# 3OBPABM in C++
# 1992 Advanced Placement Exam (AB)

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**PROBLEM 1:**

As is, doesn't change

**PROBLEM 2:**

As is, doesn't change

**PROBLEM 3:**
As is, doesn't change

**PROBLEM 4:**

Assume that $A$ is an apvector of $n$ positive integers and that the following assertion is true.

$$A[0] > A[k] \quad \text{for all } k \text{ such that } 0 < k < n$$

Which of the following is a valid conclusion?

**A.** The apevector is sorted in ascending order.

**B.** The apvector is sorted in descending order.

**C.** All values in the apvector are identical.

**D.** $A[0]$ holds the smallest value in the apvector

**E.** $A[0]$ holds the largest value in the apvector

(*only difference is starting with index 0 instead of index 1*)

**PROBLEM 5:**
A program to print a calendar includes the following code.

```
for(month = 1; month <= 12; month++)
{
    PrintHeading(month, year);
    PrintDays(month, year);
}
```

The `PrintDays` function includes the following code.

```
PrintSpaces(month, year);
for(day=1; day <= NumDaysIn(month, year); day++)
{
    cout << setw(3) << day;
    if (EndOfWeek(day, month, year))
        cout << endl;
}
```

If, when the program is run, every week on the calendar printed has eight days, which of the following funcions is most likey to contain the bug?

(*choices do not change*)

**A.** PrintHeading

**B.** PrintDays

**C.** PrintSpaces

**D.** NumDaysIn

**E.** EndOfWeek

**PROBLEM 6:**

The following code is designed to set *index* to the location of the first occurrence of *goal* in the apvecctor $A$, and to set *index* to -1 if *goal* does not occur in $A$.

```
index = 0;
while (A[index] != goal)
{
    index++;
}
if (A[index] != goal)
{
    index = -1;
}
```

Which of the following describe the condition under which this program segment will fail to perform the task described?

(*choices do not change*)

**A.** Whenever *goal* is the first element of the apvector

**B.** Whenever *goal* is the last element of the apvector

**C.** Whenever *goal* is not present in the apvector

**D.** Whenever *goal* is 0

**E.** Whenever $goal = A[goal]$

**PROBLEM 7:**

A C++ compiler runs on several different types of computers, ranging from microcomputers to mainframes. For this compiler, which of the following might be different on the different machines?

**I.** The value of `INT_MAX` in `<limits.h>`

**II.** The number of reserved words

**III.** The largest value represented by the type `double`

**A.** I only

**B.** III only

**C.** I and II

**D.** I and III

**E.** II and III

**PROBLEM 8:**

Consider the task of moving $m$ items from the rear to the front of an $n$-item list. For example, the movement of 3 items from the rear to the front in the 8-item list

$$(12, 32, 22, 44, 55, \underline{21, 77, 34})$$

creates the list

$$(\underline{21, 77, 34}, 12, 32, 22, 44, 55)$$

The following algorithm performs this task (lists are indexed beginning with position 0).

```
for(k=0;k < m;k++){
    save the item that is at the end of the list;
    shift items in positions 0..n-2 to positions 1..n-1
    put the saved item into position 0
}
```

If the list is stored in an array of $n$ elements, which of the following best describes the running time of this algorithm in terms of the number of shifts of individual items?

**A.** $m^2$

**B.** $n^2$

**C.** $mn$

**D.** $m$

**E.** $n$

(*only change is 0-index rather than 1 index*)

Questions 9-10 refer to the following function.

```
int Answer(int n)
{
    if (n == 1)
    {
        return 1;
    }
```

```
        else
        {
            return 2 * answer(n-1);
        }
    }
```

**PROBLEM 9:**

(*question and choices do not change*)
What is the value of the expression `answer(5)`?

**A.** 2

**B.** 8

**C.** 10

**D.** 32

**E.** 120

**PROBLEM 10:**
(*question and choices do not change*)
If $n$ is a postive integer, how many times will `Answer` be called to evaluate `Answer(n)` (including the initial call)?

**A.** 2

**B.** $n$

**C.** $2n$

**D.** $n^2$

**E.** $2^n$

Questions 11-12 are based on the following code.

```
bool LookUp(const Dictionary & d; int target)
// postcondition: returns true if the value of target
//                is in dictionary d; otherwise returns false
{
    if (d == NULL)
        return false;
    else if (d->value == target)
        return true;
    else if (d->value > target)
        return LookUp(d->left,target);
    else
        return LookUp(d->right,target);
}
```

**PROBLEM 11:**

(*question and choices do not change*)
Function `LookUp` is best characterized as performing a search in

**A.** an ordered binary (search) tree

**B.** an unordered binary tree

**C.** an ordered linear linked list

**D.** an unordered linear linked list

**E.** a hash table

**PROBLEM 12:**
If function `LookUp` comiles without errors, then the type definitions involved could be chosen from which of the following? (*typdefs are not part of the APCS C++ subset*)

**I.**

```
struct Item
{
    int value;
    Item * left;
    Item * right;
};

typedef Item * Dictionary;
```

**II.**

```
struct Item
{
    int value;
    Item * left;
    Item * right;
};

typedef Item Dictionary;
```

**III.**

```
struct Item
{
    int value;
    Item left;
    Item right;
};

typedef Item Dictionary;
```

**A.** I only

**B.** II only

**C.** III only

**D.** I and III only

**E.** I, II, and III

**PROBLEM 13:**
A program includes the following declarations.

```
struct Node
{
    ValueType value;
    Node * left;
    Node * right;
};
```

A function of the program includes the following code segment.

```
tree->left = tree->right;
tree->right = tree;
```

Which of the following must be true of this segment? (Assume that `tree != NULL` and that all fields of `tree` have been initialized.)

(*choices do not change*)

**A.** It will trigger a compile-time error message.

**B.** It will trigger a run-time error message.

**C.** It will result in an infinite loop.

**D.** It will result in an infinite recursion.

**E.** None of the above.

**PROBLEM 14:**

Consider the following definitions and declarations

```
struct TreeNode
{
    int info;
    TreeNode * left;
    TreeNode * right;
};

int m(int a, int b)
{
    if (a >= b) return a; else return b;
}

int f(TreeNode *t)
{
    if (t->left == 0 && t->right == 0) return t->info;
    else if (t->left == 0)             return m(t->info,f(t->right));
    else if (t->right == 0)            return m(t->info,f(t->left));
    else                               return m( m(t->info,f(t->left)),f(t->right));
}
```

(*questions and choices do not change*) If, on entrance to $f$, $t$ is a non-empty tree, then $f$ evaluates to which of the following?

**A.** the greatest value of *info* stored in the tree

**B.** the least value of *info* stored in the tree

**C.** the value of *info* at the root of the tree

**D.** the value of *info* at the last node of the tree visited during execution of *f*

**E.** the first duplicated value of *info* encountered during execution of *f*

**PROBLEM 15:**
Consider function `Print` below.

```
struct Node
{
    char info;
    Node * next;
    Node(char ch, Node * link)
      : info(ch),
        next(link)
    {

    }
};

void Print()
{
    Node * list;
    Node * temp;
    char letter;

    list = NULL;
    for(letter='1'; letter <= '5'; letter++)
    {
        temp = new Node(letter,list);
        list = temp;
    }

    while (temp != NULL)
    {
        cout << temp->info;
        temp = temp->next;
    }
    cout << endl;
}
```

(*question and choices do not change*)
What will be printed as a result of calling function `Print`?

**A.** 54321

**B.** 12345

**C.** 51

**D.** 5

**E.** 1

Questions 16-17 refer to the following Boolean expression.

```
(i <= n && a[i] == 0) || (i >= n && a[i-1] == 0)
```

**PROBLEM 16:**

Under which of the following conditions must the Boolean expressin have the value `true`?

**A.** `1 <= n || i >= n`

**B.** `a[i] == 0 && a[i-1] == 0`

**C.** `i == n`

**D.** `i < n`

**E.** `i > n`

**PROBLEM 17:**

(*question and choices do not change*)

Evaluation of the Boolean expression is guaranteed to cause a run-time error under which of the following conditions?

**A.** `i < 0`

**B.** Neither `a[i]` nor `a[i-1]` has the value zero.

**C.** Array `a` is of size `n`.

**D.** Array `a` is of size 2.

**E.** None of the above.

**PROBLEM 18:**

Consider the following declarations and definitions.

```
struct List
{
    int items[MaxLength];
    int numItems;
};

void Find(const List & list, int num,
          bool & found, int & loc)
// precondition: 0 <= list.numItems < MaxLength
{
    found = false;
    for(loc=0; loc < list.numItems; loc++)
    {
        if (list.items[loc] == num)
        {
            found = true;
            break;
        }
    }
}
```

Which of the following is a correct postcondition for function `Find`?

**A.** `found`

**B.** `found && loc >= list.numItems`

**C.** `list.item[loc] == num) || loc == list.numItems`

**D.** `loc == list.numItems`

**E.** `!found && loc < list.numItems`

Questions 19-20 are based on the following information.
As is, replace the word “record” with “struct”.

**PROBLEM 19:**

As is, no changes

**PROBLEM 20:**

As is, replace “standard Pascal” with C++.

**PROBLEM 21:**

The Boolean expression

```
num > max || !(max < num)
```

can be simplified to

**A.** `max != num`

**B.** `max == num`

**C.** `num < max && !(max < num)`

**D.** `false`

**E.** `true`

**PROBLEM 22:**

As is

**PROBLEM 23:**

As is

**PROBLEM 24:**

Suppose that a queue of integers `q` is defined using `apqueue<int> q`. Consider the following pseudocode.

```
int time,value;
do
{
    time = 0;
    q.dequeue(value);
    do
    {
        value--;
        time++;
    } while (value != 0 && time < limit);

    if (value > 0) q.enqueue(value);
} while (! q.isEmpty());
```

(*question and choices do not change*)

Suppose that initially the values in the queue are:

```
1, 10, 8, 5, 12
```

(1 is at the front of the queue, 12 is at the end of the queue.)

Which of the following is the least value of `limit` that would ensure that the total number of `Dequeue` operations is 6 or less?

**A.** 3

**B.** 5

**C.** 6

**D.** 7

**E.** 10

Questions 25-26 concern the definition of boolean operators **cand** and **cor** which aren't useful in C++ since these operators are short-circuited by the language definition. Questions 25 and 26 "do not port" to C++.

**PROBLEM 25:**

No C++ analog

**PROBLEM 26:**

No C++ analog

**PROBLEM 27:**

Assume that the following definitions have been made.

```
const int MAX_NUM = <some positive integer>;
apvector<bool> list(MAX_NUM + 3);
```

Consider the following code segment.

```
for(i=2; i <= MAX_NUM; i++)
{
    for(j=1; j <= MAX_NUM/i; j++)
    {
        list[i*j] = ! list[i*j];
    }
}
```

(*question and choices do not change*)

For `i` in the range `2..MAX_NUM`, which of the following characterizes the entries of `list` that will have value `true` after the segment above has executed?

**A.** `list[i] = true` for no values of `i`.

**B.** `list[i] = true` for all values of `i`.

**C.** `list[i] = true` for all values of `i` that are even.

**D.** `list[i] = true` for all values of `i` that are prime.

**E.** `list[i] = true` for all values of `i` that are perfect squares.

Questions 28-29 are based on the following information.

Assume that variables of type `LongInt` can represent integers of up to fifty digits. Also assume that the following operators are to be written so as to operate on `LongInt` variables, and that these are the only operators written.

```
istream & operator >> (istream & input, LongInt & long)
// reads a long integer from the stream input

ostream & operator << (ostream & output, const LongInt & long)
// writes a long integer to the stream output

LongInt operator +(const LongInt & a, const LongInt & b)
// returns a + b

bool operator < (const LongInt & a, const LongInt & b)
// returns true if a < b, otherwise returns false

LongInt & operator = (int num)
// assignment operator, assign int value num to LongInt
```

**PROBLEM 28:**

Of the following pairs of operators, which should be coded and tested first in order to facilitate the debugging of the other operators? (Assume the runtime system provides no debugging facilities.)

**A.** `operator >>` and `operator +`

**B.** `operator <<` and `operator +`

**C.** `operator <` and `operator +`

**D.** `operator =` and `operator <<`

**E.** `operator >>` and `operator =`

**PROBLEM 29:**

In order to simulate the loop

```
    for(i=1; i < n; i++)
        cout << i;
```

the following code is used (where `i`, `one`, and `n` are `LongInt` variables).

```
    one = 1;
    for(i=1; i < n; <statement>)
        cout << i;
```

Which of the following should take the place of `<statement>` in order to simulate the loop correctly?

**A.** n = one + i

**B.** one = i + n

**C.** one = i + i

**D.** i = one + n

**E.** i = i + one

**PROBLEM 30:**

Suppose a binary tree is defined as follows:

```
    struct Tree
    {
        Tree * left;
        Tree * right;
    };
```

Consider the following function:

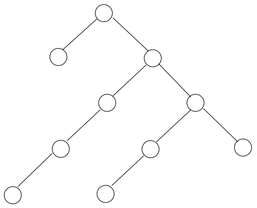
```
    int Doit(Tree * t)
    {
        if (t == NULL)
            return 0;
        else
            return Max(Height(t->left) + Height(t->right),
                       Doit(t->left),Doit(t->right));
    }
```

(*question and choices do not change*)

Suppose that the function `Max` returns the largest of its three integer arguments, and function `Height` returns the height of its tree argument, where the height of a tree is defined as follows.

> The height of an empty tree is 0.
> The height of a nonempty tree is the number of nodes on the longest path from the root to a leaf of the tree.

What value is returned when `Doit` is passed an argument representing the following tree of height 5?



**A.** 4

**B.** 5

**C.** 6

**D.** 8

**E.** 10

Questions 31-32 are based on the following code framework.

```
int i = 1;
int v = 1;
int n;
cin >> n;
while <condition>
{
    <body>
}
cout << v << endl;
```

The placeholders `<condition>` and `<body>` are to be replaced with code so that whenever the value read into variable $n$ is positive, the value output is $n!$ ($n$ factorial). Further the expression $v = i!$ is to be maintained as an invariant of the while loop.

**PROBLEM 31:**
Which of the following choices for `<body>` maintains $v = i!$ as the loop invariant?

**A.** `i += 1;`          `v *= i:`

**B.** `v *= i;`          `i += 1;`

**C.** `i += 1;`          `v = n * i;`

**D.** `v = n * i;`          `i += 1;`

**E.** `i = i * (i-1);`          `v += 1;`

**PROBLEM 32:**
Assume that `<body>` has been replaced with code that maintains $v = i!$ as the loop invariant. Which of the following choices for `condition>` ensures that if the loop terminates, the value $n!$ is output?

**A.** `i == n`

**B.** `i != n`

**C.** `i == v`

**D.** `i != v`

**E.** `i == v * n`

**PROBLEM 33:**

Consider the type and function definitions below

```
struct Node
{
    int data;
    Node * next;
};

Node * Mystery(Node * list, Node * soFar)
{
    if (list == NULL)
        return soFar;
    else
    {
        Node * temp = list->next;
        list->next = soFar;
        return Mystery(temp,list);
    }
}
```

(*question and choices do not change*)
Suppose that $p$ points the list `(1,2,3,4)`. What is the list returned by `Mystery(p,NULL)`?

**A.** `NULL`

**B.** `(1)`

**C.** `(1,1,1,1)`

**D.** `(4,3,2,1)`

**E.** `(1,2,3,4)`

Questions 34-36 are baased on the following pseudocode for a function $P$ that copies items from an array $A$ containing $n$ distinct items into a binary search tree $T$ and then prints the items.
Function $P$

```
Step 1:    Initiliaze binary search tree $T$ to be empty.
Step 2:    for (i=0; i < n; i++)
             Use the standard algorithm for insertion into a binary
             search tree to inset item $A[1]$ into $T$.
Step 3:    Print the items stored in $T$, using an inorder traversal.
```

Assume that the inset operation used in Step 2 does no balancing of $T$.

**PROBLEM 34:**
Which of the following best charactersize the output produced in step 3 of function $P$.

**A.** The items are printed in the same order in which they appear in array $A$.

**B.** The items are printed in sorted order.

**C.** The items are printed in random order.

**D.** The items are printed in the reverse of the order in which they appear in array $A$.

**E.** The value stored in $A[0]$ is printed $n$ times

**PROBLEM 35:**
As is, no changes

**PROBLEM 36:**
As is, no changes

Questions 37-38 refer to the following information.

Consider two implementations for a data structure to represent a pair of strings up up to 20 characters each. In both cases the type of the data structure is `StringPair`.

Implementation A

```
struct String
{
    apvector<char> chars;
    int  length;
    String()
      : chars(20),
        length(0)
    {}
};

struct StringPair
{
    String s1, s2;
};
```

Implementation B

```
struct String
{
    int first,last;
};

struct StringPair
{
    apvector<char> storage;
    String s1,s2;
    StringPair()
      : storage(40)
    {}
};
```

In Implementation A, `StringPair` is a struct that contains two single strings. A single string is represented by a sequence of characters stored in an apvector (starting in position 0) and an integer representing the length of the sequence.

In Implementation B, `StringPair` is a struct with three fields. The field called `storage` is an apvector of characters; the fields `s1` and `s2` each contain a pair of integers, which are indexes into the storage apvector. A single string consists of the sequence of characters `storage[first..last]`.

**PROBLEM 37:**

As is, doesn't change

**PROBLEM 38:**

add an array/apvector cell with index 0 to the front of the diagram and remove array/apvector cell with index 40. Otherwise doesn't change.

Questions 39-40 are based on the following information.

A function $T$ is defined as follows.

```
    T(0) = 1
    T(1) = 3
    T(N) = 2 * T(N - 1) - T(N - 2) for N > 1
```

Consider the follwoin to functions, `RecurT` and `IterateT`, for computing $T(N)$.

```
int RecurT(int N)
{
    if (0 == N)       return 1;
    else if (1 == N)  return 3;
    else return 2*RecurT(N-1) - RecurT(N-2);
}

int IterateT(int N)
{
    int temp1, temp2, temp3,k;
    if (0 == N)       return 1;
    else if (1 == N)  return 3;
    else
    {
        temp1 = 1;
        temp2 = 3;
        for(k=2; k <= N; k++)
        {
            temp3 = 2 * temp2 - temp1;
            temp1 = temp2;
            temp2 = temp3;
        }
        return temp3;
    }
}
```

**PROBLEM 39:**

As is, doesn't change

**PROBLEM 40:**

Change **div** to `/`, otherwise doesn't change