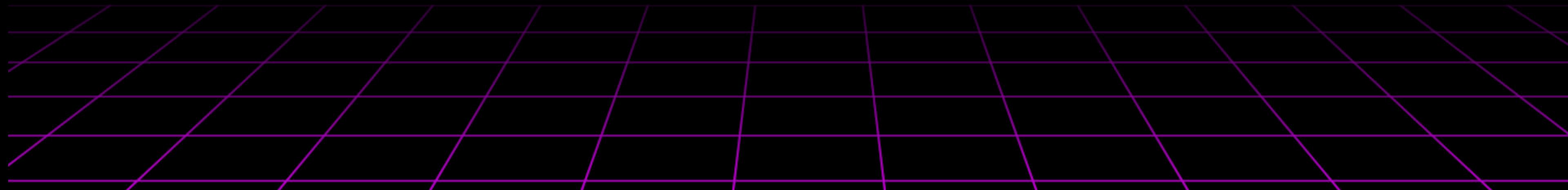




GRAB A BYTE

DYNAMIC PROGRAMMING

(KNAPSACK PROBLEM)





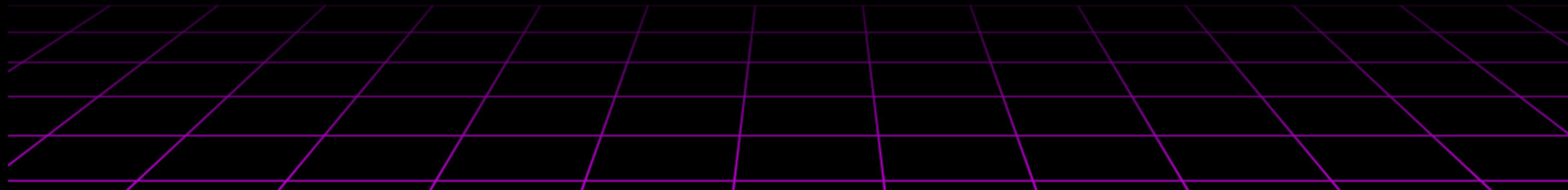
WHAT WE'VE COVERED SO FAR

Prior to Spring Break we covered: Linear and Binary Search. Bubble, Selection, Insertion, Merge and Quick Sort. Since Spring Break we have covered Breadth-First Search, Depth-First Search, Hashing and Dijkstras



WHAT WE ARE COVERING TODAY

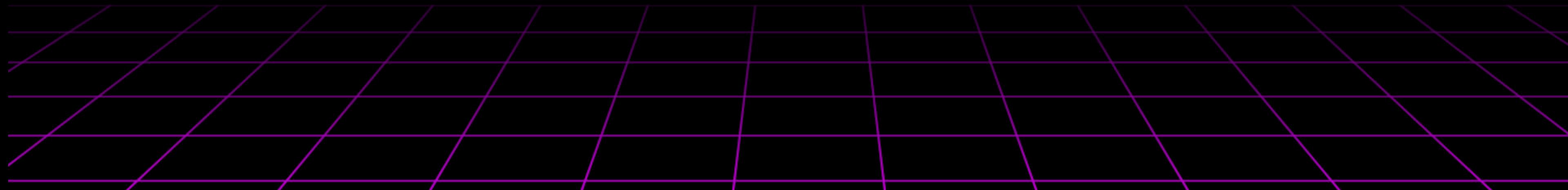
Today we are covering Dynamic Programming (Knapsack Problem)!





WHAT IS DYNAMIC PROGRAMMING

Dynamic Programming is a method for solving problems by breaking them into smaller sub-problems and reusing previously computed results.





WHAT IS DYNAMIC PROGRAMMING

Dynamic Programming Problems: Given a list of items with weight and value, and a maximum weight capacity, choose items to maximize value without going over the weight.



WHAT?



Think of it like packing a Knapsack (hence Knapsack Problem).

Your knapsack can only hold 10 lbs. So the items you pack cannot weigh more than 10 lbs combined and you want to get the most value out of what you pack.



EXAMPLE

What would you take if you could only pack 10 lbs?



Weight	Item	Value
4	Laptop	9
2	Headphones	6
3	Book	4
1	Charger	3
5	Jacket	7



Lets consider the following values and weights

values = v = [2, 2, 4, 5, 3]

weights = w = [3, 1, 3, 4, 2]



Capacity (aka. Weight)

	0	1	2	3	4	5	6	7
0								
1								
2								
3								
4								
5								

Rows are
number of
items

We will put
the value in
the cells.



So our “Knapsack” can hold 7 lbs, we have 5 items and we want to find the highest value of items.

	0	1	2	3	4	5	6	7
0								
1								
2								
3								
4								
5								



So lets look at are arrays from earlier:

```
values = v = [2, 2, 4, 5, 3]  
weights = w = [3, 1, 3, 4, 2]
```

	0	1	2	3	4	5	6	7
0								
1								
2								
3								
4								
5								



And lets group them by index

values = v = [2, 2, 4, 5, 3]
weights = w = [3, 1, 3, 4, 2]

And we'll assign
them a row

	0	1	2	3	4	5	6	7
0								
1								
2								
3								
4								
5								



And lets group them by index

values = v = [2, 2, 4, 5, 3]
weights = w = [3, 1, 3, 4, 2]

No items = empty bag

Empty

v[0], w[0] value 2, weight 3

Empty

v[1], w[1] value 2, weight 1

Empty

v[2], w[2] value 4, weight 3

Empty

v[3], w[3] value 5, weight 4

Empty

v[4], w[4] value 3, weight 2

Empty

0	1	2	3	4	5	6	7
0							
1							
2							
3							
4							
5							
6							
7							

•••••
We'll start filling out the cells starting with the first row. No items means no weights, so it is all 0s

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1								
2								
3								
4								
5								
6								
7								



What we are trying to do is to fill the cells with the best possible values we can achieve at that capacity!

Each row we do we will use the information from the previous row, as if we've already "packed" that item.

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1								
2								
3								
4								
5								



So, with row 2, we will go down the list to see if the weight of that item will fit

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1								
2								
3								
4								
5								
6								
7								



Since the weight is 3, we know it wouldn't fit in 0, 1, or 2 so we can't put the above number in all of those.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1								
2								
3								
4								
5								
6								
7								



Since the weight is 3, we know it wouldn't fit in 0, 1, or 2 so we can't put the above number in all of those.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	1	0	0	0				
2	2							
3	3							
4	4							
5	5							



When we can include the current item, we still look at the row above but shifted by the current item weight

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0], w[0] value 2, weight 3	1	0	0	0				
v[1], w[1] value 2, weight 1	2							
v[2], w[2] value 4, weight 3	3							
v[3], w[3] value 5, weight 4	4							
v[4], w[4] value 3, weight 2	5							



When we can include the current item, we still look at the row above but shifted by the current item weight

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0], w[0] value 2, weight 3	1	0	0	0				
v[1], w[1] value 2, weight 1	2							
v[2], w[2] value 4, weight 3	3							
v[3], w[3] value 5, weight 4	4							
v[4], w[4] value 3, weight 2	5							



Current weight is 3, 3 minus 3 is 0. So we can include the current item and the previous row column 0.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	1	0	0	0				
2								
3								
4								
5								
6								
7								

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



Current weight is 3, 3 minus 3 is 0. So we can include the current item and the previous row column 0.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	1	0	0	0	2			
2								
3								
4								
5								
6								
7								

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



And we can fill out the rest of this row using the same method of column - current weight, row value + current

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

1

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
Empty	0	0	0	0	0	0	0	0
$v[0], w[0]$ value 2, weight 3	1	0	0	0	2			
$v[1], w[1]$ value 2, weight 1	2							
$v[2], w[2]$ value 4, weight 3	3							
$v[3], w[3]$ value 5, weight 4	4							
$v[4], w[4]$ value 3, weight 2	5							



Col 4 - weight 3 = 1. Value at 1 in previous row is 0.

$$0 + \text{value } 2 = 2$$

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

1

$v[1], w[1]$ value 2, weight 1

2

$v[2], w[2]$ value 4, weight 3

3

$v[3], w[3]$ value 5, weight 4

4

$v[4], w[4]$ value 3, weight 2

5

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	0	2			
2								
3								
4								
5								
6								
7								



Col 4 - weight 3 = 1. Value at 1 in previous row is 0.

$$0 + \text{value } 2 = 2$$

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	1	0	0	0	2	2		
2								
3								
4								
5								
6								
7								

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



...and so forth

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2		
2								
3								
4								
5								
6								
7								



...and so forth

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	
2								
3								
4								
5								
6								
7								



...and so forth

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2								
3								
4								
5								
6								
7								



With that row done, we can move on to the next row

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0], w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1], w[1] value 2, weight 1	2							
v[2], w[2] value 4, weight 3	3							
v[3], w[3] value 5, weight 4	4							
v[4], w[4] value 3, weight 2	5							



With that row done, we can move on to the next row

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2								
3								
4								
5								



With a weight of 1 and a value of 2. We know a weight of 1 can't fit into 0, so we will make that first cell 0

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0							
3								
4								
5								

No items = empty bag Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



A weight of 1 can fit into 1, so we will do the same calculation as before. $\text{col } 1 - \text{weight } 1 = \text{col } 0$

No items = empty bag

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0							
3								
4								
5								

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



The value of the current item (2) plus the value in the previous row at 0 (which is 0) = 2

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0						
v[2] , w[2] value 4, weight 3	3							
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



The value of the current item (2) plus the value in the previous row at 0 (which is 0) = 2

No items = empty bag

Empty

v[0], w[0] value 2, weight 3

v[1], w[1] value 2, weight 1

v[2], w[2] value 4, weight 3

v[3], w[3] value 5, weight 4

v[4], w[4] value 3, weight 2

0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2
2	0	2					
3							
4							
5							



And we go down the list. $2 + \text{previous row's marked col} =$

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0], w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1], w[1] value 2, weight 1	2	0	2	2				
v[2], w[2] value 4, weight 3	3							
v[3], w[3] value 5, weight 4	4							
v[4], w[4] value 3, weight 2	5							



Here is when it gets interesting...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2				
3								
4								
5								



We can choose either the first item with a weight of 3 or the current item with a weight of 1. Both can't fit

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0], w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1], w[1] value 2, weight 1	2	0	2	2	2			
v[2], w[2] value 4, weight 3	3							
v[3], w[3] value 5, weight 4	4							
v[4], w[4] value 3, weight 2	5							



Thankfully they are the same weight so it doesn't matter,
but we would choose the smallest weight/highest value

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2				
3								
4								
5								



But things start to change again. Value of 2 plus the value in col 3 = 4.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2				
3								
4								
5								



If you think about it. A weight of 3 and a weight of 1 fit into a weight of 4

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4			
3								
4								
5								



And then we go down the line....

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4			
3								
4								
5								



Again, a value of 2 plus the value in col 4 is 2, which

equals 4

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4			
3								
4								
5								



Again, a value of 2 plus the value in col 4 is 2, which

equals 4

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4		
3								
4								
5								



...and so forth...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4		
3								
4								
5								



...and so forth...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	
3								
4								
5								



...and so forth...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3								
4								
5								



And we move on to the next row

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3								
4								
5								



And we move on to the next row

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3								
4								
5								



Here we are working with a weight of 3. So we will fill the cells with the values in the row above until 3

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3							
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



Here we are working with a weight of 3. So we will fill the cells with the values in the row above until 3

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2				
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



Once we get to 3. We do the math col 3 - weight of 3 =

	col 0							
	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2				
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



So our focus column is set!

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	1	0	0	0	2	2	2	2
2	2	0	2	2	2	4	4	4
3	3	0	2	2				
4	4							
5	5							



And we do the math again. value of current item + value

in column 0 = 4

No items = empty bag

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2					
4								
5								

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



And we do the math again. value of current item + value

in column 0 = 4

No items = empty bag

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4				
4								
5								

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



We shift and do the math again. Value of 4 plus value in

		col 1 = 6							
	0	1	2	3	4	5	6	7	
No items = empty bag	0	0	0	0	0	0	0	0	
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2	
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4	
v[2] , w[2] value 4, weight 3	3	0	2	2	4				
v[3] , w[3] value 5, weight 4	4								
v[4] , w[4] value 3, weight 2	5								



We shift and do the math again. Value of 4 plus value in

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2	4	6		
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



We shift and do the math again. Value of 4 plus value in

	col 2 = 6							
	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2	4	6		
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



We shift and do the math again. Value of 4 plus value in

	col 2 = 6							
	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2	4	6	6	
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



We shift and do the math again. Value of 4 plus value in

	col 3 = 6							
	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2	4	6	6	
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



We shift and do the math again. Value of 4 plus value in

	col 3 = 6							
	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2	4	6	6	6
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



We shift and do the math again. Value of 4 plus value in

	col 4 = 8							
	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2	4	6	6	6
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



We shift and do the math again. Value of 4 plus value in

	col 4 = 8							
	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2	4	6	6	8
v[3] , w[3] value 5, weight 4	4							
v[4] , w[4] value 3, weight 2	5							



And that row is done. We can move on to the next one

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4								
5								

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



Now that you have the idea. We'll go through the last two rows quickly.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4								
5								



Cells in cols 0-3 will be populated with the previous

row's numbers

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

1

$v[1], w[1]$ value 2, weight 1

2

$v[2], w[2]$ value 4, weight 3

3

$v[3], w[3]$ value 5, weight 4

4

$v[4], w[4]$ value 3, weight 2

5

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4				
5								



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5			
5								



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	1	0	0	0	2	2	2	2
2	2	0	2	2	2	4	4	4
3	3	0	2	2	4	6	6	8
4	4	0	2	2	4	5	7	
5	5							



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	
5								



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5								



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5								



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	1	0	0	0	2	2	2	2
2	2	0	2	2	2	4	4	4
3	3	0	2	2	4	6	6	8
4	4	0	2	2	4	5	7	7
5	5	0	2					

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	1	0	0	0	2	2	2	2
2	2	0	2	2	2	4	4	4
3	3	0	2	2	4	6	6	8
4	4	0	2	2	4	5	7	7
5	5	0	2	3				

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	1	0	0	0	2	2	2	2
2	2	0	2	2	2	4	4	4
3	3	0	2	2	4	6	6	8
4	4	0	2	2	4	5	7	7
5	5	0	2	3	5			



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5			



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7		



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	



...

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



Now that we are done, to figure out what items to include, we need to work backwards.

No items = empty bag

Empty

$v[\theta]$, $w[\theta]$ value 2, weight

v[1], w[1] value 2, weight

v[2], w[2] value 4, weight

v[3], w[3] value 5. weight

v[4], w[4] value 3, weight

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



We start at the value 10

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



We start at the value 10

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

value 2, weight 1

$v[1], w[1]$ value 2, weight 1

value 4, weight 3

$v[2], w[2]$ value 4, weight 3

value 5, weight 4

$v[3], w[3]$ value 5, weight 4

value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



The way we see if we include the item is if the number we are checking is different than the number above it.

No items = empty bag

Empty

$v[\theta]$, $w[\theta]$ value 2, weight

v[1], w[1] value 2. weight

v[2], w[2] value 4. weight

v[3], w[3] value 5. weight

v[4], w[4] value 3, weight

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



The idea being, if the two are different then the item for the row we are on must have been included

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2	4	6	6	8
v[3] , w[3] value 5, weight 4	4	0	2	2	4	5	7	7
v[4] , w[4] value 3, weight 2	5	0	2	3	5	5	7	8

9
10



Since 9 and 10 are different. The item on the row with the 10 must have been included.

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0], w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1], w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2], w[2] value 4, weight 3	3	0	2	2	4	6	6	8
v[3], w[3] value 5, weight 4	4	0	2	2	4	5	7	7
v[4], w[4] value 3, weight 2	5	0	2	3	5	5	7	8



Since 9 and 10 are different. The item on the row with the 10 must have been included.

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0], w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1], w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2], w[2] value 4, weight 3	3	0	2	2	4	6	6	8
v[3], w[3] value 5, weight 4	4	0	2	2	4	5	7	7
v[4], w[4] value 3, weight 2	5	0	2	3	5	5	7	8



Now we subtract the number of columns for the weight. So we move 2 columns to the left because the weight was 2.

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
v[0], w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1], w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2], w[2] value 4, weight 3	3	0	2	2	4	6	6	8
v[3], w[3] value 5, weight 4	4	0	2	2	4	5	7	7
v[4], w[4] value 3, weight 2	5	0	2	3	5	5	7	8



Now we subtract the number of columns for the weight. So we move 2 columns to the left because the weight was 2.

No items = empty bag

Empty

v[0], w[0] value 2, weight 3

v[1], w[1] value 2, weight 1

v[2], w[2] value 4, weight 3

v[3], w[3] value 5, weight 4

v[4], w[4] value 3, weight 2

0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2
2	0	2	2	2	4	4	4
3	0	2	2	4	6	6	6
4	0	2	2	4	5	7	7
5	0	2	3	5	5	7	8
6	1	3	5	7	9	10	10



And we check it against the value above it.

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ **value 3, weight 2**



7 and 6 are different so the item from the row we are on
as been included

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
Empty	0	0	0	0	0	0	0	0
v[0] , w[0] value 2, weight 3	1	0	0	0	2	2	2	2
v[1] , w[1] value 2, weight 1	2	0	2	2	2	4	4	4
v[2] , w[2] value 4, weight 3	3	0	2	2	4	6	6	8
v[3] , w[3] value 5, weight 4	4	0	2	2	4	5	7	9
v[4] , w[4] value 3, weight 2	5	0	2	3	5	5	7	8



7 and 6 are different so the item from the row we are on
as been included

No items = empty bag

Empty

v[θ], w[θ] value 2, weight

v[1], w[1] value 2, weight

v[2], w[2] value 4, weight

v[3], w[3] value 5, weight

v[4], w[4] value 3, weight

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



Now we move 4 cols to the left because the item is a weight of 4.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



Now we move 4 cols to the left because the item is a weight of 4.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

Empty

$v[1], w[1]$ value 2, weight 1

Empty

$v[2], w[2]$ value 4, weight 3

Empty

$v[3], w[3]$ value 5, weight 4

Empty

$v[4], w[4]$ value 3, weight 2

Empty

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



And we check it against the number in the col above.

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10

No items = empty bag

Empty

v[0] , w[0] value 2, weight 3

v[1] , w[1] value 2, weight 1

v[2] , w[2] value 4, weight 3

v[3] , w[3] **value 5, weight 4**

v[4] , w[4] **value 3, weight 2**



2 and 2 are the same so we will not include this row's item and we'll shift up.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ **value 5, weight 4**

$v[4], w[4]$ **value 3, weight 2**



0 and 2 are different so we include the current row's item.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



0 and 2 are different so we include the current row's item.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

$v[1], w[1]$ **value 2, weight 1**

$v[2], w[2]$ *value 4, weight 3*

$v[3], w[3]$ **value 5, weight 4**

$v[4], w[4]$ **value 3, weight 2**

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	2	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10



and we move one col to the left because that row's weight

is 1.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

0

1

2

3

4

5

0

0

0

0

0

0

0

2

2

2

2

2

2

2

3

3

3

3

3

3

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7

$v[1], w[1]$ **value 2, weight 1**

$v[2], w[2]$ **value 4, weight 3**

$v[3], w[3]$ **value 5, weight 4**

$v[4], w[4]$ **value 3, weight 2**



and we move one col to the left because that row's weight

is 1.

No items = empty bag

Empty

$v[0], w[0]$ value 2, weight 3

	0	1	2	3	4	5	6	7
0	0	0	0	0	0	0	0	0
1	0	0	0	0	2	2	2	2
2	0	2	2	2	4	4	4	4
3	0	2	2	4	6	6	6	8
4	0	2	2	4	5	7	7	9
5	0	2	3	5	5	7	8	10

$v[1], w[1]$ value 2, weight 1

$v[2], w[2]$ value 4, weight 3

$v[3], w[3]$ value 5, weight 4

$v[4], w[4]$ value 3, weight 2



And we check it against the item in the row above, which is the same number so that item doesn't get chosen.

	0	1	2	3	4	5	6	7
No items = empty bag	0	0	0	0	0	0	0	0
$v[0], w[0]$	value 2, weight 3	1	0	0	2	2	2	2
$v[1], w[1]$	value 2, weight 1	2	0	2	2	4	4	4
$v[2], w[2]$	value 4, weight 3	3	0	2	4	6	6	8
$v[3], w[3]$	value 5, weight 4	4	0	2	4	5	7	7
$v[4], w[4]$	value 3, weight 2	5	0	2	3	5	5	7



THE PSEUDOCODE

```
function KNAPSACK(values, weights, capacity):
    n = number of items

    CREATE 2D table dp[n+1][capacity+1] filled with 0

    FOR i from 1 to n:
        FOR w from 1 to capacity:
            IF weights[i-1] <= w THEN:
                dp[i][w] ← MAX(
                    dp[i-1][w],
                    values[i-1] + dp[i-1][w - weights[i-1]])
            ELSE:
                dp[i][w] ← dp[i-1][w]
    RETURN dp[n][capacity]
```



EXAMPLES REPLIT AND GITHUB! PLEASE GO TO:
[HTTPS://REPLIT.COM/@RIKKIEHRHART/](https://replit.com/@RIKKIEHRHART)

GRABABYTE

[HTTPS://GITHUB.COM/
RIKKITOMIKOEHRHART/GRABABYTE](https://github.com/RIKKITOMIKOEHRHART/GRABABYTE)



UP NEXT

Apr 30 - Union-Find

May 7 - Kruskal's Algorithm

May 14 - Prim's Algorithm

Questions? - rikki.ehrhart@ausitncc.edu

If you'd like the opportunity to run a Grab a Byte algorithm workshop, please let me know!