8.3 FOSSIL FUEL PRODUCTION
8.4 NON-FOSSIL FUEL POWER PRODUCTION   *HW/Study Packet*

SL/HL	
Required: READ Tsokos, pp 418-429	Supplemental: Cutnell and Johnson pp 994-995
DO Questions pp 430-432 #10,11,17,18,22,24,26,27	

REMEMBER TO….
- ✓ *Work through all of the 'example problems' in the texts as you are reading them*
- ✓ *Refer to the **IB Physics Guide** for details on what you need to know about this topic*
- ✓ *Refer to the **Study Guides** for suggested exercises to do each night*
- ✓ *First try to do these problems using only what is provided to you from the **IB Data Booklet***
- ✓ *Refer to the solutions/key ONLY after you have attempted the problems to the best of your ability*

UNIT OUTLINE

I. HISTORY OF FOSSIL FUELS
  A. WHERE THEY COME FROM
  B. FIRST USES AND INDUSTRIALIZATION
  C. GEOGRAPHY OF FOSSIL FUELS
II. FOSSIL FUEL SPECIFICS
  A. ENERGY DENSITY AND USE IN POWER STATIONS
  B. STORAGE AND TRANSPORTATION
  C. EFFICIENCY
  D. ADVANTAGES AND DISADVANTAGES
III. NUCLEAR POWER
  A. NUCLEAR FISSION AND CHAIN REACTIONS
  B. THERMAL FISSION REACTORS AND NUCLEAR POWER STATIONS
  C. ADVANTAGES AND DISADVANTAGES
IV. SOLAR POWER
  A. SOLAR HEATING PANELS AND PHOTOVOLTAIC CELLS
  B. INCIDENT SOLAR POWER ON THE EARTH
  C. ADVANTAGES AND DISADVANTAGES
V. HYDROELECTRIC POWER
  A. DIFFERENT TYPES OF HYDROELECTRIC SCHEMES
  B. ENERGY TRANSFORMATIONS IN HYDROELECTRIC SCHEMES
  C. ADVANTAGES AND DISADVANTAGES
VI. WIND POWER
  A. WIND GENERATORS
  B. ADVANTAGES AND DISADVANTAGES
VII. WAVE POWER
  A. ENERGY IN WAVES AND HOW TO EXTRACT IT
  B. ADVANTAGES AND DISADVANTAGES

$$\text{power} = \tfrac{1}{2} A \rho v^3$$

$$\text{power per unit length} = \tfrac{1}{2} A^2 \rho g v$$

$$I = \frac{\text{power}}{A}$$

WHAT YOU SHOULD BE ABLE TO DO AT THE END OF THIS TOPIC

- □ Outline the historical and geographic reasons for the widespread use of fossil fuels.
- □ Discuss the energy density of fossil fuels.
- □ State the overall efficiency of power stations fuelled by different fossil fuels.
- □ Discuss the relative advantages and disadvantages associated with the transport and storage of fossil fuels.
- □ Understand and describe the environmental problems associated with the recovery of fossil fuels and their use in power stations.
- □ Understand how energy is produced by nuclear fuels and the problems associated with it.
- □ Distinguish between controlled and uncontrolled nuclear fission.
- □ Describe the functions of the main elements of a nuclear reactor (moderator, control rods, etc).
- □ Describe the importance of Plutonium-239 as a fuel source.
- □ Distinguish between a photovoltaic cell and a solar heating panel.
- □ Outline reasons for seasonal and regional variations in solar power.
- □ State the meaning of the term 'solar constant'.
- □ Distinguish between different kinds of hydroelectric schemes and the main energy transformations within these schemes.
- □ Determine the power that can be generated by a wind generator, and the basics of this process.
- □ Describe the way an oscillating water column (OWC) works.
- □ Determine the power per unit length of a wavefront.
- □ Discuss the relative advantages and disadvantages of all of these energy sources.

HOMEWORK PROBLEMS:

1. Uranium is used as a fuel in a small research nuclear reactor. The reactor produces 24 MW of power. The efficiency of the reactor is 32 %. In the fission of one uranium-235 nucleus 3.2×10^{-11} J of energy is released.
   a) Determine the mass of uranium-235 that undergoes fission in one year in this reactor.   **[29 kg]**

   b) Explain what would happen if the moderator of this reactor were to be removed.

2. A possible fission reaction is $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + x^{1}_{0}n$.
   a) How many neutrons are produced in this reaction?   **[3]**

   b) Given the following data:

Mass of neutron	*= 1.00867 u*
Mass of U-235 nucleus	*= 234.99333 u*
Mass of Kr-92 nucleus	*= 91.90645 u*
Mass of Ba-141 nucleus	*= 140.88354 u*

   Determine the energy released when one uranium nucleus undergoes fission in the above reaction.   **[2.8 × 10^{-11} J]**

   c) A nuclear power plant that uses U-235 as fuel has a useful power output of 16 MW and an efficiency of 40 %. Assuming that each fission of U-235 undergoes the above reaction with the energy released in part (b), determine the mass of U-235 fuel used per day.   **[48 g]**

3. A sample of nuclear fuel contains 3% U-235. If the energy density of U-235 is 9 x 10^{13} J kg^{-1}, how much energy will 1kg of fuel release?   **[2.7 x 10^{12} J]**
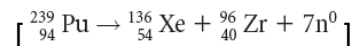
4. Plutonium-239 splits into zirconium-96 and xenon-136. Use the table to answer the following questions:

Isotope	Mass (U)
^{239}Pu	239.052158
^{96}Zr	95.908275
^{136}Xe	135.907213
neutron	1.008664

a) How many neutrons will be emitted? **[7]**

b) Write the nuclear equation for the reaction. $[\ ^{239}_{94}\text{Pu} \rightarrow\ ^{136}_{54}\text{Xe} +\ ^{96}_{40}\text{Zr} + 7\text{n}^0\ ]$

c) How much energy is released when the fission takes place? **[164 MeV]**

d) What is the mass of 1 mole of plutonium? **[239 g]**
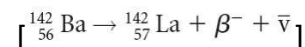
e) How many atoms are there in 1 kg of plutonium? **[2.5 x 10²⁴]**

f) How much energy in eV is released if 1kg of plutonium undergoes fission? **[4.13 x 10²⁶]**

5. Barium-142 ($^{142}_{56}Ba$) is a possible product of the fission of uranium-236. It decays by β- decay to lanthanum (La) with a half-life of 11 months.

a) Write the equation for the decay of barium. $[\ ^{142}_{56}\text{Ba} \rightarrow\ ^{142}_{57}\text{La} + \beta^- + \bar{v}\ ]$

b) Estimate how long will it take for the activity of the barium in a sample of radioactive waste to fall to $\frac{1}{1000}$ of its original value. **[9 years]**

6. A village consists of 120 houses. It is proposed that solar panels be used to provide hot water to the houses. The following data are available:

average power needed per house to heat water   = 3.0 kW
average surface solar intensity   = 650 W m^{-2}
efficiency of energy conversion of a solar panel   = 18 %

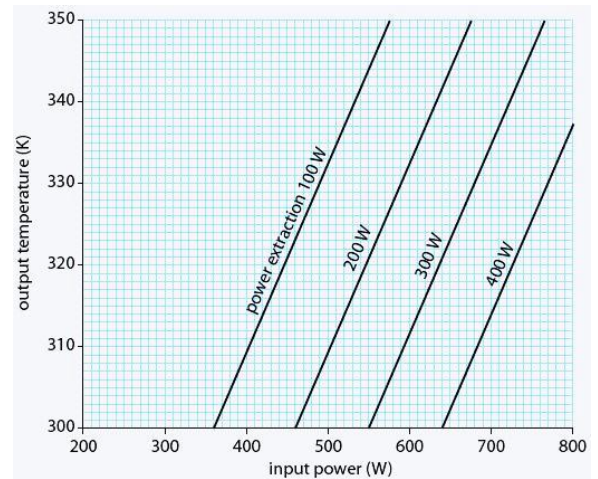Calculate the minimum surface area of the solar panels required to provide the total power for water heating.   **[3.1 x 10^3 m^2]**

7. The following data relates to the Earth and the Sun:

     Earth-Sun distance   = 1.5 × 10^{11} m
     radius of Earth   = 6.4 × 10^6 m
     radius of Sun   = 7.0 × 10^8 m
     surface temperature of Sun   = 5800 K

a) Use data from the table to calculate the power radiated by the Sun.   **[4 × 10^{26} W]**

b) Calculate the solar power incident per unit area at a distance from the Sun equal to the Earth's distance from the Sun.   **[1400 Wm^{-2}]**

c) The average power absorbed per unit area at the Earth's surface is 240 W m^{-2}. State **two** reasons why the value calculated in (b) differs from this value.

d) Show that the value for power absorbed per unit area of 240 W m^{-2} is consistent with an average equilibrium temperature for the Earth of about 255 K.

8. Some students carry out an investigation on a solar panel. They measure the output temperature of the water for different solar input powers and for different rates of extraction of thermal energy. The results are shown. Use the data from the graph to answer the following.

a) The solar panel is to provide water at 340 K whilst extracting energy at a rate of 300 W when the intensity of the sunlight incident normally on the panel is 800 W m^{-2}. Calculate the effective surface area of the panel that is required. **[0.91 m^2]**

b) Determine the overall efficiency of the panel for an input power of 500 W at an output temperature of 320 K. **[33 %]**
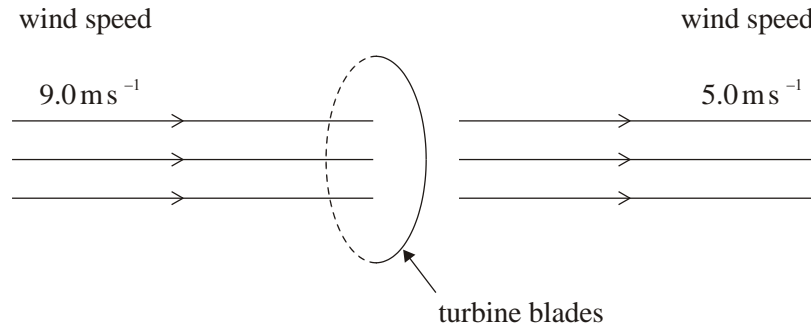
9. Your job is to design wind turbines for a wind farm. The specifics of the farm are as follows:

Total required annual electrical energy output from the wind farm : 120 TJ
Maximum number of turbines for which there is space on the farm : 20
Average annual wind speed at the site : 9.0 m s^{-1}
Density of air = 1.2 kg m^{-3}

a) Determine the average power output required from one turbine. **[0.19 MW]**

b) Estimate the blade radius of the wind turbine that will give a power output of 0.19 MW. **[12 m]**

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10. Air of constant density 1.2 kg m^{-3} is incident at a speed of 9.0 m s^{-1} on the blades of a wind turbine. The turbine blades are each of length 7.5 m. The air passes through the turbine without any change of direction. Immediately after passing through the blades, the speed of the air is 5.0 m s^{-1} as illustrated below.

wind speed

9.0 m s^{-1}

wind speed

5.0 m s^{-1}

turbine blades

The density of air immediately after passing through the blades is 2.2 kg m^{-3}. The turbine and generator have an overall efficiency of 72%.

a) Calculate the power extracted from the air by the turbine. **[53kW]**

b) Calculate the electrical power generated. **[38kW]**

11. A community in a coastal area has built a wind generator and a wave generator. The wind generator produces 5.0 kW of power for a wind speed of 6.0 m s^{-1}. The wave generator produces a power per unit length of 4.0 kW m^{-1} for waves of amplitude A and speed v.

a) Determine the power produced for a wind speed of 12.0 m s^{-1}. **[40 kW]**

b) The efficiency of the generator is constant. Determine the power per unit length obtained from waves of amplitude $2A$ and speed $2v$. **[32 kW m^{-1}]**