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École de science informatique et de génie électrique

CSI2372 Advanced Programming Concepts with C++

FINAL EXAM

Length of Examination: 3 hours **December 12, 2018, 14:00**

Professor: Jochen Lang **Page 1 of 19**

Family Name: _____

Other Names: _____

Student Number: _____

Signature _____

You are allowed ONE TEXTBOOK as a reference.

No calculators or other electronic devices are allowed.

Please answer the questions in this booklet. If you do not understand a question, clearly state an assumption and proceed.

Question	Marks	Out of
A		6
B		6
C		15
D		4
E		7
Total		38

At the end of the exam, when time is up: Stop working and close your exam booklet. Remain silent.

Part A: Short Questions (6 marks)

1. What is printed by the following program? [1]

```
class Bird {
public:
  virtual void name() { cout << "Bird" << endl; }
  void numLegs() { cout << 2 << endl; }
  bool fly() {return true;}
};

class Emu : public Bird {
public:
  void name() { cout << "Emu" << endl; }
  void numLegs() { cout << 3 << endl; }
  bool fly() {return false;}
};

int main() {
  Emu e;
  Bird& pb = e;
  Bird b;
  cout << "1: ";
  if (e.fly()) e.name();
  cout << "2: ";
  if (pb.fly()) pb.name();
  cout << "3: ";
  if (b.fly()) b.name();

  return 0;
}
```

1: 2: Emu
3: Bird

2. What is printed by the following statements? [1]

```
int array[][3]{ 1, 2, 3, 4, 5, 6, 7, 8, 9 };

int (&ptr)[3] = array[1];
std::cout << *(ptr+1);
```

5

3. What is printed by the following statements? [1]

```
vector<int> v{1,2,3,4,5,6};
auto ret= std::find(v.begin(),v.end(),0);
std::cout << *(ret-1);
```

6

4. What is printed by the following statements? [1]

```
std::set<string> s{"red","green","yellow","blue"};
for (auto x : s) {
  std::cout << x << " ";
}
```

~~green red yellow~~

5. What is printed by following statements? [1]

```
std::vector<unique_ptr<Shape>> v;
std::unique_ptr<Shape> p= make_unique<Shape>(Shape("Triangle"));
v.push_back(std::move(p));
if (p!=nullptr) std::cout<<"my pointer";
if (v[0]!=nullptr) std::cout<<"my vector";
```

my vector

6. What is printed by the following program? [1]

```
class Person {
 public:
    Person(int x)  { cout << "Person ctor called" << endl;   }
};

class Faculty : public Person {
 public:
    Faculty(int x):Person(x)   {
       cout<<"Faculty ctor called"<< endl;
    }
};

class Student : public Person {
 public:
    Student(int x):Person(x) {
        cout<<"Student ctor called"<< endl;
    }
};

class TA : public Faculty, public Student  {
public:
    TA(int x):Student(x), Faculty(x)    {
        cout<<"TA ctor called"<< endl;
    }
};

int main()  {
    TA ta1(123);
}
```

Person ctor called
Faculty ctor called
Person ctor called
Student ctor called
TA ctor called

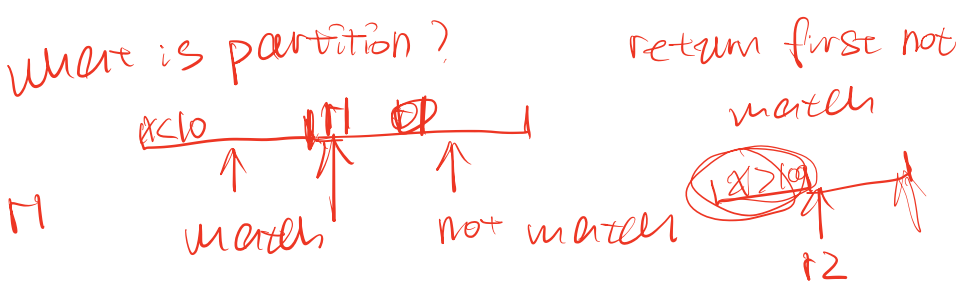
Part B: Complete the Code (6 MARKS)

1. Change the function division such that it throws a "Division by zero!" exception if the argument b equals 0. [1]

```
double division(int a, int b) {
   return (a/b);
}

int main () {
   int x = 50;
   int y = 0;
   double z = 0;

   try {
      z = division(x, y);
      cout << z << endl;
   } catch (string msg) {
      cerr << msg << endl;
   }

   return 0;
}
```

if (b == 0) {
throw("Division by zero");
} else
return.

```
double division(int a, int b) {
  if ( b == 0 ) throw string("Division by zero!");
  return (a/b);
}
```



2. Vector v1 contains a set of integers and the following two calls to `std::partition` are executed. [2]

```
auto r1= std::partition(v1.begin(),v1.end(),[](int x){ return x<10;});
auto r2= std::partition(r1,v1.end(),[](int x){ return x>100;});
```

Use the `std::copy` function to copy all the elements between 10 and 100 from vector v1 into the vector v2.

```
std::vector<int> v2;
```

std::copy(r2,v1.end(),std::back_inserter(v2));

add elements are the end!

3. Add a lambda function as the last parameter in the call to for_each so that 10 is added to each element in the vector less than 10. [1.5]

```
std::vector<int> v={2,15,22,3,32,5,7,44};

// expected result: {12,15,22,13,32,15,17,44}
for_each(v.begin(),v.end(),
```

____[](int& x) { if (x<10) x+=10; }_____);

4. Write a for loop to display the values of the vector v in reverse order, i.e. from last to first element. [1.5]

```
std::vector<int> v={2,15,22,3,32,5,7,44};
```

```
for ( auto iter = w.crbegin(); iter < w.crend(); ++iter )
 {
      cout << *iter << " ";
  }
```

Part C: Containers (15 MARKS)

The following class defines a container for elements. It adds the elements by copy.

```
template <typename T>
class Ring {
  // private internal node
  struct Node {
    T element;
    Node* next;
  };

  Node *current=nullptr;

public:

  // add an element after current
  void add(const T& element) {
    // create new element
    auto newNode= new Node({element,nullptr});
    // point to itself if single element
    newNode->next= newNode;
    // insert element in non-empty list
    if (current) {
      newNode->next= current->next;
      current->next= newNode;
    }
    // current becomes inserted element
    current= newNode;
  }

  // move current to next element and return it
  // return a default object if empty list
  T next() {
    if (current) {
      current= current->next;
      return current->element;
    } else {
      return T();
    }
  }

  Ring() = default;
};
```

1. Implement the copy constructor for the class `Ring` implementing a deep copy strategy. [3]

```
Ring( const Ring<T>& o) {
  if ( o.current ) {
    auto ptr = o.current;
    do {
       add(ptr->element);
       ptr = ptr->next;
    } while ( ptr != o.current );
    // go one notch further
    next();
  }
 }
```

2. Implement the destructor for the class `Ring` avoiding any memory leaks. [3]

```
~Ring() {
   if (current) {
     auto ptr = current;
     do {
        auto next = ptr->next;
        delete ptr;
        ptr = next;
     } while ( ptr != current );
   }
 }
```

3. Implement the assignment operator for the class `Ring` implementing a deep assignment strategy. [4]

```
Ring<T>& operator=( const Ring<T>& o) {
 if ( &o == this ) return *this;
 // delete own elements
 if (current) {
   auto ptr = current;
   do {
      auto next = ptr->next;
      delete ptr;
      ptr = next;
   } while ( ptr != current );
 }
 current = nullptr;
 if ( o.current ) {
   auto ptr = o.current;
   do {
      add(ptr->element);
      ptr = ptr->next;
   } while ( ptr != o.current );
   next();
 }
 return *this;
}
```

4. Implement the move constructor for the class `Ring`. [2]

```
Ring( Ring<T>&& rval ) noexcept :
  current(rval.current)
 {
  cout << "move ctor" << endl;
  rval.current = nullptr;
 }
```

5. Implement the move assignment operator for the class `Ring`. [3]

```
Ring<T>& operator=( Ring<T>&& rval ) noexcept
{
    if ( this != &rval ) { // could be replaced by assert
     // delete own elements
     if (current) {
        auto ptr = current;
        do {
          auto next = ptr->next;
          delete ptr;
          ptr = next;
        } while ( ptr != current );
     }
     current = rval.current;
     rval.current = nullptr;
   }
   return *this;
 }
```

Part D: Abstract Data Types (4 MARKS)

The Team class contains a list of players (`Player` class) contained in a `std::Map` in which the player's number serves as a key.

```
class Player;
class Team {

  std::Map<int,Player> players();

  …
```

a) Complete the definition of the method `addPlayer` to add a player to the team by specifying a number. If the specified number is already assigned to another player, this method returns false and does not insert. Otherwise, the player is added to the `std::Map` and the method returns true.

```
bool Team::addPlayer(int number, const Player& p) {

  auto ret= players.insert(std::make_pair(number,p));

  return ret.second;
}
```

access the value of current

b) Complete the definition of the `getNewNumber` method to obtain an unassigned player number from a starting number. The function must work with `const Team`.

```
int Team::getNewNumber(int startNumber) const {

  while (players.find(startNumber) != players.end())
    startNumber++;

  return startNumber;
}
```

c) Complete the definition of the `operator!` returning false if the team has fewer than 10 players.

```
bool Team::operator!() const {

  return players.size()< 10;
}
```

d) Complete the definition of the insertion operator (`operator <<`) allowing to display at the console the list of the numbers of players of the team.

```
ostream& operator<<(ostream &out,
                    const Team &team) {

  for( auto it = team.players.begin(); it != team.players.end(); ++it) {

    out << it->first << "\n";
  }

  return out;
}
```

Part E: Dynamic Allocation and Memory Management (7 marks)

Given the following definitions:

```
class Fruit {};

Fruit *produceFruit() {
  return new Fruit();
}

void consumeFruit(Fruit *ff) {
  delete ff;
}

Fruit* reproduceFruit(Fruit fruit) {
   Fruit* ret= new Fruit(fruit);
   return ret;
}
```

1. The function `leaky()` below includes memory leaks, however, it runs without other problems. Insert calls to delete in the function `leaky` such that no memory leak occurs. [3]

```
void leaky() {
  Fruit *f1= new Fruit();
  Fruit *f2= f1;
  Fruit *f3= new Fruit(*f1);

  delete f3;
  f3= reproduceFruit(*f1);



  consumeFruit(f3);
  f3= produceFruit();


  Fruit f4;
  f4= *f3;
  delete f1;
  delete f3;
  return;
}
```

2. Fix the original memory leaks by replacing **all** regular pointers with smart pointers. Use `std::unique_ptr` whenever possible, otherwise use `std::shared_ptr`. [4]

```
#include <memory>
using std::unique_ptr;
using std::shared_ptr;
using std::move;



unique_ptr<Fruit>  produceFruit() {

  return unique_ptr<Fruit>(new Fruit());
}



void consumeFruit( unique_ptr<Fruit> ff) {


}



unique_ptr<Fruit> reproduceFruit(Fruit fruit) {

   unique_ptr<Fruit> ret = unique_ptr<Fruit>(

            new Fruit(fruit));
   return ret;
}
```

```
void leaky() {
      shared_ptr<Fruit> f1
            = shared_ptr<Fruit>( new Fruit() );
      shared_ptr<Fruit> f2= f1;
      unique_ptr<Fruit> f3
            = unique_ptr<Fruit>( new Fruit(*f1));
      f3= reproduceFruit(*f1);

      consumeFruit( std::move(f3));
      f3= produceFruit();
      Fruit f4;
      f4= *f3;
      return;
}
```

std::copy

Defined in header <algorithm>

template< class InputIt, class OutputIt >
OutputIt copy(InputIt first, InputIt last, OutputIt d_first); (until C++20) (1)
template< class InputIt, class OutputIt >
constexpr OutputIt copy(InputIt first, InputIt last, OutputIt d_first); (since C++20)

… (omitted)

Copies the elements in the range, defined by `[first, last)`, to another range beginning at `d_first`.

1) Copies all elements in the range `[first, last)` starting from first and proceeding to last - 1. The behavior is undefined if `d_first` is within the range `[first, last)`. In this case, std::copy_backward may be used instead.

Parameters

first, last - the range of elements to copy
d_first - the beginning of the destination range.

Return value

Output iterator to the element in the destination range, one past the last element copied.

std::find

Defined in header `<algorithm>`

template< class InputIt, class T >
InputIt find(InputIt first, InputIt last, const T& value); (1) (until C++20)
template< class InputIt, class T >
constexpr InputIt find(InputIt first, InputIt last, const T& value); (since C++20)

… (omitted)

Returns the first element in the range `[first, last)` that satisfies specific criteria:

1) `find` searches for an element equal to `value`

Parameters

first, last - the range of elements to examine
value - value to compare the elements to

Return value

Iterator to the first element satisfying the condition or `last` if no such element is found.

std::for_each

Defined in header <algorithm>

template< class InputIt, class UnaryFunction >
UnaryFunction for_each(InputIt first, InputIt last, UnaryFunction f); (until C++20)
(1)
template< class InputIt, class UnaryFunction >
constexpr UnaryFunction for_each(InputIt first, InputIt last, UnaryFunction f); (since C++20)

… (omitted)

1) Applies the given function object `f` to the result of dereferencing every iterator in the range `[first, last)`, in order.

For both overloads, if the iterator type is mutable, `f` may modify the elements of the range through the dereferenced iterator. If `f` returns a result, the result is ignored.

Unlike the rest of the algorithms, for_each is not allowed to make copies of the elements in the sequence even if they are trivially copyable.

Parameters

first, last - the range to apply the function to

f - function object, to be applied to the result of dereferencing every iterator in the range `[first, last)`

The signature of the function should be equivalent to the following:

void fun(const Type &a);

The signature does not need to have const &.
The type Type must be such that an object of type InputIt can be dereferenced and then implicitly converted to Type.

Return value

1) `f` (until C++11) std::move(f) (since C++11)
2) (nothing)

std::partition

Defined in header <algorithm>

template< class BidirIt, class UnaryPredicate >
BidirIt partition(BidirIt first, BidirIt last, UnaryPredicate p); (until C++11)

(1)

template< class ForwardIt, class UnaryPredicate >
ForwardIt partition(ForwardIt first, ForwardIt last, UnaryPredicate p); (since C++11) (until C++20)

… (omitted)

1) Reorders the elements in the range `[first, last)` in such a way that all elements for which the predicate `p` returns true precede the elements for which predicate `p` returns false. Relative order of the elements is not preserved.

Parameters

first, last - the range of elements to reorder

Return value

Iterator to the first element of the second group.

Source: cppreference.com
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