ME 320 Homework 1

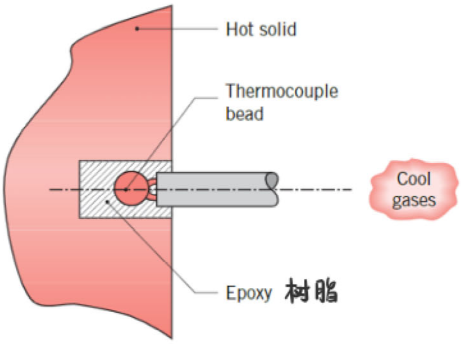
Q1

In analyzing the performance of a thermal system, the engineer must be able to identify the relevant heat transfer processes. Only then can the system behavior be properly quantified. For the following systems, identify the pertinent processes, designating them by appropriately labeled arrows on a sketch of the system. Answer additional questions that appear in the problem statement. 沥青路面

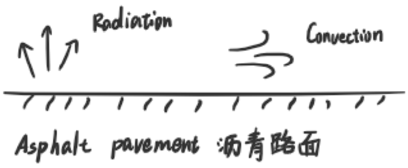
(a) Identify the heat transfer processes that determine the temperature of an asphalt pavement on a summer day. Write an energy balance for the surface of the pavement.

(b) Microwave radiation is known to be transmitted by plastics, glass, and ceramics but to be absorbed by materials having polar molecules such as water. Water molecules exposed to microwave radiation align and reverse alignment with the microwave radiation at frequencies up to $10^9\ s^{-1}$, causing heat to be generated. Contrast cooking in a microwave oven with cooking in a conventional radiant or convection oven. In each case, what is the physical mechanism responsible for heating the food? Which oven has the greater energy utilization efficiency? Why? Microwave heating is being considered for drying clothes. How would the operation of a microwave clothes dryer differ from a conventional dryer? Which is likely to have the greater energy utilization efficiency? Why?

(h) A thermocouple junction is used to measure the temperature of a solid material. The junction is inserted into a small circular hole and is held in place by epoxy. Identify the heat transfer processes associated with the junction. Will the junction sense a temperature less than, equal to, or greater than the solid temperature? How will the thermal conductivity of the epoxy affect the junction temperature?



(a).



对于 Control Surface

$\dot{E}_{in} - \dot{E}_{out} = 0$

$\dot{E}_{sun} - \dot{E}_{conv} - \dot{E}_{rad} = 0$

(b).

	Mechanism	Efficiency
Oven 烤炉	Convection	Low
Microwave Oven 微波炉	Radiation	High

Because oven heat up both air and food. Therefore, there is energy loss to air.
But microwave turned most of the energy directly into the heat of food.
Therefore, microwave is more efficient.

Same for drying clothes. In conventional dryer, there should be a heater that heat up the air and then deliver the heat to dry the clothes. It heat up both air and clothes. But microwave dryer only heat up the water on clothes.

(h).

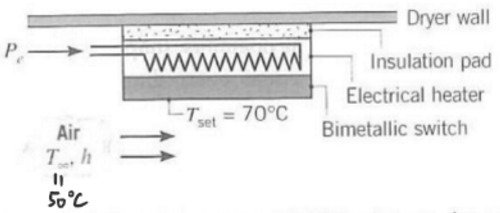
Transfer process = conduction

Measure temp is less than the real temp

Because the heat conduct speed will be affected by the heat conductivity of epoxy. The higher the heat conductivity that epoxy has, the closer the measured temp to the real temp.

Q2

The temperature controller for a clothes dryer consists of a bimetallic switch mounted on an electrical heater attached to a wall-mounted insulation pad.



The switch is set to open at 70°C, the maximum dryer air temperature. To operate the dryer at a lower air temperature, sufficient power is supplied to the heater such that the switch reaches 70°C (T_{set}) when the air temperature T is less than T_{set}. If the convection heat transfer coefficient between the air and the exposed switch surface of 30 mm^2 is 25 W/m$^2 \cdot$K, how much heater power P_e is required when the desired dryer air temperature is $T_\infty = 50°C$?

TABLE 1.5 Summary of heat transfer processes

Mode	Mechanism(s)	Rate Equation	Equation Number	Transport Property or Coefficient
Conduction	Diffusion of energy due to random molecular motion	$q''_x(\text{W/m}^2) = -k\frac{dT}{dx}$	(1.1)	k (W/m·K)
Convection	Diffusion of energy due to random molecular motion plus energy transfer due to bulk motion (advection)	$q''(\text{W/m}^2) = h(T_s - T_\infty)$ Note: T_∞ used to describe fluid temperature	(1.3a)	h (W/m^2·K)
Radiation	Energy transfer by electromagnetic waves	$q''(\text{W/m}^2) = \varepsilon\sigma(T_s^4 - T_{sur}^4)$ or $q(\text{W}) = h_r A(T_s - T_{sur})$	(1.7) (1.8)	ε h_r (W/m^2·K)

Note: T_{sur} used to describe surrounding temperature

$$T_\infty = 50 + 273 = 323 \text{ K}$$

$$T_{suf} = 70 + 273 = 343 \text{ K}$$

Convection 对流导热公式

$$q = A \cdot h \cdot (T_{suf} - T_\infty) = 30\text{mm}^2 \cdot 25 \text{ W/m}^2 \cdot \text{K} \, (343\text{ K} - 323\text{ K}) = \boxed{0.015 \text{ W}}$$

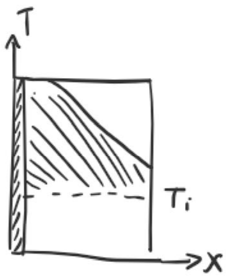
$$P_e = q = 0.015 \text{ W}$$

Q3

A method for determining the thermal conductivity k and the specific heat c_p of a material is illustrated in the sketch. Initially the two identical samples of diameter $D = 60$ mm and thickness $L = 10$ mm and the thin heater are at a uniform temperature of $T_i = 23.00°C$, while surrounded by an insulating powder. Suddenly the heater is energized to provide a uniform heat flux q_o'' on each of the sample interfaces, and the heat flux is maintained constant for a period of time, Δt_o. A short time after sudden heating is initiated, the temperature at this interface T_o is related to the heat flux as

$$T_o(t) - T_i = 2q_o''\left(\frac{t}{\pi \rho c_p k}\right)^{1/2}$$

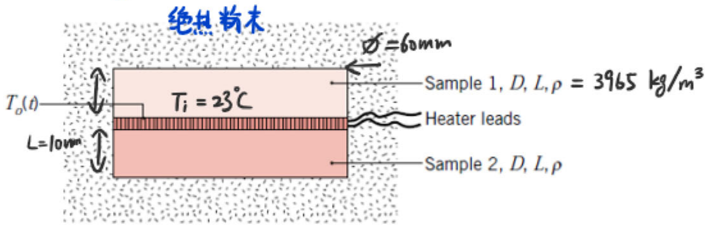
2*31.2426-24.57=
37.9152



For a particular test run, the electrical heater dissipates 15.0 W for a period of $\Delta t_o = 120$ s and the temperature at the interface is $T_o(30\text{ s}) = 24.57°C$ after 30 s of heating. A long time after the heater is deenergized, $t \gg \Delta t_o$, the samples reach the uniform temperature of $T_o(\infty) = 33.50°C$. The density of the sample materials, determined by measurement of volume and mass, is $\rho = 3965$ kg/m^3.

$$A = \pi\left(\frac{D}{2}\right)^2 = 0.0028\,m^2$$

$$V = A \cdot L = 9 \times 10^{-6}\,m^3$$



Determine the specific heat and thermal conductivity of the test material. By looking at values of the thermophysical properties in Table A.1 or A.2, identify the test sample material.

计算测试材料的比热容 c 和导热系数 k

根据能量守恒

$$\Delta E_g = 2 \cdot c_p \cdot m \cdot \Delta T$$

$$\Delta t_0 \cdot P = 2 \cdot C_p \cdot \rho \cdot A \cdot L \cdot (T_0(\infty) - T_i)$$

$$C_p = \boxed{764.95\ J/kg \cdot k}$$

$$\frac{A^2}{P^2}\left(T_{30} - T_i\right)^2 = \frac{t}{\pi \rho C_p k}$$

根据题目给出公式

$$T_0(t) - T_i = 2q_0'' \cdot \sqrt{\frac{t}{\pi \cdot \rho \cdot C_p \cdot k}}$$

$$T_0(t=30s) - T_i = 2q_0'' \cdot \sqrt{\frac{t}{\pi \cdot \rho \cdot C_p \cdot k}}$$

$$\because q = \frac{P}{2A}$$

$$\therefore T_0(t=30s) - T_i = \frac{P}{A} \cdot \sqrt{\frac{t}{\pi \cdot \rho \cdot C_p \cdot k}}$$

$$\therefore \boxed{k =} \frac{P^2 t}{A^2 (T_{30} - T_i)^2 \cdot \pi \cdot \rho \cdot C_p} = \boxed{36\ W/m \cdot k}$$

$$\frac{15^2 * 30}{0.0028^2 * (1.57^2) * 3.15 * 3965 * 764.95}$$