NUCLEAR TRAINING COURSE

COURSE 121

1 - Level
2 - Science Fundamentals
1 - MATHEMATICS

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APPENDICES

Mathematics - Course 121

OBJECTIVES

The objectives of this course are that personnel will be able to:

121.00-2 Introduction

1. Explain the implications of station reliability for Ontario Hydro's objectives in the following areas:

   (a) Public safety

   (b) Worker safety

   (c) Environmental emissions

   (d) Reliability of electricity supply

   (e) Cost

2. State the working definition of the reliability of a device.

3. State two basic limitations on the applicability of reliability theory.

121.00-3 Probability

1. State the (a) geometrical, and (b) empirical definitions of the probability of an event E.

2. State and apply the following probability rules:

   (i) $P(A \cap B) = P(A)\ P(B)$, A,B are independent

   (ii) $P(A \cup B) = P(A) + P(B) - P(A \cap B)$

   (iii) $P(A \cup B) = P(A) + P(B) - P(A)\ P(B)$, A,B independent

   (iv) $P(A \cup B) = P(A) + P(B)$, A,B mutually exclusive

   (v) $P(A \cup \overline{A}) = P(A) + P(\overline{A}) = 1$, $A,\overline{A}$ complementary

(vi) $P(A|B) = \frac{P(A \cap B)}{P(B)}$, A,B dependent

(vii) $P(A \cap B) = P(A|B)\ P(B) = P(B|A)\ P(A)$

(viii) Baye's Theorem:

$$P(A) = \sum_{i=1}^{n} P(A|B_i)\ P(B_i)$$

(ix) Expectation Value of x:

$$E(x) = \sum_{i=1}^{n} x_i P_i$$

3. State and apply the formula,

$${}_nC_r = \frac{n!}{(n-r)!r!}$$

4. Define:
   (a) independent events
   (b) mutually exclusive events
   (c) complementary events
   (d) union of events A and B
   (e) intersection of events A and B
   (f) conditional probability, $P(A|B)$

121.00-4 Safety System Analysis

1. Distinguish between:

   (a) nuclear Safety systems and Process systems

   (b) Protective and Containment Systems

   (c) conventional and nuclear accidents

2. List the <u>two</u> most dangerous possible causes of nuclear accidents and explain why they are so dangerous.

3. Explain why it is desirable to have completely independent systems for Process, Protection and Containment.

4. Define unavailability of a Safety system and distinguish between unavailability and unreliability of a Safety system.

5. Define and distinguish amongst:

   (a) Demonstrated Unavailability

   (b) Expected Unavailability

   (c) Permitted Unavailability

6. List and explain four reasons for testing Safety Systems.

7. Explain why it is impossible to guarantee the safety of a nuclear generation station, ie, to guarantee that there will never be any nuclear accidents.

8. State the accepted Safety Standard for CANDU stations.

9. Define Annual Risk of a Nuclear Accident.

121.00-5 Safety Systems Analysis - Solutions to Sample Problems

1. State and apply the formula

$$Q = \lambda \frac{T}{2}$$

   to find the unavailability of a tested component or system.

2. Given information sufficient to determine system component unavailabilities and system failure modes, apply the probability rules of lesson 121.00-3 to find system unavailability. (The difficulty of such calculations is typified by the test Examples and Assignment questions of this lesson).

3. State and apply the formula

$$ARPE = \lambda_R Q_P,$$

   to find the Annual Risk of a Power Excursion at a nuclear unit.

4. State and apply the formula

$$ARNA = \lambda_R Q_P Q_{CT},$$

to find the Annual Risk of a Nuclear Accident at a nuclear unit.

121.00-6 The Binomial Distribution and Power System Reliability

1. Apply the binomial distribution to draw up a Capacity Outage Probability Distribution table, and to calculate the expected load loss and expected load curtailment.

121.00-7 The Normal Distribution and Applications

1. Given that a variable x is normal with mean μ and standard deviation σ, find, with the aid of a Normal Distribution Table, the probability that $x > k$ or $x < k$, where k is some constant in the domain of x.

2. Given that a system (component) failure distribution function is Normal, with specified mean and standard duration, apply the skill of objective #1 to find (neglecting early and useful life failures).

   (a) the system reliability for a mission beginning at $t = 0$ and lasting for a specified mission time

   (b) the number of components failing during any specified time interval, where a specified number of identical components has been placed in service at $t = 0$.

121.00-8 Basic Reliability Concepts

1. Write down and apply in solving problems, mathematical expressions for the following:

   (i) reliability, as a function of failure rate $\lambda(t)$ and time t.

   (ii) reliability, unreliability, and failure distribution function as functions of time t in the case of constant failure rate λ

   (iii) mean time to failure as a function of constant failure rate λ.

(iv) reliability of a system of n components in series, as a function of time t.

(v) reliability of a system of n components in parallel, as a function of time t.

2. Define, as related to lifetime of a device:

(a) infant mortality/burn-in period
(b) useful life
(c) wearout region
(d) bathtub curve

3. State the "Golden Rule of Reliability".

4. State that, and explain why, there is no mathematical relationship between useful life and mean time to failure.

5. Calculate the reliability of a series-parallel network of components in terms of the component reliabilities.

6. Calculate the reliability of a network of components using Baye's Theorem.

121.00-9 Operation in the Wearout Region

1. Contrast, and explain the difference between the failure rates of a system of components under the following two component replacement schemes:

(a) components replaced preventively before expiry of their useful lives.

(b) components replaced as they fail due to wearout.

2. Given useful life failure rate, and mean and standard deviation of a normal wearout distribution function for a device, calculate its reliability for a mission extending into the wearout region.

121.00-10 Some Modern Reliability Topics

1. State three functions of each:

   (a) Safety System Design Reviews

   (b) Safety System Operating Reviews

2. Give a simple engineering system and component failure rates, carry out a Failure Modes Effects and Criticality Analysis.

3. Name two types of mathematical model used for calculating the Reliability of complex systems, and state one advantage and one disadvantage of each.

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