UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 1992/93

April 1993

EBB 218/3 - Proses-proses Pengangkutan

Masa : (3 jam)

ARAHAN KEPADA CALON:-

Sila pastikan bahawa kertas soalan ini mengandungi **lima** (5) mukasurat bercetak sebelum anda memulakan peperiksaan ini.

Sila jawab **lima** (5) soalan sahaja.

Kertas soalan ini mengandungi **tujuh** (7) soalan semuanya.

Semua soalan MESTILAH dijawab di dalam Bahasa Malaysia.

Semua jawapan mesti dimulakan pada mukasurat baru.

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1. (a) Bermula dengan persamaan Navier Stokes dalam koordinat-koordinat polar yang diberi dalam Lampiran I, terbitkan persamaan $f = 16/(Re_D)$ untuk aliran lamina melalui satu tiub. Nyatakan sebarang andaian yang dibuat dengan jelas dan terangkan keadaan-keadaan sempadan sekiranya digunakan.

(50 markah)

(b) Kira kejatuhan tekanan di dalam paip licin berukuran 3 m panjang dan 1 cm garispusat dalaman dengan mana air pada 283K mengalir pada suatu halaju purata 0.2 m/s. Pertimbangkan aliran terbentuk sepenuhnya. Apakah kejatuhan tekanan sekiranya;

i) suhu air ditingkatkan ke 353K dan halaju dikekalkan?

ii) halaju ditingkatkan kepada 0.7 m/s dengan suhu air 283K?

(50 markah)

2. (a) Dengan bantuan lakaran yang teratur, terangkan istilah "Lapisan Sempadan Halaju".

(10 markah)

(b) Dengan menggunakan kaedah kamilan, tunjukkan bahawa ketebalan lapisan sempadan halaju δ diberi sebagai $\delta = \dfrac{4.64\ X}{Re_X^{0.5}}$

bagi suatu aliran lamina melintasi suatu plat rata dengan pinggir depan yang tajam.

(50 markah)

(c) Udara pada 333K dan tekanan atmosfera mengalir melintasi kedua-dua bahagian tepi suatu plat rata yang nipis berukuran 1 m lebar dan 2 m panjang. Halaju aliran bebas ialah 1 m/s. Hitung ketebalan lapisan sempadan halaju pada jarak 1.5 m di bahagian hilir dari pinggir depan yang tajam dan hitung juga daya seret pada plat.

$Re_c = 3 \times 10^5$, untuk aliran lamina $C_f = 1.328 \times Re^{0.5}$

(Sifat-sifat udara boleh didapati dari Lampiran II)

(40 markah)

3. (a) Bermula dari Hukum Fourier bagi aliran haba dan Hukum Newtons bagi penyejukan, tentukan ungkapan untuk rintangan haba setara untuk lapisan bendalir di dalam dan di luar tiub selinder panjang 1m dan rintangan haba tiub sekiranya garis pusat dalaman tiub ialah d_i m dan luaran ialah d_o.

(40 markah)

(b) Dinding komposit ketuhar terdiri dari tiga bahan, dua darinya mempunyai pengaliran haba, k_A = 20 W/m.K dan k_C = 50 W/m.K dan dengan ketebalan L_A = 30 cm dan L_C = 15 cm. Bahan ketiga yang berada di antara bahan A dan bahan C mempunyai ketebalan L_B = 15 cm tetapi pengaliran haba K_B tidak diketahui.

Di bawah keadaan operasi mantap, ukuran menunjukkan suhu permukaan luaran, $T_{s.o.}$ = 293K, dan suhu permukaan dalaman, $T_{s.i.}$ = 873 K sementara suhu udara di dalam ketuhar adalah T_a = 1073K. Pemalar olakan dalaman bernilai 25 W/m^2.K. Dapatkan pengaliran haba untuk bahan B.

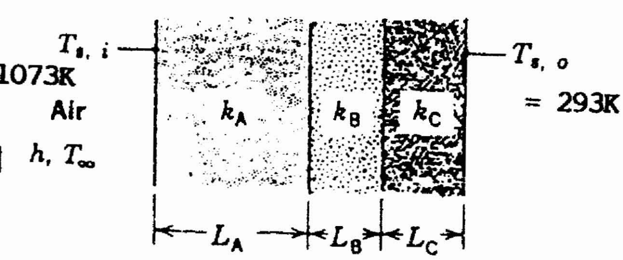

Fig. Q3 [b]

(60 markah)

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4. (a) Takrifkan istilah Nombor Nusselt dan terangkan signifikan fizikalnya.

(10 markah)

(b) Untuk suatu pemindahan haba olakan yang terbentuk sepenuhnya di bawah keadaan fluks haba konstan melalui dinding suatu tiub, buktikan Nombor Nusselt $N_u = 4.364$ sekiranya aliran ialah lamina. Diberi persamaan;

$$K\left[\frac{\partial^2 T}{\partial Z^2} + \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)\right] \approx \rho C_p\left[V_Z\frac{\partial T}{\partial Z} + V_r\frac{\partial T}{\partial r}\right]$$

(40 markah)

(c) Hitung pemalar pemindahan haba untuk aliran air melalui tiub berdiameter 25 mm pada kadar 1.5 kg/s, apabila suhu pukal min ialah 313K. Untuk aliran gelora cecair gunakan;

$$N_u = 0.0243\, Re_d^{0.8} \times Pr^{0.4}$$

(50 markah)

5. (a) Takrifkan dan jelaskan istilah-istilah berikut:

i) Nombor Grashoff

ii) Jasad kelabu

iii) Keberpancaran

(15 markah)

(b) Berdasarkan analisis dimensi buktikan bahawa

i) Nombor Nusselt merupakan suatu fungsi Nombor Reynold dan Nombor Prandtl.

(60 markah)

ii) Nombor Stanton merupakan suatu fungsi Nombor Nusselt, Reynold dan Prandtl.

(25 markah)

6. (a) Nyatakan dan terangkan Hukum Pertama dan Kedua Fick.

(20 markah)

(b) Terangkan mekanisme tindakan mangkin pelet.

(20 markah)

(c) Suatu keluli karbon 0.1% berat akan dikarbonkan. Atmosfera pengkarbonan memberikan kepekatan 0.9% berat karbon pada permukaan. Rawatan tersebut berterusan selama 24 jam pada 1123 K. Apakah ketebalan lapisan lebih dari 0.2% berat karbon selepas rawatan tersebut? Data-data berikut boleh diguna:

$R = 8.31$ kJ/ kg mol .K

Berat atom karbon = 12.0

Berat atom besi = 55.8

Pemalar peresapan karbon di dalam besi: $Q = 145 \times 10^3$ kJ/kg mol. dan

$A = 2 \times 10^{-5}\ m^2s^{-1}$ Diberi: $D = A\ e^{(-Q/RT)}$

(60 markah)

7. (a) Terangkan persamaan di antara ketiga-tiga proses-proses pengangkutan; pemindahan momentum, pemindahan haba dan pemindahan jisim.

(30 markah)

(b) Terangkan istilah;

i) tebal anjakan

ii) tebal momentum

(30 markah)

(c) Terbitkan persamaan keterusan untuk aliran kebolehmampatan 3-D dalam koordinat cartesian.

(40 markah)

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Lampiran I

TABLE 3.4-2

THE EQUATION OF MOTION IN RECTANGULAR COORDINATES (x, y, z)

In terms of τ:

x-component
$$\rho\left(\frac{\partial v_x}{\partial t} + v_x\frac{\partial v_x}{\partial x} + v_y\frac{\partial v_x}{\partial y} + v_z\frac{\partial v_x}{\partial z}\right) = -\frac{\partial p}{\partial x} - \left(\frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z}\right) + \rho g_x \qquad (A)$$

y-component
$$\rho\left(\frac{\partial v_y}{\partial t} + v_x\frac{\partial v_y}{\partial x} + v_y\frac{\partial v_y}{\partial y} + v_z\frac{\partial v_y}{\partial z}\right) = -\frac{\partial p}{\partial y} - \left(\frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z}\right) + \rho g_y \qquad (B)$$

z-component
$$\rho\left(\frac{\partial v_z}{\partial t} + v_x\frac{\partial v_z}{\partial x} + v_y\frac{\partial v_z}{\partial y} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} - \left(\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zz}}{\partial z}\right) + \rho g_z \qquad (C)$$

In terms of velocity gradients for a Newtonian fluid with constant ρ and μ:

x-component
$$\rho\left(\frac{\partial v_x}{\partial t} + v_x\frac{\partial v_x}{\partial x} + v_y\frac{\partial v_x}{\partial y} + v_z\frac{\partial v_x}{\partial z}\right) = -\frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 v_x}{\partial x^2} + \frac{\partial^2 v_x}{\partial y^2} + \frac{\partial^2 v_x}{\partial z^2}\right) + \rho g_x \qquad (D)$$

y-component
$$\rho\left(\frac{\partial v_y}{\partial t} + v_x\frac{\partial v_y}{\partial x} + v_y\frac{\partial v_y}{\partial y} + v_z\frac{\partial v_y}{\partial z}\right) = -\frac{\partial p}{\partial y} + \mu\left(\frac{\partial^2 v_y}{\partial x^2} + \frac{\partial^2 v_y}{\partial y^2} + \frac{\partial^2 v_y}{\partial z^2}\right) + \rho g_y \qquad (E)$$

z-component
$$\rho\left(\frac{\partial v_z}{\partial t} + v_x\frac{\partial v_z}{\partial x} + v_y\frac{\partial v_z}{\partial y} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left(\frac{\partial^2 v_z}{\partial x^2} + \frac{\partial^2 v_z}{\partial y^2} + \frac{\partial^2 v_z}{\partial z^2}\right) + \rho g_z \qquad (F)$$

TABLE 3.4-3

THE EQUATION OF MOTION IN CYLINDRICAL COORDINATES (r, θ, z)

In terms of τ:

r-component[a]
$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} - \frac{v_\theta^2}{r} + v_z\frac{\partial v_r}{\partial z}\right) = -\frac{\partial p}{\partial r} - \left(\frac{1}{r}\frac{\partial}{\partial r}(r\tau_{rr}) + \frac{1}{r}\frac{\partial \tau_{r\theta}}{\partial \theta} - \frac{\tau_{\theta\theta}}{r} + \frac{\partial \tau_{rz}}{\partial z}\right) + \rho g_r \qquad (A)$$

θ-component[b]
$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_r v_\theta}{r} + v_z\frac{\partial v_\theta}{\partial z}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} - \left(\frac{1}{r^2}\frac{\partial}{\partial r}(r^2\tau_{r\theta}) + \frac{1}{r}\frac{\partial \tau_{\theta\theta}}{\partial \theta} + \frac{\partial \tau_{\theta z}}{\partial z}\right) + \rho g_\theta \qquad (B)$$

z-component
$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} - \left(\frac{1}{r}\frac{\partial}{\partial r}(r\tau_{rz}) + \frac{1}{r}\frac{\partial \tau_{\theta z}}{\partial \theta} + \frac{\partial \tau_{zz}}{\partial z}\right) + \rho g_z \qquad (C)$$

In terms of velocity gradients for a Newtonian fluid with constant ρ and μ:

r-component[a]
$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta} - \frac{v_\theta^2}{r} + v_z\frac{\partial v_r}{\partial z}\right) = -\frac{\partial p}{\partial r} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_r)\right) + \frac{1}{r^2}\frac{\partial^2 v_r}{\partial \theta^2} - \frac{2}{r^2}\frac{\partial v_\theta}{\partial \theta} + \frac{\partial^2 v_r}{\partial z^2}\right] + \rho g_r \qquad (D)$$

θ-component[b]
$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{v_r v_\theta}{r} + v_z\frac{\partial v_\theta}{\partial z}\right) = -\frac{1}{r}\frac{\partial p}{\partial \theta} + \mu\left[\frac{\partial}{\partial r}\left(\frac{1}{r}\frac{\partial}{\partial r}(rv_\theta)\right) + \frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial \theta^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial \theta} + \frac{\partial^2 v_\theta}{\partial z^2}\right] + \rho g_\theta \qquad (E)$$

z-component
$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta} + v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial p}{\partial z} + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 v_z}{\partial \theta^2} + \frac{\partial^2 v_z}{\partial z^2}\right] + \rho g_z \qquad (F)$$

[a] The term $\rho v_\theta^2/r$ is the *centrifugal force*. It gives the effective force in the r-direction resulting from fluid motion in the θ-direction. This term arises automatically on transformation from rectangular to cylindrical coordinates; it does not have to be added on physical grounds. Two problems in which this term arises are discussed in Examples 3.5-1 and 3.5-2.

[b] The term $\rho v_r v_\theta/r$ is the *Coriolis force*. It is an effective force in the θ-direction when there is flow in both the r- and θ-directions. This term also arises automatically in the coordinate transformation. The Coriolis force arises in the problem of flow near a rotating disk (see, for example, H. Schlichting, *Boundary-Layer Theory*, McGraw-Hill, New York (1955), Chapter 10.

B_I

Table A.1 Physical properties of water.

Temperature, °C	Specific weight γ, kN/m^3	Density ρ, kg/m^3	Viscosity $\mu \times 10^3$, $N \cdot s/m^2$	Kinematic viscosity $\nu \times 10^6$, m^2/s	Surface tension σ, N/m	Vapor pressure p_v, kN/m^2, abs	Vapor pressure head p_v/γ m	Bulk modulus of elasticity $E_v \times 10^{-6}$, kN/m^2
0	9.805	999.8	1.781	1.785	0.0756	0.61	0.06	2.02
5	9.807	1000.0	1.518	1.519	0.0749	0.87	0.09	2.06
10	9.804	999.7	1.307	1.306	0.0742	1.23	0.12	2.10
15	9.798	999.1	1.139	1.139	0.0735	1.70	0.17	2.14
20	9.789	998.2	1.002	1.003	0.0728	2.34	0.25	2.18
25	9.777	997.0	0.890	0.893	0.0720	3.17	0.33	2.22
30	9.764	995.7	0.798	0.800	0.0712	4.24	0.44	2.25
40	9.730	992.2	0.653	0.658	0.0696	7.38	0.76	2.28
50	9.689	988.0	0.547	0.553	0.0679	12.33	1.26	2.29
60	9.642	983.2	0.466	0.474	0.0662	19.92	2.03	2.28
70	9.589	977.8	0.404	0.413	0.0644	31.16	3.20	2.25
80	9.530	971.8	0.354	0.364	0.0626	47.34	4.96	2.20
90	9.466	965.3	0.315	0.326	0.0608	70.10	7.18	2.14
100	9.399	958.4	0.282	0.294	0.0589	101.33	10.33	2.07

B_{II}

Table A.2 Physical properties of air at standard atmospheric pressure

Temperature T, °C	Temperature T, °F	Density ρ, kg/m^3	Specific weight γ, N/m^3	Viscosity $\mu \times 10^5$, $N \cdot s/m^2$	Kinematic viscosity $\nu \times 10^5$, m^2/s
−40	−40	1.515	14.86	1.49	0.98
−20	−4	1.395	13.68	1.61	1.15
0	32	1.293	12.68	1.71	1.32
10	50	1.248	12.24	1.76	1.41
20	68	1.205	11.82	1.81	1.50
30	86	1.165	11.43	1.86	1.60
40	104	1.128	11.06	1.90	1.68
60	140	1.060	10.40	2.00	1.87
80	176	1.000	9.81	2.09	2.09
100	212	0.946	9.28	2.18	2.31
200	392	0.747	7.33	2.58	3.45

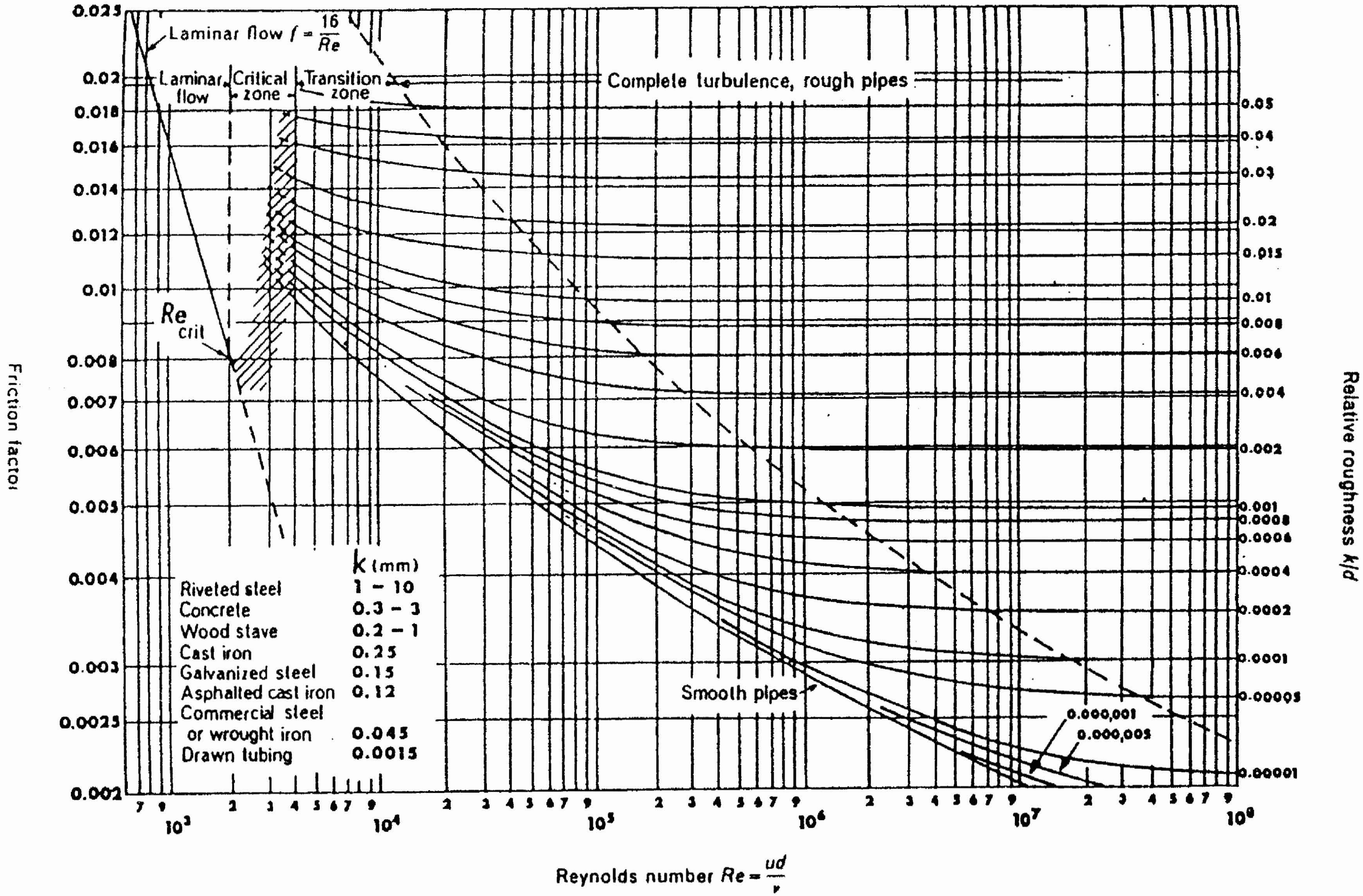

FIG. 7.2

Lampiran III (EBB 218)

(EBB 218)
Lampiran I

Fungsi Ralat , erf(x)

x	0	1	2	3	4	5	6	7	8	9
0.0	0.0000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3256	0.3389	0.3491	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4254	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5370	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8427	0.8168	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8135	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9672	0.9683	0.9695	0.9706	0.9716	0.9726	0.9735	0.9745	0.9754

1.55	1.6	1.65	1.7	1.75	1.8	1.9	2.0	2.1	2.2
0.9716	0.9763	0.9804	0.9838	0.9867	0.9891	0.9928	0.9953	0.9970	0.9981

Jadual Nilai Fungsi Ralat