NPRE 402
Nuclear Power Engineering
Fall 2024

Online Temporary Alternative Coverage and access during Avian Influenza Type A Bird Flu H5N1, H5N2 or Covid-, MonkeyPox MPox and possible resurgence through mutations and variants or WHO anticipated Gain Of Function GOF research "Disease-X"

"H5N1 bird flu is widespread in wild birds worldwide and is causing outbreaks in poultry and U.S. dairy cows."
https://www.cdc.gov/flu/avianflu/avian-flu-summary.htm

IgG4 Antibodies Induced by Repeated Vaccination May Generate Immune Tolerance to the SARS-CoV-2 Spike Protein
https://pubmed.ncbi.nlm.nih.gov/37243095/

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.

Threat of Nuclear War:
https://www.youtube.com/watch?v=HSC7Lp1nvx8
https://www.youtube.com/watch?v=M7hOpT0lPGI

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.

Number	Date Assigned	Due Date	Description
1	8/26	9/2	**Reading assignment** **Preface** **Written Assignment** Define the Terawatt unit of power. Access the internet to determine the latest available figure of total global power consumption. Use the Carl Sagan's formula to calculate our technological civilization's level on the Kardashev's cosmic scale. On the Kardashev Scale, identify the power needs in Watts for Type I, II and III civilizations. In how many years is our Earth expected to achieve a Type I status? Write a paragraph about the "Fermi Paradox". Write a paragraph on NASA's Artemis Project. In Greek mythology, who is Artemis' brother? Who was born first? https://en.wikipedia.org/wiki/Artemis_program

2	8/28	9/4	**Reading Assignment** [Preface] **Written Assignment** Use the "Sankey diagram" to calculate the percentage share of nuclear energy in: a) The primary energy supply, b) Electrical energy generation? Define the Quad unit of energy in terms of BTUs and Joules. Use the "Sankey diagram" to calculate the end use efficiencies of the following energy sectors: 1. Residential, 2. Commercial, 3. Industrial, 4. Transportation. Draw a diagram and list the components of the envisioned Internet of Things (IoT) for a future energy system.
3	8/**30**	9/6	**Reading Assignment** **1. First Human Made Reactor and Birth of Nuclear Age** **Written Assignment** Calculate the speed in meters per second of neutrons possessing the following energies: a. Fast neutrons from fission at 2 MeV, b. Intermediate energy neutrons at 10 keV, c. Thermal energy neutrons at 0.025 eV.
4	9/4	9/11	**Reading Assignment** **1. First Human Made Reactor and Birth of Nuclear Age** **Written Assignment** If a single fission reaction produces about 180 MeV of energy, use Avogadro's law to calculate the number of grams of the fissile elements: 1. U^{235} 2. Pu^{239} 3. U^{233} that would release 1 kT of TNT equivalent of energy. Assume that all the energy release is available, except for the energy carried away by the antineutrinos, as well as the delayed fission products beta particles and gamma rays, which is not fully recoverable. Hint: Use Avogadro's law to estimate the number of nuclei in a given weight of the fissile material: $N[nuclei] = \frac{g[gm]}{M[amu]} A_v, \quad A_v = 0.6\times 10^{24} [\frac{nuclei}{mole}]$
5	9/6	9/13	**Reading Assignment** **1. First Human Made Reactor and Birth of Nuclear Age** **Written Assignment** Data mine the Chart of the Nuclides for the following information on elements used in nuclear applications: 1. *Naturally* occurring isotopes and their natural abundances. 2. Atomic masses of isotopes in atomic mass units (amu). for the following elements: a) Uranium (U). b) Thorium (Th). c) Carbon (C). d) Hydrogen (H). e) Lead (Pb).

			f) Beryllium (Be). g) Lithium (Li). h) Sodium (Na). i) Boron (B). j) Cadmium (Cd). k) Fluorine (F) *Previous version of* Table of Nuclides
6	9/9	9/16	**Reading Assignment** **4. Nuclear World** **Written Assignment** Identify three elements that have a single naturally occurring isotope. Hint: You can access the Chart of the Nuclides at: https://atom.kaeri.re.kr/old/ton/ Draw a sketch of the "Ulam Teller" configuration of thermonuclear devices.
7	9/11	9/18	**Reading Assignment** **4. Nuclear World** **Written Assignment** The reported time for an ICBM to travel from the continental USA to its assigned target is about t = ½ hour. To cover the distance of 6,000 miles, calculate the speed of travel of the missile in miles / hour. What would the hypersonic Mach Number be? Hint: Use the speed of sound as 761.2 miles /hour. Read then write a one paragraph summary of the paper: Magdi Ragheb, "Restoring The Global Equatorial Ocean Current Using Nuclear Excavation," i-manager's Journal on Future Engineering & Technology, Vol. 5, No. 1, pp. 74-82, August-October, 2009. What do the following nuclear-related acronyms stand for? ICBM, ABM, MIRV, kT, MT, DU, HEU, NPT, MAD, TNT, SALT, UUV, UAV.
8	9/13	9/20	**Reading Assignment** **4. Nuclear Processes, The Strong Force** **Written Assignment** Complete the following nuclear reactions occurring when radioactive materials such as radium are placed in a sealed container of air. Small amounts of hydrogen, which does not exist in ordinary air, would appear. $_{88}Ra^{226} \rightarrow {}_{86}Rn^{222} + ?$ $? + {}_{7}N^{14} \rightarrow {}_{1}H^{1} + ?$ ____________________ $_{88}Ra^{226} + {}_{7}N^{14} \rightarrow {}_{1}H^{1} + ? + ?$ Complete the following reaction leading to the production of $Carbon^{14}$, that exists in all living creatures, with a half-life of 5,730 years as an ongoing nuclear transformation from the neutrons originating from cosmic rays bombarding $_{7}Nitrogen^{14}$ in the Earth's atmosphere:

			$_0n^1 + ? \rightarrow ? + {}_6C^{14}$ $_6C^{14} \rightarrow ? + {}_7N^{14}$ --------- $_0n^1 \rightarrow ? + ?$
9	9/16	9/23	**Reading Assignment** [4. Nuclear Processes, The Strong Force] **Written Assignment** In a possibly future matter/antimatter reactor, use the mass to energy equivalence relationship to calculate the energy release in ergs, Joules and MeV from the complete annihilation of: a. An electron/positron pair. b. An antiproton/proton pair. Consider the following masses: $m_{electron} = m_{positron} = 9.10956 \times 10^{-28}$ gram $m_{proton} = m_{antiproton} = 1.67261 \times 10^{-24}$ gram. Apply conservation of momentum and conservation of energy to calculate the Q values and the kinetic energies of the product nuclei from the following binary reactions: 1. $_1D^2 + {}_1T^3 \rightarrow {}_0n^1 + ?$ (DT fusion reaction) 2. $_1D^2 + {}_1D^2 \rightarrow {}_1H1 + ?$ (Proton branch of the DD fusion reaction) 3. $_1D^2 + {}_1D^2 \rightarrow {}_0n^1 + ?$ (Neutron branch of the DD fusion reaction) 4. $_1D^2 + {}_2He^3 \rightarrow {}_2He^4 + ?$ (Aneutronic or neutronless DHe^3 reaction).
10	9/18	9/25	**Reading Assignment** [4. Nuclear Processes, The Strong Force] **Written Assignment** Calculate the Q values or energy releases in MeV from the following nuclear fission reactions: 1. $_0n^1 + {}_{92}U^{235} \rightarrow 3\ {}_0n^1 + {}_{53}I^{137} + {}_{39}Y^{96}$ 2. $_0n^1 + {}_{92}U^{235} \rightarrow 3\ {}_0n^1 + {}_{54}Xe^{136} + {}_{38}Sr^{97}$ List the percentage composition of the known components of the known universe.
11	9/20	9/27	**Reading Assignment** [1. Radioactive Transformations Theory, The Weak Force] **Written Assignment** Prove the equivalence of the heuristic form and the differential form of the law of radioactive decay. Tritium, an isotope of hydrogen used in fusion systems and a nanotechnology and Micro Electro Mechanical Systems (MEMS) power source devices, decays through the following reaction: $_1T^3 \rightarrow {}_{-1}e^0 +$ ______ Using the law of radioactive decay calculate the fraction of the tritium isotope $(N_0-N(t))/N_0$ decaying into the He^3 isotope. The half-life of tritium is 12.33 years. 1. Within 1 year. 2. Within 12.33 years. 3. Within 24.66 years.

<table>
<tr><td>12</td><td>9/23</td><td>9/30</td><td>
Reading Assignment
1. Radioactive Transformations Theory, The Weak Force
Written Assignment
Calculate the activity of 1 gm of the radium isotope Ra^{226} in Becquerels and Curies.
Discuss the relationship to the Curie (Ci) unit of activity.

Carbon dating is used in archaeology to determine the age of artefacts.
The production of $carbon^{14}$ with a half-life of 5,730 years is an ongoing nuclear transformation from the neutrons originating from cosmic rays bombarding $nitrogen^{14}$ in the Earth's atmosphere:
Carbon exists as $C^{14}O_2$ and is inhaled by all fauna and flora. Because only living plants continue to incorporate C^{14}, and stop incorporating it after death, it is possible to determine the age of organic archaeological artifacts by measuring the activity of the $carbon^{14}$ present.
Two grams of carbon from a piece of wood found in an ancient temple are analyzed and found to have an activity of 20 disintegrations per minute (dpm). Estimate the approximate age of the wood, if it is assumed that the current equilibrium specific activity of C^{14} in carbon has been constant at 13.56 disintegrations per minute per gram.

Access the Chart of the Nuclides and generate the Neptunium artificial radioactive decay chain.
What is its end stable isotope?
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<tr><td>13</td><td>9/25</td><td>9/30</td><td>
Reading Assignment
2. Food Preservation by Radiation
Written Assignment
List two radioactive isotopes used in food and medical products sterilization.

Identify the radiation absorbed doses in rads and Grays units needed for:
1. Pasteurization,
2. Sterilization of medical and food products,
3. Sprout inhibition,
4. Disinfection from insects,
5. Sterilization of larvae of lodging insects,
6. Extend shelf life up to 30 days,
7. One year storage at room temperature of meat products.

Match the following radiological quantities to their respective equivalents:
<table>
<tr><td>1 Curie</td><td>100 [ergs/gm]</td></tr>
<tr><td>1 Becquerel</td><td>1[Joule/kg]</td></tr>
<tr><td>1 rad</td><td>1 [trans/sec]</td></tr>
<tr><td>1 Gray</td><td>$3.7x10^{10}$[trans/sec]</td></tr>
</table>

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

<table>
<tr><th>Radiological quantity</th><th>Conventional System Unit</th><th>SI System Unit</th></tr>
<tr><td>Absorbed dose</td><td></td><td></td></tr>
<tr><td>Activity</td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>14</td><td>9/27</td><td>9/30</td><td>
Reading Assignment
3. Radioisotopes Power Production
Written Assignment
The isotope $_{81}Thallium^{204}$ has a half-life of 3.78 years and can be used as a nanotechnology and Micro Electro Mechanical Systems (MEMS) power source device. It decays through beta emission into $_{82}Pb^{204}$ with a branching ratio of 97.1 percent with an average decay energy of 0.764 MeV. It also decays through electron capture to $_{80}Hg^{204}$ with a branching ratio of 2.9 percent with
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</table>

			a decay energy of 0.347 MeV. Calculate the average energy release per decay event in [MeV/disintegration] Calculate its total specific activity in [Becquerels / gm]. Calculate its total specific activity in [Curies / gm]. Calculate the specific power generation in [Watts(th) / gm]. For a 100 Watts of thermal power in a Radioisotope Heating Unit (RHU) power generator, how many grams of $_{81}Thallium^{204}$ are needed? After 3.78 years of operation, what would its power become? Use: 1 MeV/sec = $1.602x10^{-13}$ Watts, $A_v = 0.602x10^{24}$ [nuclei/mole], 1 Curie = $3.7x10^{10}$ Bq.
	First Midterm.		**Monday September 30**
15	10/2	10/9	**Reading Assignment** 5. Gamma Rays Interaction with Matter **Written Assignment** List the different processes of gamma rays interaction with matter. Use the gamma-rays exponential attenuation law: $I(x) = I_0 B(\mu x, E_\gamma).e^{-\mu(E_\gamma).x}$ to design a gamma-rays radiation shield made out of Pb with a linear attenuation coefficient $\mu = 0.771\ [cm^{-1}]$ that would attenuate a narrow beam of 1 MeV gamma-rays with a build-up factor of B = 2 to one billionth of its initial strength.
16	10/4	10/11	**Reading Assignment** 1. Nuclear Reactor Concepts and Thermodynamic Cycles **Written Assignment** List the basic principles underlying the processes of energy conversion. What do the following acronyms stand for: PWR, BWR, HTGR, AGR, LMFBR. Assuming that heat rejection occurs at an ambient temperature of 20 degrees Celsius, for the average heat addition temperatures T_a given below, compare the Carnot cycle thermal efficiencies of the following reactor concepts: 1. PWR, 168 °C. 2. BWR, 164 °C. 3. CANDU, 141 °C. 4. HTGR, 205 °C. 5. LMFBR, 215 °C.
17	10/7	10/14	**Reading Assignment** 6. Zero Point Field Power 1. Nuclear Reactor Concepts and Thermodynamic Cycles **Written Assignment** List the two forms of the Heisenberg's Uncertainty Principle Construct a table comparing the Engineered Safety Features (ESFs) of the: 1. PWR 2. BWR Reactor concepts.

18	10/9	10/16	**Reading Assignment** 1. Nuclear Reactor Concepts and Thermodynamic Cycles 2. Pressurized Water Reactors **Written Assignment** A Stirling cycle engine using a radioactive isotope for space power applications operates at a hot end temperature of 650 ^oC and rejects heat through a radiator to the vacuum of space with a cold end temperature at 120 ^oC. Calculate its ideal Stirling cycle efficiency. Apply conservation of charge and of nucleons to balance the following fissile breeding reaction: ${}_0n^1 + {}_{92}U^{238} \rightarrow {}_{92}U^?$ ${}_{92}U^? \rightarrow {}_{-1}e^0 + {}_??^?$ ${}_??^? \rightarrow {}_{-1}e^0 + {}_??^?$ --------------- ${}_0n^1 + {}_{92}U^{238} \rightarrow 2\,{}_{-1}e^0 + {}_??^?$ Apply conservation of charge and of nucleons to balance the following fissile breeding reaction: ${}_0n^1 + {}_{90}Th^{232} \rightarrow {}_{90}Th^?$ ${}_{90}Th^? \rightarrow {}_{-1}e^0 + {}_??^?$ ${}_??^? \rightarrow {}_{-1}e^0 + {}_??^?$ --------------- ${}_0n^1 + {}_{90}Th^{232} \rightarrow 2\,{}_{-1}e^0 + {}_??^?$
19	10/11	10/18	**Reading Assignment** 3. Boiling Water Reactors **Written Assignment** A Boiling Water Reactor (BWR) produces saturated steam at 1,000 psia. The steam passes through a turbine and is exhausted at 1 psia. The steam is condensed to a subcooling of 3^oF and then pumped back to the reactor pressure. Compute the following parameters: a. Net work done per pound of fluid. b. Heat rejected per pound of fluid. c. Heat added by the reactor per pound of fluid. d. The turbine heat rate defined as: [(Heat rejected +Net turbine work)/Net turbine work] in units of [BTU/(kW.hr)] e. Overall Thermal efficiency. You may use the following data: From the ASME Steam Tables, saturated steam at 1,000 psia has an enthalpy of h = 1,192.9 [BTU/lbm]. At 1 psia pressure the fluid enthalpy from an isentropic expansion is 776 [BTU/lbm]. The isentropic pumping work is 2.96 [BTU/lbm]. The enthalpy of the liquid at 1 psia subcooled to 3 ^oF is 66.73 [BTU/lbm]. 1 [kW.hr] = 3,412 [BTU]
20	10/14	10/21	**Reading Assignment** 4. High Temperature Gas Cooled Reactor **Written Assignment** For heat rejection at 20 degrees Celsius, compare the Carnot cycle efficiencies for an HTGR

			operating in the following modes: a) Process heat, b) Power generation, c) Hydrogen production.
21	10/16	10/23	
22	10/18	10/25	
23	10/21	10/28	
24	10/23	10/30	
25	10/25	11/1	
26	10/28	11/1	
27	10/30	11/1	
	Friday November 1st		NPRE 402 Second Midterm
28	11/3	11/10	

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.