NASA TN D-1762

NASA TN D-1762

10p

N63 ~~~141

Code 1

# TECHNICAL NOTE

## D-1762

# THE MAGNETIC FIELD OF THE RADIATION BELTS

Syun-Ichi Akasofu
University of Alaska
College, Alaska

Joseph C. Cain
Goddard Space Flight Center
Greenbelt, Maryland

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON June 1963

Code 1

# THE MAGNETIC FIELD OF THE RADIATION BELTS

by

Syun-Ichi Akasofu

*University of Alaska*

Joseph C. Cain

*Goddard Space Flight Center*

SUMMARY

The magnetic fields produced by various types of belts of trapped particles are presented in both tabular and graphical forms.

# THE MAGNETIC FIELD OF THE RADIATION BELTS*

by

Syun-Ichi Akasofu
*University of Alaska*

Joseph C. Cain
*Goddard Space Flight Center*

In this note we shall present in graphical form the magnetic fields produced by various types of belts of trapped particles. The chosen values of the parameters determining the field cover a wide range. It is hoped that, by interpolating the diagrams shown, the distortion of the earth's field can be approximately estimated for actually observed belts without a large amount of computation. References 1-5 discuss the method of computation.

Herein we shall state briefly the formulas used. The number density distribution along an equatorial radius $r$: $N = f_1(r)$ is given by:

$$N = N_0 e^{-g_1^2 z^2} \quad (z < 0 \text{ for the inner part of the belt});$$

$$N = N_0 e^{-g_2^2 z^2} \quad (z > 0 \text{ for the outer part of the belt}),$$

where $z = (r - r_0)/a$ , $a$ is the radius of the earth, and $r_0$ denotes the distance at which $N$ attains its maximum value $N_0$. Thus we may write

$$N = f_1(r_0, z, g_1, g_2) .$$

The pitch-angle distribution, $P = f_2(\theta, \alpha)$, is

$$P = A(\alpha) \sin^{\alpha+1} \theta ,$$

where $\theta$ denotes the pitch angle, $\alpha$ is a constant, and $A(\alpha)$ is a normalization factor.

In the energy spectrum $N = f_3(E)$, we shall consider only particles with a particular energy $E$ (or speed $v$). The functions $f_1$, $f_2$, and $f_3$ determine the electric current intensity at any point in a dipole field. The ring current field $\Delta F$ is then calculated by a method shown in Reference 2.

*This report has been published in substantially the same form minus Appendix A, in *J. Geophys. Res.* 67(10):4078-4080, September 1962.

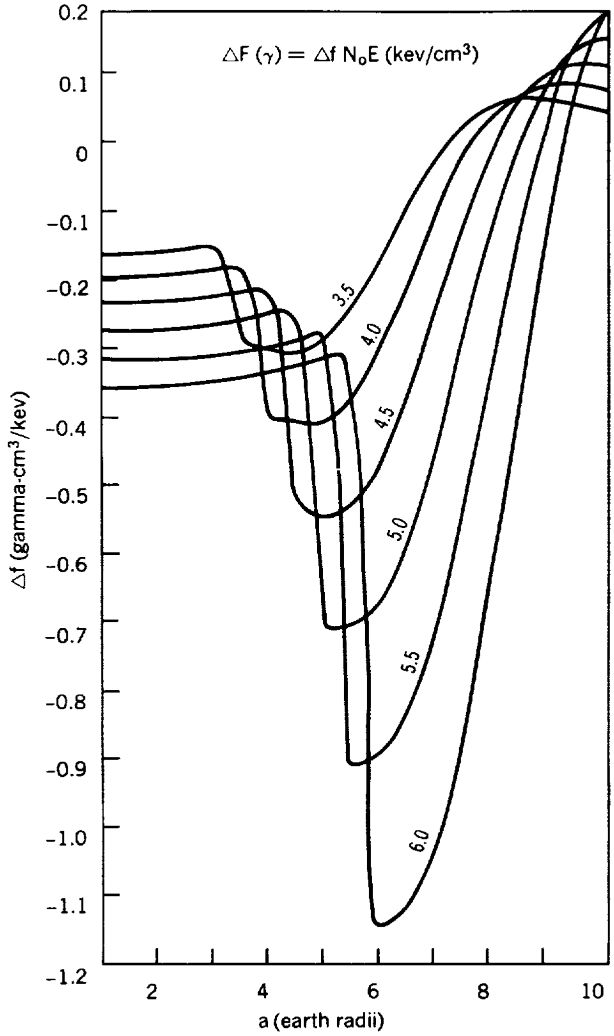


Figure 1(a)—Ring current field $\Delta f$ for several values of $r_0$.

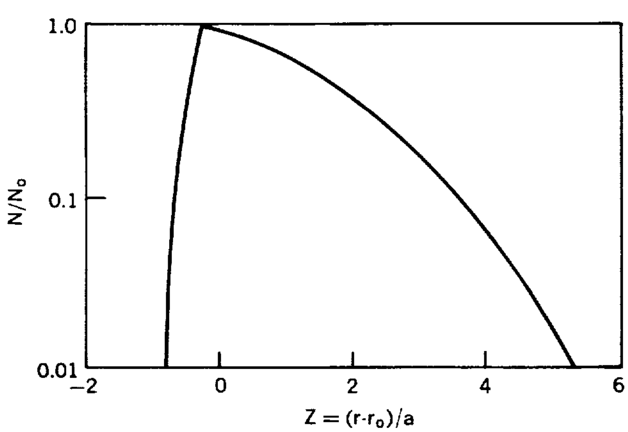


Figure 1(b)—Normalized electron density distribution.

The ring current field $\Delta F$ is given by:

$$\Delta F = f\left(r,\ r_0,\ g_1,\ g_2,\ \alpha,\ N_0,\ E\right) . \qquad (1)$$

In the first approximation, $\Delta F$ is proportional to both $N_0$ and $E$. Therefore, Equation 1 may be rewritten

$$\Delta F = \Delta f\, N_0\, E\ , \qquad (2)$$

where

$$\Delta f = f'\left(r,\ r_0,\ g_1,\ g_2,\ \alpha\right) . \qquad (3)$$

We will show $\Delta f$, as a function of equatorial radial distance $r$, for various sets of $r_0$, $g_1$, $g_2$, and $\alpha$. The vector $\Delta F$ is perpendicular to the equatorial plane and its value of $\Delta F$ is given in gammas, if the units of $N_0$ and $E$ are chosen as $cm^{-3}$ and kev, respectively.

In Figure 1(a) $\Delta f$ is shown for different values of $r_0$ (Appendix A). The other parameters $g_1$, $g_2$, and $\alpha$ are chosen in such a way that they are suitable for the quiet-time proton belt (Reference 3):

$$g_1 = 2.990 \quad \left(N/N_0 = 1/10 \text{ at } z = -0.51\right),$$

$$g_2 = 0.419 \quad \left(N/N_0 = 1/10 \text{ at } z = +3.62\right),$$

$$\alpha = 2.0 .$$

The graph of $N/N_0$ is given in Figure 1(b).

Figure 2(a) presents $\Delta f$ for different values of $g_2$, namely:

$$g_2 = 2.146 \quad \left(N/N_0 = 1/100 \text{ at } z = +1\right) ,$$

$$g_2 = 1.517 \quad \left(N/N_0 = 1/10 \text{ at } z = +1\right) ,$$

$$g_2 = 0.759 \quad (N/N_0 = 1/10 \text{ at } z = +2) ,$$

$$g_2 = 0.379 \quad (N/N_0 = 1/10 \text{ at } z = +4) .$$

The graph of $N/N_0$ for these four cases is shown in Figure 2(b). The other parameters are chosen as follows:

$$r_0 = 3.2a$$

$$g_1 = 2.146 \quad (N/N_0 = 1/100 \text{ at } z = -1) ,$$

$$\alpha = 2.0$$

In Figure 3(a) $\Delta f$ is given for different values of $\alpha$; the graph of P/A for various values of $\alpha$ is given in Figure 3(b). The other parameters are chosen as follows:

$$r_0 = 3.2a$$

$$g_1 = 2.628 \quad (N/N_0 = 1/1000 \text{ at } z = -1) ,$$

$$g_2 = 0\ 379 \quad (N/N_0 = 1/10 \text{ at } z = +4) .$$

The tabulated data from which Figures 1(a), 2(a), and 3(a) are plotted are presented in Appendix A.

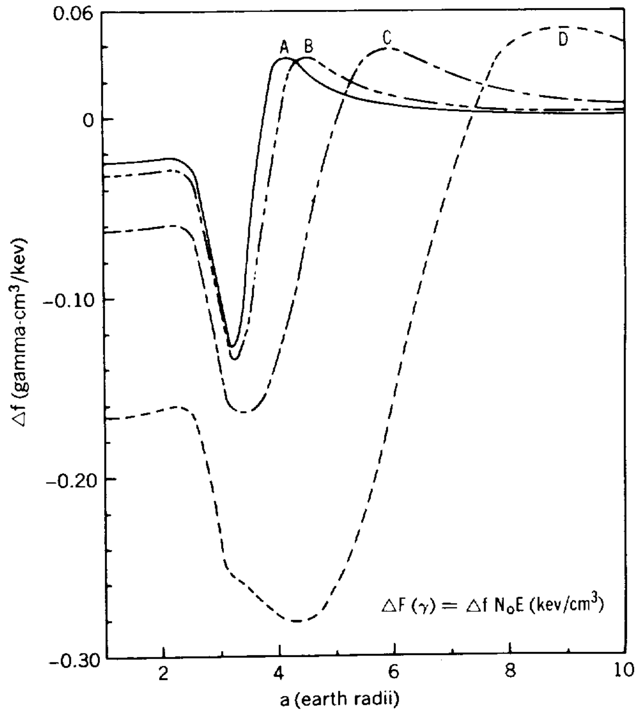


Figure 2(a)—Ring current field $\Delta f$ for several values of outer slope. The values of $g_2$ for curves A, B, C, and D are 2.146, 1.517, 0.759 and 0.379 respectively.

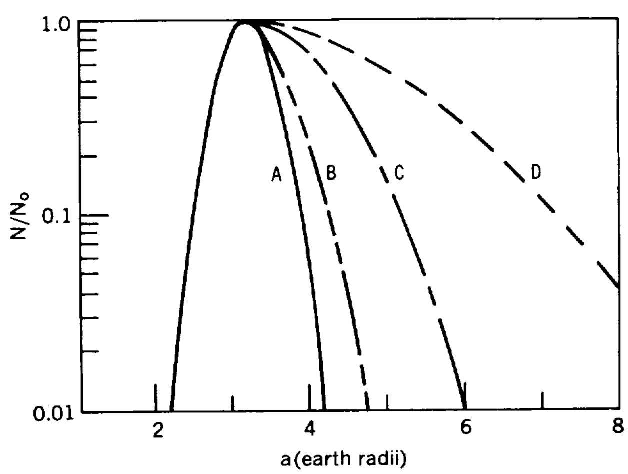


Figure 2(b)—The normalized electron density distribution. The curves A, B, C, and D are defined in Figure 4a.

## REFERENCES


1. Akasofu, S.-I., and Chapman, S., "The Ring Current, Geomagnetic Disturbance and the Van Allen Radiation Belts," *J. Geophys. Res.* 66(5):1321-1350, May 1961.

2. Akasofu, S.-I., Cain, J. C., and Chapman, S., "The Magnetic Field of a Radiation Belt, Numerically Computed," NASA Technical Note D-1447, November 1962; also *J. Geophys. Res.* 66(12):4013-4020, December 1961.

3. Akasofu, S.-I., Cain, J. C., and Chapman, S., "The Magnetic Field of the Quiet-Time Proton Belt," NASA Technical Note D-1674, 1963; also *J. Geophys. Res.* 67(7):2645-2647, July 1962.

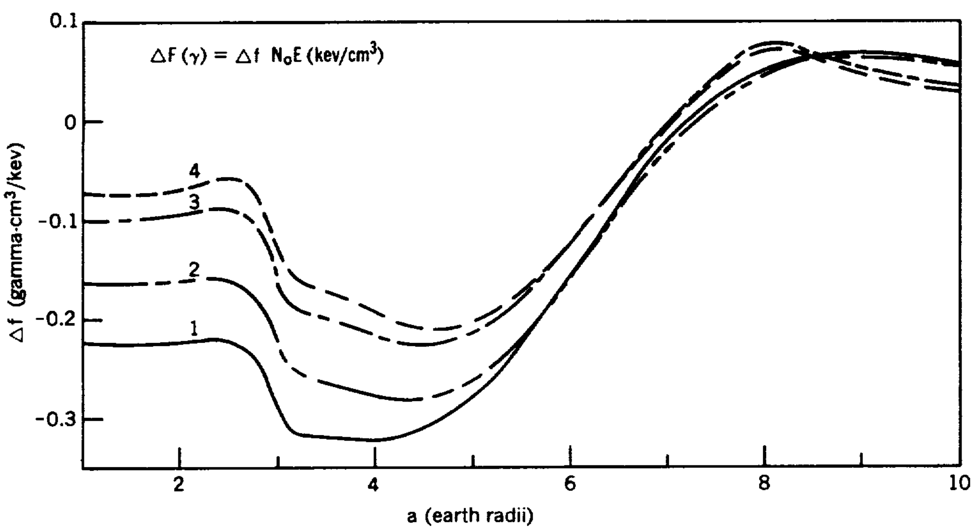


Figure 3(a)—Ring current field Δf for several $a$.

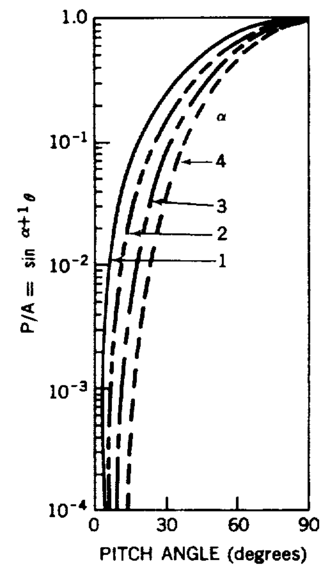


Figure 3(b)—Normalized pitch angle distribution for various $a$.


4. Beard, D. B., "Self-Consistent Calculation of the Ring Current," *J. Geophys. Res.* 67(9):3615-3616, August 1962.

5. Akasofu, S.-I., "On a Self-Consistent Calculation of the Ring Current Field," *J. Geophys. Res.* 67(9): 3617-3618, August 1962.

Appendix A

# The Ring Current Field $\triangle f$ as a Function of $r$, $g_2$, and $\alpha$

Table A1

The Value of $\Delta f$ as a Function of $r_0$.

| r (earth radii) | Ring current field (gamma) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $r_0$ = 1.5a | $r_0$ = 2.0a | $r_0$ = 2.5a | $r_0$ = 3.0a | $r_0$ = 3.5a | $r_0$ = 4.0a | $r_0$ = 4.5a | $r_0$ = 5.0a | $r_0$ = 5.5a | $r_0$ = 6.0a |
| 1.0 | -0.0578 | -0.0779 | -0.1020 | -0.1296 | -0.1604 | -0.1952 | -0.2334 | -0.2744 | -0.3169 | -0.3576 |
| 1.1 | -0.0577 | -0.0778 | -0.1019 | -0.1295 | -0.1602 | -0.1950 | -0.2332 | -0.2743 | -0.3167 | -0.3574 |
| 1.2 | -0.0576 | -0.0777 | -0.1017 | -0.1294 | -0.1600 | -0.1948 | -0.2330 | -0.2741 | -0.3166 | -0.3572 |
| 1.3 | -0.0574 | -0.0775 | -0.1016 | -0.1292 | -0.1597 | -0.1946 | -0.2328 | -0.2738 | -0.3163 | -0.3570 |
| 1.4 | -0.0572 | -0.0773 | -0.1014 | -0.1291 | -0.1594 | -0.1943 | -0.2328 | -0.2736 | -0.3161 | -0.3568 |
| 1.5 | -0.0576 | -0.0771 | -0.1012 | -0.1289 | -0.1591 | -0.1940 | -0.2323 | -0.2733 | -0.3158 | -0.3565 |
| 1.6 | -0.0591 | -0.0769 | -0.1010 | -0.1287 | -0.1587 | -0.1937 | -0.2319 | -0.2730 | -0.3156 | -0.3562 |
| 1.7 | -0.0614 | -0.0766 | -0.1007 | -0.1284 | -0.1583 | -0.1933 | -0.2316 | -0.2727 | -0.3152 | -0.3559 |
| 1.8 | -0.0640 | -0.0766 | -0.1004 | -0.1281 | -0.1578 | -0.1928 | -0.2312 | -0.2723 | -0.3149 | -0.3556 |
| 1.9 | -0.0654 | -0.0773 | -0.1000 | -0.1278 | -0.1572 | -0.1924 | -0.2308 | -0.2719 | -0.3145 | -0.3552 |
| 2.0 | -0.0662 | -0.0794 | -0.0996 | -0.1274 | -0.1566 | -0.1918 | -0.2303 | -0.2715 | -0.3141 | -0.3548 |
| 2.1 | -0.0671 | -0.0836 | -0.0991 | -0.1270 | -0.1559 | -0.1912 | -0.2297 | -0.2710 | -0.3136 | -0.3543 |
| 2.2 | -0.0683 | -0.0898 | -0.0988 | -0.1265 | -0.1552 | -0.1906 | -0.2292 | -0.2705 | -0.3131 | -0.3539 |
| 2.3 | -0.0696 | -0.0961 | -0.0991 | -0.1259 | -0.1543 | -0.1898 | -0.2285 | -0.2699 | -0.3126 | -0.3534 |
| 2.4 | -0.0709 | -0.0992 | -0.1010 | -0.1253 | -0.1534 | -0.1890 | -0.2278 | -0.2693 | -0.3120 | -0.3528 |
| 2.5 | -0.0723 | -0.1002 | -0.1061 | -0.1246 | -0.1523 | -0.1881 | -0.2270 | -0.2686 | -0.3114 | -0.3522 |
| 2.6 | -0.0737 | -0.1017 | -0.1156 | -0.1240 | -0.1512 | -0.1872 | -0.2262 | -0.2678 | -0.3107 | -0.3515 |
| 2.7 | -0.0751 | -0.1033 | -0.1288 | -0.1237 | -0.1502 | -0.1861 | -0.2253 | -0.2870 | -0.3099 | -0.3508 |
| 2.8 | -0.0764 | -0.1051 | -0.1415 | -0.1247 | -0.1498 | -0.1849 | -0.2243 | -0.2661 | -0.3091 | -0.3501 |
| 2.9 | -0.0776 | -0.1070 | -0.1472 | -0.1288 | -0.1517 | -0.1836 | -0.2231 | -0.2651 | -0.3083 | -0.3493 |
| 3.0 | -0.0786 | -0.1089 | -0.1484 | -0.1389 | -0.1590 | -0.1822 | -0.2219 | -0.2641 | -0.3073 | -0.3484 |
| 3.1 | -0.0794 | -0.1107 | -0.1502 | -0.1569 | -0.1761 | -0.1807 | -0.2206 | -0.2629 | -0.3063 | -0.3474 |
| 3.2 | -0.0800 | -0.1123 | -0.1522 | -0.1810 | -0.2061 | -0.1795 | -0.2192 | -0.2617 | -0.3052 | -0.3464 |
| 3.3 | -0.0804 | -0.1138 | -0.1544 | -0.2034 | -0.2452 | -0.1794 | -0.2177 | -0.2604 | -0.3040 | -0.3454 |
| 3.4 | -0.0804 | -0.1150 | -0.1567 | -0.2130 | -0.2807 | -0.1831 | -0.2160 | -0.2589 | -0.3028 | -0.3442 |
| 3.5 | -0.0801 | -0.1160 | -0.1589 | -0.2142 | -0.2949 | -0.1953 | -0.2142 | -0.2874 | -0.3014 | -0.3430 |
| 3.6 | -0.0794 | -0.1165 | -0.1609 | -0.2160 | -0.2955 | -0.2230 | -0.2124 | -0.2557 | -0.2999 | -0.3416 |
| 3.7 | -0.0784 | -0.1167 | -0.1626 | -0.2183 | -0.2969 | -0.2700 | -0.2110 | -0.2539 | -0.2983 | -0.3402 |
| 3.8 | -0.0771 | -0.1164 | -0.1639 | -0.2207 | -0.2989 | -0.3304 | -0.2114 | -0.2520 | -0.2967 | -0.3387 |
| 3.9 | -0.0753 | -0.1156 | -0.1648 | -0.2231 | -0.3011 | -0.3842 | -0.2176 | -0.2499 | -0.2948 | -0.3371 |
| 4.0 | -0.0732 | -0.1143 | -0.1652 | -0.2252 | -0.3031 | -0.4054 | -0.2367 | -0.2476 | -0.2929 | -0.3353 |
| 4.1 | -0.0707 | -0.1126 | -0.1651 | -0.2270 | -0.3049 | -0.4056 | -0.2784 | -0.2455 | -0.2908 | -0.3335 |
| 4.2 | -0.0679 | -0.1103 | -0.1643 | -0.2284 | -0.3062 | -0.4064 | -0.3480 | -0.2440 | -0.2886 | -0.3315 |
| 4.3 | -0.0648 | -0.1075 | -0.1628 | -0.2292 | -0.3067 | -0.4078 | -0.4361 | -0.2453 | -0.2862 | -0.3294 |
| 4.4 | -0.0614 | -0.1041 | -0.1607 | -0.2293 | -0.3065 | -0.4094 | -0.5135 | -0.2550 | -0.2837 | -0.3272 |
| 4.5 | -0.0578 | -0.1004 | -0.1579 | -0.2286 | -0.3053 | -0.4107 | -0.5439 | -0.2832 | -0.2810 | -0.3248 |
| 4.6 | -0.0540 | -0.0961 | -0.1543 | -0.2271 | -0.3031 | -0.4115 | -0.5437 | -0.3431 | -0.2785 | -0.3223 |
| 4.7 | -0.0500 | -0.0915 | -0.1501 | -0.2247 | -0.2997 | -0.4115 | -0.5435 | -0.4414 | -0.2770 | -0.3196 |
| 4.8 | -0.0458 | -0.0864 | -0.1452 | -0.2215 | -0.2952 | -0.4105 | -0.5439 | -0.5643 | -0.2796 | -0.3168 |
| 4.9 | -0.0416 | -0.0811 | -0.1397 | -0.2173 | -0.2896 | -0.4084 | -0.5443 | -0.6710 | -0.2939 | -0.3137 |
| 5.0 | -0.0373 | -0.0754 | -0.1335 | -0.2121 | -0.2827 | -0.4050 | -0.5442 | -0.7131 | -0.3337 | -0.3106 |
| 5.5 | -0.0167 | -0.0453 | -0.0958 | -0.1733 | -0.2315 | -0.3661 | -0.5265 | -0.7064 | -0.9150 | -0.3853 |
| 6.0 | -0.0002 | -0.0168 | -0.0532 | -0.1190 | -0.1601 | -0.2916 | -0.4658 | -0.6720 | -0.8990 | -1.1490 |
| 6.5 | +0.0103 | +0.0050 | -0.0150 | -0.0610 | -0.0838 | -0.1944 | -0.3619 | -0.5831 | -0.8426 | -1.1220 |
| 7.0 | +0.0153 | +0.0181 | +0.0130 | -0.0109 | -0.0175 | -0.0946 | -0.2330 | -0.4427 | -0.7182 | -1.0370 |
| 7.5 | +0.0162 | +0.0237 | +0.0290 | +0.0243 | +0.0296 | -0.0106 | -0.1050 | -0.2757 | -0.5335 | -0.8692 |
| 8.0 | +0.0149 | +0.0242 | +0.0352 | +0.0436 | +0.0560 | +0.0475 | -0.0002 | -0.1144 | -0.3211 | -0.6314 |
| 8.5 | +0.0128 | +0.0219 | +0.0348 | +0.0502 | +0.0654 | +0.0787 | +0.0705 | +0.0148 | -0.1209 | -0.3656 |
| 9.0 | +0.0106 | +0.0187 | +0.0312 | +0.0487 | +0.0641 | +0.0889 | +0.1073 | +0.1000 | +0.0365 | -0.1200 |
| 9.5 | +0.0087 | +0.0155 | +0.0266 | +0.0434 | +0.0573 | +0.0859 | +0.1182 | +0.1430 | +0.1384 | +0.0700 |
| 10.0 | +0.0071 | +0.0128 | +0.0222 | +0.0370 | +0.0490 | +0.0766 | +0.1131 | +0.1545 | +0.1885 | +0.1910 |

Table A2

The Values of $\Delta f$ as a function of $g_2$.

| r (earth radii) | Ring current field (gamma) | | | | |
|---|---|---|---|---|---|
| | $g_2$ = 2.146 | $g_2$ = 1.517 | $g_2$ = 0.759 | $g_2$ = 0.509 | $g_2$ = 0.379 |
| 1.0 | -0.0245 | -0.0320 | -0.0638 | -0.1075 | -0.1663 |
| 1.1 | -0.0245 | -0.0319 | -0.0637 | -0.1073 | -0.1661 |
| 1.2 | -0.0243 | -0.0318 | -0.0635 | -0.1071 | -0.1658 |
| 1.3 | -0.0242 | -0.0317 | -0.0633 | -0.1068 | -0.1655 |
| 1.4 | -0.0241 | -0.0315 | -0.0631 | -0.1065 | -0.1651 |
| 1.5 | -0.0239 | -0.0313 | -0.0628 | -0.1062 | -0.1647 |
| 1.6 | -0.0237 | -0.0311 | -0.0625 | -0.1058 | -0.1642 |
| 1.7 | -0.0235 | -0.0309 | -0.0621 | -0.1053 | -0.1636 |
| 1.8 | -0.0233 | -0.0306 | -0.0617 | -0.1048 | -0.1630 |
| 1.9 | -0.0230 | -0.0302 | -0.0613 | -0.1042 | -0.1623 |
| 2.0 | -0.0227 | -0.0299 | -0.0607 | -0.1036 | -0.1616 |
| 2.1 | -0.0224 | -0.0296 | -0.0603 | -0.1029 | -0.1608 |
| 2.2 | -0.0223 | -0.0294 | -0.0599 | -0.1024 | -0.1601 |
| 2.3 | -0.0226 | -0.0297 | -0.0600 | -0.1023 | -0.1599 |
| 2.4 | -0.0240 | -0.0310 | -0.0610 | -0.1032 | -0.1606 |
| 2.5 | -0.0273 | -0.0342 | -0.0640 | -0.1059 | -0.1631 |
| 2.6 | -0.0339 | -0.0407 | -0.0702 | -0.1119 | -0.1688 |
| 2.7 | -0.0449 | -0.0516 | -0.0808 | -0.1222 | -0.1789 |
| 2.8 | -0.0610 | -0.0676 | -0.0964 | -0.1375 | -0.1940 |
| 2.9 | -0.0812 | -0.0876 | -0.1160 | -0.1568 | -0.2131 |
| 3.0 | -0.1024 | -0.1087 | -0.1366 | -0.1771 | -0.2331 |
| 3.1 | -0.1199 | -0.1259 | -0.1534 | -0.1935 | -0.2491 |
| 3.2 | -0.1282 | -0.1341 | -0.1611 | -0.2008 | -0.2560 |
| 3.3 | -0.1237 | -0.1335 | -0.1630 | -0.2028 | -0.2579 |
| 3.4 | -0.1061 | -0.1261 | -0.1640 | -0.2051 | -0.2604 |
| 3.5 | -0.0786 | -0.1123 | -0.1637 | -0.2073 | -0.2634 |
| 3.6 | -0.0469 | -0.0931 | -0.1618 | -0.2093 | -0.2665 |
| 3.7 | -0.0171 | -0.0706 | -0.1580 | -0.2107 | -0.2697 |
| 3.8 | +0.0066 | -0.0470 | -0.1523 | -0.2114 | -0.2727 |
| 3.9 | +0.0225 | -0.0245 | -0.1447 | -0.2112 | -0.2755 |
| 4.0 | +0.0310 | -0.0050 | -0.1352 | -0.2100 | -0.2779 |
| 4.1 | +0.0339 | +0.0106 | -0.1240 | -0.2077 | -0.2797 |
| 4.2 | +0.0334 | +0.0218 | -0.1114 | -0.2042 | -0.2810 |
| 4.3 | +0.0312 | +0.0290 | -0.0978 | -0.1995 | -0.2815 |
| 4.4 | +0.0283 | +0.0328 | -0.0835 | -0.1935 | -0.2813 |
| 4.5 | +0.0255 | +0.0341 | -0.0688 | -0.1864 | -0.2802 |
| 4.6 | +0.0228 | +0.0335 | -0.0543 | -0.1781 | -0.2783 |
| 4.7 | +0.0205 | +0.0319 | -0.0402 | -0.1688 | -0.2754 |
| 4.8 | +0.0185 | +0.0298 | -0.0269 | -0.1585 | -0.2716 |
| 4.9 | +0.0168 | +0.0274 | -0.0145 | -0.1474 | -0.2668 |
| 5.0 | +0.0152 | +0.0251 | -0.0034 | -0.1356 | -0.2610 |
| 5.5 | +0.0100 | +0.0162 | +0.0315 | -0.0719 | -0.2186 |
| 6.0 | +0.0070 | +0.0111 | +0.0379 | -0.0143 | -0.1592 |
| 6.5 | +0.0051 | +0.0080 | +0.0319 | +0.0247 | -0.0940 |
| 7.0 | +0.0039 | +0.0060 | +0.0242 | +0.0432 | -0.0343 |
| 7.5 | +0.0030 | +0.0047 | +0.0182 | +0.0466 | +0.0118 |
| 8.0 | +0.0024 | +0.0037 | +0.0140 | +0.0421 | +0.0415 |
| 8.5 | +0.0020 | +0.0030 | +0.0110 | +0.0351 | +0.0561 |
| 9.0 | +0.0016 | +0.0025 | +0.0089 | +0.0285 | +0.0596 |
| 9.5 | +0.0013 | +0.0020 | +0.0073 | +0.0230 | +0.0565 |
| 10.0 | +0.0011 | +0.0017 | +0.0061 | +0.0188 | +0.0502 |

Table A3

The Values of $\Delta f$ as a Function of $\alpha$.

| r (earth radii) | Ring current field (gamma) | | | |
|---|---|---|---|---|
| | $\alpha = 1.0$ | $\alpha = 2.0$ | $\alpha = 3.0$ | $\alpha = 4.0$ |
| 1.0 | -0.2240 | -0.1649 | -0.1017 | -0.0784 |
| 1.1 | -0.2239 | -0.1647 | -0.1013 | -0.0779 |
| 1.2 | -0.2239 | -0.1644 | -0.1008 | -0.0773 |
| 1.3 | -0.2239 | -0.1641 | -0.1002 | -0.0766 |
| 1.4 | -0.2238 | -0.1638 | -0.0996 | -0.0758 |
| 1.5 | -0.2237 | -0.1634 | -0.0989 | -0.0749 |
| 1.6 | -0.2237 | -0.1629 | -0.0981 | -0.0739 |
| 1.7 | -0.2235 | -0.1624 | -0.0972 | -0.0728 |
| 1.8 | -0.2234 | -0.1618 | -0.0962 | -0.0715 |
| 1.9 | -0.2232 | -0.1611 | -0.0950 | -0.0700 |
| 2.0 | -0.2230 | -0.1604 | -0.0938 | -0.0684 |
| 2.1 | -0.0228 | -0.1596 | -0.0923 | -0.0665 |
| 2.2 | -0.0226 | -0.1587 | -0.0908 | -0.0645 |
| 2.3 | -0.2224 | -0.1578 | -0.0891 | -0.0623 |
| 2.4 | -0.2226 | -0.1572 | -0.0877 | -0.0603 |
| 2.5 | -0.2238 | -0.1576 | -0.0873 | -0.0592 |
| 2.6 | -0.2273 | -0.1605 | -0.0894 | -0.0606 |
| 2.7 | -0.2350 | -0.1679 | -0.0962 | -0.0669 |
| 2.8 | -0.2489 | -0.1821 | -0.1102 | -0.0805 |
| 2.9 | -0.2692 | -0.2036 | -0.1319 | -0.1023 |
| 3.0 | -0.2929 | -0.2292 | -0.1582 | -0.1290 |
| 3.1 | -0.3126 | -0.2511 | -0.1811 | -0.1525 |
| 3.2 | -0.3197 | -0.2599 | -0.1908 | -0.1626 |
| 3.3 | -0.3193 | -0.2611 | -0.1926 | -0.1648 |
| 3.4 | -0.3196 | -0.2631 | -0.1954 | -0.1681 |
| 3.5 | -0.3202 | -0.2656 | -0.1988 | -0.1721 |
| 3.6 | -0.3210 | -0.2685 | -0.2027 | -0.1767 |
| 3.7 | -0.3217 | -0.2714 | -0.2067 | -0.1815 |
| 3.8 | -0.3223 | -0.2742 | -0.2107 | -0.1863 |
| 3.9 | -0.3225 | -0.2768 | -0.2146 | -0.1911 |
| 4.0 | -0.3222 | -0.2790 | -0.2182 | -0.1956 |
| 4.1 | -0.3214 | -0.2807 | -0.2213 | -0.1998 |
| 4.2 | -0.3200 | -0.2819 | -0.2239 | -0.2034 |
| 4.3 | -0.3178 | -0.2823 | -0.2258 | -0.2065 |
| 4.4 | -0.3149 | -0.2820 | -0.2270 | -0.2088 |
| 4.5 | -0.3111 | -0.2809 | -0.2274 | -0.2104 |
| 4.6 | -0.3064 | -0.2789 | -0.2269 | -0.2111 |
| 4.7 | -0.3009 | -0.2759 | -0.2255 | -0.2109 |
| 4.8 | -0.2944 | -0.2721 | -0.2232 | -0.2098 |
| 4.9 | -0.2871 | -0.2672 | -0.2198 | -0.2076 |
| 5.0 | -0.2788 | -0.2614 | -0.2155 | -0.2045 |
| 5.5 | -0.2254 | -0.2189 | -0.1794 | -0.1740 |
| 6.0 | -0.1581 | -0.1594 | -0.1244 | -0.1236 |
| 6.5 | -0.0881 | -0.0941 | -0.0614 | -0.0637 |
| 7.0 | -0.0263 | -0.0344 | -0.0020 | -0.0060 |
| 7.5 | +0.0202 | +0.0117 | +0.0455 | +0.0409 |
| 8.0 | +0.0493 | +0.0414 | +0.0774 | +0.0731 |
| 8.5 | +0.0630 | +0.0560 | +0.0672 | +0.0634 |
| 9.0 | +0.0655 | +0.0596 | +0.0506 | +0.0473 |
| 9.5 | +0.0615 | +0.0564 | +0.0394 | +0.0366 |
| 10.0 | +0.0545 | +0.0501 | +0.0315 | +0.0291 |



NASA-Langley, 1963 G-366