# Theory of the Earth

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Appendix

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# Appendix

TABLE **A-1**
Earth Model PREM and its Functionals Evaluated at a Reference Period of 1 s.
Above 220 km the Mantle is Transversely Isotropic (see Table A-2);
the Parameters Given are "Equivalent" Isotropic Moduli and Velocities.

| Level | Radius (km) | Depth (km) | Density ($g/cm^3$) | $V_p$ (km/s) | $V_s$ (km/s) | $Q_\mu$ | $Q_K$ | $Q_P$ | $\Phi$ ($km^2/s^2$) | $K_s$ (kbar) | $\mu$ (kbar) | $\sigma$ | Pressure (kbar) | $dK/dP$ | B.P. | Gravity ($cm/s^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0. | 6371.0 | 13.08 | 11.26 | 3.66 | 85 | 1328 | 431 | 108.90 | 14253 | 1761 | 0.440 | 3638.5 | 2.33 | 0.99 | 0. |
| 2 | 100.0 | 6271.0 | 13.08 | 11.26 | 3.66 | 85 | 1328 | 431 | 108.88 | 14248 | 1759 | 0.440 | 3636.1 | 2.33 | 0.99 | 36.5 |
| 3 | 200.0 | 6171.0 | 13.07 | 11.25 | 3.66 | 85 | 1328 | 431 | 108.80 | 14231 | 1755 | 0.440 | 3628.9 | 2.33 | 0.99 | 73.1 |
| 4 | 300.0 | 6071.0 | 13.06 | 11.24 | 3.65 | 85 | 1328 | 432 | 108.68 | 14203 | 1749 | 0.440 | 3617.0 | 2.33 | 0.99 | 109.6 |
| 5 | 400.0 | 5971.0 | 13.05 | 11.23 | 3.65 | 85 | 1328 | 432 | 108.51 | 14164 | 1739 | 0.441 | 3600.3 | 2.33 | 0.99 | 146.0 |
| 6 | 500.0 | 5871.0 | 13.03 | 11.22 | 3.64 | 85 | 1328 | 433 | 108.29 | 14114 | 1727 | 0.441 | 3578.8 | 2.33 | 0.99 | 182.3 |
| 7 | 600.0 | 5771.0 | 13.01 | 11.20 | 3.62 | 85 | 1328 | 434 | 108.02 | 14053 | 1713 | 0.441 | 3552.7 | 2.33 | 0.99 | 218.6 |
| 8 | 700.0 | 5671.0 | 12.98 | 11.18 | 3.61 | 85 | 1328 | 436 | 107.70 | 13981 | 1696 | 0.441 | 3522.0 | 2.34 | 0.99 | 254.7 |
| 9 | 800.0 | 5571.0 | 12.94 | 11.16 | 3.59 | 85 | 1328 | 437 | 107.33 | 13898 | 1676 | 0.442 | 3486.6 | 2.34 | 0.99 | 290.6 |
| 10 | 900.0 | 5471.0 | 12.91 | 11.13 | 3.57 | 85 | 1328 | 439 | 106.91 | 13805 | 1654 | 0.442 | 3446.7 | 2.34 | 0.99 | 326.4 |
| 11 | 1000.0 | 5371.0 | 12.87 | 11.10 | 3.55 | 85 | 1328 | 440 | 106.45 | 13701 | 1630 | 0.442 | 3402.3 | 2.34 | 0.99 | 362.0 |
| 12 | 1100.0 | 5271.0 | 12.82 | 11.07 | 3.53 | 85 | 1328 | 443 | 105.94 | 13586 | 1603 | 0.443 | 3353.5 | 2.34 | 1.00 | 397.3 |
| 13 | 1200.0 | 5171.0 | 12.77 | 11.03 | 3.51 | 85 | 1328 | 445 | 105.38 | 13462 | 1574 | 0.443 | 3300.4 | 2.34 | 1.00 | 432.5 |
| 14 | 1221.5 | 5149.5 | 12.76 | 11.02 | 3.50 | 85 | 1328 | 445 | 105.25 | 13434 | 1567 | 0.443 | 3288.5 | 2.34 | 1.00 | 440.0 |
| 15 | 1221.5 | 5149.5 | 12.16 | 10.350. | | 0 | 57822 | 57822 | 107.24 | 13047 | 0 | 0.500 | 3288.5 | 3.75 | 1.03 | 440.0 |
| 16 | 1300.0 | 5071.0 | 12.12 | 10.30 | 0. | 0 | 57822 | 57822 | 106.29 | 12888 | 0 | 0.500 | 3245.4 | 3.65 | 1.02 | 463.6 |
| 17 | 1400.0 | 4971.0 | 12.06 | 10.24 | 0. | 0 | 57822 | 57822 | 105.05 | 12679 | 0 | 0.500 | 3187.4 | 3.54 | 1.01 | 494.1 |
| 18 | 1500.0 | 4871.0 | 12.00 | 10.18 | 0. | 0 | 57822 | 57822 | 103.78 | 12464 | 0 | 0.500 | 3126.1 | 3.46 | 1.01 | 524.7 |
| 19 | 1600.0 | 4771.0 | 11.94 | 10.12 | 0. | 0 | 57822 | 57822 | 102.47 | 12242 | 0 | 0.500 | 3061.4 | 3.40 | 1.00 | 555.4 |
| 20 | 1700.0 | 4671.0 | 11.87 | 10.05 | 0. | 0 | 57822 | 57822 | 101.12 | 12013 | 0 | 0.500 | 2993.4 | 3.35 | 1.00 | 586.1 |
| 21 | 1800.0 | 4571.0 | 11.80 | 9.98 | 0. | 0 | 57822 | 57822 | 99.71 | 11775 | 0 | 0.500 | 2922.2 | 3.32 | 1.00 | 616.6 |
| 22 | 1900.0 | 4471.0 | 11.73 | 9.91 | 0. | 0 | 57822 | 57822 | 98.25 | 11529 | 0 | 0.500 | 2847.8 | 3.30 | 1.00 | 647.0 |
| 23 | 2000.0 | 4371.0 | 11.65 | 9.83 | 0. | 0 | 57822 | 57822 | 96.73 | 11273 | 0 | 0.500 | 2770.4 | 3.29 | 1.00 | 677.1 |
| 24 | 2100.0 | 4271.0 | 11.57 | 9.75 | 0. | 0 | 57822 | 57822 | 95.14 | 11009 | 0 | 0.500 | 2690.0 | 3.29 | 1.00 | 706.9 |
| 25 | 2200.0 | 4171.0 | 11.48 | 9.66 | 0. | 0 | 57822 | 57822 | 93.48 | 10735 | 0 | 0.500 | 2606.8 | 3.29 | 1.00 | 736.4 |
| 26 | 2300.0 | 4071.0 | 11.39 | 9.57 | 0. | 0 | 57822 | 57822 | 91.75 | 10451 | 0 | 0.500 | 2520.9 | 3.30 | 1.00 | 765.5 |
| 27 | 2400.0 | 3971.0 | 11.29 | 9.48 | 0. | 0 | 57822 | 57822 | 89.95 | 10158 | 0 | 0.500 | 2432.4 | 3.32 | 1.00 | 794.2 |
| 28 | 2500.0 | 3871.0 | 11.19 | 9.38 | 0. | 0 | 57822 | 57822 | 88.06 | 9855 | 0 | 0.500 | 2341.6 | 3.34 | 1.00 | 822.4 |
| 29 | 2600.0 | 3771.0 | 11.08 | 9.27 | 0. | 0 | 57822 | 57822 | 86.10 | 9542 | 0 | 0.500 | 2248.4 | 3.36 | 1.00 | 850.2 |
| 30 | 2700.0 | 3671.0 | 10.97 | 9.16 | 0. | 0 | 57822 | 57822 | 84.04 | 9220 | 0 | 0.500 | 2153.1 | 3.39 | 1.00 | 877.4 |

**TABLE A-1** *(continued)*

| Level | Radius (km) | Depth (km) | Density ($g/cm^3$) | $V_p$ (km/s) | $V_s$ (km/s) | $Q_\mu$ | $Q_K$ | $Q_p$ | $\Phi$ ($km^2/s^2$) | $K_s$ (kbar) | $\mu$ (kbar) | $\sigma$ | Pressure (kbar) | $dK/dP$ | B.P. | Gravity ($cm/s^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | 2800.0 | 3571.0 | 10.85 | 9.05 | 0. | 0 | 57822 | 57822 | 81.91 | 8889 | 0 | 0.500 | 2055.9 | 3.41 | 1.00 | 904.1 |
| 32 | 2900.0 | 3471.0 | 10.73 | 8.92 | 0. | 0 | 57822 | 57822 | 79.68 | 8550 | 0 | 0.500 | 1956.9 | 3.44 | 1.00 | 930.2 |
| 33 | 3000.0 | 3371.0 | 10.60 | 8.79 | 0. | 0 | 57822 | 57822 | 77.36 | 8202 | 0 | 0.500 | 1856.4 | 3.47 | 1.00 | 955.7 |
| 34 | 3100.0 | 3271.0 | 10.46 | 8.65 | 0. | 0 | 57822 | 57822 | 74.96 | 7846 | 0 | 0.500 | 1754.4 | 3.49 | 1.00 | 980.5 |
| 35 | 3200.0 | 3171.0 | 10.32 | 8.51 | 0. | 0 | 57822 | 57822 | 72.47 | 7484 | 0 | 0.500 | 1651.2 | 3.52 | 1.00 | 1004.6 |
| 36 | 3300.0 | 3071.0 | 10.18 | 8.36 | 0. | 0 | 57822 | 57822 | 69.89 | 7116 | 0 | 0.500 | 1546.9 | 3.54 | 0.99 | 1028.0 |
| 37 | 3400.0 | 2971.0 | 10.02 | 8.19 | 0. | 0 | 57822 | 57822 | 67.23 | 6743 | 0 | 0.500 | 1441.9 | 3.56 | 0.99 | 1050.6 |
| 38 | 3480.0 | 2891.0 | 9.90 | 8.06 | 0. | 0 | 57822 | 57822 | 65.04 | 6441 | 0 | 0.500 | 1357.5 | 3.57 | 0.98 | 1068.2 |
| 39 | 3480.0 | 2891.0 | 5.56 | 13.71 | 7.26 | 312 | 57822 | 826 | 117.78 | 6556 | 2938 | 0.305 | 1357.5 | 1.64 | 0.99 | 1068.2 |
| 40 | 3500.0 | 2871.0 | 5.55 | 13.71 | 7.26 | 312 | 57822 | 826 | 117.64 | 6537 | 2933 | 0.304 | 1345.6 | 1.64 | 1.00 | 1065.3 |
| 41 | 3600.0 | 2771.0 | 5.50 | 13.68 | 7.26 | 312 | 57822 | 823 | 116.96 | 6440 | 2907 | 0.303 | 1287.0 | 1.64 | 1.01 | 1052.0 |
| 42 | 3630.0 | 2741.0 | 5.49 | 13.68 | 7.26 | 312 | 57822 | 822 | 116.76 | 6412 | 2899 | 0.303 | 1269.7 | 1.64 | 1.01 | 1048.4 |
| 43 | 3630.0 | 2741.0 | 5.49 | 13.68 | 7.26 | 312 | 57822 | 822 | 116.76 | 6412 | 2899 | 0.303 | 1269.7 | 3.33 | 1.01 | 1048.4 |
| 44 | 3700.0 | 2671.0 | 5.45 | 13.59 | 7.23 | 312 | 57822 | 819 | 115.08 | 6279 | 2855 | 0.302 | 1229.7 | 3.29 | 1.01 | 1040.6 |
| 45 | 3800.0 | 2571.0 | 5.40 | 13.47 | 7.18 | 312 | 57822 | 815 | 112.73 | 6095 | 2794 | 0.301 | 1173.4 | 3.24 | 1.01 | 1030.9 |
| 46 | 3900.0 | 2471.0 | 5.35 | 13.36 | 7.14 | 312 | 57822 | 811 | 110.46 | 5917 | 2734 | 0.299 | 1118.2 | 3.20 | 1.00 | 1022.7 |
| 47 | 4000.0 | 2371.0 | 5.30 | 13.24 | 7.09 | 312 | 57822 | 807 | 108.23 | 5744 | 2675 | 0.298 | 1063.8 | 3.17 | 1.00 | 1015.8 |
| 48 | 4100.0 | 2271.0 | 5.25 | 13.13 | 7.05 | 312 | 57822 | 803 | 106.04 | 5575 | 2617 | 0.297 | 1010.3 | 3.15 | 1.00 | 1010.0 |
| 49 | 4200.0 | 2171.0 | 5.20 | 13.01 | 7.01 | 312 | 57822 | 799 | 103.88 | 5409 | 2559 | 0.295 | 957.6 | 3.13 | 1.00 | 1005.3 |
| 50 | 4300.0 | 2071.0 | 5.15 | 12.90 | 6.96 | 312 | 57822 | 795 | 101.73 | 5246 | 2502 | 0.294 | 905.6 | 3.13 | 1.00 | 1001.5 |
| 51 | 4400.0 | 1971.0 | 5.10 | 12.78 | 6.91 | 312 | 57822 | 792 | 99.59 | 5085 | 2445 | 0.292 | 854.3 | 3.14 | 1.00 | 998.5 |
| 52 | 4500.0 | 1871.0 | 5.05 | 12.66 | 6.87 | 312 | 57822 | 788 | 97.43 | 4925 | 2388 | 0.291 | 803.6 | 3.16 | 1.00 | 996.3 |
| 53 | 4600.0 | 1771.0 | 5.00 | 12.54 | 6.82 | 312 | 57822 | 784 | 95.26 | 4766 | 2331 | 0.289 | 753.5 | 3.19 | 0.99 | 994.7 |
| 54 | 4700.0 | 1671.0 | 4.95 | 12.42 | 6.77 | 312 | 57822 | 779 | 93.06 | 4607 | 2273 | 0.288 | 704.1 | 3.23 | 0.99 | 993.6 |
| 55 | 4800.0 | 1571.0 | 4.89 | 12.29 | 6.72 | 312 | 57822 | 775 | 90.81 | 4448 | 2215 | 0.286 | 655.2 | 3.27 | 0.99 | 993.1 |
| 56 | 4900.0 | 1471.0 | 4.84 | 12.16 | 6.67 | 312 | 57822 | 770 | 88.52 | 4288 | 2157 | 0.284 | 606.8 | 3.32 | 0.99 | 993.0 |
| 57 | 5000.0 | 1371.0 | 4.78 | 12.02 | 6.61 | 312 | 57822 | 766 | 86.17 | 4128 | 2098 | 0.282 | 558.9 | 3.38 | 0.99 | 993.2 |
| 58 | 5100.0 | 1271.0 | 4.73 | 11.88 | 6.56 | 312 | 57822 | 761 | 83.76 | 3966 | 2039 | 0.280 | 511.6 | 3.45 | 0.99 | 993.8 |
| 59 | 5200.0 | 1171.0 | 4.67 | 11.73 | 6.50 | 312 | 57822 | 755 | 81.28 | 3803 | 1979 | 0.278 | 464.8 | 3.52 | 0.99 | 994.6 |
| 60 | 5300.0 | 1071.0 | 4.62 | 11.57 | 6.44 | 312 | 57822 | 750 | 78.72 | 3638 | 1918 | 0.275 | 418.6 | 3.59 | 0.99 | 995.7 |

**TABLE A-1** *(continued)*

| Level | Radius (km) | Depth (km) | Density (g/cm$^3$) | $V_p$ (km/s) | $V_s$ (km/s) | $Q_\mu$ | $Q_K$ | $Q_p$ | $\Phi$ (km$^2$/s$^2$) | $K_s$ (kbar) | $\mu$ (kbar) | $\sigma$ | Pressure (kbar) | d$K$/d$P$ | B.P. | Gravity (cm/s$^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 5400.0 | 971.0 | 4.56 | 11.41 | 6.37 | 312 | 57822 | 743 | 76.08 | 3471 | 1856 | 0.273 | 372.8 | 3.67 | 0.98 | 996.9 |
| 62 | 5500.0 | 871.0 | 4.50 | 11.24 | 6.31 | 312 | 57822 | 737 | 73.34 | 3303 | 1794 | 0.270 | 327.6 | 3.75 | 0.98 | 998.3 |
| 63 | 5600.0 | 771.0 | 4.44 | 11.06 | 6.24 | 312 | 57822 | 730 | 70.52 | 3133 | 1730 | 0.266 | 282.9 | 3.84 | 0.97 | 999.8 |
| 64 | 5600.0 | 771.0 | 4.44 | 11.06 | 6.24 | 312 | 57822 | 730 | 70.52 | 3133 | 1730 | 0.266 | 282.9 | 2.98 | 0.97 | 999.8 |
| 65 | 5650.0 | 721.0 | 4.41 | 10.91 | 6.09 | 312 | 57822 | 744 | 69.51 | 3067 | 1639 | 0.273 | 260.7 | 3.00 | 0.97 | 1000.6 |
| 66 | 5701.0 | 670.0 | 4.38 | 10.75 | 5.94 | 312 | 57822 | 759 | 68.47 | 2999 | 1548 | 0.279 | 238.3 | 3.03 | 0.98 | 1001.4 |
| 67 | 5701.0 | 670.0 | 3.99 | 10.26 | 5.57 | 143 | 57822 | 362 | 64.03 | 2556 | 1239 | 0.291 | 238.3 | 2.40 | 0.37 | 1001.4 |
| 68 | 5736.0 | 635.0 | 3.98 | 10.21 | 5.54 | 143 | 57822 | 362 | 63.32 | 2523 | 1224 | 0.291 | 224.3 | 2.38 | 0.37 | 1000.8 |
| 69 | 5771.0 | 600.0 | 3.97 | 10.15 | 5.51 | 143 | 57822 | 362 | 62.61 | 2489 | 1210 | 0.290 | 210.4 | 2.37 | 0.37 | 1000.3 |
| 70 | 5771.0 | 600.0 | 3.97 | 10.15 | 5.51 | 143 | 57822 | 362 | 62.61 | 2489 | 1210 | 0.290 | 210.4 | 8.09 | 1.98 | 1000.3 |
| 71 | 5821.0 | 550.0 | 3.91 | 9.90 | 5.37 | 143 | 57822 | 363 | 59.60 | 2332 | 1128 | 0.291 | 190.7 | 7.88 | 1.92 | 999.6 |
| 72 | 5871.0 | 500.0 | 3.84 | 9.64 | 5.22 | 143 | 57822 | 364 | 56.65 | 2181 | 1051 | 0.292 | 171.3 | 7.67 | 1.86 | 998.8 |
| 73 | 5921.0 | 450.0 | 3.78 | 9.38 | 5.07 | 143 | 57822 | 365 | 53.78 | 2037 | 977 | 0.293 | 152.2 | 7.46 | 1.79 | 997.9 |
| 74 | 5971.0 | 400.0 | 3.72 | 9.13 | 4.93 | 143 | 57822 | 366 | 50.99 | 1899 | 906 | 0.294 | 133.5 | 7.26 | 1.73 | 996.8 |
| 75 | 5971.0 | 400.0 | 3.54 | 8.90 | 4.76 | 143 | 57822 | 372 | 48.97 | 1735 | 806 | 0.298 | 133.5 | 3.37 | 0.83 | 996.8 |
| 76 | 6016.0 | 355.0 | 3.51 | 8.81 | 4.73 | 143 | 57822 | 370 | 47.83 | 1682 | 790 | 0.297 | 117.7 | 3.33 | 0.82 | 995.2 |
| 77 | 6061.0 | 310.0 | 3.48 | 8.73 | 4.70 | 143 | 57822 | 367 | 46.71 | 1630 | 773 | 0.295 | 102.0 | 3.30 | 0.80 | 993.6 |
| 78 | 6106.0 | 265.0 | 3.46 | 8.64 | 4.67 | 143 | 57822 | 365 | 45.60 | 1579 | 757 | 0.293 | 86.4 | 3.26 | 0.79 | 992.0 |
| 79 | 6151.0 | 220.0 | 3.43 | 8.55 | 4.64 | 143 | 57822 | 362 | 44.50 | 1529 | 741 | 0.291 | 71.1 | 3.23 | 0.78 | 990.4 |
| 80 | 6151.0 | 220.0 | 3.35 | 7.98 | 4.41 | 80 | 57822 | 195 | 37.80 | 1270 | 656 | 0.279 | 71.1 | −0.73 | −0.12 | 990.4 |
| 81 | 6186.0 | 185.0 | 3.36 | 8.01 | 4.43 | 80 | 57822 | 195 | 38.01 | 1278 | 660 | 0.279 | 59.4 | −0.72 | −0.12 | 989.1 |
| 82 | 6221.0 | 150.0 | 3.36 | 8.03 | 4.44 | 80 | 57822 | 195 | 38.21 | 1287 | 665 | 0.279 | 47.8 | −0.70 | −0.12 | 987.8 |
| 83 | 6256.0 | 115.0 | 3.37 | 8.05 | 4.45 | 80 | 57822 | 195 | 38.41 | 1295 | 669 | 0.279 | 36.1 | −0.68 | −0.13 | 986.6 |
| 84 | 6291.0 | 80.0 | 3.37 | 8.07 | 4.46 | 80 | 57822 | 195 | 38.60 | 1303 | 674 | 0.279 | 24.5 | −0.67 | −0.13 | 985.5 |
| 85 | 6291.0 | 80.0 | 3.37 | 8.07 | 4.46 | 600 | 57822 | 1447 | 38.60 | 1303 | 674 | 0.279 | 24.5 | −0.67 | −0.13 | 985.5 |
| 86 | 6311.0 | 60.0 | 3.37 | 8.08 | 4.47 | 600 | 57822 | 1447 | 38.71 | 1307 | 677 | 0.279 | 17.8 | −0.66 | −0.13 | 984.9 |
| 87 | 6331.0 | 40.0 | 3.37 | 8.10 | 4.48 | 600 | 57822 | 1446 | 38.81 | 1311 | 680 | 0.279 | 11.2 | −0.65 | −0.13 | 984.3 |
| 88 | 6346.6 | 24.4 | 3.38 | 8.11 | 4.49 | 600 | 57822 | 1446 | 38.89 | 1315 | 682 | 0.278 | 6.0 | −0.64 | −0.13 | 983.9 |
| 89 | 6346.6 | 24.4 | 2.90 | 6.80 | 3.90 | 600 | 57822 | 1350 | 25.96 | 753 | 441 | 0.254 | 6.0 | −0.00 | −0.00 | 983.9 |
| 90 | 6356.0 | 15.0 | 2.90 | 6.80 | 3.90 | 600 | 57822 | 1350 | 25.96 | 753 | 441 | 0.254 | 3.3 | 0.00 | 0.00 | 983.3 |
| 91 | 6356.0 | 15.0 | 2.60 | 5.80 | 3.20 | 600 | 57822 | 1456 | 19.99 | 520 | 266 | 0.281 | 3.3 | 0.00 | 0.00 | 983.3 |
| 92 | 6368.0 | 3.0 | 2.60 | 5.80 | 3.20 | 600 | 57822 | 1456 | 19.99 | 520 | 266 | 0.281 | 0.3 | −0.00 | −0.00 | 982.2 |
| 93 | 6368.0 | 3.0 | 1.02 | 1.45 | 0. | 0 | 57822 | 57822 | 2.10 | 21 | 0 | 0.500 | 0.2 | −0.00 | −0.00 | 982.2 |
| 94 | 6371.0 | 0. | 1.02 | 1.45 | 0. | 0 | 57822 | 57822 | 2.10 | 21 | 0 | 0.500 | 0.0 | 0.00 | 0.00 | 981.5 |

Dziewonski, A. M. and D. L. Anderson **(1981)** Preliminary Reference Earth Model, ***Phys. Earth Planet. Inter., 25,* 297–356**

TABLE **A-2**
Crust and Upper Mantle of PREM Including Directional Velocities, Anisotropic Elastic Constants and "Equivalent" Isotropic Velocities. Evaluated at Reference Periods of 1 s (top) and 200 s (bottom).

| Radius (km) | Depth (km) | Density (g/cm$^3$) | $V_{PV}$ (km/s) | $V_{PH}$ (km/s) | $V_{SV}$ (km/s) | $V_{SH}$ (km/s) | $\eta$ | $Q_\mu$ | $Q_K$ | $A$ (kbar) | $C$ (kbar) | $L$ (kbar) | $N$ (kbar) | $F$ (kbar) | $V_p$ (km/s) | $V_s$ (km/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6151.0 | 220.0 | 3.35950 | 7.80050 | 8.04862 | 4.44110 | 4.43629 | 0.97654 | 80 | 57822 | 2176 | 2044 | 663 | 661 | 831 | 7.98970 | 4.41885 |
| 6171.0 | 200.0 | 3.36167 | 7.82315 | 8.06310 | 4.43649 | 4.45423 | 0.96877 | 80 | 57822 | 2186 | 2057 | 662 | 667 | 835 | 8.00235 | 4.42580 |
| 6191.0 | 180.0 | 3.36384 | 7.84581 | 8.07760 | 4.43189 | 4.47218 | 0.96099 | 80 | 57822 | 2195 | 2071 | 661 | 673 | 839 | 8.01494 | 4.43285 |
| 6211.0 | 160.0 | 3.36602 | 7.86847 | 8.09209 | 4.42728 | 4.49013 | 0.95321 | 80 | 57822 | 2204 | 2084 | 660 | 679 | 843 | 8.02747 | 4.44000 |
| 6231.0 | 140.0 | 3.36819 | 7.89113 | 8.10659 | 4.42267 | 4.50807 | 0.94543 | 80 | 57822 | 2213 | 2097 | 659 | 685 | 847 | 8.03992 | 4.44724 |
| 6251.0 | 120.0 | 3.37036 | 7.91378 | 8.12108 | 4.41806 | 4.52602 | 0.93765 | 80 | 57822 | 2223 | 2111 | 658 | 690 | 851 | 8.05231 | 4.45458 |
| 6271.0 | 100.0 | 3.37254 | 7.93644 | 8.13558 | 4.41345 | 4.54397 | 0.92987 | 80 | 57822 | 2232 | 2124 | 657 | 696 | 854 | 8.06463 | 4.46201 |
| 6291.0 | 80.0 | 3.37471 | 7.95909 | 8.15006 | 4.40885 | 4.56191 | 0.92210 | 80 | 57822 | 2242 | 2138 | 656 | 702 | 857 | 8.07688 | 4.46953 |
| 6291.0 | 80.0 | 3.37471 | 7.95911 | 8.15008 | 4.40884 | 4.56193 | 0.92209 | 600 | 57822 | 2242 | 2138 | 656 | 702 | 857 | 8.07689 | 4.46954 |
| 6311.0 | 60.0 | 3.37688 | 7.98176 | 8.16457 | 4.40424 | 4.57987 | 0.91432 | 600 | 57822 | 2251 | 2151 | 655 | 708 | 860 | 8.08907 | 4.47715 |
| 6331.0 | 40.0 | 3.37906 | 8.00442 | 8.17906 | 4.39963 | 4.59782 | 0.90654 | 600 | 57822 | 2260 | 2165 | 654 | 714 | 863 | 8.10119 | 4.48486 |
| 6346.6 | 24.4 | 3.38076 | 8.02212 | 8.19038 | 4.39603 | 4.61184 | 0.90047 | 600 | 57822 | 2268 | 2176 | 653 | 719 | 866 | 8.11061 | 4.49094 |
| 6346.6 | 24.4 | 2.90000 | 6.80000 | 6.80000 | 3.90000 | 3.90000 | 1.00000 | 600 | 57822 | 1341 | 1341 | 441 | 441 | 459 | 6.80000 | 3.90000 |
| 6356.0 | 15.0 | 2.90000 | 6.80000 | 6.80000 | 3.90000 | 3.90000 | 1.00000 | 600 | 57822 | 1341 | 1341 | 441 | 441 | 459 | 6.80000 | 3.90000 |
| 6356.0 | 15.0 | 2.60000 | 5.80000 | 5.80000 | 3.20000 | 3.20000 | 1.00000 | 600 | 57822 | 875 | 875 | 266 | 266 | 342 | 5.80000 | 3.20000 |
| 6368.0 | 3.0 | 2.60000 | 5.80000 | 5.80000 | 3.20000 | 3.20000 | 1.00000 | 600 | 57822 | 875 | 875 | 266 | 266 | 342 | 5.80000 | 3.20000 |
| 6368.0 | 3.0 | 1.02000 | 1.45000 | 1.45000 | 0. | 0. | 1.00000 | 0 | 57822 | 21 | 21 | 0 | 0 | 21 | 1.45000 | 0. |
| 6371.0 | 0. | 1.02000 | 1.45000 | 1.45000 | 0. | 0. | 1.00000 | 0 | 57822 | 21 | 21 | 0 | 0 | 21 | 1.45000 | 0. |
| 6151.0 | 220.0 | 3.35950 | 7.72930 | 7.97975 | 4.34748 | 4.34277 | 0.97654 | 80 | 57822 | 2139 | 2007 | 635 | 634 | 849 | 7.92008 | 4.32495 |
| 6171.0 | 200.0 | 3.36167 | 7.75230 | 7.99380 | 4.34297 | 4.36033 | 0.96877 | 80 | 57822 | 2148 | 2020 | 634 | 639 | 853 | 7.93236 | 4.33212 |
| 6191.0 | 180.0 | 3.36384 | 7.77531 | 8.00786 | 4.33846 | 4.37790 | 0.96099 | 80 | 57822 | 2157 | 2034 | 633 | 645 | 856 | 7.94457 | 4.33934 |
| 6211.0 | 160.0 | 3.36602 | 7.79831 | 8.02192 | 4.33395 | 4.39547 | 0.95321 | 80 | 57822 | 2166 | 2047 | 632 | 650 | 859 | 7.95673 | 4.34665 |
| 6231.0 | 140.0 | 3.36819 | 7.82132 | 8.03598 | 4.32943 | 4.41304 | 0.94543 | 80 | 57822 | 2175 | 2060 | 631 | 656 | 863 | 7.96882 | 4.35406 |
| 6251.0 | 120.0 | 3.37036 | 7.84432 | 8.05004 | 4.32492 | 4.43061 | 0.93765 | 80 | 57822 | 2184 | 2074 | 630 | 662 | 866 | 7.98084 | 4.36155 |
| 6271.0 | 100.0 | 3.37254 | 7.86732 | 8.06410 | 4.32041 | 4.44818 | 0.92987 | 80 | 57822 | 2193 | 2087 | 630 | 667 | 869 | 7.99279 | 4.36914 |
| 6291.0 | 80.0 | 3.37471 | 7.89031 | 8.07815 | 4.31590 | 4.46574 | 0.92210 | 80 | 57822 | 2202 | 2101 | 629 | 673 | 871 | 8.00468 | 4.37682 |
| 6291.0 | 80.0 | 3.37471 | 7.94982 | 8.14037 | 4.39645 | 4.54911 | 0.92209 | 600 | 57822 | 2236 | 2133 | 652 | 698 | 859 | 8.06715 | 4.45717 |
| 6311.0 | 60.0 | 3.37688 | 7.97251 | 8.15480 | 4.39186 | 4.56700 | 0.91432 | 600 | 57822 | 2246 | 2146 | 651 | 704 | 862 | 8.07928 | 4.46480 |
| 6331.0 | 40.0 | 3.37906 | 7.99522 | 8.16924 | 4.38726 | 4.58490 | 0.90654 | 600 | 57822 | 2255 | 2160 | 650 | 710 | 865 | 8.09135 | 4.47253 |
| 6346.6 | 24.4 | 3.38076 | 8.01295 | 8.18051 | 4.38368 | 4.59887 | 0.90047 | 600 | 57822 | 2262 | 2171 | 650 | 715 | 867 | 8.10074 | 4.47863 |
| 6346.6 | 24.4 | 2.90000 | 6.79151 | 6.79151 | 3.88904 | 3.88904 | 1.00000 | 600 | 57822 | 1338 | 1338 | 439 | 439 | 460 | 6.79151 | 3.88904 |
| 6356.0 | 15.0 | 2.90000 | 6.79151 | 6.79151 | 3.88904 | 3.88904 | 1.00000 | 600 | 57822 | 1338 | 1338 | 439 | 439 | 460 | 6.79151 | 3.88904 |
| 6356.0 | 15.0 | 2.60000 | 5.79328 | 5.79328 | 3.19101 | 3.19101 | 1.00000 | 600 | 57822 | 873 | 873 | 265 | 265 | 343 | 5.79328 | 3.19101 |
| 6368.0 | 3.0 | 2.60000 | 5.79328 | 5.79328 | 3.19101 | 3.19101 | 1.00000 | 600 | 57822 | 873 | 873 | 265 | 265 | 343 | 5.79328 | 3.19101 |
| 6368.0 | 3.0 | 1.02000 | 1.44996 | 1.44996 | 0. | 0. | 1.00000 | 0 | 57822 | 21 | 21 | 0 | 0 | 21 | 1.44996 | 0. |
| 6371.0 | 0. | 1.02000 | 1.44996 | 1.44996 | 0. | 0. | 1.00000 | 0 | 57822 | 21 | 21 | 0 | 0 | 21 | 1.44996 | 0. |

Dziewonski, A. M. and D. L. Anderson **(1981)** Preliminary Reference Earth Model, ***Phys. Earth Planet. Inter., 25,* 297–356**

**TABLE A-3**
Conversion Factors

| To Convert | To | Multiply by |
|---|---|---|
| angstrom, Å | cm | $10^{-8}$ |
| | nm | 10 |
| bar | atm | 0.987 |
| | dyne/cm$^2$ | $10^6$ |
| | MPa | $10^{-1}$ |
| calorie (g), cal | joule | 4.184 |
| dyne | g cm/s$^{-2}$ | 1 |
| | newton | $10^{-5}$ |
| erg | cal | $2.39 \times 10^{-8}$ |
| | watt-second | 1 |
| | joule | $10^{-7}$ |
| gamma | gauss | $10^{-5}$ |
| | tesla | $10^{-9}$ |
| gauss | tesla | $10^{-4}$ |
| heat-flow unit (H.F.U.) | $\mu$cal/cm$^2$/s | 1 |
| | m W/m$^2$ | 41.84 |
| micrometer, $\mu$m | cm | $10^{-4}$ |
| poise | g/cm/s | 1 |
| | Pa-s | 0.1 |
| stoke | cm$^2$/s | 1 |
| watt | J/s | 1 |
| year | s | $3.156 \times 10^7$ |

**TABLE A-4**
Physical Constants

| | | |
|---|---|---|
| Speed of light | $c$ | $2.998 \times 10^8$ m/s |
| Electronic charge | $e$ | $-1.602 \times 10^{19}$ C |
| Permeability of vacuum | $\mu_0$ | $4\pi \times 10^{-7}$ N/A$^2$ |
| Permittivity of vacuum | $\varepsilon_0$ | $8.854 \times 10^{-12}$ F/m |
| Planck constant | $h$ | $6.626 \times 10^{-34}$ J |
| Boltzmann constant | $k$ | $1.381 \times 10^{-23}$ J/K |
| Stefan-Boltzmann constant | $\sigma$ | $5.67 \times 10^{-8}$ W/m$^2$/K$^4$ |
| Gravitational constant | $G$ | $6.673 \times 10^{-11}$ m$^3$/kg/s$^2$ |
| Electron rest mass | $m_e$ | $0.911 \times 10^{-10}$ kg |
| Avogadro's number | $N_A$ | $6.022 \times 10^{23}$/mol |
| Gas constant | $R$ | 8.314 J/mol/K |

**TABLE A-5**
Earth Parameters

| | |
|---|---|
| Equatorial radius, a | 6378.137 km |
| Polar radius, c | 6356.752 km |
| Equivolume sphere radius | 6371.000 km |
| Surface area | $5.1 \times 10^8$ km$^2$ |
| Geometric flattening, $(a-c)/a$ | 1/298.257 |
| Ellipticity, $(a^2-c^2)!(a^2+c^2)$ | 1/297.75 |
| GM | $3.986005 \times 10^{14}$ m$^3$ s$^{-2}$ |
| Mass, M | $5.97369 \times 10^{24}$ kg |
| Mean density | $5.5148 \times 10^3$ kg m$^{-3}$ |
| Moments of inertia | |
| Polar, C | $8.0378 \times 10^{37}$ kg m$^2$ |
| Equatorial, *A* | $8.0115 \times 10^{37}$ kg m$^2$ |
| $C/Ma^2$ | 0.33068 |
| Dynamic ellipticity (precession constant), $H = \frac{C-A}{C}$ | 1/305.51 |
| Ellipticity coefficient, $J_2 = \frac{C-A}{Ma^2}$ | $10826.3 \times 10^{-7}$ |
| Angular velocity, $\Omega$ | $7.2921 \times 10^{-5}$ rad s$^{-1}$ |
| Angular momentum, $C\Omega$ | $5.8604 \times 10^{33}$ kg m$^2$ s$^{-1}$ |
| Normal gravity at equator | 9.7803267 m s$^{-2}$ |
| Normal gravity at poles | 9.832186 m s$^{-2}$ |

# Determinants

The determinant of the second order

$$\begin{vmatrix} a & b \\ c & d \end{vmatrix}$$

stands for the expression $(ad-bc)$.

The determinant of a $3 \times 3$ matrix, or array of numbers, may be defined in terms of determinants of the second order. The determinant

$$\begin{vmatrix} a & b & c \\ d & e & f \\ g & h & k \end{vmatrix}$$

stands for

$$a \begin{vmatrix} e & f \\ h & k \end{vmatrix} - b \begin{vmatrix} d & f \\ g & k \end{vmatrix} + c \begin{vmatrix} d & e \\ g & h \end{vmatrix}$$

That is, a product of each element in a row or column, and a second-order determinant formed by elements from the other rows and columns. Definitions of determinants of higher order may be given in a similar way.