UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2007/2008

October/November 2007

EKC 212 – Fluids Flow For Chemical Engineering
[Aliran Bendalir Kejuruteraan Kimia]

Duration : 3 hours
[Masa : 3 jam]

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

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

Instructions: Answer **SEVEN** (7) questions. Answer **ALL** (4) questions from Section A. Answer **THREE** (3) questions from Section B.

*[**Arahan**: Jawab **TUJUH** (7) soalan. Jawab **SEMUA** (4) soalan dari Bahagian A. Jawab **TIGA** (3) soalan dari Bahagian B.]*

You may answer a question either in Bahasa Malaysia or in English.

[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

Section A : Answer ALL questions.
Bahagian A : Jawab SEMUA soalan.

1. [a] Give two differences between pipes and tubing in term of wall type and joints.

Berikan dua perbezaan dari segi jenis dinding dan penyambungan di antara paip dan tiub.

[2 marks/markah]

[b] Air at density of 1.6 kg/m^3 is flowing past a pitot tube. The gauge indicates a pressure difference of 24 kg/ms^2. What is the air velocity?

Udara berketumpatan 1.6 kg/m^3 melalui sebuah tiub pitot. Tolok tekanan menunjukkan perbezaan tekanan sebanyak 24 kg/ms^2. Apakah halaju udara?

[2 marks/markah]

[c] A flat-blade turbine with six blades is installed centrally in a vertical tank. The tank is 1.83m in diameter, the turbine is 0.61m in diameter and is positioned 0.61m from the bottom of the tank. The turbine blades are 127mm wide. The tank is filled to a depth of 1.83m with a solution of 50% caustic soda at 65.6°C, which has a viscosity of 12cP and a density of 1498 kg/m^3. The turbine is operated at 90 rpm. The tank was unbaffled. What power will be required to operate the mixer?

Sebuah turbin berbilah rata dengan enam bilah dipasang ditengah-tengah sebuah tangki menegak. Tangki berdiameter 1.83m, serta turbin berdiameter 0.61m berkedudukan 0.61m dari dasar tangki. Bilah turbin ini berkelebaran 127mm. Tangki diisi sedalam 1.83m dengan larutan 50% soda kaustik bersuhu 65.6°C, dengan kelikatan 12cP dan berketumpatan 1498 kg/m^3. Turbin beroperasi pada kadar 90 rpm. Tangki ini tanpa sesekat. Berapa kuasa yang diperlukan oleh turbin ini untuk beroperasi?

[6 marks/markah]

2. [a] Figure Q. 2 [a] shows an arrangement for measuring the pressure at the centre of a pipe A. The specific gravity of mercury is given as 13.56 and the density of water is 1000 kg/m^3. What is the pressure at point A? Given that the height of air from point E that levels with point D on the other side of the arm is 20cm.

Rajah S.2 [a] menunjukkan suatu susunan untuk mengukur tekanan di tengah-tengah kedudukan paip A. Nilai graviti tentu bagi merkuri ialah 13.56 dan ketumpatan air adalah 1000 kg/m^3. Apakah tekanan pada titik A? Diberi tinggi udara dari titik E yang searas dengan titik D di lengan yang satu lagi ialah 20sm.

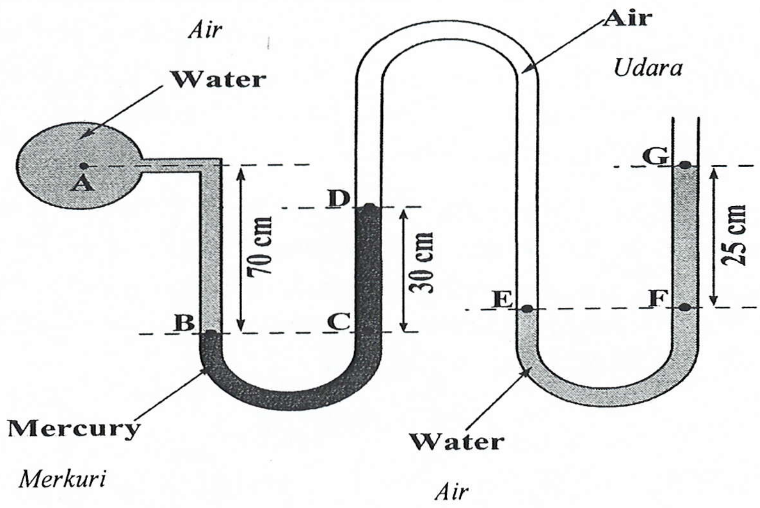

Figure Q. 2. [a]
Rajah S. 2. [a]

[4 marks/markah]

[b] Water at 303 K is flowing at the rate of 10 gal/min in a pipe having an inner diameter (I.D) of 2.067 in, calculate the Reynolds number using

Air pada suhu 303 K mengalir pada kadar 10 gal/min di dalam sebatang paip yang berdiameter dalam (I.D) 2.067 in, kirakan nombor Reynolds dengan menggunakan

[i] English units
unit Inggeris

[ii] S.I. units.
unit S.I..

Where *Re* is given by;

Di mana Re diberi sebagai;

$$Re = \frac{\rho D v}{\mu}$$

What can you say about the answers calculated from the two different units?

Apakah yang dapat anda katakan mengenai jawapan yang diperolehi daripada dua unit yang berlainan itu?

[4 marks/markah]

[c] With an aid of a diagram, describe the four different types of fluids and their characteristics.

Dengan berbantukan gambarajah, perihalkan mengenai empat jenis bendalir dan ciri-cirinya.

[2 marks/markah]

3. The resistance to motion, R for a sphere of diameter D moving at constant velocity, v on the surface of a liquid is due to the density ρ and the surface waves produced by the acceleration of gravity g. Show that the dimensionless equation linking these quantities can be written as;

Rintangan kepada pergerakan, R bagi sebuah sfera yang berdiameter, D yang bergerak pada halaju sekata, v pada permukaan suatu ceceair adalah disebabkan oleh ketumpatan, ρ dan gelombang permukaan yang disebabkan oleh pecutan graviti, g. Tunjukkan bahawa persamaan tidak berdimensi yang menghubungkan kuantiti-kuantiti di atas dapat di tulis sebagai;

$$\mathbf{Ne} = f(\mathbf{Fr})$$

where **Ne** is the Newton Number and **Fr** is the Froude number given by;

*di mana **Ne** adalah nombor Newton dan **Fr** adalah nombor Froude yang diberikan sebagai;*

$$Fr = \sqrt{\frac{v^2}{gD}}$$

[10 marks/markah]

4. Figure Q. 4. shows an imagination of collective streamlines flow in tubular shape which forms a stream tube flowing from station a to station b.

Rajah S.4. menunjukkan gambaran garis arus terhimpun yang mengalir dalam bentuk tiub dan membentuk pula tiub arus yang mengalir dari stesen a ke stesen b.

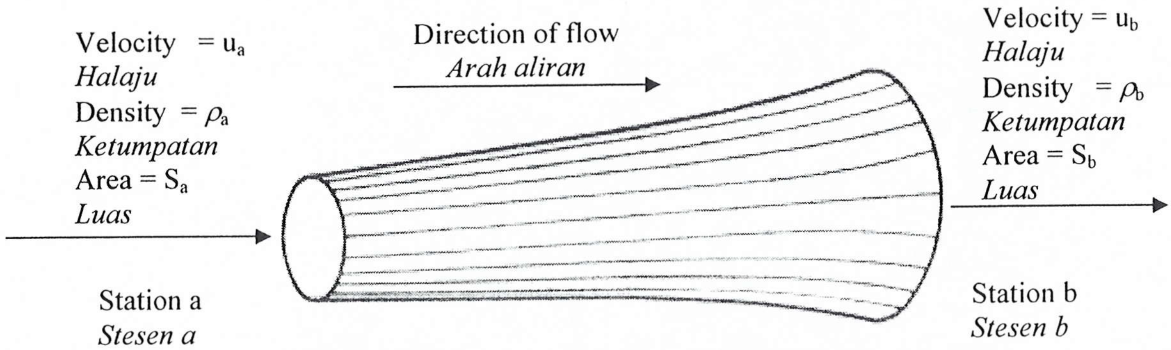

Figure Q.4.
Rajah S.4.

Using the mass-balance or continuity equation, derive the following expression:

Dengan menggunakan imbangan jisim atau persamaan keselanjaran terbitkan ungkapan berikut:

$$\frac{\overline{V}_a}{\overline{V}_b} = \left[\frac{D_b}{D_a}\right]^2$$

where: $\overline{V}_a$ = average velocity at station a
$\overline{V}_b$ = average velocity at station b
D_a = diameter of steam tube at station a
D_b = diameter of stream tube at station b

Di mana: $\overline{V}_a$ = *halaju purata di stesen a*
$\overline{V}_b$ = *halaju purata di stesen b*
D_a = *garispusat tiub arus di stesen a*
D_b = *garispusat tiub arus di stesen b*

[10 marks/markah]

<u>Section B</u> : Answer any <u>THREE</u> questions.
<u>Bahagian B</u> : Jawab mana-mana <u>TIGA</u> soalan.

5. Water at 4.4°C is to flow through a horizontal commercial steel pipe having a length of 305 m at the rate of 150 gal/min. A head of water 6.1 m is available to overcome the friction loss h_f. With the data available, use the trial-and-error method to estimate and calculate the pipe diameter.

Hint: Choose the pipe diameter value in the range of 0.06 – 0.1 m as your first trial.

Air pada 4.4°C mengalir melalui sebatang paip keluli komersil mengufuk dengan panjang 305 m pada kadar 150 gal/min. Turus air 6.1 m boleh didapati untuk mengatasi kehilangan geseran h_f. Dengan data sedia ada, gunakan kaedah cuba-ralat untuk menganggarkan dan mengira garispusat paip.

Petunjuk: Pilih garispusat paip dalam julat 0.06-0.1 m sebagai cubaan pertama anda.

[20 marks/markah]

6. Prove that when a compressible gas flows through an orifice from a container under pressure, under conditions such that maximum flow is attained, the velocity of gas through the orifice is given by;

Buktikan bahawa apabila suatu gas boleh-mampat mengalir menerusi suatu orifis daripada suatu takungan yang bertekanan di bawah keadaan di mana aliran maksimum tercapai, halaju gas menerusi orifis tersebut di beri oleh;

$$v = \sqrt{\frac{\lambda p}{\rho}}$$

Where p and ρ are the pressure and density immediately in front of the orifice and the process follows the relation given by;

di mana p dan ρ masing-masing adalah tekanan dan ketumpatan gas di hadapan orifis dan pembolehubah tersebut dapat dihubungkan melalui;

$$\frac{p}{\rho^{\lambda}} = \text{constant } [pemalar]$$

...6/-

An air compressor which takes in 11.30 m^3 of air per minute at 101 kN/m^2 and temperature of 15°C is used to maintain 310 kN/m^2 gauge pressure in a large tank whence it flows back to atmosphere through an orifice with discharge coefficient C_o=0.96. The temperature in the vessel is 23°C. Calculate a suitable diameter for the orifice. Given that, γ = 1.4 and the ideal gas constant, R = 278 J/kg K.

Suatu pemampat udara yang menyedut 11.30 m^3 udara setiap minit pada tekanan 101 kN/m^2 dan suhu 15 °C digunakan untuk menyenggara 310 kN/m^2 tekanan tolok pada sebuah tangki besar dan ia mengalir semula ke atmosfera melalui orifis dengan pekali buangan C_o = 0.96. Suhu pada tangki tersebut adalah 23 °C. Kirakan diameter yang sesuai bagi orifis tersebut. Di beri, γ = 1.4 dan pemalar gas unggul, R = 278 J/kg K.

[20 marks/markah]

7. [a] Show that the fluid pass over the venturi meter can be expressed as:

Tunjukkan bahawa bendalir yang melalui meter venturi dapat diterbitkan seperti persamaan di bawah ini:

$$G = \frac{C_D \rho A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh_v}$$

where, G = mass flowrate
A_1 = area of throat
A_2 = area of convergence
C_D = discharge coefficient
ρ = fluid density
h_v = pressure drop at convergence

di mana, G = *kadar aliran jisim*
A_1 = *luas kerongkongan*
A_2 = *luas penumpuan*
C_D = *pekali nyahcas*
ρ = *ketumpatan bendalir*
h_v = *kejatuhan tekanan dipenumpuan*

[12 marks/markah]

[b] A venturi meter of 150mm diameter at inlet and 50mm diameter at the throat is used for measuring the flow of water. If the pressure drop at convergence is 121mmH_2O and water mass flowrate is 3 kg/s, what is the discharge coefficient (C_D) at convergence part of venturi meter.

Sebuah meter venturi dengan diameter masuk 150mm dan diameter-kerongkongan 50mm diguna bagi mengukur kadar aliran air. Jika kejatuhan tekanan pada penumpuan ialah 121mmH_2O dan kadar aliran air ialah 3 kg/s, berapakah pekali nyahcas (C_D) pada bahagian penumpuan meter venturi.

[8 marks/markah]

8. [a] Define fluidization and how the minimum fluidization can be achieved?

Takrifkan perbendaliran dan bagaimana perbendaliran minimum boleh dicapai?

[3 marks/markah]

[b] Solid particles having a size of 0.12mm, a shape factor ϕ_s of 0.88, and a density of 1000kg/m^3 are to be fluidized using air at 2.0 atm and 25°C. The bed diameter is 0.62m and the bed contains 300 kg of solids. The minimum height of the fluidized bed is 1.724m.

Zarah pepejal bersaiz 0.12mm, faktor bentuk ϕ_s 0.88, dan berketumpatan 1000 kg/m^3 akan dibendalirkan dengan menggunakan udara pada tekanan 2.0 atm dan suhu 25°C. Diameter lapisan yang mengandungi 300 kg zarah pepejal ini ialah 0.62m. Tinggi minimum lapisan perbendaliran ini ialah 1.724m.

[i] Calculate the voidage at minimum fludizing condition.

Kirakan lompangan pada keadaan perbendaliran minimum.

[2 marks/markah]

[ii] Calculate the pressure drop at minimum fludizing condition.

Kirakan kejatuhan tekanan pada keadaan perbendaliran minimum.

[2 marks/markah]

[iii] Calculate the minimum velocity for fludization.

Kirakan halaju minimum bagi perbendaliran.

[2 marks/markah]

[c] [i] With an aid of a diagram, describe the three types of forces that act on a spherical particle that sinks in a stagnant fluid.

Dengan berbantukan gambarajah, perihalkan tiga jenis daya yang bertindak ke atas zarah sfera yang jatuh di dalam bendalir yang tidak bergerak.

[3 marks/markah]

[ii] Using the diagram described in [c] [i] above, show that the terminal velocity, v_t of the spherical particle is given by;

Dengan menggunakan gambarajah daripada [c] [i] di atas, tunjukkan bahawa halaju terminal bagi zarah tersebut, v_t diberikan seperti berikut;

$$v_t = \frac{gD_p^2(\rho_p - \rho_f)}{18\mu}$$

which occurs only when the particle has a Reynolds number, *Re* of less than 1.0. State the law that the particle obeys at this particular moment.

where; g = gravitational acceleration
D_p = particle diameter
ρ_p = density of particle
ρ_f = density of fluid
μ = viscosity of fluid

yang berlaku hanya apabila zarah tersebut mempunyai nombor Reynolds, Re kurang daripada 1.0. Nyatakan hukum yang dipatuhi oleh zarah tersebut pada masa halaju ini tercapai.

di mana; g = *pecutan graviti*
D_p = *diameter zarah*
ρ_p = *ketumpatan zarah*
ρ_f = *ketumpatan bendalir*
μ = *kelikatan bendalir*

[8 marks/markah]

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Lampiran

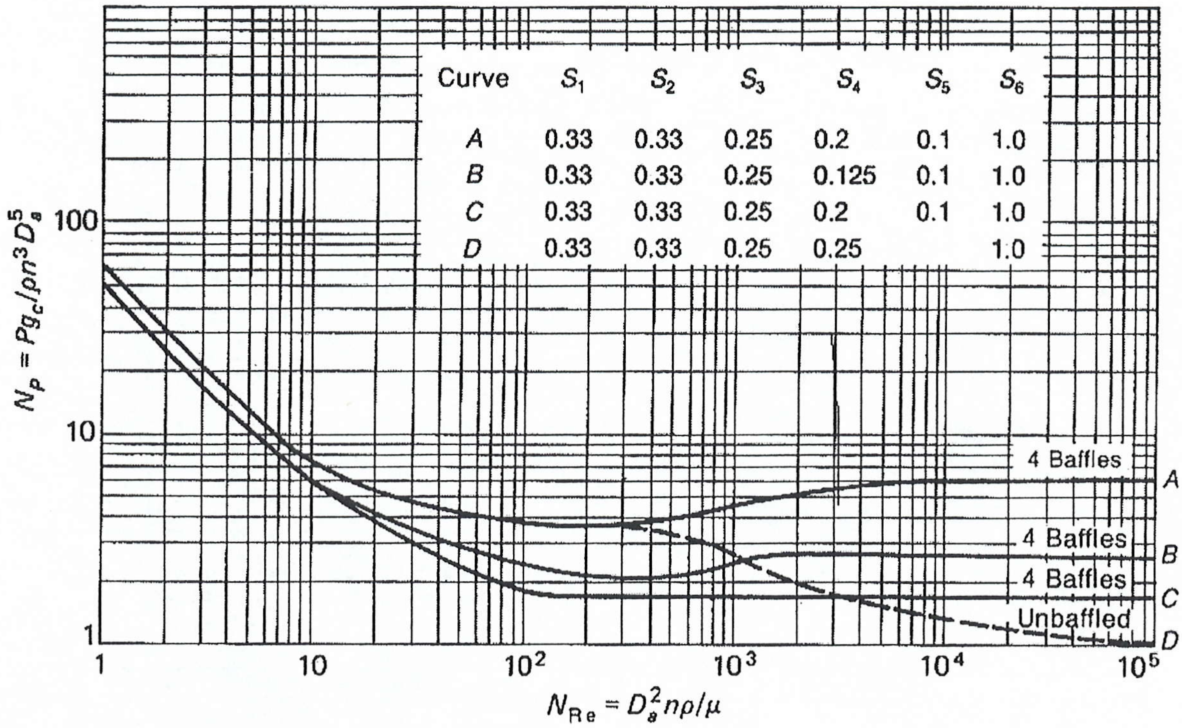

Figure
Power number N_P versus N_{Re} for six-blade turbines. With the dashed portion of curve D, the value of N_P read from the figure must be multiplied by N_{Fr}^{m}.

Table
Constants *a* and *b* for unbaffled tank

Turbine	a	b
Three blades	1.7	18.0
Six blades	1.0	40.0

Fluidization equation :

$$\frac{1.75\,(N_{\mathrm{Re},mf})^2}{\phi_S \varepsilon_{mf}^3} + \frac{150(1-\varepsilon_{mf})(N_{\mathrm{Re},mf})}{\phi_S^2 \varepsilon_{mf}^3} - \frac{D_P^3 \rho(\rho_P - \rho) g}{\mu^2} = 0$$

Air propeties at 25°C, 2 atm
[i] Density, $\rho = 2.374$ kg/m^3
[ii] Viscosity, $\mu = 1.848 \times 10^{-5}$ Pa.s

Common Engineering Conversion Factors

Length	Volume
1 ft = 12 in = 0.3048 m, 1 yard = 3 ft 1 mi = 5280 ft = 1609.344 m 1 nautical mile (nmi) = 6076 ft	1 ft^3 = 0.028317 m^3 = 7.481 gal. 1 bbl = 42 U.S. gal 1 U.S. gal = 231 in^3 = 3.7853 L = 4 qt = 0.833 Imp. gal. 1 L = 0.001 m^3 = 0.035315 ft^3 = 0.2642 U.S. gal
Mass	**Density**
1 slug = 32.174 lb_m = 14.594 kg 1 lb_m = 0.4536 kg = 7000 grains	1 slug/ft^3 = 515.38 kg/m^3, 1 g/cm^3 = 1000 kg/m^3 1 lb_m/ft^3 = 16.0185 kg/m^3, 1 lb_m/in^3 = 27.68 g/cm^3
Acceleration & Area	**Velocity**
1 ft/s^2 = 0.3048 m/s^2 1 ft^2 = 0.092903 m^2	1 ft/s = 0.3048 m/s, 1 knot = 1 nmi/h = 1.6878 ft/s 1 mi/h = 1.4666666 ft/s (fps) = 0.44704 m/s
Mass Flow & Mass Flux	**Volume Flow**
1 slug/s = 14.594 kg/s. 1 lb_m/s = 0.4536 kg/s 1 kg/m^2-s = 0.2046 lb_m/ft^2-s = 0.00636 slug/ft^2-s	1 gal/min = 0.002228 ft^3/s = 0.06309 L/s 1 million gal/day = 1.5472 ft^3/s = 0.04381 m^3/s
Pressure	**Force and Surface Tension**
1 lb_f/ft^3 = 47.88 Pa, 1 torr = 1 mm Hg 1 psi = 144 psf, 1 bar = 10^5 Pa 1 atm = 2116.2 psf = 14.696 psi = 101, 325 Pa = 29.9 in. Hg = 33.9 ft H_2O	1 lb_f = 4.448222 N = 16 oz, 1 dyne = 1 g-cm/s^2 = 10^{-5} N 1 kg_f = 2.2046 lb_f = 9.80665 N 1 U.S. (short) ton = 2000 lb_f, 1 N = 0.2248 lb_f 1 N/m = 0.0685 lb_f/ft
Power	**Energy and Specific Energy**
1 hp = 550 (ft-lb_f)/s = 745.7 W 1 (ft-lb_f)/s = 1.3558 W 1 Watt = 3.4123 Btu/h = 0.00134 hp	1 ft-lb_f = 1.35582 J, 1 hp-h = 2544.5 Btu 1 Btu = 252 cal = 1055.056 J = 778.17 ft-lb_f 1 cal = 4.1855 J, 1 ft-lb_f /lb_m = 2.9890 J/kg
Specific Weight	**Heat Flux**
1 lb_f/ft^3 = 157.09 N/m^3	1 W/m^2 = 0.3171 Btu/(h-ft^2)
Viscosity	**Kinematic Viscosity**
1 slug/(ft-s) = 47.88 kg/(m-s) = 478.8 poise (p) 1 p=1 g/(cm-s)=0.1 kg/(m-s)=0.002088 slug/(ft-s)	1 ft^2/h = 2.506 .10^{-5} m^2/s, 1 ft^2/s = 0.092903 m^2/s 1 stoke (st) = 1 cm^2/s = 0.0001 m^2/s = 0.001076 ft^2/s

Temperature Scale Readings

°F = (9/5)°C + 32   °C = (5/9) (°F − 32)   °R = °F + 459.69   °K = °C + 273.16

Specific Heat or Gas Constant*	Thermal Conductivity*
1 (ft-lb_f)/(slug-°R) = 0.16723 (N-m) (kg-K) 1 Btu/(lb-°R) = 4186.8 J/(kg-K)	1 cal/(s-cm-°C) = 242 Btu/(h-ft-°R) 1 Btu/(h-ft-°R) = 1.7307 W/(m-K)

- Note that the intervals in absolute (Kelvin) and °C are equal. Also, 1 °R = 1 °F.

Latent heat: 1 J/kg = 4.2995 x 10-4 Btu/lb_m = 10.76 lb_f-ft/slug = 0.3345 lb_f – ft/lb_m. 1 Btu/lb_m = 2325.9 J/kg.
Heat transfer coefficient: 1 Btu/(h-ft^2-°F) = 5.6782 W/(m^2 - °C).
Heat generation rate: 1 W/m^3 = 0.09665 Btu/(h-ft^3)
Heat transfer per unit length: 1 W/m = 1.0403 Btu/(h-ft)
Mass transfer coefficient: 1 m/s = 11.811 ft/h, 1 lbmol/(h-ft^2) = 0013562 kgmol/(s-m^2)

Density of Liquid Water

Temperature K	°C	Density g/cm³	kg/m³	Temperature K	°C	Density g/cm³	kg/m³
273.15	0	0.99987	999.87	323.15	50	0.98807	988.07
277.15	4	1.00000	1000.00	333.15	60	0.98324	983.24
283.15	10	0.99973	999.73	343.15	70	0.97781	977.81
293.15	20	0.99823	998.23	353.15	80	0.97183	971.83
298.15	25	0.99708	997.08	363.15	90	0.96534	965.34
303.15	30	0.99568	995.68	373.15	100	0.95838	958.38
313.15	40	0.99225	992.25				

Source: R. H. Perry and C. H. Chilton, *Chemical Engineers' Handbook*, 5th ed. New York: McGraw-Hill Book Company, 1973. With permission.

Viscosity of Liquid Water

Temperature K	°C	Viscosity [(Pa · s) 10³, (kg/m · s) 10³, or cp]	Temperature K	°C	Viscosity [(Pa · s) 10³, (kg/m · s) 10³, or cp]
273.15	0	1.7921	323.15	50	0.5494
275.15	2	1.6728	325.15	52	0.5315
277.15	4	1.5674	327.15	54	0.5146
279.15	6	1.4728	329.15	56	0.4985
281.15	8	1.3860	331.15	58	0.4832
283.15	10	1.3077	333.15	60	0.4688
285.15	12	1.2363	335.15	62	0.4550
287.15	14	1.1709	337.15	64	0.4418
289.15	16	1.1111	339.15	66	0.4293
291.15	18	1.0559	341.15	68	0.4174
293.15	20	1.0050	343.15	70	0.4061
293.35	20.2	1.0000	345.15	72	0.3952
295.15	22	0.9579	347.15	74	0.3849
297.15	24	0.9142	349.15	76	0.3750
298.15	25	0.8937	351.15	78	0.3655
299.15	26	0.8737	353.15	80	0.3565
301.15	28	0.8360	355.15	82	0.3478
303.15	30	0.8007	357.15	84	0.3395
305.15	32	0.7679	359.15	86	0.3315
307.15	34	0.7371	361.15	88	0.3239
309.15	36	0.7085	363.15	90	0.3165
311.15	38	0.6814	365.15	92	0.3095
313.15	40	0.6560	367.15	94	0.3027
315.15	42	0.6321	369.15	96	0.2962
317.15	44	0.6097	371.15	98	0.2899
319.15	46	0.5883	373.15	100	0.2838
321.15	48	0.5683			

Source: Bingham, *Fluidity and Plasticity*. New York: McGraw-Hill Book Company, 1922. With permission.

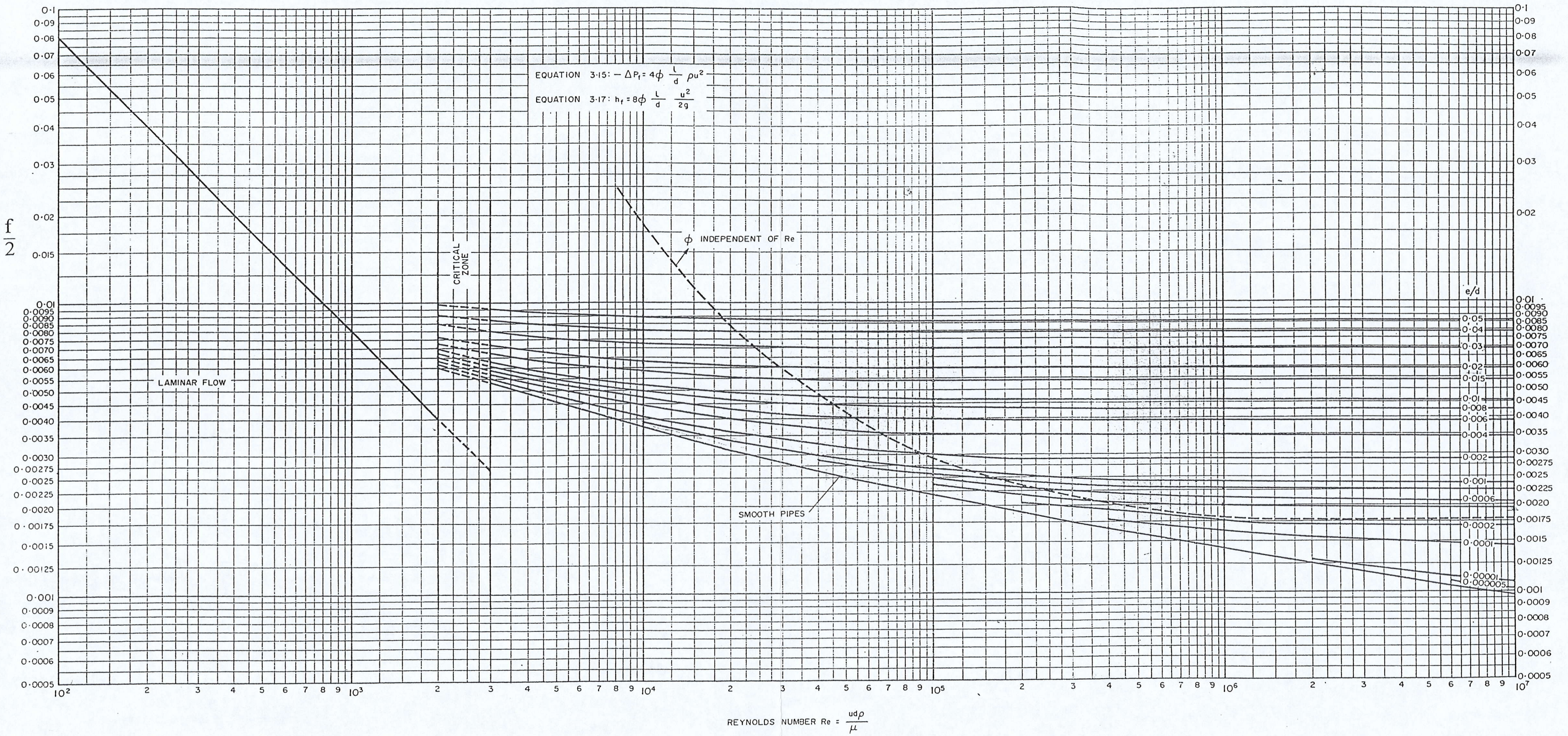

FIG. 3.7. Pipe friction chart ϕ versus *Re*.