EMP5103 - Final Exam 2001

1. **A robot system can either fail completely or it undergoes preventative maintenance. Prove, using the Markov method that its steady state availability is given by:**

$$AV_{SS} = \frac{\mu_f \mu_p}{\mu_f \mu_p + \lambda_p \mu_f + \lambda_f \mu_p}$$

where

AV_{SS} is the robot system steady availability
λ_p is the robot system preventative maintenance rate
λ_f is the robot system failure rate
μ_p is the repair rate with respect to preventative maintenance
μ_f is the robot system repair rate from failed state

2. **(a) What are the four classifications of reliability cost? Discuss each category in detail.**

   (b) List at least ten major responsibilities of a reliability engineering department.

3. **(a) List and discuss at least 10 tasks of a Reliability Engineer.**

   (b) Describe the following:

(i) **Bathtub hazard rate curve**
(ii) **AND gate**
(iii) **OR gate**
(iv) **Cumulative distribution function**
(v) **Exponential distribution**

4. **Prove that the mean time to failure of a given system is given by:**

$$MTTF = \theta \sum_{j=1}^{n} \frac{1}{j}$$

θ is the mean time to failure of a unit with exponentially distributed failure times
n is the total number of units in the system

State any assumptions associated with your derivations.

EMP5103 – Final Exam 2000

1. **(a) What are the four classifications of reliability cost? Discuss each category in detail.**

   (b) List at least ten major responsibilities of a reliability engineering department.

2. **(a) Write down general expressions for the following:**

- **Cumulative distribution function**
- **Reliability**
- **Mean time to failure**
- **Hazard rate**
- **Failure density function**

(b) Develop an expression for "n" independent unit series system mean time to failure when each of its unit's times to failure are exponentially distributed.

3. Prove, using the Markov method that a system's steady state unavailability, UV_{SS} is given by:

$$UV_{SS} = \frac{\lambda}{\lambda + \mu}$$

where

λ is the constant failure rate of the system

μ is the constant repair rate of the system

4. Obtain hazard rate expressions for the following failure probability density, f(t), and reliability, R(t), functions:

(i) $f(t) = \lambda e^{-\lambda t}$

(ii) $R(t) = e^{-\frac{1}{\theta} t^{\beta}}$

where t is time

λ is the constant failure rate

θ is the scale parameter

β is the shape parameter

EMP5103 – Final Exam 1999

1. A robot system can either fail completely or it undergoes preventative maintenance. Prove, using the Markov method that its steady state availability is given by:

$$AV_{SS} = \frac{\mu_f \mu_p}{\mu_f \mu_p + \lambda_p \mu_f + \lambda_f \mu_p}$$

where

AV_{SS} is the robot system steady availability
λ_p is the robot system preventative maintenance rate
λ_f is the robot system failure rate
μ_p is the repair rate with respect to preventative maintenance
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2. Obtain hazard rate expressions for the following failure probability density, f(t), and reliability, R(t), functions:

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(ii) $R(t) = e^{-\frac{1}{\theta} t^{\beta}}$

where t is time

λ is the constant failure rate
θ is the scale parameter
β is the shape parameter

3. (a) List and discuss at least 10 tasks of a Reliability Engineer.

(b) Describe the following:

(i) **Bathtub hazard rate curve**
(ii) **AND gate**
(iii) **OR gate**
(iv) **Cumulative distribution function**
(v) **Exponential distribution**

4. Prove that the mean time to failure of a given system is given by:

$$MTTF = \theta \sum_{j=1}^{n} \frac{1}{j}$$

θ is the mean time to failure of a unit with exponentially distributed failure times
n is the total number of units in the system

State any assumptions associated with your derivations.

EMP5103 – Final Exam 1997

1. Prove, using the Markov method that a system's steady state unavailability, UV_{SS} is given by:

$$UV_{SS} = \frac{\lambda}{\lambda + \mu}$$

where

λ is the constant failure rate of the system
μ is the constant repair rate of the system

2. Prove that the mean time to failure of a given system is given by:

$$MTTF = \theta \sum_{j=1}^{n} \frac{1}{j}$$

θ is the mean time to failure of a unit with exponentially distributed failure times
n is the total number of units in the system

State any assumptions associated with your derivations.

3. Obtain hazard rate expressions for the following failure probability density, f(t), and reliability, R(t), functions:

(i) $f(t) = \lambda e^{-\lambda t}$

(ii) $R(t) = e^{-\frac{1}{\theta} t^{\beta}}$

where t is time
λ is the constant failure rate
θ is the scale parameter
β is the shape parameter

4. (a) List and discuss at least 10 tasks of a Reliability Engineer.

(b) Describe the following:

(i) Bathtub hazard rate curve
(ii) AND gate
(iii) OR gate
(iv) Cumulative distribution function
(vi) Exponential distribution

EMP5103 – Final Exam 1996

1. Define the following terms:

- **A three state device**
- **Mutually exclusive events**
- **Markov method**
- **Common-cause failure**
- **Failure modes and effect analysis (FMEA)**

2. A system has three independent and non –identical active units. At least two and the three units must function normally for the system's successful operation. Develop expressions for the system reliability ad mean-time-to-failure if its unit failure times are exponentially distributed.

3. Write down expressions for exponential, Rayleigh and Weibull probability density functions. Using these expressions, develop equations for reliability, cumulative distribution function, and hazard rate for all these three distributions.

4. A mechanical component's stress and strength are described by the exponential distribution. Develop an expression for the component reliability.

EMP5103 Final Exam 2001

1. A robot system can either fail completely or it undergoes preventative maintenance. Prove, using the Markov method that its steady state availability is given by:

$$AV_{SS} = \frac{\mu_f \mu_p}{\mu_f \mu_p + \lambda_p \mu_f + \lambda_f \mu_p}$$

where

AV_{SS} is the robot system steady availability

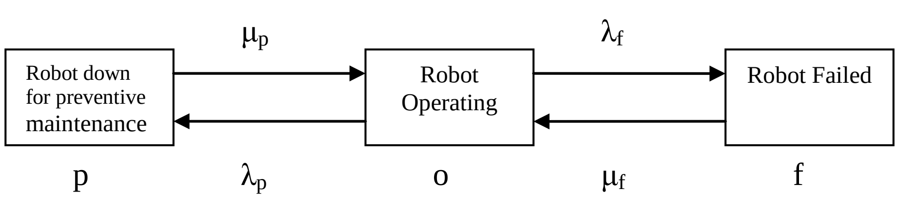
λ_p is the robot system preventative maintenance rate

λ_f is the robot system failure rate

μ_p is the repair rate with respect to preventative maintenance

μ_f is the robot system repair rate from failed state

<u>Solution</u>:



$$P_o(t+\Delta t) = P_o(t)(1-\lambda_f \Delta t)(1-\lambda_p \Delta t) + P_f(t)\mu_f \Delta t + P_p(t)\mu_p \Delta t$$
$$P_f(t+\Delta t) = P_f(t)(1-\mu_f \Delta t) + P_o(t)\lambda_f \Delta t$$
$$P_p(t+\Delta t) = Pp(t)(1-\mu_p \Delta t) + P_o(t)\lambda_p \Delta t$$
$$P_o(t+\Delta t) = P_o(t) - (\lambda_f + \lambda_p)P_o(t)\Delta t + P_f(t)\mu_f \Delta t + P_p(t)\mu_p \Delta t$$
$$\lim_{\Delta t \to 0} \frac{P_o(t+\Delta t) - P_o(t)}{\Delta t} = -(\lambda_f + \lambda_p)P_o(t) + P_f(t)\mu_f + P_p(t)\mu_p$$
$$\frac{dP_o(t)}{dt} = -(\lambda_f + \lambda_p)P_o(t) + P_f(t)\mu_f + P_p(t)\mu_p$$
$$\frac{dP_p(t)}{dt} + \mu_p P_p(t) = P_o(t)\lambda_p$$
$$\frac{dP_f(t)}{dt} + \mu_f P_f(t) = P_o(t)\lambda_f$$
$$At\_time\_t = 0, P_o(0) = 1, P_p(0) = P_f(0) = 0$$

Final value Theorem: $\boxed{\lim_{t \to 0} f(t) = \lim_{s \to 0} sf(s)}$

$$sP_o(s) - P_o(s) + (\lambda_f + \lambda_p)P_o(s) = P_p(s)\mu_p + P_f(s)\mu_f$$
$$sP_o(s) - 1 + (\lambda_f + \lambda_p)P_o(s) = P_p(s)\mu_p + P_f(s)\mu_f$$

$$sP_p(s) + \mu_p P_p(s) = P_o(s)\lambda_p$$
$$P_p(s) = \frac{P_o(s)\lambda_p}{s + \mu_p}$$

$$sP_f(s) + \mu_f P_f(s) = P_o(s)\lambda_f$$
$$P_f(s) = \frac{P_o(s)\lambda_f}{s + \mu_f}$$

Plug $\mathrm{P_f(s)}$ and $\mathrm{P_p(s)}$ into $\mathrm{P_o(s)}$ above to get :

$$P_o(s) = \frac{(s+\mu_f)(s+\mu_p)}{s\left[s^2 + s(\mu_f + \mu_p + \lambda_p + \lambda_f) + \mu_f\mu_p + \lambda_p\mu_f + \lambda_f\mu_p\right]}$$
$$A = \left[s^2 + s(\mu_f + \mu_p + \lambda_p + \lambda_f) + \mu_f\mu_p + \lambda_p\mu_f + \lambda_f\mu_p\right]$$
$$P_p(s) = \frac{\lambda_f(s+\mu_p)}{sA}$$
$$P_f(s) = \frac{\lambda_p(s+\mu_f)}{sA}$$

$$\boxed{A_{ss} = P_o = \lim_{s \to 0} sP_o(s) = \frac{\mu_f\mu_p}{\mu_f\mu_p + \lambda_p\mu_f + \lambda_f\mu_p}}$$

2. (a) What are the four classifications of reliability cost? Discuss each category in detail.

(b) List at least ten major responsibilities of a reliability engineering department.

<u>Solutions</u>:

(a) Reliability cost = PC+ AC + IFC + EFC

<u>Prevention Cost</u>:

- Redundancy
- Parts
- Hourly cost and overhead rates for design engineers, reliability engineers, etc…

<u>Appraisal Cost</u>:

- Hourly cost and overhead rates for evaluation, reliability qualification, reliability demonstration, life-testing, etc…
- Vendor assurance cost for new component qualification, inspection, etc…
- Etc…

<u>Internal Failure Cost</u>:

- Hourly cost and overhead rates for troubleshooting and repair, retesting, failure analysis, etc…
- Replaced part's cost.
- Spare parts inventory.
- Etc…

<u>External Failure Cost</u>:

- Cost to failure or repair.
- Replaced parts cost.
- Cost of failure analysis.
- Warranty administration and reporting cost.
- Liability insurance.
- Etc…

(b)

- Establishing reliability policy, plan, and procedures.
- Reliability allocation.
- Reliability prediction (MIL-HDBK-217).
- Specification and design reviews with respect to reliability.
- Reliability growth monitoring.
- Providing reliability related inputs to design specification and proposals.
- Reliability demonstration (MIL-STD-471).
- Training reliability manpower and performing reliability-related research and development work.
- Monitoring subcontractors', if any, reliability activities.
- Auditing the reliability activities.
- Failure data collection and reporting.
- Failure data analysis.
- Consulting.
- Etc…

3. (a) List and discuss at least 10 tasks of a Reliability Engineer.

(b) Describe the following:

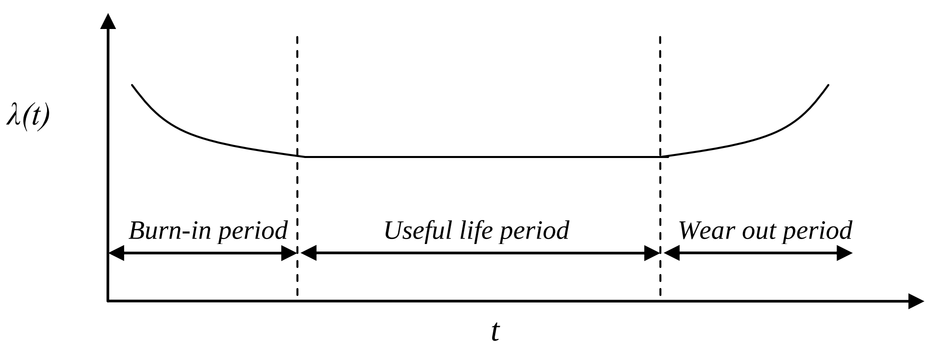
) **Bathtub hazard rate curve**
i) **AND gate**
OR gate
Cumulative distribution function
Exponential distribution

<u>Solution</u>:

(a)

- Performing analysis of a proposed design.
- Analyzing customer complaints with reliability.
- Investigating field failures.
- Running tests on the system, sub-system and parts.
- Developing tests on the system, subsystem and components.
- Budgeting the tolerable system failure down to the component level.
- Developing a reliability program plan.
- Determining reliability of alternative designs.
- Providing information to designers or management concerning reliability.
- Monitoring sub-contractor's reliability performance.
- Participating in evaluating requests for proposals.
- Developing reliability models and techniques.
- Participating in design reviews.
- Etc…

(b) <u>Bathtub Hazard Rate Curve</u>:



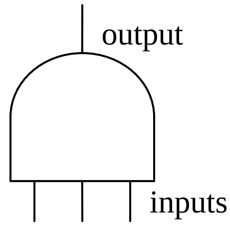
Has three time periods: burn-in period, useful life period, and wear out period.

$$\lambda(t) = k\lambda c t^{c-1} + (1-k) b t^{b-1} \beta e^{\beta t^{b}}$$

For $b, c, \beta, \lambda > 0$ $\quad 0 \le k \le 1 \quad$ $t \ge 0$
And $c = 0.5$ *and* $b = 1$ *to get the shape above*

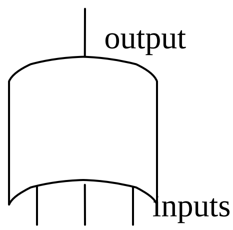
b, c = *shape parameters*
β, λ = *scale parameters*
t = *time*

AND Gate:



The AND gate denotes that an output event occurs if and only if all the input events occur.

OR Gate:



The OR gate denotes that an output event occurs if any one or more of the input events occur.

Cumulative Distribution Function:

$$F(t) = \int_0^t f(x)dx$$

where $f(x)$ is the probability density function

Exponential Distribution:

$$f(t) = \lambda \exp(-\lambda t)$$

$$F(t) = \int_0^t \lambda \exp(-\lambda x)dx = -\exp(-\lambda x)\Big|_0^t = 1 - \exp(-\lambda t)$$

$$R(t) = 1 - F(t) = \exp(-\lambda t)$$

$$\lambda(t) = \frac{f(t)}{R(t)} = \lambda$$

4. Prove that the mean time to failure of a parallel system is given by:

$$MTTF = \theta \sum_{j=1}^{n} \frac{1}{j}$$

θ is the mean time to failure of a unit with exponentially distributed failure times
n is the total number of units in the system

State any assumptions associated with your derivations.

<u>Solution</u>:

For a given unit, the reliability is denoted as: $\exp(-\lambda t)$

For a given unit, the MTTF is denoted as: $\int_0^\infty \exp(-\lambda t)dt = \frac{1}{\lambda} = \theta$

In a parallel system with n identical components, the reliability is:

$$R_p = 1 - (1 - R)^n$$
$$R_p = 1 - (1 - \exp(-\lambda t))^n$$

$$MTTF_p = \int_0^\infty R_p(t)dt = \int_0^\infty \left[1 - (1 - \exp(-\lambda t))^n\right]dt$$

$$u = 1 - \exp(-\lambda t)$$
$$du = \lambda \exp(-\lambda t)dt \rightarrow dt = \frac{du}{\lambda \exp(-\lambda t)} = \theta \frac{du}{1-u}$$

$$t = 0 \Rightarrow u = 0, t = \infty \Rightarrow u = 1$$

$$\boxed{MTTF_p = \theta \int_0^1 \frac{1-u^n}{1-u} du = \theta \int_0^1 \sum_{i=1}^n u^{i-1} du = \theta \sum_{i=1}^n \frac{u^i}{i}\Big|_0^1 = \theta \sum_{i=1}^n \frac{1}{i}}$$

EMP5103 Final Exam 2000

1. Same as question 2 from 2001.

2. Same as question 3 from 2001.

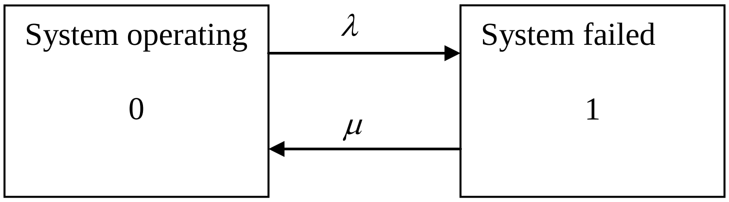
3. Prove, using the Markov method that a system's steady state unavailability, UV_{SS} **is given by:**

$$UV_{SS} = \frac{\lambda}{\lambda + \mu}$$

where

λ is the constant failure rate of the system
μ is the constant repair rate of the system

Solution:



$$P_0(t+\Delta t) = P_0(t)(1-\lambda\Delta t) + P_1(t)\mu\Delta t$$
$$P_1(t+\Delta t) = P_1(t)(1-\mu\Delta t) + P_0(t)\lambda\Delta t$$

At time $t = 0$, $P_0(0) = 1$ and $P_1(0) = 0$

$$\frac{dP_0(t)}{dt} = -P_0(t)\lambda + P_1(t)\mu$$
$$\frac{dP_1(t)}{dt} = -P_1(t)\mu + P_0(t)\lambda$$

$$sP_0(s) - P_0(0) = -P_0(s)\lambda + P_1(s)\mu$$
$$(s+\lambda)P_0(s) = 1 + P_1(s)\mu$$
$$P_0(s) = \frac{1}{s+\lambda} + \frac{\mu}{s+\lambda}P_1(s)$$

$$sP_1(s) - P_1(0) = -P_1(s)\mu + P_0(s)\lambda$$
$$(s+\mu)P_1(s) = P_0(s)\lambda$$

$$P_1(s) = \frac{\lambda}{s+\mu} P_0(s)$$

$$P_0(s) = \frac{1}{s+\lambda} + \frac{\mu}{s+\lambda}\frac{\lambda}{s+\mu} P_0(s)$$

$$P_0(s)\left(1 - \frac{\mu}{s+\lambda}\frac{\lambda}{s+\mu}\right) = \frac{1}{s+\lambda}$$

$$P_0(s) = \frac{s+\mu}{(s+\lambda)(s+\mu) - \mu\lambda} = \frac{s+\mu}{s^2 + (\mu+\lambda)s}$$

$$P_1(s) = \frac{\lambda}{s+\mu}\frac{s+\mu}{s^2+(\mu+\lambda)s} = \frac{\lambda}{s^2+(\mu+\lambda)s}$$

$$UAV_{ss} = \lim_{s\to 0} sP_1(s) = \lim_{s\to 0}\frac{\lambda}{s+(\mu+\lambda)} = \frac{\lambda}{\mu+\lambda}$$

$$\boxed{UAV_{ss} = \frac{\lambda}{\lambda+\mu}}$$

4. Obtain hazard rate expressions for the following failure probability density,
f(t), and reliability, R(t), functions:

(i) $f(t) = \lambda e^{-\lambda t}$

(ii) $R(t) = e^{-\frac{1}{\theta}t^{\beta}}$

where t is time

λ is the constant failure rate

θ is the scale parameter

β is the shape parameter

<u>Solution</u>:

$$(i) F(t) = 1 - \exp(-\lambda t)$$
$$R(t) = 1 - F(t) = \exp(-\lambda t)$$
$$\lambda(t) = \frac{f(t)}{R(t)} = \frac{\lambda \exp(-\lambda t)}{\exp(-\lambda t)} = \lambda$$

$$(ii) \lambda(t) = -\frac{1}{R(t)}\frac{dR(t)}{dt} = -\frac{1}{\exp\left(-\frac{1}{\theta}t^{\beta}\right)}\left[-\frac{\beta}{\theta}t^{\beta-1}\exp\left(-\frac{1}{\theta}t^{\beta}\right)\right] = \frac{\beta}{\theta}t^{\beta-1}$$

Final Exam EMP5169

Describe the following:

1. a three state device
2. AND gate
3. Constant Fail Rate
4. Standby System
5. Infant mortality region of the bathtub hazard rate curve
6. Weibull distribution
7. Mutually exclusive events
8. Markov method
9. Common cause failure
10. FMEA- Failure modes and effect analysis
11. Failure density function

Final Exam EMP5103/MCG 5171

Describe the following:

1. Bathtub hazard rate curve
2. OR gate
3. Cumulative distribution function
4. Exponential distribution
5. Rayleigh distribution
6. Reliability
7. Mean time to failure
8. Hazard Rate

Answer:

1. a Three state device

2. ***AND gate***
   And gate denotes that an output event occurs if and only if all the input event occur. Output P(AB)=P(A).P(B)
3. ***OR gate***
   The OR gate denotes that an output event occurs if any one or more of the input events occur. P(A+B)=P(A)+P(B)
4. ***Standby system***
   A. Identical and independent units
   B. Perfect switch
   C. Standby units remains as good as new in their standby models.

EMP5103/MCG 5171

Q4/2001????

Q4/2000

Answer:

(1) $\because f(t) = \lambda e^{-\lambda t}$

$$F(t) = \int_0^t f(t)dt = \int_0^t \lambda . e^{-\lambda t} dt = 1 - e^{-\lambda t}$$

$$R(t) = 1 - F(t) = 1 - (1 - e^{-\lambda t}) = e^{-\lambda t}$$

$$\therefore \lambda(t) = \frac{f(t)}{R(t)} = \frac{\lambda e^{-\lambda t}}{e^{-\lambda t}} = \lambda$$

(2)

$$\because R(t) = e^{\frac{-t^{\beta}}{\theta}}$$

$$\lambda(t) = \frac{f(t)}{R(t)} = -\frac{1}{R(t)}\frac{dR(t)}{dt} = -\frac{e^{\frac{-t^{\beta}}{\theta}}(-\frac{1}{\theta})\beta t^{\beta-1}}{e^{\frac{-t^{\beta}}{\theta}}}$$

$$\therefore \lambda(t) = \frac{\beta}{\theta} t^{\beta-1}$$

Q3/2000 (Middle Exam Covered in ***EMP5169*** Already)
Q2/2000 (Handwriting Paper)

Q1/2000

A. Four classifications of reliability cost.

Answer: Reliability cost = PC+AC+IFC+EFC

PC-Prevention Cost

. Reliability Engineers
. Technicians
. Redundancy
. Reliability Screening
. Preventive maintanence program

AC-Appraisal Cost

. Reliability Evaluation
. Reliability demonstration
. Life testing
. Assembly testing. Etc.

IFC-Internal Failure Cost

. Trouble-shooting and repair
. Retest and failure analysis
. Replaced parts cost
. Spare parts inventory Etc…

EFC-External Failure Cost

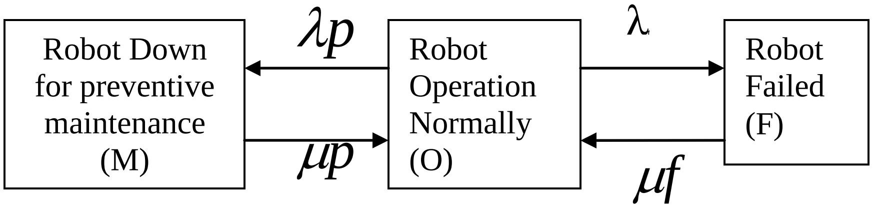
. Cost to repaire a failure
. Cost of service kits.
. Cost of failure analysis
. Warranty administration cost
. Cost of liability insurance Etc.

Q1/2000

B. Ten major responsibilities of a reliability engineering department

1. Establishing reliability policy, plans and produres
2. Reliability allocation
3. Reliability prediction
4. specification and design reviews with respect to reliability.
5. Reliability growth monitoring
6. Providing reliability related inputs to design specifications and proposed
7. Reliability demonstration
8. Training reliability manpower
9. Monitoring subcontractors if any reliability activities
10. auditing the reliability activities.
11. Failure data collection and reporting
12. Analysis of failure data
13. Consulting Etc…

Q1/2001



Assumptions:
. All failures are statistically independent.
. All failure and repair rates are constant
. The repaired system is as good as new.
Markov Method:
Assumptions:

1. The probability of more than one transition in time interval Δt from one state to the next state is negligible
2. The transitional probability from one state to the next in time interval Δt is given by λ Δt, where the λ is the constant failure rate associated with Markov states.
3. The occurrences are independent

A. $P_0(t+\Delta t) = P_0(t)(1-\lambda_f \Delta t)(1-\lambda_p \Delta t) + P_p(t)\mu_p \Delta t + P_f(t)\mu_f \Delta t$

B. $P_p(t+\Delta t) = P_p(t)(1-\mu_p \Delta t) + P_0(t)\lambda_p \Delta t$

C. $P_f(t+\Delta t) = P_f(t)(1-\mu_f \Delta t) + P_0(t)\lambda_f \Delta t$

Simplifier foumla A $\because \lambda_f \Delta t . \lambda_p \Delta t$ very small➔negligible

$\therefore P_0(t+\Delta t) - P_0(t) = -P_0(t)\lambda_f \Delta t - P_0(t)\lambda_p \Delta t + P_p(t)\mu_p \Delta t + P_f(t)\mu_f \Delta t$

$$\lim_{\Delta t \to 0} \frac{P_0(t+\Delta t) - P_0(t)}{\Delta t} = -P_0(t)\lambda_f - P_0(t)\lambda_p + P_p(t)\mu_p + P_f(t)\mu_f$$

1. $\frac{dP_0(t)}{dt} = -(\lambda_f + \lambda_p)P_0(t) + P_p(t)\mu_p + P_f(t)\mu_f$

2. $\frac{dP_p(t)}{dt} + \mu_p P_p(t) = P_0(t)\lambda_p$

3. $\frac{dP_f(t)}{dt} + \mu_f P_f(t) = P_0(t)\lambda_f$

t=0, $P_0(0) = 1 \quad P_p(0) = P_f(0) = 0$

Laplace Transform: $P(s) = \int_0^\infty e^{-st} P(t) dt$

$\frac{P(t)}{e^{-at}}$	$\frac{P(s)}{1/(s+a)}$
$\frac{dP(t)}{dt}$	$sP(s) - P(0)$

Final Value Theorem: $\lim_{t \to \infty} f(t) = \lim_{s \to 0} sf(s)$

$$\therefore s P_0(s) - P_0(0) + (\lambda_f + \lambda_p) P_0(s) = P_p(s)\mu_p + P_f(s)\mu_f$$

$$P_0(s) = \frac{(s+\mu_f)(s+\mu_p)}{S\left[s^2 + s(\mu_p+\mu_f + \lambda_f + \lambda_p) + \mu_p\mu_f + \lambda_p\mu_f + \lambda_f\mu_p\right]}$$

$$A = s^2 + s(\mu_p+\mu_f + \lambda_f + \lambda_p) + \mu_p\mu_f + \lambda_p\mu_f + \lambda_f\mu_p$$

$$P_f(s) = \frac{\lambda_f(s+\mu_p)}{SA} \qquad P_o(s) + P_f(s) + P_p(s) = 1/s$$

$$P_p(s) = \frac{\lambda_p(s+\mu_f)}{SA} \qquad P_o(t) + P_f(t) + P_p(t) = 1$$

Steady State Availabiilty

$$AVss = \lim_{s\to 0} s P_o(s) = \frac{\mu_p\mu_f}{\mu_f\mu_p + \lambda_p\mu_f + \lambda_f\mu_p}$$

5169 Final Exam

Q1/1996 (Handwriting Paper)
Q2/1999, Q2/1996 (Previous Year Middle Exam)
Q3/1999 (Previous Year Middle Exam)

Q3/1996
Answer:

Exponential:

$$f(t) = \lambda.e^{-\lambda t}, F(t) = \int_0^t \lambda e^{-\lambda t} dt = 1 - e^{-\lambda t}$$

$$R(t) = 1 - F(t) = e^{-\lambda t}, \lambda(t) = f(t)/R(t) = \lambda$$

Rayleigh:

$$f(t) = \frac{2}{\beta}.t.e^{-\frac{1}{\beta}t^2}$$

$$F(t) = \int_0^t (\frac{2}{\beta}.t.e^{-\frac{1}{\beta}t^2})dt = 1 - e^{-t^2/\beta}$$

$$R(t) = 1 - F(t) = e^{-t^2/\beta}$$

$$\lambda(t) = f(t)/R(t) = \frac{2}{\beta}t$$

Weibull:

$$f(t) = \frac{b}{\beta}(t-\alpha)^{b-1} e^{-\left[(t-\alpha)^b/\beta\right]}$$

$$F(t) = \int_0^t \left\{ \frac{b}{\beta}(t-\alpha)^{b-1} e^{-\left[(t-\alpha)^b/\beta\right]} \right\} dt = 1 - e^{-\left[(t-\alpha)^b/\beta\right]}$$

$$R(t) = 1 - F(t) = e^{-\left[(t-\alpha)^b/\beta\right]}, \lambda(t) = f(t)/R(t) = \frac{b}{\beta}(t-\alpha)^{b-1}$$

Q4/1999

A. 5 types of Human Error and define:

1. Design errors: mistakes made in design stage
2. Operate errors: use wrong way to operate system
3. Fabrication errors: mistakes made in assembly line.
4. Maintenance errors: use wrong maintenance frequency
5. Inspection errors: Don't find out defective parts.

Define: a failure to perform a prescribed task (or performance of a prohibition action) which would result in damage to equipment and properity or distribution of scheduled operation

B. handwriting paper.

Q1/1999, Q4/1996

Answer:

The probability density function of the strength: S

The probability density function of the Stress: s

$$f_1(S) = \alpha.e^{-\alpha S}, \; f_2(s) = \lambda.e^{-\lambda s}$$

$$Rc = P(s < S) = P(S > s) = \int_0^\infty f_2(s) \left[\int_s^\infty f_1(S) dS \right] ds$$

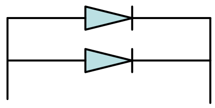
$$= \int_0^\infty \lambda.e^{-\lambda s} \left[\int_s^\infty \lambda.e^{-\alpha S} dS \right] ds = \frac{\lambda}{\lambda + \alpha} = \frac{s_m}{s_m + S_m}$$

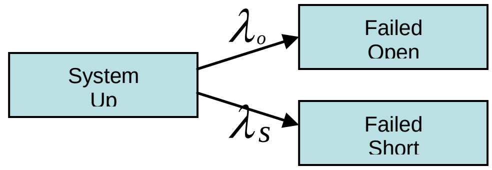
$$\alpha = \frac{1}{S_m}, S_m - mean\,Strength$$

$$\lambda = \frac{1}{s_m}, s_m - mean\,Stress$$

Q2/2002

Answer:





$$(P + q_o + q_s)^n = 1$$

P-Success q_o -Failed in open mode q_s -Failed in short mode

When n = 2, open mode failure probability Qo

$$(P + q_o + q_s)^2 = 1 = P^2 + 2Pq_o + 2Pq_s + q_o^2 + 2q_o q_s + q_s^2$$

$$Q_{o=} q_o^2$$

Short mode failure probability Qs

$$(P + q_o + q_s)^2 = 1 = P^2 + 2Pq_o + 2Pq_s + q_o^2 + 2q_o q_s + q_s^2$$

$$Q_{s=} q_s^2 + 2Pq_s + 2q_o q_s$$

$$\because P = 1 - q_o - q_s$$

$$\therefore Q_s = q_s^2 + 2(1 - q_o - q_s)q_s + 2q_s q_o = -q_s^2 - 2q_s$$

$$= 1 - (1 - q_s)^2$$

$$\because F_T = Q_s + Q_o$$

$$R = 1 - F_T = 1 - Q_s - Q_o = (1 - q_s)^2 - q_o^2$$

$$when\_n = 3$$

$$\because R = (1 - q_s)^3 - q_o^3$$

$$\therefore General\_R = (1 - q_s)^n - q_o^n$$