

# NPRE 457

## Safety Analysis of Nuclear Reactor Systems

### Fall 2017

Number	Date Assigned	Due Date	Description															
1	8/28	9/6	<p>Consider a design goal of <math>10^{-7}</math> [LOCAs / (reactor.year)] for the failure likelihood of a Loss Of Coolant Accident (LOCA) in the next generation of nuclear power plants. Calculate the yearly frequency of a LOCA occurrence for:</p> <p>a. 100 reactors in service in the USA,  b. 400 reactors operational globally.</p>															
2	8/30	9/6	<p>a) Briefly describe the difference in terminology between the natural events:</p> <ol style="list-style-type: none"> <li>1. Hurricanes,</li> <li>2. Typhoons,</li> <li>3. Cyclones.</li> </ol> <p>b) Identify the 10 most devastating known natural disasters in terms of human casualties and order them in a descending order.</p>															
3	9/1	9/8	<p>1. The difference between two Richter scale magnitudes is given by:</p> $\Delta M = \log_{10} \frac{M_2}{M_1}$ <p>Estimate the ratio of the actual magnitude (9.0M) to the design-basis magnitude (8.6M) for the Fukushima March 11, 2011 earthquake.</p> <p>2. The relationship between the intensity (E) and magnitude (M) scales can be expressed as:</p> $\frac{E_2}{E_1} = 10^{1.5(M_2 - M_1)}$ <p>Estimate the ratio of the actual intensity to the design-basis intensity for the Fukushima March 11, 2011 earthquake.</p>															
4	9/6	9/13	<p>List the names of the known scales used to describe the severity of natural disasters.</p> <p>Describe the difference in the wind speeds and the effects on human structures between a category IV and a category V hurricane on the Saffir- Simpson scale.</p> <p>Estimate the risk to individuals in the USA population from the different types of traffic accidents shown in the table.  Use the appropriate units.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">Consequences</th> <th style="text-align: center;">Number/year</th> <th style="text-align: center;">Risk</th> </tr> </thead> <tbody> <tr> <td>Fatalities in traffic crashes</td> <td style="text-align: center;">41,059</td> <td></td> </tr> <tr> <td>Injuries in traffic crashes</td> <td style="text-align: center;">2,491,000</td> <td></td> </tr> <tr> <td>Alcohol related deaths</td> <td style="text-align: center;">12,998</td> <td></td> </tr> <tr> <td>Speeding related deaths</td> <td style="text-align: center;">13,040</td> <td></td> </tr> </tbody> </table>	Consequences	Number/year	Risk	Fatalities in traffic crashes	41,059		Injuries in traffic crashes	2,491,000		Alcohol related deaths	12,998		Speeding related deaths	13,040	
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5	9/8	9/15	<p>List the initiating events usually leading to the occurrence of man-made accidents.</p> <p>Identify and classify the initiating events resulting in the following accidents:</p> <ol style="list-style-type: none"> <li>1. Space orbiter Challenger,</li> <li>2. Space orbiter Columbia.</li> <li>3. Titanic sinking,</li> <li>4. Bhopal chemical plant,</li> <li>5. Hindenburg dirigible,</li> <li>6. Macombo oil well blowout,</li> <li>7. Texas City oil refinery fire,</li> <li>8. Exxon Valdez tanker oil spill,</li> <li>9. Costia Concordia cruise ship sinking,</li> <li>10. Chicago fire.</li> </ol>
6	9/11	9/11	<p>Plot (using a plotting routine, e. g. Excel) the discrete probability distributions representing the following random variables:</p> <ol style="list-style-type: none"> <li>1. Flipping a coin,</li> <li>2. Throwing a 6-faced die,</li> <li>3. Throwing a hypothetical 8-faced die.</li> </ol> <p>Identify the probable outcomes and their associated probabilities and the associated units, if any.</p> <p>Consider a hypothetical single die with 7 faces instead of 6.</p> <ol style="list-style-type: none"> <li>1. What is the random variable describing the probable outcomes from throwing the die and their associated probability distribution?</li> <li>2. Calculate its mean value, or mathematical expectation, or first moment.</li> <li>3. Calculate its second moment.</li> <li>4. Calculate its variance.</li> <li>5. Calculate the standard deviation.</li> </ol>
7	9/13	9/20	<p>Consider a component that fails at a constant rate <math>\lambda</math> and its probability density function: (pdf): <math>\lambda e^{-\lambda t}</math>.</p> <ol style="list-style-type: none"> <li>1. Prove that the pdf satisfies the normalization condition.</li> <li>2. Calculate the mean time to failure:</li> </ol> $\bar{t} = \frac{\int_0^{\infty} t \cdot \lambda e^{-\lambda t} dt}{\int_0^{\infty} \lambda e^{-\lambda t} dt} .$ <p>If the fuzzy variable Y = “tolerable” is represented by the discrete membership function:</p> $\mu_Y = \begin{pmatrix} 1.0 & 1.0 & 1.0 \\ 0 & 5 & 10 \end{pmatrix},$ <p>Calculate the performance level of the security:</p> <p><math>g = X</math> is Y = Failure rate is tolerable,</p> <p>for the following discrete probability density functions representing X = “failure rate” :</p>

			<p>a) <math>p_{x1} = \begin{pmatrix} 0.1 &amp; 0.8 &amp; 0.1 \\ 0 &amp; 5 &amp; 10 \end{pmatrix}</math></p> <p>b) <math>p_{x2} = \begin{pmatrix} 0.2 &amp; 0.6 &amp; 0.2 \\ 5 &amp; 10 &amp; 15 \end{pmatrix}</math></p> <p>c) <math>p_{x3} = \begin{pmatrix} 0.3 &amp; 0.4 &amp; 0.3 \\ 10 &amp; 15 &amp; 20 \end{pmatrix}</math></p> <p>Plot the discrete functions and discuss the obtained results for the security performance levels.</p>
8	9/15	9/22	<p>Prove that the power law for the energy release in an earthquake:</p> $P(E)dE = \frac{E_0}{E^2} dE, \quad E \geq E_0,$ <p>is a probability density function.</p> <p>Briefly explain:</p> <ol style="list-style-type: none"> <li>1. Black Swan event,</li> <li>2. Critical states,</li> <li>3. Fingers of instability,</li> <li>4. Minsky moment.</li> </ol> <p><i>Self-Organized Criticality Experiment:</i> A home experiment is proposed by Per Bak, Chao Tang and Kurt Wiesenfeld, to test the concepts of self-organized critical equilibrium. One uses a shoe box and a cup or two of sand, sugar, salt or rice or wheat kernels. The experimenter would wet the sand with a small amount of water, then gather it into the steepest slope in one corner of the shoe box. The threshold slope or angle of repose is larger for wet sand than it is for dry sand. As the water is allowed to evaporate, one would observe a sequence of slides, some very small, and some quite large occurring at random positions in the pile. The evaporation process can be accelerated by placing the shoe box on a warm surface or in direct sunlight, preferably at the beach. Dropping individual or collections of grains of sand or kernels of wheat can also precipitate local avalanches. Describe your setup of the experiment and your observations and relate them to the described theory. Include a photograph of the setup if possible.</p>
9	9/18	9/25	<p>An insurance company requires a 20 percent overhead on the premiums it collects from its customers. If the payment to a beneficiary is \$100,000 and it collects \$1,200 per year in premiums, what is the probability of death in the year that the insurance company used to calculate the collected premium? Compare the result to the case of breakeven for the actuarial risk.</p> <p>In terms of perceived risk versus objective risk assessment, estimate the distance travelled by a car at a speed of 65 miles / hour during the 4.6 seconds taken by a texting event.</p>
10	9/20	9/27	<p>Radon<sup>222</sup> as a daughter in the decay chain of uranium is gaseous at room temperature. It is an inert or noble gas that does not interact chemically in the body. However it decays into Pb<sup>210</sup> which attaches itself to vegetation such as tobacco leaves as a solid and subsequently decays into Po<sup>210</sup> which emits an energetic alpha particle with 5.3 MeV of energy. The inhalation of these two isotopes in the particulate matter of cigarettes smoke delivers to the average smoker a radiation dose equivalent or effective dose of 8 rems (radiation equivalent man) per year to the basal cells of the bronchial tissue. The “cancer dose” is the total radiation dose that</p>

			if spread through a population would cause one additional cancer death and is considered to be approximately 2,000 rems. Calculate the ensuing radiological risk in units of cancer deaths per year in a population of one million smokers.
11	9/22	9/29	<p>For the Emergency Core Cooling System (ECCS) for a Pressurized Water Reactor (PWR) system the annualized cost of the Engineered Safety Feature (ESF) is:</p> $C=1.5 \times 10^6 \text{ [$/year]}$ <p>The existing risk from n identified accident sequences is:</p> $\sum_{i=1}^n f_i R_i = 1.0 \times 10^5 \text{ [person.rem/year]}$ <p>The risk from m accident sequences after implementation of the ESF is:</p> $\sum_{i=1}^m f_i R_i' = 3.0 \times 10^4 \text{ [person-rem/year]}$ <p>Estimate the cost-benefit ratio, clearly showing its units.</p>
12	9/25	10/2	

### Assignments Policy

Assignments will be turned in at the beginning of the class period, one week from the day they are assigned.

The first five minutes of the class period will be devoted for turning in, and returning graded assignments.

Late assignments will be assigned only a partial grade. Please try to submit them on time since once the assignments are graded and returned to the class, late assignments cannot be accepted any more. If you are having difficulties with an assignment, you are encouraged to seek help from the teaching assistants (TAs) during their office hours. Questions may be emailed to TA's, but face-to-face interaction is more beneficial.

Although you are encouraged to consult with each other if you are having difficulties, you are kindly expected to submit work that shows your individual effort. Please do not submit a copy of another person's work as your own. Copies of other people's assignments are not conducive to learning, and are unacceptable.

For further information, please read the detailed assignments guidelines.