Intermediate Programming

Day 23

Outline

- Templates and the STL
- `std::vector`
- Iterators
- Review questions

Templates (overview)

Q: What is a *template*?

A: Consider an example:

- What needs to change if I want to make the payload member a float/string/etc. instead of an int?

```
…
using std::cout;
using std::endl;

template< class PType >
struct Node
{
    PType payload;
    Node* next;
};

template< class T >
void print( const Node< T >* n )
{
    cout << n->payload << " ";
    if( next ) print( n->next );
    else       cout << endl;
}

int main( void )
{
    Node< int >* n;
    …
    print( n );
}
```

Templates (overview)

Q: What is a *template*?

A: Templates are a way of writing a generic class (Node) or function (print) and allowing it to work with a parameterized family of types*

⇒ Instead of defining a single class / function, we provide the compiler with a recipe for generating the class / function for whichever type we need

```
…
using std::cout;
using std::endl;

template< class PType >
struct Node
{
        PType payload;
        Node* next;
};

template< class T >
void print( const Node< T >* n )
{
        cout << n->payload << " ";
        if( next ) print( n->next );
        else       cout << endl;
}

int main( void )
{
        Node< int >* n;
        …
        print( n );
}
```

*More on this later

Templates (overview)

In this example:

- Node is now a *template* class, parameterized by a type referred to as PType

```
…
using std::cout;
using std::endl;

template< class PType >
struct Node
{
	PType payload;
	Node* next;
};

template< class T >
void print( const Node< T >* n )
{
	cout << n->payload << " ";
	if( next ) print( n->next );
	else       cout << endl;
}

int main( void )
{
	Node< int >* n;
	…
	print( n );
}
```

Templates (overview)

In this example:

- Node is now a *template* class, parameterized by a type referred to as PType
    - We declare payload to be of generic type PType

```
…
using std::cout;
using std::endl;

template< class PType >
struct Node
{
        PType payload;
        Node* next;
};

template< class T >
void print( const Node< T >* n )
{
        cout << n->payload << " ";
        if( next ) print( n->next );
        else        cout << endl;
}

int main( void )
{
        Node< int >* n;
        …
        print( n );
}
```

Templates (overview)

In this example:

- Node is now a *template* class, parameterized by a type referred to as PType
- When declaring a variable of type Node, we specify the payload type, in angle brackets

```
…
using std::cout;
using std::endl;

template< class PType >
struct Node
{
        PType payload;
        Node* next;
};

template< class T >
void print( const Node< T >* n )
{
        cout << n->payload << " ";
        if( next ) print( n->next );
        else       cout << endl;
}

int main( void )
{
        Node< int >* n;
        …
        print( n );
}
```

Templates (overview)

In this example:

- Node is now a *template* class, parameterized by a type referred to as PType
- When declaring a variable of type Node, we specify the payload type, in angle brackets
- When defining a function with a generic Node argument, the function is templated by Node's parameter
    - We are creating a recipe for the function
    - Note:
      We do not need to use the same parameter name
      $T \neq PType$

```
…
using std::cout;
using std::endl;

template< class PType >
struct Node
{
    PType payload;
    Node* next;
};

template< class T >
void print( const Node< T >* n )
{
    cout << n->payload << " ";
    if( next ) print( n->next );
    else       cout << endl;
}

int main( void )
{
    Node< int >* n;
    …
    print( n );
}
```

Templates (overview)

In this example:

- Node is now a *template* class, parameterized by a type referred to as PType
- When declaring a variable of type Node, we specify the payload type, in angle brackets
- When defining a function with a generic Node argument, the function is templated by Node's parameter
  - We specify Node's parameter to be the generic type T

```
…
using std::cout;
using std::endl;

template< class PType >
struct Node
{
	PType payload;
	Node* next;
};

template< class T >
void print( const Node< T >* n )
{
	cout << n->payload << " ";
	if( next ) print( n->next );
	else       cout << endl;
}

int main( void )
{
	Node< int >* n;
	…
	print( n );
}
```

The Standard Template Library

- The Standard Template Library (STL) is C++'s compendium of useful data structures and algorithms
  - pair – pair of values (possibly of different types)
  - tuple – a tuple of values (possibly of different types and arbitrary long)
  - list – linked list!
  - vector – dynamically-sized array
  - array – fixed-length array (not as useful as vector)
  - map – associative list, i.e. dictionary
  - stack – last-in first-out (LIFO)
  - deque – double-ended queue, flexible combo of LIFO/FIFO
  - and many more

Outline

- Templates and the STL
- std::vector
- Iterators
- Review questions

std::vector

A dynamically sized array of elements:

- The template parameter specifies the element type

main.cpp

```
#include <iostream>
#include <vector>
using std::vector;
using std::cin;
using std::cout;
int main( void )
{
        vector< float > grades;
        float grade;
        while( cin >> grade ) grades.push_back( grade );
        grades.insert( grades.begin() , 100 );
        cout << "First grade was " << grades[1] << endl;
        cout << "Last grade was " << grades[ grades.size()-1 ] << endl;
        return 0;
}
```

std::vector

- push_back:
  - inserts an element at the end
- insert
  - Insert an element before the prescribed position
- [ ] operator:
  - gives access to an element at a prescribed index
- size:
  - returns the number of elements in the vector

main.cpp

```
#include <iostream>
#include <vector>
using std::vector;
using std::cin;
using std::cout;
int main( void )
{
        vector< float > grades;
        float grade;
        while( cin >> grade ) grades.push_back( grade );
        grades.insert( grades.begin() , 100 );
        cout << "First grade was " << grades[1] << endl;
        cout << "Last grade was " << grades[ grades.size()-1 ] << endl;
        return 0;
}
```

std::vector

- back:
  - returns the last element
- pop_back:
  - removes the last element
- resize:
  - resizes the vector to be able to store a specified number of elements
- erase
- clear
- at
- empty

See:
http://www.cplusplus.com/reference/vector/vector/
for more std::vector functionality

std::vector

Using the [ ] operator and the **size** method, we can iterate over the entries of a **vector**

main.cpp

```
#include <iostream>
#include <vector>
using std::vector;
using std::cout;
using std::endl;
int main( void )
{
    vector< int > values;
    values.push_back( 1 );
    values.push_back( 3 );
    values.push_back( 2 );
    for( int i=0 ; i<values.size() ; ++i )
        cout << values[i] << “ “;
    cout << endl;
    return 0;
}
```

```
>> ./a.out
1 3 2
>>
```

std::vector

Using the [ ] operator and the **size** method, we can iterate over the entries of a **vector**

Or we can use **iterators**

main.cpp

```
#include <iostream>
#include <vector>
using std::vector;
using std::cout;
using std::endl;
int main( void )
{
        vector< int > values;
        values.push_back( 1 );
        values.push_back( 3 );
        values.push_back( 2 );
        for( vector< int >::iterator it=values.begin() ; it!=values.end() ; ++it )
                cout << *it << “ “;
        cout << endl;
        return 0;
}
```

```
>> ./a.out
1 3 2
>>
```

std::vector

Using the [ ] operator and the size method, we can iterate over the entries of a vector

Or we can use iterators:

- Iterators are “clever pointers” that know how to move over elements of a container
    - Container could be simple (e.g. array) or more complicated (e.g. linked list) or very complicated (e.g. tree)

main.cpp

```
#include <iostream>
#include <vector>
using std::vector;
using std::cout;
using std::endl;
int main( void )
{
    vector< int > values;
    values.push_back( 1 );
    values.push_back( 3 );
    values.push_back( 2 );
    for( vector< int >::iterator it=values.begin() ; it!=values.end() ; ++it )
        cout << *it << “ “;
    cout << endl;
    return 0;
}
```

```
>> ./a.out
1 3 2
>>
```

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Forward iterators

```
vector< int > values;
…
for( vector< int >::iterator it=values.begin() ; it!=values.end() ; ++it ) cout << *it << “ “;
```

For an STL container of type T (in this example , vector<int>):

- The forward iterator has type T::iterator

Forward iterators

```
vector< int > values;
…
for( vector< int >::iterator it=values.begin() ; it!=values.end() ; ++it ) cout << *it << “ “;
```

For an STL container of type T (in this example , vector<int>):

- The forward iterator has type T::iterator
- The container defines a T::begin method
  - Returns an iterator to the first element in the container

Forward iterators

```
vector< int > values;
…
for( vector< int >::iterator it=values.begin() ; it!=values.end() ; ++it ) cout << *it << “ “;
```

For an STL container of type T (in this example , vector<int>):

- The forward iterator has type T::iterator
- The container defines a T::begin method
- The container defines a T::end method
  - Returns an iterator to the element just past the last element in the container

Forward iterators

```
vector< int > values;
…
for( vector< int >::iterator it=values.begin() ; it!=values.end() ; ++it ) cout << *it << “ “;
```

For an STL container of type T (in this example , vector<int>):

- The forward iterator has type T::iterator
- The container defines a T::begin method
- The container defines a T::end method
- The iterator overloads the pre-increment operator **++**
    - Advances the iterator to the next element

Forward iterators

```
vector< int > values;
…
for( vector< int >::iterator it=values.begin() ; it!=values.end() ; ++it ) cout << *it << “ “;
```

For an STL container of type T (in this example , vector<int>):

- The forward iterator has type T::iterator
- The container defines a T::begin method
- The container defines a T::end method
- The iterator overloads the pre-increment operator ++
- The iterator overloads the inequality operator !=
    - Checks if two iterators are different

Forward iterators

```
vector< int > values;
…
for( vector< int >::iterator it=values.begin() ; it!=values.end() ; ++it ) cout << *it << " ";
```

For an STL container of type T (in this example , vector<int>):

- The forward iterator has type T::iterator
- The container defines a T::begin method
- The container defines a T::end method
- The iterator overloads the pre-increment operator ++
- The iterator overloads the inequality operator !=
- The iterator overloads the dereference operator *
  - Returns the contents of what the iterator is “pointing to”

Reverse iterators

```
vector< int > values;
…
for( vector< int >::reverse_iterator it=values.rbegin() ; it!=values.rend() ; ++it ) cout << *it << “ “;
```

For an STL container of type T (in this example , vector<int>):

- The reverse iterator has type T::reverse_iterator
- The container defines a T::rbegin method
- The container defines a T::rend method

Reverse iterators

```
vector< int > values;
…
for( vector< int >::reverse_
```

For an STL contain

- The reverse iter
- The container d
- The container d

main.cpp

```
#include <iostream>
#include <vector>
using std::vector;
using std::cout;
using std::endl;
int main( void )
{
	vector< int > values;
	values.push_back( 1 );
	values.push_back( 3 );
	values.push_back( 2 );
	for( vector< int >::reverse_iterator it=values.rbegin() ; it!=values.rend() ; ++it )
		cout << *it << " ";
	cout << endl;
	return 0;
}
```

```
>> ./a.out
2 3 1
>>
```

Constant iterators

```
vector< int > values;
…
for( vector< int >::const_iterator it=values.cbegin() ; it!=values.cend() ; ++it ) cout << *it << “ “;
```

For an STL container of type `T` (in this example , `vector<int>`):

- The constant iterator has type `T::const_iterator`
  - The contents of the container cannot be modified
- The container defines a `T::cbegin` method
- The container defines a `T::cend` method

Constant iterators

```
vector< int > values;
…
for( vector< int >::const_it
```

For an STL contain

- The constant ite
  - The contents c
- The container d
- The container d

main.cpp

```
#include <iostream>
#include <vector>
using std::vector;
using std::cout;
using std::endl;
int main( void )
{
	vector< int > values;
	values.push_back( 1 );
	values.push_back( 3 );
	values.push_back( 2 );
	for( vector< int >::const_iterator it=values.cbegin() ; it!=values.cend() ; ++it )
		cout << *it << " ";
	cout << endl;
	return 0;
}
```

```
>> ./a.out
1 3 2
>>
```

Iterators

In general, iterators act like “smart” pointers, allowing us to iterate through the contents of a container and get its values.

For iterators `iter1` and `iter2`, supported operations include:

- Increment: `iter1++ or ++iter1`
- Dereference: `*iter`
- Assignment: `iter1=iter2`
- Comparison: `iter1!=iter2` or `iter1==iter2`

Random access iterators

Like pointers, some iterators also support arithmetic (random access).

For iterators `iter1` and `iter2` and integer `n` supported operations include:

- Arithmetic: `iter1=iter2+n` or `iter1=iter2-n`
- Compound arithmetic: `iter1+=n` or `iter1-=n`
- Comparison: `iter1<=iter2`, `iter1>iter2`, etc.
- Differencing: `n=iter2-iter1`

Note:

Not all iterators support random access:

✓ Iterators for vectors do

✗ Iterators for linked lists do not

Outline

- Templates and the STL
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Review questions

1. What is a template in C++?

A way of writing an object (generalization of a struct) so that they can work with any type

Review questions

2. What is the standard template library?

A collection of standardly used, templated objects and functions

Review questions

3. How do you iterate a std::vector and print out its elements?

```
        for( int i=0 ; i<v.size() ; i++ ) std::cout << v[i] << std::endl;
```

or

```
        for( vector<type>::iterator it=v.begin() ; it!=v.end ; it++ )
                std::cout << *it << std::endl;
```

Review questions

4. What is an iterator in C++?

Clever pointers that know how to move over the components of a data structure (e.g. support increment and dereferencing)

Review questions

5. How do you add an element to an existing `std::vector`?

Use the `push_back` or `insert` method.

Review questions

6. (Bonus) What is the output of this program?

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
    vector< double > v;
    for( int i=1 ; i<=10 ; i++ )
    {
        if( i%2==1 ) v.insert( v.begin() , i/2.0 );
        else v.push_back( i*2.0 );
    }
    vector< double >::iterator it = v.begin();
    cout << "first == " << *it << endl;
    cout << "middle1 == " << *(it + 4) << endl;
    cout << "middle2 == " << *(it + 5) << endl;
    cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

v = {}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
    vector< double > v;
    for( int i=1 ; i<=10 ; i++ )
    {
        if( i%2==1 ) v.insert( v.begin() , i/2.0 );
        else v.push_back( i*2.0 );
    }
    vector< double >::iterator it = v.begin();
    cout << "first == " << *it << endl;
    cout << "middle1 == " << *(it + 4) << endl;
    cout << "middle2 == " << *(it + 5) << endl;
    cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

i=1

v = {0.5}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
        vector< double > v;
        for( int i=1 ; i<=10 ; i++ )
        {
                if( i%2==1 ) v.insert( v.begin() , i/2.0 );
                else v.push_back( i*2.0 );
        }
        vector< double >::iterator it = v.begin();
        cout << "first == " << *it << endl;
        cout << "middle1 == " << *(it + 4) << endl;
        cout << "middle2 == " << *(it + 5) << endl;
        cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

i=2

v = {0.5, 4.}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
    vector< double > v;
    for( int i=1 ; i<=10 ; i++ )
    {
        if( i%2==1 ) v.insert( v.begin() , i/2.0 );
        else v.push_back( i*2.0 );
    }
    vector< double >::iterator it = v.begin();
    cout << "first == " << *it << endl;
    cout << "middle1 == " << *(it + 4) << endl;
    cout << "middle2 == " << *(it + 5) << endl;
    cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

i=3

v = {1.5, 0.5, 4.}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
    vector< double > v;
    for( int i=1 ; i<=10 ; i++ )
    {
        if( i%2==1 ) v.insert( v.begin() , i/2.0 );
        else v.push_back( i*2.0 );
    }
    vector< double >::iterator it = v.begin();
    cout << "first == " << *it << endl;
    cout << "middle1 == " << *(it + 4) << endl;
    cout << "middle2 == " << *(it + 5) << endl;
    cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
    vector< double > v;
    for( int i=1 ; i<=10 ; i++ )
    {
        if( i%2==1 ) v.insert( v.begin() , i/2.0 );
        else v.push_back( i*2.0 );
    }
    vector< double >::iterator it = v.begin();
    cout << "first == " << *it << endl;
    cout << "middle1 == " << *(it + 4) << endl;
    cout << "middle2 == " << *(it + 5) << endl;
    cout << "last == " << *(it + 9) << endl;
}
```

i=4

v = {1.5, 0.5, 4., 8.}

Review questions

6. (Bonus) What is the output of this program?

i=5

v = {2.5, 1.5, 0.5, 4., 8.}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
	vector< double > v;
	for( int i=1 ; i<=10 ; i++ )
	{
		if( i%2==1 ) v.insert( v.begin() , i/2.0 );
		else v.push_back( i*2.0 );
	}
	vector< double >::iterator it = v.begin();
	cout << "first == " << *it << endl;
	cout << "middle1 == " << *(it + 4) << endl;
	cout << "middle2 == " << *(it + 5) << endl;
	cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

i=6

v = {2.5, 1.5, 0.5, 4., 8., 12.}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
    vector< double > v;
    for( int i=1 ; i<=10 ; i++ )
    {
        if( i%2==1 ) v.insert( v.begin() , i/2.0 );
        else v.push_back( i*2.0 );
    }
    vector< double >::iterator it = v.begin();
    cout << "first == " << *it << endl;
    cout << "middle1 == " << *(it + 4) << endl;
    cout << "middle2 == " << *(it + 5) << endl;
    cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

i=7

v = {3.5, 2.5, 1.5, 0.5, 4., 8., 12.}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
	vector< double > v;
	for( int i=1 ; i<=10 ; i++ )
	{
		if( i%2==1 ) v.insert( v.begin() , i/2.0 );
		else v.push_back( i*2.0 );
	}
	vector< double >::iterator it = v.begin();
	cout << "first == " << *it << endl;
	cout << "middle1 == " << *(it + 4) << endl;
	cout << "middle2 == " << *(it + 5) << endl;
	cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

i=8

v = {3.5, 2.5, 1.5, 0.5, 4., 8., 12., 16.}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
        vector< double > v;
        for( int i=1 ; i<=10 ; i++ )
        {
                if( i%2==1 ) v.insert( v.begin() , i/2.0 );
                else v.push_back( i*2.0 );
        }
        vector< double >::iterator it = v.begin();
        cout << "first == " << *it << endl;
        cout << "middle1 == " << *(it + 4) << endl;
        cout << "middle2 == " << *(it + 5) << endl;
        cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

i=9

v = {4.5, 3.5, 2.5, 1.5, 0.5, 4., 8., 12., 16.}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
	vector< double > v;
	for( int i=1 ; i<=10 ; i++ )
	{
		if( i%2==1 ) v.insert( v.begin() , i/2.0 );
		else v.push_back( i*2.0 );
	}
	vector< double >::iterator it = v.begin();
	cout << "first == " << *it << endl;
	cout << "middle1 == " << *(it + 4) << endl;
	cout << "middle2 == " << *(it + 5) << endl;
	cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?

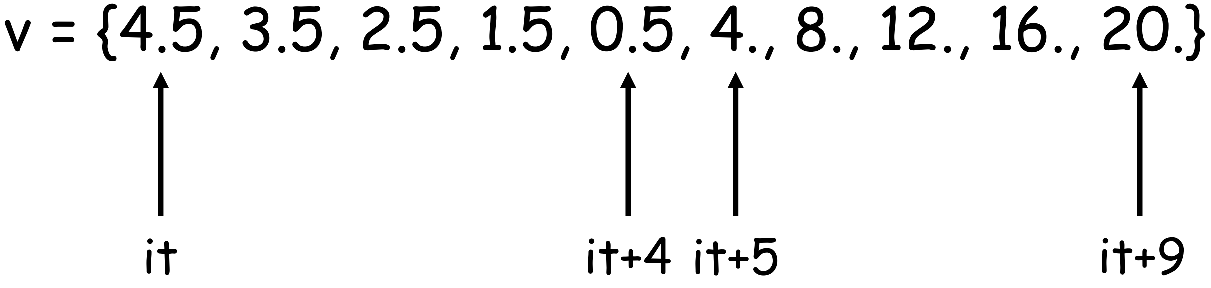
i=10

v = {4.5, 3.5, 2.5, 1.5, 0.5, 4., 8., 12., 16., 20.}

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
      vector< double > v;
      for( int i=1 ; i<=10 ; i++ )
      {
            if( i%2==1 ) v.insert( v.begin() , i/2.0 );
            else v.push_back( i*2.0 );
      }
      vector< double >::iterator it = v.begin();
      cout << "first == " << *it << endl;
      cout << "middle1 == " << *(it + 4) << endl;
      cout << "middle2 == " << *(it + 5) << endl;
      cout << "last == " << *(it + 9) << endl;
}
```

Review questions

6. (Bonus) What is the output of this program?



v = {4.5, 3.5, 2.5, 1.5, 0.5, 4., 8., 12., 16., 20.}

it

it+4 it+5

it+9

```
#include <iostream>
#include <vector>
using std::cin;
using std::cout;
using std::endl;
using std::vector;
int main( void )
{
    vector< double > v;
    for( int i=1 ; i<=10 ; i++ )
    {
        if( i%2==1 ) v.insert( v.begin() , i/2.0 );
        else v.push_back( i*2.0 );
    }
    vector< double >::iterator it = v.begin();
    cout << "first == " << *it << endl;
    cout << "middle1 == " << *(it + 4) << endl;
    cout << "middle2 == " << *(it + 5) << endl;
    cout << "last == " << *(it + 9) << endl;
}
```

Exercise 8-1

- Website -> Course Materials -> ex8-1

Exercise 8-1

- Website -> Course Materials -> ex8-1

Merge Sort:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

Exercise 8-1

- Website -> Course Materials -> ex8-1

Merge Sort:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

- Split in two {1, 27, 7, 5, -2} {6, 5, 3, 13}

Exercise 8-1

- Website -> Course Materials -> ex8-1

<u>Merge Sort</u>:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

- Split in two {1, 27, 7, 5, -2} {6, 5, 3, 13}
- Sort the two halves independently {-2, 1, 5, 7, 27} {3, 5, 6, 13}

Exercise 8-1

- Website -> Course Materials -> ex8-1

Merge Sort:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

- Split in two {1, 27, 7, 5, -2} {6, 5, 3, 13}

↓ ↓

- Sort the two halves independently {-2, 1, 5, 7, 27} {3, 5, 6, 13}
- Merge the two sorted halves into a single sorted array { }

Exercise 8-1

- Website -> Course Materials -> ex8-1

Merge Sort:

Given an array of values	{1, 27, 7, 5, -2, 6, 5, 3, 13}
- Split in two	{1, 27, 7, 5, -2} {6, 5, 3, 13}
	↓ ↓
- Sort the two halves independently	{-2, 1, 5, 7, 27} {3, 5, 6, 13}
- Merge the two sorted halves into a single sorted array	{-2 }

Exercise 8-1

- Website -> Course Materials -> ex8-1

Merge Sort:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

- Split in two {1, 27, 7, 5, -2} {6, 5, 3, 13}

↓ ↓

- Sort the two halves independently {-2, 1, 5, 7, 27} {3, 5, 6, 13}
- Merge the two sorted halves into a single sorted array {-2, 1 }

Exercise 8-1

- Website -> Course Materials -> ex8-1

<u>Merge Sort</u>:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

- Split in two {1, 27, 7, 5, -2} {6, 5, 3, 13}

↓ ↓

- Sort the two halves independently {-2, 1, 5, 7, 27} {3, 5, 6, 13}
- Merge the two sorted halves into a single sorted array {-2, 1, 3 }

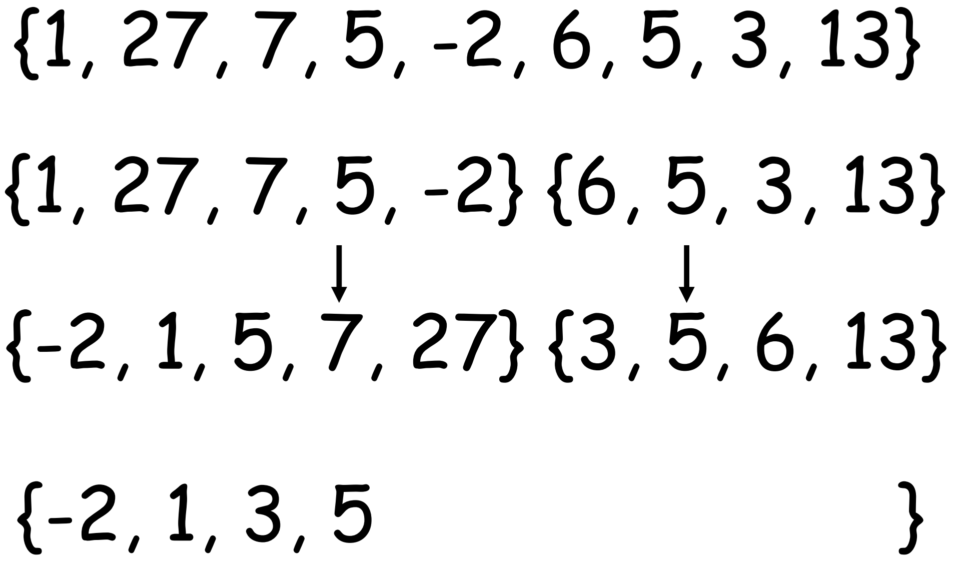
Exercise 8-1

- Website -> Course Materials -> ex8-1

<u>Merge Sort</u>:

Given an array of values

- Split in two
- Sort the two halves independently
- Merge the two sorted halves into a single sorted array



{1, 27, 7, 5, -2, 6, 5, 3, 13}

{1, 27, 7, 5, -2} {6, 5, 3, 13}

{-2, 1, 5, 7, 27} {3, 5, 6, 13}

{-2, 1, 3, 5 }

Exercise 8-1

- Website -> Course Materials -> ex8-1

Merge Sort:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

- Split in two {1, 27, 7, 5, -2} {6, 5, 3, 13}

↓ ↓

- Sort the two halves independently {-2, 1, 5, 7, 27} {3, 5, 6, 13}
- Merge the two sorted halves into a single sorted array {-2, 1, 3, 5, 5 }

Exercise 8-1

- Website -> Course Materials -> ex8-1

Merge Sort:

Given an array of values	{1, 27, 7, 5, -2, 6, 5, 3, 13}
• Split in two	{1, 27, 7, 5, -2} {6, 5, 3, 13}
• Sort the two halves independently	{-2, 1, 5, 7, 27} {3, 5, 6, 13}
• Merge the two sorted halves into a single sorted array	{-2, 1, 3, 5, 5, 6 }

Exercise 8-1

- Website -> Course Materials -> ex8-1

Merge Sort:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

- Split in two {1, 27, 7, 5, -2} {6, 5, 3, 13}

↓ ↓

- Sort the two halves independently {-2, 1, 5, 7, 27} {3, 5, 6, 13}
- Merge the two sorted halves into a single sorted array {-2, 1, 3, 5, 5, 6, 7 }

Exercise 8-1

- Website -> Course Materials -> ex8-1

<u>Merge Sort</u>:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

- Split in two {1, 27, 7, 5, -2} {6, 5, 3, 13}

↓

- Sort the two halves independently {-2, 1, 5, 7, 27} {3, 5, 6, 13}
- Merge the two sorted halves into a single sorted array {-2, 1, 3, 5, 5, 6, 7, 13 }

Exercise 8-1

- Website -> Course Materials -> ex8-1

Merge Sort:

Given an array of values {1, 27, 7, 5, -2, 6, 5, 3, 13}

- Split in two {1, 27, 7, 5, -2} {6, 5, 3, 13}
- Sort the two halves independently {-2, 1, 5, 7, 27} {3, 5, 6, 13}
- Merge the two sorted halves into a single sorted array {-2, 1, 3, 5, 5, 6, 7, 13, 27}