You have 90 minutes to work on this exam. It is a "closed-book/closed-notes" test. Pay attention to point values, since you may not have time to work all 18 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. (8 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. predicate
   B. universal quantifiers
   C. constructor operations
   D. operational specification
   E. axioms
   F. pre-condition
   G. model-based specification
   H. post-condition
   I. assignment function
   J. Lotos
   K. inspection operations
   L. component and application assembly
   M. existential quantifiers
   N. operation signature
   O. algebraic specification
   P. Z

___ That part of a schema which defines conditions that are always true.

___ Used to assert that some predicate holds FOR AT LEAST ONE or FOR SOME member of a given set.

___ A specification approach that explicitly exposes system state and defines operations by defining how they affect system state.

___ Used to specify program data mappings; its domain corresponds to the initial data states that would be transformed into final data states by a suitable program.

___ A specification approach well suited for specifying the interfaces of objects and abstract data types.

___ Provides the name and parameter types for an operation.

___ A mature notation for model-based specification that uses sets and relations between sets.

___ Defines the semantics of operations defined over a sort in an algebraic specification.
2. (7 pts.) Suppose we wished to develop an algebraic specification for an abstract data type representing arrays. Assume that arrays are collections of elements of generic type "Elem" (including the special element "Undefined"). Individual array elements are referenced via their numeric index. Create takes lower and upper index bounds as parameters and creates an array, initializing its values to Undefined. Operations First and Last take an array as a parameter and return the array's lower and upper index bounds, respectively. Assign creates a new array which is the same as the input array with the referenced element assigned the given value. Eval returns the value of a referenced array element. If an attempt is made to access a value outside the bounds of the array, the value returned is "Undefined". Assume arrays are of type "Array", and that numeric indices are of type "Integer".

Give the "signature" part (and ONLY the signature part) of the specification.

3. (9 pts.) Using pre- and post-conditions, formally specify a program that sets variable I to the index of the last instance of the constant value K in the non-empty array A[1:N], or to -1 if there is no instance of K.

4. (5 pts.) Use function-based specification to formally specify the following program.

```plaintext
if X>0 then
    X := X*Y
    Y := 0
end_if
```
5. (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. E.g., |-4| = |4| = 4.) (Note that to compensate for random guessing, you will receive +2 pts. for each correct answer and -2 pts. for each incorrect answer. No points will be added to or subtracted from your score if you do not circle an answer.)

a. \{x=1\} y := x-1; input(x) \{y\leq x\}  
   true false

b. \{x>0 \lor x=-5\} if x<5 then x := x-1 \{x\geq 0 \lor x=-6\}  
   true false

c. \{x=y^k\} y := y+1 \{x-k=y^k\}  
   true false

d. \{|x|=17\} while x <> 5 do x := x+1 \{x=5\}  
   true false

e. [\{x>0\} s1 \{y=x\}] => [\{x=5\} s1 \{y\geq x\}]  
   true false

6. (10 pts.) Use the **WEAKEST PRECONDITION-BASED METHOD** to prove the following assertion. Show ALL steps as illustrated in class. (Note: “|X|” refers to the absolute value of variable X. E.g., |-4| = |4| = 4.)

\{Y=X\} if X<0 then Y := X-(2*X) \{Y=|X|\}
7. **a. (3 pts.)** Give the antecedents (“initialization, preservation, and finalization”) for the while loop Rule of Inference (ROI): (Fill-in the blanks.)

\[
{P} \quad \text{while } b \text{ do } S \quad \{Q\}
\]

**b. (10 pts.)** Prove the following assertion of weak correctness using the while-loop ROI with the given invariant, \( I \). Assume that all program variables represent INTEGER values. Show ALL steps as illustrated in class. (Note that “!” represents the factorial function. E.g., \(4! = 4*3*2*1 = 24\). Also, recall that \(0! = 1! = 1\).)

\[
\{ x > 0 \} \quad \text{Use } I: \quad y = x(k-1)!
\]

\[
\begin{align*}
&k := 1 \\
&y := x \\
&\text{while } k <> x \text{ do} \\
&\quad y := y * k \\
&\quad k := k + 1 \\
&\text{end_while}
\end{align*}
\]

\[
\{ y = x! \}
\]
8. (7 pts.) Prove $f = [P]$ where program $P$ is: if $X < 0$ then $Y := X - (2*X)$ end_if and intended function $f$ is: $(X < 0 \rightarrow X, Y := X, |X|) \mid X \geq 0 \rightarrow X, Y := X, Y)$. Show all steps.

9. Sommerville identifies a number of “design issues that have to be considered in distributed systems engineering.”

   a. (3 pts.) Briefly describe the **transparency** issue.

   b. (3 pts.) Briefly describe the **openness** issue.
10. (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 example of this type of architecture might be an easily extendable data mining system comprised of multiple standard data sources, a number of independent data “integrators” each attempting to deduce different relationships, graphical relationship “visualizers,” and report generators.

___ Applications with relatively stable end-user functionality used in an environment with well-established system management.

___ Commonly used in real-time systems where there may be separate processors associated with data acquisition from the system’s environment, data processing, and computation and actuator management.

___ Structures a system as a set of separate, stateless services that may be provided by multiple providers and distributed. Typically, transactions are short, whereby a service is called, does something, and then returns a result.

___ Appropriate for computationally intensive applications for which it is possible to separate the processing required into a large number of independent computations (e.g., protean “folding at home”).

___ Objects provide general services that may be called on by other objects. This approach may be used for implementing client-server systems.

___ An example of this type of C/S architecture is an Internet banking system in which the bank’s customer database supports database processing, a web server provides the application services and data management, and the user’s computer supports an Internet browser.

___ Appropriate where the system primarily involves the exchange of information between individual computers on a network and there is no need for this information to be centrally stored or managed (e.g., file-sharing systems).

___ Provides functionality on a remote server with client access through a web browser. The server maintains the user’s data and state during an interaction session. Transactions are usually long (e.g., editing a document).

___ An example of this type of architecture is a banking ATM system for which the hardware in the teller machine carries out most of the customer-related processing associated with transactions.
11. (10 pts.) Match each description below to the SINGLE MOST APPROPRIATE AOSD RELATED TERM among the following. (Note: terms may apply to none, one, or more than one description.)

A. advice  
B. scattering  
C. knotting  
D. aspect  
E. core concerns  
F. braiding  
G. join point  
H. knitting  
I. tangling  
J. join point model  
K. guidance  
L. pointcut  
M. cross-cutting concerns  
N. feature  
O. weaving  
P. scrambling

___ Aspect code implementing a concern
___ Occurs when a module in a system includes code that implements different system requirements
___ Functional requirements that directly relate to a system’s primary purpose
___ Act of combining objects, methods, and aspects to create an executable program
___ An event in an executing program where the advice associated with an aspect may be executed
___ An abstraction designed to encapsulate functionality associated with a cross cutting concern
___ Occurs when the implementation of a concern is dispersed across more than one component in a program
___ The set of events that may be referenced in a pointcut
___ Requirements such as those associated with quality of service issues that apply to a system as a whole rather than those associated with the primary functional services a system provides
___ A statement, included in an aspect, that defines where advice should be inserted into a program

12. (4 pts.) Briefly explain why program inspections and white-box testing can be problematic with aspect oriented programs.
13. (3 pts.) Which one of the following is the specific point that was illustrated in class with the following diagram? (Circle ONE only.)

![Diagram]

a. “Flattening” an aspect-oriented program for reading is problematic.

b. AOSD involves isolating potentially changeable “cross-cutting concerns” in separate program aspects.

c. The mapping between requirements and components is 1:1 in most large systems.

d. Some consider the problems of inspecting and deriving structural tests for aspect oriented programs to be a significant barrier to the adoption of AOSD.

e. An aspect-oriented program is created by automatically combining objects, methods, and aspects.

f. (None of the above)

14. (6 pts.) Fred Brooks, author of *The Mythical Man-Month*, argues that adding people to a late software project can actually make it later. **Graphically** depict the three general relationships one would expect to see between the number of PEOPLE working (horizontal scale) vs. calendar TIME (vertical scale) for (a) *perfectly* partitionable tasks (i.e., tasks that can be partitioned with no additional cost or overhead), (b) tasks that are *not* partitionable, and (c) software development projects.

<table>
<thead>
<tr>
<th>a. perfectly partitionable</th>
<th>b. not partitionable</th>
<th>c. software development</th>
</tr>
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<tbody>
<tr>
<td>more TIME</td>
<td>more TIME</td>
<td>more TIME</td>
</tr>
<tr>
<td>less PEOPLE</td>
<td>less PEOPLE</td>
<td>less PEOPLE</td>
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<tr>
<td>few</td>
<td>many</td>
<td>few</td>
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</tbody>
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15. (4 pts.) According to Sommerville, a **risk** exists when there is a probability that some adverse circumstance will occur. Based on this interpretation, briefly describe the different objectives of an **avoidance strategy** and a **minimization strategy**.

16. (6 pts.) Briefly describe the three stages of the generic process improvement cycle. (A sentence or two describing the basic activities associated with each stage is sufficient.)

17. (6 pts.) Sommerville describes two general process change problems, one of which is related to what he calls “change persistence.” Briefly describe: (a) the problem he identifies in connection with “change persistence”, (b) the circumstances under which it is “particularly likely” to occur, and (c) the approach that the CMMI model “argues strongly for” to counter it.
18. (10 pts.) Consider the following statements related to the CMMI process improvement framework. Circle either "true" or "false" as (most) appropriate. (Note that to compensate for random guessing, you will receive +2 pts. for each correct answer and -2 pts. for each incorrect answer. No points will be added to or subtracted from your score if you do not circle an answer.)

a. The *staged* CMMI model allows an organization’s process capability to be assessed and assigned a maturity level from 1 to 5.

b. CMMI *generic* goals and practices are NOT technical but are associated with the institutionalization of good practice.

c. CMMI assessments involve directly examining the processes employed during one randomly selected on-going project and rating these on a six-point scale.

d. The result of a *continuous* CMMI model assessment is a capability profile showing each process area and its associated process capability assessment.

e. The CMMI identifies specific *recommended* practices that are associated with each of 24 process areas relevant to software process capability and improvement.

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.

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SIGNATURE