CSE 12 Week 7 Discussion

2-16-21

Focus: Maps

Reminders

- PA7 is a **closed** assignment - no collaborating!
  - Due Tuesday, March 2nd11:59 PM

- PA4 Resubmission due Friday, February 19th 11:59 PM
- PA5 Resubmission due Friday, February 26th 11:59 PM

Maps

Maps

Maps are an Abstract Data Type (ADT)
Assign a **key** to each **value** we are trying to keep track of.

Key 1 ---> Some value a

Key 2 ---> Some value b

Key 3 ---> Some value c

etc...

Map<K,V> Interface

- Implemented in Java by AbstractMap, HashMap, TreeMap etc.
- Index for an entry is determined by a hash function that calculates an index using the key value (useful for quick lookup and insert)
- Contains methods such as get(Object key), put(K key, V value), size(), replace(K key, V value) etc.
- Keys need to be unique
- Existing data structures can be used to implement this - ArrayList!

Inserting Into Map

Key	Value
“a”	“apple”
“o”	“orange”

```
Insert some entries into map:

put(“a”, “apple”);

put(“o”, “orange”);
```

Note - this is a simplified view of map entries.
May not be in this exact order

Inserting Into Map

Key	Value
“a”	“apple”
“o”	“orange”

Note - this is a simplified view of map entries.
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Can we insert the following as a new entry?

put(“a”, “apricot”)

A. Yes
B. No
C. Will only work this time since values are different at key = 1

Answer - B

Key	Value
“a”	“apricot”
“o”	“orange”

Note - this is a simplified view of map entries.
May not be in this exact order

Maps can only hold unique key values. If you try inserting value to an existing key, the old value will be overwritten.

Inserting Into Map

Key	Value
“a”	“apple”
“o”	“orange”

Note - this is a simplified view of map entries.
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Can we insert the following as a new entry?

```
put(“c”, “orange”)
```

A. Yes
B. No
C. I don’t know

Answer - A

Key	Value
“a”	“apple”
“o”	“orange”
“c”	“orange”

Note - this is a simplified view of map entries.
May not be in this exact order

Values across key-value pairs in maps do not need to be unique.

HashMaps - Separate Chaining

Example Hash Functions

```
int hash1(String s) {
  return s.length();
}
```

```
int hash2(String s) {
  int hash = 0;
  for(int i = 0; i < s.length(); i += 1) {
    hash += Character.codePointAt(s, i);
  }
  return hash;
}
```

```
public int hash3(String s) {
  int h = 0;
  for (int i = 0; i < s.length(); i++) {
    h = 31 * h + Character.codePointAt(s, i);
  }
  return h;
}
```

What is a bucket?

A: The collection of key values at a specific index

B: The sum of the keys in a given hash map

C: The collection of elements at a specific index

D: The collection of keys at a specific index

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Given the example below, what does the HashMap look like after line: `set("red", 70)`?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```

0	
1	
2	
3	

A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):
  hashed = hash(key)
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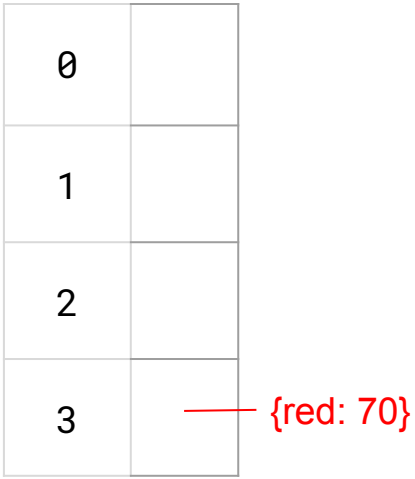

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```

Given the example below, what does the HashMap look like after line: `set("blue", 90)`?

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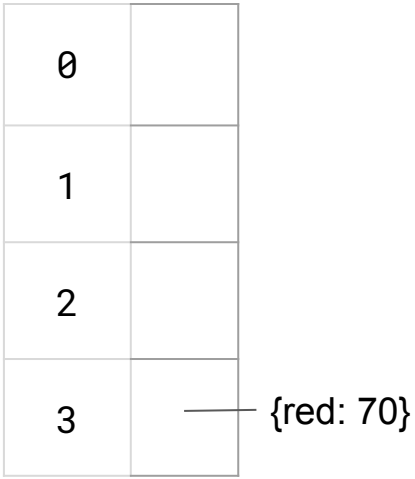

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```

Given the example below, what does the HashMap look like after line: `set("blue", 90)`?

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Start buckets array with size 4
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```
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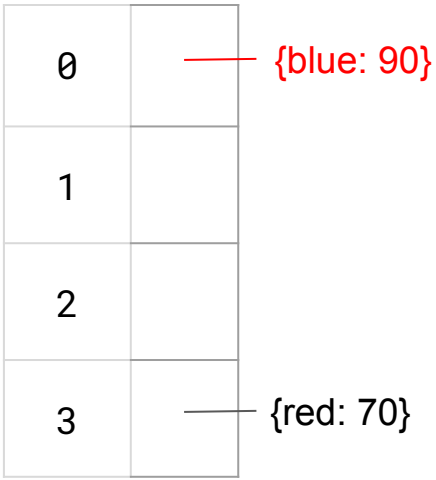

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```

Given the example below, what does the HashMap look like after line: `set("pink", 100)`?

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```
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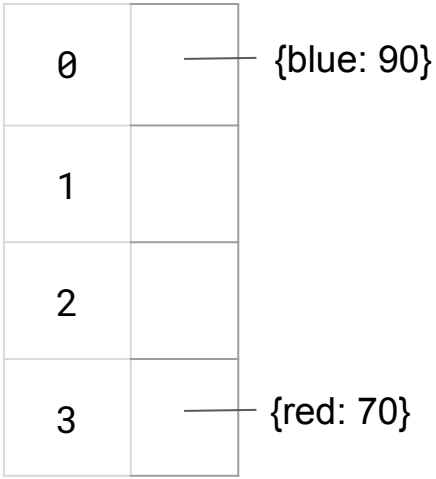

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    bucket = buckets[index]
    add {key: value} to end of bucket


Value get(key):
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```

Given the example below, what does the HashMap look like after line: `set("pink", 100)`?

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```
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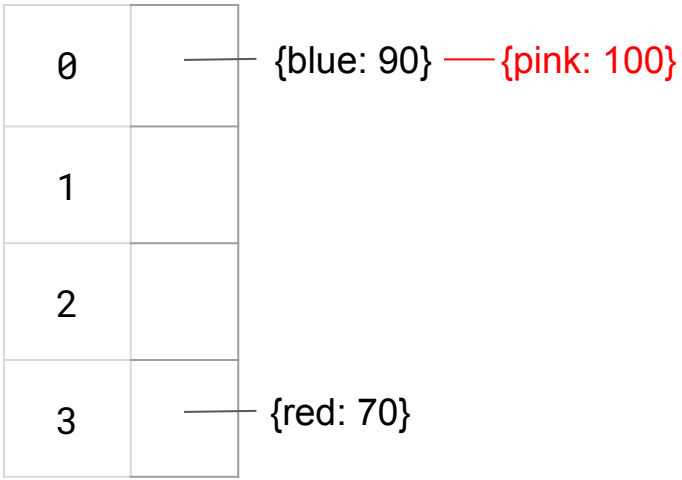

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```

Assuming the above example has been executed, how many elements are in bucket 0?

A: 0

B: 1

C: 2

D: 3

E: more than 3

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Assuming the above example has been executed, how many elements are in bucket 1?

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B: 1

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D: 3

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D: 3

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Assuming the above example has been executed, how many entries are checked for `get("purplish")`?

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Please complete the below HashMap, assuming the entire example code has executed.

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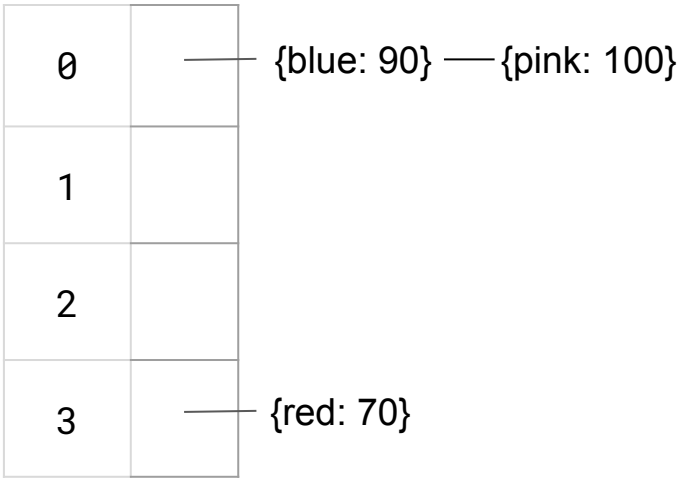

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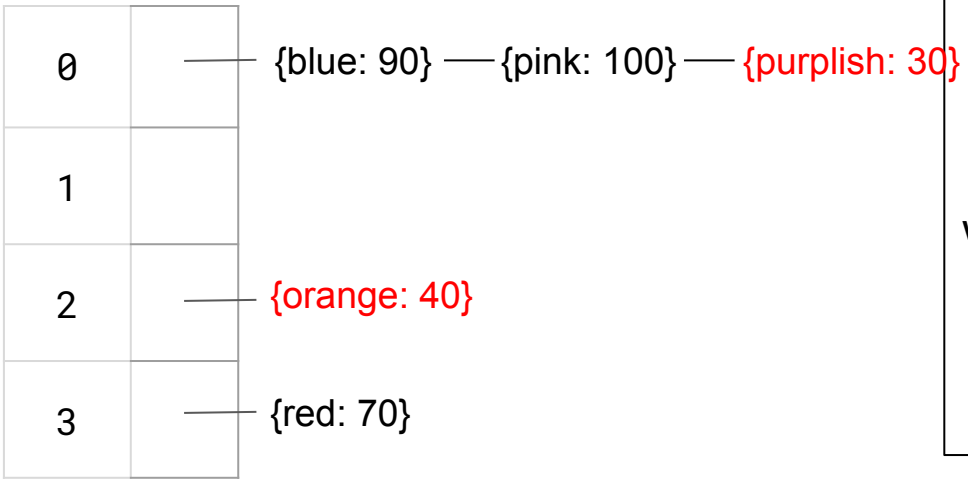

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What is the load factor?

A: # elements * # buckets / 2

B: # buckets * # elements

C: # buckets / # elements

D: # elements / # buckets

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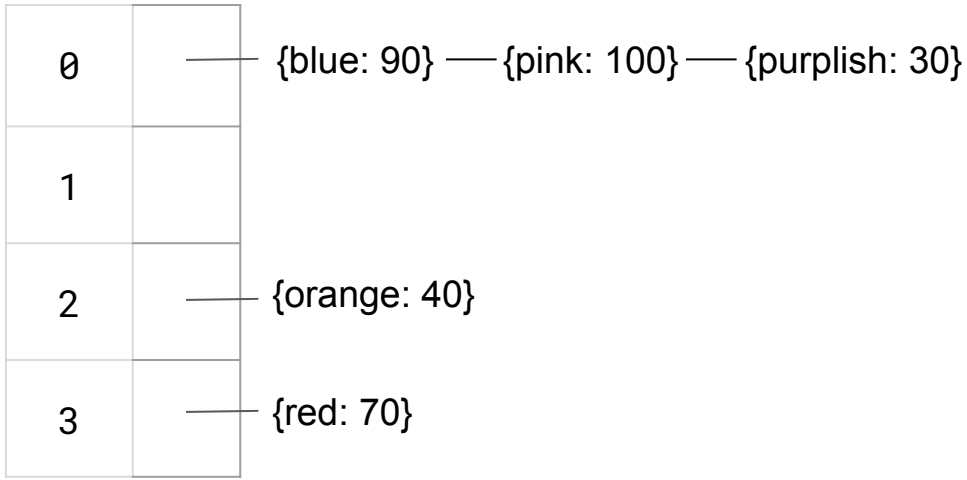
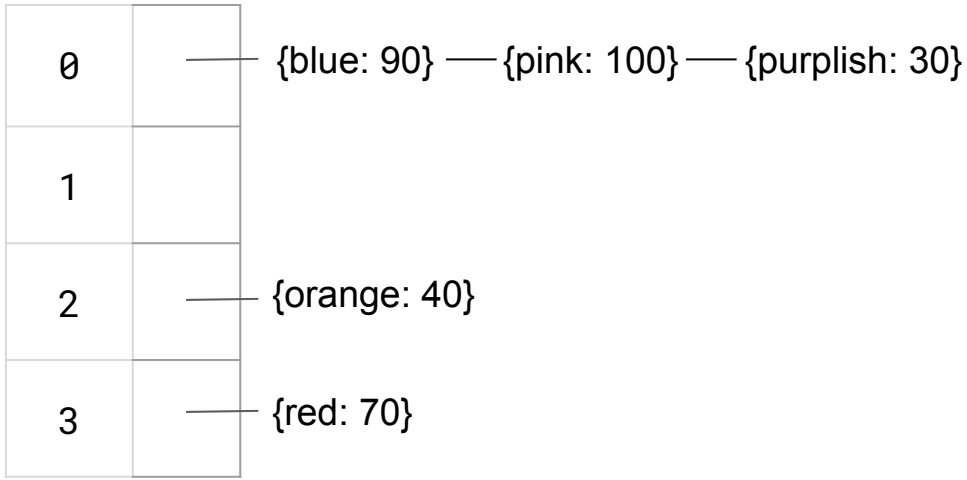
What is the load factor of the HashMap below?



What is the load factor of the HashMap below?



Load Factor: 5/4

What is the load factor after the line `set("red", 70)` is executed?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```

0	
1	
2	
3	

A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What is the load factor after the line `set("red", 70)` is executed?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```

0	
1	
2	
3	

Load Factor: 1/4

A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

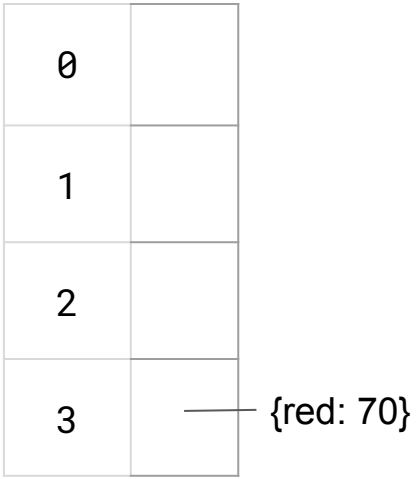
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What is the load factor after the line `set("blue", 90)` is executed?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

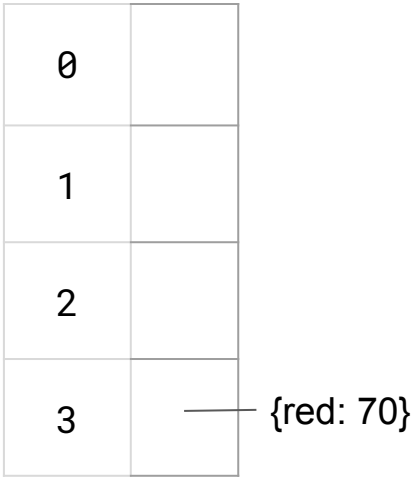
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What is the load factor after the line `set("blue", 90)` is executed?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



Load Factor: 1/2

A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

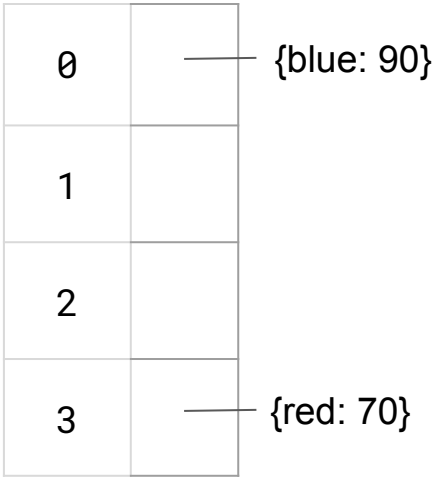
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What is the load factor after the line `set("pink", 100)` is executed?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

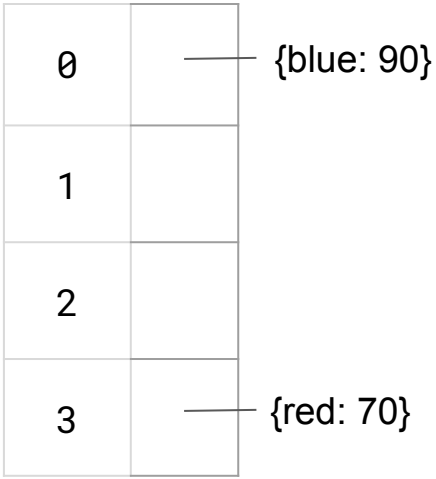
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What is the load factor after the line `set("pink", 100)` is executed?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



Load Factor: 3/4

A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

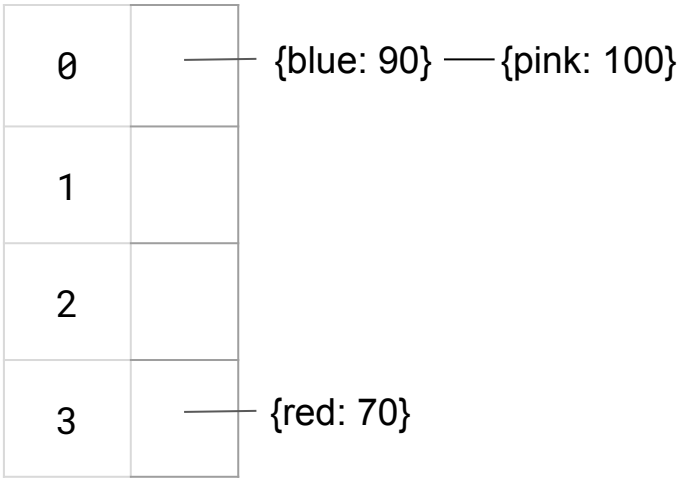
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What is <u>different</u> when the line `set("orange", 40)` is executed?

<u>Example:</u>
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

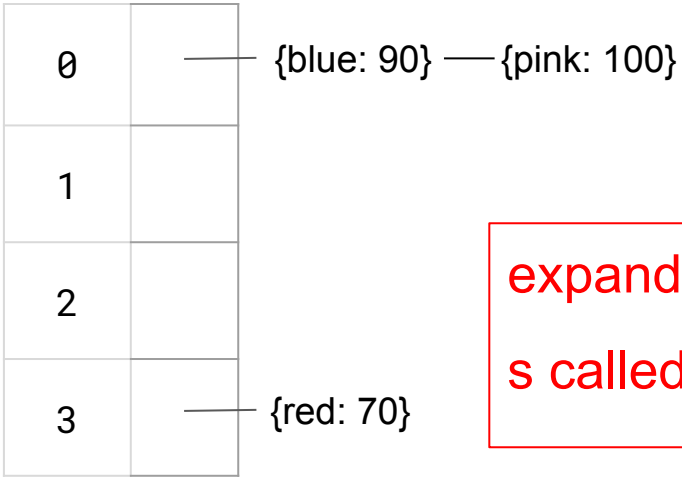
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What is <u>different</u> when the line `set("orange", 40)` is executed?

<u>Example:</u>
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



expandCapacityis called!

A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What does the HashMap look like after expandCapacity is called in set("orange", 40)?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```

0	
1	
2	
3	

4	
5	
6	
7	

A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

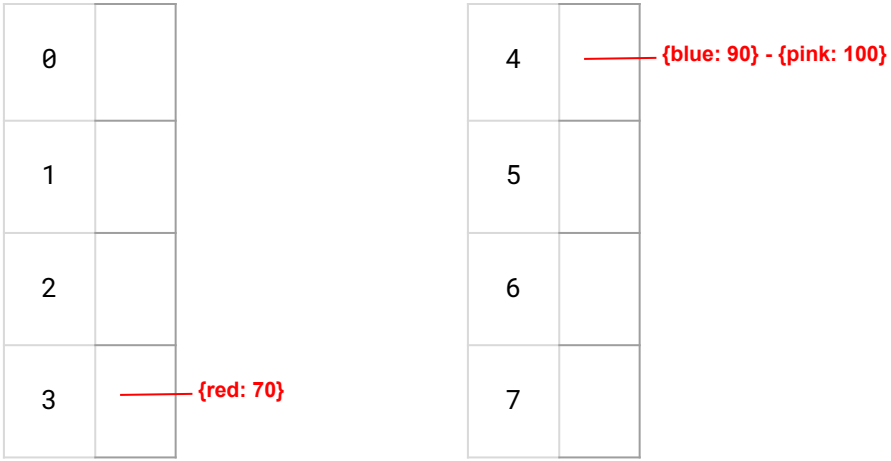
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What does the HashMap look like after expandCapacity is called in set("orange", 40)?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

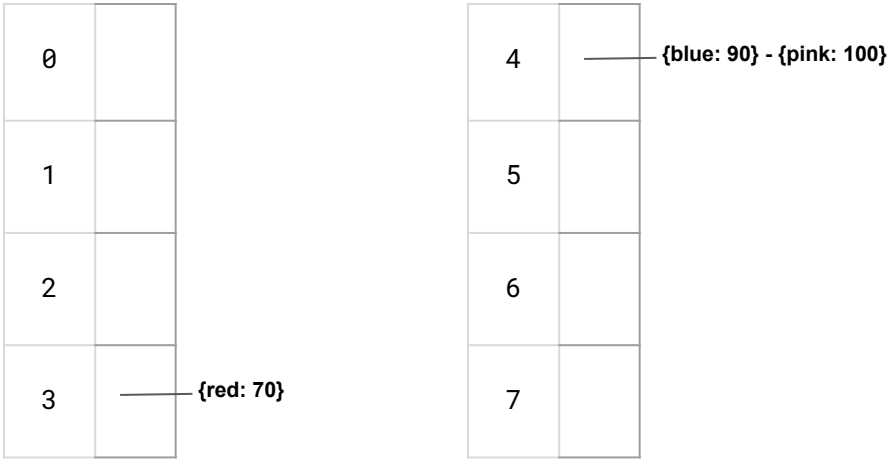
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What does the HashMap look like after set("orange", 40) is called?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

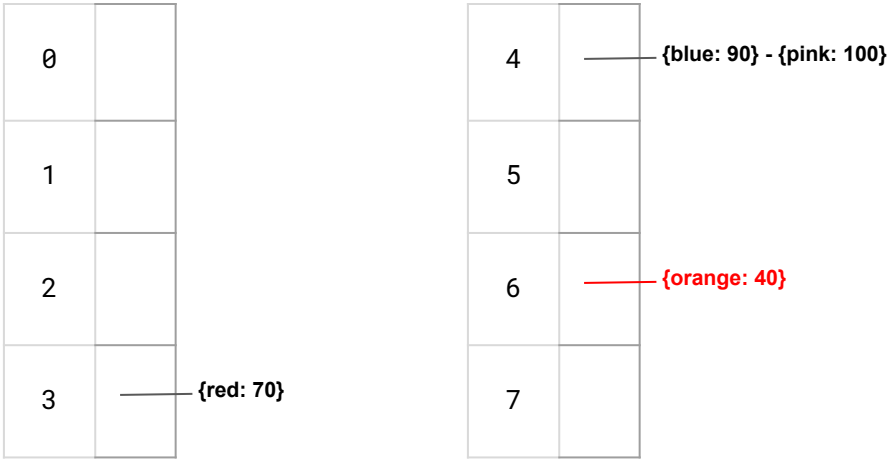
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What does the HashMap look like after set("orange", 40) is called?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



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- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

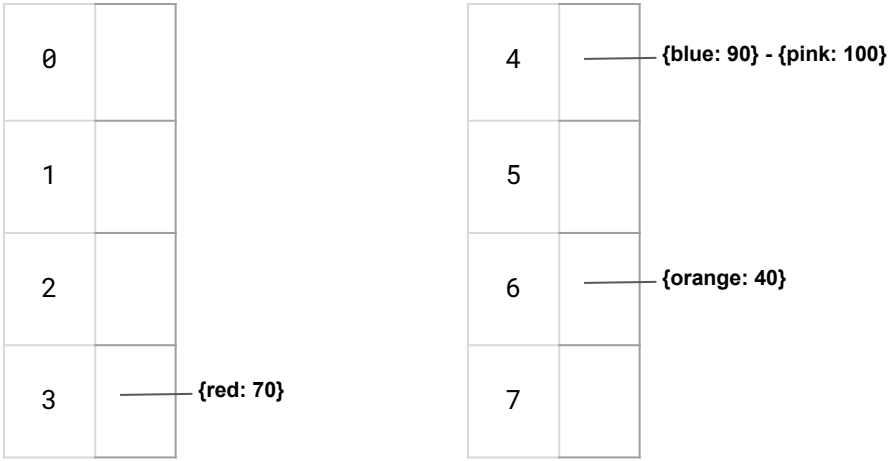
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What does the HashMap look like after set("purplish", 40) is called?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



A HashMap<Key, Value> using Separate Chaining has:

- size: an int
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- hash: a hash function for the Key type

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```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

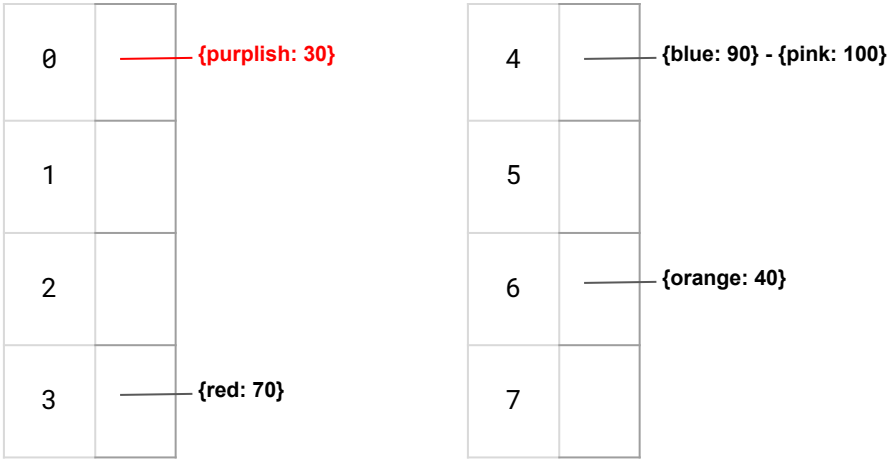
  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

What does the HashMap look like after set("purplish", 30) is called?

Example:
Start buckets array with size 4
Use string length as the hash function **(In general this is a BAD hash function)**

```
set("red", 70)
set("blue", 90)
set("pink", 100)
set("orange", 40)
set("purplish", 30)
```



A HashMap<Key, Value> using Separate Chaining has:

- size: an int
- buckets: an array of lists of Entries
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):

  if LoadFactor > 0.5: expandCapacity()

  ... as before ...


void expandCapacity():
  newBuckets = new List[this.buckets.length * 2];
  oldBuckets = this.buckets
  this.buckets = newBuckets
  this.size = 0
  for each list of entries in oldBuckets:
    for each {k: v} in the list:
      this.set(k, v)
```

HashMaps - Linear Probing

What does the HashMap below look like after the example code has executed?

```
Example:
Start buckets array with size 4, containing null
ASCII code as hash function ("a" = 97)

set("b", 70) # note 98 % 4 is 2
set("f", 90)
set("f", 100)
```

0	
1	
2	
3	

A HashMap<Key, Value> using Linear Probing has:

- size: an int
- buckets: an array of Entries (not of lists of Entries!)
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):
  if loadFactor > 0.67: expandCapacity()
  hashed = hash(key)
  index = hashed % array length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key):
      b.value = value
      return
    index += 1

  // key not in table, add it at first index containing null
  this.buckets[index] = {key: value}


Value get(key):
  hashed = hash(key)
  index = hashed % this.buckets.length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key): return b.value
    index += 1

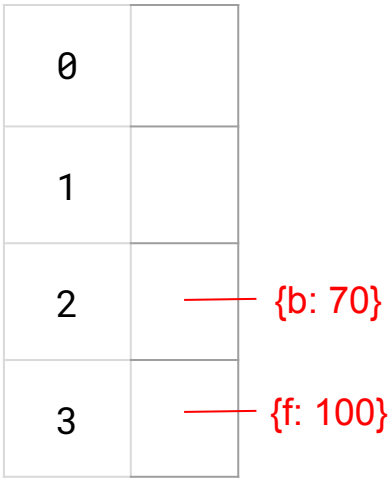
  // haven't found the key
  return null/throw exception


void expandCapacity():
  newEntries = new Entry[this.buckets.length * 2];
  oldEntries = this.buckets
  this.buckets = newEntries
  this.size = 0
  for each entry {k:v} in oldEntries:
    this.set(k, v)
```

What does the HashMap below look like after the example code has executed?

```
Example:
Start buckets array with size 4, containing null
ASCII code as hash function ("a" = 97)

set("b", 70) # note 98 % 4 is 2
set("f", 90)
set("f", 100)
```



A HashMap<Key, Value> using Linear Probing has:

- size: an int
- buckets: an array of Entries (not of lists of Entries!)
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):
  if loadFactor > 0.67: expandCapacity()
  hashed = hash(key)
  index = hashed % array length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key):
      b.value = value
      return
    index += 1

  // key not in table, add it at first index containing null
  this.buckets[index] = {key: value}


Value get(key):
  hashed = hash(key)
  index = hashed % this.buckets.length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key): return b.value
    index += 1

  // haven't found the key
  return null/throw exception


void expandCapacity():
  newEntries = new Entry[this.buckets.length * 2];
  oldEntries = this.buckets
  this.buckets = newEntries
  this.size = 0
  for each entry {k:v} in oldEntries:
    this.set(k, v)
```

```
Example:
Start buckets array with size 4, containing null
ASCII code as hash function ("a" = 97)

set("b", 70) # note 98 % 4 is 2
set("f", 90) # note 'f' = 102
set("f", 100)
```

Assuming the above example has been executed, how many elements are in bucket 1?

A: 0

B: 1

C: 2

D: 3

E: more than 3

A HashMap<Key, Value> using Linear Probing has:

- size: an int
- buckets: an array of Entries (not of lists of Entries!)
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):
  if loadFactor > 0.67: expandCapacity()
  hashed = hash(key)
  index = hashed % array length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key):
      b.value = value
      return
    index += 1

  // key not in table, add it at first index containing null
  this.buckets[index] = {key: value}


Value get(key):
  hashed = hash(key)
  index = hashed % this.buckets.length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key): return b.value
    index += 1

  // haven't found the key
  return null/throw exception


void expandCapacity():
  newEntries = new Entry[this.buckets.length * 2];
  oldEntries = this.buckets
  this.buckets = newEntries
  this.size = 0
  for each entry {k:v} in oldEntries:
    this.set(k, v)
```

```
Example:
Start buckets array with size 4, containing null
ASCII code as hash function ("a" = 97)

set("b", 70) # note 98 % 4 is 2
set("f", 90)
set("f", 100)
```

Assuming the above example has been executed, how many elements are in bucket 1?

A: 0

B: 1

C: 2

D: 3

E: more than 3

A HashMap<Key, Value> using Linear Probing has:

- size: an int
- buckets: an array of Entries (not of lists of Entries!)
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
void set(key, value):
  if loadFactor > 0.67: expandCapacity()
  hashed = hash(key)
  index = hashed % array length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key):
      b.value = value
      return
    index += 1

  // key not in table, add it at first index containing null
  this.buckets[index] = {key: value}


Value get(key):
  hashed = hash(key)
  index = hashed % this.buckets.length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key): return b.value
    index += 1

  // haven't found the key
  return null/throw exception


void expandCapacity():
  newEntries = new Entry[this.buckets.length * 2];
  oldEntries = this.buckets
  this.buckets = newEntries
  this.size = 0
  for each entry {k:v} in oldEntries:
    this.set(k, v)
```

```
Example:
Start buckets array with size 4, containing null
ASCII code as hash function ("a" = 97)

set("b", 70) # note 98 % 4 is 2
set("f", 90)
set("f", 100)
```

Assuming the above example has been executed, how many elements are in bucket 2?

A: 0

B: 1

C: 2

D: 3

E: more than 3

A HashMap<Key, Value> using Linear Probing has:

- size: an int
- buckets: an array of Entries (not of lists of Entries!)
- hash: a hash function for the Key type

An Entry is a single {key: value} pair.

```
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  for each entry {k:v} in oldEntries:
    this.set(k, v)
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```
Example:
Start buckets array with size 4, containing null
ASCII code as hash function ("a" = 97)

set("b", 70) # note 98 % 4 is 2
set("f", 90)
set("f", 100)
```

Assuming the above example has been executed, how many elements are in bucket 2?

A: 0

B: 1

C: 2

D: 3

E: more than 3

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Assuming the above example has been executed, how many elements are in bucket 3?

A: 0

B: 1

C: 2

D: 3

E: more than 3

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```

Assuming the above example has been executed, how many elements are in bucket 3?

A: 0

B: 1

C: 2

D: 3

E: more than 3

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Start buckets array with size 4, containing null
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set("b", 70) # note 98 % 4 is 2
set("f", 90)
set("f", 100)
```

Assuming the above example has been executed,

how many entries are checked when doing

`set("f", 100)`?

A: 0

B: 1

C: 2

D: 3

E: more than 3

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B: 1

C: 2

D: 3

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set("b", 70) # note 98 % 4 is 2
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```

Assuming the above example has been executed,

what will the result of `get("f")` be after this sequence?

A: 70

B: 90

C: 100

D: null

E: error

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set("f", 90)
set("f", 100)
```

Assuming the above example has been executed,

what will the result of `get("f", 100)` be after this sequence?

A: 70

B: 90

C: 100

D: null

E: error

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What does the HashMap below look like after the example code has executed?

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0	
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2	
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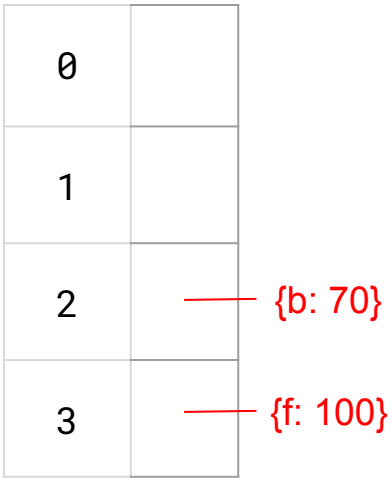

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```

Assuming the above example has been executed,

and an additional line is added below: set(“c”, 40),

Which bucket is “c” stored in?

A: 0

B: 1

C: 2

D: 3

E: it causes an error

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E: it causes an error (ArrayIndexOutOfBounds)

A HashMap<Key, Value> using Linear Probing has:

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How can we fix the ArrayOutOfBounds issue?

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An Entry is a single {key: value} pair.

When you get to the end of the array just fall off the end, wrap around to the beginning, and starting searching again at 0.

We would no longer have ArrayIndexOutOfBounds issue!

Loadfactor - never update size!!! Where should we increment size?

Asume load factor is size/currentlength (helper method)

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Are there any other issues that need to be fixed?

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Are there any other issues that need to be fixed?

A HashMap<Key, Value> using Linear Probing has:

- `size`: an `int`
- `buckets`: an array of Entries (not of lists of Entries!)
- `hash`: a hash function for the Key type

An Entry is a single {key: value} pair.

YES! `size` is never being updated!

(Let's assume `loadFactor` is actually a helper method that returns the current size divided by the current length.)

```
void set(key, value):
  if loadFactor() > 0.67: expandCapacity()
  hashed = hash(key)
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What happens if we set `loadFactor` to be 1 instead of 0.67?

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An Entry is a single {key: value} pair.

INFINITE LOOP!

There would be an infinite loop once the array is full. If the array is full of entries the method will search until it finds a bucket equal to null and there is no null to find.

```
void set(key, value):
  if loadFactor() > 0.67: expandCapacity()
  hashed = hash(key)
  index = hashed % array length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key):
      b.value = value
      return
    index += 1
    index = index % buckets.length
  // key not in table, add it at first index containing null
  this.buckets[index] = {key: value}
  size += 1

Value get(key):
  hashed = hash(key)
  index = hashed % this.buckets.length
  while this.buckets[index] != null:
    b = this.buckets[index]
    if b.key.equals(key): return b.value
    index += 1
    index = index % buckets.length
  // haven't found the key
  return null/throw exception


void expandCapacity():
  newEntries = new Entry[this.buckets.length * 2];
  oldEntries = this.buckets
  this.buckets = newEntries
  this.size = 0
  for each entry {k:v} in oldEntries:
    this.set(k, v)
```