NPRE 457
Safety Analysis of Nuclear Reactor Systems
Fall 2022

Online Temporary Alternative Coverage and access during Covid-19 Pandemic and possible resurgence through mutations and variants

1. Please read the assigned-reading lecture-notes chapters.
2. Then answer the corresponding written assignment,
3. For questions about the assignments, please access the teaching assistants by email:
https://www.mragheb.com/NPRE%20402%20ME%20405%20Nuclear%20Power%20Engineering/talist.htm
4. Submit the corresponding written assignment through email to https://canvas.illinois.edu
5. Please use either the Word or pdf formats
6. In case of internet "rationing" (e. g. to health and government authorities), instability, or collapse through overload, please read the lecture notes and submit the corresponding assignments. Already-taken tests and submitted assignments would be used in assessing the final grade.

SIMULTANEOUS EXISTENTIAL FILTER RISKS TO HUMANITY

Gain of Function GOF Research
"Profoundly-Unwise" Gain of Function GOF Research in Boston, USA:
Dr. John Campbell, **https://www.youtube.com/watch?v=_WTZo9ieBKY**

Threat of nuclear war
https://www.youtube.com/watch?v=M7hOpT0lPGI
https://www.youtube.com/watch?v=HSC7Lp1nvx8
https://www.defconlevel.com/

Global Climatic Change
Climatic Change, A Historical Perspective

TRIPLEDEMIC OF FLU, RESPIRATORY SYNCYTIAL VIRUS (RSV) AND CORONAVIRUS

In the United States, there were 20,104 newly reported COVID-19 cases and 383 newly reported COVID-19 deaths on October 6, 2022

	Total Reported	7-Day Average (October 6)
Cases	92,832,282	29,677
Deaths	1,046,659	379

"US influenza hospital admissions have hit the highest rate in a decade as vaccinations sag, USA officials say.

Health experts are worried a so-called tripledemic of flu, respiratory syncytial virus (RSV) and coronavirus could swamp hospitals this winter.

At least 730 people have died of flu this year (2022), according to the Centers for Disease Control and Prevention (CDC).

CDC data shows there have been at least 1.6 million flu cases overall and some 13,000 people have been taken to hospital.

This season's severity has not been matched at this point in the year since the H1N1 swine flu pandemic hit the US in 2009.

It has also coincided with a country-wide surge in RSV, a cold-like infection that is estimated to claim more than 14,000 lives annually in the USA, mostly among older Americans."

Regrettably, some 3,278 colleges and universities across the USA have been impacted by the Covid-19 pandemic, with many temporarily closing their campuses and switching to online classes, affecting more than 22 million students.

To all and everyone we wish good health and well-being.

<table>
<tr><th>Number</th><th>Date Assigned</th><th>Due Date</th><th>Description</th></tr>
<tr><td>1</td><td>8/22</td><td>8/29</td><td>Reading assignment
Preface
1. Overview
Written Assignment
For a rare failure event in chemical reaction vessels with a design failure likelihood of 10^{-4} failures / (vessel.year), calculate the frequency of occurrence for:
a. 100 vessels in service,
b. 1,000 vessels in service.

For a Loss Of Coolant Accident (LOCA) likelihood of 10^{-5} [occurrences / (reactor.year)], calculate the frequency of occurrence for:
a. 97 reactors in service in the USA,
b. 448 reactors globally.</td></tr>
<tr><td>2</td><td>8/24</td><td>8/31</td><td>Reading assignment
Preface
1. Overview
Written Assignment
Estimate the "Risk" to individuals in the USA population of 319 million persons from the different types of traffic accidents shown in the table in units of fatalities / (person . year)
<table>
<tr><th>Consequences</th><th>fatalities / year</th><th>Risk</th></tr>
<tr><td>Fatalities in traffic crashes</td><td>41,059</td><td></td></tr>
<tr><td>Injuries in traffic crashes</td><td>2,491,000</td><td></td></tr>
<tr><td>Alcohol related deaths</td><td>12,998</td><td></td></tr>
<tr><td>Speeding related deaths</td><td>13,040</td><td></td></tr>
</table>
Generate the corresponding fraction of land area required to provide for the energy needs in the USA using different energy options.
Hint: The USA existing power flux is 0.4 Watts / m^2
<table>
<tr><th>Energy option</th><th>Power flux [Watts / m^2]</th><th>Fraction of Land area needed</th></tr>
<tr><td>Energy crops, biomass, plants</td><td>0.5</td><td></td></tr>
<tr><td>Wind power</td><td>2.5</td><td></td></tr>
<tr><td>Solar Photo Voltaic panels, (PV)</td><td>5.0-20.0</td><td></td></tr>
<tr><td>Concentrated thermal solar power, deserts</td><td>15.0-20.0</td><td></td></tr>
<tr><td>Nuclear electricity</td><td>1,000.0</td><td></td></tr>
</table></td></tr>
</table>

3	8/26	9/2	**Reading assignment** **2. Natural Disasters and Man Made Accidents** **Written Assignment** Briefly describe any differences between the natural events: 1. Hurricanes, 2. Typhoons, 3. Cyclones. Identify the 10 most devastating known natural disasters in terms of human casualties and order them in a descending order.
4	8/**29**	9/**5**	**Reading assignment** **2. Natural Disasters and Man Made Accidents** **Written Assignment** The difference between two Richter Scale magnitudes is given by: $\Delta M = \log_{10} \frac{M_2}{M_1}$ Estimate the ratio of the actual magnitude (9.0M) to the design-basis magnitude (8.6M) for the Fukushima March 11, 2011 earthquake. 2. The relationship between the intensity (E) and magnitude (M) scales can be expressed as: $\frac{E_2}{E_1} = 10^{1.5(M_2 - M_1)}$ Estimate the ratio of the actual intensity to the design-basis intensity for the Fukushima March 11, 2011 earthquake.
5	8/31	9/7	**Reading assignment** **2. Natural Disasters and Man Made Accidents** **Written Assignment** List the names of the scales used to describe the expected damage from the following natural hazards: 1. Astral impacts, 2. Earthquakes, 3. Hurricanes, 4. Tornadoes. For each scale, list the description of the expected maximum damage level. Identify any: 1. Design flaws, 2. Equipment failures, 3. Human errors, 4. Natural Events. In the following accidents: 1. Challenger space shuttle accident, 2. Columbia space shuttle accident.
6	9/2	9/9	**Reading assignment** **3. Safety Definitions and Terminology** **Written Assignment**

			If the fuzzy variable Y = “tolerable” is represented by the discrete membership function: $\mu_Y = \begin{bmatrix} 1.0 & 1.0 & 1.0 & 0.0 & 0.0 \\ 0 & 5 & 10 & 15 & 20 \end{bmatrix}$ Calculate the performance levels of the information granule: g = X *is* Y = “Failure rate” *is* “tolerable”, for the following discrete probability density functions representing X = “failure rate” : a) $p_{X1} = \begin{bmatrix} 0.1 & 0.8 & 0.1 & 0.0 & 0.0 \\ 0 & 5 & 10 & 15 & 20 \end{bmatrix}$ b) $p_{X2} = \begin{bmatrix} 0.0 & 0.2 & 0.6 & 0.2 & 0.0 \\ 0 & 5 & 10 & 15 & 20 \end{bmatrix}$ c) $p_{X3} = \begin{bmatrix} 0.0 & 0.0 & 0.3 & 0.4 & 0.3 \\ 0 & 5 & 10 & 15 & 20 \end{bmatrix}$ Plot the discrete functions and discuss the obtained results for the security performance levels.
7	9/**7**	9/14	**Reading Assignment** **4. Accidents Occurrence** **Written Assignment** Identify on a diagram the different modes of stability. Carry out the shoe box experiment suggested by Per Bak, Chao Tang and Kurt Wiesenfeld, to test the concepts of self-organized critical equilibrium. Describe your observations. Prove that the power law for the energy release in an earthquake: $P(E)dE = \frac{E_0}{E^2}dE,\ \ E \ge E_0,$ is a probability density function (pdf). Hint: Apply the normalization condition for a pdf. Briefly explain: 1. Black Swan event, 2. Critical states, 3. Fingers of instability, 4. Minsky moment.
8	9/9	9/16	**Reading Assignment** **5. Risk Quantification** **Written Assignment** An insurance company requires an overhead on the premiums it collects from its customers. If the payment to a beneficiary is \$100,000 and it collects \$1,000 per year in premiums, what is the probability of death in the year that the insurance company used to calculate the collected premium if the overhead charge is: 1. 10 percent 2. 20 percent. 3. 30 percent? Compare the result to the case of breakeven for the actuarial risk.
9	9/12	9/19	**Reading Assignment** 6. Incidence and Likelihood Risk and Safety Indices **Written Assignment**

			Describe the difference between: 1. Incidence risk indices, 2. Likelihood risk indices. 1. Calculate the likelihood risk indices for: a) Obtaining a value of “heads” in the flip of a coin. b) Obtaining a value of “six” in the throw of a single die.
10	9/14	9/21	**Reading Assignment** 7. The Risk Assessment Methodology **Written Assignment** List the conditions for the existence of “Risk”. For the *discrete* random variable of the outcomes from throwing a single die, plot: 1. The probability distribution as a function of the outcomes x_i. 2. The cumulative distribution function (cdf) as a function of the outcomes x_i. 3. The complementary cumulative density functions as a function of the outcomes x_i. Use the same scale for comparison, and briefly explain the meaning conveyed by each one of these plots. Hint: For a discrete probability distribution, Cumulative distribution function: $cdf(x) = \sum_{x_i \leq x} p_i(x)$ Complementary cumulative distribution function $ccdf(x) = 1 - cdf(x)$ Consider a component that fails at a constant rate λ and a probability density function (pdf): $\lambda e^{-\lambda t}$. 1. Prove that the pdf satisfies the normalization condition. 2. Derive the expression for the mean time to failure or the first moment of the pdf. $\overline{t} = \dfrac{\int_0^\infty t.\lambda e^{-\lambda t} dt}{\int_0^\infty \lambda e^{-\lambda t} dt}$
11	9/16	9/23	**Reading Assignment** **7. The Risk Assessment Methodology** **12. Cost Effectiveness Analysis** **Written Assignment** In Probabilistic Risk Assessment (PRA), risk profiles are generated for likelihoods as a function of outcomes. Consider the probability (likelihood) density function (pdf): λ exp (-λt) for the time t to failure of a component with a constant failure rate λ. Derive an expressions for, then use a plotting routine to plot the following: 1. The probability density functions as a function of t. 2. The cumulative distribution functions (cdf) as a function of t. 3. The complementary cumulative density function (ccdf) as a function of t. This is designated as the Farmer's Curve or the Risk Profile. Use the same scale for comparison, and briefly explain the meaning conveyed by each one of these plots. Hint: For a *continuous* pdf: f(x)dx, Cumulative distribution function: $cdf(x) = \int_0^x f(x)dx$ Complementary cumulative distribution function $ccdf(x) = 1 - \int_0^x f(x)dx = \int_x^\infty f(x)dx = 1 - cdf(x)$

Generate the level of Risk against the cost of risk reduction or Cost-Effectiveness graph for the case of an automobile safety design where extra safety measures are being introduced seeking reduced risk levels. Use tentative values for the entries in the table.

Risk Reduction Measure	**Risk Reduction ratio**	**Cost of Risk Reduction [$]**
Seat belts	1/2	$200
Anti-lock brakes	---	---
Front air bags	---	---
Side air bags	---	---
Backup camera	---	---
Front collision avoidance radar	---	---
Lane change sensor	---	---

12 9/19 9/26

Reading Assignment

12. Cost Effectiveness Analysis

Written Assignment

In Risk Assessment using Cost/ Benefit Analysis or Marginal Cost Analysis, calculate the Cost to Benefit Ratio (CBR) using the following information:

The annualized cost of an Engineered Safety Feature (ESF) is $C = 15x10^6$ [$/year], the risk before addition of the safety feature is $R_{before}=1.4x10^5$ [person.rem/year], and the risk after the addition of the safety feature is $R_{after} = 2.5x10^4$ [person.rem/year].

The current Nuclear Regulatory Commission (NRC) guideline is to spend $1,000 per [person.rem] reduction in the risk from a radiological accident.

What is your recommendation as a Safety Engineer regarding the addition of this ESF?

For the following radiological quantities, fill out the table showing the corresponding units and their abbreviations.

Radiological quantity	Conventional System Unit	SI System Unit
Effective dose, dose equivalent		
Absorbed dose		
Activity		
Exposure		

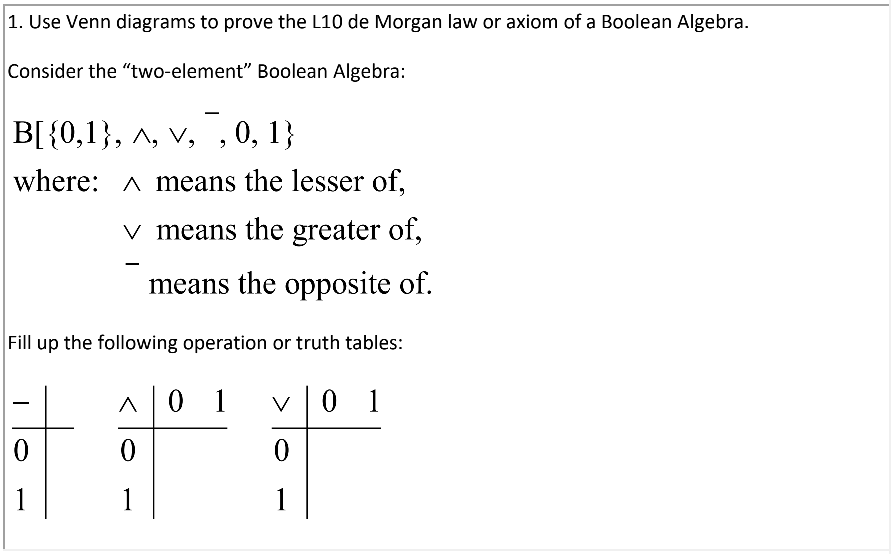
13 9/21 9/28

Reading Assignment

13. Boolean Algebra

Written Assignment

Use Venn diagrams to prove the L10 de Morgan law or axiom of a Boolean Algebra.



1. Use Venn diagrams to prove the L10 de Morgan law or axiom of a Boolean Algebra.

Consider the "two-element" Boolean Algebra:

$$B[\{0,1\}, \wedge, \vee, \bar{\ }, 0, 1\}$$

where: $\wedge$ means the lesser of,

$\vee$ means the greater of,

$\bar{\ }$ means the opposite of.

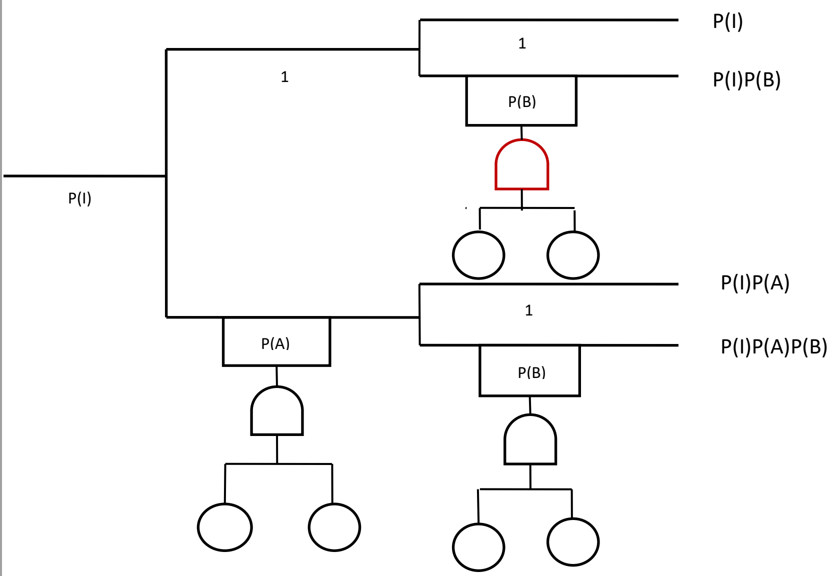
Fill up the following operation or truth tables:

$-$	
0	
1	

$\wedge$	0	1
0		
1		

$\vee$	0	1
0		
1		

14	9/23	9/30	**Reading Assignment** **14. Fuzzy de Morgan Algebra** **Written Assignment** Use Zadeh diagrams to prove the L10 de Morgan law or axiom of a Fuzzy De Morgan Algebra. Use Kosko's interpretation of fuzzy sets as points on the unit interval, unit square, unit cube and unit hypercube to analytically calculate, and graphically show: 1. On the unit interval, the point A:{1/3}, A^c, (A OR A^c), (A AND A^c). 2. In the unit square, the fuzzy set A:{2/3,1/4}, A^c, (A OR A^c), (A AND A^c). 3. In the unit cube, the fuzzy set, A:{1/4,1/2,2/3}, A^c, (A OR A^c), (A AND A^c). 4. For the case of the four dimensional hypercube set, A:{1/3, 1/4, 1/2, 3/4} calculate A^c, (A OR A^c), (A AND A^c).
15	9/26	9/30	**Reading Assignment** 15. Probabilistic and Possibilistic Fault Tree Analysis **Written Assignment** Consider the Boolean expression for a Fault Tree: T=A+(B.C.D)+(E.F.G) 1. Graphically construct the corresponding Fault Tree. 2. Analytically deduce the expression for the "operational" tree as the complement of the Fault Tree, and show it graphically. 3. Calculate the *probability* of failure for the top event for probabilities of failures of the basic events equal to 10^{-2}. 4. Show how you can reduce the top event failure probability by modifying the design. Show your suggestion graphically and write its Boolean expression. 5. Compare the failure probability of the modified design to that of the original one.
16	9/28	9/30	**Reading Assignment** 15. Probabilistic and Possibilistic Fault Tree Analysis **Written Assignment** For the Fault tree with the Boolean expression: T=A+(B.C)+(E.F), 1. Graphically construct the corresponding Fault Tree. 2. Analytically deduce the expression for the "operational" tree as the complement of the Fault Tree, and show it graphically. 3. Calculate the *possibility* of failure for the top event for the following possibilities of failures of the basic events: $\Pi(A)=10^{-2}$, $\Pi(B)= \Pi(C)= \Pi(D)= \Pi(E)= \Pi(F)= \Pi(G)=10^{-3}$ Construct a simple Fault Tree describing the top event: "Car would not start in winter-time."
		9/30	**First Midterm Exam. During class period**
17	10/3	10/10	**Reading Assignment** **16. Event Tree Analysis** **Written Assignment** An initiating event for an accident occurs with a probability $P(I)=10^{-3}$. To mitigate that type of accident the system was designed with three Engineered Safety Features (ESFs). The probabilities of failure of these ESFs are: $P(A) = 10^{-2}$, $P(B) = 10^{-3}$, and $P(C) = 10^{-4}$. a. Construct the event tree that describes this system. b. Using the small probabilities approximation, calculate the probabilities of failure for each of the different accident sequences in the Event Tree. c. If we consider that we have a possibilistic rather than a probabilistic Event Tree, calculate the possibilities for the different accident sequences, for: $\pi(I)=10^{-3},\pi(A)=10^{-2},\pi(B)=10^{-3},\pi(C)=10^{-4}$. In the shown coupled event and fault tree, if the probabilities of failure of the basic events are all equal to 10^{-4}, and the probability of the initiating event is 10^{-5}, calculate the probabilities of the different accident sequences. If one uses the same values as possibilities of failure, estimate the possibilities of the different accident sequences.

			
18	10/5	10/12	**Reading Assignment** **21. Fluid Mechanics Equations** **Written Assignment** From Euler's equation: $dp = -\rho V dV$ Derive the expression for Bernoulli's law suggesting that the sum of the static and kinetic pressures is a constant between two points in an inviscid flow without body forces. A wind rotor airfoil is placed in the air flow at sea level conditions with a free stream velocity of 10 m/s. The density at standard sea level conditions is 1.23 kg/m^3 and the pressure is 1.01 x 10^5 Newtons/m^2. At a point along the rotor airfoil the pressure is 0.90 x 10^5 Newtons/m^2. By applying Bernoulli's equation estimate the velocity at this point.
19	10/7	10/14	**Reading Assignment** **22. Safety Computational Fluid Dynamics** **Written Assignment** List the four basic relationships that define Computational Fluid Dynamics (CFD) for single phase flow. List the variables used in a numerical CFD one phase flow computational scheme together with their units in the conventional cgs (centimeter, gram, sec) system of units c) In CFD, the discretization of the energy conservation equation proceeds as follows. The specific internal energy can be calculated based on the work done on the slab assuring conservation of energy through the thermodynamic relation: $dE = -pdV, \Delta E \simeq -p\Delta V$ $E^{n}_{j-\frac{1}{2}} - E^{n-1}_{j-\frac{1}{2}} = ?$ $E^{n}_{j-\frac{1}{2}} = ?$
20	10/10	10/17	**Reading Assignment** **23. Loss of Coolant Accident, LOCA**

<table>
<tr><td></td><td></td><td></td><td>Written Assignment
1. What does the acronym “LOCA” stand for?

Briefly describe the difference between:
a) The large-break LOCA,
b) The small-break LOCA.

2. Consider a model of the Small-break Loss Of Coolant Accident (LOCA).
If the water evaporation volumetric rate as a result of decay heat generation in a typical Light Water Reactor (LWR), Loss of Coolant Accident (LOCA) is 0.01 m^3/sec, its effective wetted core area is 3 m^2, and its core height is 4 m.
1. Calculate the core uncovery rate in cm/sec.
2. If the core is half filled with water, estimate the time in minutes for total core uncovery.</td></tr>
<tr><td>21</td><td>10/12</td><td>10/19</td><td>Reading Assignment
9. The Source Term
Written Assignment
Calculate the effective half-lives in terms of the radioactive and biological half-lives of the following fission products of safety concern:
a. Sr^{90}
b. Cs^{137}
c. I^{131}
d. T^3

Identify the health physics concerns from the following fission products that could potentially be released in a nuclear reactor accident:
<table>
<tr><th>Isotope</th><th>Half life</th><th>Health Concern</th></tr>
<tr><td>Sr^{90}</td><td>28 a</td><td></td></tr>
<tr><td>Cs^{137}</td><td>33 a</td><td></td></tr>
<tr><td>I^{131}</td><td>8 d</td><td></td></tr>
<tr><td>Kr^{87}</td><td>78 m</td><td></td></tr>
</table></td></tr>
<tr><td>22</td><td>10/14</td><td>10/21</td><td>Reading Assignment
10. Environmental Remediation of Radioactive Contamination
Written Assignment
List the decontamination approaches for the radioactive isotope CS^{137}.</td></tr>
<tr><td>23</td><td>10/17</td><td>10/24</td><td>Reading Assignment
10. Environmental Remediation of Radioactive Contamination
Written Assignment
The soil to plant transfer ratio for Cs^{137} for tropical fruit grown on the Bikini Island ranges between 2 to 40. For crops grown on continental soils this factor ranges between the much smaller values of 0.005 to 0.5.

1. Calculate the specific activity of Cs^{137} in a contaminated soil in [Bq/gm] if the percentage weight of the isotope in the soil is 0.01 percent.
2. Calculate the corresponding ranges of the specific activities of Cs^{137} of plants grown in contaminated tropical and continental soils in Bq/gm.</td></tr>
<tr><td>24</td><td>10/19</td><td>10/26</td><td>Reading Assignment
11. Decay Heat Generation in Fission Reactors
Written Assignment
A nuclear power reactor is operated according to the following power history:
1. Operation at a power level of 3,000 MWth for 1 year, followed by,
2. Operation at a power level of 1,500 MWth, for 6 months, followed by a scram (shut-down).
Using the analytical formulae derived in the class, determine the decay-heat power in MWth:
1. Six minutes after shutdown,
2. One day after shutdown,
3. One month after shutdown.
Hint: The decay-heat contributions from the two operational periods add up linearly.</td></tr>
<tr><td>25</td><td>10/21</td><td>10/28</td><td>Reading Assignment
11. Decay Heat Generation in Fission Reactors
24. Debris Bed Cooling</td></tr>
</table>

			Written Assignment A nuclear power reactor is operated according to the following power history: 1. Operation at a power level of 3,000 MWth for 1 year, followed by, 2. Operation at a power level of 1,500 MWth, for 6 months, followed by a scram (shut-down). Using the Systems Analysis Handbook graphs, determine the decay heat power at one day after shutdown. Compare the levels of heat generation for debris beds having the following particles diameter sizes: a) 4 mm, b) 0.1 mm.
26	10/24	10/31	**Reading Assignment** **25. Steam Explosions** **Written Assignment** Consider a model of a “Steam explosion” with an energy release of 2 GJ. a) If the mass of a generated vertically moving water piston is 9 metric tonnes, and it acquires the energy release as kinetic energy, calculate its vertical speed in m/sec. b) Assuming that the top concrete shielding plate with a weight of 700 metric tonnes exchanges momentum with the water piston upon their collision, by applying the law of conservation of momentum, calculate its vertical speed in m/sec. c) Estimate the height in meters to which that top plate would have risen vertically as a result of the collision with the water piston by applying conservation of the kinetic and potential energies and use the gravity acceleration constant as $g = 9.81\ m/sec^2$.
27	10/26	10/31	**Reading Assignment** **26. Clad Ballooning Accident** **27. China Syndrome** **Written Assignment** List the sources of pressure buildup in the Clad Ballooning accident. What are the consequences of such an occurrence? Briefly describe the difference between: 1. Evaluation, 2. Best-estimate, safety analysis computational models. Write a short description of the “China Syndrome”
28	1/28	10/31	**Reading Assignment** **28. Containment Structures** List the Engineered Safety Features, ESFs of the PWR reactor design List the Engineered Safety Features, ESFs of the BWR reactor design
		10/31	Second Midterm Exam. Given during class period.
29	11/2	11/9	**Reading Assignment** **46. Solar Storms Effects on Nuclear and Electrical Installations** **Written Assignment** List the possible effects of solar storms on nuclear and electrical installations. Briefly describe “The Carrington Event Briefly describe the NOAA Space Weather Scale for geomagnetic storms. Briefly describe the NOAA Space Weather scale for solar radiation storms.
30	11/4	11/11	**Reading Assignment** **8. Risk and Safety Ethics** **Written Assignment** If the expected maximum loading on a structural member is about 1,000 kgs, a

			prudent designer would use an ignorance factor of ?, and a safety factor of ?. Then the design load would be ? kgs. The concept of acceptable risk defines the professional and ethical dimension of the engineering profession. Because of the element of uncertainty involved in risk, a bias or predisposition in favor of one set of values or another is inevitable. Explain the difference between the observed two sets of values, biases or orientations: 1. The Good Science (GS) approach 2. The Respect for Persons (RP) approach
31	11/7	11/14	**Reading Assignment** **37. Experimental Breeder Reactor Number I, EBR I Criticality Accident** **38. Stationary Low Power Plant Number 1, SL-1 Accident** **Written Assignment** Briefly describe what caused the criticality-steam-explosion accident at the SL-1 reactor. Identify the cause of the accident at the Experimental Breeder Reactor Number 1, EBR I. What is the lesson to be learned for future breeder reactor designs?
32	11/9	11/16	**Reading Assignment** **39. Sodium-Graphite Reactor Experiment, SRE incident** **41. Fermi 1 Fuel Meltdown Incident** **Written Assignment** Identify any possible: i) Human error, ii) Equipment failure, iii) Design flaw, 1. In the Fermi 1 fast reactor accident, 2. In the SRE thermal reactor accident.
33	11/11	11/18	**Reading Assignment** **40. Windscale Accident** **42. Steam Generator Leakage at the BN-350 Desalination Plant** **Written Assignment** Write the Lorentz Equation from electromagnetics and describe how an electromagnetic pump for the pumping of a liquid metal or a molten salt would be an alternative replacement to an impeller pump. Briefly describe what is meant by “Wigner Energy” in graphite-moderated reactors. What is referred to as: “Cockcroft follies”? Identify any: 1. Human errors, 2. Equipment failures, 3. Design flaws, in the Windscale accident. The UK National Radiological Board estimated that as a result of the Windscale accident about 30 additional cancer deaths may have resulted in the general public, representing 0.0015 percent increase in the cancer deaths rate:

<table>
<tr><td></td><td></td><td></td><td>$$\frac{\Delta C}{C_0} = \frac{C - C_0}{C_0} = \frac{30}{C_0} = \frac{0.0015}{100}$$
where: C_0 is the population cancer deaths from all other causes.
Calculate the number of cancer deaths that the general population suffered from all other causes.</td></tr>
<tr><td>34</td><td>11/14</td><td>11/28</td><td>Reading Assignment
36. Chernobyl Accident
Written Assignment
Identify any possible:
1. Human error,
2. Equipment failure,
3. Design flaw,
in the Chernobyl accident.

Identify the similarities and differences between:
1. The Windscale accident,
2. The Chernobyl accident.</td></tr>
<tr><td>35</td><td>11/16</td><td>11/28</td><td>Reading Assignment
43. Browns Ferry Fire
Written Assignment
Identify any possible:
1. Human error,
2. Equipment failure,
3. Design flaw,
in the Browns Ferry fire.</td></tr>
<tr><td>36</td><td>11/18</td><td>11/28</td><td>Reading Assignment
35. The Three Mile Island Accident
Written Assignment
Identify any possible:

1. Human error,
2. Equipment failure,
3. Design flaw,
in the Three-Mile Island accident.

Match each of the following nuclear reactor accident events to an associated main characteristic.

<table>
<tr><th>Accident</th><th>Characteristic</th></tr>
<tr><td>Fukushima</td><td>Small break LOCA</td></tr>
<tr><td>Chernobyl</td><td>Steam explosion</td></tr>
<tr><td>Three Mile Island</td><td>Positive power coefficient of reactivity</td></tr>
<tr><td>SL-1</td><td>Insulator fire</td></tr>
<tr><td>Browns Ferry</td><td>Wigner energy annealing</td></tr>
<tr><td>Windscale, Sellafield</td><td>Equipment flooding</td></tr>
<tr><td>Fermi-1</td><td>Flow blockage</td></tr>
</table>
</td></tr>
<tr><td>37</td><td>11/28</td><td>12/5</td><td></td></tr>
<tr><td>38</td><td>11/30</td><td>12/7</td><td></td></tr>
<tr><td>39</td><td>12/2</td><td>12/7</td><td></td></tr>
<tr><td>40</td><td>12/5</td><td>12/7</td><td></td></tr>
<tr><td></td><td>12/7</td><td>Third Exam</td><td>Exam
~~Monday, December 12, 2022, 7-10 pm~~
Wednesday, December 7, during class period</td></tr>
</table>

Assignments Policy

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

They need to be submitted earlier when tests are scheduled.

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 e-mailed to the 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.