Analysis of the Absorber Plate in a Solar Water Heater – Conduction and Convection

Analyze the following problem and document conclusions and recommendations based on the results of your analysis following the guidelines given in the Department of Mechanical Engineering's Writing Materials (see http://me.byu.edu/students/resources). Follow the IMRaD format, and focus on the underlined sections in the following table. In particular, review the sample technical report, http://me.byu.edu/sites/default/files/Example%20Report%20Baja%20Acceleration_5.0.pdf. I expect your report to be professionally prepared and to resemble this sample report. Your grade will be based on the extent to which you demonstrate mastery of relevant course outcomes and the extent to which you demonstrate progress toward becoming an influential engineer. The grading rubric and the course outcomes are included for your reference.

Guidance on Elements of an IMRaD Paper

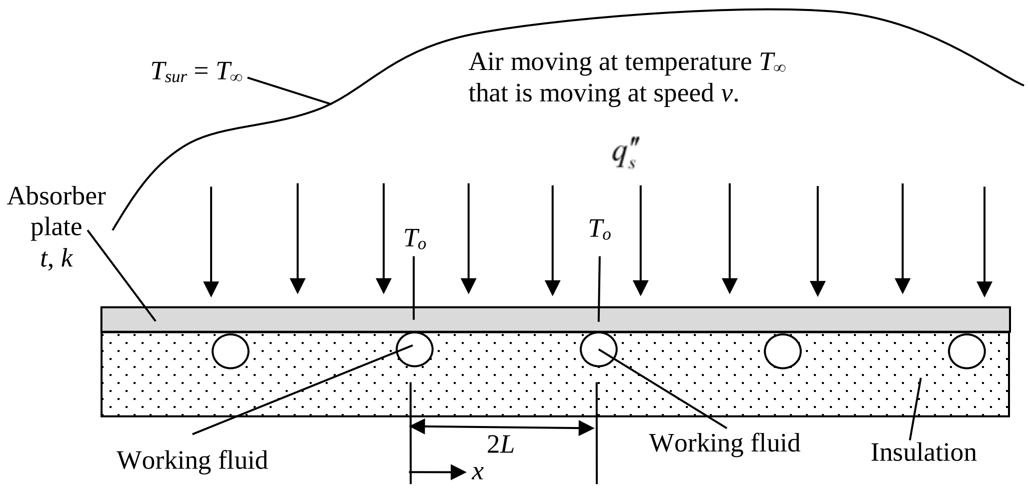
Introduction	Methods	Results	Discussion
How to write an introduction. How to write a literature review. How to write an objective statement.	How to write a technical theory section. How to write a methods section.	How to write a results and discussion of results section. How to make a table. How to make a figure.	How to write a results and discussion of results section. How to write a summary and conclusions section.

The introduction should be brief, and explain why the problem is significant. A literature review is not required, but sources such as the textbook should be used and cited. Cite sources using the format specified for ASME Journals (see attached).

As in all work submitted, your focus should be on demonstrating mastery of course outcomes and progress toward becoming an influential engineer. Recall influential engineers write persuasive arguments supporting the results of their analyses. Please ensure that your report clearly and thoroughly addresses each of the following questions†: 1. What **claims** – conclusions and recommendations – can be drawn based on my modeling and analysis? 2. Are my claims supported by **sound, logical reasoning** based on **basic concepts** and **fundamental laws**? 3. Did I clearly introduce all relevant **evidence** in support of my reasoning? 4. Do I acknowledge limitations on my claims due to **approximations**, **assumptions** and **simplifications** made in modeling and analysis? 5. Are these approximations, assumptions and simplifications **justified** to the extent possible?

†Booth, W.C., Colomb, G.G. and Williams, J.M., 2008, "Making Good Arguments: An Overview", Chapter 7, The Craft of Research, 3rd Ed., The University of Chicago Press, Chicago, IL. USA.

The design of the absorber plate of a solar water heater is illustrated in the figure below. The thickness of the absorber plate, t, is small, so temperature gradients across the plate may be neglected. The thermal conductivity of the plate is a known constant, k. The absorber plate is exposed to a uniform solar flux, and the fraction of the radiative flux that is absorbed is equal to β. Copper tubing is welded to the absorber plate, and the water circulating through the tubing maintains the temperature of the absorber plate immediately above the tubes at a temperature of T_o. The bottom of the absorber plate is well insulated while the top is exposed to air flowing at 3 m/s.



L = 10 cm $\quad$ t = 1 mm $\quad$ k = 177 W/m-K $\quad$ q_s'' = 800 W/m^2

ε = 0.2 $\quad$ T_o = 320 K $\quad$ T_∞ = 300 K $\quad$ β = 0.95 $\quad$ v = 3 m/s

a. Assuming that the temperature profile in the absorber plate is one-dimensional in the x-direction and that the radiative exchange with the surrounding may be linearized using a radiation heat transfer coefficient, what is the steady-state temperature profile, $T(x)$, for the conditions specified? Justify the assumption that the temperature gradient in the y-direction is negligible.

b. The efficiency of the solar water heater may be defined as the ratio of the rate energy is transferred to the water to the rate solar energy is incident on the absorber plate. Using this definition, calculate the efficiency of the solar water heater. How much will the efficiency of the solar panel increase if losses due to convection are eliminated using a cover plate?

Grading Rubric			
	Excellent	*Good*	*Poor*
Argument	6 points • Organized format • Solution flows logically from step to step • Understanding of the problem and the significance of the results is demonstrated • The claim is clearly stated and is supported using evidence and reason	3-5 points • Organized format • The solution flows logically from step to step • The claim is clearly stated	2 points or less • Solution is difficult to read • Unstructured format • The solution lacks a logical flow
Modeling	6 points • The system and its interactions with the surroundings are clearly identified • Models of the system and the relevant interactions are developed using fundamental laws and basic concepts • Approximations are clearly stated • The models may be used to address the questions asked	3-5 points • The system and its interactions with the surroundings are clearly identified • Approximations are clearly stated • The models may be used to address the questions asked	2 points or less • The system and its interactions with the surroundings are not clearly identified • Approximations are not justifiable or unstated. • Relevant interactions are not considered or irrelevant interactions are included in the model
Analysis	6 points • Each step in the analysis follows logically from the previous step • Any simplifications are clearly stated and justified • No mathematical or logical errors • Solution is reasonable	3-5 points • Each step in the analysis follows logically from the previous step • Any simplifications are clearly stated • No mathematical errors	2 points or less • Analysis contains mathematical or logical errors • Solution is not reasonable
Outcomes	7 points • Progress in achieving all the relevant course outcomes is demonstrated	3-6 points • Progress in achieving some of the relevant course outcomes is demonstrated.	2 points or less • Limited progress in achieving the relevant course outcomes is demonstrated

Me En 340 Course Outcomes

1. *Conservation Principles* – Each student can build models of heat transfer processes and systems by applying conservation of mass and energy to a system.

2. *Fundamentals of Conduction* - Each student can describe the physical mechanisms involved in conduction heat transfer. Each student can use Fourier's law in conjunction with conservation of energy to develop the heat diffusion equation.

3. *Conduction Analysis* - Each student can utilize solution methods for the heat diffusion equation to analyze 1D, 2D, steady and transient problems, including the use of thermal circuits and analytical and numerical methods.

4. *Extended Surfaces* - Each student can analyze extended surfaces using the fundamentals of conduction and convection. Each student can use fin efficiency and fin effectiveness to evaluate the performance of a fin or fin array.

5. *Fundamentals of Convection* - Each student can describe the physical phenomena associated with convection and use non-dimensional parameters to analyze convection heat transfer. Each student can calculate local and global convective heat fluxes using Newton's law of cooling.

6. *Convection Analysis* - Each student can use empirical correlations to analyze external and internal, forced and free convection problems.

7. *Fundamentals of Radiation* - Each student can describe the physical mechanisms involved in radiation heat transfer. Each student can model radiative heat transfer processes and include radiative processes when analyzing heat transfer at a surface.

8. *Radiative Heat Exchange* - Each student can calculate total, hemispherical radiative properties of surfaces from their spectral, directional counterparts and evaluate the radiative heat exchange between diffuse, gray surfaces in enclosures.

9. *Problem Solving* – Each student can identify heat transfer phenomena in real-world applications, use a systematic method (e.g. 5 Ps of Problem Definition) to formulate a useful engineering problem statement, use basic concepts and fundamental laws to build a model that addresses the engineering problem, solve the engineering problem using a systematic method (e.g. SAFER), and document their analysis to convey conclusions and recommendations.

References

ASME Journals Digital Submission Tool Guidelines and Information

References

Within the text, references should be cited in numerical order according to their order of appearance. The numbered reference citation within text should be enclosed in brackets.

Example: It was shown by Prusa [1] that the width of the plume decreases under these conditions.

In the case of two citations, the numbers should be separated by a comma [1,2]. In the case of more than two references, the numbers should be separated by a dash [5-7].

Note: ASME primarily uses the Chicago Manual of Style for reference format. Authors are encouraged to seek out precise instructions via: http://www.chicagomanualofstyle.org/. ASME does not allow references to Wikipedia.

Sample References

References should be listed together at the end of the paper; footnotes should not be used for this purpose.

References should be arranged in numerical order according to the sequence of citations within the text. Each reference should include the last name of each author followed by initials.

Website Content

- [2] Wayne, John "John Cowboy Videos 2009," YouTube video, 7:00, November 13, 2009, http://www.you tube.com/ watch?v= aBcDeFgH9yz.
- [3] "Apple Privacy Policy," last modified February 4, 2009, accessed July 19, 2010, http://www.apple.com/intl/en/privacypolicy.html.
- [17] "WD2000: Visual Basic Macro to Assign Clipboard Text to a String Variable," revision 1.3, Microsoft Help and Support, last modified November 23, 2006, http://support.microsoft.com/kb/212730.
- **Note:** If a site ceases to exist before publication, or if the information is modified or deleted, this must be included: [8] As of February 22, 2013, Sullivan was claiming on her website that … (a claim that had disappeared from her page by March 4, 2013).

Journal Articles and Papers in Serial Publications

- [3] Adams, Z., 2014, "Bending of an Infinite Beam on an Elastic Substrate," ASME J Appl. Mech., 3, pp. 221-228.
- [9] Zhang, T. W., Khun, C., Liu, Q., and Miller, A. P., 2011, "Self-Healing Techniques," Nature, 332(6662), pp. 888-892.

Textbooks and Monographs

- [10] Gibson, T.A., and Tucker, M. T., 2008, The Big Book of Cellular Studies, John Wiley and Sons, NY.

Chapter Within a Book

- [32] Stevens, T. T., 1999, “Stochastic Fields and Their Digital Simulation,” Stochastic Methods. T. A. Sulle, and M. Siiu, eds., Martinius Publishers, Dordrecht, Germany, pp. 22-36.

Individual Conference Papers/Papers in Compiled Proceedings/Collection of Works by Numerous Authors

- [21] Wions, T. T., and Mills, C. D., 2006, “Structural Dynamics in Parallel Manipulation,” Proceedings of the IDETC/CIE, New Orleans, LA, September 10-13, 2005, ASME Paper No. DETC2005-99532, pp. 777-798.

Theses and Technical Reports

- [1] Oligaria, T. T., Fredy, C. W., Popullo, A. Z., and Tucker, M. A., 20111, “Characterization of PKM Dynamics,” SAE Technical Paper No. 2011-02-8345, 07ATC-96.
- [25] Mollen, T., P., 2014, “Use of General Nonlinear Material in Articulated Systems,” Ph.D. dissertation, University of Boston, Boston, MA.
- [27] Clinton, D., 2013, “Review of Rocket Technology,” NASA Report No. NASA RE-8842.

Books Consulted Online

- [23] Smith, John, 2014, A Dog’s Life in Berlin. Oxford University Press, New York. Doi: 10.1055/acprof.oso/97890.0394.000.