# General Physics II: Tutorial Material

## Lecture 13 (Chapter 10& 11, Thermodynamic potentials and Heat transfer)

**1) Isothermal heat of surface expansion**: A system consists of a thin film of surface area $A$, of internal energy $E_{int}(S, A)$, where $dE_{int} = TdS + \gamma dA$. $\gamma$ is the surface tension given by:

$$\gamma(S, A) = \frac{\partial E_{int}(S, A)}{\partial A} \tag{1}$$

Express the heat $Q_{if}$ to provide to the film for a variation of $\Delta A_{if} = A_f - A_i$ of the surface of the film through an isothermal process at temperature $T$, that brings the film from an initial state $i$ to a final state $f$, in terms of $\gamma(T, A)$ and its partial derivatives.

**2) Two questions related to thermal conductivity and Fourier's law for the heat flow rate**

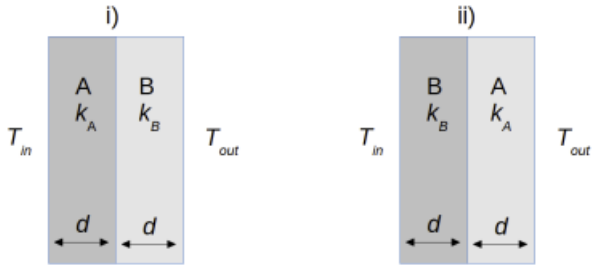
$$\dot{Q} \equiv \frac{dQ}{dt} = -kA\frac{dT}{dx} \tag{2}$$

I) Let us consider a wall consisting of two plates, A and B: both plates have a thickness $d$ with thermal conductivities, $k_A$ and $k_B$, respectively, and $k_A > k_B$. We use this wall for a house and can make i) surface A facing inside of the house and ii) surface B facing inside of the house. In winter when the outside temperature, $T_{out}$, is lower than the room temperature $T_{in}$, i.e., $T_{in} > T_{out}$.

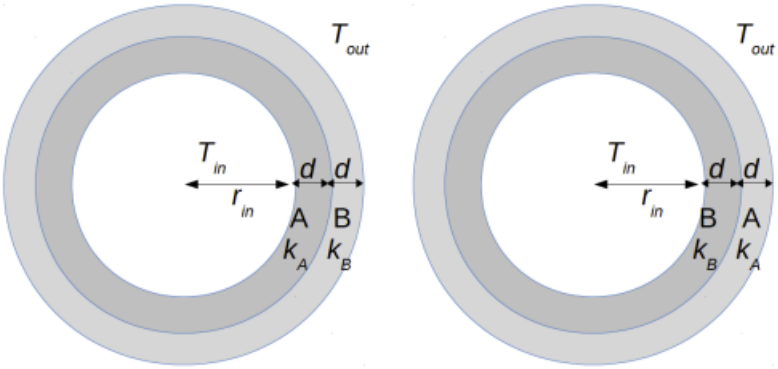
a) Calculate the heat flow rate from the room to outside through wall with configuration i).

b) Calculate the heat flow rate from the room to outside through wall with configuration ii).

c) Are the temperature profiles through the wall from the inside to the outside surface for the two configurations same or different? Which configuration loses more thermal energy to outside?



II) A pipe consists of the two layers of material with a same thickness d. The inner radius of the pipe is $r_{in}$. Two material A and B with thermal conductivities, $k_A$ and $k_B$, respectively, are available for the layers where $k_A > k_B$. This pipe is used to transport hot water with a temperature $T_{in}$ through cold outside with a temperature of $T_{out}$, where $T_{in} > T_{out}$. Figures below show the cross-sections of the pipes.

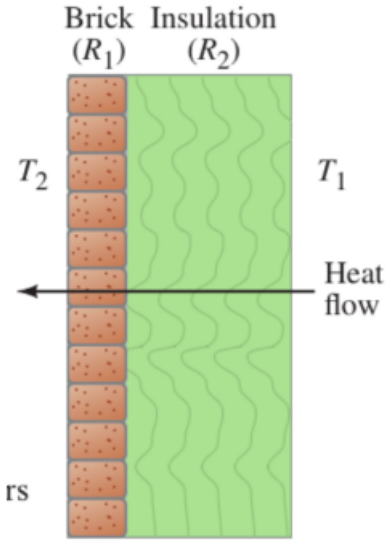



a) Calculate the heat rate from the water to outside for a pipe where the inner layer with material A.

b) Calculate the heat rate from the water to outside for a pipe where the inner layer with material B.

c) Are the radial temperature profiles different between the two configurations? Which configuration loses more thermal energy to outside?

**3)** Suppose the insulating qualities of the wall of a house come mainly from a 4.0 inch layer of brick and an R-19 layer of insulation as shown below. What is the total rate of heat loss through such a wall if its total area is 195 feet$^2$ and the temperature difference across it is 35 F?




Definition of R values: the R value, i.e. the thermal resistance, specifies insulation properties of a building material, defined for a given thickness l of the material: R = l/k with k being the thermal conductivity.

Larger R means a better insulation from heat or cold. Here, we exceptionally work with R units in British units [ft2 h F/Btu]; [Btu] is the British unit for heat with one BTU equal to about $1,055J$. Below you can see a table giving some R values for common building materials.

**TABLE 14–5 *R*-values**

| Material | Thickness | *R*-value ($ft^2 \cdot h \cdot F°/Btu$) |
|---|---|---|
| Glass | $\frac{1}{8}$ inch | 1 |
| Brick | $3\frac{1}{2}$ inches | 0.6–1 |
| Plywood | $\frac{1}{2}$ inch | 0.6 |
| Fiberglass insulation | 4 inches | 12 |