INTERNATIONAL UNIVERSITY OF EAST AFRICA

'Learning to Succeed'

FACULTY OF SCIENCE AND TECHNOLOGY

END OF SEMESTER EXAMINATIONS - APRIL 2025

PROGRAMME: BSSE
YEAR/SEM: YEAR 3/SEMESTER 1
COURSE CODE: SWE3100
NAME: FORMAL METHODS OF SOFTWARE ENGINEERING

DATE:
TIME:

INSTRUCTIONS TO CANDIDATES:

SECTION A

Attempt All

Question 1:

1.Given the sets: A={1,2,3,4,5}, B={3,4,5,6,7} ,C={5,6,7,8,9} **(8 marks)**

Compute the following:

a) AuB

b) AnB

c) B-C

d) Power set of A

2.Given the set S={a,b,c,d,e}, find:
(4 marks)

a) The cardinality of S, i.e., |S|

b) The number of subsets of S

3.Given the sets: X={1,2} and Y={a,b,c}, compute the Cartesian product X×Y **(2 marks)**

4.Consider the relation R={(1,2),(2,3),(3,4)} on the set S={1,2,3,4} Determine:
(6 marks)

a) The domain of R.

b) The range of R.

c) Is R a function? Justify your answer.

5) Why are formal methods necessary in software development? (6 marks).

6) What are some of the major challenges in applying formal methods in software engineering? (4 marks)

7.Translate each of the following statements into the language of sentential logic. Use the first letter of the capitalised word(s).

i. It is RAINING or OVERCAST, but in any case it is not SUNNY. (2mark)

ii. I will SUCCEED only if I WORK hard and take RISKS. (2 marks)

iii. It is not RAINING, but it is still too WET to play. (2 marks)

iv. If neither JAY nor KAY is home this weekend, we will go to the BEACH;otherwise,we will STAY home. (2 marks)

v.Either Jones is a FOOL or he is DISHONEST. (2 marks)

a.

Question 2:

1.Given the sets: A={1,2,3,4,5}, B={3,4,5,6,7} ,C={5,6,7,8,9} (8 marks)

Compute the following:

a) AuB

b) AnB

c) B-C

d) Power set of A

2.Given the set S={a,b,c,d,e}, find: (4 marks)

a) The cardinality of S, i.e., |S|

b) The number of subsets of S

3.Given the sets: X={1,2} and Y={a,b,c}, compute the Cartesian product X×Y (2 marks)

4.Consider the relation R={(1,2),(2,3),(3,4)} on the set S={1,2,3,4} Determine:

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b) The range of R.

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v.Either Jones is a FOOL or he is DISHONEST. (2 marks)

a.

SECTION B

Attempt only three

Question 1:

Using examples of predicate calculus explain the following terms in formal specification **(20 marks)**

a) Predicates and Functions

b) Constants

c) Variables

d) Quantifiers

Connectives

Question 2:

(a) Using truth tables, prove whether the following are tautologies, contradications or a

contingent. Give reason for your answer.(10 marks)

i. $\sim (P \vee (P \wedge Q)) \vee P$.
ii. $((P \rightarrow Q) \rightarrow P) \rightarrow P$

(c) For each of the following, state whether its true or false giving reason for your answer.

A, B and C are sets.

i). If |A| = 3 and |B| = 4, then |AUB| = 7.
(5 marks)

ii). if |A| = 3,|B| = |C | = 5,|A n B| = 2, |B n C | = 3 and |A n C | = |A n B n C | = 1,

then |A u B u C | =
8. (5 marks)

Question 3:

a) Show that: (6marks)

$$\nvdash [\forall x \in D\, R(x,x)] \vee [\forall x \in D\, \neg R(x,x)]$$

b)Show that**:** (5 marks)

$$\nvdash \forall x, y \in D\, [R(x,y) \vee x = y \vee R(y,x)]$$

Explain your answer both your answers.

c) Consider the following pairs of sentences. For each pair, determine if one implies the other, if they are equivalent, or neither. Explain your answers. **(9 marks)**

$\forall x\ \forall y\ P(x,y)$	$\forall y\ \forall x\ P(x,y)$
$\exists x\ \exists y\ P(x,y)$	$\exists y\ \exists x\ P(x,y)$
$\forall x\ \exists y\ P(x,y)$	$\forall y\ \exists x\ P(x,y)$

Question 4:

a)Provide examples of real-world applications where formal methods have been successfully employed. **(06 marks)**

b) Using the suggested abbreviations (the capitalized words), translate each of the following into the language of predicate logic

i) Some SENATORS are not HONEST. (**2 marks).**

ii) Everyone who isn't VACATIONING is WORKING. **(2 marks).**

iii) The only FRESHMEN who PASS intro logic are the ones who WORK. **(2marks).**

iv)CATS and DOGS that have RABIES are not SUITABLE pets**.** **(2 marks).**

v) If anyone PASSES the exam, then everyone will be HAPPY. **(2 marks).**

c) Evaluate the impact of formal methods on software development practices, considering both benefits and challenges. **(04 marks)**

Question 5:

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a) Prove the following and explain your answer.

(10 marks)

$$(A \rightarrow B) \leftrightarrow (\neg A \vee B)$$

$$(A \leftrightarrow B) \leftrightarrow ((A \rightarrow B) \wedge (B \rightarrow A))$$

b) Explain the various proof rules that are often used with propositional calculus statements and write their symbolic representation. **(10 marks)**

Question 6:

a) Discuss the significance of correctness, consistency, and completeness in formal specifications and how do these attributes contribute to software reliability? **(10 marks)**

b) Describe the role of formal verification in software development and how does it differ from traditional testing methods? **(10 marks)**

Question 7:

a) Specify using comprehension notation **(4 marks)**

a) Odd positive integers

b) The squares of integers, i.e. { 0, 1, 4, 9, 16,... }

b) Express the following logic properties on sets without using the # operator. **(10 marks)**

a) Set has at least one element

b) Set has no elements

c) Set has exactly one element

d) Set has at least two elements

e) Set has exactly two elements

c) What kind of functions are Abs, Squares and Rel? **(6 marks)**

Abs : $\mathbb{Z} \times \mathbb{N} = \{ (x, y) : \mathbb{Z} \times \mathbb{N} \mid (x < 0 \text{ and } y = -x) \text{ or } (x \# 0 \text{ and } y = x) \}$

How about Squares?

Squares : $\mathbb{Z} \times \mathbb{N} = \{ (x, y) : \mathbb{Z} \times \mathbb{N} \mid y = x \cdot x \}$

How about Rel?

Rel : $\mathbb{Z} \times \mathbb{N} = \{ (x, y) : \mathbb{Z} \times \mathbb{N} \mid y = 2 \cdot x \text{ if } x >= 0,$

$y = 2 \cdot (-x) - 1 \text{ if } x < 0 \}$

Question 8:

a) Discuss the significance of correctness, consistency, and completeness in formal specifications and how do these attributes contribute to software reliability? (10 marks)

b) Describe the role of formal verification in software development and how does it differ from traditional testing methods? (10 marks)

Question 9:

a) What is the syntax according to the offcial grammar from the course notes of the formula and give a brief explaination for your answer.(6 marks)

$$\neg a \vee \neg b$$

$$\neg a \rightarrow b$$

b) Does the following hold? and explain your answer (6 marks)

$$(a \rightarrow b) \rightarrow c \equiv a \rightarrow (b \rightarrow c)$$

$$f \equiv g \text{ iff} \vDash f \leftrightarrow g$$

c) Consider the sentence: where 'iff' is an abbreviation of if and only if . What in this sentence can occur in a formula of propositional logic give reasons to why? (5 marks)

d) Consider the following two logical equivalences that express logical laws:Which of these hold and give a reason. (3 marks)

$$\neg \forall x \in D\, f \equiv \exists x \in D\, \neg f$$

$$\neg(f \leftrightarrow g) \equiv \neg f \leftrightarrow \neg g$$

Question 10:

a) What are formal methods in software engineering, and why are they important? (4 marks)

b) Explain the difference between formal specification, formal verification, and formal validation. (6 marks)

c) How do formal methods improve software reliability and security? (4 marks)

d) Discuss the challenges and limitations of using formal methods in real-world software development.(6 marks)

Question 11:

a) What is a well-formed formula (WFF) in predicate calculus? (3marks)

b) Explain the difference between constants, variables, and predicates in predicate calculus.(6 marks)

c) What are the two main types of quantifiers in predicate calculus, and how are they used?(6 marsk)

d) How does predicate arity affect the meaning of predicates?(4 marsk)

d) What is the difference between free and bound variables in predicate logic?(2 marks)

Question 12:

a)Define atomic propositions and give examples.(3 marks)

b)List and explain the main logical connectives used in propositional calculus.(5 marks)

c)How are truth tables used to define logical connectives?(3 marks)

d)Explain the difference between modus ponens and modus tollens with examples.(5 marks)

e)What is resolution inference, and why is it useful in AI systems?(4 marks)