Heat and mass transfer mills solutions manuals online free pdf

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have an expression for the thermal resistance of a pin fin for use in thermal circuits. Cowan, E. When programs such as CONV, PHASE, and BOIL are used, properties evaluation and intermediate calculation steps can also be checked when the final results do not agree. = ---- , 1+ 1 v/8/9(/5L)2 + s - * , V l 2 + ' 2' V = (il/5)t2L 5 = (roi3/16f){i4B-(L/4f)ln[(4/B/L)+A]} M = 1+ (8 r/L 2), B = \ j \ + (4'2/ i 2) a,bNote that the formulas for rjy were derived assuming dS' = dx (straight fins) and dS —& d x (spines). A large number of correlation formulas fol low; instructors can discuss selected geometrical configurations as class time allows, and students can use the associated computer program CONV to reliably calculate heat transfer coefficients and skin friction coefficients or pressure drop for a wide range of configurations. To Kaori For your loving support. » All rights reserved. Steady One-Dimensional Heat Conduction 3. ~ Nearly equal ~ Of the same order of magnitude | All quantities in the term to the left of the bar are evaluated at x xiii xiv NOTES TO THE INSTRUCTOR AND STUDENT EXAMPLES Use of standard format for presenting the solutions of engineering problems is a good practice. An even simpler result 79 2.4 FINS can be obtained if the temperature distribution along the fin is assumed identical to that for an infinitely long fin, for which the appropriate boundary condition is lim T = Te (2.33c) .v—>°o Figure 2.10 illustrates these boundary conditions. Since we wish to examine the performance of the fin itself, it is appropriate to take its base temperature as known; that is, (2.32) 7 l* = o = Tb At the other end, the fin loses heat by Newton's law of cooling: dT Ack— = Achc{T\x=L Te) (2.33a) x —L where the convective heat transfer coefficient here is, in general, different from the one for the sides of the fin because the geometry is different. Parametric studies, which are the essence of engineer ing design, are relatively easily performed. As a result, Basic Heat and Mass Transfer contains the following chapters and appendixes: 1. Chapter 8 expands the presentation of the thermal analysis of heat exchangers beyond the customary and includes the calculation of exchanger pressure drop, thermal-hydraulic design, heat transfer surface selection for compact heat exchang ers, and economic analysis leading to the calculation of the benefit-cost differential associated with heat recovery operations. 2.16. 83 2.4 FINS Computer Program FIN1 The program FIN1 calculates the temperature distribution, fin efficiency, and base heat flow of straight rectangular fins. Tari, B. The student must be able to define an appropriate system, recognize whether the system is open or closed, and decide whether a steady state can be assumed. In practical engineering problems, these modes of heat transfer usually occur simultaneously. If we guess a mean temperature of 1500 K for the uranium oxide, Table A.2 gives &uo2 —2.6 W/m K, and T- 1Q'"rf ___ (8.73 x 108)(0.00413)2 „ „ „ „ = T"+ 4 J ^ = 923+ -------- (4) f e -------L = 2 3 5 5 K To check if our guessed mean temperatures are appropriate, we first determine the mean temperature of the tube. Required: Power dissipated by 8 fins. Thus, the units of thermal conductivity could also be written [W/m°C], but this is not the recommended practice when using the SI system of units. It is always assumed that the problem statement precedes the solution (as in the text) or that it is readily available (as in the Solutions Manual). Myhre, B. We are preparing a Windows version of the BHMT software and will announce its availability on the website. Chapter 1 is a brief but self-contained introduction to heat transfer. Edwards (Radiation Heat Transfer Notes, Hemisphere, 1981). The first law is used to derive the governing differential equation, which, when solved subject to appropriate boundary conditions, gives the temperature distribution along the fin. Required: Efficiency and heat dissipated. The com puter programs HEX2 and CTOWER assist the student to explore the consequences of changing the many parameters involved in the design process. In linking thermodynamics to heat transfer, some ambiguity in notation arises when common practice in both subjects is followed. The second term in Eq. (1.6b) is often negligible as will be assumed throughout this text. The exercises have been ordered to correspond with the order in which the mate rial is presented in the text, rather than in some increasing degree of difficulty. Use of FIN1 is illustrated in the example that follows. Figure 1.4 shows an elemental volume AV located between x and x-\-Ax', AV is a closed system, and the energy conservation principle in the form of Eq. (1.2) applies. R Dooher, M. The insulation of buildings in extreme climates is a familiar ex ample, but there are many others. Solution Given: Straight fin with a parabolic profile. Thus, preoccupation with a third or fourth significant figure is misplaced (unless required to prevent error magnification in operations such as subtraction). Next, we transform the problem statement into the new variables. Section 1.3 introduces the three important modes of heat transfer: heat conduction, thermal radiation, and heat convection. The tubes have a 1.75 cm pitch in a square array. In Section 1.6, the subject of mass transfer is briefly introduced and its relation to heat transfer explained. Then heat transfer by molecules is governed by laws analogous to those for radiation. If an appropriate selection of this material is taught, I am confident that Accreditation Board for Engi neering and Technology guidelines for design content will be met. vii viii PREFACE TO THE SECOND EDITION which the software is used by students because of the unique exact correspondence between the software and the text material. Also, the traditional role formerly played by textbooks as professional manuals for engineering practice has been significantly affected. Eqs. Professor Coimbra brings to this venture the perspec tive and skills of a younger generation of heat transfer educators and his own special expertise in areas of heat transfer research. Classical thermodynamics deals with systems in equilibrium. Basic Heat and Mass Transfer complements Heat Transfer, which is published concurrently. 2.16 can be treated as fins since the temperature varia tion across the plates is small compared to the temperature variation along the plates between the hot and cold streams. For some purposes, however, it will prove convenient to return to Eq. (1.1) as a statement of the first law. Using Table 2.2, item 4, 1/2 p \kt J 2800 [(187)(0.003) /3Z. I would also like to thank former students S. = 923 + --------- (4)(25)------- = 2412 ~ 2400 K CHAPTER 2 STEADY ONE-DIMENSIONAL HEAT CONDUCTION Comments 1. I gratefully acknowledge the contributions of these gentlemen, both to this book and to my professional career. All Rights Reserved. —► ^ -> Conduction or convection heat flow Radiation heat flow Fluid flow Species flow MATHEMATICAL SYMBOLS Symbols that may need clarification are as follows. Hwang, M. 77 2.4 FINS Figure 2.8 Some heat sinks incorporating fins for cooling of standard packages for integrated circuits. The computer program UNITS can be used xvi NOTES TO THE INSTRUCTOR AND STUDENT for conversions to other systems of units. Solution Given: Aluminum annular fin. Required: Heat dissipation, mass. Notice the use of h = hc + hr to account for radiation. If we have a composite wall of two slabs of material, as shown in Fig. In practice, insulation is used to reduce heat flow and seldom can be regarded as perfect. Traditionally, however, the discipline that has been most concerned with heat transfer is mechanical engineering because of the importance of heat transfer in energy conversion systems, from coal-fired power plants to solar water heaters. Then riiA + -y- + g zj = Q + W (1.3) where m [kg/s] is the mass flow rate, h [J/kg] is the specific enthalpy, V [m/s] is velocity, g [m/s2] is the gravitational acceleration, z is elevation [m], Q [W] is the net rate of heat transfer, as before, and W [W] is the rate at which external (shaft) work is done on the system .2 Notice that the sign convention here is that external work done on the system is positive; the opposite sign convention is also widely used. The software is intended to serve primarily as a tool for the student, both at college and after graduation in engineering practice. (1.1)-(1.4), Q = Qm — Q0ut is the net heat transfer into the whole system. 2.14. In presenting calculations for the examples in Basic Heat and Mass Transfer, we have rounded off results at each stage of the calculation. Kim, Kukmin University; and Professor A. Mills Bill Stenquist Executive Editor william_stenquist @prenhall.com ACKNOWLEDGEMENTS TO THE FIRST AND SECOND EDITIONS Reviewers commissioned for the first edition, published by Richard D. Under Assumptions, the main assumptions required to solve the problem are listed; when appropriate, they are discussed further in the body of the solution. Many heat exchangers are used to transfer heat from one process stream to another, to reduce the total energy consumption by the refinery. The software facilitates self-study by the student. The develop ment of faster computers is now severely constrained by the difficulty of controlling the temperature of very small components, which dissipate large amounts of heat. Assumptions: 1. Gopinath, J. The phenomenological law gov erning heat conduction was proposed by the French mathematical physicist J. © 2015 by A.F. Mills and C.F.M. Coimbra. Bennion provided a chemical engineering perspective to some of the material on mass exchangers. The largest thermal resistance in the circuit is at the fuel-cladding interface. I have also drawn on material in radiation heat transfer from a more recent text by D. For example, heat transfer across a steel pipe wall is by conduction, whereas heat transfer from the Sun to the Earth or to a spacecraft is by thermal radiation. Donald K. The examples that follow relate to Figs. I have found the impact of the software on the educational process to be encouraging. Elizabeth Jones was the sponsoring editor, and Kelley Butcher was the senior developmental editor. Take the conductivity of aluminum as 205 W/m K. For air, at normal temperatures, experi ments show that the heat transfer coefficient for natural convection on a vertical wall can be approximated by the following formulas: Figure 1.11 A natural-convection boundary layer on a vertical wall, showing the variation of local heat transfer coefficient. = (70.65)(0.02) = 1.413 1/2 = 70.65 m-l CHAPTER 2 V STEADY ONE-DIMENSIONAL HEAT CONDUCTION 2 2 [4(/3L)2 + l]1/2 + 1 [4(1.413)2 + l]1/2 + 1 0.500 21 1/2 1.044 = (0.02) (1.044) + = 0.0406 m For a unit width of fin, Q = hcS/(TB- T e)vf = (2800)(0.0406)(500-300)(0.500) = 11,370 W/m From Table A. Because the same amount of heat is flowing into AV across the face at x, and out of AV across the face at x + Ax, Q\x — Q |x+Ax Since the rate of heat transfer is constant for all x, we simplify the notation by drop ping the I* and 1*+^ subscripts (see the footnote on page 9), and write Q = Constant But from Fourier's law, Eq. (1.8), Q = qA — —kA —— dx The variables are separable: rearranging and integrating across the wall, where Q and A have been taken outside the integral signs since both are constants. For unit length of rod, the heat flow across the Zircaloy tube wall is Q — Qv [nD1j 4)(1): Q = (8.73 x 108)(tt/4)(0.825 x 10~2)2(1) Tube = 46,700 W/m Q""*......................... The ordering of the material and the pace at which it is presented have been carefully chosen so that the beginning student can proceed from the most elementary concepts to those that are more difficult. . NOTES TO THE INSTRUCTOR AND STUDENT serve most needs of the student, as well as of the practicing engineer, for doing r You're Reading a Free Preview Pages 38 to 71 are not shown in this preview. Assumptions: Constant heat transfer coefficient over fin surface. The format used for the examples in Basic Heat and Mass Transfer, which is but one possible approach, is as follows. The subscript c denotes "cross section" and not "con vection" as in the heat transfer coefficient hc. The heat flow Q through the wall is in the direction of decreasing temperature: if 3 In thermodynamics, the term insulated is often used to refer to a perfectly insulated (zero-heat-flow or adiabatic) surface. Consistent with this viewpoint, thermodynamics recognizes only two modes of heat transfer: conduction and radiation. We can even go one step further when evaluating a con vective heat transfer coefficient from a new correlation not contained in CONV: if a corresponding item is chosen, the values of relevant dimensionless groups can also be obtained from CONV, further simplifying the calculations. 12c TableA.12d Table A.12e Table A.12/ Table A.13a Table A.13b Table A.14a Table A. The temperature variation along TV Duel Hot gases Thermocouple Figure 2.15 A thermocouple immersed in a fluid system. There are many additional exercises that can be solved using the software but that do not have the logo designation. Radiation properties are initially defined on a total energy basis, and the shape factor is introduced as a simple geometrical concept. These modes of heat transfer occur on a molecular or subatomic scale. Of particular importance to mechanical engineers is simultaneous heat and mass transfer, and this topic is given detailed consideration with a focus on problems involving water evaporation into air. 1.3 MODES OF HEAT TRANSFER 9 Figure 1.4 Steady one-dimensional conduction across a plane wall, showing the application of the energy conservation principle to an elemental volume Ax' thick. You're Reading a Free Preview Pages 308 to 330 are not shown in this preview. The programs are also described at appropriate locations in the text. The focus is on diffusion in a sta tionary medium and low mass-transfer rate convection. It is important to understand the essential difference between the engineering dis cipline of heat transfer and what is commonly called thermodynamics. cm. More complex heat transfer problems are often governed by differential equations that are difficult or impossible to solve analytically. Heat generation within the system has not been included. (c) Forced flow through a tube bank as found in a shell-and-tube heat exchanger, (d) Laminar and turbulent natural convection boundary layers on vertical walls, (e) Laminar natural convection about a heated horizontal plate, (f) Cellular natural convection in a horizontal enclosed fluid layer. Fabbri, F. For example, in CONV both the wall and fluid temperatures can be set equal to the desired temperature to obtain property values required for convection calculations. Usually the engineer requires the total heat transfer from a surface and is not too interested in the actual variation of heat flux along the surface. Chao, and A. If the heat transfer coefficient is 400 W/m2 K for both streams, calculate the overall heat transfer coefficient. The symbol AX means Xout —Xjn, or the change in X. In gases, the location of the transition is determined by a critical value of a dimensionless group called the Grashof num ber. You're Reading a Free Preview Pages 554 to 582 are not shown in this preview. Examples of convective heat transfer include heat transfer from the radiator of an automobile or to the skin of a hypersonic vehicle. from the shell surface can be predominantly by convection rather than by radiation (see Exercise 1-20). The first step is to choose dimensionless forms of the independent variable x and the dependent variable T. Determine the heat dissipation by the fin when its base temperature is 500 K and it is exposed to fluid at 300 K with a heat transfer coefficient of 2800 W/m2 K. Edwards, our teacher. etc. 2.15 and 2.16, and Exercise 2-88 is based on Fig. Condensation, Evaporation, and Boiling 8. w Figure 1.2 Application of the energy conservation principle to a steady-flow open system. The common vapor cycle refrigeration or air-conditioning system has an evaporator where heat is absorbed at low temperature and a condenser where heat is rejected at a higher tem perature. The convection is natural convection: the heated air adjacent to the radiator surface rises due to its buoyancy, and cooler air flows in to take its place. EXAMPLE 2.6 Error in Thermocouple Readings Duplex thermocouple leads have both wires embedded in polyvinyl electrical insulation. We certainly welcome input and suggestions from users to improve our product. Apart from the usual lower-division mathematics and science courses, the preparation required of the student includes introductory courses in fluid mechanics and thermodynamics, and preferably the usual juniorlevel engineering mathematics course. Rodriguez, B. A careful examination of an automobile radiator will show how it is designed to provide a large exterior surface. Two boundary conditions are required; the first comes from symmetry: r = 0: dT_ dr = 0 (2.27a) To obtain a result of some generality, we will take as the second boundary condition a specified temperature on the outer surface of the cylinder: n; T = T{ (2.27b) In a typical engineering problem, T\ might not be specified; however, we shall see that the result will be in a form suitable for problem solving. PROPERTY DATA A considerable quantity of property data has been assembled in Appendix A. Basic Heat and Mass Transfer was developed by omitting some of the more advanced heat transfer material from Heat Transfer and adding a chapter on mass transfer. 96 CHAPTER 2 STEADY ONE-DIMENSIONAL HEAT CONDUCTION EXAMPLE 2.8 Cooling Fin for a Transistor An aluminum annular fin is used to cool a transistor. If each fin were 100% efficient, it would be dissipate h(9>L)(JB - Te) = (8)(2.72 x 10~4)(340 - 300) = 8.70 x 10-2 W 84 CHAPTER 2 STEADY ONE-DIMENSIONAL HEAT CONDUCTION Since the fins are only 88.1% efficient, Q = (0.881)(8.70 x 10"2) = 7.67 x 10'2 W For 8 fins, Qtotal = (8)(7.67 x 10"2) = 0.613 W. Friedman, and C. Thermal conductivity and kAc values are given in the following table. CHAPTER 1 INTRODUCTION AND ELEMENTARY HEAT TRANSFER substance when conditions within the system, such as temperature and velocity, are unchanging over some appropriate time interval. For short fins of high thermal conductivity, 77/ is large, but as the fin length increases, rff decreases. The high efficiency suggests that the thickness of such fins is determined by rigidity rather than by heat transfer considerations. Tsai, B. FINS Heat transfer from a system can be increased by extending the surface area through the addition of fins. and Coimbra, C. Alternatively, electronic versions of portions of the text are used during the course, or course readers containing selected material from the text may be used. Thus, an important distinction between conduction and radiation is that the energy carriers for conduc tion have a short mean free path, whereas for radiation the carriers have a long mean free path. The air temperature is 350 K, 87 2.4 FINS and the wall temperature is 300 K. An oil refinery has a great variety of heat transfer equipment, including rectification columns and thermal crackers. As was the case with heat convection in Chapter 4, mass convection is introduced using dimensional analysis and the Buckingham pi theorem. EXAMPLE 2.5 Fins to Cool a Transistor An array of eight aluminum alloy fins, each 3 mm wide, 0.4 mm thick, and 40 mm long, is used to cool a transistor. Solution Given: Aluminum fins to cool a transistor. Mills Professor o f M echanical and Aerospace Engineering, Emeritus The University o f California at Los Angeles, Los Angeles, CA C. You're Reading a Free Preview Pages 412 to 415 are not shown in this preview. Fundamental constants are rounded off to no more than five significant figures. Figure 1.11 shows a natural convection flow on a heated vertical surface, as well as a schematic of the associated variation of hc along the surface. From the thermal circuit, (0.00328 + 0.00149/2) 7 tube — 4 0 0 + (9 -)^ „ 0 0 6 4 2 + 0 0 0 [49 + 0 0 0 3 2 8) - which is close enough to our guess of 600 K. L2 d § 2 =o c The boundary condition Eq. (2.32) becomes £ - 0: 0 = 1(2.53a) and the boundary condition Eq. (2.33b) becomes cTB - T e) d O _ L dt, or df) = 0 (2.53b) The differential equation is now put in dimensionless form. Students are encouraged to solve the difference equations by writing their own computer programs, or by using standard mathematics software such as Mathcad or MATLAB. (2.38) and (2.40) give the same result, which is to be expected since there is no heat loss from the end of the fin. Equation (1.3) has been written as if h, V, and z are uniform in the streams crossing the control volume boundary. Students are given an overview of the subject and some material needed in subsequent chapters. The rules of the transformation are X = L$ T = (TB - T e)0 + Te dx = Ld% d T = {TB - T e)dO and Eq. (2.31) becomes (7 W ^) 0 _ hcg?{TB _ Tt)e = o or _ /? Thermal control of temperature-sensitive components in a communications satellite orbiting the Earth is a particularly difficult problem. We remain dedicated to further refining the text in future editions, and encourage you to contact us with any suggestions or comments you might have. Solution using FIN1 The required input is: Boundary condition = 2 Half-thickness, length, and width = 0.0002, 0.040, 0.003 Thermal conductivity = 175 Heat transfer coefficient = 8 Base temperature and ambient temperature = 340, 300 *-range for plot = 0.0, 0.04 FIN 1 gives the output: rjf = 0.881 Q = 7.67 x 10'2 (watts) Comments 1. However, because the area of the end, Ac, is small compared to the side area, the heat loss from the end is correspondingly small and usually can be ignored. Nevertheless, it remains common practice to describe these interactions as transfer, transport, or flow, of heat. The wires are (i) copper and constantan (type T), (ii) iron and constantan (type J), and (iii) chromel and alumel (type K). Since environmental considerations have required the phasing out of CFC refrigerants, R -12 and R-l 13 property data, worked examples and exercises, have been replaced with corresponding material for R-22 and R-l34a. Tan, J. At a specific location along the bundle the coolant water is at 400 K and the convective heat transfer coefficient hc is 1.0 x 104 W/m2 K. Assumptions: Steady one-dimensional heat flow. The hot water home heating system shown in Fig. *?/ = S' = L B + (L2/2t)(2t/L + B) 4. These are important concepts used in the analysis of more complex heat transfer problems. Dimensional analysis using the Buckingham pi theorem is used to introduce the required dimensional groups and to allow a discussion of the importance of laboratory experiments. 7'' = - ^ T r >+C2 Substituting back gives the desired temperature distribution, T(r): 1 ti" T - h = - ^ - { r] - r 2) (2.28) The maximum temperature is at the centerline of the cylinder. To make a cup of coffee we may plug in a kettle, inside which heat is transferred from an elec trical resistance element to the water, heating the water until it boils. Thermal control of space stations present even greater problems, since reliable life-support systems are also necessary. A power plant, whether the fuel be fossil or nuclear, has a boiler in which water is evaporated to produce steam to drive the turbines, and a condenser in which the steam is con densed to provide a low back pressure on the turbines and for water recovery. Some ex amples in the text show sample inputs from the DOS version of the software. However, in air at the very low pressures characteristic of high-vacuum equipment, the mean free path of molecules can be much longer than the equipment dimensions, so the molecules travel unimpeded from one surface to another. A supporting feature of Basic Heat and Mass Transfer is the fully integrated software available from the author's website3. Any consistent system of units can be used with FIN1. The programs are designed to reduce the effort required to obtain reliable numerical results and thereby increase the efficiency and effectiveness of the engineer. All heat transfer processes encountered in engineering are irre versible and generate entropy. However, all the heat transfer components (excluding material relevant to Chapter 9 only) are already available in the Windows HT (Heat Transfer) package on the book companion website at www.temporalpublishing.com/bhmt. In particular, the first law of thermodynamics is used, generally in par ticularly simple forms since work effects can often be ignored. Sometimes it is not obvious that the situation resembles that for a cooling fin, yet the assumption of negligible temperature variation in the thin direction of a wire or plate gives a differential equation similar to Eq. (2.30). It is my experience that students can be best in troduced to design methodology through an increased focus on equipment such as heat and mass exchangers: Basic Heat and Mass Transfer presents more extensive coverage of exchanger design than do comparable texts. In heat transfer, it is common practice to refer to the first law as the energy conservation principle or simply as an energy or heat balance when no work is done. There are other criteria for choosing thermocouple pairs, including operating temperature range, emf output, and corrosion resistance. EXAMPLE 2.4 Temperature Distribution in a Nuclear Reactor Fuel Rod Uranium oxide fuel is contained inside 0.825 cm-I.D., 0.970 cm-O.D. Zircaloy-4 tubes. The plates are thin enough for a fin-type analysis to be valid. 1 1 Books can be ordered directly at discounted prices at www.temporalpublishing.com V PREFACE This entailed first converting the previous edition of Basic Heat and Mass Transfer to LaTeX, which we could then modify efficiently. C. Multidimensional and Unsteady Conduction 4. Thermal Radiation 7. Although G = (§ ,^), the definite integral in Eq. (2.55) is not a function of §, so that Vf = Vf (x) (2.56) which corresponds to the analytical solution, Eq. (2.42). Appendix A should serve most needs of the student, as well as of the practicing engineer, for doing routine calculations. The principle of conservation of energy requires that over a time interval A t [s], Change in internal energy _ Net heat transferred within the system ~ into the system AU = QAt + QvAt Heat generated within the system (1.1) Dividing by At and letting At go to zero gives dU i f - . For mathematical convenience, let 0 — T — Te and /32 = hc& / k A c\ then Eq. (2.31) becomes 0 - i 3 20 = O (2.34) For P a constant, Eq. (2.34) has the solution e = Cie^I + C2e~px or 0 = B i sinh fix + B2 cosh fix The second form proves more convenient; thus, we have T — Te = B\ sinh fix + B2 cosh fix (2.35) Using the two boundary conditions, Eqs. For large /3, T approaches the fluid temperature at the tip of the fin.2 Heat Loss The heat dissipated from the fin can be found by integrating the heat loss over the side surface of the fin (there is no heat loss from the fin tip): Q = [L hc0 > (T - T e)dx Jo (2.37) with T obtained from Eq. (2.36). The instructor is free to choose the extent to ? If additional figures are retained for the complete calculations, discrepancies in the last figure will be observed. Martin Crawford, University of Alabama—Birmingham Lea Der Chen, University of Iowa Prakash R. For x, an obvious choice is § = x /L , where L is the length of the fin; § then varies from zero to unity as x varies from zero to L. A company called Temporal Publishing LLC was created to publish quality engineering textbooks at more reasonable prices. We say that all pin fins with the same value of X are similar, even though their sizes, materials, or heat transfer coefficients may be quite different. If a heat transfer research project requires accurate and reliable thermophysical property data, the prudent researcher should carefully check relevant primary data sources. Many thermal design problems require reducing heat transfer rates by providing suitable insulation. Mills Santa Barbara, CA C. The authors and publisher shall not be liable in any event for incidental or consequential damages in connection with, or arising out of, the furnishing, performance, or use of the theory, results and/or programs. Edwards and V. Thus, for cooling, the average temperature difference (Ts — Te) is lower on a finned surface compared with the unfinned surface, and an appropriate thermal resistance for a fin is \ / h cA r\f, where A is the surface area of the fin and 77/ is the efficiency of the fin (0 < r\f < 1). 1! L\ " 20 mm ^ — L i - 4 mm OOOO OOOO O O O O O O O O O O O O O O O O O O O O O O oooooooooooooooooooooooooooooooooo ooooooooooooooooooooooooooooooooo oooooooooooooooooooooooooooooooooo oooooooooooooooooooooooooooooooooo oooooooooooooooooooooooooooooooooo iO O O O O O O O O O O O O O Q Q O O O O O O O O O O Q O O Q 5. Design alternatives can also be explored using CONV. In Chapter 4 the student is taught how to use con vection correlations before encountering the partial differential equations governing momentum and energy conservation in Chapter 5. The author and publisher appreciate the-efforts of all those who provided input that helped develop and improve the text. Since SI units were used here, the base heat flow is in watts, and the mass of the fin is in kilograms. From Table A.lb, the conductivity of Duralumin at a guessed average fin temperature of (1/2) (500 + 300) = 400 K is 187 W/m K. Notice that Table B.3b gives e~x times /o(.*) and I\ (*) to simplify the tabulation. For example, Fig. The power averaged over the volume including the space between the fuel rods is 152.4 W/cm3. Hermance, University of Vermont Harold R. Since the caloric theory of heat has been long discredited, we do not imagine a "heat substance" flowing from the object to the surroundings. The perforated plates in the heat exchanger shown in Fig. For gas radiation, the ubiquitous Hottel charts have been replaced by the more accurate methods developed by Edwards; the accompanying computer program RAD3 makes their use particularly simple. The physics of convection is explained in a brief introduction, and the heat transfer coefficient is defined. A common thermal design problem is the transfer of heat from one fluid to an other. Equation (1.4) is the usual starting point for the heat transfer analysis of steady-state open systems. You're Reading a Free Preview Pages 368 to 381 are not shown in this preview. Substituting gives hc&{TB - T e) [L f i = .."cos'hjSZ uo,r w Jo To simplify the integration, let § = /3(L - *) ; then dx = - d £ //3 and 2 A c in /3 = (hc& / k A cy / 2 is the cross-sectional area of the fin. For all three options, rjf is defined in terms of an isothermal fin heat loss of Q = hc& L(7# — Te). k Material W/m K Copper Aluminum Brass (70% Cu, 30% Zn) Mild steel Stainless steel, 18-8 Mercury Concrete Pyrex glass Water Neoprene rubber Engine oil, SAE 50 White pine, perpendicular to grain Polyvinyl chloride (PVC) Freon 12 Cork Fiberglass (medium density) Polystyrene Air 386 204 111 64 15 8.4 1.4 1.09 0.611 0.19 0.145 0.10 0.092 0.071 0.043 0.038 0.028 0.027 Note: Appendix A contains more comprehensive data. SOFTWARE The Basic Heat and Mass Transfer software has a menu that describes the content of each program. The area for convective heat loss is the surface area o f the fin, & L . Solution Given: Duplex thermocouple leads for types T, J, and K thermocouples. Equation (2.38) can be rewritten as q Q — ______ ~ ________ \/[{hc0>/p) tanh pL] • (2 4 3) {} Thus, the thermal resistance of a pin fin is Rfl" = (hc'P /P) tank p L = hc 3? Answers to all exercises are listed in the Solutions Manual provided to instructors. There are no authorized electronic or international hardcopy versions of this book. Parabolic y = r(l - x / L) 2 nf-(2V2mh{2 M Tjf = r ■. Traditionally, students bought a required textbook, became familiar with it in taking the course, and then retained the book as a tool for subsequent courses and an engineering career. 2.4.3 Other Fin Type Analyses The key feature of the fin analysis presented in Section 2.4.1 was that the thinness of the fin allowed us to ignore the temperature variation across the fin and, hence, to account for the convective loss from the surface directly in the differential equation for T(x). Weatherly, A. Practice hand calculations can be immediately checked using the software. I. Solution Given: Nuclear reactor fuel rod. The extent to which engineering design should be introduced in a heat transfer course is a controversial subject. Inmany types of heat transferequipment, no external work is done, and changes in kinetic and potential energy arenegligible; Eq.(1.3) then reduces to mAh = Q (1.4) The specific enthalpy h is related to the specific internal energy u as h = u + Pv (1*5) where P [N/m2 or Pa] is pressure, and v is specific volume [m3 /kg]. The treatment of condensation and evaporation heat transfer in Chapter 7 has novel features, while the treatment of pool boiling is quite conventional. Includes bibliographical references and index. Heat Exchangers PREFACE TO THE SECOND EDITION ix 9. Also, given our closer association with the print-on-demand process, it will be easy for the authors to im-plement small improvements in subsequent printings of this edition. Fin Efficiency Let us now put Eq. (2.38) in dimensionless form by dividing through by hc0>L(TB - T e): Q hc&»L(TB - Te) 1 tanh PL PL (2.41) The dimensions of the left-hand side of this equation are [W]/[W/m2 K][m][m][K] = 1, as desired. F. Our objective here is to analyze heat flow in a fin to determine the temperature variation along the fin and, hence, to evaluate its efficiency r)f. Owing to the complexity of such processes, boiling and condensation are often regarded as distinct heat transfer processes. Equations (1.21) and (1 .2 2) are only valid at some distance from the pipe entrance and indicate that the heat transfer coefficient is then independent of position along the pipe. Such an approach is especially important for the analysis of convective heat transfer, as is shown in advanced texts. The flow is initially laminar because of the "bell-mouth" entrance but becomes turbulent downstream, (b) Laminar forced flow over a cylinder, Re# ~ 25. For one fin, Ac = (0.003) (0.0004) = 1.2 x 10~6m2 IP = 2(0.003 + 0.0004) = 6.8 x 10-3 m r hi.V = kAc (8.0 W/m2 K) (6.8 x 10"3 m) ~ (175 W/m 1C)(1-2 x 10-6 m2) = 259 m-2 P = 16.1 m-1 % = fiL= (16.1 m" ')(0.040m) = 0.644 Substituting in Eq. (2.42) 1 ________ rif = 0.644 tanh (0.644) 1 *2(0.644) _ ! 0.644 *2(0.644) + 1 = 0.881 The side surface area of one fin is £?L = (6.8 x 10 3)(0.040) = 2.72 x 10 4 m2. The thermocouple junction is at a lower temperature than the air since the conduction heat flow along the thermocouple wires to the colder wall must be balanced by convection from the air. Whenever possible, we have used the most accurate data that we could obtain, but accuracy was not always the primary concern. Hyperbolic y = t(n/r) Jr- I - 2/3 (| Pr2y / r2/ n ^ - I 2/3 (|/3 r 2 x / ^ / n) 1-2/3 (| 0 n) + n) /|/3 (2 p r,) /2/3 ^ p r 2y/ r 2/ r ^ - / _ 2/ 3 (f /3r2v/r 2//*i) / - 1/3 5 - 2 ^ { c - B + (r /2)lnJc + (j j f i ^ } + V = t o r i (r2 - r i) C = \ / (r | / n)2 + 12 Spines (Circular Cross Section) 7. the thermocouple is identical to that for a pin fin, so Eq. (2.36), with appropriate choices for the kAc product, can be used to determine the error expected in the thermocouple reading. Then Eq. (1.2) states that the net heat flow into the system is zero. All the tables are in SI units, with temperature in kelvins. Shamsundar, University of Houston; Professor S. PREFACE For this third edition of Basic Heat and Mass Transfer Anthony Mills is joined by Carlos Coimbra as a co-author. In the steady-flow energy equation, Eq. (1.3), convec tion of internal energy is contained in the term thAh, which is on the left-hand side of the equation, and heat transfer by conduction and radiation is on the right-hand side, as Q. Denny {Transfer Processes 1/e, Holt, Rinehart & Winston, 1973; 2/e Hemisphere-McGraw-Hill, 1979). Being able to do parametric studies with a wide variety of correlations enhances the students' understanding more than can be accomplished by hand calculations. Convection Fundamentals and Correlations 5. In principle, all numbers generated by the software can be calculated manually from formulas, graphs, and data given in the text. A closed system containing a fixed mass of a solid is shown in Fig. Figure 1.2 shows an open system (or control volume), for which a useful form of the first law is the steady-flow energy equation. 2.15 shows a thermocouple installation used to measure the temperature of a hot air stream. W. It is safe to say that no engineering heat transfer calculation will be accurate to within 1 %, and that most experienced engineers will be pleased with results accurate to within 1 0 % or 20%. You're Reading a Free Preview Pages 498 to 508 are not shown in this preview. Thus, for example, if & and A c are both doubled, rjf remains the same. Type T thermocouples are to be avoided when conduction along the wires may cause a significant error. We can deduce these dimensionless groups without actually solving the governing equations, as was done in Section 2.4.1. For this purpose, we use dimensional analysis, for which a number of methods are available. Heat transfer coefficient constant along fin. The new value of Tmax is (8.73 x 108)(0.00413)2 .... Notice that we cannot extend the thermal circuit into the rod because Q is not constant when there is internal heat generation. Solution Given: A perforated-plate heat exchanger. Thus, in Sec tion 1.4, the analysis of heat transfer by combined modes is introduced. For example, they do not have to wait a week or two until homework is returned to find that a calculated convective heat transfer coefficient was incorrect because a property table was misread. Use of the exact expressions for S' and S when calculating Q from r \f gives a result in better agreement with exact numerical solutions for two-dimensional conduction in short fins (for long fins the difference is negligible). Often the design problem is one of thermal control, that is, maintaining the op erating temperature of temperature-sensitive components within a specified range. HEAT TRANSFER AND ITS RELATION TO THERMODYNAMICS When a hot object is placed in cold surroundings, it cools: the object loses internal energy, while the surroundings gain internal energy. Near the pipe entrance, heat transfer coefficients tend to be higher, due to the generation of large-scale vortices by upstream bends or sharp comers and the effect of suddenly heating the fluid. 2.17 can be treated as fins, as can the circuit board between the conductors. Chapters 2 and 3 present a relatively conventional treatment of heat conduction, though the outdated and approximate Heissler and Grober charts are replaced by exact charts and the computer program COND2. Often such an assumption can be made; if not, an integration across each stream is required to give appropriate average values. E. The computer program HEX2 serves to introduce students to computer-aided design of heat exchangers. Exclusive Publishing Rights to Temporal Publishing, LLC - San Diego, CA 92130 The authors and the publisher have used their best efforts in preparing this book. The heat loss from the fin is then obtained and put in dimensionless form as the fin efficiency. The fluids flow through high-conductivity perforated plates separated by insulating spacers. In keeping with the overall philosophy of the book, the objective of Chapter 4 is to develop the students' ability to calculate convective heat transfer coefficients. There are three options for the tip boundary condition: (1) infinitely long fin, (2) insulated, and (3) convective heat loss. 16, the conductivity of Zircaloy-4 is 17.2 W/m K, and Tu = 400 + 46,700(0.00642 + 0.00149 + 0.00328) = 923K Now Eq. (2.29) can be used to obtain Tmax. Coimbra p. In preparing the second edition, I have had useful input from a number of peo ple, including Professor F. Of course, computer programs are not a substitute for a proper understanding. Mills & Carlos F. In Chapter 6 radiation properties are introduced on a total energy basis and the shape factor is introduced as a geo metrical concept to allow engineering problem solving before having to deal with the directional and spectral aspects of radiation. Thus, the solution must be of the form or (2.55) For this simple case, the fin efficiency appears quite naturally as the dimensionless form of the heat dissipation rate. Analysis of heat transfer processes does require using some thermodynamics concepts. From the foregoing examples, it is clear that heat transfer involves a great variety of physical phenomena and engineering systems. Figure 2.11 shows a plot of Eq. (2.36). The dimensionless groups relevant to a given problem are required for use of the similarity principle. Chapter 1 is an overview of the subject and introduces key topics at an elementary level. B. The right-hand side is a function of the dimensionless parameter /3L only; we will set fiL = x as a fin parameter, and then Eq. (2.41) can be written in the compact form = ta n h X X (2t, the ratio gPjAc is simply \ / t , and /3 = (hc/ k t)]/ 2. My special thanks to the secretarial staff at UCLA and the University of Auck land: Phyllis Gilbert, Joy Wallace, and Julie Austin provided enthusiastic and expert typing of the manuscript. The analysis for option 2 was given above; the analyses for options 1 and 3 are given as

Exercises 2-58 and 2-59, respectively. Figure 1.1 5 1.2 HEAT TRANSFER AND ITS RELATION TO THERMODYNAMICS The system contains a fixed mass (p V); thus, we can write dU = pVdu, where u is the specific internal energy [J/kg]. O.................... However, as in thermodynamics, it is essential that the correct form of the first law be used. Particular care has been taken to order the material on these topics from simpler to more difficult concepts. For the pin fin, A c is independent of x; using Fourier's law q — —k d T / d x with k constant gives (2.31) kAc- ^ - h c9 > (T - T e) = 0 which is a second-order ordinary differential equation for T — T[x). Use of the text index is recommended for locating the program descriptions and examples. Coimbra Professor o f M echanical and Aerospace Engineering The University o f California at San Diego, La Jolla, CA Temporal Publishing, LLC - San Diego, CA 92130 Library of Congress Cataloging-in-Publication Data Mills, A. la the density of Duralumin is 2770 kg/m3; thus, Fin mass = App — ~^tLp = Q) (0.003)(0.02)(2770) =0.1108kg/m Solution using FIN2 The required input in SI units is: Item number = 4 Thermal conductivity and density of the fin = 187, 2770 Heat transfer coefficient = 2800 Base temperature and ambient temperature = 500, 300 t = 0.003 L = 0.02 FIN2 gives the following output: Fin efficiency = 0.500 Base heat flow = 11,370 (watts/meter) Mass of fin = 0.1108 (kilograms/meter) Comments Exercise 2-113 shows that this fin profile gives the maximum heat loss for a given weight of any profile. 14b Table A.14c Table A.14d Table A .\4e Table A .14/ Table A.15 Table A.16 Table A.17« Table A.17b Table A.18 Table A.19 Table A.20 Table A.21 Table A.22a Table A.22b Table A.23 Table A.24 Table A.25 Table A.26 xxiii Temperature variation of total hemispherical emittance for selected surfaces 917 Spectral and total absorptances of metals for normal incidence 918 Spectral absorptances at room temperature and an angle of incidence of 25° from the normal 919 Gases: Thermal properties 920 Dielectric liquids: Thermal properties 924 Liquid metals: Thermal properties 927 Volume expansion coefficients for liquids 928 Density and volume expansion coefficient of water 929 Surface tensions in contact with air 930 Thermodynamic properties of saturated steam 931 Thermodynamic properties of saturated ammonia 934 Thermodynamic properties of saturated nitrogen 935 Thermodynamic properties of saturated mercury 936 Thermodynamic properties of saturated refrigerant-22 937 Thermodynamic properties of saturated refrigerant-134a 938 Aqueous ethylene glycol solutions: Thermal properties 939 Aqueous sodium chloride solutions: Thermal properties 940 Dimensions of commercial pipes [mm] (ASA standard) 941 Dimensions of commercial tubes [mm] (ASTM standard) 942 Dimensions of seamless steel tubes for tubular heat exchangers [mm] (DIN 28 180) 943 Dimensions of wrought copper and copper alloy tubes for condensers and heat exchangers [mm] (DIN 1785-83) 943 Dimensions of seamless cold drawn stainless steel tubes [mm] (LN 9398) 944 Dimensions of seamless drawn wrought aluminum alloy tubes [mm] (LN 9223) 944 U.S. standard atmosphere 945 Selected physical constants 946 Diffusion coefficients in air at 1 atm 947 Schmidt number for vapors in dilute mixture in air at normal temperature, 948 Schmidt numbers for solution in water at 300 K 949 Diffusion coefficients in solids 950 Selected atomic weights 951 Henry constants for dilute aqueous solutions at moderate pressures 952 Equilibrium compositions for the NH 3 -water system 953 Equilibrium compositions for the S0 2 -water system 953 Solubility and permeability of gases in solids 954 Solubility of inorganic compounds in water 956 Combustion data 957 Thermodynamic properties of water vapor-air mixtures at 1 atm 958 XXIV CONTENTS B UNITS, CONVERSION FACTORS, AND MATHEMATICS 959 Table B .la Table B .lb Table B .lc TableB.lt/ Table B.2 Table B.3 Table B.3a Table B.3b Table B.4 CHARTS Base and supplementary SI units 960 Derived SI units 960 Recognized non-SI units 961 Multiples of SI units 961 Conversion factors 962 Bessel functions 963 Bessel functions of the first and second kinds Modified Bessel functions of the first and second kinds The complementary error function 968 969 Figure C .la Figure CAb Figure C .lc Figure C.2a Figure C.2b Figure C.2c Figure C.3a C.3b C.3c C.4a Figure CAb Figure C.4c Figure C.4d Bibliography Nomenclature Index 993 964 966 Centerplane temperature response for a convectively cooled slab; Bi = hcL /k , where L is the slab half-width 970 Centerline temperature response for a convectively cooled cylinder; Bi = hcR /k 971 Center temperature response for a convectively cooled sphere; Bi = hcR /k 971 Fractional energy loss for a convectively cooled slab; Bi = hcL /k , where L is the slab half-width 972 Fractional energy loss for a convectively cooled cylinder; Bi = hcR /k 972 Fractional energy loss for a convectively cooled sphere; Bi = hcR /k 973 Shape (view) factor for coaxial parallel disks 973 Shape (view) factor for opposite rectangles 974 Shape (view) factor for adjacent rectangles 974 LMTD correction factor for a heat exchanger with one shell pass and 2, 4, 6 , . Introducing a constant of proportionality k, (1 .8) where k is the thermal conductivity of the substance, and, by inspection of the equa tion, must have units [W/m K]. Take k = 200 W/m K for the aluminum. The mean temperature of the fuel rod is _ 923 + 2355 ^ T u o 2 ----------- 2------- = and at this temperature, &uo2 = 2.5 W/m K. Mrs. If the fluid enters the system at state 1 and leaves at state 2: 1. As a result, the book should prove to be quite versatile. Devices for this purpose are called heat exchangers. This principle can be formulated in many ways by excluding forms of energy that are irrelevant to the problem under consideration, or by simply redefining what is meant by energy. Rather, we understand that internal energy has been transferred by complex interactions on an atomic or sub atomic scale. Also, when properly used, dimensional analysis facilitates the estimation of errors incurred in making simplifying assumptions. But thermodynamics cannot tell us how long we will have to wait for the temperature to drop to 100°C. In Chapter 2 one-dimensional conduction and fins are treated before deriving the general partial differential heat conduction equation in Chapter 3. They fall into two categories: (1) relatively straightforward exercises designed to help students understand fundamental concepts, and (2) exercises that introduce new technology and that have a practical flavor. Parabolic y = f(l —x / L) 1/2 2L, S' = ,B + (t2/2L)]n(2L/t + B) P L I - 1/3 (j ^) B = V + 4 L-jt2, Ap — jtL nt 1 /, (2jSL) s ' = 2Vrr + I ? The engineering discipline of heat transfer is concerned with calculation of the rate at which heat flows within a medium, across an interface, or from one surface to another, as well as with the calculation of associated temperatures. Since many of the example calculations are quite lengthy, we believe our policy will facilitate checking a particular calculation step of concern. Because fins are thin in one direction, it can be assumed that the temperature variation in this direction is negligible; this key assumption allows the conduction along the fin to be treated as if it were one-dimensional, which greatly simplifies the analysis. Strictly speaking, a property should not be evaluated until its need is identified by the analysis. If the small variation of k with temperature is ignored for the present we obtain 11 1.3 MODES OF HEAT TRANSFER e = T a ,) Comparison of Eq. (1.9) with Ohm's law, I = E /R , suggeststhatAT = T\ — Tz can be viewed as a driving potential for flow ofheat, analogous to voltagebeing the driving potential for current. On a cold day we put on more clothing to reduce heat transfer from our warm body to cold surroundings. EXERCISES The diskette logo next to an exercise statement indicates that it can be solved using the Basic Heat and Mass Transfer software, and that the sample solution provided to the instructor has been prepared accordingly. In fact, it could be argued that the second iteration for Tmax was unwarranted due to uncertainty in the value of hj. Next, boundary conditions for Eq. (2.31) must be specified. When the base is at 340 K andthe ambient air is at 300 K, how much power do they dissipate if the combined convection and radiation heat transfer coefficient is estimated to be 8 W/m2 K? On a domestic refrigerator, the condenser is usually in the form of a tube coil with cooling fins to assist transfer of heat to the surroundings. Since there is a large thermophysical property database stored in the software package, the programs can also be conveniently used to evaluate these properties for other purposes. We cannot immediately use Eq. (2.29) to obtain Tmsx because the surface temperature of the fuel rod is unknown. The author would like to thank the following for their contributions to the first edition. It is particularly frustrating to instructors of subsequent design and laboratory courses to find that the students no longer have appropriate textbooks. For example, if a 1 kg ingot of iron is quenched from 1000°C to 100°C in an oil bath, thermodynamics tells us that the loss in internal energy of the ingot is mass (1 kg) x specific heat capacity (~450 J/kg K) x temperature change (900 K), or approximately 405 kJ. However, in routine calculations, such as evaluation of convective heat transfer coefficients, it NOTES TO THE INSTRUCTOR AND STUDENT XV is often convenient to list all the property values taken from an Appendix A table in one place. As a result, our main motivation in publishing a third edition has been a different consideration. The inner and outer radii are 5 mm and 20 mm, respectively, and the thickness is 0.2 mm. Required: Length of immersion for a specified error. Chang, D. T\ > 7 2 , Q is in the positive x direction .4 The phenomenological law governing this heat flow is Fourier's law of heat conduction, which states that in a homogeneous substance, the local heat flux is proportional to the negative of the local temperature gradient: (1.7) where q is the heat flux, or heat flow per unit area perpendicular to the flow direction [W/m2], T is the local temperature [K or °C], and x is the coordinate in the flow direction [m]. Triangular y = r(l —x/L) = pL y/4(pL)2 + 1 + 1 5 = ^ /1 + 4 /2 /L 2, Ap = \ tL Annular Fins 5. Mano, Tufts University Robert J. Chapter 9 is an introduction to mass transfer. It is used widely in the thermody namic analysis of equipment such as turbines and compressors. O*..."-""WV 1 (yV,) _|_ 2nrjhj 2nrjt^ Water -o From the thermal circuit, as shown, Tu = Te + Q Z R = 400 + 46,700 1 | ln(0.485/0.413) | 1 (2tt) (0.00413) (6000) (2*r) (0.00485) (104)_ = 400 + 46,700(0.00642 + 0.0256/&Zr + 0.00328) As a guess, we take the mean temperature of the tube to be 600 K; from Table A. Parabolic 2 y = t (1 —x / L) 1/2 /1 (%y/2PL) (fv/2/3Z .)/o (f \/2 0 Z ,) ' s = (t47t/6L2){(4L2/ t 2 + l) 3/2 —1} V = (n/2)t2L 9. NOTES TO THE INSTRUCTOR AND STUDENT These notes have been prepared to assist the instructor and student and should be read before the text is used. This law will be introduced here by considering the simple problem of one-dimensional heat flow across a plane wall—for example, a layer of insu lation .3 Figure 1.4 shows a plane wall of surface area A and thickness L, with its face at x = 0 maintained at temperature T\ and the face at jc = L maintained at 7 2 . 2.9. The cross-sectional area is Ac = tzR2 where R is the radius of the pin, and the perimeter & — 2 k R. Finally, in Section 1.7, the International System of units (SI) is reviewed, and the units policy that is followed in the text is discussed. Although commonly used, the term radiator is misleading since heat transfer CHAPTER 1 INTRODUCTION AND ELEMENTARY HEAT TRANSFER Figure 1.3 A hot-water home heating system illustrating the modes of heat transfer. Charts In a first course, the focus is always on the key topics of conduction, convection, radiation, and heat exchangers. There is net heat transfer into the system at a rate of Q [J/s or W], and heat may be generated within the solid, for example, by nuclear fission or by an electrical current, at a rate Qv [W]. Transistors and diodes must not overheat, batteries must not freeze, telescope optics must not lose alignment due to thermal expansion, and photographs must be processed at the proper temperature to ensure high resolution. For ideal gases with Pv = RT, Ah = [2 CpdT (1.6a) Ji\ where R [J/kg K] is the gas constant and cp [J/kg K] is the constant-pressure specific heat. More than 300 new exercises have been added for this edition. Also, for an incompressible solid, du = cvdT, where cv is the constant-volume specific heat1 [J/kg K], and T [K] is tempera ture. Also, there is an entropy increase associated with this heat flow. The similarity principle for this problem is simply the statement that r\f is a function of £ only. Since the conversion proved to be a major project in itself, our objective with this third edition is rather modest. For an annular fin, /32 = hc/kt\ (8.2) P = (205)(0.1 x 10-3) = 400m~- j3 = 20m-1 20 mm The fin effectiveness is given by Eq. (2.52): Vf lSri 5 mm (2n /P) K\ (Pn)I\ (Pr2) - 1\ (j3r\)K\ (pr2) (fj - r\) Ko(Pr\)/) (Pr2)+Io(pr\)K] (Pr2) (20) (0.005) = 0.1; jSr2 = (20)(0.020) = 0.4 From Appendix B, Table B.3b, the required values of Bessel functions are: Pr /o h Ko Ki 0.1 0.4 1.0025 0.0501 0.2040 2.4271 9.8538 2.1843 Substituting in Eq. (2.52), (2)(0.005)/(20) (9.8538)(0.2040) - (0.0501)(2.1843) n f ~ (0.0202 —0.0052) (2.4271)(0.2040) + (1.0025)(2.1843) _ ' The heat dissipation is the efficiency times the dissipation for an isothermal fin: Q = nAl*c)(Mx)(r22 -r i) (T B- T e) = (0.944)(8.2)(2)(tz) (0.0202 - 0.0052) (380 —300) = 1.46W 97 2.4 FINS Solution using FIN2 The required input in SI units is: Item number = 5 Thermal conductivity and density of the fin = 205, 2700 Heat transfer coefficient = 8.2 Base temperature and ambient temperature = 380, 300 t = 0.0001 n and r2 = 0.005, 0.020 FIN2 gives the following output: Fin efficiency = 0.944 Base heat flow = 1.459 (watts) Mass of fin = 6.362 x 10~4 (kilograms) Comments 1. You're Reading a Free Preview Pages 596 to 655 are not shown in this preview. The appropriate second boundary condition is then Eq. (2.33a), which transforms into 2.5 CLOSURE 101 The Biot number Bi = hcL /k was discussed in Section 1.5.1. This boundary con dition introduces a second parameter into the problem; the temperature distribution must now be of the form e = e(Thus, the left-hand side of Eq. (2.41) can be viewed as the ratio of the actual heat loss to the maximum possible and is termed the fin efficiency, r]f. 2.17. Required: Maximum rod temperature at location where the cool water is at Te = 400 K. It is now possible to assign more meaningful and interesting problems, because the students need not get bogged down in lengthy calculations. Notice that hc varies as x ~ 1/4 in the laminar region but is independent of x in the turbulent region. Under Comments, the significance of the results can be discussed, the validity of assumptions further evaluated, or the broader implications of the problem noted. For each wire, Ac = (7t/4)(0.25 x 10-3)2 = 4.91 x 10~8 m2, and for the insulation Ac ~ 10 x 10" 8m2. Throughout the text, the emphasis is on engineering calculations, and each topic is developed to a point that will provide students with the tools needed to practice the art of design. The spacer is 4 mm wide and 0.86 mm thick. Assumptions: Temperature variation across lead is small compared to the variation along the lead. 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Most often, however, energy conservation is simply a consideration in the overall economic evaluation of the design. For the Windows version the inputs are essentially the same. Equation (1.3) applies to a pure 1 The terras specific heat capacity and specific heat are equivalent and interchangeable in the heat transfer literature. Each of the three important subject areas of heat transfer will now be introduced: conduction, in Section 1.3.1; radiation, in Section 1.3.2; and convection, in Section 1.3.3. 1.3.1 Heat Conduction On a microscopic level, the physical mechanisms of conduction are complex, en compassing such varied phenomena as molecular collisions in gases, lattice vibra tions in crystals, and flow of free electrons in metals. Sometimes it is quite obvious that the situation is similar to that for a cooling fin. Usually there is an important trade-off between energy costs associated with the operation of the system and the capital costs required to construct the equipment. Fins are added to increase the hcA product and hence decrease the convective thermal resistance 1/h cA. where A/ is the surface area of the fins and A is the total heat transfer surface area, including the fins and exposed tube or other surface. The radiators are heat exchang ers. Then R = L/kA can be viewed as a thermal resistance analogous to electrical resistance. 2.4.5 The Similarity Principle and Dimensional Analysis To conclude our analysis of fins we use the pin fin problem of Section 2.4.1 to illustrate the similarity principle and dimensional analysis. These exercises are intended to give the student practice in hand calculations, and thus the sample solutions were also prepared manually. In this sense, convec tion is usually regarded as a distinct mode of heat transfer. Thus, the Given and Required statements are concise and focus on the essential features of the problem. For gases, transition from a laminar to turbulent flow occurs at a Grashof number of approximately 109; hence xtr — [109v2//3ATg]1/ 3. You're Reading a Free Preview Pages 512 to 523 are not shown in this preview. Yuen. The accuracy of the result depends primarily on our ability to obtain a reliable value of hj. Basic methodology and data are more easily and reliably obtained from a familiar text than from an internet search. Damshala, University of Tennessee— Chattanooga Tom Diller, Virginia Polytechnic Institute and State University Abraham Engeda, Michigan State University Glenn Gebert, Utah State University Clark E. The total surface efficiency r\t of a surface with fins of fin efficiency ?]/ is obtained by adding the unfinned portion of the surface area at 100% efficiency to the surface area of the fins at efficiency rjf. ISBN 978-0-9963053-0-3 CIP data available. Small discrepancies may be seen when interpolation in graphs or property tables is required, since some of the data are stored in the software as polynomial curve fits. Transport of energy by the hot water from the basement is true convection as defined above; we do not call this a heat transfer process. The worked examples not only illustrate the use of relevant equations but also teach modeling as both an art and science. The alloy has a conductivity of 175 W/m K.

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