A Quiz #3 most excellent review

ENM 565 Reliability Engineering

Another opportunity to do good
The Glorious Exam

- Date/Time: Monday, March 25: 4:30 pm to 5:45 pm
- Topic: chapters 9 -11, a single component
  - Either a renewal process or minimal repair process
  - Having some repair distribution
  - Find reliabilities, mean times, availabilities, and so much more…
1. A First Problem

There are two candidate suppliers for an Antilock Braking System (ABS).

<table>
<thead>
<tr>
<th>Candidate</th>
<th>Unit Cost</th>
<th>Failure Distribution (time in miles)</th>
<th>Repair Distribution</th>
<th>Repair Concept</th>
<th>(PM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC</td>
<td>$655</td>
<td>Based on power law intensity function with $a = 10^{-7}$ and $b = 1.4$</td>
<td>Weibull with $\beta = 2.1$; $\theta = 8$ hr. MTTR = 7.09</td>
<td>Minimal repair with parts cost = $120 + labor</td>
<td>Not available</td>
</tr>
<tr>
<td>DEF</td>
<td>$540</td>
<td>Weibull with $\beta = 2.1$ and $\theta = 100,000$ miles MTTF = 88,569</td>
<td>Lognormal with $s = 0.5$; $t_{med} = 2$ hr. MTTR = 2.3</td>
<td>Renewal process remove &amp; replace at unit cost + labor</td>
<td>Part e. only</td>
</tr>
</tbody>
</table>

The design life of a vehicle that will utilize the ABS is 150,000 miles. Repair labor rate is $60 per hour.

[1] Labor cost should be based upon the MTTR
(a) Determine the expected number of failures and the reliability of both candidates over a 50,000 mile warranty. Assume no preventive maintenance.

\[
m(t) = \int_{0}^{t} abt^{b-1} \, dt' = at^b
\]

ABC: \( m(t) = at^b \)
\[
m(50,000) = 10^{-7} \times (50,000)^{1.4} = .3789
\]
\[
R(50,000) = e^{-0.3789} = .6846
\]

DEF: renewal
MTBF = 88,569
\[
m(50,000) = \frac{50,000}{88,569} = .5645
\]
\[
R(50,000) = \text{Exp}(-\frac{50,000}{100,000})^{2.1} = .792
\]
(b) The vehicle’s manufacturer requires that repair of a failed ABS be accomplished within a typical 8 hour work day. Find the percent of repairs for both models that will meet this specification.  Pr\{X < 8\} = H(8)

ABC:
H(8) = 1 - \exp\left[-\left(\frac{8}{8}\right)^{2.1}\right] = 1 - e^{-1} = .632

DEF:
H(8) = \Phi\left(\frac{1}{.5}\ln\frac{8}{2}\right) = \Phi(2.77) = .9972
(c) Based upon the unit cost, expected number of failures, and the expected repair cost compare the life cycle costs of the two candidates over the vehicle design life. Assume no preventive maintenance.

\[
\text{Cost} = C_u + m((t) ( C_f + C_v \ \text{MTTR})
\]

**ABC:** \( M(150,000) = 1.764; \ \text{MTTR} = 7.09; \)

\[
\text{Cost} = 655 + 1.764(120 + 60 \times 7.09) = $1,617
\]

---

**DEF:** \( M(150,000) = 1.6935; \ \text{MTTR} = 2.3; \)

\[
\text{Cost} = 540 + 1.6935(540 + 60 \times 2.3) = $1,688
\]
(d) For the ABC system, determine when the system should be replaced at its unit cost in order to minimize the relevant costs per mile.

\[ T^* = \left[ \frac{655}{(120 + 60 \cdot 7.09)(10^{-7})(1.4 - 1)} \right]^{1/1.4} = 219,381 \text{ miles} \]

\[ t^* = \left[ \frac{C_u}{C_f a(b - 1)} \right]^{1/b} \]

EQ: 10.14
(e) For the DEF system, find the reliability at 50,000 miles if a 15,000 mile preventive maintenance interval is required that restores the ABS to as good as new condition.

\[ n = 3 \]
\[ R(15,000) = \exp\left[-\left(\frac{15,000}{100,000}\right)^{2.1}\right] = .98156; \]
\[ R(5,000) = .998149; \]
\[ R_m(50,000) = (.98156)^3 (.998149) = .94394 \]
(f) For the ABC system, at what (maximum) unit cost is it as economical to discard and replace the unit upon failure over a 100,000 mile warranty rather than (minimally) repair it? Assume a 10 percent cannibalization rate and no initial fixed costs to repair or discard. The MTTR for discarding and replacing is estimated to be 3 hours at the prevailing labor rate.

\[ f = m(100,000) = 10^{-7} (100,000)^{1.4} = 1.0 \]

eq. 10.10:

\[ c = \frac{a_r - a_d}{f(1-k)} + \frac{b_r - b_d}{(1-k)} = \frac{120 + 60(7.09) - 3(60)}{1-.1} = $405.7 \]
2. Yet Another Problem

The Available Company operates a machine that has been in operation for four years (1000 operating days). In order to plan for next year’s production levels, the availability of the machine must be determined. The Company works a single 8-hr shift, 250 days out of the year. Based upon both scheduled and unscheduled maintenance, determine the expected availability of the equipment over the coming year (i.e. the next 250 operating days).

<table>
<thead>
<tr>
<th>Failures</th>
<th>Minimal repair with a power law intensity function having $a = 0.0001$ and $b = 1.825$ with time measured in operating days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repairs</td>
<td>Repair time is lognormal with $t_{med} = 3$ days and $s = 0.758$</td>
</tr>
<tr>
<td>Scheduled</td>
<td>A preventive maintenance downtime of one-day every five weeks (25 operating days).</td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
</tr>
</tbody>
</table>

Eq. 9.7 $MTTR = 3e^{0.758^2/2} \approx 4$
More of Yet Another Problem

\[ m(t) = at^b = .0001t^{1.825} \]

\[ m(1000,1250) = .0001\left[1250^{1.825} - 1000^{1.825}\right] = 15 \]

\[ PM = \left(\frac{250}{25}\right)(1\text{ day}) = 10\text{ days} \]

\[ A = \frac{250}{250 + (15)(4) + 10} = .781 \]
3. No, not another one!

- A timing belt on a new Major Motors automobile has a Weibull failure distribution with a shape parameter of 1.841 and a characteristic life of 500,000 miles.
  - How often should the belt be replaced if 98 percent reliability is desired?

**find the .98 design life:** \( t_d = 500,000 \left(-\ln .98\right)^{1/1.841} = 60,048 \)
(b) Given your replacement interval in (a), compare the timing belt reliability at 100,000 miles and 150,000 with and without replacement.

\[ R(100,000) = 0.94965 \]
\[ R_{m}(100,000) = R(60048) \cdot R(100,000-60048) = 0.9707 \]

\[ R(150,000) = 0.89674 \]
\[ R_{m}(150,000) = R(60048)^2 \cdot R(150,000 - 2 \times 60048) = 0.9551 \]

\[ R(t) = e^{-\left(\frac{t}{500,000}\right)^{1.841}} \]
The time required to replace a timing belt has a lognormal distribution with a mean of 5 hours and a shape parameter of .668.

If a customer brings an automobile into the shop to replace the timing belt and work begins promptly at 8:00 am. What is the probability it will be ready at the promised time of 3:00 pm that same day. Assume that the technician gets 45 minutes for lunch.

\[ t_{med} = \frac{5}{\exp\left(\frac{.688^2}{2}\right)} = 4; \quad H(6.25) = \Phi\left(\frac{1}{.668} \ln \frac{6.25}{4}\right) = .7479 \]

If a customer wants to be 95 percent certain that the work in a. has been completed, when should the customer return to pick up the automobile? The service center starts work at 8:00 am and stops work at 4:45 pm each day with a 45-minute lunch break.

\[ H(t) = \Phi\left(\frac{1}{.668} \ln \frac{t}{4}\right) = .95; \quad z = 1.645 = \frac{1}{.668} \ln \frac{t}{4}; \quad t = 12 \text{ hrs} \]

12 work hrs or noon the next day
4. ALERT, ALERT – new problem

- A robotic machine used in manufacturing brake pads experiences minimal repair upon failure with an intensity function given by $\rho(t) = 0.00017635 \cdot t^{0.7635}$ where $t$ is measured in operating days.

- The machine has been in use for 500 operating days (workdays) (approximately 2 years).

- When the machine fails, repair is accomplished by a single technician at a labor rate of $\$424$ per day.
  - Time to repair is exponential with a MTTR of 2 workdays.
  - Each day that the machine is down, there is also a $\$750$ lost production cost.

\[ b = 1.7635 \quad \text{and} \quad a = 0.00017635/1.7635 = 0.0001 \]
How many machine failures are expected over the next 250 operating days (approximately one year)?

\[ m(500, 750) = 0.0001 \left[ 750^{1.7635} - 500^{1.7635} \right] = 6 \]

The machine costs $35,000. When should the machine be replaced in operating days?

\[
\text{repair cost} = 2 \times (424 + 750) \quad \text{and} \quad t^* = \left[ \frac{35,000}{(2348 \times 0.0001 \times 0.7635)} \right]^{1/1.7635} = 1000
\]

What is the machine's availability over the next 250 operating days?

\[
A = \frac{250}{250 + 6 \times 2} = 0.954
\]

Assuming a HPP, what is the probability of more than two failures over the next 250 operating days?

\[
1 - p(0) - p(1) - p(2) = 1 - e^{-6} - 6e^{-6} - 36e^{-6}/2 = 0.938
\]
5. M-Bar and beyond

A component is repaired minimally upon failure with an intensity function given by \( \rho(t) = 0.0006t^{1.4} \) where \( t \) is in operating days. The time to repair the component is lognormal with \( t_{\text{med}} = 4 \) days and \( s = 0.85 \).

If preventive maintenance (PM) is performed every 10 days and it takes one day to complete, what is the Mean System Downtime (M-bar) over the first 100 operating days?

\[
M(100) = 0.00025 \times (100)^{2.4} = 15.77 \text{ failures}
\]
\[
\text{MTTR} = 4 \times \exp\left[\frac{0.85^2}{2}\right] = 5.74 \text{ days}
\]

\[
\text{M-bar} = \left[15.77 \times 5.74 + 10 \times 1\right] / \left[15.77 + 10\right] = 3.9 \text{ days}
\]

Assuming all maintenance (both scheduled and unscheduled) is performed with a crew size of one, determine the maintenance workdays per operating day (MH/OH) for the situation in part a.

\[
\text{MH/OH} = \left[15.77 \times 5.74 + 10 \times 1\right] / 100 = 1.0 \text{ days per operating day}
\]
6. This is problem 6

A ground radar unit will operate continuously (7/24) except for scheduled and unscheduled downtimes. The power supply of the unit is a high failure component.

1. The power supply has a Weibull failure distribution with a shape parameter of 2.4 and a characteristic life of 100 operating hours. When the power supply fails it is replaced (a renewal process) with a replacement time that is lognormal with a median of 10 hours and a shape parameter of .84.

(a) What is the probability that a failed power supply will be replaced in 12 hours?

\[ H(12) = \Phi \left( \frac{1}{.84} \ln \frac{12}{10} \right) = .5859 \]
(b) What is the expected number of failures of the power supply over a 30-day period?

\[ m(30) = \frac{30(24)}{100\Gamma\left(1+\frac{1}{2.4}\right)} = 8.12 \]

(c) What is the power supply’s achieved availability if a 2-hour preventive maintenance is performed every 10 days?

\[ MTBM = \frac{30(24)}{8.12 + 3} = 64.75 \text{ hr.} \]
\[ MTTR = 10e^{.84} = 14.23 \text{ hr.} \]
\[ \bar{M} = \frac{8.12(14.23) + 3(2)}{8.12 + 3} = 10.93 \text{ hr.} \]
\[ A = \frac{MTBM}{MTBM + \bar{M}} = \frac{64.75}{64.75 + 10.93} = .856 \]
7. Exponential Availability

The Comm Pewter Company is marketing a new desktop computer. Mr. N. Jenair, a reliability engineer has determined that the new computer has a CFR of .02 failures per day and a constant repair rate of .10 repairs per day. If the computer has been in operation for 5 days, compute its interval availability over the next 10 days and its point availability on day 15.

\[
A_{15-5} = \frac{r}{r + \lambda} + \frac{\lambda}{(r + \lambda)^2(t_2 - t_1)} \left[ e^{-(\lambda + r)t_1} - e^{-(\lambda + r)t_2} \right]
\]

\[
= \frac{.1}{.1 + .02} + \frac{.02}{(.1 + .02)^2(15 - 5)} \left[ e^{-.02(.02 + .1)5} - e^{-.02(.02 + .1)15} \right] = .8866
\]

\[
A(15) = \frac{r}{\lambda + r} + \frac{\lambda}{\lambda + r} e^{-(\lambda + r)t} = \frac{.1}{.02 + .1} + \frac{.02}{.02 + .1} e^{-.02(.02 + .1)t} = .8608
\]

\[
A_\infty = \frac{50}{50 + 10} = .8333
\]
Problem 9.4

- Bolt fails in accordance with lognormal (s = 2, MTTF = 10,000 hr.)
- PM replace bolt. What is reliability at 550 hr with and without PM. PM are done every 100 hr.
Problem 9.4 Solution

\[ t_{med} = \frac{MTTF}{e^{s^2/2}} = \frac{10,000}{e^{2^2/2}} = 1353.353 \text{ hrs} \]

\[ T = 100 \text{ hrs} \quad , \quad n = 5 \quad , \quad \text{and} \quad t = 550 \text{ hours} \]

\[ R_m(550) = R(100)^5 R(50) = \left[ 1 - \Phi \left( \frac{1}{2} \ln \frac{100}{1353.353} \right) \right]^5 \left[ 1 - \Phi \left( \frac{1}{2} \ln \frac{50}{1353.353} \right) \right] \]

\[ = \left[ 1 - .0968 \right]^5 \left[ 1 - .0495 \right] = .5735 \]

\[ R(550) = 1 - \Phi \left( \frac{1}{2} \ln \frac{550}{1353.353} \right) = 1 - .3264 = .6736 \]
Failure Distribution without PM

Hazard Rate

0 10 20 30 40 50 60 70 80
Problem 9.6

Equipment failures are uniform from 0 to 1000 hr. \( f(t) = .001 \)

a) Determine MTTF
b) Determine MTTF if PM every 100 hr.
c) Compare \( R(225) \) with and without PM
   a) Maintenance induced \( p = .01 \)
d) Repeat for 50 hr PM
Problem 9.6 Solution

(a) \[ MTTF = \int_0^{1000} R(t)\,dt = \int_0^{1000} (1 - .001t)\,dt = \left[ t - (.001t^2) / 2 \right]_0^{1000} = 500 \text{ hrs} \]

(b) \[ MTTF_M = \frac{\int_0^{100} (1 - .001t)\,dt}{1 - R(100)} = \frac{95}{.1} = 950 \text{ hrs} \]

(c) \[ R(225) = 1 - .001(225) = .775 \]

\[ R_M(225) = R(100)^2 ( .99 )^2 R(225 - 200) = .9^2 (.99)^2 (1 - .001(25)) = .774 \]

(d) \[ R_M(225) = R(50)^4 ( .99 )^4 R(225 - 200) = .95^4 (.99)^4 [1 - .001(25)] = .763 \]
Problem 9.11

- Part can be replaced or be minimally repaired
- If replaced – time between failures is lognormal ($t_{med} = 1150$, $s = .9$)
- Minimal repair; $\rho(t) = (.4 \times 10^{-8})(1.8)t^{1.8}$
- Failure occurs at $t = 400$. Should part be replaced if another 300 hr. use required?
Problem 9.11 Solution

Replace:

\[ R(300) = 1 - \Phi \left( \frac{1}{s} \ln \frac{t}{t_{med}} \right) = 1 - \Phi \left( \frac{1}{.9} \ln \frac{300}{1150} \right) = .9312 \]

Repaired:

\[ (\cdot4 \times 10^{-8})(1.8) \int_{400}^{700} t^{1.8} dt = \frac{(\cdot4 \times 10^{-8})(1.8)}{2.8} \left[ t^{2.8} \right]_{400}^{700} = .188277 \]

Therefore \( \Pr\{N(700) - N(400) = 0\} = e^{-188277} = .828 \)

Conclusion: Replace the part.
Problem 9.23

- Automobile has minimal repair with

\[ \rho(t) = e^{-7.5 + .003t}; \ t \text{ in hrs} \]

- (a) Find \( m(0,1000) \)
- (b) and \( R(100) \)

\[
m(0,1000) = \int_0^{1000} e^{-7.5 + .003t} \, dt = \left[ \frac{e^{-7.5 + .003t}}{.003} \right]_0^{1000} = 3.52
\]

\[
m(0,100) = \left[ \frac{e^{-7.5 + .003t}}{.003} \right]_0^{100} = .0645 \quad R(100) = e^{-0.645} = .9375
\]
Problem 10.2

- System has CFR = .0521 / hr.
- Lognormal repair with $t_{med} = 8.6$ hr. and $s = 1.5$
- Scheduled 4-hr. PM every 10 days
- Find mean system downtime

$$
\bar{M} = \frac{\lambda \cdot MTTR + \frac{1}{T_p} \cdot MPMT}{\lambda + \frac{1}{T_p}} = \frac{.0521 \left[ 8.6 e^{\frac{1.5^2}{2}} \right] + \frac{1}{10 \cdot 24}}{.0521 + \frac{1}{10 \cdot 24}} = 24.824 \text{ hrs}
$$
Problem 10.6

- Fuel pump has NHPP power law process with $a = 6 \times 10^{-9}$ and $b = 2.5$
- If repair - $500 for tools and MTTR = 6 hr.
- If discard – remove & replace takes 1 hr.
- Labor rate is $55 / hr.$
- Pump to be replaced at overhaul (10,000 hr.)
- Determine unit cost for which it is no longer economical to discard.
- Crew size is 1 and condemnation rate is .05
Problem 10.6

\[ f = m(10,000) = \int_0^{10,000} \rho(t) \, dt = \left[ 6 \cdot 10^{-9} t^{2.5} \right]_0^{10,000} = 60 \]

Repair cost
\[ = a_r + b_r f + c k f = 500 + (55 \times 1 \times 6)(60) + c \cdot 0.05 \cdot 60 = 20300 + 3c \]

discard cost
\[ = a_d + c f + b_d f = 0 + c \times 60 + (55 \times 1 \times 1) \times 60 = 60c + 3300 \]
\[ 20300 + 3c = 60c + 3300 \]
\[ 57c = 17000 \quad \rightarrow \quad c = 298.24 \]
Problem 10.7

- Same pump, determine optimal replacement time if unit cost is $400 and pump is repaired upon failure.
- Compare with current policy to overhaul and replace at 10,000 hr.
- Cost to repair = $55 \times 6 = $330

\[ t^* = \left[ \frac{C_u}{C_f a (b - 1)} \right]^{1/b} = \left[ \frac{400}{330(6 \times 10^{-9})(2.5 - 1)} \right]^{1/2.5} = 1785 \text{ Operating hours} \]
Problem 10.8

- Find optimum PM interval
- Power law with \( a = 2.47 \times 10^{-4} \) and \( b = 1.5 \).
- PM cost is $50 and failure cost is $200
- Machine operates 8 hr/day, 20 days per month

\[
T^* = \left[ \frac{C_s}{C_r a(b-1)} \right]^{1/b} = \left[ \frac{50}{200(2.47 \times 10^{-4})(1.5 - 1)} \right]^{1/1.5} = \frac{160 \text{ hrs} = 160 \times \frac{1}{8} \times \frac{1}{20} = 1 \text{ month}}
\]
Problem 11.14a

- Weibull failures with beta = 2.4 and theta = 400 hr.
- Lognormal repair with $t_{med} = 4.8$ hr. and $s = 1.2$
- Find inherent availability

$$MTBF = 400 \Gamma(1 + 1 / 2.4) = 354.54$$

$$MTTR = t_{med} e^{s^2/2} = 4.8 e^{1.2^2/2} = 9.86$$

$$A_i = \frac{MTBF}{MTBF + MTTR} = \frac{354.54}{354.54 + 9.86} = .9729$$
Problem 11.14b

- 6-hr PM every 200 hr.
- assume steady-state renewal process
- find achieved availability

\[
\overline{M} = \frac{\lambda MTTR + \frac{1}{T_p} MPMT}{\lambda + \frac{1}{T_p}} = \frac{1}{354.54} + \frac{1}{200} = 7.39 \text{ hrs}
\]

\[
MTBM = \frac{1}{\frac{1}{MTBF} + \frac{1}{T_p}} = \frac{1}{\frac{1}{354.54} + \frac{1}{200}} = 127.87
\]

\[
A_a = \frac{MTBM}{MTBM + \overline{M}} = \frac{127.87}{127.87 + 7.39} = .945
\]
Is everything clear now?
What About The Computer?

- Chapter 9
  - Renewal process
  - Minimal repair
  - Preventive maintenance
  - Active redundancy with repair
  - Standby with repair

- Chapter 10/11
  - Repair performance measures
  - Exponential availability model
  - Inspect and repair model

What can this computer do for me today?
Practice Quiz #3

A most amazing integration of the concepts in chapters 9, 10, and 11 into two comprehensive problems – a minimal repair process and a renewal process.
Minimal repair Problem

- Unless down for maintenance, the radio transmitter for WKRP radio (147.7 MHz FM) operates continuously (24/7) providing a steady-stream of nauseating country and western music to the greater Dayton area. It has the following characteristics:

<table>
<thead>
<tr>
<th>Failure process</th>
<th>Minimal repair with intensity function $\rho(t) = (0.76)(1.5)t^{\frac{5}{6}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair time distribution</td>
<td>Lognormal with $s = 1.25$ and $t_{med} = 2.9$ days</td>
</tr>
<tr>
<td>Unit cost</td>
<td>$65,000$</td>
</tr>
<tr>
<td>Current age</td>
<td>Three years</td>
</tr>
<tr>
<td>Maintenance labor rate</td>
<td>$825$ per day (applies also to preventive maintenance – PM)</td>
</tr>
<tr>
<td>PM policy</td>
<td>2-day Preventive Maintenance every 30 operating days</td>
</tr>
</tbody>
</table>
The Questions

1. What is the instantaneous MTBF in days given the transmitter’s current age?

2. What is the (a) expected number of failures over the next operating year? (b) Assuming a nonhomogeneous Poisson process (NHPP), what is the probability of more than 2 failures over the next year?

3. What is the transmitter’s reliability over the next month (1/12 of a year)?

4. If the transmitter fails, (a) what is the probability it will be repaired within one day? (b) How many days to insure a 75 percent repair probability?

5. What are the (a) MTTR and the (b) most likely repair time (mode) in days?

6. What is the transmitter’s (a) inherent availability over the next year (365 operating days) and (b) what will be the transmitter’s interval MTBF in days during the next year (365 operating days)?
The Questions

7. Based upon the cost per failure (i.e. using the labor rate and the MTTR) and the unit cost, at what age in **years** should the transmitter be replaced?

8. What is the (a) mean system downtime in days ( ) and (b) mean time between maintenance (MTBM) in days over the next year?

9. What is the achieved availability over the next year?

10. What is the **total** expected maintenance cost for the next operating year?

   Based upon the expected number of failures, mean repair time, and the total PM actions.
### Renewal Process Problem

A weather satellite in geosynchronous orbit (22,236 miles) operates continuously (24/7) monitoring earth’s weather and climate. Upon failure, the satellite is replaced in orbit from the Xichang Satellite Launch Center in southwestern China. It has the following characteristics:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure process</td>
<td>Renewal process with the time between failures having an exponential distribution with $\lambda = 0.0012$ failures per day</td>
</tr>
<tr>
<td>Repair (replace) time distribution</td>
<td>Exponential with a MTTR = 25 days</td>
</tr>
<tr>
<td>Current time in orbit</td>
<td>21 days</td>
</tr>
<tr>
<td>Preventive maintenance policy</td>
<td>2-day PM every 30 (operating) days</td>
</tr>
</tbody>
</table>

[1] The satellite sensors are powered down while the satellite is repositioned and reoriented in orbit.
The Questions

1. What is the satellite’s MTBF in days given its current age?
2. What is the expected number of failures over the next ten (operating) years?
3. What is the satellite’s reliability over the next 90 day’s operation?
4. (a) If the satellite fails, what is the probability that it will take more than 20 days to launch a replacement satellite into orbit? (b) Ninety percent of all launches to replace a failed satellite will occur within how many days?
5. What is the (a) mean system downtime in days ( ) and (b) mean time between maintenance (MTBM) in days?
6. What is the satellite’s steady-state (a) inherent availability and (b) achieved availability?
The Questions

7. If there are two (identical) active satellites that provide overlapping coverage of a portion of the earth’s surface, (a) what is the one-year coverage reliability allowing for replacement of a failed satellite and (b) what is the (system) MTTF in years? Assume both satellites have just been placed in orbit.

8. If a (single) satellite is called upon to track a tropical storm in the Pacific Ocean over the next 20 days, (a) what is its mission availability? (b) What is its point availability on day 20?

9. What is the probability of (a) exactly three failures during the first 10 years? What is the probability that the 3rd failure will occur after 10 years have elapsed since the first satellite was placed in orbit?

10. Assuming a steady-state renewal process, what are the expected maintenance days (scheduled + unscheduled) per year? An operating year is defined as 365 operating days.
This Concludes the Quiz 3
Most Excellent Review

Minimal repair and renewal processes, failure and repair distributions, preventive maintenance, replacement cost, and repair versus discard cost – how am I suppose to keep all this straight in my mind?