The Papua New Guinea University of Technology

Department of Mechanical Engineering

ME 313: Heat Transfer

Third Year First Semester Examination – 2023

Friday, June 02, 2023 – 8:20 am

Time Allowed: Two (2) Hours

Instructions

(1) You have **10** minutes to read the paper. **Do not** write anything during this time.

(2) There are **four (4)** questions. Answer **each** question.

(3) All questions must be answered in the booklet provided. No other written material will be accepted.

(4) Calculators are permitted in the examination room. Notes and books are **not** allowed. Any student found in cheating will be **disqualified**.

(5) Write your name clearly on the front page using block letters.

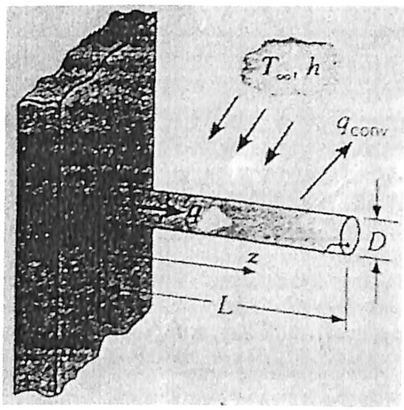
(6) All questions carry equal marks.

Q1. Consider a fin in the shape of solid circular cylinder attached to a hot flat wall as shown in the diagram below. The diameter of the rod is D and its length is L. The temperature at the base of the fin (i.e., at the flat wall) is T_b. The fin is cooled by convective air whose temperature at a large distance from the fin is T_∞. The thermal conductivity of the fin, k, and the heat transfer coefficient between the fin surface and the air, h, may be assumed to be constant. The heat loss at the fin may be treated as internal heat generation, $\dot{Q}_g'''$. The temperature T(z) along the cylinder is decreasing being maximum at the wall. Using cylindrical conduction equation with steady state condition and outlining the appropriate assumptions, find the following: **(25 Marks)**

(a) The differential equation and the boundary conditions.

(b) The differential equation and the boundary conditions in the dimensionless form with the following dimensionless variables:

$$\theta = \frac{T-T_\infty}{T_b-T_\infty}, \quad \zeta = \frac{z}{L} \text{ and } N = \sqrt{\frac{4hL^2}{kD}}.$$



Q2. Show that the conduction equation in the cylindrical coordinate system is the following:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(kr\frac{\partial T}{\partial r}\right) + \frac{1}{r^2}\frac{\partial}{\partial \varphi}\left(k\frac{\partial T}{\partial \varphi}\right) + \frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right) + \dot{Q}_g''' = \rho C_p \frac{\partial T}{\partial t}$$ **(25 Marks)**

Q3. Using dimensional analysis, show that for forced convection over a plate, $Nu = f(Re, Pr)$. **(25 Marks)**

Q4. Air at 27°C and 1 atm flows over a flat plate at a speed of 2 m/s. For this flow, assume that the plate is heated over its entire length to a temperature of 60°C. Calculate the heat transferred in the first 40 cm of the plate. Assume unit depth in the z direction. The local Nusselt number for isothermal plate, $Nu_x = 0.332 Re_x^{1/2} Pr^{1/3}$. **(25 Marks)**

Table A-5 | Properties of air at atmospheric pressure.†

The values of μ, k, c_p, and Pr are not strongly pressure-dependent and may be used over a fairly wide range of pressures

T, K	ρ kg/m^3	c_p kJ/kg · °C	$\mu \times 10^5$ kg/m · s	$\nu \times 10^6$ m^2/s	k W/m · °C	$\alpha \times 10^4$ m^2/s	Pr
100	3.6010	1.0266	0.6924	1.923	0.009246	0.02501	0.770
150	2.3675	1.0099	1.0283	4.343	0.013735	0.05745	0.753
200	1.7684	1.0061	1.3289	7.490	0.01809	0.10165	0.739
250	1.4128	1.0053	1.5990	11.31	0.02227	0.15675	0.722
300	1.1774	1.0057	1.8462	15.69	0.02624	0.22160	0.708
350	0.9980	1.0090	2.075	20.76	0.03003	0.2983	0.697
400	0.8826	1.0140	2.286	25.90	0.03365	0.3760	0.689
450	0.7833	1.0207	2.484	31.71	0.03707	0.4222	0.683
500	0.7048	1.0295	2.671	37.90	0.04038	0.5564	0.680
550	0.6423	1.0392	2.848	44.34	0.04360	0.6532	0.680
600	0.5879	1.0551	3.018	51.34	0.04659	0.7512	0.680
650	0.5430	1.0635	3.177	58.51	0.04953	0.8578	0.682
700	0.5030	1.0752	3.332	66.25	0.05230	0.9672	0.684
750	0.4709	1.0856	3.481	73.91	0.05509	1.0774	0.686
800	0.4405	1.0978	3.625	82.29	0.05779	1.1951	0.689
850	0.4149	1.1095	3.765	90.75	0.06028	1.3097	0.692
900	0.3925	1.1212	3.899	99.3	0.06279	1.4271	0.696
950	0.3716	1.1321	4.023	108.2	0.06525	1.5510	0.699
1000	0.3524	1.1417	4.152	117.8	0.06752	1.6779	0.702
1100	0.3204	1.160	4.44	138.6	0.0732	1.969	0.704
1200	0.2947	1.179	4.69	159.1	0.0782	2.251	0.707
1300	0.2707	1.197	4.93	182.1	0.0837	2.583	0.705
1400	0.2515	1.214	5.17	205.5	0.0891	2.920	0.705
1500	0.2355	1.230	5.40	229.1	0.0946	3.262	0.705
1600	0.2211	1.248	5.63	254.5	0.100	3.609	0.705
1700	0.2082	1.267	5.85	280.5	0.105	3.977	0.705
1800	0.1970	1.287	6.07	308.1	0.111	4.379	0.704
1900	0.1858	1.309	6.29	338.5	0.117	4.811	0.704
2000	0.1762	1.338	6.50	369.0	0.124	5.260	0.702
2100	0.1682	1.372	6.72	399.6	0.131	5.715	0.700
2200	0.1602	1.419	6.93	432.6	0.139	6.120	0.707
2300	0.1538	1.482	7.14	464.0	0.149	6.540	0.710
2400	0.1458	1.574	7.35	504.0	0.161	7.020	0.718
2500	0.1394	1.688	7.57	543.5	0.175	7.441	0.730

†From *Natl. Bur. Stand. (U.S.) Circ.* 564, 1955