Solution to Sample Midterm Test (Open book and note)

Part I : Multiple – Choice Questions (60%). There will be 12 questions in this part, each 5 points. Select one correct answer in each question.

1. Suppose we observe a system for a long period of time. The average customer arrival rate is 10 customers/hr. The average customer throughput (note: not the customer service rate) for those not being rejected is 8 customers/hr. The average number of customers in the system is 4. Which of the following is not necessarily true? Apply Little's law and the utilization law for this problem.
(a) the customer loss rate is 2 customers/hr
$\surd$ (b) the utilization of the system is 0.8
(c) the response time per customer for those not being rejected is 0.5 hours.
(d) the rejection probability is 0.2.
(e) none of above.

2. Suppose we observe a system for 1000 minutes. Within this period, the utilization of the system is 0.9, the total number of customers completed is 90000 and the average response time per customer is 0.05 minute. Which of the following is not true?
(a) The throughput of the system is 90 customers/minute.
(b) the wait time per customer is 0.04 minute.
(c) The service time (not including the waiting time) per customer is 0.01 minute.
(d) The average number of customers in the system is 4.5
$\surd$ (e) none of above

3. A computer science department admits on the average 20 students to the PhD program and 80 students to the master's program every year. An average PhD student takes 5 years to finish the degree requirements, while an average master's student takes about 2 years. Use Little's law to calculate the total number of graduate students enrolled.
(a) 220
(b) 240
$\surd$ (c) 260
(d) 280
(e) none of above.

4. A component obeying exponential failure law has a constant failure rate of 0.01 hr^{-1}. It does not have repair capabilities. Which one of the following is not true?
(a) the unreliability of this component at 100 hours is $1 - e^{-1}$
(b) the unavailability of this component at 100 hours is $1 - e^{-1}$
(c) the reliability of the system at $t = \infty$ is 0
(d) the availability of the system at $t = \infty$ is 0
$\surd$ (e) none of above.

5. Which one of the following is not true for a series-parallel block diagram with components in common?

(a) can be solved with SHARPE's fault tree models
(b) can be solved with SHARPE's reliability graph models
√ (c) can be solved with SHARPE's reliability block diagram models
(d) can be solved with SHARPE's Markov models
(e) none of above.

6. Consider that a system can recover from a faulty state if it can perform a reconfiguration to remove the fault faster than the fault causing a system error. Suppose that the mean time to perform a system reconfiguration is 50 msec and the mean time for the fault to cause a system error is 150 msec. What is the probability that a system error will occur after the system encounters a fault?
√ (a) 0.25
(b) 0.50
(c) 0.75
(d) 1/50
(e) none of above.

7. Which one of the following is false?
(a) In an M/M/1 system, the system throughput is equal to the job arrival rate if the system is stable
(b) In an M/M/3/8 system, the system throughput is less than the job arrival rate
(c) An M/M/3/8 system is always stable
√ (d) An M/M/n system cannot have more than n customers in the system
(e) none of above

8. Suppose a component's failure time is an exponentially distributed random variable with a constant arrival rate of α. Which one of the following is not true?

(a) the component obeys the exponential failure law.

(b) $\alpha = \frac{pdf(t)}{1-CDF(t)}$ where $pdf(t)$ and $CDF(t)$ are the probability and cumulative density functions of the variable

√ **(c)** $CDF(t)$ of the random variable is the reliability of the component at time t.

(d) without repair capability, availability of the component is the same as reliability of the component.

(e) none of above

9. Which one of the following is not true for Markov models?

(a) can model the time order at which failures occur

(b) can model fault coverage

√ **(c)** can model hardware components which do not obey the exponential failure law

(d) can model repair dependency

(e) none of above

10. Which one of the following is not true for irreducible Markov models?

    (a) they have no absorbing states

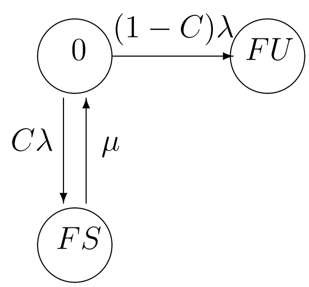
    (b) can be used for availability modeling

    √ **(c)** can be used for reliability modeling

    (d) can be used to model steady-state behavior of a system.

    (e) none of above

11. A Markov model of a computer module with failure rate λ, repair rate μ, and a fault coverage factor C is shown below. State FU means that the system fails unsafely and state FS means that the system fails safely.

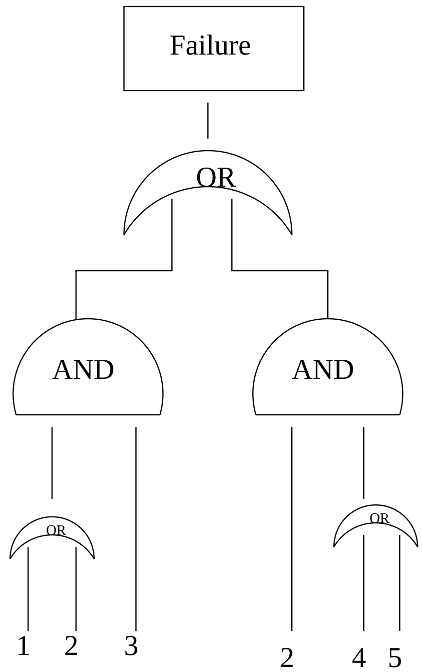


    What is the reliability of the system at time t?

    √ (a) $e^{-\lambda t}$
    (b) $P_0(t)$
    (c) $P_0(t) + P_{FS}(t)$
    (d) $\frac{\mu}{\mu+\lambda} + \frac{\lambda}{\mu+\lambda} e^{-(\mu+\lambda)t}$
    (e) none of above.

12. Continue from the last problem. What is the availability of the system at time t?
    (a) $e^{-\lambda t}$
    √ (b) $P_0(t)$
    (c) $P_0(t) + P_{FS}(t)$
    (d) $\frac{\mu}{\mu+\lambda} + \frac{\lambda}{\mu+\lambda} e^{-(\mu+\lambda)t}$
    (e) none of above.

13. Suppose we define the safety of the system as the probability the system is operational or fails safely during the time interval [0,t]. What is the safety of the system?
    (a) $e^{-\lambda t}$
    (b) $P_0(t)$
    √ (c) $P_0(t) + P_{FS}(t)$
    (d) $\frac{\mu}{\mu+\lambda} + \frac{\lambda}{\mu+\lambda} e^{-(\mu+\lambda)t}$
    (e) none of above.



14. Which statement in the following is false for the fault tree model shown above?

√ **(a)** the system fails when component 2 fails

(b) the system fails when components 1 and 3 fail

(c) the system is alive when components 2 and 3 are alive

(d) component 2 is a shared component

(e) none of above.

15. Consider a 5-component bridge structure as in slide #57. Suppose you are given the failure rate of each component. Which of the following techniques cannot be used to get the reliability of the bridge system?
(a) Markov modeling
(b) reliability graph
(c) minimal cut set
(d) fault tree
√ (e) none of above.

16. The service rate of a communication line is 150 bytes/second. The input traffic rate to the line is 8,000 bytes per minute. What is the average response time per byte?
(a) 1/8000 minutes
(b) 8/9000 minutes
(c) 9/8000 minutes
√ (d) 1/1000 minutes
(e) none of above.

17. Consider a TMR system with each component having an independent failure rate of λ and an independent repair rate of μ. Assume that alive components can still fail regardless of the states of other components. Which one of the following is true?
(a) we cannot calculate the reliability of the system since it has repair capabilities
(b) we can calculate the reliability of the system using a fault tree model
√ (c) we can calculate the availability of the system using a fault tree model
(d) the reliability of the system is the same as that of a TMR system having the same set of components but without repair capabilities
(e) none of above.

18. Suppose the steady-state availability of four independent components are $A_A = 0.7$, $A_B = 0.8$, $A_C = 0.9$, and $A_D = 0.9$, respectively. A system consisting of these 4 components is available as long as at least A or B is available AND at least C or D is available. What is the steady state system availability?
(a) 0.4536
√ (b) 0.9306
(c) 0.9400
(d) 0.9900
(e) none of above.

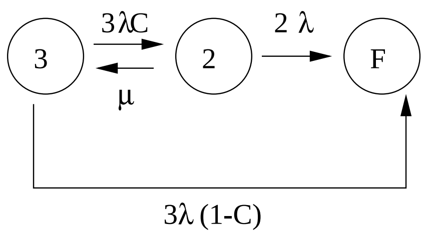
19. Suppose a system's unreliability is 1 - $e^{-\alpha t}$ - $e^{-\beta t}$, what is the mean time to failure of the system?
√ (a) $1/\alpha + 1/\beta$
(b) $1 - 1/\alpha - 1/\beta$
(c) $\alpha e^{-\alpha t} + \beta e^{-\beta t}$.
(d) $1/(\alpha + \beta)$
(e) none of above

20. Consider an $M/M/3/\infty$ queueing facility with arrival rate of λ and service rate of μ for each server. Let P_i stand for the steady-state probability that the system contains i customers (including both queueing and in service). Which one of the following is true for a stable system?
(a) the average number of customers is $\sum_{i=3}^{\infty}(i \times P_i)$
(b) the average rejection rate is $P_3 \times \lambda$.
(c) the throughput is $(1 - P_0) \times \lambda$
√ (d) the response time per customer is $\frac{\sum_{i=0}^{\infty}(i \times P_i)}{\lambda}$
(e) none of above.

21. Which one of the following is not true for a Markov model?
(a) it can be used to model the steady state behavior of a system
(b) it can be used to model the transient behavior of a system
√ (c) no two state components can change their values simultaneously by a single state transition

(d) no two state events are allowed to occur simultaneously
(e) none of above.

22. A Markov model for a TMR system with a fault coverage factor C is shown below. The failure rate is λ and the repair rate is μ for each TMR component. The system is operational when at least 2 out of 3 components are operational. State 3 means that all 3 components are functional, state 2 means that 2 components are functional, and state F means a failure state. The fault coverage factor C represents the probability that the system is able to reconfigure successfully upon one component failure in state 3.

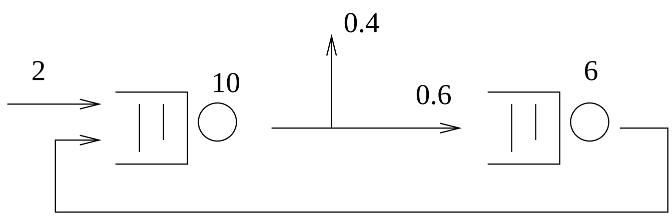


Let $P_3(t)$, $P_2(t)$ and $P_F(t)$ be the probability that the system is in states 3, 2 and F, at time t, respectively. Suppose we assign a reward of one to state F, and a reward of zero to states 3 and 2. The expected instantaneous reward rate E[Z(t)] under this reward assignment is equal to
(a) the mean time to failure of the TMR system
(b) the reliability of the system at time t
(c) the availability of the system at time t
√ (d) the unreliability of the system at time t
(e) the unavailability of the system at time t

23. Suppose we assign a reward of 1 to states 3 and 2 and a reward of 0 to state F. The expected cumulative reward until absorption E[Y(∞)] under this reward assignment is equal to
(a) the mean time to repair
√ (b) the mean time to failure
(c) it is meaningless
(d) the mean number of jobs the system can service before it fails
(e) none of above

24. Suppose that a closed system has two classes of jobs A and B. It is known that the response time of a class A job is $R_A = 10$, the response time of a class B job is $R_B = 15$, the throughput for class A jobs is $X_A = 6$ and the throughput for class B jobs is $X_B = 4$. What is the average number of jobs in the closed system?
(a) 100
(b) 110
√ (c) 120
(d) 130
(e) 140

25. Consider an open queueing network system shown below that has a product-form solution. As shown in the figure, the external arrival rate to the system is 2 jobs/sec and the service rates at the two centers are 10 jobs/sec and 6 jobs/sec, respectively. When a job departs center 1, it completes its service (and thus leaves the system) with probability 0.4 or conversely goes to center 2 with probability 0.6. When a job departs center 2, it goes to center 1 with probability 1. Which of the following is not true for the system described above?
(a) system throughput is 2 jobs/sec
(b) job arrival rate to center 2 is 3 jobs/sec
√ (c) response time at center 2 per visit is 1/6
(d) average number of jobs found at center 1 is 1
(e) average number of jobs found at center 2 is 1



26. Consider the closed QNM below consisting of a terminal center (T) with M terminals and a central subsystem (F, C, D and P). Suppose that the throughputs of centers T, F, C, D, P are X_T, X_F, X_C, X_D, and X_P, respectively. The average response times per job per visit at centers T, F, C, D, P are r_T, r_F, r_C, r_D, and r_P, respectively. Which one of the following is not true?
(a) the throughput of the central subsystem is $X_F \times P_0$
(b) the throughput of the central subsystem is X_T
√ (c) the average amount of time a terminal job stays in the central subsystem is $r_F + r_C + r_D + r_P$
(d) the average number of terminal users in the central subsystem is $M - (r_T \times X_T)$
(e) $X_C \times P_3 = X_D$