Worksheet IB8.1: Energy Production

Fuel	Specific energy/ MJ kg^{-1}	Energy density/ MJ m^{-3}
Wood	16	1×10^4
Coal	20–60	$(20–60) \times 10^6$
Gasoline (petrol)	45	35×10^6
Natural gas at atmospheric pressure	55	3.5×10^4
Uranium (nuclear fission)	8×10^7	1.5×10^{15}
Deuterium/tritium (nuclear fusion)	3×10^8	6×10^{15}
Water falling through 100 m in a hydroelectric plant	10^{-3}	10^3

Energy Density and Efficiency

1. What is the energy content of 10.0 g of petrol (gasoline)? (450 kJ)
2. How many grams of coal must you burn to get 125 kJ of heat energy? Use a specific energy of 40.0 MJ kg^{-1}. (3.13 g)
3. How many grams of petrol must you burn to raise the temperature of 750. ml of water (C_{water} = 4186 J kg^{-1} $^oC^{-1}$) from 15.0 ^oC to 100.0 ^oC? if the stove is 100% efficient? What if it is 65.0% efficient? (5.93 g, 9.12 g)
4. A gas water heater contains 189 liters of water at 15.0 ^oC. If it is 55.0% efficient, and it burns 0.889 kg of natural gas, what is the <u>final</u> temperature of the water? (49.0 ^oC, the delta T is 34.0 ^oC)
5. An on demand water heater needs to heat 17.0 liters of water per minute from a temperature of 13.0 ^oC to 54.3 ^oC. How many grams of natural gas will it burn in one minute if it is 58.0% efficient? (92.1 g)
6. A gas water heater can raise the temperature of 178 liters of water from 21.0 ^oC to 65.0 ^oC by burning 1.10 kg of natural gas. What is its efficiency? (54.2%)
7. A power plant generates 125 MW of power. How much energy does it generate in a day? If it is 37.0% efficient, what is the energy input in a day? How many kilograms of coal would it burn to produce that amount of energy? (Use an specific energy of 40.0 MJ kg^{-1}) How many kilograms of Uranium would it go through in a day? (1.08×10^{13} J, 2.92×10^{13} J, 7.30×10^5 kg or 730 metric tons, 0.365 kg of Uranium)
8. A power plant is 37.0% efficient and burns 4190 kg of natural gas a day. What is its average power output? (987 kW)
9. A natural gas generation plant generates a power output of 0.850 MW. It consumes 159 kg of natural gas per hour. What is its efficiency? (35.0%)
10. How many kg of natural gas will a 145 MW natural gas electrical generation plant that is 34.0% efficient burn in a year? (2.45×10^8 kg)

Thermal Conduction (L_f for ice is 3.33×10^5 J kg^{-1})

11. A wall is 19.1 cm thick (2x8 wall), measures 2.10 m by 8.50 m, and 12,800 J flow through the wall in 15.0 minutes when there is a temperature difference of 12.5 ^oC between the inside and the outside of the wall. What is the thermal conductivity of the wall? (0.0122 W m^{-1} $^oC^{-1}$)
12. You design a cooler. It has a surface area of 3.45 m^2, and you want it to keep 2.27 kg (5 lbs) of ice from melting in 6.0 hours when there is a temperature difference of 22.0 ^oC between the inside and the outside. How thick in cm must the insulation be if it has a thermal conductivity of 0.0372 W m^{-1} $^oC^{-1}$? (8.07 cm)
13. A glass window pane is 4.85 mm thick and has a thermal conductivity of 0.841 W m^{-1} $^oC^{-1}$. How much heat flows through the 1.42 m x 2.36 m window in a day if the temperature difference from one side of the pane to the other is 0.650 ^oC? (32.6 MJ)
14. A cooler has 5.20 cm thick walls and insulation with a thermal conductivity of 0.0540 W m^{-1} $^oC^{-1}$. What mass of ice will melt (Assume it is at 0 ^oC) in one hour if the cooler has an outside area of 3.84 m^2, and the temperature outside is 18.0 ^oC? (0.776 kg)
15. You want there to be a heat transfer of 185,000 Joules per second into fluid that is moving down a copper (k = 380 W m^{-1} $^oC^{-1}$) pipe. What total surface area do you need if the temperature difference is 45.0 ^oC from the inside to the outside of the tubing with a wall thickness of 1.65 mm? (0.0179 m^2) Super smart – what length of 3/4" diameter pipe would you need? (29.8 cm)

Pumped Storage

16. A pumped storage system allows water to fall through a vertical distance of 270. m at a rate of 450. kg s^{-1}. What is the total power being transformed? If the generation system has an overall efficiency of 56.0 % what is the electrical power output? (1.19 MW, 667 kW)
17. You are designing a pumped storage system. You can raise the reservoir a height of 85.0 m above the generation site, and the overall efficiency is 62.0%. What flow rate in kg s^{-1} do you need to have to generate 125 kW? (242 kg s^{-1})
18. A pumped storage facility is generating 860. kW of electrical power with a flow rate of 712 kg s^{-1}, and an overall efficiency of 67.0%. What height is the reservoir above the generation site? (184 m)
19. A pumped storage system is generating 413 kW of electricity with a reservoir that is 312 m above the generation site, and is operating a flow rate of 237 kg s^{-1}. What is its overall efficiency? (56.9%)
20. A 72.0% efficient pumped storage plant operates with a vertical displacement of 185 m, and lets 2740 kg of water per <u>minute</u> into the generator. What is its power output? (59.7 kW)

Solar

21. A house has solar panels that measure 1.65 m by 0.991 m, and are 22.3% efficient. If the sunlight has an intensity of 850. W m^{-2}, what is the electrical power generated by a single panel? How many panels would you need to generate at least 4 kW? (310. W, 13)
22. A house has 12 solar panels with an efficiency of 21.5% that measure 1.57 m by 1.05 m, and are generating 4020 W of power. What is the intensity of the solar radiation? (945 W m^{-2})
23. You need to generate 5.60 kW of power for a house with solar panels that have an efficiency of 23.0% and the average intensity of sunlight is 450. W m^{-2}. What area do you need? (54.1 m^2)
24. Some solar panels measure 1.60 m by 1.02 m, each one generating 275 W of power when the sunlight intensity is 750. W m^{-2}. What is the efficiency of the panels? (22.5%)
25. A house has 35.0 m^2 total area of solar panels with an efficiency of 24.0%. What is the power output when the sunlight intensity is 1020 W m^{-2}? (8570 W)