NPRE 402
Nuclear Power Engineering
Spring 2024

<u>Online Temporary Alternative Coverage and access during Covid-19 Pandemic and possible resurgence through mutations and variants or WHO anticipated Gain Of Function GOF research "Disease-X"</u>

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	1/17	1/24	**Reading assignment** **Preface** **Written Assignment** Write a paragraph about the "Fermi Paradox". 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?
2	1/19	1/26	**Reading assignment** **Preface** **Written assignment** Define the Quad unit of energy in terms of BTUs and Joules Define the Terawatt unit of power. Use the Sankey diagram to calculate the end use efficiencies of the following energy sectors: 1. Residential, 2. Commercial, 3. Industrial, 4. Transportation.

			What is the percentage share of nuclear energy in: a) The primary energy supply, b) Electrical energy generation? Draw a diagram and list the components of the envisioned Internet of Things (IoT) for a future energy system.
3	1/22	1/29	**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. Identify the following Technical Specifications (Tech Specs) of the Chicago Pile number 1 (CP-1) reactor. 1. Thermal power in Watts(thermal), Wth. 2. Fuel material 3. Moderator material 4. Control rods material 5. Safety (Scram) material Access the internet for the electrical power Pe(MWe) and thermal power Pth(MWth) level of a typical nuclear power plant of an 33.33 percent thermal efficiency and compare it to the power level of CP1. Note: thermal efficiency = Pe / Pth.

4	1/24	1/31	**Reading assignment**
			Chart of the Nuclides http://atom.kaeri.re.kr/
			1. First Human Made Reactor and Birth of Nuclear Age
			Written Assignment
			Write a one paragraph summary about the **Bulletin of Atomic Scientists'** Doomsday Clock that was introduced by Robert Oppenheimer**:**
			https://www.bbc.com/news/world-us-canada-68017445
			
			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 the naturally occurring 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)

5	1/26	2/2	**Reading Assignment** **1. First Human Made Reactor and Birth of Nuclear Age** **Nukemap Simulator https://nuclearsecrecy.com/nukemap/** **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} 4. Np^{237} 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: $$N[nuclei] = \frac{g[gm]}{M[amu]} A_v, \quad A_v = 0.6 \times 10^{24} [\frac{nuclei}{mole}]$$ Run a hypothetical "Nukemap" simulation of a 100 kT (kiloton) nuclear device targeting the city of Champaign Illinois. Report the level of casualties and effects for an 1,000 feet height burst.
6	1/29	2/5	**Reading Assignment** **2. German Nuclear Program** **3. Japanese Nuclear Weapons Program** **4. Nuclear World** **Nukemap Simulator https://nuclearsecrecy.com/nukemap/** **Written Assignment** Run a hypothetical "Nukemap" simulation of a 1 Mt (Megaton) of TNT equivalent Thermonuclear (hydrogen) nuclear device targeting the city of Chicago, Illinois. Report the level of casualties and effects for an 1,000 feet height burst. Write a paragraph about the German heavy water (D_2O, HDO) natural uranium subcritical assembly at Haigerloch, Germany. Write a paragraph about the "Alsos Team" mission in Germany following World War II.
7	1/31	2/7	**Reading Assignment** **4. Nuclear World** **4. Nuclear Processes, The Strong Force** **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.) Balance the following nuclear reactions using conservation of charge and nucleons: 1. $_1D^2 + _1T^3 \rightarrow _0n^1 + ?$ (DT fusion reaction) 2. $_1D^2 + _1D^2 \rightarrow _1H^1 + ?$ (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). 5. $_0n^1 + _3Li^6 \rightarrow ? + ?$ (Tritium breeding reaction) 6. $_0n^1 + _3Li^7 \rightarrow _0n^1 + ? + ?$ (Tritium breeding reaction) 7. $_1T^3 + _1T^3 \rightarrow 2_0n^1 + ?$ (Neutron multiplier reaction) 8. $_0n^1 + _5B^{10} \rightarrow _2He^4 + ?$ (Neutron absorption reaction) Complete the following transmutations nuclear reactions occurring when alpha particle emitting

			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. $$_{88}Ra^{226} \rightarrow {}_{86}Rn^{222} + ?$$ $$? + {}_{7}N^{14} \rightarrow {}_{1}H^{1} + ?$$ _____ $$_{88}Ra^{226} + {}_{7}N^{14} \rightarrow {}_{1}H^{1} + {}_{86}Rn^{222} + ?$$
8	2/2	2/9	**Reading Assignment** **4. Nuclear World** **4. Nuclear Processes, The Strong Force** **Written Assignment** 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: $$_{0}n^{1} + ? \rightarrow ? + {}_{6}C^{14}$$ $$_{6}C^{14} \rightarrow ? + {}_{7}N^{14}$$ – – – – – – – – $$_{0}n^{1} \rightarrow ? + ?$$ What do the following nuclear-related acronyms stand for? ICBM, ABM, MIRV, kT, MT, DU, HEU, NPT, MAD, TNT, SALT. 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.
9	2/5	2/12	**Reading Assignment** **4. Nuclear Processes, The Strong Force** **Written Assignment** Combine the two equations for the energy of a mass m and the energy of radiation with a frequency υ and a wavelength λ: $$E = mc^{2} \, [ergs]$$ $$E = h\nu = h\frac{c}{\lambda}$$ to deduce the inverse equation that describes the conversion of radiation to mass: $$m = R\nu$$

where: $R = \dfrac{h}{c^2} = 7.365864 \times 10^{-48} \dfrac{\text{erg.sec}^3}{\text{cm}^2}$ is a constant of nature.

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 mass/energy to calculate the Q values of 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 DHe³ reaction).

Reading Assignment
4. Nuclear Processes, The Strong Force
10. Limited Nuclear War
Written Assignment

Apply conservation of charge and of nucleons to balance the following fissile breeding reaction of Pu²³⁹ from U²³⁸:

$$_0n^1 + {}_{92}U^{238} \rightarrow {}_{92}U^?$$

$$_{92}U^? \rightarrow {}_{-1}e^0 + {}_?\,?^?$$

$$_?\,?^? \rightarrow {}_{-1}e^0 + {}_?\,?^?$$

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$$_0n^1 + {}_{92}U^{238} \rightarrow 2\,_{-1}e^0 + {}_?\,?^?$$

Apply conservation of charge and of nucleons to balance the following fissile breeding reaction from Th²³² to U²³³, considering that Th is four times more abundant than U in the Earth's crust:

$$_0n^1 + {}_{90}Th^{232} \rightarrow {}_{90}Th^?$$

$$_{90}Th^? \rightarrow {}_{-1}e^0 + {}_?\,?^?$$

$$_?\,?^? \rightarrow {}_{-1}e^0 + {}_?\,?^?$$

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$$_0n^1 + {}_{90}Th^{232} \rightarrow 2\,_{-1}e^0 + {}_?\,?^?$$

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. $_0n^1 + {}_{92}U^{235} \rightarrow 3\,_0n^1 + {}_{54}Xe^{136} + {}_{38}Sr^{97}$

Apply **conservation of momentum** and energy to calculate the Q values and the **kinetic energies of the product nuclei** from the following binary nuclear reactions:

10	2/7	2/15	

			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). Write a paragraph about the Princeton University simulation of a postulated Limited Nuclear Exchange. Read then write a one paragraph summary of the paper: Magdi Ragheb, "Lanchester Law, Shock and Awe Strategies," J. Def. Manag. 2015, 6:1, http://dx.doi.org/10.4172/2167-0374.1000137
11	2/9	2/16	**Reading Assignment** **1. Radioactive Transformations Theory, The Weak Force** **Written Assignment** Prove the equivalence of the heuristic form and the differential calculus 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. 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. 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. In the field of archaology, this is the technique of "Carbon Dating". 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.
12	2/12	2/19	**Reading Assignment** **1. Radioactive Transformations Theory, The Weak Force** **Written Assignment** In neutron cancer therapy, the following reaction can be used to destroy tumors with boron inserted at a cancer tumor's site: $$_0n^1 + _5B^{10} \rightarrow _2He^4 + \ ?$$ Calculate the Q value of this nuclear reaction. A fusion process uses the pB^{11} fusion reaction producing a C^{12} nucleus in its excited state. This excited C^{12} nucleus decays to Be^8 and He^4. Be^8 within 10^{-13} sec further decays into two more He^4 nuclei. This is the only nuclear energy releasing process in that it releases fusion energy and helium nuclei, but no initial neutrons, making ideal for nuclear rocket propulsion. $$m(_1H^1) = 1.0078250\,amu, \ m(_5B^{11}) = 11.0093055\,amu, \ m(_2He^4) = 4.0026032\,amu$$

			1 amu =931.481 MeV 1. Balance the nuclear reactions. 2. Calculate the Q value of the overall reaction. $$? + {}_5B^{11} \rightarrow {}_6C^{12*}$$ $$_6C^{12*} \rightarrow {}_4Be^8 + ?$$ $$_4Be^8 \rightarrow ? + ?$$ $$\overline{}$$ $$? + ? \rightarrow ?$$
13	2/14	2/19	**Reading Assignment** **2. Food Preservation by Radiation** **9. Gamma and X rays Detection** **Written Assignment** Match the following radiological quantities to their respective equivalents: 1 Curie 100 [ergs/gm] 1 Becquerel 1[Joule/kg] 1 rad 1 [trans/sec] 1 Gray 3.7×10^{10}[trans/sec] Draw a diagram of a Geiger-Muller tube Radiation preservation of food can be accomplished through two processes: 1. Pasteurization: This is accomplished with low doses of radiation in the range of ????? kGy, and is used for prolonging the shelf life or storage time. 2. Sterilization: Requires high level doses in the range of ????? kGy, and allows long term storage without refrigeration.
14	2/16	2/19	**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 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 = 1.602×10^{-13} Watts, $A_v = 0.602 \times 10^{24}$ [nuclei/mole], 1 Curie = 3.7×10^{10} Bq
	2/19	Class period	First Midterm Test
15	2/21	2/28	**Reading Assignment** **3. Terrestrial Radioactivity and Geothermal Energy** **Written Assignment** Calculate the ratio of heat conduction in rocks to that of incident solar radiation.

			Compare the result to the ratio of energy available in photosynthesis, storage in plants, and fossil fuels to the incident solar radiation. Discuss the implication concerning geothermal energy and bioenergy and fossil sources.
16	2/**23**	3/1	**Reading Assignment** **4. Biogenic and Abiogenic Petroleum** **Written Assignment** Write a paragraph on the Cassini spacecraft, using its radar system, discovering evidence for hydrocarbon lakes on the Titan's moon of Saturn and the possibility of primordial abiogenic hydrocarbons existence in the solar system. The Fischer-Tropsch process has been suggested as a possible mode of formation of abiogenic hydrocarbons in the Earth's mantle and crust. In the industrial process, carbon monoxide is reacted with hydrogen to synthesize hydrocarbons. The synthesis conditions are at 150 bar and 700 K in the presence of a catalyst. With Ni and Co used as catalysts, the following reaction would occur: $$nCO + 2nH_2 \xrightarrow{Ni,Co} nH_2O + C_nH_{2n}$$ If, instead, a Fe catalyst is used the reaction proceeds as follows: $$2nCO + nH_2 \xrightarrow{Fe} nCO_2 + C_nH_{2n}$$ Identify the potential hydrocarbon products for n=1 and n=2.
17	2/26	3/4	**Reading Assignment** **5. Gamma Rays Interaction with Matter** **Written Assignment** List the different processes of gamma rays interaction with matter. Compare the thicknesses of the following different materials that would attenuate a narrow beam of 1 MeV gamma rays in "good geometry" with a buildup factor of unity to one millionth of its initial strength, given their linear attenuation coefficients in cm^{-1}:
18	2/28	3/6	**Reading Assignment** **1. Nuclear Reactor Concepts and Thermodynamic Cycles** **Written Assignment** List the principles governing energy conversion and extraction from the environment and their corollaries. Construct a table comparing the Engineered Safety Features (ESFs) of the: 1. PWR 2. BWR Reactor concepts.

Table for row 17:

Material	Density [gm/cm^3]	Linear attenuation coefficient, μ at 1 MeV, [cm^{-1}]
Pb	11.3	0.771
H$_2$O	1	0.071
Concrete	2.35	0.149

19	3/1	3/8	What do the following acronyms stand for? PWR BWR HTGR LMFBR GCFBR

20	3/4	3/18	**Reading Assignment**
			1. Nuclear Reactor Concepts and Thermodynamic Cycles
			3. Boiling Water Reactors
			Written Assignment
			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 ºC.
			    2. BWR, 164 ºC.
			    3. HTGR, 205 ºC.
			    4. LMFBR, 215 ºC.
			
			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 3ºF 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]

21	3/6	3/18	**Reading Assignment** **2. Pressurized Water Reactors** **Written Assignment** Construct a table comparing the main Technical Specifications (Tech Specs) of the PWR and the BWR concepts. 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. Hint: Under complete regeneration, the Stirling cycle efficiency is equal to the ideal Carnot cycle efficiency.
22	3/8	3/18	**Reading Assignment** **1. Energy Hydrogenation and Decarbonization** **Written Assignment** As a reverse reaction to the electrolysis process, write the two half reactions describing the reverse reaction as the simple fuel cell concept.

			High Temperature Electrolysis (HTE) has a high efficiency $\eta_{electrolysis} > 0.90.$ Calculate the efficiency of a hydrogen production system for a future transportation alternative for the cases of: 1. A nuclear system using the Steam Cycle with an overall thermal efficiency of 33.3 percent, 2. A nuclear system using the Brayton Gas Turbine Cycle with an overall thermal efficiency of 50 percent. Discuss the implication of this observation concerning future nuclear power plants designs. Hint: Overall efficiency = efficiency of nuclear process X efficiency of electrolysis process.
23	3/18	3/25	**Reading Assignment** **1. Energy Hydrogenation and Decarbonization** **Written Assignment** Compare the voltages generated by a single fuel cell element using hydrogen as an energy carrier when it is operated at: a. 20 ºC, b. 100 ºC. Use: $n = 2, \quad \Delta E = \dfrac{T\Delta S - \Delta H}{n.F}, \quad \Delta S = -163.2 \ J/K, \quad \Delta H = -285,800 J,$ F (Faraday's constant) = 96,487 [Coulombs] or [Joules/Volt]. For the operation of a 12 Volt battery, how many cells are needed?

24	3/20	3/27	**Reading Assignment**
			1. Energy Hydrogenation and Decarbonization
			4. High Temperature Gas Cooled Reactor
			5. Heavy Water Reactor
			7. Fast Breeder Reactors
			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.
			
			Compare the prices of electricity produced by:
			    1. CANDU reactor
			    2. Coal
			    3. Natural gas
			at capacity factors of:
			    1. 20 percent,
			    2. 80 percent.

25	3/22	3/29	**Reading Assignment** **7. Fast Breeder Reactors** **6. Fourth Generation Reactor Concepts** **8. Autonomous Battery Reactors** **Written Assignment** List the reactors concepts considered in the "Fourth Generation" initiative and their associated acronyms.
26	3/25	4/1	**Reading Assignment** **11. Traveling Wave Reactor** **12. Modular Integral Compact Underground Reactor** **13. Underwater Power Plants** **14. Floating Nuclear Barges**

			Written Assignment Once built and operational, nuclear power plants become cash cows for their operators. Consider a 1,000 MWe nuclear power plant costing about $5,000 per installed kWe of capacity. Calculate: 1. The capital cost of the plant in billions of dollars. 2. If it operates for 60 years at a capacity factor of 90 percent, the amount of electrical energy in kW.hr it would produce per year. 3. Sold to electrical consumers at 5 cents / kW.hr, the generated income stream in $ million /year. 4. The total income stream in $ billion over 60 years of operation.
27	3/27	4/1	**Reading Assignment** **10. Isotopic Separation and Enrichment** **Written Assignment** Identify the level of U^{235} enrichment of: 1. Natural uranium, 2. Enrichment level of Depleted Uranium, DU, 3. Level of enrichment for LWRs. Draw a diagram showing the stages of the uranium chemical refinement process.
28	3/29	4/1	**Reading Assignment** **10. Isotopic Separation and Enrichment** **Written Assignment** An executive at an electrical utility company needs to order natural uranium fuel from a mine. The utility operates a single Heavy Water Reactor (HWR) 500 MWe power plant of the CANDU type using natural uranium and operating at an overall thermal efficiency of 1/3. What is the yearly amount of: a. U^{235} burned up by the reactor? b. U^{235} consumed by the reactor? c. Natural uranium fuel that the executive must contract with the mine per year as feed to his nuclear unit? An executive at an electrical utility company needs to order uranium fuel from a mine. This utility operates a single 500 MWe PWR power plant operating at an overall thermal efficiency of 33.33 percent. The fuel needs to be enriched to the 5 w/o in U^{235}. Consider that the enrichment plant generates tailings at the 0.2 w/o in U^{235} level. Calculate the yearly amount of natural uranium metal that the executive must contract with the mine as feed to his nuclear unit. Compare the results for the CANDU and the PWR nuclear reactor designs.
	4/1	Class period	Second Midterm Exam
29	4/3	4/10	**Reading Assignment** **10. Isotopic Separation and Enrichment** **Written Assignment** List the methods used in the enrichment of the heavy-element isotopes. Compare the ratio and the difference in the separation radii in the electromagnetic separation method (Calutron) for the separation of the ions of the isotopes and molecules of: a) U^{235} and U^{238}, b) Li^6 and Li^7
30	4/8	4/15	**Reading Assignment** **1. Transport Theory**

				Written Assignment List nine examples of physical processes governed by the Transport Equation. Write the Integro-Differential general form of the neutron Transport Equation. List the approximations used in solving the neutron Transport Equation. Write the one-dimensional form of the neutron Transport Equation
31				
32				
33				

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.