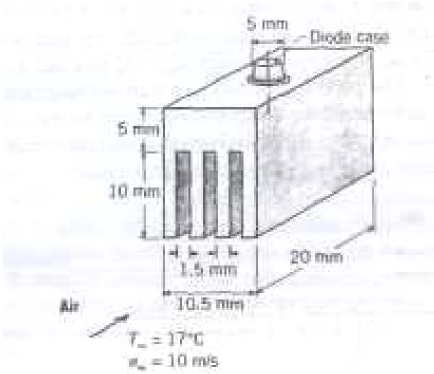
Part G-4: Sample Exams

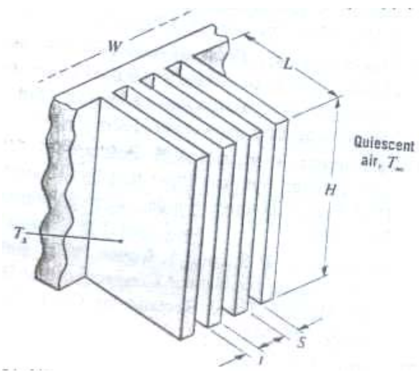
Cairo University Faculty of Engineering Mechanical Power Engineering Dept.	M.Sc.: Electronics Cooling Final Exam (Sample 1) Time allowed 2 Hours

Solve as much as you can.

1. A heat sink constructed from 2024 aluminum alloy is used to cool a power diode dissipating 5 W. The internal thermal resistance between the diode junction and the case is 0.8 °C/W, while the thermal contact resistance between the case and the heat sink is 10^{-5} m^2. °C/W. Convection at the fin surface may be approximated as that corresponding to a flat plate in parallel flow.
a) Assuming that all the diode power is transferred to the ambient air through the rectangular fins; estimate the operating temperature of the diode.
b) Explore options for reducing the diode temperature, subject to the constraints that the air velocity and fin length may not exceed 25 m/s and 20 mm, respectively, while the fin thickness may not be less than 0.5 mm. All other conditions, including the spacing between fins, remain as prescribed.



2. Consider an array of vertical rectangular fins, which is lo be used lo cool an electronic device mounted in quiescent, atmospheric air at T_∞= 27 °C. Each fin has L = 20 mm and H = 150 mm and operates at an approximately uniform temperature of T_s = 77 °C. For the optimum value of fin spacing S and a fin thickness of t = 1.5 mm, estimate the rate of heat transfer from the fins for an array of width W = 355 mm.



3a. What are the factors affected on filter selection to be mounted on electronic chassis?

3b. What's the difference between active and passive immersion cooling techniques?

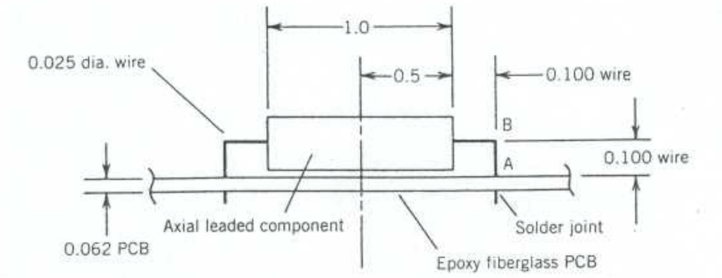
4. The interface temperature of an electronic assembly dissipating 10 W must be limited to 40 ^oC in a 50 ^oC environment. It is assumed that all of the generated heat will be removed by thermoelectrics and that heat absorbed from the environment is negligible. The interface temperature difference between the assembly and the thermoelectric can be held to 2 ^oC. The temperature difference between the thermoelectric and ambient can be held to 8 ^oC. The bismuth telluride element used has a length of 0.3 cm and a cross-area of 0.01 cm^2.

Determine the size and performance characteristics of the thermoelectric temperature control device. Knowing that
The equivalent material properties of the thermoelectric couples is

$\rho_e = 0.00267\ \Omega.cm$
$\alpha_e = 425 \times 10^{-6}$ V/K
$k_e = 0.00785$ W/cm.K

NB: Design for maximum refrigeration capacity.

5. Determine the axial force in the lead wire for the resistor shown in figure below, when bending of the PCB is included in the analysis over a temperature cycling range from -50 to +90 °C, which produce total horizontal displacement expected at the top of the wire will be 0.0003 in. (Note: All dimensions in inches)
Assuming that:
$E_W = 16 \times 10^6$ Ib/in^2 (copper wire modulus elasticity)
$E_P = 1.95 \times 10^6$ Ib/in^2 (PCB modulus of elasticity)



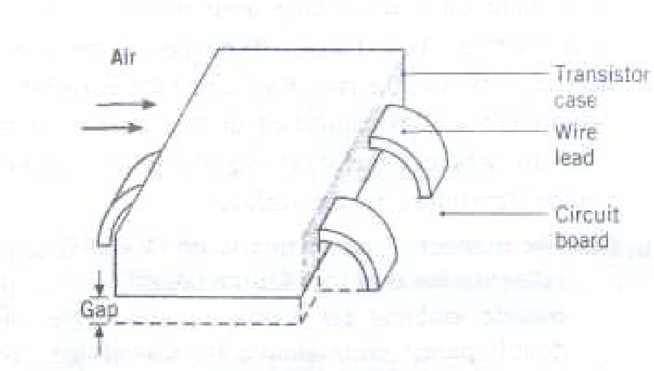
Cairo University	M.Sc.: Electronics Cooling
Faculty of Engineering	Final Exam (Sample 2)
Mechanical Power Engineering Dept.	Time allowed 2 Hours.

Solve as much as you can.

1. Consider a surface-mount type transistor on a circuit board whose temperature is maintained at 35 °C. Air at 20 °C flows over the upper surface of dimensions 4 mm by 8 mm with a convection coefficient of 50 W/m^2.K.Three wire leads, each of cross section 1 mm by 0.25 mm and length 4 mm, conduct heat from the case to the circuit board. The gap between the case and the board is 0.2 mm.

a) Assuming the case is isothermal and neglecting radiation; estimate the case temperature when 150mW are dissipated by the transistor and (i) stagnant air or (ii) a conductive paste fills the gap. The thermal conductivities of the wire leads, air. And conductive pastes are 25, 0.0263, and 0.12 W/m.K. respectively.

b) Using the conductive paste to fill the gap, we wish to determine the extent to which increased heat dissipation may be accommodated, subject to the constraint that the case temperature not exceeds 40 °C. Options include increasing the air speed to achieve a larger convection coefficient h and/or changing the lead wire material to one of larger thermal conductivity. Independently considering leads fabricated from materials with thermal conductivities of 200 and 400 W/m.K., compute and plot the maximum allowable heat dissipation for variations in h over the range $50 \leq h \leq 250$ W/m^2.K.

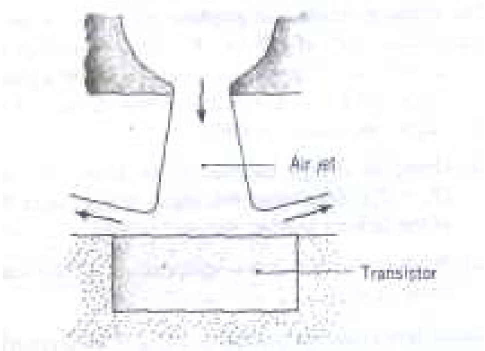


2. A 35 W power transistor is fitted to a duralumin plate 150 x 165 mm and 5 mm thick. The plate is finned on the other side by 15 fins spaced 9 mm apart. The fins are 2 mm thick and protrude 40 mm. In an ambience of 40 °C, how long would it take this transistor, after turning it on, to be within 5 ^{o}C from its final temperature? Neglect effect of radiation.

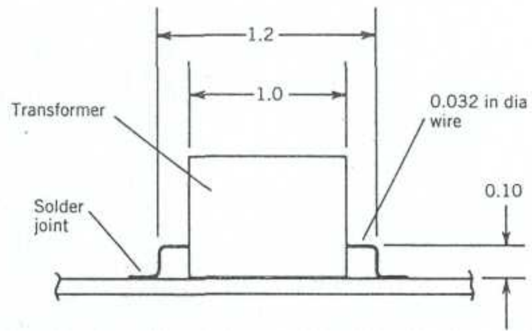
3a. Describe with neat sketch the components of a heat pipe.

3b. Discuss briefly the types of Printed Wiring Board.

4. A circular transistor of 10 mm diameter is cooled by impingement of an air jet exiting a 2-mm diameter round nozzle with a velocity of 20 m/s and a temperature of 15 °C. The jet exit and the exposed surface of the transistor are separated by a distance of 10 mm. If the transistor is well insulated at all but its exposed surface and the surface temperature is not to exceed 85 ^{o}C, what is the transistor's maximum allowable operating power?



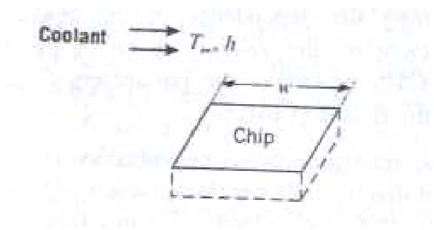
5. Determine the deflections and thermal stresses expected in the lead wires and solder joints of the surface mounted transformer shown in the following figure, when it is mounted on an aluminum composite PCB which experiences in plane (X and Y) thermal expansion during rapid temperature cycling tests over a temperature range from -30 to +80 °C, with no electrical operation. (Note: All dimensions in inches)
Assuming that:
$a_T = 35 \times 10^{-6}$ in/in/°C (average TCE of transformer)
$a_P = 20 \times 10^{-6}$ in/in/°C (average TCE of composite PCB)
$E_W = 16 \times 10^{6}$ psi (modulus of elasticity, copper wire)



Cairo University	M.Sc.: Electronics Cooling
Faculty of Engineering	Final Exam (Sample 3)
Mechanical Power Engineering Dept.	Time allowed 2 Hours.

Solve as much as you can.

1. A square isothermal chip is of width w = 5 mm on a side and is mounted in a substrate such that its side and back surfaces are well insulated, while the front surface is exposed to the flow of a coolant at T_∞ = 15 °C. From reliability considerations, the chip temperature must not exceed T = 85 °C.
If the coolant is air and the corresponding convection coefficient is h = 200 W/m^2.K. What is the maximum allowable chip power? If the coolant is a dielectric liquid for which h = 3000 W/m^2.K. What is the maximum allowable power?

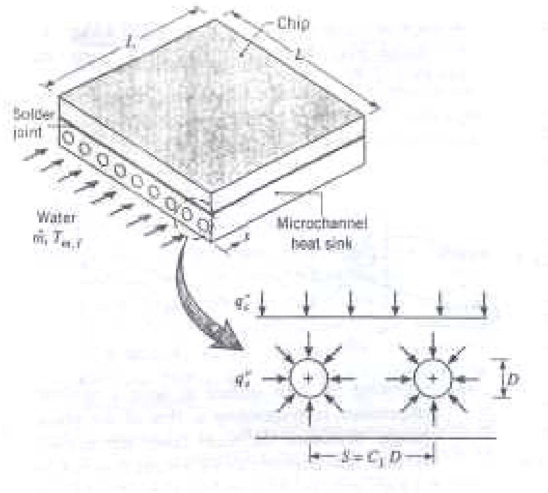


2. A common procedure for cooling a high-performance computer chip involves joining the chip to a heat sink within which circular microchannels are machined. During operation, the chip produces a uniform heal flux q_c'' at its interface with the heat sink, while a liquid coolant (water) is routed through the channels. Consider a square chip and heat sink, each L x L on a side, with microchannels of diameter D and pitch S = C_1D, where the constant C_1 is greater than unity. Water is supplied at an inlet temperature $T_{m,i}$ and a total mass flow rate $m^\bullet$ (for the entire heat sink).

a) Assuming that q_c'' is dispersed in the heat sink such that a uniform heat flux q_c'' is maintained at the surface of each channel; obtain expressions for the longitudinal distributions of the mean fluid, $T_m(x)$, and surface. $T_s(x)$, temperatures in each channel. Assume laminar, fully developed flow throughout each channel, and express your results in terms of $m^\bullet$. q_c''. C_1, D, and/or L, as well as appropriate thermophysical properties.

b) For L = 12 mm, D = 1 mm, C_1 = 2, q_c'' = 20 W/cm^2, $m^\bullet$ = 0.010 kg/s, and $T_{m,i}$ = 290 K, compute and plot the temperature distributions $T_m(x)$ and T_s (x).

c) A common objective in designing such heat sinks is to maximize q_c'' while maintaining the heat sink at an acceptable temperature. Subject to prescribed values of L = 12 mm and $T_{m,i}$ = 290 K and the constraint that $T_{s,max} \le$ 50°C, explore the effect on q_c'' of variations in heat sink design and operating conditions.



3a. Describe the limitation of operation with heat pipe.

3b. What are the considerations that must be taken in electronics chassis design?

4. A thermoelectric cooling system is to be designed to cool a PCB through cooling a conductive plate mounted on the back surface of the PCB. The thermoelectric cooler is aimed to maintain the external surface of the plate at 40 ^{o}C, when the environment is 48 ^{o}C. Each thermoelectric element will be cylindrical with a length of 0.125 cm and a diameter of 0.1 cm. The thermoelectric properties are:

	p	n
α (V/K)	170 x 10^{-6}	-190 x 10^{-6}
ρ (Ω.cm)	0.001	0.0008
k (W/cm K)	0.02	0.02

Assume the cold junction at 38 ^{o}C and the warm junction at 52 ^{o}C, and the electrical resistance of the leads and junctions = 10 % of the element resistance and design for maximum refrigeration capacity. If 10 W are being dissipated through the plate and steady-state conditions then determine:

1- Number of couples required.
2- Rate of heat rejection to the ambient.
3- The COP.
4- The voltage drop across the d.c. power source.

5. Determine the resonant frequency of a rectangular plug-in epoxy fiberglass PCB simply supported (or hinged) on all four sides, 0.080 in thick, with a total weight of 1.0 pounds, as shown in figure. (Note: All dimensions in inches)
Assuming that:
$E = 2 \times 10^6$ Ib/in^2 (PCB modulus of elasticity)
$\mu = 0.12$ (Poisson's ratio, dimensionless)