


## Algorithms Practical 3 - Ruth Dooley 19300753 Answers

### Warm-up questions

1. What are the two principal characteristics of a recursive algorithm?
  - A recursive algorithm must have a base case, the most basic version of the problem
  - The recursive algorithm must call itself recursively, therefore changing its state and moving closer towards the base case to which the problem can be solved

2. Recursion is..

Answer	
	theoretically interesting but rarely used in actual programs
	theoretically uninteresting and rarely used in programs
	theoretically powerful and often used in algorithms that could benefit from recursive methods

3. True or false: All recursive functions can be implemented iteratively  
True
4. True or false: if a recursive algorithm does NOT have a base case, the compiler will detect this and throw a compile error?  
True, the compiler will not run correctly otherwise
5. True or false: a recursive function must have a void return type.  
False
6. True or False: Recursive calls are usually contained within a loop.  
True
7. True or False: Infinite recursion can occur when a recursive algorithm does not contain a base case.  
True
8. Which of these statements is true about the following code?  

```
int mystery(int n)
{
    if (n>0) return n + mystery(n-1);
    return 0;
}
```

Your answer	
	The base case for this recursive method is an argument with any value which is greater than zero.

	The base case for this recursive function is an argument with the value zero.
👍	There is no base case.

9. List common bugs associated with recursion?

	No base case provided
	Base case is never reached
	An infinite loop is reached and the program runs infinitely
	Takes up a lot of space in the program

10. What method can be used to address recursive algorithms that excessively recompute?

- Re-evaluate the base case given. Is this the most fundamental and basic question that can be answered.
- Re-evaluate how to divide the steps to work towards the base case, whether or not this is the most efficient way to achieve this result.

**Fibonacci Exercise**

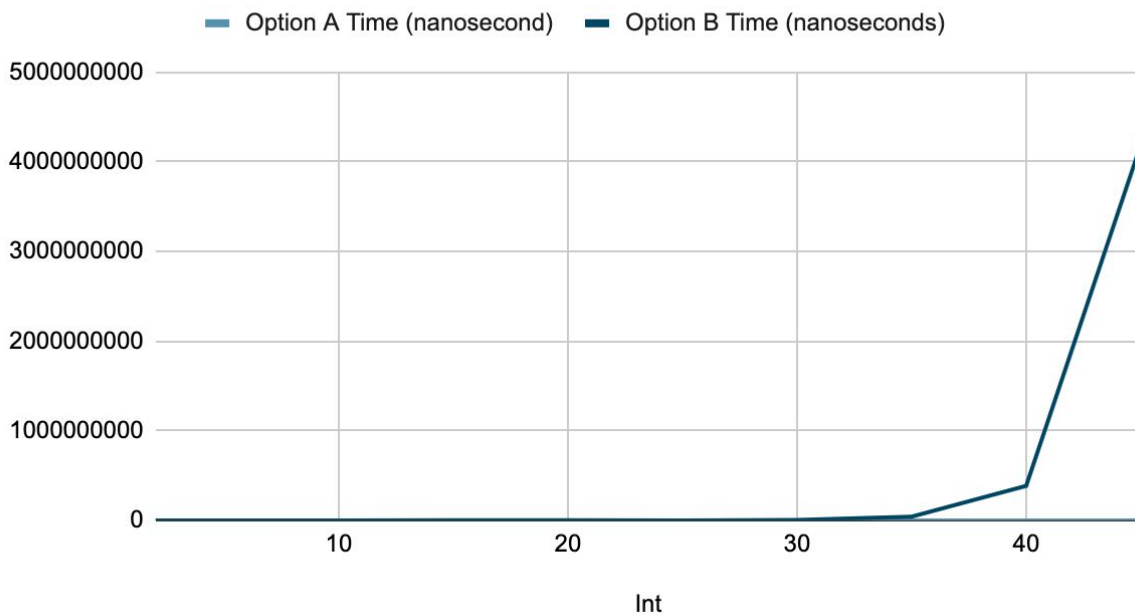
Option A

Int	Answer	Option A Time (nanosecond)	Option B Time (nanoseconds)
2	1	36680	5559
4	3	2924	4543
8	21	3368	9366
10	55	3187	17931
15	610	3640	319400
20	6765	3951	463138
25	75025	4728	185946
30	832040	3716	5016615
35	9227465	4635	42026987
40	102334155	3514	385210232
45	1134903160	4496	4186446357

\*At 50 int max size reached

## Time Complexity Graph

Option A Time (nanosecond) vs Option B Time (nanoseconds)



Hanoi Exercise (Disks start from index 0)

Int (disk)	Time (NanoSeconds)	Output Received	No of Moves
0	1152195	Move disk 0 from rod 1 to 3	1
1	1131258	Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3	3
2	1297284	Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 2 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3	7
3	2320973	Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 3 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2	15

		Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3	
4	2095249	Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 2 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 3 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 2 from rod 3 to 2 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 4 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 2 from rod 2 to 1 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 3 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 2 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3	31
5	3800015	Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 3 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 4 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2	63

		Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 3 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 5 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 3 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 4 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 3 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3	
6	7985134	Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 2 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 3 from rod 1 to 2 Move disk 0 from rod 3 to 2	127

		Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 2 from rod 3 to 2 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 4 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 2 from rod 2 to 1 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 3 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 2 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 5 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 2 from rod 3 to 2 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 3 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 2 from rod 2 to 1 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 4 from rod 3 to 2 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 2 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 3 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 2 from rod 3 to 2 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2	
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		Move disk 6 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 2 from rod 2 to 1 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 3 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 2 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 4 from rod 2 to 1 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 2 from rod 3 to 2 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 3 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 2 from rod 2 to 1 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 5 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 2 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 3 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 2 from rod 3 to 2 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 4 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 2 from rod 2 to 1 Move disk 0 from rod 3 to 2	
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		Move disk 1 from rod 3 to 1 Move disk 0 from rod 2 to 1 Move disk 3 from rod 2 to 3 Move disk 0 from rod 1 to 3 Move disk 1 from rod 1 to 2 Move disk 0 from rod 3 to 2 Move disk 2 from rod 1 to 3 Move disk 0 from rod 2 to 1 Move disk 1 from rod 2 to 3 Move disk 0 from rod 1 to 3	
7	8103093	Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 3 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 4 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 3 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 5 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 3 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2	255



		Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 4 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 3 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 6 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 3 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 4 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 3 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 5 from rod 3 to 2 Move disk 0 from rod 1 to 2	
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		Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 3 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 4 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 3 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 7 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 3 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 4 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2	
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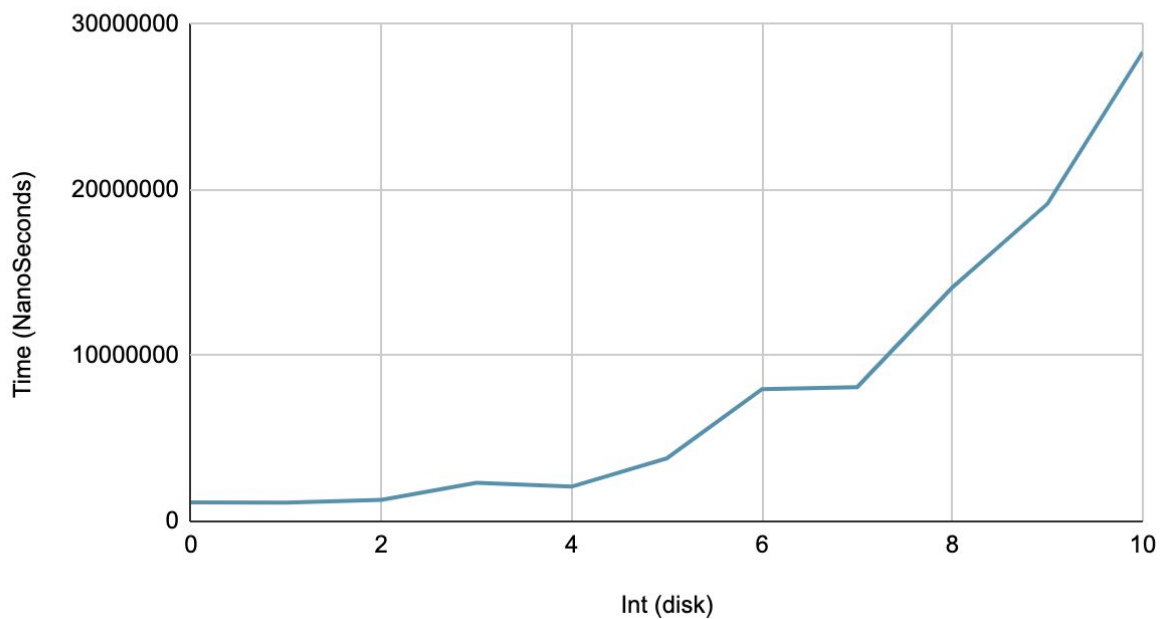
		Move disk 3 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 5 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 3 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 4 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 3 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 6 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 3 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2	
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		Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 4 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 3 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 5 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 3 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 2 from rod 3 to 1 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 4 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 2 from rod 1 to 2 Move disk 0 from rod 3 to 1 Move disk 1 from rod 3 to 2 Move disk 0 from rod 1 to 2 Move disk 3 from rod 1 to 3 Move disk 0 from rod 2 to 3 Move disk 1 from rod 2 to 1 Move disk 0 from rod 3 to 1 Move disk 2 from rod 2 to 3 Move disk 0 from rod 1 to 2 Move disk 1 from rod 1 to 3 Move disk 0 from rod 2 to 3	
8	14116493		511
9	19169552		1023

10	28319851		2047
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### Time Complexity Graph

Time (NanoSeconds) vs Int (disk)



Time (NanoSeconds) and No of Moves

