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AIR ATTENUATION CORRECTIONS FOR NEUTRON CALIBRATIONS

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ABSTRACT

An analysis of the effects of relative humidity, temperature, and atmospheric pressure on neutron air attenuation at the distances commonly used for calibration of neutron detecting devices at NPL has been performed. The opportunity was taken to use the most up to date cross sections (ENDF/B-VIII) for the various components of the air. The effects of humidity variations are completely negligible. Corrections for pressure and density variations are larger, and since they are easily performed should be incorporated in any analysis procedure. New values have been calculated for the linear attenuation coefficients for monoenergetic neutrons as a function of energy at closely spaced intervals, and also the spectrum averaged values for the radionuclide sources commonly used for calibrations.

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Approved on behalf of NPL by
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1 INTRODUCTION

When neutron measuring devices are calibrated in reference fields, derived either from radionuclide neutron sources or produced using a charged-particle accelerator, corrections have to be performed for the effects of scattered neutrons. This is because the irradiations are performed in air, and also almost invariably in an enclosed shielded room. At NPL corrections for neutrons scattered into the measuring device from the air and from the walls, floor and ceiling of the calibration lab are usually performed using the shadow cone technique. The magnitude of the correction depends on the size of the room; decreasing as the size of the room increases, which is the reason for the very large, so called low-scatter area, used for these calibrations at NPL. The room is roughly 24 m long by 18 m wide and 18 m high and because of the large size the air in-scattering component is comparable to the room in-scattering component and becomes the larger of the two at large calibration distances.

The shadow cone technique, described in ISO Standard 8529 Part 2(1), or in more detail in reference [2], involves placing a solid cone, with negligible neutron transmission, between the source of neutrons and the device being calibrated. This excludes all direct neutrons while allowing scattered neutrons to strike the device. A subtraction of the response with shadow cone from that without cone corrects for the response to all in-scattered neutrons. It does not, however, correct for neutrons emitted from the source into the solid angle defined by the measuring device that are out-scattered, or removed by absorption in the air, and thus never arrive at the device. At typical distances in calibration labs (0.5 to 5 m) the correction is small, but nevertheless needs to be performed, especially for the larger distances in this range. The air attenuation increases as the neutron energy decreases so is more important for lower energy neutrons, typically 1 to 500 keV, than higher energy ones in the 1 to 20 MeV region.

Corrections for neutrons that do not arrive at the device because of air attenuation are usually performed by a calculation allowing for scattering and absorption events in the main constituents of the air. However, little attention has been paid to how this correction is affected by temperature, pressure, and humidity. This report investigates these effects and quantifies them using the latest cross section data for interactions between the neutrons and the air.

2 CALCULATION OF NEUTRON AIR ATTENUATION

ISO Standard 8529 Part 2 outlines an approach to performing air attenuation corrections. In Annex C it states: “The only significant contribution to air attenuation (out-scatter) is the scattering from oxygen and nitrogen.” The equation for the air-attenuation factor F_A for a temperature of 21 ºC, a pressure of 100.4 kPa, and 50% relative humidity, is given as:

$$\begin{aligned} F_A(l,\Sigma(E)) &= \exp[\Sigma(E)\cdot l] \\ &= \exp(\{[3.88\cdot\sigma_N(E)+1.04\cdot\sigma_O(E)]\cdot 10^{-5}\cdot l\} \end{aligned} \quad (1)$$

where:

l is the distance, in cm, from the source to the device,

$\Sigma(E)$ is the linear attenuation coefficient for air at neutron energy E, with units cm^{-1}, (sometimes referred to as the macroscopic cross section), and

$\sigma_N(E)$ and $\sigma_O(E)$ are the total neutron cross sections, in barns, (10^{-24} cm^2) for nitrogen and oxygen at neutron energy E.

The parameters 3.88 and 1.04 are the number densities, i.e. atoms per cm^3, for nitrogen and oxygen respectively divided by 10^{19}. The cross sections can be obtained from any evaluated data set, e.g. ENDF/B or JEFF (available from https://www-nds.iaea.org/exfor/endf.htm).

Extending the analysis to include other constituents of air the equation becomes:

$$F_A(l, \Sigma(E)) = \exp(\Sigma(E) \cdot l) = \exp(\{[\sum_{k=1}^{N} a_k \cdot \sigma_k(E)] \cdot 10^{-5} \cdot l\} \qquad (2)$$

where:

N is the number of elements to be considered, which can be more than the number of gases present if any of the gases are compounds,

a_k is the number density of element k in atoms per cm^3 × 10^{-19},

$\sigma_k(E)$ is the cross section for element k at energy E in barns.

When performing a calibration with a point source of neutrons, with known emission rate in the direction of the device being calibrated, the fluence is determined using the inverse square law and the distance, d, from the source to the reference point of the device. For many instruments the reference point is within the instrument. If this is the case the distance l in equation (1) should not be d but the distance from the source to the nearest surface of the instrument. For most calibration distances and most instrument sizes the air attenuation correction is sufficiently small that the effect of using d rather than l is negligible.

2.1 Number densities for the constituents of air

The number density, a_{ki}, of atoms of element k in gas i, which is one of the gases in a mixture, can be obtained from the number of moles, n_i, of gas i, Avogadro's number, A_0, and d_{ki} the number of atoms of element k in a molecule of gas i:

$$a_{ki} = n_i \cdot A_0 \cdot d_{ki} \qquad (3)$$

For nitrogen or oxygen, which are diatomic, d_{ki}=2, for argon which is monatomic d_{ki}=1, and for water d_{ki}=2 for hydrogen and 1 for oxygen. Knowing the volume fraction of a gas in a mixture (this is the usual way of specifying the composition) the number of moles is given by:

$$n_i = \frac{m_i}{w_i} = \frac{\rho_{0i} \cdot v_i / V}{w_i} \qquad (4)$$

where:

m_i is the mass of gas i,

w_i is the gram molecular weight for gas i,

v_i/V is the volume fraction of gas i, (equal to the partial pressure and mole fraction), and

ρ_{0i} is the density of gas i at a particular temperature and pressure.

If element k occurs in more than one gas in the mixture, then the total number density, a_k, for element k is obtained by summing the a_{ki} values over all the gases containing element k.

For the current calculations the chosen temperature and pressure for the base calculations was Normal Temperature and Pressure, NTP, i.e. 20 °C and 1 atm. = 101.325 kPa.

Table 1 lists the molar masses, volume fractions, and densities of the components of dry air. The only ones that need to be considered for neutron air attenuation are nitrogen, oxygen, and argon.

Although all the other concentrations are essentially negligible, allowance was made for the 0.04% of carbon dioxide by adding the oxygen component in this gas to the oxygen total. Using equations (3) and (4) gives a_k values for dry air of: 3.910 × 10^{19} for nitrogen, 1.050 × 10^{19} for oxygen, and 2.34 × 10^{17} for argon (c.f. 3.88 × 10^{19} for nitrogen, 1.04 × 10^{19} for oxygen given in ISO Standard 8529-2.)

Table 1. Composition[3] and density at NTP[4] for dry air

Constituent	Molar mass w_i (g mol^{-1})	Mole fraction ≡ volume fraction	Density at NTP (g cm^{-3})
N_2	28.0134	0.780848	1.165×10^{-3}
O_2	31.9988	0.209390	1.331×10^{-3}
Ar	39.948	0.009332	1.661×10^{-3}
CO_2	44.01	0.00040	1.842×10^{-3}
Ne	20.18	0.000018	9.002×10^{-4}
He	4.0	0.000005	1.664×10^{-4}
CH_4	16.0	0.000002	6.68×10^{-4}
Kr	83.8	0.000001	3.71×10^{-3}
H_2	2.0	$< 1.0\times10^{6}$	8.99×10^{-5}
N_2O	44	$< 1.0\times10^{6}$	1.98×10^{-3}
CO	28	$< 1.0\times10^{6}$	1.165×10^{-3}
Xe	131	$< 1.0\times10^{6}$	5.851×10^{-3}

Because air is not usually dry, a more detailed analysis should involve the water vapour content. Adding this component, and maintaining a set pressure and temperature, means reducing the number densities for the other components as water molecules replace them in the gas. There is also the problem of deriving the number density for the water molecules from the measured parameter which is usually the relative humidity. Equation (4) can be used provided v_i/V can be determined for the water vapour as a function of the relative humidity. An equation for the mole fraction, x_v, which is equal to the volume fraction, is given in a Metrologia paper on a *Revised formula for the density of air (CIPM-2007)*[3].

$$x_v = \frac{v_i}{V} = h \cdot f(P,t) \cdot \frac{p_{sv}(T)}{P} \tag{5}$$

where:

h is the relative humidity as a percentage figure,

$f(P,t)$ is an 'enhancement factor, (t is the temperature in °C), and

$p_{sv}(T)$ is the vapour pressure at saturation,

T is the temperature in kelvin, K,

P is the pressure in pascals, Pa.

Equations are presented in reference [3] for both $f(P,t)$ and $p_{sv}(T)$. These are:

$$f(P,t) = \alpha + \beta \cdot P + \gamma \cdot t^2 \tag{6}$$

with:

$\alpha = 1.00062$,

$\beta = 3.14 \times 10^{-8}$ Pa^{-1}, and

$\gamma = 5.6 \times 10^{-7}$ °C^{-2}.

$$p_{sv}(T) = 1\,Pa \times \exp(A \cdot T^2 + B \cdot T + C + D / T) \tag{7}$$

with:

A = 1.2378847 × 10^{-5} K^{-2},

B = -1.912131 × 10^{-2} K^{-1},

C = 33.93711047,

D = -6.3431645 × 10^{3} K.

For T = 293.15 K (20 ºC) the vapour pressure at saturation, $p_{sv}(T)$ is 2.3392 kPa. With the volume ratio for water vapour calculated from eq. (5) as a function of the relative humidity the volume ratios for all the other gases present can be calculated. They reduce as the water vapour content increases and are listed in Table 2 for air at NTP.

Table 2. Volume ratios at NTP for the main constituents of air as a function of relative humidity.

Relative Humidity %	Volume ratio v_i/V				Total fraction
	Nitrogen	Oxygen	Argon	H_2O vapour	
0	0.78085	0.20979	0.00933	0.00000	0.99997
10	0.77905	0.20931	0.00931	0.00231	0.99997
20	0.77724	0.20882	0.00929	0.00462	0.99997
30	0.77544	0.20834	0.00927	0.00693	0.99997
40	0.77364	0.20785	0.00925	0.00923	0.99997
45	0.77274	0.20761	0.00924	0.01039	0.99997
50	0.77183	0.20737	0.00922	0.01154	0.99997
60	0.77003	0.20688	0.00920	0.01385	0.99997
70	0.76823	0.20640	0.00918	0.01616	0.99997
80	0.76643	0.20592	0.00916	0.01847	0.99997
90	0.76462	0.20543	0.00914	0.02078	0.99997
100	0.76282	0.20495	0.00912	0.02309	0.99997

The fact that the total fraction is marginally less than unity is a result of ignoring the components with intensities less than that of carbon dioxide. All the necessary input to calculate the atom number densities using eq. (3) are thus available. As a check of the calculational approach the density of air as a function of relative humidity was calculated from:

$$\rho = \sum_{i=1}^{j} \frac{v_i}{V} \cdot \rho_{0i} \tag{8}$$

and compared with values calculated using the formula in reference [3] for the density of moist air. Agreement was within 0.05%. The value of ρ_{0i} for water vapour was calculated from:

$$\rho_{0i} = \frac{w_i \cdot P}{R \cdot T} \tag{9}$$

where:

w_i is the molar mass of water vapour, equal to 18.01528 g mol^{-1} from reference [3], and

R is the universal gas constant 8314.46 cm^3·kPa·K^{-1}·mol^{-1}.

Note that eq. (9) gives identical values for the densities of the gases to those listed in Table 1.

The values calculated for the atom number densities are presented in Table 3. The oxygen atoms in the water molecules and the carbon dioxide are included in the oxygen column.

Table 3. Number densities for the main components of air at NTP as a function of relative humidity

Relative humidity %	Atom number density a_k (g cm^{-3})				
	Nitrogen	Oxygen	Argon	Hydrogen	Sum
0	3.910×10^{19}	1.050×10^{19}	2.336×10^{17}	0.0	4.983×10^{19}
10	3.901×10^{19}	1.054×10^{19}	2.331×10^{17}	1.156×10^{17}	4.989×10^{19}
20	3.892×10^{19}	1.057×10^{19}	2.325×10^{17}	2.312×10^{17}	4.995×10^{19}
30	3.883×10^{19}	1.060×10^{19}	2.320×10^{17}	3.468×10^{17}	5.001×10^{19}
40	3.874×10^{19}	1.064×10^{19}	2.315×10^{17}	4.624×10^{17}	5.007×10^{19}
45	3.869×10^{19}	1.066×10^{19}	2.312×10^{17}	5.202×10^{17}	5.010×10^{19}
50	3.865×10^{19}	1.067×10^{19}	2.309×10^{17}	5.779×10^{17}	5.013×10^{19}
60	3.856×10^{19}	1.071×10^{19}	2.304×10^{17}	6.935×10^{17}	5.018×10^{19}
70	3.846×10^{19}	1.074×10^{19}	2.298×10^{17}	8.091×10^{17}	5.024×10^{19}
80	3.837×10^{19}	1.077×10^{19}	2.293×10^{17}	9.247×10^{17}	5.030×10^{19}
90	3.828×10^{19}	1.081×10^{19}	2.288×10^{17}	1.040×10^{18}	5.036×10^{19}
100	3.819×10^{19}	1.084×10^{19}	2.282×10^{17}	1.156×10^{18}	5.042×10^{19}

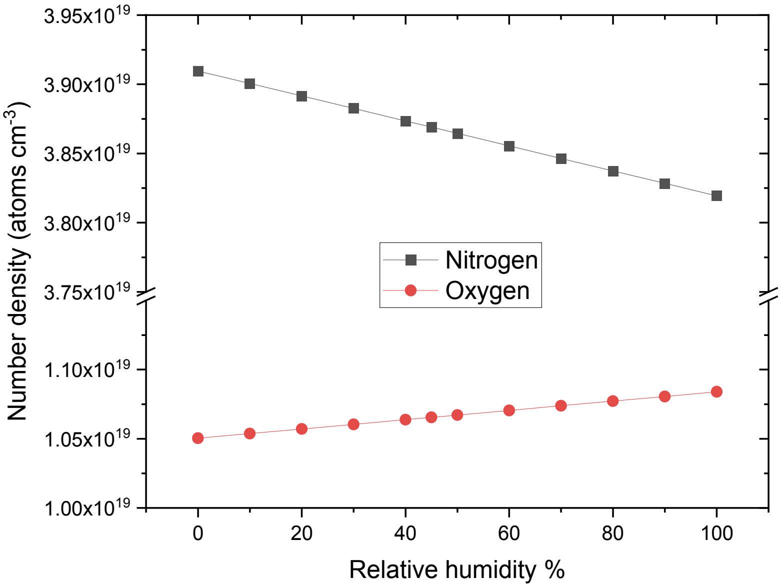

Figure 1. Nitrogen and oxygen atom number densities as a function of relative humidity.

The variations of the atom number densities are plotted in Figure 1 and Figure 2 where it can be seen that the values for nitrogen and argon decrease slightly with increasing relative humidity while those for hydrogen and oxygen increase.

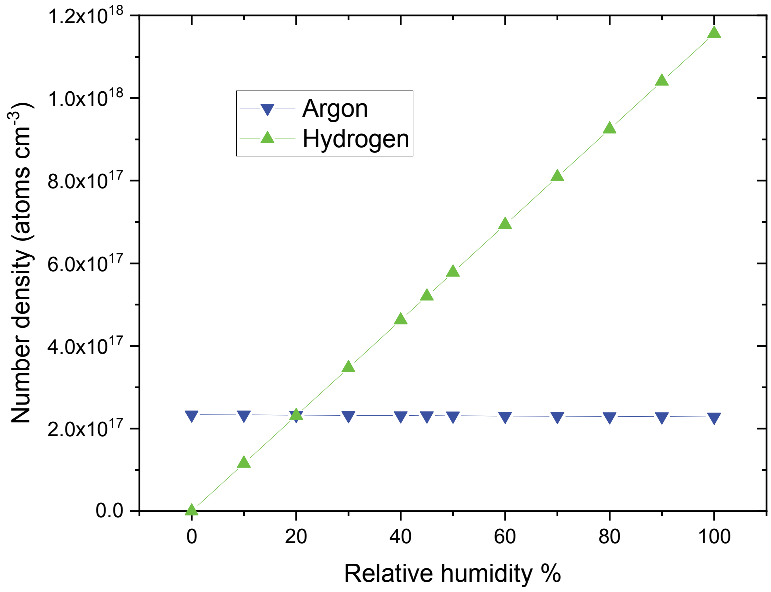

Figure 2. Argon and nitrogen atom number densities as a function of relative humidity.

2.2 Cross sections for the relevant atoms

Figure 3 shows the cross sections for nitrogen, oxygen, argon, and hydrogen over the energy range from 10 meV to 20 MeV derived from ENDF/B-VIII[5].

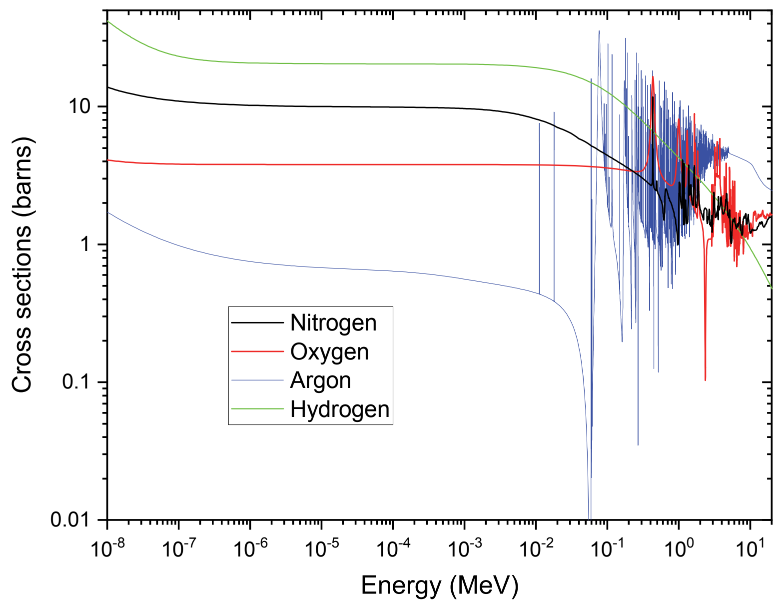

Figure 3. Cross sections for elements relevant to neutron reactions in air.

The data plotted in Figure 3 are for the total cross section and these are the appropriate parameters to use when calculating the number of neutrons removed by the air in the cone defined by a neutron detector as all reactions, except small angle scattering, result in a neutron failing to arrive at the detector. A more informative presentation of the data is given in Figure 4 where the cross sections have been multiplied by the atom number densities. A value of 45% was chosen for the relative humidity as being typical of that found in calibration labs.

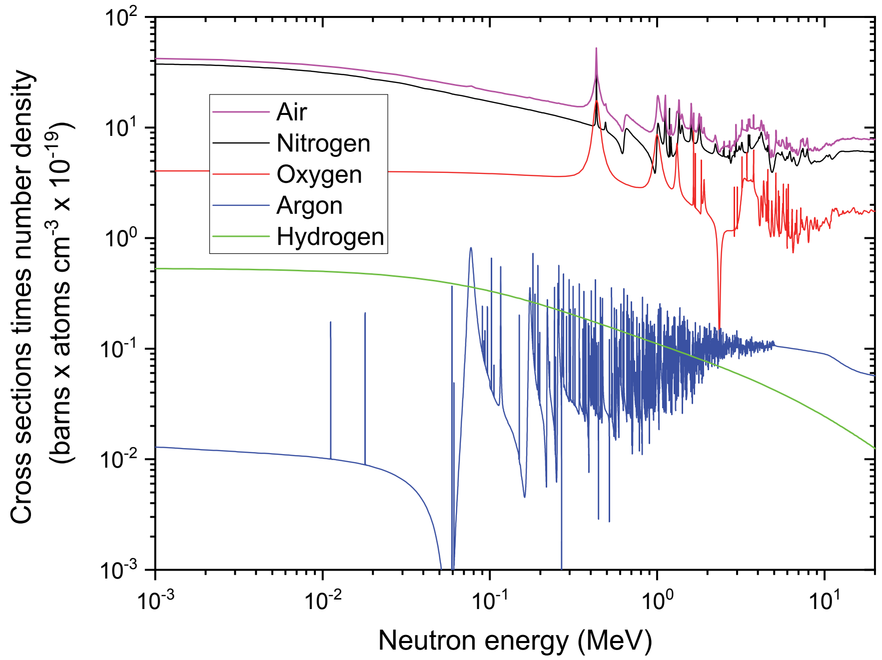

Figure 4. Cross sections multiplied by the atom number densities for air at NTP and 45% relative humidity.

Clearly, the argon and hydrogen contributions to the out-scattering and absorption are negligible compared to the nitrogen and oxygen. This suggests that the presence or absence of water vapour, within the likely ranges of the relative humidity, can probably be ignored as far as air attenuation is concerned.

2.3 Air attenuation corrections for monoenergetic neutrons

Figure 5 and Figure 6 confirm that humidity variations produce negligible effects in terms of air attenuation corrections over the range where monoenergetic standards are available.

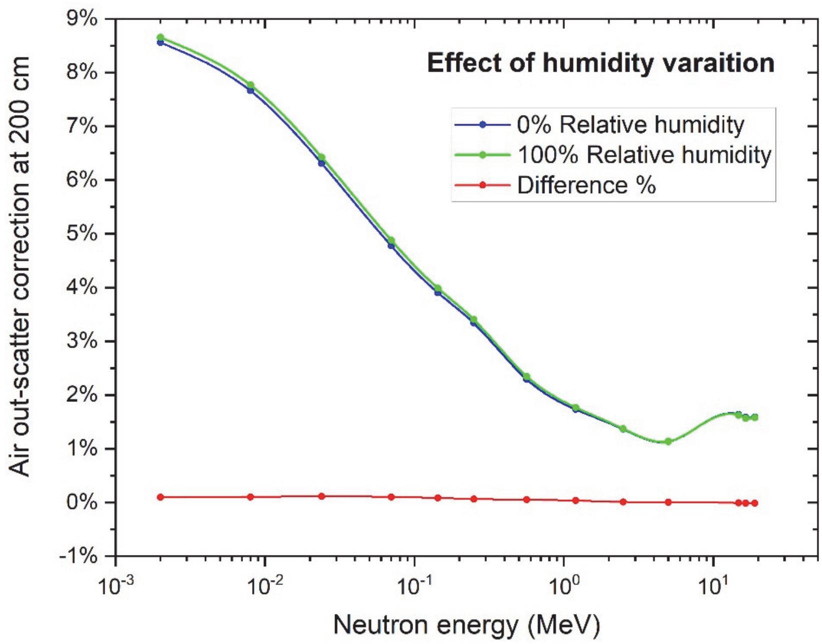

Figure 5. Air attenuation corrections for a distance of 200 cm for two extremes of the relative humidity.

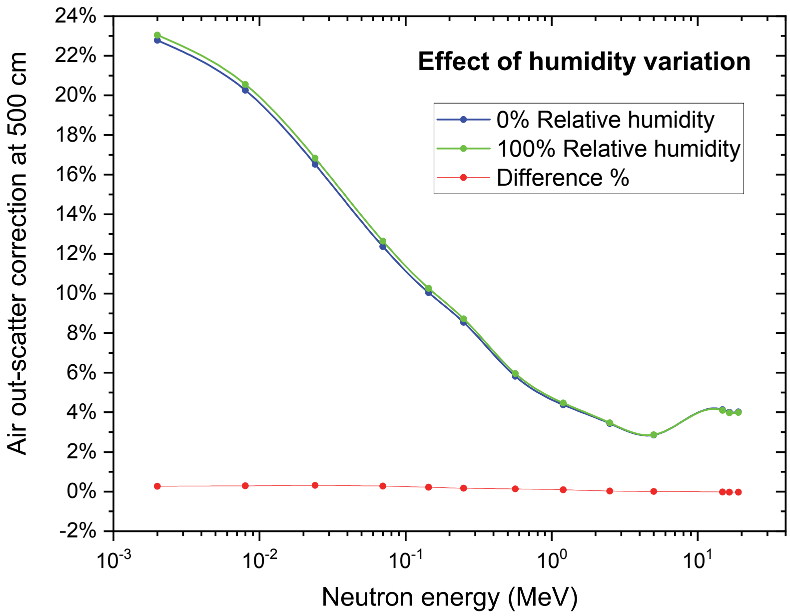

Figure 6. Air attenuation corrections for a distance of 500 cm for two extremes of the relative humidity.

Even where the air attenuation correction is a maximum, i.e. at low energies and large distances, the difference between 0% relative humidity and 100% is very small being <0.5% for a distance of 5 m at energies around 10 keV. The points in Figure 5 and Figure 6 correspond to the energies recommended for monoenergetic neutron calibrations in ISO standard 8529-1[(6)], with the addition of points at 8 and 70 keV which are energies that are sometimes used.

Air attenuation is much more affected by variations in the temperature and pressure. It increases as the temperature drops and as the pressure rises. To illustrate this, calculations were performed, at a fixed relative humidity of 45%. for a temperature of 12 °C and a pressure of 2.5% above NTP, and these were compared with values for 28 °C and a pressure 2.5% below NTP. These are roughly the expected ranges for temperature and pressure in a laboratory. Figure 7 shows the data for a distance of 200 cm and Figure 8 for a distance of 500 cm.

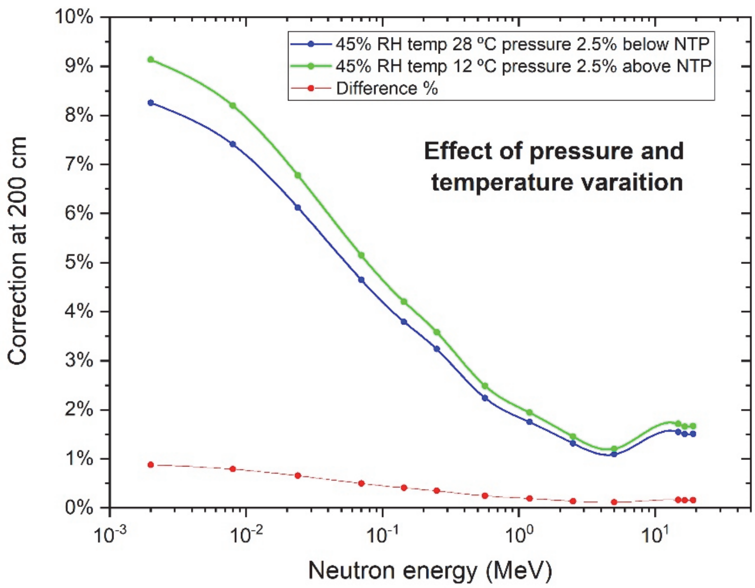

Figure 7. Comparison of air attenuation for two extremes of temperature and pressure at a calibration distance of 200 cm.

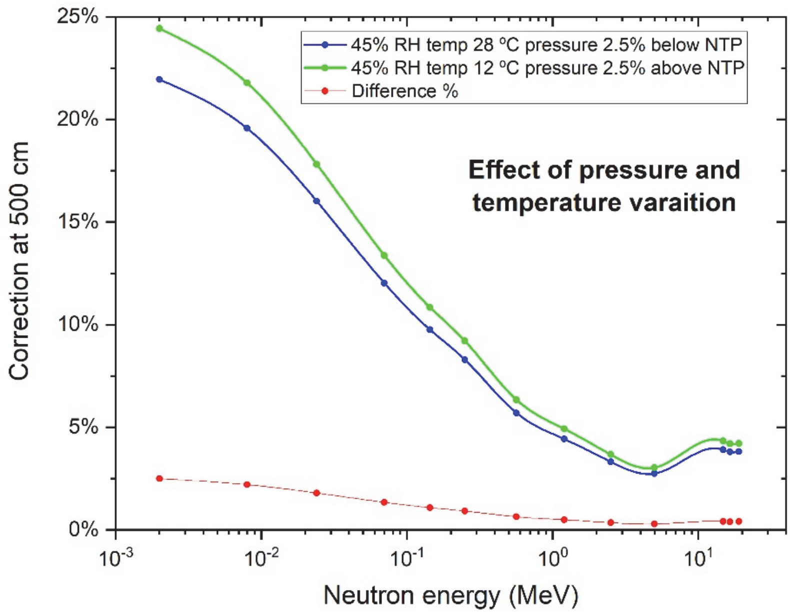

Figure 8. Comparison of air attenuation for two extremes of temperature and pressure at a calibration distance of 500 cm.

From Figure 7 and Figure 8 it would appear that temperature and pressure corrections might be appropriate for the most accurate measurements at low energies and large distances. With a set of base values, for NTP and a relative humidity of 45% for example, corrections, based on the ratio of the temperatures in kelvin and the pressures, can easily be performed.

From Figure 4 it can be seen that the cross sections have sharp structures in some energy regions. Because the air attenuation correction is small these variations tend not to be too important. However, because the calculation of these corrections as a function of energy is simple with modern computer codes, they are easily calculated with a fine energy structure. The appendix contains a table of 2558 values extending from the thermal region to 20 MeV. This was produced with a Fortran program that interpolates the cross section data and multiples the cross sections at a particular energy with the relevant atom number densities. It is advisable to avoid performing calibrations at monoenergetic energies where there is a particularly large resonance, e.g. at 433 keV where there is a significant resonance in oxygen.

2.4 Spectrum averaged air attenuation corrections for radionuclide sources

ISO Standard 8529-2[(1)] lists spectrum-averaged air linear attenuation correction factors, $\bar{\Sigma}$, for four radionuclide sources, D_2O moderated ^{252}Cf, bare ^{252}Cf, ^{241}Am-B, and ^{241}Am-Be. Although the approach to deriving these numbers is specified as being “by averaging the total neutron cross-sections for nitrogen and oxygen over the spectral neutron distribution of the source”, neither the precise method of performing the averaging nor the cross section evaluation used are documented.

Radioactive neutron source spectral distributions are commonly given in terms of group fluences, i.e. the fluences in bins extending from a low energy boundary to a high energy boundary. The task of averaging a continuous quantity over such a spectral representation is commonly performed by summing the product of the fluence per bin and the quantity at the mid-point of the bin, and then dividing this sum by the total fluence in the spectrum. For a spectrum plotted on a logarithmic energy scale a logarithmic mid-point would normally be chosen rather than a linear one. This approach works well for quantities such as fluence to dose equivalent conversion coefficients where the quantity varies smoothly with energy, or in situations where the bins are narrow, but for relatively wide bins, such as those used for the source spectra in ISO 8529-1, it may not work well for a quantity such as the air attenuation coefficient which has sharp peaks and troughs. This is illustrated in Figure 9 and Figure 10.

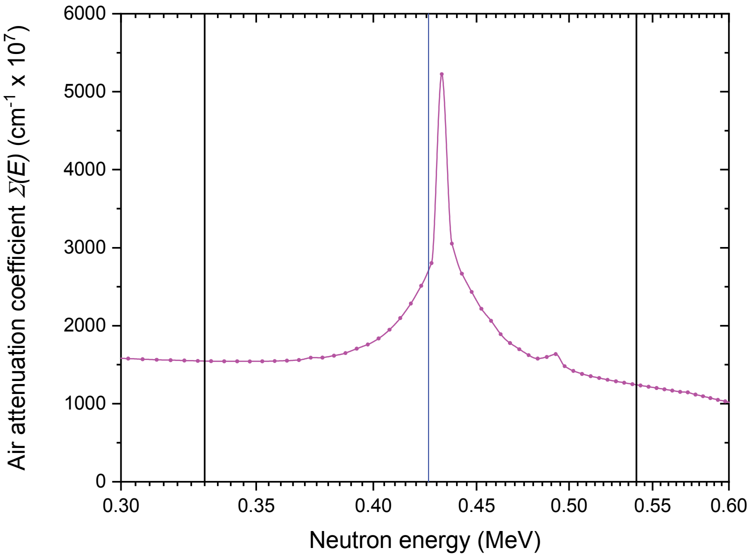

Figure 9. Air linear attenuation coefficients *Σ(E)* in the 0.3 to 0.6 MeV energy region. The black vertical lines indicate the group boundaries and the blue line the logarithmic mid-point energy of the 0.33 to 0.54 MeV group which occurs in the ISO spectrum for ^{241}Am-Be.

The 0.33 MeV to 0.54 MeV group shown in Figure 9 occurs in the ISO spectrum for ^{241}Am-Be. It straddles a peak in the air attenuation coefficient at 0.433 MeV which is due to a narrow resonance in nitrogen and a broader one in oxygen at the same energy. The logarithmic mean energy is 0.426 MeV, just below the highest point of the peak, and the air attenuation coefficient *Σ(E)* there is 2682 × 10^{-7} cm^{-1}. Averaging the air attenuation values over the group gives 1857 × 10^{-7} cm^{-1}, which is 31% smaller.

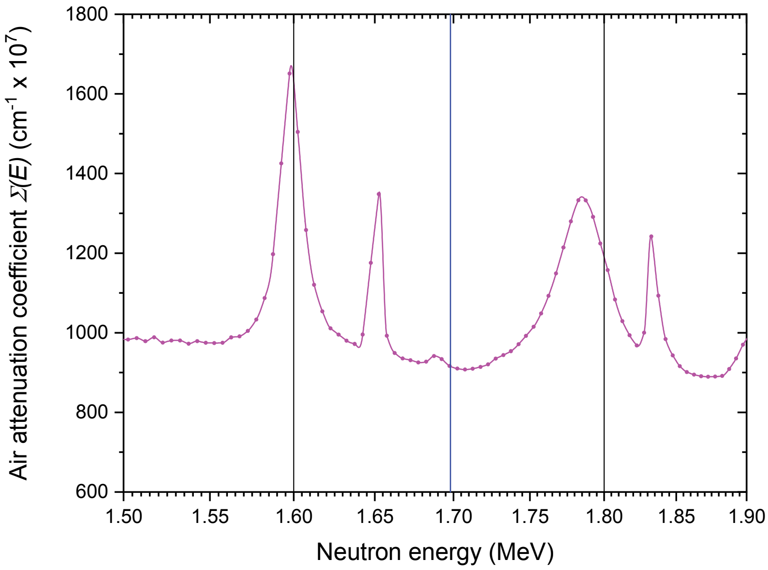

Figure 10. Air linear attenuation coefficients *Σ(E)* in the energy region from 1.5 to 1.9 MeV. The black vertical lines indicate the group boundaries and the blue line the logarithmic mid-point energy of the of the 1.6 to 1.8 MeV group which occurs in the ISO spectrum for ^{252}Cf.

Figure 10 shows an example from the energy group structure of the ^{252}Cf spectrum in ISO 8529-1[(6)]. The group from 1.6 to 1.8 MeV includes several resonances. The logarithmic mid-point of the group is at 1.7 MeV where the air attenuation coefficient $\Sigma(E)$ is 924×10^{-7} cm^{-1}, whereas the averaged value is 15% higher at 1064×10^{-7} cm^{-1}.

These examples highlight the need to perform the averaging using all the air attenuation values within a group. A Fortran computer code was written to perform the averaging by taking account of the average value between adjacent points in the air attenuation data within a group and then averaging these values. The results are shown in Table 4 for both approaches to performing the spectrum averaging and are compared to the values in ISO 8529-2[(1)].

Table 4. Spectrum-averaged air linear attenuation coefficients (10^{-7} cm^{-1}) for calibration sources calculated with different approaches and compared to the values in ISO 8529-2. The attenuation coefficients used were those for the new calculations at NTP with a relative humidity of 45%.

Source	ISO 8529-2 value	Air linear attenuation coefficient from log mid-point energy	Difference to ISO 8529-2	Averaged linear air attenuation coefficient	Difference to ISO 8529-2
D_2O mod ^{252}Cf	2964	3142	+6.0%	3141	+6.0%
^{252}Cf	1055	1065	+0.9%	1086	+2.9%
^{241}Am-B	833	862	+3.5%	859	+3.1%
^{241}Am-Be	890	942	+5.8%	914	+2.7%

The ISO standard 8529-2 was published in 2000 and the calculations for the air attenuation coefficients must have been performed with cross section data available up to this date. In fact, the coefficients had not changed since an earlier version of this standard published in 1996[(7)]. The current calculations were performed with the most recent version of the ENDF/B evaluated data set (version VIII.0). The new air linear attenuation coefficients are a little larger than the ISO values, and the two approaches to calculating the spectrum-averaged coefficients give similar values. This is presumably because the errors introduced by using the coefficient at the logarithmic mid-point energy of a bin tend to cancel out; some values being higher than they should be and some lower. The averaging approach is, however, the more correct.

The slight increases in the present coefficients compared to those in ISO 8529 result in a negligible change in the air attenuation for the vast majority of cases. A worst-case scenario of a D_2O moderated ^{252}Cf source at 500 cm from a detector would involve increasing the air attenuation from 16% to 17%, but most calibrations are performed closer to the source and the air attenuation coefficients are smaller for the other commonly used calibration sources.

Without information about the cross section data set used in the 1996 version of the ISO standard it is difficult to know whether the differences are due to changes in the cross sections or the calculational approach, but in view of the small size of the air attenuation correction these changes will not seriously affect neutron calibrations.

2.5 Radionuclide source spectra in revised ISO standard

The spectrum averaged linear attenuation coefficients for radionuclide sources tabulated in ISO Standard 8529-2 are for the spectra recommended in ISO Standard 8529-1(6). This standard is currently being revised(8). The revised document will no longer include ^{241}Am-B and the other three source spectra will change slightly. The new ^{252}Cf spectrum will be based on the most recent ENDF/B evaluation(9), the D_2O ^{252}Cf spectrum was re-calculated specifically for the standard(10), and for the ^{241}Am-Be source two spectra will be listed one for a physically ‘small’ ^{241}Am-Be source containing about 37 GBq (1 Ci) of ^{241}Am, and one for a physically ‘large’ source containing typically 370 GBq (10 Ci) of ^{241}Am(11). The values for the spectrum averaged air linear attenuation coefficients for the revised spectra with the newly calculated coefficients are given in Table 5.

Table 5. Spectrum-averaged air linear attenuation coefficients (10^{-7} cm^{-1}) for the spectra of the calibration sources proposed for the revised version of ISO 8529-1. The attenuation coefficients used were those for the new calculations at NTP with a relative humidity of 45%.

Source	ISO 8529-2 value	Averaged linear air attenuation coefficient	Difference to ISO 8529-2
D_2O mod ^{252}Cf	2964	3050	+2.9%
^{252}Cf	1055	1081	+2.5%
^{241}Am-Be ‘small’	890	915	+2.8%
^{241}Am-Be ‘large’		940	+5.6%

Again, the differences with the values in ISO 8529-2 2000 are not large in view of the fact the overall correction is small.

2.6 Small angle scattering

The cross sections used in these air attenuation calculations are total cross sections, and thus include every possible reaction including small angle elastic scattering. If the scattering angle is sufficiently small and the detector being calibrated is large, the scattered neutron may still arrive at the detector. An analytical calculation of this effect is complicated by the fact that the angle by which the neutron must be scattered to avoid hitting the detector increases as the neutron approaches the detector. An unpublished PTB Report by Siebert(12) provides an equation for performing the calculation, although results are only provided for one rather atypical situation. For a 25.4 cm detector at 536 cm and 10 MeV neutrons the correction for ignoring the small angle effect is 6% which is negligible in view of the overall uncertainties and the size of the air attenuation correction which is 3.7%.

The ideal approach to calculating the effect of small angle scattering events not arriving at the detector is by Monte Carlo simulation. In a report(13) on MCNP calculations of neutron scatter in the experimental facility at NPL calculations are reported for ^{252}Cf and ^{241}Am-Be sources at 75 cm and 150 cm. The MCNP calculations of air attenuation were compared with the results from the simple formula of eq. (1) and the differences were negligible. In fact, the MCNP values for the correction were marginally greater than those from the analytical approach in contrast to what might have been expected if small angle scattering events, where the neutron was not lost to the detector, were significant.

2.7 Conclusions

An analysis of the effects of relative humidity on neutron air attenuation at the distances commonly used for calibration of neutron detecting devices showed that the effects of humidity were completely negligible.

Corrections for pressure and density variations are larger, and since they are easily performed should be incorporated in the analysis procedure. New coefficients have been calculated as a function of energy at closely spaced intervals using the most up-to-date cross sections for the components of the air. The resonant structures in the cross section make this detailed energy scale necessary. Tables are provided in the Appendix, or the data can be obtained from the author in other formats, e.g. an Excel file, if required.

New air attenuation coefficients have been calculated for commonly-used radionuclide calibration sources. These are slightly larger than those tabulated in ISO standard 8529-2 2000, but the differences are too small to significantly affect air attenuation corrections for these sources.

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Appendix Table of air linear attenuation coefficients

New air attenuation coefficients from ENDF/B-VIII.0
N, O, A, and water vapour at NTP and 45% relative humidity 2558 energy points
File: AIRATNEW.DAT

Parameter units 10^{-7} cm^{-1}
Parameter relationship linear-linear
Energies in MeV.

Energy	Param	Energy	Param	Energy	Param	Energy	Param	Energy	Param	Energy	Param
1×10-8	6016.2	3×10-8	5200.1	1×10-7	4771.2	1×10-6	4470.3	1×10-5	4387.2	0.0001	4351.4
0.0001	4259.3	0.0025	4135.2	0.0075	3787.5	0.0125	3539.4	0.0175	3331.0	0.0225	3164.3
0.0275	3044.2	0.0325	2924.1	0.0375	2801.8	0.0425	2710.4	0.0475	2642.5	0.0525	2574.8
0.0575	2507.1	0.0625	2449.3	0.0675	2406.2	0.0725	2375.6	0.0775	2394.6	0.0825	2299.7
0.0875	2253.7	0.0925	2216.7	0.0975	2181.6	0.1025	2149.9	0.1075	2124.4	0.1125	2098.7
0.1175	2075.0	0.1225	2048.3	0.1275	2027.7	0.1325	2006.9	0.1375	1986.1	0.1425	1965.4
0.1475	1948.0	0.1525	1930.3	0.1575	1912.7	0.1625	1895.2	0.1675	1881.3	0.1725	1896.5
0.1775	1866.0	0.1825	1842.9	0.1875	1826.0	0.1925	1811.9	0.1975	1798.1	0.2025	1784.3
0.2075	1771.6	0.2125	1759.7	0.2175	1747.4	0.2225	1747.4	0.2275	1729.0	0.2325	1716.7
0.2375	1705.0	0.2425	1693.5	0.2475	1681.8	0.2525	1671.8	0.2575	1678.2	0.2625	1657.7
0.2675	1644.6	0.2725	1638.9	0.2775	1629.6	0.2825	1621.2	0.2875	1615.8	0.2925	1605.3
0.2975	1598.7	0.3025	1592.5	0.3075	1583.1	0.3125	1576.7	0.3175	1571.0	0.3225	1565.9
0.3275	1561.5	0.3325	1557.9	0.3375	1555.3	0.3425	1555.4	0.3475	1551.9	0.3525	1552.1
0.3575	1555.5	0.3625	1564.1	0.3675	1576.3	0.3725	1603.9	0.3775	1600.2	0.3825	1620.2
0.3875	1652.4	0.3925	1705.4	0.3975	1758.6	0.4025	1839.0	0.4075	1950.0	0.4125	2097.6
0.4175	2289.7	0.4225	2525.1	0.4275	2818.8	0.4325	5260.3	0.4375	3075.1	0.4425	2674.1
0.4475	2426.0	0.4525	2206.2	0.4575	2053.7	0.4625	1884.1	0.4675	1770.8	0.4725	1694.8
0.4775	1621.3	0.4825	1584.4	0.4875	1612.8	0.4925	1648.1	0.4975	1488.0	0.5025	1422.4
0.5075	1383.4	0.5125	1354.1	0.5175	1333.5	0.5225	1311.3	0.5275	1291.5	0.5325	1274.4
0.5375	1256.5	0.5425	1240.8	0.5475	1224.9	0.5525	1208.4	0.5575	1192.3	0.5625	1174.9
0.5675	1158.1	0.5725	1153.0	0.5775	1123.8	0.5825	1102.5	0.5875	1080.0	0.5925	1056.9
0.5975	1039.5	0.6025	1008.7	0.6075	980.0	0.6125	952.3	0.6175	932.2	0.6225	932.2
0.6275	970.5	0.6325	1059.5	0.6375	1159.1	0.6425	1243.1	0.6475	1292.3	0.6525	1311.1
0.6575	1311.6	0.6625	1306.1	0.6675	1293.3	0.6725	1278.9	0.6775	1261.5	0.6825	1247.0
0.6875	1233.6	0.6925	1220.6	0.6975	1207.5	0.7025	1195.4	0.7075	1183.2	0.7125	1171.6
0.7175	1178.4	0.7225	1157.6	0.7275	1145.3	0.7325	1135.0	0.7375	1125.3	0.7425	1115.8
0.7475	1106.7	0.7525	1097.7	0.7575	1094.0	0.7625	1082.5	0.7675	1073.6	0.7725	1065.3
0.7775	1058.9	0.7825	1049.4	0.7875	1044.7	0.7925	1035.3	0.7975	1027.7	0.8025	1020.3
0.8075	1013.0	0.8125	1005.3	0.8175	1008.4	0.8225	995.6	0.8275	987.9	0.8325	982.0
0.8375	975.2	0.8425	968.8	0.8475	962.1	0.8525	955.8	0.8575	952.7	0.8625	949.1
0.8675	940.9	0.8725	940.0	0.8775	936.6	0.8825	929.0	0.8875	924.2	0.8925	920.8
0.8975	917.3	0.9025	919.1	0.9075	916.6	0.9125	921.4	0.9175	918.5	0.9225	930.4
0.9275	925.6	0.9325	932.9	0.9375	950.2	0.9425	954.0	0.9475	969.5	0.9525	989.9
0.9575	1013.6	0.9625	1049.3	0.9675	1080.6	0.9725	1126.0	0.9775	1184.7	0.9825	1265.9
0.9875	1382.7	0.9925	1541.0	0.9975	1734.2	1.0025	1798.0	1.0075	1956.1	1.0125	1938.5
1.0175	1890.3	1.0225	1799.9	1.0275	1713.7	1.0325	1630.5	1.0375	1551.7	1.0425	1476.0
1.0475	1413.1	1.0525	1359.0	1.0575	1306.6	1.0625	1262.8	1.0675	1225.3	1.0725	1193.6
1.0775	1168.0	1.0825	1152.8	1.0875	1141.8	1.0925	1146.1	1.0975	1178.5	1.1025	1259.2

1.1075	1409.5	1.1125	1721.1	1.1175	1955.6	1.1225	1673.8	1.1275	1349.5	1.1325	1135.6
1.1375	1043.1	1.1425	985.1	1.1475	947.7	1.1525	922.7	1.1575	893.7	1.1625	879.7
1.1675	873.1	1.1725	859.5	1.1775	859.1	1.1825	956.4	1.1875	902.7	1.1925	858.0
1.1975	875.9	1.2025	949.4	1.2075	1061.0	1.2125	1066.3	1.2175	963.3	1.2225	889.3
1.2275	866.7	1.2325	856.9	1.2375	856.8	1.2425	856.4	1.2475	862.5	1.2525	871.9
1.2575	889.5	1.2625	894.1	1.2675	909.2	1.2725	937.5	1.2775	974.8	1.2825	1000.1
1.2875	1047.2	1.2925	1113.6	1.2975	1193.7	1.3025	1281.2	1.3075	1362.9	1.3125	1405.7
1.3175	1405.1	1.3225	1371.8	1.3275	1354.0	1.3325	1354.8	1.3375	1420.2	1.3425	1588.0
1.3475	1772.8	1.3525	1759.9	1.3575	1557.2	1.3625	1362.5	1.3675	1258.3	1.3725	1208.6
1.3775	1191.2	1.3825	1196.5	1.3875	1216.7	1.3925	1250.4	1.3975	1296.4	1.4025	1320.0
1.4075	1322.4	1.4125	1298.4	1.4175	1265.7	1.4225	1217.0	1.4275	1170.7	1.4325	1135.1
1.4375	1108.8	1.4425	1091.1	1.4475	1076.0	1.4525	1052.8	1.4575	1050.5	1.4625	1035.3
1.4675	1021.4	1.4725	1015.9	1.4775	1009.4	1.4825	1003.6	1.4875	997.6	1.4925	994.1
1.4975	991.1	1.5025	989.3	1.5075	992.8	1.5125	984.8	1.5175	994.9	1.5225	981.5
1.5275	986.7	1.5325	986.8	1.5375	978.9	1.5425	985.4	1.5475	981.5	1.5525	981.0
1.5575	981.7	1.5625	995.4	1.5675	998.2	1.5725	1011.8	1.5775	1040.2	1.5825	1094.2
1.5875	1204.5	1.5925	1432.5	1.5975	1658.1	1.6025	1511.7	1.6075	1265.8	1.6125	1128.1
1.6175	1061.2	1.6225	1017.8	1.6275	1002.2	1.6325	988.5	1.6375	980.5	1.6425	1002.9
1.6475	1182.5	1.6525	1334.7	1.6575	999.1	1.6625	956.5	1.6675	942.4	1.6725	938.0
1.6775	932.6	1.6825	934.9	1.6875	939.7	1.6925	930.5	1.6975	928.4	1.7025	928.6
1.7075	929.2	1.7125	931.4	1.7175	933.9	1.7225	936.7	1.7275	946.7	1.7325	951.4
1.7375	961.2	1.7425	978.6	1.7475	999.4	1.7525	1022.2	1.7575	1056.0	1.7625	1100.0
1.7675	1156.7	1.7725	1222.0	1.7775	1287.5	1.7825	1340.8	1.7875	1340.6	1.7925	1299.4
1.7975	1232.3	1.8025	1167.5	1.8075	1095.5	1.8125	1041.5	1.8175	1003.3	1.8225	975.7
1.8275	1004.1	1.8325	1248.6	1.8375	1097.2	1.8425	989.5	1.8475	950.0	1.8525	924.1
1.8575	910.1	1.8625	904.3	1.8675	901.2	1.8725	900.9	1.8775	902.4	1.8825	904.9
1.8875	922.4	1.8925	946.4	1.8975	976.3	1.9025	1000.8	1.9075	1001.1	1.9125	976.0
1.9175	938.2	1.9225	906.5	1.9275	888.1	1.9325	874.0	1.9375	858.9	1.9425	850.0
1.9475	838.4	1.9525	831.0	1.9575	829.5	1.9625	822.5	1.9675	820.3	1.9725	818.7
1.9775	816.5	1.9825	807.4	1.9875	805.1	1.9925	801.4	1.9975	802.5	2.0025	799.3
2.0075	792.9	2.0125	789.5	2.0175	786.8	2.0225	788.7	2.0275	786.9	2.0325	785.0
2.0375	781.0	2.0425	779.4	2.0475	781.8	2.0525	781.8	2.0575	774.5	2.0625	770.2
2.0675	768.8	2.0725	768.7	2.0775	766.3	2.0825	764.7	2.0875	762.9	2.0925	761.7
2.0975	763.8	2.1025	759.7	2.1075	757.1	2.1125	757.0	2.1175	754.4	2.1225	751.7
2.1275	753.4	2.1325	753.1	2.1375	751.0	2.1425	753.1	2.1475	751.4	2.1525	751.8
2.1575	752.4	2.1625	753.2	2.1675	757.3	2.1725	760.9	2.1775	766.0	2.1825	771.8
2.1875	780.4	2.1925	792.0	2.1975	797.4	2.2025	808.4	2.2075	822.5	2.2125	839.5
2.2175	853.0	2.2225	857.8	2.2275	853.0	2.2325	847.1	2.2375	832.8	2.2425	823.6
2.2475	807.0	2.2525	791.2	2.2575	775.4	2.2625	759.5	2.2675	746.9	2.2725	737.6
2.2775	727.2	2.2825	714.1	2.2875	700.6	2.2925	689.9	2.2975	681.6	2.3025	667.7
2.3075	661.0	2.3125	648.3	2.3175	643.5	2.3225	632.8	2.3275	623.3	2.3325	617.0
2.3375	612.5	2.3425	606.3	2.3475	606.8	2.3525	608.3	2.3575	606.5	2.3625	607.2
2.3675	610.8	2.3725	611.6	2.3775	615.5	2.3825	619.4	2.3875	622.8	2.3925	629.1
2.3975	637.5	2.4025	643.5	2.4075	644.3	2.4125	648.9	2.4175	652.9	2.4225	654.3
2.4275	655.5	2.4325	656.2	2.4375	657.8	2.4425	662.4	2.4475	663.6	2.4525	665.1
2.4575	667.4	2.4625	670.1	2.4675	674.5	2.4725	659.0	2.4775	678.1	2.4825	678.8

2.4875	677.9	2.4925	680.9	2.4975	685.1	2.5025	690.5	2.5075	726.9	2.5125	756.5
2.5175	687.1	2.5225	682.8	2.5275	681.0	2.5325	678.9	2.5375	679.3	2.5425	679.6
2.5475	680.1	2.5525	679.3	2.5575	679.7	2.5625	680.3	2.5675	679.9	2.5725	679.8
2.5775	680.6	2.5825	682.3	2.5875	682.5	2.5925	682.5	2.5975	681.6	2.6025	679.2
2.6075	676.5	2.6125	678.4	2.6175	682.0	2.6225	684.6	2.6275	687.1	2.6325	690.4
2.6375	695.1	2.6425	697.2	2.6475	694.6	2.6525	687.7	2.6575	680.6	2.6625	672.8
2.6675	665.9	2.6725	664.0	2.6775	665.2	2.6825	664.4	2.6875	667.5	2.6925	675.0
2.6975	695.1	2.7025	732.0	2.7075	763.3	2.7125	737.2	2.7175	692.2	2.7225	662.6
2.7275	646.9	2.7325	637.1	2.7375	629.8	2.7425	623.5	2.7475	618.3	2.7525	615.0
2.7575	615.8	2.7625	621.1	2.7675	626.6	2.7725	634.3	2.7775	641.6	2.7825	650.5
2.7875	659.2	2.7925	666.2	2.7975	673.3	2.8025	679.9	2.8075	682.7	2.8125	686.0
2.8175	690.2	2.8225	693.2	2.8275	696.0	2.8325	695.0	2.8375	695.5	2.8425	696.0
2.8475	696.7	2.8525	697.8	2.8575	699.4	2.8625	698.1	2.8675	695.0	2.8725	695.3
2.8775	701.8	2.8825	714.6	2.8875	754.9	2.8925	743.8	2.8975	709.5	2.9025	696.1
2.9075	684.7	2.9125	698.0	2.9175	718.6	2.9225	724.1	2.9275	728.8	2.9325	737.3
2.9375	750.6	2.9425	774.2	2.9475	818.6	2.9525	930.8	2.9575	1070.0	2.9625	943.3
2.9675	831.8	2.9725	790.8	2.9775	771.1	2.9825	764.1	2.9875	761.8	2.9925	761.3
2.9975	762.7	3.0025	766.4	3.0075	780.7	3.0125	761.6	3.0175	766.3	3.0225	770.8
3.0275	773.2	3.0325	775.3	3.0375	778.3	3.0425	781.5	3.0475	785.9	3.0525	790.6
3.0575	795.4	3.0625	802.0	3.0675	811.5	3.0725	823.6	3.0775	836.9	3.0825	850.4
3.0875	857.5	3.0925	854.5	3.0975	846.4	3.1025	838.8	3.1075	834.0	3.1125	831.9
3.1175	830.9	3.1225	831.9	3.1275	835.4	3.1325	838.2	3.1375	840.7	3.1425	842.1
3.1475	845.0	3.1525	853.9	3.1575	865.6	3.1625	878.7	3.1675	894.8	3.1725	912.3
3.1775	929.7	3.1825	948.8	3.1875	969.2	3.1925	989.6	3.1975	1007.6	3.2025	1021.1
3.2075	1037.6	3.2125	1194.2	3.2175	1021.7	3.2225	1009.2	3.2275	1001.2	3.2325	992.9
3.2375	984.5	3.2425	978.2	3.2475	974.6	3.2525	971.3	3.2575	969.8	3.2625	968.3
3.2675	967.3	3.2725	967.3	3.2775	966.4	3.2825	965.9	3.2875	965.9	3.2925	965.9
3.2975	965.3	3.3025	965.2	3.3075	965.0	3.3125	964.6	3.3175	963.1	3.3225	961.7
3.3275	960.4	3.3325	959.6	3.3375	958.7	3.3425	958.6	3.3475	958.6	3.3525	957.7
3.3575	956.4	3.3625	955.6	3.3675	955.1	3.3725	954.7	3.3775	955.1	3.3825	955.2
3.3875	954.8	3.3925	954.1	3.3975	953.5	3.4025	950.1	3.4075	945.9	3.4125	943.2
3.4175	942.0	3.4225	941.1	3.4275	940.1	3.4325	937.2	3.4375	949.1	3.4425	1047.1
3.4475	942.3	3.4525	939.3	3.4575	937.9	3.4625	939.1	3.4675	942.6	3.4725	948.0
3.4775	954.7	3.4825	962.2	3.4875	978.7	3.4925	1006.3	3.4975	1053.1	3.5025	1122.8
3.5075	1195.3	3.5125	1197.0	3.5175	1124.9	3.5225	1050.6	3.5275	1039.2	3.5325	1040.7
3.5375	1041.8	3.5425	1042.8	3.5475	1047.2	3.5525	1060.0	3.5575	1083.1	3.5625	1134.6
3.5675	1204.3	3.5725	1174.9	3.5775	1101.2	3.5825	1061.0	3.5875	1043.3	3.5925	1031.5
3.5975	1024.7	3.6025	1019.3	3.6075	1014.2	3.6125	1010.3	3.6175	1007.1	3.6225	1003.5
3.6275	999.8	3.6325	996.8	3.6375	994.8	3.6425	996.0	3.6475	992.6	3.6525	992.4
3.6575	992.6	3.6625	992.9	3.6675	993.3	3.6725	993.2	3.6775	991.5	3.6825	990.4
3.6875	990.1	3.6925	990.0	3.6975	989.3	3.7025	988.7	3.7075	989.5	3.7125	990.6
3.7175	992.0	3.7225	993.6	3.7275	996.0	3.7325	999.8	3.7375	1007.3	3.7425	1018.4
3.7475	1036.0	3.7525	1069.0	3.7575	1131.2	3.7625	1236.3	3.7675	1306.9	3.7725	1226.1
3.7775	1122.5	3.7825	1062.4	3.7875	1029.3	3.7925	1010.6	3.7975	999.5	3.8025	992.6
3.8075	988.4	3.8125	986.0	3.8175	984.2	3.8225	982.9	3.8275	982.1	3.8325	980.9
3.8375	979.4	3.8425	978.5	3.8475	978.6	3.8525	980.1	3.8575	981.0	3.8625	980.9

3.8675	980.9	3.8725	981.3	3.8775	982.1	3.8825	983.1	3.8875	984.4	3.8925	986.1
3.8975	988.1	3.9025	989.0	3.9075	990.3	3.9125	992.9	3.9175	995.2	3.9225	996.7
3.9275	997.7	3.9325	998.8	3.9375	1000.2	3.9425	1000.6	3.9475	1000.1	3.9525	1000.2
3.9575	1000.9	3.9625	1001.4	3.9675	1001.9	3.9725	1002.5	3.9775	1003.0	3.9825	1003.1
3.9875	1002.9	3.9925	1002.8	3.9975	1003.4	4.0025	1004.4	4.0075	1005.0	4.0125	1005.6
4.0175	1006.3	4.0225	1006.5	4.0275	1005.3	4.0325	1003.5	4.0375	1001.2	4.0425	998.4
4.0475	994.8	4.0525	990.6	4.0575	986.0	4.0625	980.6	4.0675	973.8	4.0725	967.0
4.0775	961.5	4.0825	957.0	4.0875	953.9	4.0925	951.0	4.0975	948.2	4.1025	948.7
4.1075	952.4	4.1125	958.8	4.1175	967.8	4.1225	978.2	4.1275	989.2	4.1325	1001.5
4.1375	1015.7	4.1425	1032.6	4.1475	1051.6	4.1525	1072.3	4.1575	1094.5	4.1625	1116.3
4.1675	1135.9	4.1725	1152.1	4.1775	1163.4	4.1825	1168.2	4.1875	1166.8	4.1925	1160.0
4.1975	1149.7	4.2025	1138.8	4.2075	1127.2	4.2125	1114.6	4.2175	1101.1	4.2225	1087.2
4.2275	1073.4	4.2325	1059.2	4.2375	1044.6	4.2425	1030.1	4.2475	1016.0	4.2525	1002.8
4.2575	990.6	4.2625	978.9	4.2675	967.8	4.2725	958.4	4.2775	951.7	4.2825	949.1
4.2875	952.3	4.2925	963.1	4.2975	981.7	4.3025	1005.9	4.3075	1032.4	4.3125	1053.2
4.3175	1065.2	4.3225	1068.3	4.3275	1063.9	4.3325	1053.9	4.3375	1040.7	4.3425	1026.5
4.3475	1012.6	4.3525	998.6	4.3575	984.5	4.3625	971.1	4.3675	958.8	4.3725	947.2
4.3775	936.4	4.3825	926.5	4.3875	916.8	4.3925	907.7	4.3975	899.3	4.4025	891.3
4.4075	883.5	4.4125	876.4	4.4175	870.3	4.4225	864.8	4.4275	859.6	4.4325	855.0
4.4375	851.0	4.4425	847.9	4.4475	845.4	4.4525	844.8	4.4575	840.9	4.4625	816.2
4.4675	788.9	4.4725	788.7	4.4775	794.2	4.4825	799.6	4.4875	804.3	4.4925	808.6
4.4975	812.1	4.5025	814.6	4.5075	814.7	4.5125	813.8	4.5175	810.3	4.5225	825.0
4.5275	970.0	4.5325	849.5	4.5375	801.7	4.5425	788.4	4.5475	790.9	4.5525	797.8
4.5575	804.4	4.5625	812.0	4.5675	820.1	4.5725	828.2	4.5775	835.8	4.5825	843.3
4.5875	851.0	4.5925	880.1	4.5975	874.7	4.6025	849.6	4.6075	840.2	4.6125	831.0
4.6175	821.8	4.6225	816.0	4.6275	829.9	4.6325	855.8	4.6375	777.0	4.6425	748.1
4.6475	729.6	4.6525	714.5	4.6575	700.6	4.6625	687.9	4.6675	676.4	4.6725	665.5
4.6775	655.6	4.6825	646.6	4.6875	638.1	4.6925	630.2	4.6975	622.7	4.7025	615.2
4.7075	608.0	4.7125	600.8	4.7175	594.0	4.7225	588.2	4.7275	583.7	4.7325	579.6
4.7375	574.9	4.7425	569.8	4.7475	564.7	4.7525	559.8	4.7575	555.0	4.7625	550.5
4.7675	546.6	4.7725	543.5	4.7775	541.2	4.7825	539.5	4.7875	538.8	4.7925	539.5
4.7975	541.9	4.8025	546.6	4.8075	554.3	4.8125	565.5	4.8175	580.6	4.8225	597.3
4.8275	613.7	4.8325	625.6	4.8375	630.9	4.8425	629.6	4.8475	623.5	4.8525	614.5
4.8575	604.6	4.8625	595.2	4.8675	586.4	4.8725	578.8	4.8775	572.3	4.8825	566.9
4.8875	562.3	4.8925	558.5	4.8975	555.6	4.9025	553.3	4.9075	551.5	4.9125	549.7
4.9175	548.1	4.9225	546.9	4.9275	546.0	4.9325	545.4	4.9375	544.8	4.9425	544.8
4.9475	545.6	4.9525	546.6	4.9575	548.1	4.9625	549.9	4.9675	551.7	4.9725	553.3
4.9775	555.2	4.9825	557.6	4.9875	560.7	4.9925	564.3	4.9975	568.2	5.0025	572.8
5.0075	578.1	5.0125	584.7	5.0175	591.6	5.0225	599.1	5.0275	607.7	5.0325	617.3
5.0375	627.6	5.0425	638.7	5.0475	650.2	5.0525	661.7	5.0575	673.0	5.0625	683.8
5.0675	694.4	5.0725	704.6	5.0775	714.3	5.0825	724.0	5.0875	733.8	5.0925	744.7
5.0975	758.5	5.1025	776.9	5.1075	803.4	5.1125	843.3	5.1175	899.0	5.1225	950.0
5.1275	948.7	5.1325	898.7	5.1375	847.7	5.1425	812.9	5.1475	790.7	5.1525	776.3
5.1575	766.4	5.1625	759.7	5.1675	755.0	5.1725	751.6	5.1775	749.1	5.1825	746.9
5.1875	744.9	5.1925	743.3	5.1975	741.9	5.2025	740.8	5.2075	740.0	5.2125	739.2
5.2175	738.4	5.2225	737.6	5.2275	736.7	5.2325	735.6	5.2375	734.3	5.2425	733.3

5.2475	732.5	5.2525	731.7	5.2575	730.8	5.2625	729.6	5.2675	728.2	5.2725	726.9
5.2775	725.7	5.2825	724.4	5.2875	722.8	5.2925	721.3	5.2975	719.7	5.3025	718.3
5.3075	822.2	5.3125	720.9	5.3175	715.8	5.3225	713.2	5.3275	711.2	5.3325	709.2
5.3375	707.3	5.3425	705.3	5.3475	703.1	5.3525	700.8	5.3575	698.2	5.3625	697.1
5.3675	781.2	5.3725	750.1	5.3775	722.4	5.3825	712.1	5.3875	707.3	5.3925	704.1
5.3975	701.9	5.4025	700.1	5.4075	698.7	5.4125	697.4	5.4175	696.3	5.4225	695.3
5.4275	694.4	5.4325	693.4	5.4375	692.6	5.4425	692.0	5.4475	691.4	5.4525	690.9
5.4575	690.7	5.4625	690.6	5.4675	690.8	5.4725	691.1	5.4775	691.4	5.4825	692.0
5.4875	693.0	5.4925	694.2	5.4975	695.7	5.5025	697.2	5.5075	699.0	5.5125	701.1
5.5175	703.8	5.5225	707.0	5.5275	710.7	5.5325	715.0	5.5375	719.7	5.5425	725.4
5.5475	732.0	5.5525	738.6	5.5575	745.4	5.5625	751.8	5.5675	757.2	5.5725	761.4
5.5775	764.3	5.5825	766.0	5.5875	766.8	5.5925	767.4	5.5975	768.1	5.6025	769.1
5.6075	771.0	5.6125	773.3	5.6175	775.8	5.6225	778.0	5.6275	779.4	5.6325	779.2
5.6375	777.0	5.6425	772.8	5.6475	767.1	5.6525	761.4	5.6575	756.8	5.6625	753.9
5.6675	756.1	5.6725	779.8	5.6775	856.3	5.6825	740.3	5.6875	728.6	5.6925	725.2
5.6975	722.2	5.7025	719.0	5.7075	715.7	5.7125	712.1	5.7175	708.2	5.7225	704.3
5.7275	700.3	5.7325	696.3	5.7375	692.3	5.7425	688.4	5.7475	684.4	5.7525	680.7
5.7575	677.0	5.7625	673.5	5.7675	670.0	5.7725	666.8	5.7775	663.8	5.7825	660.8
5.7875	657.8	5.7925	655.1	5.7975	652.4	5.8025	650.1	5.8075	648.2	5.8125	646.5
5.8175	645.1	5.8225	644.0	5.8275	643.1	5.8325	642.5	5.8375	642.2	5.8425	642.1
5.8475	642.2	5.8525	642.6	5.8575	643.2	5.8625	643.9	5.8675	645.5	5.8725	647.6
5.8775	650.5	5.8825	654.6	5.8875	661.0	5.8925	670.3	5.8975	685.4	5.9025	708.7
5.9075	743.5	5.9125	788.3	5.9175	821.2	5.9225	808.8	5.9275	769.8	5.9325	733.9
5.9375	708.8	5.9425	692.5	5.9475	681.3	5.9525	674.1	5.9575	668.2	5.9625	662.9
5.9675	657.4	5.9725	651.5	5.9775	644.8	5.9825	639.3	5.9875	642.7	5.9925	679.4
5.9975	727.1	6.0025	717.6	6.0075	695.3	6.0125	679.4	6.0175	669.0	6.0225	662.3
6.0275	658.1	6.0325	655.5	6.0375	653.8	6.0425	652.6	6.0475	651.9	6.0525	652.2
6.0575	653.7	6.0625	657.5	6.0675	669.5	6.0725	739.3	6.0775	779.8	6.0825	689.1
6.0875	690.6	6.0925	706.2	6.0975	709.3	6.1025	705.0	6.1075	701.3	6.1125	699.4
6.1175	698.9	6.1225	699.2	6.1275	700.1	6.1325	701.5	6.1375	702.9	6.1425	704.7
6.1475	706.7	6.1525	708.7	6.1575	711.0	6.1625	713.0	6.1675	714.8	6.1725	716.5
6.1775	718.0	6.1825	719.4	6.1875	720.7	6.1925	721.8	6.1975	722.9	6.2025	724.0
6.2075	725.2	6.2125	725.8	6.2175	725.9	6.2225	725.1	6.2275	723.4	6.2325	720.6
6.2375	716.7	6.2425	711.3	6.2475	704.8	6.2525	698.0	6.2575	691.6	6.2625	685.7
6.2675	679.7	6.2725	673.7	6.2775	667.8	6.2825	662.0	6.2875	656.2	6.2925	650.7
6.2975	645.6	6.3025	641.0	6.3075	637.0	6.3125	633.6	6.3175	630.8	6.3225	629.0
6.3275	628.1	6.3325	627.8	6.3375	628.2	6.3425	628.9	6.3475	630.2	6.3525	632.4
6.3575	635.6	6.3625	639.9	6.3675	645.4	6.3725	652.4	6.3775	660.5	6.3825	669.7
6.3875	679.0	6.3925	686.7	6.3975	690.6	6.4025	688.7	6.4075	681.5	6.4125	670.6
6.4175	658.1	6.4225	646.3	6.4275	636.0	6.4325	628.3	6.4375	622.3	6.4425	617.8
6.4475	614.9	6.4525	613.1	6.4575	611.8	6.4625	611.4	6.4675	611.5	6.4725	612.0
6.4775	612.7	6.4825	613.8	6.4875	615.1	6.4925	616.9	6.4975	618.7	6.5025	621.0
6.5075	623.3	6.5125	625.5	6.5175	627.7	6.5225	630.1	6.5275	632.0	6.5325	633.9
6.5375	635.7	6.5425	637.7	6.5475	638.7	6.5525	639.8	6.5575	640.7	6.5625	641.4
6.5675	642.3	6.5725	643.0	6.5775	643.5	6.5825	643.7	6.5875	643.5	6.5925	643.0
6.5975	642.3	6.6025	641.4	6.6075	640.3	6.6125	639.1	6.6175	637.5	6.6225	635.8

6.6275	633.8	6.6325	631.7	6.6375	629.5	6.6425	627.3	6.6475	625.2	6.6525	623.6
6.6575	623.1	6.6625	625.3	6.6675	631.6	6.6725	636.8	6.6775	628.9	6.6825	617.7
6.6875	609.8	6.6925	604.7	6.6975	601.1	6.7025	598.2	6.7075	596.2	6.7125	594.8
6.7175	593.7	6.7225	593.0	6.7275	592.7	6.7325	592.6	6.7375	592.8	6.7425	593.1
6.7475	593.4	6.7525	593.9	6.7575	594.7	6.7625	595.9	6.7675	597.3	6.7725	599.1
6.7775	601.3	6.7825	603.7	6.7875	607.3	6.7925	612.3	6.7975	618.6	6.8025	627.3
6.8075	637.0	6.8125	645.9	6.8175	649.8	6.8225	640.9	6.8275	626.5	6.8325	611.4
6.8375	597.4	6.8425	588.6	6.8475	582.0	6.8525	576.6	6.8575	573.1	6.8625	570.5
6.8675	568.2	6.8725	566.5	6.8775	565.0	6.8825	563.9	6.8875	563.5	6.8925	563.5
6.8975	563.5	6.9025	563.7	6.9075	563.9	6.9125	564.1	6.9175	564.5	6.9225	564.9
6.9275	565.6	6.9325	566.4	6.9375	567.3	6.9425	568.2	6.9475	569.2	6.9525	570.3
6.9575	571.5	6.9625	572.9	6.9675	574.4	6.9725	576.2	6.9775	578.2	6.9825	580.3
6.9875	582.7	6.9925	585.1	6.9975	587.7	7.0025	590.3	7.0075	593.1	7.0125	595.8
7.0175	598.5	7.0225	601.2	7.0275	603.9	7.0325	606.7	7.0375	609.6	7.0425	612.4
7.0475	615.2	7.0525	617.9	7.0575	620.4	7.0625	622.4	7.0675	624.0	7.0725	625.5
7.0775	627.0	7.0825	628.8	7.0875	630.9	7.0925	633.0	7.0975	635.3	7.1025	637.5
7.1075	639.9	7.1125	642.4	7.1175	644.9	7.1225	647.5	7.1275	650.2	7.1325	652.9
7.1375	655.8	7.1425	659.0	7.1475	662.6	7.1525	666.3	7.1575	670.4	7.1625	675.3
7.1675	681.3	7.1725	688.8	7.1775	698.3	7.1825	710.7	7.1875	725.3	7.1925	742.5
7.1975	759.4	7.2025	767.3	7.2075	765.7	7.2125	761.7	7.2175	758.1	7.2225	755.3
7.2275	752.9	7.2325	750.7	7.2375	748.8	7.2425	747.4	7.2475	746.7	7.2525	747.0
7.2575	748.5	7.2625	750.7	7.2675	753.1	7.2725	755.4	7.2775	757.8	7.2825	760.4
7.2875	763.3	7.2925	766.3	7.2975	769.1	7.3025	770.6	7.3075	771.1	7.3125	773.6
7.3175	776.8	7.3225	776.5	7.3275	774.2	7.3325	770.6	7.3375	765.1	7.3425	760.3
7.3475	757.3	7.3525	756.4	7.3575	757.2	7.3625	755.9	7.3675	753.4	7.3725	756.9
7.3775	769.4	7.3825	779.7	7.3875	786.5	7.3925	790.8	7.3975	793.3	7.4025	794.7
7.4075	794.9	7.4125	795.0	7.4175	794.8	7.4225	793.5	7.4275	791.3	7.4325	788.5
7.4375	785.7	7.4425	783.2	7.4475	780.5	7.4525	777.2	7.4575	773.1	7.4625	768.1
7.4675	761.9	7.4725	755.3	7.4775	748.3	7.4825	741.6	7.4875	735.5	7.4925	729.8
7.4975	724.5	7.5025	719.8	7.5075	715.9	7.5125	712.4	7.5175	709.2	7.5225	705.8
7.5275	702.6	7.5325	699.9	7.5375	697.6	7.5425	695.5	7.5475	693.6	7.5525	691.9
7.5575	690.2	7.5625	688.4	7.5675	686.9	7.5725	685.8	7.5775	684.4	7.5825	683.0
7.5875	681.9	7.5925	681.0	7.5975	680.4	7.6025	680.1	7.6075	680.0	7.6125	680.2
7.6175	680.4	7.6225	680.5	7.6275	680.8	7.6325	681.3	7.6375	681.8	7.6425	682.4
7.6475	683.0	7.6525	683.8	7.6575	684.8	7.6625	685.9	7.6675	687.1	7.6725	688.4
7.6775	689.8	7.6825	691.2	7.6875	692.7	7.6925	694.2	7.6975	695.7	7.7025	697.1
7.7075	698.5	7.7125	700.0	7.7175	701.6	7.7225	703.3	7.7275	705.1	7.7325	707.4
7.7375	709.9	7.7425	712.8	7.7475	716.1	7.7525	719.3	7.7575	722.6	7.7625	725.8
7.7675	728.9	7.7725	732.0	7.7775	735.0	7.7825	738.0	7.7875	741.1	7.7925	744.1
7.7975	747.3	7.8025	750.5	7.8075	753.9	7.8125	757.3	7.8175	760.7	7.8225	764.1
7.8275	767.3	7.8325	770.1	7.8375	773.2	7.8425	776.7	7.8475	780.7	7.8525	784.8
7.8575	788.8	7.8625	792.7	7.8675	796.9	7.8725	800.3	7.8775	802.6	7.8825	803.3
7.8875	802.2	7.8925	799.8	7.8975	796.1	7.9025	790.3	7.9075	782.6	7.9125	774.2
7.9175	765.2	7.9225	756.6	7.9275	748.6	7.9325	740.6	7.9375	732.6	7.9425	724.6
7.9475	716.5	7.9525	708.3	7.9575	700.2	7.9625	692.5	7.9675	684.9	7.9725	677.6
7.9775	670.6	7.9825	664.2	7.9875	658.5	7.9925	653.5	7.9975	649.0	8.0025	645.0

8.0075	641.6	8.0125	638.7	8.0175	636.1	8.0225	633.8	8.0275	632.0	8.0325	630.6
8.0375	629.5	8.0425	628.6	8.0475	627.9	8.0525	627.4	8.0575	626.8	8.0625	626.4
8.0675	626.2	8.0725	625.9	8.0775	626.0	8.0825	626.5	8.0875	627.0	8.0925	627.5
8.0975	628.1	8.1025	628.7	8.1075	629.3	8.1125	630.0	8.1175	630.7	8.1225	631.4
8.1275	632.3	8.1325	633.4	8.1375	634.5	8.1425	635.5	8.1475	636.5	8.1525	637.4
8.1575	638.2	8.1625	638.9	8.1675	639.6	8.1725	640.2	8.1775	640.8	8.1825	641.2
8.1875	641.7	8.1925	642.2	8.1975	642.6	8.2025	643.0	8.2075	643.3	8.2125	643.6
8.2175	643.9	8.2225	644.2	8.2275	644.4	8.2325	644.5	8.2375	644.4	8.2425	644.2
8.2475	643.9	8.2525	643.3	8.2575	642.5	8.2625	641.5	8.2675	640.5	8.2725	639.4
8.2775	638.3	8.2825	637.1	8.2875	635.9	8.2925	634.8	8.2975	633.7	8.3025	632.8
8.3075	631.8	8.3125	630.6	8.3175	629.3	8.3225	627.8	8.3275	626.4	8.3325	625.0
8.3375	623.8	8.3425	622.7	8.3475	621.9	8.3525	621.5	8.3575	621.3	8.3625	621.1
8.3675	620.9	8.3725	620.8	8.3775	620.5	8.3825	620.0	8.3875	619.7	8.3925	619.5
8.3975	619.4	8.4025	619.5	8.4075	619.8	8.4125	620.2	8.4175	620.5	8.4225	620.9
8.4275	621.3	8.4325	621.7	8.4375	622.2	8.4425	622.6	8.4475	622.9	8.4525	623.2
8.4575	623.3	8.4625	623.4	8.4675	623.4	8.4725	623.4	8.4775	623.3	8.4825	623.1
8.4875	622.9	8.4925	622.6	8.4975	622.2	8.5025	621.7	8.5075	620.9	8.5125	620.2
8.5175	619.6	8.5225	619.1	8.5275	618.6	8.5325	618.1	8.5375	617.8	8.5425	617.6
8.5475	617.5	8.5525	617.6	8.5575	617.8	8.5625	618.1	8.5675	618.6	8.5725	619.1
8.5775	619.9	8.5825	620.9	8.5875	621.9	8.5925	623.1	8.5975	624.4	8.6025	625.9
8.6075	627.5	8.6125	629.3	8.6175	631.1	8.6225	632.9	8.6275	634.8	8.6325	636.6
8.6375	638.4	8.6425	640.2	8.6475	641.9	8.6525	643.6	8.6575	645.3	8.6625	646.9
8.6675	648.4	8.6725	649.9	8.6775	651.4	8.6825	652.8	8.6875	654.3	8.6925	655.6
8.6975	657.0	8.7025	658.3	8.7075	659.6	8.7125	660.7	8.7175	661.7	8.7225	662.5
8.7275	663.2	8.7325	663.8	8.7375	664.1	8.7425	664.3	8.7475	664.4	8.7525	664.3
8.7575	664.2	8.7625	664.0	8.7675	663.6	8.7725	662.9	8.7775	662.1	8.7825	661.2
8.7875	660.0	8.7925	658.7	8.7975	657.4	8.8025	656.0	8.8075	654.5	8.8125	653.0
8.8175	651.5	8.8225	649.9	8.8275	648.4	8.8325	646.8	8.8375	645.2	8.8425	643.5
8.8475	641.9	8.8525	640.3	8.8575	638.8	8.8625	637.2	8.8675	635.7	8.8725	634.1
8.8775	632.6	8.8825	631.3	8.8875	630.0	8.8925	628.7	8.8975	627.4	8.9025	626.2
8.9075	625.1	8.9125	624.2	8.9175	623.6	8.9225	623.3	8.9275	623.2	8.9325	623.1
8.9375	623.2	8.9425	623.4	8.9475	624.0	8.9525	625.3	8.9575	626.8	8.9625	627.8
8.9675	628.1	8.9725	628.3	8.9775	628.5	8.9825	628.9	8.9875	629.6	8.9925	630.6
8.9975	631.9	9.0025	633.1	9.0075	634.2	9.0125	635.3	9.0175	636.4	9.0225	638.1
9.0275	640.4	9.0325	643.0	9.0375	645.6	9.0425	648.0	9.0475	649.8	9.0525	650.1
9.0575	648.8	9.0625	646.9	9.0675	645.6	9.0725	644.3	9.0775	642.8	9.0825	641.4
9.0875	640.6	9.0925	640.2	9.0975	639.9	9.1025	639.2	9.1075	638.3	9.1125	637.4
9.1175	636.4	9.1225	635.5	9.1275	634.6	9.1325	633.7	9.1375	632.8	9.1425	631.9
9.1475	631.0	9.1525	630.2	9.1575	629.4	9.1625	628.7	9.1675	627.9	9.1725	627.1
9.1775	626.4	9.1825	625.6	9.1875	624.9	9.1925	624.1	9.1975	623.5	9.2025	622.8
9.2075	622.3	9.2125	621.8	9.2175	621.4	9.2225	621.0	9.2275	620.6	9.2325	620.3
9.2375	620.0	9.2425	619.8	9.2475	619.6	9.2525	619.5	9.2575	619.5	9.2625	619.5
9.2675	619.5	9.2725	619.7	9.2775	619.9	9.2825	620.0	9.2875	620.2	9.2925	620.5
9.2975	620.8	9.3025	621.2	9.3075	621.9	9.3125	622.6	9.3175	623.4	9.3225	624.3
9.3275	625.1	9.3325	626.0	9.3375	627.0	9.3425	627.9	9.3475	628.7	9.3525	629.3
9.3575	629.9	9.3625	630.5	9.3675	631.2	9.3725	632.0	9.3775	633.0	9.3825	634.1

9.3875	634.9	9.3925	635.3	9.3975	635.4	9.4025	635.2	9.4075	634.9	9.4125	634.6
9.4175	634.2	9.4225	634.0	9.4275	633.9	9.4325	633.6	9.4375	633.4	9.4425	633.3
9.4475	633.3	9.4525	633.3	9.4575	633.4	9.4625	633.6	9.4675	633.9	9.4725	634.3
9.4775	634.6	9.4825	634.9	9.4875	635.1	9.4925	635.4	9.4975	635.7	9.5025	636.0
9.5075	636.3	9.5125	636.6	9.5175	636.9	9.5225	637.2	9.5275	637.5	9.5325	637.8
9.5375	638.1	9.5425	638.5	9.5475	638.8	9.5525	639.1	9.5575	639.5	9.5625	639.8
9.5675	640.1	9.5725	640.4	9.5775	640.8	9.5825	641.1	9.5875	641.4	9.5925	641.8
9.5975	642.2	9.6025	642.6	9.6075	643.2	9.6125	643.7	9.6175	644.3	9.6225	645.0
9.6275	645.6	9.6325	646.3	9.6375	647.0	9.6425	647.7	9.6475	648.3	9.6525	649.0
9.6575	649.7	9.6625	650.5	9.6675	651.2	9.6725	651.9	9.6775	652.7	9.6825	653.5
9.6875	654.3	9.6925	655.1	9.6975	655.8	9.7025	656.5	9.7075	657.2	9.7125	657.9
9.7175	658.7	9.7225	659.4	9.7275	660.1	9.7325	660.8	9.7375	661.5	9.7425	662.1
9.7475	662.8	9.7525	663.4	9.7575	664.0	9.7625	664.6	9.7675	665.2	9.7725	665.8
9.7775	666.4	9.7825	666.9	9.7875	667.3	9.7925	667.8	9.7975	668.1	9.8025	668.4
9.8075	668.7	9.8125	668.9	9.8175	669.0	9.8225	669.2	9.8275	669.3	9.8325	669.5
9.8375	669.6	9.8425	669.7	9.8475	669.9	9.8525	670.0	9.8575	670.1	9.8625	670.3
9.8675	670.4	9.8725	670.5	9.8775	670.6	9.8825	670.7	9.8875	670.8	9.8925	670.9
9.8975	671.0	9.9025	671.2	9.9075	671.3	9.9125	671.6	9.9175	671.9	9.9225	672.2
9.9275	672.6	9.9325	673.1	9.9375	673.6	9.9425	674.2	9.9475	674.8	9.9525	675.5
9.9575	676.2	9.9625	677.0	9.9675	677.8	9.9725	678.6	9.9775	679.4	9.9825	680.2
9.9875	681.0	9.9925	681.8	9.9975	682.6	10.005	683.9	10.015	685.6	10.025	687.5
10.035	689.4	10.045	691.3	10.055	693.3	10.065	695.3	10.075	697.3	10.085	699.3
10.095	701.2	10.105	703.0	10.115	704.7	10.125	706.3	10.135	707.8	10.145	709.3
10.155	710.8	10.165	712.2	10.175	713.5	10.185	714.8	10.195	716.1	10.205	717.2
10.215	718.0	10.225	718.7	10.235	719.4	10.245	720.0	10.255	720.4	10.265	720.7
10.275	721.0	10.285	721.3	10.295	721.6	10.305	721.6	10.315	721.0	10.325	719.9
10.335	718.5	10.345	716.8	10.355	714.9	10.365	713.0	10.375	711.1	10.385	709.1
10.395	707.1	10.405	705.6	10.415	704.4	10.425	703.3	10.435	702.0	10.445	700.6
10.455	698.9	10.465	697.2	10.475	695.6	10.485	694.2	10.495	693.0	10.505	692.6
10.515	693.0	10.525	693.5	10.535	694.1	10.545	694.6	10.555	694.9	10.565	695.8
10.575	697.0	10.585	698.4	10.595	699.8	10.605	701.1	10.615	702.0	10.625	703.0
10.635	704.0	10.645	704.9	10.655	705.8	10.665	706.6	10.675	707.1	10.685	707.6
10.695	708.3	10.705	708.8	10.715	707.0	10.725	701.5	10.735	697.7	10.745	700.1
10.755	702.4	10.765	703.1	10.775	703.1	10.785	702.7	10.795	702.1	10.805	701.8
10.815	701.5	10.825	701.1	10.835	700.3	10.845	699.1	10.855	697.5	10.865	695.6
10.875	693.6	10.885	692.0	10.895	690.6	10.905	689.3	10.915	688.3	10.925	687.7
10.935	688.6	10.945	690.9	10.955	694.3	10.965	696.6	10.975	696.8	10.985	695.8
10.995	695.6	11.005	695.5	11.015	696.0	11.025	696.7	11.035	697.6	11.045	698.6
11.055	699.7	11.065	700.9	11.075	702.1	11.085	703.5	11.095	704.8	11.105	706.5
11.115	708.2	11.125	709.8	11.135	711.1	11.145	711.9	11.155	712.3	11.165	712.4
11.175	712.5	11.185	712.6	11.195	712.7	11.205	712.8	11.215	712.8	11.225	712.8
11.235	712.8	11.245	712.9	11.255	712.9	11.265	713.0	11.275	713.1	11.285	713.3
11.295	713.5	11.305	713.7	11.315	714.0	11.325	714.3	11.335	714.6	11.345	714.9
11.355	715.3	11.365	715.7	11.375	716.3	11.385	717.0	11.395	717.8	11.405	719.0
11.415	720.4	11.425	722.0	11.435	723.6	11.445	725.2	11.455	726.8	11.465	728.4
11.475	730.0	11.485	731.6	11.495	733.1	11.505	734.7	11.515	736.1	11.525	737.6

11.535	738.9	11.545	740.2	11.555	741.4	11.565	742.6	11.575	743.7	11.585	744.7
11.595	745.6	11.605	746.4	11.615	747.1	11.625	747.7	11.635	748.2	11.645	748.6
11.655	749.1	11.665	749.4	11.675	749.8	11.685	750.2	11.695	750.6	11.705	751.0
11.715	751.3	11.725	751.7	11.735	752.4	11.745	753.4	11.755	755.2	11.765	757.4
11.775	759.7	11.785	761.7	11.795	762.6	11.805	763.1	11.815	763.2	11.825	763.4
11.835	763.4	11.845	763.5	11.855	763.5	11.865	763.4	11.875	763.4	11.885	763.4
11.895	763.5	11.905	763.7	11.915	764.2	11.925	764.7	11.935	765.3	11.945	766.1
11.955	767.0	11.965	767.9	11.975	768.4	11.985	768.5	11.995	768.4	12.005	768.8
12.015	769.3	12.025	769.5	12.035	769.3	12.045	768.5	12.055	767.0	12.065	764.9
12.075	763.3	12.085	762.4	12.095	762.0	12.105	762.1	12.115	762.4	12.125	762.9
12.135	763.3	12.145	763.1	12.155	762.7	12.165	762.8	12.175	763.3	12.185	763.7
12.195	764.1	12.205	764.7	12.215	765.5	12.225	766.5	12.235	767.4	12.245	768.4
12.255	769.3	12.265	770.2	12.275	770.9	12.285	771.7	12.295	772.4	12.305	773.1
12.315	773.8	12.325	774.4	12.335	775.0	12.345	775.6	12.355	776.2	12.365	776.8
12.375	777.4	12.385	777.9	12.395	778.5	12.405	779.0	12.415	779.4	12.425	779.8
12.435	780.2	12.445	780.5	12.455	780.9	12.465	781.2	12.475	781.6	12.485	781.9
12.495	782.2	12.505	782.5	12.515	782.8	12.525	783.1	12.535	783.4	12.545	783.6
12.555	783.9	12.565	784.1	12.575	784.3	12.585	784.6	12.595	784.7	12.605	784.8
12.615	784.8	12.625	784.8	12.635	784.7	12.645	784.7	12.655	784.7	12.665	784.7
12.675	784.7	12.685	784.7	12.695	784.7	12.705	784.8	12.715	785.2	12.725	785.6
12.735	786.1	12.745	786.8	12.755	787.5	12.765	788.4	12.775	789.3	12.785	790.3
12.795	791.3	12.805	792.3	12.815	793.2	12.825	794.2	12.835	795.2	12.845	796.0
12.855	796.5	12.865	797.0	12.875	797.4	12.885	797.8	12.895	797.8	12.905	797.5
12.915	797.1	12.925	796.4	12.935	795.6	12.945	794.7	12.955	793.7	12.965	792.7
12.975	791.6	12.985	790.5	12.995	789.5	13.005	788.7	13.015	788.1	13.025	787.4
13.035	786.8	13.045	786.1	13.055	785.6	13.065	785.3	13.075	785.2	13.085	785.3
13.095	785.4	13.105	785.5	13.115	785.6	13.125	785.7	13.135	785.7	13.145	785.8
13.155	785.9	13.165	785.9	13.175	785.8	13.185	785.7	13.195	785.6	13.205	785.5
13.215	785.2	13.225	785.0	13.235	784.8	13.245	784.6	13.255	784.4	13.265	784.2
13.275	784.0	13.285	783.9	13.295	783.8	13.305	783.7	13.315	783.7	13.325	783.7
13.335	783.8	13.345	783.8	13.355	783.9	13.365	784.0	13.375	784.1	13.385	784.2
13.395	784.3	13.405	784.4	13.415	784.6	13.425	784.8	13.435	785.0	13.445	785.2
13.455	785.4	13.465	785.7	13.475	786.0	13.485	786.2	13.495	786.5	13.505	786.6
13.515	786.8	13.525	786.8	13.535	786.9	13.545	787.0	13.555	787.0	13.565	787.0
13.575	787.1	13.585	787.1	13.595	787.2	13.605	787.3	13.615	787.5	13.625	787.8
13.635	788.1	13.645	788.5	13.655	788.8	13.665	789.1	13.675	789.4	13.685	789.8
13.695	790.2	13.705	790.6	13.715	791.0	13.725	791.4	13.735	791.6	13.745	791.4
13.755	790.8	13.765	790.2	13.775	790.1	13.785	790.6	13.795	791.2	13.805	791.8
13.815	791.9	13.825	791.6	13.835	791.2	13.845	790.8	13.855	790.5	13.865	790.2
13.875	789.9	13.885	789.7	13.895	789.4	13.905	789.2	13.915	788.9	13.925	788.7
13.935	788.4	13.945	788.1	13.955	787.9	13.965	787.6	13.975	787.4	13.985	787.2
13.995	787.0	14.005	786.8	14.015	786.8	14.025	786.7	14.035	786.7	14.045	786.8
14.055	786.9	14.065	787.0	14.075	787.1	14.085	787.3	14.095	787.5	14.105	787.7
14.115	787.9	14.125	788.1	14.135	788.3	14.145	788.5	14.155	788.7	14.165	788.9
14.175	789.1	14.185	789.3	14.195	789.5	14.205	789.7	14.215	789.9	14.225	790.1
14.235	790.3	14.245	790.5	14.255	790.7	14.265	790.9	14.275	791.2	14.285	791.4

14.295	791.6	14.305	791.9	14.315	792.1	14.325	792.3	14.335	792.5	14.345	792.7
14.355	792.9	14.365	793.1	14.375	793.3	14.385	793.5	14.395	793.8	14.405	794.0
14.415	794.3	14.425	794.6	14.435	794.9	14.445	795.2	14.455	795.5	14.465	795.8
14.475	796.2	14.485	796.5	14.495	796.8	14.505	797.1	14.515	797.5	14.525	797.9
14.535	798.2	14.545	798.6	14.555	799.0	14.565	799.4	14.575	799.8	14.585	800.2
14.595	800.6	14.605	801.0	14.615	801.4	14.625	801.8	14.635	802.2	14.645	802.6
14.655	803.0	14.665	803.4	14.675	803.8	14.685	804.2	14.695	804.6	14.705	805.0
14.715	805.4	14.725	805.8	14.735	806.2	14.745	806.5	14.755	806.9	14.765	807.3
14.775	807.7	14.785	808.1	14.795	808.5	14.805	808.8	14.815	809.2	14.825	809.5
14.835	809.8	14.845	810.1	14.855	810.2	14.865	810.4	14.875	810.5	14.885	810.6
14.895	810.7	14.905	810.7	14.915	810.8	14.925	810.9	14.935	811.1	14.945	811.2
14.955	811.3	14.965	811.4	14.975	811.4	14.985	811.5	14.995	811.5	15.05	810.2
15.15	803.1	15.25	796.7	15.35	792.6	15.45	793.2	15.55	795.6	15.65	797.5
15.75	797.6	15.85	795.5	15.95	791.4	16.05	787.5	16.15	786.8	16.25	786.7
16.35	786.3	16.45	785.3	16.55	783.5	16.65	782.8	16.75	784.2	16.85	786.6
16.95	789.1	17.05	790.6	17.15	792.2	17.25	792.5	17.35	791.9	17.45	789.9
17.55	788.6	17.65	788.1	17.75	787.7	17.85	787.2	17.95	786.2	18.05	784.7
18.15	783.2	18.25	782.0	18.35	781.1	18.45	781.1	18.55	781.9	18.65	783.4
18.75	785.3	18.85	787.0	18.95	788.4	19.05	788.0	19.15	787.1	19.25	785.9
19.35	784.7	19.45	783.3	19.55	782.4	19.65	782.3	19.75	782.5	19.85	782.8
19.95	782.7	20.05	782.4								