UNIVERSITI SAINS MALAYSIA

Supplementary Semester Examination
Academic Session 2010/2011

June 2011

IEK 212 - PROCESS HEAT TRANSFER
[PEMINDAHAN HABA PROSES]

Duration: 3 hours
Masa: [3 jam]

Please check that this examination paper consists of TWELVE pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi DUABELAS muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer FIVE questions. You may answer the questions either in Bahasa Malaysia or in English.

[Arahan: *Jawab LIMA soalan. Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

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 furnace wall consisting of 0.30 m of fire clay brick (k_1 = 1.56 W/m.K), 0.20 m of kaolin insulating brick (k_2 = 0.173 W/m.K) and a 0.10 m outer layer of masonry brick (k_3 = 0.692 W/m.K) is exposed to furnace gas at 1370 K with air at 300 K adjacent to the outer wall. The inside and outside convective heat transfer coefficients are 115 and 23 $W/m^2.K$, respectively. Determine the heat loss per square meter and the intermediate temperatures between walls..

(100 marks)

2. (a) Benzene condenses at atmospheric pressure on the outside of a 25-mm steel pipe and air at 15°C flows within at 6 m/s. The pipe wall is 3.5 mm thick. h_i = 20 $W/m^2.{}^oC$. h_o = 1,200 $W/m^2.{}^oC$. k_m = 45 $W/m.{}^oC$. Calculate the overall heat transfer coefficients based on both inside and outside areas.

(30 marks)

(b) An organic liquid (c_p = 0.837 $J/g.{}^oC$) flowing at 19,000 kg/h is to be cooled from 85 to 40°C using 13,500 kg/h of cooling water (c_p = 4.1868 $J/g.{}^oC$) at 20°C. The film coefficient for the organic liquid, outside the tubes, is 1,700 $W/m^2.{}^oC$. The wall resistance can be neglected. h_i = 11,000 $W/m^2.{}^oC$. What area is needed if the flow is

(i) countercurrent;
(ii) parallel?

(70 marks)

3. Water is flowing in a horizontal steel pipe of ID 0.0266 m and OD 0.0334 m at an average temperature of 65.6°C and a velocity of 2.44 m/s. It is being heated by condensing steam at 107.8°C on the outside of the pipe wall. The steam side coefficient has been estimated as h_o = 10,500 $W/m^2.K$.

(a) Calculate the convective coefficient h_i for the water inside the pipe.

(b) Calculate the overall coefficient U_i based on the inside surface area.

(c) Calculate the heat-transfer rate for 0.305 m of pipe with the water at an average temperature of 65.6°C.
For water at 65.6°C, Pr = 2.72, ρ = 980 kg/m^3, k = 0.633 W/m.K,
$\mu = 4.32 \times 10^{-4}$ kg/m.s

(100 marks)

4. Water enters a 3.0-cm-diameter tube at 15.56^{o}C and leaves at 37.78^{o}C. The mass flow rate is 1.0 kg/s. and the tube wall temperature is constant at 60^{o}C. Determine the length of the tube. For water, c_p = 4.18 J/kg.^{o}C, k =.0.614 W/m.^{o}C.

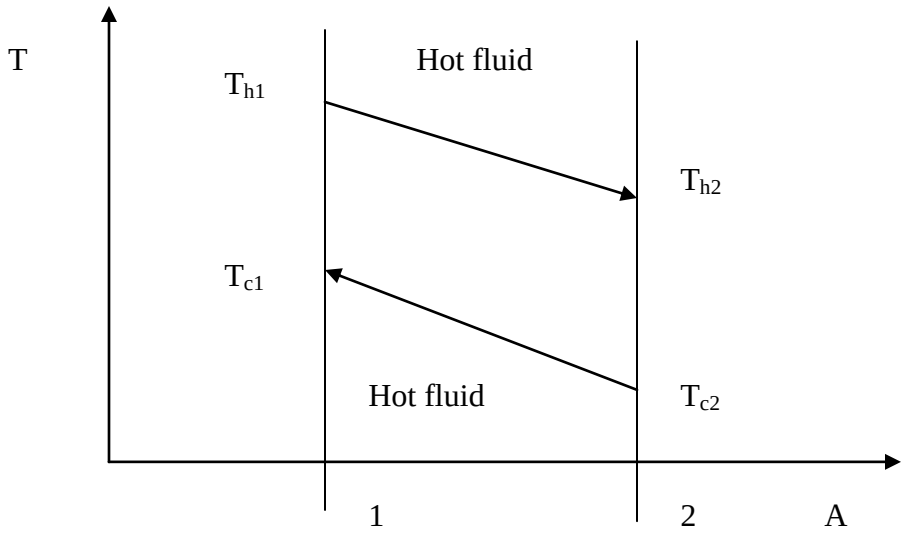
(100 marks)

5. It is desired to use a double-pipe counter-current heat exchanger to cool 3 kg/s of oil (c_p = 2.1 kJ/kg.K) from 120^{o}C. Cooling water (c_p = 4.2 kJ/kg.K) at 20^{o}C enters the heat exchanger at a rate of 10 kg/s. The overall heat transfer coefficient of the heat exchanger is 600 W/m^2.K and the heat transfer area is 6 m^2. Calculate the exit temperature of oil and water.

Given information:

$$\varepsilon = \frac{1 - exp\left[\frac{-UA}{C_{min}}\left(1 - \frac{C_{min}}{C_{max}}\right)\right]}{1 - \frac{C_{min}}{C_{max}}\left[\frac{-UA}{C_{min}}\left(1 - \frac{C_{min}}{C_{max}}\right)\right]} \qquad NTU = \frac{UA}{C_{min}}$$

$$\varepsilon_h = \frac{T_{h1} - T_{h2}}{T_{h1} - T_{c2}} \quad \text{Or} \quad \varepsilon_c = \frac{T_{c1} - T_{c2}}{T_{h1} - T_{c2}}$$



(100 marks)

6. A single effect evaporator is to be used to concentrate a food solution containing 15% (by weight) dissolved solids to 50% solids. The feed stream enters the evaporator at 291 K with a feed rate of 1.0 kg/s. Steam of 0.07 bar is maintained in the evaporator at temperature 399K. Assuming that the properties of the solution are the same as those of water, and taking the overall heat transfer coefficient to be 2.3 $kWm^{-2}K^{-1}$, calculate the rate of steam consumption and the necessary heat transfer surface area. Calculate also the economy of the evaporator involved.

   Given information:
   λs = 2185 kJ/kg, h_V= 2572 kJ/kg, T_s= 399K, h_L=163 kJ/kg and T_L=312 K, h_F = 75.5 kJ/kg

(100 marks)

1. *Satu dinding relau yang mengandungi selapisan bata tanah liat api tebalnya 0.30 m (k_1 = 1.56 W/m.K), selapisan bata penebat kaolin tebalnya 0.20 m (k_2 = 0.173 W/m.K) dan selapisan luar bata batu tebalnya 0.10 m (k_3 = 0.692 W/m.K) didedahkan kepada satu gas relau pada 1370 K dan udara pada 300 K di luar dinding. Pekali pemindahan haba perolakan dalaman dan luaran ialah masing-masing 115 dan 23 W/m^2.K. Tentukan kehilangan haba per meter persegi dan suhu-suhu di antara lapisan-lapisan.*

(100 markah)

2. *(a) Benzena mengkondensasi pada tekanan atmosfera di luar satu paip keluli yang berdiameter 25 mm dan udara pada 15^{o}C mengalir di dalam paip pada 6 m/s. Ketebalan dinding paip ialah 3.5 mm. h_i = 20 W/m^2.^{o}C. h_o = 1,200 W/m^2.^{o}C. k_m = 45 W/m.^{o}C. Hitungkan pekali pemindahan haba keseluruhan berdasarkan kedua-dua luas dalaman dan luaran.*

(30 markah)

(b) Satu cecair organik (c_p = 0.837 J/g.^{o}C) yang mengalir pada 19,000 kg/h akan disejukkan dar 85 hingga 40^{o}C dengan menggunakan 13,500 kg/h air penyejuk (c_p = 4.1868 J/g.^{o}C) pada 20^{o}C. Pekali pemindahan haba bagi cecair organik tersebut, di luar tiub, ialah 1,700 W/m^2.^{o}C. Rintangan dinding tiub boleh diabaikan. h_i = 11,000 W/m^2.^{o}C. Apakah luas diperlukan jika aliran ialah

(i) aruslawan;
(ii) selari.

(70 markah)

3. *Air mengalir di dalam satu paip keluli mendatar yang mempunyai ID 0.0266 m dan OD 0.0334 m pada suhu purata 65.6^{o}C dan halaju 2.44 m/s. Air tersebut akan dipanaskan dengan stim yang mengkondensasi pada 107.8^{o}C di luar dinding paip. Pekali pemindahan sebelah stim ialah h_o = 10,500 W/m^2.K.*

(a) Hitungkan pekali pemindahan haba perolakan h_i bagi air di dalam paip.

(b) Hitungkan pekali pemindahan haba keseluruhan U_i berdasarkan luas permukaan dalaman.

(c) Hitungkan kadar pemindahan haba bagi 0.305 m (panjang) paip dengan air pada suhu purata 65.6^{o}C.

Bagi air pada 65.6^{o}C, Pr = 2.72, ρ = 980 kg/m^3, k = 0.633 W/m.K,
μ = 4.32 x 10^{-4} kg/m.s

(100 markah)

…6/-

4. *Air memasuki satu tiub yang berdiameter 3.0 cm pada 15.56^oC dan keluar pada 37.78^oC. Kadar aliran jisim ialah 1.0 kg/s, dan suhu dinding tiub ialah malar pada 60^oC. Tentukan panjang tiub tersebut. Bagi air, c_p = 4.18 J/kg.^oC, k =.0.614 W/m.^oC.*

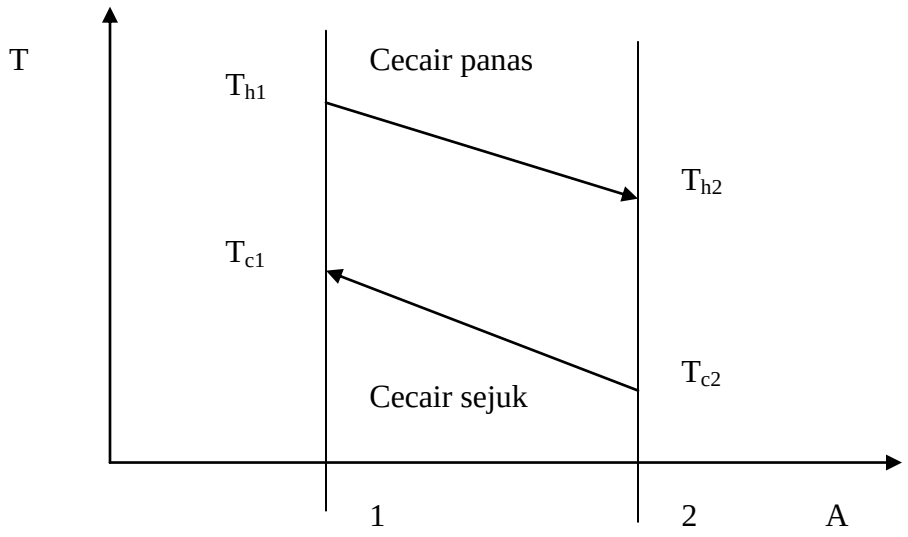
(100 markah)

5. *Satu penukar haba paip berganda aliran berlawanan digunakan untuk menyejukkan 3 kg/s minyak panas (c_p= 2.1 kJ/kg.K) bersuhu 120^oC. Air penyejuk (c_p = 4.2 kJ/kg.K) pada suhu 20^oC memasuki penukar haba pada kadar aliran 10 kg/s. Pemalar pemindahan haba keseluruhan ialah 600 W/m^2.K dan luas permukaan penukaran haba ialah 6 m^2. Kira suhu akhir minyak dan air yang keluar dari penukar haba.*

Maklumat diberi :

$$\varepsilon = \frac{1-exp\left[\frac{-UA}{C_{min}}\left(1-\frac{C_{min}}{C_{max}}\right)\right]}{1-\frac{C_{min}}{C_{max}}\left[\frac{-UA}{C_{min}}\left(1-\frac{C_{min}}{C_{max}}\right)\right]} \qquad NTU = \frac{UA}{C_{min}}$$

$$\varepsilon_h = \frac{T_{h1}-T_{h2}}{T_{h1}-T_{c2}} \quad \text{or} \quad \varepsilon_c = \frac{T_{c1}-T_{c2}}{T_{h1}-T_{c2}}$$



(100 markah)

…7/-

6. *Satu penyejat kesan tunggal digunakan untuk memekatkan larutan makanan mengandungi 15% (berat) pepejal terlarut kepada 50% (berat) pepejal. Aliran suapan memasuki penyejat tunggal pada suhu 291 K dengan kadar aliran 1.0 kg/s. Stim yang dibekalkan pada tekanan 0.07 bar ke dalam penyejat bersuhu 399 K. Dengan mengandaikan sifat-sifat larutan makanan tersebut menyerupai sifat-sifat air dan pemalar pemindahan haba keseluruhan ialah 2.3 $kWm^{-2}K^{-1}$, kirakan kadar penggunaan stim dan luas permukaan penukaran haba yang diperlukan. Kirakan juga ekonomi penyejat yang digunakkan.*

   Maklumat yang diberi:
   λ_S = 2185 kJ/kg, h_V= 2572 kJ/kg, h_L=163 kJ/kg and T_L=312 K, h_F = 75.5 kJ/kg

   (100 markah)