You have 90 minutes to work on this exam. It is a "closed-book/closed-notes" test.

IMPORTANT: Students who have already taken UF course CEN 4072/6070, Software Testing and Verification, should work PROBLEMS 1-10 AND 15-16 ONLY. All other students should work PROBLEMS 1-14 ONLY. NO CREDIT WILL BE GIVEN for working additional problems.

PRINT your name above NOW and sign the pledge at the bottom of the last page, if appropriate, when you are finished.

Please PRINT answers in the space provided only – PREFERABLY USING A BALLPOINT PEN TO INCREASE LEGIBILITY. Good luck!

1. (6 pts.) Using pre- and post-conditions, formally specify a program that would satisfy the following requirements:

   "Set Boolean variable NPRIME to true if positive integer (input) variable N is prime and to false otherwise."

2. (6 pts.) Provide a function-based specification that is equivalent to the function computed by the program given below.

   if X>10 then
   Y := Y+X;
   X := 0
   else if X>5 then
   Y := Y-X;
   X := Y+X
   end_if_else
3. (10 pts.) Match each description below to the **SINGLE MOST APPROPRIATE TERM** among the following. (Note: terms may apply to none, one, or more than one description.)

A. schema predicate  
B. constructor operations  
C. operational specification  
D. axioms  
E. pre-condition  
F. model-based specification  
G. schema signature  
H. inspection operations  
J. function-based specification  
K. post-condition  
L. operation signatures  
M. algebraic specification

____ Defines invariants, constraints, pre- and post-conditions in Z-based specifications.  
Example would be: \((A > B \rightarrow A, B, \text{MAX} := A, B, A | \text{true} \rightarrow A, B, \text{MAX} := A, B, B)\)

____ A specification approach whereby a system is specified in terms of its operations and their relationships via *axioms*.

____ Expresses conditions/relationships among program variables that capture obligatory conditions after program execution.

Example would be:

```markdown
Storage tank  
\begin{align*}
&\text{contents: } N \\
&\text{capacity: } N \\
&\text{light: } \{\text{off, on}\} \\
&\text{reading: } N \\
&\text{danger level: } N \\
\end{align*}
\begin{align*}
&\text{contents} \leq \text{capacity} \\
&\text{light = on} \iff \text{reading} \leq \text{danger level} \\
&\text{reading} = \text{contents} \\
&\text{capacity} = 500 \\
&\text{danger level} = 50 \\
\end{align*}
```

____ Defines the entities that make up the state of the system being specified using Z.  
Example would be: pre-condition: \(\{T\}\)  
post-condition: \(\{[(\text{MAX}=A \text{ AND } A \geq B) \text{ OR } (\text{MAX}=B \text{ AND } B \geq A)] \text{ AND UNCH}(A,B)\}\)

____ This specification approach can become cumbersome when object operations are not independent of object state.

____ Expresses constraints on program variables that an implementer may assume will hold before program execution.
4. (4 pts.) According to Sommerville, which one of the following is “the most important development that has affected distributed software systems in the past few years”?
(Circle ONE only.)
   a. The service-oriented approach.
   b. The CORBA middleware standard.
   c. The message-based (non-synchronous) distributed component interaction model.
   d. Client-server computing.
   e. Peer-to-peer technologies.

5. (10 pts.) Match each application or description below to the SINGLE MOST APPROPRIATE type of architecture among the following. (Note: architecture types may apply to none, one, or more than one application or description.)

   A. two-tier client/server (C/S) architecture with thin clients
   B. two-tier client/server (C/S) architecture with fat clients
   C. multi-tier client/server (C/S) architecture
   D. distributed component architecture
   E. peer-to-peer architecture (P2P)
   F. software as a service (SaaS)
   G. service-oriented architecture (SOA)
   H. master-slave architecture

   ____ An approach to structuring a software system as a set of separate, stateless services that may entail multiple providers and may be distributed.
   ____ Well know examples include web-based mail systems such as Yahoo! and Gmail, and office application such as Google docs.
   ____ Sommerville illustrates this architecture with a real-time traffic control system that has three logical processes that run on separate processors.
   ____ This architecture has the advantage of being highly redundant and therefore both fault-tolerant and tolerant of nodes disconnecting from the network.
   ____ Some developers of systems based on this architecture have opted to replace existing “inefficient” protocols developed to be open standards with so-called RESTful protocols having inherently lower overhead.
   ____ Sommerville illustrates this architecture with a bank ATM system which delivers cash and other banking services to users.
   ____ Browsing the Web is the most common example of a situation where this architecture is used.
   ____ Sommerville illustrates this architecture with a data mining system that looks for relationships between the data stored in a number of databases.
   ____ Examples of systems employing this architecture include Freenet, ICQ, and Jabber.
   ____ Sommerville illustrates this architecture with a scalable Internet banking system.
6. (4 pts.) Sommerville notes that “Aspects are completely different from other program abstractions...”. Which one of the following best describes the distinguishing characteristic of aspects? (Circle ONE only.)

a. There is a clear separation between the definition of the abstraction and its use. (You cannot tell by examining an aspect where it will be called from.)

b. The interaction between aspects and other program abstractions is strictly asynchronous.

c. Aspects may only communicate with core components via middleware using remote procedure or method calls.

d. Aspect transactions are typically “brief,” whereby a cross-cutting service is called, does something, and returns a result. With other abstractions, transactions are usually “long,” e.g., editing a document.

e. Unlike other abstractions, an aspect itself includes a specification of where it should be executed.

7. (4 pts.) Which one of the following best reflects the point that Fred Brooks makes with the title of his popular book about being a software project manager? (Circle ONE only.)

a. He chose “The Mythical Man-Mouse” as his title to make the point that effective software project managers facing difficult decisions should always ask themselves: “Are we Mice or Men?”

b. The title he chose, “The Mythical Mammoth,” refers to an overbearing and threatening project manager, which (he argues) is largely extinct today since project managers now understand that most of their tasks are people-oriented and that poor people skills are an important contributor to project failures.

“The Mythical (Woolly) Mammoth Project Manager”

c. He chose “The Mythical Man-Month” as his title to make the point that not all software engineers are men.

(continued on next page)
d. The title he chose, “The Mythical Man-Month,” represents the idea that a “man month” – i.e., a person working productively on the same software development task for a month – is completely unrealistic and therefore “mythical.”

![Image](image1.png)

e. He chose “The Mythical Man-Moth” as his title to make the point that the “new-technology man-moth” (which refers to a “half-man, half-moth super hero who can successfully integrate new technology in an organization and then just ‘fly away’ without risk of recidivism”) is just a myth.

![Image](image2.png)

f. He chose the title “The Mythical Man-Mouth” to make the point that project managers who communicate with their development staff in a domineering or abusive fashion (Brooks calls such managers “Man-Mouths”) are largely a myth.

![Image](image3.png)

g. He chose the title “The Mythical Man-Moose” to make the point that a manager who does not “keep his eyes on the progress of a project” cannot, in fact, compensate for this even with “moose-like heightened senses of smell and hearing”.

![Image](image4.png)

h. The title he chose, “The Mythical Man-Month,” refers to a popular measure of effort for software development, the “man-month,” which implies calendar time and people are perfectly interchangeable. The measure, therefore, is “mythical.”

![Graph](image5.png)
8. (4 pts.) Sommerville describes Maslow’s human needs hierarchy as “being helpful up to a point” in explaining what motivates people, but feels there is a specific problem with it. Which one of the following best describes this problem? (Circle ONE only.)

a. He feels that “the opportunity for self-actualization and establishing satisfying relationships in the workplace are perhaps the most important contributors to motivating team members.”

b. He feels that it takes an exclusively personal viewpoint on motivation, and does not take adequate account of the fact that people feel themselves to be part of an organization, a professional group, and one or more cultures.

c. He feels Maslow does not adequately consider the importance of allowing people to fully experience what life has to offer outside the workplace. (Sommerville quips that “all work and no play does much more harm than simply making Jack a dull boy.”)

d. He feels that “praise from immediate managers, leadership attention (for example, one-on-one conversations), and a chance to lead projects or task forces” are even more effective motivators than meeting the needs identified by Maslow.

9. (4 pts.) In his Chapter on Process Improvement, Sommerville notes that for small projects, where there are only a few team members, sophisticated development tools are particularly important, but that paradoxically, such tools are less important in large projects. Briefly summarize his explanation for this.

10. (8 pts.) Sommerville identifies ten examples of “software process attributes” that may be targets for improvement (understandability, standardization, visibility, measurability, supportability, acceptability, reliability, robustness, maintainability, and rapidity), but notes that it is not possible to make process improvements that optimize all process attributes simultaneously. To illustrate this point, he cites three specific examples of “inverse relationships” that exist among the ten attributes listed. Briefly describe and explain TWO of the THREE specific examples he cites.
11. (10 pts.) Consider each of the following assertions and circle either “true” or “false” as appropriate. (Note: “|x|” refers to the absolute value of variable x, and “<>” means “NOT EQUAL TO.”) To compensate for random guessing, you will receive +2 pts. for each correct answer and -2 pts. for each incorrect answer. (The minimum score possible for this problem is 0 pts.) Therefore, DON’T CIRCLE AN ANSWER UNLESS YOU ARE MORE THAN 50% SURE THAT IT IS CORRECT!

a. {-|x|≥0} y := x+1 {y≥0}  
   true  false

b. {true} while x <> 5 do x := x+17 {x≤10}  
   true  false

c. [{x≥0} S {x=17}] ⇒ [{x=17} S {x≥0}]  
   true  false

d. {a<xy} a := a+x; y := y-1 {a≤xy+2x}  
   true  false

e. {X[I+1]=I} J := I+1 {X[J]=J+1}  
   true  false

12. (8 pts.) Use the WEAKEST PRECONDITION-BASED METHOD to prove the following assertion. SHOW ALL STEPS as illustrated in class.

{x=-5} if x<>0 then y := -x {y>0}
NOTE: if you have already taken CEN 4072/6070, Software Testing and Verification, DO NOT work the problems on this page! (Work problems 15-16 instead.)

13. a. (3 pts.) Give the antecedents ("initialization, preservation, and finalization") to complete the while loop Rule of Inference (ROI):

{P} while b do S {Q}

b. (4 pts.) Consider the assertion: {true}

\[Z := X \quad \text{while } Z \neq (X + Y) \quad \text{do} \quad Z := Z + X \quad \text{end}_\text{while} \]

\{Z = XY\}

and the hypothesized invariant, I: true

Which one of the following correctly identifies the while_do statement ROI antecedents that WOULD hold when attempting to prove this assertion using the given hypothesized invariant? (Circle ONE only.)

i. initialization only 
ii. preservation only
iii. finalization only
iv. initialization and finalization only
v. initialization and preservation only
vi. preservation and finalization only
vii. initialization, preservation, and finalization
viii. (none would hold)

14. (5 pts.) Use the complete (functional) correctness conditions for sequencing to prove \(f = [P]\) where \(f = (x, y := y + 2, y)\) and \(P\) is: \(x := y + 2; \ y := x - 2\). You may assume that \((x, y := y + 2, y) = [x := y + 2]\) and that \((x, y := x, x - 2) = [y := x - 2]\). Show that ALL other sequencing correctness conditions required to prove \(f = [P]\) hold as illustrated in class.
NOTE: problems 15-16 are for students who have already taken CEN 4072/6070, Software Testing and Verification, ONLY! All other students should work problems 11-14 instead.

15. Consider the intended program function $f = (y, z := y+z, 0)$.

a. (3 pts.) Give the weakest $f$-adequate invariant over the $D(f)$ for while loops computing $f$. (Hint: use the expression $q(X)$ from the Invariant Status Theorem.)

b. Consider program $P_1$: while $z<>0$ do
   if $z<0$ then
     $y := y-1$;
     $z := z+1$
   else
     $y := y+1$;
     $z := z-1$
   end_if_else
end_while

i. (2 pts.) Give the sequence of states $X_0, X_1, ..., X_n$ produced by each iteration of the loop given that the initial state, $X_0 = (y_0, z_0)$, is $(17,-4)$.

ii. (2 pts.) Show that each of these states “agrees with $q(X)$.” (Note: if the states do NOT agree with $q(X)$, you have either incorrectly answered part (a) and/or part (i) above.)

iii. (3 pts.) Consider the state $X_k = (-5, 18)$. Is this one of the states in the sequence of states from $X_0$ to $X_n$ you identified in part (i) above? Does it agree with $q(X)$? Explain the implication of your answers to these two questions.
10

NOTE: problems 15-16 are for students who have already taken CEN 4072/6070, Software Testing and Verification, ONLY! All other students should work problems 11-14 instead.

15. b. (cont’d)

iv. (3 pts.) Consider the state $X_t = (0, 0)$. Is this one of the states in the sequence of states from $X_0$ to $X_n$ you identified in part (i) above? Does it agree with $q(X)$? **Once again, explain the implication of your answers to these two questions.**

c. Consider program P2: 

```plaintext
while z<>0 do
    y := y+z;
    z := 0
end_while
```

i. (2 pts.) Given the sequence of states $X_0, X_1, ..., X_n$ produced by each iteration of the loop given that the initial state, $X_0 = (y_0,z_0)$, is (3,4).

ii. (2 pts.) Show that each of these states agrees with $q(X)$.

d. Consider (non-looping) program P3: 

```plaintext
y := y+z;
z := 0
```

i. (2 pts.) Given that the initial state, $X_0 = (y_0,z_0)$, is (-6,3), the final state, $X_1$, is obviously (-3,0). Show that each of these two states also agrees with $q(X)$.

ii. (3 pts.) In this case, while P3 is obviously not a while loop, it still computes $f$, and $q(X)$ still agrees with the given initial state and the resultant final state. **Is this the case for all programs that compute $f$? Justify your answer.**
NOTE: problems 15-16 are for students who have already taken CEN 4072/6070, Software Testing and Verification, ONLY! All other students should work problems 11-14 instead.

16. In this problem, we consider an example that sheds light on two issues related to the last question posed in problem 15: (1) Are there functions computed by while loops for which \( q(X) \) does not hold? and (2) Are there functions that cannot be computed by while loops?

Consider the function \( f' = (y := y+1) \).

a. (2 pts.) What does the expression \( q(X) \) from the Invariant Status Theorem yield for this function?

b. (2 pts.) Consider the program: \( y := y+1 \) (which obviously computes \( f' \)). Clearly, for any program that computes \( f' \), if the initial state is \( y_0 \), then the final state must be \( y_0 + 1 \). Do these initial and final states agree with \( q(X) \) from part (16.a) above?

c. (4 pts.) Is there a program of the form “while b do s” that computes \( f' \)? If so, provide such a program. If not, explain why this is so. (Hint: recall that in learning about the Iteration Recursion Lemma, it was observed that any while loop computing a function, \( f \), maintains an important property of state across iterations – i.e., when the loop predicate is evaluated. What is this property and what is the implication of the property NOT holding?)

On my honor, I have neither given nor received unauthorized aid on this exam and I pledge not to divulge information regarding its contents to those who have not yet taken it.

_____________________
SIGNATURE