UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2009/2010 Academic Session

April/May 2010

IEK 205 – AIR POLLUTION CONTROL TECHNOLOGY
[TEKNOLOGI KAWALAN PENCEMARAN UDARA]

Duration: 3 hours
Masa: [3 jam]

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

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

Instructions: Answer FOUR (4) questions. You may answer the questions either in Bahasa Malaysia or in English.

[Arahan: *Jawab EMPAT (4) 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) Define air pollution and distinguish between primary and secondary air pollutants.

(30 marks)

(b) Explain why air pollution is generally worse in developing countries than in highly developed countries.

(70 marks)

2. (a) Derive the equation for the air-to-cloth ratio, V_S, through a surface filter where filter cake is deposited on the filter medium. The filter is filtering a dirty gas stream. The equation derived should take into account the cake resistance as well as the cloth or medium resistance analogous to Ohm's law for two resistors in series.

(30 marks)

(b) A baghouse has six compartments, each with 100 bags that are 6 in. in diameter and 20 ft long with an active area of 31 ft^2 per bag. The gas being cleaned has a flow rate of 80,000 ft^3/min. The pressure drop through a freshly cleaned baghouse is estimated to be 0.5 in. H_2O. The bags are operated until the pressure drop is 3 in. H_2O, at which time they are taken out of service and cleaned. The cleaning frequency is once per hour. The incoming gas has a particle loading of 13 grains/ft^3. The collection efficiency is 99 %, and the filter cake is estimated to be 50 % solids, with the balance being voids.

Given: 1 lbm = 7000 grains
Particle density = 2000 kg/m^3
Dirty gas temperature = 25^oC
(Refer Appendix 3 for the approximate value of the dirty gas dynamic viscocity)

(i) Estimate how thick (mm) the cake is when the bags are taken out of service for cleaning.

(30 marks)

(ii) What is the permeability, k, of the cake?

(10 marks)

(c) Briefly explain all of the following terms:

(i) Depth Filter
(ii) Separation Number
(iii) Target Efficiency
(iv) HEPA

(30 marks)

3. (a) (i) Derive the equation for terminal velocity of a particle falling in air under Stoke's condition. All symbols and assumptions must be stated.

(20 marks)

(ii) and use the equation in 3a(i) to compute the terminal velocity in air of a spherical particle 1 μm in diameter.

(10 marks)

(iii) Explain briefly the **Cunningham correction factor** and **aerodynamic diameter**.

(10 marks)

Given:

For laminar condition, Drag Coefficient = 24/(Particle Reynolds Number)
Particle density = 2000 kg/m^3
Air density = 1.20 kg/m^3
Air viscocity = 1.8 x 10^{-5} kg/m.s
Gravitational accelaration = 9.81 m/s^2

(b) (i) Show how the efficiency equation of an electrostatic precipitator (ESP) can be derived for a mixed flow situation. All symbols and assumptions must be stated.

Given:
Charge on a particle, $q = 3\Pi\,[\varepsilon/(\varepsilon+2)]\varepsilon_o\, D^2 E_o$

For laminar condition, Drag Coefficient = 24/(particle Reynolds number)

(20 marks)

(c) The cyclone efficiency of collection of various particle sizes can be determined from an empirical expression and graph (Appendix 4) developed by Lapple (1951):

$$d_{0.5} = \left[\frac{9\mu B^2 H}{\rho_p Q_g \theta} \right]^{1/2}$$

where

$d_{0.5}$ = cut diameter
μ = dynamic viscocity of gas, Pa.s
B = width of entrance, m
H = height of entrance, m
ρ_p = particle density, kg/m^{3}s
Q_g = gas flow rate, m^3/s
Θ = effective number of turns

The value of Θ may be determined approximately by the following equation:

$$\Theta = \frac{\pi}{H}(2L_1 + L_2)$$

where L_1 and L_2 are the length of the cylinder and cone, respectively.

(i) Determine the cut diameter for a cyclone having the following characteristics for dust particles 10 μm in diameter with a density of 800 kg/m3:

Cyclone diameter = 0.5 m
Gas flow rate = 5.0 m^3/s
Gas temperature = 30^{o}C

(30 marks)

(ii) Calculate the efficiency of the cyclone.

(10 marks)

Apendix 4 can be used to help in solving question 3c.

4. (a) Evaporation rates of hydrocarbon liquids from horizontal surfaces are approximately given by

$$Evaporation\ rate = \left(0.5 \frac{mol}{m^2.s}\right)\frac{p}{P}$$

where p is the vapor pressure of the liquid and P is the atmospheric pressure.

(i) We have spilled a layer of oil on a metal pan. It forms a layer 1 mm thick. Its density is 1 g/cm^3 and its molecular weight is 400 g/mol. Its vapor pressure is approximately 10^{-7} torr at 20 ^{o}C. Estimate how long it will take all of this oil to evaporate at 20 ^{o}C.

(ii) Repeat the calculation for a 1 mm layer of gasoline. Use the vapor pressure, molecular weight, and density of gasoline as 6 psia, 60 g/mol, and 47 lb/ft^3 respectively.

(50 marks)

(b) You wish to design an incinerator to destroy acrolein in a 10000 scfm waste gas stream. The acrolein in the waste gas stream must be 99.99% destroyed. The kinetics of acrolein destruction are well represented by the values shown in the TABLE 1. What volume must the combuster and retention chamber have to get 99.99% destruction of acrolein at a temperature of 1200 ^{o}F.

(50 marks)

TABLE 1: Thermal oxidation parameters, based on first-order kinetics

Compound	A,1/s	E, kcal/mol	k, 1/s; at 1000°F	k, 1/s; at 1200°F	k, 1/s; at 1400°F
Acrolein	3.30E + 10	35.9	6.99258	102.37	841.47
Acrylonitrile	2.13E + 12	52.1	0.01946	0.96	20.34
Allyl alcohol	1.75E + 06	21.4	2.99528	14.83	52.07
Allyl chloride	3.89E + 07	29.1	0.56034	4.93	27.21
Benzene	7.43E + 21	95.9	0.00011	0.14	38.59
1-Butene	3.74E + 14	58.2	0.07760	6.02	183.05
Chlorobenzene	1.34E + 17	76.6	0.00031	0.09	8.41
Cyclohexane	5.13E + 12	47.6	0.76467	26.84	438.42
1,2-Dichloroethane	4.82E + 11	45.6	0.24851	7.51	109.11
Ethane	5.65E + 14	63.6	0.00411	0.48	19.93
Ethanol	5.37E + 11	48.1	0.05869	2.14	35.97
Ethyl acrylate	2.19E + 12	46.0	0.88094	27.44	407.99
Ethylene	1.37E + 12	50.8	0.02804	1.25	24.64
Ethyl formate	4.39E + 11	44.7	0.39562	11.18	154.04
Ethyl mercaptan	5.20E + 05	14.7	56.86353	170.64	404.29
Hexane	6.02E + 08	34.2	0.36628	4.72	35.13
Methane	1.68E + 11	52.1	0.00153	0.08	1.60
Methyl chloride	7.43E + 08	40.9	0.00708	0.15	1.66
Methyl ethyl ketone	1.45E + 14	58.4	0.02658	2.09	64.38
Natural gas	1.65E + 12	49.3	0.08565	3.41	61.61
Propane	5.25E + 19	85.2	0.00058	0.34	49.99
Propylene	4.63E + 08	34.2	0.28171	3.63	27.02
Toluene	2.28E + 13	56.5	0.01358	0.93	25.54
Triethylamine	8.10E + 11	43.2	1.85139	46.78	590.11
Vinyl acetate	2.54E + 09	35.9	0.53822	7.88	64.77
Vinyl chloride	3.57E + 14	63.3	0.00313	0.36	14.58

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5. (a) A plant is emitting 750 g/s of particulates. The stack height is 100 m and the plume rise is 50 m. The wind speed is 7 m/s and the stability category is C.

(i) What is the maximum estimated ground level concentration?
(ii) How far downwind does it occur?

(50 marks)

(b) A factory is emitting 300 tons/day of SO_2 from a stack. The stack height is 300 m. The stack is located in a simple terrain and can be approximated by the equation below

$$c = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp -0.5\left(\frac{y}{\sigma_y}\right)^2 \left[exp - 0.5\left(\frac{z-H}{\sigma_z}\right)^2 + exp - 0.5\left(\frac{z+H}{\sigma_z}\right)^2\right]$$

Based on these assumptions, calculate the maximum ground level SO_2 concentration for A stability and a wind speed of 3 m/s.

(Refer to the Appendix to answer this question).

(50 marks)

1. *(a) Takrifkan pencemaran udara dan bezakan antara pencemar udara primer dan sekunder.*

(30markah)

(b) Jelaskan kenapa pencemaran udara secara amnya lebih teruk dialami oleh negara yang sedang membangun berbanding negara maju.

(70 markah)

2. *(a) Terbitkan persamaan untuk nisbah udara-kain, V_s , melalui suatu penuras permukaan yang terdapat kek turas terdeposit di atas medium turas. Penuras itu digunakan untuk menuras aliran gas kotor. Persamaan itu mesti mengambilkira rintangan kek dan juga rintangan kain atau medium secara anologi dengan hukum Ohm untuk dua rintangan bersiri.*

(30 markah)

(b) Terdapat enam bahagian di dalam sebuah rumah beg. Setiap bahagian ada 100 beg yang setiap satunya bergaris pusat 6 in dan 20 ka panjang. Luas aktif setiap beg ialah 31 ka^2. Udara yang dibersihkan mengalir pada kadar 80,000 ka^3/min. Jatuhan tekanan melalui rumah beg bersih dianggarkan pada 0.5 in H_2O. Beg beroperasi sehingga tekanan 3 in. H_2O, kemudian operasi dihentikan untuk pembersihan . Kekerapan pembersihan ialah sejam sekali. Gas masuk pada beban partikel 13 grains/ft^3. Keberkesanan kutipan ialah 99 %, dan kek turas dianggarkan terdiri dari 50 % pepejal dan selebihnya ialah rongga kosong.

Diberi: 1 lbm = 7000 grains
Ketumpatan partikel = 2000 kg/m^3
Suhu gas kotor = 25^oC
(Rujuk Apendik 3 untuk nilai anggaran kelikatan dinamik gas kotor)

(i) Anggar tebal kek (mm) ketika beg dibersihkan.

(30 markah)

(ii) Apakah nilai permeabiliti, k, untuk kek turas?

(10 markah)

(c) Jelaskan secara ringkas tentang perkara berikut:

(i) Penuras Dalaman
(ii) Nombor Pemisahan
(iii) Keberkesanan Sasaran
(iv) HEPA

(30 markah)

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3. (a) (i) *Terbitkan persamaan halaju tamatan bagi suatu partikel yang jatuh dalam udara menurut keadaan Stoke. Semua simbol dan andaian mestilah dinyatakan*

(20 markah)

(ii) *kemudian gunakan persamaan yang diterbitkan dalam bahagian 3a(i) untuk mengira halaju tamatan suatu sfera yang bergaris pusat 1 µm.*

(10 markah)

(iii) *Jelaskan dengan ringkas tentang* ***faktor pembetulan Cunningham*** *dan* ***garis pusat aerodinamik****.*

(10 markah)

Diberi:

Untuk keadaan laminar, Koefisien Hela = 24/(Nombor Reynolds Partikel)
Ketumpatan partikel = 2000 kg/m^3
Ketumpatan udara = 1.20 kg/m^3
Kelikatan udara = 1.8 x 10^{-5} kg/m.s
Pecutan graviti = 9.81 m/s^2

(b) (i) *Tunjukkan bagaimana persamaan kecekapan untuk sebuah pemendak elektrostatik (ESP) boleh diterbitkan untuk keadaan aliran bercampur. Semua simbol dan andaian mestilah dinyatakan.*

Diberi:
Cas ke atas satu partikel $q = 3\Pi\,[\varepsilon/(\varepsilon+2)]\varepsilon_o\, D^2 E_o$

Untuk keadaan laminar, Koefisien Hela = 24/(nombor Reynolds partikel).

(20 markah)

(c) Keberkesanan kutipan suatu siklon untuk saiz partikel yang berbagai boleh ditentukan dari ungkapan empirikal dan graf (Apendik 4) yang dibangunkan oleh Lapple (1951):

$$d_{0.5} = \left[\frac{9\mu B^2 H}{\rho_p Q_g \theta} \right]^{1/2}$$

untuk persamaan ini

$d_{0.5}$ = *garis pusat potongan*
μ = *kelikatan dinamik gas, Pa.s*
B = *lebar salur masuk, m*
H = *tinggi salur masuk, m*
ρ_p = *ketumpatan partikel, kg/m^{3}s*
Q_g = *kadar aliran gas, m^3/s*
Θ = *bilangan pusingan berkesan*

Nilai Θ boleh ditentukan secara anggaran melalui persamaan berikut:

$$\Theta = \frac{\pi}{H}(2L_1 + L_2)$$

L_1 dan L_2 adalah panjang masing-masingnya panjang silinder dan panjang kon.

(i) Tentukan garis pusat potongan suatu siklon yang memproses partikel bergaris pusat 10 μm dan ketumpatan 800 kg/m3:

Garis pusat siklon = 0.5 m
Kadar aliran gas = 5.0 m^3/s
Suhu gas = 30 ^{o}C

(30 markah)

(ii) Kira keberkesanan siklon itu.

(10 markah)

Apendik 4 boleh digunakan untuk membantu dalam menyelesaikan soalan 3c ini.

4. (a) *Kadar pemeruapan sejenis cecair hidrokarbon dari permukaan yang melintang diberi seperti berikut*

$$Kadar\ pemeruapan = \left(0.5\frac{mol}{m^2.s}\right)\frac{p}{P}$$

di mana p ialah tekanan gas cecair tersebut dan P ialah tekanan atmosfera.

(i) *Minyak tersebut telah ditumpahkan ke dalam satu piring logam. Ketebalan lapisan minyak itu ialah 1 mm. Ketumpatan dan berat molekular minyak tersebut ialah 1 g/cm^3 dan 400 g/mol. Tekanan gas minyak itu pula 10^{-7} torr pada 20 ^oC. Anggar berapa lama masa yang diperlukan untuk memeruap kesemua minyak tersebut pada 20 ^oC.*

(ii) *Ulangi pengiraan untuk lapisan gasolin setebal 1 mm pula. Gunakan tekanan gas, berat molekular dan ketumpatan yang masing-masing bernilai 6 psia, 60 g/mol dan 47 lb/ft^3.*

(50 markah)

(b) *Anda ingin reka sebuah insinerator untuk memusnahkan "acrolein" yang terdapat dalam aliran sisa gas pada kadar alir 10000 scfm. "Acrolein" mesti dimusnahkan sebanyak 99.99% daripada aliran gas sisa tersebut. Kinetik "acrolein" boleh didapati dalam JADUAL 1. Apakah isipadu ruang pembakaran dan ruang simpanan sementara yang diperlukan untuk mencapai 99.99% pemusnahan "acrolein" pada suhu 1200 ^oF.*

(50 markah)

JADUAL 1: Parameter pengoksidan termal, berdasarkan kinetik darjah pertama

Bahan	A,1/s	E, kcal/mol	k, 1/s; pada		
			1000°F	1200°F	1400°F
Acrolein	3.30E + 10	35.9	6.99258	102.37	841.47
Acrylonitrile	2.13E + 12	52.1	0.01946	0.96	20.34
Allyl alcohol	1.75E + 06	21.4	2.99528	14.83	52.07
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Vinyl chloride	3.57E + 14	63.3	0.00313	0.36	14.58

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5. (a) *Satu kilang mengeluarkan 750 g/s partikulat dari cerobongnya setinggi 100 m. Plum tersebut menaik sebanyak 50 m. Kelajuan angin ialah 7 m/s dan kategori kestabilan ialah C.*

(i) Apakah kepekatan partikulat yang maksimum pada aras bumi?

(ii) Berapa jauhkah tempat berlakunya kepekatan partikulat maksimum dari cerobong tersebut?

(50 markah)

(b) *Satu kilang mengeluarkan 300 tons/hari SO_2 dari cerobongnya setinggi 300 m. Cerobong tersebut terletak di suatu kawasan yang mempunyai permukaan bumi yang rata. Persamaan berikut boleh digunakan*

$$c = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp -0.5\left(\frac{y}{\sigma_y}\right)^2 \left[exp - 0.5\left(\frac{z-H}{\sigma_z}\right)^2 + exp - 0.5\left(\frac{z+H}{\sigma_z}\right)^2\right]$$

Berdasarkan anggapan di atas, hitung kepekatan maksimum SO_2 pada aras bumi untuk kestabilan A dan kelajuan angin 3 m/s.

(Rujuk Appendik untuk menjawab soalan ini.

(50 markah)