UNIVERSITI SAINS MALAYSIA

First Semester Examination
2010/2011 Academic Session

November 2010

IEK 212 – PROCESS HEAT TRANSFER
[PEMINDAHAN HABA PROSES]

Duration: 3 hours
[Masa: 3 jam]

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

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

Instructions: Answer FIVE questions. All questions can be answered either in Bahasa Malaysia or English.

[Arahan: *Jawab LIMA soalan. Semua soalan boleh dijawab sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggah pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

1. An organic liquid having a heat capacity of 3350 J/kg.^{o}C is flowing through the inner pipe of a double-pipe heat exchanger at a mass flow rate of 12,000 kg/h. The organic liquid is to be cooled from 93^{o}C to 38^{o}C. The entering and exit temperatures of the cooling water are 25^{o}C and 35^{o}C, respectively. The overall heat-transfer coefficient based on the outside area of the inner pipe is 290 W/m^{2}.^{o}C. The heat capacity of the cooling water is 4190 J/kg.^{o}C.

   (a) Calculate the mass flow rate of the cooling water.
   (b) Estimate the heating area of the heat exchanger if the flows are

      (i) parallel;
      (ii) countercurrent.

   (100 marks)

2. A ceramic tube [k_2 = 1.046 W/m.^{o}C] having an ID of 60 mm and an OD of 90 mm is covered with an outer layer of insulation [k_3 = 0.058 W/m.^{o}C] 50 mm thick. A liquid having a mean bulk temperature of 95^{o}C is flowing through it. The outside surface temperature of the insulating layer is 35^{o}C. The film heat-transfer coefficient inside the tube is h_1 = 133.66 W/m^{2}.^{o}C. Compute the heat losses per unit length of tube and the temperature of the inside tube.

   (100 marks)

3. A liquid is flowing at 1.0 m/s through a steel pipe [k_m = 45 W/m.^{o}C] of 75-mm-ID and 86-mm-OD. It is being heated by steam outside the pipe. The steam-film coefficient is 11.5 kW/m^{2}.^{o}C. At certain point along the pipe, the temperature of the liquid is 50^{o}C, its density, viscosity, thermal conductivity, and heat capacity are 880 kg/m^{3}, 2.1 cP, 0.135 W/m.^{o}C, and 2170 J/kg.^{o}C, respectively. Neglecting the effect of wall temperature on the viscosity,

   (a) what is the overall heat-transfer coefficient at this point based on the inside area of the pipe, U_i?

   (b) If the temperature of the steam is 115^{o}C, what is the heat flux at this point based on the outside area of the pipe?

   (100 marks)

4. An oil is to be warmed from 315 K to 337 K at a mass velocity G = 3263.5 kg/m^2.s. It passes through a stack of very thin tubes of diameter 20 mm and length 1.5 m. Steam flows outside the tubes at a flow rate of 0.0275 kg/s and condenses at 373 K and has a film heat-transfer coefficient of h_o = 10,000.00 W/m^2.K. How many tubes are needed? For steam, λ_s = 2256 kJ/kg. The properties of the oil are: k = 0.14 W/m.K, C_p = 2100 J/kg.K, μ = 0.0042 N.s/m^2, μ_w = 0.00172 N.s/m^2.

   1 N = 1 kg.m/s^2, 1 cP = 1 x 10^{-3} kg/m.s, 1 W = 1 J/s

   (100 marks)

5. A counter-flow double pipe heat exchanger is to heat water from 20^{o}C to 80^{o}C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160^{o}C at a mass flow rate of 2 kg/s. The inner tube is thin-walled and has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640 W/m^2.^{o}C, determine the length of the heat exchanger required to achieve the desired heating. Comment on the value of the length and give your suggestion.

   The specific heats of water and geothermal fluid are 4.18 and 4.31 kJ/kg.^{o}C respectively.

   Assume steady state operating conditions exist, the heat exchanger is well insulated so that heat loss to the surroundings is negligible, no fouling effect and fluid properties are constant.

   (100 marks)

6. A single effect evaporator is required to concentrate a solution from 10% solids to 30% solids at the rate of 250 kg of feed per hour. If the pressure in the evaporator is 77 kPa absolute, and if steam is available at 300 kPa absolute (T_s = 134 ^{o}C, λ_s= 2164 kJ kg^{-1}), calculate the quantity of steam required per hour and the area of heat transfer surface if the overall heat transfer coefficient is 1700 Jm^{-2}s^{-1} ^{o}C^{-1}.

   Assume that the temperature of the feed is 18°C and that the boiling point of the solution under the pressure of 77 kPa absolute is 92° C. Assume, also, that the specific heat of the solution is the same as for water, that is 4.186 x 10^3 J kg^{-1} °C^{-1}, and the latent heat of vaporization of the solution can be taken as 2287 kJ kg^{-1}.

   (100 marks)

1. *Satu cecair organik yang mempunyai muatan haba 3350 J/kg.^oC mengalir menerusi paip dalaman satu penukar haba dwi-paip pada kadar aliran jisim 12,000 kg/h. Cecair organik tersebut akan disejukkan dan 93^oC hingga 38^oC. Suhu masuk dan suhu keluar untuk air penyejuk ialah masing-masing 25^oC dan 35^oC. Pekali pemindahan-haba keseluruhan berdasarkan luas luaran bagi paip dalaman ialah 290 W/m^2.^oC. Muatan haba bagi air penyejuk ialah 4190 J/kg.^oC.*

   (a) Hitungkan kadar aliran jisim bagi air penyejuk.
   (b) Anggarkan luas pemanasan penukar haba tersebut jika aliran adalah

      (i) selari;
      (ii) arus berlawanan

   (100 markah)

2. *Satu tiub seramik [k_2 = 1.046 W/m.^oC] yang mempunyai ID 60 mm dan OD 90 mm diliputi dengan satu lapisan penebatan luar [k_3 = 0.058 W/m.^oC] yang mempunyai ketebalan 50 mm. Satu cecair yang bersuhu purata 95^oC mengalir menerusi tiub tersebut. Suhu permukaan luar lapisan penebat ialah 35^oC. Pekali pemindahan-haba di dalam tiub ialah h_1 = 133.66 W/m^2.^oC. Hitung kehilangan haba seunit panjang tiub dan suhu di dalam tiub.*

   (100 markah)

3. *Satu cecair mengalir pada 1.0 m/s menerusi satu paip keluli [k_m = 45 W/m.^oC] yang mempunyai ID 75 mm dan OD 86 mm. Cecair tersebut akan dipanaskan oleh stim di luar paip. Pekali filem stim ialah 11.5 kW/m^2.^oC. Pada lokasi tertentu di sepanjang paip, suhu cecair ialah 50^oC. Ketumpatan, kelikatan, kekonduksian terma, dan muatan haba bagi cecair tersebut ialah masing-masing 880 kg/m^3, 2.1 cP, 0.135 W/m.^oC, and 2170 J/kg.^oC. Dengan mengabaikan kesan suhu dinding ke atas kelikatan,*

   (a) apakah nilai pekali pemindahan-haba keseluruhan pada lokasi ini berdasarkan luas dalaman paip, U_i?

   (b) Jika suhu stim ialah 115^oC, apakah fluks haba pada lokasi ini berdasarkan luas luaran paip?

   (100 markah)

4. *Satu minyak akan dipanaskan dari 315 K hingga 337 K pada halaju jisim G = 3263.5 kg/m^2.s. Minyak tersebut mengalir menerusi sekumpulan tiub yang amat nipis yang mempunyai diameter 20 mm dan panjang 1.5 m. Stim mengalir di luar tiub pada kadar aliran 0.0275 kg/s dan terkondensasi pada 373 K dan mempunyai pekali pemindahan-haba h_o = 10,000.00 W/m^2.K. Berapa bilangan tiub diperlukan? Bagi stim, λ_s = 2256 kJ/kg. Sifat-sifat bagi minyak tersebut ialah: k = 0.14 W/m.K, C_p = 2100 J/kg.K, μ = 0.0042 N.s/m^2, μ_w = 0.00172 N.s/m^2.*

   1 N = 1 kg.m/s^2, 1 cP = 1 x 10^{-3} kg/m.s, 1 W = 1 J/s

   (100 markah)

5. *Satu penukar haba tiub berganda aliran berlawanan digunakan untuk memanaskan air daripada suhu 20^{o}C kepada 80^{o}C dengan kadar aliran 1.2 kg/s. Pemanasan diperolehi daripada bendalir geoterma yang bersuhu 160^{o}C dengan kadar aliran jisim 2kg/s. Tiub dalaman penukar haba terdiri daripada dinding nipis berdiameter 1.5 cm. Jika pekali pemindahan haba penukar haba tersebut ialah 640 W/m^2.^{o}C, tentukan panjang penukar haba yang diperlukan bagi mendapatkan kesan pemanasan yang dikehendaki. Komen nilai yang diperolehi dan beri cadangan anda.*

   Muatan haba spesifik air dan bendalir geoterma ialah 4.18 dan 4.31 kJ/kg.^{o}C masing-masing.

   Anggap keadaan operasi mantap, penukar haba ditebat, tiada kesan kotoran dan sifat-sifat cecair adalah malar.

   (100 markah)

6. *Satu penyejat kesan tunggal digunakan untuk memekatkan satu larutan 10% kepada 30% pepejal dengan kadar 250 kg suapan sejam. Jika tekanan di dalam penyejat berada pada 77 kPa mutlak, dan stim berada pada 300 kPa mutlak (T_s = 134^{o}C, λ= 2164 kJ kg^{-1}), kira kuantiti stim yang diperlukan sejam dan luas permukaan pemindahan haba jika pekali pemindahan haba ialah 1700 Jm^{-2}s$^-$1.^{o}C^{-1}.*

   Anggapkan bahawa suhu suapan berada pada 18^{o}C dan takat didih larutan pada 77 kPa mutlak ialah 92^{o}C. Anggapkan juga muatan haba spesifik larutan adalah sama dengan air iaitu 4.186×10^3 Jkg^{-1} ^{o} C^{-1} dan haba pendam pengewapan bagi larutan tersebut 2287 kJkg^{-1}.

   (100 markah)