

# La importància d'un bon mapa

Carlos Luna-Mota

## Pensament Computacional

- Processos vs resultats
- Abstracció: l'enemic comú

Assistència: [ja.cat/hanoi2026a](http://ja.cat/hanoi2026a)

Avaluació: [ja.cat/hanoi2026b](http://ja.cat/hanoi2026b)

## Les Torres de Hanoi

- El problema clàssic
- Variants

# Pensament Computacional

# Processos vs resultats

Com sabem si l'alumnat sap multiplicar nombres?

**Fent multiplicacions!**

Com sabem si l'alumnat sap multiplicar polinomis?

**Fent multiplicacions!**

# Processos vs resultats

Com es multipliquen els polinomis?

**(algorisme)**

Aquest mètode funciona sempre?

**(factibilitat)**

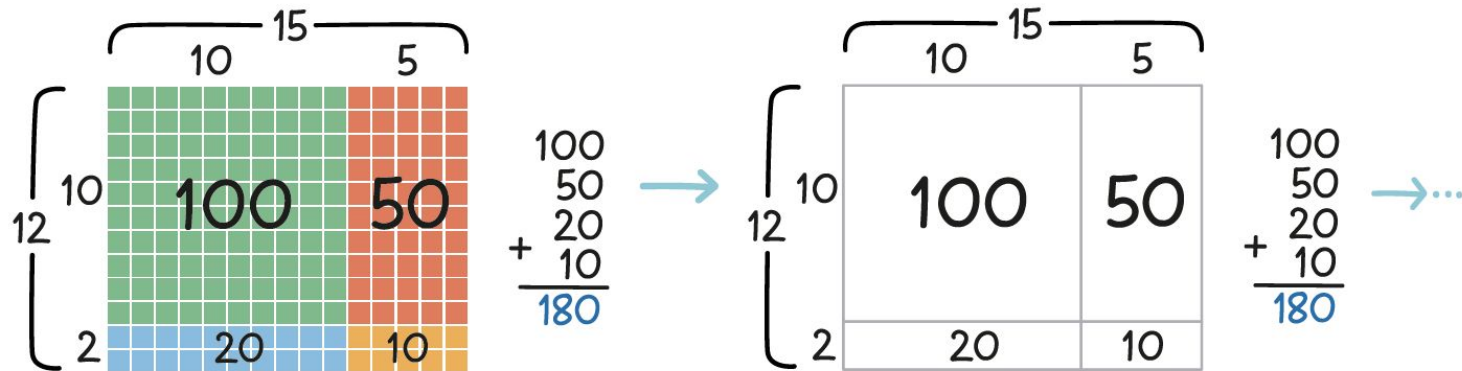
Hi ha altres mètodes? Quin és millor?

**(eficiència)**

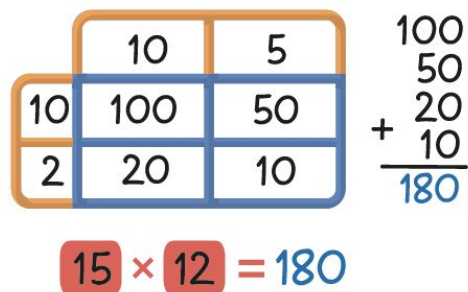
	<b>/1</b>	<b>/2</b>	<b>/3</b>	<b>/4</b>	<b>Escons</b>
Partit A	<b>100,000*</b>	<b>50,000*</b>	<b>33,333*</b>	<b>25,000*</b>	<b>4</b>
Partit B	<b>80,000*</b>	<b>40,000*</b>	<b>26,667*</b>	20,000	<b>3</b>
Partit C	<b>30,000*</b>	15,000	10,000	7,500	<b>1</b>
Partit D	20,000	10,000	6,667	5,000	<b>0</b>

**La regla D'Hondt = Llei de l'oferta i la demanda**

Model rectangular (concret)



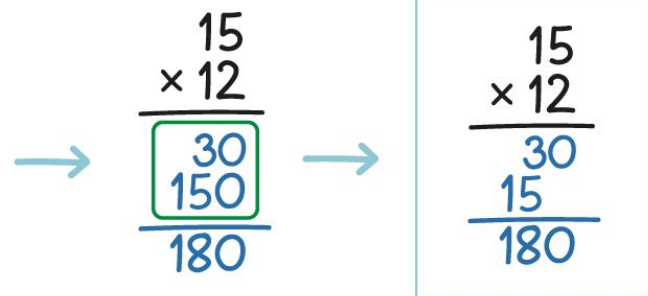
Esquema multiplicatiu (representatiu)



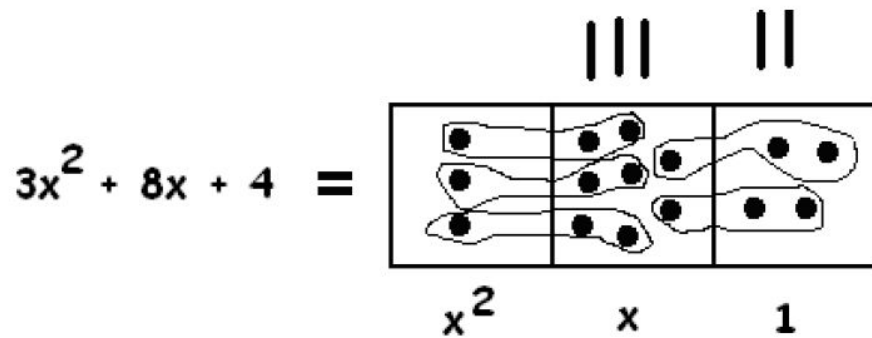
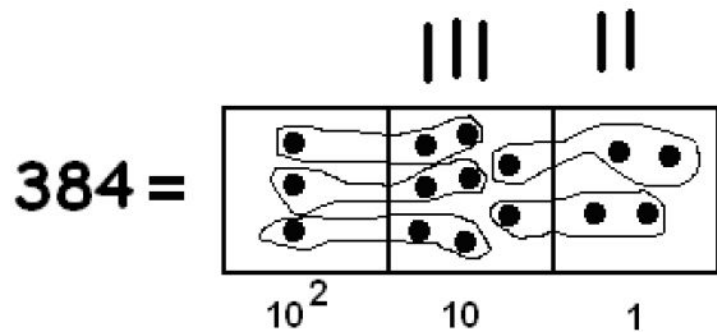
Algorisme estàndard (abstracte)



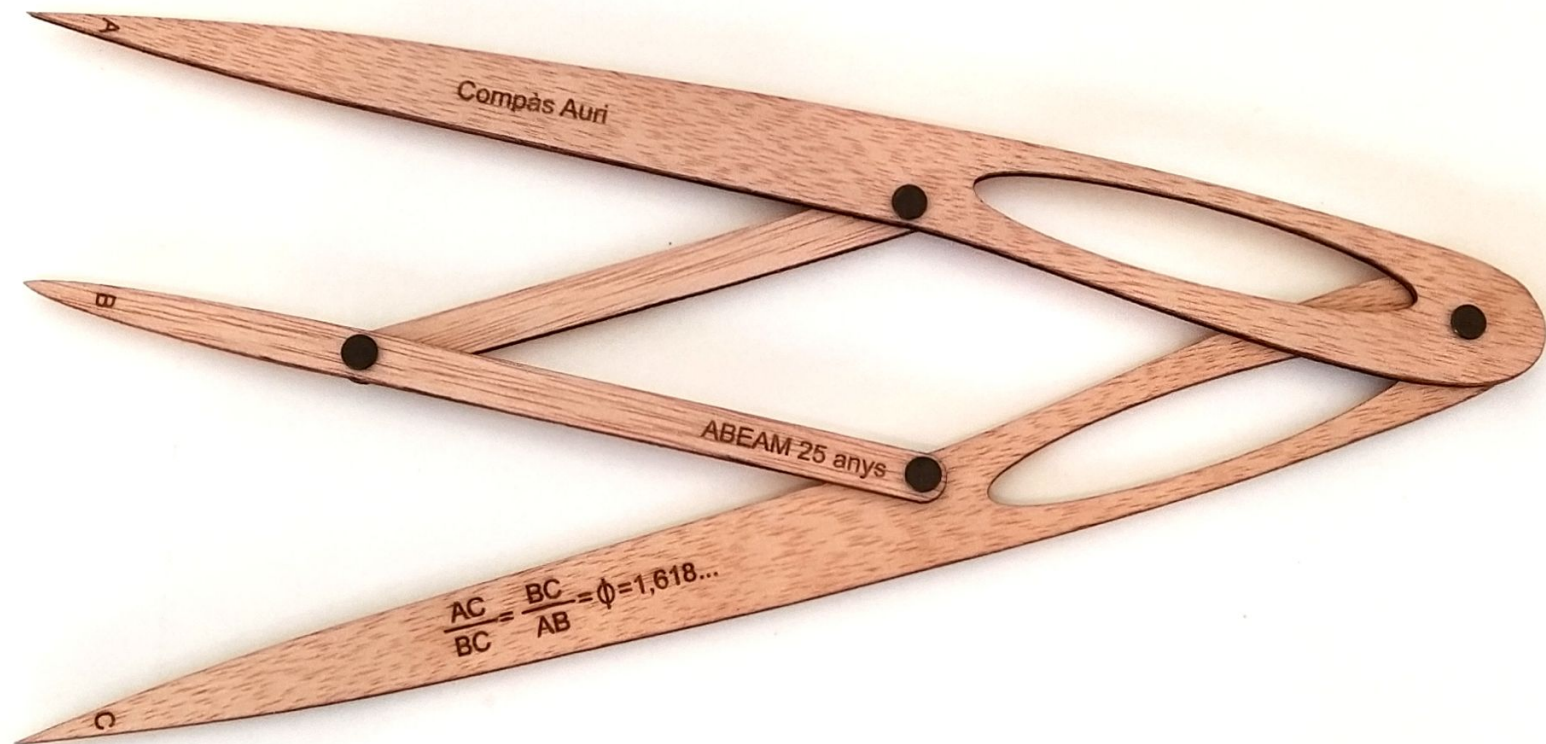
Algorisme estàndard compacte



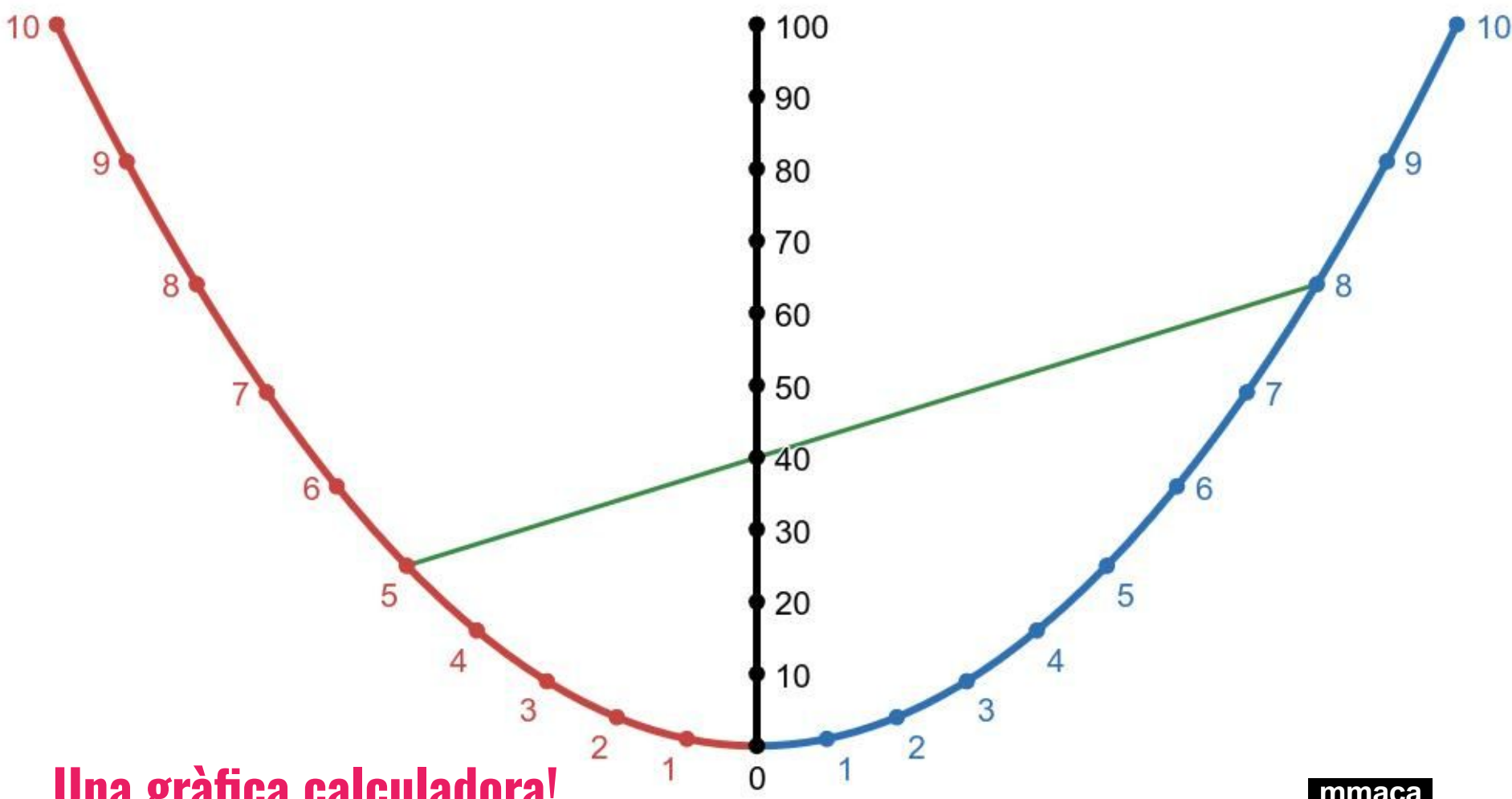
Quin és millor?



Quin és millor?



**Una calculadora de fusta!**



**Una gràfica calculadora!**

# Processos vs resultats

- Cada grup de 7 o 8 alumnes té 25 caramels
- Cada alumne té assignat un número diferent
- S'ordenen mitjançant preguntes: **A < B ?**
- Una pregunta = un caramel
- Quan creguin que estan ordenats paren
- Un error = perdre tots els caramels sobrants!



# Abstracció: l'enemic comú

Problema:

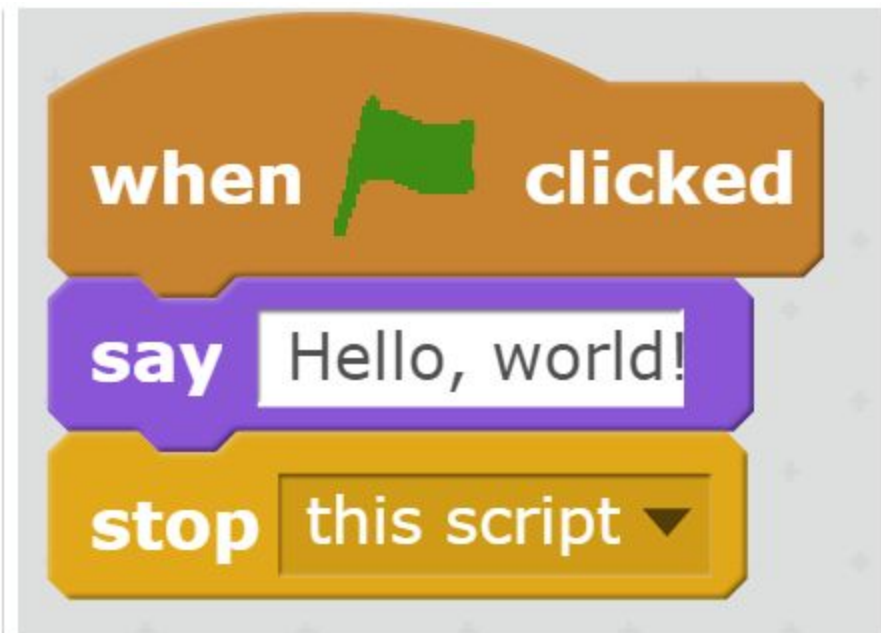
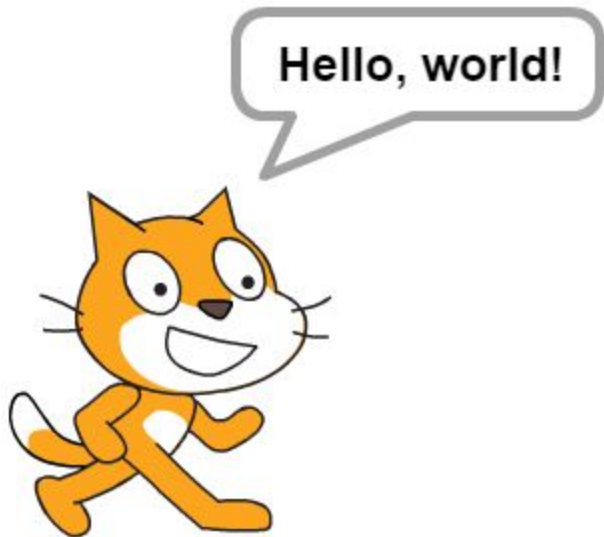
**ABSTRACCIÓ**

Solucions:

**EXPERIMENTAR / REPRESENTAR**

+++++ [ >+++  
++++ >++++++  
+>+++>+<<<<- ] >+  
+ . >+ . +++++ . . +  
++ . >++ . <<++++++  
+++++ . > . ++  
+ . - - - - . - - - -  
- - . >+ . > .

Hello, World!

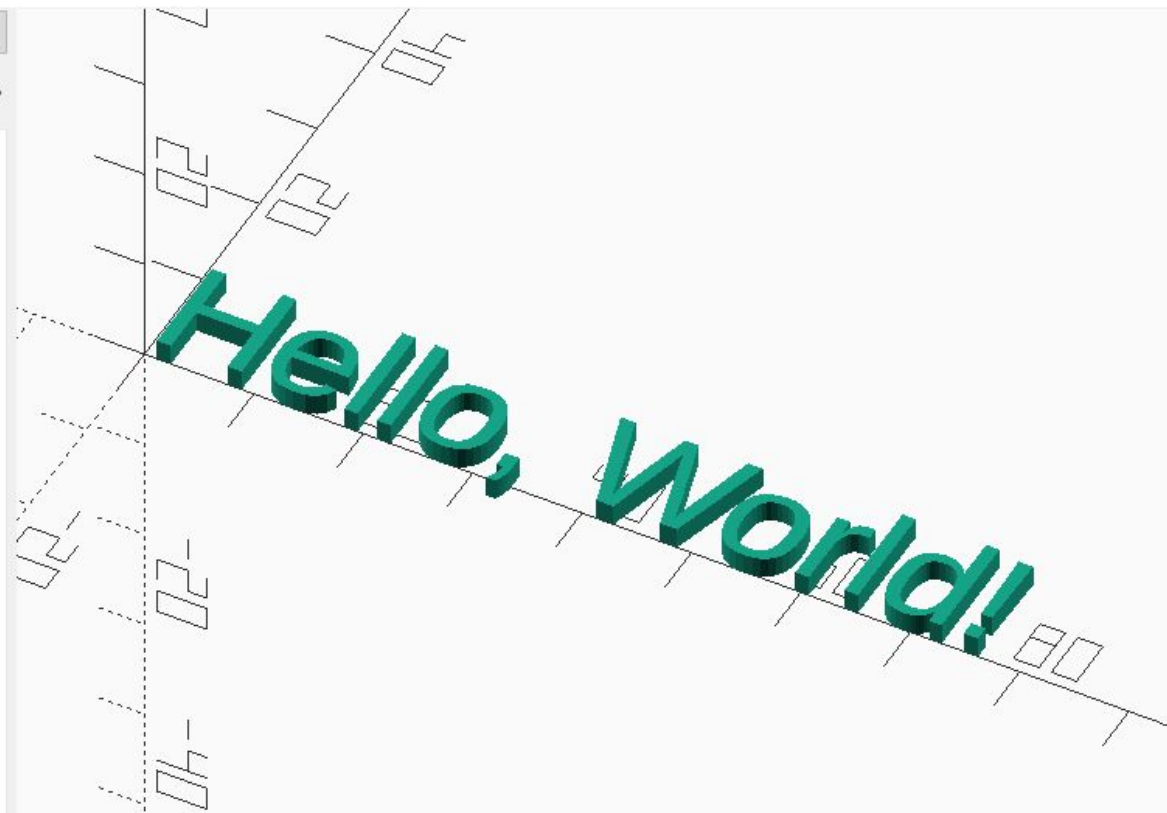


**Hello, World!**

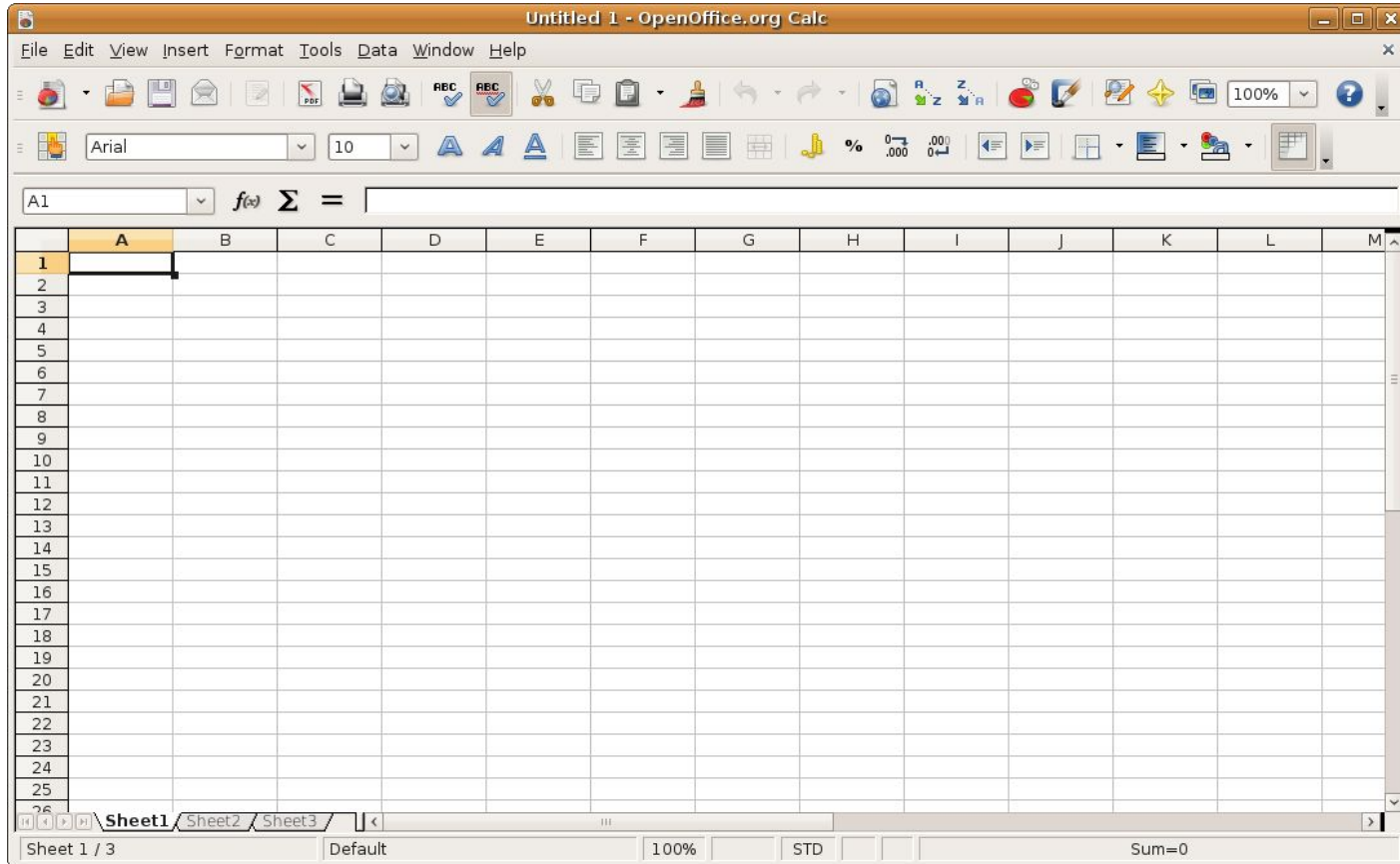
Editor



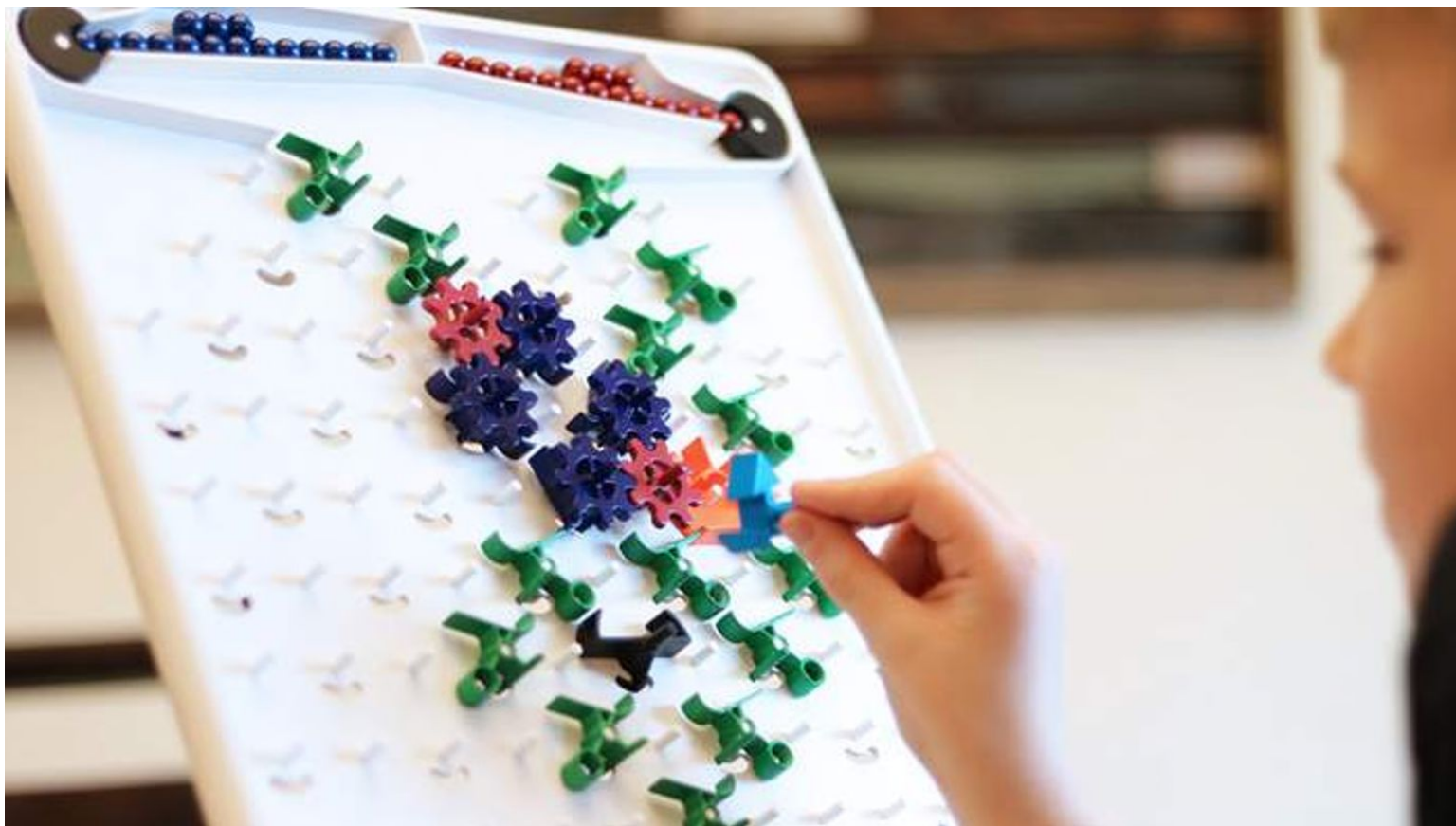
```
1  
2 linear_extrude(2)  
3   text("Hello, World!");
```



**Hello, World!**



**Programming for Dummies!**



**Computant amb bales (de vidre)**

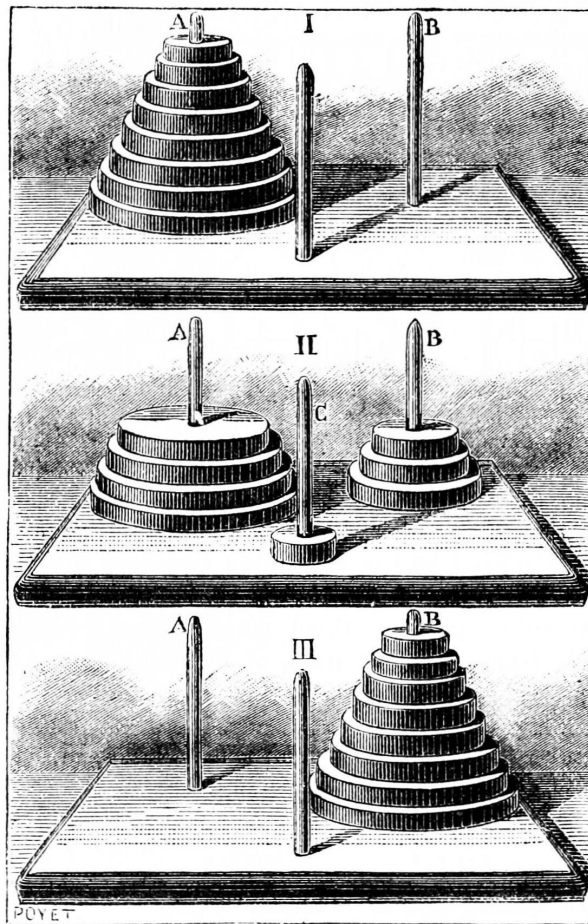
# Les Torres de Hanoi

***Al gran temple de Benarés, sota la cúpula que marca el centre del món, s'alcen tres agulles de diamant.***

***A l'inici del temps, els déus va posar seixanta-quatre discos d'or pur en una d'aquestes agulles.***

***Nit i dia, els monjos treballen movent els discos sense desviar-se ni un moment de les regles immutables imposades pels déus.***

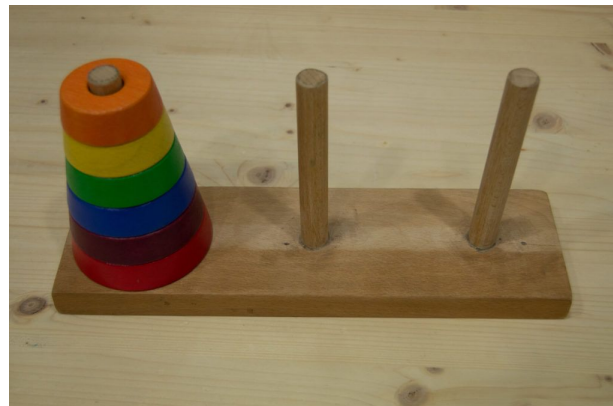
***Quan hagin aconseguit traslladar tota la torre a la tercera agulla, el temple s'esfondrarà i arribarà la fi del món.***



“És broma”

—Edouard Lucas  
(1842–1891)

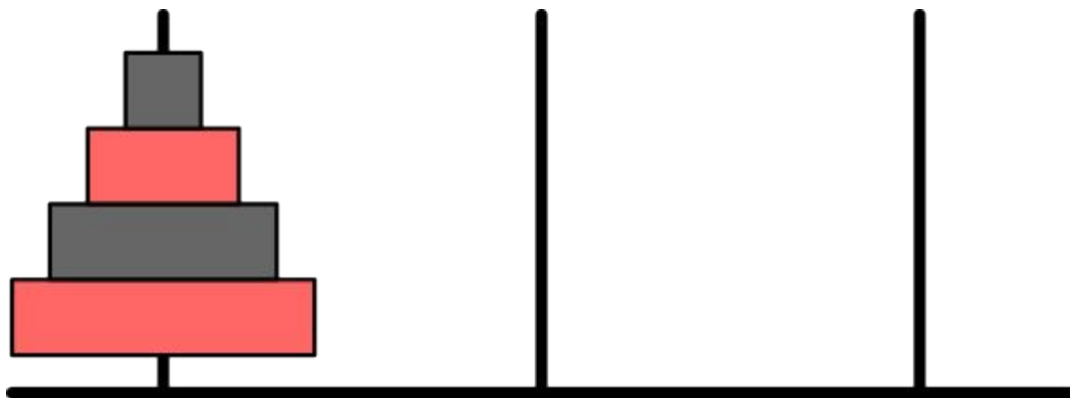




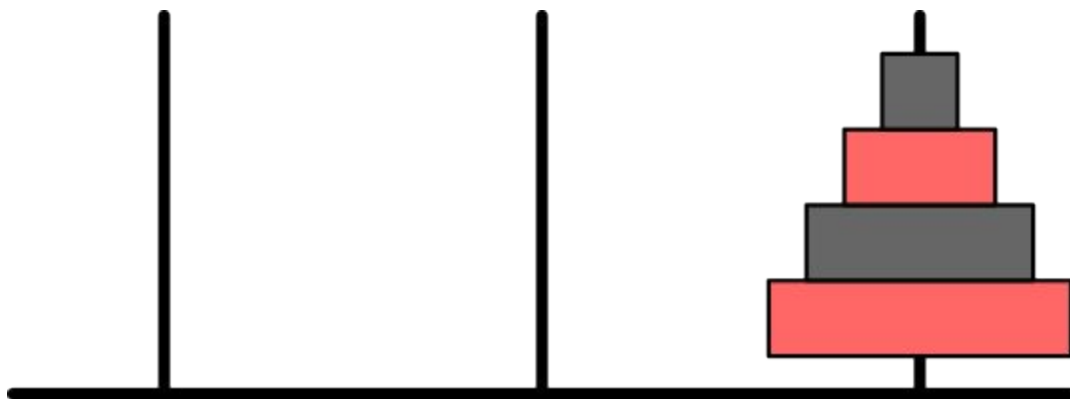
Un trencaclosques molt popular

# Les torres de Hanoi

- Mou els discos de la primera agulla a la darrera...



**Posició inicial**



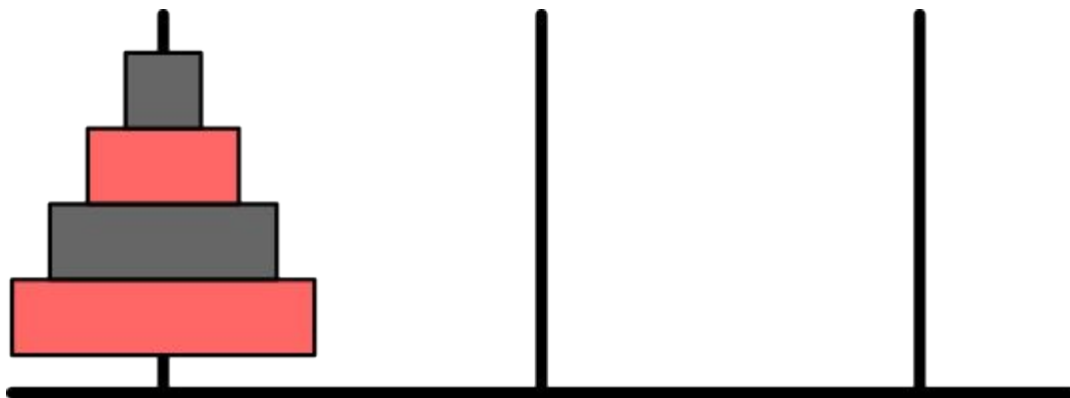
**Posició final**

# Les torres de Hanoi

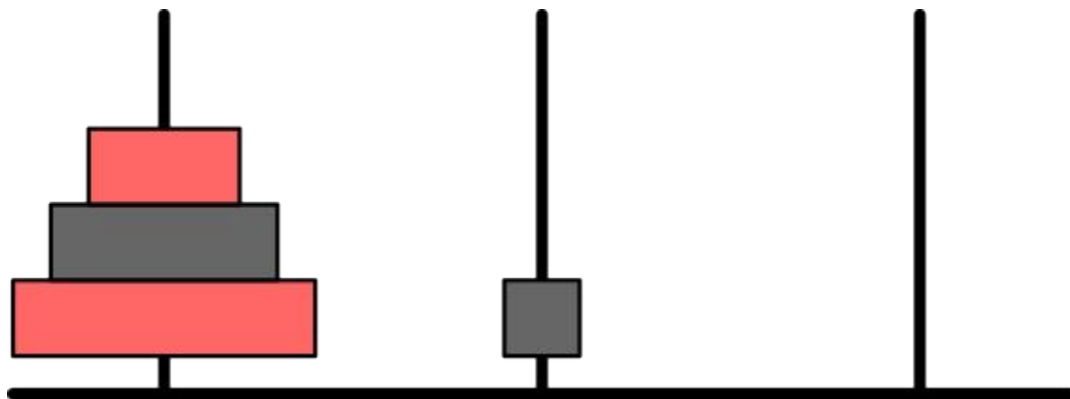
- Mou els discos de la primera agulla a la darrera...
- ...d'un en un...

# Les torres de Hanoi

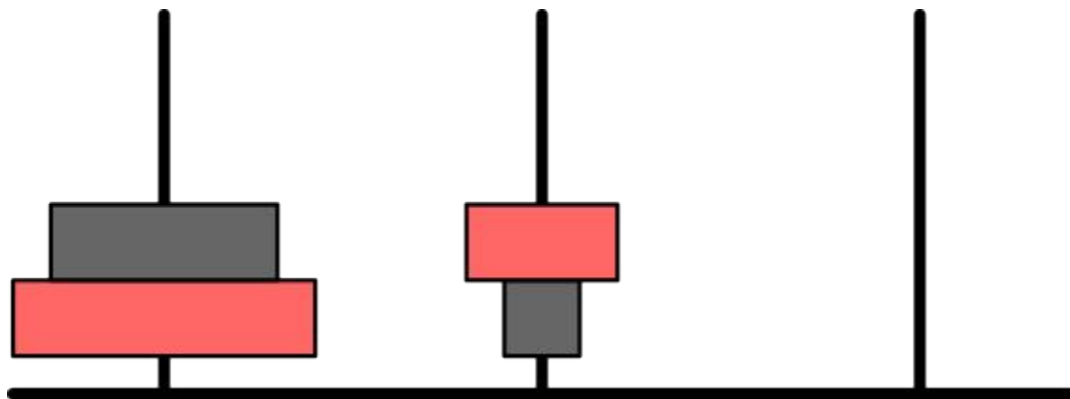
- Mou els discos de la primera agulla a la darrera...
- ...d'un en un...
  - L'input del problema és “N”, el nombre de discos
  - Moure-los de K en K  $\approx$  Moure-los d'1 en 1



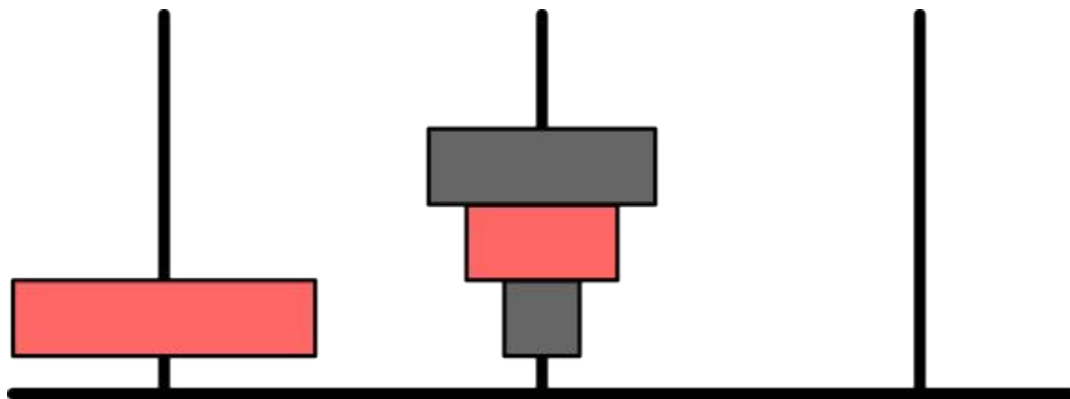
**Segon intent!**



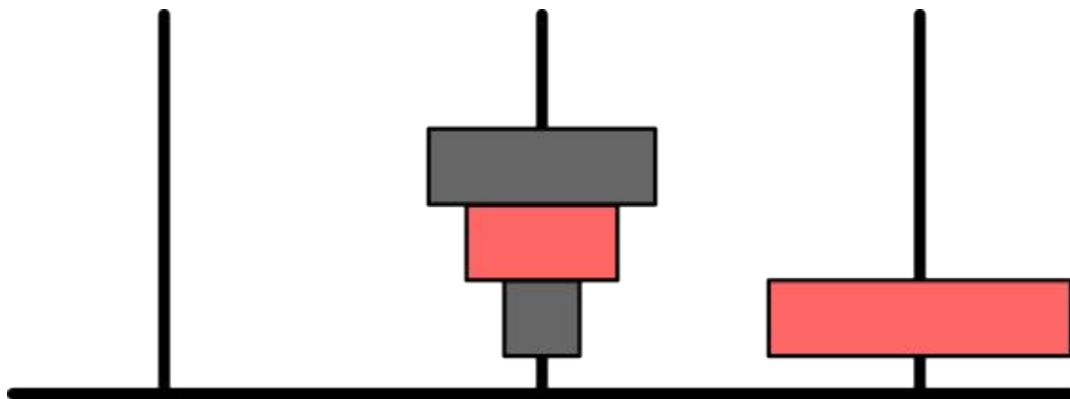
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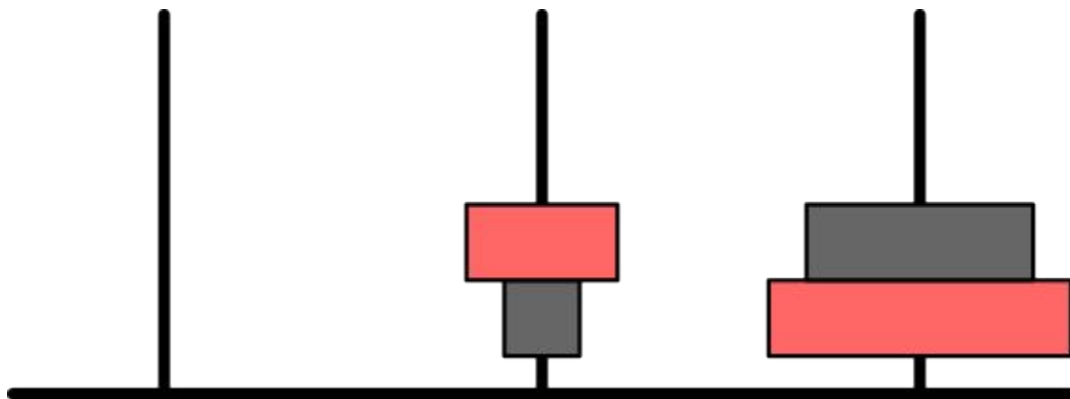
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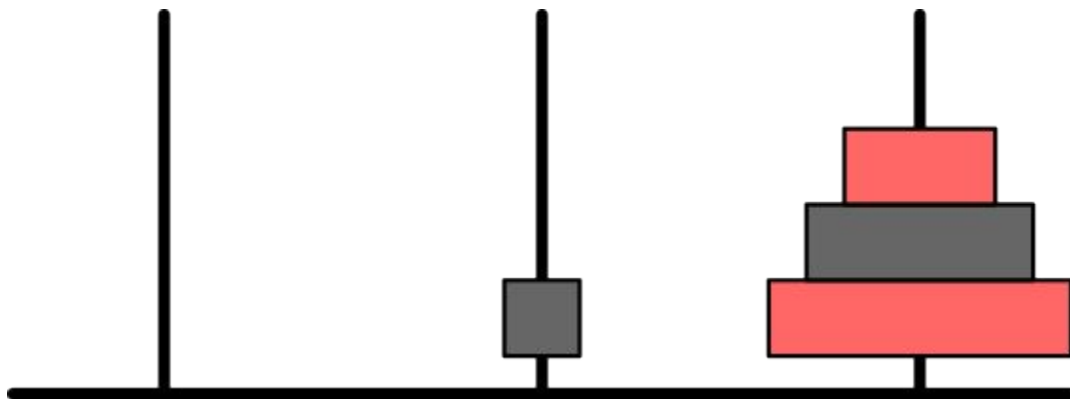
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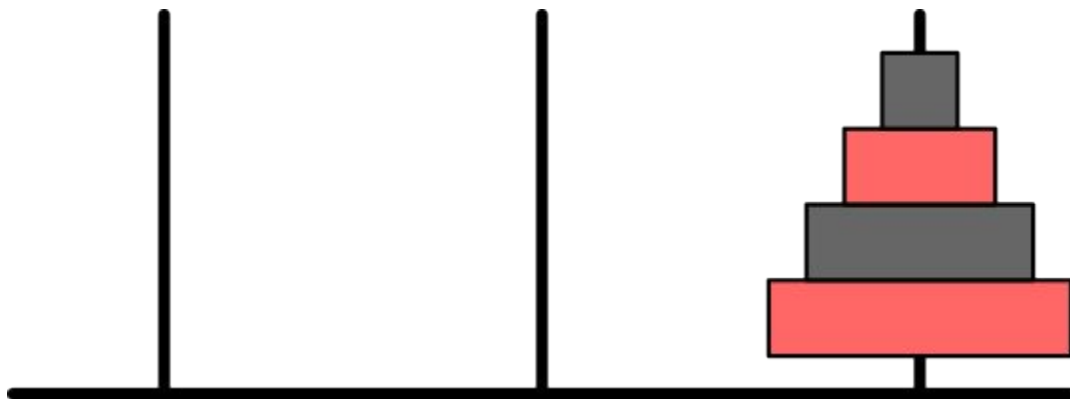
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**Segon intent!**



**Segon intent!**

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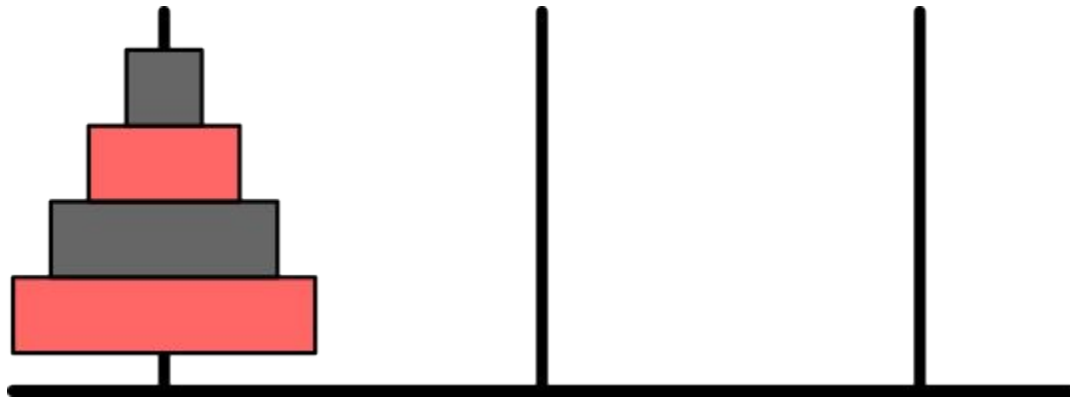
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- ...sense posar mai un disc gran sobre un de més petit.

# Les torres de Hanoi

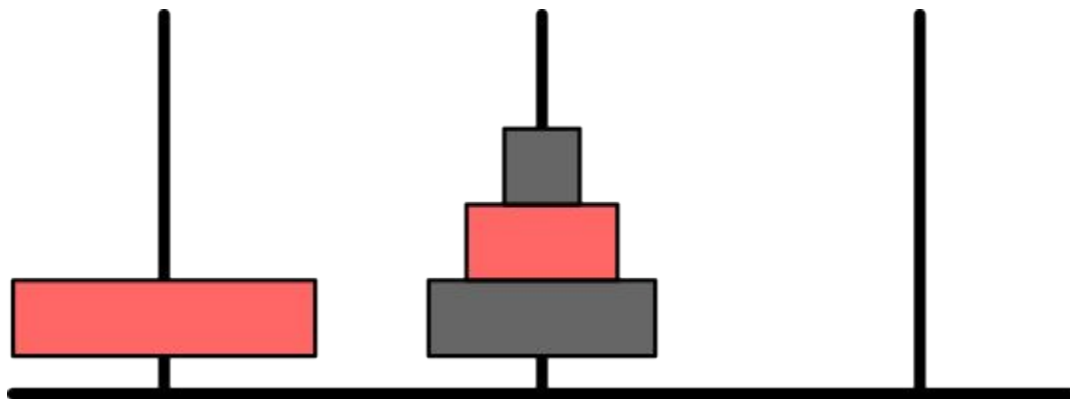
- Mou els discos de la primera agulla a la darrera...
- ...d'un en un...
- ...sense posar mai un disc gran sobre un de més petit.
  - **És possible? Quant tardarem? Com trobarem el camí?**  
(factibilitat)      (eficiència)      (algorismes)

# Les torres de Hanoi - Idees clau

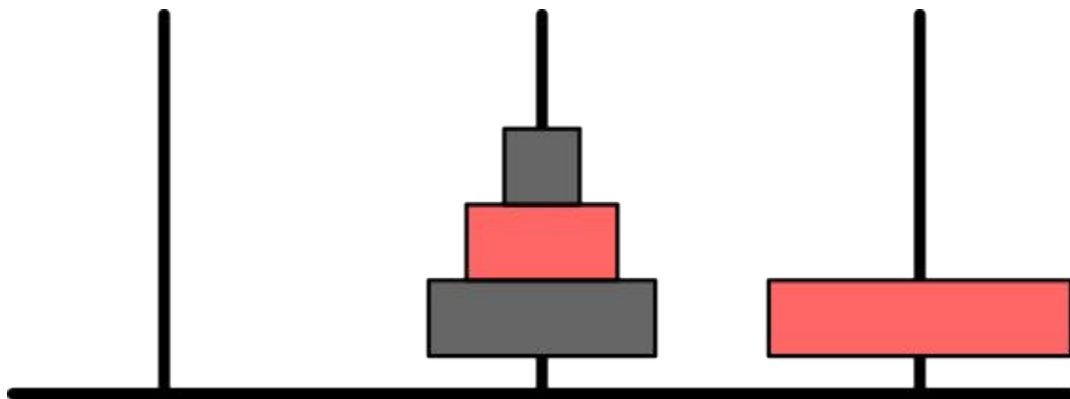
- Moure una torre de mida  $N-1$   $\Rightarrow$  Moure una torre de mida  $N$



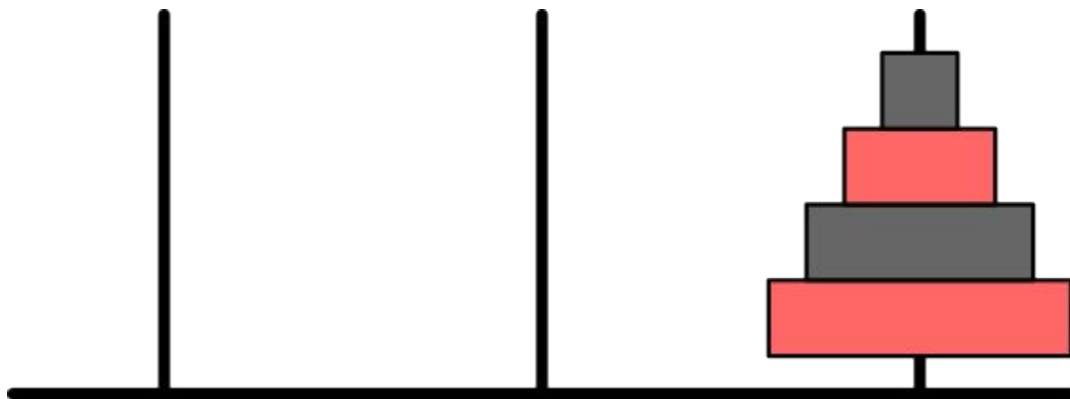
**La clau de tot plegat**



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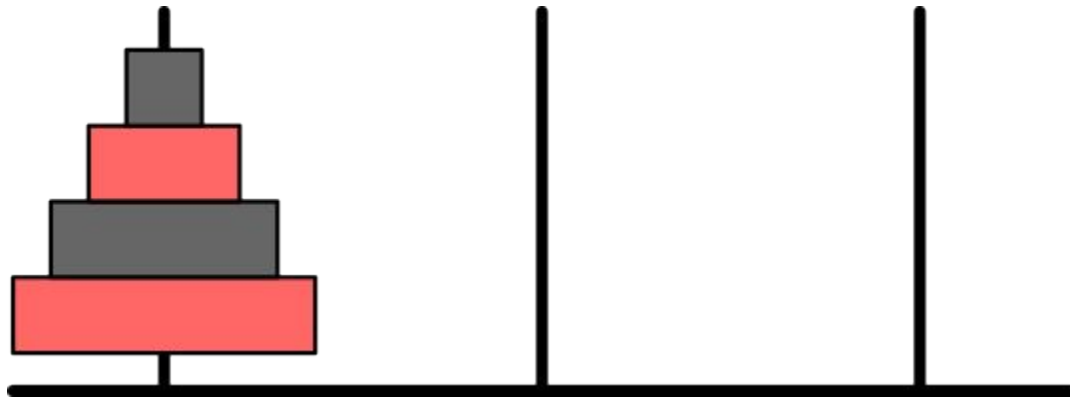
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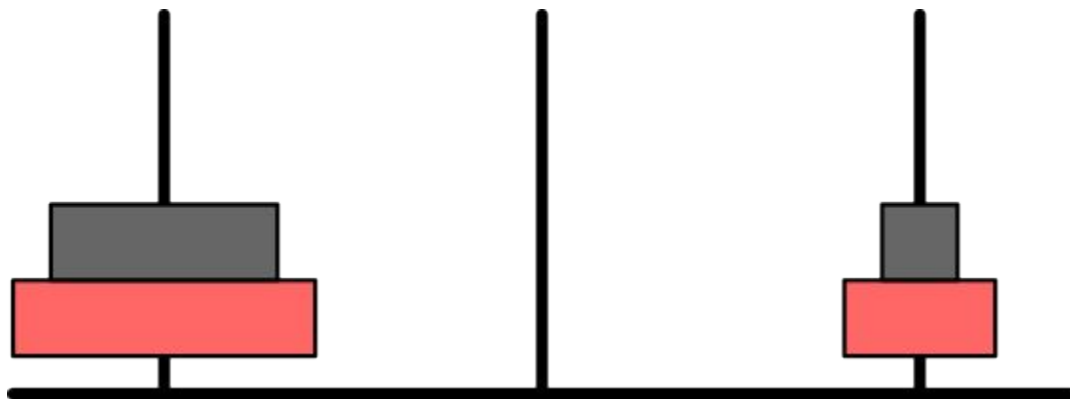
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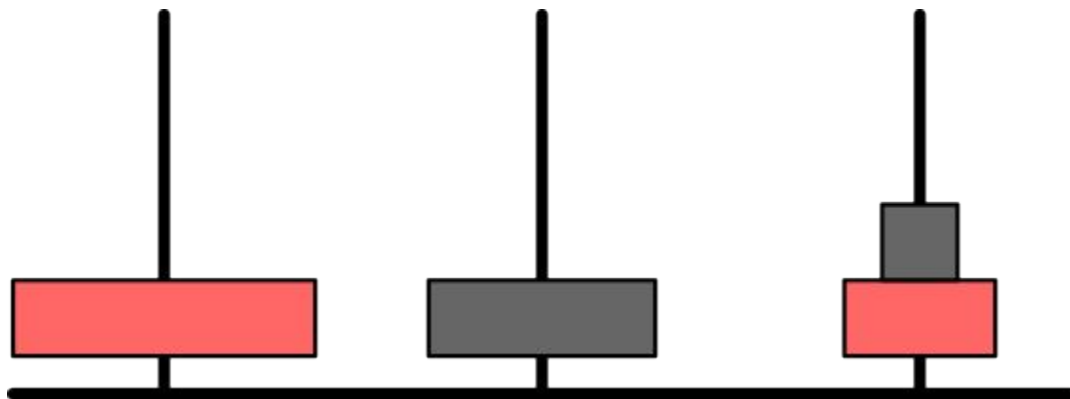
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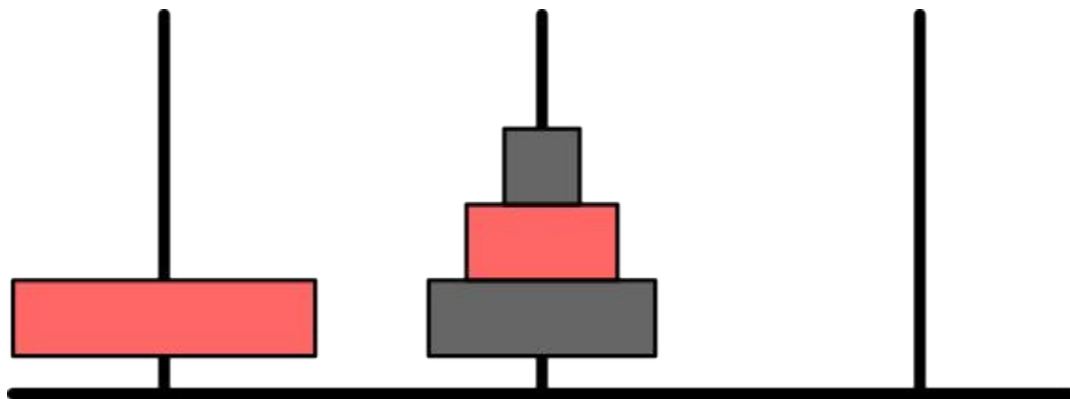
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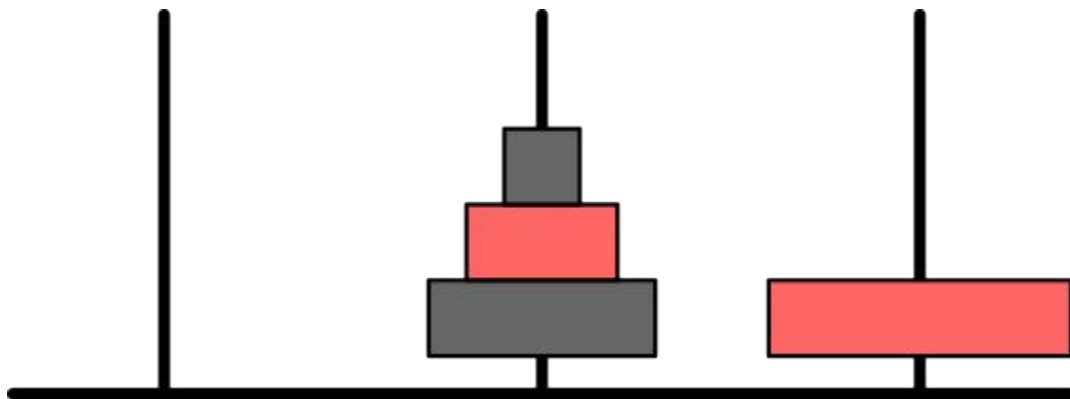
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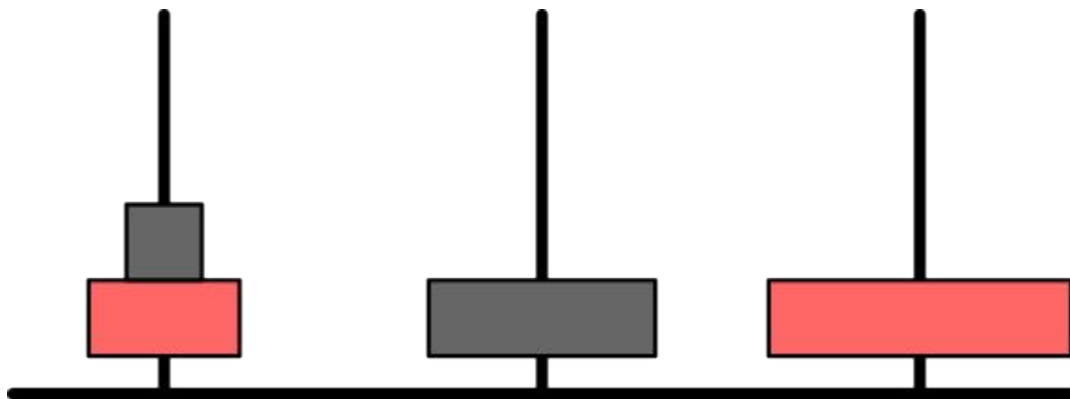
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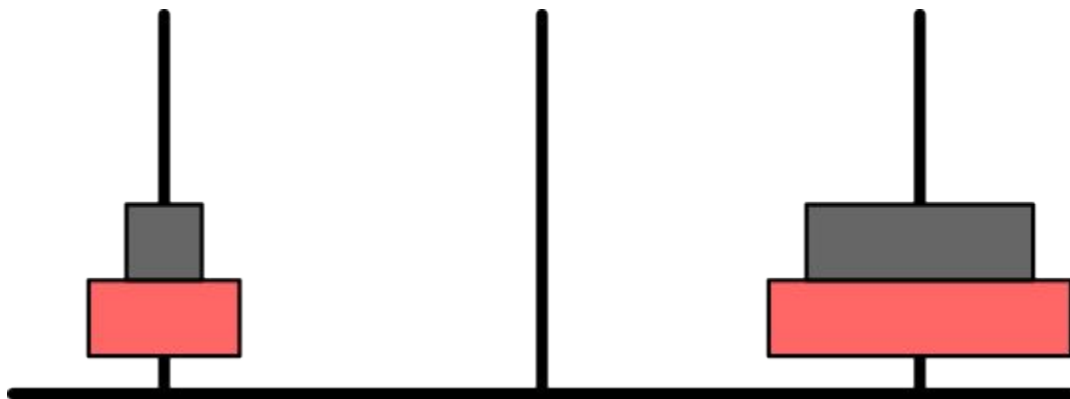
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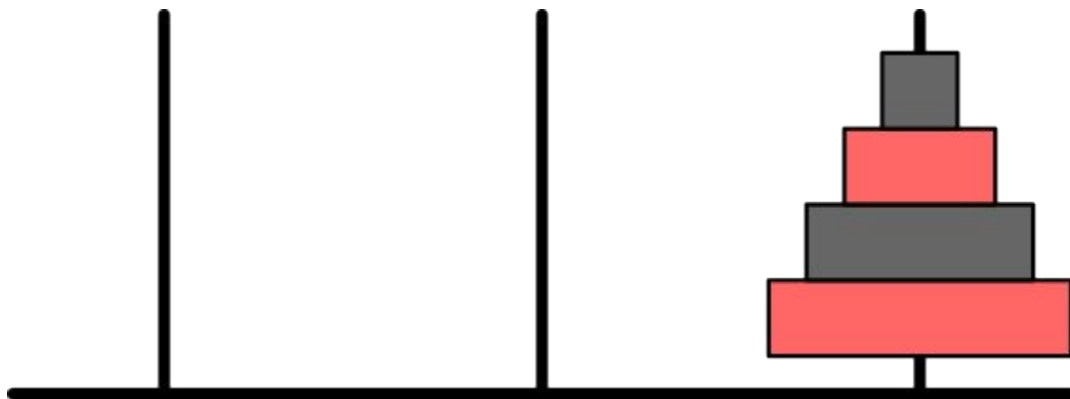
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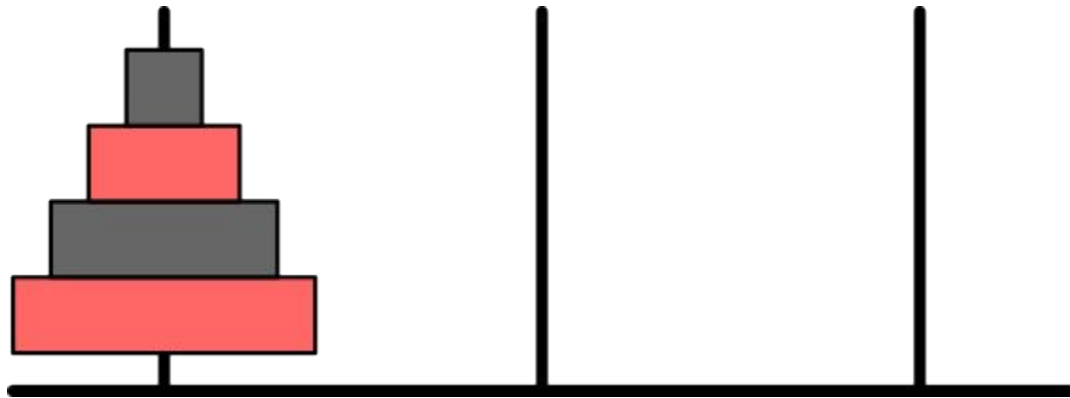
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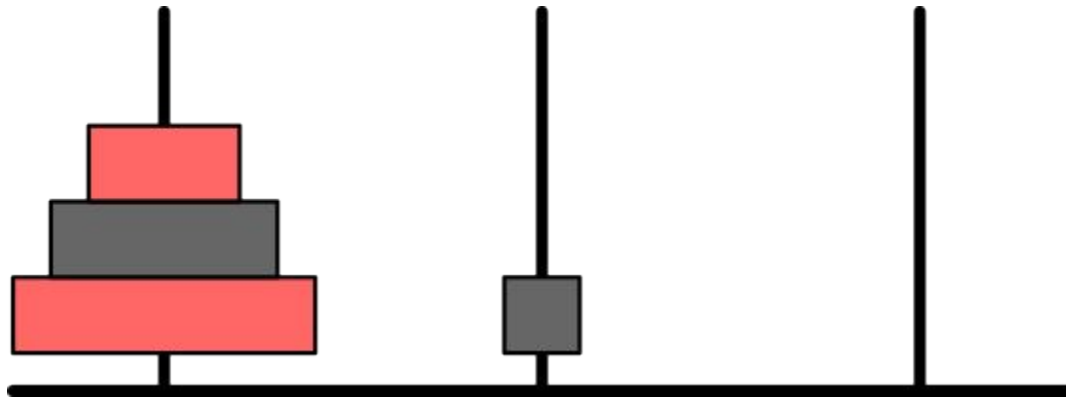
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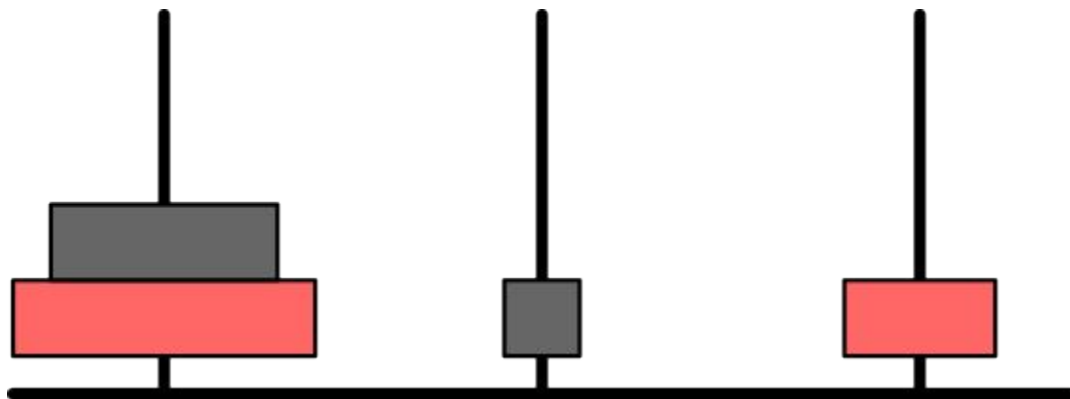
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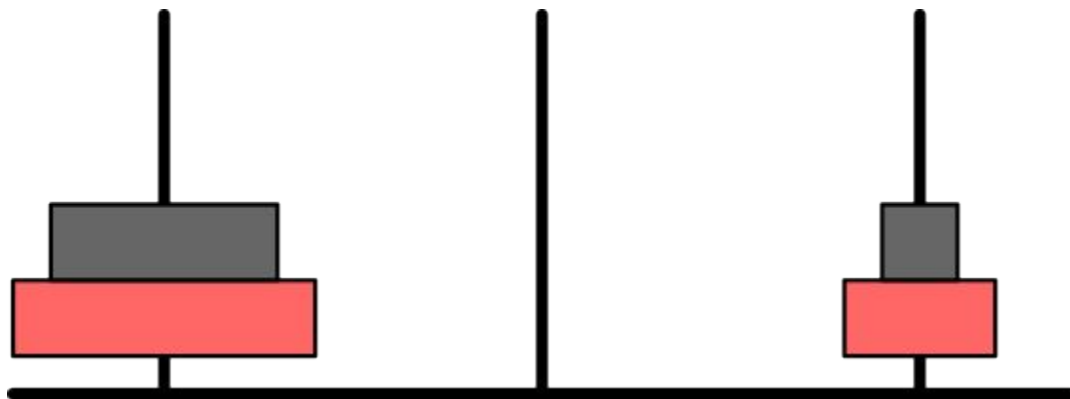
**La tercera és la bona!**



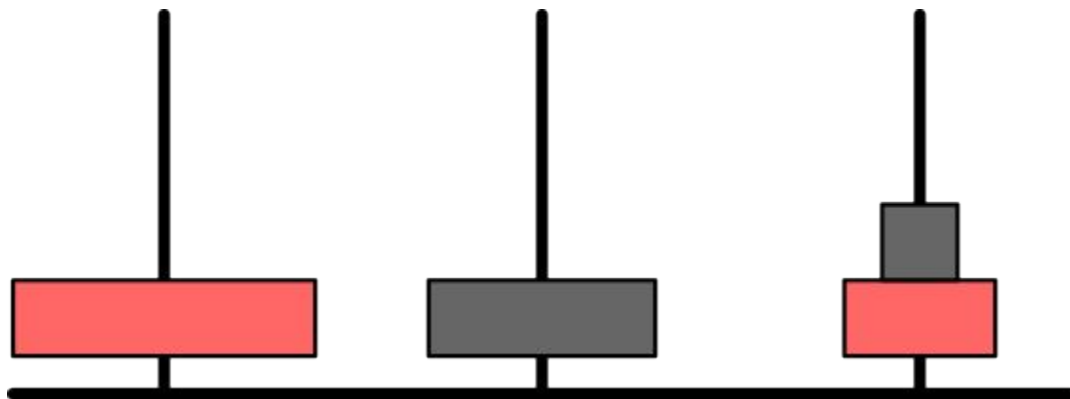
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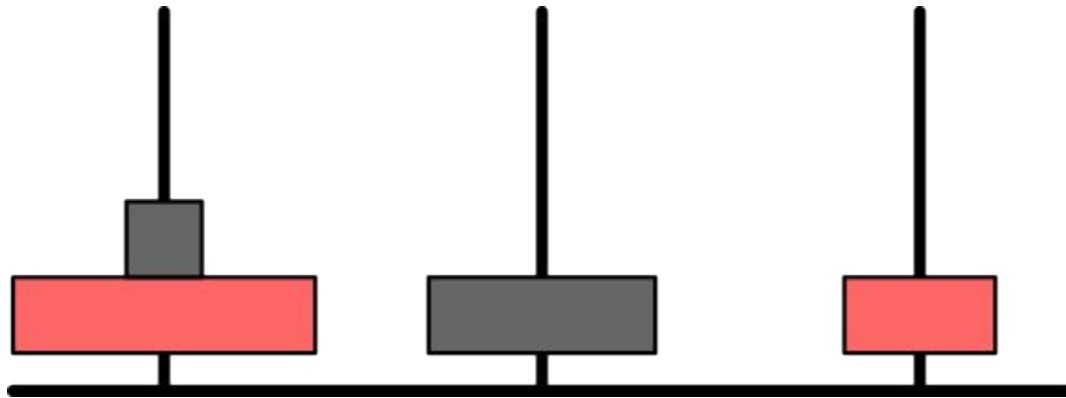
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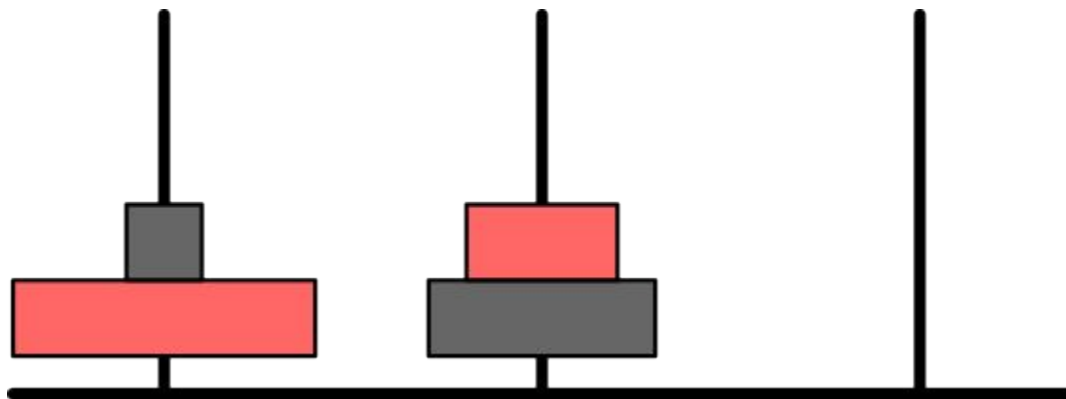
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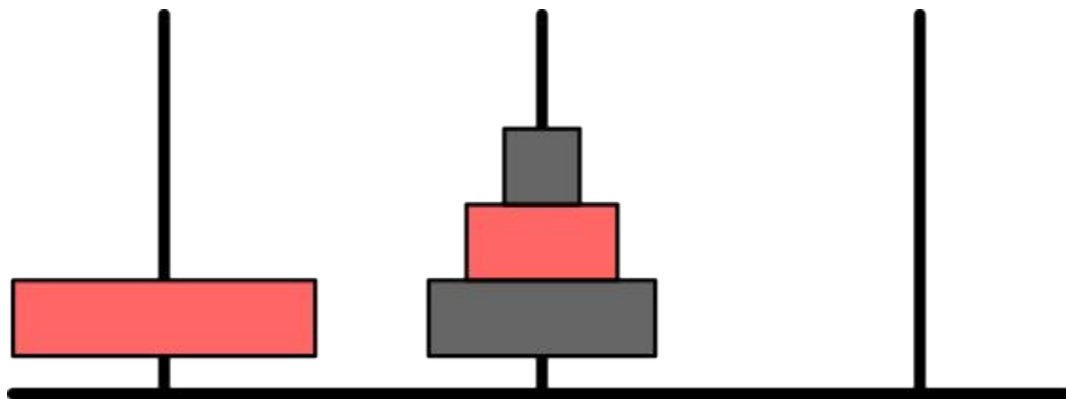
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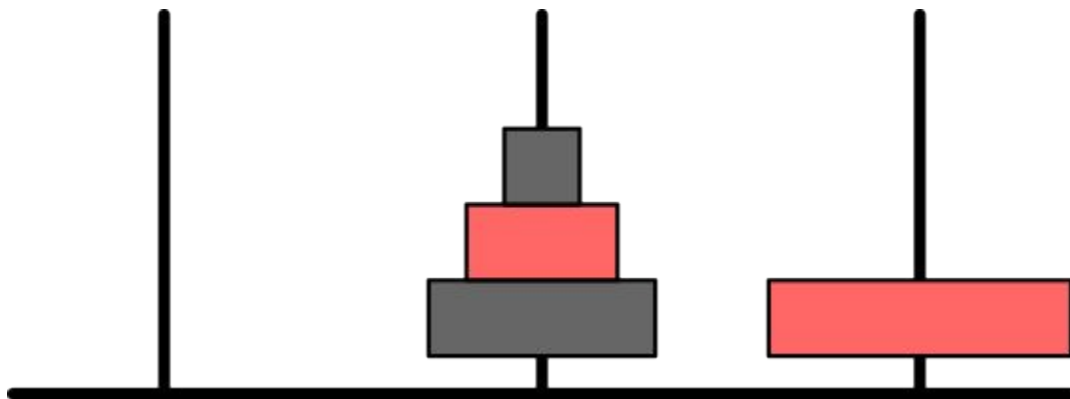
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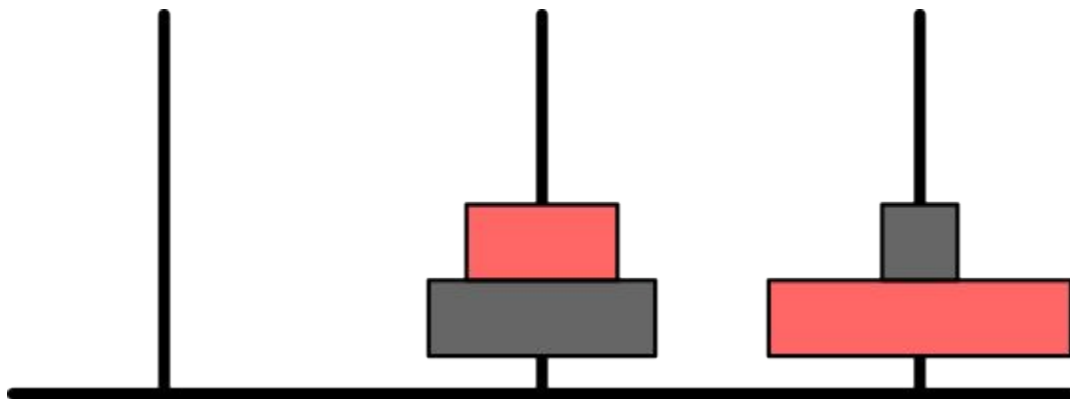
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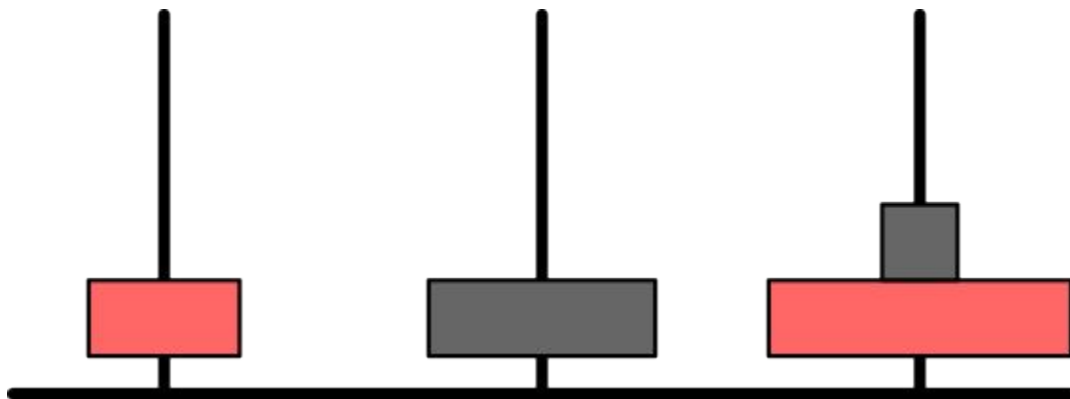
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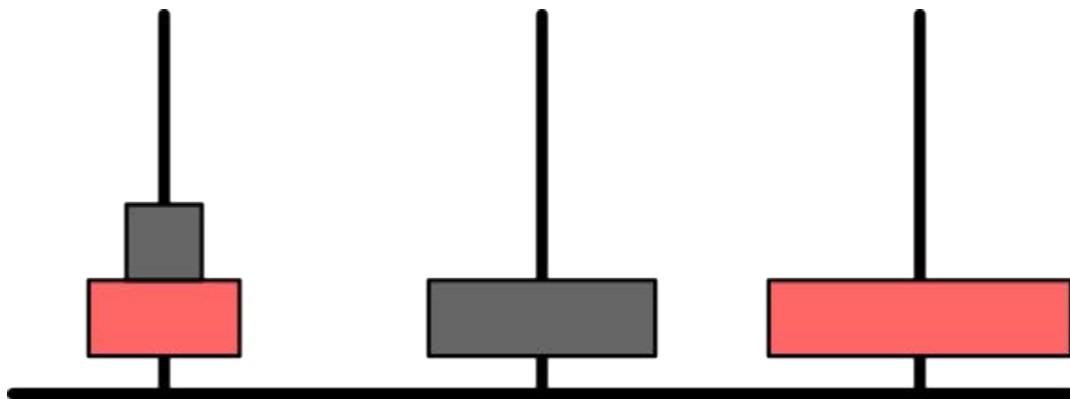
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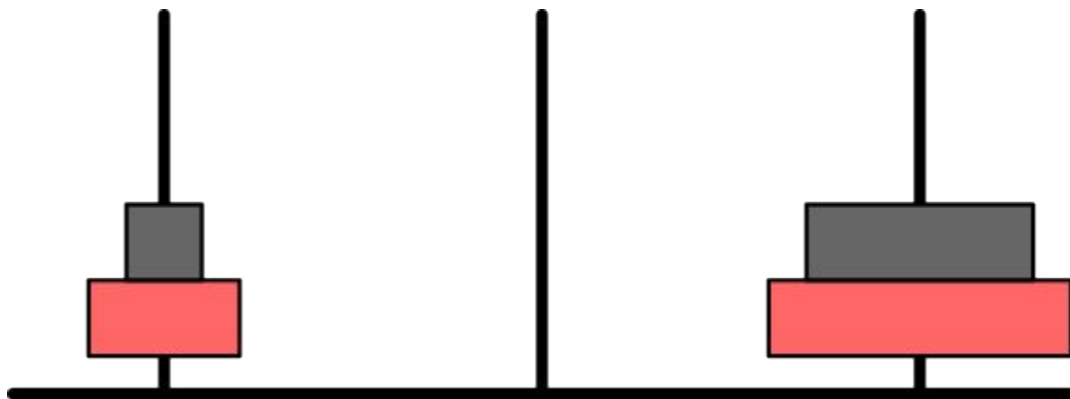
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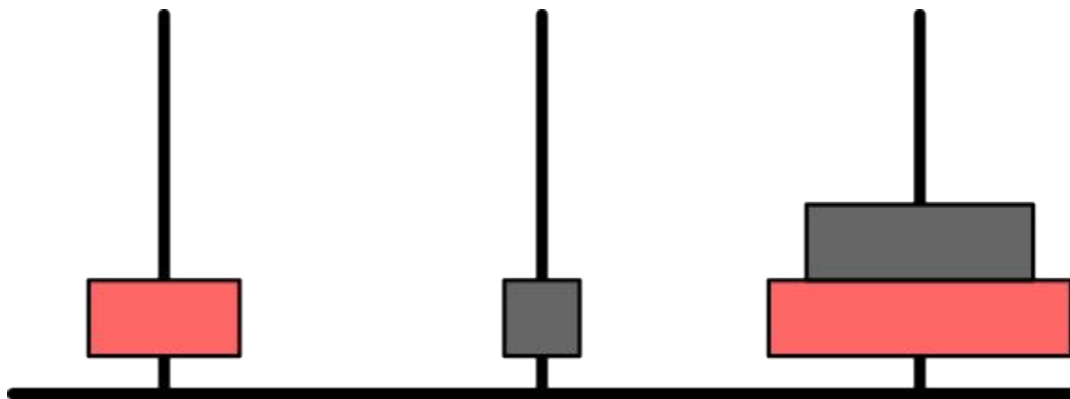
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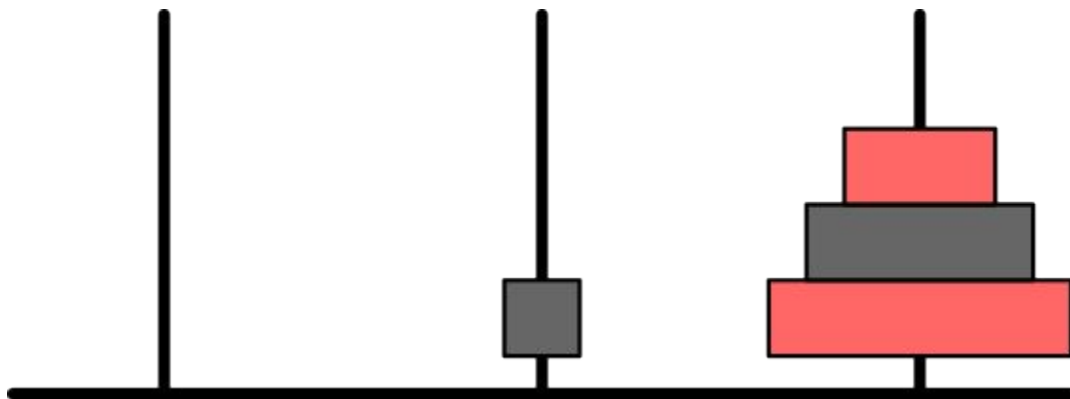
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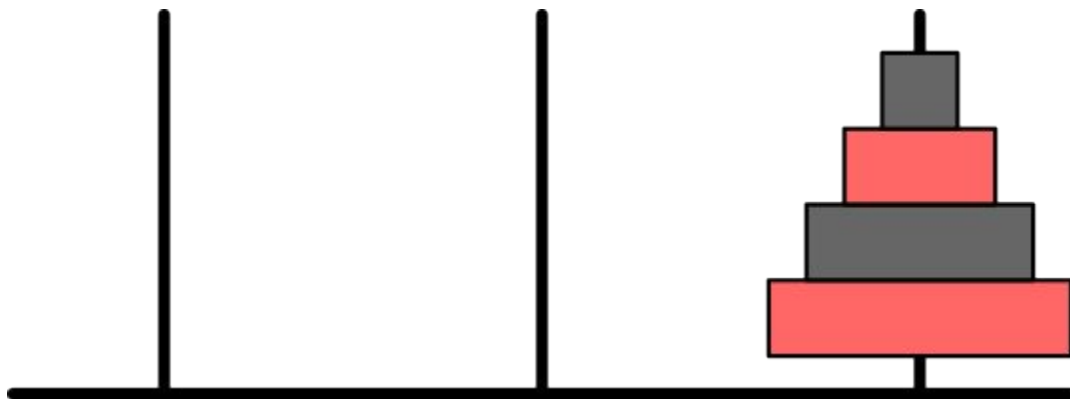
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# Les torres de Hanoi - Idees clau

- Moure una torre de mida  $N-1 \Rightarrow$  Moure una torre de mida  $N$
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- ...fins i tot si estan ocupades per peces més grans!
- Com més gran, menys es mou! (el disc  $k$  es mou  $2^{(N-k)}$  vegades)

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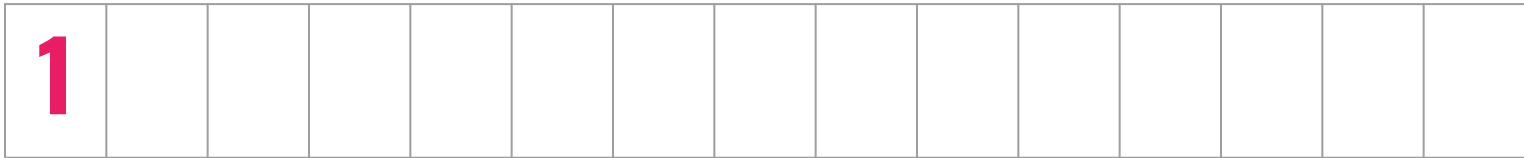
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1	2	1	3	1	2	1	4	1	2	1	3	1	2	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

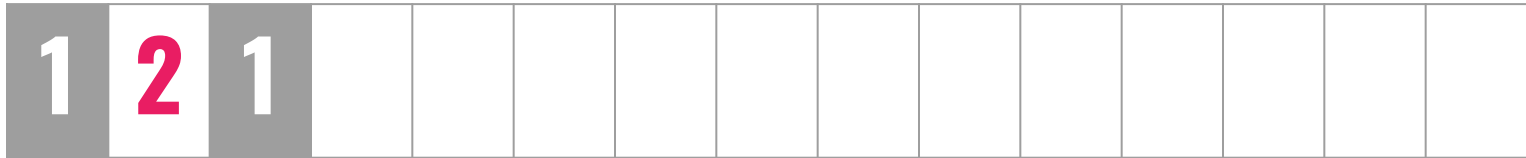
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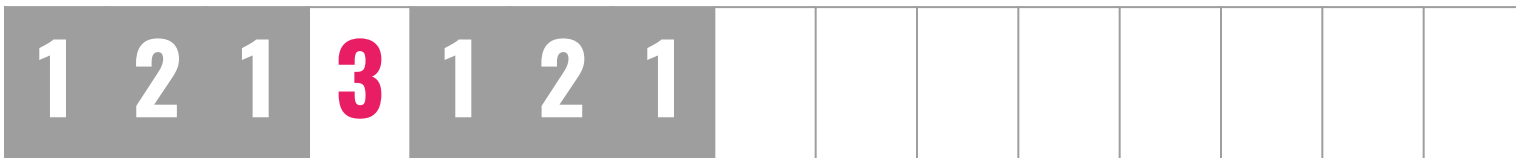
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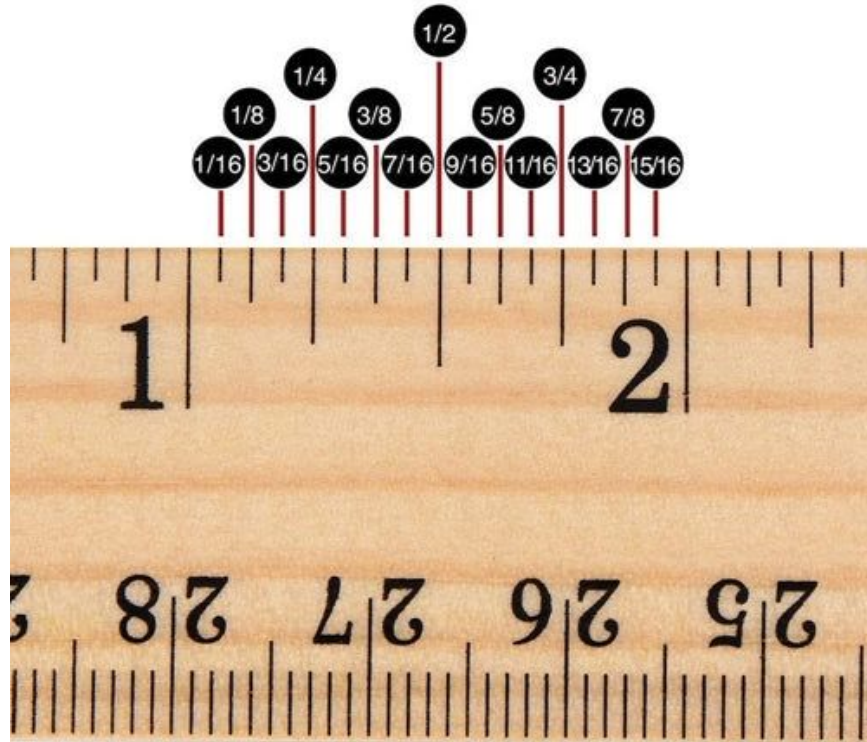
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1 2 1 3 1 2 1 4 1 2 1 3 1 2 1

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- Com més gran, menys es mou! (el disc  $k$  es mou  $2^{(N-k)}$  vegades)

1	2	1	3	1	2	1	4	1	2	1	3	1	2	1
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---



**1213121!**

## Codi de Gray

Canvis 0  $\rightleftharpoons$  1

3	2	1
0	0	0
0	0	1
0	1	1
0	1	0
1	1	0
1	1	1
1	0	1
1	0	0

1213121!

3	2	1
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

## Codi Binari

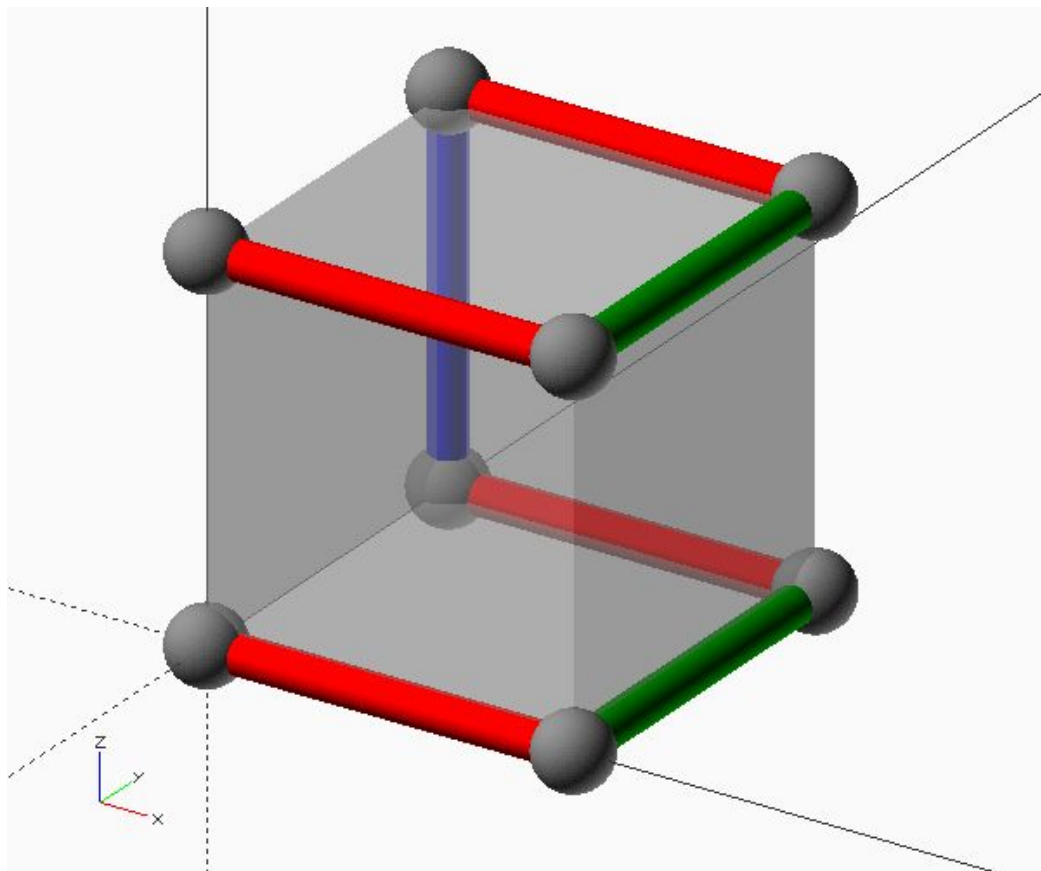
El 0 menys significatiu

L'1 menys significatiu

Canvis 0  $\rightarrow$  1



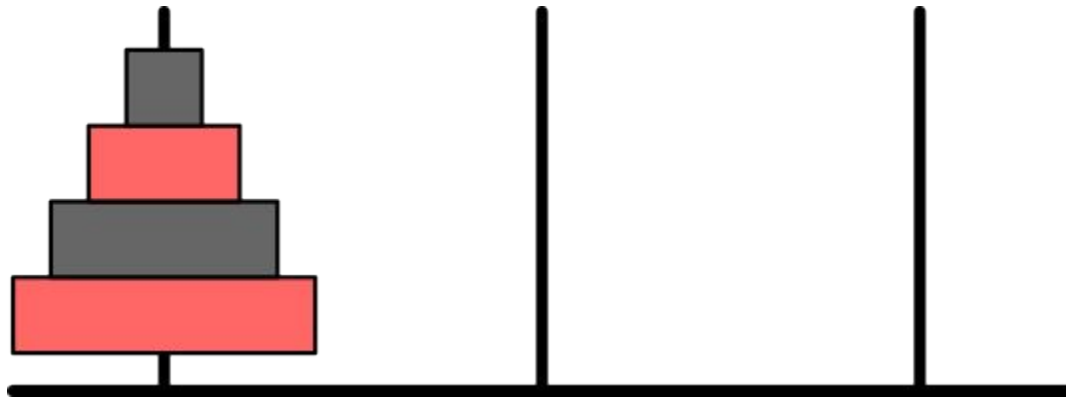
1213121!



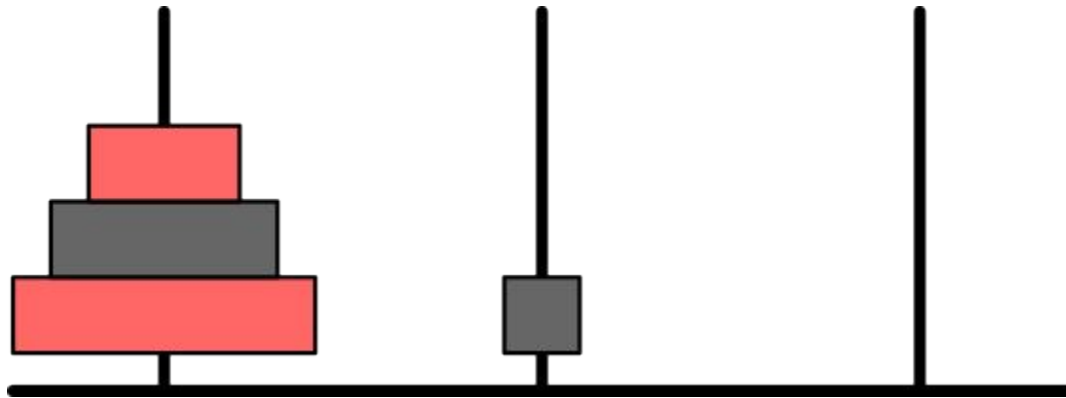
**1213121!**

# Les torres de Hanoi - Idees clau

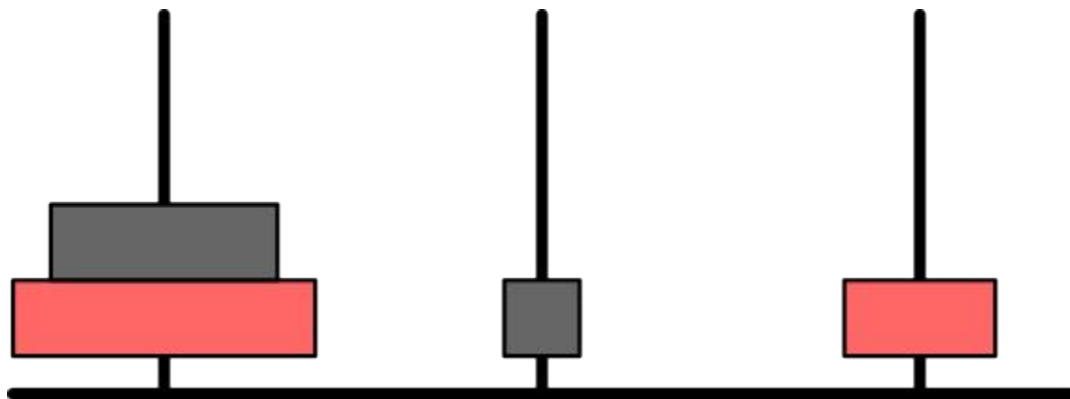
- Moure una torre de mida  $N-1 \Rightarrow$  Moure una torre de mida  $N$
- Puc fer servir agulles temporalment...
- ...fins i tot si estan ocupades per peces més grans!
- Com més gran, menys es mou! (el disc  $k$  es mou  $2^{(N-k)}$  vegades)
- Els colors no són casuals!



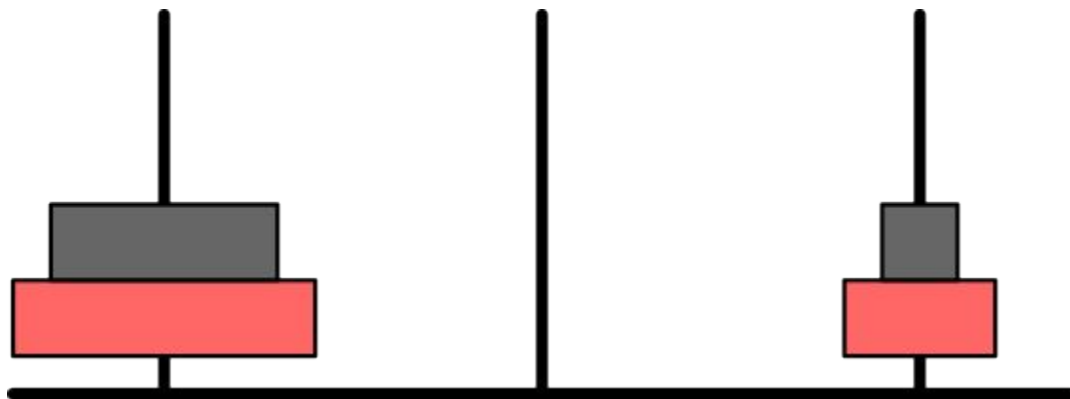
**Els colors no són casuals!**



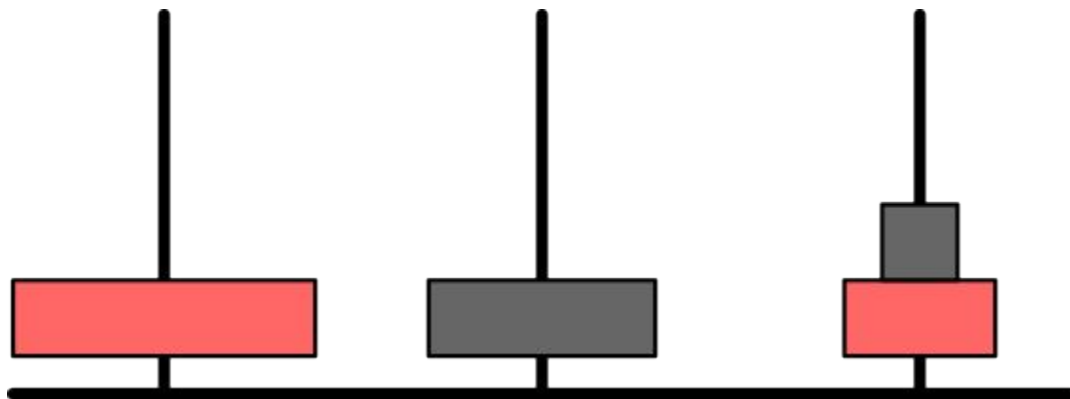
**Els colors no són casuals!**



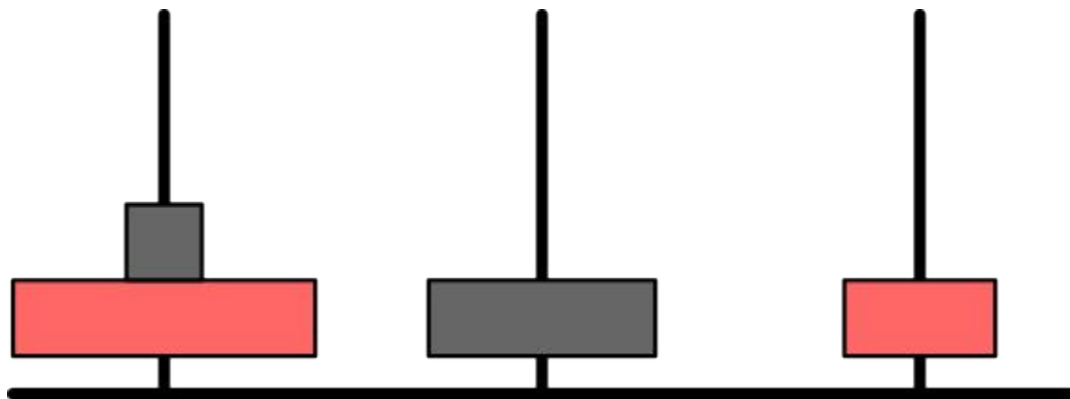
**Els colors no són casuals!**



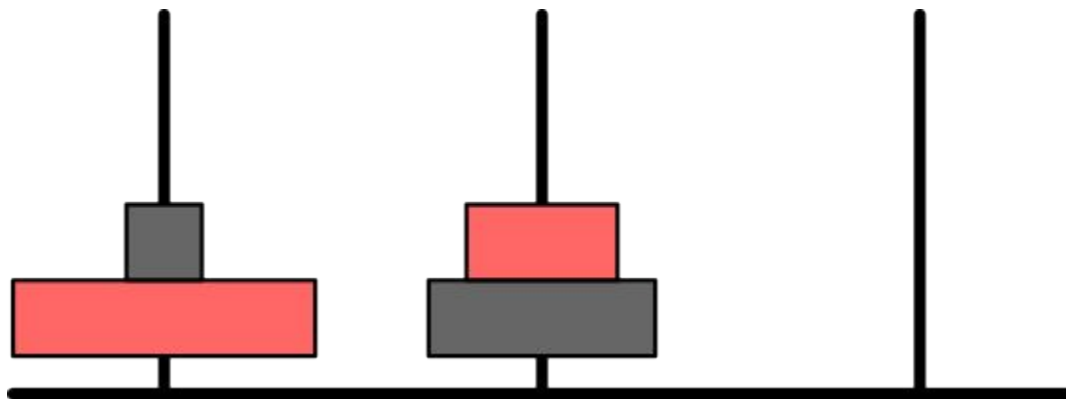
**Els colors no són casuals!**



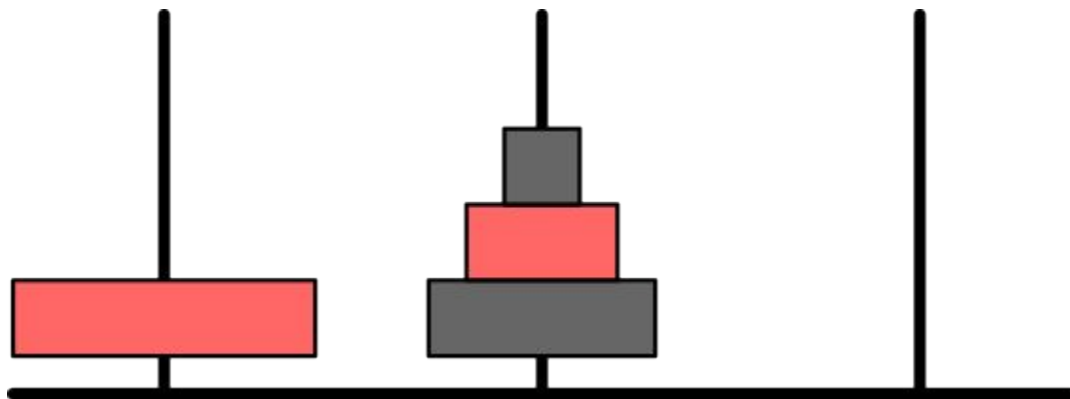
**Els colors no són casuals!**



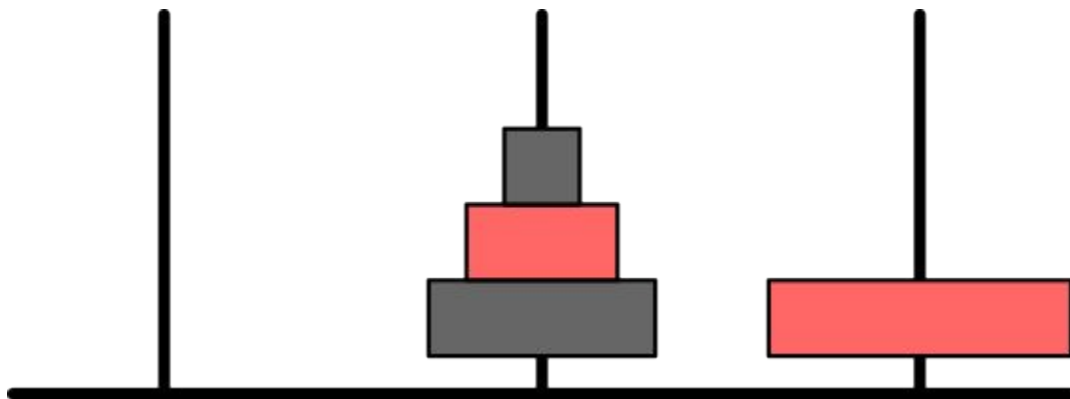
**Els colors no són casuals!**



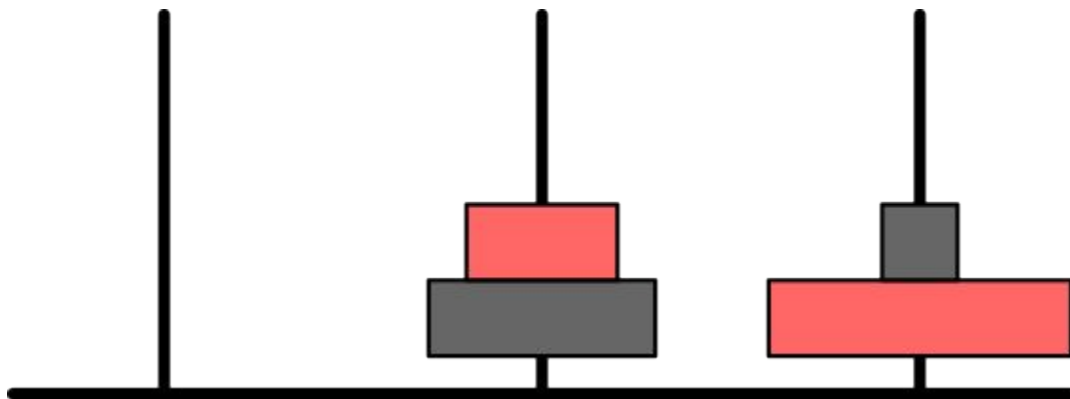
**Els colors no són casuals!**



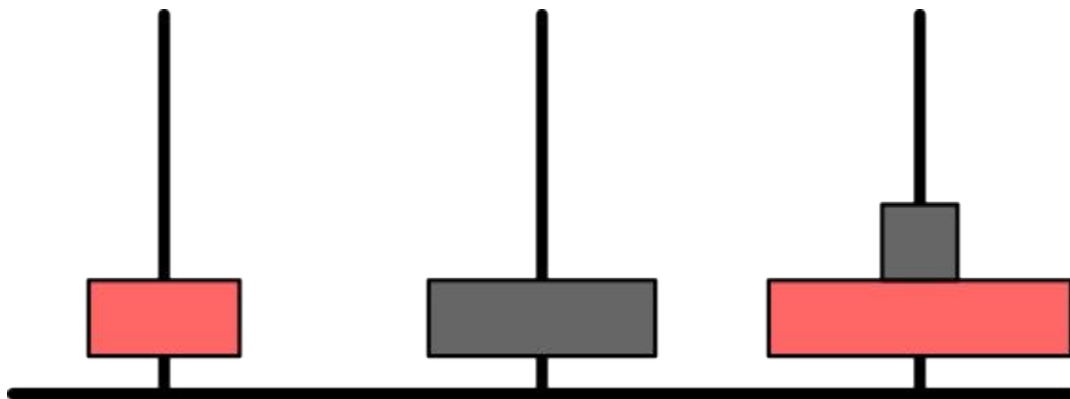
**Els colors no són casuals!**



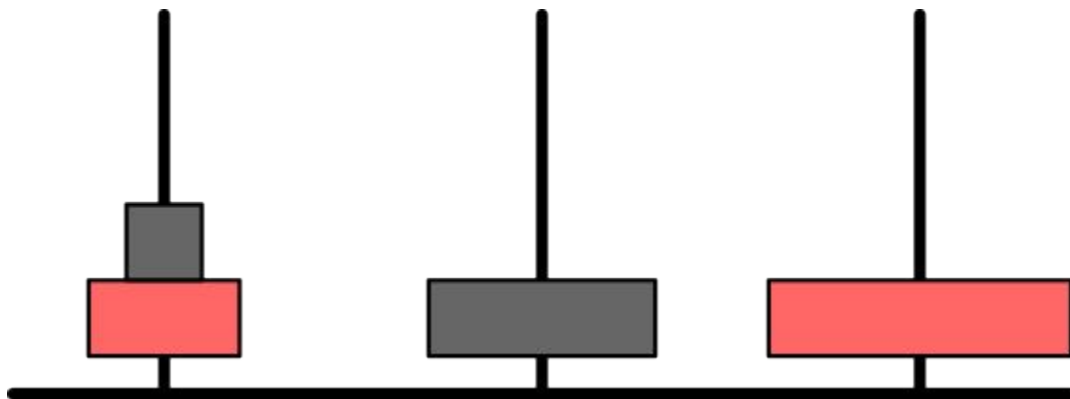
**Els colors no són casuals!**



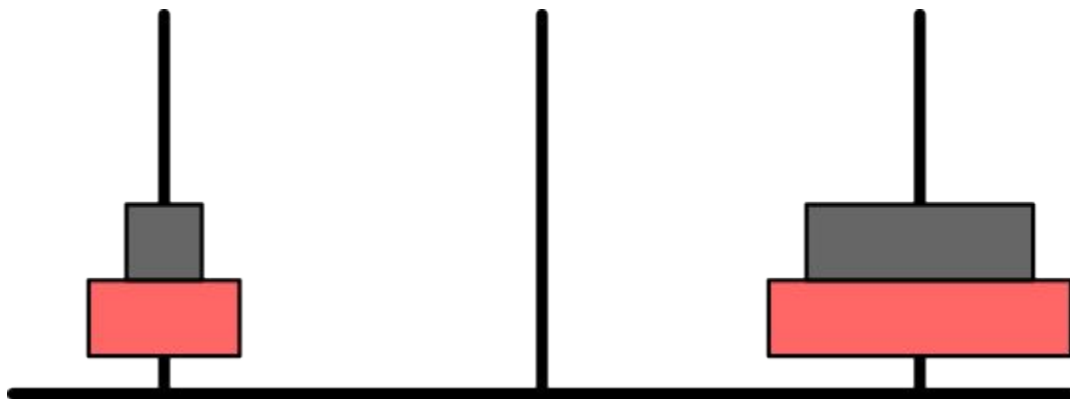
**Els colors no són casuals!**



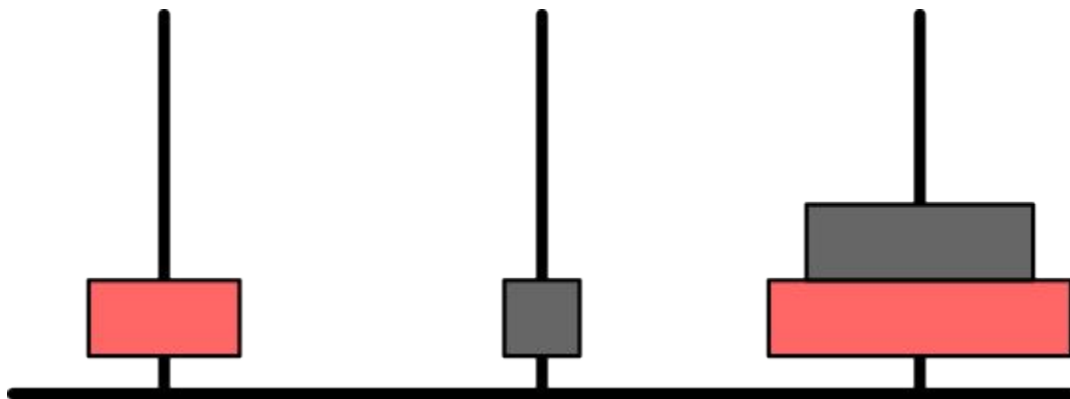
**Els colors no són casuals!**



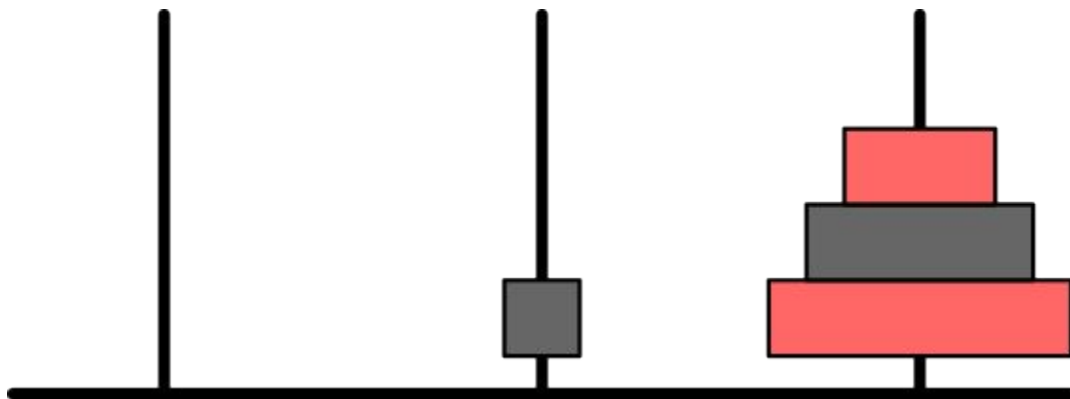
**Els colors no són casuals!**



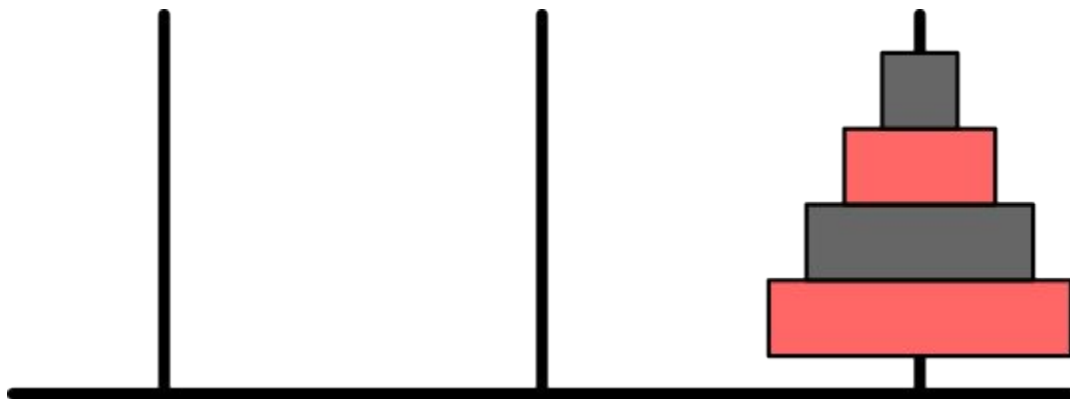
**Els colors no són casuals!**



**Els colors no són casuals!**



**Els colors no són casuals!**



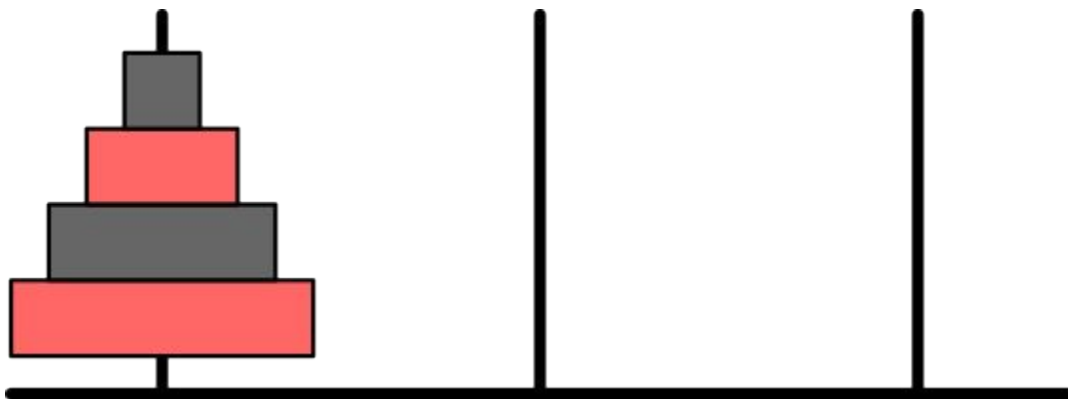
**Els colors no són casuals!**

# Les torres de Hanoi - Idees clau

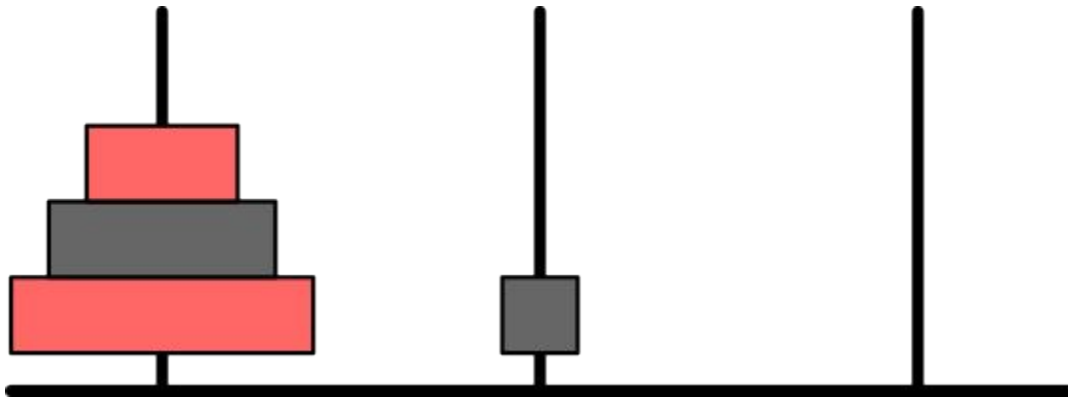
- Moure una torre de mida  $N-1 \Rightarrow$  Moure una torre de mida  $N$
- Puc fer servir agulles temporalment...
- ...fins i tot si estan ocupades per peces més grans!
- Com més gran, menys es mou! (el disc  $k$  es mou  $2^{(N-k)}$  vegades)
- Els colors no són casuals! (intercalats i movent-se en sentits oposats)

# Les torres de Hanoi - Idees clau

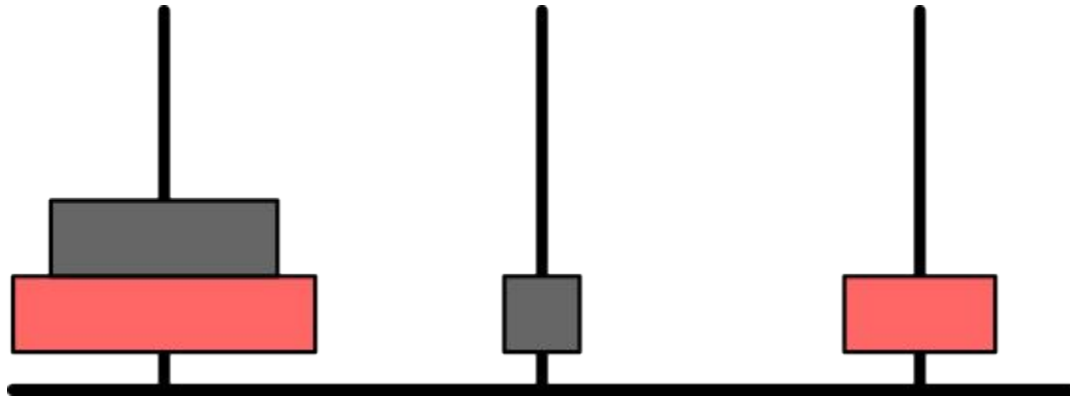
- Moure una torre de mida  $N-1 \Rightarrow$  Moure una torre de mida  $N$
- Puc fer servir agulles temporalment...
- ...fins i tot si estan ocupades per peces més grans!
- Com més gran, menys es mou! (el disc  $k$  es mou  $2^{(N-k)}$  vegades)
- Els colors no són casuals! (intercalats i movent-se en sentits oposats)
- El moviments són cíclics! ...  $(A \rightleftharpoons B), (A \rightleftharpoons C), (B \rightleftharpoons C)$  ...



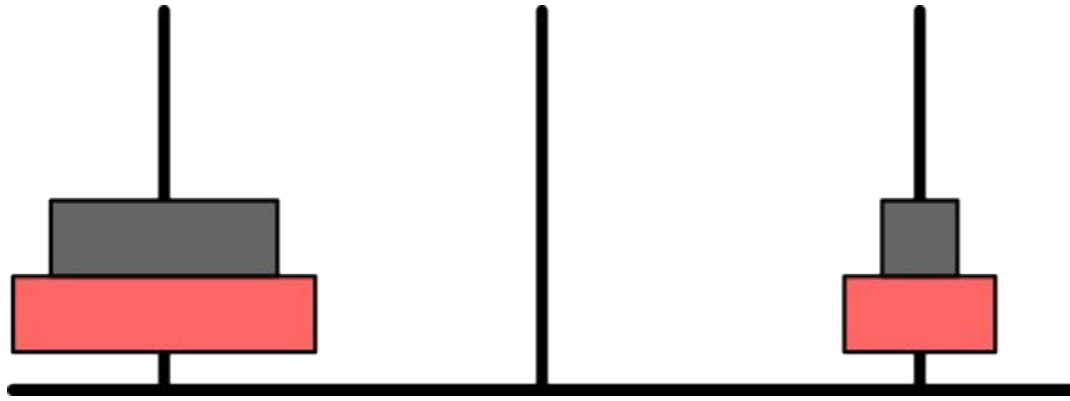
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



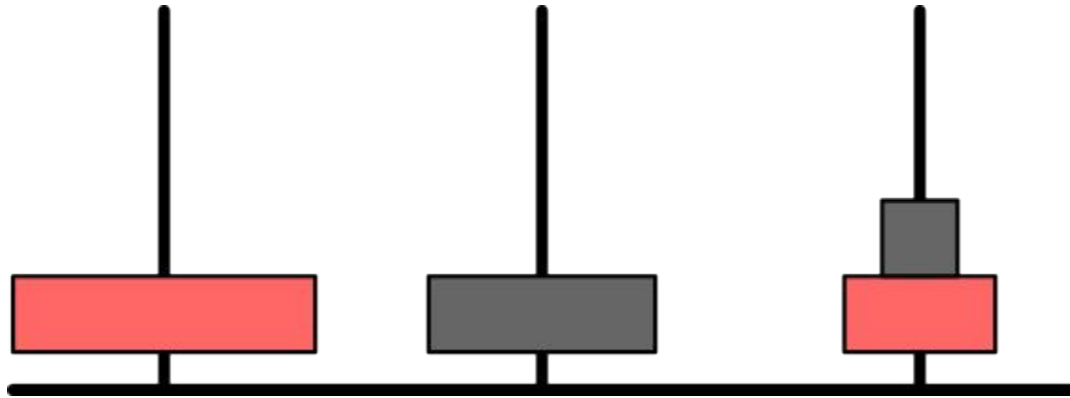
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



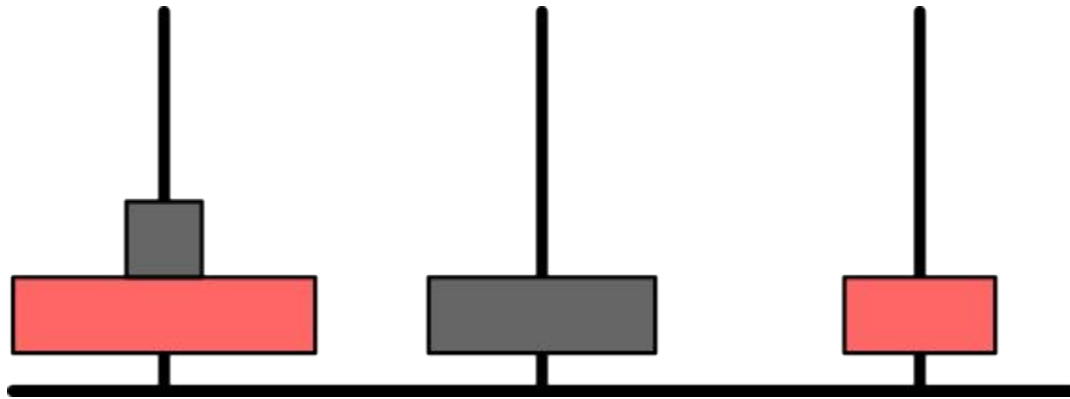
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



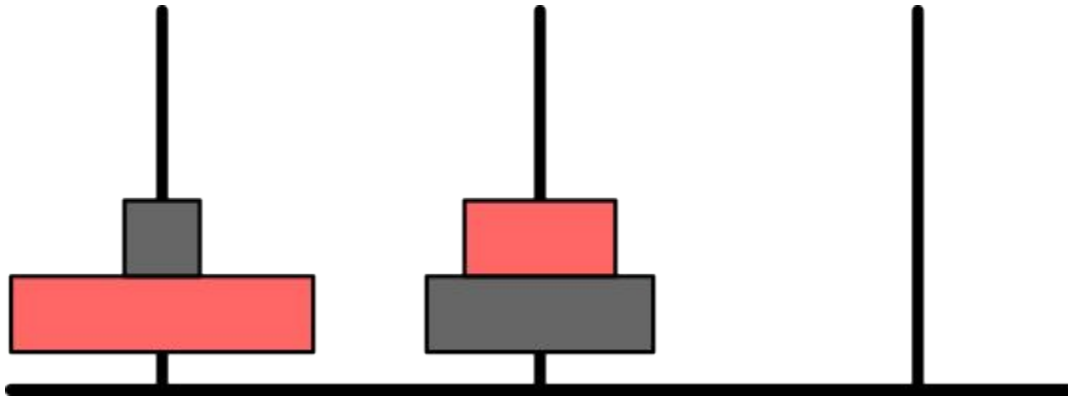
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



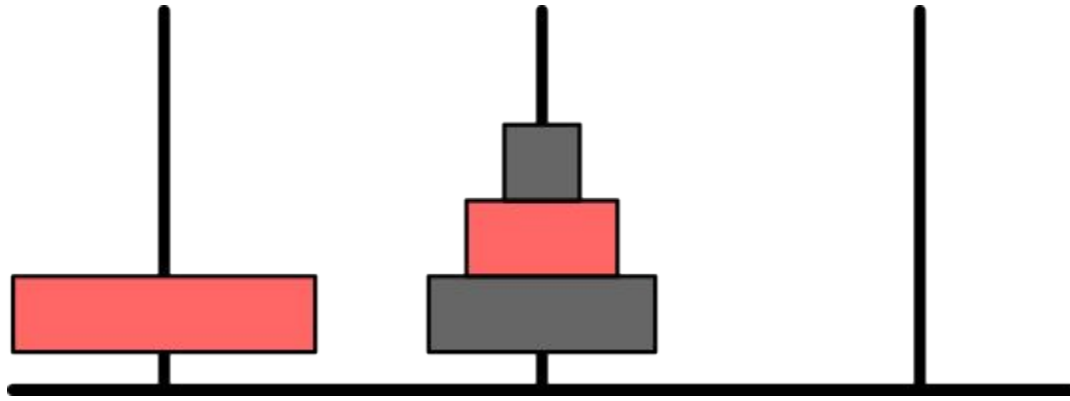
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



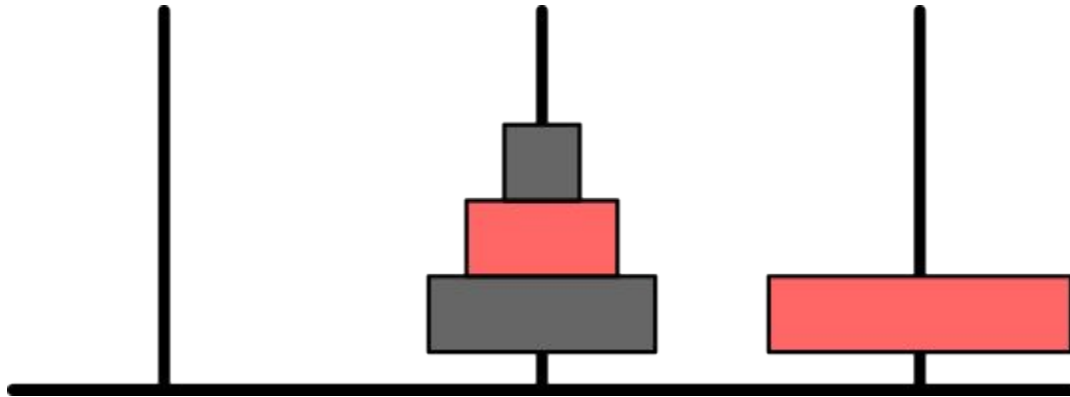
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



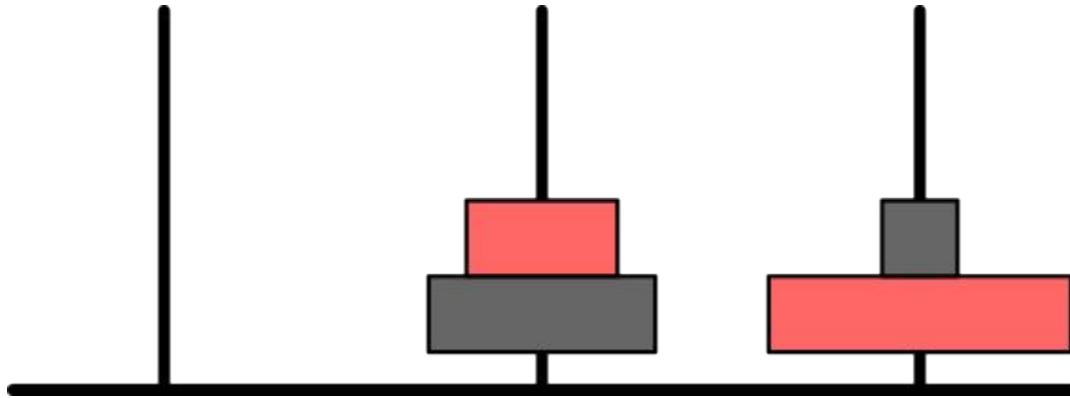
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



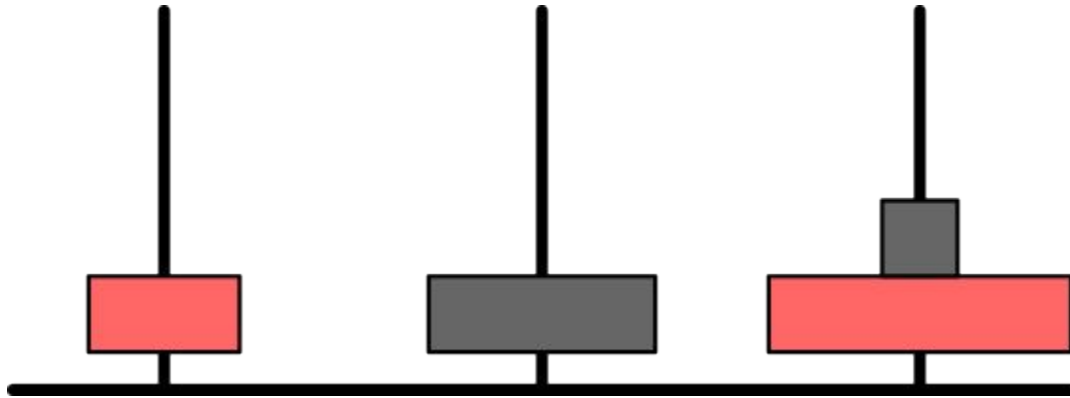
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



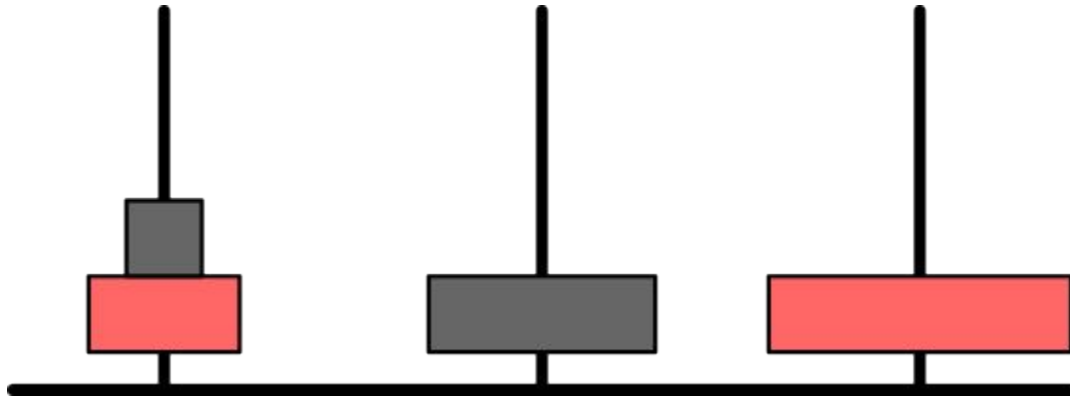
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



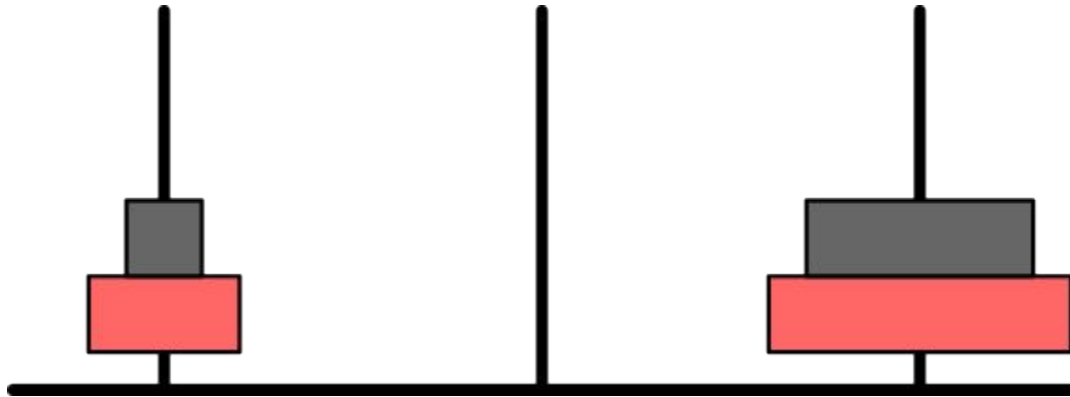
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



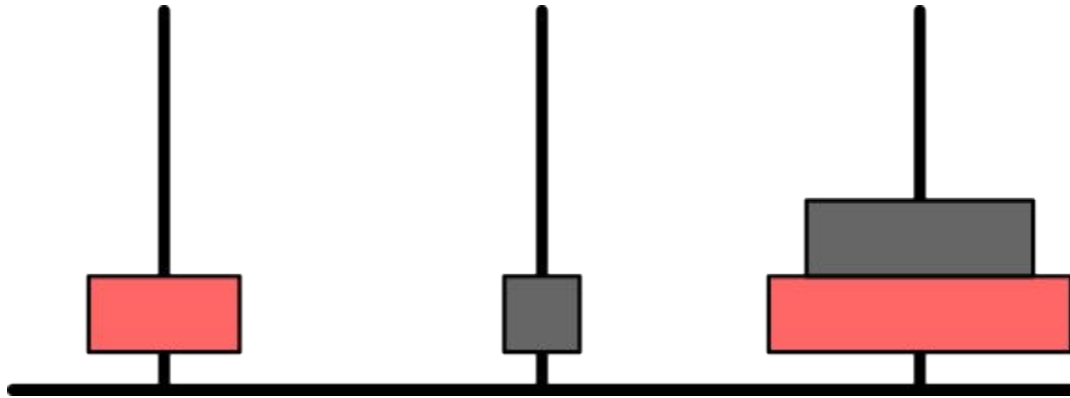
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



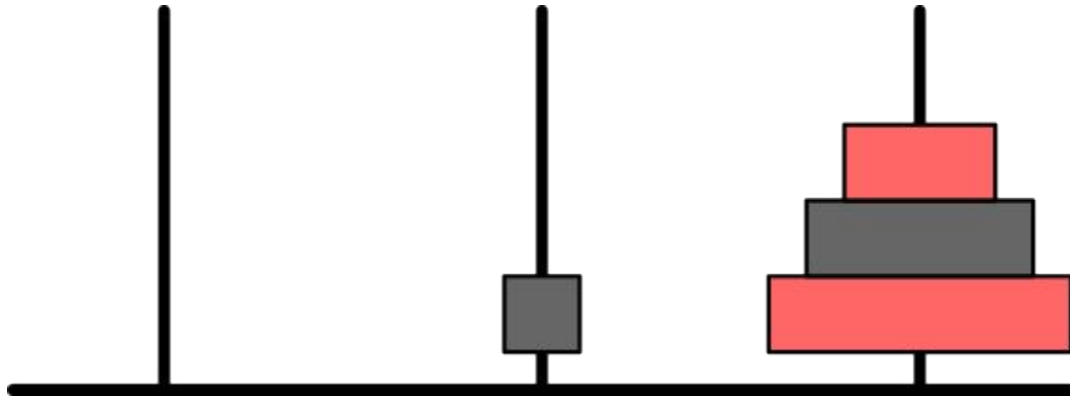
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



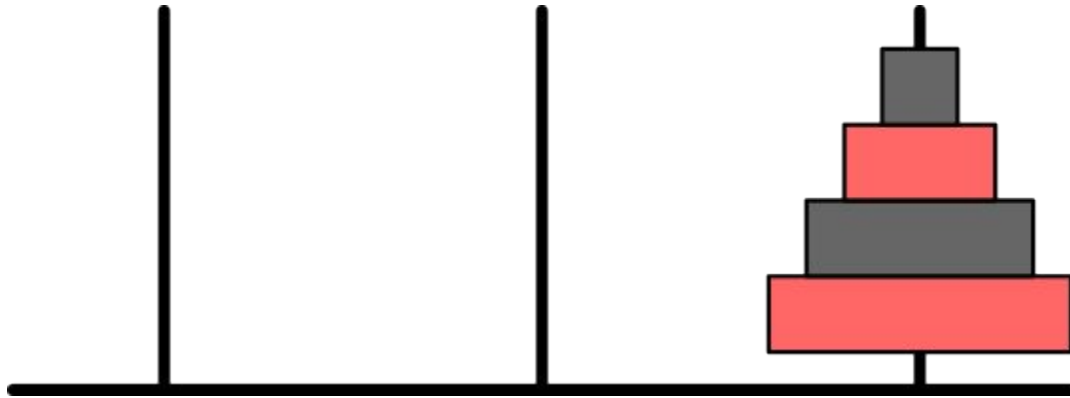
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



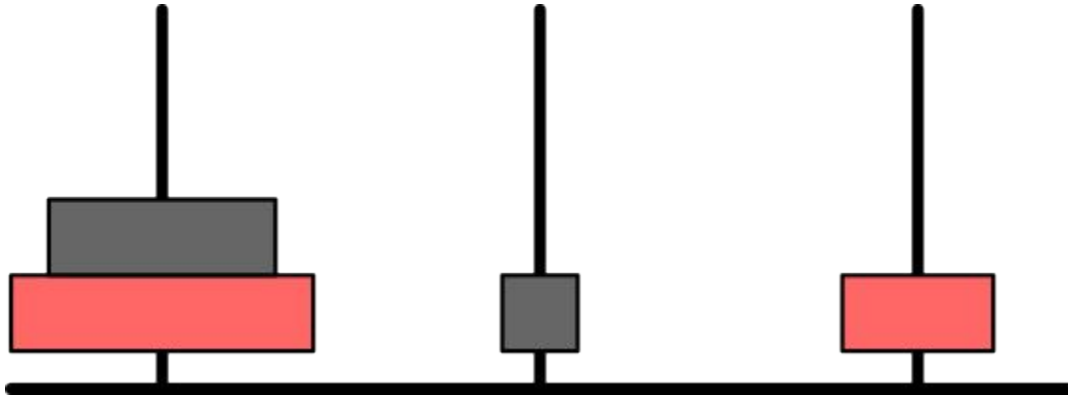
...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...



...  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$  ...

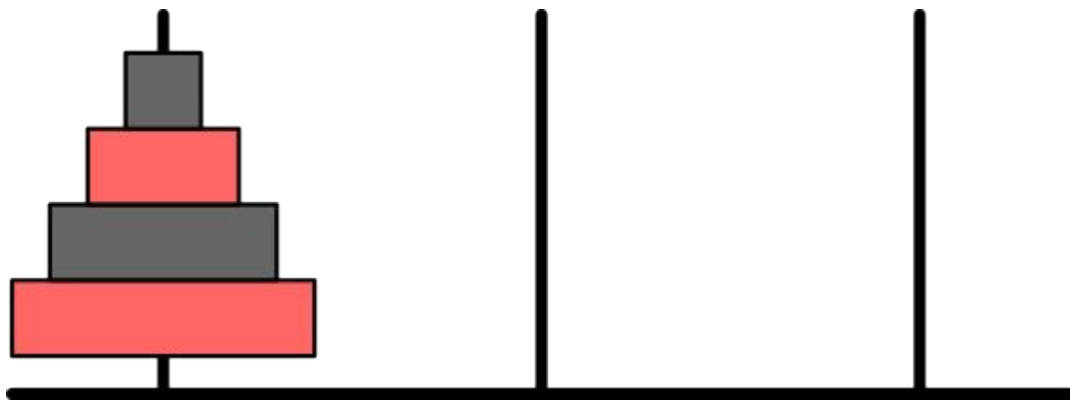
# Les torres de Hanoi - Notació

- Tres moviments des de cada posició:  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$



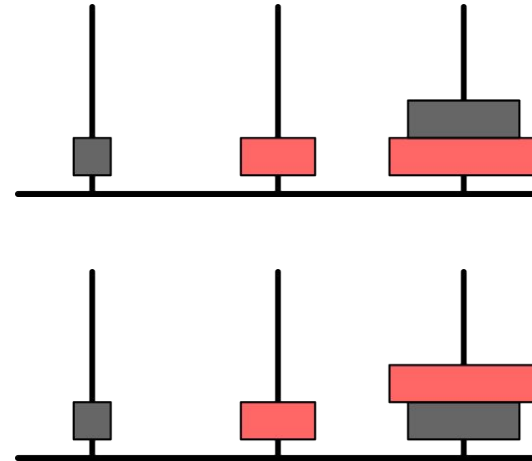
# Les torres de Hanoi - Notació

- Tres moviments des de cada posició:  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$



# Les torres de Hanoi - Notació

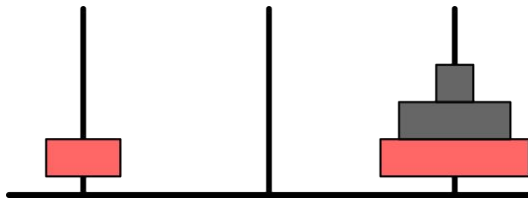
- Tres moviments des de cada posició:  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$
- Generar posicions aleatòries:  $\text{Permutacions}(\#\#123\dots N)$



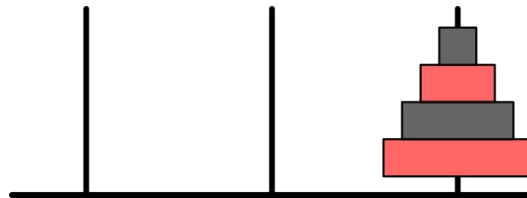
# Les torres de Hanoi - Notació

- Tres moviments des de cada posició:  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$
- Generar posicions aleatòries: **Permutacions(##123...N)**
- Posicions legals: **Paraules de longitud N amb "A", "B" i "C"**

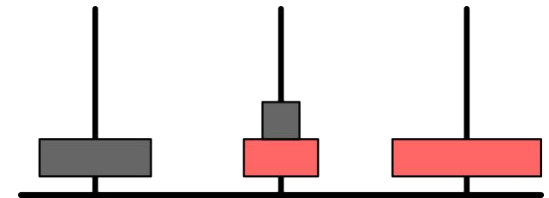
**CCAC**



**CCCC**



**CABB**



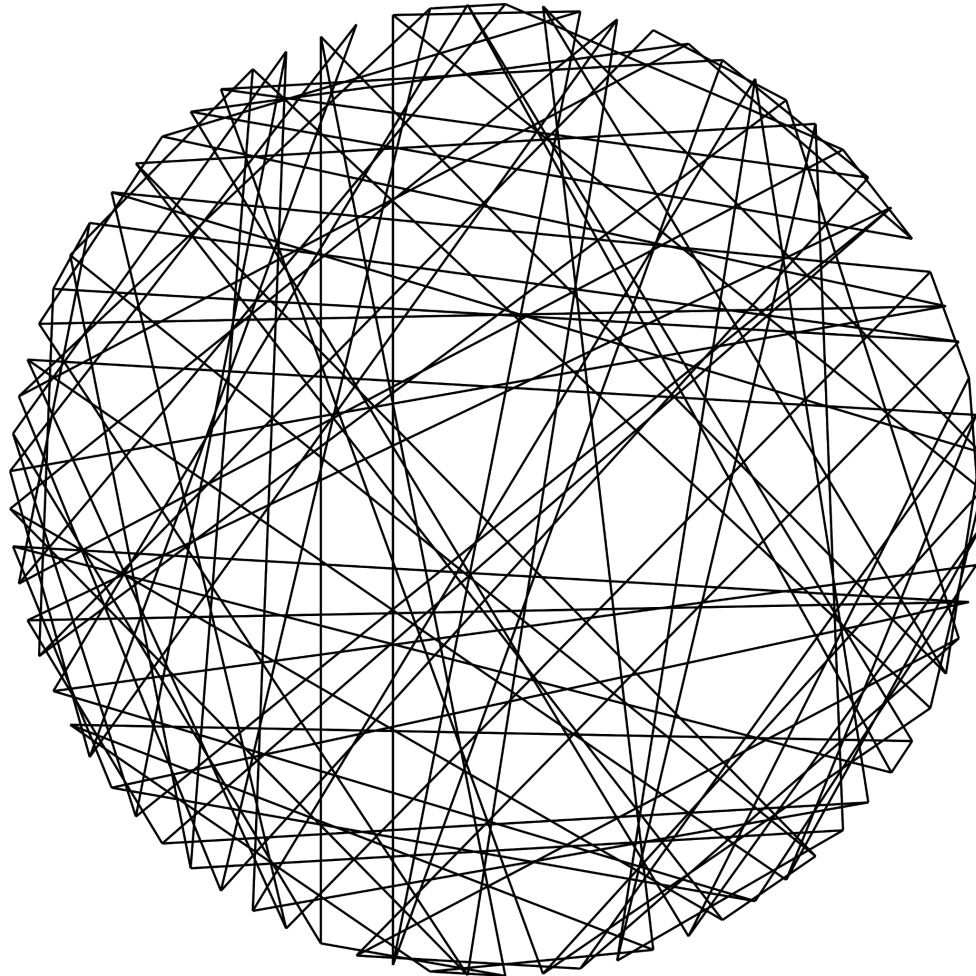
# Les torres de Hanoi - Dibuixem un bon mapa!

- Posicions legals: Paraules de longitud  $N$  amb “A”, “B” i “C”

⇒  $3^N$  nodes

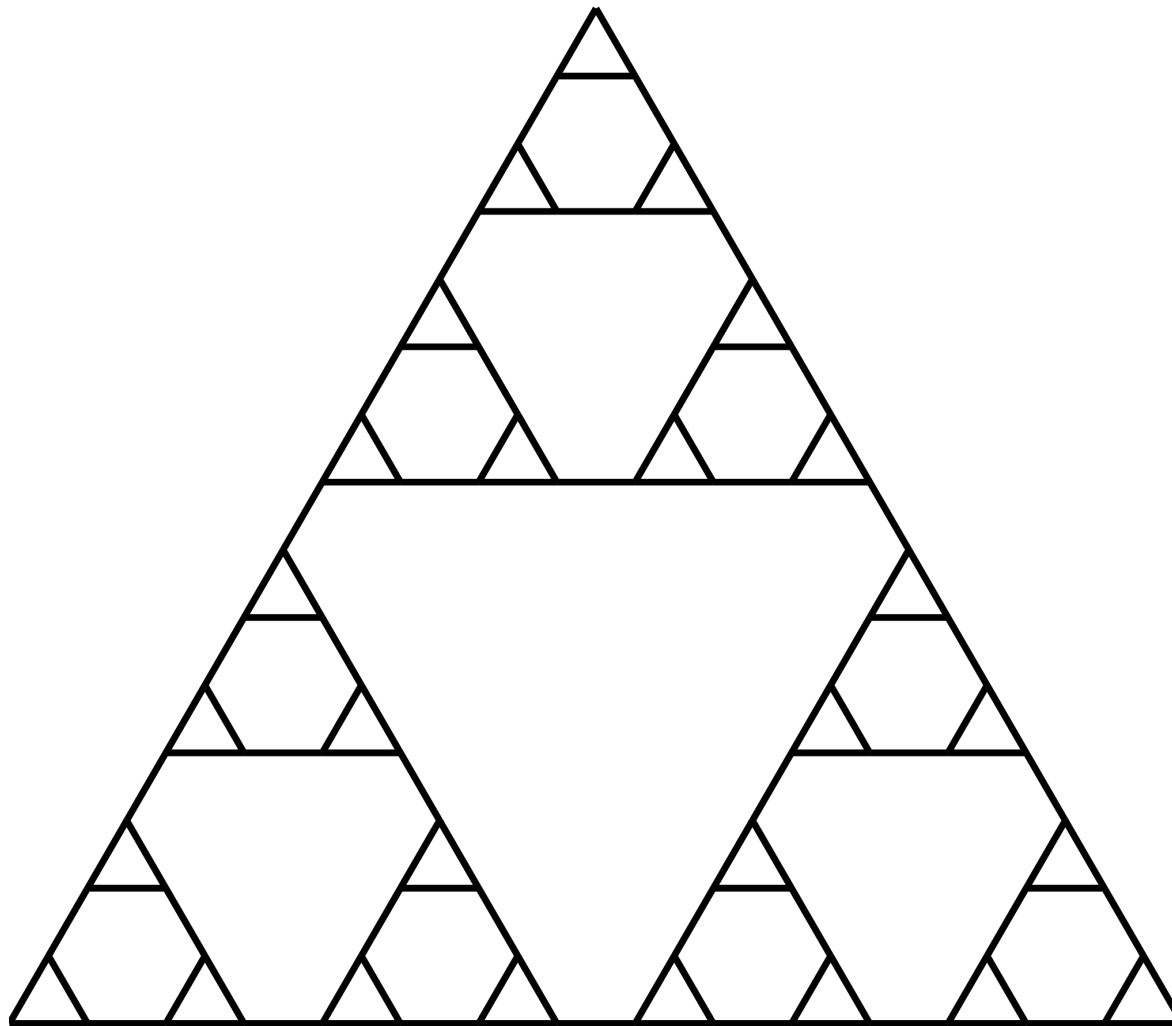
- Tres moviments des de cada posició:  $(A \rightleftharpoons B)$ ,  $(A \rightleftharpoons C)$ ,  $(B \rightleftharpoons C)$

⇒  $(3^{(N+1)} - 3) / 2$  arestes

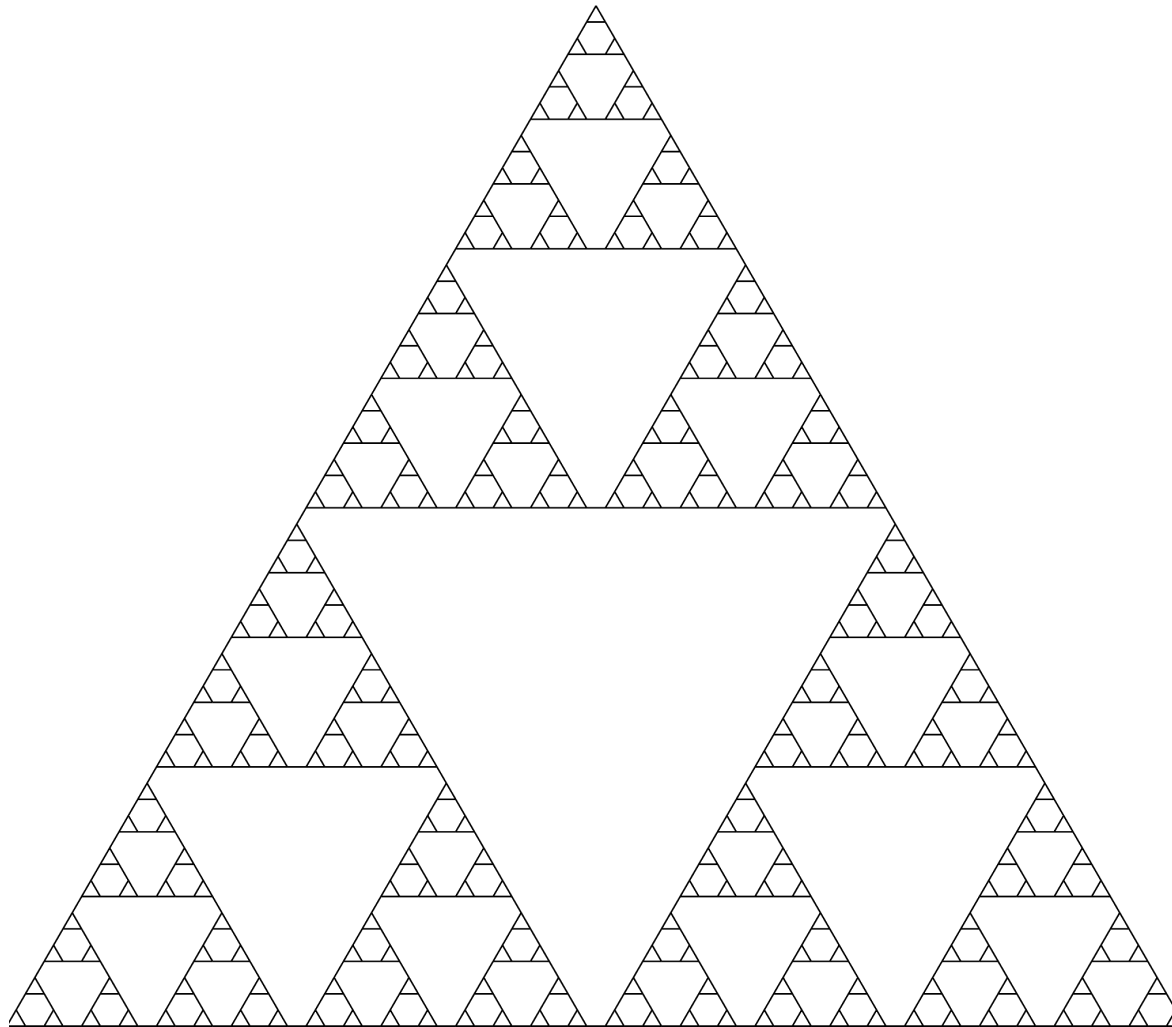


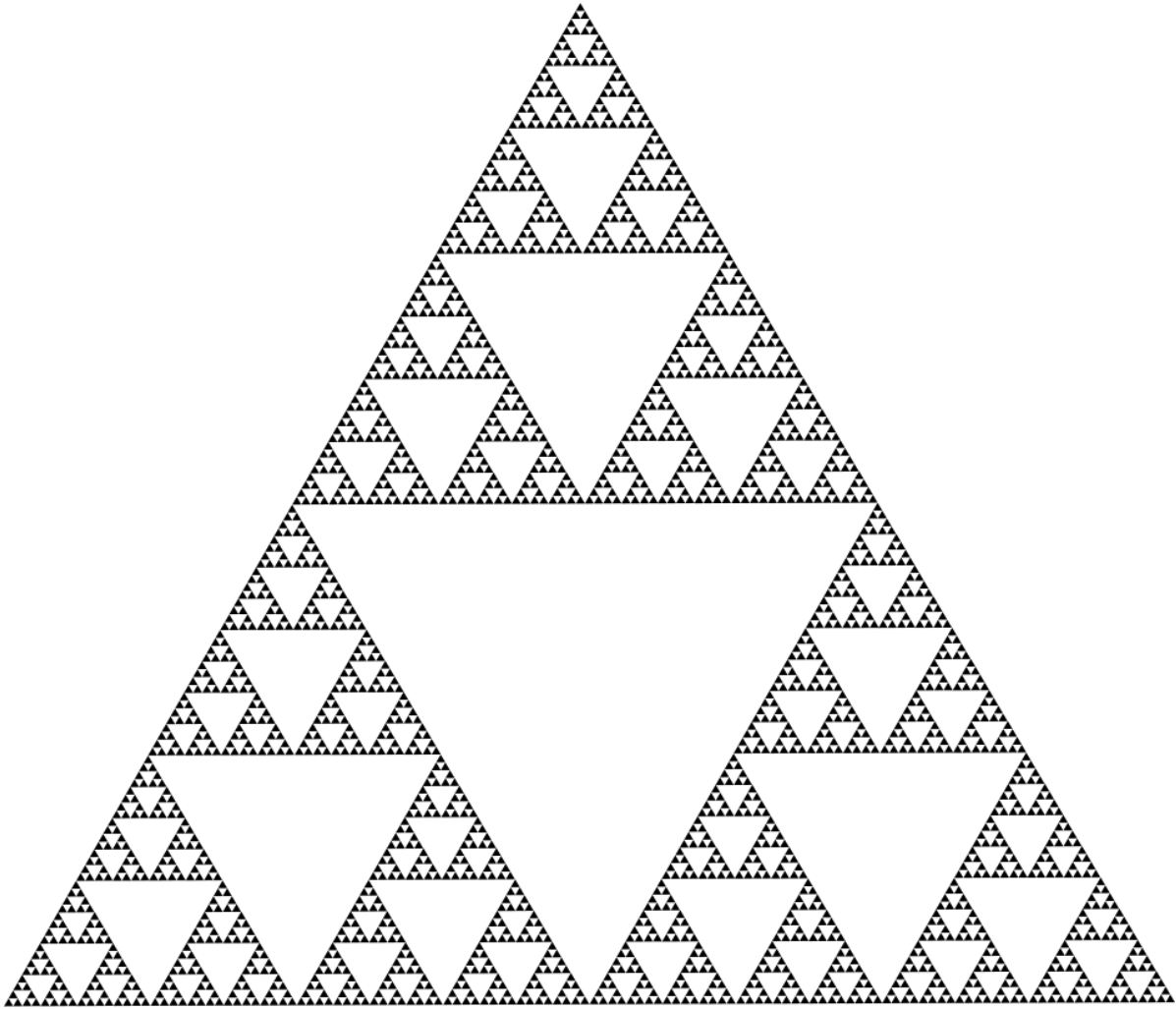
**Hanoi(4)**

**Hanoi(4)**

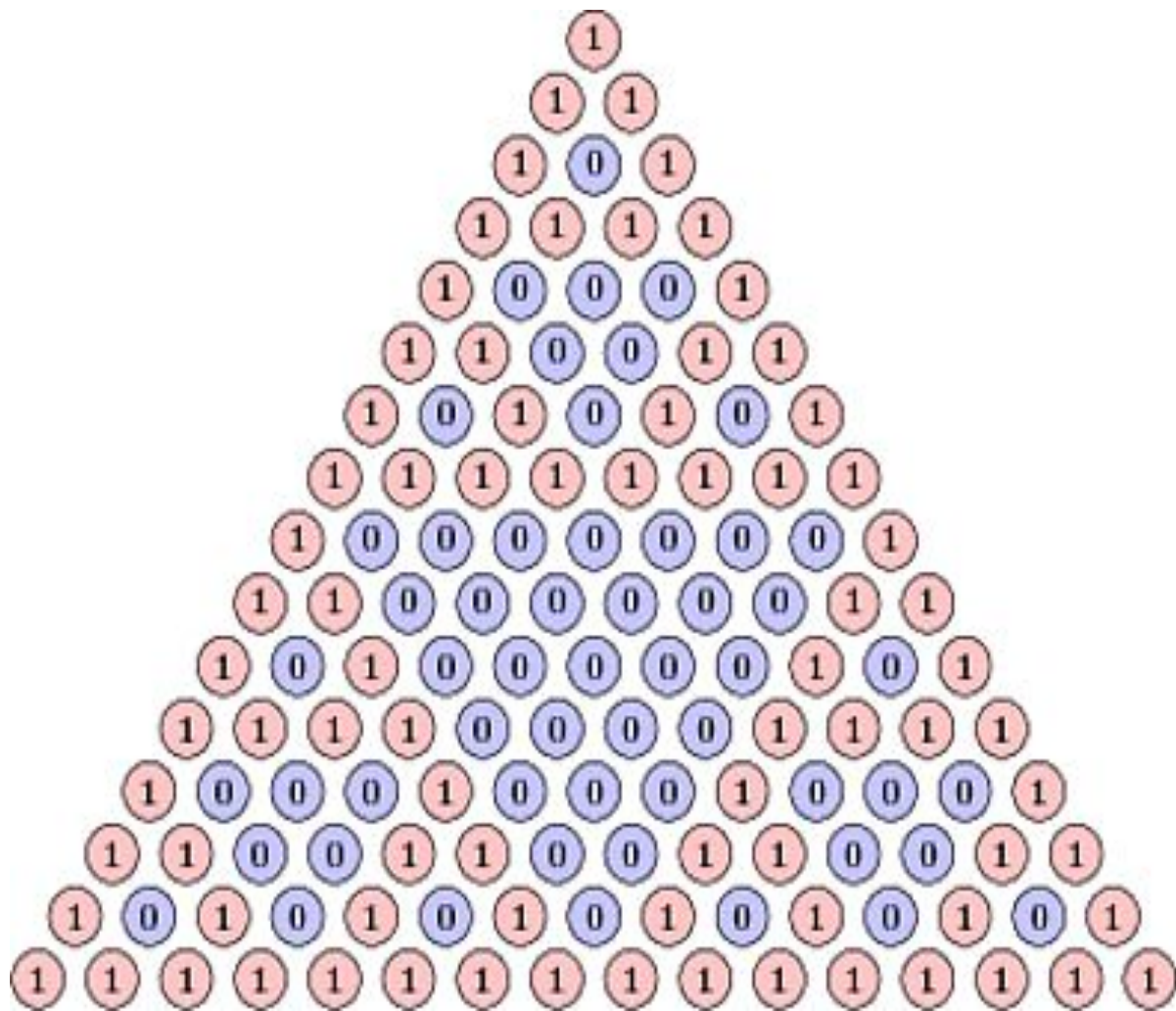


**Hanoi(6)**



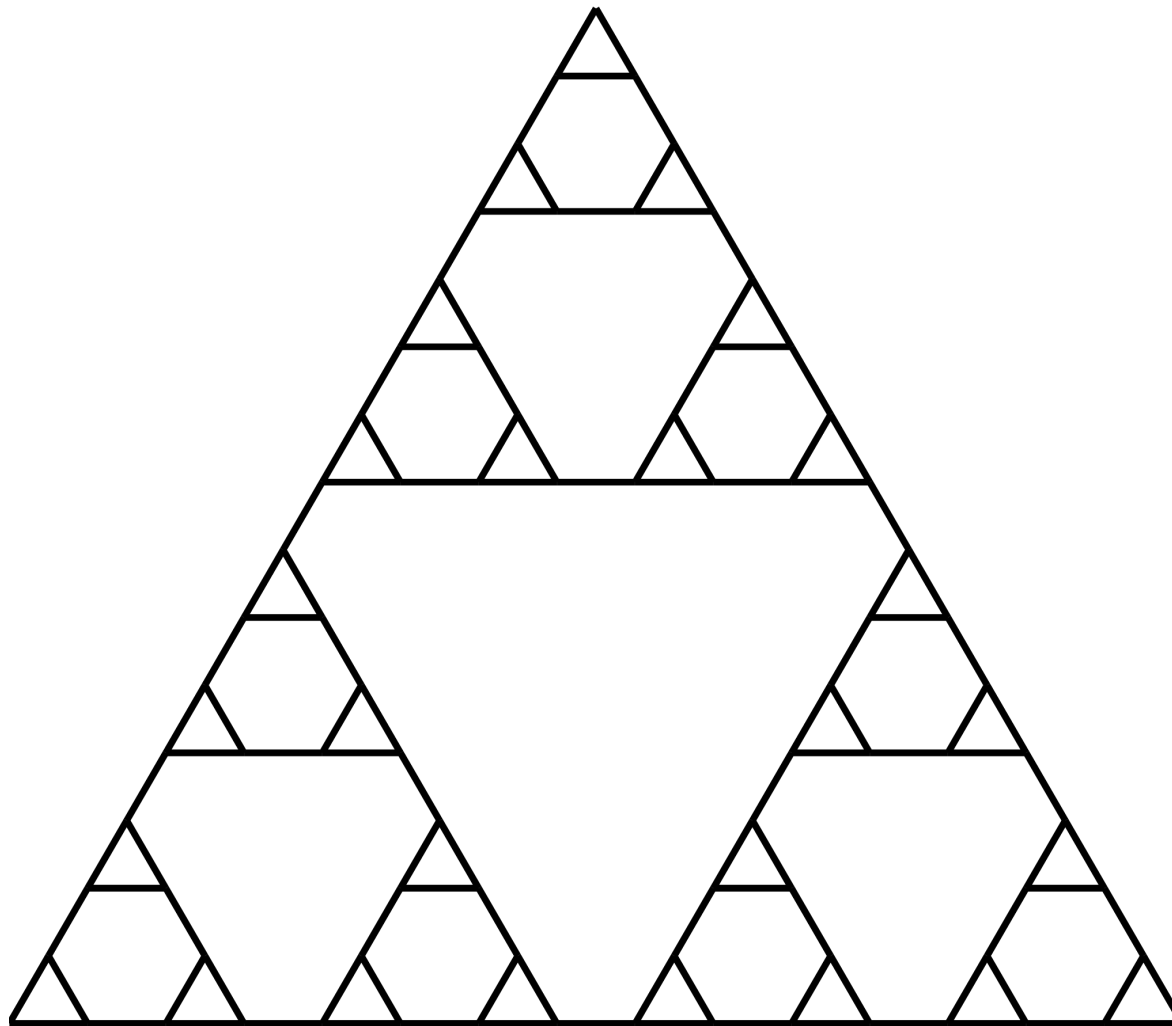


**Sierpiński**

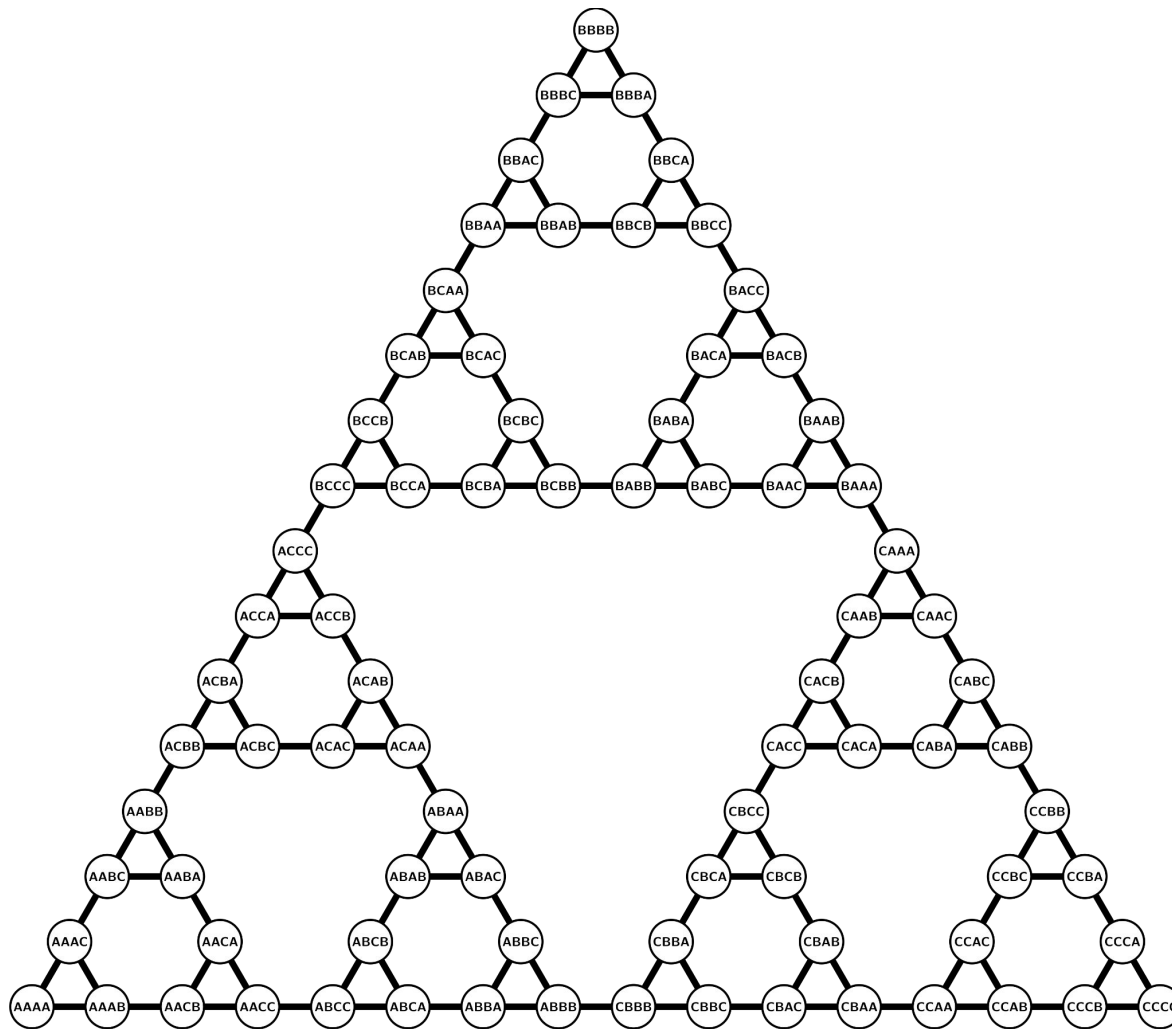


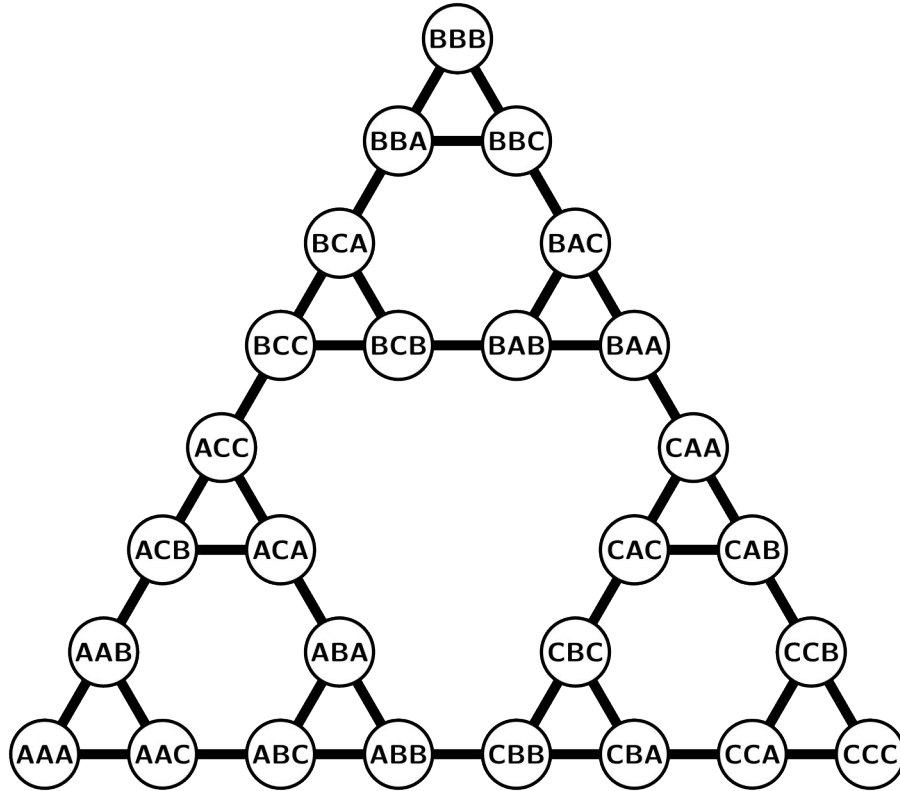
Pascal

**Hanoi(4)**

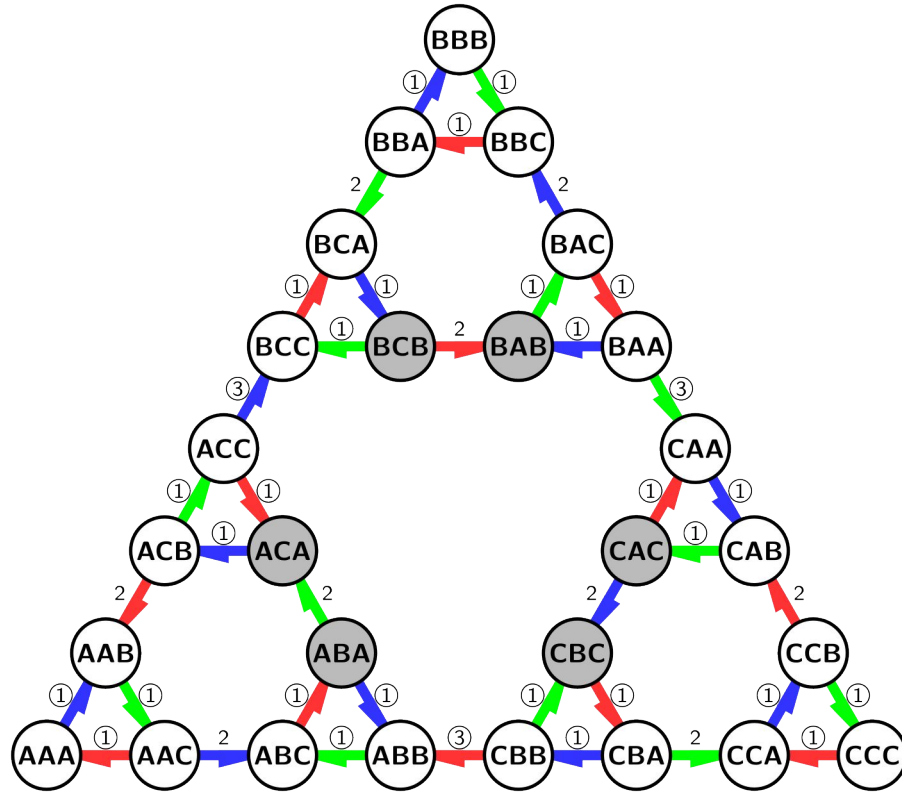


# Hanoi(4)





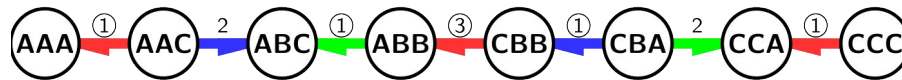
**Hanoi(3)**

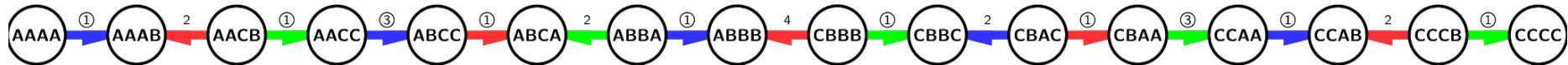


Hanoi(3)

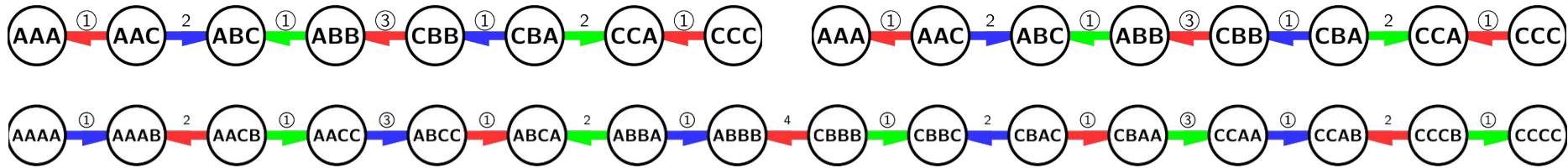


# Hanoi(3)





Hanoi(4)



**Hanoi(4) vs Hanoi(3) + Hanoi(3)**



# Les torres de Hanoi - El problema clàssic

Extrem  $\rightarrow$  Extrem

- $T(1) = 1$
- $T(N) = 2 \cdot T(N-1) + 1$

N	T(N)
1	1
2	3
3	7
4	15
5	31
6	63

# Les torres de Hanoi - El problema clàssic

Extrem  $\rightarrow$  Extrem

- $T(1) = 1$
- $T(N) = 2 \cdot T(N-1) + 1$
- $T(N) = \sum 2^k$
- $T(N) = 2^N - 1$

N	T(N)	$2^k$	$\sum 2^k$
1	1	000001	000001
2	3	000010	000011
3	7	000100	000111
4	15	001000	001111
5	31	010000	011111
6	63	100000	111111

# Les torres de Hanoi - El problema clàssic

## Extrem $\rightarrow$ Extrem

- $T(N) = 2^N - 1$  moviments
- $3^N$  posicions legals però  $2^N$  posicions visitades
- N parell:  $(A \rightleftharpoons B), (A \rightleftharpoons C), (B \rightleftharpoons C)$
- N senar:  $(A \rightleftharpoons C), (A \rightleftharpoons B), (B \rightleftharpoons C)$
- Discos vermells i negres sempre s'alternen
- Discos vermells i negres es mouen en sentits diferents

# Les torres de Hanoi - El problema clàssic

Extrem → Extrem

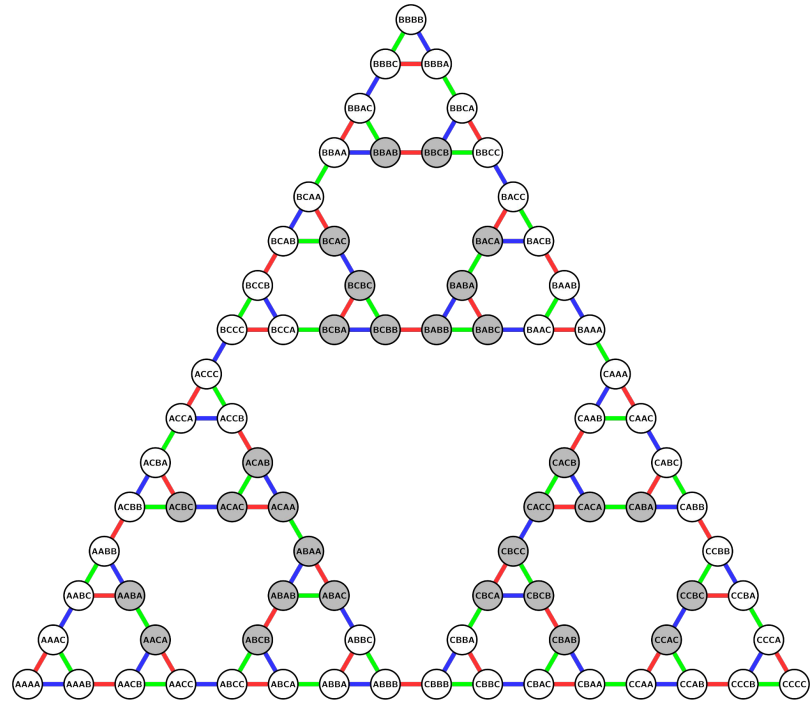
- $T(N) = 2^N - 1$  moviments

Per cert, **que ningú es posi nerviós**

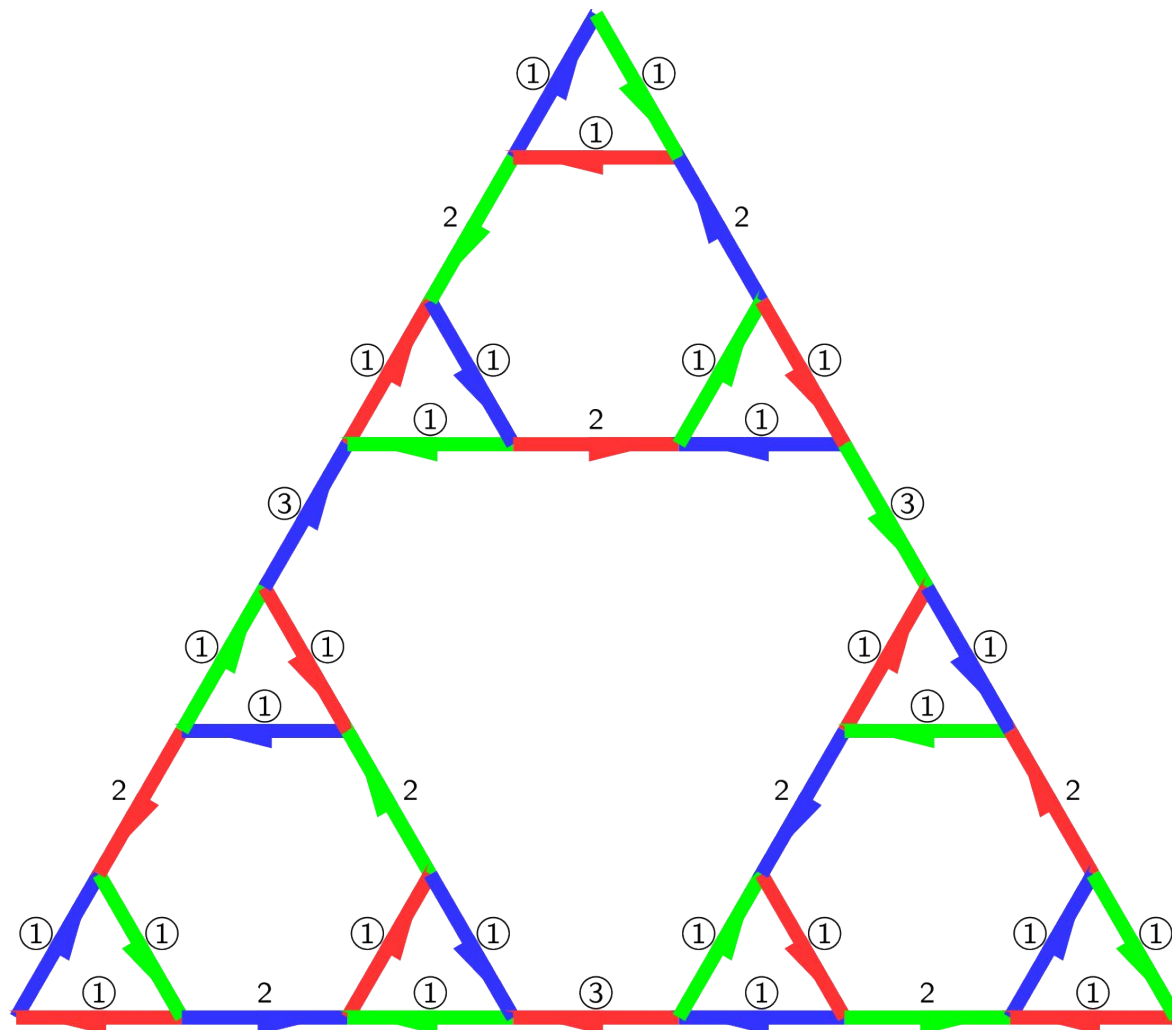
- $2^{64} - 1$  segons
- $\approx 584.942$  milions d'anys
- $\approx 42$  vegades l'edat de l'univers

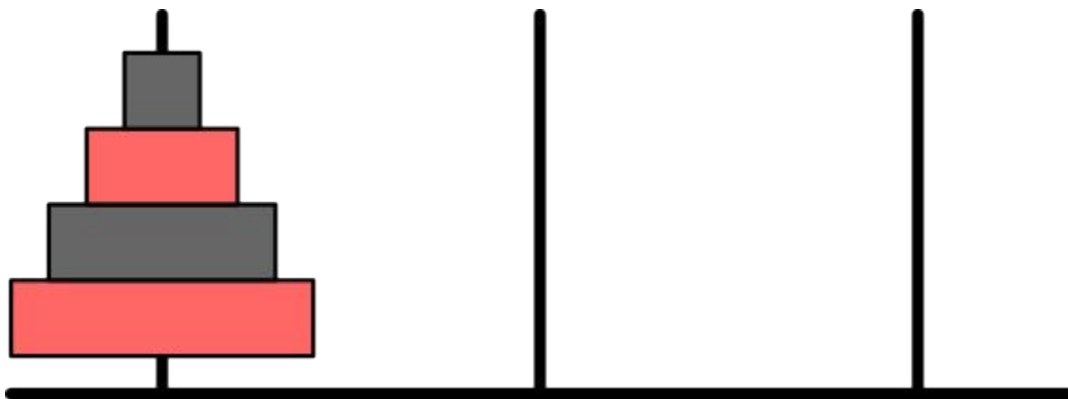
# Les torres de Hanoi - Variants

- Extrem → Extrem ✓
- Legal → Extrem ?
- Legal → Legal ?
- Il·legal → Legal ?
- Amb més agulles ?
- Bicolor ?
- Cíclic ?
- Lineal (No  $A \Leftrightarrow C$ ) ?

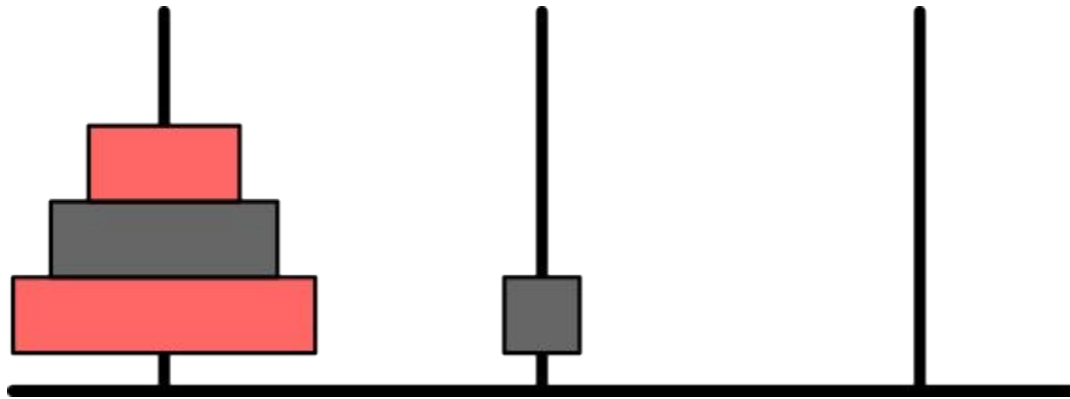


# Cíclic

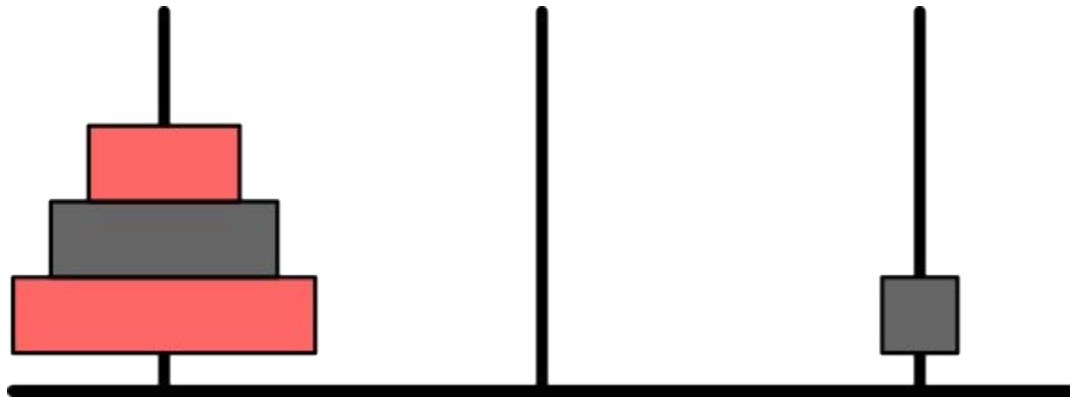




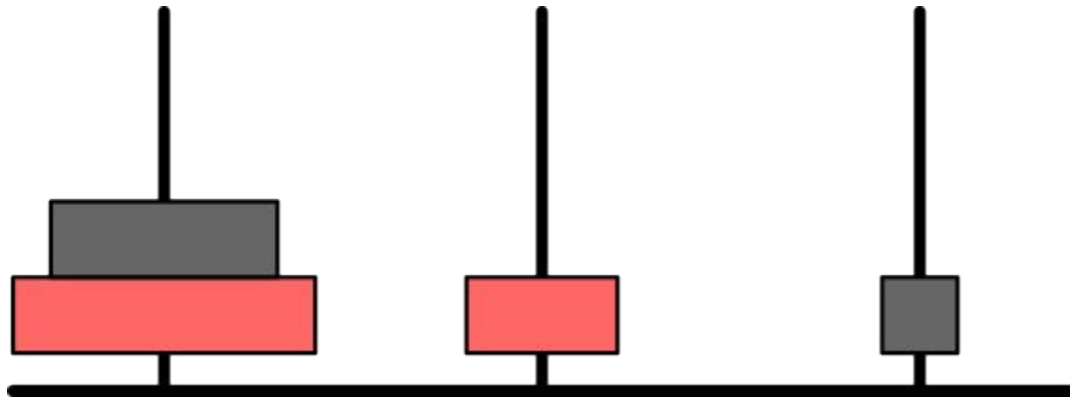
AAAA



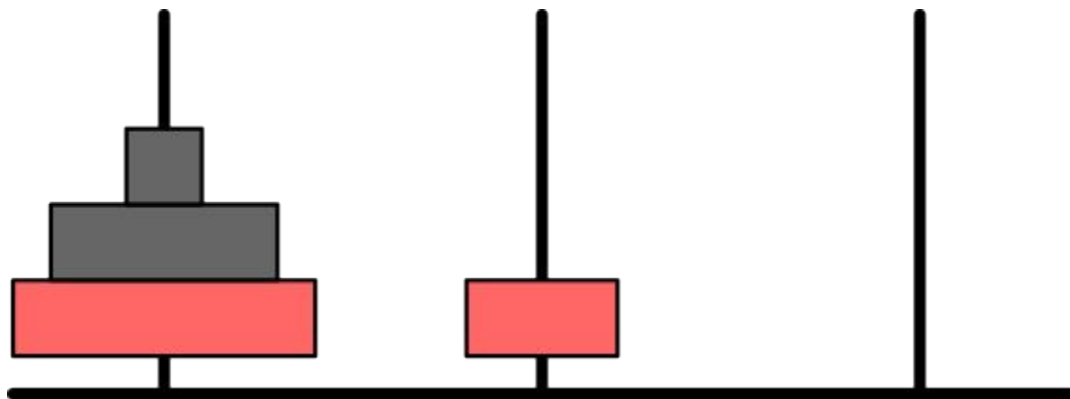
AAAB



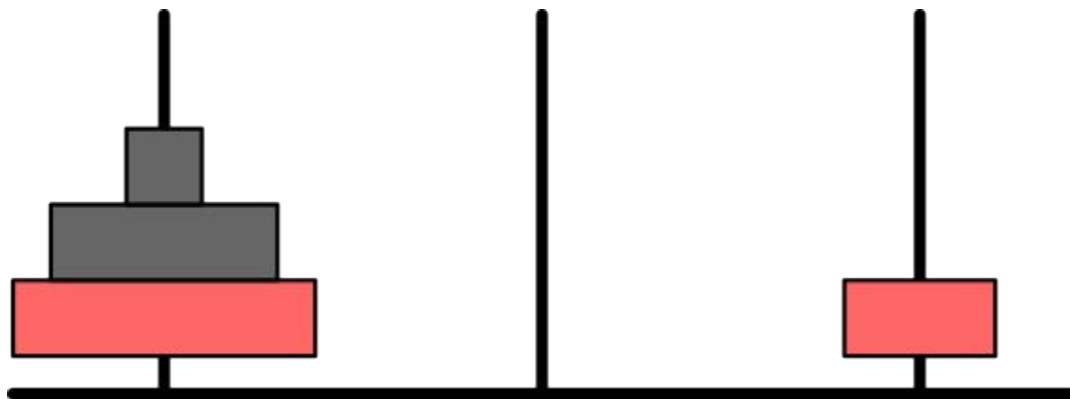
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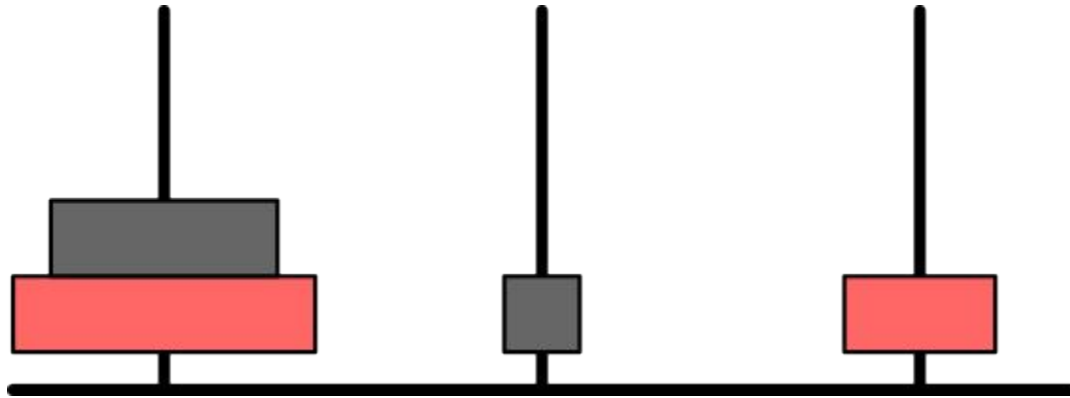


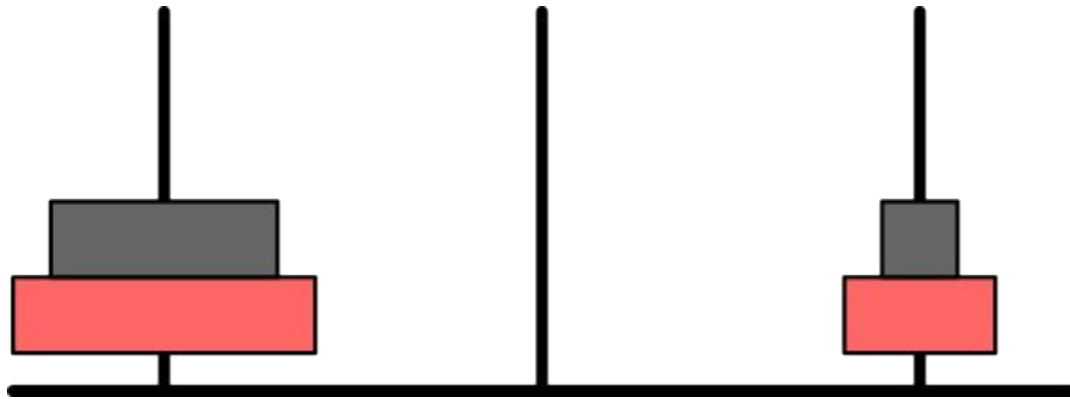
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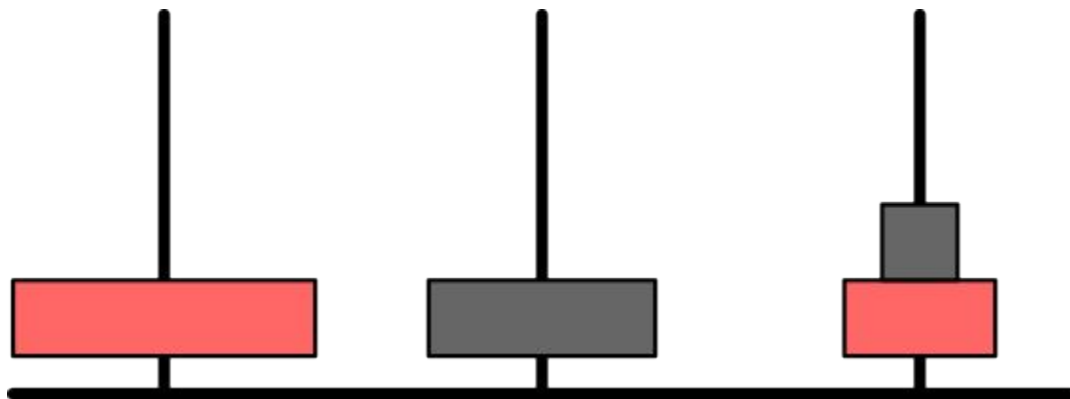
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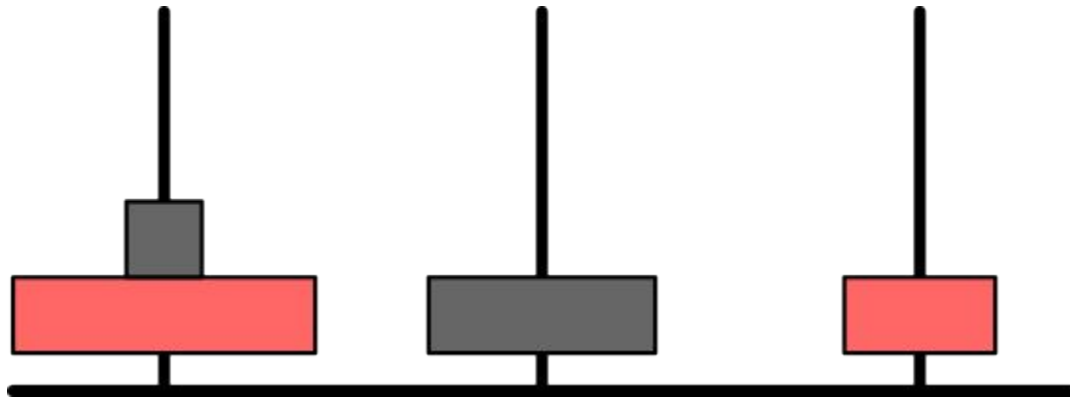




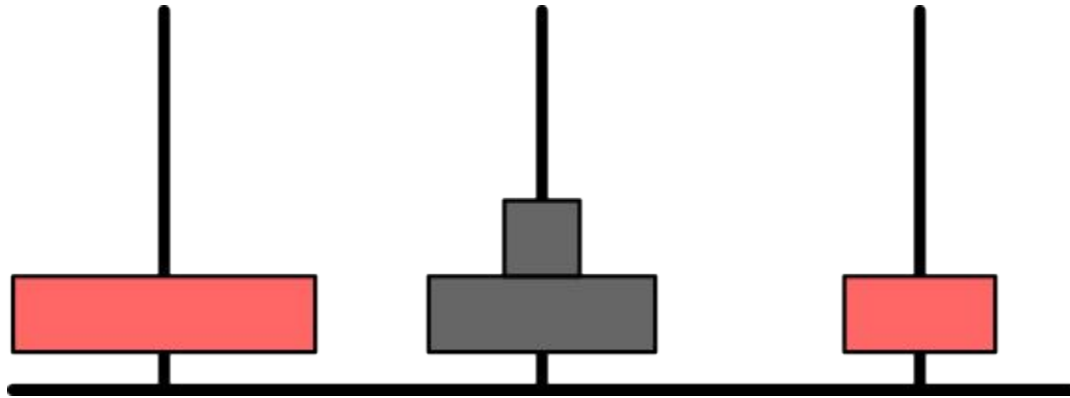
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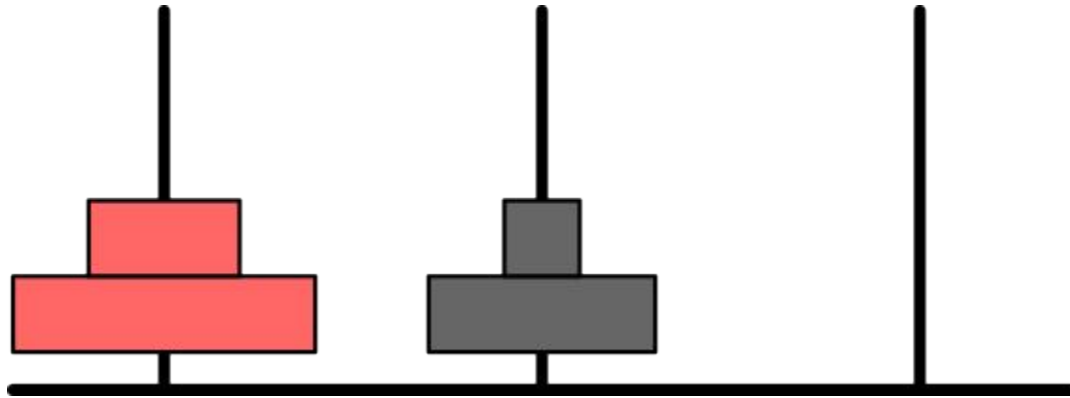
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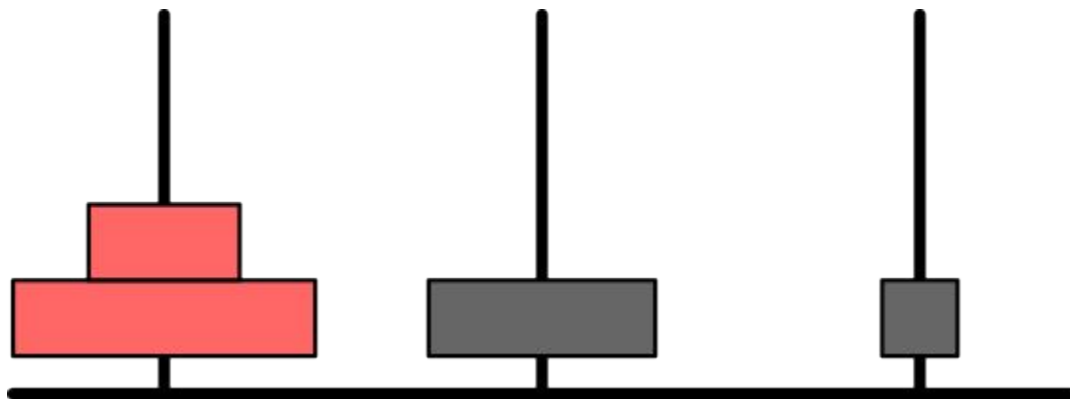
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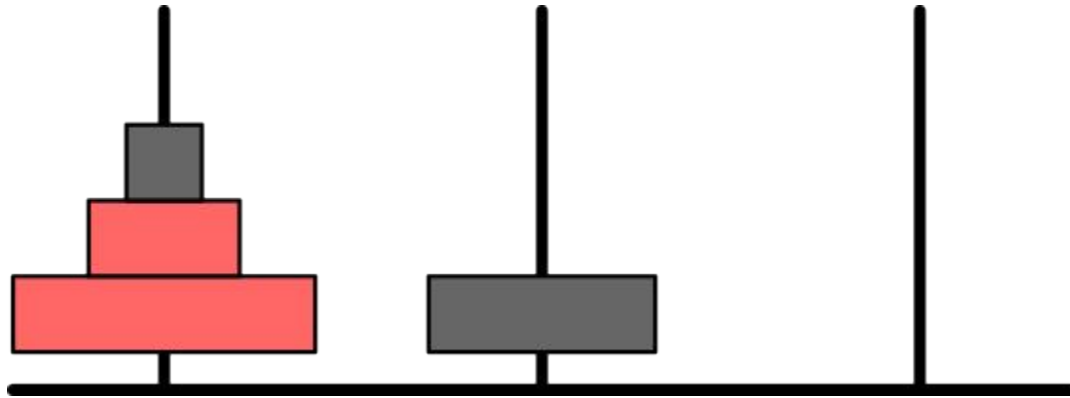
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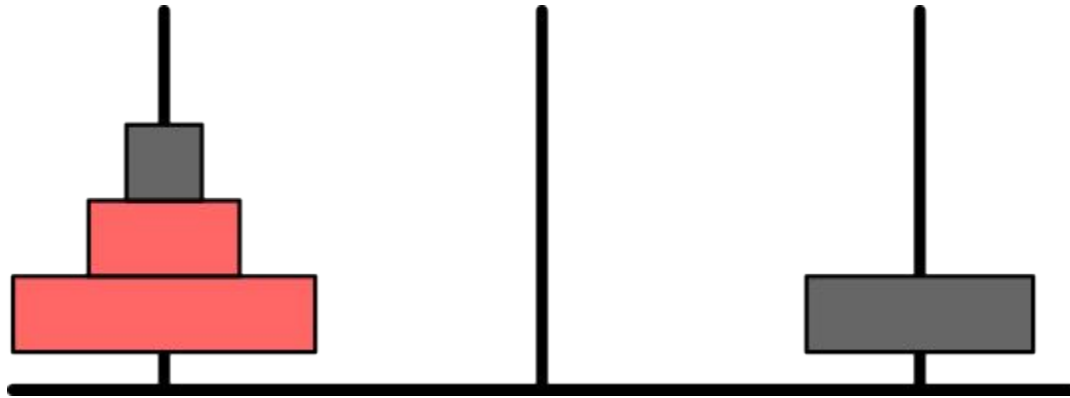
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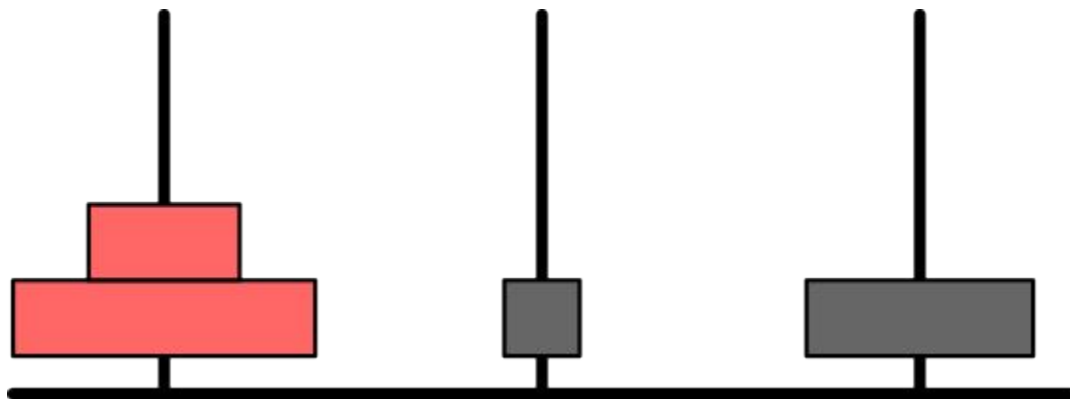


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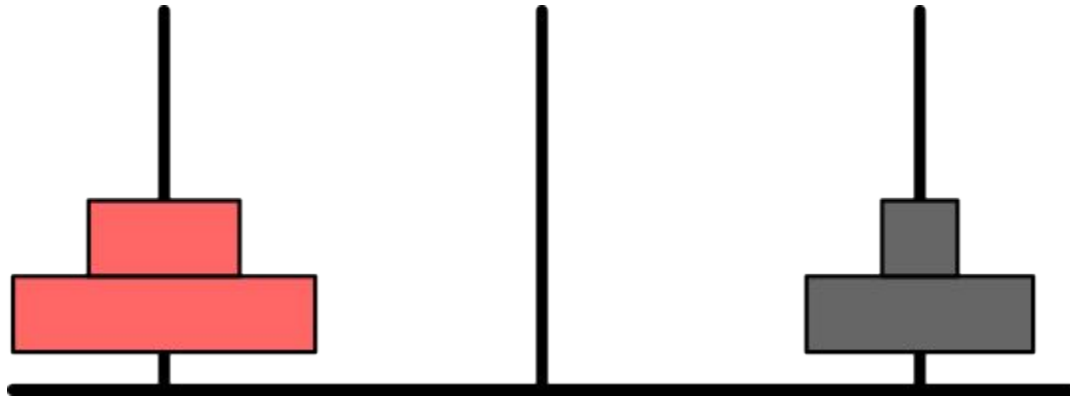


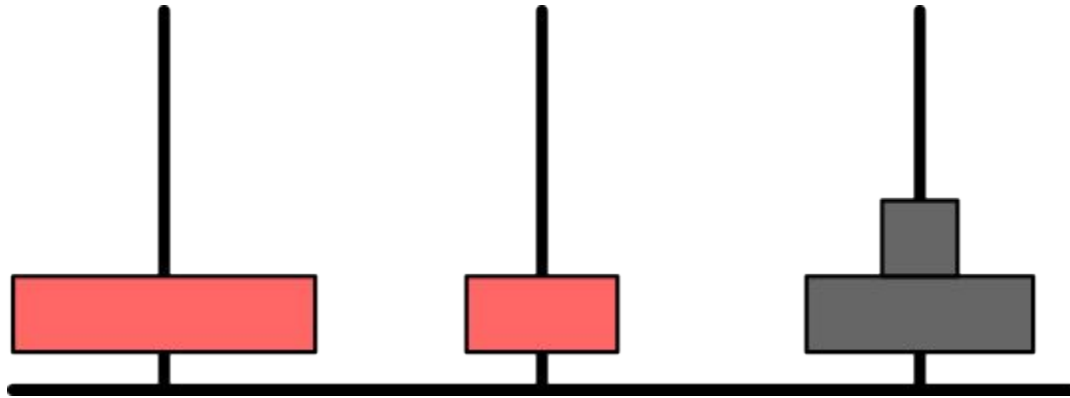
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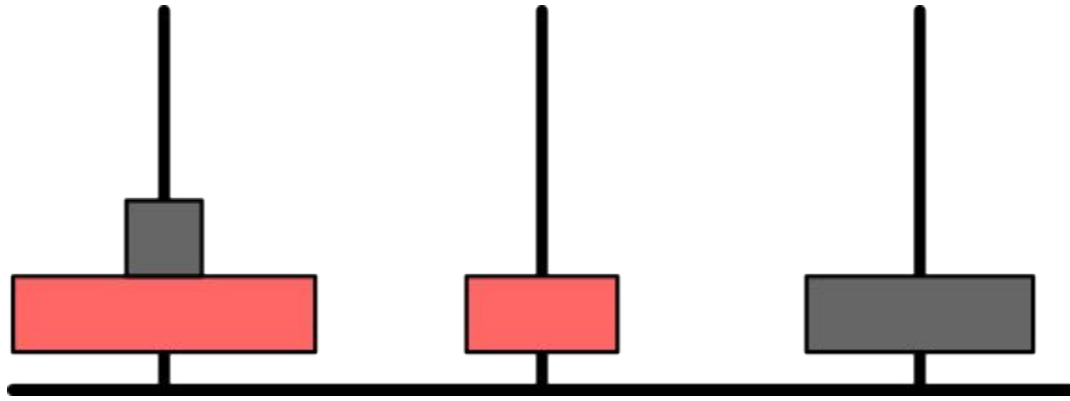


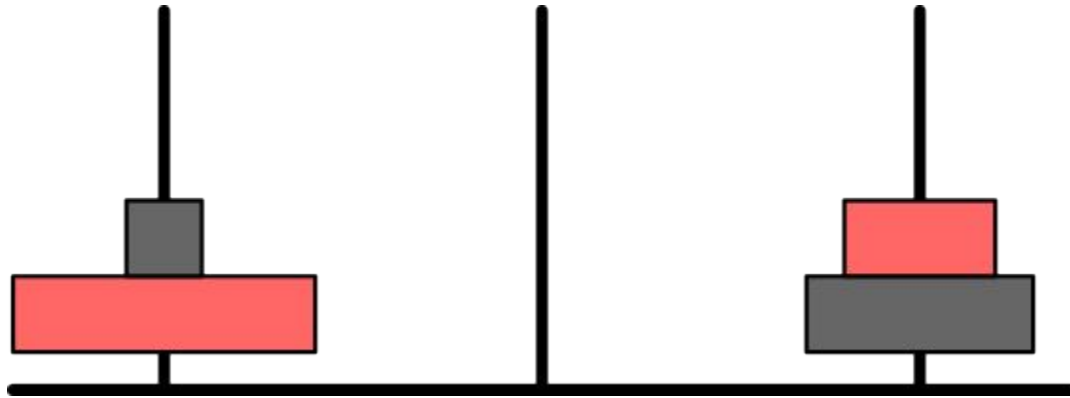


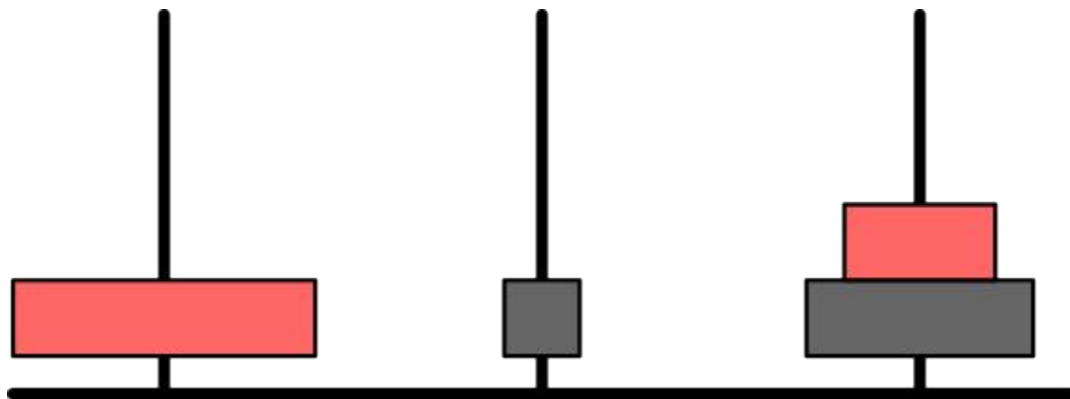
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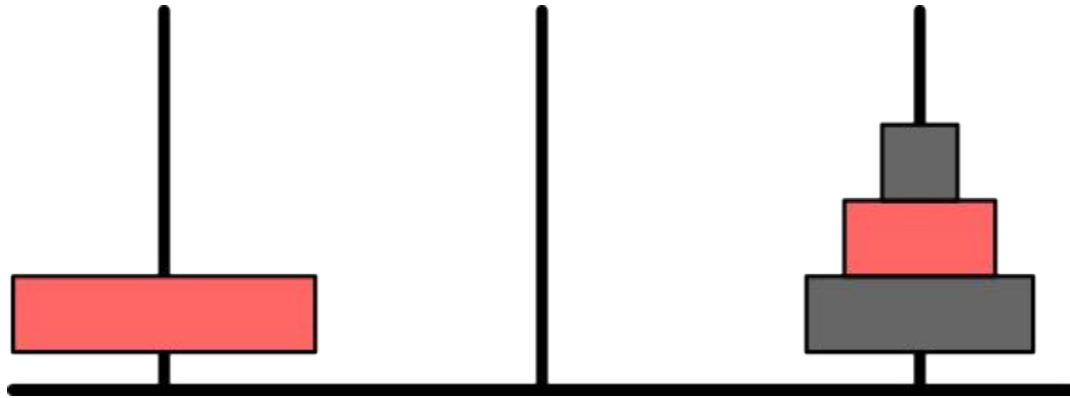




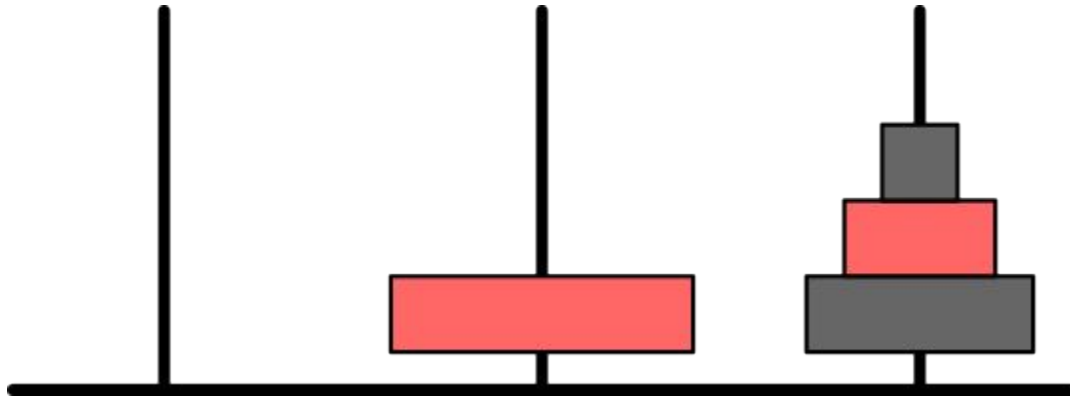




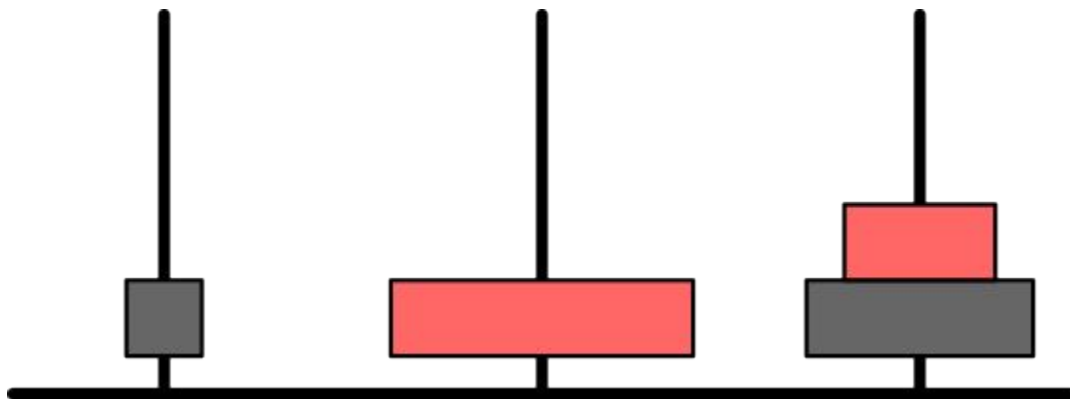
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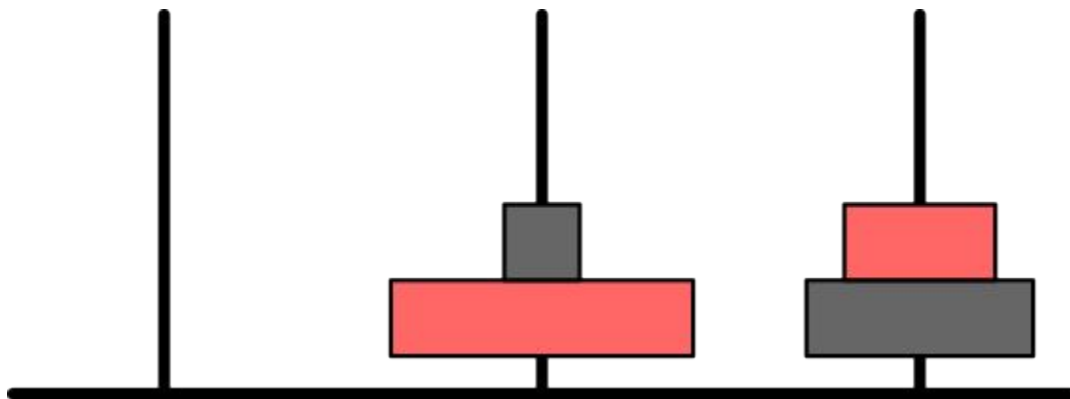


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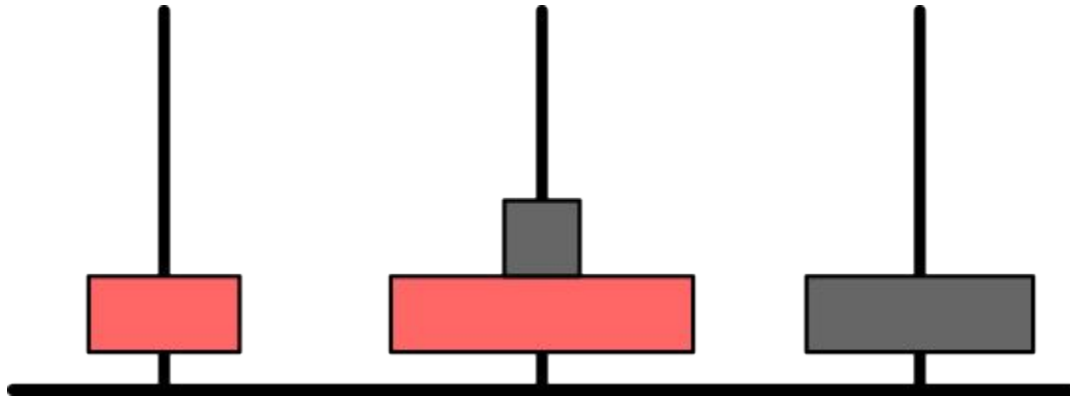


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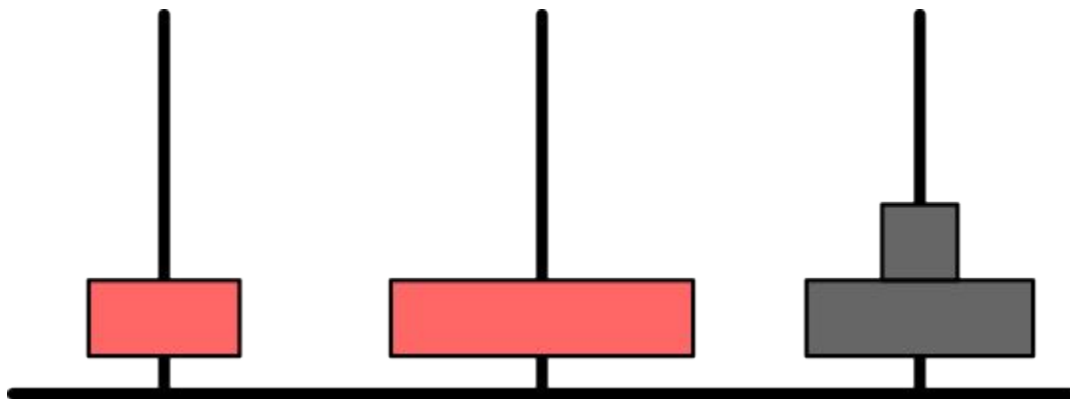


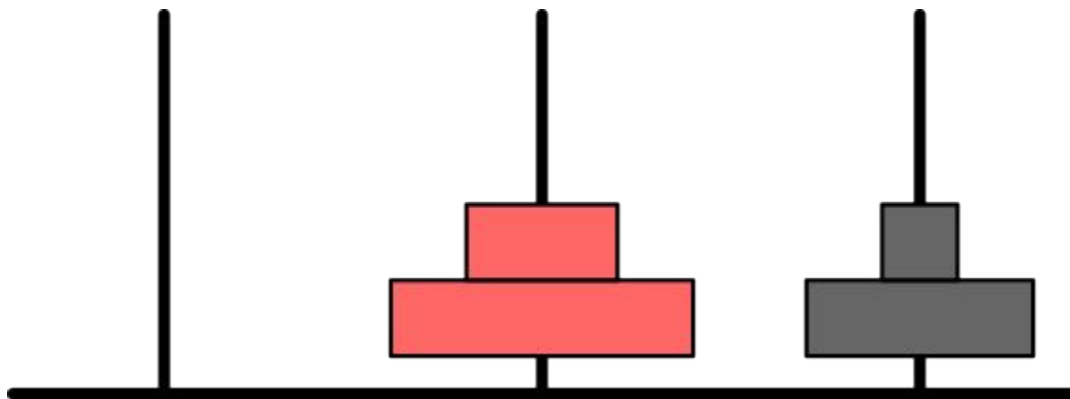


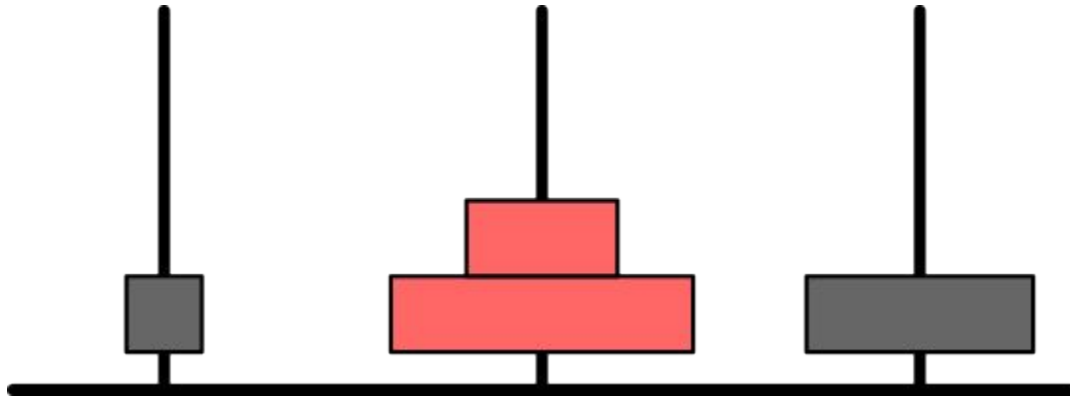
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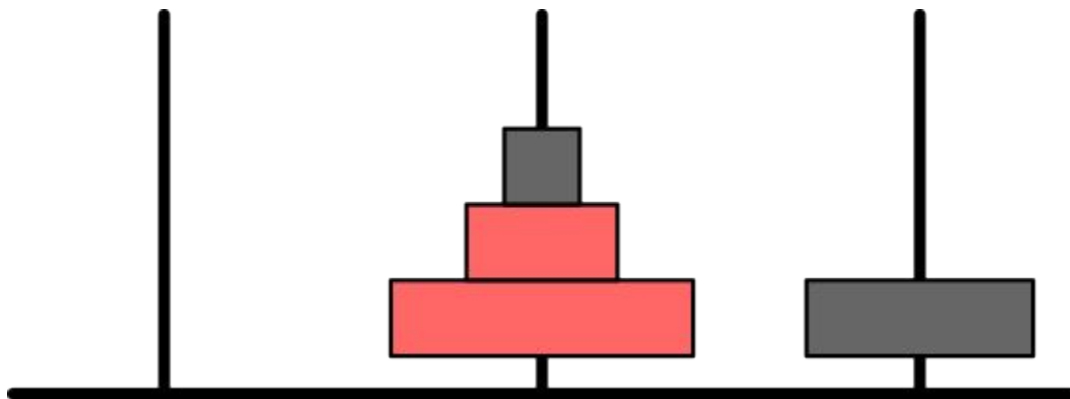


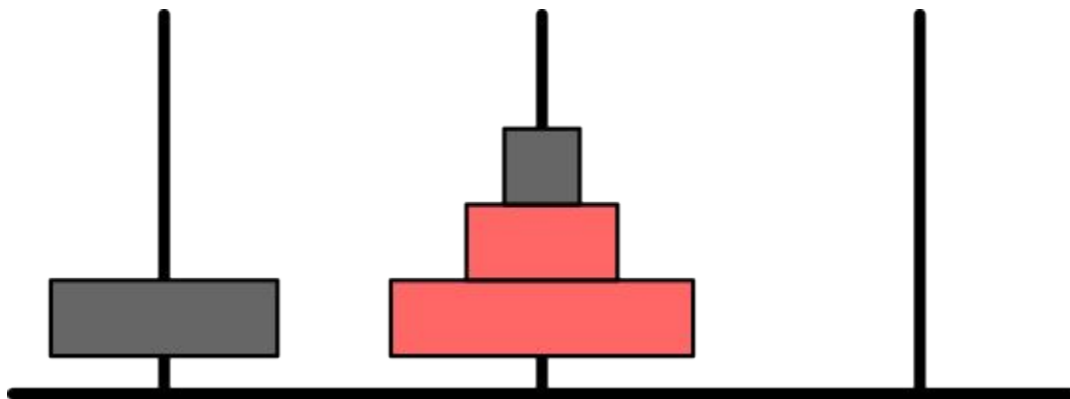
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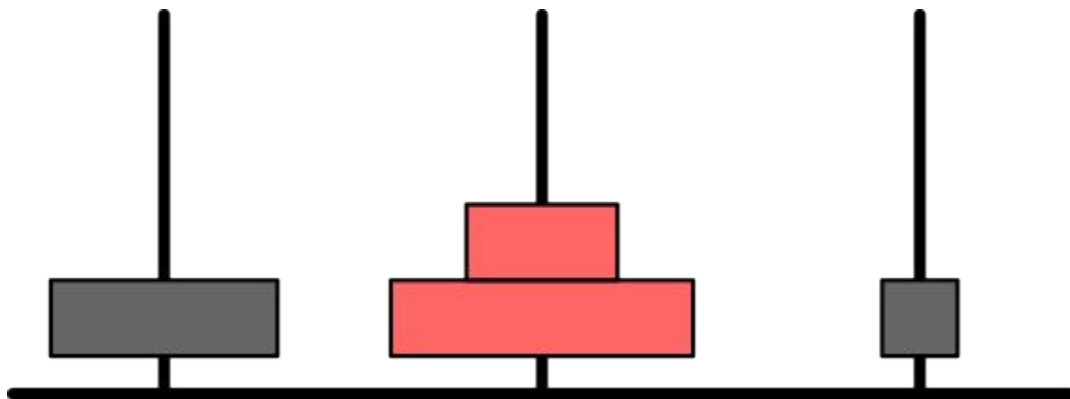




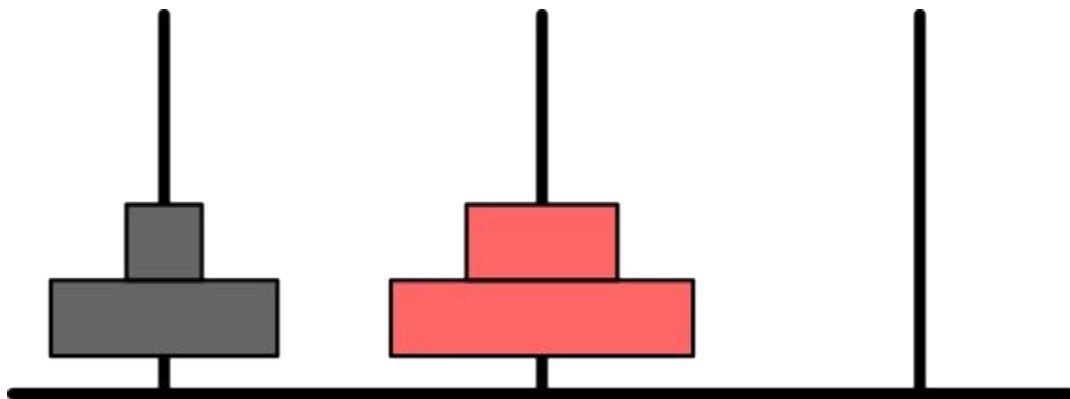




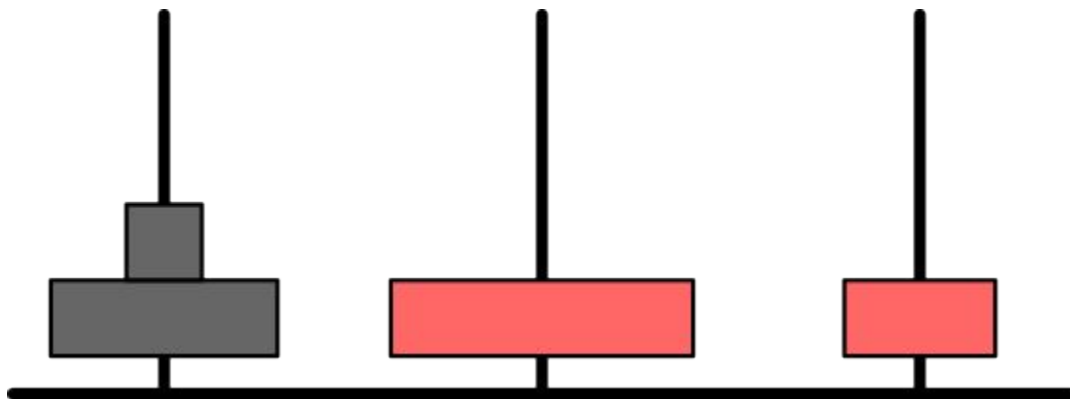
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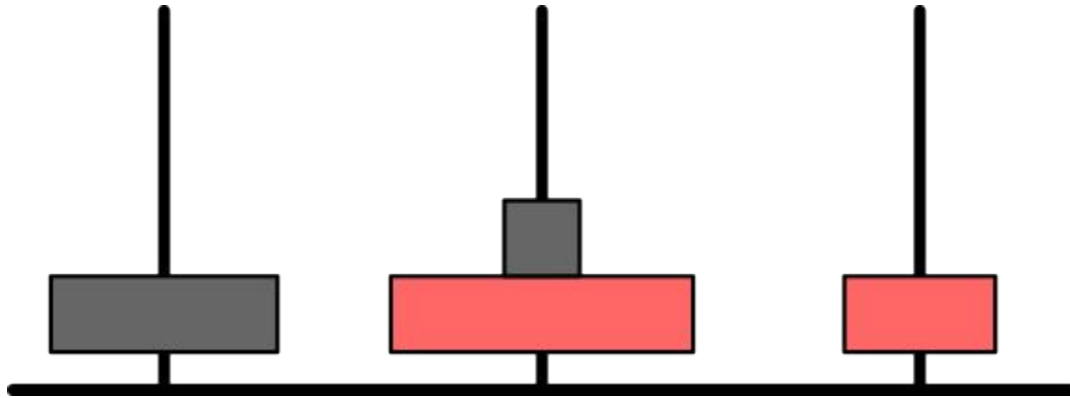
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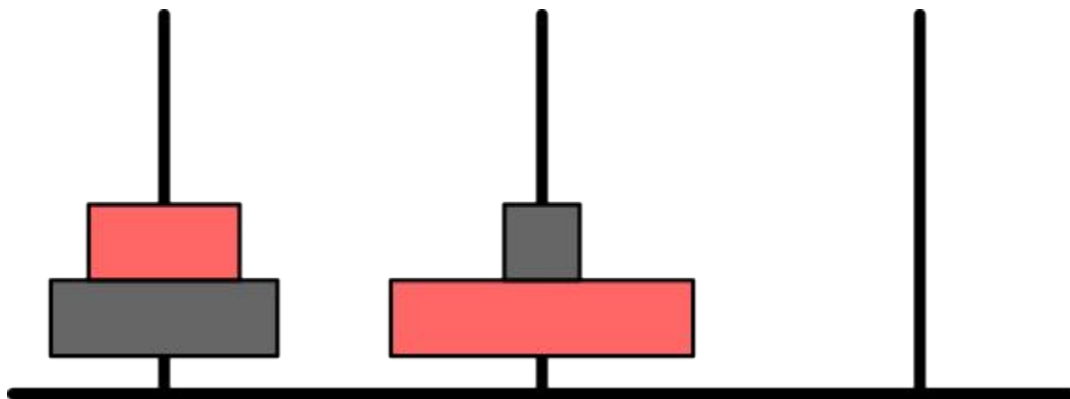
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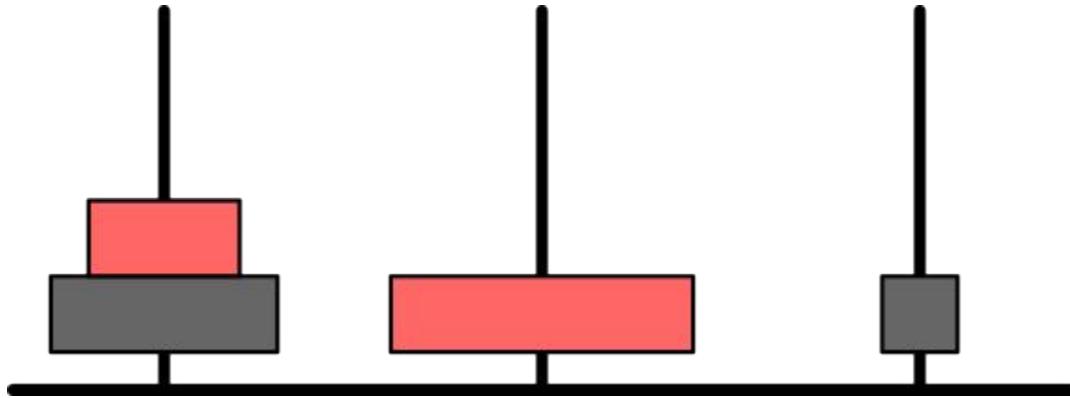
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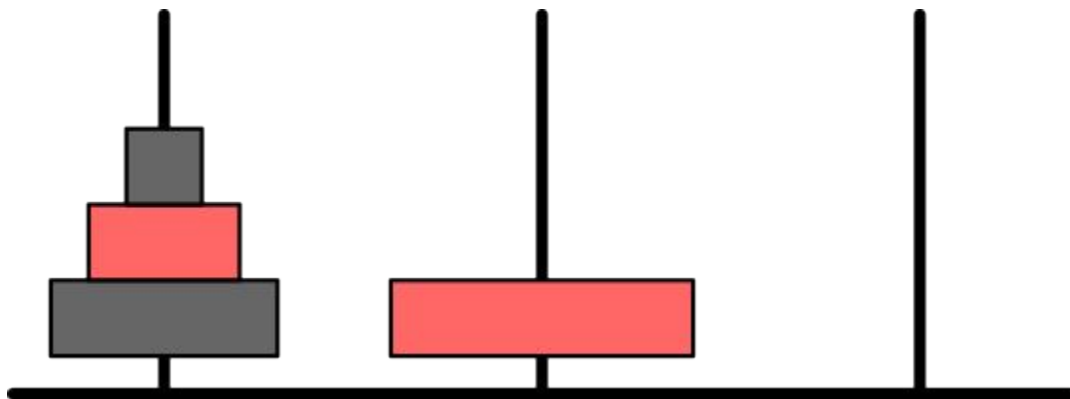
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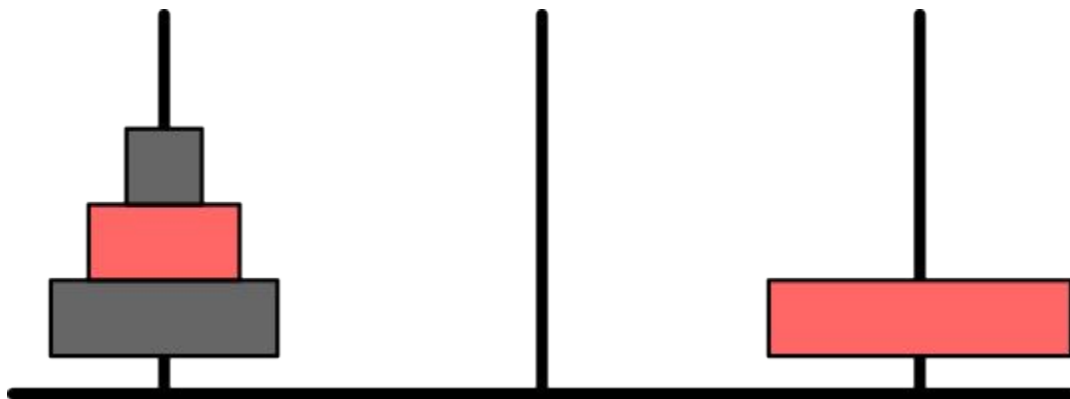
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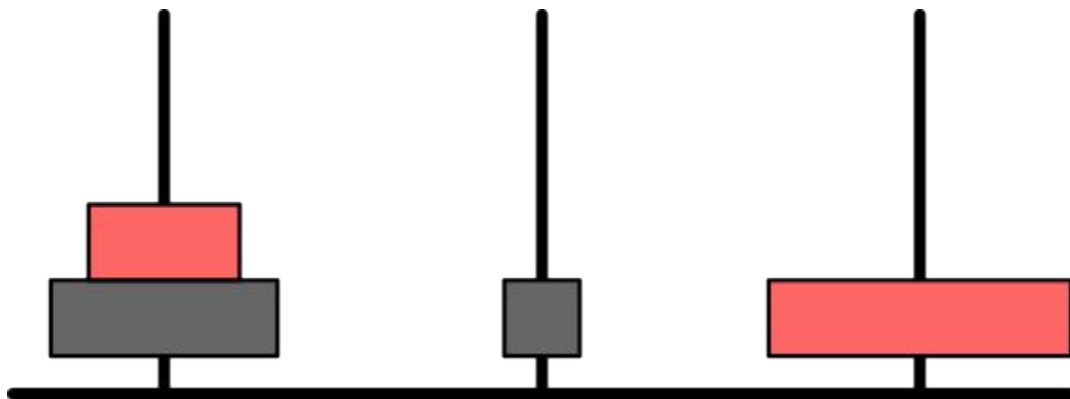
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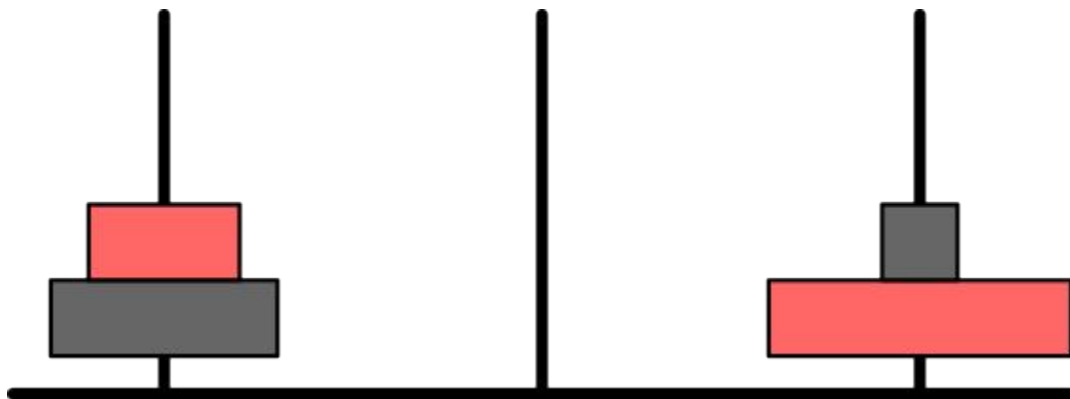


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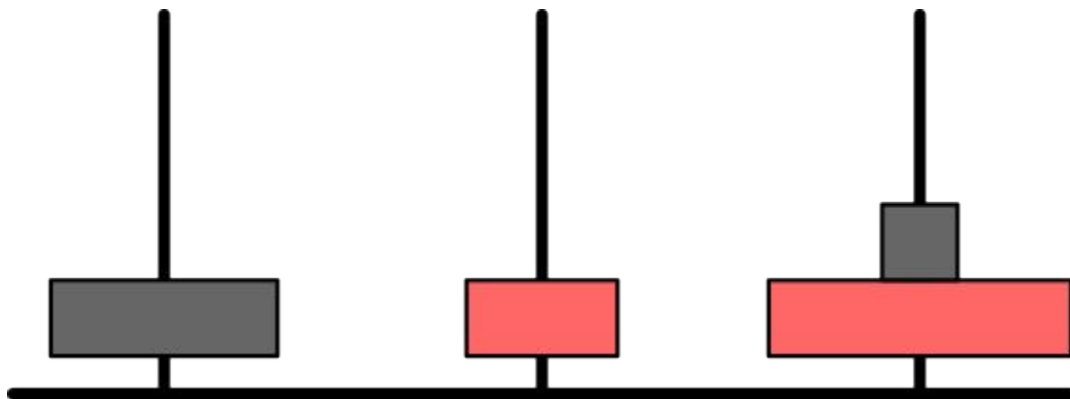


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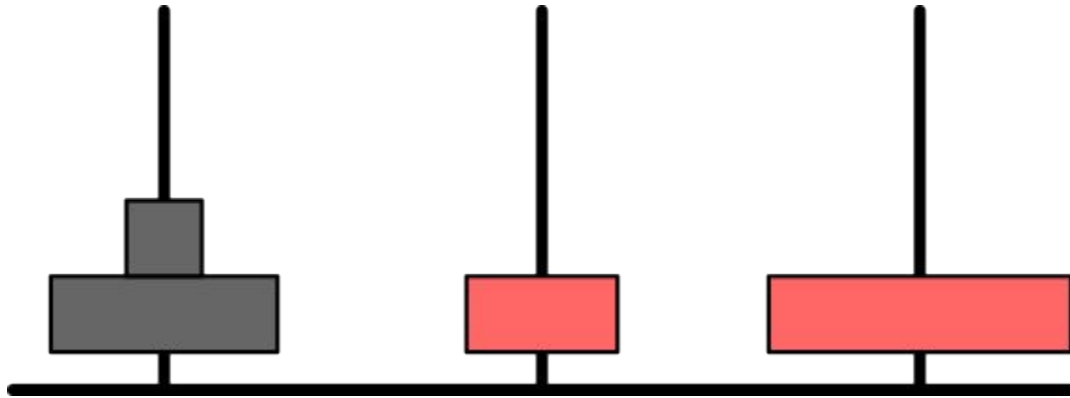




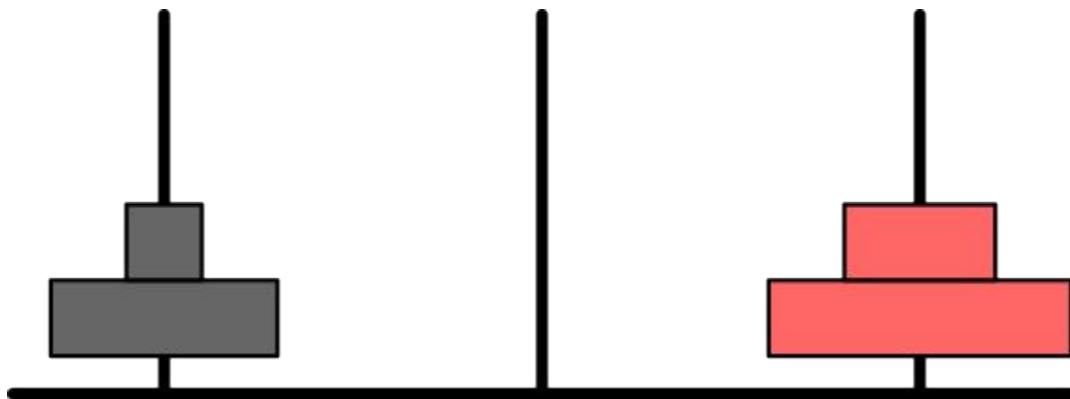
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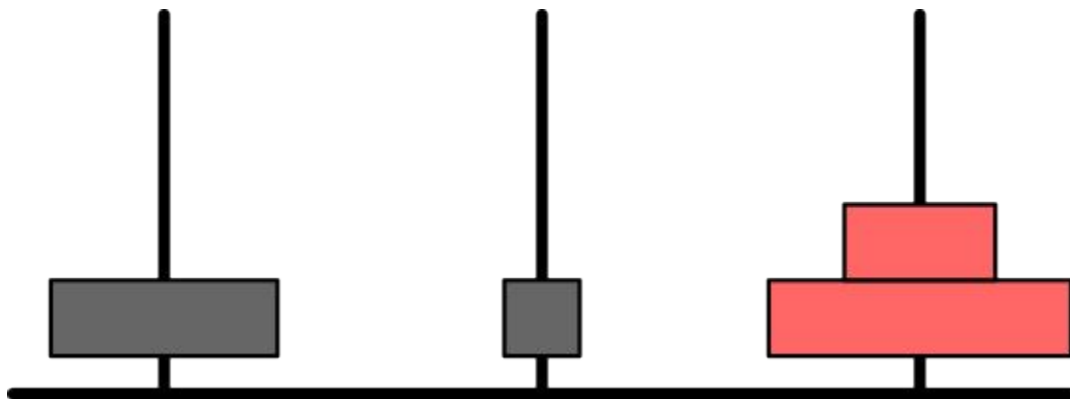
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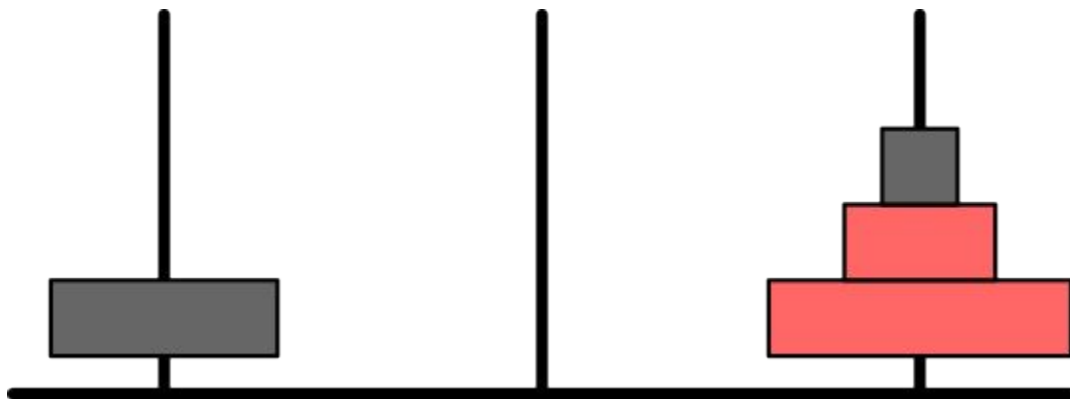


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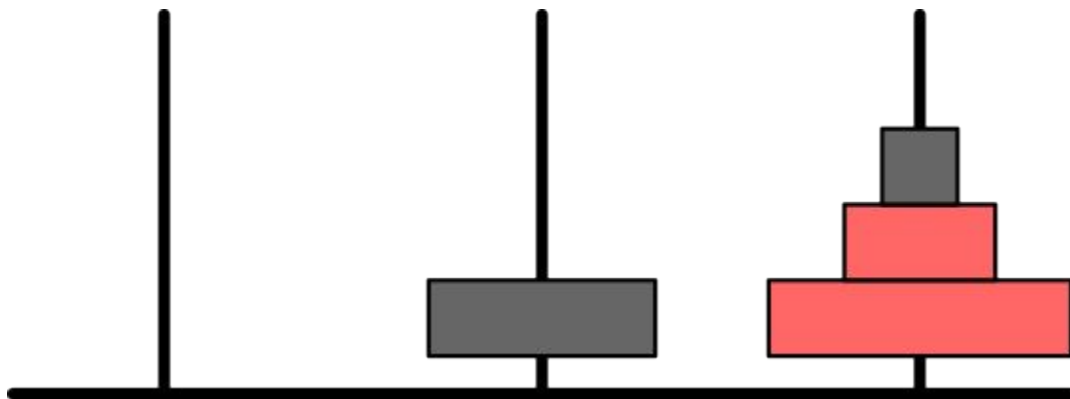


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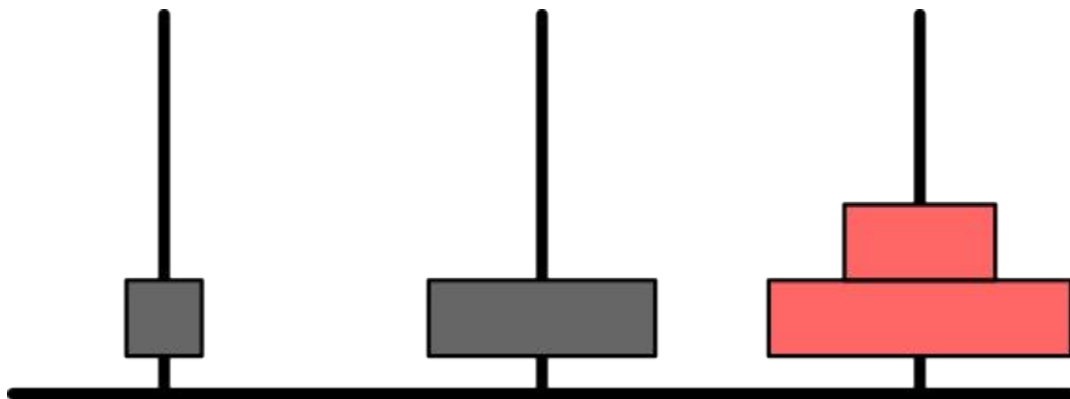


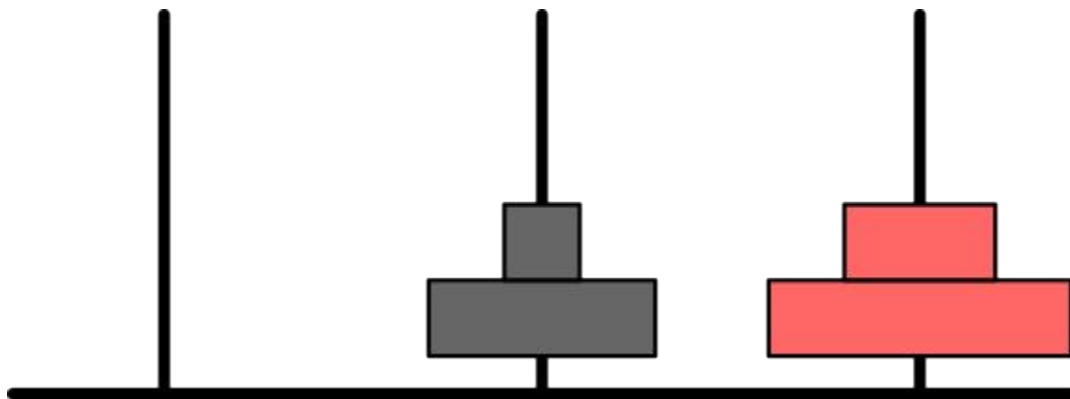


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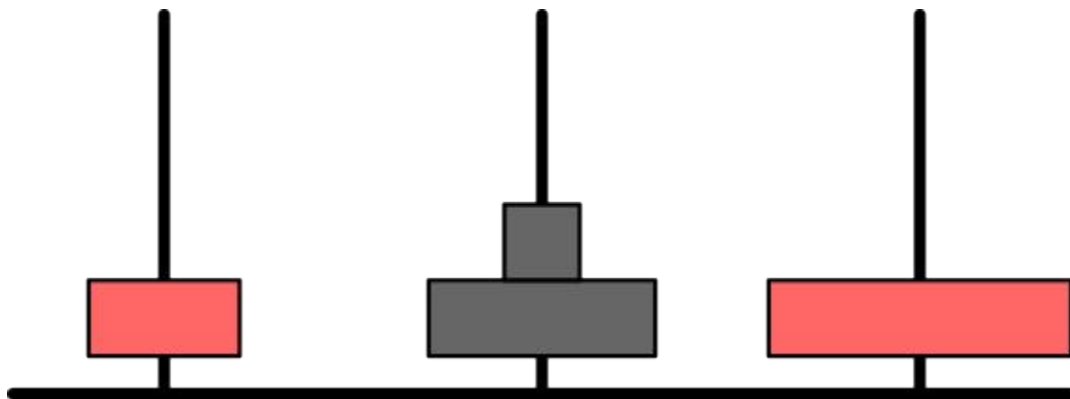


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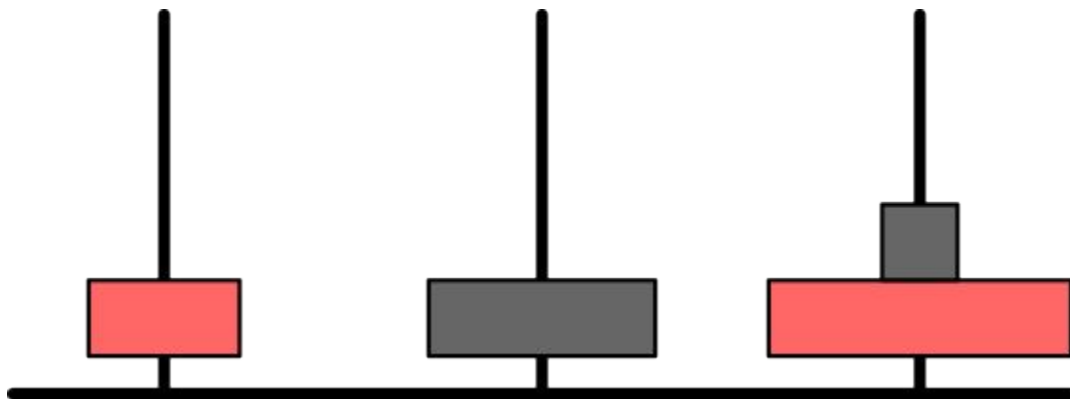




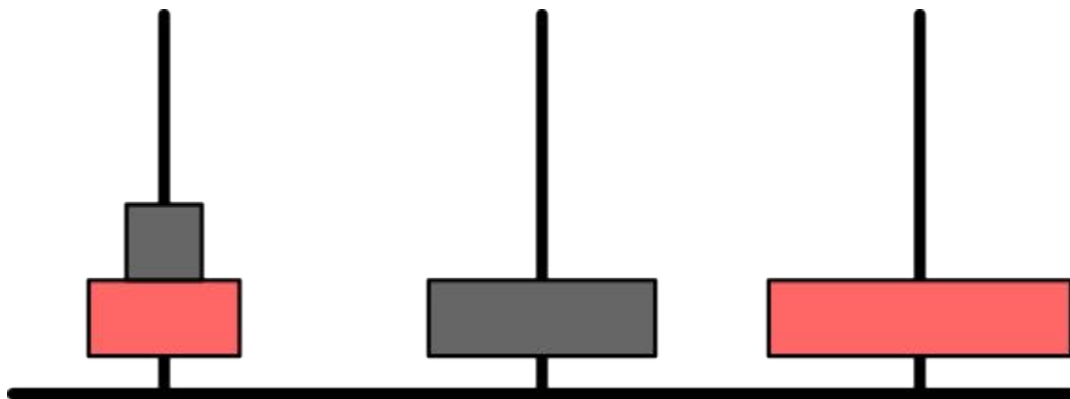
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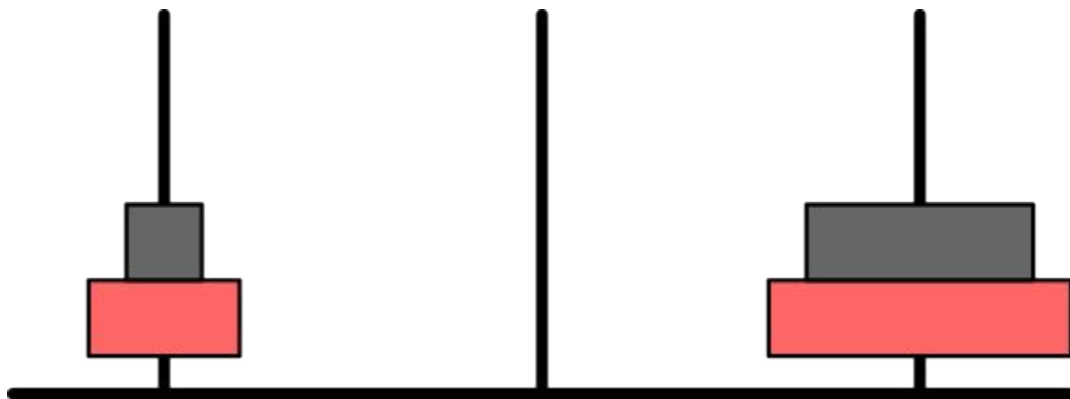


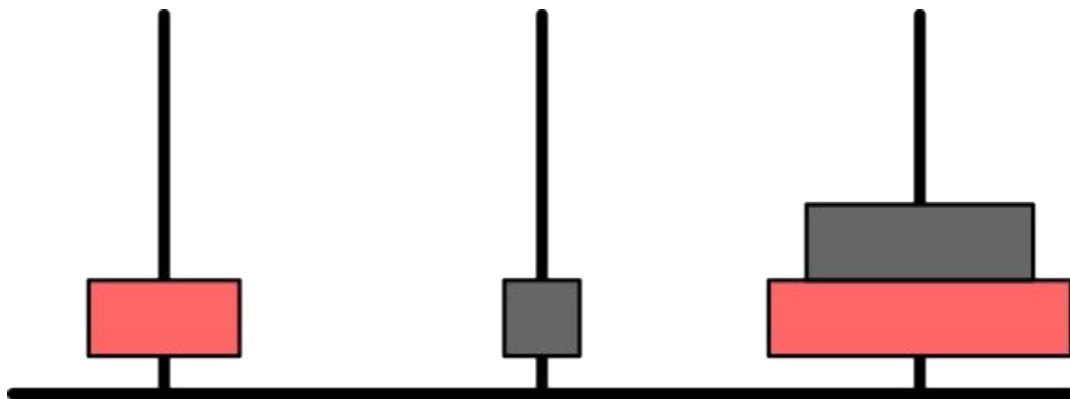
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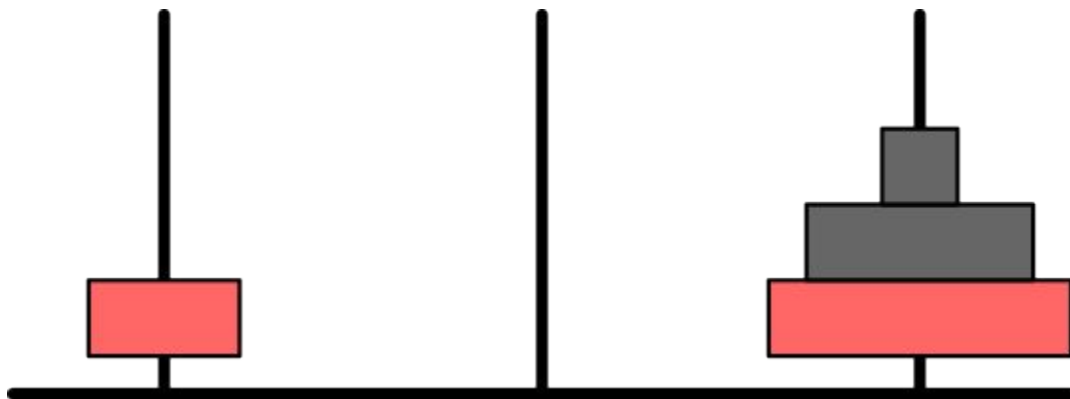


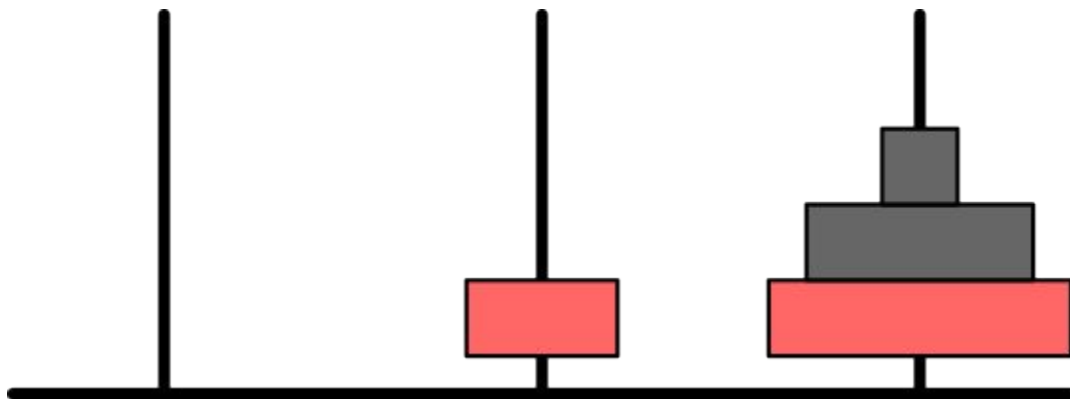
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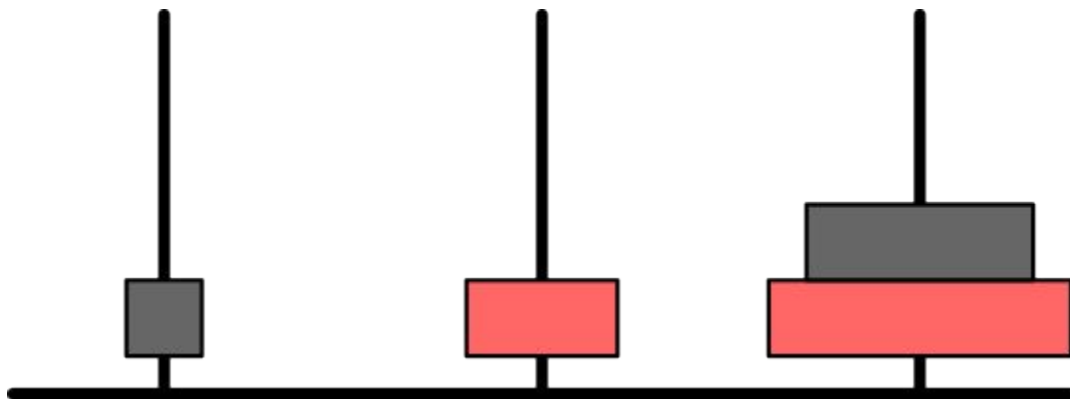


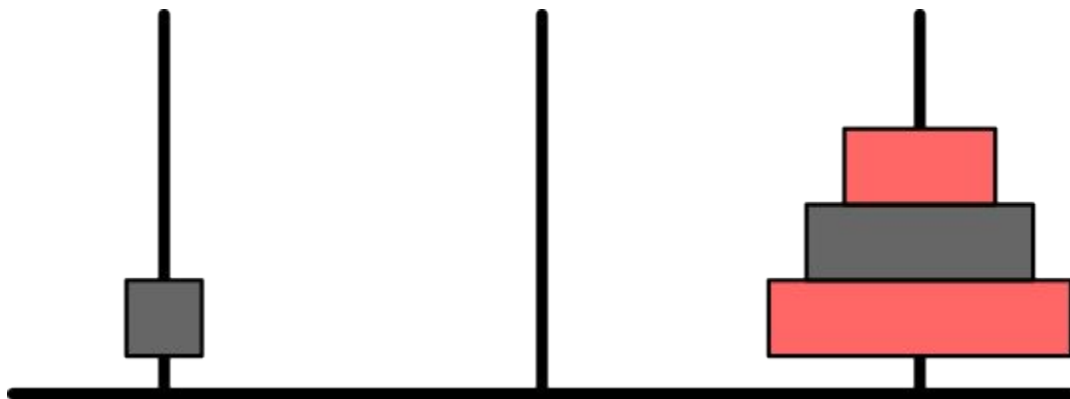


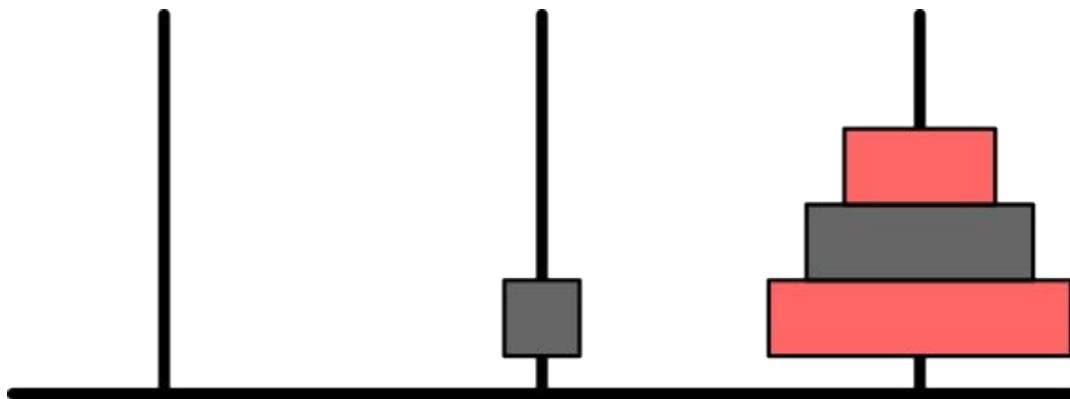


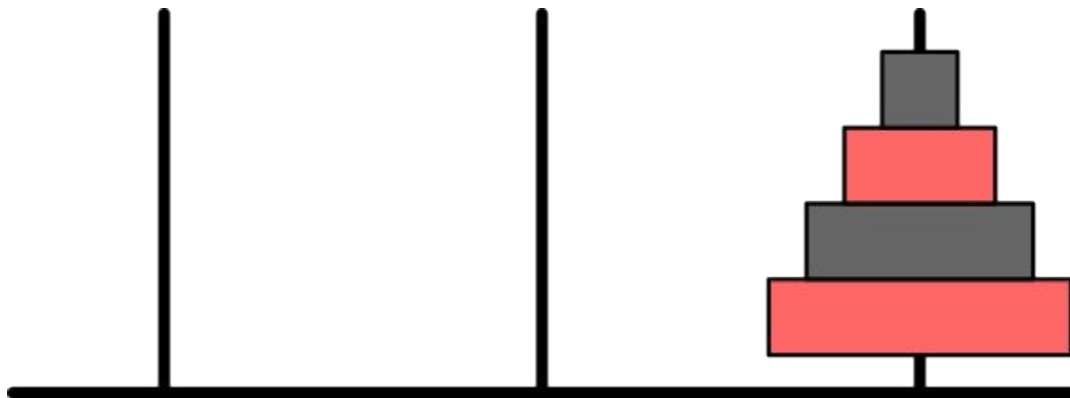






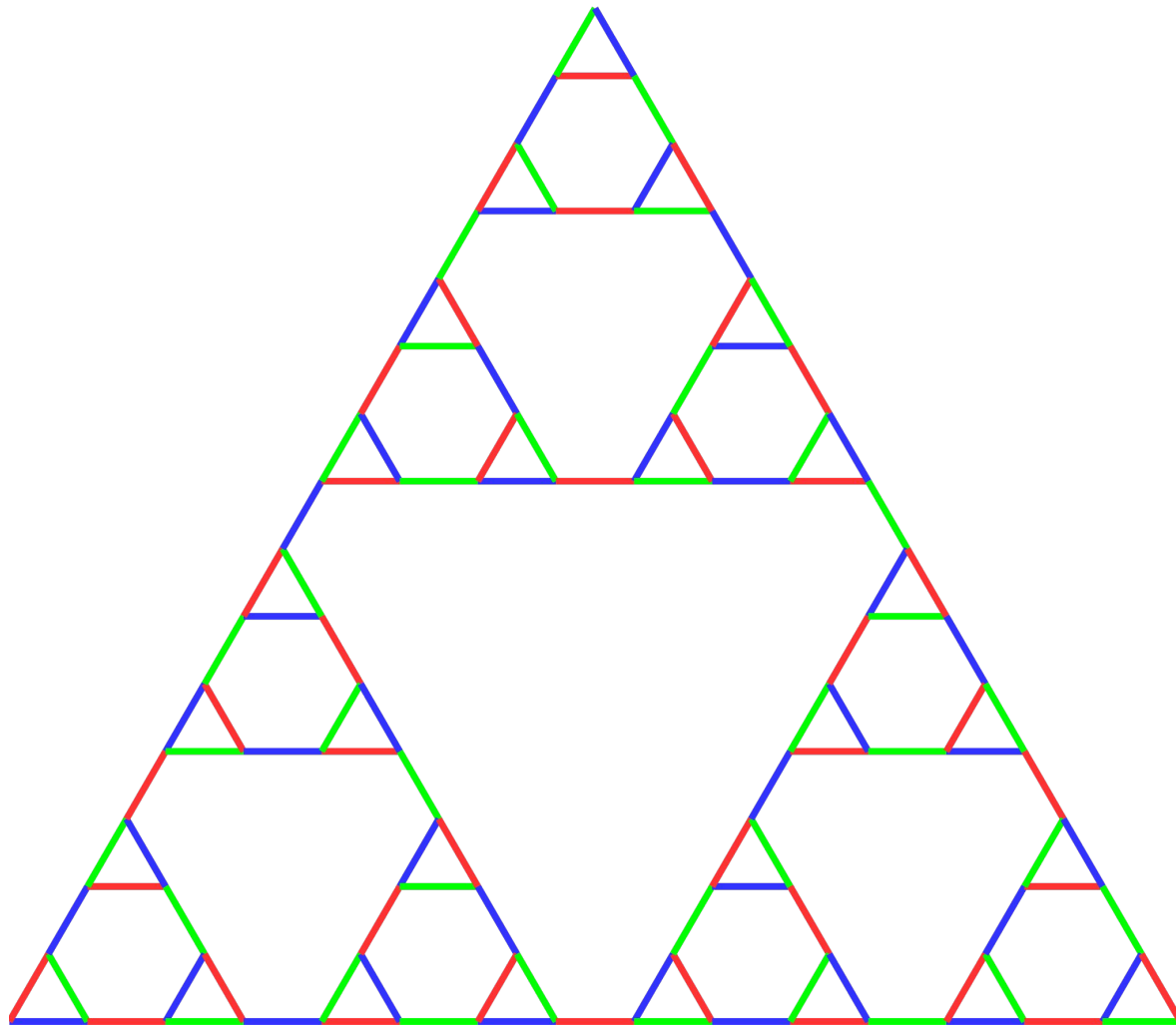




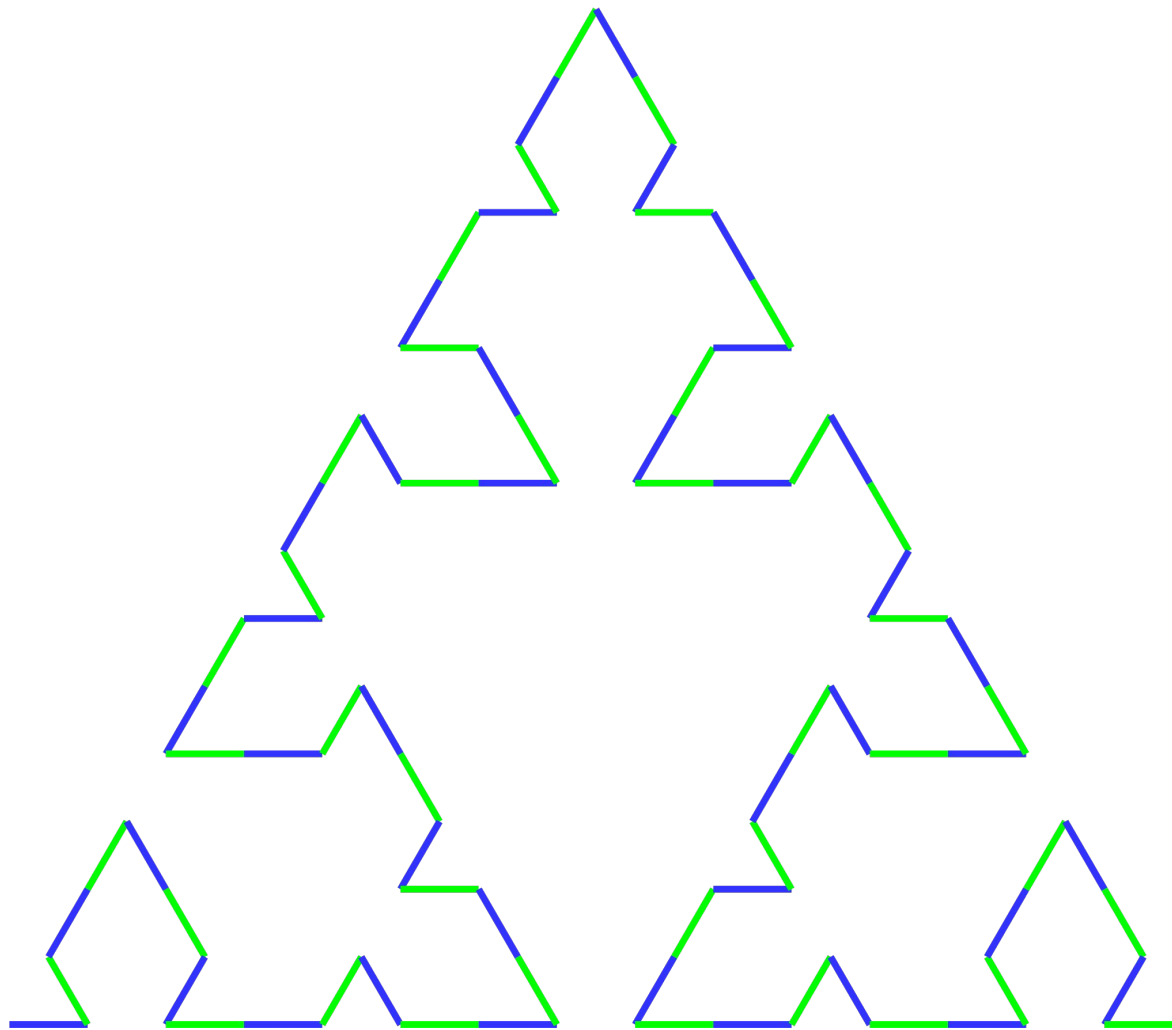


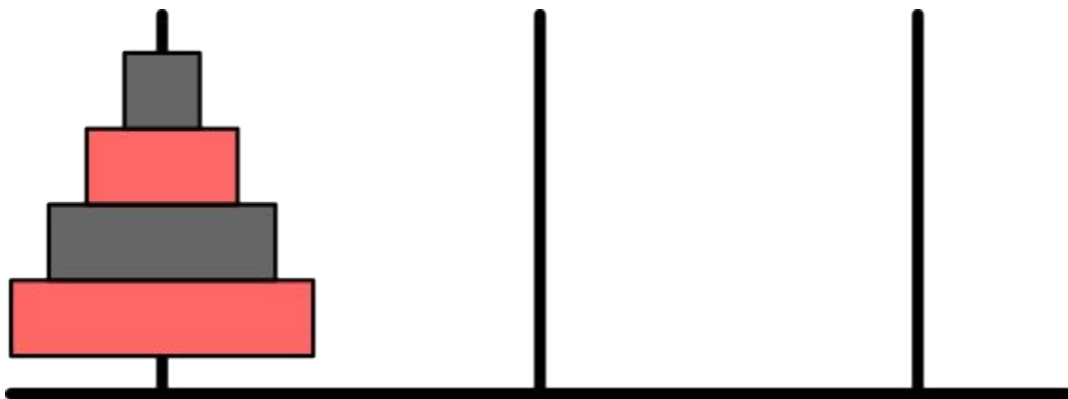
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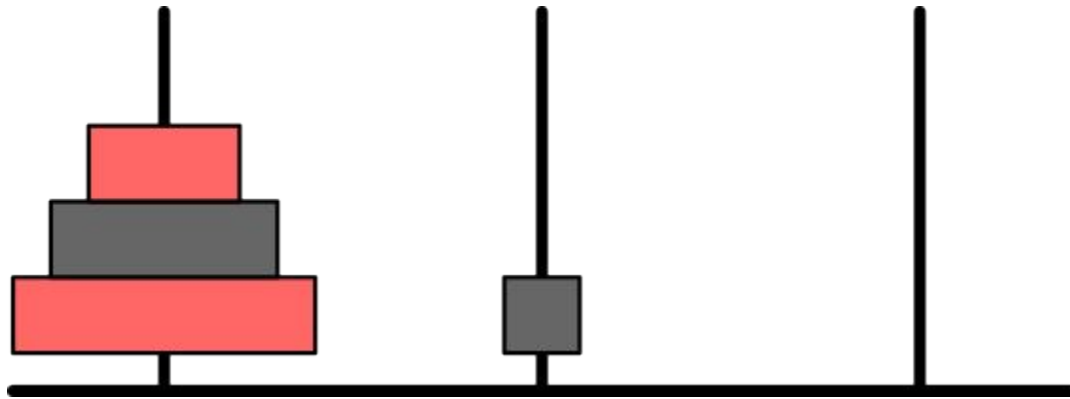


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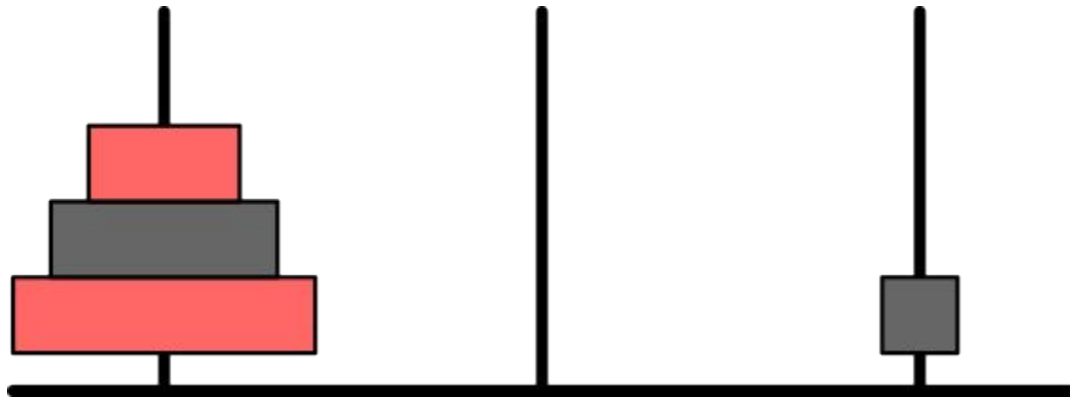




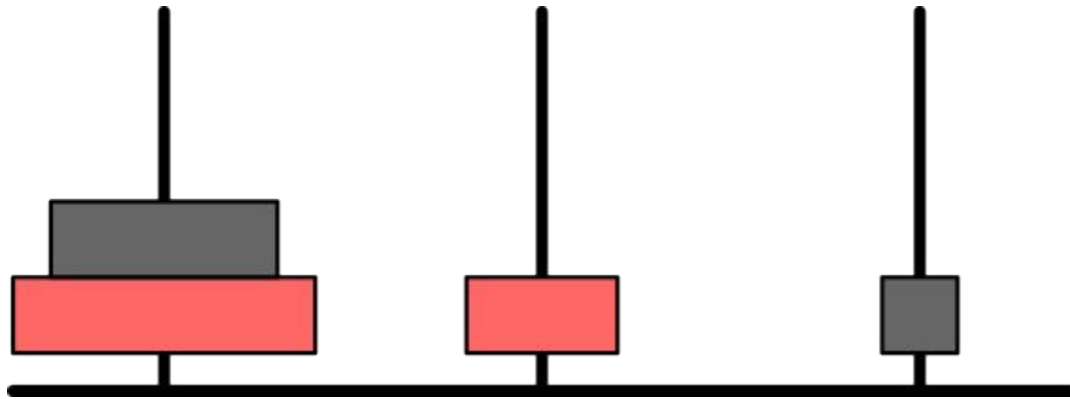
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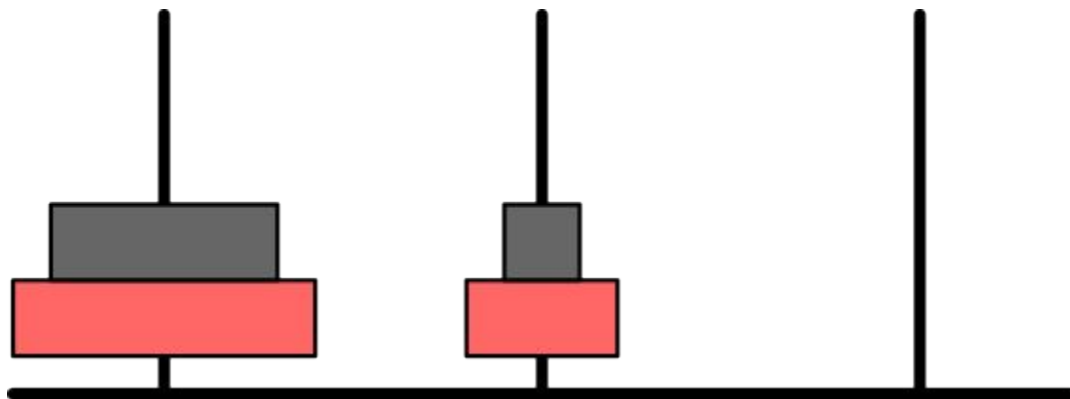
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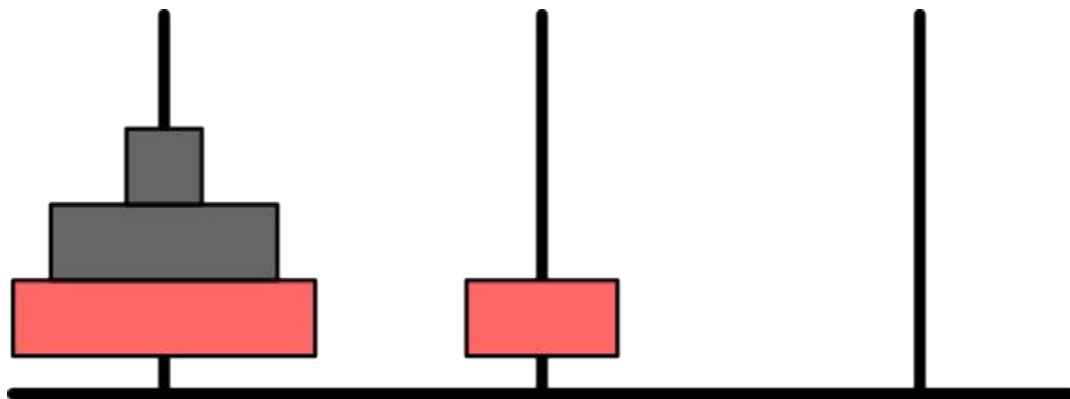
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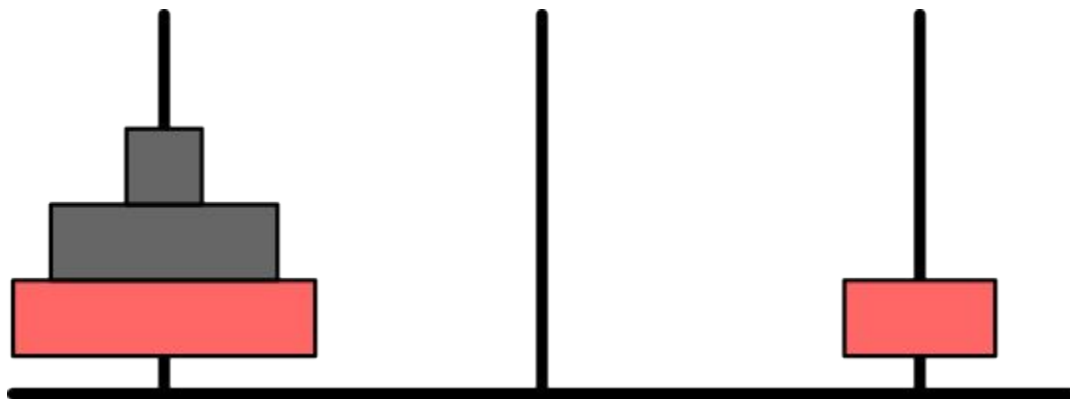
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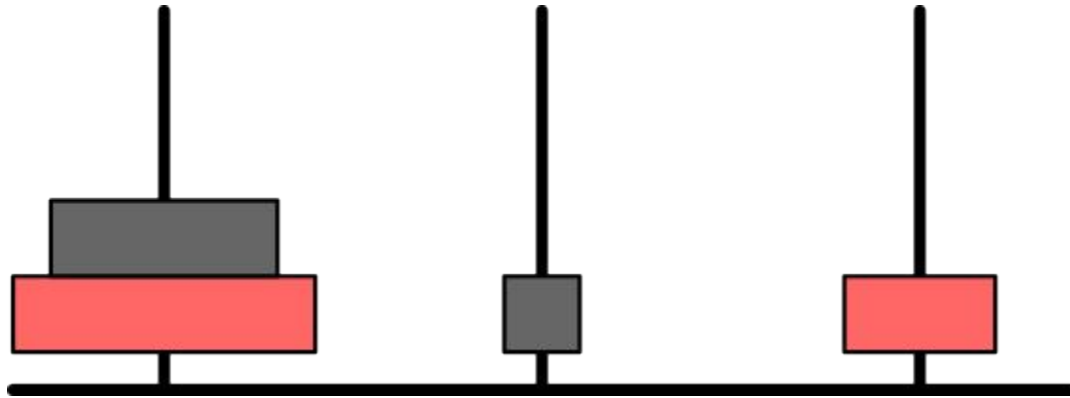


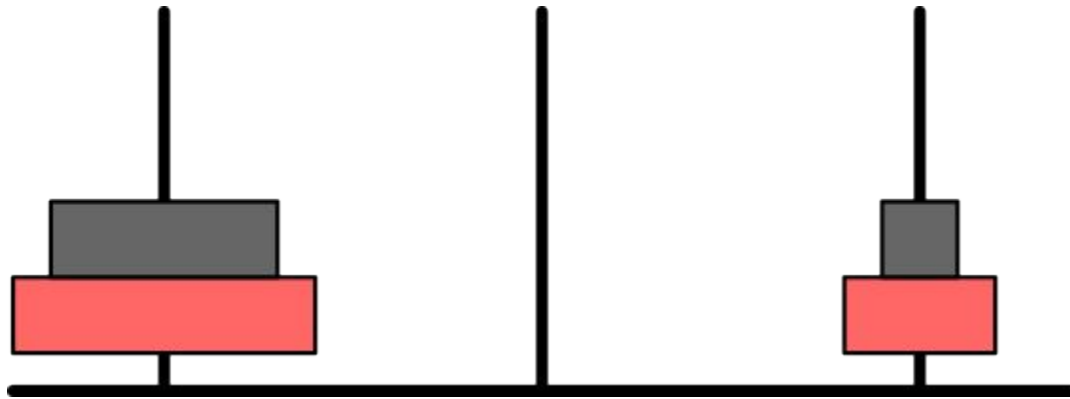
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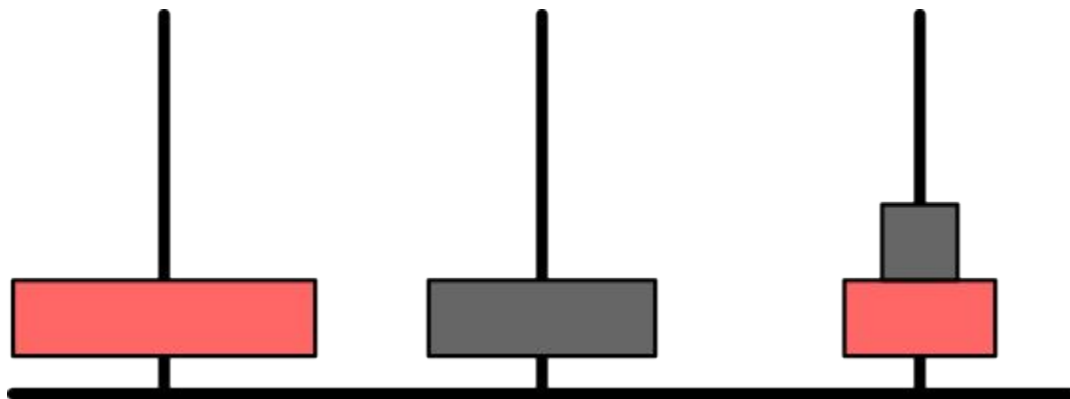
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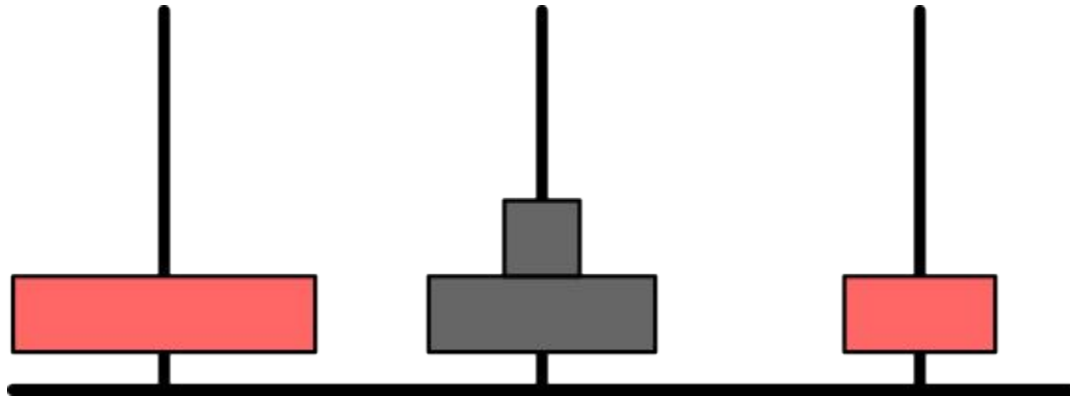




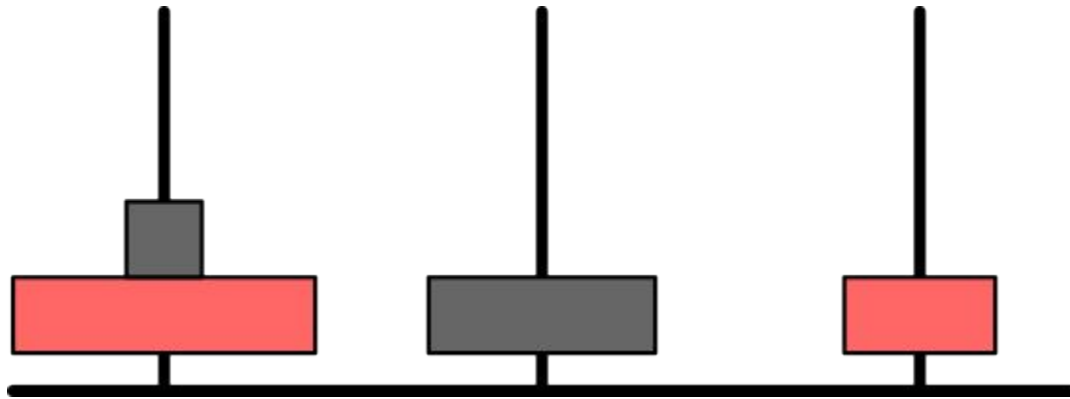
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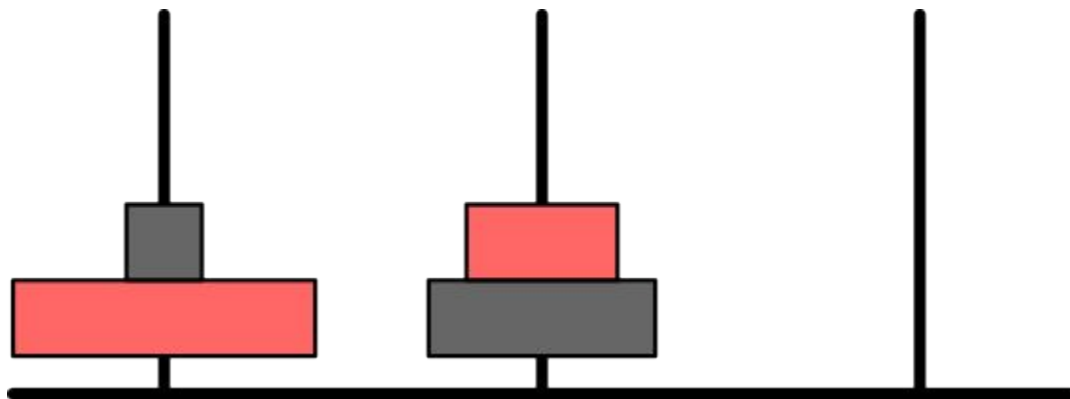
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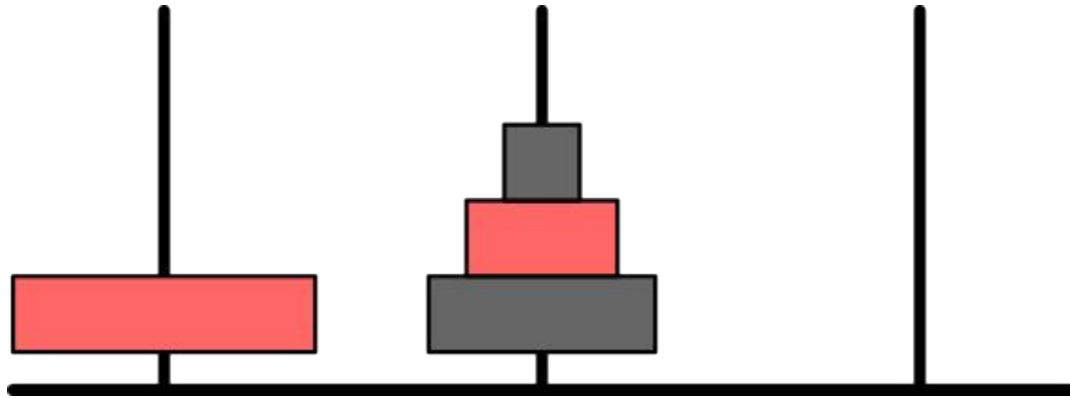
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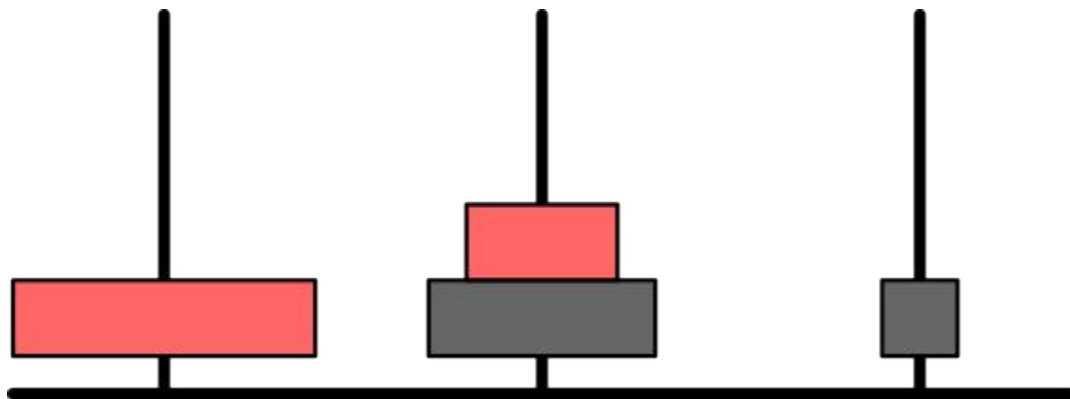
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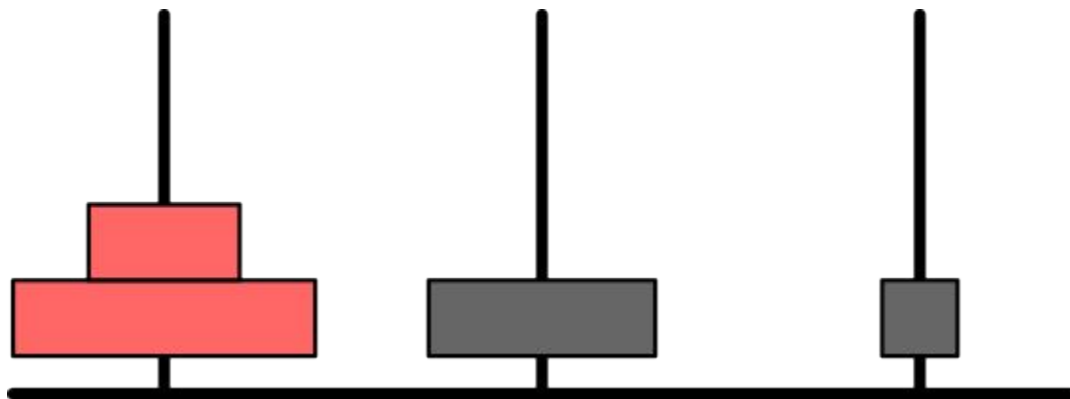
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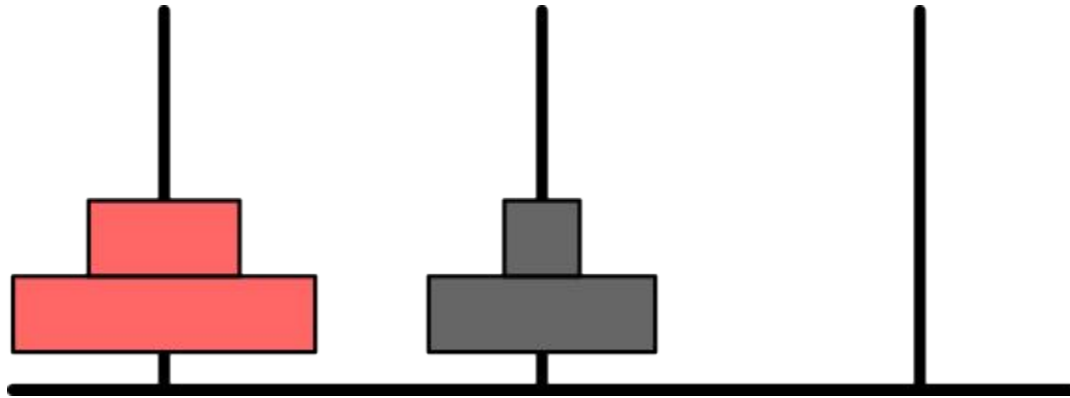
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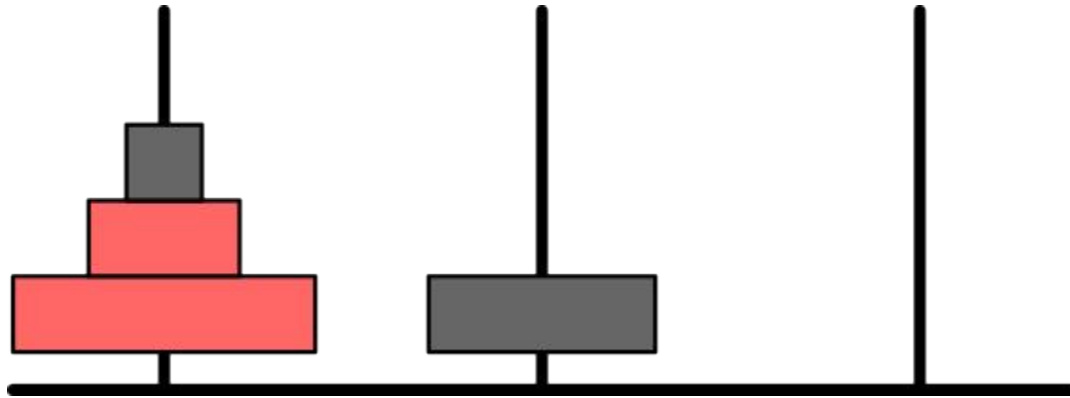
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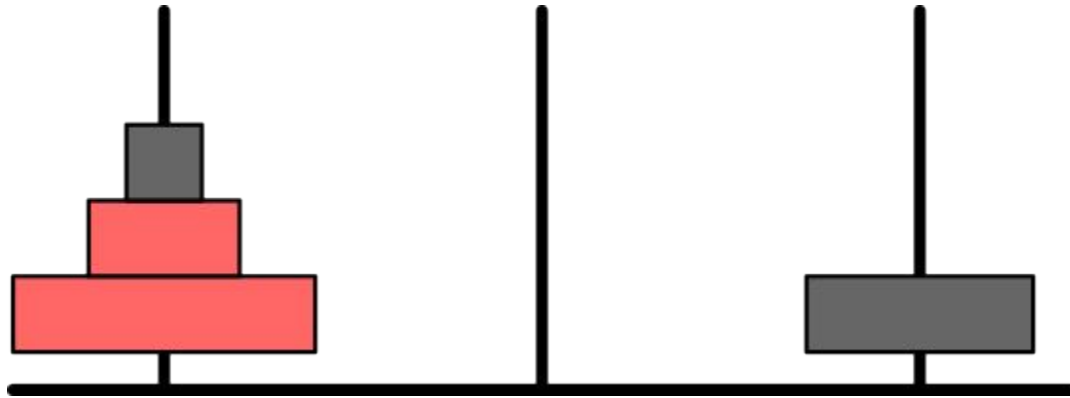
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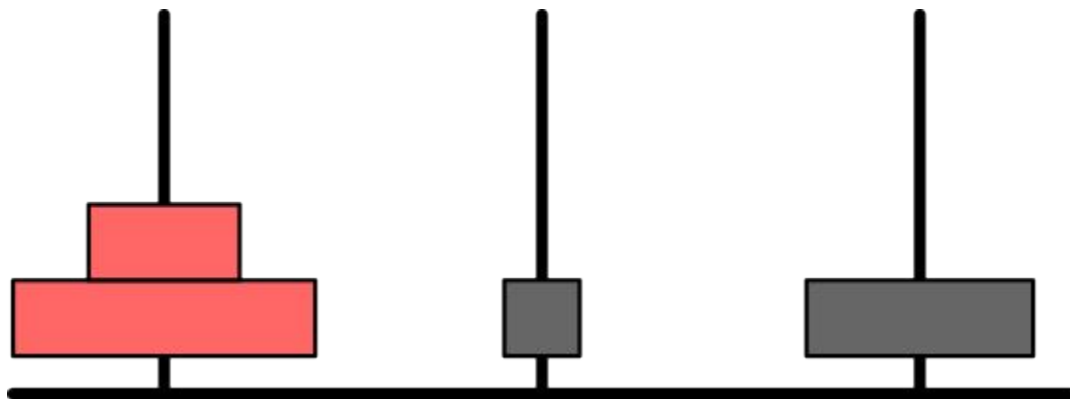


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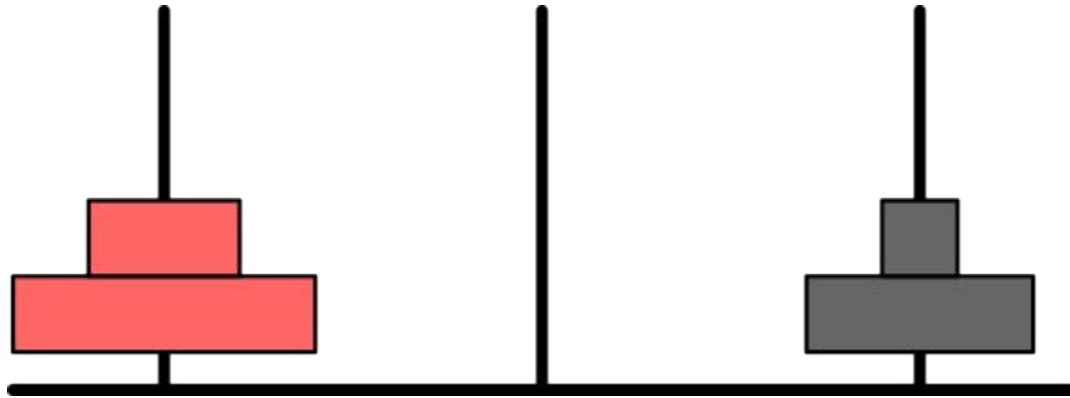


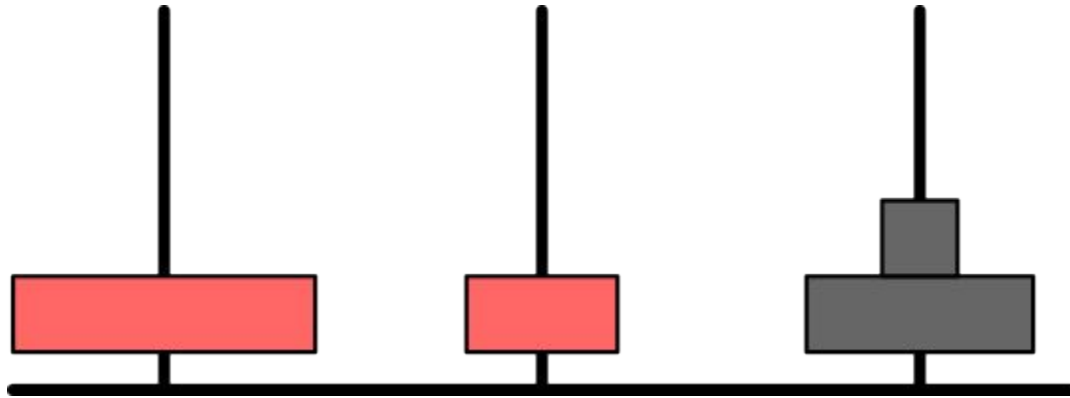
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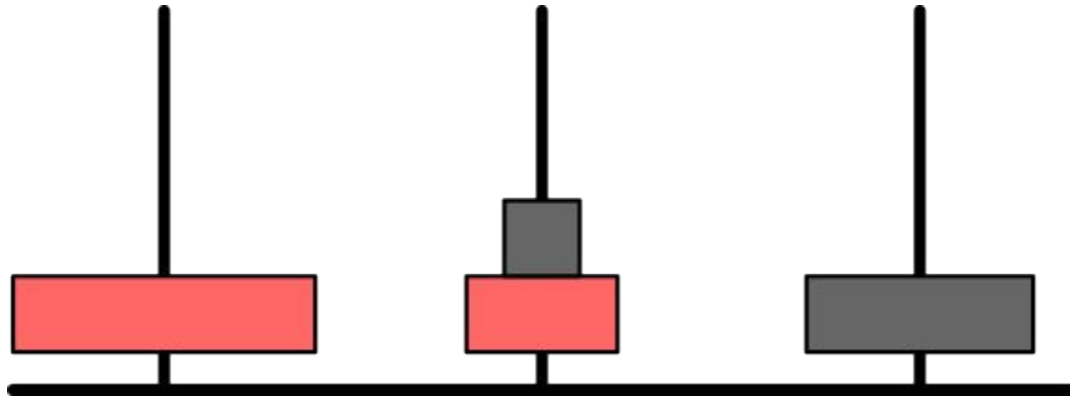


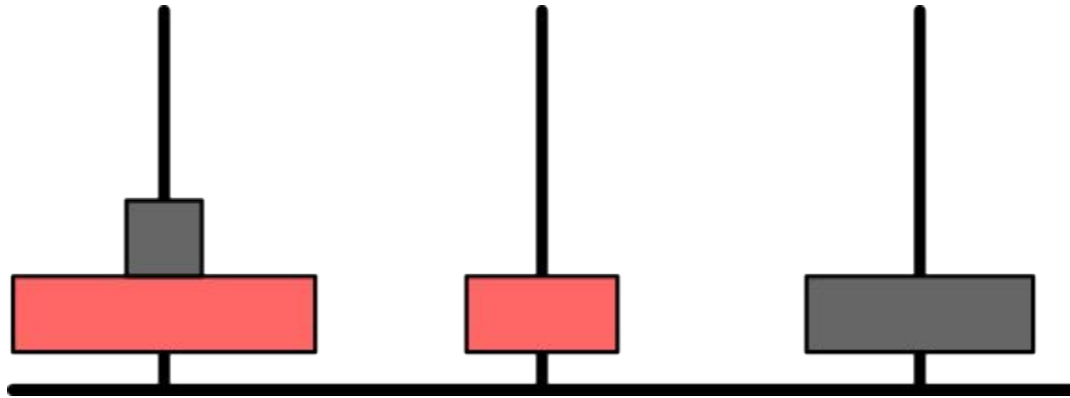


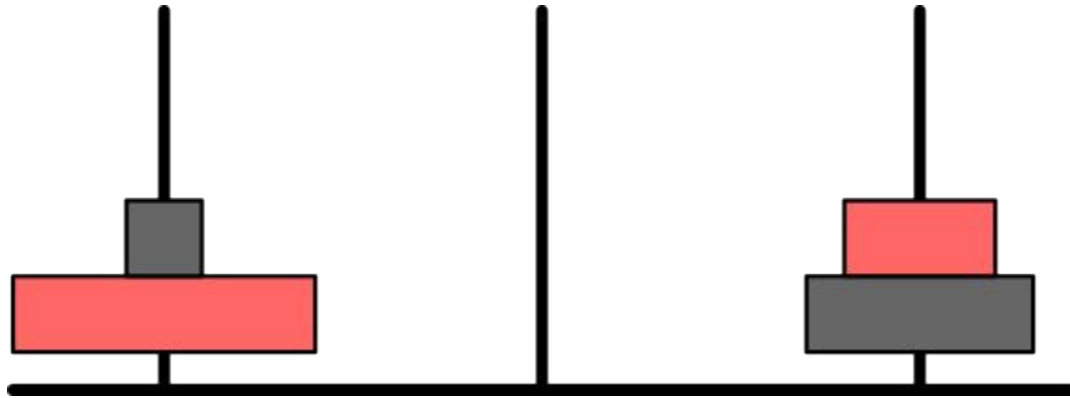
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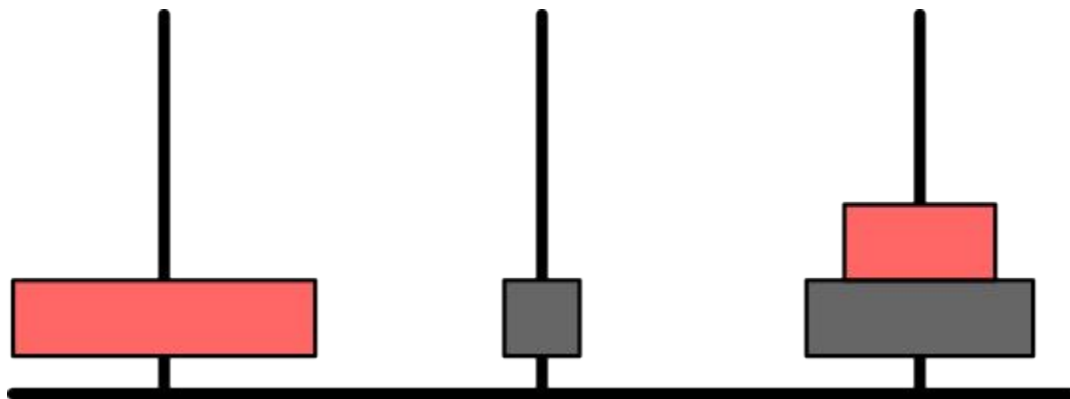




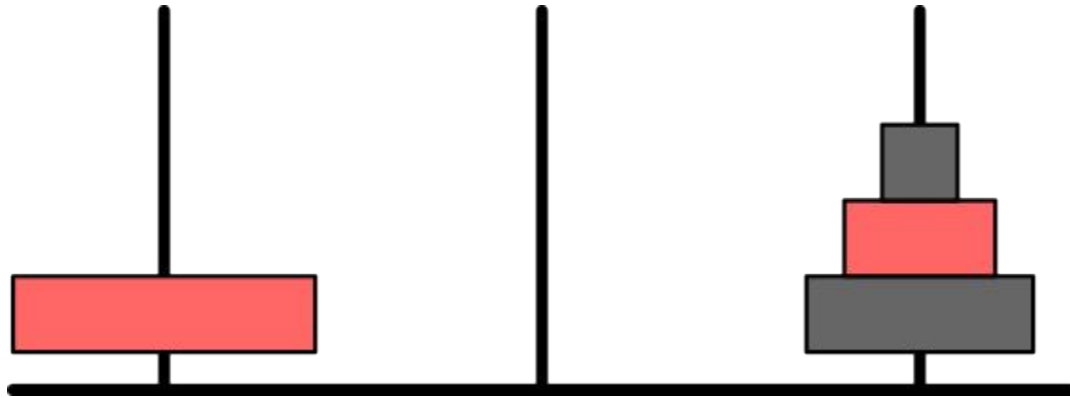




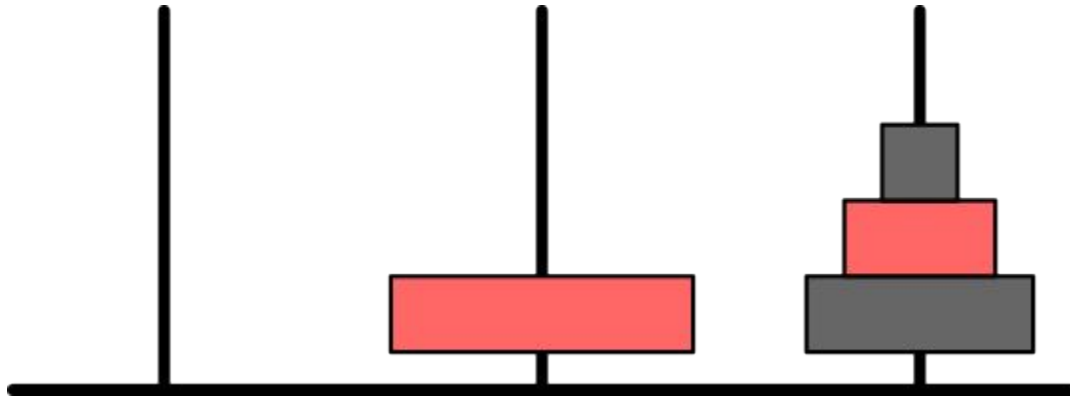




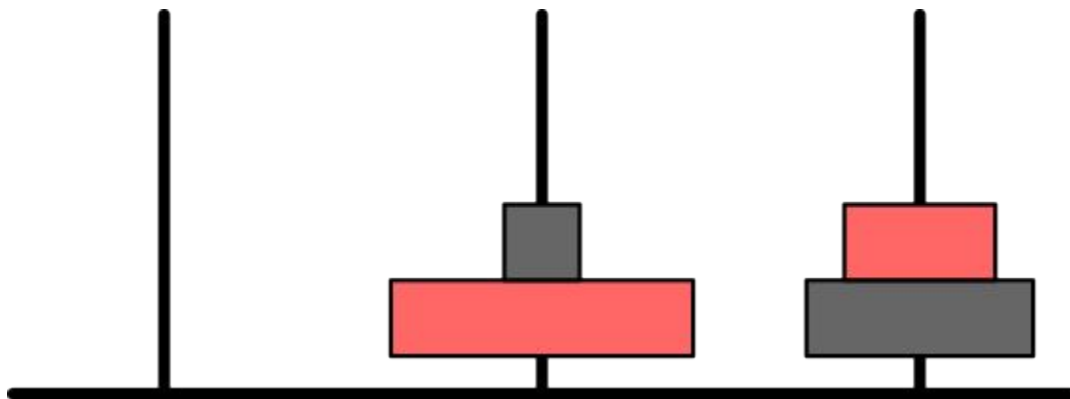
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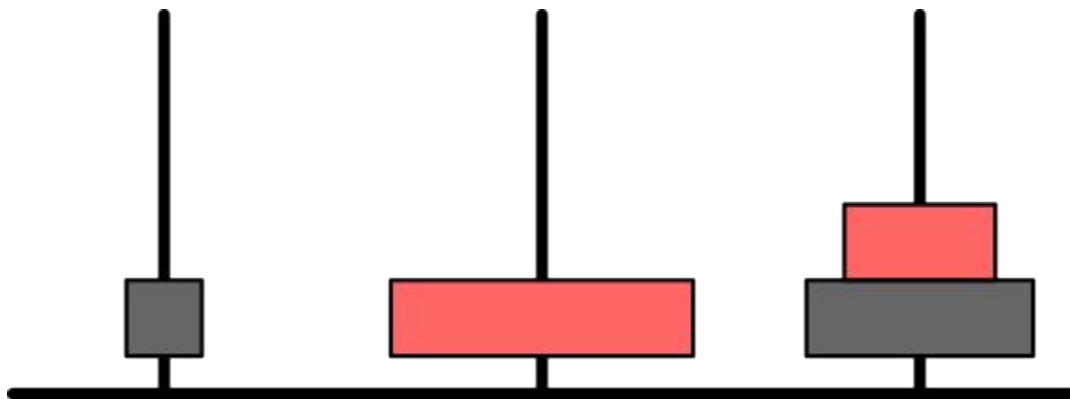
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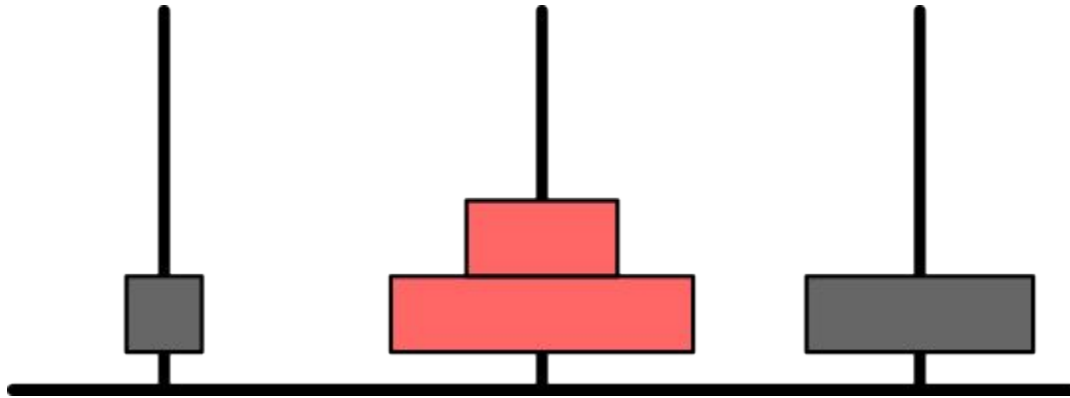


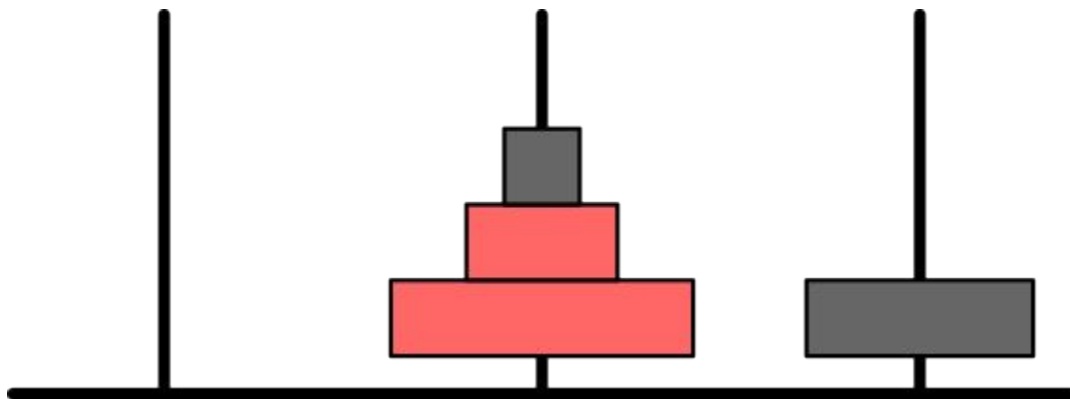
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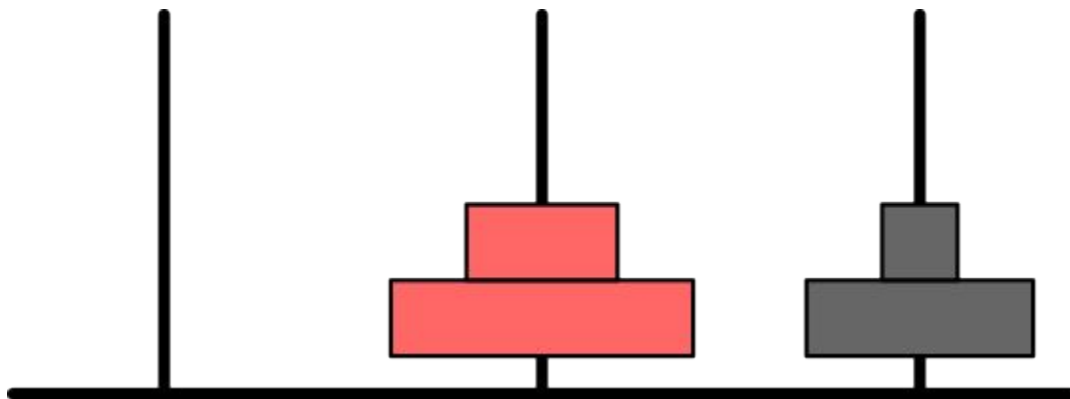


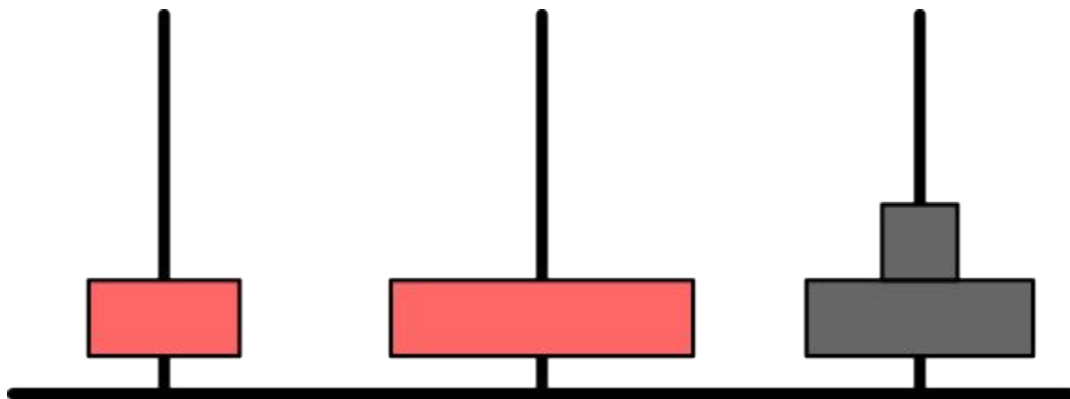
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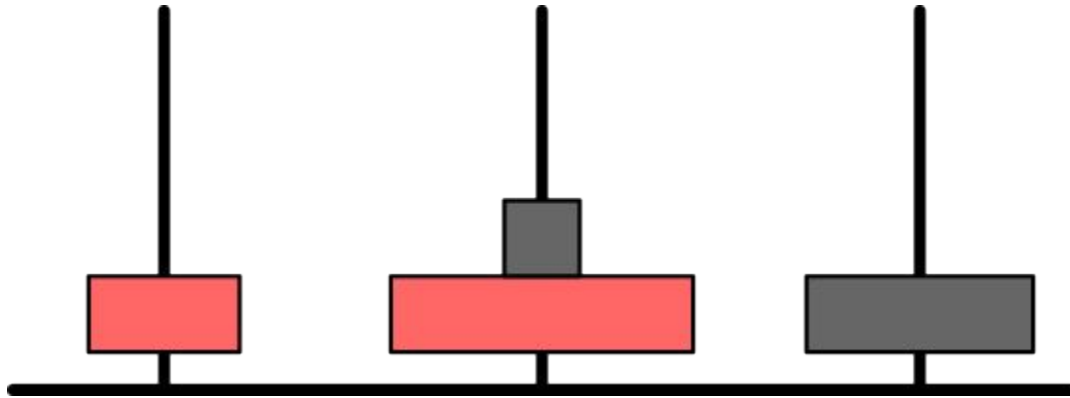




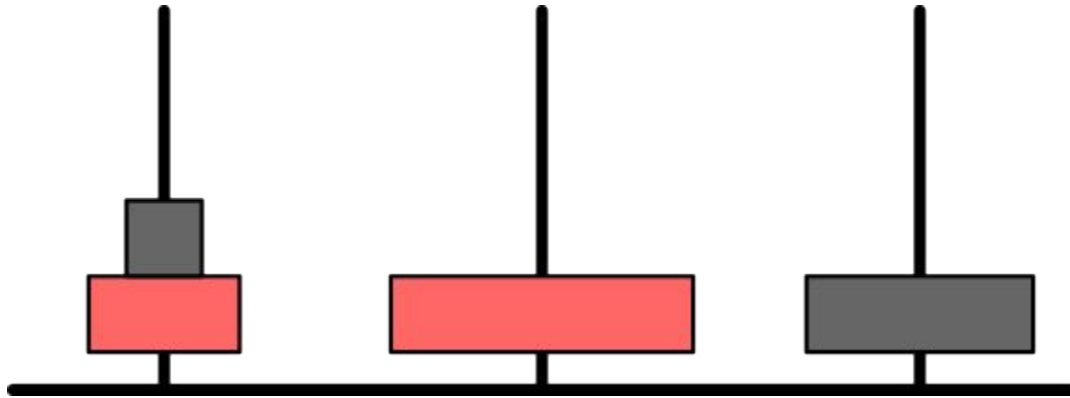




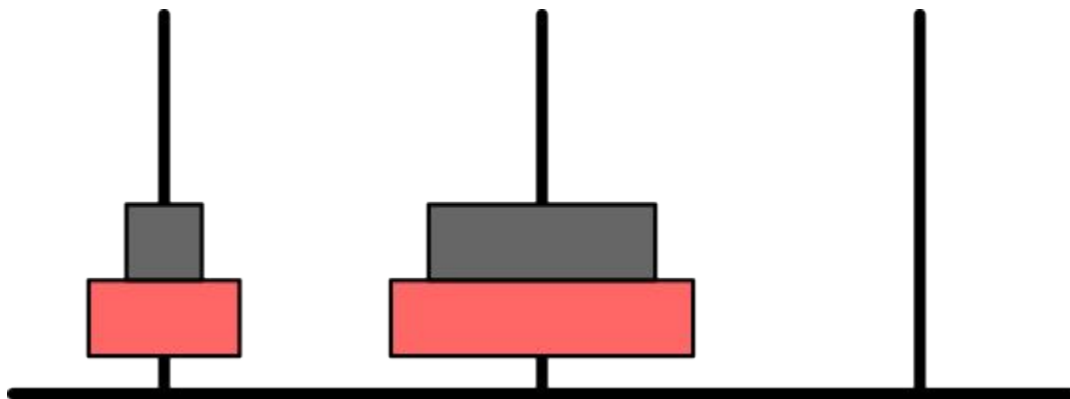




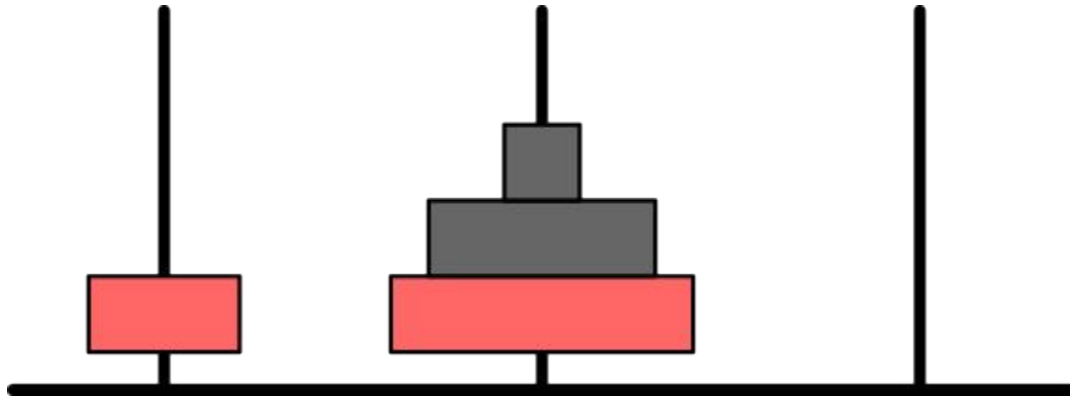
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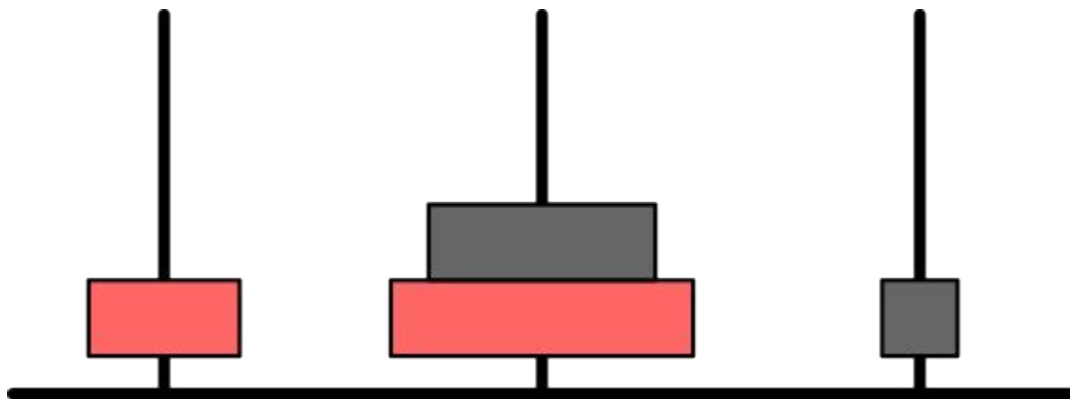
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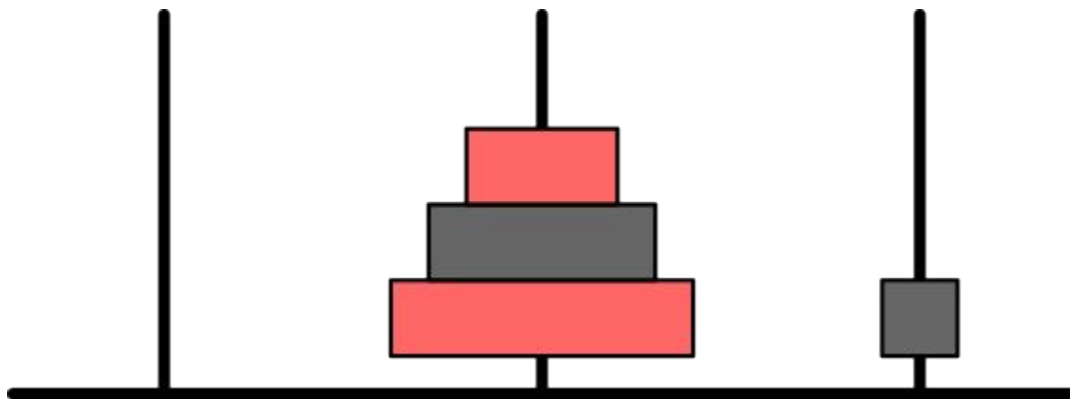
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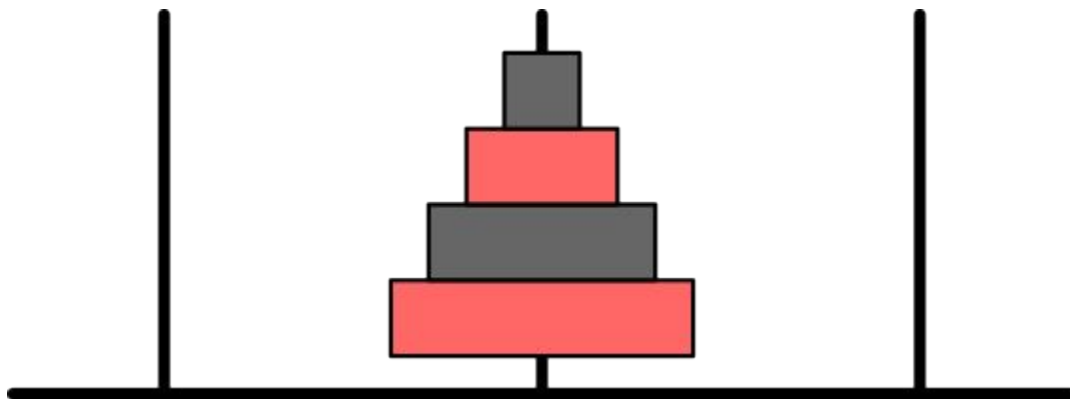
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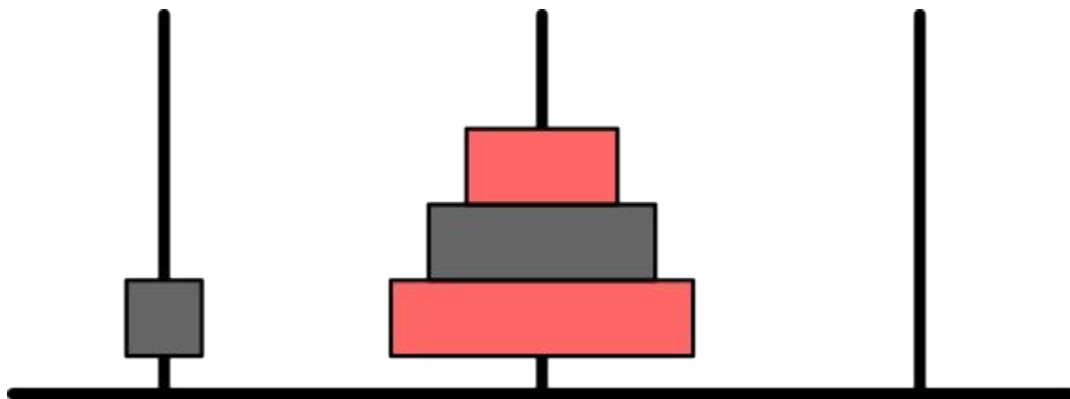
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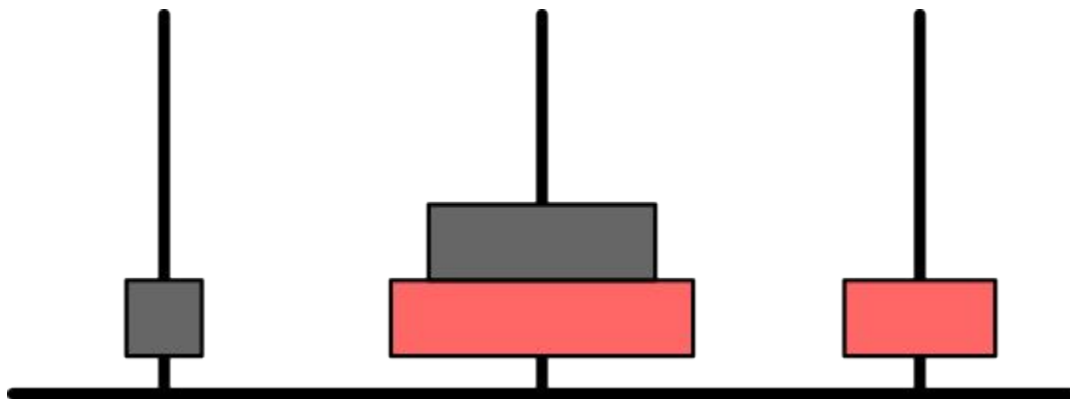
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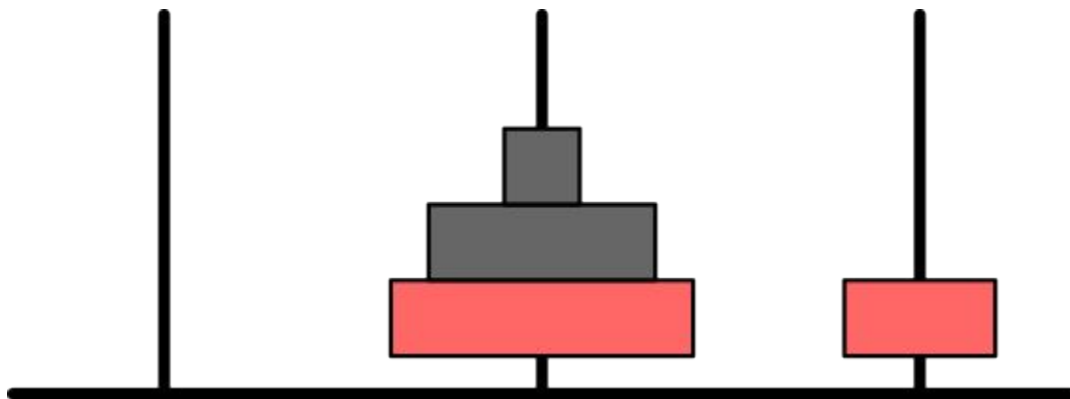


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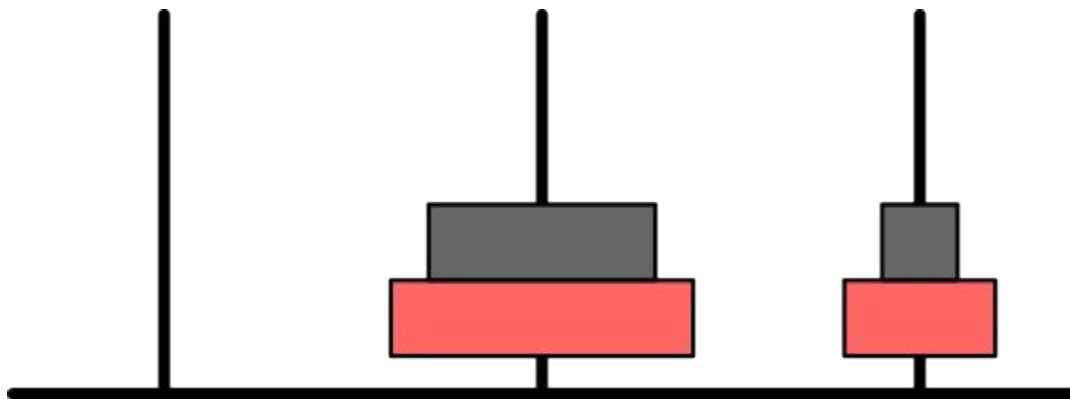


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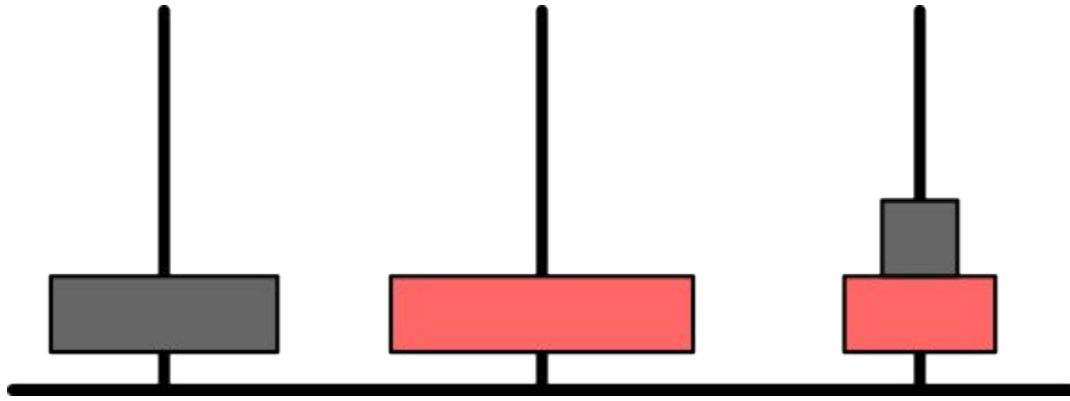




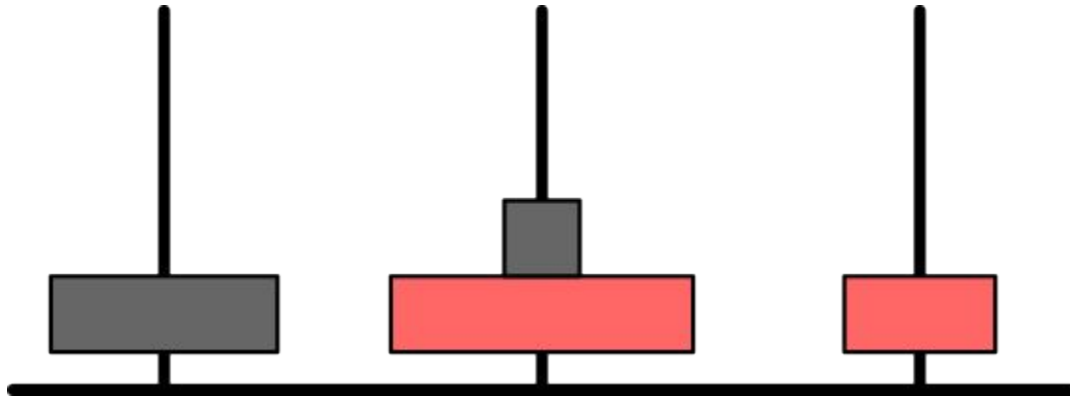
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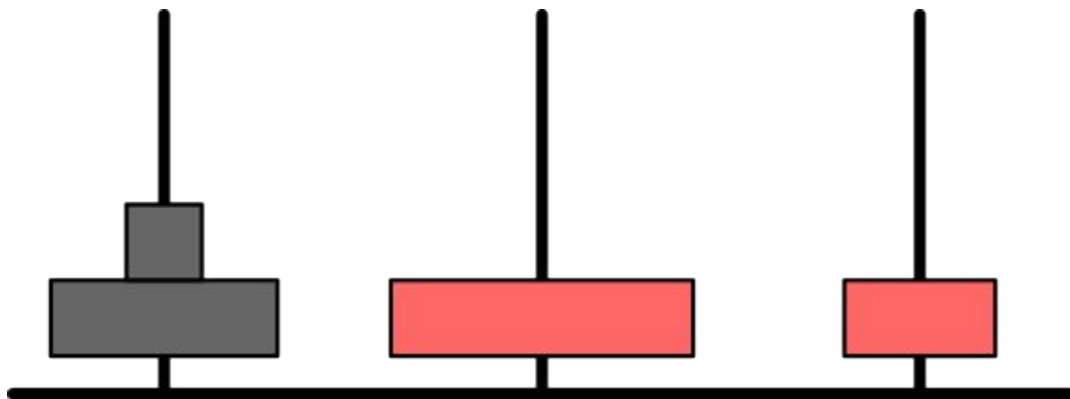
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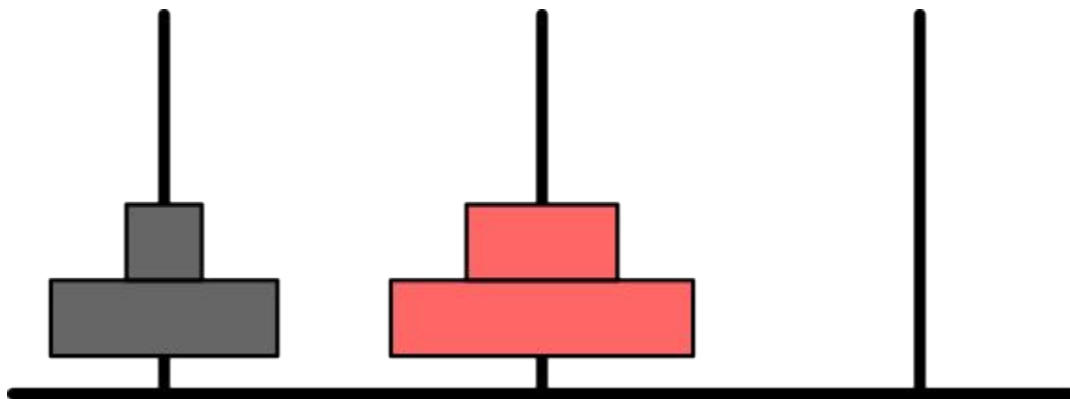
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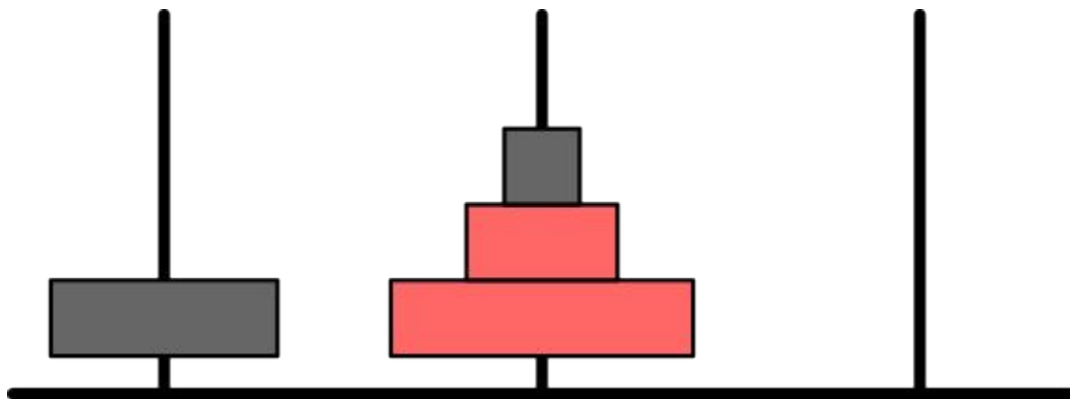
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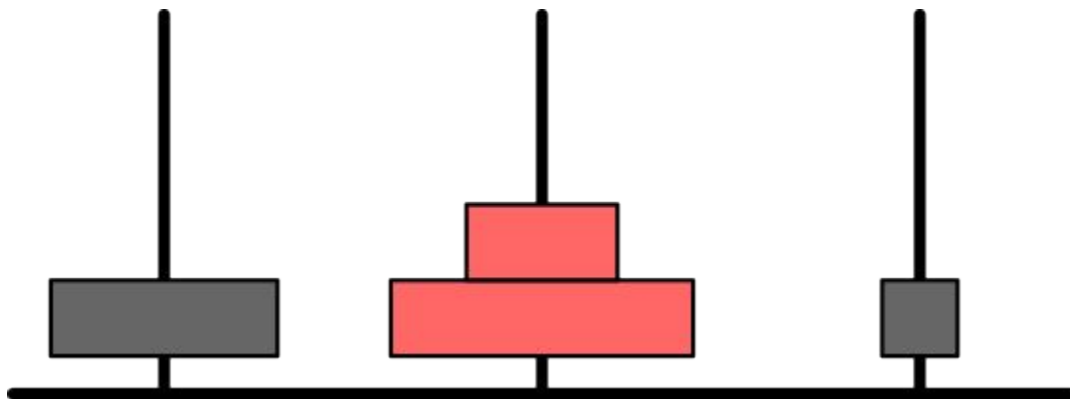
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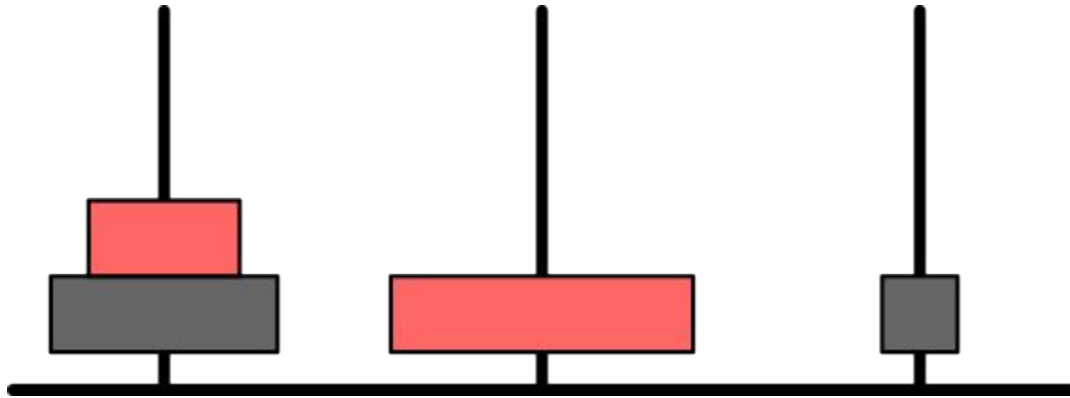
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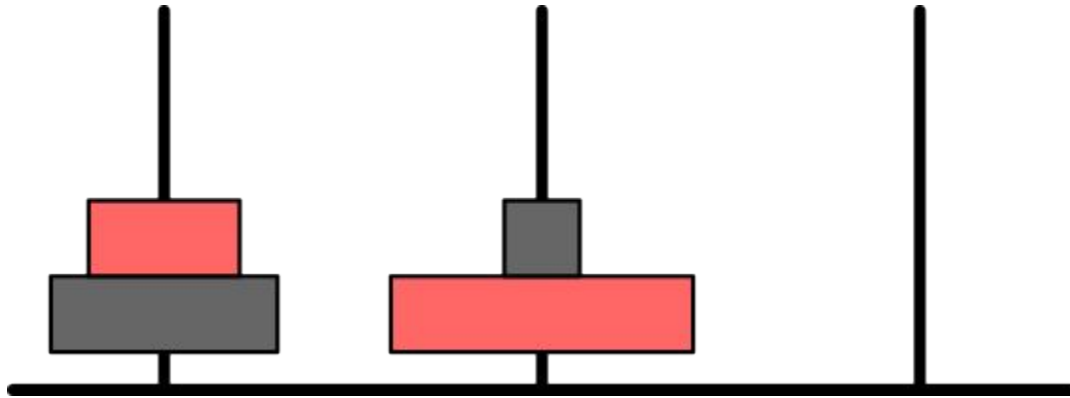
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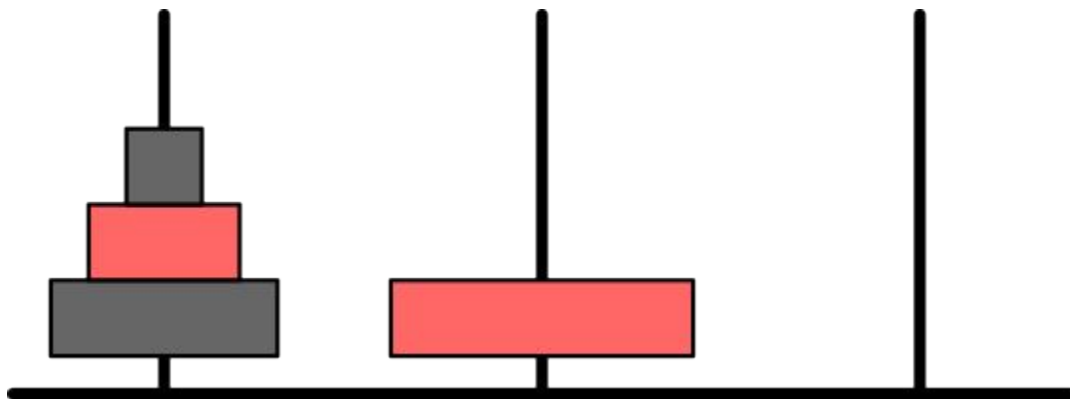
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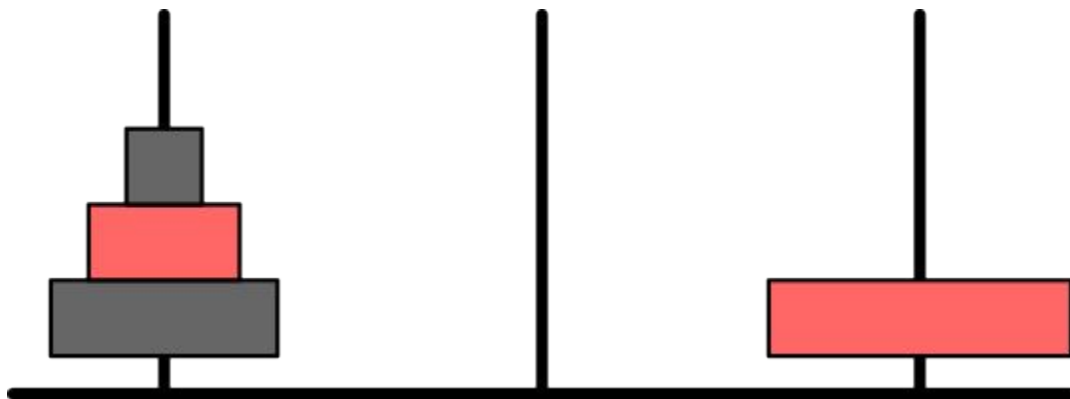
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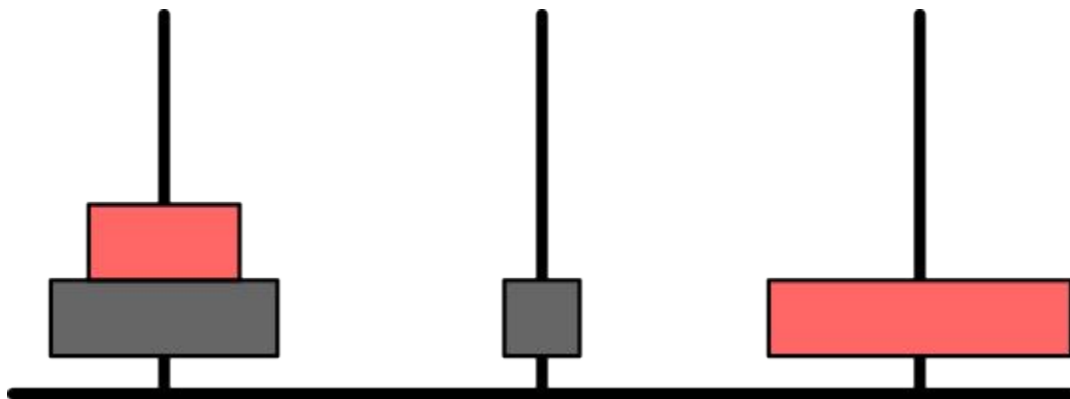
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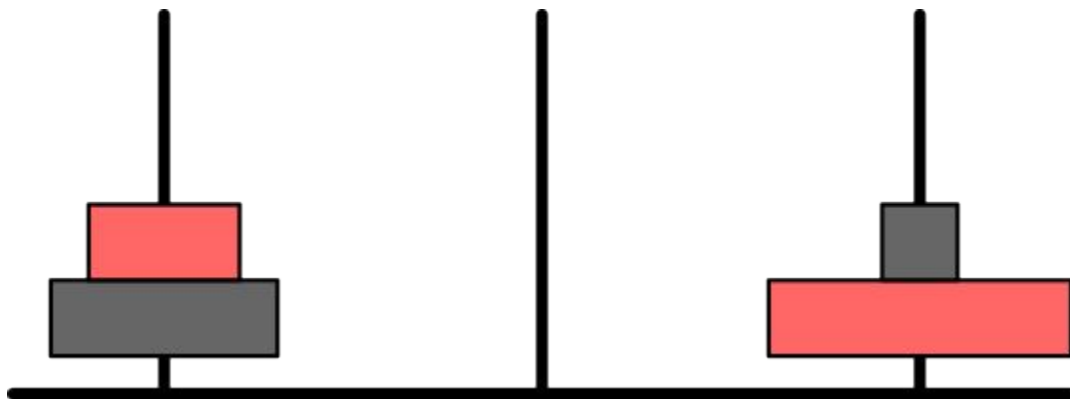


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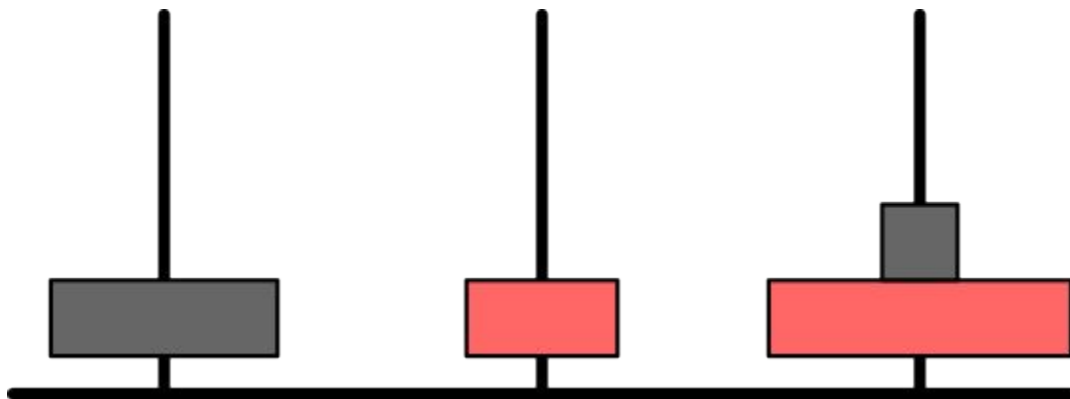


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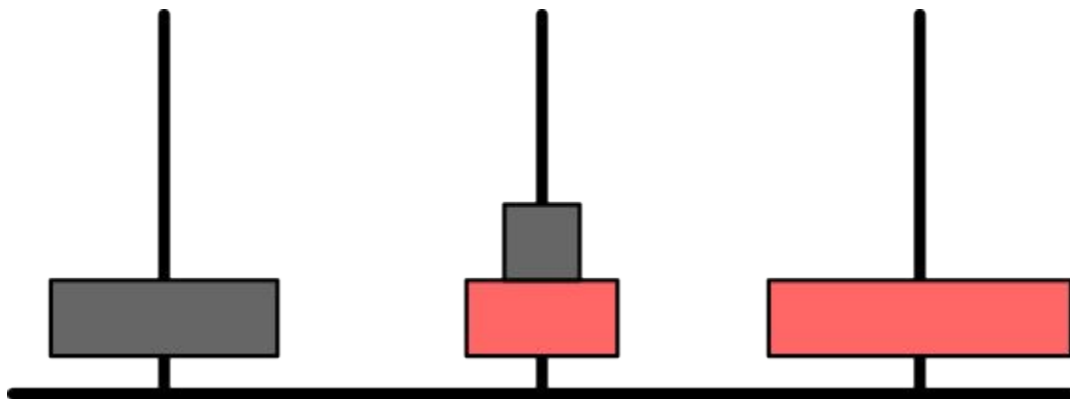


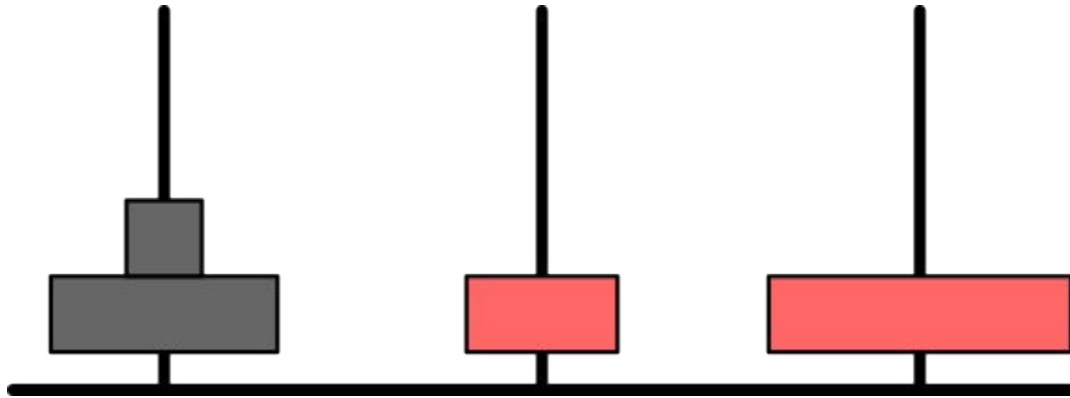


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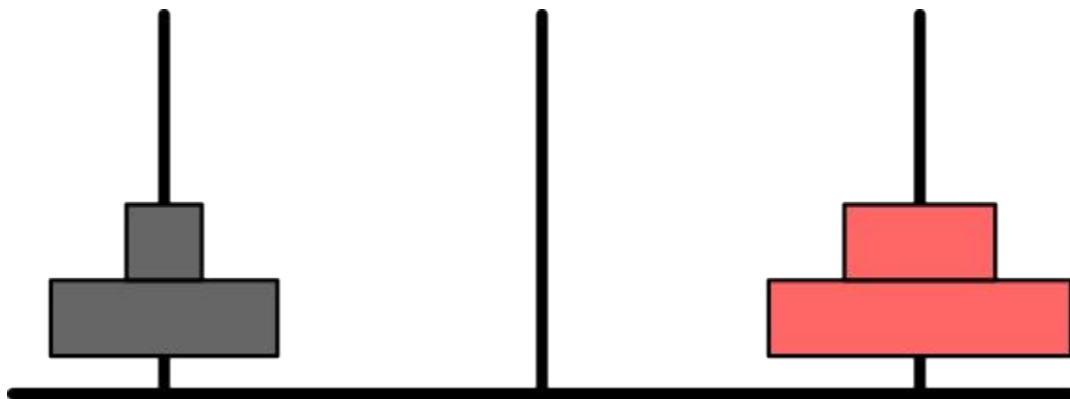


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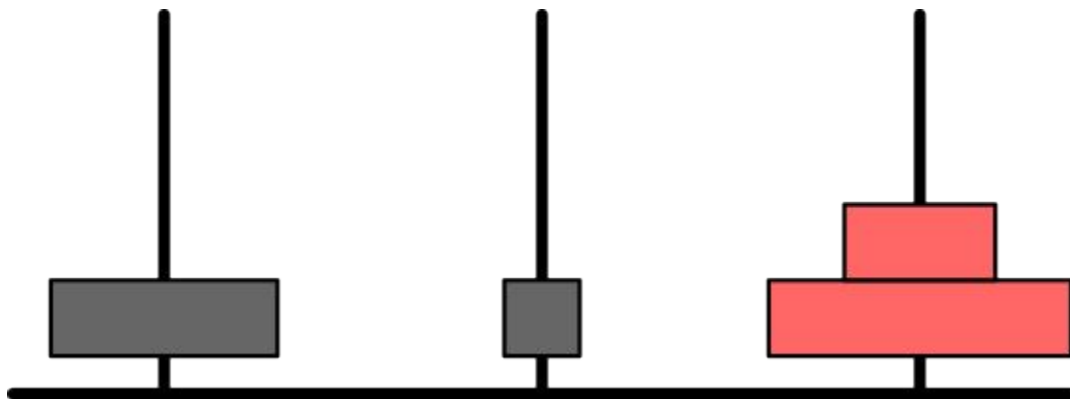


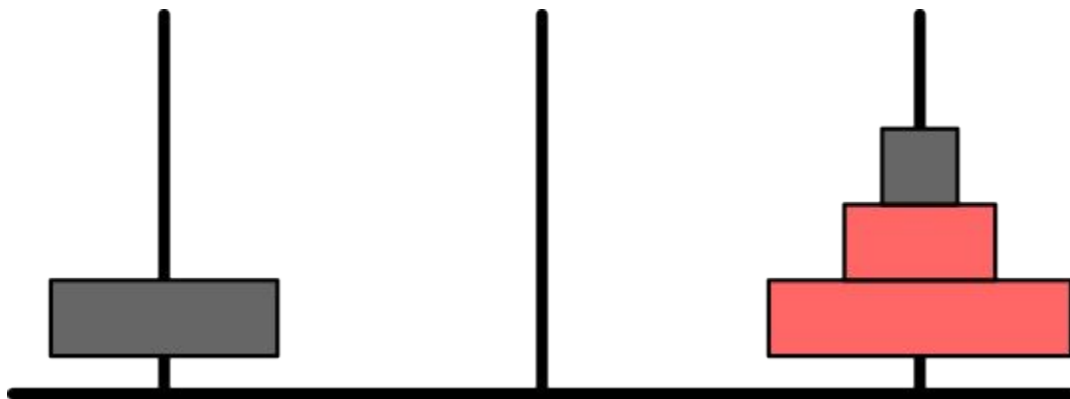


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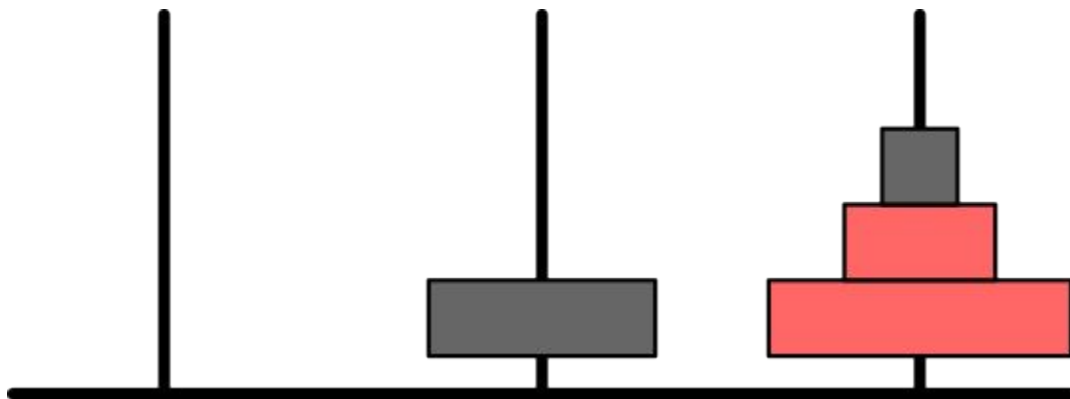


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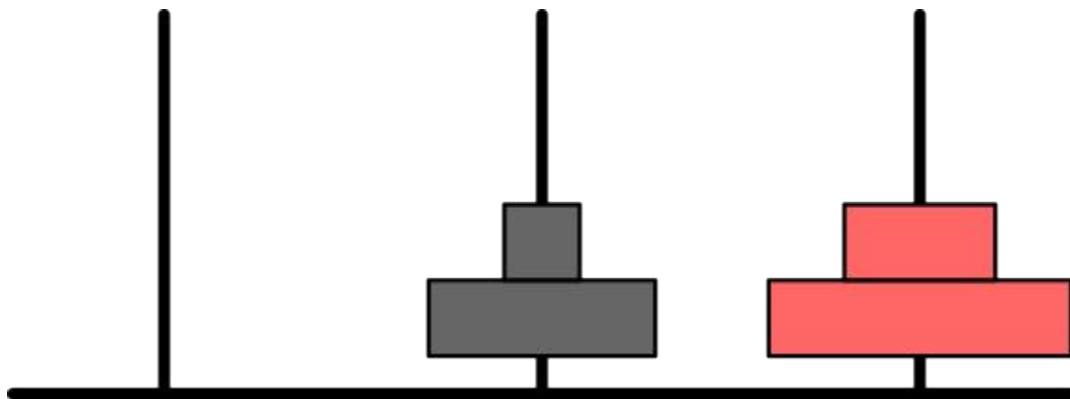




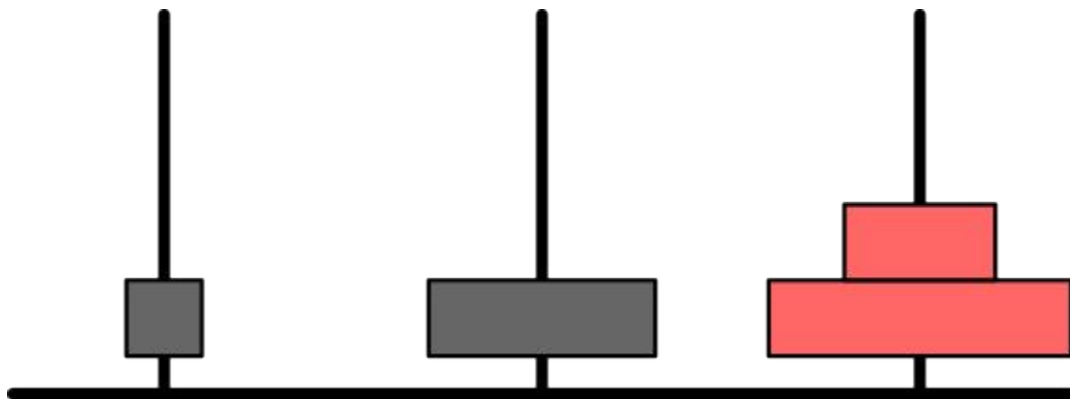
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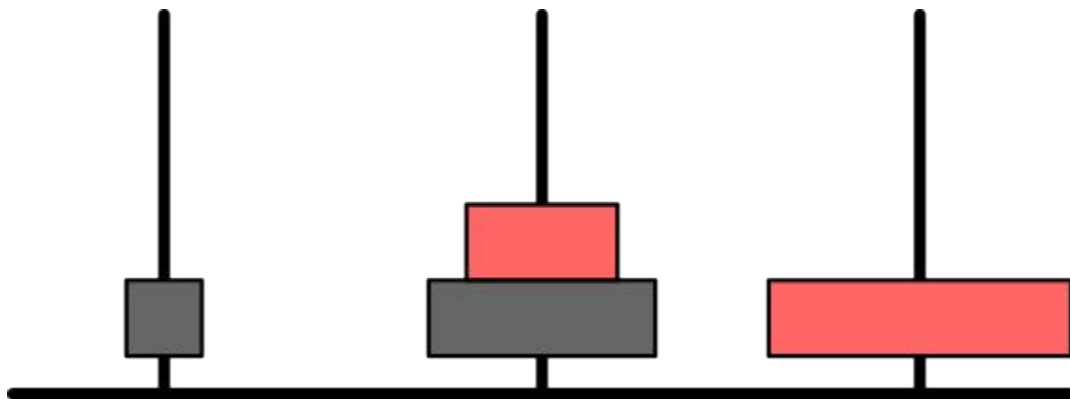


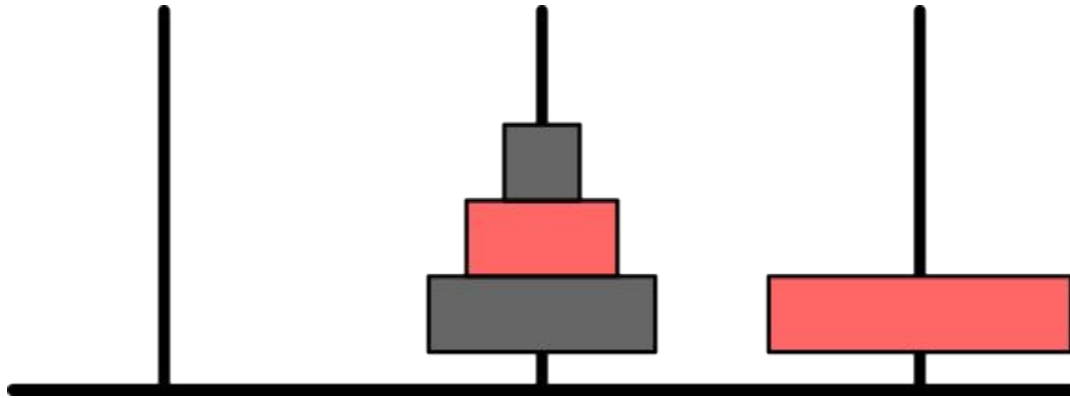
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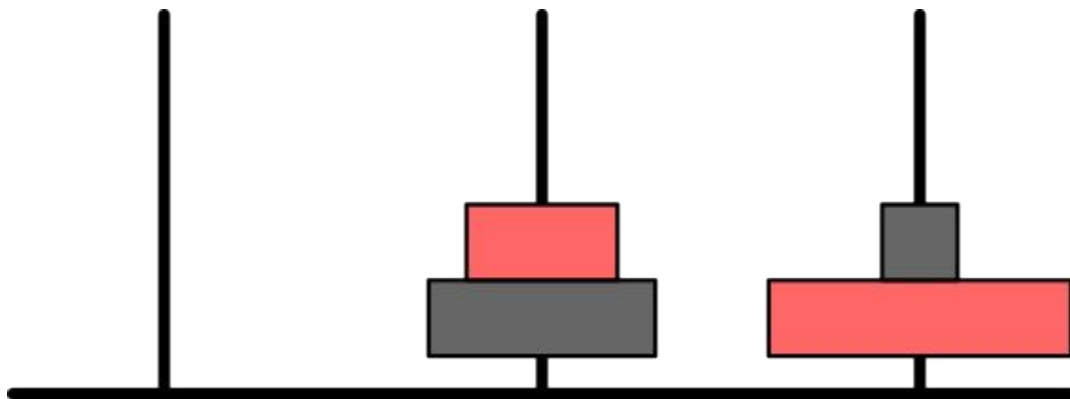
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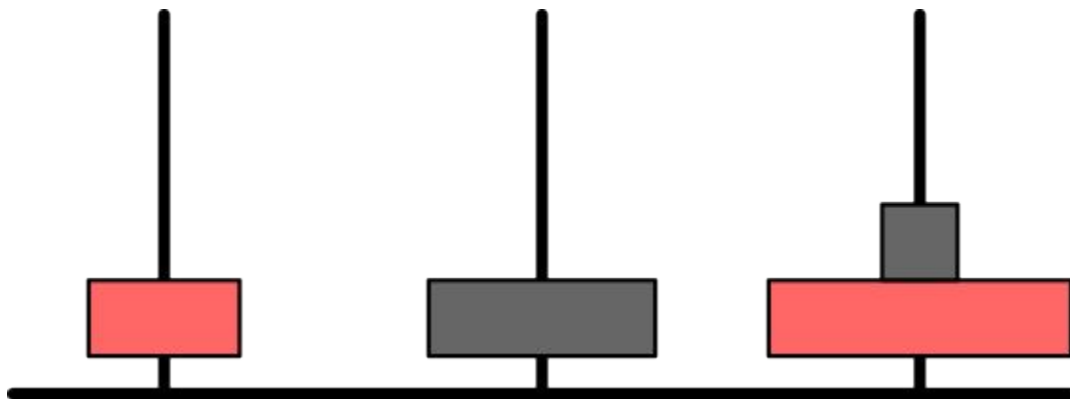




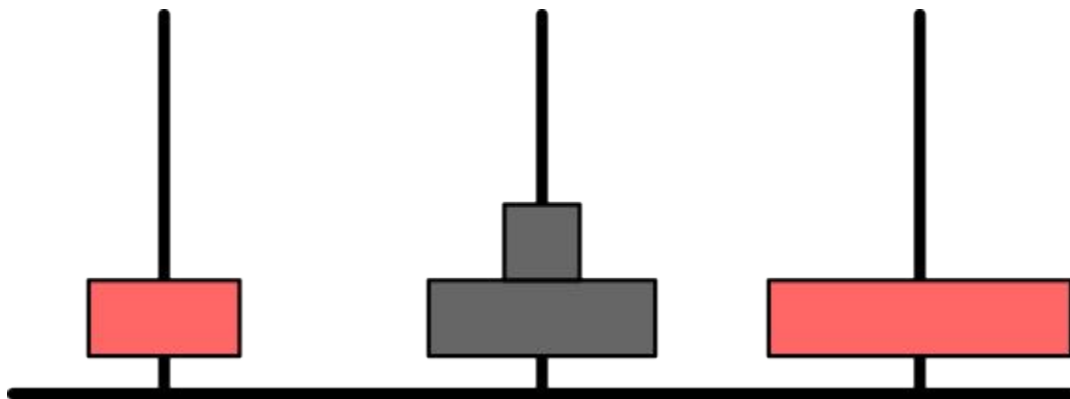


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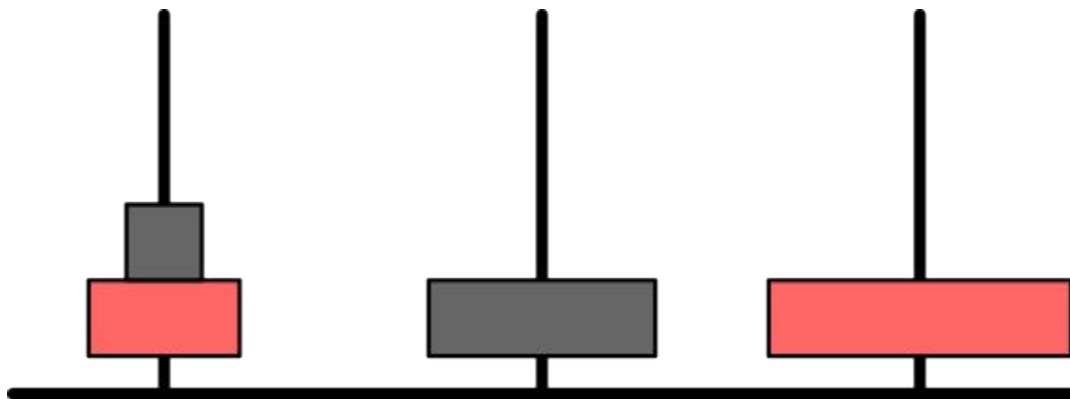


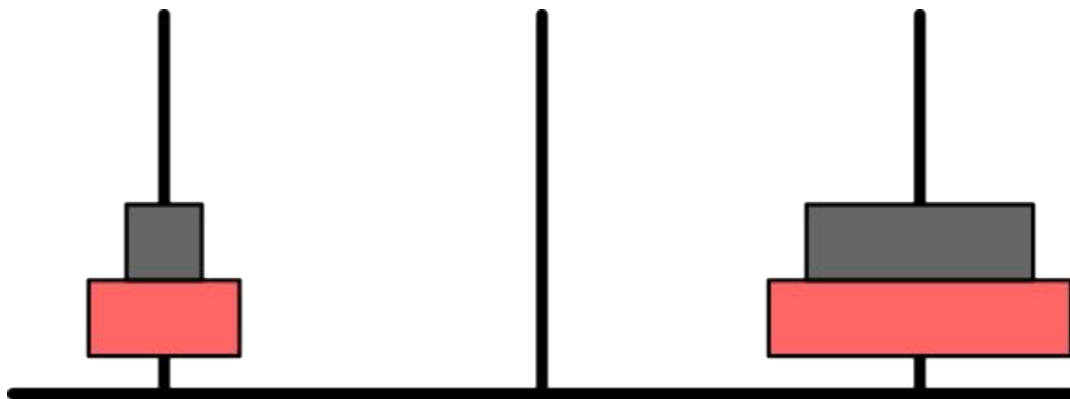


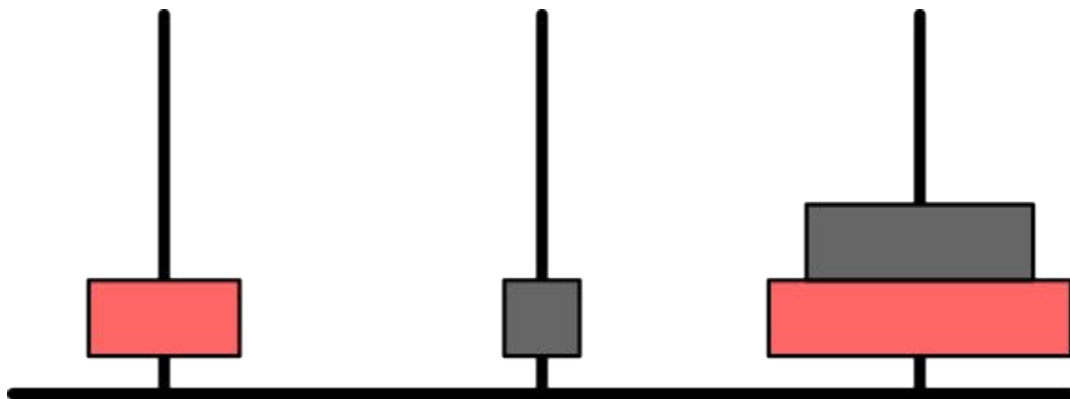
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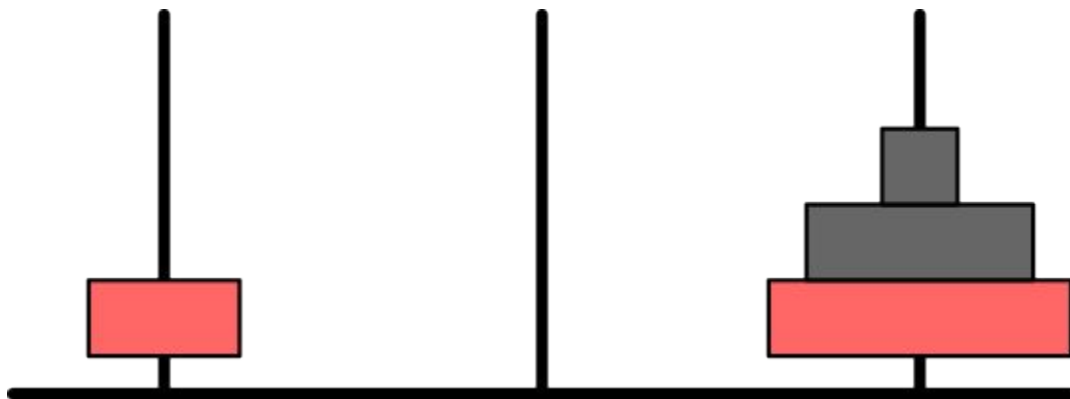


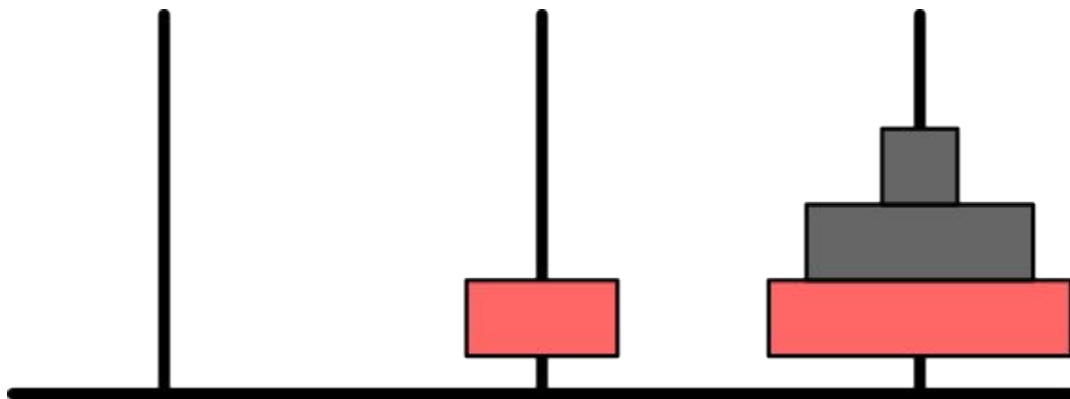
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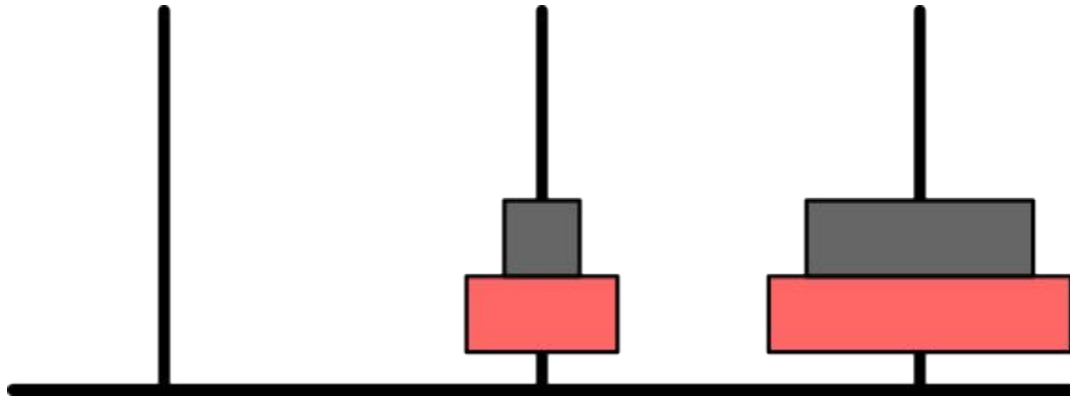


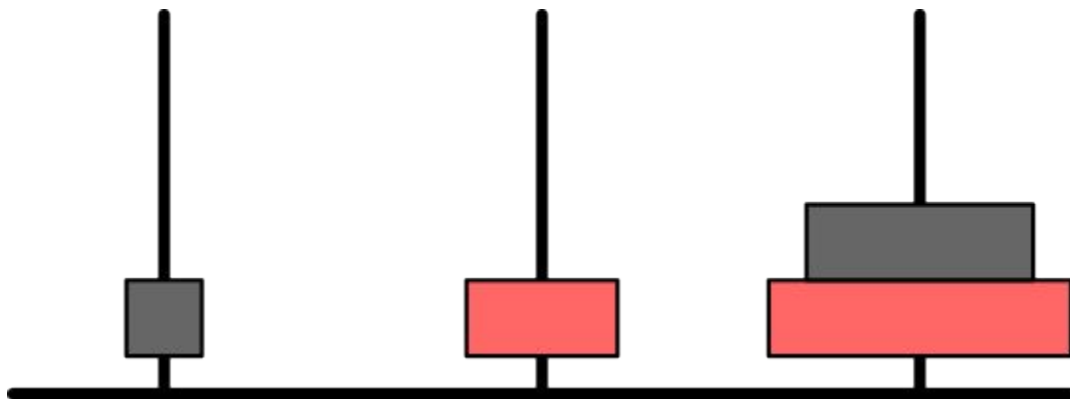


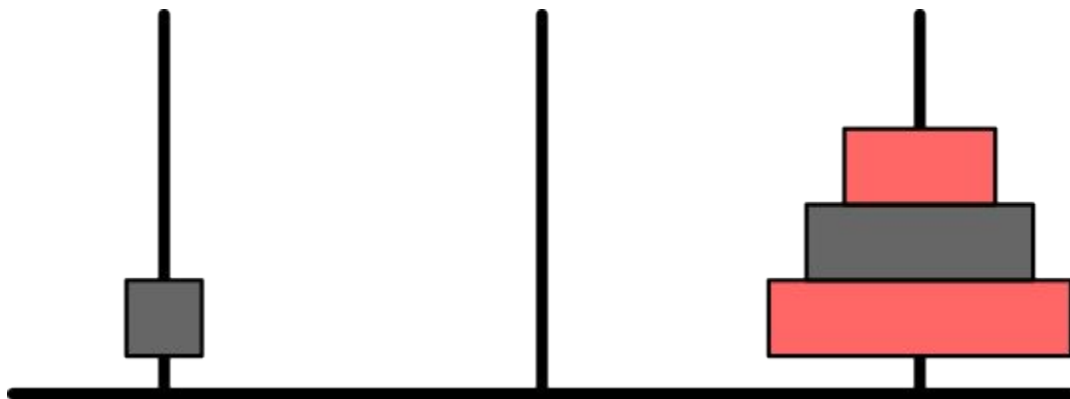


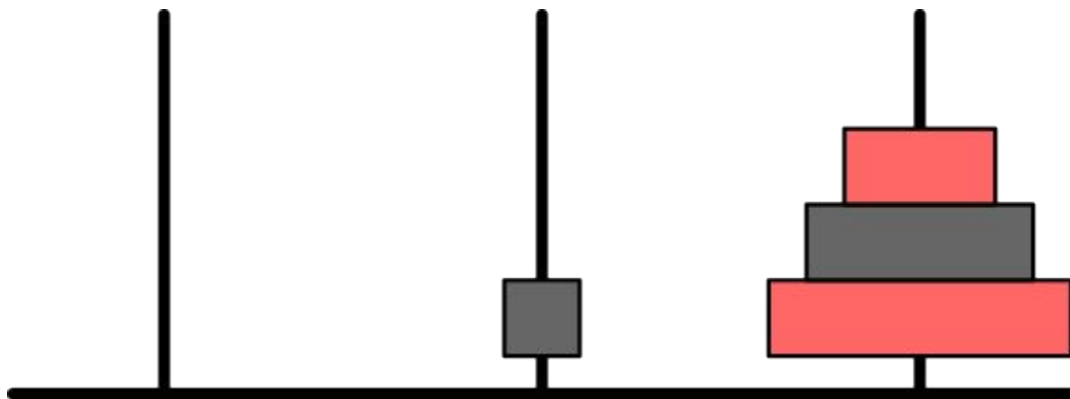


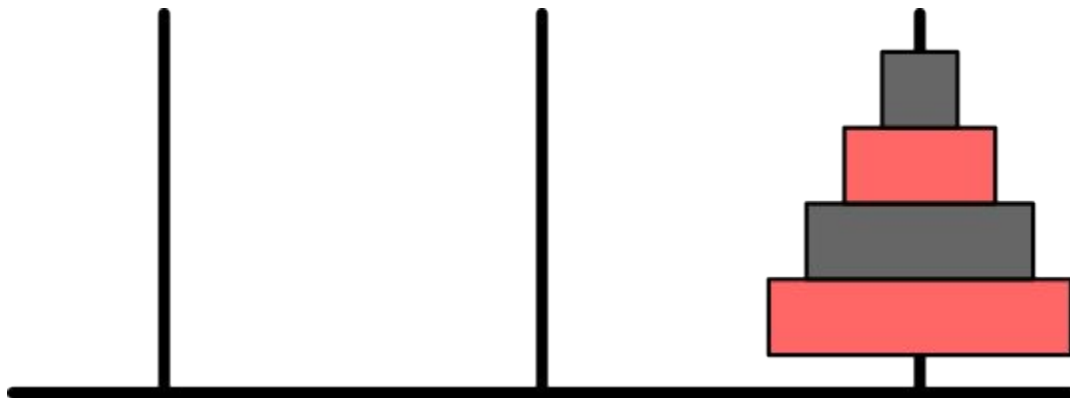






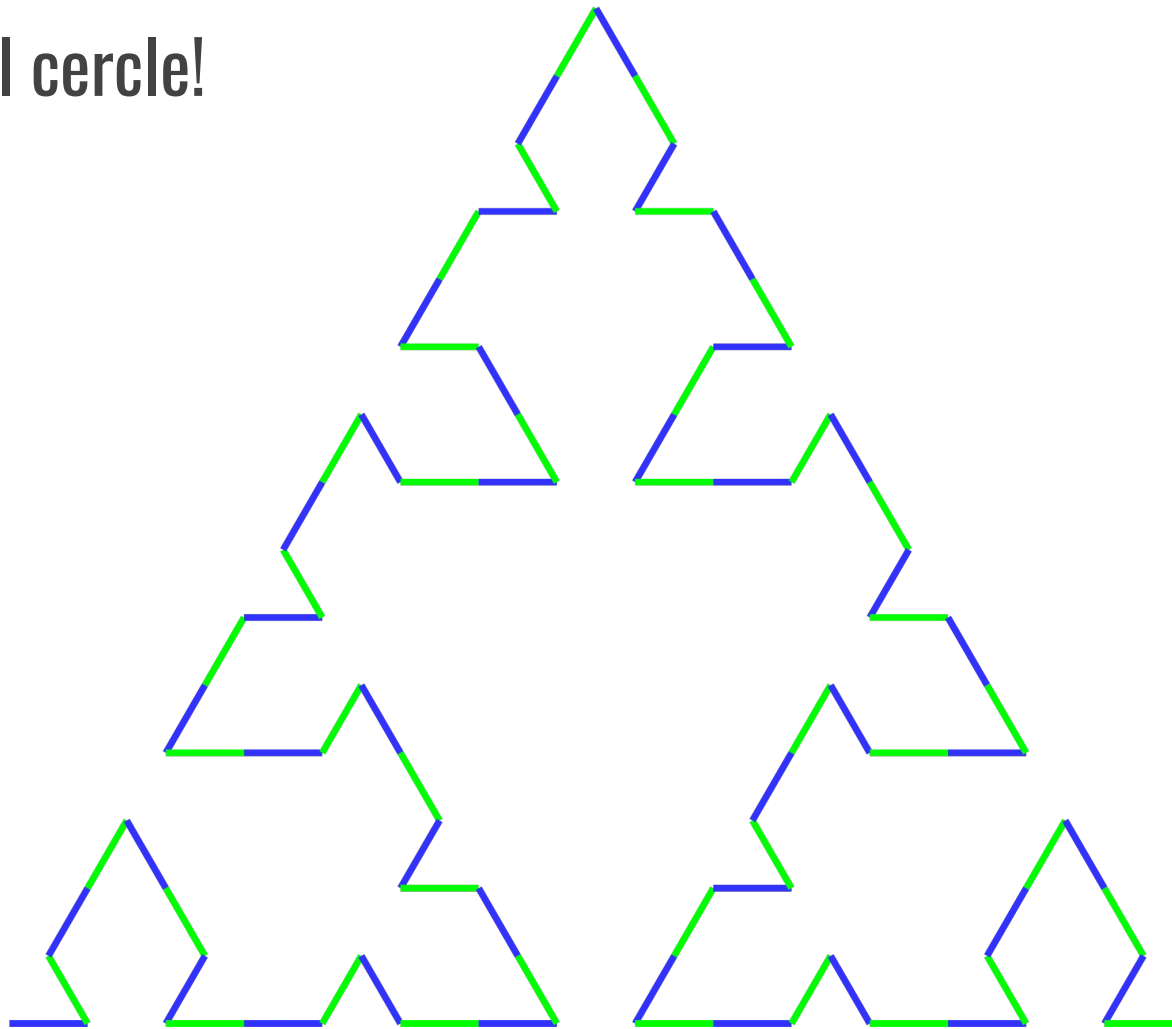




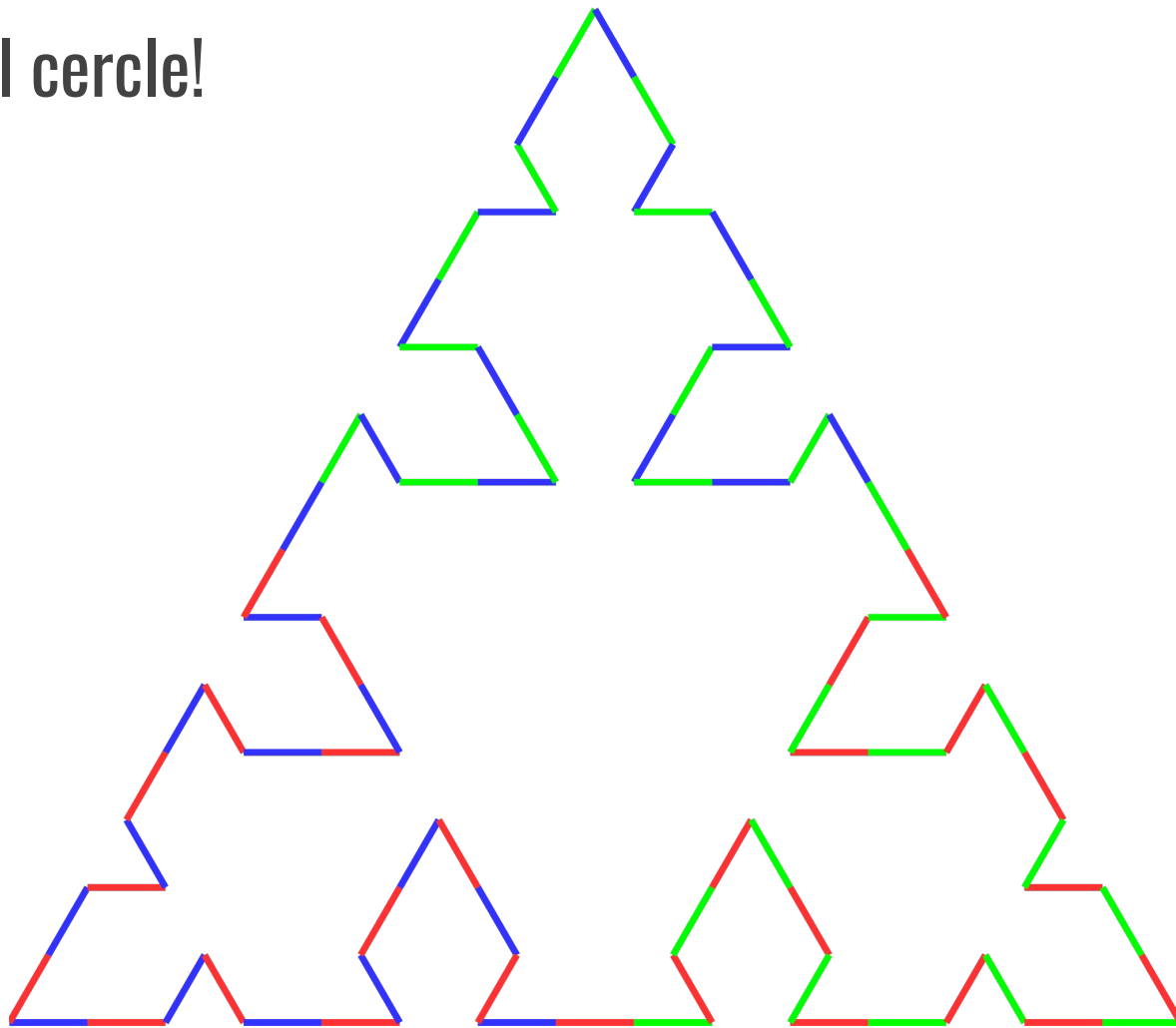


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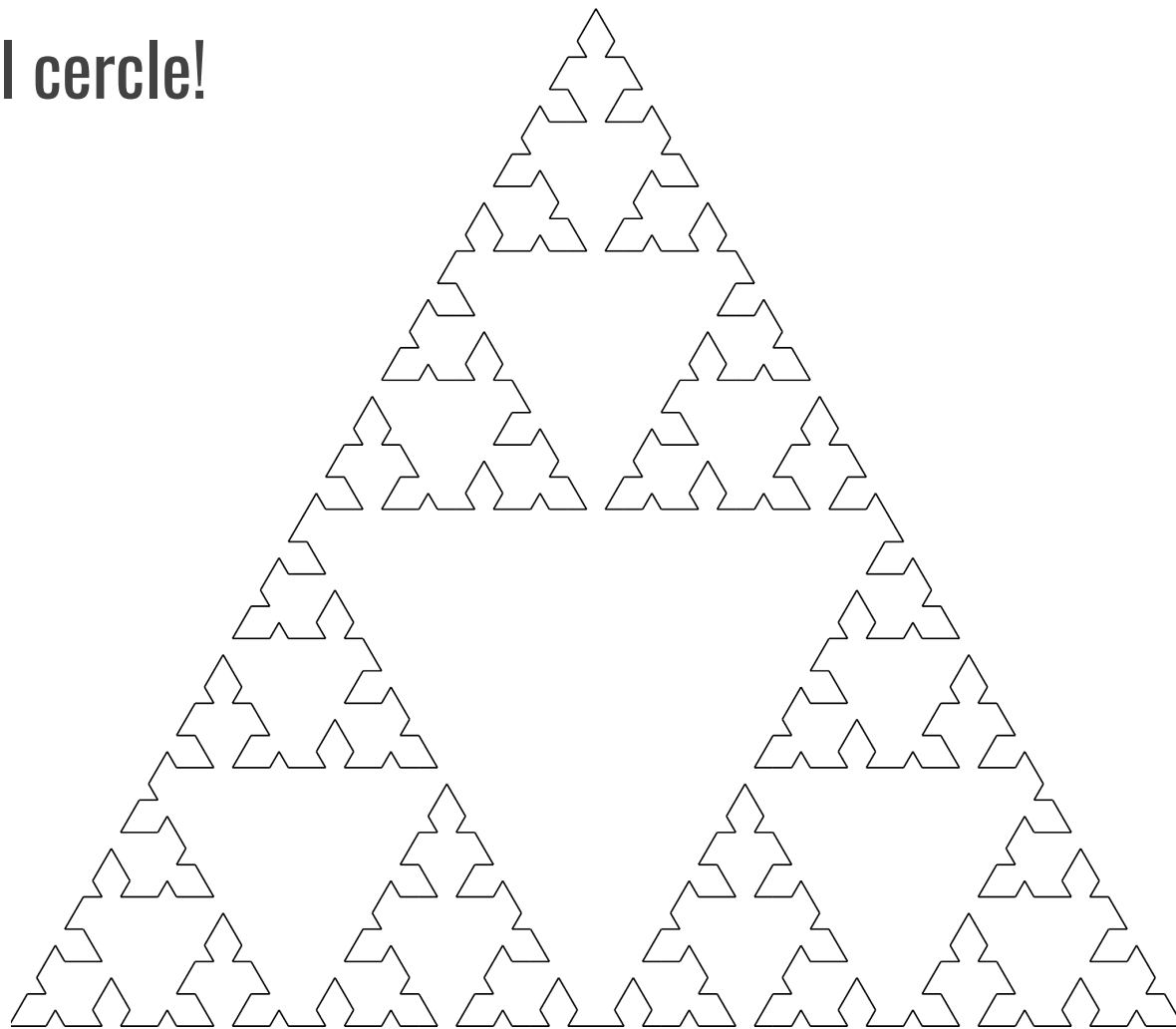
# Tanquem el cercle!



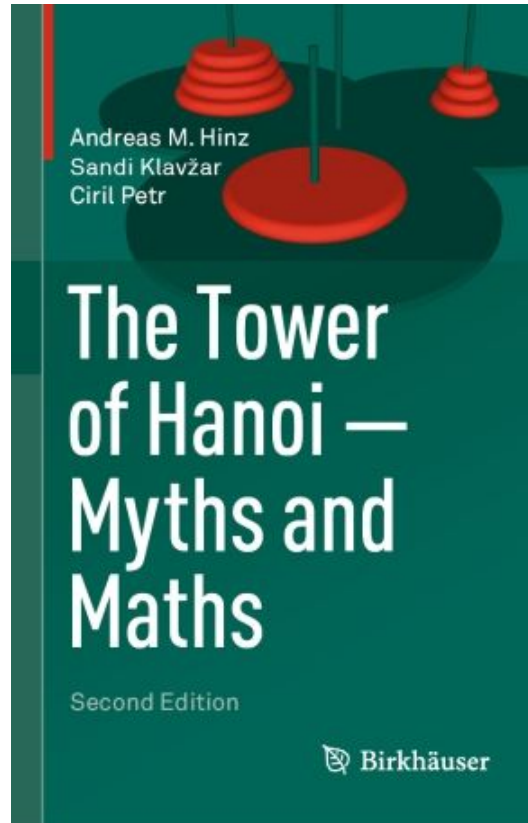
# Tanquem el cercle!



# Tanquem el cercle!



# Les torres de Hanoi - Referències



**LA referència**

**mmaca**  
**cornellà**

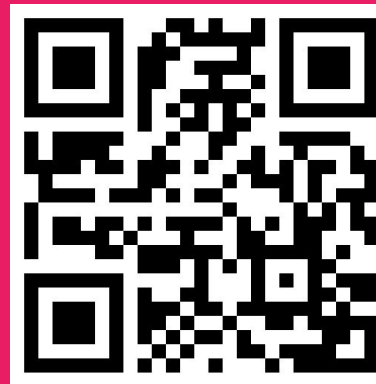
# Les torres de Hanoi - Referències

<https://puzzles.schwandtner.info/compendium/>





**Moltes gràcies!**



**Assistència:** [ja.cat/hanoi2026a](https://ja.cat/hanoi2026a)  
**Avaluació:** [ja.cat/hanoi2026b](https://ja.cat/hanoi2026b)