UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2016/2017

December 2016 / January 2017

EMH 441 – Heat Transfer
[Pemindahan Haba]

Duration : 3 hours
Masa : 3 jam

Please check that this paper contains **ELEVEN(11)** printed pages, **FOUR(4)** page Appendix and **FIVE(5)** questions before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **SEBELAS(11)** mukasurat beserta **EMPAT(4)** mukasurat Lampiran dan **LIMA(5)** soalan yang bercetak sebelum anda memulakan peperiksaan.]*

Appendix/*Lampiran* :

1.	Heat Exchanger NTU	[**1 page**/mukasurat]
2.	Radiation Heat Transfer Chart	[**1 page**/mukasurat]
3.	Materials Properties	[**2 page**/*mukasurat*]

INSTRUCTIONS : Answer **ALL** questions.

*[**ARAHAN** : Jawab **SEMUA** 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.]

NOTE:
Provided: Formula Booklet
Dibekalkan: Buku formula

Q1. Water flows through a cast steel pipe (k = 50 W/m K) with an outer diameter of 104 mm and 2 mm wall thickness.

Air mengalir melalui paip keluli tuang (k = 50 W/m K) yang mana diameter luaran ialah 104 mm dan tebal dinding 2 mm.

[a] Calculate the heat loss by convection and conduction per meter length of uninsulated pipe as shown in Figure Q1 [a]. The water temperature is 15 °C and the outside air temperature is -10 °C. Given the water heat transfer coefficient is 30 kW/m^2 and the outside air heat transfer coefficient is 20 W/m^2 K.

Kirakan kehilangan haba melalui perolakan dan konduksi per meter panjang untuk paip tidak ditebat seperti dalam Rajah S1 [a]. Suhu air ialah 15 °C dan udara di luar paip tersebut ialah -10 °C. Diberikan pekali pemindahan haba air 30 kW/m^2 dan pekali pemindahan haba udara di luar paip ialah 20 W/m^2 K.

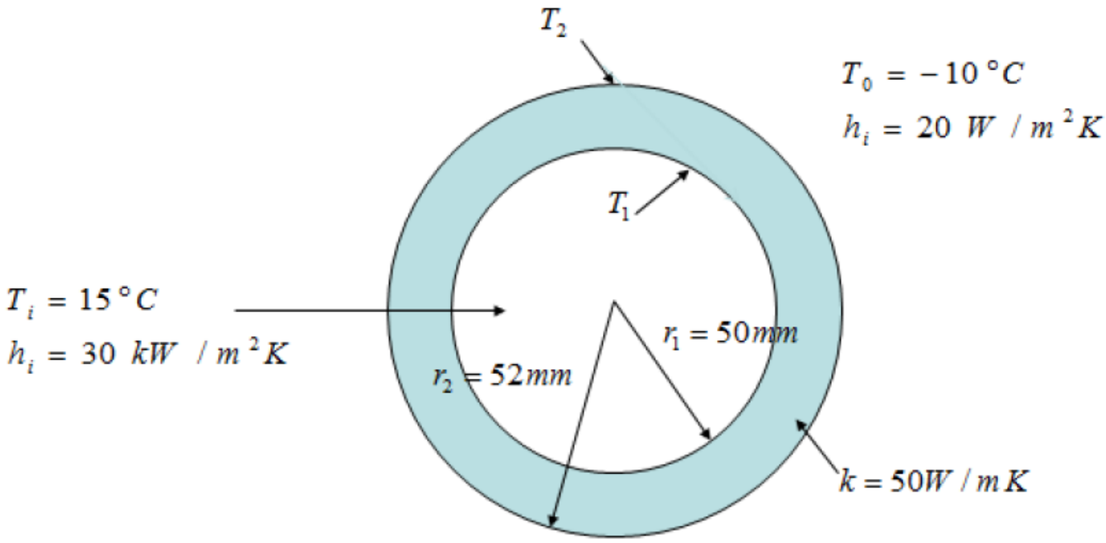

Figure Q1[a]
Rajah S1[a]

(40 marks/*markah*)

…3/-

[b] **Calculate the corresponding heat loss when the pipe is insulated with insulation having an outer diameter of 300 mm. Given the insulation thermal conductivity is k = 0.05 W/m K.**

Kirakan kehilangan haba apabila paip tersebut ditebat dengan penebat yang berdiameter luar paip 300 mm. Diberikan konduktiviti haba penebat tersebut ialah k = 0.05 W/m K.

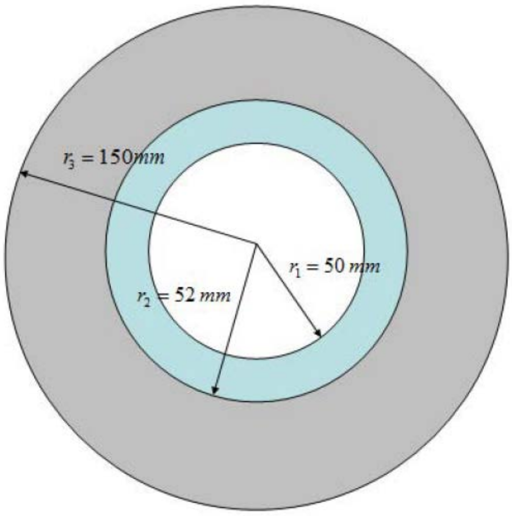

Figure Q1[b]
Rajah S1[b]

(40 marks/*markah*)

[c] **Justify the corresponding heat loss with respect to your answer in [a] and [b].**

Wajarkan tentang kehilangan haba yang terlibat untuk jawapan anda di dalam [a] dan [b].

(20 marks/*markah*)

Q2. **Figure Q2 shows the heat sink to be used in an electronic application. There are total of 9 aluminium fins (k = 175 W/m K, Cp = 900 J/kg K, ρ = 2700 kg/m^3) of rectangular cross-section. Each of the fin is 60 mm long, 40 mm wide and 1 mm thick. The spacing between the adjacent fins, s, is 3mm. The temperature of the base of the heat sink has a maximum design value of T_b = 60 °C, when the ambient air temperature T_f = 20 °C. Under these conditions, the ambient heat transfer coefficient h = 12 W/m^2 K.**

The fin can be assumed to be sufficiently thin so that the heat transfer from the tip can be neglected. The surface temperature T, at a distance x, from the base of the fin is given by;

Rajah S2 menunjukkan sinki haba yang akan digunakan dalam aplikasi elektronik. Terdapat sejumlah 9 sirip aluminium (k = 175 W / m K, Cp = 900 J / kg K, ρ = 2700 kg / m^3) segi empat tepat keratan rentas. Setiap satu daripada sirip ialah 60 mm, 40 mm lebar dan 1 mm tebal. Jarak di antara sirip bersebelahan, s, ialah 3 mm. Suhu asas sinki haba mempunyai nilai reka bentuk maksimum Tb = 60 °C, apabila suhu ambien udara T_f = 20 °C. Dalam keadaan ini, pekali pemindahan haba ambien, h = 12 W / m^2 K.

Sirip boleh dianggap sangat nipis dan pemindahan haba dari hujung boleh diabaikan. Suhu permukaan, T, pada jarak x, dari pangkal sirip diberikan oleh;

$$\boldsymbol{T - T_f = \frac{(T_b - T_f)\cosh m\,(L - x)}{\sinh mL}}$$

Where;

$$\boldsymbol{m^2 = \frac{h\,P}{k\,A_c}}$$

$$\boldsymbol{A_c = cross\ sectional\ area}$$

Given also,

$$\boldsymbol{Q_f = (hPkA_c)^{1/2}(T_b - T_f)tanh\,(mL)}$$

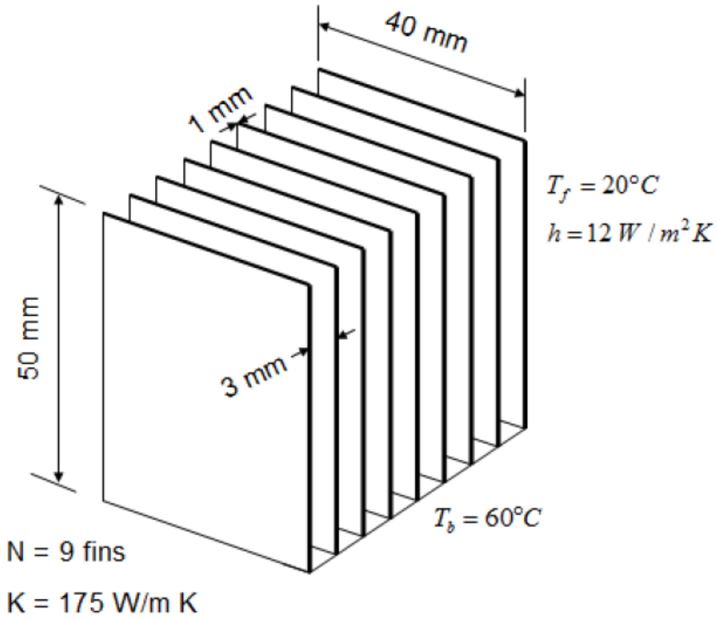

Figure Q2
Rajah S2

[a] **Calculate the total convective heat transfer from the heat sink.**
Kirakan jumlah pemindahan haba perolakan daripada sinki haba.

(40 marks/*markah***)**

[b] **Calculate the fin efficiency, η_{fin}**
Kirakan kecekapan sirip, η_{fin}

(30 marks/*markah*)

[c] **Propose and justify ways to improve the thermal performance in this system.**
Cadangkan dan wajarkan cara-cara untuk meningkatkan prestasi terma dalam sistem ini.

(30 marks/*markah***)**

Q3. **Figure Q3 shows part of the heat exchanger tube. Hot water flows through the 20 mm diameter tube and is cooled by fins that are positioned with their longest side vertical. The exchange heat by convection to the surrounding is at 27 °C. Estimate the convective heat loss per fin for the following conditions. You may ignore the contribution and effect of the cut-out for the tube on the flow and heat transfer.**

Rajah S3 menunjukkan sebahagian daripada tiub penukar haba. Air panas mengalir melalui tiub diameter 20 mm dan disejukkan oleh sirip yang berada pada kedudukan dengan bahagian yang paling panjang menegak. Pertukaran haba secara perolakan kepada suhu persekitaran pada 27 ° C. Anggarkan kehilangan haba perolakan setiap sirip untuk syarat-syarat berikut. Anda boleh mengabaikan sumbangan dan kesan potongan hujung untuk tiub aliran dan haba pemindahan.

The following correlation may be used without proof, although you must give reasons to support your choice of answer.

Korelasi berikut boleh digunakan tanpa pembuktian, walau bagaimanapun anda perlu memberikan alasan untuk menyokong pilihan anda dalam jawapan.

- $Nu_x = 0.3\, Re_x^{1/2}\, Pr^{1/3}$ $\quad Re_x < 3 \times 10^5$
- $Nu_x = 0.02\, Re_x^{0.8}\, Pr^{1/3}$ $\quad Re_x \geq 3 \times 10^5$
- $Nu_x = 0.5\, Gr_x^{1/4}\, Pr^{1/4}$ $\quad Gr_x < 10^9$
- $Nu_x = 0.1\, Gr_x^{1/3}\, Pr^{1/3}$ $\quad Gr_x \geq 10^9$

Given also,
Diberikan,

$$h_{av} = \frac{h_{x=L}}{3/4}$$

$$h_{av} = \frac{h_{x=L}}{1/2}$$

$$Nu_{av} = \frac{2}{3}(Gr_L \cdot Pr)^{1/4}$$

$$Nu_{av} = 0.6\, Re_L^{1/2}\, Pr^{1/3}$$

For air at these conditions, take:
Untuk udara pada keadaan tersebut, ambil:

Pr	**0.7**
k	**0.02 W/ m K**
μ	**1.8 x 10^{-5} kg/ m s**
ρ	**1.0 kg /m^3**

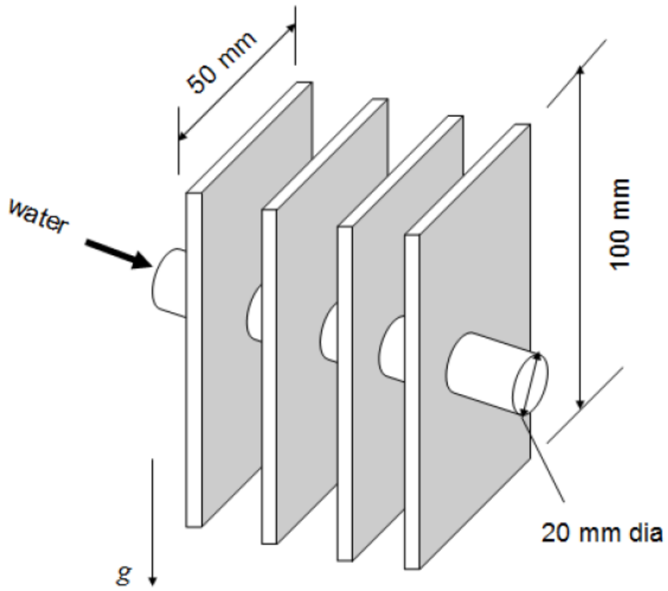

Figure Q3
Rajah S3

[a] **Free convection with an average fin surface temperature of 47 °C.**

Perolakan bebas dengan suhu purata permukaan sirip ialah 47 °C.

(50 marks/*markah*)

[b] **Forced convection with an air flow of 15 m/s blowing parallel to the short side of the fin and with an average fin surface temperature of 37 °C.**

Perolakan paksa dengan aliran udara 15 m/s bertiup selari dengan sisi lebih pendek daripada sirip dan dengan purata suhu permukaan sirip 37 °C.

(50 marks/*markah*)

Q4. [a] **Figure Q4[a] shows the heat flux, $q^{"}$, profile against excess temperature for pool boiling water. Describe phases between points AB, BC, CD and DE as shown in Figure Q4[a]. Justify why $q^{"}$ between points CD decreasing with excess temperature.**

Rajah S4[a] menunjukkan profil fluks haba, $q^{"}$, melawan suhu lebihan untuk kolam air mendidih. Terangkan fasa-fasa di antara titik-titik AB, BC, CD dan DE seperti ditunjukkan pada Rajah S4[a]. Wajarkan kenapa $q^{"}$ di antara titik-titik DC menurun dengan suhu lebihan.

(**25 marks**/*markah*)

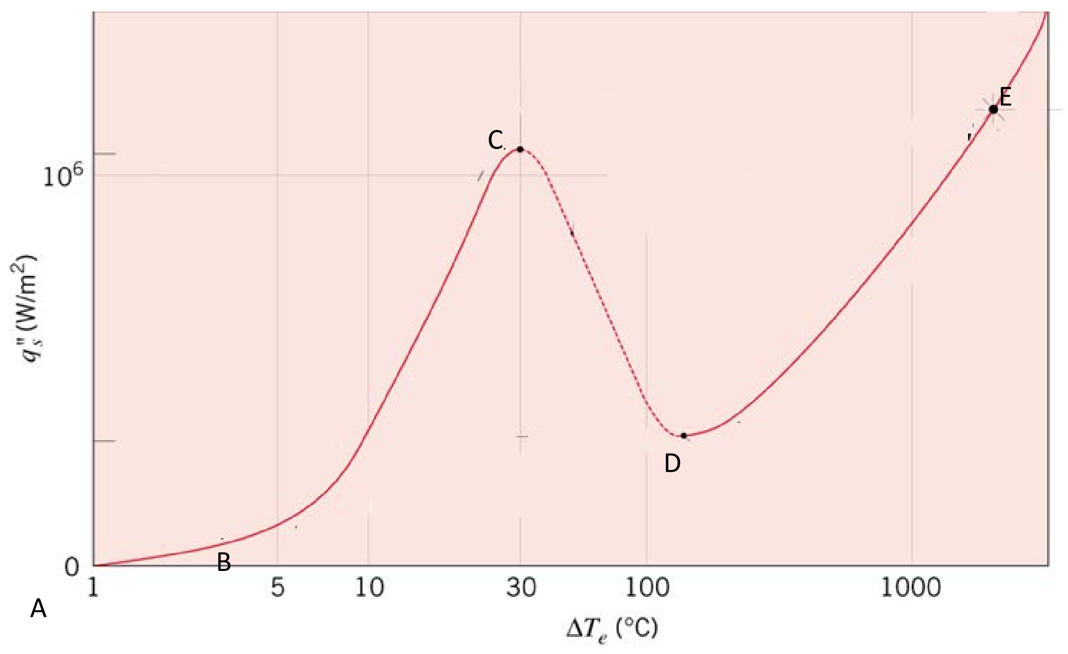

Figure Q4[a]
Rajah S4[a]

[b] **Figure Q4[b] shows that water (Cp=4200 J/kg.K, ρ = 1000 kg / m^3) is utilized to cool hot oil (Cp=2100 J/kg.K, ρ = 850 kg / m^3) using heat exchanger. The inner tubes are thin with a diameter of 0.05m and length of 500m. The diameter and thickness of outer tube are 0.0916m and 3mm. Water velocity through the inner tubes is 1m/s, and the oil velocity through the outer tube is 2m/s. Calculate:**

Rajah S4[b] menunjukkan air (Cp=4200 J/kg.K, ρ = 1000 kg / m^3) digunakan untuk menyejukkan minyak panas (Cp=2100 J/kg.K, ρ = 850 kg / m^3) menggunakan penukar haba. Tiub dalaman yang nipis mempunyai diameter 0.05m dan panjang 1m. Diameter dan tebal tiub luar ialah 0.0916m dan 3mm. Halaju air melalui tiub dalaman ialah 1m/s dan halaju minyak melalui tiub luar ialah 2m/s. Kirakan:

(i) **Calculate the rate of heat transfer, water outlet temperature and overall heat transfer coefficient.**

Kirakan kadar pemindahan haba, suhu alur keluar air dan pekali pemindahan haba keseluruhan.

(ii) **In your opinion, is the temperature of hot air outlet possible? Justify your answer. Do you think overall convection heat transfer at the inlet cold water is similar to overall heat transfer at the outlet hot water? Justify your answer.**

Pada pendapat anda, adakah suhu alur keluar air panas mungkin berlaku? Wajarkan jawapan anda. Adakah pekali pemindahan haba keseluruhan pada alur masuk air sejuk sama dengan pekali perpindahan haba keseluruhan pada alur keluar air panas. Wajarkan jawapan anda.

(iii) **As an engineer, assess how to reduce material cost of this heat exchanger without reducing overall heat transfer coefficient.**

Sebagai seorang jurutera, taksirkan bagaimana untuk mengurangkan kos bahan penukar haba tanpa mengurangkan pekali perpindahan haba keseluruhan.

(**75 marks**/*markah*)

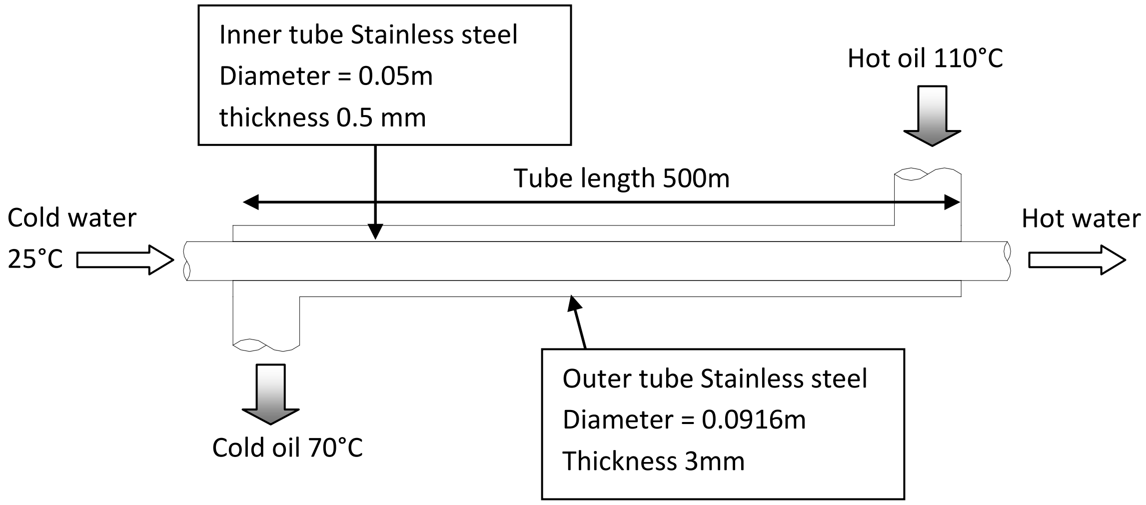

Figure Q4[b]
Rajah S4[b]

Q5. [a] Hot oil (Cp=2100 J/kg.K, ρ = 850 kg / m^3) is to be cooled water (Cp=4200 J/kg.K, ρ = 1000 kg / m^3) in the heat exchanger as shown in Figure Q5[a]. The tubes are 3mm thin-walled stainless steel with a diameter and length of 2.0cm and 1.2m respectively. The overall heat transfer coefficient is 340W/m^2.K. Water mass flow rate is 0.1kg/s and oil mass flow rate is 0.2kg/s. Water and oil inlet temperatures are 18°C and 160°C respectively. Calculate the rate of heat transfer in the heat exchanger and outlet temperature of water and oil. In this case, in your opinion, is calculated outlet oil temperature similar to actual outlet oil temperature? Give one reason for your answer.

Minyak panas (Cp=2100 J/kg.K, ρ = 850 kg / m^3) disejukkan oleh air (Cp=4200 J/kg.K, ρ = 1000 kg / m^3) dalam penukar haba seperti yang ditunjukkan dalam Rajah S5[a]. Tiub-tiub berketebalan 3mm keluli tahan karat dengan berdiameter 2.0cm dan panjang 1.2m. Pekali pemindahan haba keseluruhan ialah 340W/m^2.K. Kadar aliran jisim air ialah 0.1kg/s dan kadar aliran jisim minyak ialah 0.2kg/s. Suhu masuk air ialah 18°C dan suhu minyak masuk ialah 160°C. Kirakan kadar pemindahan haba dalam penukar haba dan suhu keluar air dan minyak. Pada pendapat anda, adakah suhu-suhu alur keluar minyak yang dikira sama dengan suhu alur keluar minyak yang sebenar? Berikan satu alasan untuk jawapan anda.

(**60 marks**/*markah*)

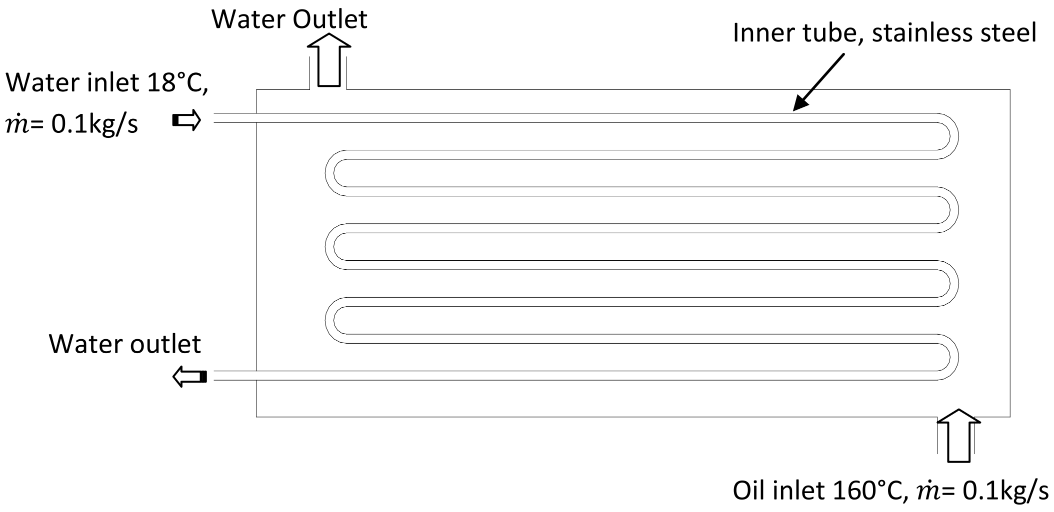

Figure Q5[a]
Rajah S5[a]

[b] **All surfaces of 5m x 5m x 5m cubical furnace as shown in Figure Q5[b] are black surface. All surfaces have uniform temperature. Calculate net radiation heat transfer from the bottom surface.**

Semua permukaan 5m x 5m x 5m relau kubus seperti Rajah S5[b] ialah permukaan hitam. Semua permukaan mempunyai suhu sekata. Kirakan pemindahan haba radiasi bersih dari pemukaan bawah.

(**40 marks**/*markah*)

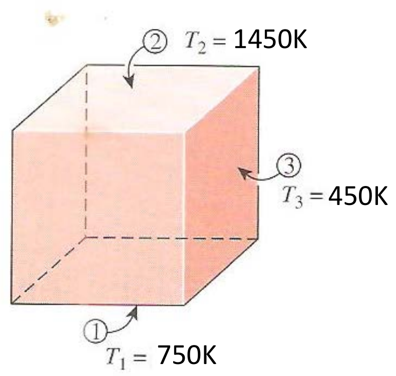

Figure Q5[b]
Rajah S5[b]

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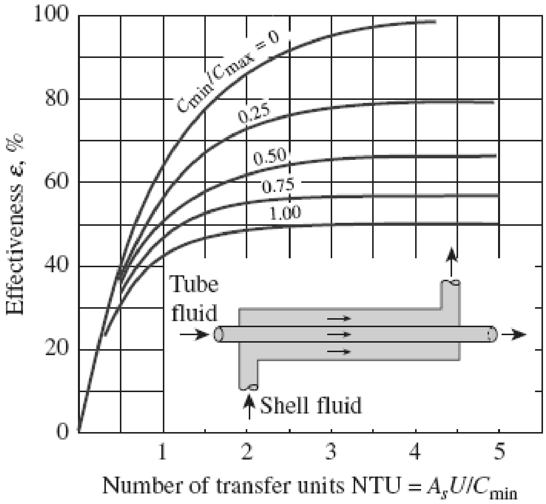
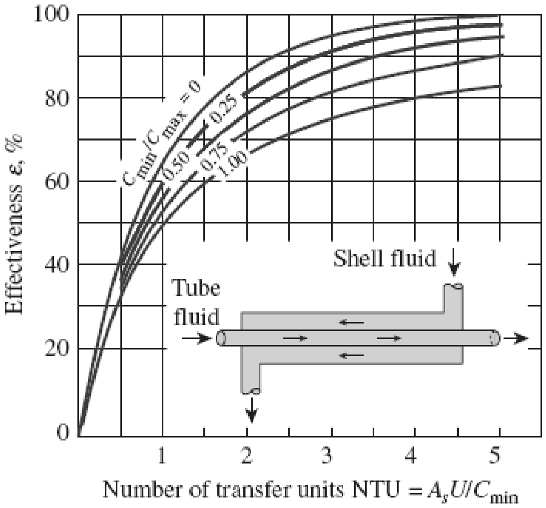
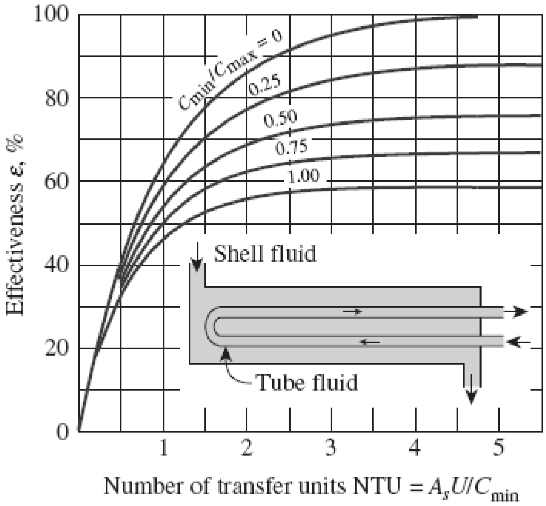
APPENDIX 1
LAMPIRAN 1



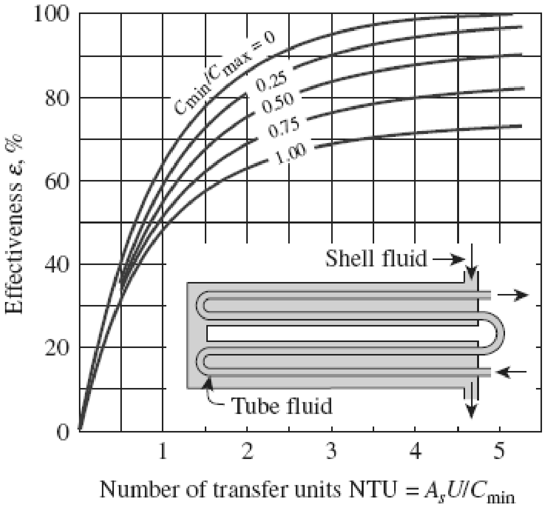
(*a*) Parallel-flow



(*b*) Counter-flow

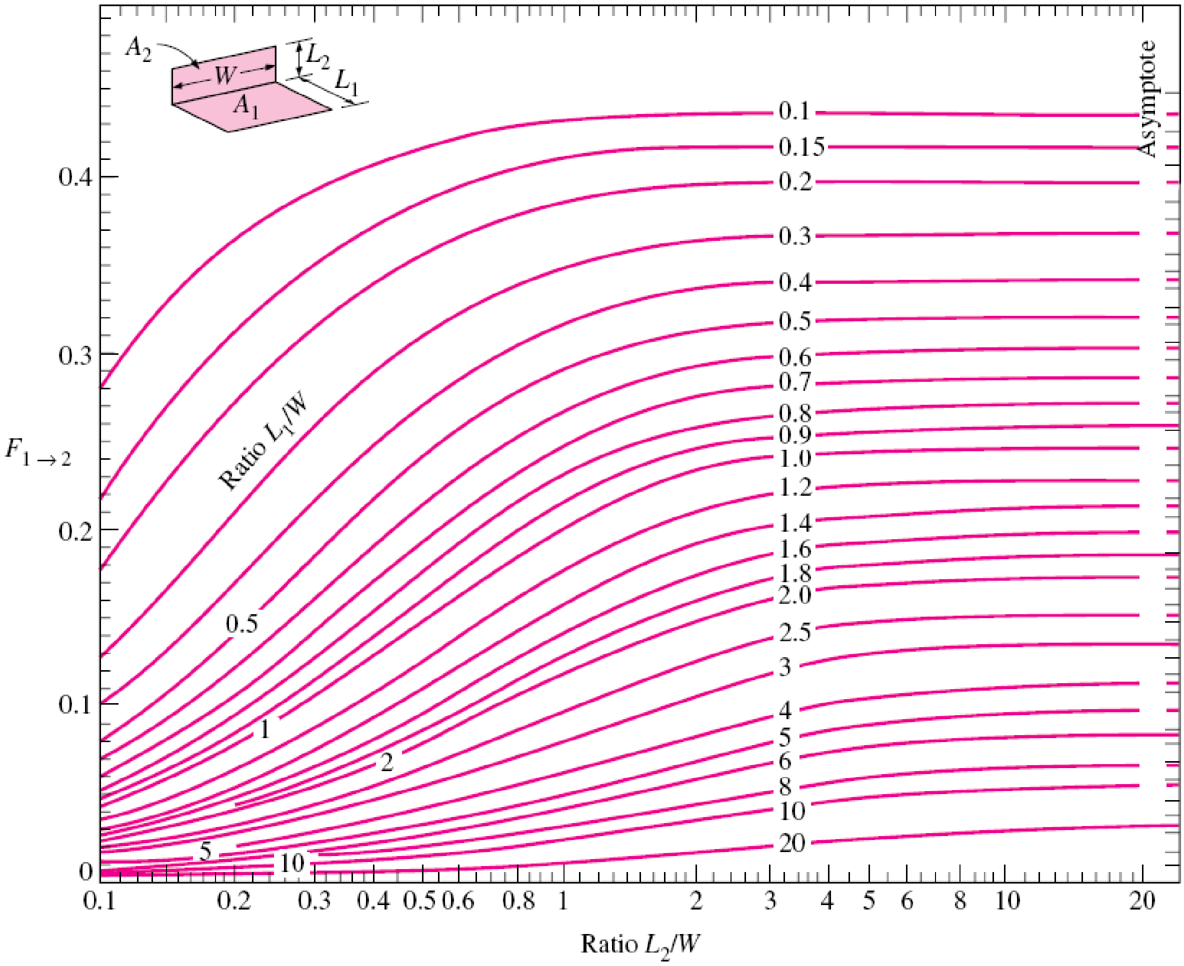


(*c*) One-shell pass and 2, 4, 6, … tube passes



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

APPENDIX 2
LAMPIRAN 2



APPENDIX 3
LAMPIRAN 3

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APPENDIX

TABLE A–3
Properties of solid metals

Properties of Various Temperature (K), K(W/m.K)/C_p(J/Kg.K)

Composition	Melting Point, K	ρ kg/m^3 (Properties at 300 K)	c_p J/kg·K	k W/m·K	$\alpha \times 10^6$ m^2/s	100	200	400	600
Aluminum:									
Pure	933	2702	903	237	97.1	302	237	240	231
						482	798	949	1033
Alloy 2024-T6 (4.5% Cu, 1.5% Mg, 0.6% Mn)	775	2770	875	177	73.0	65	163	186	186
						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 (90% Cu, 10% Al)	1293	8800	420	52	14		42	52	59
							785	160	545
Phosphor gear bronze (89% Cu, 11% Sn)	1104	8780	355	54	17		41	65	74
							—	—	—
Cartridge brass (70% Cu, 30% Zn)	1188	8530	380	110	33.9	75	95	137	149
							360	395	425
Constantan (55% Cu, 45% Ni)	1493	8920	384	23	6.71	17	19		
						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% Si ≤ 0.1%)		7854	434	60.5	17.7			56.7	48.0
								487	559
AISI 1010		7832	434	63.9	18.8			58.7	48.8
							487	559	685
Carbon–silicon (Mn ≤ 1% 0.1% < Si ≤ 0.6%)		7817	446	51.9	14.9			49.8	44.0
								501	582

APPENDIX 4
LAMPIRAN 4

TABLE A–3

Properties of solid metals

Composition	Melting Point, K	Properties at 300 K: ρ kg/m³	c_p J/kg·K	k W/m·K	$\alpha \times 10^6$ m²/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