Due: 8 Oct 2025

Energy: Science, Technology, and Society

Problem Set 5

Indicate assistance obtained with each of the tasks defined below, e.g., by naming web source (Wikipedia, Google/Gemini, ChatGPT,…) and a (summary) prompt.

1. Consequential Climate Trends

The Greenland glacier (latitude 69° 38' 7.50" N) covers an area of $A = 1.7 \cdot 10^6$ km^2 and has a total volume of approximately $V = 2.85 \cdot 10^6$ km^3. According to current observations, the glacier is melting at a slightly faster rate than its accumulation gain from precipitation.

a) Estimate the total weight of the glacier in metric tons and the associated pressure.

b) Calculate by how much the global sea level would rise if the glacier melted completely. (Neglect a possible rise of the land.)

c) Calculate the total energy that the melting process in b) would require.

d) Adopt a simple geological model of Earth' crust, where the land mass floats on a liquid upper mantle layer. By order of magnitude, give a rough estimate of the uplift Greenland could expect from the buoyancy effect associated with the lower weight of an iceless land mass.

Densities: $\rho_i \approx 917$ kg/m^3(ice), $\rho_m \approx 3$ t/m^3(Earth' upper mantle).

2. Venusian Climate

The planet Venus is in many respects Earth like, with mass ($M_V = 4.87 \cdot 10^{24}$kg) and radius (R_V = 6,052 km) similar to those of Earth, but it orbits the Sun with a mean orbital radius of only $R_{SV} = 1.082 \cdot 10^8$ km. Like Earth, Venus has a near-circular orbit but a shorter year (225 Earth days).

Venus' climate is significantly influenced by its large albedo (a_V = 0.76) and the (extremely corrosive) atmosphere consisting largely of sulfuric acid vapors and dust leading to substantial greenhouse effects.

a) Use the model introduced in class for evaluating the radiative balance of Earth and calculate the solar constant S_V for Venus and its equilibrium surface temperature T_0 without an atmospheric greenhouse effect.

b) Given the measured surface temperature of T_{SV} = 730 K for Venus, what temperature T_{Sat} would the Venusian troposphere have to have, assuming it to be a layer with a large temperature laps rate?

3. Heat Radiation and Equilibration

A finned, cast-iron hot water (@110^{0}C) radiator (50kg, surface area A=2.5m^2) is to be used to heat a V=4m·5m·3m closed living room, which is insulated from the outside. At the start time, *t=0,* the still room air is at the ambient temperature of $\boldsymbol{T_{amb}}(t=0)$**=**15^{0}C.

Make first order (linearization) approximations in your evaluation as justified.

a) Write down the thermal masses (inertias) of radiator ($\boldsymbol{C_R}$) and air ($\boldsymbol{C_{Air}}$), and the expression relating heat energy content to temperature of the radiator.

b) Write down the rate equation for the net electromagnetic heat radiation Q(t) emitted in time by the radiator into the room.

c) Include air convection in the equation for the total net heat transfer rate Q(t)from the radiator surface to the air.

d) Calculate the heating curve $\boldsymbol{T_{amb}}(t)$. When is the desired temperature of 22^{0}C reached?

e) Calculate final room temperature reached, if the radiator water supply is turned off, as soon as $\boldsymbol{T_{amb}}$=22^{0}C has been reached.

Data: Specific heat capacities: Iron $\mathbf{c_{Fe}}$=450J/kg, air $\mathbf{c_{AIR}}$=1.005 kJ/(kg·K), radiator emissivity ε=0.9. Thermal mass of the room $C_{room} = 1 \cdot 10^6\ J/K$ Typical convection heat transfer coefficient for air is **h**=5W/m^2·K.