

1. This is a closed book examination; a handwritten study sheet is allowed.
2. Please check the entire examination immediately to ensure that your copy has all eight pages.
3. Put your name on all pages of the examination.
4. All questions have equal mark value.
5. Neatness counts.
6. You must clearly show your work; take time to prepare a legible answer.
7. Good luck and have fun!

name SOLUTION

student id _____

email address _____

1. _____	5. _____
2. _____	6. _____
3. _____	7. _____
4. _____	total _____

1.a What does reliability measure?

THE RELIABILITY $r(t)$ IS THE PROBABILITY
A SYSTEM CONTINUES TO OPERATE FROM
THE START TO TIME t .

1.b How is the MTTF calculated from the reliability?

$$MTTF = \int_0^{\infty} r(t) dt$$

1.c What analytical tools, rather than software, do we employ to calculate the reliability and MTTF?

MARKOV MODEL FACILITATES $r(t)$ CALCULATION.

LAPLACE TRANSFORM YIELD MTTF VIA

$$-(1, 1, 1, \dots, 1) M^{-1} P(0).$$

HERE M IS THE TRANSITION MATRIX
FOR THE MARKOV MODEL.

2.a What is disk array declustering and why is it used?

DECLUSTERING SPREADS STRIPES
OVER ADDITIONAL DISKS,

DECLUSTERING LOWERS THE
INCREMENTAL WORKLOAD WHEN
IN DEGRADED MODE.

2.b Why are disk storage systems configured as RAID ensembles?

IMPROVED PARALLELISM FOR SMALL OPERATIONS
IMPROVED BANDWIDTH FOR LARGE OPERATIONS
LOWER POWER CONSUMPTION

HIGHER RELIABILITY OVER JUST A
BUNCH OF DISKS.

3. A storage system is to utilize 19 disks. Determine a permutation for two groups each of nine disks; the permutation should evenly distributed the reconstruction workload. What permutation works for three groups each of six disks?

$W = 2$ SUFFICES AS PRIMITIVE ELEMENT; 3 ALSO WORKS

1, 2, 4, 8, 16, ³²13, ²⁶7, ²⁸14, ³⁶9, ³⁴18, ³⁰17, ²²15, ²⁴11, 3, 6, 12, 5, 10

$$B_0 = \{1, 4, 16, 7, 9, 17, 11, 6, 5\}$$

$$B_1 = \{2, 8, 13, 14, 18, 15, 3, 12, 10\}$$

2 GROUPS OF NINE

O : 1, 4, 5, 6, 7, 9, 11, 16, 17; 2, 3, 8, 10, 12, 13, 14, 15, 18;

$$B_0 = \{1, 8, 7, 18, 11, 12\}$$

$$B_1 = \{2, 16, 14, 17, 3, 5\}$$

$$B_2 = \{4, 13, 9, 15, 6, 10\}$$

3 GROUPS OF SIX

O : 1, 7, 8, 11, 12, 18; 2, 3, 5, 14, 16, 17;

4, 6, 9, 10, 13, 15.

Data Layouts

name _____

A disk array consists of seven disks is configured with stripe width four in which each stripe contains one check disk.

4.a What stripe units are in the stripe with stripe unit 347?

$$\text{FIRST STRIPE UNIT} \equiv 0 \pmod{3}$$

$$\lfloor 347/3 \rfloor \cdot 3 = 345$$

THE STRIPE UNITS ARE 345, 346, & 347

4.b For the PRIME layout, which disks contain stripe unit 347 as well as the other disks within the stripe? What is the offset for each stripe unit within the stripe?

$$n = 7 \quad R = 4$$

$$P = \lfloor 347/(7 \cdot 3) \rfloor = 16 \quad \textcircled{1}$$

$$y = 16 \bmod 6 + 1 = 5 \quad \textcircled{2}$$

$$\text{disk}(345) = 345.5 \bmod 7 = 3 \quad \textcircled{3}$$

$$\text{disk}(346) = 346.5 \bmod 7 = 1$$

$$\text{disk}(347) = 347.5 \bmod 7 = 6$$

$$\text{parity} = 348.5 \bmod 7 = 4 \quad \textcircled{3/4}$$

$$\text{offsetData} = \lfloor 345/7 \rfloor + 16 = 65 \quad \text{ALL THREE} \quad \textcircled{5}$$

$$\text{offsetParity} = 17 \cdot 4 - 1 = 67 \quad \textcircled{6}$$

5.a Explain what the linear transformation (i.e. matrix) within the scheme accomplishes. What condition is necessary?

The transformation maps m data bytes to an encoded version consisting of $m+c$ bytes that include the original data as well as redundant values. It is necessary that any m columns of the $m \times (m+c)$ matrix G be linearly independent.

5.b What matrix configuration obtains RAID-5 like behavior?

The matrix G must be of the form $(I | P)$ where I is the $m \times m$ identity matrix and P an $m \times c$ matrix.

6.a What do service time and response time measure?

Service time: The time to complete an operation from start to finish.

Response time: the time spent in queue awaiting service plus the service time.

6.b Why can the service time decrease when the response time increases?

It is the case that as the queue lengthens, the response time increases; however, with more choices possible, the service time can improve/decrease by reducing the seek time. That is, the queue is NOT FIFO.

7.a What are the possible phases of a seek operation?

- a) accelerate constant force
- b) coast constant velocity (optional may not occur)
- c) decelerate constant force
- d) settle

A disk drive has the operational parameters – 10,000 rpm, 300 sectors per track, and 4.9 ms average seek time.

7.b What is the average service time for an 8KB read operation on a single disk? Label the various service time components within your calculation.

$$\begin{aligned}
 &4.9 + 3.0 + 6 \cdot \frac{16}{300} = 8.22 \text{ ms} && \text{NOTRACK SWITCH} \\
 \text{seek} \quad \text{latency} \quad \text{transfer} &= 9.22 \text{ ms} && \text{TRACK SWITCH INCLUDED} \\
 \text{probability of track switch} &= \frac{15}{300} = \frac{1}{20} \\
 8.22 \cdot \frac{19}{20} + 9.22 \cdot \frac{1}{20} &= \underline{8.27 \text{ ms}}
 \end{aligned}$$

7.c What is the maximum number of 8KB read operations per second from the drive?

INVERT THE SERVICE TIME.

$$1/8.22 = 121 \text{ ops/sec}$$

$$1/8.27 = 120 \text{ ops/sec}$$