**UNIVERSITI SAINS MALAYSIA**

**Peperiksaan Semester Pertama**

**Sidang Akademik 1997/98**

**September 1997**

**EBB 308/3 - 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.

...2/-

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 Pengatoman.

*Atomization Fabrication Techniques.*

(40 markah)

...3/-

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

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

| Julat saiz, μm<br>*Size range, μm* | Berat (g)<br>*Weight (g)* |
|---|---|
| 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.*

...4/-

[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 I. Cumulative normal distribution.*

(60 markah)

2. [a] Serbuk kuprum elektrolit dengan saiz zarah 150 ke 45 μm 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 (μm 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, g $cm^{-3}$ | : | 2.78 | 2.75 | 2.73 | 2.68 |
| *apparent density g $cm^{-3}$* | : | *2.78* | *2.75* | *2.73* | *2.68* |
| Ketumpatan anum, g $cm^{-3}$ | : | 6.59 | 6.68 | 6.48 | 6.37 |
| *green density 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 lelurus (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)

...6/-

[b] Samada serbuk logam ataupun seramik, adalah penting untuk dipisahkan campuran-campuran homogen dalam julat saiz zarah daripada 10 hingga 250 μm. 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 $kgm^{-3}$, diaplikasikan kepada campuran serbuk besi yang homogen, lukiskan satu graf yang menghubungkan garispusat zarah terapung kepada halaju udara dalam ruangan terkembang tiub tersebut.

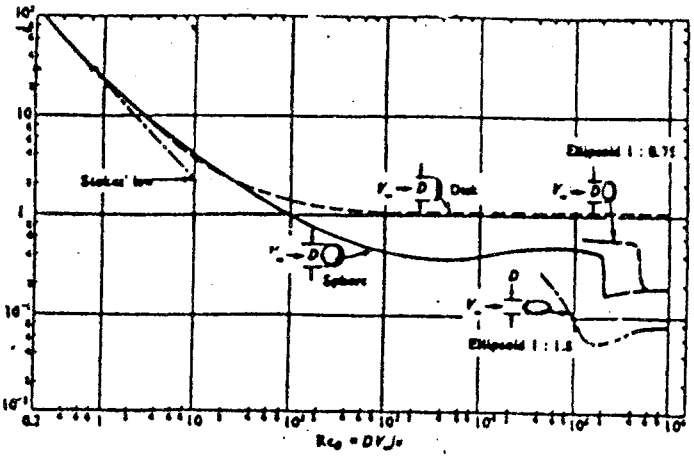
Ambil : Kelikatan air = $1.8 \times 10^{-5}$ $kgm^{-1}$ $s^{-1}$,
Ketumpatan air = 1.18 $kgm^{-3}$.

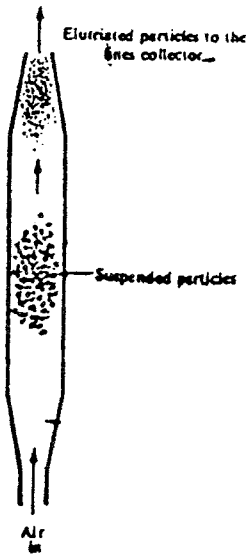
*With either metallic or ceramic powders, it is important to separate homogeneous mixtures in the range of particles sizes from 10 to 250 μm. For this purpose we apply the principle of air elutriation, which is illustrated by the device shown below. The force exerted by the air stream is great enough 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 $Kgm^{-3}$, 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.*

...7/-

*Take viscosity of air = 1.8 x $10^{-5}$ kgm$^{-1}$ s$^{-1}$*

*density of air = 1.18 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) penekan 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 0.95MPa. Calculate (1) the pressure at midway of the compact. (2) The average compaction stress. Take the radial stress = 0.25Mpa, 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 μm, 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 μm, 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 : $\sigma = K \sigma_o \rho^m$

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

...10/-

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

*Where $\sigma$ is the strength, $\sigma_o$ 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 $Z = (1- \varepsilon )^{3/2} /(1+C \varepsilon )^{1/2}$

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

Z adalah kemuluran relatif, $\varepsilon$ % keliangan

*Z: relative ductility, $\varepsilon$ 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 :-*

...11/-

[i] $^{J}/_{Jo} = (1-\varepsilon)/(1+n\varepsilon^2)$

$^{J}/_{Jo}$ ialah nisbah kekonduksian berliang kepada kekondusian jasad tumpat sepenuhnya.

*$J/J_o = (1-\varepsilon)/(1+n\varepsilon^2)$*

*J/Jo ratio of the porous conductivity to the conductivity of fully densified material. n = 11 , ε = porosity %*

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

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

[iii] $\varphi/\varphi_o = \rho^{1/3}$ ,

dimana $\varphi/\varphi_o$= pengembangan terma efektif / pengembangan terma tempawan

$\rho$ = ketumpatan pecahan

$\varepsilon + \rho = 1$

$\varphi/\varphi_o = \rho^{1/3}$ ,

$\varphi/\varphi_o$= *effective thermal expansion/wrought thermal expansion*

$\rho$ = *fractional density;* $\varepsilon + \rho = 1$

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 $sm^2$ dengan panjang 1 sm) yang mengandungi serbuk molibdenum dengan ketumpatan ketara 4.5 $g/cm^3$. Pada satu atmosfera kebezaan tekanan (2 atm ke 1 atm), halaju aliran terukur adalah 0.15 sm/saat. Apakah garispusat sfera ekuivalen?

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

Ketumpatan molibdenum = 10.2 g $sm^{-3}$

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

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

*Molybdenum density = 10.2 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 watt/km dan bagi seramik ialah 50 watt/km. Anggarkan kekonduksian terma komposit tersebut.

...13/-

*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)

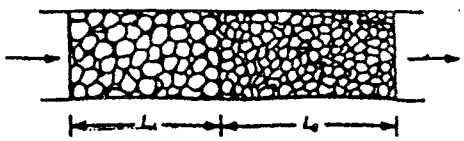


TABLE A.1 Cumulative Normal Distribution *continued*

| 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 | .6046 | .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 Reston Publication) Reprinted by permission of Prentice-Hall, Englewood Cliffs, New Jersey

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 | .0005 | .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 |