# IB Paper 4: Heat Transfer
# Hints on Examples Paper 6

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S1. The problem set-up is identical to the example in Lecture §6.3.3. You should review the definitions of irradiation and radiosity in Lecture §6.

1. Because all the radiation leaving the sample reaches the enclosure, we can proceed on a per unit area basis, i.e. set $A_i = 1$ and $F_{ij} = 1$. At equilibrium, the radiation emitted by the sample is equal to that absorbed. Equating these two terms and simplifying yields Kirchoff's identity.

2., 3. First work out the view factors using symmetry, reciprocity, and the unity sum requirement. As the area of the environment is large, the view factors from it are small. Carefully draw out the resistor network. We can neglect the surface resistance of the reflector, because it is insulated and there is no net heat flow. We can take the surface resistance of the environment as zero due to the large area. Finally evaluate the total thermal resistance between heater and environment, and hence the heat flow.

4. The radiation to the room side can be found using the given area and temperatures. For the radiation to the wall side, the temperature of the wall must be determined first. Write an expression for the net heat transfer to the wall from the radiator, room, and outside (be careful of sign conventions). In steady state this is equal to zero and can be solved numerically for the unknown wall temperature. With the radiation shield, a new wall temperature can be found by another balance of net heat transfer, this time with no radiation term because the wall is perfectly reflective. The total heat flow to the room is equal to the sum of both radiator sides minus the loss to the outside. This is because the radiator is the only source of heat, and the outside is the only sink.

5. Draw a diagram, tabulate the given data and work out the view factors. Lay out the resistor network. There are two simplifications that can be made: the workpiece is insulated so no voltage drop across the surface resistance, and large environment area gives negligible surface resistance. Apply Kirchoff's Current Law to the workpiece node to derive the radiosity off the heater surface. Apply Kirchoff's Current Law to the heater junction to find the heater temperature. Finally, look at the voltage drop across the heater surface resistance to get the heat input.

6. From Wikipedia: $T_{\text{sun}} \sim 5.7 \times 10^3\,\text{K}$, $d_{\text{sun}} \sim 1.5 \times 10^{11}\,\text{m}$, $R_{\text{sun}} \sim 7.0 \times 10^8\,\text{m}$, $R_{\text{earth}} \sim 6.3 \times 10^6\,\text{m}$, and world energy consumption is $\mathcal{P} \sim 113\,009\,\text{TW h} = 1.3 \times 10^{13}\,\text{W}$. Spread the total black-body emission from the sun surface over a sphere with radius equal to the distance of the earth from the sum, i.e. an inverse square law. Viewed from the sun, the projected area of the earth receiving this radiation is $\pi R_{\text{earth}}^2$.

7. Evaluate the fluid properties. Find the flow velocity from mass flow and area, then evaluate the correlation for heat transfer coefficient. Heat transfer to the thermocouple is due to radiation (to wall temperature) and convection (to gas temperature). Equate the net heat transfer to zero in steady state and solve for the thermocouple temperature. For part (c), set the thermocouple temperature to 5 K under the gas temperature and solve to get a new heat transfer coefficient. Consider how $Nu$ varies with $d$ to evaluate the new diameter.