COMP SCI 2ME3 and SFWR ENG 2AA4 Midterm
McMaster University

Answer Key: Large arrow ($\Longleftarrow$) for correct

Day Class 01 **Version 1** Dr. S. Smith

DURATION: 1.5 hours March 1, 2017

Please CLEARLY print:

NAME:

Student ID: | | | | | | | | | |

This examination paper includes 20 pages and 30 questions. You are responsible for ensuring that your copy of the examination paper is complete. Bring any discrepancy to the attention of your invigilator.

Special Instructions:

1. It is your responsibility to ensure that the answer sheet is properly completed. Your examination result depends upon proper attention to these instructions:
   - A heavy mark must be made, completely filling the circular bubble, with an HB pencil.
   - Print your name, student number, course name, course number and the date in the space provided on the top of Side 1 and fill in the corresponding bubbles underneath.
   - **Fill in the bubble corresponding to your version number.**
   - Mark only **ONE** choice from the alternatives (1, 2, 3, 4, 5 or A, B, C, D, E) provided for each question. If there is a True/False question, mark 1 (or A) for True, and 2 (or B) for False. The question number is to the left of the bubbles. Make sure that the number of the question on the scan sheet is the same as the number on the examination paper.
   - Pay particular attention to the "Marking Directions" given on the scan sheet.
   - Begin answering the questions using the first set of bubbles, marked "1." Answer all questions.
2. Any notes or textbook are permitted.
3. Calculators, computers, cell phones, and all other electronic devices are **not** to be utilized.
4. Read each question carefully.
5. Try to allocate your time sensibly and divide it appropriately between the questions.
6. Select the **best** answer for each question.
7. The set $\mathbb{N}$ is assumed to include 0.

Question 1 [1 mark]
Under rotation by ϕ radians, the point (x, y) is transformed into the point (x', y') with coordinates given by:

$$x' = \cos(\phi)x - \sin(\phi)y$$
$$y' = \sin(\phi)x + \cos(\phi)y$$

Using the PointT class we defined in class and `import math`, the following mutator method correctly implements the rotation of the point. Is this statement True or False?

```
def rotate(self, phi):
    self.xpos = math.cos(phi)*self.xpos - math.sin(phi)*self.ypos
    self.ypos = math.sin(phi)*self.xpos + math.cos(phi)*self.ypos
```

A. True.

B. False. ⟸

ANSWER:
A temporary variable is necessary to store the original value of xpos.

Question 2 [1 mark]
Assignment 1 and 2 for 2AA4/2ME3 both presented formal specifications of modules. Is this statement True or False?

A. True

B. False ⟸

ANSWER:
answer

Question 3 [1 mark]
For the set of integers S, what does the following expression return?

$$+(x : \mathbb{Z} | x \in S \wedge x\%2 = 0 : 1)$$

A. The count of odd numbers in S.

B. The count of even numbers in S. ⟸

C. The sum of all odd numbers in S.

D. The sum of all even numbers in S.

E. 1.

ANSWER:
answer

Question 4 [1 mark]
The following is a class whose instances are two-dimensional vectors:

```
import math

class Vector:

    def __init__(self, x, y):
        self.xpos = x
        self.ypos = y

    def getX(self):
        return self.xpos

    def getY(self):
        return self.ypos

    def magnitude(self):
        return math.sqrt((self.getX() ** 2.0) + (self.getY() ** 2.0))

    def scalarMultiply(self, s):
        return Vector(s * self.getX(), s * self.getY())

    def add(self, v):
        return Vector(self.getX() + v.getX(), self.getY() + v.getY())
```

Suppose that the representation of a vector used in this class were changed from Cartesian to polar coordinates by replacing the fields `xpos` and `ypos` with `r` and `theta`. We would like all the methods in this modified class to have exactly the same external interface (same inputs and outputs) as the corresponding methods in the original class. Which methods of the class other than the `__init__` method *must* be rewritten to achieve this objective?

A. None of the methods.

B. `getX` and `getY`. ⟸

C. `getX`, `getY`, and `magnitude`.

D. `getX`, `getY`, `scalarMultiply`, and `add`.

E. All of the methods.

ANSWER:
magnitude, scalarMulitply and add are defined using the getters. As long as the getters correctly return x and y, their behaviour does not depend on the state variable representation.

Question 5 [1 mark]
Consider the specification of the add method for a sequence abstract object, where the state variable is a sequence s:
add(i, p):

- transition: $s := s[0..i-1]|| < p > ||s[i..|s|-1]$

This specification is implemented using the following code:

```
@staticmethod
def add(i, p):
    s = Seq.s
    size = len(s)
    missing code
    Seq.s = s
```

Which option best describes the Python code that could be substituted in place of the *missing code*?

A.
```
s = s[0:i] + [p] + s[i:size]
```

B.
```
s = s[0:i-1] + [p] + s[i:size-1]
```

C.
```
r = []
for j in range(i):
    r.append(s[j])
r.append(p)
for j in range(i, size):
    r.append(s[j])
s = r
```

D. A and C ⟸

E. B and C

ANSWER:
Option B looks like the specification, but Python array slicing is 1 index less at the upper bound than our mathematical notation. Options A and C are different ways of calculating the same thing.

Question 6 [1 mark]
All correct programs are robust, but all robust programs are not necessarily correct. Is this statement True or False?

A. True.

B. False. $\Longleftarrow$

ANSWER:
A correct program is not necessarily robust.

Question 7 [1 mark]
Code to implement an ambiguous specification is not verifiable. Is this statement True or False?

A. True. $\Longleftarrow$

B. False.

ANSWER:
You cannot verify code if you do not know what the code is supposed to do.

Question 8 [1 mark]
We need to calculate the average assignment grade (out of 100) for all assignments and all students in our class. Assume that you have a list (g), where g[i] is the sum of the ith students grades on their assignments. You can assume that each student has completed all 4 assignments (worth 400 points total), unless they have an MSAF, in which case they will have completed 3 assignments (worth 300 points total). The parallel lists MSAF will have MSAF[i] = True if student i has an MSAF, and False otherwise.
The following code will calculate the average.

```
add = lambda x, y: x + y
dv4 = lambda x: x/4.0
dv3 = lambda x: x/3.0
n = len(g)
avg = reduce(add, missing code)/n
```

Which option best describes the Python code that could be substituted in place of the *missing code*?

A. `[dv3(g[i]) if MSAF[i] else dv4(g[i]) for i in range(n)]`

B. `[dv3(g[i]) for i in range(n) if MSAF[i]] + [dv4(g[i]) for i in range(n) if not(MSAF[i])]`

C. `map(lambda p: p[1](p[0]), [[g[i], dv3 if MSAF[i] else dv4] for i in range(n)])`

D. A and B

E. All of the above ⟸

ANSWER:
answer

Question 9 [1 mark]
For every import statement in your Python implementation of a module, there has to be a corresponding Uses clause in the MIS. Is this statement True or False?

A. True

B. False ⟸

ANSWER:
There can be import statements that do no appear in the MIS, such as importing the math library.

Question 10 [1 mark]

Template Module

triangleADT

Uses

pointADT

Syntax

Exported Types

TriT = ?

Exported Access Programs

Routine name	In	Out	Exceptions
new TriT	PointT, PointT, PointT	TriT	NOT_VALID_TRIANGLE
centroid		PointT	
area		real	
pointInside	PointT	Boolean	
triangleIntersect	TriT	Boolean	

The interface for this module is essential; that is, unnecessary access programs are omitted.

A. True ⟸

B. False

ANSWER:
The services provided be each access program cannot be reproduced by any combination of the other access programs.

Question 11 [1 mark]
The triangleIntersect access program for the TriangleADT (shown in Question 10) is changed to the following:

Routine name	In	Out	Exceptions
intersect	ShapeT	Boolean	

where ShapeT is a superclass for different shapes, such as CircleT, TriT, BoxT, etc. What effect does this change have on the interface?

A. The interface that was previously not essential, now has the property of being essential.

B. The interface that was previously not minimal, now has the property of being minimal.

C. The generality of the interface has been improved. $\Longleftarrow$

D. The implementation independence of the interface has been improved.

E. The new interface now provides a means for the programmer to test for the conditions that would generate exceptions, before calling the access programs.

ANSWER:
answer

Question 12 [1 mark]
If a module's interface is changed to improve the quality of minimality. (A minimal interface avoids access routines that offer two different services that might be requested separately by the user.) What will happen to the number of access programs?

A. The number of access programs will stay the same, or decrease.

B. The number of access programs will always decrease.

C. The number of access programs will stay the same, or increase. $\Longleftarrow$

D. The number of access programs will always increase.

E. The number of access programs will always stay the same.

ANSWER:
answer

Question 13 [1 mark]
A module is to be implemented where the state variable s is a set of values of type T. When the access program $add(v)$ is called, the state transition is $s = s \cup \{v\}$. The programmer decides to represent the state variable using a `list` in Python. Two versions of the implementation are proposed:

A. The list is always sorted. When a new item v is added, it is placed in the sorted position.

B. When a new item is added, it is appended to the end of the list.

Which of the following statements best describes the two options?

A. The sorted list will be slow for addition, but fast for checking for set membership.

B. The sorted list is only possible if the type T is sortable.

C. The specification requires that the list not be sorted.

D. A and B. $\Longleftarrow$

E. B and C.

ANSWER:
answer

Question 14 [1 mark]
What can we say about a Parnas style diagram that shows how a software application is decomposed into modules by their secrets?

A. The decomposition will be a tree.

B. The top decomposition is split between hardware hiding, software decision hiding and behaviour hiding.

C. The lines in the diagram represent an IS_COMPONENT_OF relation.

D. The leaf modules are the ones that need to be implemented.

E. All of the above. $\Longleftarrow$

ANSWER:
answer

Question 15 [1 mark]
If a bi-directional association exists in a UML diagram, then the uses relation cannot be a hierarchy. Is this statement True or False?

A. True $\Longleftarrow$

B. False

ANSWER:
answer

Question 16 [1 mark]
Consider the following specification for returning the rank of the natural number i in a sequence of integers A of length n.
$\text{rank}(i, A) : \mathbb{N} \times \mathbb{N}^n \to \mathbb{N}$
$\text{rank}(i, A) \equiv \min(\text{indexSet}(i, \text{sort}(A)))$

$\text{indexSet}(i, B) : \mathbb{N} \times \mathbb{N}^n \to$ set of $\mathbb{N}$
$\text{indexSet}(i, B) \equiv \{j : \mathbb{N} | j \in [0..|B| - 1] \wedge B[j] = i : j\}$

$\text{sort}(A) : \mathbb{N}^n \to \mathbb{N}^n$
$\text{sort}(A) \equiv B : \mathbb{N}^n,$ such that
$\forall(a : \mathbb{N} | a \in A : \exists(b : \mathbb{N} | b \in B : b = a) \wedge \text{count}(a, A) = \text{count}(b, B)) \wedge \forall(i : \mathbb{N} | i \in \mathbf{S} : B[i] \geq B[i + 1])$

$\text{count}(a, A) : \mathbb{N} \times \mathbb{N}^n$
$\text{count}(a, A) : +(x : \mathbb{N} | x \in A \wedge x = a : 1)$

$\min(C) :$ set of $\mathbb{N} \to \mathbb{N}$
$\min(C) \equiv m$ such that $\forall(x : \mathbb{N} | m \in C \wedge x \in C : m \leq x)$

In the sort function, what should the value of the set **S** be?

A. $[0..|A|]$

B. $[0..|A| - 1]$

C. $[0..|A| - 2] \Longleftarrow$

D. $[1..|A| - 1]$

E. $[1..|A| - 2]$

ANSWER:
answer

Question 17 [1 mark]
Using the specification for rank from Questions 16, what is the value of rank(4, [3, 9, 9, 9, 4, 3, 4, 7])?

A. 5

B. 4 $\Longleftarrow$

C. 3

D. 2

E. 1

ANSWER:
answer

Question 18 [1 mark]
Other versions of the ranking function, as given in Questions 16 can be obtained by changing the min function to instead return a maximum of the index set, or an average of the index set. Is this statement True or False?

A. True $\Longleftarrow$

B. False

ANSWER:
answer

Question 19 [1 mark]
In our MIS specifications, when do we use environment variables?

A. When the specification needs to inspect or change the state of something external to the software. $\Longleftarrow$

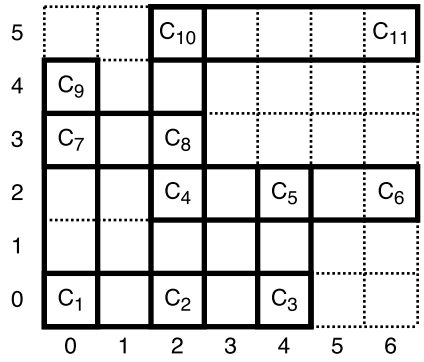
B. When we need to change the search PATH used by the software.

C. Every time the module state machine undergoes a state transition.

D. When we are working on sustainable green computing project.

ANSWER:
answer

Question 20 [1 mark]
A maze is defined on a rectangular grid, as shown in the following picture. The segments of the maze can only be horizontal or vertical.



C_i represents the ith cell. A path through the maze is given by a sequence of cells. If the length of a path is measured by the number of grid blocks, which of the following paths is the shortest between C_1 and C_{11}?

A. C_1, C_2, C_{10}, C_{11}

B. C_1, C_2, C_4, C_8, C_{10}, C_{11}

C. C_1, C_7, C_8, C_{10}, C_{11}

D. A and C.

E. All of the above. $\Longleftarrow$

ANSWER:
answer

Question 21 [1 mark]
Assuming that cellT (tuple of (x: integer, y: integer)) and segT (tuple of (s: cellT, f: cellT)) are exported from other modules (cellADT and segADT, respectively), with the obvious constructors and getters (getx(), gets() etc.), the module interface syntax for a module to store the maze can be specified as follows.

Module

maze

Uses

cellADT, segADT

Syntax

Exported Access Programs

Routine name	In	Out	Exceptions
ms_init			
ms_setStart	cellT		
...	...	...	...
ms_addSeg	segT		
ms_sameSeg	cellT, cellT	Boolean	

Semantics

State Variables

m: set of segT
start: cellT
end: cellT

The uses relation expresses what modules are needed to interpret the specification, analogous to how import is used in Python. With this in mind, segADT is necessary in the Uses clause. Is this statement True or False?

A. True $\Longleftarrow$

B. False

ANSWER:
answer

Question 22 [1 mark]
If we add a state invariant that $|m| \leq$ MAX_SIZE to the interface for the maze module given in Question 21, what changes do we need to make to the interface?

A. No changes are necessary. The presence of the invariant in the specification guarantees that it will be satisfied.

B. An exception could be added for the case where the ms_addSeg is called on a maze that already holds MAX_SIZE elements.

C. A conditional rule could be added to ms_addSeg to specify behaviour in the case of $|m| =$ MAX_SIZE, such that the new behaviour does not increase the size of the set.

D. B or C. $\Longleftarrow$

ANSWER:
answer

Question 23 [1 mark]
In Questions 21 the maze is specified as an abstract object, as opposed to an abstract data type (ADT). Potential reasons for this decision are as follows:

A. Many modules will need to read the data from the maze module. Using an abstract object means it can be used directly, without a need to pass a reference to an instance of the class (object).

B. Without the need for a constructor and tracking "self" the interpreted code can be more efficient.

C. An abstract object provides better support for the principle of information hiding than an ADT.

D. A and B. $\Longleftarrow$

E. All of the above.

ANSWER:
answer

Question 24 [1 mark]
In Question 21 the access program ms_sameSeg(c1, c2) returns True if cells c1 and c2 are in the set of cells that make up the beginning and end points of the segments in the maze, and c1 and c2 are both on the same segment in the maze. Therefore, the specification of the output of ms_sameSeg(c1, c2) is:

$out := c1 \in \text{mazeNodes}() \wedge c2 \in \text{mazeNodes}() \wedge \text{shareSeg}(c1, c2)$

You are given the following Python code to create a maze. (This maze represents a portion of the maze from Question 20).

```
c1 = cellT(0,0)
c2 = cellT(2,0)
c3 = cellT(4,0)
c10 = cellT(2,5)
c12 = cellT(2,1)

s1 = segT(c1, c3)
s6 = segT(c2, c10)

ms.addSeg(s1)
ms.addSeg(s6)

print ms.sameSeg(c1,c3), ms.sameSeg(c1,c10), ms.sameSeg(c2,c12)
```

What is the output of the print statement?

A. False, False, False

B. True, True, True

C. True, False, True

D. True, True, False

E. True, False, False ⟸

ANSWER:
answer

Question 25 [1 mark]
In a particular implementation of the module maze, equality of objects is only determined based on equality of their references. Given this, what will the output be for Question 24, if s1 and s6 are modified as follows:

```
s1 = segT(cellT(0,0), cellT(4,0))
s6 = segT(cellT(2,0), cellT(2,5))
```

A. False, False, False ⟸

B. True, True, True

C. True, False, True

D. True, True, False

E. True, False, False

ANSWER:
answer

Question 26 [1 mark]
To fully define ms_sameSeg(c1, c2) from Questions 24, we need to define the local function mazeNodes(). This local function returns the set of cells that are in the maze. For instance, for the maze in Questions 20, the set of cells would be C_1 to C_{11}. Which of the following specifications for the definition of mazeNodes() captures the required behaviour?

A. $\{s|s \in m : s.\text{gets}()\} \cup \{s|s \in m : s.\text{getf}()\}$ ⟸

B. $\{s|s \in m : s.\text{gets}()\} \cap \{s|s \in m : s.\text{getf}()\}$

C. $\{s|s \in m : s.\text{gets}().\text{getx}()\} \cup \{s|s \in m : s.\text{gets}().\text{getx}()\} \cup \{s|s \in m : s.\text{gets}().\text{gety}()\} \cup \{s|s \in m : s.\text{gets}().\text{gety}()\}$

D. $\{s|s \in m : s.\text{gets}().\text{getx}()\} \cap \{s|s \in m : s.\text{gets}().\text{getx}()\} \cap \{s|s \in m : s.\text{gets}().\text{gety}()\} \cap \{s|s \in m : s.\text{gets}().\text{gety}()\}$

E. $\{s|s \in m : \text{segT}(s.\text{gets}().\text{getx}(), s.\text{gets}().\text{gety}())\}$

ANSWER:
answer

Question 27 [1 mark]
As part of the definition of ms_sameSeg(c1, c2), a local function ptOn(c, s) is introduced. This function determines whether the cell c lies on segment s. Using $x(c) \equiv c$.getx(), $x(s) \equiv s$.gets().getx(), $x(f) \equiv s$.getf().getx(), etc., which of the following correctly specifies the output of ptOn(c, s)?

A.

$$\begin{aligned}(x(c) = x(s) \Rightarrow & \begin{array}{r}(y(s) \leq y(f) \Rightarrow y(s) \leq y(c) \leq y(f)| \\ y(s) > y(f) \Rightarrow y(f) \leq y(c) \leq y(s))\end{array} \\ |y(c) = y(s) \Rightarrow & \begin{array}{r}(x(s) \leq x(f) \Rightarrow x(s) \leq x(c) \leq x(f)| \\ x(s) > x(f) \Rightarrow x(f) \leq x(c) \leq x(s)))\end{array}\end{aligned}$$

B.

$$\begin{aligned}(x(c) = x(s) \Rightarrow & \begin{array}{r}(x(s) \leq x(f) \Rightarrow x(s) \leq x(c) \leq x(f)| \\ x(s) > x(f) \Rightarrow x(f) \leq x(c) \leq x(s))\end{array} \\ |y(c) = y(s) \Rightarrow & \begin{array}{r}(y(s) \leq y(f) \Rightarrow y(s) \leq y(c) \leq y(f)| \\ y(s) > y(f) \Rightarrow y(f) \leq y(c) \leq y(s)))\end{array}\end{aligned}$$

C.

$$\begin{aligned}(x(c) = x(s) \Rightarrow & \begin{array}{r}(y(s) \leq y(f) \Rightarrow y(s) \leq y(c) \leq y(f)| \\ y(s) > y(f) \Rightarrow y(f) \leq y(c) \leq y(s))\end{array} \\ |y(c) = y(s) \Rightarrow & \begin{array}{r}(x(s) \leq x(f) \Rightarrow x(s) \leq x(c) \leq x(f)| \\ x(s) > x(f) \Rightarrow x(f) \leq x(c) \leq x(s))\end{array} \\ |x(c) \neq x(s) \wedge y(c) \neq y(s) \Rightarrow & \text{False})\end{aligned}$$

$\Longleftarrow$

D.

$$\begin{aligned}(x(c) = x(s) \Rightarrow & \begin{array}{r}(x(s) \leq x(f) \Rightarrow x(s) \leq x(c) \leq x(f)| \\ x(s) > x(f) \Rightarrow x(f) \leq x(c) \leq x(s))\end{array} \\ |y(c) = y(s) \Rightarrow & \begin{array}{r}(y(s) \leq y(f) \Rightarrow y(s) \leq y(c) \leq y(f)| \\ y(s) > y(f) \Rightarrow y(f) \leq y(c) \leq y(s))\end{array} \\ |x(c) \neq x(s) \wedge y(c) \neq y(s) \Rightarrow & \text{False})\end{aligned}$$

E. $(y(s) \leq y(c) \leq y(f)) \vee (x(s) \leq x(c) \leq x(f))$

ANSWER:
answer

Question 28 [1 mark]
The following Python code can be used to implement shareSeg(c1, c2) from Questions 24:

```
reduce(lambda x,y: x or y, [ptOn(c1,s) and ptOn(c2,s) for s in ms.m],
    False)
```

The meaning of ptOn(c,s) is given in Question 27. How would shareSeg(c1, c2) be represented as a mathematical specification?

A. $\exists(s|s \in m : \text{ptOn}(c1, s) \vee \text{ptOn}(c2, s))$

B. $\exists(s|s \in m : \text{ptOn}(c1, s) \wedge \text{ptOn}(c2, s))$ $\Longleftarrow$

C. $\forall(s|s \in m : \text{ptOn}(c1, s) \vee \text{ptOn}(c2, s))$

D. $\forall(s|s \in m : \text{ptOn}(c1, s) \wedge \text{ptOn}(c2, s))$

ANSWER:
answer

Question 29 [1 mark]
The specification of ms_sameSeg(c1, c2) (Question 24) used the definition of several local functions, including mazeNodes() (Question 26), ptOn(c, s) (Question 27) and shareSeg(c1, c2) (Question 28). Therefore, the implementation of ms_sameSeg(c1, c2) will require that each of the listed local functions also be implemented. Is this statement True or False?

A. True

B. False $\Longleftarrow$

ANSWER:
answer

Question 30 [1 mark]
Which of the following qualities are improved by using the design principle of information hiding?

A. Performance

B. Portability

C. Maintainability

D. B and C $\Longleftarrow$

E. All of the above

ANSWER:
answer

Please make sure your **version number** is clearly marked on your scan sheet!

THE END.