UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 1996/97

April 1997

EMK 203 - Termodinamik Gunaan

Masa : [3 jam]

ARAHAN KEPADA CALON:

Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEMBILAN** muka surat serta 2 lampiran dan **TUJUH** soalan yang bercetak sebelum anda memulakan peperiksaan ini.

Jawab **LIMA** soalan dengan memilih sekurang-kurangnya **DUA** dari Bahagian A dan **DUA** dari Bahagian B.

Sekurang-kurangnya satu (1) soalan mesti dijawab dalam bahasa Malaysia. Soalan-soalan lain boleh dijawab sama ada dalam bahasa Malaysia atau bahasa Inggeris.

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BAHAGIAN A:

S1. [a] Dua gas bercampur secara adiabatik di dalam sebuah tiub berisipadu tetap. Berikan persamaan suhu campuran tersebut dengan menggunakan hukum termodinamik pertama.

Two gases mix adiabatically in a constant volume vessel. Obtain the equation for temperature of the mixture using first law of thermodynamics.

(30 markah)

[b] Dua tiub bersambungan dengan sebuah paip yang mempunyai injap. Satu tiub berisipadu 0.3 m^3 mengandungi udara pada 7 bar dan 32°C, dan satu lagi mengandungi 0.03 m^3 oksigen pada 21 bar dan 15°C. Injap dibuka dan dua gas dibenarkan bercampur. Anggapkan sistem ini terbebat dengan sempurna, kirakan:

[i] C_p, C_v, R dan M campuran,
[ii] suhu akhir campuran,
[iii] tekanan akhir campuran.

Diberi C_v untuk N_2 and O_2 masing-masing adalah 20.825 $\frac{kJ}{kmole\ K}$ dan 21.07 $\frac{kJ}{kmole\ K}$. Udara hanya mengandungi oksigen dan nitrogen.

Two vessels are connected by a pipe in which there is a valve. One vessel of 0.3 m^3 contains air at 7 bar and 32°C, and the other of 0.03 m^3 contains oxygen at 21 bar and 15°C. The valve is opened and the two gases are allowed to mix. Assuming that the system is well lagged, calculate:

[i] C_p, C_v, R and M of the mixture,
[ii] final temperature of the mixture,
[iii] final pressure of the mixture.

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Take C_v for N_2 and O_2 as 20.825 $\frac{\text{kJ}}{\text{kmole K}}$ *and* 21.07 $\frac{\text{kJ}}{\text{kmole K}}$ *respectively. Air consists only oxygen and nitrogen.*

(70 markah)

S2. [a] **Terangkan proses-proses pembakaran biasa dan tak biasa dalam SI dan CI enjin.**

Explain the normal and abnormal combustion processes in SI and CI engines.

(50 markah)

[b] **Sebuah enjin empat-lejang, pencucuhan bunga api mempunyai enam silinder. Jara = 85 mm, lejang = 75 mm. Nisbah mampatan = 9. Nilai kalori bahanapi = 44 MJ/kg. Ujian ke atas enjin memberi keputusan-keputusan berikut:-**

Laju	=	**5000 pusingan/min,**
Kilas keluaran	=	**177.6 Nm,**
Kadar aliran bahanapi	=	**27 kg/jam,**
Aliran udara	=	**340 m^3/jam pada keadaan ambien,**
Tekanan ambien	=	**1.1 bar,**
Suhu ambien	=	**17°C,**

Kilasan yang dikehendaki untuk enjin motor = 18.2 Nm.

Kirakan brek dan nyatakan kecekapan-kecekapan haba, kecekapan mekanik, kegunaan bahanapi tentu bagi brek, nisbah udara-bahanapi dan kecekapan isipadu.

A four-stroke, spark ignition engine has six cylinders. Bore = 85 mm, stroke = 75 mm. Compression ratio = 9. Calorific valve of fuel = 44 MJ/kg. A test on the engine gave the following results:

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Speed	=	*5000 rev/min,*
Output torque	=	*177.6 Nm,*
Fuel flow rate	=	*27 kg/h,*
Air flow	=	*340 m^3/h at ambient conditions,*
Ambient pressure	=	*1.1 bar,*
Ambient temperature	=	*17°C,*
Torque required to motor engine	=	*18.2 Nm.*

Calculate the brake and indicated thermal efficiencies, mechanical efficiency, brake specific fuel consumption, air-fuel ratio, and volumetric efficiency.

(50 markah)

S3. [a] **Mengapakah antara penyejukan penting bagi sebuah pemampat salingan udara? Tentukan keadaan minimum kerja mampatan bagi sebuah pemampat.**

Why is intercooling necessary in a multistage reciprocating air compressor? Obtain the condition for minimum compression work for such a compressor.

(40 markah)

[b] **Tindakan salingan tunggal dua peringkat bagi sebuah pemampat udara mempunyai silinder tekanan rendah 250 mm garispusat dengan 250 mm lejang. Tekanan dan suhu pengambilan masing-masing adalah 100 kN/m^2 dan 20°C. Tekanan hantaran adalah 700 kN/m^2 dan pemampat bekerja pada 5 pusingan/s. Indeks politropik adalah 1.3 semasa mampatan dan pengembangan. Tekanan peralihan adalah unggul dan antara penyejukan adalah lengkap. Kecekapan keseluruhan bagi loji adalah 70%. Isipadu kelegaan adalah 5% daripada isipadu tersapu. Tentukan:**

[i] kadar aliran jisim bagi udara yang melalui pemampat,
[ii] kuasa masukan bagi menjalankan pemampat.

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A two stage single acting reciprocating air compressor has a low pressure cylinder 250 mm diameter with a 250 mm stroke. The intake pressure and temperature are 100 kN/m^2 and 20°C respectively. Delivery pressure is 700 kN/m^2 and compressor runs at 5 rev/s. The polytropic index is 1.3 during compression and expansion. The intermediate pressure is ideal and intercooling is complete. The overall efficiency of the plant is 70%. The clearance volume is 5% of swept volume. Determine:

[i] mass flow rate of air through compressor,
[ii] power input to drive compressor.

(60 markah)

S4. [a] Takrifkan kelembapan mutlak dan tunjukkan persamaannya yang berhubungan dengan tekanan separa.

Define absolute humidity and derive the equation for its relationship with partial pressure.

(20 markah)

[b] Tunjukkan proses-proses berikut di atas carta psikrometer:

[i] penyejukan dan penyahlembapan,
[ii] penyahlembapan kimia,
[iii] pencampuran arus udara,
[iv] haba pendam dan penyejukan.

Show the following processes on psychrometric chart:

[i] cooling and dehumidification,
[ii] chemical dehumidification,
[iii] mixing of air stream,
[iv] latent heating and cooling.

(20 markah)

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[c] **Bagi seunit penyaman udara 3.5 m^3/s udara pada 27°C DBT, 50 peratus kelembapan nisbi dan tekanan piawai atmosfera masuk ke unit. Keadaan udara keluar adalah 13°C DBT dan 90% kelembapan nisbi. Dengan menggunakan sifat-sifat dari carta psikrometer**

[i] kirakan kemampuan penyejukan dalam kW,
[ii] tentukan kadar pemindahan air dari udara.

In an air-conditioning unit 3.5 m^3/s of air at 27°C DBT, 50 percent relative humidity and standard atmospheric pressure enters the unit. The exit condition of air is 13°C DBT and 90% relative humidity. Using properties from psychrometric chart

[i] calculate the capacity is kW,
[ii] determine the rate of water removal from the air.

(60 markah)

BAHAGIAN B:

S5. Sebuah aci berkeluli panjang 10 sm garispusat dipanaskan di dalam sebuah relau yang mana gas dan dinding pada 1000°C. Aci bermula pada 25°C.

[a] Apakah kadar sinaran bersih pemindahan haba antara dinding relau dan aci dalam unit panjang aci selepas saja pemanasan bermula? Keberpancaran bagi permukaan keluli adalah 0.8.

A long steel shaft of 10 cm diameter is heated in a furnace in which the gas and the wall are at 1000°C. The shaft is initially at 25°C.

[a] What is the rate of net radiation heat transfer between the furnace wall and the shaft per unit length of the shaft right after the start of heating? Emissivity of the steel surface is 0.8.

(35 markah)

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[b] **Jika gabungan pemalar pemindahan haba adalah 100 W/m^{2}K, berapa lamakah masa yang mesti aci ditinggalkan di dalam relau bagi suhu garis tengah mencapai 550°C ?**

If the combined heat transfer coefficient is 100 W/m^{2}K, how long must the shaft remain in the furnace for its centerline temperature to reach 550°C ?

(45 markah)

[c] **Berapakah banyak haba yang telah berpindah pada aci dalam unit panjang bagi tempoh masa yang dikira dalam [b]?**

Bagi keluli khusus: k = 50 W/mK, ρ = 7800 kg/m^3, c_p = 540 J/kgK

How much heat has been transferred to the unit length of the shaft during the period of time calculated in [b]?

For the particular steel: k = 50 W/mK, ρ = 7800 kg/m^3, c_p = 540 J/kgK

(20 markah)

S6. **Arus elektrik melalui dinding sebuah paip keluli yang bergarispusat dalaman 20 mm memberi permukaan yang sekata bagi fluks haba 15000 W/m^2. Permukaan luar paip adalah tertebat seluruhnya. Air pada 20°C dan aliran 0.1 kg/s masuk ke dalam tiub.**

[a] **Berapakah panjang paip yang dikehendaki bagi suhu air keluar bagi mencapai 40°C ?**

Electric current through the wall of a steel pipe of inside diameter 20 mm provides a uniform surface heat flux of 15000 W/m^2. The outside surface of the pipe is completely insulated. Water at 20°C and at rate 0.1 kg/s enters the tube.

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[a] *What is the required pipe length for the water outlet temperature to reach 40°C ?*

(30 markah)

[b] **Berapakah suhu permukaan tiub pada alur keluar?**

Bagi air: $\rho = 1000\ kg/m^3$,
$\mu = 800 \times 10^{-6}\ N\text{-}s/m^2$,
$k = 0.62\ W/mK$,
$c_p = 4180\ J/kg\ K$,
$Pr = 5.4$.

What is the tube surface temperature at the outlet?

For water: $\rho = 1000\ kg/m^3$,
$\mu = 800 \times 10^{-6}\ N\text{-}s/m^2$,
$k = 0.62\ W/mK$,
$c_p = 4180\ J/kg\ K$,
$Pr = 5.4$.

(70 markah)

S7. **Kulit dan tiub bagi sebuah penukar haba beroperasi dengan satu tiub, dalam susunan aliran berlawanan. Penukar telah dibuat dari 100 tiub tembaga dengan garispusat dalaman dan luaran masing-masing 6 dan 8 mm bagi setiap 5 m panjang. Penukar digunakan bagi menyejuk 1 kg/s minyak enjin yang mana pada 140°C. Air penyejuk pada kadar 2 kg/s dan 15°C tersedia. Minyak mengalir di dalam tiub dengan h_i = 300 W/m^2 K dan air mengalir pada bahagian kulit dengan h_o = 500 W/m^2 K.**

[a] **Kirakan pemalar pemindahan haba keseluruhan berdasarkan luas permukaan luaran tiub (abaikan kekotoran dan rintangan dinding).**

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A shell and tube heat exchanger with one tube pass operates in a counter flow arrangement. The exchanger is made of 100 copper tubes with inner and outer diameters of 6 and 8 mm respectively each 5 m long. The exchanger is used to cool 1 kg/s of engine oil which is at 140°C. Cooling water at a rate of 2 kg/s and at 15°C is available. Oil flows inside tubes with $h_i = 300$ *W/m*^{2} *K and water flows in the shell side with* $h_o = 500$ *W/m*^{2} *K.*

[a] *Calculate the overall heat transfer coefficient based on the tube outside surface area (neglecting fouling and wall resistances).*

(20 markah)

[b] **Apakah nilai kecekapan penukar?**

What is the value of the exchanger effectiveness?

(60 markah)

[c] **Kirakan suhu minyak pada alur keluar.**

$C_{p\ minyak} = 2120$ **J/kg K** $C_{p\ air} = 4180$ **J/kg K**

Calculate the oil outlet temperature.

$C_{p\ oil} = 2120$ *J/kg K* $C_{p\ water} = 4180$ *J/kg K*

(20 markah)

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Summary of convection heat transfer correlations for external flow

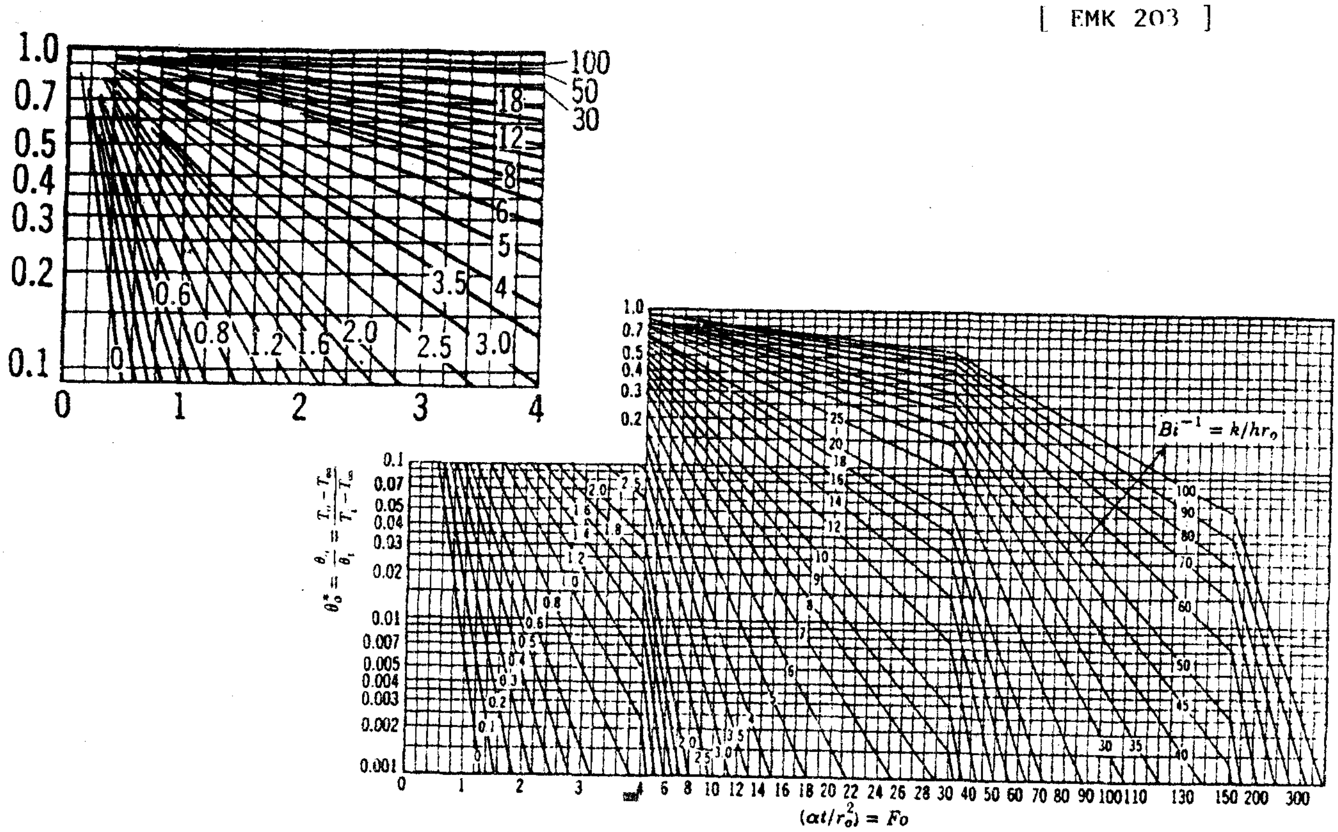
CORRELATION	GEOMETRY	CONDITIONS
$\overline{Nu}_D = 0.3 + [0.62 Re_D^{1/2} Pr^{1/3}] [1 + (0.4/Pr)^{2/3}]^{-1/4} \cdot [1 + (Re_D/282{,}000)^{5/8}]^{4/5}$	Cylinder	Average, T_f, $Re_D Pr > 0.2$
$Nu_x = 0.332 Re_x^{1/2} Pr^{1/3}$	Flat plate	Laminar, local, T_f, $0.6 \leq Pr \leq 50$
$\overline{Nu}_x = 0.664 Re_x^{1/2} Pr^{1/3}$	Flat plate	Laminar, average, T_f, $0.6 \leq Pr \leq 50$
$Nu_x = 0.0296 Re_x^{4/5} Pr^{1/3}$	Flat plate	Turbulent, local, T_f, $Re_x \leq 10^8$, $0.6 \leq Pr \leq 60$

Summary of convection correlations for internal flow

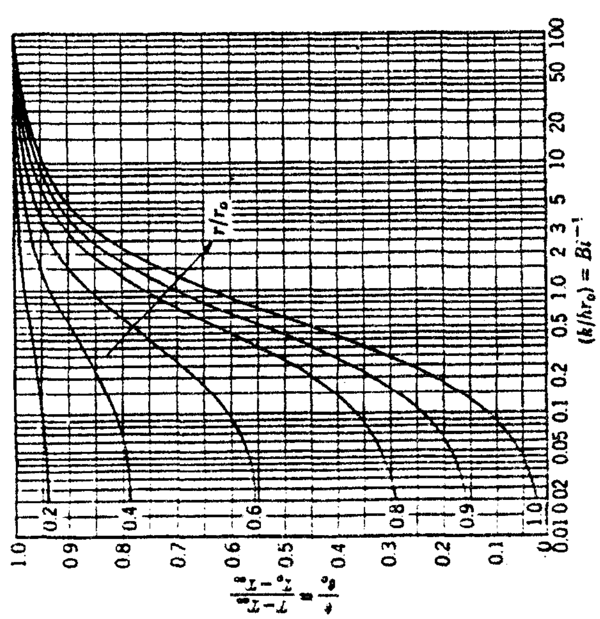
CORRELATION	CONDITIONS
$f = 64/Re_D$	Laminar, fully developed
$Nu_D = 4.36$	Laminar, fully developed, constant q_s'', $Pr \geq 0.6$
$Nu_D = 3.66$	Laminar, fully developed, constant T_s, $Pr \geq 0.6$
$Nu_D = 0.023 Re_D^{4/5} Pr^n$	Turbulent, fully developed, $0.6 \leq Pr \leq 160$, $L/D \geq 10$, $n = 0.4$ for $T_s > T_m$ and $n = 0.3$ for $T_s < T_m$ **or n = 1/3**

Heat exchanger effectiveness relations

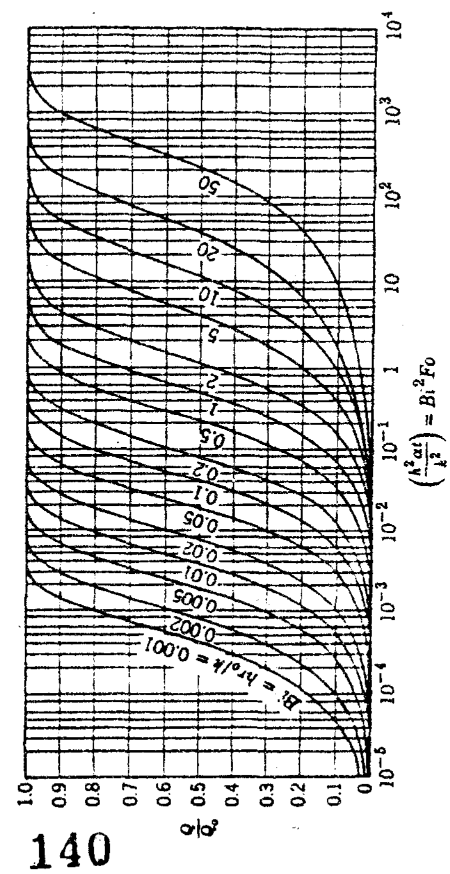
FLOW ARRANGEMENT	RELATION
Concentric tube	
Parallel flow	$\varepsilon = \dfrac{1 - \exp[-NTU(1 + C_r)]}{1 + C_r}$
Counterflow	$\varepsilon = \dfrac{1 - \exp[-NTU(1 - C_r)]}{1 - C_r \exp[-NTU(1 - C_r)]}$
Shell and tube	
One shell pass (2, 4, ... tube passes)	$\varepsilon_1 = 2\left\{1 + C_r + (1 + C_r^2)^{1/2} \times \dfrac{1 + \exp[-NTU(1 + C_r^2)^{1/2}]}{1 - \exp[-NTU(1 + C_r^2)^{1/2}]}\right\}^{-1}$
n Shell passes ($2n$, $4n$, ... tube passes)	$\varepsilon = \left[\left(\dfrac{1 - \varepsilon_1 C_r}{1 - \varepsilon_1}\right)^n - 1\right]\left[\left(\dfrac{1 - \varepsilon_1 C_r}{1 - \varepsilon_1}\right)^n - C_r\right]^{-1}$
Cross flow (single pass)	
Both fluids unmixed	$\varepsilon = 1 - \exp\left[\left(\dfrac{1}{C_r}\right)(NTU)^{0.22}\{\exp[-C_r(NTU)^{0.78}]$
C_{max} (mixed), C_{min} (unmixed)	$\varepsilon = \left(\dfrac{1}{C_r}\right)(1 - \exp\{-C_r[1 - \exp(-NTU)]\})$
C_{min} (mixed), C_{max} (unmixed)	$\varepsilon = 1 - \exp(-C_r^{-1}\{1 - \exp[-C_r(NTU)]\})$
All exchangers ($C_r = 0$)	$\varepsilon = 1 - \exp(-NTU)$



Centerline temperature as a function of time for an infinite cylinder of radius r_o



Temperature distribution in an infinite cylinder of radius r_o



Internal energy change as a function of time for an infinite cylinder of radius r_o