UNIVERSITI SAINS MALAYSIA

First Semester Examination
2010/2011 Academic Session

November 2010

EKC 512 – Safety Engineering and Environmental Management
[Kejuruteraan Keselamatan dan Pengurusan Persekitaran]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of SEVEN pages of printed material and FOUR pages of Appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi TUJUH muka surat yang bercetak dan EMPAT muka surat Lampiran sebelum anda memulakan peperiksaan ini.]

Instruction: Answer **ALL** (4) questions.

*[**Arahan:** Jawab **SEMUA** (4) soalan.]*

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.]

Answer ALL questions.
Jawab SEMUA soalan.

1. [a] Why the understanding of the nitrogen cycle is important before a sustainable development can be formulated?
Mengapa pengetahuan tentang kitaran nitrogen penting sebelum pembangunan lestari boleh dirangka?

[4 marks/markah]

[b] Give an example of the undesirable consequence resulting from the imbalance in the nitrogen cycle.
Berikan satu contoh tentang akibat buruk ekoran daripada ketidakseimbangan di dalam kitaran nitrogen.

[2 marks/markah]

[c] Provide the chemical reaction during the nitrification and denitrification. What are the micro organisms that facilitate the process?
Berikan tindak balas kimia semasa nitrifikasi dan dinitrifikasi. Apakah organisma mikro yang membantu proses berkenaan?

[6 marks/markah]

[d] Describe waste hierarchy by giving proper illustration.
Simpulkan hierarki sisa dengan memberikan ilustrasi bersesuaian.

[3 marks/markah]

[e] Explain the waste minimization procedure in industries and give examples.
Terangkan prosedur peminimuman sisa di industri dan berikan contoh-contohnya.

[6 marks/markah]

[f] Explain (with suitable diagram) the activity associated with *bearable, viable, equitable and sustainable.*
Terangkan (dengan rajah yang bersesuaian) aktiviti yang dikaitkan dengan boleh tahan, daya maju, kebolehsamaan dan lestari.

[4 marks/markah]

2. [a] Provide LCA framework for biodegradable plastic bags.
Berikan satu contoh rangka kerja LCA untuk beg plastik biorosot.

[10 marks/markah]

[b] Why biodegradable plastic bags are not an effective proposal? What are the alternatives?
Mengapa beg plastik biorosot bukan suatu usul yang efektif? Apakah alternatifnya?

[5 marks/markah]

[c] Ground level concentration of SO_2 emitted from a plant can be calculated using the Diffusion model. Determine the maximum ground level concentration of SO_2 (in g/m^3) at 1 km from the plant. Stack height = 3 m, stack tip radius = 3 m, exit velocity = 15 m/s, exit temperature = 250 ºC, wind speed = 10 m/s, horizontal dispersion = 75 m, vertical dispersion = 33 m, source strength = 1.1 Mg/s, ambient temperature = 30 ºC and pressure = 100 kPa.

Kepekatan aras bumi SO_2 yang dilepaskan dari sebuah kilang boleh dikira menggunakan model pembauran. Kirakan kepekatan maksimum aras bumi SO_2 (dalam g/m^3) pada jarak 1 km daripada kilang. Diberikan, ketinggian serombong = 3 m, jejari serombong = 3 m, kelajuan keluar = 15 m/s, suhu keluar = 250 ºC, kelajuan angin = 10 m/s, penyerakan mendatar = 75 m, penyerakan menegak = 33 m, kekuatan sumber = 1.1 Mg/s, suhu persekitaran = 30 ºC dan tekanan = 100 kPa.

[6 marks/markah]

[d] Calculate the concentration using the Box model and give the reasons for the discrepancy from the Diffusion model. (Assume mixing height = Stack height, mixing length = distance from the plant)

Kirakan kepekatan menggunakan model Box dan berikan sebab perbezaan daripada model Pembauran. (Andaikan ketinggian campuran = ketinggian serombong, panjang campuran = jarak daripada kilang)

[4 marks/markah]

3. [a] With the aid of simple sketches, describe the differences between Solid Plume and Point Source radiation models.

Dengan bantuan lakaran-lakaran ringkas, terangkan perbezaan-perbezaan antara model Sinaran Plum Padu dan Punca Titik.

[5 marks/markah]

[b] A pool fire has occurred due to the released of hydrocarbon A. The hydrocarbon liquid escaped from a leak at a volumetric rate of 0.2 m^3/s. A circular dike with a 30 m diameter contained the leak. The result of the consequence analysis indicated that the radiation intensity of the pool fire was 12.5 kW/m^2 being experienced by a worker who stood 75 m away from the source. Estimate the heat of combustion of the liquid by using the Point Source Model.

Suatu kebakaran berkolam terjadi disebabkan pembebasan hidrokarbon A. Cecair hidrokarbon tersebut terbebas daripada satu kebocoran pada kadar isipadu 0.2 m^3/s. Satu takungan berbentuk bulat dengan garispusat 30 m menakung kebocoran tersebut. Hasil daripada analisa impak menunjukkan keamatan sinaran daripada kebakaran berkolam itu adalah 12.5 kW/m^2, dirasakan pada seorang pekerja yang berdiri sejauh 75 m daripada punca tersebut. Anggarkan haba pembakaran cecair tersebut dengan menggunakan Model Punca Titik.

[20 marks/markah]

Data:
Data:

Heat of vaporization of the liquid *Haba pengewapan cecair*	400	kJ/kg
Boiling point of the liquid *Takat didih cecair*	370	K
Ambient temperature *Suhu persekitaran*	298	K
Liquid density *Ketumpatan cecair*	750	kg/m^3
Heat capacity of liquid *Muatan haba cecair*	3.0	kJ/kg-K

4. [a] One of the main criteria in safety engineering is to determine the tolerable risk value for both existing and new plants via Quantitative Risk Assessment. Outline the steps taken in conducting the Quantitative Risk Assessment.

Salah satu kriteria penting dalam kejuruteraan keselamatan adalah menganggarkan nilai risiko yang dibenarkan bagi kedua-dua loji baru dan sedia ada melalui Penilaian Risiko Kuantitatif. Lakarkan langkah-langkah yang perlu diambil dalam menjalankan Penilaian Risiko Kuantitatif tersebut.

[10 marks/markah]

[b] Figure Q.4.[b] illustrates the Fault Tree for the system operation shown in Figure Q.4.[a]. The reactor is monitored by two temperature elements (TE) and two pressure transmitters (PT). High system pressure or temperature indicates a possible exothermic reaction in progress. The processor provides a shutdown signal if it receives a high signal from either the TE or the PT. The reaction pressure and temperature are continuously monitored. The processor is tested once every shift (8 hrs). If the processor (combination of output card and CPU) is failed, the reaction is shut down while the processor is repaired.

Rajah S.4.[b] menunjukkan Pokok Kegagalan bagi operasi sistem yang ditunjukkan dalam Rajah S.4.[a]. Reaktor tersebut diawasi dengan dua elemen suhu (TE) dan dua penghantar tekanan (PT). Sistem tinggi tekanan atau suhu menunjukkan kemungkinan tindak balas eksotermik berlaku. Sistem pemprosesan memberi isyarat penutupan sekiranya ia menerima isyarat tinggi samada daripada TE atau PT. Suhu dan tekanan tindak balas diawasi secara berterusan. Sistem pemprosesan dicuba sekali setiap giliran (8 jam). Sekiranya pemprosesan (kombinasi keluaran kad dan CPU) gagal, tindak balas tersebut akan ditutup sementara pemprosesan itu dibaiki.

[i] Based on Figure Q.4.[b], determine the combination of possible minimal cut set number.

Berdasarkan Rajah S.4.[b], tentukan kombinasi nombor set potongan minima.

[ii] Calculate the probability of the top event based on both minimal cut set and gate to gate method. [Data : Table Q.4.]

Kirakan kebarangkalian bagi peristiwa teratas berdasarkan kedua-dua teknik set potongan minima dan get ke get. [Data : Jadual S.4.]

[15 marks/markah]

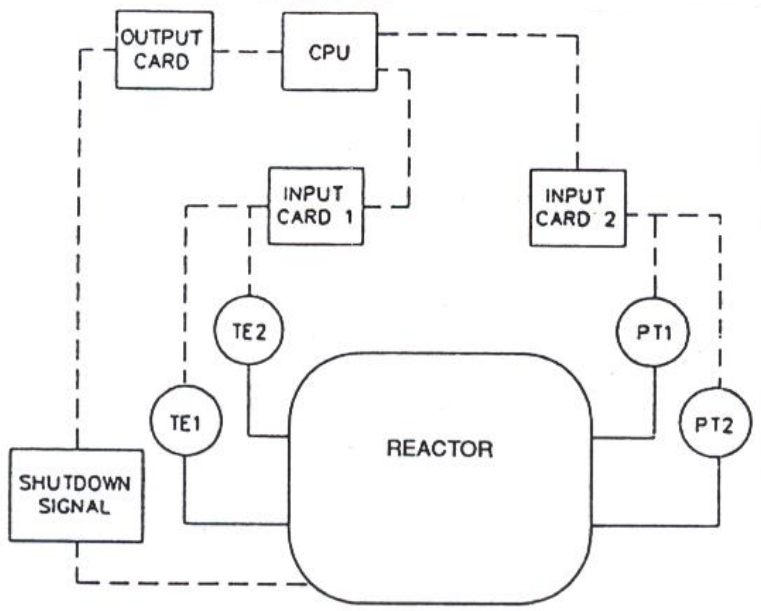


Figure Q.4.[a]
Rajah S.4.[a].

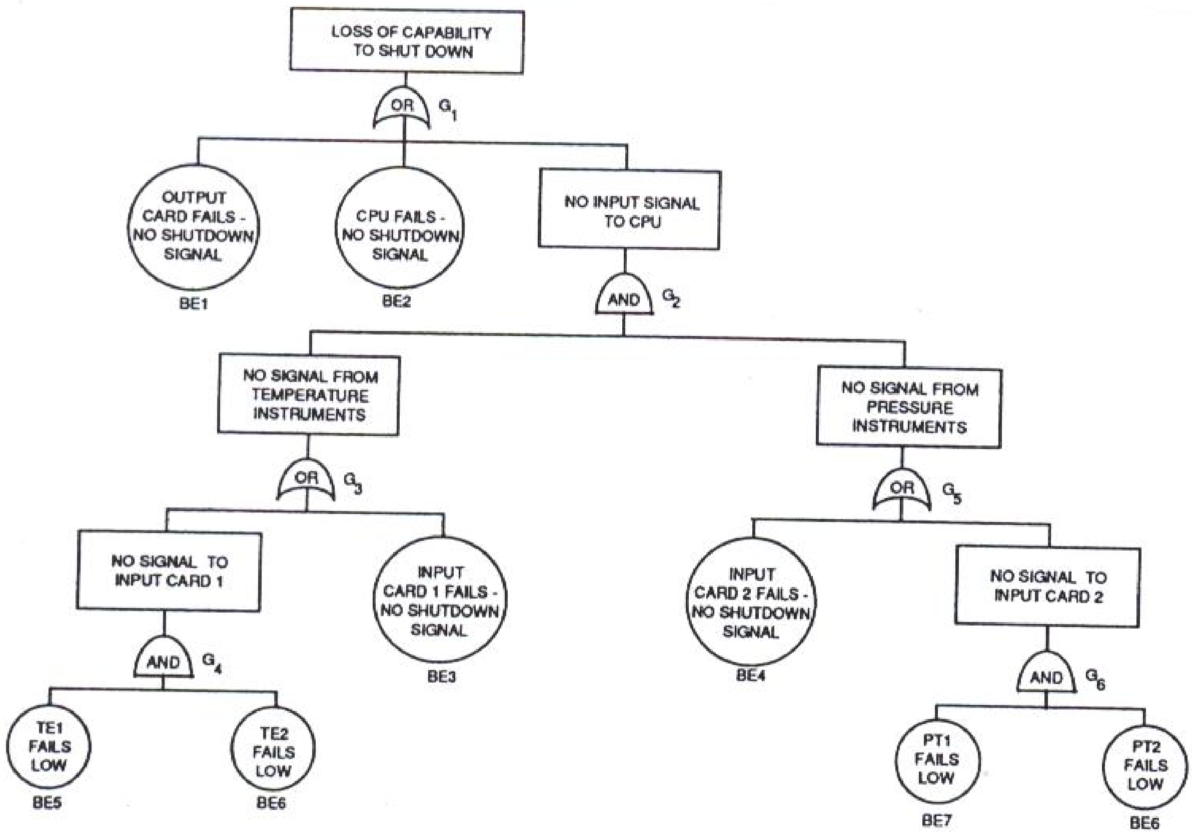


Figure Q.4.[b].
Rajah S.4.[b].

Basic event	Description	Failure rate λ (hr $^{-1}$)	Restoration time τ (hr)
BE1	Output card fails—no shutdown signal	1.3×10^{-6}	—
BE2	CPU fails—no shutdown signal	1.0×10^{-4}	—
BE3	Input Card 1 fails—no shutdown signal	1.3×10^{-6}	24
BE4	Input Card 2 fails—no shutdown signal	1.3×10^{-6}	24
BE5	TE-1 fails low	4.6×10^{-7}	16
BE6	TE-2 fails low	4.6×10^{-7}	16
BE7	PT-1 fails low	2.2×10^{-7}	16
BE8	PT-2 fails low	2.2×10^{-7}	16

Table Q.4.: Failure Rate For Basic Event
Jadual S.4.: Kadar Kegagalan Bagi Peristiwa Asas

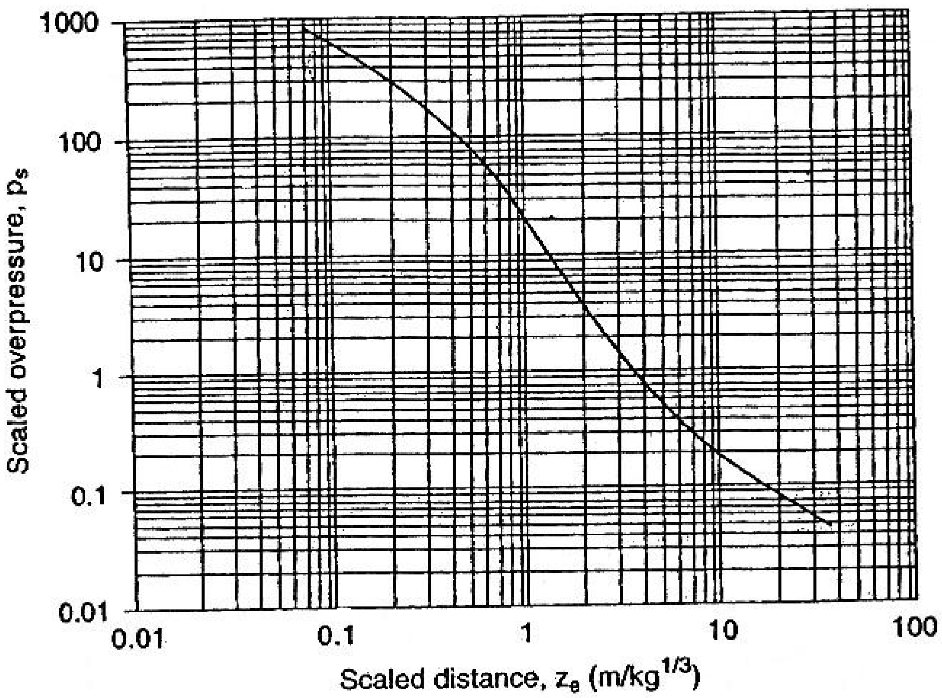
- ooo O ooo -

Appendix

$$C(x,y,z) = \frac{q}{2\pi\sigma_y\sigma_z v}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

$$C(t) = \frac{qL}{vH}\left(1 - e^{(-vt/L)}\right)$$

$$\Delta H = \frac{2v_s r_s}{v}\left[1.5 + 2.68\times10^{-2} P\left(\frac{T_s - T_a}{T_s}\right)2r_s\right]$$



Correlation between scaled distance and explosion peak side-on overpressure foı a TNT explosion occurring on a flat surface. Source: G. F. Kinney and K. J. Graham, *Explosive Shocks in Air* (Berlin: Springer-Verlag, 1985).

$$\frac{p_o}{p_a} = \frac{1616\left[1 + \left(\frac{z_e}{4.5}\right)^2\right]}{\sqrt{1 + \left(\frac{z_e}{0.048}\right)^2}\sqrt{1 + \left(\frac{z_e}{0.32}\right)^2}\sqrt{1 + \left(\frac{z_e}{1.35}\right)^2}}$$

Volume Equivalents

in^3	ft^3	US gal	L	m^3
1	5.787×10^{-4}	4.329×10^{-3}	1.639×10^{-2}	1.639×10^{-5}
1728	1	7.481	28.32	2.832×10^{-2}
231	0.1337	1	3.785	3.785×10^{-3}
61.03	3.531×10^{-2}	0.2642	1	1.000×10^{-3}
6.102×10^4	35.31	264.2	1000	1

Ideal Gas Constant R_g

1.9872 cal/g-mol K
1.9872 Btu/lb-mol°R
10.731 psia ft^3/lb-mol°R
8.3143 kPa m^3/kg-mol K = 8.314 J/g-mol K
82.057 cm^3 atm/g-mol K = 8.2057×10^{-5} m^3 atm/mol K
0.082057 L atm/g-mol K = 0.082057 m^3 atm/kg-mol K
21.9 (in Hg) ft^3/lb-mol°R
0.7302 ft^3 atm/lb-mol°R
1,545.3 ft lb_f/lb-mol°R

Gravitational Constant, g_c

32.174 ft-lb_m/lb_f-s^2
1 (kg m/s^2)/N
1 (g cm/s^2)/dyne

Miscellaneous

1 Poise = 100 centipoise = 0.1 kg/m s = 0.1 Pa s = 0.1 N s/m^2
1 N = 1 kg m/s^2
1 J = 1 N m = 1 kg m^2/s^2
1 centipoise = 1×10^{-3} kg/m s = 2.4191 lb/ft-hr = 6.7197×10^{-4} lb/ft s

Source Model

$$\frac{P_2 - P_1}{\rho} + \frac{g}{g_c}(z_2 - z_1) + \frac{1}{2g_c}(v_2^2 - v_1^2) + \sum e_f + \frac{W_s}{\dot{m}} = 0$$

$$e_f = K_f\left(\frac{v^2}{2g_c}\right)$$

$$K_f = \frac{K_1}{N_{RE}} + K_\infty\left(1 + \frac{1}{ID_{inches}}\right)$$

$$\dot{m} = AC_D\sqrt{2\rho g_c(P_1 - P_2)}$$

$$\dot{m} = \rho vA = \rho AC_D\sqrt{2\left(\frac{g_c P_g}{\rho} + gh_L\right)}$$

$$Q_m = C_o AP_o\sqrt{\left(\frac{2g_c M}{R_g T_o}\frac{\gamma}{\gamma - 1}\right)\left[\left(\frac{P}{P_o}\right)^{2/\gamma} - \left(\frac{P}{P_o}\right)^{(\gamma+1)/\gamma}\right]}$$

$$\frac{P_{choked}}{P_o} = \left(\frac{2}{\gamma - 1}\right)^{\gamma/(\gamma-1)}$$

$$(Q_m)_{choked} = C_o AP_o\sqrt{\left(\frac{g_c M}{R_g T_o}\right)\left[\left(\frac{2}{\gamma + 1}\right)^{(\gamma+1)/(\gamma-1)}\right]}$$

Dispersion Models

$$\langle C\rangle_{max} = \frac{\dot{m}}{\pi\sigma_y\sigma_z u}$$

$$\langle C\rangle_{ppm} = \frac{\dot{m}}{\pi\sigma_y\sigma_z u}\left[\frac{RT}{MP}\times 10^6\right]$$

$$\sigma_y = \exp\left[4.23 + 0.9222\ln\left(\frac{x}{1000}\right) - 0.0087\left[\ln\left(\frac{x}{1000}\right)\right]^2\right]$$

$$\sigma_x = \exp\left[3.414 + 0.7371\ln\left(\frac{x}{1000}\right) - 0.0316\left[\ln\left(\frac{x}{1000}\right)\right]^2\right]$$

Equations related to Fire Modeling

Pool Fires:

$$\dot{y}_{max} = 1.27\times 10^{-6}\frac{\Delta H_c}{\Delta H^*}$$

$$\Delta H^* = \Delta H_v + \int_{T_a}^{T_{BP}} C_p\,dT$$

$$m_B = 1\times 10^{-3}\frac{\Delta H_c}{\Delta H^*}$$

$$D_{max} = 2\sqrt{\frac{\dot{V}_L}{\pi\,\dot{y}}}$$

$$\frac{H}{D} = 42\left(\frac{m_B}{\rho_a\sqrt{gD}}\right)^{0.61}$$

$$E_{av} = E_m e^{-SD} + E_s\left(1 - e^{-SD}\right)$$

$$F_P = \frac{1}{4\pi x^2}$$

$$\tau_a = 2.02(P_W X_S)^{-0.09}$$

$$E_r = \tau_a Q_r F_P = \tau_a \eta m_B \Delta H_c A F_P$$

Jet Fires:

$$\frac{L}{d_j} = \frac{5.3}{C_T}\sqrt{\frac{T_f/T_j\left[C_T + (1 - C_T)\frac{M_a}{M_f}\right]}{\alpha_T}}$$

$$E_r = \tau_a Q_r F_p = \tau_a \eta\,\dot{m}\,\Delta H_c F_P$$

Equations related to Explosion Modeling

TNT Model

$$W = \frac{\eta M E_c}{E_{TNT}}$$

$$Z_e = \frac{R}{M_{TNT}}$$

$$P_S = \frac{P_o}{P_a}$$

TNO Model

$$\bar{R} = \frac{R}{(E/P_o)^{1/3}}$$

$$P_s = \Delta\bar{P}_s . P_o$$

$$t_+ = \bar{t}_+\left[\frac{(E/P_o)^{1/3}}{c_o}\right]$$

Damage Estimates for Common Structures Based on Overpressure (these values are approximations)[1]

Pressure		
psig	**kPa**	**Damage**
0.02	0.14	Annoying noise (137 dB if of low frequency, 10–15 Hz)
0.03	0.21	Occasional breaking of large glass windows already under strain
0.04	0.28	Loud noise (143 dB), sonic boom, glass failure
0.1	0.69	Breakage of small windows under strain
0.15	1.03	Typical pressure for glass breakage
0.3	2.07	"Safe distance" (probability 0.95 of no serious damage below this value); projectile limit; some damage to house ceilings; 10% window glass broken
0.4	2.76	Limited minor structural damage
0.5–1.0	3.4–6.9	Large and small windows usually shatter; occasional damage to window frames
0.7	4.8	Minor damage to house structures
1.0	6.9	Partial demolition of houses, made uninhabitable
1–2	6.9–13.8	Corrugated asbestos shatters; corrugated steel or aluminum panels, fastenings fail, followed by buckling; wood panels (standard housing), fastenings fail, panels blow in
1.3	9.0	Steel frame of clad building slightly distorted
2	13.8	Partial collapse of walls and roofs of houses
2–3	13.8–20.7	Concrete or cinder block walls, not reinforced, shatter
2.3	15.8	Lower limit of serious structural damage
2.5	17.2	50% destruction of brickwork of houses
3	20.7	Heavy machines (3000 lb) in industrial buildings suffer little damage; steel frame buildings distort and pull away from foundations
3–4	20.7–27.6	Frameless, self-framing steel panel buildings demolished; rupture of oil storage tanks
4	27.6	Cladding of light industrial buildings ruptures
5	34.5	Wooden utility poles snap; tall hydraulic presses (40,000 lb) in buildings slightly damaged
5–7	34.5–48.2	Nearly complete destruction of houses
7	48.2	Loaded train wagons overturned
7–8	48.2–55.1	Brick panels, 8–12 in thick, not reinforced, fail by shearing or flexure
9	62.0	Loaded train boxcars completely demolished
10	68.9	Probable total destruction of buildings; heavy machine tools (7000 lb) moved and badly damaged, very heavy machine tools (12,000 lb) survive
300	2068	Limit of crater lip

[1] V. J. Clancey, "Diagnostic Features of Explosion Damage," paper presented at the *Sixth International Meeting of Forensic Sciences* (Edinburgh, 1972).