



+ Code



30s + Text



```
# https://www.programiz.com/python-programming/online-compiler/
# use this online compiler, copy my code then run it
# Quantum Physics - Statistical Mechanics - Maxwell-Boltzmann distribution
# Author: Stephanie Zhang
# https://github.com/pandanomial
```



```
...
Physics 4D
Statistical Mechanics
PS4-2
1. Six identical but distinguishable particles share seven units of energy.
Each particle can have energy only in integral amounts.
Create a table that lists all possible macrostates and for each macrostate
compute its multiplicity.
'''
```

```
# You can update NUM_OF_PARTICLES and NUM_OF_ENERGY as needed, eg
NUM_OF_ENERGY = 7
NUM_OF_PARTICLES = 6
```

```
# DO NOT change any code below
```

```
# total macrostates
macrostates = 0
# total microstates
microstates = 0
# temp holding each macrostate detailed info
macrostate_dict = {}
# holds all macrostates detailed info
total_macrostates_dict = {}
```

```
# for students who don't know python or don't know how to install
# any libraries. I wrote this factorial function for students' convince
def factorial(n):
    fact = 1
    for i in range(1, n+1):
        fact = fact * i
    return fact
```

```
# If the object is a dictionary, create a new dictionary and recursively copy its contents
def deep_copy(obj):
    #if isinstance(obj, dict):
    new_dict = {}
    for key, value in obj.items():
        new_dict[key] = value
    return new_dict
```

```
# Maxwell-Boltzmann distribution in visual presentation:
# each star * represents each particle
def format_distribution(macrostate_dict):
    rows = []
```



RAM

Disk

Disk



```

for n in range(NUM_OF_ENERGY, -1, -1):
    e_level = f"\033[92m{n}\033[0m"
    row = [str(e_level)]
    #row.append('\033[94mThis is blue text\033[0m')

    stars = macrostate_dict[n]
    for i in range(NUM_OF PARTICLES):
        if i < stars:
            # ANSI escape code for colored text
            # print("\033[91mThis is red text\033[0m")
            row.append('\033[91m*\033[0m')
        else:
            # ANSI escape code for colored text
            # print("\033[92mThis is green text\033[0m")
            row.append('\033[92m-\033[0m')

    row.append(f"\033[92m|\033[0m Energy level = \033[92m{n}\033[0m")
    row.append(f", Particles at this level = \033[91m{stars}\033[0m")
    rows.append(' '.join(row))
return '\n'.join(rows)

# total macrostates saved in variable macrostates
def solve_macrostates(index, energy_sum, particle_sum):
    global macrostates

    if index == NUM_OF_ENERGY + 1:

        # for print out microstates of each macrostate
        str_microstate = ''
        for i in range(NUM_OF_ENERGY + 1):
            if i < NUM_OF_ENERGY:
                str_microstate = str_microstate + str(macrostate_dict[i]) + '! * '
            else:
                str_microstate = str_microstate + str(macrostate_dict[i]) + '!!'

        # for calculating actuarial microstates of each macrostate
        int_microstate = factorial(NUM_OF_PARTICLES)
        for i in range(NUM_OF_ENERGY + 1):
            int_microstate = int(int_microstate / factorial(macrostate_dict[i]))

        # Recursive: Base case to check if the current configuration meets the conditions
        if energy_sum == NUM_OF_ENERGY and particle_sum == NUM_OF_PARTICLES:
            macrostates += 1
            print('\n\n\n\n\n')
            print(f"Macrostate # {macrostates}")
            print(format_distribution(macrostate_dict))
            print("\033[1;35m")
            print(f"                                {NUM_OF_PARTICLES}!")
            print("Microstates = -----")
            print('          ' + str_microstate)
            print(f"Microstates = {int_microstate}\033[0m")
            print()
            total_macrostates_dict[macrostates] = deep_copy(macrostate_dict)

    return

    # Try all possible values for macrostate_dict[index]
    for value in range(NUM_OF_ENERGY):
        macrostate_dict[index] = value
        # Recursively solve for the next index
        solve_macrostates(index + 1, energy_sum + macrostate_dict[index] * index,
                          particle_sum + macrostate_dict[index])

# total microstates saved in microstates
def total_microstates():

```

```

global microstates
microstates = factorial(NUM_OF_ENERGY + NUM_OF_PARTICLES - 1)/factorial(NUM_OF_ENERGY)/factorial(NUM_OF_PARTICLES)

print("\033[1;35m           (NUM_OF_ENERGY + NUM_OF_PARTICLES - 1)!")
print("Total Microstates = -----")
print("           (NUM_OF_ENERGY!) * (NUM_OF_PARTICLES - 1)!")
print()
print(f"Total Microstates = {int(microstates)}\033[0m")

# print out again
def print_total_macrostates_dict(total_macrostates_dict):
    for key, value in total_macrostates_dict.items():
        print(key, value)

# print out tables
def display_probabilities():
    print("You can update \033[1mNUM_OF_PARTICLES\033[0m and \033[1mNUM_OF_ENERGY\033[0m as needed, eg")
    print()
    print("\033[1mSix\033[0m identical but distinguishable particles share \033[1mseven\033[0m units of energy.")
    print("Each particle can have energy only in integral amounts.")
    print()
    print("Create a table that lists all possible macrostates and for each macrostate")
    print("compute its multiplicity.")
    print()
    print(f"\033[0;32mNUM_OF_PARTICLES = {NUM_OF_PARTICLES}")
    print(f"NUM_OF_ENERGY = {NUM_OF_ENERGY}\033[0m")
    print()
    total_microstates()
    solve_macrostates(0, 0, 0)
    print("\033[91mA Again, print out all the macrostates in a different format:\033[0m")
    print_total_macrostates_dict(total_macrostates_dict)

display_probabilities()

```

→ You can update **NUM\_OF\_PARTICLES** and **NUM\_OF\_ENERGY** as needed, eg

**Six** identical but distinguishable particles share **seven** units of energy.  
Each particle can have energy only in integral amounts.

Create a table that lists all possible macrostates and for each macrostate  
compute its multiplicity.

```
NUM_OF_PARTICLES = 6
NUM_OF_ENERGY = 7
```

```
(NUM_OF_ENERGY + NUM_OF_PARTICLES - 1)!
Total Microstates = -----
           (NUM_OF_ENERGY!) * (NUM_OF_PARTICLES - 1)!
```

```
Total Microstates = 792
```

```

Macrostate # 1
7| - - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - - | Energy level = 5 , Particles at this level = 0
4| - - - - - | Energy level = 4 , Particles at this level = 0
3| - - - - - | Energy level = 3 , Particles at this level = 0
2| * - - - - | Energy level = 2 , Particles at this level = 1
1| * * * * * - | Energy level = 1 , Particles at this level = 5
0| - - - - - | Energy level = 0 , Particles at this level = 0

6!
Microstates = -----
           0! * 5! * 1! * 0! * 0! * 0! * 0! * 0!
Microstates = 6
```



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```
→ Macrostate # 2
7| - - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - - | Energy level = 5 , Particles at this level = 0
4| - - - - - | Energy level = 4 , Particles at this level = 0
3| - - - - - | Energy level = 3 , Particles at this level = 0
2| * * - - - | Energy level = 2 , Particles at this level = 2
1| * * * - - | Energy level = 1 , Particles at this level = 3
0| * - - - - | Energy level = 0 , Particles at this level = 1
```

6!

Microstates = -----  
                1! \* 3! \* 2! \* 0! \* 0! \* 0! \* 0! \* 0!  
Microstates = 60

**Microstates = 60**

```
Macrostate # 3
7 | - - - - - | Energy level = 7 , Particles at this level = 0
6 | - - - - - | Energy level = 6 , Particles at this level = 0
5 | - - - - - | Energy level = 5 , Particles at this level = 0
4 | - - - - - | Energy level = 4 , Particles at this level = 0
3 | * - - - - | Energy level = 3 , Particles at this level = 1
2 | - - - - - | Energy level = 2 , Particles at this level = 0
1 | * * * * - | Energy level = 1 , Particles at this level = 4
0 | * - - - - | Energy level = 0 , Particles at this level = 1
```

6!

```
Microstates = -----
           1! * 4! * 0! * 1! * 0! * 0! * 0! * 0!
Microstates = 30
```

**Microstates = 30**

```
Macrostate # 4
7| - - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - - | Energy level = 5 , Particles at this level = 0
4| - - - - - | Energy level = 4 , Particles at this level = 0
3| - - - - - | Energy level = 3 , Particles at this level = 0
2| * * * - - | Energy level = 2 , Particles at this level = 3
1| * - - - - | Energy level = 1 , Particles at this level = 1
0| * * - - - | Energy level = 0 , Particles at this level = 2
```

6!

```
Microstates = -----  
              2! * 1! * 3! * 0! * 0! * 0! * 0! * 0!  
Microstates = 60
```



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A set of small, light-gray navigation icons located at the bottom of the page. From left to right, they include: an upward arrow, a downward arrow, a circular arrow, a speech bubble, a gear, a square with a diagonal line, a trash can, and three vertical dots.

```
Macrostate # 5
7| - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - | Energy level = 5 , Particles at this level = 0
4| - - - - | Energy level = 4 , Particles at this level = 0
3| * - - - | Energy level = 3 , Particles at this level = 1
2| * - - - | Energy level = 2 , Particles at this level = 1
1| ** - - - | Energy level = 1 , Particles at this level = 2
0| ** - - - | Energy level = 0 , Particles at this level = 2
```

6!

```
Microstates = -----  
              2! * 2! * 1! * 1! * 0! * 0! * 0! * 0!  
Microstates = 180
```

**MICROSTATES = 180**

<>

A small, dark gray rectangular button with a white right-pointing arrow icon in the center.

```
Macrostate # 6
7| - - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - - | Energy level = 5 , Particles at this level = 0
4| * - - - - | Energy level = 4 , Particles at this level = 1
3| - - - - - | Energy level = 3 , Particles at this level = 0
2| - - - - - | Energy level = 2 , Particles at this level = 0
1| * * * - - | Energy level = 1 , Particles at this level = 3
0| * * - - - | Energy level = 0 , Particles at this level = 2
```

6!

```
Microstates = -----  
              2! * 3! * 0! * 0! * 1! * 0! * 0! * 0!  
Microstates = 60
```

MICROSTATES = 60

```
Macrostate # 7
7| - - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - - | Energy level = 5 , Particles at this level = 0
4| - - - - - | Energy level = 4 , Particles at this level = 0
3| * - - - - | Energy level = 3 , Particles at this level = 1
2| ** - - - - | Energy level = 2 , Particles at this level = 2
1| - - - - - | Energy level = 1 , Particles at this level = 0
0| *** - - - | Energy level = 0 , Particles at this level = 3
```

6!

```
Microstates = -----  
                  3! * 0! * 2! * 1! * 0! * 0! * 0! * 0!  
Microstates = 60
```

Microstates = 60

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```
→ Macrostate # 8
7| - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - | Energy level = 5 , Particles at this level = 0
4| - - - - | Energy level = 4 , Particles at this level = 0
3| * * - - - | Energy level = 3 , Particles at this level = 2
2| - - - - | Energy level = 2 , Particles at this level = 0
1| * - - - - | Energy level = 1 , Particles at this level = 1
0| * * * - - | Energy level = 0 , Particles at this level = 3
```

6!

$$\text{Microstates} = \dots$$

Microstates = 60

```
Macrostate # 9
7| - - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - - | Energy level = 5 , Particles at this level = 0
4| * - - - - | Energy level = 4 , Particles at this level = 1
3| - - - - - | Energy level = 3 , Particles at this level = 0
2| * - - - - | Energy level = 2 , Particles at this level = 1
1| * - - - - | Energy level = 1 , Particles at this level = 1
0| * * * * * | Energy level = 0 , Particles at this level = 3
```

61

$$\text{Microstates} = \frac{6!}{3! * 1! * 1! * 0! * 1! * 0! * 0!} = 60$$

**Microstates = 120**

Macrostate # 19

```
Macrostate # 10  
7| - - - - - | Energy level = 7 , Particles at this level = 0  
6| - - - - - | Energy level = 6 , Particles at this level = 0  
5| * - - - - | Energy level = 5 , Particles at this level = 1  
4| - - - - - | Energy level = 4 , Particles at this level = 0  
3| - - - - - | Energy level = 3 , Particles at this level = 0  
2| - - - - - | Energy level = 2 , Particles at this level = 0  
1| * * - - - | Energy level = 1 , Particles at this level = 2  
0| * * * - - | Energy level = 0 , Particles at this level = 3
```

6!

$$\text{Microstates} = \frac{N!}{(n_1! n_2! \dots n_k!)}$$

**Microstates = 60**



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## {x} Macrostate # 11

```
7| - - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - - | Energy level = 5 , Particles at this level = 0
4| * - - - - | Energy level = 4 , Particles at this level = 1
3| * - - - - | Energy level = 3 , Particles at this level = 1
2| - - - - - | Energy level = 2 , Particles at this level = 0
1| - - - - - | Energy level = 1 , Particles at this level = 0
0| * * * * - - | Energy level = 0 , Particles at this level = 4
```

6!

```
Microstates = -----
4! * 0! * 0! * 1! * 1! * 0! * 0! * 0!
```

```
Microstates = 30
```



## Macrostate # 12

```
7| - - - - - | Energy level = 7 , Particles at this level = 0
6| - - - - - | Energy level = 6 , Particles at this level = 0
5| * - - - - | Energy level = 5 , Particles at this level = 1
4| - - - - - | Energy level = 4 , Particles at this level = 0
3| - - - - - | Energy level = 3 , Particles at this level = 0
2| * - - - - | Energy level = 2 , Particles at this level = 1
1| - - - - - | Energy level = 1 , Particles at this level = 0
0| * * * * - - | Energy level = 0 , Particles at this level = 4
```

6!

```
Microstates = -----
4! * 0! * 1! * 0! * 0! * 1! * 0! * 0!
```

```
Microstates = 30
```

## Macrostate # 13

```
7| - - - - - | Energy level = 7 , Particles at this level = 0
6| * - - - - | Energy level = 6 , Particles at this level = 1
5| - - - - - | Energy level = 5 , Particles at this level = 0
4| - - - - - | Energy level = 4 , Particles at this level = 0
3| - - - - - | Energy level = 3 , Particles at this level = 0
2| - - - - - | Energy level = 2 , Particles at this level = 0
1| * - - - - | Energy level = 1 , Particles at this level = 1
0| * * * * - - | Energy level = 0 , Particles at this level = 4
```

6!

```
Microstates = -----
4! * 1! * 0! * 0! * 0! * 0! * 1! * 0!
```

```
Microstates = 30
```



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→

```
Macrostate # 13
7| - - - - | Energy level = 7 , Particles at this level = 0
6| * - - - | Energy level = 6 , Particles at this level = 1
5| - - - - | Energy level = 5 , Particles at this level = 0
4| - - - - | Energy level = 4 , Particles at this level = 0
3| - - - - | Energy level = 3 , Particles at this level = 0
2| - - - - | Energy level = 2 , Particles at this level = 0
1| * - - - | Energy level = 1 , Particles at this level = 1
0| * * * * - | Energy level = 0 , Particles at this level = 4
```

6!

**Microstates = -----**

$$4! * 1! * 0! * 0! * 0! * 0! * 1! * 0!$$

**Microstates = 30**

```
Macrostate # 14
7| * - - - - | Energy level = 7 , Particles at this level = 1
6| - - - - - | Energy level = 6 , Particles at this level = 0
5| - - - - - | Energy level = 5 , Particles at this level = 0
4| - - - - - | Energy level = 4 , Particles at this level = 0
3| - - - - - | Energy level = 3 , Particles at this level = 0
2| - - - - - | Energy level = 2 , Particles at this level = 0
1| - - - - - | Energy level = 1 , Particles at this level = 0
0| * * * * * - | Energy level = 0 , Particles at this level = 5
```

6!

Microstates = -----

5! \* 0! \* 0! \* 0! \* 0! \* 0! \* 0! \* 0! \* 1!

Microstates = 6

Again, print out all the macrostates in a different format:

```
1 {0: 0, 1: 5, 2: 1, 3: 0, 4: 0, 5: 0, 6: 0, 7: 0}
2 {0: 1, 1: 3, 2: 2, 3: 0, 4: 0, 5: 0, 6: 0, 7: 0}
3 {0: 1, 1: 4, 2: 0, 3: 1, 4: 0, 5: 0, 6: 0, 7: 0}
4 {0: 2, 1: 1, 2: 3, 3: 0, 4: 0, 5: 0, 6: 0, 7: 0}
5 {0: 2, 1: 2, 2: 1, 3: 1, 4: 0, 5: 0, 6: 0, 7: 0}
6 {0: 2, 1: 3, 2: 0, 3: 0, 4: 1, 5: 0, 6: 0, 7: 0}
7 {0: 3, 1: 0, 2: 2, 3: 1, 4: 0, 5: 0, 6: 0, 7: 0}
8 {0: 3, 1: 1, 2: 0, 3: 2, 4: 0, 5: 0, 6: 0, 7: 0}
9 {0: 3, 1: 1, 2: 1, 3: 0, 4: 1, 5: 0, 6: 0, 7: 0}
10 {0: 3, 1: 2, 2: 0, 3: 0, 4: 0, 5: 1, 6: 0, 7: 0}
11 {0: 4, 1: 0, 2: 0, 3: 1, 4: 1, 5: 0, 6: 0, 7: 0}
12 {0: 4, 1: 0, 2: 1, 3: 0, 4: 0, 5: 1, 6: 0, 7: 0}
13 {0: 4, 1: 1, 2: 0, 3: 0, 4: 0, 5: 0, 6: 1, 7: 0}
14 {0: 5, 1: 0, 2: 0, 3: 0, 4: 0, 5: 0, 6: 0, 7: 1}
```