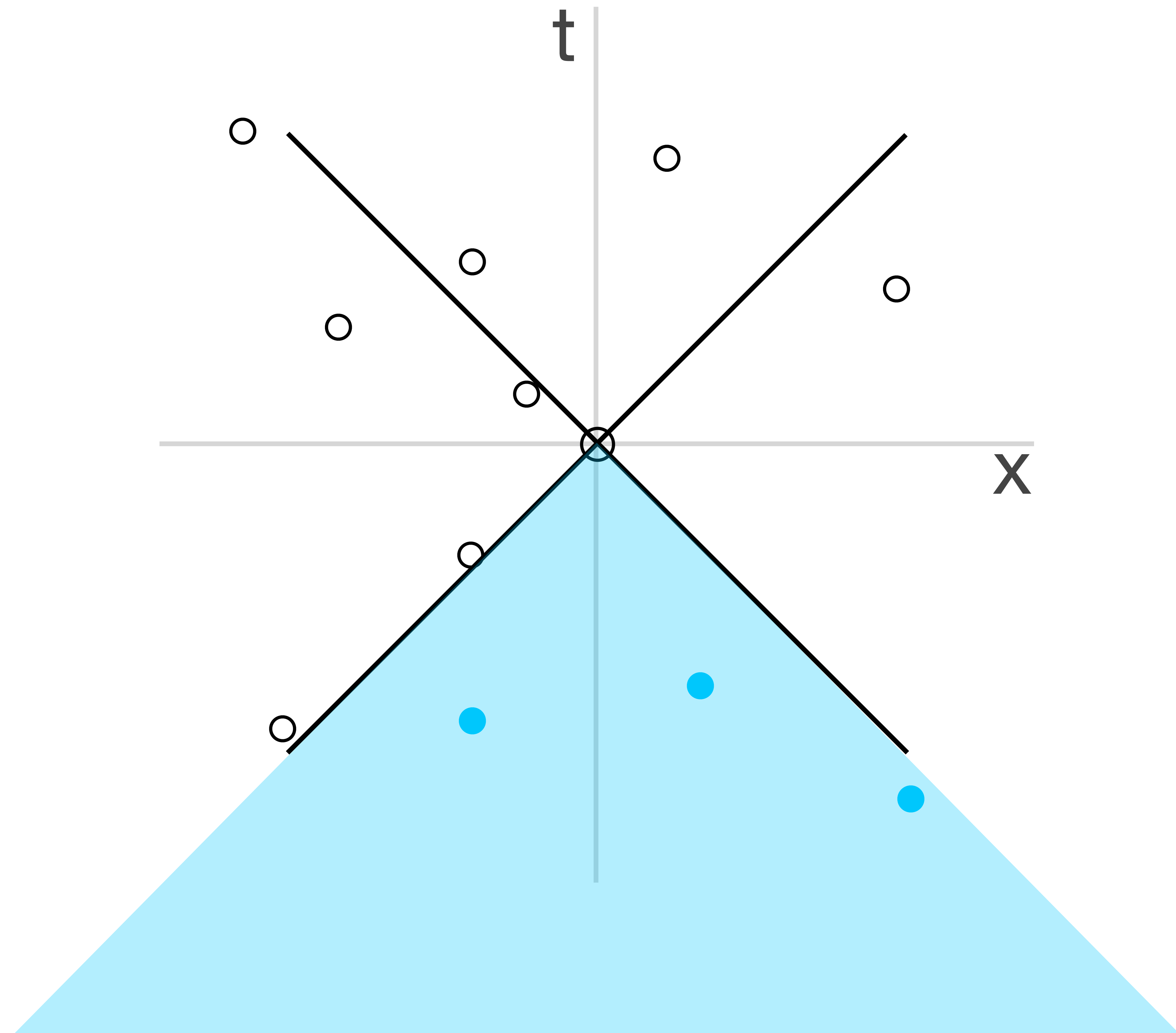
lokalitás

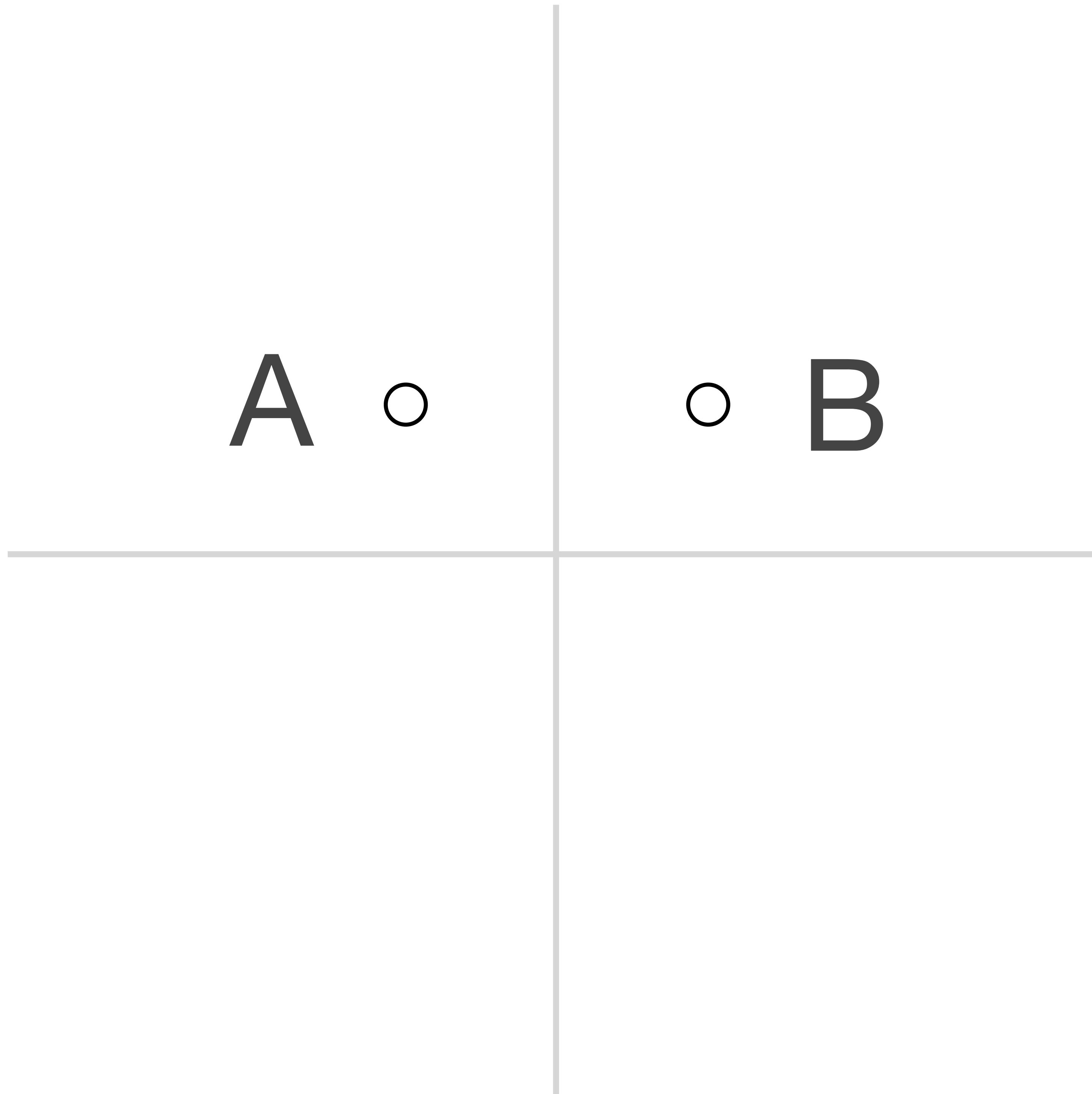

t
x

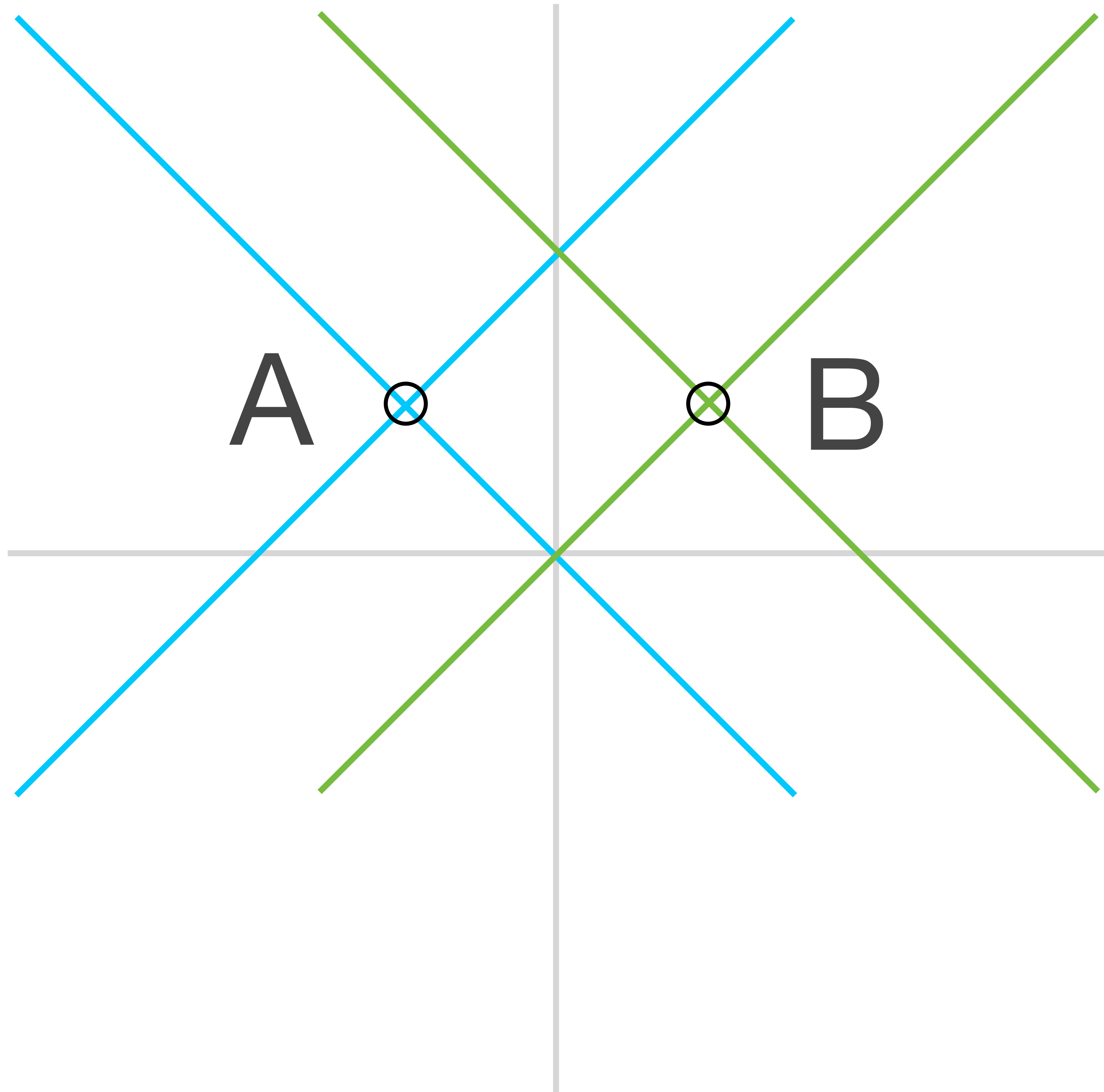

t
x

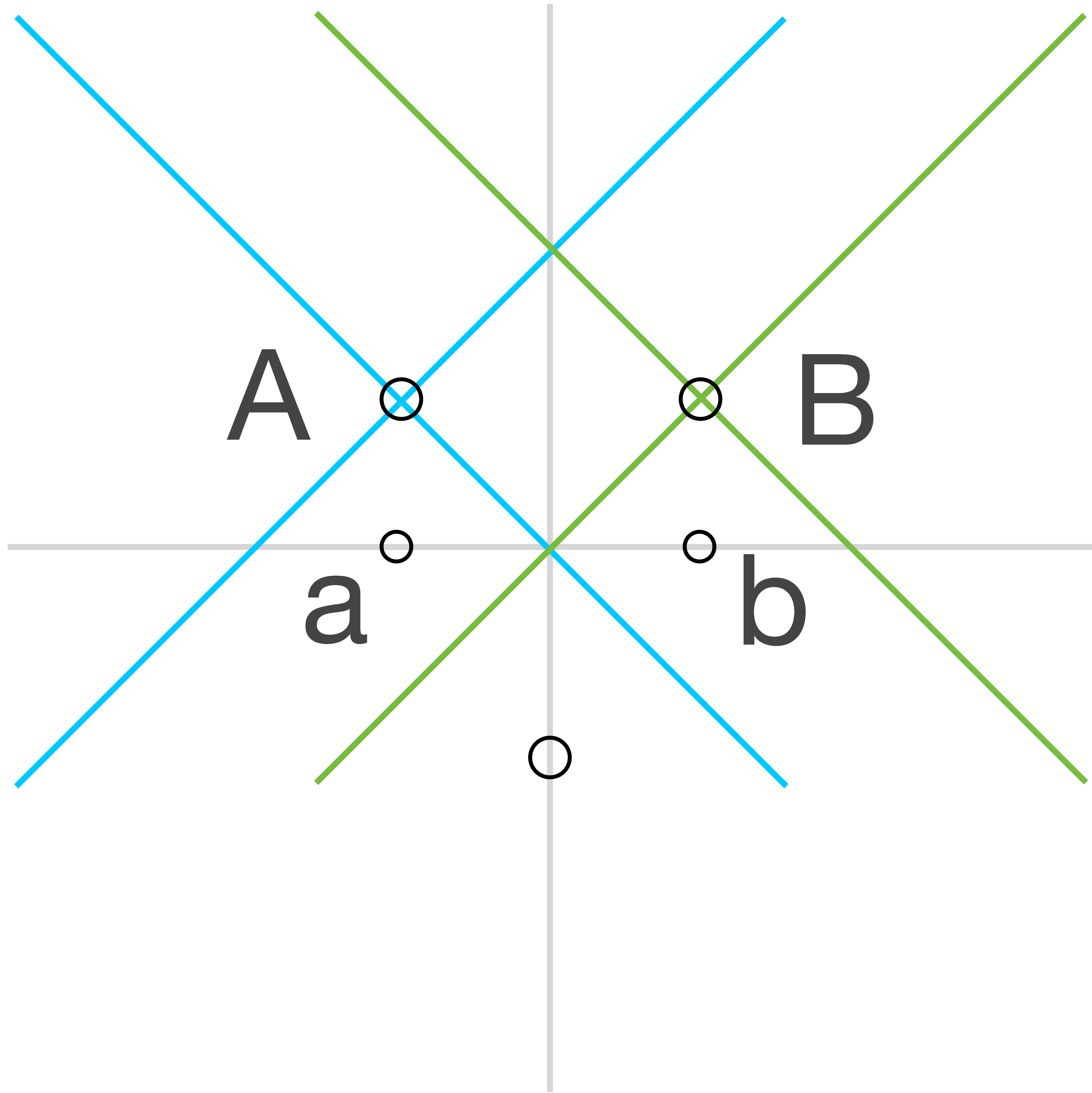

t
x

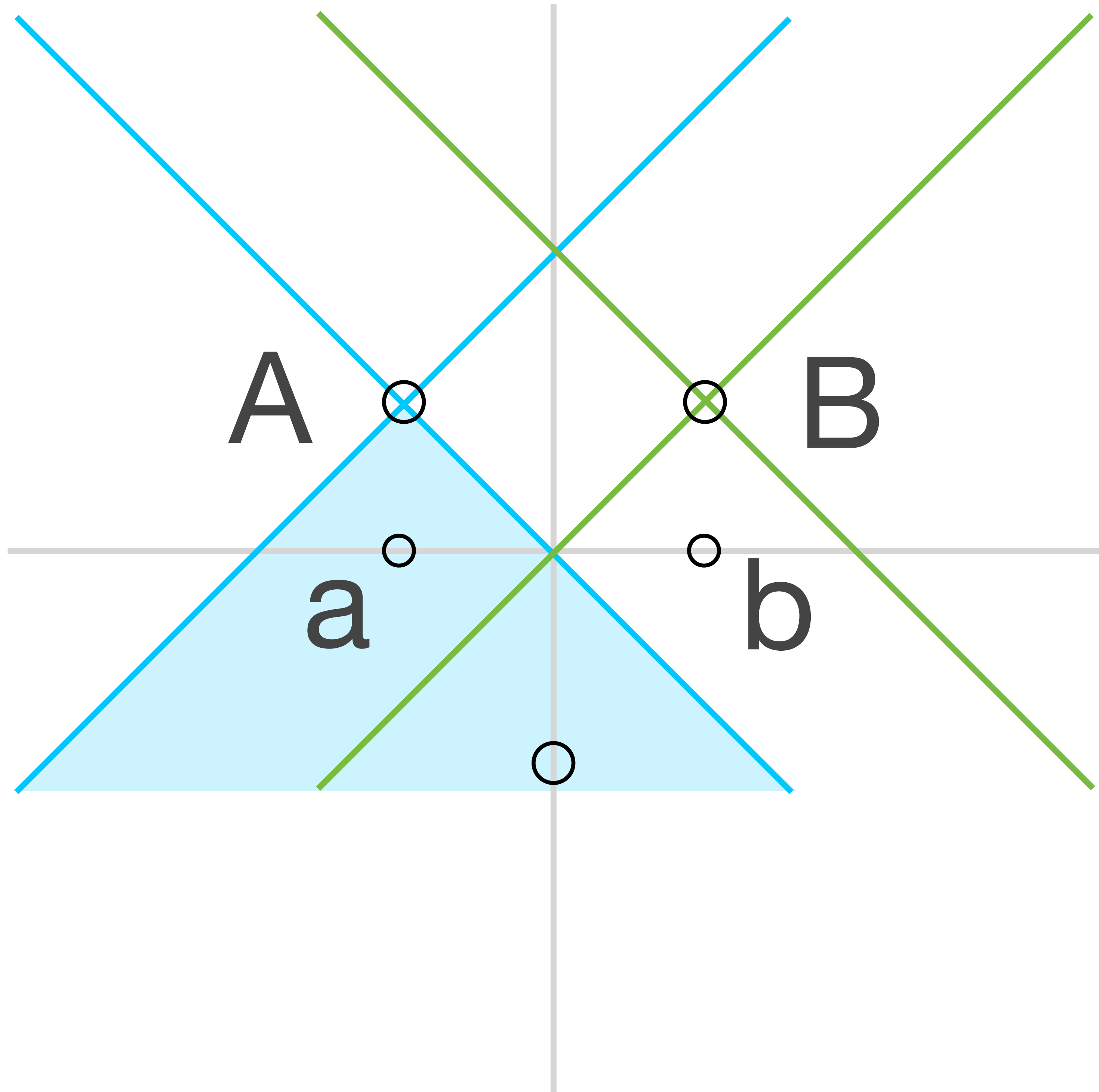

t
x

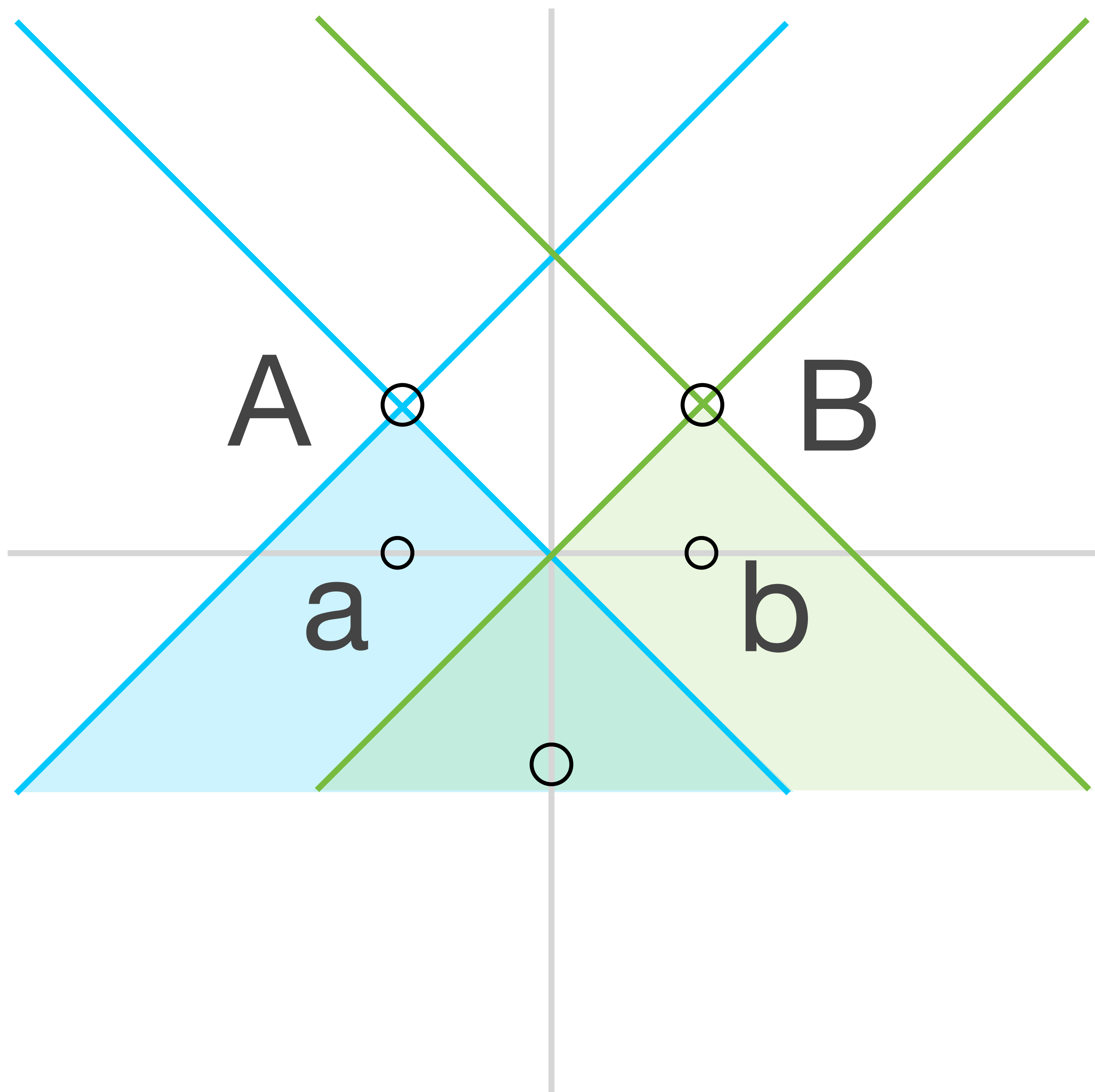

t
x

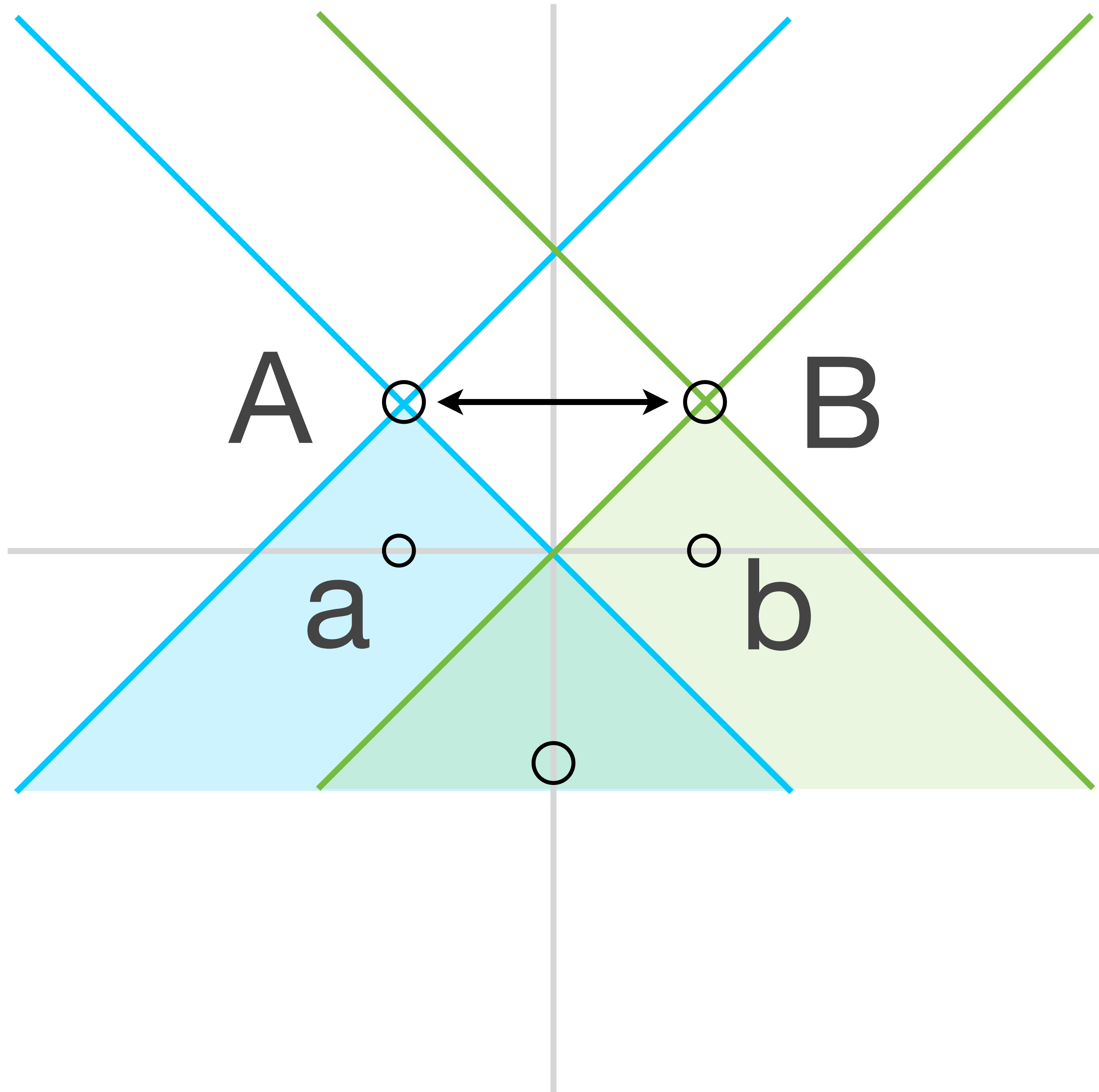

A
B

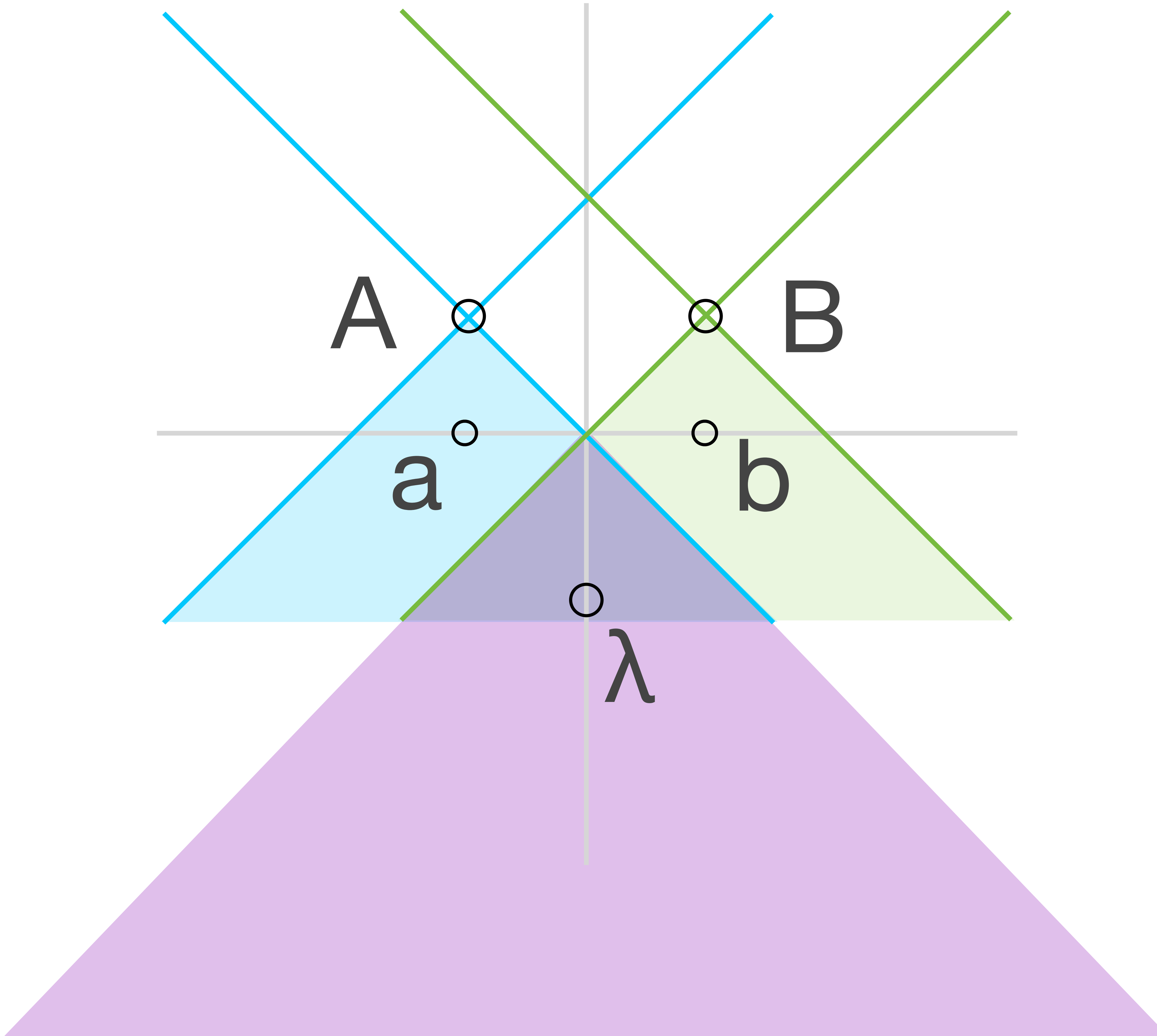

A
B


A
B
a
b


A
B
a
b


A
B
a
b


A
B
a
b



A
B
a
b
λ

II. Bell-egyenlőtlenségek

feltevések

i. LDM-világ

Lokális
Determinisztikus
Markovi

ii.

$$P(a(\lambda,\alpha)) = P(a(\alpha))$$

$$P(b(\lambda,\beta)) = P(a(\beta))$$

i. LDM-világ

ii. $P(a(\lambda,\alpha)) = P(a(\alpha))$

$P(b(\lambda,\beta)) = P(a(\beta))$

i. LDM-világ

ii. $P(a(\lambda,\alpha)) = P(a(\alpha))$
$P(b(\lambda,\beta)) = P(a(\beta))$

$$-1 \leq p(A1 \wedge B1|a1 \wedge b1)+p(A1 \wedge B2|a1 \wedge b2)+p(A2 \wedge B2|a2 \wedge b2)-p(A2 \wedge B1|a2 \wedge b1)-p(A1|a1)-p(B2|b2) \leq 0$$

$$-1 \leq p(A2 \wedge B1|a2 \wedge b1)+p(A2 \wedge B2|a2 \wedge b2)+p(A1 \wedge B2|a1 \wedge b2)-p(A1 \wedge B1|a1 \wedge b1)-p(A2|a2)-p(B2|b2) \leq 0$$

$$-1 \leq p(A1 \wedge B2|a1 \wedge b2)+p(A1 \wedge B1|a1 \wedge b1)+p(A2 \wedge B1|a2 \wedge b1)-p(A2 \wedge B2|a2 \wedge b2)-p(A1|a1)-p(B1|b1) \leq 0$$

$$-1 \leq p(A2 \wedge B2|a2 \wedge b2)+p(A2 \wedge B1|a2 \wedge b1)+p(A1 \wedge B1|a1 \wedge b1)-p(A1 \wedge B2|a1 \wedge b2)-p(A2|a2)-p(B1|b1) \leq 0$$

Lokális, λ modell → Bell >-ek igazak

Lokális, λ modell → Bell >-ek igazak

QM valószínűségek

$$P(A|a) = \frac{1}{2}$$

$$P(A \wedge B|a \wedge b) = \frac{1}{2} \sin^2 \frac{\mathbf{ab}}{2ab}$$

Lokális, λ modell → Bell >-ek igazak

QM valószínűségek → Bell >-ek sérülnek

Lokális, λ modell ← Bell >-ek igazak

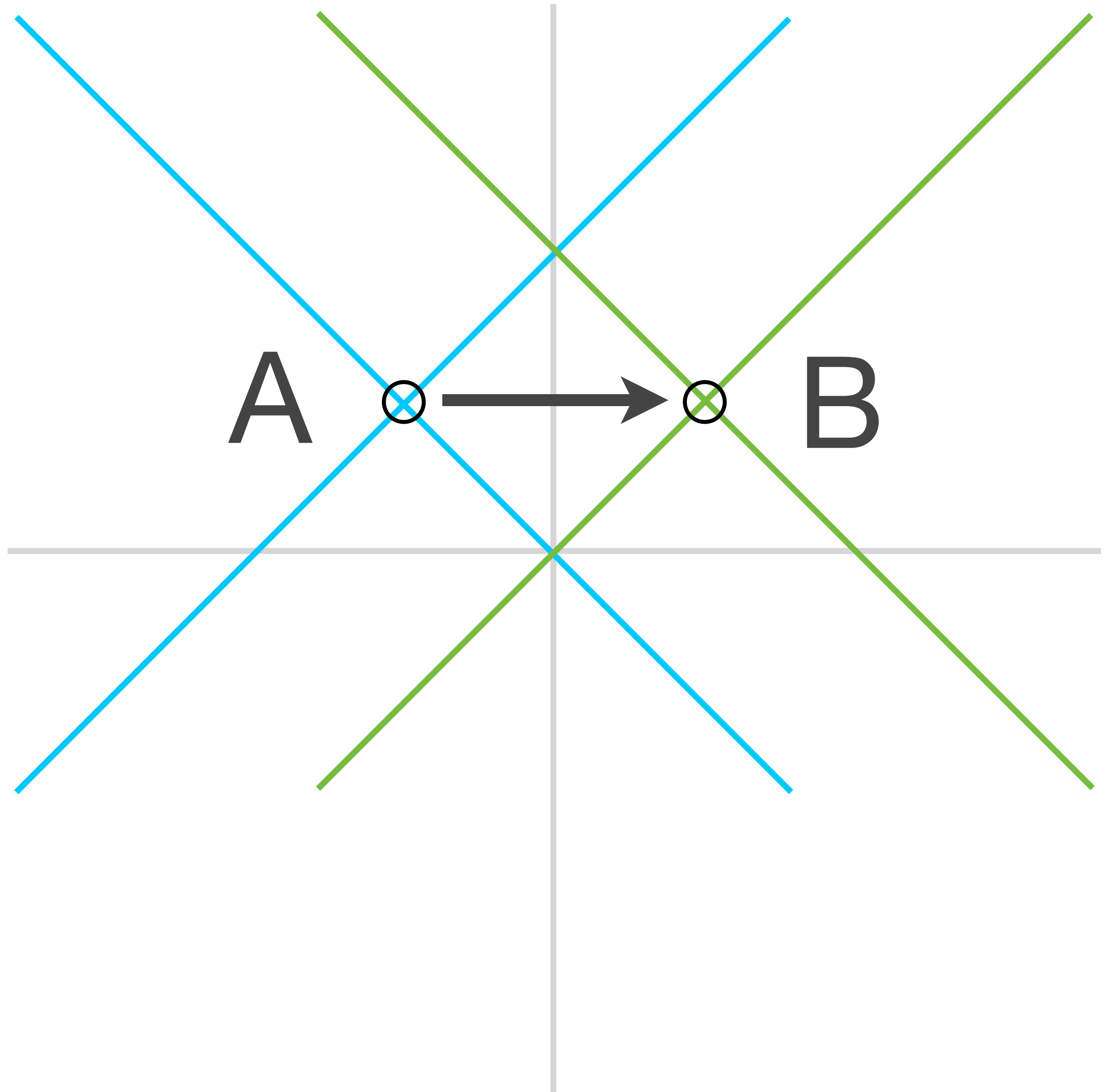
QM valószínűségek ← Bell >-ek sérülnek

$$\neg(1) \longrightarrow \neg(2) \longrightarrow (1)$$

¬(1)
¬(2)
(1)

III. feloldások

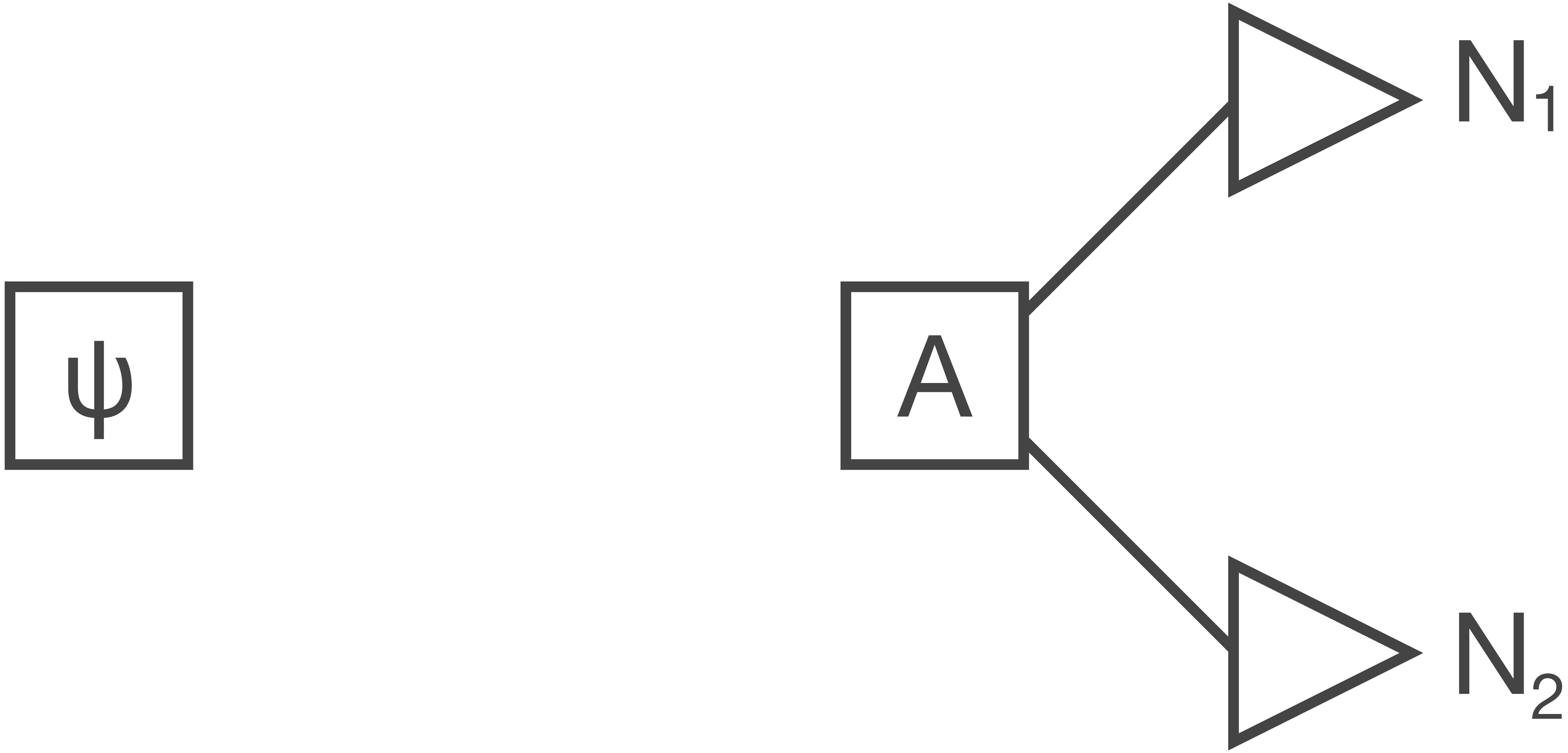
lokalitás elvetése

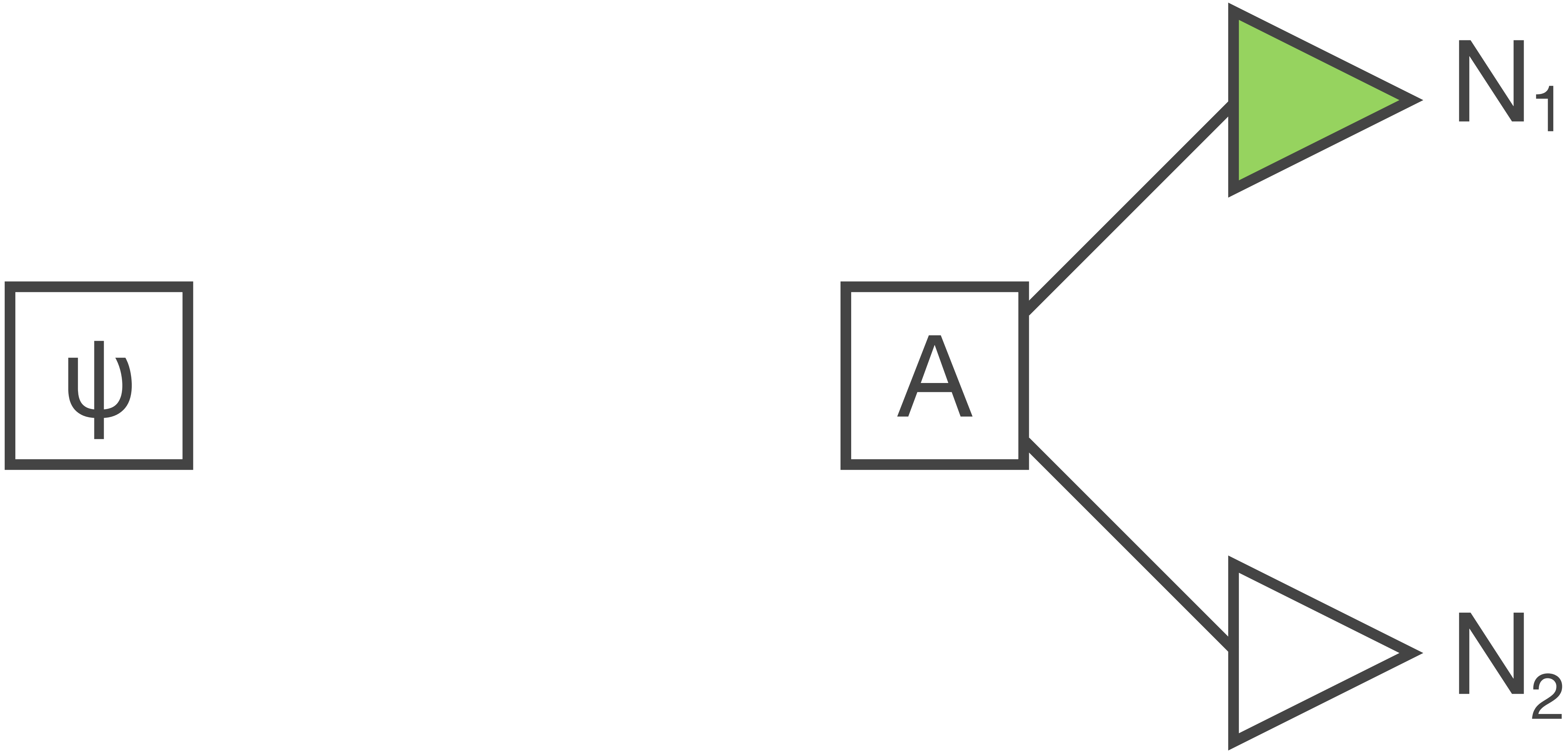

A
B

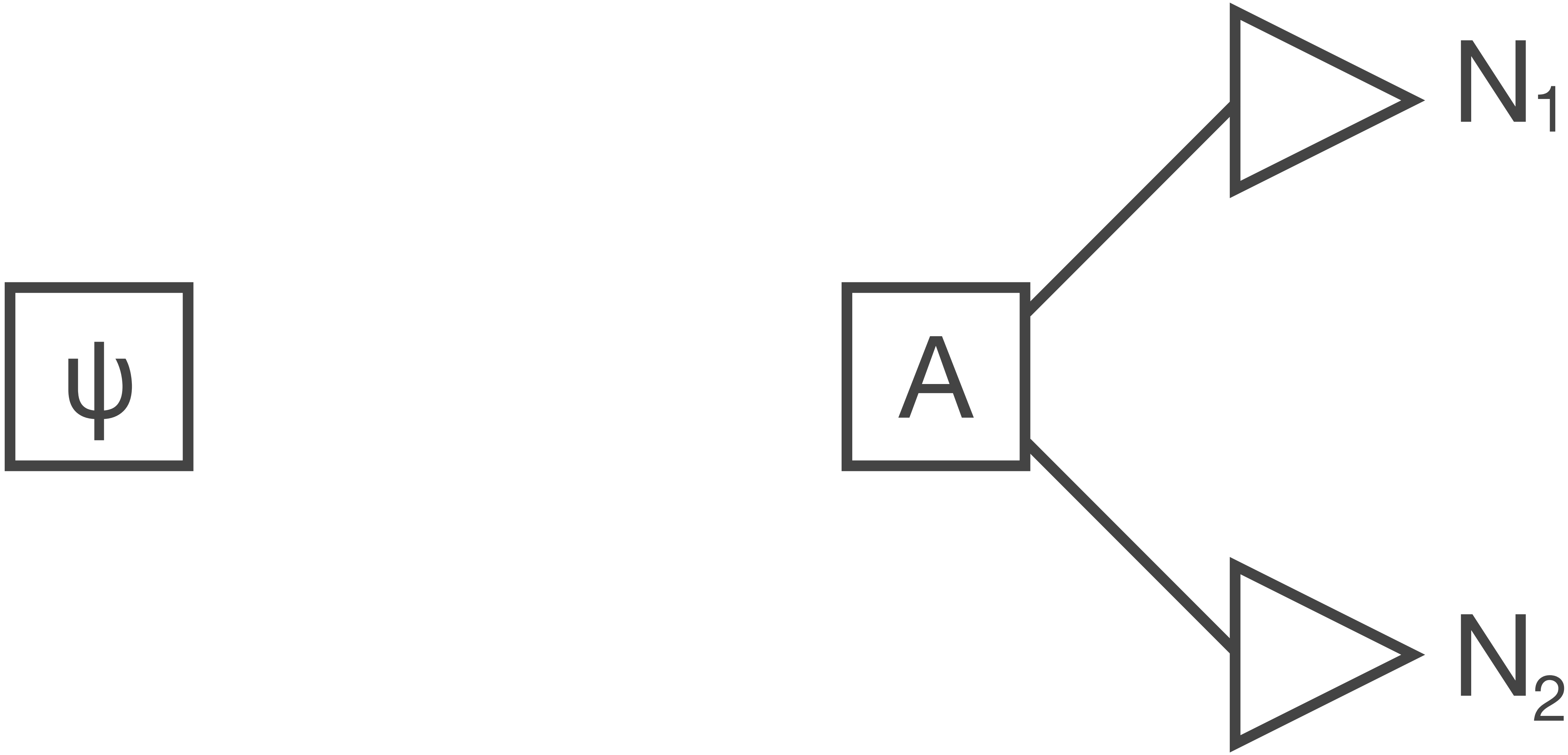
összeesküvés

‘detection loophole’

kvantum P( ) ≠ relatív gyakoriság

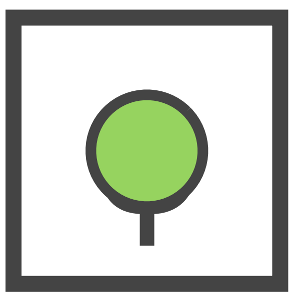

ψ
A
N1
N2

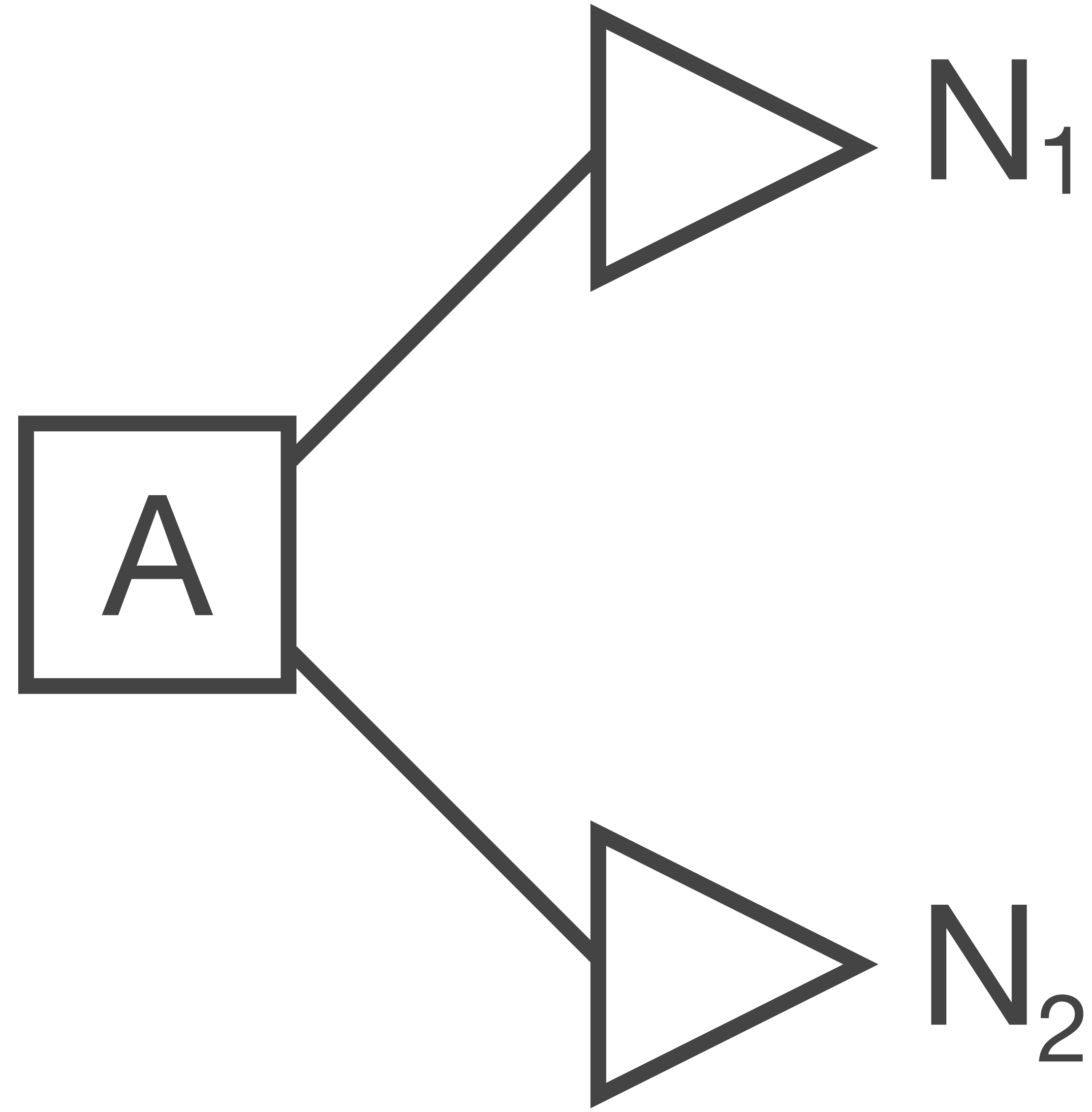

ψ
A
N1
N2

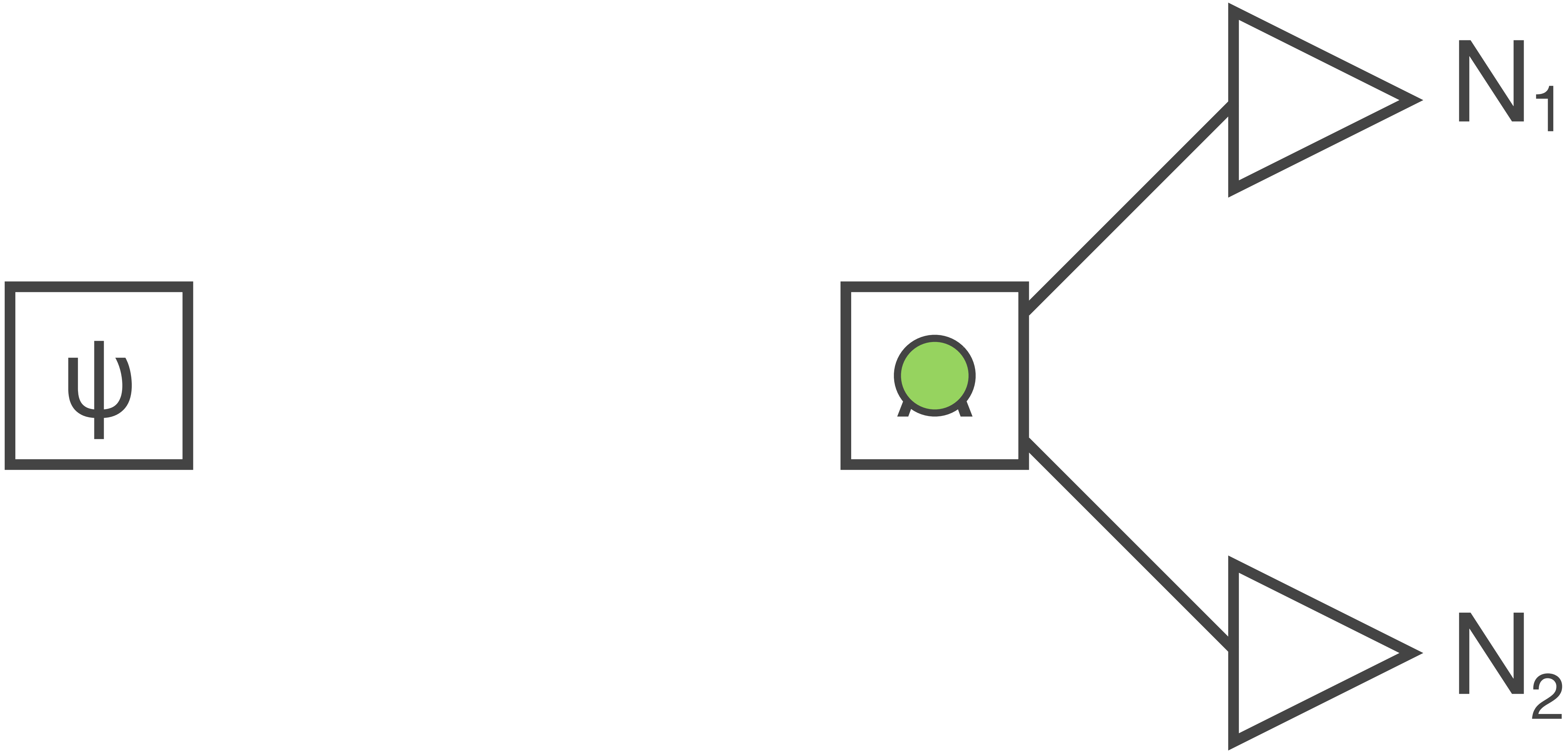

ψ
A
N1
N2

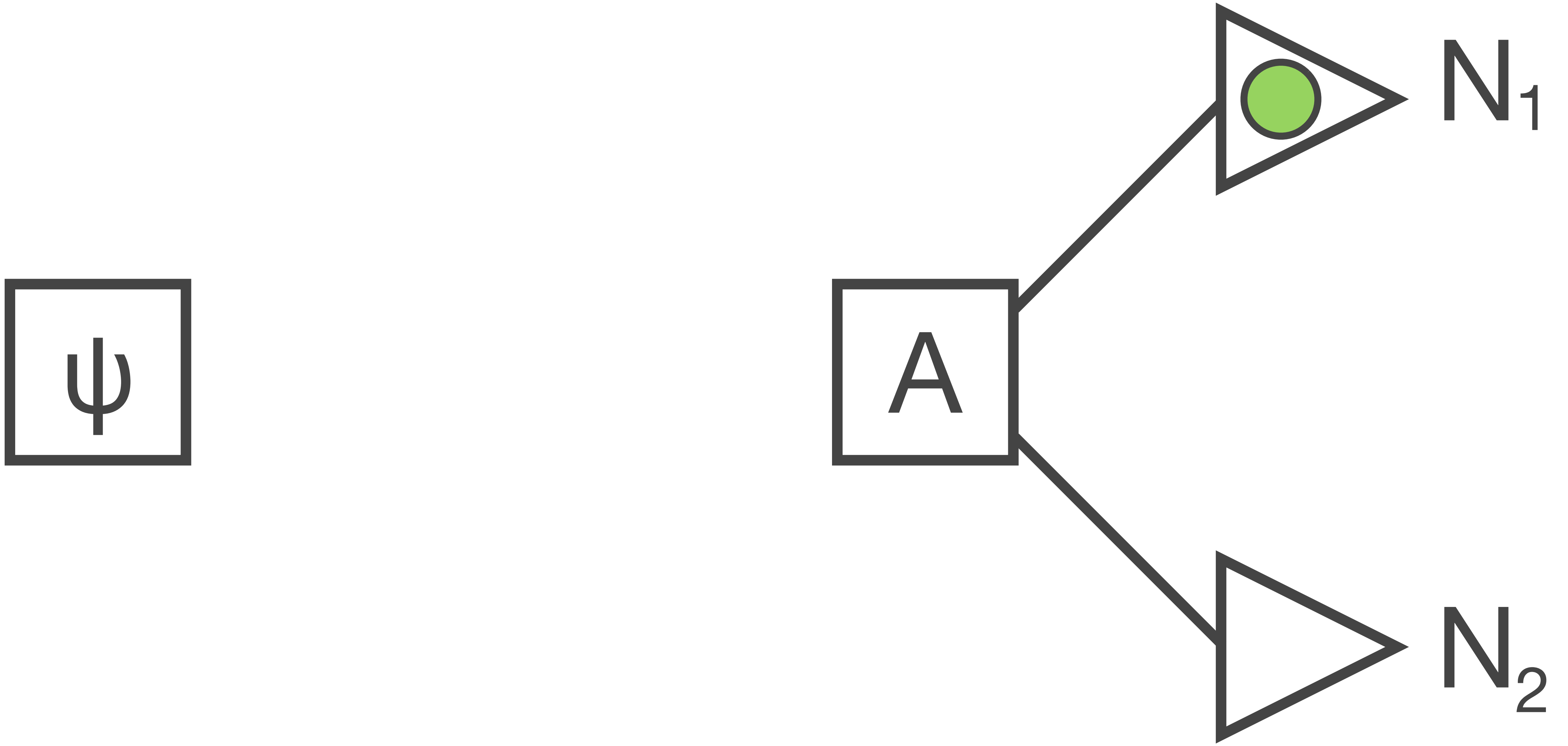
$$\mathrm{tr}(W A_i) = \frac{N_i}{\sum N_i} = 1$$

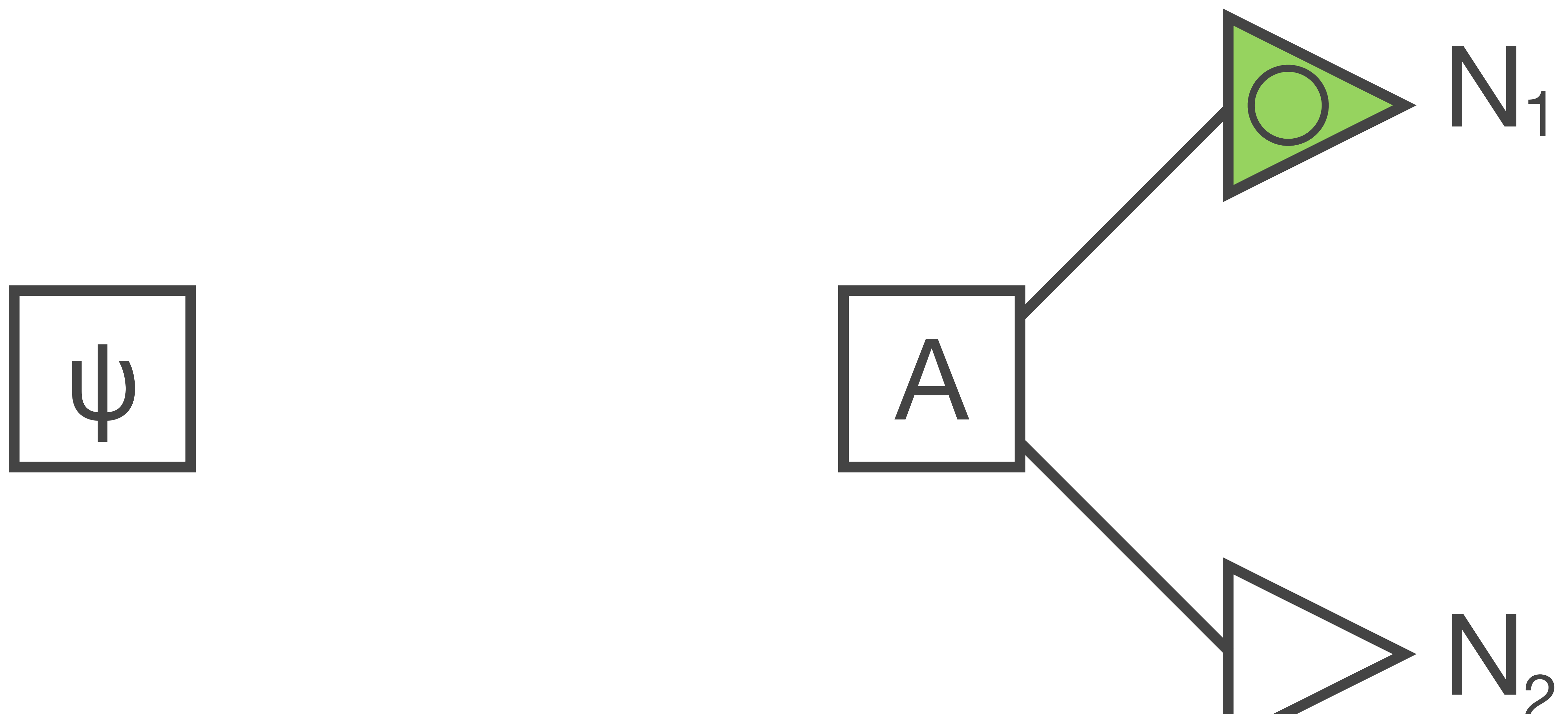
amit feltételezünk hogy történik




A
N1
N2


ψ
N1
N2


ψ
A
N1
N2



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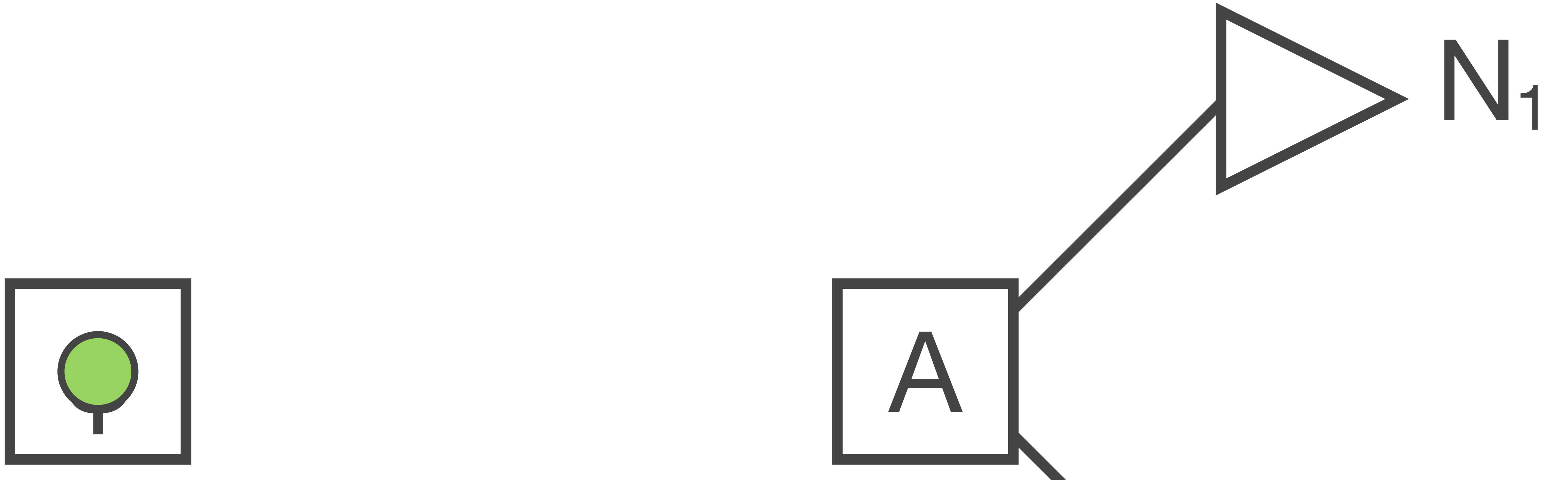
ami ‘igazából’ törénik



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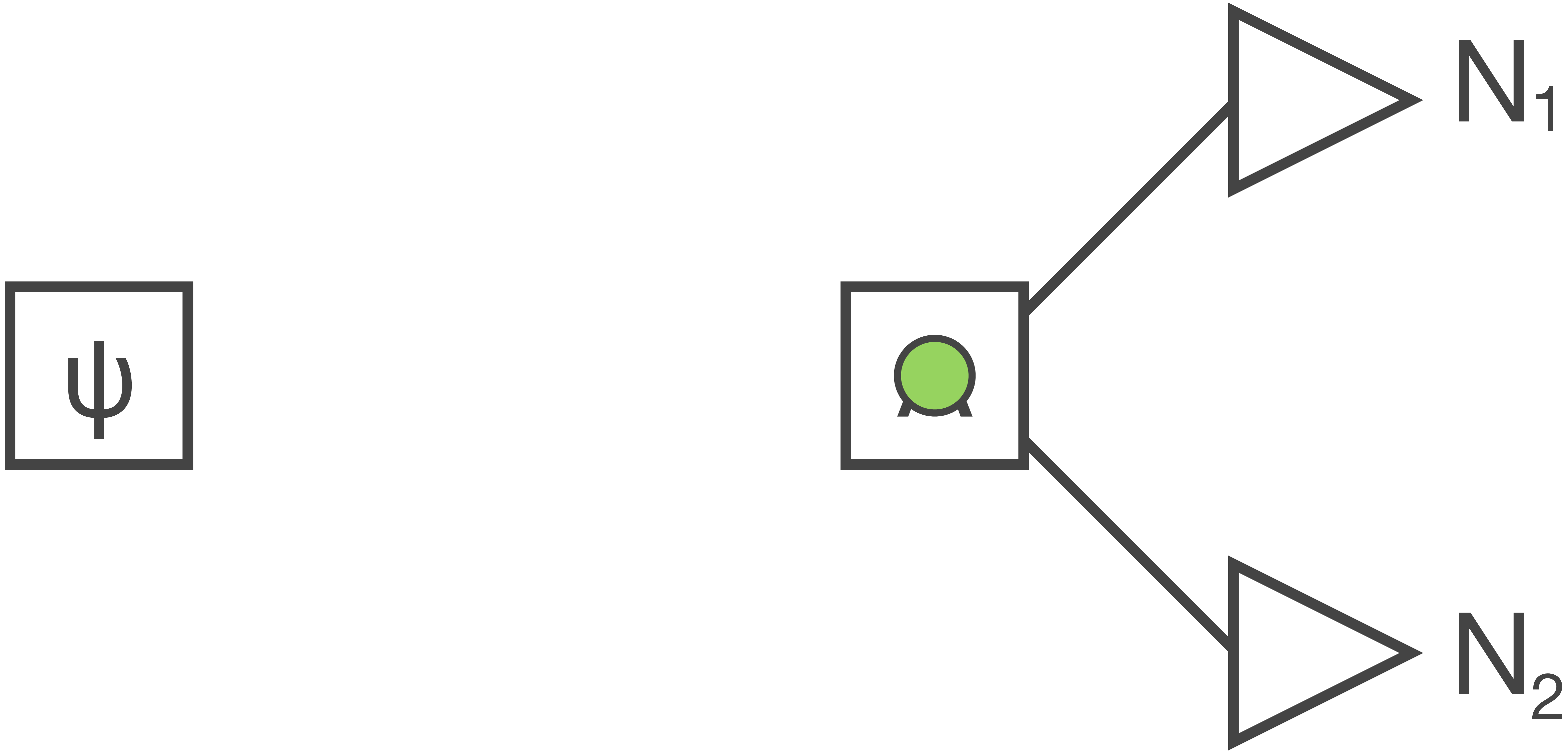
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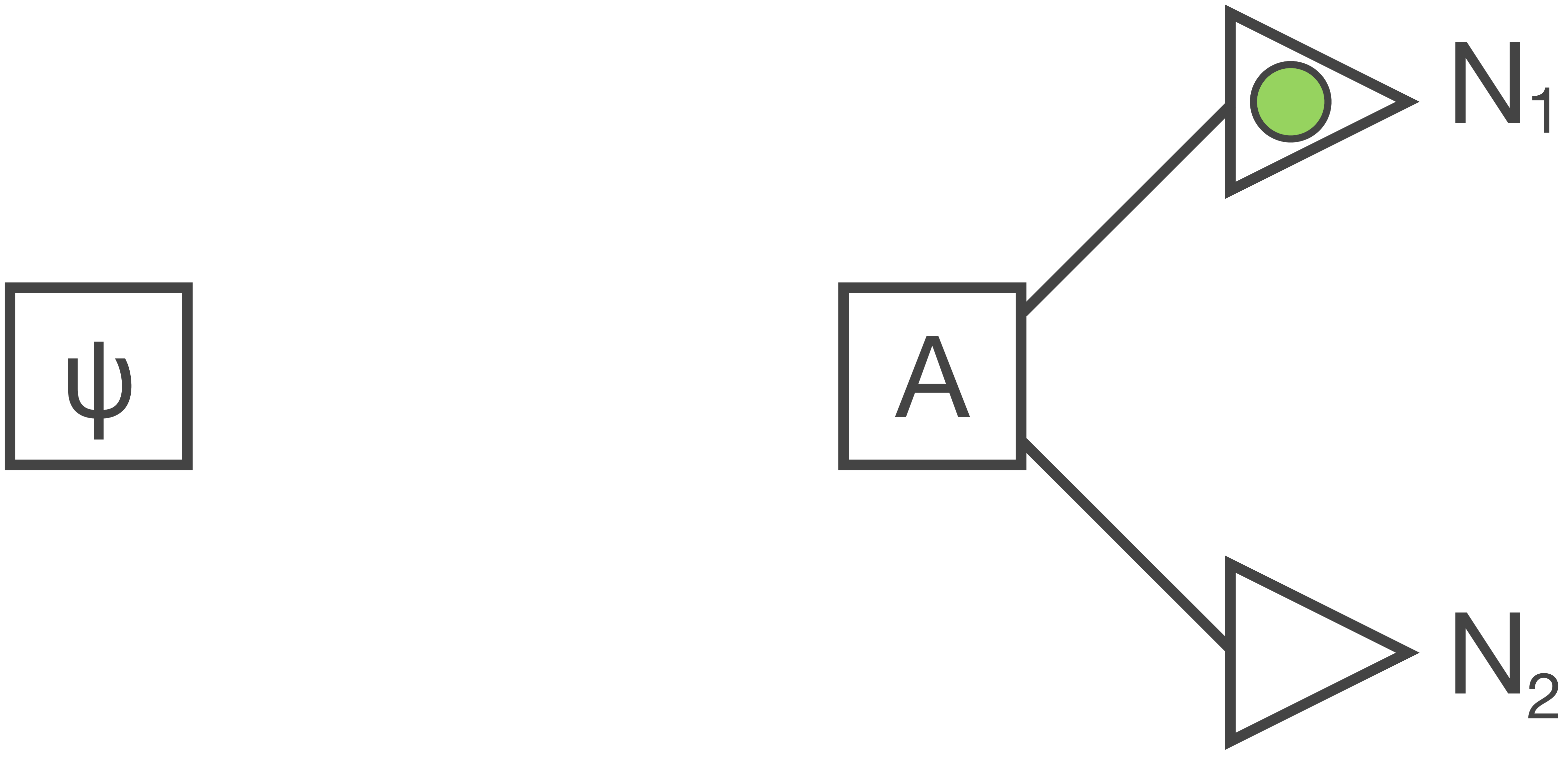
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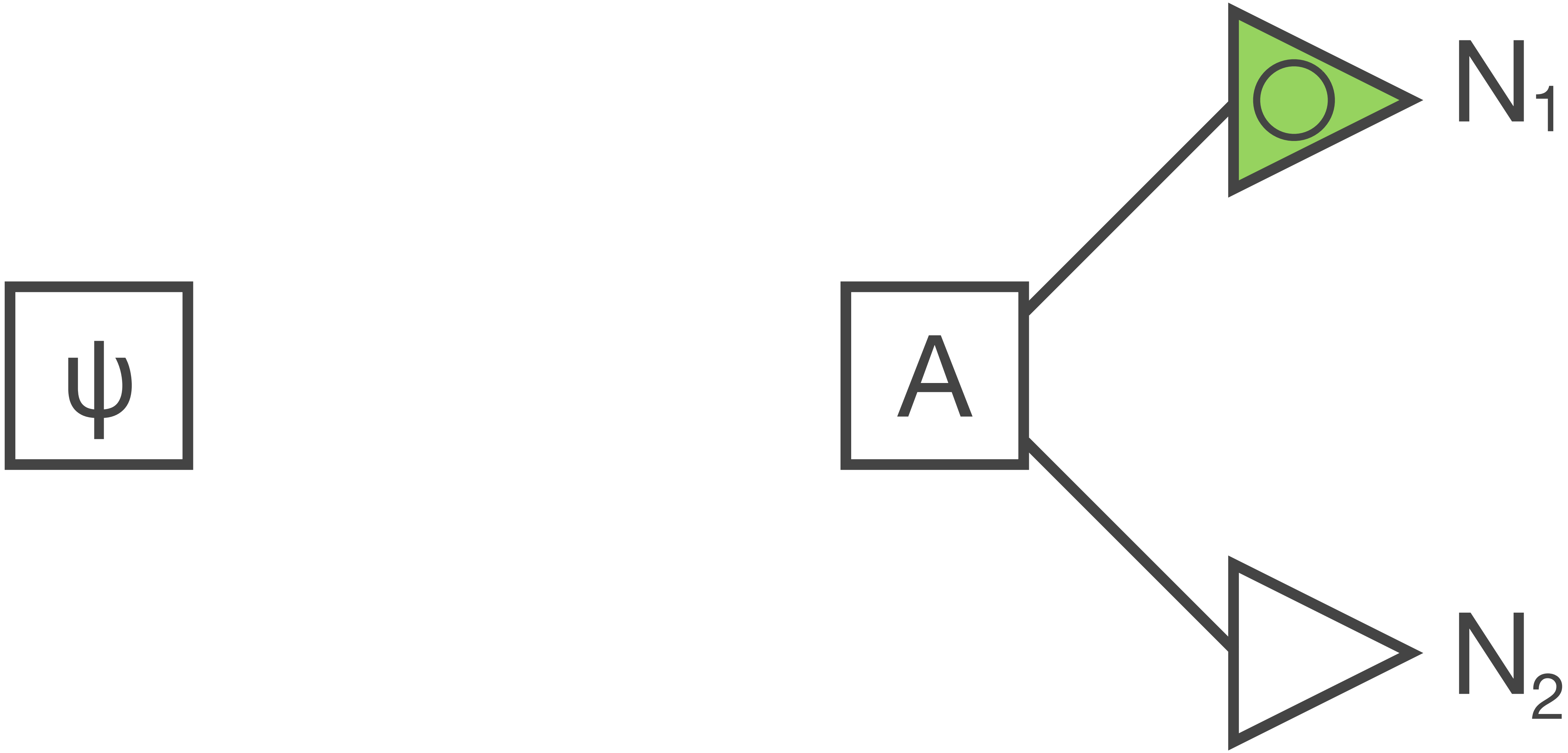
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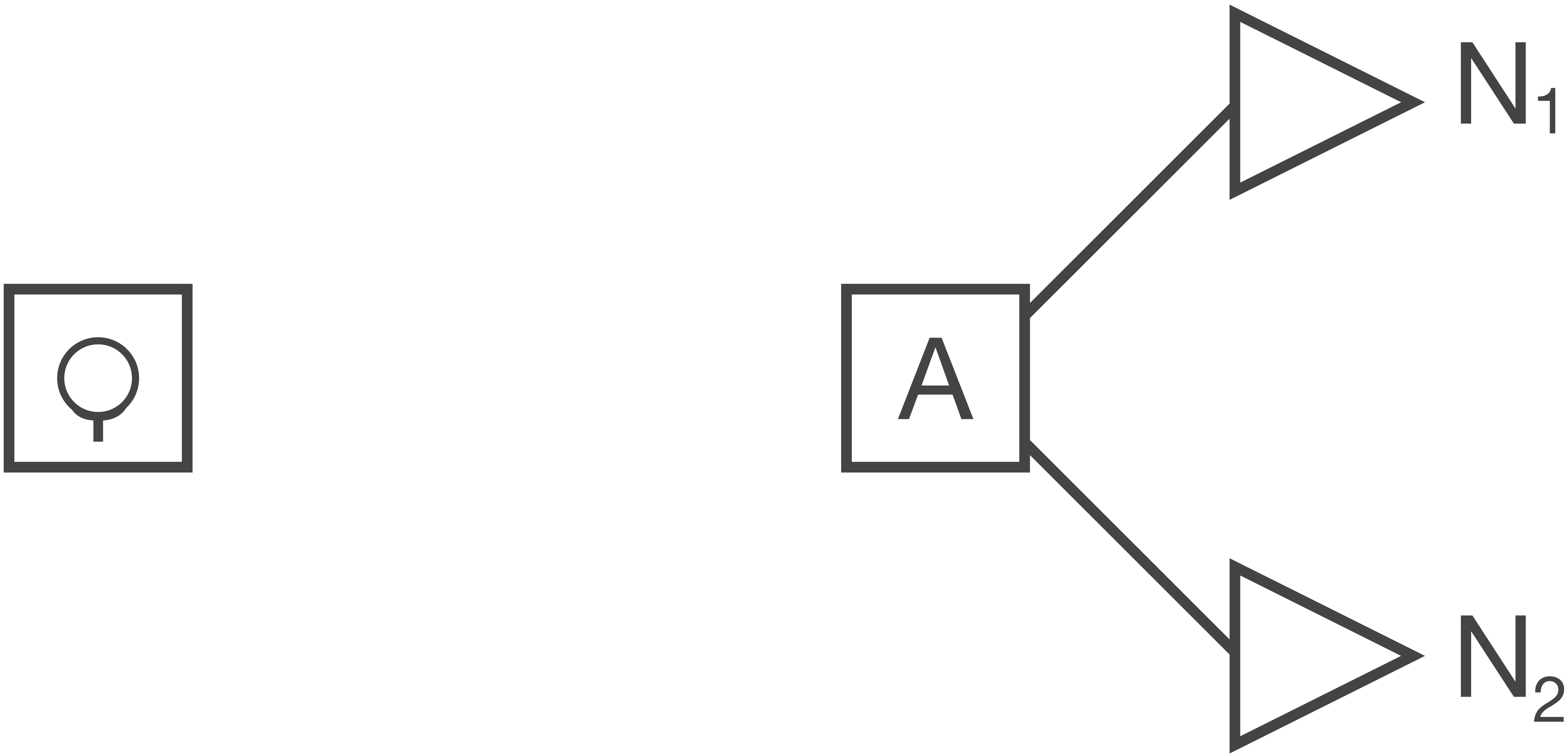
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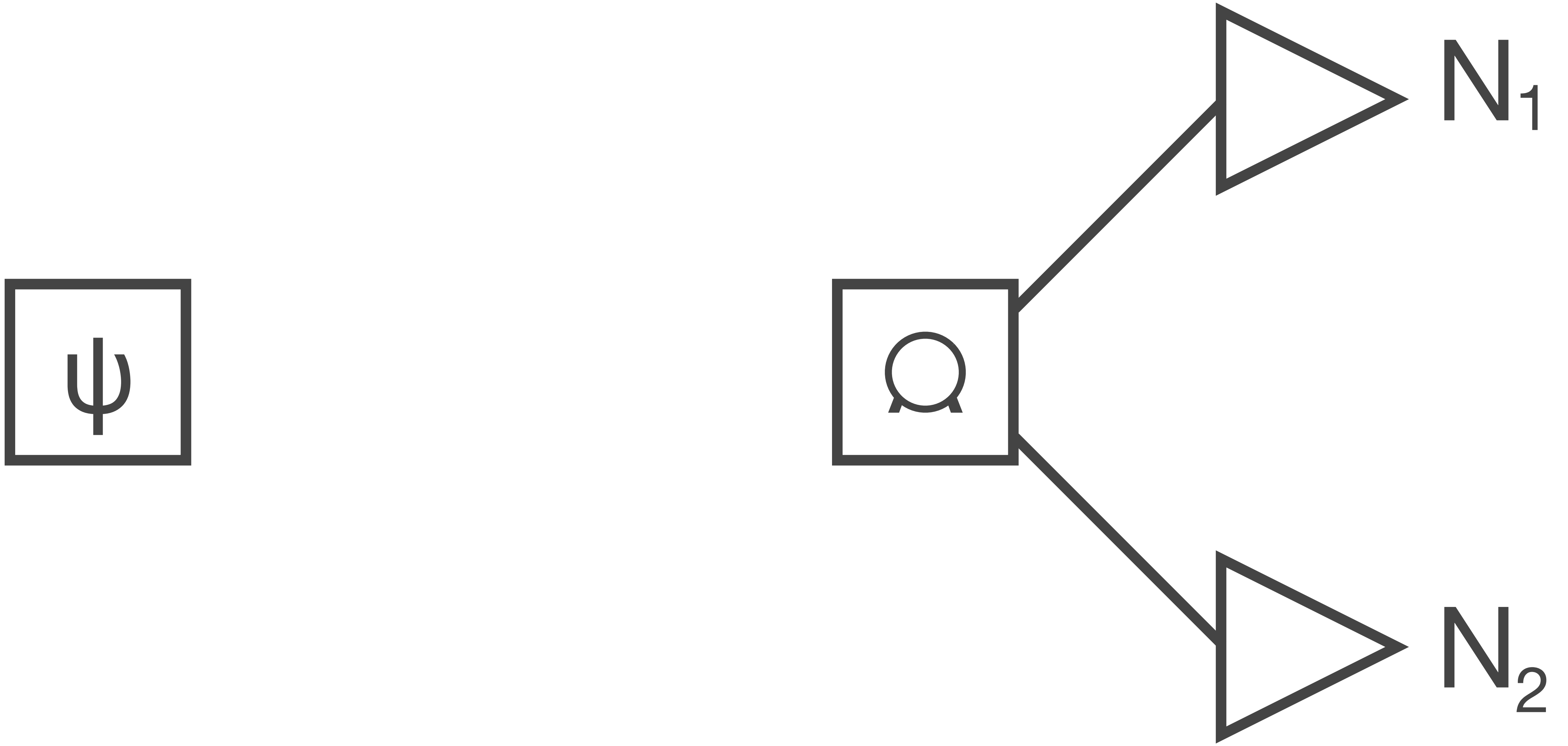
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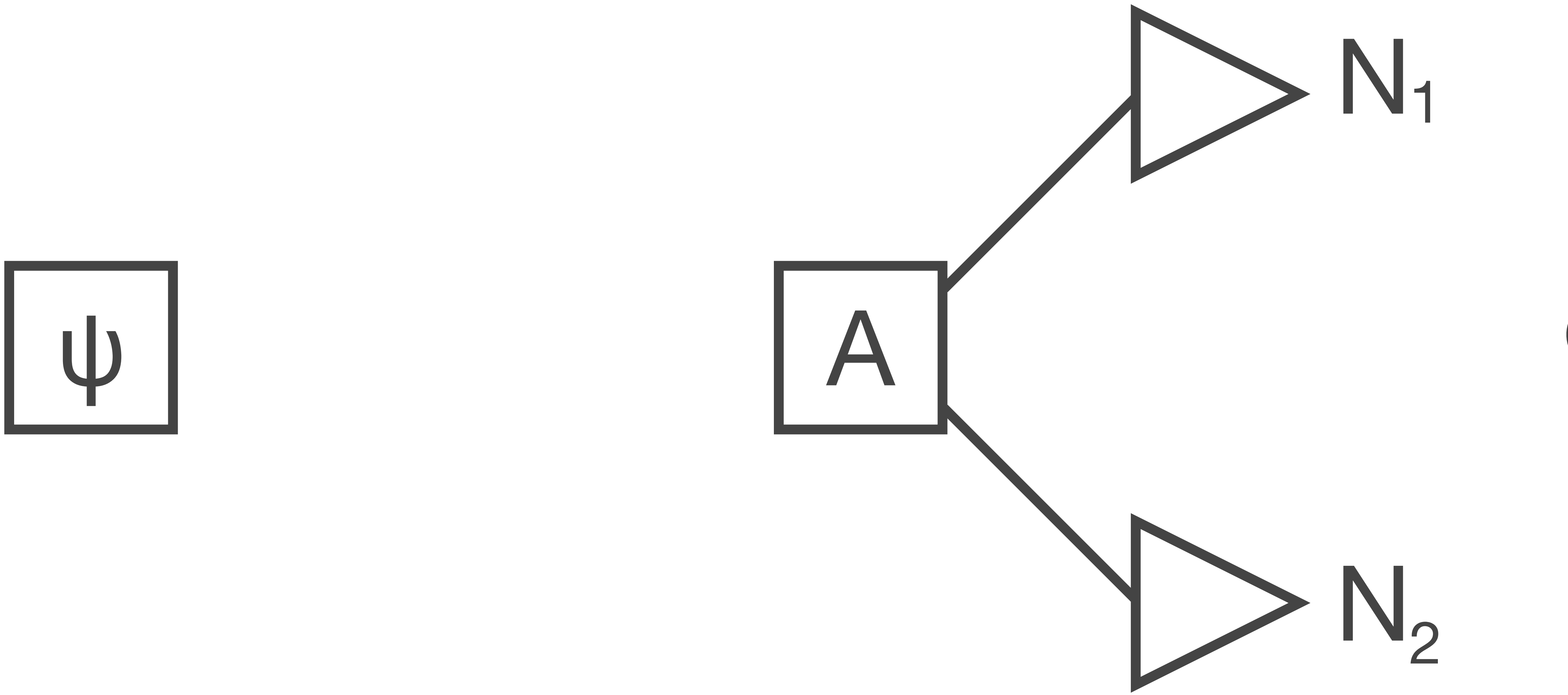
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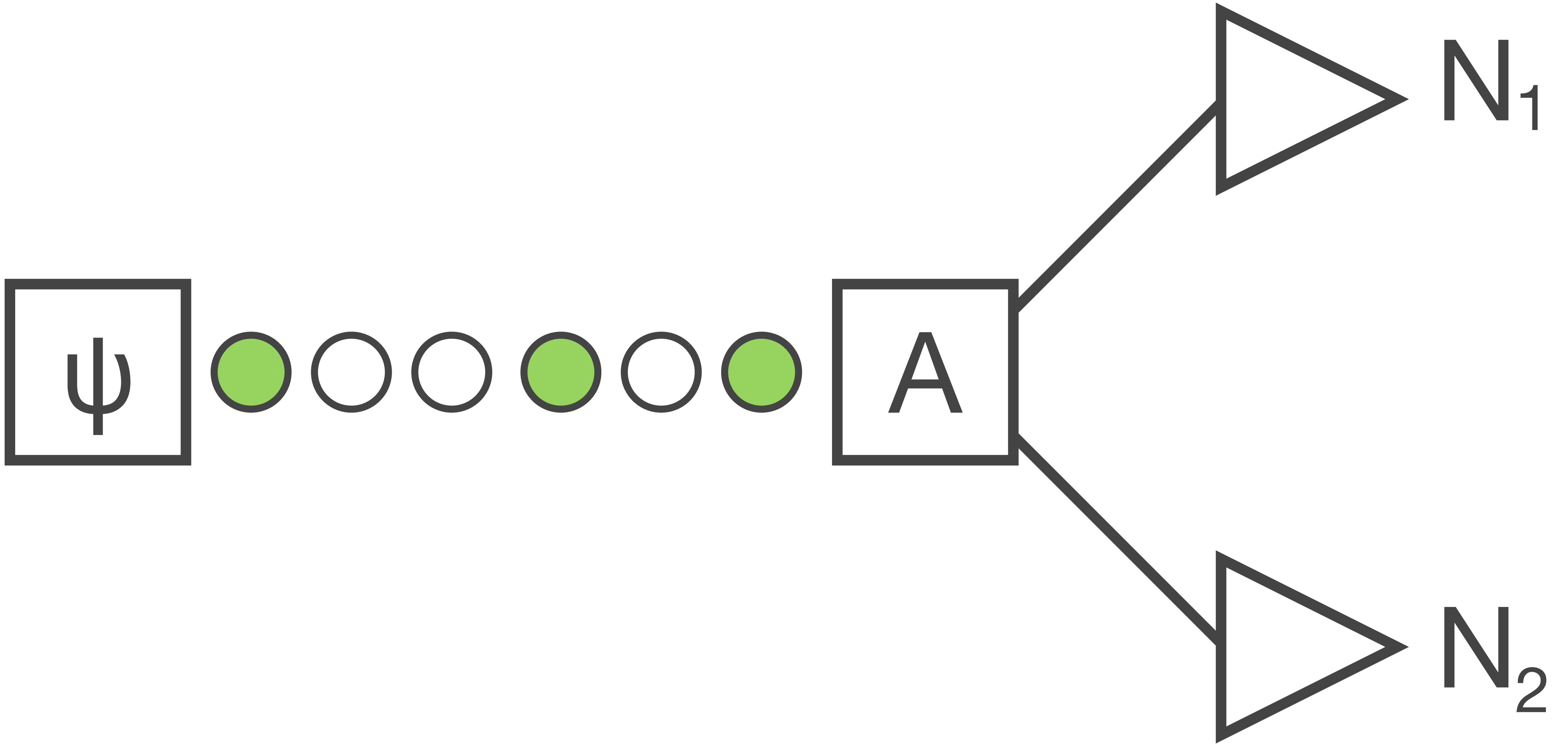
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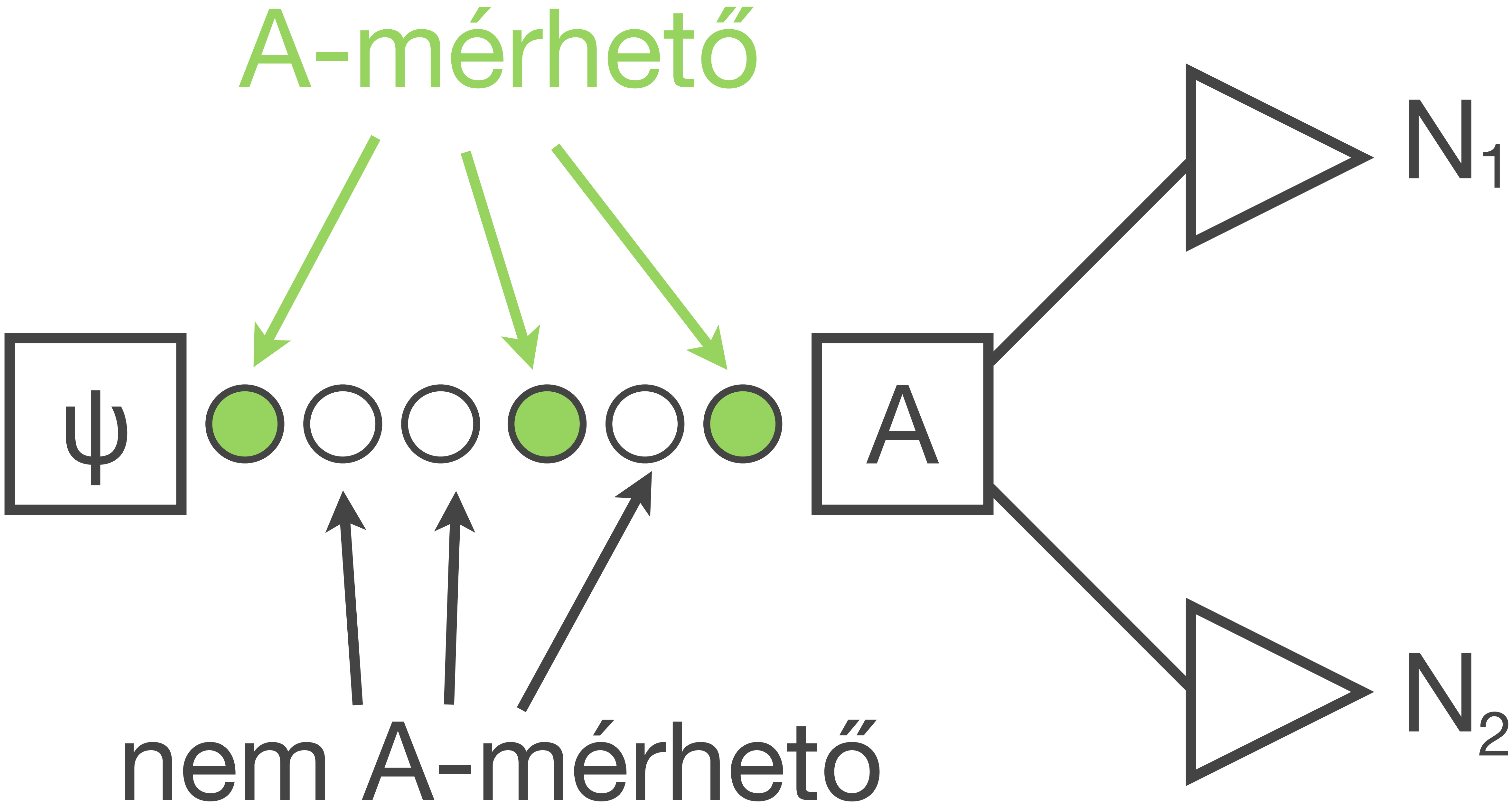
A-mérhető
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nem A-mérhető