Foundations of Information Systems

Final Exam

February 12, 2025

Last Name: ______________________________

First Name: ______________________________

Signature: ______________________________

1. Simplify the following Boolean algebra expressions as much as possible.

   (a) $(a \wedge 0)'$

   (b) $a \vee (a \wedge b)$

   (c) $a' \vee b' \vee (a \wedge b)$

(5+5+5)

(a) $(a \wedge 0)' \underset{\uparrow}{=} 0' = 1$

Theorem 2 (dual version) from class

(b) $a \vee (a \wedge b) = (a \wedge 1) \vee (a \wedge b)$ (identity)

$= a \wedge (1 \vee b)$ (distributivity)

$= a \wedge 1$ (Theorem 2 from class)

$= a$ (identity)

Note: This is the "absorption" law. If you recognize and name it, the answer would be accepted, too.

(c) $a' \vee b' \vee (a \wedge b) = (a \wedge b)' \vee (a \wedge b)$ (De Morgan)

$= 1$ (complement)

2. Consider a 7-bit floating-point representation where a floating point number has 1 sign bit followed by 3 exponent bits, and 3 bits for the significant. According to the IEEE standard, subnormal numbers have the exponent 000; the bias for a 3-bit exponent is $2^{3-1} - 1 = 3$. Answer the following questions:

   (a) Which number is represented by the bit pattern 1 100 111?

   (b) Write out the bit pattern for the representation of 5.5.

   (c) What is the smallest positive number ε in this floating point representation such that $1 \oplus \varepsilon > 1$?

of the form $\varepsilon = 2^i$

(5+5+5)

(a) $\underbrace{1}_{-\text{sign}}\ \underbrace{100}_{(4)_{10}}\ \underbrace{111}_{\text{represents } (1.111)_2}$

exponent is $4 - \text{bias} = 1$

$\Rightarrow$ number is $-(1.111)_2 \cdot 2^1 = -(11.11)_2 = -(2 + 1 + 0.5 + 0.25) = -3.75$

(b) $(5.5)_{10} = (101.1)_2 = (1.\underbrace{011}_{})_2 \cdot 2^2$ $\Rightarrow$ biased exponent is $2 + 3 = 5 = (\underset{\sim}{101})_2$

$\Rightarrow$ bit pattern is $\underbrace{0}_{+\text{sign}}\ \underset{\sim}{101}\ \underline{011}$

(c) $1 = (1.000)_2$ (normal number with 3-bit significant)

The smallest number $\varepsilon = 2^i$ such that $1 \oplus \varepsilon > 1$ therefore is

$\varepsilon = (0.001)_2$

which has bit representation 0 000 100 (it is subnormal!)

<u>Note</u>: The smallest such ε which is not a power of 2 is

$\varepsilon = (0.00011)_2$ with bit representation 0 000 011

due to the "round to nearest rule: $1.000 \oplus 0.00011 = 1.001$

But $1.000 \oplus 0.00010 = 1.000$

("round to even")

3. Construct a finite state transducer that reads an input string which consists of letter characters, as well as ␣ (space) to separate words. It outputs a string containing only the first letters of each word. Assume the sentence is terminated by a single . (period).

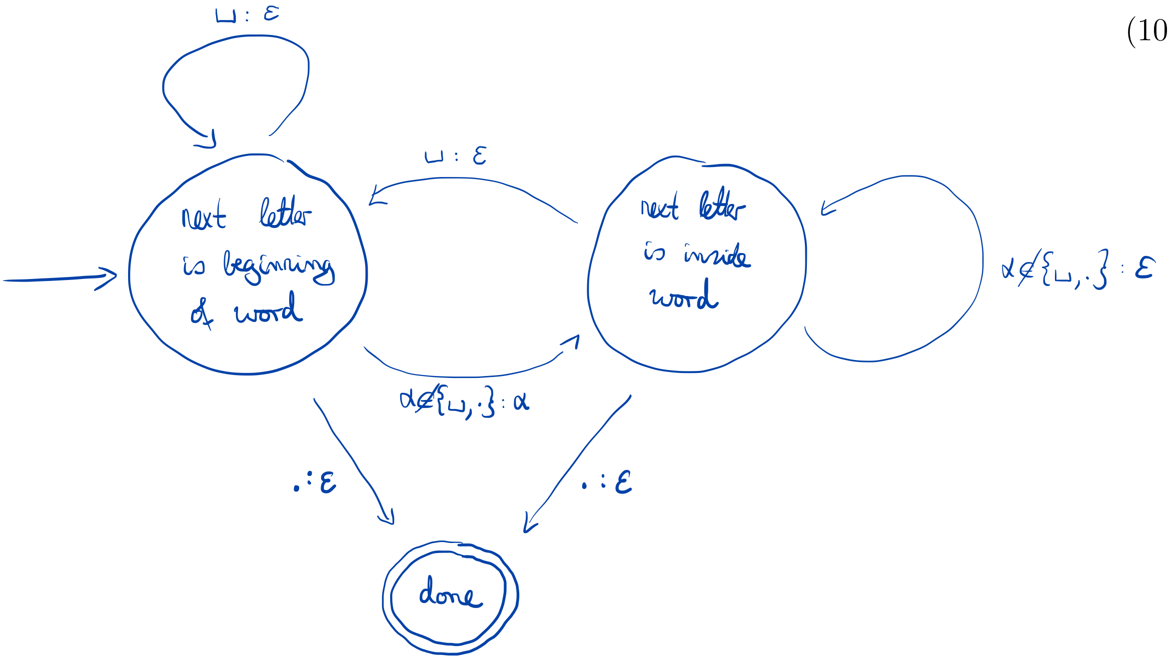
   Example: Input

   ```
   Smart people enjoy language lessons.
   ```

   should produce output

   ```
   Spell
   ```

   (10)



4. A web service accepts file upload via ZIP archives, converts the uploaded files to PDF, and a provides a preview of the converted files. Within a short period of time, the service is compromised by hackers. What could have possibly gone wrong, given that ZIP archives can contain symbolic links? (5)

The service might not have checked whether the ZIP archive contains symbolic links.

In that case, an attacker could ship a symbolic link to any server-internal file (configuration of the web server, password hashes, web server scripts, private SSH key, ...). The contents of such file would be converted to PDF and displayed to the attacker.

To compromise the server, the attacker would typically need to find another vulnerability (bad configuration, exploitable bug in server scripts, weak passwords, ...), but the search for such problems would be significantly easier.

(This security issue is an "information leak", and often associated with allowing for unchecked symbolic links in a security context.)

5. (a) Encode the data word 1000 using the Hamming-(8,4) code.

(b) You receive the following Hamming-(8,4)-encoded message:

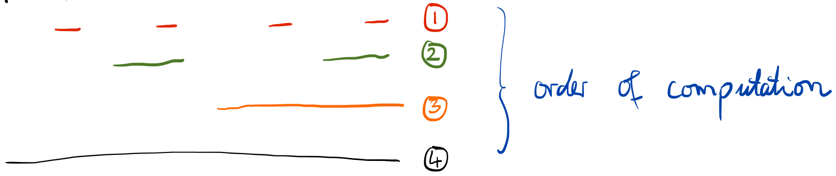
11100111

Extract the message, if possible, correcting single-bit errors as appropriate. The bit-order convention is the one used in class. Show all steps in your work.

(5+5)

(a)

p_0	p_1	p_2	d_0	p_4	d_1	d_2	d_3
1	1	1	1	0	0	0	0



(b)

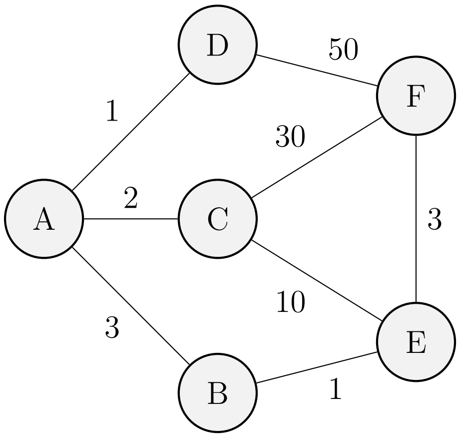
p_0	p_1	p_2	d_0	p_4	d_1	d_2	d_3
1	1	1	0	0	1	1	1

p_0 is correct (even parity) => no or double-bit error

p_4 is incorrect (odd parity)

=> a double-bit error is detected, discard message.

6. Consider the following router network:



(a) Use Dijkstra's algorithm to compute the shortest path from router A to every other router in the network.

(b) State the information that is contained in the link state packet that router C sends to its neighbors, with the actual data corresponding to the network shown.

(10+5)

(a)

Step	Remaining	$d_A(A)$	$d_A(B)$	$d_A(C)$	$d_A(D)$	$d_A(E)$	$d_A(F)$
0	~~A~~,B,C,D,E,F	0 (A)	∞	∞	∞	∞	∞
1	B,C,~~D~~,E,F	0	3 (B)	2 (C)	1 (D)	∞	∞
2	B,~~C~~,E,F	0	3	2	1	∞	51 (D)
3	~~B~~,E,F	0	3	2	1	12 (C)	32 (C)
4	~~E~~,F	0	3	2	1	4 (B)	32
5	F	0	3	2	1	4	7 (B)

Routing table for A: (not required)

Dest.	A	B	C	D	E	F
Next hop	A	B	C	D	B	B
cost	0	3	2	1	4	7

(b) The LSP contains: ID of self: "C", neighbors and cost of link: "A":2, "F":30, "E":10

plus a sequence number and initial TTL ("time to live") that can be configured

7. You are given the following library database schema:

`Borrower(BorrowerID, Name)`
`Book(BookID, Title)`
`Checkout(BorrowerID, BookID, DueDate)`

(a) Underline the primary keys and dashed-underline all foreign keys.

(b) Write a query, using relational algebra or SQL, to list the titles of all overdue books ("`DueDate` < `TODAY`") together with the name of the person who borrowed the book.

(5+5)

(a) see above. Note that, formally, (Borrower ID, Book ID) could be a primary key for relation Checkout, but there is no corresponding foreign key, so this is often omitted because not useful.

(b) Relational algebra version:

$$\pi_{(\text{Title},\ \text{Name})}\ \sigma_{\text{DueDate} < \text{TODAY}}\ (\text{Borrower} \bowtie \text{Checkout} \bowtie \text{Book})$$

SQL version:

```
SELECT
    Title, Name
FROM
    Borrower, Checkout, Book
WHERE
    DueDate < TODAY      ← not correct, actual command depends on SQL dialect
    AND Borrower.BorrowerID = Checkout.BorrowerID
    AND Book.BookID = Checkout.BookID
```

(Solution ctd./scratch paper)