KOLEJ UNIVERSITI TEKNOLOGI TUN HUSSEIN ONN

PEPERIKSAAN AKHIR
SEMESTER I
SESI 2006/2007

NAMA MATA PELAJARAN : **PEMINDAHAN HABA**

KOD MATA PELAJARAN : **BDA 3063/BKM 3333/BKM 4033**

KURSUS : BTJ/BKJ

TARIKH PEPERIKSAAN : NOVEMBER 2006

JANGKA MASA : 3 JAM

ARAHAN :

1. JAWAB **EMPAT (4)** DARIPADA **TUJUH (7)** SOALAN
2. SIMBOL YANG DIGUNAKAN MEMPUNYAI TAKRIFAN YANG LAZIM KECUALI JIKA DINYATAKAN SEBALIKNYA.
3. NYATAKAN ANDAIAN YANG DIBUAT BAGI SETIAP SOALAN.

KERTAS SOALAN INI MENGANDUNGI 11 MUKA SURAT

S1 Dinding sebuah relau dibalut dengan penebat (k = 0.05 W/m K). Kehilangan haba berlaku secara olakan dari permukaan luar penebat melalui pekali pemindahan haba 10 W/m^2 K ke persekitaran yang bersuhu 27^o C seperti yang ditunjukkan dalam **Rajah S1**.

(a) Relau dibakar oleh oleh gas semulajadi yang mempunyai nilai kalori 30 MJ/m^3 dan ketumpatan 0.8 kg/m^3. Jika kos gas ialah RM 1.00 per kg, kira kos gas per kWh haba yang hilang melalui dinding.

(c) Jika suhu operasi relau ialah 600^o C, kira ketebalan ekonomi penebat. Bahan penebat bernilai RM 1000 per m^3 dan nilai faedah ke atasnya ialah 5%. Andaikan aliran haba 1-D melalui penebat.

(25 markah)

S2 (a) Dinding sebuah pesawat angkasa terdiri daripada lapisan aluminium setebal 5 mm dan penebat setebal 50 mm. Kekonduksian terma penebat ialah 0.02 W/m K dan permukaan luarnya mempunyai kepancaran 0.1. Suhu di dalam pesawat ialah 25^o C dan suhu langit berkesan ialah -200^o C seperti yang ditunjukkan dalam **Rajah S2a**.

(i) Tunjukkan bahawa suhu kulit pesawat angkasa ialah kira-kira -25^o C apabila berada di orbit.

(ii) Kira kehilangan haba per unit luas permukaan pesawat.

(b) Lakarkan profil suhu bagi sebuah rod yang mempunyai nilai panjang tertentu, yang menghubungkan dua takungan yang berada pada suhu mantap 100^o C dan 0^o C. Suhu persekitaran ialah 20 ^oC. Apakah keadaan-keadaan yang menyebabkan hal-hal berikut wujud pada profil:

(i) titik lengkok balas; dan

(ii) kecerunan suhu sifar?

(25 markah)

S3 (a) Sebuah cerek elektrik mempunyai gegelung pemanas seperti dalam Rajah 3. Bahagian luaran gegelung pemanas terdiri daripada lapisan nipis keluli tahan karat (*stainless steel*) dan penebat seramik mempunyai nilai kekonduksian terma, k = 0.25 W/mK. Wayar yang ditunjukkan berdiameter 2 mm dengan nilai kekonduksian terma, k = 14 W/mK dengan rintangan terma 2 x $10^{-6}\Omega$m. Suhu maksimum wayar ketika operasi adalah 550°C. Dengan mengambil suhu air = 20°C dan pekali pemindahan haba = 500 W/m^{2}K:

(i) Lakarkan agihan suhu jejarian di dalam gegelung;

(ii) Kirakan arus di dalam wayar semasa operasi; dan

(iii) Nyatakan pandangan anda sekiranya sirip keluli tahan karat digunakan untuk menggantikan lapisan sedia ada. Berikan justifikasi.

(b) Sebuah bekas berbentuk silinder berdiameter 1 meter dan 2 meter tinggi mengandungi sisa nuklear dan ditanam di dalam tanah. Ianya mempunyai kekonduksian terma 0.52 W/mK. Bekas tersebut menjana kuasa 100W secara mantap. Suhu permukaan tanah ialah 30°C. Sekiranya suhu silinder tidak boleh melebihi 100°C, kirakan kedalaman silinder itu perlu ditanam.

(25 markah)

S4 Haba dipindahkan daripada enjin motosikal kepada atmosfera yang bersuhu 20°C yang mengalir melalui sirip aluminium. Sirip tersebut boleh dianggap sesuhu (pada suhu 140°C) dan aliran udara pada sirip boleh dianggap sama seperti aliran di atas plat rata. Sirip tersebut mempunyai panjang 200 mm dan 100 mm tinggi dengan ketebalan 3 mm. Sekiranya jumlah sirip adalah 8 unit dan jumlah haba yang perlu dibuang daripada enjin ialah 2 kW, kirakan:

(i) Halaju motosikal itu perlu bergerak untuk menyingkirkan humlah haba yang dijana tersebut; dan

(ii) Adakah penyelesaian dalam soalan S4(i) diatas praktikal? Sekiranya tidak, sila cadangkan penambahbaikan dengan meningkatkan nilai pekali pemindahan haba.

(25 markah)

S5 (a) Sebuah alat transistor berbentuk disk dengan diameter 0.1 m, dipasang pada sebuah blok aluminium pada suhu 300 K seperti yang ditunjukkan dalam **Rajah 5**. Transistor tersebut dilekatkan pada blok aluminium menggunakan lapisan *epoxy resin* yang memberikan rintangan sentuh 5 x 10-5 m^2K/W. Media ambien adalah udara tenang pada 300 K. Jika suhu maksima operasi alat adalah 355 K, tentukan kehilangan haba maksima.

(b) Sebuah rumah dua tingkat dicadang untuk dibina dengan sebuah alat penyaman udara dipasang pada salah satu aras rumah tersebut. Berdasarkan kehilangan haba olakan secara semulajadi, aras yang manakah akan disejukkan. Terangkan jawapan anda.

(25 markah)

S6 Sebuah penukar haba jenis *shell-and-tube* terdiri daripada satu laluan pada bahagian *shell* dan satu laluan pada bahagian tiub. Dua konfigurasi yang mungkin bagi alat penukar haba tersebut adalah seperti dalam **Rajah 6**. Air bertekanan memasuki tiub pada suhu 30°C manakala gas bertekanan tinggi mengalir pada bahagian *shell* pada suhu 300°C. pekali pemindahan haba pada bahagian laluan gas adalah 100 W/m^2K. Halaju air yang mengalir dalam tiub ialah 2 m/s. Kadar alir gas pada bahagian masukan penukar haba adalah 5 kg/s. Kira suhu keluaran bagi setiap kes.

Spesifikasi alat penukar haba adalah seperti berikut:

diameter *shell* = 1.5 m

panjang *shell* = 5 m

diameter tiub = 25 mm

ketebalan tiub =2.5 mm

bilangan tiub = 2000

bahan tiub = stainless steel AISI 304

Sifat-sifat udara boleh diambil sebagai sifat gas.

(25 markah)

S7 Sebuah alat pengganding suhu berdiameter 2 mm (ε = 0.6) diletakkan pada paip berdiamater 100 mm dengan suhu dinding paip 20°C seperti yang ditunjukkan dalam **Rajah 7**. Alat pengganding suhu tersebut digunakan untuk mengukur suhu gas panas yang mengalir melalui paip. Permukaan dalam paip mempunyai kebolehpancaran 0.8. Alat pengganding suhu menunjukkan bacaan 200°C. Bagi tujuan memperbaiki ketepatan alat pengganding suhu dan mengurangkan kehilangan haba disebabkan radiasi dari wayar, suatu plat nipis pelindung berdiameter 10 mm dicadang untuk diletakkan di mengelilingi pengganding suhu tersebut. Berapakah kebolehpancaran pelindung, ε_s yang diperlukan bagi mengurangkan kehilangan haba sebanyak 50%?

(25 markah)

S1 The walls of a furnace are covered with an insulation (k = 0.05 W/m K). Heat is lost by convection from the outer surface of insulation through a heat transfer coefficient of 10 W/m^2 K to an ambient at 27^0 C as shown in **Figure 1**.

(a) The furnace is fired by natural gas having a calorific value of 30 MJ/m^3 and a density of 0.8 kg/m^3. If gas costs RM 1.00 per kg, calculate the cost of gas per kWh of heat lost through the wall.

(b) If the furnace operating temperature is 600^0 C, calculate the economic thickness of insulation. The insulation material costs RM 1000 per m^3 and interest on it is at 5%. Assume 1-D heat flow through the insulation.

(25 marks)

S2 (a) The wall of a space shuttle consists of a 5 mm thick layer of aluminum and a 50 mm thick layer of insulation. The thermal conductivity of the insulation is 0.02 W/m K and its outer surface has an emissivity of 0.1. The temperature inside the shuttle is 25^0 C and the effective sky temperature is -200^0 C as shown in **Figure 2**.

(i) Show that the temperature of the shuttle skin is about -25^0 C when in orbit.
(ii) Calculate the heat loss per unit area of shuttle surface.

(b) Sketch the temperature profile in a rod of finite length connecting two reservoirs at steady temperatures of 100^0 C and 0^0 C. The ambient temperature is 20^0 C. Under what conditions will the following occur in the profile: (i) an inflexion point and (ii) a zero temperature gradient?

(25 marks)

S3 (a) An electric water-heating kettle has heating coils with a construction as shown In **Figure 3**. The outer stainless sheath is thin and the ceramic insulation has k = 0.25 W/m K. The 2 mm diameter wire has k = 14 W/m K and an effective electrical resistivity of 2 x 10^{-6} Ω.m. The maximum operating temperature of the wire is 550^0 C. Take the temperature of water as 20^0 C and the waterside heat transfer coefficient as 500 W/m^2 K.

(i) Sketch the radial temperature distribution in the coil.

(ii) Calculate the current rating of the wire.

(iii) Do you recommend placing fins of stainless steel over the stainless steel sheath on the water side? Give reasons for your answer.

(b) A cylindrical canister 1.0 m diameter and 2m long, containing nuclear wastes is buried in the earth, whose effective thermal conductivity is 0.52 W/m K. The canister steadily generates 100 W. The surface temperature of earth is 30^0 C. If the surface temperature of the cylinder is not to exceed 100^0 C, calculate the maximum depth at which the cylinder may be buried in the ground.

(25 marks)

S4 Heat is removed from the cylinder head of a motorcycle engine by atmospheric air at 20^0 C that flows past aluminum fins that are provided on the engine. The fins can be taken to be isothermal (140^0 C) and airflow past a fin can be approximated as flow past a flat plate. The fins are 200 mm long and 100 mm in height. The number of fins is eight. The fins are 3 mm thick. The required heat removal rate through the fins is 2.0 kW.

(i) At what speed should the motor cycle be traveling to dissipate this quantity of heat?

(ii) Is this solution reasonable? If not, what would your suggestion be, to achieve the heat removal through a higher heat transfer coefficient?

(25 marks)

S5 (a) A power transistor, shaped as a disc 0.1 m in diameter, is mounted flush on a large aluminum block at 300 K as shown in **Figure 5.** It is bonded to the block by a layer of epoxy resin, which offers a contact resistance of 5 x 10^{-5} m^2

K/W. The ambient medium is quiescent air at 300 K. If the maximum operating temperature of the device is 355 K, calculate the maximum heat dissipation.

(b) It is proposed to build a house with two floors and air-condition one of the floors. Based on natural convection heat loss, which floor should be air-conditioned? Explain your choice.

(25 marks)

S6 A shell-and-tube heat exchanger has a single pass on the shell-side and a single pass on the tube-side. Its two possible configurations are shown in **Figure 6**. Pressurized water enters the tubes at 30^0 C and a high pressure gas at 300^0 C flows on the shell side. The heat transfer coefficient on the gas side is 100 W/m^2 K. Water flows with a velocity of 2 m/s through the tubes. Gas flow rate at entry to the heat exchanger is 5 kg/s. Calculate the outlet temperatures in each case. The geometric details of the heat exchanger are as below:

Shell diameter = 1.5 m, Shell length = 5m, Tube diameter = 25 mm, Tube thickness = 2.5 mm, Number of tubes in the shell = 2000. Material of the tube = Stainless steel AISI 304.

Properties of gas may be approximated as that of air.

(25 marks)

S7 A 2 mm diameter thermocouple junction ($\boldsymbol{\varepsilon}$= 0.6) is placed as shown in **Figure 7** within a pipe of 100 mm diameter whose walls are at 20^0 C. The thermocouple measures the temperature of the hot gas flow through the pipe. The pipe inner surface has an emissivity 0.8. The thermocouple reads 200^0 C. In order to reduce the radiation heat loss from the wire and improve the accuracy of the thermocouple, a thin shield of 10 mm diameter is proposed to be placed around it. What is the emissivity of the shield, $\boldsymbol{\varepsilon_s}$, is required to reduce the heat loss by 50 %?

(25 marks)

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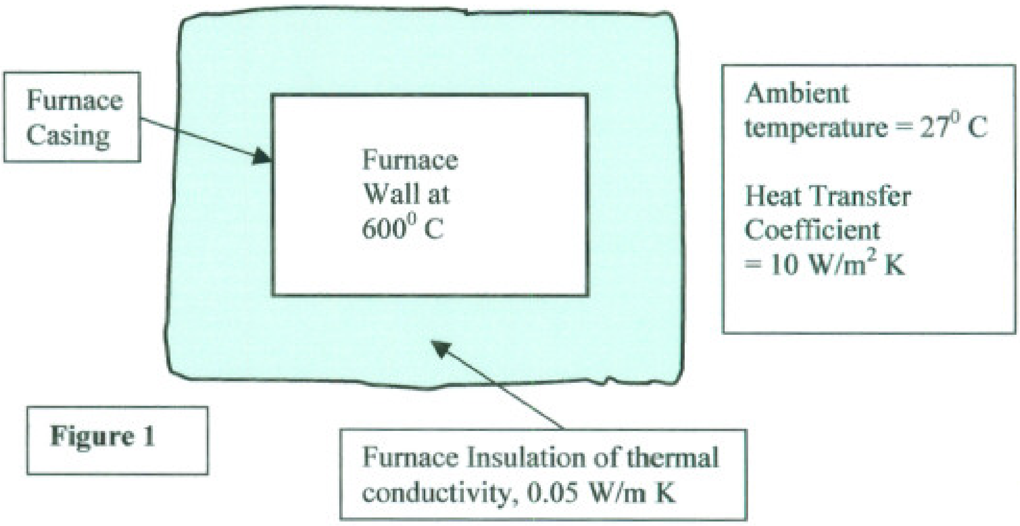

Figure 1

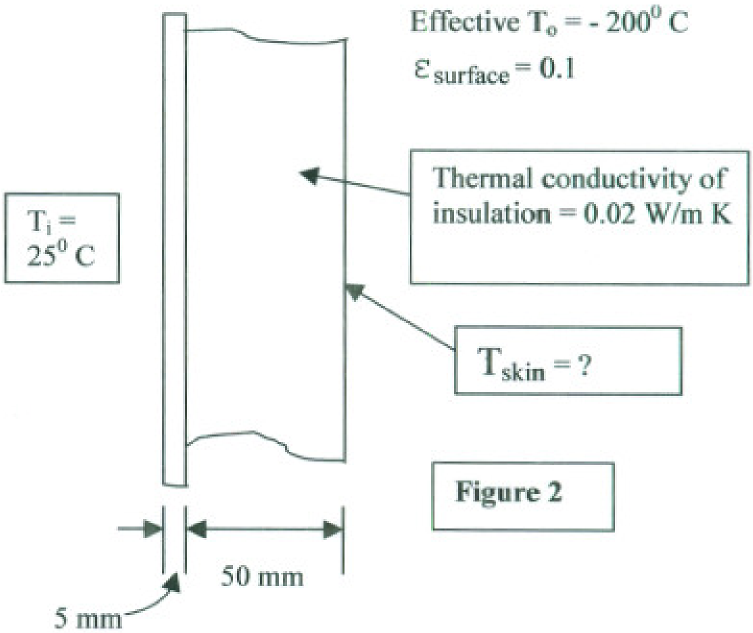

Figure 2

PEPERIKSAAN AKHIR

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MATA PELAJARAN : PEMINDAHAN HABA
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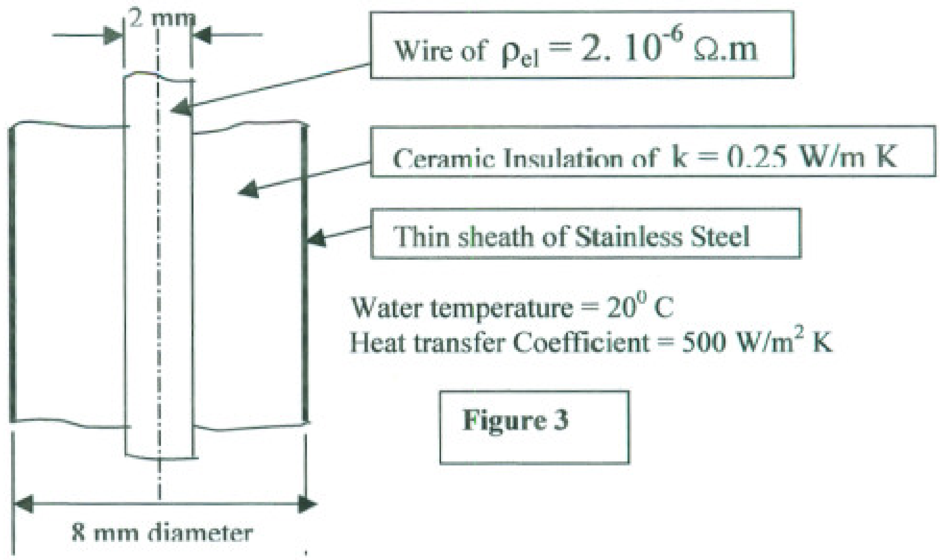

Figure 3

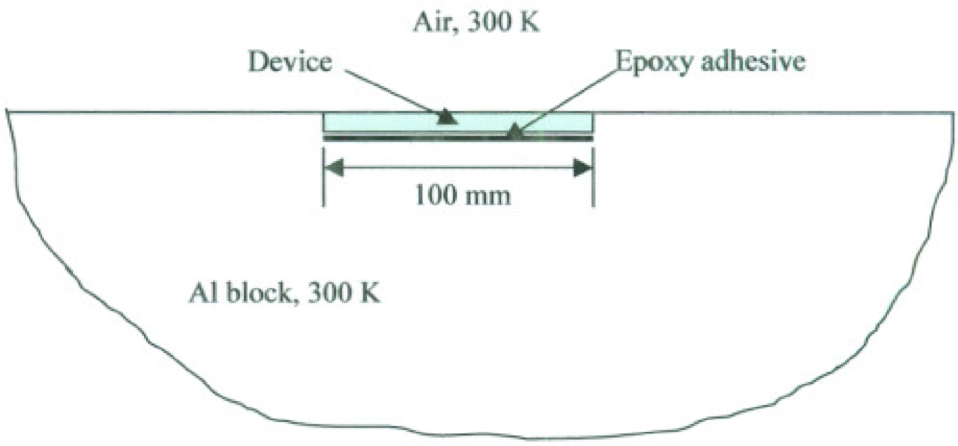

Figure 5

PEPERIKSAAN AKHIR

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MATA PELAJARAN : PEMINDAHAN HABA KOD MATA PELAJARAN : BDA 3063

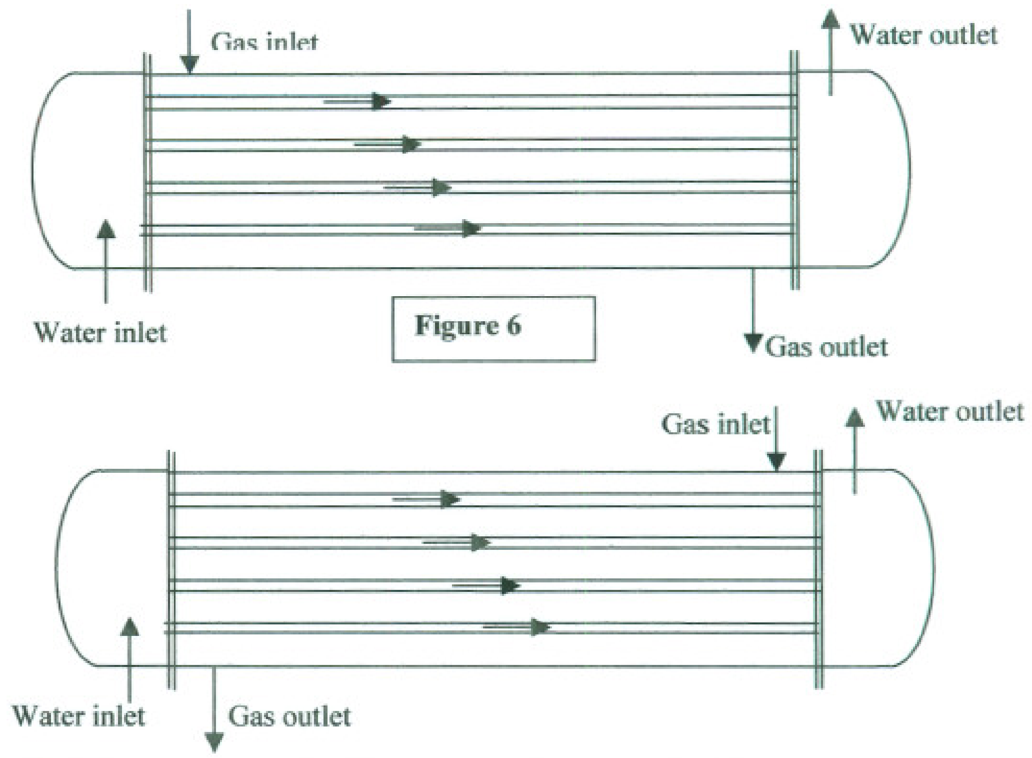
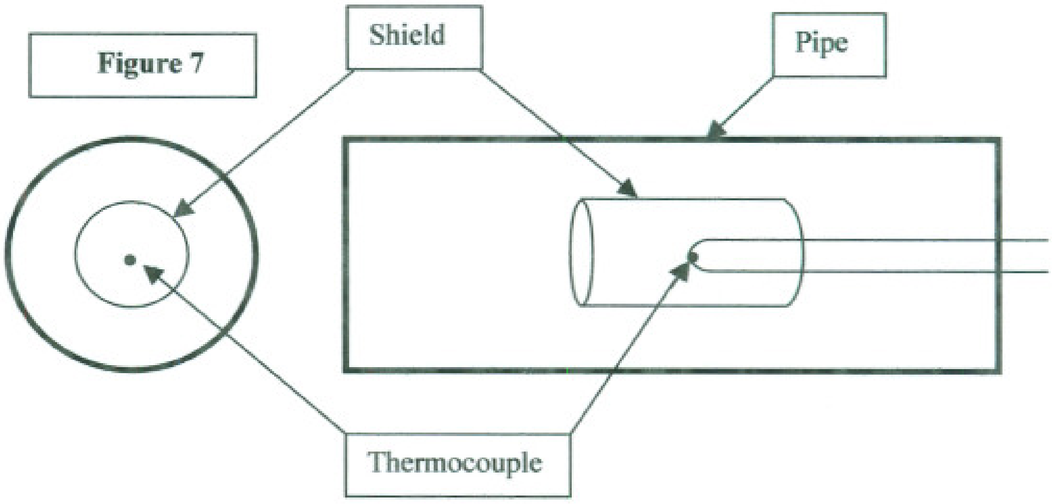


Figure 6

Figure 7



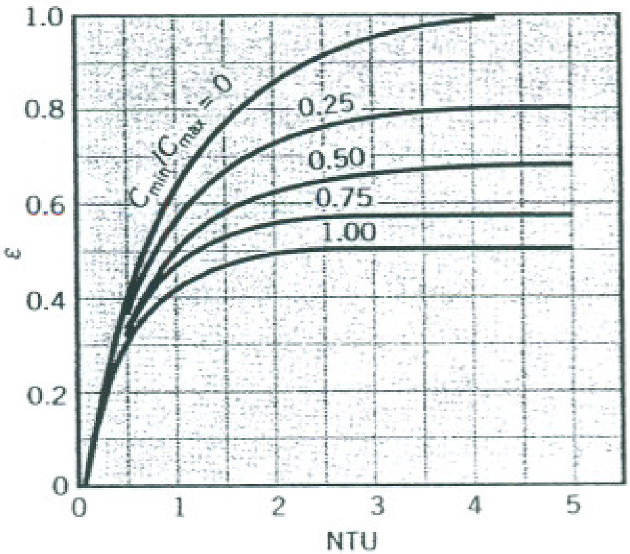


FIGURE 11.14 Effectiveness of a parallel-flow heat exchanger (Equation 11.29).

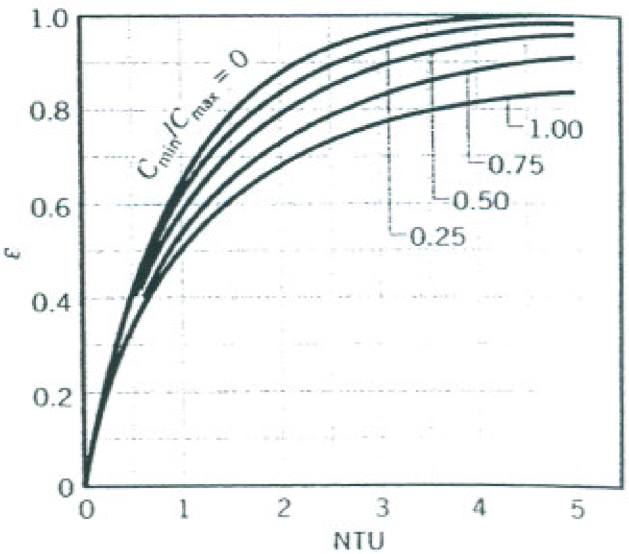
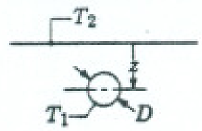
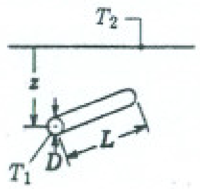
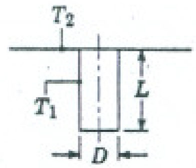
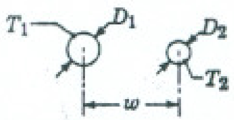
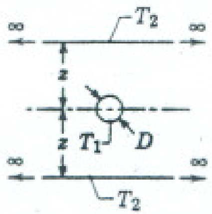
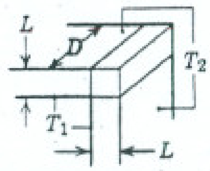
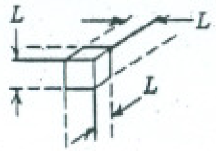
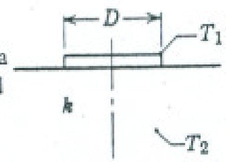
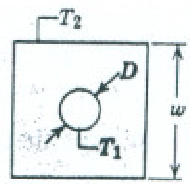
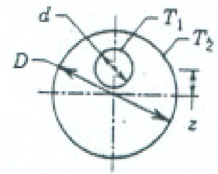


FIGURE 11.15 Effectiveness of a counterflow heat exchanger (Equation 11.30).

TABLE 11.3 Heat Exchanger Effectiveness Relations [5]

Flow Arrangement	Relation		
Concentric tube			
Parallel flow	$\varepsilon = \frac{1 - \exp[-\text{NTU}(1 + C_r)]}{1 + C_r}$		(11.29a)
Counterflow	$\varepsilon = \frac{1 - \exp[-\text{NTU}(1 - C_r)]}{1 - C_r \exp[-\text{NTU}(1 - C_r)]}$	$(C_r < 1)$	
	$\varepsilon = \frac{\text{NTU}}{1 + \text{NTU}}$	$(C_r = 1)$	(11.30a)
Shell and tube			
One shell pass (2, 4, . . . tube passes)	$\varepsilon_1 = 2\left\{1 + C_r + (1 + C_r^2)^{1/2} \times \frac{1 + \exp[-\text{NTU}(1 + C_r^2)^{1/2}]}{1 - \exp[-\text{NTU}(1 + C_r^2)^{1/2}]}\right\}^{-1}$		(11.31a)
n Shell passes (2*n*, 4*n*, . . . tube passes)	$\varepsilon = \left[\left(\frac{1 - \varepsilon_1 C_r}{1 - \varepsilon_1}\right)^n - 1\right]\left[\left(\frac{1 - \varepsilon_1 C_r}{1 - \varepsilon_1}\right)^n - C_r\right]^{-1}$		(11.32a)
Cross flow (single pass)			
Both fluids unmixed	$\varepsilon = 1 - \exp\left[\left(\frac{1}{C_r}\right)(\text{NTU})^{0.22}\{\exp[-C_r(\text{NTU})^{0.78}] - 1\}\right]$		(11.33)
C_{max} (mixed), C_{min} (unmixed)	$\varepsilon = \left(\frac{1}{C_r}\right)(1 - \exp\{-C_r[1 - \exp(-\text{NTU})]\})$		(11.34a)
C_{max} (mixed), C_{min} (unmixed)	$\varepsilon = 1 - \exp(-C_r^{-1}\{1 - \exp[-C_r(\text{NTU})]\})$		(11.35a)
All exchangers ($C_r = 0$)	$\varepsilon = 1 - \exp(-\text{NTU})$		(11.36a)

Conduction shape factors for
selected two-dimensional systems [$q = Sk(T_1 - T_2)$]

SYSTEM	SCHEMATIC	RESTRICTIONS	SHAPE FACTOR
Isothermal sphere buried in a semiinfinite medium		$z > D/2$	$\dfrac{2\pi D}{1 - D/4z}$
Horizontal isothermal cylinder of length L buried in a semiinfinite medium		$L \gg D$ $L \gg D$, $z > 3D/2$	$\dfrac{2\pi L}{\cosh^{-1}(2z/D)}$ $\dfrac{2\pi L}{\ln(4z/D)}$
Vertical cylinder in a semiinfinite medium		$L \gg D$	$\dfrac{2\pi L}{\ln(4L/D)}$
Conduction between two cylinders of length L in infinite medium		$L \gg D_1, D_2$ $L \gg w$	$\dfrac{2\pi L}{\cosh^{-1}\left(\dfrac{4w^2 - D_1^2 - D_2^2}{2D_1D_2}\right)}$
Horizontal circular cylinder of length L midway between parallel planes of equal length and infinite width		$z \gg D/2$ $L \gg z$	$\dfrac{2\pi L}{\ln(8z/\pi D)}$
Conduction through the edge of adjoining walls		$D > L/5$	$0.54D$
Conduction through corner of three walls with a temperature difference of ΔT_{1-2} across the walls		$L \ll$ length and width of wall	$0.15L$
Disk of diameter D and T_1 on a semiinfinite medium of thermal conductivity k and T_2		None	$2D$
Circular cylinder of length L centered in a square solid of equal length		$w > D$ $L \gg w$	$\dfrac{2\pi L}{\ln(1.08\, w/D)}$
Eccentric circular cylinder of length L in a cylinder of equal length		$D > d$ $L \gg D$	$\dfrac{2\pi L}{\cosh^{-1}\left(\dfrac{D^2 + d^2 - 4z^2}{2Dd}\right)}$