First Semester Examination
Academic Session 2018/2019

December 2018/January 2018

EMH 441 – Heat Transfer
[Pemindahan Haba]

Duration : 3 hours
[Masa : 3 jam]

Please check that this paper contains **SIXTEEN [16]** printed pages including appendix before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **ENAM BELAS [16]** mukasurat bercetak beserta lampiran sebelum anda memulakan peperiksaan.]*

INSTRUCTIONS : Answer **ALL FIVE [5]** questions.
*[**ARAHAN** : Jawab **SEMUA LIMA [5]** soalan.]*

Answer Questions In **English** OR **Bahasa Malaysia**.
*[Jawab soalan dalam **Bahasa Inggeris** ATAU **Bahasa Malaysia**.]*

Answer to each question must begin from a new page.
[Jawapan bagi setiap soalan mestilah dimulakan pada mukasurat yang baru.]

In the event of any discrepancies, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

1. [a] **Describe heat transfer mechanism for different heat transfer modes: heat conduction, heat convection and heat radiation.**

Terangkan mekanisme pemindahan haba untuk mod pemindahan haba yang berbeza: konduksi haba, perolakan haba dan sinaran haba.

(30 marks/*markah*)

[b] **A metal rod made of aluminum with $30cm$ length and $5cm$ diameter (as depicted in Figure 1[b]). The temperature at the surface of one of the tip (T_1) of the rod is 30^0C and 60^0C at the surface of another tip of the rod (T_2). Assume the heat transfer is purely heat conduction and the surface of the rod (except both rod tips) is fully insulated. The heat conductivity (k) of the rod is $237\,W/m.K$. Calculate the heat transfer rate $(\dot{Q})$ of the aluminum rod.**

Batang logam diperbuat daripada aluminum dengan ukuran panjang sebanyak $30cm$ dan ukuran diameter sebanyak $5cm$ (seperti yang digambarkan dalam Rajah 1[b]). Suhu di permukaan di salah satu hujung (T_1) rod adalah 30^0C dan 60^0C pada permukaan di hujung rod yang lain (T_2). Anggapkan pemindahan haba adalah pengaliran haba sepenuhnya dan permukaan rod (kecuali kedua-dua hujung rod) ditebat. Kekonduksian haba (k) rod ialah $237\,W/m.K$. Kirakan kadar pemindahan haba $(\dot{Q})$ rod aluminum tersebut.

(20 marks/*markah*)

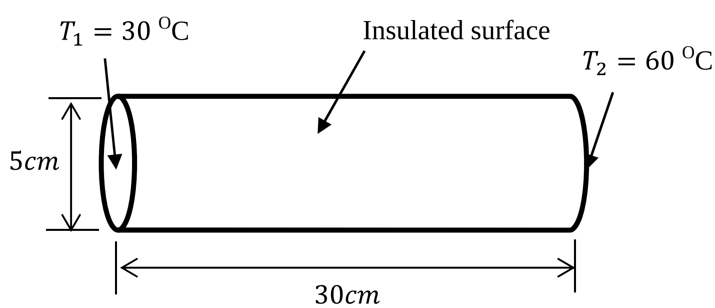

Figure 1[b]
Rajah 1[b]

[a] **Heat is transferred via radiation from surface A to surface B, as illustrated in Figure 1[c]. Heat is also transferred from surface B to surface C with thickness of $0.5m$ via conduction with thermal conductivity of $3.2\,W/m.K$. The temperature at surface A (T_1) is 100^0C and the temperature at surface C (T_3) is 60^0C. The heat flux via radiation $(\dot{q}_{\text{rad}})$ is given to be $20W/m^2$. Assumed that the emissivity of the surface A is 0.95 and Stefan-Boltzmann constant (σ) is $5.67 \times 10^{-8}\ W/m^2.K^4$. Calculate the temperature T_2 and the conduction heat flux $(\dot{q}_{\text{cond}})$.**

Haba dipindahkan melalui radiasi dari permukaan A ke permukaan B, seperti yang digambarkan pada Rajah 1[c]. Haba dipindahkan dari permukaan B ke permukaan C dengan ketebalan $0.5m$ melalui konduksi dengan kekonduksian terma sebanyak $3.2\,W/m.K$. Suhu di permukaan A (T_1) ialah 100^0C dan suhu di permukaan C ialah 60^0C. Fluks haba melalui radiasi $(\dot{q}_{rad})$ adalah sebanyak $20W/m^2$. Dianggap bahawa kebolehpancaran permukaan A ialah 0.95 dan pekali Stefan-Boltzmann (σ) ialah $5.67 \times 10^{-8}\ W/m^2.K^4$. Kirakan suhu T_2 dan fluks haba bagi pemindahan haba secara konduksi $(\dot{q}_{cond})$.

(50 marks/*markah*)

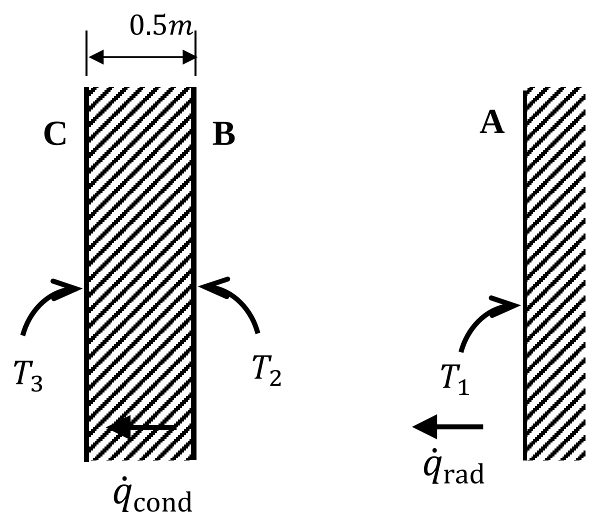

Figure 1[c]
Rajah 1[c]

2. [a] **Define Prandtl number (Pr) and describe the significance of Prandtl number for i) $Pr < 1$, ii) $Pr = 1$ and iii) $Pr > 1$. Sketch the thermal boundary layer for thermal flow for $Pr < 1$, $Pr = 1$ and $Pr > 1$ for fluid flow over a flat plate.**

Takrifkan nombor Prandtl (Pr) dan huraikan kepentingan nombor Prandtl untuk i) $Pr < 1$, ii) $Pr = 1$ dan iii) $Pr > 1$. Lakarkan lapisan sempadan terma untuk aliran haba untuk $Pr < 1$, $Pr = 1$ dan $Pr > 1$ untuk aliran bendalir di atas plat rata.

(20 marks/*markah*)

[b] **Air flows at $5 m/s$ past a flat plat with $40 cm$ length and $20 cm$ width, as depicted in Figure 2[b]. The temperature along the plate is assumed to be constant at $60\,^{o}C$ and the ambient temperature of the air is $20\,^{o}C$. The thermal conductivity of air is $0.026\, W/m.K$. Assume that the kinematic viscosity and the thermal diffusivity of air are $1 \times 10^{-5}\ m^2/s$ and $1.9 \times 10^{-5} m^2/s$, respectively. Calculate:**

Aliran udara pada $5m/s$ melepasi plat rata dengan panjang $40cm$ dan lebar $20cm$, seperti yang digambarkan dalam Rajah 2[b]. Suhu di sepanjang plat diandaikan tetap pada $60^{o}C$ dan suhu udara sekitar adalah $20\,^{o}C$. Kekonduksian haba udara ialah $0.026\, W/m.K$. Anggapkan bahawa kelikatan kinematik ialah $1 \times 10^{-5}\ m^2/s$ dan kemeresapan haba udara ialah $1.9 \times 10^{-5}\ m^2/s$ .Kirakan:

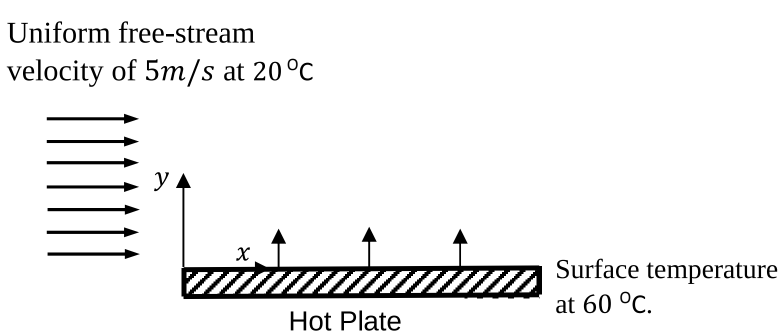

Figure 2[b]
Rajah 2[b]

(i) **The velocity boundary layer thickness (δ) at $20cm$ from the leading edge.**
Ketebalan lapisan sempadan halaju (δ) pada $20cm$ dari pinggir depan.

(20 marks/*markah*)

(ii) **The thermal boundary layer thickness (δ_t) at $20cm$ from the leading edge.**
Ketebalan lapisan sempadan terma (δ_t) pada $20cm$ dari pinggir depan.

(20 marks/*markah*)

(iii) **The average Nusselt number (Nu).**
Purata nombor Nusselt (Nu).

(20 marks/*markah*)

(iv) **The rate of heat transfer $(\dot{Q})$ by forced convection from the hot plate to air. Note that the air cooling is only on upper surface of the plate.**
Kadar pemindahan haba $(\dot{Q})$ dengan perolakan paksa dari plat panas ke udara. Penyejukan udara hanya berada di permukaan atas plat.

(20 marks/*markah*)

3. [a] **Describe the characteristics of the temperature profile for thermal flow in a tube in i) thermal entrance region and ii) thermally fully-developed region.**

Huraikan ciri-ciri profil suhu untuk aliran therma dalam tiub di i) kawasan pintu masuk terma dan ii) kawasan terma terbentuk penuh.

(20 marks/*markah*)

[b] **Water flows in a tube with $20mm$ inner diameter and $10m$ length at a fixed mass flow rate of $0.01kg/s$. At the entrance of the tube, the water is $20\ ^0C$. The surface temperature of the tube is fixed at $40\ ^0C$. Assume the fully-developed flow condition over the entire tube. The water properties are shown in Table 3[b]. Calculate:**

Air mengalir dalam tiub dengan diameter dalam sebanyak $20mm$ dan $10m$ panjang pada kadar aliran jisim tetap $0.01kg/s$. Di pintu masuk tiub, suhu air ialah $20\ ^0C$. Suhu permukaan tiub ditetapkan pada $40\ ^0C$. Anggapkan aliran terbentuk penuh dalam tiub. Sifat-sifat air diberikan dalam Jadual 3[b]. Kirakan:

Table 3[b]
Jadual 3[b]

Density (ρ) **:** *Ketumpatan*	$1000\,kg/m^3$
Dynamic viscosity (μ) **:** *Kelikatan dinamik*	$0.001\,kg/m.s$
Thermal conductivity (k)**:** *Keberkonduktan terma*	$0.6\,W/m.K$
Specific heat (c_p) **:** *Haba tentu*	$4186\,J/kg.K$

(i) **The average flow velocity and the Reynolds number.**
Halaju aliran purata dan nombor Reynolds.

(**20 marks**/*markah*)

(ii) **The average convective heat transfer coefficient**(h)**.**
Purata pekali pemindahan haba perolakan (h)*.*

(**20 marks**/*markah*)

(iii) **The mean mixed water temperature at the exit of the tube.**
Suhu air campuran pada aliran keluar tiub.

(**20 marks**/*markah*)

(iv) **The rate of heat transfer across the tube.**
Kadar pemindahan haba di sepanjang tiub tersebut.

(**20 marks**/*markah*)

4. [a] **A vertical plate with** $0.2m$ **width and 0.1m height with surface temperature at** $80\,^0C$ **is exposed to atmospheric air at** $20\,^0C$**, as illustrated in Figure 4[a]. Calculate the average Nusselt number for natural convection. Assume gravitational acceleration** (g) **to be** $9.81\,m/s^2$**. The thermal expansion coefficient** (β) **for air is** $0.0034/K$**. The air properties are given in Appendix III.**

Plat menegak berukuran $0.2m$ *lebar dan 0.1m tinggi dengan suhu permukaan pada* $80\,^0C$ *terdedah kepada udara atmosfera pada* $20\,^0C$*, seperti digambarkan dalam Rajah 4[a]. Kirakan purata nombor Nusselt untuk perolakan semulajadi. Anggapkan pecutan graviti* (g) *ialah* $9.81\,m/s^2$*. Pekali pengembangan haba* (β) *untuk udara ialah* $0.0034/K$*. Sifat-sifat udara diberikan dalam Lampiran III.*

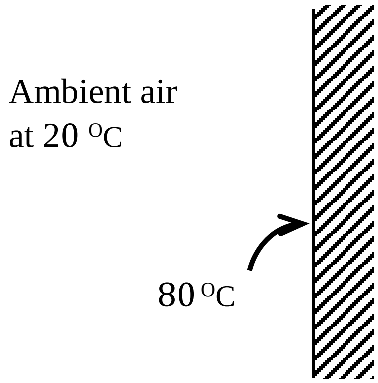

Figure 4[a]
Rajah 4[a]

(50 marks/*markah*)

[b] Figure 4[b] illustrates boiling curve for water at atmospheric pressure. Explain why heat transfer for boiling water decreases from Point C to Point D.

Rajah 4[b] menunjukkan lengkuk air mendidih pada tekanan atmospfera, Terangkan kenapa perpindahan haba untuk air mendidih berkurang dari Titik C ke Titik D.

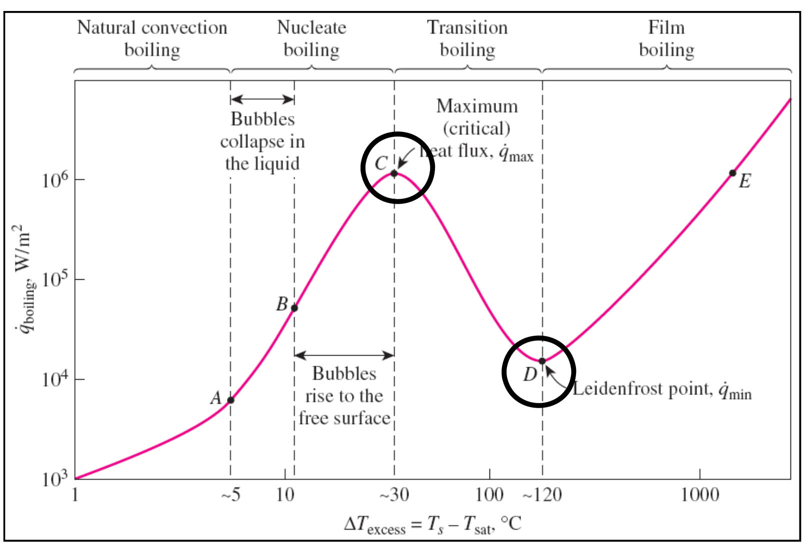

Figure 4[b]
Rajah 4[b]

(**15 marks**/*markah*)

[c] **Surfaces 1 and 2 are concave surfaces with Surface 1 area = 15m^2 and Surface 2 area = 4m^2. The gap between Surface 1 and Surface 2 is 2m as illustrated in Figure 4[c]. Calculate view factor (F_{12}) from Surface 1 to Surface 2.**

Permukaan 1 dan 2 adalah permukaan cekung dengan luas Permukaan 1 = 15m^2 dan luas Permukaan 2 = 4m^2. Jurang antara Permukaan 1 dan Permukaan 2 ialah 2m seperti yang ditunjuk pada Rajah 4[c]. Kirakan faktor penglihatan (F_{12}) dari Surface 1 ke Surface 2.

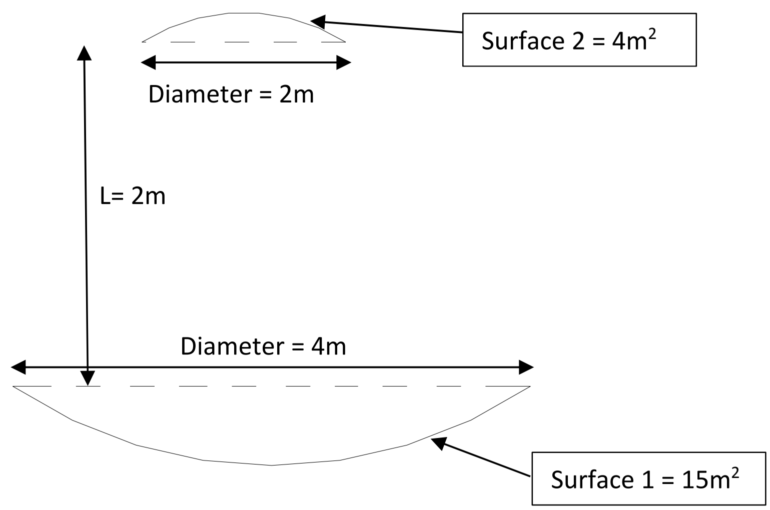

Figure 4[c]
Rajah 4[c]

(**35 marks**/*markah*)

5. [a] **Water (c_p=4200 J/kg.K, ρ = 1000 kg / m^3) is utilized to heat crude oil (c_p=2500 J/kg.K, ρ = 800 kg / m^3) as illustrated in Figure 5[a] using counter flow heat exchanger. A very thin copper inner tube has diameter of 2.5cm and length of 50cm; and diameter of outer tube is 5cm. Water flows through inner tube and crude oil flows through outer tube. The velocities of water and crude oil are 0.25m/s and 0.2m/s, respectively. By using LMTD method,**

Air (c_p=4200 J/kg.K, ρ = 1000 kg / m^3) digunakan untuk memanaskan minyak mentah (c_p=2500 J/kg.K, ρ = 800 kg / m^3) seperti yang ditunjukkan seperti Rajah 5[a] menggunakan penukar haba aliran lawan. Satu tiub dalaman tembaga yang sangat nipis mempunyai diameter 2.5cm dan panjang 50cm; dan diameter tiub luaran adalah 5cm. Air mengalir dalan tiub dalaman dan minyak mentah mengalir dalam tiub luaran. Halaju air dan minyak mentah adalah 0.25m/s dan 0.2m/s. Dengan mengunakan kaedah LMTD,

(i) **Calculate heat transfer rate, crude oil outlet temperature and overall heat transfer coefficient.**
Kirakan kadar perpindahan haba, suhu keluaran minyak mentah dan pekali perpindahan haba keseluruhan.

(**45 marks**/*markah*)

(ii) **In your opinion, give ONE method to improve overall heat transfer coefficient without changing pump power supply. Justify your answer.**
Pada pendapat kamu, berikan SATU kaedah untuk meningkatkan pekali perpindahan haba keseluruhan tanpa mengubah bekalan kuasa pam. Justifikasikan jawapan anda.

(**20 marks**/*markah*)

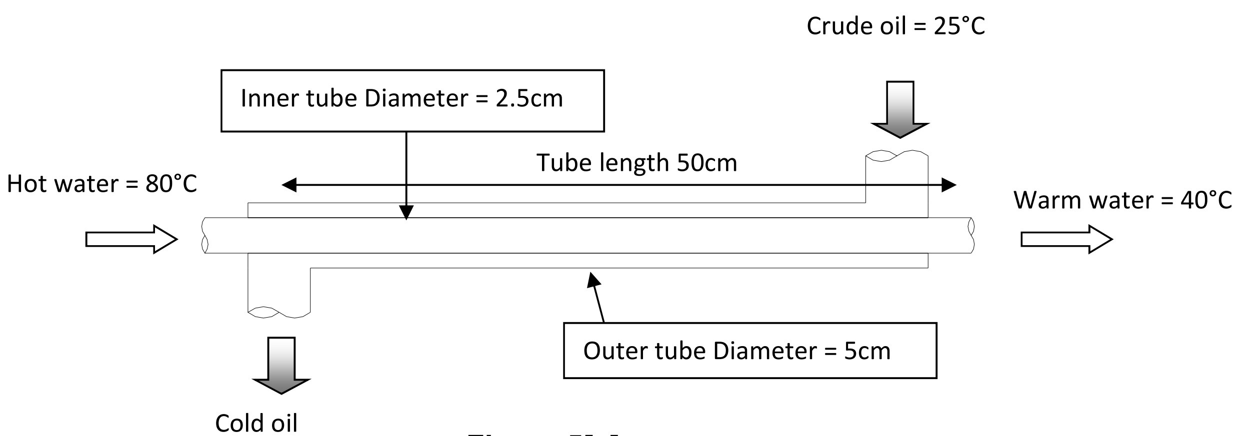

Figure 5[a]
Rajah 5[a]

[b] **Hot water (c_p=4200 J/kg.K, ρ = 1000 kg / m^3) is to be warm special liquid (c_p=5000 J/kg.K, ρ = 1100 kg / m^3) in the single shell and tube heat exchanger as shown in Figure 5[b]. The total area of tubes is 6m^2. The overall heat transfer coefficient is 500 W/m^2K. The special liquid mass flow rate is 0.3 kg/s and hot water is 0.4762 kg/s. Special liquid and hot water inlet temperatures are 18°C and 95°C respectively. By using NTU method, calculate total heat transfer rate; and outlet temperature of special liquid and hot water.**

Air panas (c_p=4200 J/kg.K, ρ = 1000 kg / m^3) digunakan untuk memanaskan cecair istimewa (c_p=5000 J/kg.K, ρ = 1100 kg / m^3) dalam penukar haba kelompang dan tiub tunggal seperti yang ditunjukkan dalam Rajah 5[b]. Luas keseluruhan tiub adalah 6m^2. Pekali pemindahan haba keseluruhan ialah 500 W/m^2.K. Kadar aliran jisim cecair istimewa ialah 0.3 *kg/s dan kadar aliran jisim air panas ialah 0.4762 kg/s. Suhu masukan cecair istimewa ialah 18°C dan suhu masukan air panas ialah 95°C. Dengan menggunakan kaedah NTU, kirakan kadar pemindahan haba dalam penukar haba dan suhu keluaran cecair istimewa dan air panas.*

(**35 marks**/*markah*)

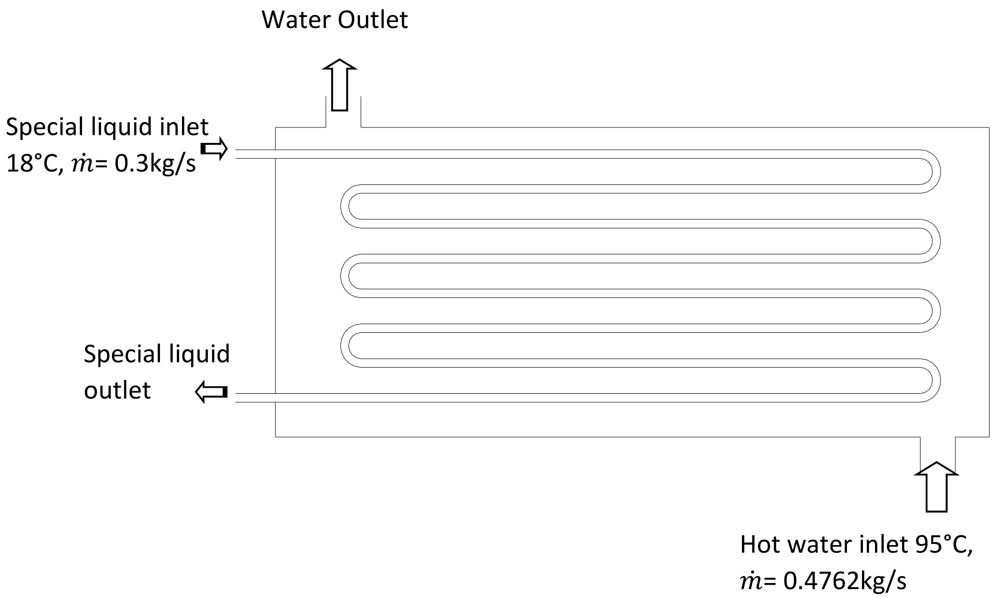

Figure 5[b]
Rajah 5[b]

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APPENDIX 1
LAMPIRAN 1

Formulation

General formulations:

Heat conduction: $\dot{q}_{\text{cond}} = -k\frac{dT}{dx}$

Heat convection: $\dot{q}_{\text{conv}} = h(T_s - T_\infty)$

Heat radiation: $\dot{q}_{\text{rad}} = \varepsilon\sigma\,(T_s^4 - T_{surr}^4)$

External forced convection heat transfer formulations:

Flow over flat plate

Velocity boundary layer thickness, $\delta(x) = \frac{5.0x}{Re_x^{1/2}}$

Thermal boundary layer thickness, $\delta_t(x) = \frac{\delta}{Pr^{1/3}} = \frac{5.0x}{Pr^{1/3}Re_x^{1/2}}$

where $Pr = \nu/\alpha$

Forced convection heat transfer over flat plate

i) Isothermal along the plate

a) Local Nusselt number

Laminar:	$Nu_x = 0.332Re_x^{0.5}Pr^{1/3}$	For $Re_x < 5 \times 10^5$, $Pr > 0.6$
Turbulent:	$Nu_x = 0.0296Re_x^{0.8}Pr^{1/3}$	For $5 \times 10^5 \leq Re_x \leq 10^7$, $0.6 \leq Pr \leq 60$

b) Average Nusselt number

Laminar:	$Nu = 0.664Re_L^{0.5}Pr^{1/3}$	for $Re_L < 5 \times 10^5$, $Pr > 0.6$
Turbulent:	$Nu = 0.037Re_L^{0.8}Pr^{1/3}$	for $5 \times 10^5 \leq Re_L \leq 10^7$, $0.6 \leq Pr \leq 60$

ii) Uniform heat flux along the plate

a) Local Nusselt number

Laminar:	$Nu_x = 0.453Re_x^{0.5}Pr^{1/3}$	for $Re_x < 5 \times 10^5$, $Pr > 0.6$
Turbulent:	$Nu_x = 0.0308Re_x^{0.8}Pr^{1/3}$	for $5 \times 10^5 \leq Re_x \leq 10^7$, $0.6 \leq Pr \leq 60$

APPENDIX 2
LAMPIRAN 2

Internal forced convection heat transfer formulations:

Flow regime in circular pipe:

Laminar when $Re_D < 2300$

Turbulent when $Re_D > 10{,}000$

For laminar fully developed thermal flow for circular tube:

Constant surface temperature, $Nu = \frac{hL}{k} = 3.66$

Constant surface heat flux, $Nu = \frac{hL}{k} = 4.36$

Constant surface heat flux along circular tube:

$$\frac{\partial T_m}{\partial x} = \frac{\partial T_s}{\partial x} = \frac{\partial T}{\partial x} = \frac{\dot{q}_s p}{\dot{m} c_p}$$

Constant surface temperature along circular tube:

Temperature at exit of tube, $T_e = T_s - (T_s - T_i)\exp(-hA_s/\dot{m}c_p)$

where A_s is the surface area of the tube.

Heat transfer rate, $\dot{Q} = hA_s \Delta T_{ln}$

Logarithmic mean temperature difference, $\Delta T_{ln} = \frac{T_i - T_e}{\ln\left[\frac{T_s - T_e}{T_s - T_i}\right]}$

Natural convection heat transfer formulations:

Rayleigh number:

$$Ra_L = \frac{g\beta(T_s - T_\infty)L_c^3}{\nu^2} Pr$$

<u>Empirical correlations for natural convection over surfaces</u>

Vertical plates with characteristic length L (plate height),

$Nu = 0.59 Ra_L^{1/4}$, for $10^4 < Ra < 10^9$

$Nu = 0.1 Ra_L^{1/3}$, for $10^{10} < Ra < 10^{13}$

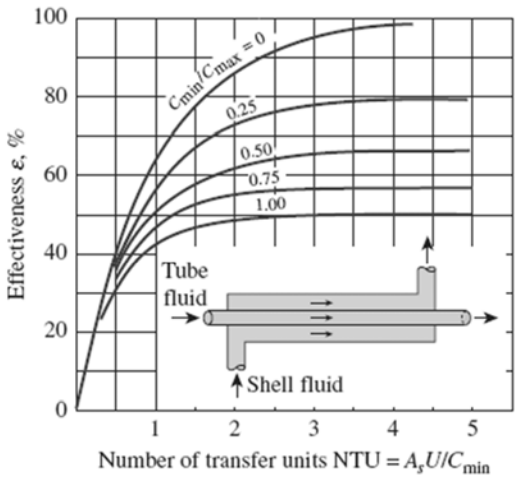
APPENDIX 3
LAMPIRAN 3

Table: Properties of air at 1atm pressure

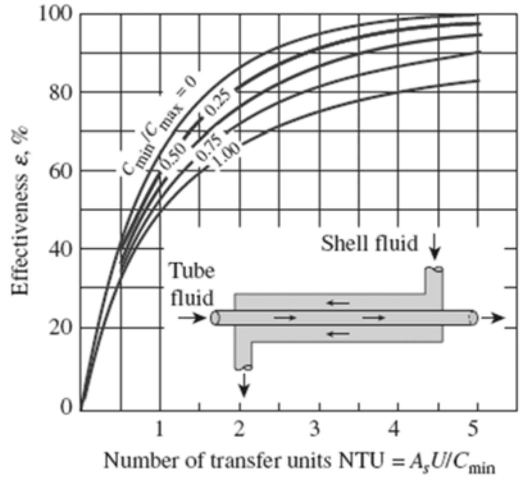
Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m³	Specific Heat c_p, J/kg·K	Thermal Conductivity k, W/m·K	Thermal Diffusivity α, m²/s	Dynamic Viscosity μ, kg/m·s	Kinematic Viscosity ν, m²/s	Prandtl Number Pr
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	0.7246
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-5}	5.837×10^{-6}	0.7263
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	0.7440
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	0.7436
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	0.7425
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	0.7408
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	0.7255
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	0.7241
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	0.7228
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	0.7202
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	0.7177
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	0.7154
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}	0.7132
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}	0.7111

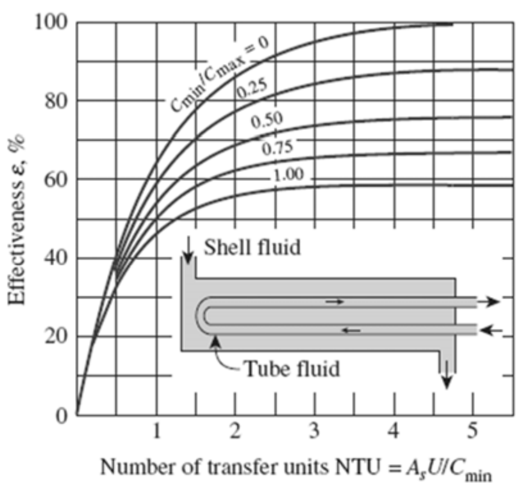
APPENDIX 4
LAMPIRAN 4



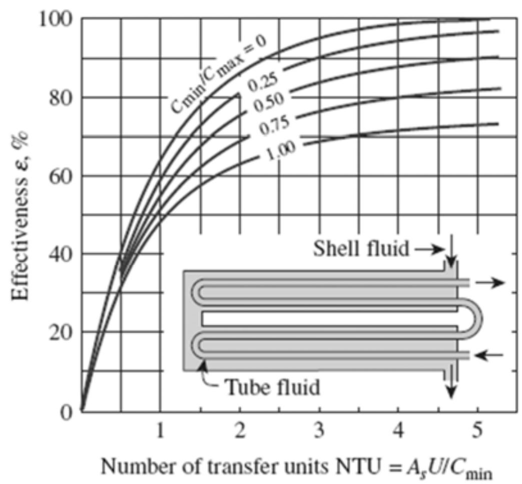
(*a*) Parallel-flow



(*b*) Counter-flow

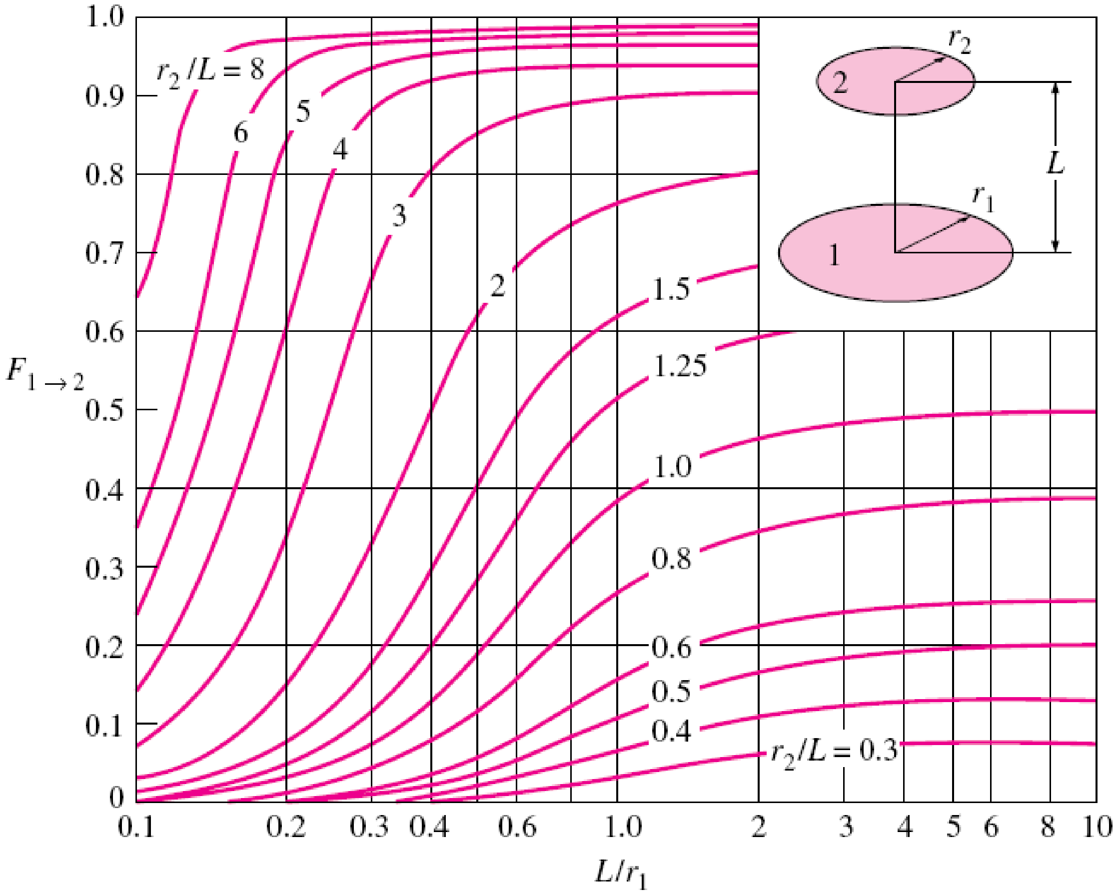


(*c*) One-shell pass and 2, 4, 6, … tube passes



(*d*) Two-shell passes and 4, 8, 12, … tube passes

APPENDIX 5
LAMPIRAN 5



View factor diagram

APPENDIX 6

LAMPIRAN 6

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APPENDIX

TABLE A–3

Properties of solid metals

Composition	Melting Point, K	Properties at 300 K: ρ kg/m^3	c_p J/kg·K	k W/m·K	$\alpha \times 10^6$ m^2/s	Properties of Various Temperature (K), K(W/m.K)/C_p(J/Kg.K): 100	200	400	600
Aluminum:									
Pure	933	2702	903	237	97.1	302	237	240	231
						482	798	949	1033
Alloy 2024-T6	775	2770	875	177	73.0	65	163	186	186
(4.5% Cu, 1.5% Mg,									
0.6% Mn)						473	787	925	1042
Alloy 195, Cast									
(4.5% Cu)		2790	883	168	68.2			174	185
Beryllium	1550	1850	1825	200	59.2	990	301	161	126
						203	1114	2191	2604
Bismuth	545	9780	122	7.86	6.59	16.5	9.69	7.04	
						112	120	127	
Boron	2573	2500	1107	27.0	9.76	190	55.5	16.8	10.6
						128	600	1463	1892
Cadmium	594	8650	231	96.8	48.4	203	99.3	94.7	
						198	222	242	
Chromium	2118	7160	449	93.7	29.1	159	111	90.9	80.7
						192	384	484	542
Cobalt	1769	8862	421	99.2	26.6	167	122	85.4	67.4
						236	379	450	503
Copper:									
Pure	1358	8933	385	401	117	482	413	393	379
						252	356	397	417
Commercial bronze	1293	8800	420	52	14		42	52	59
(90% Cu, 10% Al)							785	160	545
Phosphor gear bronze	1104	8780	355	54	17		41	65	74
(89% Cu, 11% Sn)							—	—	—
Cartridge brass	1188	8530	380	110	33.9	75	95	137	149
(70% Cu, 30% Zn)							360	395	425
Constantan	1493	8920	384	23	6.71	17	19		
(55% Cu, 45% Ni)						237	362		
Germanium	1211	5360	322	59.9	34.7	232	96.8	43.2	27.3
						190	290	337	348
Gold	1336	19,300	129	317	127	327	323	311	298
						109	124	131	135
Iridium	2720	22,500	130	147	50.3	172	153	144	138
						90	122	133	138
Iron:									
Pure	1810	7870	447	80.2	23.1	134	94.0	69.5	54.7
						216	384	490	574
Armco									
(99.75% pure)		7870	447	72.7	20.7	95.6	80.6	65.7	53.1
						215	384	490	574
Carbon steels:									
Plain carbon (Mn ≤ 1%		7854	434	60.5	17.7			56.7	48.0
Si ≤ 0.1%)								487	559
AISI 1010		7832	434	63.9	18.8			58.7	48.8
							487	559	685
Carbon–silicon (Mn ≤ 1%		7817	446	51.9	14.9			49.8	44.0
0.1% < Si ≤ 0.6%)								501	582