

ROY G. PERRY COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY

ASSESSMENT REPORT COVER PAGE

MCEG 3301 Heat Transfer

SPRING 2022 SEMESTER

NAME OF INSTRUCTOR: Dr. Yuhao Xu

Revised: 05/19/2022

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 - 5.1 Assignments assessing students' ability to identify, formulate, and solve complex engineering problems (CEP) by applying principles of engineering, science, and mathematics. (Outcome 1)

Detailed Course Syllabus
(Distributed to Students at the beginning of the Semester)
ABET Outcomes measured using course should be
explicitly listed in the syllabus

Course Description in ABET Format

MCEG 3301 Heat Transfer

1. **Course number and name:** MCEG 3301 Heat Transfer
2. **Credits and contact hours:** 3 credit hours; 3 contact hours
3. **Instructor's or course coordinator's name:** Dr. Yuhao Xu
4. **Textbook: Title:** Fundamentals of Heat and Mass Transfer
 Author: Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, and David P. DeWitt
 Publisher, Year & Edition: John Wiley & Sons, 2011, 7th Edition
- a. Other Supplemental material: Fundamentals of Heat and Mass Transfer, Frank P. Incropera, David P. DeWitt, Theodore L. Bergman, and Adrienne S. Lavine, 6th Edition, John Wiley & Sons, 2006.
5. **Specific course information**
 - a. Brief description of the content of the course (catalog description) MCEG 3301 Heat Transfer: Credit 3 semester hours. Study of the fundamental modes of heat transfer, conduction, convection, and thermal radiation, separately and in combination. Theoretical, numerical, and design methods of analysis of steady, transient, single, and multidimensional problems will be emphasized.
 - b. Prerequisites or Co-requisites MATH 2320 Differential Equations
MCEG 3306 Fluid Mechanics
 - c. *Indicate whether a required, elective, or selected elective (as per definition provided) course in the program Required

6. Specific goals for the course

- a. Specific outcomes of instruction (e.g., The student will be able to explain the significance of current research about a particular topic.)

Students will be able to:

- (1) display and apply an understanding of the various ways or modes (conduction, convection, and radiation) in which heat can be transferred and relate these to other engineering requirements using the First Law of Thermodynamics Analysis.
- (2) evaluate, compare, and assess the significance of heat transfer in multi-mode applications.
- (3) determine the local rate of heat transfer and the relationship it has with thermodynamics properties, fluid flow properties, and other non-dimensional properties (e.g., the Reynolds and Biot numbers).
- (4) address heat transfer design requirements in processes or devices subject to specified or implied constraints.
- (5) apply engineering approximation, methodology, design, and analysis (empirical, analytical, and numerical) of both steady and transient problems in both simple and complex geometries.

- b. Explicitly indicate which of the student outcomes listed in Criterion 3 or any other outcomes are addressed by the course.

The specific goals for the course-specific outcomes listed on the left column will address the following student learning outcomes:

Outcome 1

An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

Outcome 2

An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

7 Brief list of topics to be covered

Introduction to heat transfer	(3 hours)
Introduction to conduction	(3 hours)
One-dimensional steady-state conduction	(3 hours)
Two-dimensional steady-state conduction	(3 hours)
Transient conduction	(3 hours)
Introduction to convection	(4.5 hours)
External convection	(4.5 hours)
Internal convection	(3 hours)
Free convection	(3 hours)
Heat exchangers	(3 hours)
Radiation processes and properties	(3 hours)
Radiation between surfaces	(3 hours)

Additional Course Syllabus Information

Course Title	Heat Transfer
Course Prefix & No	MCEG 3301
Section	P02 (CRN: 20217)
Credit	3 Credit Hour
Instructor Name	Yuhao Xu, Ph.D.
Office Location	C. L. Wilson Engineering Building, Room 105B
Office Phone	936-261-9963
Email Address	yuxu@pvamu.edu
Office Hours	As Posted. Tentatively as follows: Tuesdays: 9:00 AM – 9:30 AM; 11:00 AM – 12:30 PM; 1:00 PM – 3:00 PM; Thursdays: 9:00 AM – 9:30 AM; 11:00 AM – 12:30 PM; Or by appointment
Class Days & Times and Location	TR, 9:30 AM – 10:50 AM New Electrical Engr Bldg 117
Catalog Description	MCEG 3301 Heat Transfer: Credit 3 semester hours. Study of the fundamental modes of heat transfer, conduction, convection, and thermal radiation, separately and in combination. Theoretical, numerical, and design methods of analysis of steady, transient, single, and multidimensional problems will be emphasized.
Pre-requisite(s)	MATH 2320 Differential Equations (Old Course Number: MATH 2043) MCEG 3306 Fluid Mechanics (Old Course Number: MCEG 3063)
Required Textbook	Fundamentals of Heat and Mass Transfer, Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, and David P. DeWitt, 7 th Edition, John Wiley & Sons, 2011. ISBN-13: 978-0470-50197-9. College of Engineering Textbook Policy – Students MUST acquire the required textbook that is listed on the course syllabus for this course. The textbook must be acquired by the 10 th class day. Students are not allowed to share textbooks with students who are currently registered in the same class. Failure to acquire (or show proof of purchase) the required textbook by the 10 th class day will result in the student being administratively dropped from the course. The University will assess financial obligations for the course to the student as with any other dropped class according to the fee schedule as well as your financial aid may be affected. If you are not financially able to purchase a required textbook for an engineering course prior to the 10 th class day, you may apply to the College of Engineering Textbook Fund for a textbook voucher. The voucher can only be used at the Campus Bookstore. This voucher is a loan and must be paid back to the College of Engineering prior to the start of pre-registration for the coming semester. If the loan is not repaid, a hold will be placed on your account. Additional information and application materials can be obtained from the Assistant Dean's Office (SR Collins Rm 349) and obtained online at the College of Engineering website under student resources. <i>Please refer to https://www.pvamu.edu/engineering/textbook-policy/ for the Roy G. Perry College of Engineering Textbook Policy. You will find the Textbook Policies and Procedures, Textbook Application and the Textbook Evaluation Form</i>
Supplemental Text	1. Fundamentals of Heat and Mass Transfer, Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, and David P. DeWitt, 8 th Edition, John Wiley & Sons, 2017. 2. A Heat Transfer Textbook, John H. Lienhard V and John H. Lienhard IV, 4 th Edition, Dover Publications, 2011. 3. Experimental Methods for Engineers, Jack Holman, 8 th Edition, McGraw-Hill Education, 2011.

**Access to Learning
Resources:**

PVAMU Library:
Phone: (936) 261-1500
Web: <http://www.pvamu.edu/library/>

University Bookstore:
Phone: (936) 261-1991;
Web: <https://www.bkstr.com/Home/10001-10734-1?demoKey=d>

**Course Goals or
Overview:**

Heat Transfer is a junior-level course intended to establish a basis for engineering synthesis, analysis, design, and experimentation in the thermal science area.

**Course
Outcomes/Objectives:**

The objectives of this course are to (1) establish a fundamental understanding of the various ways or modes (conduction, convection, and radiation) in which heat can be transferred; (2) establish an analytical basis for determining the local rate of energy transfer and the relationship it has with thermodynamic properties, fluid flow properties, and other non-dimensional parameters (e.g., the Reynolds and Biot numbers); (3) establish a basis for engineering approximation, methodology, design, and analysis (empirical, analytical, and numerical) of both steady and transient problems in both simple and complex geometries; (4) form a basis for advanced study and design involving combined mode heat transfer; (5) establish the basis for advance studies in the thermal science area; (6) establish a basis for other design courses and projects.

**Course Requirements
& Evaluation Methods**

This course will utilize the following instruments to determine student grades and proficiency of the learning outcomes for the course:

Reading:	Requiring students to read sections of the textbook ahead of time and become proficiency in solving heat transfer problems.
Homework:	Requiring students to perform basic analysis of problem, formal homework presented using the required format.
Project:	Requiring students to use class materials to solve an engineering problem and apply engineering design to produce solutions that meet specified needs.
Tests:	There will be a total of <u>THREE</u> tests.
Class Attendance:	Daily attendance and participation in class discussions are required.

Grading Matrix

Instrument	Total (%)
Homework Assignments (Many for Practice only)	5
Project	10
Test 1	27
Test 2	27
Test 3	31
Total	100

Grade Determination

A = 90 – 100
B = 80 – 89
C = 70 – 79
D = 60 – 69
F = 0 – 59

Note: The instructor reserves the right to alter it during the semester.

If a student has stopped attending the course (i.e. “stopped out”) at any point after the first day of class but did not officially withdraw from the course and has missed assignments and exams, including the final exam, and performed below the grade level of a D, a grade of FN (failed-non attendance) will be assigned for the final course grade to ensure

compliance with the federal Title IV financial aid regulations. In contrast, if the student has completed all assignments and exams, including the final exam, but performed below the grade level of a D, a grade of F will be assigned for the final course grade.

Course Policy

Academic Integrity

Academic dishonesty of any sort (plagiarism, cheating, fabrication or facilitation) is prohibited under any circumstance. There is a zero-tolerance policy for academic dishonesty. Cheating of whatsoever will result in an automatic “F” in this course, and the matter will be turned over to the appropriate student disciplinary committee.

Use of eCourses, PVAMU email, and Taskstream

All class-related materials will be posted on eCourses. All emails will be sent to students’ registered PVAMU email addresses. Students are responsible for checking their PVAMU email frequently.

Assignments & Due Dates

Homework problems will be mainly for practice to get students ready for the tests. The instructor will select questions at random from homework assignments to grade for points.

All assignments need to be submitted at the beginning of class on the due date. Late homework and reports will be charged a 25% penalty for each day late – weekend days do count.

Circumstances beyond your control (i.e., illness, severe weather, etc.) will be considered on a case-by-case basis, but they should be reported to the instructor before the class begins.

Attendance

Class attendance is mandatory. Late class for more than **10** minutes will count as **one** absence. If you have **3 or more than 3** absences, you will receive an “F” automatically.

Examinations & Quizzes

All tests are open book (**hard-copy** of the required textbook only). **There will be NO make-up tests** given during the semester except under **documented** emergencies (for instance, medical emergency of him/herself and close relatives, with valid hospital records or doctor’s note).

MCEG 3301 Heat Transfer, Spring 2022

Tentative Topics and Schedule

(Note that the schedule may change based on the needs during the semester)

Week #	Chapters*	Topics Covered
1	1	Introduction to heat transfer
2	2	Introduction to conduction
3	3	One-dimensional steady-state conduction
4	4	Two-dimensional steady-state conduction
5	5	Transient conduction TEST #1
6	5 6	Transient conduction Introduction to convection
7	6 7	Introduction to convection External flow
8	7	External flow
9		SPRING BREAK
10	8	Internal flow TEST #2
11	8 9	Internal flow Free convection
12	9 11	Free convection Heat exchangers
13	12	Radiation processes and properties
14	12 13	Radiation processes and properties Radiation between surfaces Project Report Due
15	13	Radiation between surfaces
16	REVIEW	REVIEW TEST #3 (Date and Time TBD)

*Note: These reading assignments are from chapters of the required textbook. The suggested readings provide an alternative presentation of materials. The text includes much more materials than those covered in class.

How Mechanical Engineering Courses meet Department Objectives & ABET Criterion 3

Specific objectives of the Mechanical Engineering Program are to produce graduates who will:

1. have the necessary knowledge and skills to enable them have successful careers in mechanical engineering and related fields;
2. have leadership skills to advance their careers through increasing levels of responsibilities and leadership;
3. have the necessary educational background to successfully pursue graduate or advanced professional degrees and continuing professional development, and
4. actively participate in professional and community services.

Program Outcomes and Assessment:

Engineering Programs must demonstrate that their graduates have:

ABET Student Learning Outcome 1:

An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

ABET Student Learning Outcome 2:

An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

Program Outcomes

Covered by Course

Program Outcomes “1” and “2” as defined above

Program Outcomes

Measured by Course

Program Outcomes “1” and “2” as defined above

End of Semester Course Assessment Report

This summary contains the following Information

1. Performance Statistics

- Total number of students in class
- The class average performance (**stated as %**) in each course outcome assessed in this class and the **two previous times course was assessed**.
- The acceptable class average for the class in each outcome area as set by your Department. **You cannot use any number of your choice**
- Percentage of students who scored below the expected average in each outcome.

2. Implementation Summary

- Brief summary of plans implemented during the semester based on last assessment report

3. Perceived Problems

- Instructor's **critical evaluation** of perceived problems that affected students' performance. **Realistic problems should be identified throughout the semester and summarized in this section of the report.**

4. New Plans for Addressing Problems

- Instructor's plans for addressing the perceived problems the next time the class is taught. **These should be specific enough for another instructor to implement. Most of these should be things that, you, the instructor can implement to help students to improve. Be creative.**

5. Overall Trend over last three assessment periods

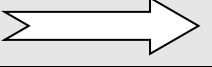
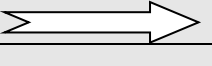
- Instructors summary of overall performance trend for each outcome measured over the last three periods.

6. Were Expectations Met?

- Answer **YES** if the **class average was above the expected average** and the **stated percentage of students** scored at or above the expected average, else answer **NO**.

END OF SEMESTER COURSE OUTCOME ASSESSMENT REPORT
MCEG 3301-P02 Heat Transfer
SPRING 2022 SEMESTER

Report Prepared by: Dr. Yuhao Xu
 Report Date: May 19, 2022

Semester	Analysis Type	Number of Students	Outcome 1 Ability to identify, formulate, and solve complex engineering problems (CEP) by applying principles of engineering, science, and mathematics.				Outcome 2 Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.			
			Expected/Acceptable Class Average/	Expected Percent of students at or above average	Class Average	% Students meeting Acceptable Average	Expected/Acceptable Class Average/	Expected Percent of students at or above average	Class Average	% Students meeting Acceptable Average
Spring 2022, P02	Direct	22	70	70	77.2	72.7				
Fall 2021, P01	Direct	18					70	70	77.7	72.2
Spring 2021, Z02	Direct	11	70	70	76.5	72.7				
Fall 2020, Z01	Direct	27					70	70	75.6	70.4
Fall 2019, P01	Direct	22	70	70	67.4	54.5				
Fall 2018, P01	Direct	30	70	70	56.5	16.7				
Implementation Summary	Items implemented from previous report or after meeting previous instructor 		Students were given enough time to work on the project. The instructor spent extra time teaching students how to correctly use property tables to find relevant properties.				OUTCOME 2 WAS NOT ASSESSED IN SPRING 2022.			
Perceived Problems	Perceived problems are directly related to the PC and the sub items under them 		Some students failed to complete all required tasks outlined in the Project Description. Some students had difficulty in using the correct conditions to find necessary thermophysical properties.				OUTCOME 2 WAS NOT ASSESSED IN SPRING 2022.			
Plans for Addressing Problems	Plans for address specific measures to address PC and their sub areas 		The instructor will spend more time explaining the detailed requirements for the project report. More time will be spent teaching students how to use property tables to identify needed properties for calculations.				OUTCOME 2 WAS NOT ASSESSED IN SPRING 2022.			
Overall Trend over Periods	Ascertain if there were improvements over previous semesters 		The class average was 77.2%, which is above the expected class average. 72.7% of students had an average above the 70% level. The overall expectation was met in Outcome "1".				OUTCOME 2 WAS NOT ASSESSED IN SPRING 2022.			
Were Expectations Met?			YES				OUTCOME 2 WAS NOT ASSESSED IN SPRING 2022.			

**Grade Sheet Showing
Student and Class Performance in Outcomes
The computed semester average in each outcome
as stated in the Assessment report are
highlighted in boldface**

Grade Sheet Showing Student and Class Performance in Course Outcomes
MCEG 3301 Heat Transfer, SPRING 2022 Semester

Student #	Grade
1	59
2	75
3	100
4	96
5	73
6	94
7	70
8	87
9	61
10	100
11	98
12	78
13	82
14	71
15	78
16	94
17	66
18	51
19	48
20	80
21	67
22	71
AVERAGE	77.2
% Students Meeting Acceptable Average	72.7

**OUTCOME SPECIFIC ASSIGNMENTS
USED TO ASSESS OUTCOMES**

ASSIGNMENTS FOR OUTCOME 1

Ability to identify, formulate, and solve complex engineering problems (CEP) by applying principles of engineering, science, and mathematics.

**MECHANICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
MCEG 3301 Heat Transfer
SPRING 2022**

Instructor: Dr. Yuhao Xu

Title of Assignment

Design of the Cooling Mechanism of an Electronic Device

Outcome Measured Using this Assignment

Outcome 1

An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematic.

Check the engineering design characteristics related to this assignment

Assignment problem	
	involves wide-ranging or conflicting technical issues,
x	has no obvious solution
	Addresses problems not encompassed by current standards and codes
	involves diverse groups of stakeholders
x	includes many component parts or sub-problems
	involves multiple disciplines
	has significant consequences in a range of contexts
Assignment problem involves the application of the principles of	
x	engineering
	science
	mathematics

Brief justification of why this assignment is suitable for this outcome

Students need to correctly identify the thermal contact resistance for aluminum plates with air at the interface and thus formulate the problem. Students also need to draw a thermal contact resistance and make appropriate engineering assumptions to proceed. Students are required to perform a literature search to find out the methods used in engineering practices to reduce thermal contact resistance in electronics and thus prevent the electronic devices from overheating.

MCEG 3301 Heat Transfer Course Project
Spring 2022
Design of the Cooling Mechanism of an Electronic Device

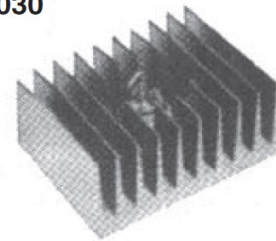
Due: April 28, 2022, at 9:30 am (CDT)

Taskstream submission is required.

PROJECT DESCRIPTION

Consider 100 mm by 40 mm thin rectangular electronic devices that are assembled in mass quantity in a manufacturing plant. The top surface of the electronic device is made of aluminum and is attached with an HS 5030 aluminum heat sink positioned horizontally. An image of the HS 5030 heat sink is shown on the right. The electronic device dissipates 50.8 W of heat through the heat sink. Both aluminum surfaces have a roughness of about $10\text{ }\mu\text{m}$ and an average interface pressure of 10^5 N/m^2 . To prevent the electronic device from overheating, the top surface temperature should be kept below 85°C in an ambient surrounding of 23°C . The combined (natural convection and radiation) thermal resistance of an HS 5030 heat sink, attached horizontally, is 1.2 K/W .

HS 5030



Your task as a product engineer is to ensure that the heat sink attached to the device's top surface is capable of keeping the device from overheating. You need to determine whether or not the top surface temperature of the electronic device, with an HS 5030 heat sink attached to it, is higher than 85°C . If so, what action can be taken to reduce the surface temperature to below 85°C ? Complete the following tasks for this design project.

(a) Using relevant tables in the required textbook for this class (as outlined in the syllabus), find the thermal contact resistance, in $\text{m}^2\cdot\text{K/W}$, for aluminum plates with air at the interface ($10\text{-}\mu\text{m}$ surface roughness, 10^5 N/m^2).

(b) Calculate the top surface temperature of the electronic device, with an HS 5030 heat sink attached to it, and determine whether this surface temperature is higher than 85°C . Clearly list all the assumptions you use for your calculations. Draw a thermal resistance network to support your calculations, and clearly label the heat transfer rate (or the heat flux, as appropriate), all temperatures, and corresponding thermal resistances on the network. Show all steps in your calculations and type equations directly in Microsoft Word.

(c) If the surface temperature computed in (b) exceeds 85°C , what action can be taken to reduce the surface temperature to below 85°C ? Provide relevant calculations to support your conclusion. Note that since your company has a vast quantity of the HS 5030 heat sinks in the inventory, replacing the heat sinks with more effective ones is too costly and is not a viable solution.

(d) Perform a literature search to find out the methods used in engineering practices to reduce thermal contact resistance in electronics and thus prevent the electronic devices from overheating. Discuss your findings. Note that you should have a "References" section at the end of your report to include all books and other materials consulted in the process of the literature search. All reference materials should be directly referenced in the report. The ASME standard for listing references is recommended.

REPORT REQUIREMENTS

A detailed report should be submitted for the project, and the following contents should be included:

1. (2%) A “Cover Page” with the course number and name, section number, semester, and your name. See the next page for a sample cover page.
2. (3%) A “Project Description” page that includes the original problem (as provided on the previous page of this document).
3. (5%) An “Abstract” page summarizes your design, calculations/justifications, and literature review results.
4. (80%) A detailed presentation of all technical components of your design (i.e., Tasks a-d in the “Project Description” section).

SUBMISSION

5. (10%) Upload your report in Microsoft Word format (.doc or .docx), which includes all the contents described in the “Report Requirements” section, to both **Taskstream** and **“Project Submission” portals on eCourses (Canvas)**. Moreover, submit a hard copy of the report (printed single-sided) by 9:30 am (CDT) on April 28, 2022.

Sample of student's solutions:

**MECHANICAL ENGINEERING DEPARTMENT
PRAIRIE VIEW A&M UNIVERSITY**



**MCEG 3301-P02
Heat Transfer
Spring 2022**

COVER PAGE

**REPORT ON
“Design of the Cooling Mechanism of an Electronic Device”**

**Submitted by
Caleb Combs**

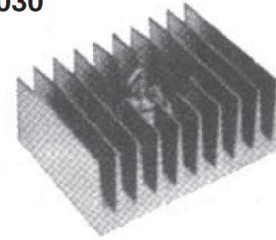
**On
April 27, 2022**

**To
Professor Yuhao Xu**

PROJECT DESCRIPTION

Consider 100 mm by 40 mm thin rectangular electronic devices that are assembled in mass quantity in a manufacturing plant. The top surface of the electronic device is made of aluminum and is attached with an HS 5030 aluminum heat sink positioned horizontally. An image of the HS 5030 heat sink is shown on the right. The electronic device dissipates 50.8 W of heat through the heat sink. Both aluminum surfaces have a roughness of about $10\text{ }\mu\text{m}$ and an average interface pressure of 10^5 N/m^2 . To prevent the electronic device from overheating, the top surface temperature should be kept below 85°C in an ambient surrounding of 23°C . The combined (natural convection and radiation) thermal resistance of an HS 5030 heat sink, attached horizontally, is 1.2 K/W .

HS 5030



Your task as a product engineer is to ensure that the heat sink attached to the device's top surface is capable of keeping the device from overheating. You need to determine whether or not the top surface temperature of the electronic device, with an HS 5030 heat sink attached to it, is higher than 85°C . If so, what action can be taken to reduce the surface temperature to below 85°C ? Complete the following tasks for this design project.

(a) Using relevant tables in the required textbook for this class (as outlined in the syllabus), find the thermal contact resistance, in $\text{m}^2\cdot\text{K/W}$, for aluminum plates with air at the interface ($10\text{-}\mu\text{m}$ surface roughness, 10^5 N/m^2).

(b) Calculate the top surface temperature of the electronic device, with an HS 5030 heat sink attached to it, and determine whether this surface temperature is higher than 85°C . Clearly list all the assumptions you use for your calculations. Draw a thermal resistance network to support your calculations, and clearly label the heat transfer rate (or the heat flux, as appropriate), all temperatures, and corresponding thermal resistances on the network. Show all steps in your calculations and type equations directly in Microsoft Word.

(c) If the surface temperature computed in (b) exceeds 85°C , what action can be taken to reduce the surface temperature to below 85°C ? Provide relevant calculations to support your conclusion. Note that since your company has a vast quantity of the HS 5030 heat sinks in the inventory, replacing the heat sinks with more effective ones is too costly and is not a viable solution.

(d) Perform a literature search to find out the methods used in engineering practices to reduce thermal contact resistance in electronics and thus prevent the electronic devices from overheating. Discuss your findings. Note that you should have a "References" section at the end of your report to include all books and other materials consulted in the process of the literature search. All reference materials should be directly referenced in the report. The ASME standard for listing references is recommended.

ABSTRACT

For this project, it was determined that under the conditions provided in the problem description, the electronic will experience overheating. This was determined by first calculating the surface temperature of the electronic. The surface temperature value was found to be equal to 87.45°C ;

since this calculated surface temperature is greater than 85°C , it was concluded that overheating occurs under the given conditions. However, it was found that the electronic can be kept from overheating, without replacing the HS 5030 heat sink with a more effective one. It was determined that sufficiently reducing the thermal contact resistance will prevent the electronic from overheating. This was proved by using an electronic surface temperature value of 85°C to calculate the resulting thermal contact resistance. The calculated value of thermal contact resistance was less than the thermal contact resistance provided in the problem statement. Therefore, it was concluded that if the thermal contact resistance was reduced even further, the temperature would drop below 85°C and, in turn, prevent the electronic from overheating. An example calculation was also provided to test this conclusion, proving that further reducing the thermal contact resistance value will result in a surface temperature that is less than 85°C . It was determined that hydrogen, silicone oil, and glycerine are materials that can be used as the interfacial fluid to sufficiently reduce the thermal contact resistance and, in turn, prevent overheating. Finally, there is discussion on the reduction of thermal contact resistance by using thermal interface materials, increasing contact pressure, and polishing the electronic surface.

DETAILED DESCRIPTION OF ALL TECHNICAL COMPONENTS OF MY DESIGN

Assumptions:

- Steady operating conditions
- Electronic device is maintained at a constant surface temperature

- Heat transfer is one dimensional

Task (a):

The thermal contact resistance, in $\text{m}^2 \cdot \text{K}/\text{W}$, for aluminum plates with air at the interface (10- μm surface roughness, $10^5 \text{ N}/\text{m}^2$) is found in Table 3.1 of the course required textbook.

$$R''_{t,c} = 2.75 \times 10^{-4} \left(\frac{\text{m}^2 \times \text{K}}{\text{W}} \right)$$

Task (b):

To calculate the top surface temperature of the electronic device, the following method is used.

$R_{t,c}$ is the thermal contact resistance of the interface layer, in K/W . $R''_{t,c}$ is the thermal contact resistance of the interface layer, in $\text{m}^2 \cdot \text{K}/\text{W}$. A is the area of the rectangular plate, in m^2 . $R_{h,s}$ is the combined thermal resistance of a HS 5030 heat sink, which is equal to $1.2 \text{ K}/\text{W}$. R_{tot} is the total thermal resistance of the system, in K/W .

$A = \text{length of aluminum plate} \times \text{width of aluminum plate}$

$$A = (0.1\text{m}) \times (0.02\text{m})$$

$$A = 4 \times 10^{-3} \text{ m}^2$$

$$R_{t,c} + R_{h,s} = R_{tot}$$

$$\frac{R''_{t,c}}{A} + R_{h,s} = R_{tot}$$

$$\frac{2.75 \times 10^{-4} \left(\frac{\text{m}^2 \times \text{K}}{\text{W}} \right)}{4 \times 10^{-3} (\text{m}^2)} + 1.2 \left(\frac{\text{K}}{\text{W}} \right) = R_{tot}$$

$$R_{tot} = 1.26875 \left(\frac{\text{K}}{\text{W}} \right)$$

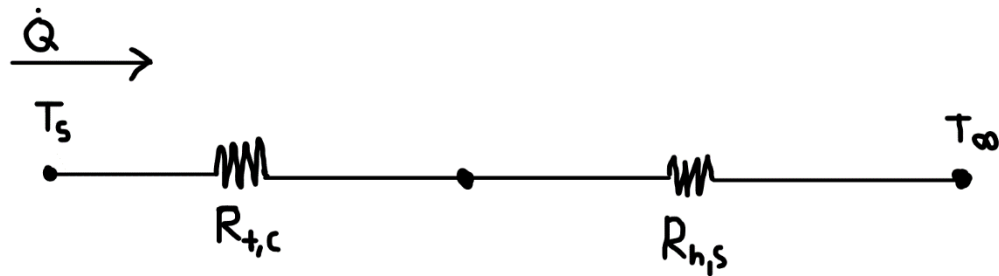
The rate of heat transfer through the layers is $\dot{Q}$ which is equal to 50.8W . T_s is the surface temperature of the electronic device. T_∞ is the ambient surrounding temperature, which is equal to 23°C or 296.15K .

$$\dot{Q} = \frac{T_s - T_\infty}{R_{tot}}$$

$$T_s = (\dot{Q} \times R_{tot}) + T_\infty = \left(50.8(W) \times 1.26875 \left(\frac{K}{W} \right) \right) + 296.15(K) = 360.6(K) \\ = 87.45^\circ C$$

Hence, the temperature at the surface of the electronic device is at $87.45^\circ C$, which is higher than $85^\circ C$. Therefore, the electronic device will experience overheating.

The thermal resistance network to support the calculations previously performed is shown below.



Task (c):

The surface temperature can be reduced to be below $85^\circ C$, without replacing the heat sinks with more effective ones, by reducing the thermal contact resistance. The calculations proving this solution are provided below. For the calculations below, a surface temperature value of $358.15K$ ($85^\circ C$) is used to solve for $R''_{t,c}$.

$$\frac{R''_{t,c}}{A} + R_{h,s} = R_{tot}$$

$$R''_{t,c} = A(R_{tot} - R_{h,s})$$

$$R''_{t,c} = A \left(\frac{T_s - T_\infty}{\dot{Q}} - R_{h,s} \right)$$

$$R''_{t,c} = 4 \times 10^{-3} (m^2) \left(\frac{358.15(K) - 296.15(K)}{50.8(W)} - 1.2 \left(\frac{K}{W} \right) \right)$$

$$R''_{t,c} = 0.8189 \times 10^{-4} \left(\frac{m^2 \times K}{W} \right)$$

As is evident in the calculations above, in order to drop the surface temperature value to $85^\circ C$, the thermal contact resistance needed to be reduced to a value of $0.8189 \times 10^{-4} \left(\frac{m^2 \times K}{W} \right)$.

Therefore, in order for the surface temperature to be below $85^\circ C$, the thermal contact resistance must be below $0.8189 \times 10^{-4} \left(\frac{m^2 \times K}{W} \right)$. An example calculation proving this is provided below.

$$\frac{R''_{t,c}}{A} + R_{h,s} = R_{tot}$$

$$\frac{0.5 \times 10^{-4} \left(\frac{m^2 \times K}{W} \right)}{4 \times 10^{-3} (m^2)} + 1.2 \left(\frac{K}{W} \right) = R_{tot}$$

$$R_{tot} = 1.2125 \left(\frac{K}{W} \right)$$

$$\dot{Q} = \frac{T_s - T_\infty}{R_{tot}}$$

$$T_s = (\dot{Q} \times R_{tot}) + T_\infty = \left(50.8(W) \times 1.2125 \left(\frac{K}{W} \right) \right) + 296.15(K) = 357.745(K)$$

$$= 84.595^\circ C < 85^\circ C$$

By referring to Table 3.1 of the course required textbook, it is determined that hydrogen, silicone oil, or glycerine can be used as the interfacial fluid in order to prevent the electronic from overheating; this is because using these materials as the interfacial fluid results in thermal contact resistances that are all less than $0.8189 \times 10^{-4} \left(\frac{m^2 \times K}{W} \right)$.

Task (d):

There are many engineering practices that can be utilized to reduce the thermal contact resistance in electronics to prevent them from overheating. Thermal interface materials, otherwise known as TIMs, are typically utilized to decrease thermal contact resistance. Some examples of TIMs are pressurized gases (e.g. helium, hydrogen), thermal greases (e.g. silicone oil, glycerin), thermal adhesives, thermal conductive pads, and certain polymer matrixes [1]. The most important properties of a TIM are high thermal conductivity and high compliance; since only a small number of homogeneous materials possess both these properties, TIMs are normally composite materials with metallic or ceramic fillers in a polymeric matrix [2]. These thermal interface materials are commonly inserted between the surfaces in contact with each other in order to reduce the thermal contact resistance. The thermal contact resistance can also be reduced

by increasing the pressure with which the electronic device is pushed against the heat sink; this is because increasing the contact pressure causes microscopic irregularities to deform, in turn, increasing the contact area between the electronic and the heat sink [3]. Also, highly polishing the contacting surface will help reduce air gaps, thereby, decreasing the thermal contact resistance [4]. The reduction of these air gaps, by polishing the contacting surface, decreases thermal contact resistance because the air gaps have a low thermal conductivity. The low thermal conductivity of the air gaps means the air gaps are causing extra resistance to the flow of heat. Therefore, removing some of these air gaps by polishing the contact surface gets rid of hinderances to heat flow at the area of contact between the electronic and heat sink, which can be interpreted as reducing the thermal contact resistance.

References

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