ENVIRONMENT AND ECOLOGY

Problem 1

A type of anthracite contains 90 % carbon by weight. How much CO_2 is produced from the combustion of 1 metric ton of this anthracite? How much CO_2 is produced from the combustion of 1 Mcf (1,000,000 ft^3 at standard conditions) of propane?

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Problem 2 (ME405s23q3)

A 400 MW electric power plant with an thermal efficiency 38 % uses bituminous coal, which contains 70 % carbon, 2 % sulfur with the rest being volatile matter and ash. The heating value of this coal is 26,500 kJ/kg. Determine:

(a) how much heat the plant needs annually, if it operates continuously;

(b) how much of this coal the power plant uses daily and annually; and

(c) how much CO_2 and SO_2 the power plant produces annually.

Answer: (a) 3.32 10^{10} MJ/year (b) 1.25 10^9 kg coal/year (c) 3.21 10^9 kg CO_2/year

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Problem 3

Three coal power plants with a total power producing capacity of 1,000 MW and average thermal efficiency 36 %, are substituted by one nuclear power plant with 33 % thermal efficiency. What is the annual amount of CO_2 that is not emitted to the atmosphere? What is the increase of the waste heat produced? The heating value of the coal that was used is 28,000 kJ/kg and contains 80 % carbon.

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Problem 4

Three coal power plants with a total capacity of 1,000 MW and average thermal efficiency 36 %, are substituted by ten smaller gas units that use methane. The new units have an average thermal efficiency 43 %. What is the annual amount of CO_2 that is not emitted to the atmosphere because of this substitution? Assume that the heating value of coal is 30,000 kJ/kg and contains 90 % carbon, and that of methane is 50,020 kJ/kg.

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Problem 5

The coal power plant of problem 2 is fitted with a sulfur abatement system that has 99.6 % efficiency. How much of the SO_2 mass is removed by the abatement system and how much is released in the atmosphere?

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Problem 6

What effect the following parameters would have on the long-term temperature of the atmosphere? Write a short statement to explain your reasons.

(a) A decrease of the earth's core temperature.

(b) An increase of the average cloudiness.

(c) A decrease of the earth's reflectance.

(d) An increase of the amount of atmospheric methane.

(e) An increase of the surface temperature of Venus.

(f) Producing 10 % of the total electric power from solar cells.

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Problem 7

''The melting of the polar ice caps will be a major environmental calamity because it will increase the average temperature by 10.41 C.'' Comment by writing a short (250–300 word) essay.

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Problem 8

A lake has a surface area of 18 square kilometers and an average depth of 6 m. The average pH of the lake is 6.9. How many tons of acid rain in the form of H_2SO_3 would reduce the pH of the lake from 6.9 to 3.2?

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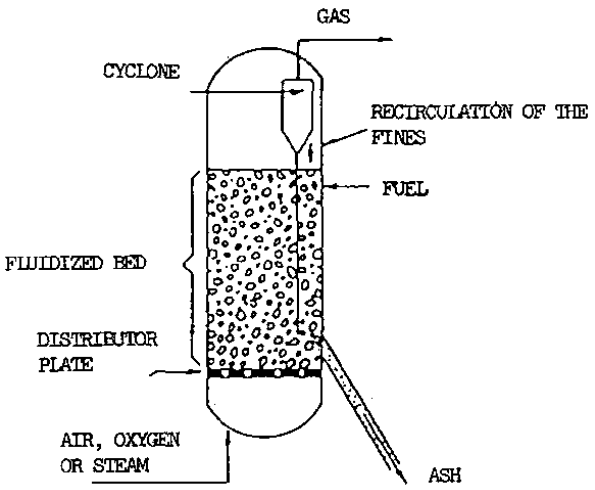
Problem 9 (ME436s17q1 / ME436s18q1)



Three Fluidized Bed Reactors (FBR's) consume bituminous coal with 65 % carbon, 2.3 % sulfur by weight and heating value 24 10^3 kJ/kg. The FBR's supply with heat power a 600 MW coal power plant with 42 % overall thermal efficiency. Determine:

(a) How much heat the set of FBR's produce annually;

(b) How much coal they consume; and

(c) How much $Ca(OH)_2$ must be supplied to the FBR's in order to remove the SO_2 produced?

Answer: (a) $Q = 4.51\ 10^{13}$ kJ/year

(b) $m_{coal} = 1.88\ 10^9$ kg/year

(c) $Ca(OH)_2 = 4.99\ 10^7$ kg/year

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Problem 10

A certain type of leaded gasoline contains 1.2 % of tetra-ethyl lead by weight. How much lead oxide, PbO, is released in the environment with every litter and with every gallon of this gasoline? Assume that all Pb is converted to PbO.

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Problem 11

Calculate the amount of heat, in TJ (10^{12} J), rejected annually from the following types of electric power plants assuming that they operate continuously.

(a) A 400 MW coal plant with thermal efficiency of 40 %.

(b) A 1,000 MW nuclear power plant with thermal efficiency of 33 %.

(c) A 35 MW geothermal power plant with 14 % thermal efficiency.

(d) A 10 MW thermal solar plant with 18 % thermal efficiency.

(e) An 80 MW natural gas power plant with 46 % thermal efficiency.

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Problem 12

The wet cooling towers of power plants use air and water for the cooling of the condensers. Air enters the cooling tower of such a plant at 22 C, 50 % relative humidity and exits at 34 C, 90 % relative humidity. Determine:

(a) the amount of heat removed by 1 kg of (dry) air from this cooling system; and

(b) the amount of water (in kg) consumed for every kg of air that passes through the cooling tower.

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Problem 13

The cooling tower of a 200 MW coal power plant with 40% thermal efficiency admits air at 15 C, 70 % relative humidity and rejects it at 32 C, 95 % relative humidity. Determine:

(a) How much cooling air passes through the cooling system of this plant per minute?

(b) How much water is used annually?

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Problem 14

It is recommended that ten small geothermal power plants of 20 MW each (total 200 MW) substitute a coal power plant. If the average thermal efficiency of the geothermal power plants is 14 %, how much water will be used annually?

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Problem 15

A 1,000 MW nuclear power plant with a 32 % thermal efficiency discharges its waste heat in a lake with 22 km surface and 3 m depth.

(a) If there is no other cooling effect for the lake, what would be the average increase of the water temperature annually?

(b) What other factors would nullify this temperature increase?

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Problem 16 (ME405s23h3)

What is the Carbon footprint of the following activities? For all, you will need to find the wattage of the pertinent appliances in your residence. In the case of electric appliances, you may assume that 70 % of the electricity comes from coal power plants with an overall thermal efficiency of 38 %.

(a) Watching television for 1 hour.

(b) Using a microwave oven for 10 minutes.

(c) Forgetting to switch off a 100 W light bulb for 12 hours.

(d) Driving for 500 km in a SUV, which goes 8 km on a liter of Diesel.

(e) Driving for 500 km in a compact car, which goes 16 km on a liter of gasoline.

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Problem 17

‘‘The human society in its current form has failed to create a sustainable future for us and the next generations. Humans should abandon the cities and urban life and create a sustainable future for themselves and their children by producing their own food and fuel from products they have grown for millennia and can depend on in the future.’’ Comment by writing a short (250–300 word) essay.

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Problem 18 (ME436s18f-3 / ME405s18f-3 / ME436s21m-1 / ME405s21m-1)

Consider a power plant with typical efficiency of 33 % and plant electrical output of 1000 MW_e. Suppose 15 % of waste heat goes up the smokestack and 85 % is taken away by cooling water drawn from a nearby river, which has a flow rate of 100 m^3/s and a temperature of 20 °C. Environmental guidelines suggest that the plant should limit coolant water temperature rise to 10 °C. What flow rate is needed from the river to carry the waste heat away? What will be the rise in river temperature?

Specific heat of water: c_p = 4.187 kJ/kg.K

Answer: $\dot{m}$ = 41.2 tons/s

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Problem 19 (ME436s19q1 / ME405s19q1)

The average energy released in a fission of U-235 nucleus is about 200 MeV. Suppose we had 1.0 g of U-235, and assume fission of all of the nuclei.

(a) How much energy would be released?

(b) Estimate how much coal it would take to produce the same amount of energy.

1 eV = 1.602 10^{-19} J

Heating value of coal: 30 000 kJ/kg

Atomic Mass of U-235: 235.044 amu (g/mol)

Avagadro's number: 6.022 10^{23} atoms/mol

Answer: (a) 8.21 10^{7} kJ

(b) 2736 kg

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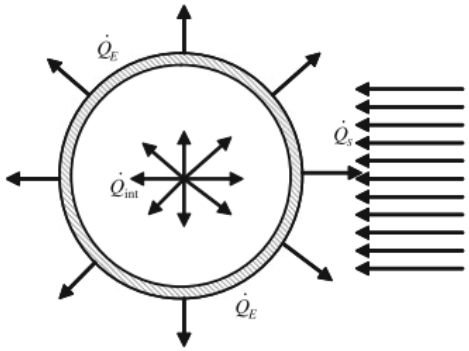
Problem 20 (ME436s21q3 / ME405s21q3)

Identify all the symbols in the energy-balance equation of the Earth atmosphere system:

$$4\,\pi\,R^2\,H\,\rho\,c_E\,\frac{dT_E}{dt} = \pi\,R^2\,\sigma\,\alpha_E\,T_S^4 - 4\,\pi\,R^2\,\sigma\,\varepsilon_E\,T_E^4 + 4\,\pi\,R^2\,k_E\,\frac{T_{int} - T_E}{H}$$



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Problem 21 (ME405s21q13)

Briefly explain the term "Greenwashing". Provide a simple example.

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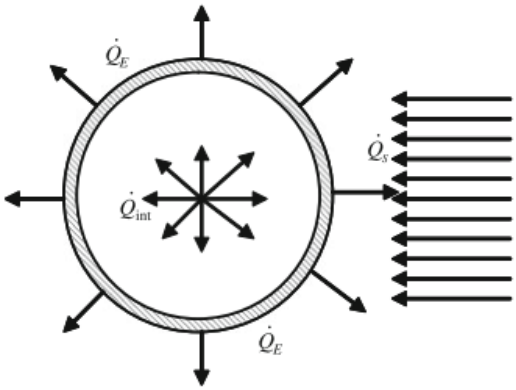
Problem 22 (ME436s21h3 / ME405s21h3 / ME436s22h3)

Make reasonable engineering assumption for all the parameters in the equation below

$$4\,\pi\,R^2\,H\,\rho\,c_E\,\frac{dT_E}{dt} = \pi\,R^2\,S\,\alpha_E + 4\,\pi\,R^2\,k_E\,\frac{T_{int} - T_E}{H} - 4\,\pi\,R^2\,\sigma\,\varepsilon_E\,T_E^4$$

and solve for the steady-state temperature, T_E, of the earth-atmosphere system.



R: Radius of the earth, m

H: Thickness of the atmosphere, m

ρ: Density of the atmosphere, kg/m^3

c_E: Specific heat of the atmosphere, J/kg.K

T_E: Equilibrium temperature of the earth-atmosphere system, K

t: time, s

S: Solar constant

Thickness of the atmosphere	H, m	…
Solar constant	S, W/m^2	1366
Stephan-Boltzmann constant	σ, W/m^2.K^4	5.67 10^{-8}
Absorptivity of the atmosphere	α_E	…
Emissivity of the atmosphere	ε_E	…
Thermal conductivity of the earth	k_E, W/m.K	…
Internal temperature of the earth	T_{int}, K	…

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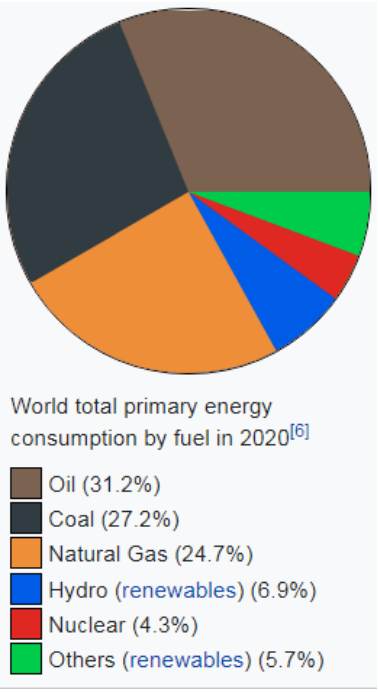
Problem 23 (ME436s22q2 / ME405s22q2)

Hydro Power meets about 7 % of our global primary energy consumption as shown in the Figure. It is basically following these steps to generate electricity:



- Build dams along streams to create reservoirs;
- Allow water to flow through the dam;
- Spin a turbine-generator couple to produce electricity.

The following advantages can be cited:

- Produces no pollution;
- Totally renewable;
- Can be used for flood control;
- Can be used as a water resource (irrigation, cooling water for power plants, etc.);
- Can be used for recreation (sailing, water skiing, etc).

It seems like it is a win-win situation. Or is it? Can you think of any disadvantage(s)?

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Problem 24 (ME436s22h2 / ME405s22h2)

Whether alternative energy sources such as renewable energies biofuels, hydrogen, solar, wind, and geothermal, or the non-renewable nuclear energy, can meet energy demands better than finite fossil fuels such as oil, coal, and natural gas remains hotly debated.

Proponents of alternative energy argue that fossil fuels are inefficient, unsustainable, environmentally destructive, and the primary contributor to global climate change. They say renewable energies are a viable and immediately needed alternative to fossil fuel use that could boost the economy and reduce reliance on foreign energy sources of a country.

Opponents contend that many technological hurdles have to be overcome before alternative energy can replace even a small portion of the power provided by fossil fuels. They say that fossil fuels will last hundreds of years longer, be made increasingly efficient, remain the most economical choice, and that reliance on inefficient alternative energies will hurt the economy.

What do YOU say? Write a short essay.

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Problem 25 (ME405f22q2)

Energy is called “sustainable” if it meets the needs of the present without compromising the ability of future generations to meet their own needs.

What do you think about “hydrogen energy” as a form of “sustainable energy”? Write down few advantages and few disadvantages that you can think of.

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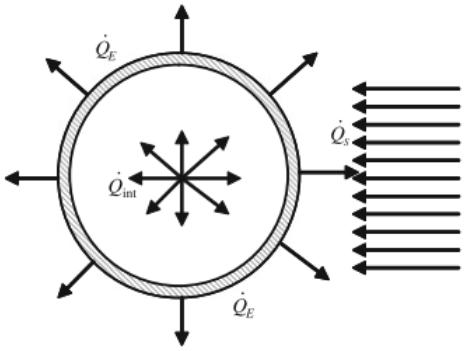
Problem 26 (ME405f22q3)



A simple model for energy balance on the earth-atmosphere system is given by the equation below. Using the data given in the table below, find the steady-state temperature, T_E, of the earth-atmosphere system.

$$4\,\pi\,R^2\,H\,\rho\,c_E\,\frac{dT_E}{dt} = \pi\,R^2\,S\,\alpha_E + 4\,\pi\,R^2\,k_E\,\frac{T_{int} - T_E}{H} - 4\,\pi\,R^2\,\sigma\,\varepsilon_E\,T_E^4$$

Thickness of the atmosphere	H, m	10000
Solar constant	S, W/m^2	1366
Stephan-Boltzmann constant	σ, $W/m^2.K^4$	$5.67\ 10^{-8}$
Absorptivity of the atmosphere	α_E	0.8
Emissivity of the atmosphere	ε_E	0.7
Thermal conductivity of the earth	k_E, W/m.K	1.5
Internal temperature of the earth	T_{int}, K	6000

Answer: $T_E \cong 15\ ^\circ C$

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Problem 27 (ME405f22h2)

Write a short essay (no more than one page) on “sustainable energy” from the point of view of energy resources and use in Turkey.

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Problem 28 (ME405f22h3)

Write a short essay (about a page long) on Environmental Impact Assessment (EIA).

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Problem 29

Briefly explain what the “Love Canal” Disaster and its legacy were in the US.

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Problem 30 (ME405f24h2)

In several countries, including Türkiye, an automobile must pass an emissions test before it can be registered for operation. Two components usually found in the exhaust gases are considered to be harmful when emitted to the environment, and the quantities of those two components are restricted by legislation. Name those two compounds and explain why the emission of each is restricted.

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