



**UNIVERSITI SAINS MALAYSIA**

**Peperiksaan Semester Pertama**

**Sidang Akademik 1997/98**

**September 1997**

**EBB 209/3 - TEKNOLOGI SERBUK**

**Masa: [3 jam]**

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**Arahan kepada Calon:-**

Sila pastikan kertas peperiksaan ini mengandungi **TIGA BELAS (13)** muka surat bercetak dan **SATU (1) LAMPIRAN** sebelum anda memulakan peperiksaan.

Kertas soalan ini mengandungi **ENAM (6)** soalan.

Jawab mana-mana **LIMA (5)** soalan sahaja.

Mulakan Jawapan anda bagi setiap soalan pada muka surat yang baru

Semua soalan mesti di jawab dalam Bahasa Malaysia, atau maksimum **DUA (2)** soalan boelh di jawab dalam Bahasa Inggeris.

1. [a] Dengan bantuan gambarajah yang sesuai, terangkan dengan ringkas setiap satu yang berikut:-

*Explain briefly with the aids of diagrams each of the following :*

- [i] Teknik Fabrikasi Serbuk Mekanik.

*Mechanical Powder Fabrication Techniques.*

- [ii] Teknik Fabrikasi Serbuk Elektrolit.

*Electrolytic Powder Fabrication Techniques.*

- [iii] Teknik Fabrikasi Serbuk Kimia.

*Chemical Powder Fabrication Techniques.*

- [iv] Teknik Fabrikasi Penguapan.

*Atomization Fabrication Techniques.*

(40 markah)

- [b] Data yang diambil bagi serbuk aluminium (ketumpatan  $e = 2.7 \text{ g/cm}^3$ ) yang melalui sedimentasi adalah seperti berikut:-

*Data collected by sedimentation for an aluminum powder (density  $e=2.7\text{g/cm}^3$ ) as follows :*

Julat saiz, $\mu\text{m}$ <i>Size range, <math>\mu\text{m}</math></i>	Berat (g) <i>Weight (g)</i>
0 - 1	0
1 - 2	0.4
2 - 4	5.5
4 - 8	23.4
8 - 12	19.0
12 - 20	17.6
20 - 32	5.9
32 - 44	1.1
44 - 88	0.3
> 88	0

- [i] Plot histogram bagi data tersebut dengan menunjukkan saiz mod.

*Plot histogram of this data showing the mode size.*

- [ii] Berikan plot taburan saiz zarah yang menunjukkan % berat kumulatif lawan log saiz zarah.

*Give a particle size distribution plot showing the cumulative weight percent versus the log of the particle size.*

[iii] Apakah saiz purata (mean size) berdasarkan berat?

*What is the mean particle size on a weight basis?*

[iv] Anggarkan saiz purata zarah berdasarkan kelompok.

*Estimate the mean particle size on a population basis?*

[v] Teknik-teknik manakah yang sesuai sebagai analisis saiz bagi serbuk ini (nama dan lakarkan skematik sahaja).

*What techniques for size analysis would be applicable to this powder? (name and schematic drawing only).*

Hint : Gunakan Jadual 1 - Taburan Normal Kumulatif

*Hint : Use the Table 1. Cumulative normal distribution.*

(60 markah)

2. [a] Serbuk kuprum elektrolit dengan saiz zarah 150 ke 45  $\mu\text{m}$  berikan ketumpatan ketara dan ketumpatan anum berikut (dengan tekanan mampatan 350 MPa) dan dengan pelincir zink stearat dalam amaun berbeza:

*Electrolytic copper powder of 150 to 45 ( $\mu\text{m}$  particles size gives the following apparent densities and green densities (350 MPa compaction pressure) with varying amount of zinc stearate lubricant :*

Amaun berat % pelincir	:	0	0.5	1	2.0
amount wt% lubricant	:	0	0.5	1	2.0

...5/-

Ketumpatan ketara, $\text{g cm}^{-3}$ :	2.78	2.75	2.73	2.68
<i>apparent density</i> $\text{g cm}^{-3}$ :	2.78	2.75	2.73	2.68
Ketumpatan anum, $\text{g cm}^{-3}$ :	6.59	6.68	6.48	6.37
<i>green density</i> $\text{g cm}^{-3}$ :	6.59	6.68	6.48	6.37

- [i] Terangkan kenapa ketumpatan ketara berkurangan apabila amaun pelincir bertambah.

*Explain why the apparent density decreases as the amount of lubricant is increased.*

- [ii] Terangkan kenapa ketumpatan anum menunjukkan perbezaan tak lurus (nonlinear) dengan amaun pelincir.

*Explain why the green density has a nonlinear variation with the amount of lubricant.*

- [iii] Lakarkan perbezaan kekuatan anum yang dijangkakan dengan amaun pelincir.

*Sketch the expected green strength variation with amount of lubricant.*

(40 markah)

- [b] Samada serbuk logam ataupun seramik, adalah penting untuk dipisahkan campuran-campuran homogen dalam julat saiz zarah daripada 10 hingga 250  $\mu\text{m}$ . Untuk ini, kita gunakan prinsip cuci godak udara (air elutriation), yang digambarkan oleh peranti di bawah. Daya yang dikenakan oleh aliran udara adalah cukup kuat untuk mengapungkan zarah-zarah yang bergarispusat tertentu ke atas dan ke pengumpul zarah halus. Zarah-zarah kasar jatuh ke bawah melalui aliran udara dan ke dalam kebuk mendapan. Untuk peranti ini beroperasi secara berkesan maka adalah perlu untuk diketahui saiz zarah terapung pada satu kadar aliran. Dengan mengandaikan zarah adalah sfera, dengan ketumpatan  $4000 \text{ kgm}^{-3}$ , diaplikasikan kepada campuran serbuk besi yang homogen, lukiskan satu graf yang menghubungkan garispusat zarah terapung kepada halaju udara dalam ruangan terkembang tiub tersebut.

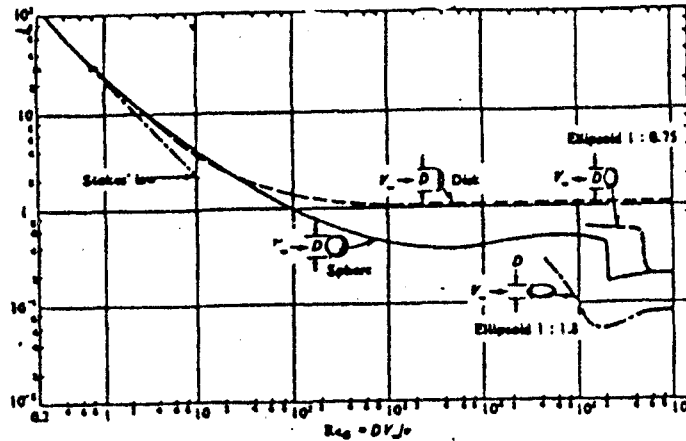
Ambil : Kelikatan air =  $1.8 \times 10^{-5} \text{ kgm}^{-1} \text{ s}^{-1}$ ,

Ketumpatan air =  $1.18 \text{ kgm}^{-3}$ .

*With either metallic or ceramic powders, it is important to separate homogeneous mixtures in the range of particles sizes from 10 to 250  $\mu\text{m}$ . For this purpose we apply the principle of air elutriation, which is illustrated by the device shown below. The force exerted by the air stream is great enough to suspend particles of a given diameter and be carried upward to the collector of fines. Larger particles fall back against the air stream and down into a settling chamber. For the effective operation of this device it is necessary to know the size of particles suspended at a given flow rate.*

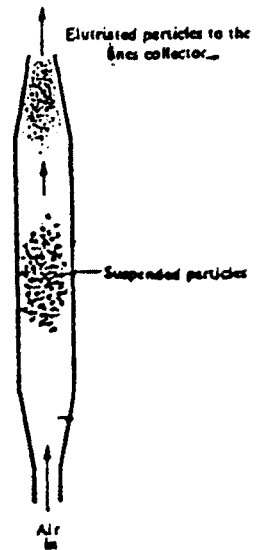
*Assuming that a spherical particle, with a density of  $4000 \text{ Kgm}^{-3}$ , applies to a homogeneous mixture of Iron powder, draw a graph that relates the diameter of suspended particles to the velocity of the air in the expanded portion of the tube.*

Take : viscosity of air =  $1.8 \times 10^{-5} \text{ kgm}^{-1} \text{ s}^{-1}$ ,  
density of air =  $1.18 \text{ kgm}^{-3}$ .



Rajah 1 : Faktor geseran untuk jasad tenggelam

Figure 1 : Friction factors for submerged bodies.



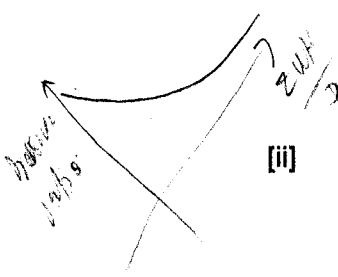
(60 markah)

3. [a] Lakarkan :

Sketch :

- [i] Garis-garis ketumpatan malar (kontur) dalam silinder-silinder berserbuk logam melawan tinggi dan jejari untuk (a) penekanan tindakan tunggal (b) penekanan tindakan kembar.

*Constant density lines (contours) in cylinders of compacted metal powder versus height and radius for both (a) Single action (b) Double action pressing.*



- [ii] Taburan tekanan (kontur) bagi silinder serbuk logam tertekan bagi nisbah ketinggian kepada garispusat yang berbeza (penekanan tindakan tunggal).

*Pressure distribution (contours) compacted metal powder cylinders of different height to diameter ratios (single action pressing).*

(40 markah)

- [b] Satu padatan silinder akan dibentuk; garispusat luar  $D = 2$  sm, dan tinggi  $H = 4$  sm oleh penekanan tindakan tunggal. Tekanan dikenakan  $0.95$  MPa. Hitung:-

- [i] tekanan pada separuh padatan tersebut.  
[ii] tegasan mampatan purata.

Ambilkan tegasan jejari =  $0.25$  MPa dan koefisien geseran antara serbuk dan dinding dai =  $0.25$ .

*A cylindrical compact is to be formed; outer diameter  $D = 2$  cm and Height  $H = 4$  cm by single action pressing. The applied pressure is  $0.95$  MPa. Calculate (1) the pressure at midway of the compact. (2) The average compaction stress. Take the radial stress =  $0.25$  Mpa, the coefficient of friction between the powder and the die wall =  $0.25$ .*

(60 markah)

4. [a] Ringkaskan proses persinteran.  
*Summarize the processes of sintering.*

(30 markah)

...9/-



- [b] Data berikut diambil daripada padatan besi teratom air yang tersinter. Serbuknya kurang daripada 150  $\mu\text{m}$ , ditekankan kepada bar-bar tensil pada tekanan yang berbeza dan disinter pada 1200°C dalam hidrogen.

*The following data were taken from sintered compacts of water atomized iron. The powder was less than 150  $\mu\text{m}$ , pressed into tensile bars at various pressures, and sintered at 1200°C in hydrogen.*

Keliangan % Porosity %	Kekuatan MPa Strength MPa	Pemanjangan % Elongation %
0	330	30
12	208	9
21	142	5
31	82	3
37	49	2
43	34	1

- [i] Terangkan kenapa kekuatan menurun dengan peningkatan keliangan.

*Explain why the strength decreases with an increasing porosity.*

- [ii] Bandingkan data ini dengan persamaan :  $\sigma = K \sigma_0 \rho^m$

*Compare this data with the equation :  $\sigma = K \sigma_0 \rho^m$*

Dimana  $\sigma$  ialah kekuatan,  $\sigma_0$  ialah kekuatan tempawan (wrought strength) bagi bahan yang sama, K adalah pemalar geometri dan pemrosesan, m adalah eksponen yang bergantung kepada ketumpatan dan  $\rho$  ialah ketumpatan pecahan.

*Where  $\sigma$  is the strength,  $\sigma_0$  is the wrought strength of the same material, K is a geometric and processing constant, m exponential dependence on density, and  $\rho$  is the fractional density.*

[iii] Tentukan nilai C dalam persamaan  $Z = (1 - \epsilon)^{3/2} / (1 + C \epsilon)^{1/2}$

*Determine the C value in the equation  $Z = (1 - \epsilon)^{3/2} / (1 + C \epsilon)^{1/2}$*

Z adalah kemuluran relatif,  $\epsilon$  % keliangan

*Z: relative ductility,  $\epsilon$  porosity %.*

(70 markah)

5. [a] Lakarkan kekonduksian terma relatif, kemuluran dan koefisien pengembangan terma melawan ketumpatan pecahan yang lebih sensitif kepada liang-liang?

Gunakan maklumat berikut:-

*Plot the relative thermal conductivity, ductility and thermal expansion coefficient versus fractional density which is more sensitive to pores?*

*Use the following information :-*

[i]  $J/J_0 = (1-\epsilon)/(1+n\epsilon^2)$

$J/J_0$  ialah nisbah kekonduksian berliang kepada kekondusian jasad tumpat sepenuhnya.

$J/J_0 = (1-\epsilon)/(1+n\epsilon^2)$

$J/J_0$  ratio of the porous conductivity to the conductivity of fully densified material.  $n = 11$ ,  $\epsilon =$  porosity %

[ii]  $Z = (1 - \epsilon)^{3/2} / (1 + C\epsilon)^{1/2}$       Z : kemuluran relatif, C = 1600

$Z = (1 - \epsilon)^{3/2} / (1 + C\epsilon)^{1/2}$       Z : relative ductility, C = 1600

[iii]  $\phi / \phi_0 = \rho^{1/3}$  ,

dimana  $\phi/\phi_0 = \frac{\text{pengembangan terma efektif}}{\text{pengembangan terma tempawan}}$

$\rho =$  ketumpatan pecahan

$\epsilon + \rho = 1$

$\phi / \phi_0 = \rho^{1/3}$  ,

$\phi/\phi_0 =$  effective thermal expansion/wrought thermal expansion

$\rho =$  fractional density;  $\epsilon + \rho = 1$

Berikan komen anda bagi setiap lakaran.

Make your comments of each plot?

(60 markah)

...12/-

- [b] Udara telah tertelap menembusi suatu tiub (2 luas keratan rentas  $1 \text{ cm}^2$  dengan panjang  $1 \text{ cm}$ ) yang mengandungi serbuk molibdenum dengan ketumpatan ketara  $4.5 \text{ g/cm}^3$ . Pada satu atmosfera kebezaan tekanan ( $2 \text{ atm}$  ke  $1 \text{ atm}$ ), halaju aliran terukur adalah  $0.15 \text{ cm/saat}$ . Apakah garispusat sfera ekuivalen?

$$\text{Kelikatan udara} = 1.8 \times 10^4 \text{ g cm}^{-1} \text{ s}^{-1}$$

$$\text{Ketumpatan molibdenum} = 10.2 \text{ g cm}^{-3}$$

*Air is permeated through a tube ( $1 \text{ cm}^2$  cross sectional area by  $1 \text{ cm}$  long) containing Molybdenum powder with an apparent density of  $4.5 \text{ g/cm}^3$ . At one atmosphere pressure differential ( $2 \text{ atm}$  to  $1 \text{ atm}$ ) the measured flow velocity is  $0.15 \text{ cm/sec}$ . What is the equivalent spherical diameter?*

$$\text{Air viscosity} = 1.8 \times 10^4 \text{ g cm}^{-1} \text{ s}^{-1}$$

$$\text{Molybdenum density} = 10.2 \text{ g cm}^{-3}$$

(40 markah)

6. [a] Tunjukkan dengan lakaran skematik kedua-dua mod penurasan untuk logam tersinter.

*Show by schematic drawings the two modes of filtration for sintered metals.*

(35 markah)

- [b] Satu komposit seramik-logam mengandungi 10% fasa seramik telah disediakan dengan penekanan isostatik panas dicampurkan hingga 100% ketumpatan. Kekonduksian terma logam adalah  $350 \text{ watt/km}$  dan bagi seramik ialah  $50 \text{ watt/km}$ . Anggarkan kekonduksian terma komposit tersebut.

A metal-ceramic composite containing 10% ceramic phase is prepared by hot iso-statically pressing mixed to 100% density. The thermal conductivity of the metal and ceramic components are 350 and 30 watt/(km) respectively. Estimate the thermal conductivity of the composite.

(15 markah)

- [c] Serbuk sfera alumina telah disusun dalam aturan bersiri seperti ditunjukkan di bawah supaya oksida "dros" diasingkan daripada leburan aluminium. Susunan padatan pertama yang bertembung dengan aliran memerangkap zarah-zarah "dros" yang besar, dan padatan kedua memerangkap zarah dros yang lebih kecil. Diberikan  $L_A = 0.7 L_B$ ,  $W_A = W_B$ ,  $D_{PA} = 2D_{PB}$ . Tentukan nisbah kejatuhan tekanan merentasi A kepada tekanan menerusi B bagi
- [a] nombor Reynolds yang sangat rendah
  - [b] nombor Reynolds yang sangat tinggi

$W_A, W_B$  - pecahan rongga

$D_{PA}, D_{PB}$  - garispusat bagi zarah A dan B

$Al_2O_3$  spherical powder was arranged in series as shown in order to remove drossy oxides from molten aluminum. The first packing encountered by the flow captures large drossy particles, and the second packing captures the smaller drossy particles. Given  $L_A = 0.7L_B$ ,  $W_A = W_B$ ,  $D_{PA} = 2D_{PB}$ .

- Compute the ratio of the pressure drop through A to the pressure through B for
- (a) very low Reynolds numbers,
  - (b) very high Reynolds numbers

$W_A, W_B$  = void fraction

$D_{PA}, D_{PB}$  = particle diameter of A & B respectively.

(50 markah)

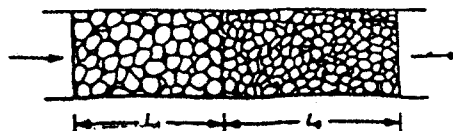


TABLE A.1 Cumulative Normal Distribution *continued*

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.00	5000	5040	5080	5120	5160	5199	5239	5279	5319	5359
.10	5398	5438	5478	5517	5557	5596	5636	5675	5714	5753
.20	5793	5832	5871	5910	5948	5987	6026	6064	6103	6141
.30	6179	6217	6255	6293	6331	6368	6406	6443	6480	6517
.40	6554	6591	6628	6664	6700	6736	6772	6808	6844	6879
.50	6915	6950	6985	7019	7054	7088	7123	7157	7190	7224
.60	7257	7291	7324	7357	7389	7422	7454	7486	7517	7549
.70	7580	7611	7642	7673	7704	7734	7764	7794	7823	7852
.80	7881	7910	7939	7967	7995	8023	8051	8078	8106	8133
.90	8159	8186	8212	8238	8264	8289	8315	8340	8365	8389
1.00	8413	8438	8461	8485	8508	8531	8554	8577	8599	8621
1.10	8643	8665	8686	8708	8729	8749	8770	8790	8810	8830
1.20	8849	8869	8888	8907	8925	8944	8962	8980	8997	9015
1.30	9032	9049	9066	9082	9099	9115	9131	9147	9162	9177
1.40	9192	9207	9222	9236	9251	9265	9279	9292	9306	9319
1.50	9332	9345	9357	9370	9382	9394	9406	9418	9429	9441
1.60	9452	9463	9474	9484	9495	9505	9515	9525	9535	9545
1.70	9554	9564	9573	9582	9591	9599	9608	9616	9625	9633
1.80	9641	9649	9656	9664	9671	9678	9686	9693	9699	9706
1.90	9713	9719	9726	9732	9738	9744	9750	9756	9761	9767
2.00	9772	9778	9783	9788	9793	9798	9803	9808	9812	9817
2.10	9821	9826	9830	9834	9838	9842	9846	9850	9854	9857
2.20	9861	9864	9868	9871	9875	9878	9881	9884	9887	9890
2.30	9893	9896	9898	9901	9904	9906	9909	9911	9913	9916
2.40	9918	9920	9922	9925	9927	9929	9931	9932	9934	9936
2.50	9938	9940	9941	9943	9945	9946	9948	9949	9951	9952
2.60	9953	9955	9956	9957	9959	9960	9961	9962	9963	9964
2.70	9965	9966	9967	9968	9969	9970	9971	9972	9973	9974
2.80	9974	9975	9976	9977	9977	9978	9979	9979	9980	9981
2.90	9981	9982	9982	9983	9984	9984	9985	9985	9986	9986
3.00	9987	9987	9987	9988	9988	9989	9989	9989	9990	9990
3.10	9990	9991	9991	9991	9992	9992	9992	9992	9993	9993
3.20	9993	9993	9994	9994	9994	9994	9994	9995	9995	9995
3.30	9995	9995	9995	9996	9996	9996	9996	9996	9996	9997

Source: J. Banks/R. G. Heikes, *Handbook of Tables and Graphs for the Industrial Engineer and Manager*, © 1984, pp. 44-45 (A. Rexton Publication).  
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TABLE A.1 Cumulative Normal Distribution

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
-3.40	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
-3.30	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
-3.20	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0006	.0005	.0005
-3.10	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
-3.00	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
-2.90	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
-2.80	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
-2.70	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
-2.60	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
-2.50	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
-2.40	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
-2.30	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
-2.20	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
-2.10	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
-2.00	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
-1.90	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
-1.80	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
-1.70	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
-1.60	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
-1.50	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
-1.40	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
-1.30	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
-1.20	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
-1.10	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
-1.00	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
-.90	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
-.80	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
-.70	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
-.60	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
-.50	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
-.40	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
-.30	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
-.20	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
-.10	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
-.00	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641