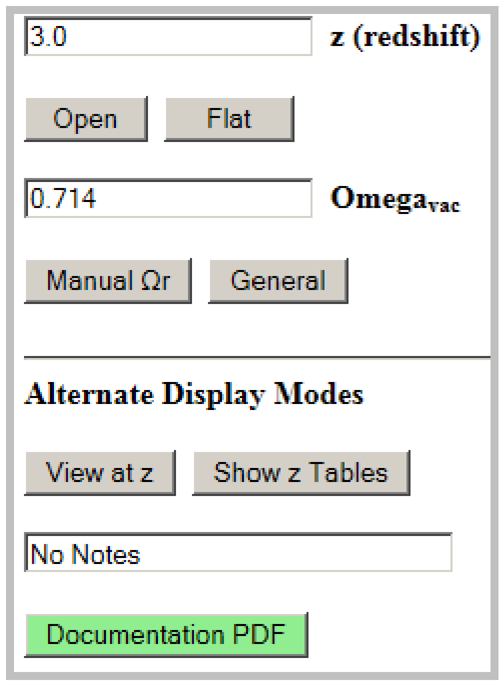
How to "View at z" in the Future

Partial Input Form



If you have arrived here – you should already be familiar with the "View at z" options for moving the Observer to the past. If not, please read that section of the documentation and try a couple of Observer moves (and associated z Tables) to familiarize yourself with the procedure. Once done, continuing reading here.

Note: You cannot simply put a big number like 2183 in for the "z (redshift)" and have the model understand it. Keep reading, it will get interesting.

Unlike moving an Observer to the past, where all that is required is basically the z value, moving the Observer to the future requires an **explanation of the z scale** and **how to calculate future z values** and associated input data, such as for **CMBz, H_0, Omega$_M$ (Ωm), and Omega$_{vac}$ (Ωvac)** for those future z values.

<u>The z Scale</u>

The **z scale (redshift scale)** as most people, even some in the Cosmology field, view it **begins at zero** (z=0.000) now (**today**) and gets bigger the farther back in time an object (like a galaxy) emitted light (photons or other equivalently fast moving, detectable signals). The farthest detectable signal as of now is ~**z=1091 and this for the Cosmic Microwave Background (CMB)** at the **edge of the currently-visible universe.**

As an example, z=3.000 means that whatever the **distance from Earth an object (galaxy) <u>was</u> when emitting light that we now see today** (**Proper Distance**), that light had to travel not only that original starting distance but some additional distance to cover some of the newly-expanding space between z=3.000 and Earth along the way. Once arriving at Earth, it can be determined that the **distance to that object <u>today</u> (Comoving radial distance) is the original Proper Distance plus an additional 3.000 times that original distance for a total of 4.000 (1+z) times the Proper Distance** when the photon began its journey to Earth.

The expansion of space <u>between Earth and the object</u> during the time the light was travelling to Earth is different than the amount of time (based upon the speed of light) that the photon used to reach Earth because the rate of space expansion is different than the speed of light.

Instead of a factor of 4.000-to-1, <u>time</u> was increased by a different factor of 2.185-to-1. The light travel time taken was the original Proper Distance in light years plus the time required to cross some of the newly-expanded space.

(The z Scale continued-1)

Two specific examples that are part of the preloaded Input Data Form and have Proper Distances, Comoving radial distances, and Light travel times shown on the Default Output are detailed below:

Z = 1091 (CMB)

Proper Distance For z=1091 41,674,426 light years
[Multiply by (1+z) or 1092 =]
Comoving radial distance (today) = ~ 45,508,473,670 light years

Light travel time was 13,720,271,156 years
[Divide travel time by Proper Distance above =]
Time Expansion ratio 329.225 to 1.000

Space expanded by 1091 times but travel time expanded by only 328.225 times.

Z = 3.000

Proper Distance For z=3.000 5,284,773,065 light years
[Multiply by (1+z) or 4.000 =]
Comoving radial distance (today)= ~ 21,139,260,424 light years

Light travel time was 11,549,274,017 years
[Divide travel time by Proper Distance above =]
Time Expansion ratio= 2.185 to 1.000

Space expanded by 3.000 times but travel time expanded by only 1.185 times.

As the examples show, the z scale is not a scale that correlates well to time and distance in any sort of linear fashion. And, depending upon the observer location, changes very dramatically.

(The z Scale continued-2)

The **z scale** for **past events** goes from: **z=0.000 to z=1091.000** (for now).

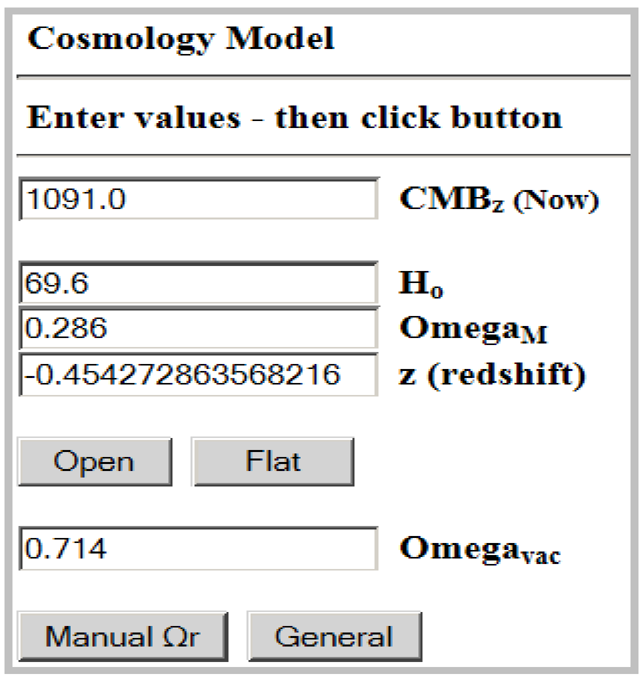
The **z scale** for **future events** goes from: **z=0.000 to z= -1.000** (forever).

To calculate a future z now and a future CMBz value from that, requires a different approach.

First the specific future CMBz approach. For example, if the user wanted to see the universe in the future when the CMBz will have a redshift of 2000 (CMBz=2000), the following calculation would be used:

z = (1+1091)/(1+2000) -1.000 or (1+ObserverCMBz)/(1+FutureCMBz)-1.000
z = 1092/2001 – 1.000
z = -0.454272863568216

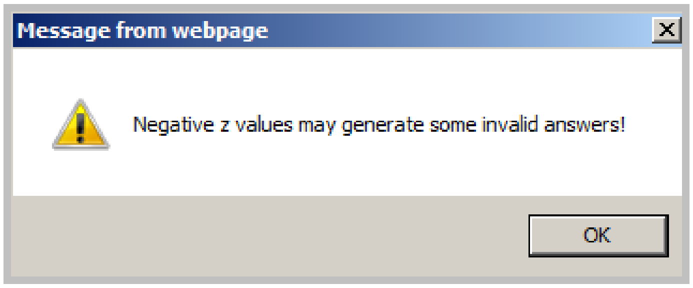
By entering this negative value in the Input Data Form and selecting a geometry (**Open**, **Flat**, or **General**) as below:



To show the output, the next image was calculated with the "**General**" button.

(The z Scale continued-3)

Simply ignore this warning box – click **OK**:

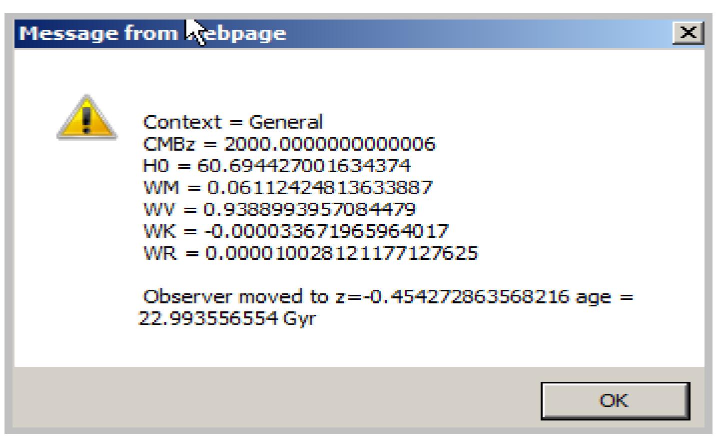


Along with some of the other calculations, there will be Default Output Section 5:

- **CMB temperature at redshift -0.454 age was 1.48726 °K.**
- **CMB redshift (at redshift -0.454) was 2000.000000.**
- **At z - H_z Calcs = ΩOmega$_{mz}$ = 0.0464828, Ω_{vacz} = 0.7140000, Ω_{Kz} = -0.0000256, Ω_{Rz} = 0.0000076**
- **Ω Fractions at z= ΩOmega$_{mz}$ = 0.0611242, Ω_{vacz} = 0.9388994, Ω_{Kz} = -0.0000337, Ω_{Rz} = 0.0000100**
- **Hubble Parameter (Omega Calc)(at redshift -0.454) was 60.69443 k/s/Mpc.(E(z)=0.872046).**
- **Actual Time Expansion ratio (from redshift -0.454) is (-9.272910732) / (-12.659631828) = 0.732.**
- **Light from z=-0.454273 first reached Observer at age 0.000000000 Gyr (age z = 0.000000000).**
- **Visible universe then was CMBz= 1091.000000 at a proper radial distance of 45.508473670 Gly.**

This section shows the necessary information for the model to repopulate the Input Data Form with the CMBz=2000 information.

Now, just click the "**View at z**" button and the Observer will be moved to future and the model will produce a visible universe with the CMB of 2000.



(The z Scale continued-4)

After clicking **OK**, the model produces this:

Cosmology Model Input Parameters:
Observer located at Age = 22.993556567 Gyr using z=0.00 and CMB_z viewed as redshift = 2000.000
H_o = 60.694, ΩOmega$_m$ = 0.06112, Ω_{vac} = 0.93889940, Ω_K = -0.00003367, Ω_R = 0.00001003 [General]

First using: z_{cmb} = 2000.000 (aka Last Scattering)

- **It is now 22.993556567 Gyr since the Big Bang (Observer located at "now" or z = 0.0). <== basec**
- **Age at Last Scattering (LS) was 0.000374666 Gyr or 374,666 yrs.**
- **Light travel time from Last Scattering to now was 22.993181901 Gyr.**
- **Proper radial distance that goes into Hubble's law is 29,435.274 Mpc or 96.005024260 Gly.**
- **Proper volume (within redshift 2000.000) is 106,804.365 Gpc^3 or 3,705,669.025 Gly^3.**
- **Angular size distance D_A (for redshift 2000.000) was 14.707350 Mpc or 47,968,961 ly.**
- **This gives a D_A scale of 0.071303 kpc/"**
- **Luminosity distance D_L (redshift 2000.000) is 58,888,245.694 Mpc or 192,067.769 Gly.**
- **LS-Photon (CMB_z) Proper Distance (at LS) was 0.047978523 Gly or 47,978,523 ly.**
- **LS-Photon (CMB_z) Proper Distance (at LS) minus Angular size distance was or 9,562 ly.**
- **Observer-adjusted Scale factor (for redshift 2000.00000) (1/(1+z)) = 0.000499750.**

- **CMB temperature now is 1.48726 °K.**
- **CMB temperature at Last Scattering was 2976.00576 °K.**
- **Hubble Time is 16.110082424 Gyr (Age vs. Hubble Time Ratio = 142.728%).**
- **Average CMB_z recession since the LS is 4.1733 ly/yr**
- **Current CMB_z recession usng input H_o is 5.9593 ly/yr**
- **Universe expansion accelerates at z=2.1321 (+/- 0.0001) at age 7.293023424 Gyr.**
- **==> Hubble Parameter =101.88064 with CMB_z viewed as z = 637.86849.**
- **Maximum LS-Photon proper distance is 8.955826897 Gly at z = 2.349049 (+/- 0.0001).**
- **Points for integrals = 1,000 Note: "Displaced Viewer"=ON**

This is only the top half of the output (visible universe description). The bottom half dealing with a specific z value in the described visible universe is defaulted to z=1.000.

If the user wanted to look back at today (CMB=1091, etc.) from CMBz=2000, the calculation for the z value for the Input Data Form would be:

z = (1+2000)/(1+1091) -1.000 or (1+ObserverCMBz)/(1+PastCMBz)-1.000
z = 2001/1092 – 1.000
z = 0.832417582417582

(The z Scale continued-5)

Entering **z = 0.832417582** allows the model to look back at today from the perspective of a future Observer at CMBz=2000.

0.832417582417582	**z (redshift)**

The bottom half of the Default Output, in part, shows:

Now using: z_{input} = 0.83241758 [More on redshift]

- **Age since Big Bang (at redshift 0.832) was 13.720645822 Gyr.**
- **Light travel time (from redshift 0.832) to now was 9.272910732 Gyr.**
- **Proper radial distance that goes into Hubble's law is 3,881.461 Mpc or 12.659631828 Gly.**
- **Proper volume (within redshift 0.832) is 244.947 Gpc^3 or 8,498.652 Gly^3.**
- **Angular size distance D_A (for redshift 0.832) was 2,118.211 Mpc or 6.908680684 Gly.**
- **This gives a D_A scale of 10.269377 kpc/"**
- **Luminosity distance D_L is 7112.432 Mpc or 23.198 Gly.**
- **LS-Photon Proper Distance (at/from redshift 0.832) was 2,118.218 Mpc or 6.908704626 Gly.**
- **Observer-adjusted Scale factor (for redshift 0.83242) (1/(1+z)) = 0.545727136.**

- **CMB temperature at redshift 0.832 age was 2.72528 °K.**
- **CMB redshift (at redshift 0.832) was 1091.000000.**
- **At z - H_z Calcs = ΩOmega$_{mz}$ = 0.3760858, Ω_{vacz} = 0.9388994, Ω_{Kz} = -0.0001131, Ω_{Rz} = 0.0001131**
- **Ω Fractions at z= ΩOmega$_{mz}$ = 0.2860000, Ω_{vacz} = 0.7140000, Ω_{Kz} = -0.0000860, Ω_{Rz} = 0.0000860**
- **Hubble Parameter (Omega Calc)(at redshift 0.832) was 69.60000 k/s/Mpc.(E(z)=1.146728).**
- **Actual Time Expansion ratio (from redshift 0.832) is (9.272910732) / (6.908704626) = 1.342.**
- **Light from z=0.832418 first reached Observer at age 0.079205105 Gyr (age z = 65.367777839).**
- **Visible universe then was CMBz= 29.150173 at a proper radial distance of 0.191753152 Gly.**

- **CMB_z proper distance (from redshift 0.832) (Then) was 45.508473670 Gly.**
- **Expansion part of CMB_z proper distance (from redshift 0.832) (Then) was 45.466799243 Gly.**
- **% of LS-Proper Distance (CMB_z) used (by redshift 0.832) was 86.861% or 0.041674426 Gly.**
- **PDtoCMB$_z$ (at redshift 0.832) was 16,071.180 Mpc or 52.417178296 Gly.**
- **Expansion part of the PDtoCMB$_z$ (at redshift 0.832) was 52.410874199 Gly.**
- **% of LS-Proper Distance (CMB_z) remaining was 13.139% or 0.006304096 Gly.**

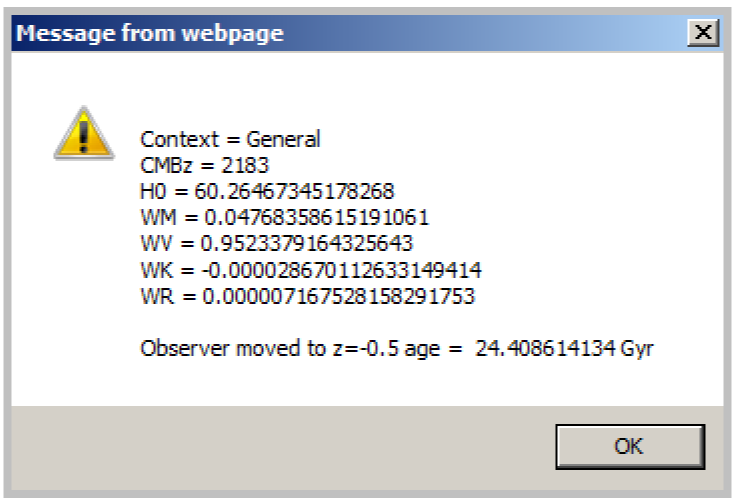
Note that the age (13.720645822 Gyr), CMB proper distance (45.508473670 Gly), Hubble Parameter (69.6), and the Omega fractions are what would be expected.

(The z Scale continued-5)

The second example of a future z value is a ratio example. If the user wanted to "double" (multiply by 2) the CMBz, the calculation of the z value to enter into the Input Data Form would be as follows:

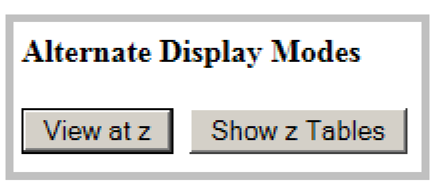
z = (1+1091)/(2*(1+1091)) -1.000
    or (1+ObserverCMBz)/(2*(1+ObserverCMbz))-1.000
z = 1092/2184 – 1.000
z = -0.5000000

By entering this negative value in the Input Data Form and selecting a geometry (**Open**, **Flat**, or **General**), and the click the "View at z" button, the model will produce:



Following the same procedures as in the previous example, the user can enter z=1.000 to view "today" from the perspective of an Observer in the future at CMBz=2083 and at the age of 24.408614134 Gyr.

The "**View z Tables**" button is available from these future observer location and the user can see trends (or trend changes) in in many values over billions of years into the future. Just click the right side button:



View Today from z=2183

Cosmology Model Input Parameters:
Observer located at Age = 24.408614134 Gyr using z=0.00 and CMB_z viewed as redshift = 2183.000
H_o = 60.265, $\Omega Omega_m$ = 0.04768, Ω_{vac} = 0.95233792, Ω_K = -0.00002867, Ω_R = 0.00000717 [General]

First using: z_{cmb} = 2183.000 (aka Last Scattering)

- It is now 24.408614134 Gyr since the Big Bang (Observer located at "now" or z = 0.0). <== based upon "View at z" input data.
- Age at Last Scattering (LS) was 0.000374666 Gyr or 374,666 yrs.
- Light travel time from Last Scattering to now was 24.408239468 Gyr.
- Proper radial distance that goes into Hubble's law is 32,576.915 Mpc or 106.251686884 Gly.
- Proper volume (within redshift 2183.000) is 144,781.039 Gpc^3 or 5,023,302.313 Gly^3.
- Angular size distance D_A (for redshift 2183.000) was 14.913114 Mpc or 48,640,071 ly.
- This gives a D_A scale of 0.072301 kpc/"
- Luminosity distance D_L (redshift 2183.000) is 71,133,404.321 Mpc or 232,006.135 Gly.
- LS-Photon (CMB_z) Proper Distance (at LS) was 0.048650040 Gly or 48,650,040 ly.
- LS-Photon (CMB_z) Proper Distance (at LS) minus Angular size distance was or 9,969 ly.
- Observer-adjusted Scale factor (for redshift 2183.00000) (1/(1+z)) = 0.000457875.

- CMB temperature now is 1.36264 °K.
- CMB temperature at Last Scattering was 2976.00576 °K.
- Hubble Time is 16.224965069 Gyr (Age vs. Hubble Time Ratio = 150.439%).
- Average CMB_z recession since the LS is 4.3511 ly/yr
- Current CMB_z recession usng input H_o is 6.5487 ly/yr
- Universe expansion accelerates at z=2.4185 (+/- 0.0001) at age 7.293146744 Gyr.
- ==> Hubble Parameter =101.87933 with CMB_z viewed as z = 637.87670.
- Maximum LS-Photon proper distance is 9.369172962 Gly at z = 2.500811 (+/- 0.0001).
- Points for integrals = 1,000 Note: "Displaced Viewer"=ON

Now using: z_{input} = 1.00000000 [More on redshift]

- Age since Big Bang (at redshift 1.000) was 13.720645822 Gyr. **Today**
- Light travel time (from redshift 1.000) to now was 10.687968312 Gyr.
- Proper radial distance that goes into Hubble's law is 4,689.815 Mpc or 15.296132299 Gly.
- Proper volume (within redshift 1.000) is 432.070 Gpc^3 or 14,991.024 Gly^3.
- Angular size distance D_A (for redshift 1.000) was 2,344.898 Mpc or 7.648033669 Gly.
- This gives a D_A scale of 11.368385 kpc/"
- Luminosity distance D_L is 9379.591 Mpc or 30.592 Gly.
- LS-Photon Proper Distance (at/from redshift 1.000) was 2,344.908 Mpc or 7.648066150 Gly.
- Observer-adjusted Scale factor (for redshift 1.00000) (1/(1+z)) = 0.500000000.

- CMB temperature at redshift 1.000 age was 2.72528 °K.
- CMB redshift (at redshift 1.000) was 1091.000000.
- At z - H_z Calcs = $\Omega Omega_{mz}$ = 0.3814687, Ω_{vacz} = 0.9523379, Ω_{Kz} = -0.0001147, Ω_{Rz} = 0.0001147
- Ω Fractions at z= $\Omega Omega_{mz}$ = 0.2860000, Ω_{vacz} = 0.7140000, Ω_{Kz} = -0.0000860, Ω_{Rz} = 0.0000860
- Hubble Parameter (Omega Calc)(at redshift 1.000) was 69.60000 k/s/Mpc.(E(z)=1.154905). **Hubble Today**
- Actual Time Expansion ratio (from redshift 1.000) is (10.687968312) / (7.648066150) = 1.397.
- Light from z=1.000000 first reached Observer at age 0.101604235 Gyr (age z = 60.439567555).
- Visible universe then was CMBz= 34.547125 at a proper radial distance of 0.250343541 Gly.

- CMB_z proper distance (from redshift 1.000) (Then) was 45.508473670 Gly. **Today**
- Expansion part of CMB_z proper distance (from redshift 1.000) (Then) was 45.466799243 Gly.
- % of LS-Proper Distance (CMB_z) used (by redshift 1.000) was 85.662% or 0.041674426 Gly. **Last Scattering Proper Distance**
- $PDtoCMB_z$ (at redshift 1.000) was 16,297.869 Mpc or 53.156539820 Gly.
- Expansion part of the $PDtoCMB_z$ (at redshift 1.000) was 53.149564206 Gly.
- % of LS-Proper Distance (CMB_z) remaining was 14.338% or 0.006975613 Gly.

- CMB_z Recession Speed ($PDtoCMB_z$ from Observer's location) (Then) using H_z was 3.7837 ly/y.
- Actual CMB_z Recession Speed (from redshift point 1.000) (Then) was 3.2393 ly/y.
- Actual z Recession Speed for redshift point 1.000 from Observer was 0.5444 ly/y.**
  ** Recession speed crosses below 1.000 ly/y at maximum LS-Photon distance.
- Current CMB Recession Speed (from redshift point 1.000) (now) is 5.6059 ly/y.
- Current Observer Recession Speed to redshift point 1.000 (now) is 0.9428 ly/y.
- Average CMB_z recession for ($PDtoCMB_z$) since LS (at redshift 1.000) was 3.8738 ly/y.
- Average CMB_z recession (for/at redshift point 1.000) since LS was 3.3138 ly/y.

Table-1 for CMBz=2083 at age=24.408808305 Gyr:

Table-1 Main_Answers_Table__(using pts/integral=1,000)

Input: CMBz=2183.000 H_o=60.265 Ω_m=0.04768359 Ω_{vac}=0.95233792 Ω_K=-0.00002867 Ω_R=0.00000717

General .... Redshift ...(z)..	....Age_at.... ...Redshift... ....(years)...	.....Light.... ....Travel.... .....Time..... ....(years)...	....Comoving... .....Radial.... ....Distance... ......(ly).....	.... .Comoving .Volume.. .(Gpc^3).	...Angular... .....Size.... ...Distance.. .....(ly)....	.... Luminiosity ..Distance. ...(Gyr)...
0.00	24,408,614,134	0	0	0.00	0	0.000
0.01	24,247,225,994	161,388,140	162,191,292	0.00	160,585,437	0.164
0.02	24,087,544,304	321,069,830	324,264,479	0.00	317,906,352	0.331
0.03	23,929,537,799	479,076,335	486,217,478	0.01	472,055,801	0.501
0.04	23,773,176,132	635,438,002	648,048,192	0.03	623,123,257	0.674
0.05	23,618,429,831	790,184,302	809,754,521	0.06	771,194,773	0.850
0.06	23,465,270,273	943,343,861	971,334,355	0.11	916,353,149	1.030
0.07	23,313,669,644	1,094,944,490	1,132,785,577	0.18	1,058,678,085	1.212
0.08	23,163,600,916	1,245,013,217	1,294,106,065	0.26	1,198,246,320	1.398
0.09	23,015,037,813	1,393,576,321	1,455,293,687	0.37	1,335,131,772	1.586
0.10	22,867,954,784	1,540,659,350	1,616,346,309	0.51	1,469,405,666	1.778
0.20	21,473,376,020	2,935,238,114	3,218,974,306	4.03	2,682,478,084	3.863
0.30	20,203,193,008	4,205,421,126	4,805,725,767	13.40	3,696,710,578	6.247
0.40	19,040,555,385	5,368,058,749	6,374,435,371	31.27	4,553,164,764	8.924
0.50	17,972,080,376	6,436,533,758	7,922,974,229	60.04	5,281,976,801	11.884
0.60	16,986,928,876	7,421,685,258	9,449,292,007	101.86	5,905,797,933	15.119
0.70	16,076,164,048	8,332,450,086	10,951,455,867	158.57	6,442,018,838	18.617
0.80	15,232,296,271	9,176,317,862	12,427,684,623	231.73	6,904,249,879	22.370
0.90	14,448,954,550	9,959,659,584	13,876,376,878	322.58	7,303,330,725	26.365
1.00	13,720,645,822	10,687,968,312	15,296,132,299	432.07	7,648,033,669	30.592
1.50	10,754,678,017	13,653,936,117	21,927,114,963	1272.77	8,770,769,441	54.817
2.00	8,628,005,556	15,780,608,577	27,747,021,737	2579.01	9,248,877,994	83.240
2.4185	7,293,146,744	17,115,467,390	32,019,157,478	3963.06	9,366,260,532	109.455
2.50	7,069,681,539	17,338,932,595	32,792,104,465	4257.05	9,368,989,832	114.770
2.500811	7,067,510,553	17,341,103,580	32,799,703,765	4260.01	9,368,990,005	114.823
3.00	5,903,204,810	18,505,409,324	37,152,849,323	6191.19	9,287,979,616	148.608
3.50	5,011,410,408	19,397,203,726	40,933,387,716	8279.96	9,096,031,733	184.195
4.00	4,315,769,067	20,092,845,067	44,230,763,266	10446.38	8,845,838,523	221.146
4.50	3,762,987,931	20,645,626,203	47,127,768,375	12636.32	8,568,339,719	259.192
5.00	3,316,314,141	21,092,299,993	49,692,317,600	14813.42	8,281,681,722	298.141
5.50	2,949,938,167	21,458,675,966	51,979,243,869	16954.12	7,996,414,573	337.849
6.00	2,645,394,197	21,763,219,937	54,032,643,576	19043.73	7,718,540,034	378.208
6.50	2,389,227,537	22,019,386,597	55,888,058,987	21073.59	7,451,318,725	419.137
7.00	2,171,463,679	22,237,150,455	57,574,294,444	23039.10	7,196,353,795	460.567
7.50	1,984,587,813	22,424,026,321	59,114,858,170	24938.36	6,954,248,060	502.444
8.00	1,822,853,182	22,585,760,952	60,529,083,801	26771.25	6,725,006,504	544.726
8.50	1,681,804,393	22,726,809,740	61,832,996,470	28538.80	6,508,284,782	587.373
9.00	1,557,943,456	22,850,670,678	63,039,981,367	30242.77	6,303,543,411	630.354
9.50	1,448,492,129	22,960,122,005	64,161,301,579	31885.38	6,110,143,555	673.643
10.00	1,351,220,287	23,057,393,847	65,206,501,395	33469.06	5,927,406,274	717.216
25.00	371,553,957	24,037,060,177	80,803,668,146	63685.78	3,107,465,079	2,100.646
108.20	42,509,109	24,366,105,025	95,663,552,962	105672.97	875,894,348	10,444.725
135.50	30,272,558	24,378,341,576	97,150,604,168	110677.21	711,604,113	13,258.786
181.00	19,512,272	24,389,101,861	98,833,590,179	116528.54	542,945,426	17,984.524
272.00	10,467,615	24,398,146,518	100,819,018,880	123692.18	369,232,303	27,518.514
363.00	6,706,249	24,401,907,885	101,993,138,268	128063.52	280,148,024	37,118.493
545.00	3,558,393	24,405,055,741	103,369,564,824	133317.75	189,284,830	56,428.836
727.00	2,257,445	24,406,356,689	104,176,045,140	136462.06	143,070,776	75,825.222
1091.00	1,177,433	24,407,436,701	105,108,989,570	140160.64	96,234,352	114,756.001
2183.00	374,666	24,408,239,468	106,251,686,884	144781.04	48,640,071	232,006.135

Back to Documentation Main Table of Contents:

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