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KINEMATICS OF THE

RELATIVISTIC TWO-BODY PROBLEM

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Abstract

The kinematics of elastic scattering, inelastic scattering, and the two body reaction problem is developed in the relativistic limit and exact expressions obtained for the energies, angles, and solid-angle transformations involved. The results are specialized for zero rest mass of one or more of the particles involved. An outline for the coding of the problem on the I.B.M. Electronic Data Processing Machine, Type 701 is presented.

Acknowledgment

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I. Introduction

The general problem of the collision of two point masses of rest mass m_1 and m_2 is soluble analytically by application of the principles of conservation of energy and momentum. Consider the target particle m_2 at rest in the laboratory frame of reference C, and the bombarding particle m_1 incident with kinetic energy T_o in the positive X direction. The center-of-mass frame of reference C' is then a coordinate system translating in the positive X direction with respect to C at such velocity that the net momentum four-vector $(p_x, p_y, p_z, \frac{E}{c^2})$ transforms exactly as does the space-time four-vector (x, y, z, t). We can then write the appropriate Lorentz transformations of pertinent dynamical quantities as follows:

$$p_x = \left(p_x' + u' \frac{E'}{c^2} \right) \gamma' \qquad p_x' = \left(p_x - u' \frac{E}{c^2} \right) \gamma'$$

1) $p_y = p_y'$ 2) $p_y' = p_y$

$$p_z = p_z' \qquad p_z' = p_z$$

$$\frac{E}{c^2} = \left(\frac{E'}{c^2} + \frac{u'}{c^2} p_x' \right) \gamma' \qquad \frac{E'}{c^2} = \left(\frac{E}{c^2} - \frac{u'}{c^2} p_x \right) \gamma'$$

where $\gamma' = \left(1 - \frac{u'^2}{c^2} \right)^{-1/2}$ and c = velocity of light. The remaining notation is described below:

Notation

m_1 = rest mass of incident particle before collision

m_2 = rest mass of target particle before collision

M_1 = rest mass of particle making an angle θ with positive x-axis

M_2 = rest mass of particle making an angle β with positive x-axis

p_1 = momentum of incident particle

p_2 = momentum of target particle

E_1 = total energy of incident particle

E_2 = total energy of target particle

T_1 = kinetic energy of incident particle

T_2 = kinetic energy of target particle

u_1 = velocity of incident particle

u_2 = velocity of target particle

u_{cg} = velocity of frame C' relative to frame C

Ω = angle which velocity of particle M_1 makes with positive x-axis in the center-of-mass frame C' after collision

θ = angle which velocity of particle M_1 makes with positive x-axis in the lab frame C after collision

β = angle which velocity of particle M_2 makes with positive x-axis in the lab frame C after collision.

NOTE. Above quantities are primed when in the center-of-mass frame C' and imprimed in the lab frame C. The superscript "i" is used to signify a quantity before the collision has occurred and a superscript "f" after the collision.

II. Elastic Scattering

For the case where the particles collide elastically we have the following simplifications:

3) $M_1 = m_1 \qquad M_2 = m_2$

4) $i_{u'_1} = f_{u'_1} \qquad i_{u'_2} = f_{u'_2}$ hence 5) $i_{p'_1} = f_{p'_1} = p'_1$

$i_{p'_2} = f_{p'_2} = p'_2$

Considering the general principles of relativistic mechanics, we have for any particle of mass m moving with velocity v the following results:

6) $E = mc^2\gamma$ where $\gamma = (1 - \beta^2)^{-1/2}$ $\beta = v/c$

7) $\frac{E^2}{c^2} = p^2 + m^2 c^2$

It follows from 6) and 7) that

8) $p = mc\,(\gamma^2 - 1)^{1/2}$

and considering that the total energy E is just the sum of the rest energy mc^2 and the kinetic energy T we have:

9) $T = mc^2\,(\gamma - 1)$

Making the further simplification that particle m_2 be at rest in the lab frame we have that

10) $\gamma_2 = (1 - \frac{u_2}{c^2})^{-1/2} = 1$ since $u_2 = 0$

and further that the translational velocity of frame C', u_{cg}, is just

11) $u_{cg} = u'_2 \quad \therefore \gamma_{cg} = \gamma'_2$, where $\gamma'_2 = (1 - \frac{u'^2_2}{c^2})^{-1/2}$

$\gamma_{cg} = (1 - \frac{u_{cg}^2}{c^2})^{-1/2}$

Making a Lorentz transformation 2) from the lab frame to C', we have for p'_1

12) $p_1' = m_1 c \left[(\gamma_1^2 - 1)^{1/2} - \gamma_1 \beta_2' \right] \delta_2'$

and since $\gamma_2' = (1 - \beta_2'^2)^{-1/2}$ we can substitute for β_2'. From Eq. 8) however we see that

13) $p_1' = m_1 c (\gamma_1'^2 - 1)^{1/2}$

and from the property of the C' frame that the net momentum be zero we have:

14) $p_1' = p_2' = m_2 c (\gamma_2'^2 - 1)^{1/2} = m_1 c (\gamma_1'^2 - 1)^{1/2}$

Equating 12) and 14) we obtain

15) $m_2 c (\gamma_2'^2 - 1)^{1/2} = m_1 c \left[\gamma_2' (\gamma_1^2 - 1)^{1/2} - \gamma_1 (\gamma_2'^2 - 1)^{1/2} \right]$.

Solving for γ_2' we have

16) $\gamma_2' = \left(\frac{m_2}{m_1} + \gamma_1 \right) \Big/ \left[\left(\frac{m_2}{m_1} \right)^2 + 2 \left(\frac{m_2}{m_1} \right) \gamma_1 + 1 \right]^{1/2}$.

We might also obtain γ_1' in terms of γ_1 by a similar procedure. Make a Lorents transformation 2) from frame C to C' to obtain p_1'.

17) $p_1' = m_1 c \left[\gamma_2' (\gamma_1^2 - 1)^{1/2} - \gamma_1 (\gamma_2'^2 - 1)^{1/2} \right]$

Noting also from 8) that p_1' is given by

18) $p_1' = m_1 c (\gamma_1'^2 - 1)^{1/2}$

and combining Eq. 17) and Eq. 18) we derive:

19a) $\gamma_1' = \left(\frac{m_1}{m_2} + \gamma_1 \right) \Big/ \left[\left(\frac{m_1}{m_2} \right)^2 + 2 \left(\frac{m_1}{m_2} \right) \gamma_1 + 1 \right]^{1/2}$ or equivalently

19b) $\gamma_1' = \left[\frac{m_1 + \gamma_1 m_2}{m_2 + \gamma_1 m_1} \right] \gamma_2'$

Then one can obtain the velocity of particle m_1 in C' frame as

20) $u_1' = \frac{c}{\gamma_1'} (\gamma_1'^2 - 1)^{1/2}$

Then one can obtain the total energies ${}^1E_1'$ and ${}^1E_2'$ directly from Eq. 6)

21a) $^{i}E_1' = m_1c^2\gamma_1' = {}^{f}E_1' = E_1'$

21b) $^{i}E_2' = m_2c^2\gamma_2' = {}^{f}E_2' = E_2'$

and from Eq. 9) we have the results for kinetic energy T.

22a) $T_1' = m_1c^2 (\gamma_1' - 1)$

22b) $T_2' = m_2c^2 (\gamma_2' - 1)$

together with the initial quantities

23) $E_1 = m_1c^2\gamma_1$ where $\gamma_1 = (1 - \beta_1^2)^{-1/2}$

24) $E_2 = m_2c^2$

25) $T_1 = T_0 = m_1c^2(\gamma_1 - 1)$ hence $\gamma_1 = \frac{T_0}{m_1c^2} + 1$

26) $T_2 = 0$

27) $p_1 = m_1c\,(\gamma_1^2 - 1)^{1/2}$

28) $p_2 = 0$

Eq. 27) together with Eq. 25) then yield for u_1

29) $$u_1 = \frac{c}{\frac{T_0}{m_1c^2} + 1}\left[\left(\frac{T_0}{m_1c^2}\right)^2 + 2\left(\frac{T_0}{m_1c^2}\right)\right]^{1/2}$$

30) $u_2 = 0$

31) $u_2' = \frac{c}{\gamma_2}\,(\gamma_2'^2 - 1)^{1/2}$

After the collision has occurred we seek relations between the angle of scattering in the C frame and in the C frame. First, to relate θ and Ω we note from Fig. 1 that in lab frame:

32) $$\tan\theta = \frac{{}^{f}p_{y_1}}{{}^{f}p_{x_1}}$$

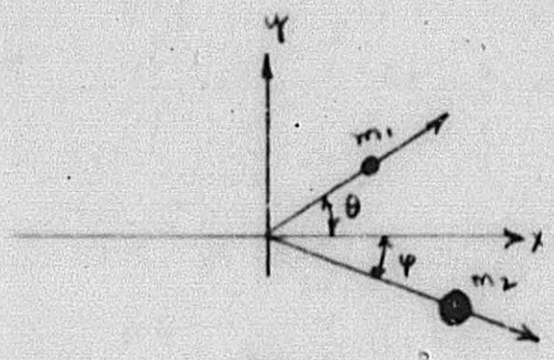

Fig. 1

In the frame C' the particle momenta are opposed in direction as in Fig. 2. Then, by making a Lorentz transformation 1) from the frame C' to the lab frame we obtain

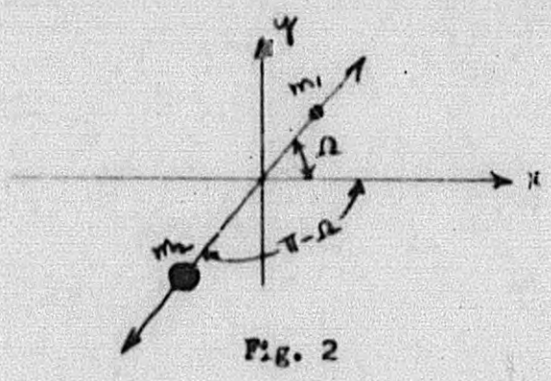

Fig. 2

$$33)\quad {}^{f}p_{x_1} = \left({}^{f}p_{x_1'} + u_{cg}\frac{E_1'}{c^2}\right)\gamma_2' = m_1 c\left[\gamma_2'\left(\gamma_1'^2-1\right)^{1/2}\cos\Omega + \gamma_1'\left(\gamma_2'^2-1\right)^{1/2}\right]$$

and

$$34)\quad {}^{f}p_{y_1} = {}^{f}p_{y_1'} = m_1 c\left(\gamma_1'^2-1\right)^{1/2}\sin\Omega$$

Where we have used the result 5) that the momenta of the particles in frame C' are not altered by the collision. Then substituting 33) and 34) into 32) we obtain

$$35)\quad \tan\theta = \frac{\sin\Omega}{\gamma_2'\left[\cos\Omega + \alpha_1\right]} \qquad \text{where} \quad \alpha_1 = \left(\frac{\gamma_1'}{\gamma_2'}\frac{m_1}{m_2}\right);$$

making the substitution

$$36)\quad \tan\chi_1 = \gamma_2'\tan\theta$$

we can then solve Eq. 35) for $\cos\Omega$ and obtain a quadratic expression with solution:

$$37a)\quad \cos\Omega = \frac{1}{\left(\tan^2\psi_1+1\right)}\left[-\alpha_1\tan^2\psi_1 \pm \sqrt{\tan^2\psi_1\left(1-\alpha_1^2\right)+1}\right]$$

Eq. 37) may be written in the equivalent form:

$$37b)\quad \cos\Omega = \frac{1}{\left(\gamma_1'^2\tan^2\theta+1\right)}\left[-\frac{m_1}{m_2}\gamma_1'\gamma_2'\tan^2\theta \pm \sqrt{1-\frac{m_1^2-m_2^2}{m_2^2}\tan^2\theta}\right]$$

We can graphically represent angle χ by considering Eq. 35).

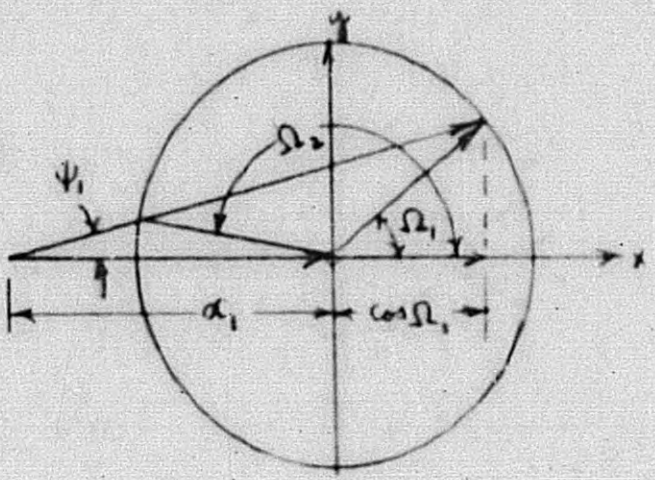

Fig. 3

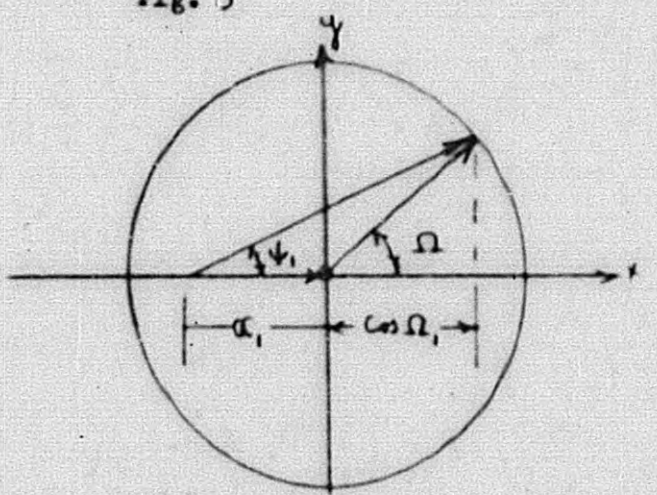

Fig. 4

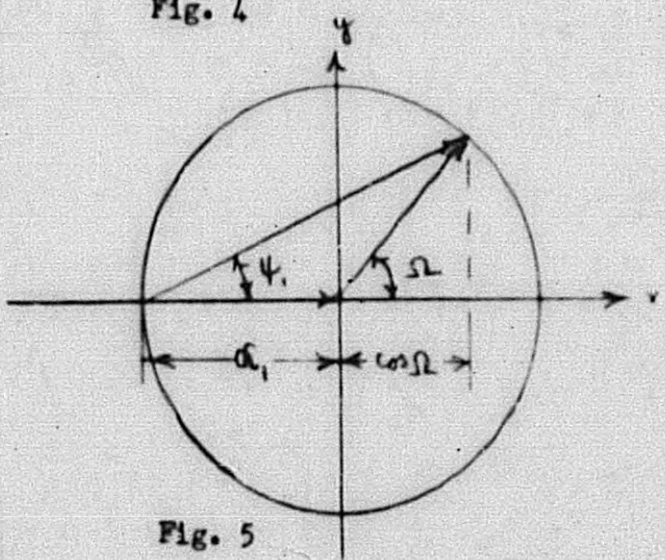

Fig. 5

If we construct a vector in a unit circle making an angle Ω with the positive x direction, then the components of this vector are $\sin\Omega$ and $\cos\Omega$. Angle Ψ_1 is then the angle between the x-axis and the sum of the vectors of magnitude a_1 and $\cos\Omega$ in the x-direction and $\sin\Omega$ in the y-direction. There are clearly three cases.

Case a): In Fig. 3 we have $a_1 > 1$ (this is equivalent to criterion $m_1 > m_2$). There are clearly two possible directions of the unit vector, and hence two values of Ω which produce a given Ψ_1. Hence we must use both the + and - sign in the equation. 37).

Since the radical in 37) cannot be negative there must be a maximum value of θ when

$$\frac{m_1^2 - m_2^2}{m_2^2} \tan^2\theta_{max} = 1 \text{ which yields}$$

$$38)\quad \theta_{max} = \sin^{-1}\frac{m_2}{m_1} .$$

Case b): In Fig. 4 we have $a_1 < 1$ (This criterion is equivalent to $m_1 < m_2$). There can be only one angle Ω for a given Ψ_1 and consequently $\cos\Omega$ is single valued. Inspection of Fig. 4 and Eq. 37a) shows that $\cos\Omega$ must start out for small angles Ψ_1 as + 1 and approach the value - a_1 as $\Psi_1 \to 90^\circ$, passing through the value $\cos\Omega = 0$ for some intermediate angle Ψ_1. For $\Psi_1 > 90^\circ$,

$\cos\Omega$ increases negatively from $-a_1$ to -1 as $\chi_1 \to 180^\circ$. To realize these conditions the following criteria result:

(1) for $\chi_1 < 90^\circ$ use + sign in Eq. 37.

(2) for $\chi_1 > 90^\circ$ use - sign in Eq. 37.

Angle χ_1 and hence θ may take on all values from 0 to 180°.

Case c): In Fig. 5 we have $a_1 = 1$. (This criterion is equivalent to $m_1 = m_2$). The diagram shows that there are two possible values of Ω for a given χ_1, but one root is always 180°. This corresponds to using the negative root in Eq. 37). We may reject this root and always use + sign, in which case Eq. 37) simplifies to:

$$39) \quad \cos\Omega = \frac{1 - \frac{\gamma_1 + 1}{2}\tan^2\theta}{1 + \frac{\gamma_1 + 1}{2}\tan^2\theta}$$

We may also find angle ϕ in terms of Ω as follows:

From Fig. 1 and 2 it is observed that

$$40) \quad \tan\phi = \frac{f_{p_{y_2}}}{f_{p_{x_2}}}$$

Use Lorentz transformation 1) to the lab frame to obtain

$$41) \quad f_{p_{x_2}} = m_2 c(\gamma_2'^2 - 1)^{1/2}\,\gamma_2'\left[1 - \cos\Omega\right] = f_{p_2'}\,\gamma_2'\left[1 - \cos\Omega\right]$$

$$42) \quad f_{p_{y_2}} = -p_2' \sin\Omega$$

Substituting Eq. 41) and 42) into 40) we obtain

$$43) \quad \tan\phi = -\frac{1}{\gamma_2'}\cot\frac{\Omega}{2}$$

The simultaneous solution of Eq. 35) and Eq. 43) gives

$$44) \quad \tan\theta = \frac{2\tan\varphi}{\left[(\alpha_1 + 1)\,\gamma_2'^2\tan^2\phi + (\alpha_1 - 1)\right]}$$

which, for $m_1 = m_2$ reduces to

45) $$\tan\theta = -\frac{2}{\gamma_1' + 1}\cot\phi$$

Finally we consider the particle energies. For the total energy of particle m_1 after collision in the C' frame, use Eq. 6) to obtain

46) $$^{f}E_1' = m_1c^2\gamma_1'$$

Perform a Lorentz transformation to lab frame and use Eq. 13) to obtain:

47) $$^{f}E_1 = \left[^{f}E_1' + u_{cg}\, m_1 c\, (\gamma_1'^2 - 1)^{1/2}\cos\Omega\right]\gamma_2'$$

$$^{f}E_1 = m_1c^2\left[\gamma_1'\gamma_2' + (\gamma_1'^2 - 1)^{1/2}(\gamma_2'^2 - 1)^{1/2}\cos\Omega\right]$$

It will then be observed that for case a) there are two possible values of $^{f}E_1$ for a given θ.

Using Eq. 6) we write for the total energy of particle m_2 after collision in the C' frame

48) $$^{f}E_2' = m_2c^2\gamma_2'$$

and from a Lorentz transformation to lab frame we obtain

49) $$^{f}E_2 = m_2c^2\left[\gamma_2'^2 - (\gamma_2'^2 - 1)\cos\Omega\right]$$

Substitution of Eq. 43) into 49) yields

50) $$^{f}E_2 = m_2c^2\left[\frac{\gamma_2'^2(\tan^2\varphi + 2) - 1}{\gamma_2'^2\tan^2\varphi + 1}\right]$$

It may be seen from Eq. 43) that for case a) there are two possible values of ϕ for a given θ. Then from Eq. 50) we have two possible values $^{f}E_2$.

Using Eq. 9) we obtain the final kinetic energies

51a) $$^{f}T_2 = 2\, m_2c^2\left[\frac{\gamma_2'^2 - 1}{\gamma_2'^2\tan^2\varphi + 1}\right]$$

which may be reduced to the alternate form

51b) $$^{f}T_2 = 2\, m_2c^2\left[\frac{^{i}p_1^2\cos^2\varphi}{\left(\frac{^{i}E_1}{c} + m_2c\right)^2 - {}^{i}p_1^2\cos^2\varphi}\right]$$

in terms of the initial energy and momentum.

By making a Lorentz transformation to the lab frame we write for the momentum of particle m_2

$$52) \quad {}^{f}p_2 = \frac{2 m_1 c (\gamma_1'^2 - 1)^{\frac{1}{2}}}{\gamma_1'^2 \tan^2\varphi + 1} \sqrt{\gamma_1'^2 \tan^2\varphi + 2}$$

and from the definition of momentum

$$^{f}p_2 = m_2 \, {}^{f}u_2 \gamma_2 = m_2 \, {}^{f}u_2 \Big/ \sqrt{1 - \frac{{}^{f}u_2^2}{c^2}} \, .$$

we obtain

$$53) \quad {}^{f}u_2 = {}^{f}p_2 \, c \Big/ \sqrt{m_2^2 c^2 + {}^{f}p_2^2} \, .$$

To obtain an analytical expression for ${}^{f}T_1$ we must consider each case separately. In case a) ${}^{f}E_1$ is a double-valued function for a given θ and consequently we have two values of ${}^{f}T_1$:

$$54) \quad {}^{f}_{a}T_1(1) = {}^{f}E_1(1) - m_1 c^2$$

$$ {}^{f}_{a}T_1(2) = {}^{f}E_1(2) - m_1 c^2 \, .$$

For case b) we have only one value of ${}^{f}E_1$ to consider from Eq. 47). Then

$$55) \quad {}^{f}_{b}T_1 = {}^{f}E_1 - m_1 c^2 \, .$$

Finally for case c) we use Eq. 39) in 47) to obtain a simplified form for ${}^{f}E_1$:

$$56) \quad {}^{f}_{c}E_1 = m_1 c^2 \left[\frac{2\gamma_1 + (\gamma_1 + 1)\tan^2\theta}{2 + (\gamma_1 + 1)\tan^2\theta} \right]$$

from which we can immediately write the kinetic energy

$$57a) \quad {}^{f}_{c}T_1 = m_1 c^2 \left[\frac{2(\gamma_1 - 1)\cos^2\theta}{(\gamma_1 + 1) - (\gamma_1 - 1)\cos^2\theta} \right]$$

An alternate form for ${}^{f}_{c}T_1$ is obtained by substituting the initial kinetic energy T_o into 57a)

$$57b) \quad {}^{f}_{c}T_1 = \frac{T_o \cos^2\theta}{1 + \frac{1}{2}\left(\frac{T_o}{m_1 c^2}\right)\sin^2\theta}$$

The pertinent dynamical quantities are presented in tabular form in Tables I, II, III, and IV.

To obtain the transformation of intensity for the C' frame to the lab frame let us first derive several additional relations among the angles. We observed that Eq. 33) gives ${}^{f}p_{x_1}$ in the lab system. Furthermore, Eq. 7) gives for ${}^{f}p_1$ in the lab frame

$$58) \qquad {}^{f}p_1 = \sqrt{\frac{{}^{f}E_1^2}{c^2} - m_1^2 c^2}$$

from which we can write ${}^{f}p_{x_1}$ as:

$$59) \qquad {}^{f}p_{x_1} = \cos\theta \sqrt{\frac{{}^{f}E_1^2}{c^2} - m_1^2 c^2}$$

Equating Eq. 59) and 33) we obtain the result

$$60) \qquad \cos\theta \sqrt{\left(\frac{{}^{f}T_1}{m_1 c^2}\right)^2 + 2\left(\frac{{}^{f}T_1}{m_1 c^2}\right)} = \gamma_2'(\gamma_1'^2 - 1)^{\frac{1}{2}} \cos\Omega + \beta_1'(\gamma_2'^2 - 1)^{\frac{1}{2}}$$

Again, Eq. 34) gives ${}^{f}p_{y_1}$. We can obtain an alternate expression for ${}^{f}p_{y_1}$ by noting:

$$61) \qquad {}^{f}p_{y_1} = \sqrt{\frac{{}^{f}E_1^2}{c^2} - m_1^2 c^2}\, \sin\theta$$

Equating Eqs. 61) and 34), we find:

$$62) \qquad \sin\theta = \frac{(\gamma_1'^2 - 1)^{\frac{1}{2}} \sin\Omega}{\sqrt{\left(\frac{{}^{f}T_1}{m_1 c^2}\right)^2 + 2\left(\frac{{}^{f}T_1}{m_1 c^2}\right)}} .$$

In both Eqs. 60) and 62) the substitution ${}^{f}E_1 = {}^{f}T_1 + m_1 c^2$ has been made.

Differentiating Eq. 60) and considering ${}^{f}E_1$ as a function of Ω as in Eq. 47) we obtain:

$$63) \qquad \frac{I(\Omega)}{I(\theta)} \equiv \frac{\sin\theta\, d\theta}{\sin\Omega\, d\Omega} = (\gamma_1'^2 - 1)^{1/2} \left[\frac{\gamma_2' \sqrt{\left(\frac{{}^{f}T_1}{m_1 c^2}\right)^2 + 2\left(\frac{{}^{f}T_1}{m_1 c^2}\right)} - \cos\theta \left(\frac{{}^{f}T_1}{m_1 c^2} + 1\right)(\gamma_2'^2 - 1)^{\frac{1}{2}}}{\left(\frac{{}^{f}T_1}{m_1 c^2}\right)^2 + 2\left(\frac{{}^{f}T_1}{m_1 c^2}\right)} \right]$$

In the same manner we can write expressions relating ϕ and Ω. A Lorentz transformation to the lab frame gives for ${}^{f}p_{x_2}$:

$$64) \quad {}^{f}p_{x_2} = m_2 c \left[-\gamma_2' (\gamma_2'^2 - 1)^{1/2} \cos\Omega + \gamma_2' (\gamma_2'^2 - 1)^{1/2} \right].$$

Noting again that ${}^{f}p_{x_2}$ may also be written by virtue of Eq. 7):

$$65) \quad {}^{f}p_{x_2} = \sqrt{\frac{{}^{f}E_2^2}{c^2} - m_2^2 c^2}\, \cos\varphi$$

we can equate Eqs. 64) and 65) to obtain:

$$66) \quad \cos\phi \sqrt{\left(\frac{{}^{f}T_2}{m_2c^2}\right)^2 + 2\left(\frac{{}^{f}T_2}{m_2c^2}\right)} = \gamma_2' (\gamma_2'^2 - 1)^{\frac{1}{2}} (1 - \cos\Omega)$$

By similar reasoning we find that a Lorentz transformation gives for ${}^{f}p_{y_2}$:

$$67) \quad {}^{f}p_{y_2} = {}^{f}p_{y_2}' = -m_2 c (\gamma_2'^2 - 1)^{1/2} \sin\Omega$$

and we also have for ${}^{f}p_{y_2}$

$$68) \quad {}^{f}p_{y_2} = -\sqrt{\frac{{}^{f}E_2^2}{c^2} - m_2^2 c^2}\, \sin\varphi$$

Equating Eqs. 67) and 68) we have:

$$69) \quad \sin\phi = \frac{(\gamma_2'^2 - 1)^{1/2} \sin\Omega}{\sqrt{\left(\frac{{}^{f}T_2}{m_2c^2}\right)^2 + 2\left(\frac{{}^{f}T_2}{m_2c^2}\right)}}$$

In both equations 66) and 69) the relation ${}^{f}E_2 = {}^{f}T_2 + m_2c^2$ has been used.

To derive the intensity transformation, differentiate Eq. 66) considering ${}^{f}E_2$ as a function of Ω as in Eq. 49) and obtain

$$70) \quad \frac{I(\Omega)}{I(\theta)} \equiv \frac{\sin\phi\, d\phi}{\sin\Omega\, d\Omega} = (\gamma_2'^2 - 1)^{1/2} \left[\frac{\cos\varphi \left(\frac{{}^{f}T_2}{m_2c^2} + 1\right) (\gamma_2'^2 - 1)^{\frac{1}{2}} - \gamma_2' \sqrt{\left(\frac{{}^{f}T_2}{m_2c^2}\right)^2 + 2\left(\frac{{}^{f}T_2}{m_2c^2}\right)}}{\left(\frac{{}^{f}T_2}{m_2c^2}\right)^2 + 2\left(\frac{{}^{f}T_2}{m_2c^2}\right)} \right]$$

TABLE I

(LAB FRAME C BEFORE COLLISION)

	REST MASS	MOMENTUM 'p	KINETIC ENERGY 'T	TOTAL ENERGY 'E	VELOCITY 'u
	m_1	$m_1 c(\gamma_1^2-1)^{\frac{1}{2}}$	$m_1c^2(\gamma_1-1)$	$m_1c^2\gamma_1$	$c\sqrt{\left(\frac{T_1}{m_1c^2}\right)^2+2\left(\frac{T_1}{m_1c^2}\right)}\Big/\left(\frac{T_1}{m_1c^2}+1\right)$
	m_2	0	0	m_2c^2	0
c-g	m_1+m_2	$(m_1+m_2)c(\gamma_2'^2-1)^{\frac{1}{2}}$	$(m_1+m_2)c^2(\gamma_2'-1)$	$(m_1+m_2)c^2\gamma_2'$	$\frac{c}{\gamma_2'}(\gamma_2'^2-1)^{\frac{1}{2}}$

TABLE II

(LAB FRAME C AFTER COLLISION)

	REST MASS	MOMENTUM ^4p	KINETIC ENERGY ^4T	TOTAL ENERGY ^4E	VELOCITY ^4u
	m_1	$\sqrt{\frac{{}^4E_1^2}{c^2}-m_1^2c^2}$	${}^4E_1-m_1c^2$	$m_1c^2\left[\gamma_1'\gamma_2'+(\gamma_1'^2-1)^{\frac{1}{2}}(\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega\right]$	$\frac{{}^4p_1c}{\sqrt{m_1^2c^2+{}^4p_1^2}}$
	m_2	$\frac{2m_2c(\gamma_2'^2-1)^{\frac{1}{2}}\sqrt{\gamma_2'^2\tan^2\varphi+2}}{\gamma_2'^2\tan^2\varphi+1}$	$2m_2c^2\left[\frac{(\gamma_2'^2-1)}{\gamma_2'^2\tan^2\varphi+1}\right]$	$m_2c^2\left[\frac{\gamma_2'^2(\tan^2\varphi+2)-1}{\gamma_2'^2\tan^2\varphi+1}\right]$	$\frac{{}^4p_2c}{\sqrt{m_2^2c^2+{}^4p_2^2}}$
c-g	m_1+m_2	$(m_1+m_2)c(\gamma_2'^2-1)^{\frac{1}{2}}$	$(m_1+m_2)c^2(\gamma_2'-1)$	$(m_1+m_2)c^2\gamma_2'$	$\frac{c}{\gamma_2'}(\gamma_2'^2-1)^{\frac{1}{2}}$

TABLE III

(CENTER-OF-MASS FRAME C' BEFORE COLLISION)

	REST MASS	MOMENTUM 'p'	KINETIC ENERGY 'T'	TOTAL ENERGY 'E'	VELOCITY 'u'
	m_1	$m_1 c(\gamma_1'^2-1)^{\frac{1}{2}}$	$m_1c^2(\gamma_1'-1)$	$m_1c^2\gamma_1'$	$\frac{c}{\gamma_1}, (\gamma_1'^2-1)^{\frac{1}{2}}$
	m_2	$m_2 c(\gamma_2'^2-1)^{\frac{1}{2}}$	$m_2c^2(\gamma_2'-1)$	$m_2c^2\gamma_2'$	$\frac{c}{\gamma_2}, (\gamma_2'^2-1)^{\frac{1}{2}}$
c-g	m_1+m_2	0	0	$(m_1+m_2)c^2$	0

TABLE IV

(CENTER-OF-MASS FRAME C' AFTER COLLISION)

	REST MASS	MOMENTUM 'p'	KINETIC ENERGY 'T'	TOTAL ENERGY 'E'	VELOCITY 'u'
	m_1	$m_1 c(\gamma_1'^2-1)^{\frac{1}{2}}$	$m_1c^2(\gamma_1'-1)$	$m_1c^2\gamma_1'$	$\frac{c}{\gamma_1}, (\gamma_1'^2-1)^{\frac{1}{2}}$
	m_2	$m_2 c(\gamma_2'^2-1)^{\frac{1}{2}}$	$m_2c^2(\gamma_2'-1)$	$m_2c^2\gamma_2'$	$\frac{c}{\gamma_2}, (\gamma_2'^2-1)^{\frac{1}{2}}$
c-g	m_1+m_2	0	0	$(m_1+m_2)c^2$	0

III. Reactions

We can carry over some of the ideas of the preceding section by noting that before the reaction occurs, the dynamical properties of particles m_1 and m_2 are identical, such as ${}^{i}\gamma_1'$, ${}^{i}\gamma_2'$ and $\gamma_{cq} = {}^{i}\gamma_2'$. Since the center-of-mass frame C' translates with the same velocity before collision as after, then γ_{cq} is also unchanged. Further, the conservation of momentum requires that since there is no net momentum in frame C' before collision, there can be none after, i.e., ${}^{f}p_1' = {}^{f}p_2'$ These expressions are given as:

FIG. 6

(Lab System Before Reaction)

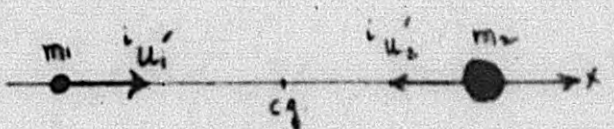

FIG. 7

(C-M System Before Reaction)

71) ${}^{f}p_1' = M_1 c \left({}^{f}\gamma_1'^2 - 1\right)^{\frac{1}{2}}$

72) ${}^{f}p_2' = M_2 c \left({}^{f}\gamma_2'^2 - 1\right)^{\frac{1}{2}}$

Equating these results we can express ${}^{f}\gamma_1'$ in terms of ${}^{f}\gamma_2'$

73) ${}^{f}\gamma_1' = \sqrt{\left(\frac{M_2}{M_1}\right)^2 \left({}^{f}\gamma_2'^2 - 1\right) + 1}$

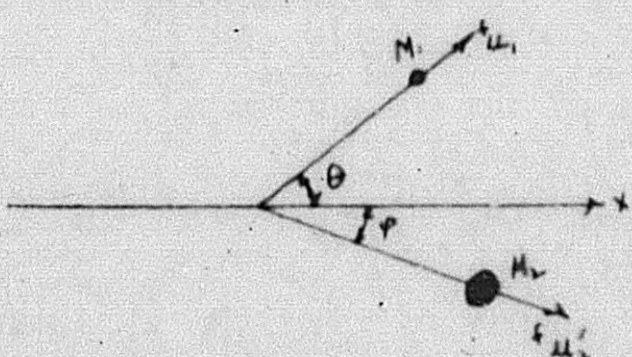

FIG. 8

(Lab System After Reaction)

The total energies of the particles after the reaction are:

74) ${}^{f}E_1' = M_1 c^2 {}^{f}\gamma_1'$

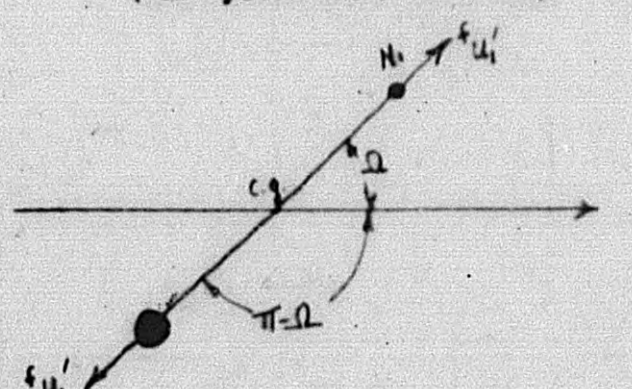

FIG. 9

(C-M System After Reaction)

75) ${}^{f}E_2' = M_2 c^2 {}^{f}\gamma_2'$

Writing ${}^{i}\gamma_1' = \gamma_1'$ and ${}^{i}\gamma_2' = \gamma_2'$

and noting that the expressions for $'E_1'$ and $'E_2'$ are the same as in the preceding section, we can apply the conservation of energy

76) $$'E_1' + 'E_2' = {}^fE_1' + {}^fE_2'$$

and obtain the relation for ${}^f\gamma_2'$ in terms of γ_2'. Then substituting Eq. 16) for γ_2' in terms of γ_1 we have:

77) $${}^f\gamma_2' = \frac{A^2 - B^2}{2AM_2}$$

where $A^2 = m_1^2 + 2m_1m_2\gamma_1 + m_2^2$ and

$$B^2 = M_1^2 - M_2^2$$

Substitution of this into Eq. 73) yields for ${}^f\gamma_1'$:

78) $${}^f\gamma_1' = \frac{A^2 + B^2}{2AM_1}$$

To obtain an expression for ${}^fE_1$ make a Lorents transformation to the lab system and using Eq. 71) we have:

79) $${}^fE_1 = M_1c^2\left[{}^f\gamma_1'\gamma_2' + (\gamma_2'^2-1)^{\frac{1}{2}}({}^f\gamma_1'^2-1)^{\frac{1}{2}}\cos\Omega\right]$$

To determine the function $\cos\Omega$ we must first transform the components ${}^fp_{x_1}'$ and ${}^fp_{y_1}'$ to the lab system, obtaining:

80) $${}^fp_{x_1} = M_1c\left[\gamma_2'({}^f\gamma_1'^2-1)^{\frac{1}{2}}\cos\Omega + {}^f\gamma_1'(\gamma_2'^2-1)^{\frac{1}{2}}\right]$$

81) $${}^fp_{y_1} = M_1c({}^f\gamma_1'^2-1)^{\frac{1}{2}}\sin\Omega$$

Dividing Eq. 81) by Eq. 80) and noting from Fig. 8 that $\tan\theta = \frac{{}^fp_{y_1}}{{}^fp_{x_1}}$ we have

82) $$\tan\theta = \frac{\sin\Omega}{\gamma_2'[\cos\Omega + \alpha_1]} \qquad \text{where} \quad \alpha_1 = \frac{{}^f\gamma_1'(\gamma_2'^2-1)^{\frac{1}{2}}}{\gamma_2'({}^f\gamma_1'^2-1)^{\frac{1}{2}}}$$

Solving Eq. 82) for $\cos\Omega$ we obtain a quadratic expression with solution

83) $$\cos\Omega = \frac{1}{1+\tan^2\psi_1}\left[-\alpha_1\tan^2\psi_1 \pm \sqrt{1-\tan^2\psi_1(\alpha_1^2-1)}\right]$$

where $\tan\psi_1 = \gamma_2'\tan\theta$

Inspection of Eqs. 82) and 83) shows that again we have three cases possible, case a) where $\alpha_1 > 1$, case b) where $\alpha_1 < 1$ and case c) where $\alpha_1 = 1$. The same considerations apply for each of these cases as in the preceding section, and Figs. 3, 4, and 5 are still pertinent. For a given angle θ, case a) still gives two solutions for $\cos\Omega$ and hence for ${}^{f}E_1$. For case a) we again have a maximum value for θ resulting when the radical in Eq. 83) goes to zero. Then

84a) $$\tan^2\theta_{max} = \frac{1}{\gamma_2'^2(\alpha_1^2-1)}$$ or alternately

84b) $$\theta_{max} = \sin^{-1}\left(\frac{1}{\sqrt{1+\gamma_2'^2(\alpha_1^2-1)}}\right)$$

In case c) we again find a redundant root using the negative radical in Eq. 83) for which $\Omega = 180^\circ$. Using only the positive radical, Eq. 83) simplifies to

85) $$\cos\Omega = \frac{1-\tan^2\psi_1}{1+\tan^2\psi_1}$$

It may be noted that the criteria that $\alpha_1 > 1$, $\alpha_1 < 1$, and $\alpha_1 = 1$ have no analogy here to $\frac{m_1}{m_2} \gtrless 1$ as they did in the elastic scattering case. However it is quite generally true that $\alpha_1 = \frac{\mu c^2}{U_1'}$ as may be seen by direct substitution, and consequently our criteria for the various cases is equivalent to asking whether the velocity of center-of-mass is greater than, less than, or equal to the center-of-mass velocity of particle M_1 after reaction. This concept is capable of geometrical presentation.

To obtain ${}^{f}E_2$ we make a Lorentz transformation to the lab coordinates and have

86) $${}^{f}E_2 = M_2c^2\left[\gamma_2'\,{}^{f}\gamma_2' - \left(\gamma_2'^2-1\right)^{\frac{1}{2}}\left({}^{f}\gamma_2'^2-1\right)^{\frac{1}{2}}\cos\Omega\right]$$

Again we can find φ in terms of Ω by transforming momentum components ${}^{f}p_{x_2}'$ and ${}^{f}p_{y_2}'$ to the lab system and noting from Fig. 8 that $\tan\varphi = \frac{{}^{f}p_{y_2}}{{}^{f}p_{x_2}}$.

87) $${}^{f}p_{x_2} = M_2c\left[-\gamma_2'\left({}^{f}\gamma_2'^2-1\right)^{\frac{1}{2}}\cos\Omega + {}^{f}\gamma_2'\left(\gamma_2'^2-1\right)^{\frac{1}{2}}\right]$$

88) $${}^{f}p_{y_2} = -M_2 c \left({}^{f}\gamma_2'^2 - 1\right)^{\frac{1}{2}} \sin\Omega$$

Then divide Eq. 88) by 87), obtaining

89) $$\tan\varphi = \frac{\sin\Omega}{\gamma_2'\left[\cos\Omega - \alpha_2\right]} \qquad \text{where } \alpha_2 = \frac{{}^{f}\gamma_2'\left(\gamma_2'^2-1\right)^{\frac{1}{2}}}{\gamma_2'\left({}^{f}\gamma_2'^2-1\right)^{\frac{1}{2}}}$$

Setting $\tan\psi_2 = \gamma_2'\tan\varphi$ we can obtain an alternate expression for $\cos\Omega$ by solving Eq. 88):

90) $$\cos\Omega = \frac{1}{1+\tan^2\psi_2}\left[\alpha_2\tan^2\psi_2 \pm \sqrt{1-\tan^2\psi_2\left(\alpha_2^2-1\right)}\right]$$

Several additional relations may be obtained relating the center-of-mass to lab angles by transforming the momentum components to the center-of-mass system. We have:

91) $${}^{f}p_{x_1}' = \left[\gamma_2'\sqrt{\frac{{}^{f}E_1^2}{c^2} - M_1^2c^2}\cos\theta - \left(\gamma_2'^2-1\right)^{\frac{1}{2}}\frac{{}^{f}E_1}{c}\right]$$

where we have again used Eq. 7). However, we also know that ${}^{f}p_{x_1}'$ can be expressed as

92) $${}^{f}p_{x_1}' = M_1 c\left({}^{f}\gamma_1'^2 - 1\right)^{\frac{1}{2}}\cos\Omega.$$

Equating Eqs. 91) and 92) one finds

93) $$\gamma_2'\sqrt{\frac{{}^{f}E_1^2}{c^2} - M_1^2c^2}\cos\theta - \left(\gamma_2'^2-1\right)^{\frac{1}{2}}\frac{{}^{f}E_1}{c} = M_1 c\left({}^{f}\gamma_1'^2-1\right)^{\frac{1}{2}}\cos\Omega$$

Transformation of the component ${}^{f}p_{y_2}'$ to the lab system yields:

94) $${}^{f}p_{y_2} = {}^{f}p_{y_2}' = -M_2 c\left({}^{f}\gamma_2'^2-1\right)^{\frac{1}{2}}\sin\Omega$$

But we already have from Eq. 7) that

95) $${}^{f}p_{y_2} = -\sqrt{\frac{{}^{f}E_2^2}{c^2} - M_2^2c^2}\sin\varphi$$

Equating Eqs. 94) and 95) one obtains:

96) $$\sin\Omega = \frac{\sqrt{\left(\frac{{}^{f}T_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^{f}T_2}{M_2c^2}\right)}}{\left({}^{f}\gamma_2'^2-1\right)^{\frac{1}{2}}}\sin\varphi$$

where we have used the result that ${}^{f}E_2 = {}^{f}T_2 + M_2c^2$. By a similar procedure we can relate $\sin\Omega$ and $\sin\theta$ by transforming ${}^{f}p_{y_1}'$ to the lab system:

97) $${}^{f}p_{y_1} = {}^{f}p'_{y_1} = M_1 c \left({}^{f}\gamma_1'^2 - 1\right)^{\frac{1}{2}} \sin\Omega$$

But we already have from Eq. 7) that

98) $${}^{f}p_{y_1} = \sqrt{\frac{{}^{f}E_1^2}{c^2} - M_1^2 c^2}\ \sin\theta$$

Equating Eqs. 97) and 98) and noting that ${}^{f}E_1 = {}^{f}T_1 + M_1 c^2$ we get:

99) $$\sin\Omega = \frac{\sqrt{\left(\frac{{}^{f}T_1}{M_1 c^2}\right)^2 + 2\left(\frac{{}^{f}T_1}{M_1 c^2}\right)}}{\left({}^{f}\gamma_1'^2 - 1\right)^{\frac{1}{2}}}\ \sin\theta$$

Finally we may relate $\cos\Omega$ to $\cos\varphi$ by transformation of ${}^{f}p_{x_2}$ to the center-of-mass system and obtain:

100) $${}^{f}p'_{x_2} = \left[\gamma_2' \sqrt{\frac{{}^{f}E_2^2}{c^2} - M_2^2 c^2}\ \cos\varphi - \left(\gamma_2'^2 - 1\right)^{\frac{1}{2}} \frac{{}^{f}E_2}{c}\right]$$

and noting that it follows from Eq. 72) that:

101) $${}^{f}p'_{x_2} = -M_2 c \left({}^{f}\gamma_2'^2 - 1\right)^{\frac{1}{2}} \cos\Omega$$

Equating Eqs. 100) and 101) we arrive at:

102) $$\gamma_2' \sqrt{\frac{{}^{f}E_2^2}{c^2} - M_2^2 c^2}\ \cos\varphi - \left(\gamma_2'^2 - 1\right)^{\frac{1}{2}} \frac{{}^{f}E_2}{c} = -M_2 c \left({}^{f}\gamma_2'^2 - 1\right)^{\frac{1}{2}} \cos\Omega$$

To obtain the relationship between the intensity of particles M_1 in the center-of-mass and lab system, differentiate Eq. 93) regarding ${}^{f}E_1$ as a function of Ω as given by Eq. 79) and obtain

103) $$\frac{I(\Omega)}{I(\theta)} \equiv \frac{\sin\theta\, d\theta}{\sin\Omega\, d\Omega} = \left({}^{f}\gamma_1'^2 - 1\right)^{\frac{1}{2}} \left[\frac{\gamma_2' \sqrt{\left(\frac{{}^{f}T_1}{M_1 c^2}\right)^2 + 2\left(\frac{{}^{f}T_1}{M_1 c^2}\right)} - \cos\theta \left(\frac{{}^{f}T_1}{M_1 c^2} + 1\right)\left(\gamma_2'^2 - 1\right)^{\frac{1}{2}}}{\left(\frac{{}^{f}T_1}{M_1 c^2}\right)^2 + 2\left(\frac{{}^{f}T_1}{M_1 c^2}\right)}\right]$$

To derive the intensity relation between particles M_2 in the center-of-mass system and lab system, differentiate Eq. 102) regarding ${}^{f}E_2$ as a function of Ω as given by Eq. 85) and obtain:

104) $$\frac{I(\Omega)}{I(\varphi)} \equiv \frac{\sin\varphi\, d\varphi}{\sin\Omega\, d\Omega} = \left({}^{f}\gamma_2'^2 - 1\right)^{\frac{1}{2}} \left[\frac{\cos\varphi \left(\frac{{}^{f}T_2}{M_2 c^2} + 1\right)\left(\gamma_2'^2 - 1\right)^{\frac{1}{2}} - \gamma_2' \sqrt{\left(\frac{{}^{f}T_2}{M_2 c^2}\right)^2 + 2\left(\frac{{}^{f}T_2}{M_2 c^2}\right)}}{\left(\frac{{}^{f}T_2}{M_2 c^2}\right)^2 + 2\left(\frac{{}^{f}T_2}{M_2 c^2}\right)}\right]$$

Finally we can write expressions for θ in terms of φ by simultaneously solving Eqs. 96) and 99), eliminating $\sin\Omega$ between them and obtain:

$$105)\quad \sin\theta = \left\{\frac{M_2\left[\left(\frac{T_2}{M_2c^2}\right)^2 + 2\left(\frac{T_2}{M_2c^2}\right)\right]}{M_1\left[\left(\frac{T_1}{M_1c^2}\right)^2 + 2\left(\frac{T_1}{M_1c^2}\right)\right]}\right\}^{\frac{1}{2}} \sin\varphi$$

Solving Eqs. 93) and 102) simultaneously and eliminating $\cos\Omega$ between them, we have

$$106)\quad \cos\varphi = \frac{(\gamma_2'^2-1)^{\frac{1}{2}}\left[\frac{(\gamma_2'^2-1)^{\frac{1}{2}}}{(\gamma_2'^2-1)^{\frac{1}{2}}}\left(\frac{T_2}{M_2c^2}+1\right) + \frac{(\beta_2'^2-1)^{\frac{1}{2}}}{(\gamma_1'^2-1)^{\frac{1}{2}}}\left(\frac{T_1}{M_1c^2}+1\right) - \frac{\gamma_2'}{(\gamma_1'^2-1)^{\frac{1}{2}}}\sqrt{\left(\frac{T_1}{M_1c^2}\right)^2+2\left(\frac{T_1}{M_1c^2}\right)}\cos\theta\right]}{\gamma_2'\sqrt{\left(\frac{T_2}{M_2c^2}\right)^2+2\left(\frac{T_2}{M_2c^2}\right)}}$$

For convenience, many of the pertinent dynamical relations in this section are tabulated in tables V, VI, VII, and VIII.

TABLE V

(Lab System Before Reaction)

Particle	Rest Mass	Momentum 'p	Kinetic Energy 'T	Total Energy 'E	Velocity 'u
incident	m_1	$m_1 c (\gamma_1^2-1)^{\frac{1}{2}}$	$T_0 = m_1 c^2 (\gamma_1 - 1)$	$m_1 c^2 \gamma_1$	$c\sqrt{\left(\frac{T_0}{m_1 c^2}\right)^2+2\left(\frac{T_0}{m_1 c^2}\right)}\Big/\left(\frac{T_0}{m_1 c^2}+1\right)$
target	m_2	0	0	$m_2 c^2$	0
c - g	m_1+m_2	$(m_1+m_2)c(\gamma_2'^2-1)^{\frac{1}{2}}$	$(m_1+m_2)c^2(\gamma_2'-1)$	$(m_1+m_2)c^2\gamma_2'$	$\frac{c}{\gamma_2'}(\gamma_2'^2-1)^{\frac{1}{2}}$

TABLE VI

(Center-of-Mass System Before Reaction)

Particle	Rest Mass	Momentum 'p'	Kinetic Energy 'T'	Total Energy 'E'	Velocity 'u'
incident	m_1	$m_1 c(\gamma_1'^2-1)^{\frac{1}{2}}$	$m_1 c^2(\gamma_1'-1)$	$m_1 c^2 \gamma_1'$	$\frac{c}{\gamma_1'}(\gamma_1'^2-1)^{\frac{1}{2}}$
target	m_2	$m_2 c(\gamma_2'^2-1)^{\frac{1}{2}}$	$m_2 c^2(\gamma_2'-1)$	$m_2 c^2 \gamma_2'$	$\frac{c}{\gamma_2'}(\gamma_2'^2-1)^{\frac{1}{2}}$
c - g	m_1+m_2	0	0	$(m_1+m_2)c^2$	0

(Lab System After Reaction)

Particle	Rest Mass	Momentum	Kinetic Energy	Total Energy	Velocity
incident	M_1	$\sqrt{\frac{{}^4E_1^2}{c^2} - M_1^2c^2}$	${}^4E_1 - M_1c^2$	$M_1c^2\left[{}^4\gamma_1'\gamma_2' + ({}^4\gamma_1'^2-1)^{\frac{1}{2}}(\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega\right]$	$\frac{c^4p_1}{\sqrt{{}^4p_1^2 + M_1^2c^2}}$
target	M_2	$\sqrt{\frac{{}^4E_2^2}{c^2} - M_2^2c^2}$	${}^4E_2 - M_2c^2$	$M_2c^2\left[\gamma_2'{}^4\gamma_1' - (\gamma_2'^2-1)^{\frac{1}{2}}({}^4\gamma_1'^2-1)^{\frac{1}{2}}\cos\Omega\right]$	$\frac{c^4p_2}{\sqrt{{}^4p_2^2 + M_2^2c^2}}$
c - g	M_1+M_2	$(M_1+M_2)c(\gamma_{cg}^2-1)^{\frac{1}{2}}$	$(M_1+M_2)c^2(\gamma_{cg}-1)$	$(M_1+M_2)c^2\gamma_{cg}$	$\frac{c}{\gamma_2'}(\gamma_2'^2-1)^{\frac{1}{2}}$

TABLE VII

(Center-of-Mass System After Reaction)

Particle	Rest Mass	Momentum	Kinetic Energy	Total Energy	Velocity
incident	M_1	$M_1c({}^4\gamma_1'^2-1)^{\frac{1}{2}}$	$M_1c^2({}^4\gamma_1'-1)$	$M_1c^2{}^4\gamma_1'$	$\frac{c}{{}^4\gamma_1'}({}^4\gamma_1'^2-1)^{\frac{1}{2}}$
target	M_2	$M_2c({}^4\gamma_2'^2-1)^{\frac{1}{2}}$	$M_2c^2({}^4\gamma_2'^2-1)$	$M_2c^2{}^4\gamma_2'$	$\frac{c}{{}^4\gamma_2'}({}^4\gamma_2'^2-1)^{\frac{1}{2}}$
c - g	M_1+M_2	0	0	$(M_1+M_2)c^2$	0

TABLE VIII

For the two-body reaction problem where all of the particles involved have finite rest masses, there are several additional quantities useful to compute. Consider the following four special cases.

case a) In reactions such as

$$p^+ + p^- \longrightarrow \pi^+ + \pi^-$$

it may be necessary to compute m_2 and T_o, knowing M_1, M_2, ${}^fT_2$, ${}^fT_1$, θ, φ and m_1. In the lab frame we write the conservation of energy

107) $$m_1c^2 + T_o + m_2c^2 = M_1c^2 + {}^fT_1 + M_2c^2 + {}^fT_2$$

and the conservation of momentum:

108) $$\sqrt{\frac{{}^fE_1^2}{c^2} - m_1^2c^2} = \sqrt{\frac{{}^fE_1^2}{c^2} - M_1^2c^2}\cos\theta + \sqrt{\frac{{}^fE_2^2}{c^2} - M_2^2c^2}\cos\varphi$$

which are simultaneous equations in the two unknowns.

Solving we have

109) $$T_o = -m_1c^2 + \sqrt{(m_1c^2)^2 + D}$$

where $$D = \left[M_1c^2 \sqrt{\left(\frac{{}^fT_1}{M_1c^2}\right)^2 + 2\left(\frac{{}^fT_1}{M_1c^2}\right)}\cos\theta + M_2c^2 \sqrt{\left(\frac{{}^fT_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^fT_2}{M_2c^2}\right)}\cos\varphi \right]^2$$

and we take the positive square root in Eq. 109) since T_o must be positive. Then we solve for m_2c^2:

110) $$m_2c^2 = \left[M_1c^2 + M_2c^2 + {}^fT_1 + {}^fT_2 - \sqrt{(m_1c^2)^2 + D} \right]$$

These results may also be useful for meson production reactions by nucleon-nucleon and nucleon-nuclei collisions.

case b) With such reactions where we desire to find m_1 and T_o, knowing M_1, M_2, ${}^fT_1$, ${}^fT_2$, θ, φ, and m_2 we can proceed as in previous case and write down conservation of energy in lab frame:

111) $$m_1c^2 + T_0 + m_2c^2 = M_1c^2 + M_2c^2 + {}^fT_1 + {}^fT_2$$

and conservation of momentum

112) $$m_1c^2\sqrt{\left(\frac{T_0}{m_1c^2}\right)^2 + 2\left(\frac{T_0}{m_1c^2}\right)} = M_1c^2\sqrt{\left(\frac{{}^fT_1}{M_1c^2}\right)^2 + 2\left(\frac{{}^fT_1}{M_1c^2}\right)}\cos\theta + M_2c^2\sqrt{\left(\frac{{}^fT_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^fT_2}{M_2c^2}\right)}\cos\varphi$$

Solving simultaneously we find

113) $$m_1c^2 = \left[M_1c^2 + M_2c^2 + {}^fT_1 + {}^fT_2 - D\right]^2$$

where $$D = \left[M_1c^2\sqrt{\left(\frac{{}^fT_1}{M_1c^2}\right)^2 + 2\left(\frac{{}^fT_1}{M_1c^2}\right)}\cos\theta + M_2c^2\sqrt{\left(\frac{{}^fT_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^fT_2}{M_2c^2}\right)}\cos\varphi\right]^2$$

114) $$T_0 = -\sqrt{M_1c^2 + M_2c^2 + {}^fT_1 + {}^fT_2 - m_2c^2 - D} + M_1c^2 + M_2c^2 + {}^fT_1 + {}^fT_2 - m_2c^2$$

case c) Another useful case occurs when m_1 is not an ionising particle and we desire to find m_1 and T_0 for such reactions as

$$\nu + n \rightarrow p + e$$

or any neutron reaction. It is not possible to know θ and φ but only $\theta + \varphi = F$. If we also know M_1, M_2, ${}^fT_1$, ${}^fT_2$, and m_2 then we can solve for the four unknowns m_1, T_0, θ and φ from the conservation equations in the lab system: -

115) $$m_1c^2 + m_2c^2 + T_0 = M_1c^2 + M_2c^2 + {}^fT_1 + {}^fT_2$$

116) $$\sqrt{\frac{{}^fE_1^2}{c^2} - m_1^2c^2} = \sqrt{\frac{{}^fE_1^2}{c^2} - M_1^2c^2}\cos\theta + \sqrt{\frac{{}^fE_2^2}{c^2} - M_2^2c^2}\cos\varphi$$

117) $$\sqrt{\frac{{}^fE_1^2}{c^2} - M_1^2c^2}\sin\theta = \sqrt{\frac{{}^fE_2^2}{c^2} - M_2^2c^2}\sin\varphi$$

118) $\theta + \varphi = \xi$

Solving simultaneously we find

119) $$\cos\varphi = \frac{A\cos\xi + B}{\sqrt{A^2 + 2AB\cos\xi + B^2}}$$

120) $$\cos\theta = \frac{A + B\cos\xi}{\sqrt{A^2 + 2AB\cos\xi + B^2}}$$

121) $$m_1c^2 = \left[\left(M_1c^2 + M_2c^2 - m_2c^2 + {}^kT_1 + {}^kT_2 \right)^2 - c^4\left(A^2 + 2AB\cos\xi + B^2\right) \right]^{\frac{1}{2}}$$

122) $$T_0 = -m_1c^2 + \sqrt{(m_1c^2)^2 + c^4\left(A^2 + 2AB\cos\xi + B^2\right)}$$

where we have written

$$A = M_1\sqrt{\left(\frac{{}^kT_1}{M_1c^2}\right)^2 + 2\left(\frac{{}^kT_1}{M_1c^2}\right)}$$

$$B = M_2\sqrt{\left(\frac{{}^kT_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^kT_2}{M_2c^2}\right)}$$

case d) It is also of interest to calculate ${}^fT_2$ and m_2 when θ, φ, M_1, M_2, m_1, T_0, and ${}^fT_1$ are known. We can solve for ${}^fT_2$ directly by writing down the conservation of momentum equation in y-direction:

123) $$\sqrt{\frac{{}^fE_1^2}{c^2} - M_1^2c^2}\,\sin\theta = \sqrt{\frac{{}^fE_2^2}{c^2} - M_2^2c^2}\,\sin\varphi$$

which yields

124) $${}^fT_2 = -M_2c^2 + \sqrt{(M_2c^2)^2 + E}$$

where $$E = \left(M_1c^2\frac{\sin\theta}{\sin\varphi}\right)^2\left[\left(\frac{{}^kT_1}{M_1c^2}\right)^2 + 2\left(\frac{{}^kT_1}{M_1c^2}\right)\right]$$

125) $$m_2c^2 = M_1c^2 + {}^kT_1 - m_1c^2 - T_0 + \sqrt{(M_2c^2)^2 + E}$$

IV. Two-Body Reactions Involving Zero Rest Mass Particles.

In this section we consider reactions involving photons and neutrinos either as incident or product particles. In general, m_2 is finite.

case a) Consider the reaction illustrated in Fig. 10. The kinematics of this class of reactions is applicable to photonuclear processes, photodisintegration, as well as photo-meson production from either a photon-nucleon collision or a photon-nuclei collision.

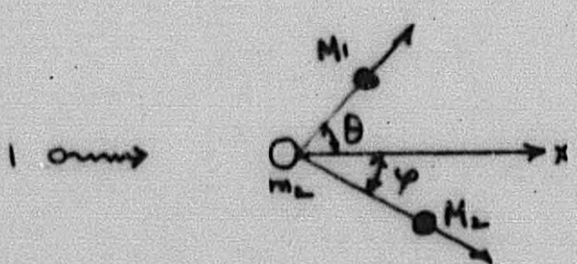

Fig. 10

Such neutrino reactions as

$$\nu + p \rightarrow n + e$$
$$\nu + n \rightarrow p + e$$

are also included, if one assumes the neutrino to have a zero rest mass. If the neutrino has a finite rest mass, the formalism of section III is applicable.

The initial conditions in the lab frame may be written as follows:

126) $$'E_1 = T_0 = \hbar\omega$$
$$'E_2 = m_2c^2$$
$$'p_1 = \frac{T_0}{c}$$
$$'p_2 = 0$$

and in the center-of-mass frame as: -

127) $$'E_1' = 'p_1'c = m_2c^2('\gamma_2'^2-1)^{\frac{1}{2}}$$
$$'E_2' = m_2c^2\,'\gamma_2'$$
$$'p_1' = 'p_2'$$
$$'p_2' = m_2c('\gamma_2'^2-1)^{\frac{1}{2}}$$

If we transform ${}^{i}E_1$ to the c-g frame by a Lorentz transformation

128) $$\frac{{}^{i}E_1'}{c^2} = \left[\frac{{}^{i}E_1}{c^2} - \frac{{}^{i}\mu_2'}{c^2}\left(\frac{T_0}{c}\right)\right] {}^{i}\gamma_2'$$

and equate this to the value of ${}^{i}E_1'$ in Eq. 127), then we can solve for ${}^{i}\gamma_2'$ as

129) $$ {}^{i}\gamma_2' = \frac{1 + \left(\frac{T_0}{m_2c^2}\right)}{\left[1 + 2\left(\frac{T_0}{m_2c^2}\right)\right]^{\frac{1}{2}}}$$

After the reaction we have the following conditions in the c-g frame:

130) $$ {}^{f}E_1' = M_1c^2\,{}^{f}\gamma_1' $$
$$ {}^{f}E_2' = M_2c^2\,{}^{f}\gamma_2' $$
$$ {}^{f}p_1' = M_1c\,({}^{f}\gamma_1'^2 - 1)^{\frac{1}{2}} $$
$$ {}^{f}p_2' = M_2c\,({}^{f}\gamma_2'^2 - 1)^{\frac{1}{2}} $$

It will be will be recognised that these results are identical to those obtained in the previous section in Eqs. 71), 72), 74), and 75). Hence it is only necessary to write a new expression for ${}^{f}\gamma_1'$ and note that ${}^{f}\gamma_2'$ can be written in terms of ${}^{f}\gamma_1'$ from the last two relations of Eqs. 130):

131) $$ {}^{f}\gamma_2' = \left[\frac{M_1^2}{M_2^2}({}^{f}\gamma_1'^2 - 1)^{\frac{1}{2}} + 1 \right]^{\frac{1}{2}}$$

From the conservation of energy in the c-g frame we can write

132) $$ m_2c^2({}^{i}\gamma_2'^2 - 1)^{\frac{1}{2}} + m_2c^2\,{}^{i}\gamma_2' = M_1c^2\,{}^{f}\gamma_1' + M_2c^2\,{}^{f}\gamma_2'$$

which may be solved for ${}^{f}\gamma_1'$ as:

133) $$ {}^{f}\gamma_1' = \frac{m_2^2\left[1 + 2\left(\frac{T_0}{m_2c^2}\right)\right] + M_1^2 - M_2^2}{2\,m_2 M_1 \sqrt{1 + 2\left(\frac{T_0}{m_2c^2}\right)}}$$

Then all of the resultant expressions in section III follow.

case b) In Fig. 11 is illustrated the possibility of both an incident and product particle having zero rest mass. Such processes might include compton scattering and photo-excitation of a nucleus with subsequent decay to the ground state. The kinematical situation before the reaction is identical to

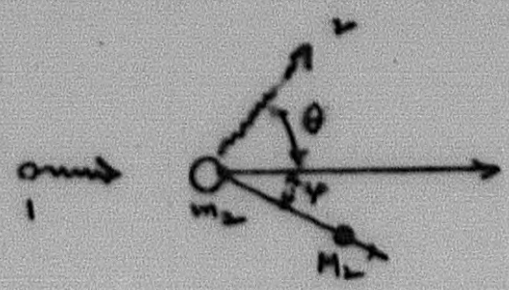

Fig. 11

case a) and consequently ${}^{1}\gamma_2'$ is given by Eq. 129). After reaction we have in the c-g frame;

134) $${}^{f}E_1' = {}^{f}p_1'c = M_2c^2({}^{1}\gamma_2'^2-1)^{\frac{1}{2}}$$
$${}^{f}E_2' = M_2c^2\,{}^{f}\gamma_2'$$
$${}^{f}p_1' = {}^{f}p_2'$$
$${}^{f}p_2' = M_2c({}^{1}\gamma_2'^2-1)^{\frac{1}{2}}$$

The conservation of energy in the c-g frame requires that

135) $$m_2c^2({}^{1}\gamma_2'^2-1)^{\frac{1}{2}} + m_2c^2\gamma_2' = M_2c^2({}^{f}\gamma_2'^2-1)^{\frac{1}{2}} + M_2c^2\,{}^{f}\gamma_2'$$

and upon substitution of Eq. 129) for ${}^{1}\gamma_2'$ we have

136) $${}^{f}\gamma_2' = \frac{m_2^2\left[1+2\left(\frac{T_0}{m_2c^2}\right)\right] + M_2^2}{2\,m_2 M_2\sqrt{1+2\left(\frac{T_0}{m_2c^2}\right)}}$$

Noting that for a zero rest mass particle Eq. 7) gives for the momentum $p = \frac{E}{c}$ we can make a Lorentz transformation of ${}^{f}E_1'$ to the lab system and obtain

137) $${}^{f}E_1 = M_2c^2({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}\left[{}^{1}\gamma_2' + ({}^{1}\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega\right]$$

Similarly a Lorentz transformation yields for ${}^{f}E_2$:

138) $${}^{f}E_2 = M_2c^2\left[{}^{1}\gamma_2'\,{}^{f}\gamma_2' - ({}^{1}\gamma_2'^2-1)^{\frac{1}{2}}({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega\right]$$

To find relations between c-g and lab angles we first find components of momenta:

139) $${}^{f}p_{x_1} = \left[{}^{f}p_{x_1}' + \lambda_1' \frac{{}^{f}E_1'}{c}\right]\gamma_1' = M_2 c\left[{}^{f}\gamma_1'({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega + ({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}({}^{f}\gamma_1'^2-1)^{\frac{1}{2}}\right]$$

140) $${}^{f}p_{y_1} = {}^{f}p_{y_1}' = M_2 c\,({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}\sin\Omega$$

141) $${}^{f}p_{x_2} = \left[{}^{f}p_{x_2}' + \lambda_2' \frac{{}^{f}E_2'}{c}\right]\gamma_2' = M_2 c\left[{}^{f}\gamma_2'({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega + {}^{f}\gamma_2'({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}\right]$$

142) $${}^{f}p_{y_2} = {}^{f}p_{y_2}' = -M_2 c\,({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}\sin\Omega$$

Recalling that $\tan\theta = \frac{{}^{f}p_{y_1}}{{}^{f}p_{x_1}}$ we divide Eq. 140) by Eq. 139) and obtain

143) $$\tan\psi_1 = \frac{\sin\Omega}{\cos\Omega + \alpha_1}$$

where $\alpha_1 = \frac{({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}}{{}^{f}\gamma_2'}$ and ${}^{f}\gamma_2'\tan\theta = \tan\psi_1$

This can be inverted as before to find $\cos\Omega$:

144) $$\cos\Omega = \frac{-\alpha_1\tan^2\psi_1 \pm \sqrt{1-(\alpha_1^2-1)\tan^2\psi_1}}{1+\tan^2\psi_1}$$

where we have two cases for $\alpha_1 \lesssim 1$? The kinetic energies follow from the definition, i.e., ${}^{f}T_1 = {}^{f}E_1$ and ${}^{f}T_2 = {}^{f}E_2 - M_2c^2$

Noting that we can also write ${}^{f}p_{y_1}$ as

145) $${}^{f}p_{y_1} = \frac{{}^{f}E_1}{c}\sin\theta$$

then equating 145) and 140) yields:

146) $$\sin\theta = \frac{({}^{f}\gamma_2'^2-1)^{\frac{1}{2}}}{\left(\frac{{}^{f}T_1}{M_2c^2}\right)}\sin\Omega$$

and further since ${}^{f}p_{y_2}$ may also be written

147) $${}^{f}p_{y_2} = -\sqrt{\frac{{}^{f}E_2^2}{c^2} - M_2^2c^2}\sin\varphi$$

* It will be noted that α_1 cannot be greater than unity and approaches unity only in the high energy limit.

We can equate 147) and 148) to obtain:

$$148)\quad \sin\varphi = \frac{(\gamma_2'^2-1)^{\frac{1}{2}}}{\sqrt{\left(\frac{T_2}{M_2c^2}\right)^2+2\left(\frac{T_2}{M_2c^2}\right)}}\sin\Omega$$

To obtain the cosine relations write p_{x_2} as

$$149)\quad p_{x_2} = \frac{E_1}{c}\cos\theta$$

and equate 149) and 139) obtaining:

$$150)\quad \left(\frac{T_1}{M_2c^2}\right)\cos\theta = \gamma_2'(\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega + (\gamma_2'^2-1)^{\frac{1}{2}}(\gamma_2'^2-1)^{\frac{1}{2}}$$

Also write p_{x_2} as

$$151)\quad p_{x_2} = \sqrt{\frac{E_2^2}{c^2}-M_2^2c^2}\cos\varphi$$

and equate 151) with 141) yielding:

$$152)\quad \sqrt{\left(\frac{T_2}{M_2c^2}\right)^2+2\left(\frac{T_2}{M_2c^2}\right)}\cos\varphi = \gamma_2'(\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega + \gamma_2'(\gamma_2'^2-1)^{\frac{1}{2}}$$

The intensity relation $J(\theta) = \frac{I(\Omega)}{I(\theta)} \equiv \frac{\sin\theta\, d\theta}{\sin\Omega\, d\Omega}$ is obtained by differentiating Eq. 150) regarding T_2 as a function of Ω:

$$153)\quad J(\theta) = \frac{(\gamma_2'^2-1)^{\frac{1}{2}}}{\left(\frac{T_1}{M_2c^2}\right)}\left[\gamma_2' - (\gamma_2'^2-1)^{\frac{1}{2}}\cos\theta\right]$$

The intensity relation $J(\varphi) = \frac{I(\Omega)}{I(\varphi)} \equiv \frac{\sin\varphi\, d\varphi}{\sin\Omega\, d\Omega}$ is obtained by differentiating Eq. 152) regarding T_2 as a function of Ω:

$$154)\quad J(\varphi) = \frac{(\gamma_2'^2-1)^{\frac{1}{2}}\left[\cos\varphi\,(\gamma_2'^2-1)^{\frac{1}{2}}\left(\frac{T_2}{M_2c^2}+1\right) - \gamma_2'\right]}{\sqrt{\left(\frac{T_2}{M_2c^2}\right)^2+2\left(\frac{T_2}{M_2c^2}\right)}}$$

case c) Consider a reaction such as shown in Fig. 12 where one of the product particles has zero rest mass. Before reaction, the kinematical equations are identical to those in section II where $'\gamma_2'$ is given by Eq. 16). After reaction the kinematics is identical to that in case IVb except that $^4\gamma_2'$ must be recomputed.

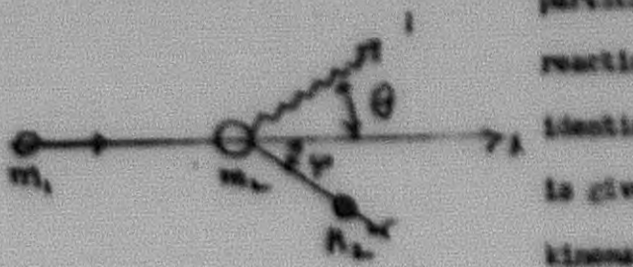

Fig. 12

Writing the conservation of energy in the center-of-mass system:

$$155)\quad m_1c^2\,{}'\gamma_1' + m_2c^2\,{}'\gamma_2' = M_1c^2\,{}^4\gamma_1' + M_2c^2\,({}^4\gamma_2' - 1)$$

and substituting in $'\gamma_2'$ and $'\gamma_1'$ from section II we obtain:

$$156)\quad {}^4\gamma_2' = \frac{2m_2^2\,{}'\gamma_1'\,{}'\gamma_2' + m_1^2 - m_1^2 + M_2^2 + 2m_2\,{}'\beta_2'\sqrt{m_1^2\,({}'\gamma_2'^2-1)+m_1^2}}{2M_2\left[\sqrt{m_2^2\,({}'\gamma_2'^2-1)+m_1^2} + m_2\,{}'\gamma_2'\right]}$$

where as usual $^4\gamma_1'$ is given by

$$^4\gamma_1' = \sqrt{\frac{m_2^2}{m_1^2}\,({}'\gamma_2'^2-1)+1}$$

case d) A final possibility is that both initial particles will annihilate, as illustrated in Fig. 13. Before reaction we again have the same kinematical situation as in section II with $'\gamma_2'$ given by Eq. 16). After the reaction the dynamical relations are given in the c-g system by:

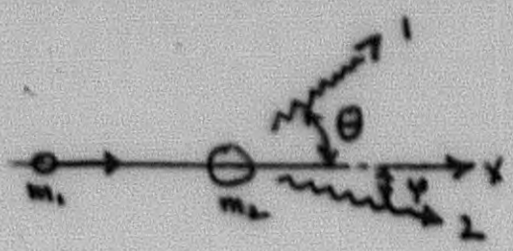

Fig. 13

157) $$^{4}E_1' = {}^{4}T_1$$
$$^{4}E_2' = {}^{4}E_1'$$
$$^{4}p_1' = \frac{^{4}E_1'}{c}$$
$$^{4}p_2' = {}^{4}p_1'$$

and setting $^{f}E_1' = {}^{f}E_2' = {}^{f}E'$ we can write the conservation of energy in the c-g system:

158) $$^{4}E' + {}^{4}E' = m_1c^2\gamma_2' + c^2\left[m_2^2(\gamma_2'^2-1)+m_2^2\right]^{\frac{1}{2}}$$

which yields

159) $$^{4}E' = \frac{1}{2}m_1c^2\left[\sqrt{\gamma_2'^2-1+\left(\frac{m_2}{m_1}\right)^2}+\gamma_2'\right]$$

A Lorentz transformation to the lab frame yields $^{f}E_1$:-

160) $$^{4}E_1 = {}^{4}E'\left[\gamma_2' + (\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega\right] = {}^{4}T_1$$

and a further transformation to the lab frame yields for $^{f}E_2$:-

161) $$^{4}E_2 = {}^{4}E'\left[\gamma_2' - (\gamma_2'^2-1)^{\frac{1}{2}}\cos\Omega\right] = {}^{4}T_2$$

To find the angle relations we transform the momentum components to the lab frame:

162) $$^{4}p_{x_1} = \frac{^{4}E'}{c}\left[\beta_2'\gamma_2'\cos\Omega + (\beta_2'^2\gamma_2'^2)^{\frac{1}{2}}\right]$$

163) $$^{4}p_{y_1} = {}^{4}p_{y_1}' = \frac{^{4}E'}{c}\sin\Omega$$

164) $$^{4}p_{x_2} = \frac{^{4}E'}{c}\left[-\beta_2'\gamma_2'\cos\Omega + (\beta_2'^2\gamma_2'^2)^{\frac{1}{2}}\right]$$

165) $$^{4}p_{y_2} = {}^{4}p_{y_2}' = -\frac{^{4}E'}{c}\sin\Omega$$

Then using the relation that $\tan\theta = \frac{{}^{f}p_{y_1}}{{}^{f}p_{x_1}}$ we have the usual results

166) $\tan\psi_1 = \frac{\alpha_1 \sin\Omega}{\cos\Omega + \alpha_1}$ where $\alpha_1 = \frac{(\gamma_2'^2-1)^{\frac{1}{2}}}{\gamma_2'}$

also $\gamma_2' \tan\theta = \tan\psi_1$

167) $\cos\Omega = \frac{-\alpha_1 \tan^2\psi_1 \pm \sqrt{1-(\alpha_1^2-1)\tan^2\psi_1}}{1+\tan^2\psi_1}$

and with the two cases $\alpha_1 \lessgtr 1$. Noting that ${}^{f}p_{y_2}$ is also given by

168) ${}^{f}p_{y_1} = \frac{{}^{f}T_1}{c} \sin\theta$

We equate Eq. 168) with Eq. 163) and obtain

169) $\sin\theta = \frac{{}^{f}E'}{{}^{f}T_1} \sin\Omega$

Similarly writing

170) ${}^{f}p_{y_2} = -\frac{{}^{f}T_2}{c} \sin\varphi$

and equating 170) with 165) we have

171) $\sin\varphi = \frac{{}^{f}E'}{{}^{f}T_2} \sin\Omega$

For the cosine relations we note that

172) ${}^{f}p_{x_1} = \frac{{}^{f}T_1}{c} \cos\theta$

and equating this with 162) we obtain

173) ${}^{f}T_1 \cos\theta = {}^{f}E' \left[\gamma_2' \cos\Omega + (\gamma_2'^2-1)^{\frac{1}{2}}\right]$

In like fashion write ${}^{f}p_{x_2}$ as

174) ${}^{f}p_{x_2} = \frac{{}^{f}T_2}{c} \cos\varphi$

and equate with 164) getting

175) $${}^{4}T_{2}\cos\varphi = {}^{4}E'\left[{}^{4}\gamma_{c}'\cos\Omega + ({}^{4}\gamma_{c}'^{2}-1)^{\frac{1}{2}}\right]$$

Then to obtain $J(\theta) = \dfrac{I(\Omega)}{I(\theta)} \equiv \dfrac{\sin\theta\, d\theta}{\sin\Omega\, d\Omega}$ we differentiate Eq. 173) regarding ${}^{f}T_{1}$ as a function of Ω :

176) $$J(\theta) = \frac{{}^{4}E'}{{}^{f}T_{1}}\left[{}^{4}\gamma_{c}' - ({}^{4}\gamma_{c}'^{2}-1)^{\frac{1}{2}}\cos\theta\right]$$

Finally to write $J(\varphi) = \dfrac{I(\Omega)}{I(\varphi)} \equiv \dfrac{\sin\varphi\, d\varphi}{\sin\Omega\, d\Omega}$ by differentiating Eq. 175) regarding ${}^{f}T_{2}$ as a function of Ω :

177) $$J(\varphi) = \frac{{}^{4}E'}{{}^{f}T_{2}}\left[\cos\varphi\,({}^{4}\gamma_{c}'^{2}-1)^{\frac{1}{2}} - {}^{4}\gamma_{c}'\right]$$

V. Decay Processes in Flight or at Rest with Two Product Particles

We consider here three physically interesting cases with $M_{2}^{m_{1}=0}\,\theta$.

case a) Consider the decay in which one of the products, M_1, has zero rest mass as in Fig. 14. In this case, $\gamma_1 = \gamma_{c_1} = {}^{4}\gamma_{c}'$ and from Eq. 25 we write this as

178) $${}^{4}\gamma_{c}' = \frac{T_{0}}{m_{2}c^{2}} + 1$$

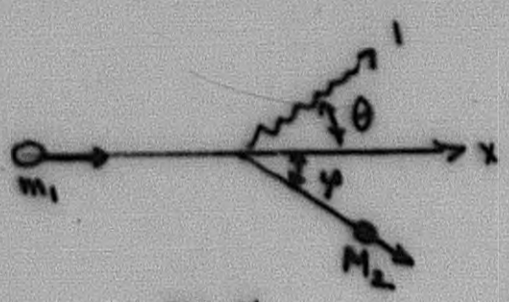

Fig. 14

After the decay we have in the c-g frame

179) $${}^{4}E_{1}' = {}^{4}p_{1}'c = M_{2}c^{2}({}^{4}\gamma_{c}'^{2}-1)^{\frac{1}{2}}$$

$${}^{4}E_{2}' = M_{2}c^{2}\,{}^{4}\gamma_{c}'$$

$${}^{4}p_{1}' = {}^{4}p_{2}'$$

$${}^{4}p_{2}' = M_{2}c\,({}^{4}\gamma_{c}'^{2}-1)^{\frac{1}{2}}$$

These are the identical relations which were obtained in section IVb. Hence all of the resulting relations in that section are applicable here except that we must re-express ${}^{4}\gamma_2'$. Writing the conservation of energy in c-g frame:

180) $$m_1c^2 = M_2c^2({}^{4}\gamma_2' - 1) + M_2c^2\,{}^{4}\gamma_2'$$

and solving for ${}^{4}\gamma_2'$ we find:

181) $${}^{4}\gamma_2' = \frac{1 + \left(\frac{m_1}{M_2}\right)^2}{2\left(\frac{m_1}{M_2}\right)}$$

As example of this process consider the reactions (meson) :

$$K \rightarrow \mu + \nu$$
$$\pi \rightarrow \mu + \nu$$

case b) There is also the possibility of a particle of finite mass decaying into two zero rest mass particles such as the reaction

$$\pi^0 \rightarrow 2\gamma$$

illustrated in Fig. 15. Before decay we have the same dynamical situation as in case Va with

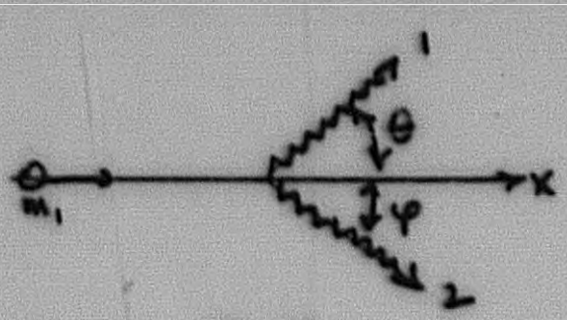

Fig. 15

$${}^{4}\gamma_2' = \frac{T_0}{m_1c^2} + 1$$

After the decay the dynamics is identical to case IVd, except that we must re-evaluate ${}^{4}B'$. Writing the conservation of energy in c-g frame:

182) $${}^{4}E' = \tfrac{1}{2} m_1c^2$$

case c) Finally we consider the break-up of one particle into two finite rest mass particles, such as

$$\gamma \rightarrow \pi^+ + N^0$$

$$\theta_0 \rightarrow \pi^0 + \pi^-$$

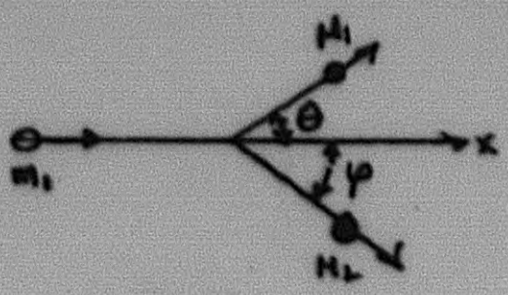

Fig. 16

as is illustrated in Fig. 16). Before break-up we write as in previous cases:

$$'\gamma_2' = \frac{T_0}{M_1 c^2} + 1$$

After break-up the dynamical situation is identical to the reaction case considered in section III. The results obtained there are still pertinent except that we must rewrite ${}^f\gamma_2'$. Writing the conservation of energy in the c-g frame

183) $$m_1 c^2 = c^2\sqrt{M_2^2({}^f\gamma_2'^2 - 1) + M_1^2} + M_2 c^2\, {}^f\gamma_2'$$

We can solve for ${}^f\gamma_2'$ and obtain

184) $${}^f\gamma_2' = \frac{m_1^2 + M_2^2 - M_1^2}{2 m_1 M_2}$$

There are several special results which may be desirable with respect to this case. Consider first that M_1, M_2, ${}^fT_1$, ${}^fT_2$, and $\Gamma = \theta + \varphi$ are known. Then to obtain m_1, T_0, θ, and φ we write down the conservation equations. Conservation of energy in lab frame:

185) $$M_1 c^2 \gamma_1 = M_1 c^2\, {}^f\gamma_1 + M_2 c^2\, {}^f\gamma_2$$

Conservation of x-momentum

186) $$m_1 c\,(\gamma_1^2 - 1)^{\frac{1}{2}} = M_1 c\,({}^f\gamma_1^2 - 1)^{\frac{1}{2}} \cos\theta + M_2 c\,({}^f\gamma_2^2 - 1)^{\frac{1}{2}} \cos\varphi$$

Conservation of y-momentum:

187) $$M_1 c\,(\gamma_1'^2-1)^{\frac{1}{2}} \sin\theta = M_2 c\,(\gamma_2'^2-1)^{\frac{1}{2}} \sin\varphi$$

Eqs. 185), 186), and 187) can be solved simultaneously together with the relation $\theta+\varphi=\gamma$ to obtain the results

188) $$\cos\varphi = \frac{A\cos\gamma + B}{\sqrt{A^2+2AB\cos\gamma+B^2}}$$

189) $$\cos\theta = \frac{A+B\cos\gamma}{\sqrt{A^2+2AB\cos\gamma+B^2}}$$

190) $$T_0 = c^2\left[M_1\gamma_1' + M_2\gamma_2' - m_1\right]$$

191) $$M_1 = \left[M_1^2 + 2M_1M_2\left\{\gamma_1'\gamma_2' - (\gamma_1'^2-1)^{\frac{1}{2}}(\gamma_2'^2-1)^{\frac{1}{2}}\cos\gamma\right\} + M_2^2\right]^{\frac{1}{2}}$$

where

$$\gamma_1' = \frac{T_1'}{M_1c^2}+1$$

$$\gamma_2' = \frac{T_2'}{M_2c^2}+1$$

$$A = M_1(\gamma_1'^2-1)^{\frac{1}{2}}$$

$$B = M_2(\gamma_2'^2-1)^{\frac{1}{2}}$$

Another special result of interest is to compute M_1, given T_0, T_2', m_1, M_2 and φ. Using Eq. 102) we can write $\cos\Omega$ directly in terms of the unknown M_1

192) $$\gamma_2'\sqrt{T_2'^2+2T_2'M_2c^2}\cos\varphi - \sqrt{\left(\frac{T_0}{M_1c^2}\right)^2+2\left(\frac{T_0}{M_1c^2}\right)}\,(T_2'+M_2c^2) = -M_1c^2(\gamma_2'^2-1)^{\frac{1}{2}}\cos\beta$$

from which we can solve for $\cos\Omega$ and obtain

193) $$\cos\Omega = \frac{\left(\frac{T_2'}{M_1c^2}+1\right)\sqrt{\left(\frac{T_0}{M_1c^2}\right)^2+2\left(\frac{T_0}{M_1c^2}\right)} - \left(\frac{T_0}{M_1c^2}+1\right)\sqrt{\left(\frac{T_2'}{M_1c^2}\right)^2+2\left(\frac{T_2'}{M_1c^2}\right)}\cos\gamma}{(\gamma_2'^2-1)^{\frac{1}{2}}}$$

where ${}^{+}\gamma_2'$ is explicitly a function of M_1 as in Eq. 184). Substituting this value of $\cos\Omega$ in the pertinent result for ${}^{f}E_2$, namely Eq. 86) we obtain

$$194)\quad \left(\frac{{}^{f}T_2}{M_1c^2}+1\right) = \left(\frac{T_0}{m_1c^2}+1\right){}^{f}\gamma_2' - \sqrt{\left(\frac{T_0}{m_1c^2}\right)^2+2\left(\frac{T_0}{m_1c^2}\right)}\ [A-B\cos\varphi]$$

from which we solve for ${}^{f}\gamma_2'$

$$195)\quad {}^{f}\gamma_2' = \frac{\left(\frac{{}^{f}T_2}{M_1c^2}+1\right)+\sqrt{\left(\frac{T_0}{m_1c^2}\right)^2+2\left(\frac{T_0}{m_1c^2}\right)}\ [A-B\cos\varphi]}{\left(\frac{T_0}{m_1c^2}+1\right)}$$

Then solving Eq. 184) for M_1 we finally obtain:

$$196)\quad M_1 = \sqrt{m_1^2 - 2m_1M_2\,{}^{f}\gamma_2' + M_2^2}$$

FLOW DIAGRAM

Input

$m_1(3,7)$; $m_2(3,7)$; $M_1(3,7)$; $M_2(3,7)$, $T_0(5,5)$; $\Delta\theta(5,5)$, ; $\delta = 931.160$

compute & store

$m_1\delta$; $m_2\delta$; $M_1\delta$; $M_2\delta$

TEST

$m_1 = 0$ / $m_1 \neq 0$; $m_2 = 0$ / $m_2 \neq 0$; $M_1 = 0$ / $M_1 \neq 0$; $M_2 = 0$ / $M_2 \neq 0$

	IVb ($M_1=0$, $M_2=0$)	IVa ($M_1=0$, $M_2\neq 0$)	Vb ($m_2=0$, $M_1=0$, $M_2=0$)	Va ($m_2=0$, $M_1=0$, $M_2\neq 0$)	Vt ($m_2=0$, $M_1\neq 0$)	IVd ($m_2\neq 0$, $M_2=0$)	IVc ($m_2\neq 0$, $M_2\neq 0$)	III ($M_1\neq 0$)
γ_1	not needed	not needed	III	III	III	III	III	$\frac{T_0}{m_1c^2}+1$
$'\gamma_2'$	$\frac{1+T_0/m_2c^2}{\left[1+2\left(T_0/m_2c^2\right)\right]^{1/2}}$	IVb	γ_1	γ_1	γ_1	III	III	$\frac{\frac{m_2}{m_1}+\gamma_1}{\left[\left(\frac{m_2}{m_1}\right)^2+2\left(\frac{m_2}{m_1}\right)\gamma_1+1\right]^{1/2}}$
$^+\gamma_1'$	not needed	(11)	not needed	not needed	$\frac{M_1^2+M_2^2-M_3^2}{2M_1M_2}$	not needed	not needed	$\frac{A^2+B^2}{2AM_1}$
$^+\gamma_2'$	$\frac{m_2^2\left[1+2\left(T_0/m_2c^2\right)\right]+M_2^2}{2m_2M_2\left[1+2\left(T_0/m_2c^2\right)\right]^{1/2}}$	III	not needed	$\frac{1+\left(\frac{m_2}{M_2}\right)^2}{2\left(\frac{m_2}{M_2}\right)}$	III	not needed	(6)	$\left[\frac{M_1^2}{M_2^2}\left(^+\gamma_1'^2-1\right)+1\right]^{1/2}$
α_1	$\frac{\left('\gamma_2'^2-1\right)^{1/2}}{'\gamma_2'}$	III	IVb	IVb	III	IVb	IVb	$\frac{^+\gamma_1'\left(^+\gamma_2'^2-1\right)^{1/2}}{'\gamma_2'\left(^+\gamma_1'^2-1\right)^{1/2}}$
θ_{max}	III	III	III	III	III	III	III	$\sin^{-1}\left(\frac{1}{1+{}^+\gamma_2'^2-(^+\gamma_1'^2-1)}\right)$
$\cos\Omega$	III	III	III	III	III	III	III	$\frac{-\alpha\tan^2\frac{\theta}{2}\pm\sqrt{1-\tan^4\frac{\theta}{2}(\alpha^2-1)}}{1+\tan^2\frac{\theta}{2}}$
$^+E_1$	$Mc^2\left(^+\gamma_2'-1\right)+\left[^+\gamma_2'+\left(^+\gamma_2'^2-1\right)^{1/2}\cos\Omega\right]$	III	IVb	IVb	III	$^+E'\left[^+\gamma_2'+\left(^+\gamma_2'^2-1\right)^{1/2}\cos\Omega\right]$	IVb	$Mc^2\left[^+\gamma_1'\,^+\gamma_2'+\left(^+\gamma_1'^2-1\right)^{1/2}\left(^+\gamma_2'^2-1\right)^{1/2}\cos\Omega\right]$
$^+E_2$	$Mc^2\left[^+\gamma_1'\,^+\gamma_2'-\left(^+\gamma_1'^2-1\right)^{1/2}\left(^+\gamma_2'^2-1\right)^{1/2}\cos\Omega\right]$	III	IVb	IVb	III	$^+E'\left[^+\gamma_2'-\left(^+\gamma_2'^2-1\right)^{1/2}\cos\Omega\right]$	IVb	$Mc^2\left[^+\gamma_1'\,^+\gamma_2'-\left(^+\gamma_1'^2-1\right)^{1/2}\left(^+\gamma_2'^2-1\right)^{1/2}\cos\Omega\right]$
$^+T_1$	III	III	III	III	III	III	III	$^+E_1-M_1c^2$
$^+T_2$	III	III	III	III	III	III	III	$^+E_2-M_2c^2$
$J(\theta)$	$\frac{\left(^+\gamma_2'^2-1\right)^{1/2}}{\left(^+T_1/M_2c^2\right)}\left[^+\gamma_2'-\left(^+\gamma_2'^2-1\right)^{1/2}\cos\theta\right]$	III	pIVd	qIVb	III	$\frac{^+E'}{^+T_1}\left[^+\gamma_2'-\left(^+\gamma_2'^2-1\right)^{1/2}\cos\theta\right]$	qIVb	(1)
$J(\varphi)$	(7)	III	pIVd	qIVb	III	$\frac{^+E'}{^+T_2}\left[\cos\varphi\left(^+\gamma_2'^2-1\right)^{1/2}-{}^+\gamma_2'\right]$	qIVb	(2)
$\cos\varphi$	(8)	III	pIVd	qIVb	III	(10)	qIVb	(3)
$\sin\varphi$	(9)	III	pIVd	qIVb	III	(5)	qIVb	(4)

where $A^2 = m_1^2 + 2m_1 m_2 \gamma_1 + m_2^2$

$B^2 = M_1^2 - M_2^2$

$^4E' = \frac{1}{2} m_2 c^2 \left[\sqrt{{}^1\gamma_2'^2 - 1 + \left(\frac{m_1}{m_2}\right)^2} + {}^1\gamma_2' \right]$

* use here $^4E' = \frac{1}{2} m_1 c^2$

EQUATIONS FROM TABLE

(1) $$J(\theta) = ({}^4\gamma_1'^2 - 1)^{\frac{1}{2}} \left[\frac{{}^1\gamma_2' \sqrt{\left(\frac{{}^4T_1}{M_1c^2}\right)^2 + 2\left(\frac{{}^4T_1}{M_1c^2}\right)} - \cos\theta \left(\frac{{}^4T_1}{M_1c^2} + 1\right) ({}^1\gamma_2'^2 - 1)^{\frac{1}{2}}}{\left(\frac{{}^4T_1}{M_1c^2}\right)^2 + 2\left(\frac{{}^4T_1}{M_1c^2}\right)} \right]$$

(2) $$J(\varphi) = ({}^4\gamma_2'^2 - 1)^{\frac{1}{2}} \left[\frac{\cos\varphi \left(\frac{{}^4T_2}{M_2c^2} + 1\right) ({}^1\gamma_2'^2 - 1)^{\frac{1}{2}} - {}^1\gamma_2' \sqrt{\left(\frac{{}^4T_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^4T_2}{M_2c^2}\right)}}{\left(\frac{{}^4T_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^4T_2}{M_2c^2}\right)} \right]$$

(3) $$\cos\varphi = \frac{({}^1\gamma_2'^2 - 1)^{\frac{1}{2}} \left(\frac{{}^4T_2}{M_2c^2} + 1\right) - ({}^4\gamma_2'^2 - 1)^{\frac{1}{2}} \cos\Omega}{{}^1\gamma_2' \sqrt{\left(\frac{{}^4T_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^4T_2}{M_2c^2}\right)}}$$

(4) $$\sin\varphi = \frac{M_1 \sqrt{\left(\frac{{}^4T_1}{M_1c^2}\right)^2 + 2\left(\frac{{}^4T_1}{M_1c^2}\right)}}{M_2 \sqrt{\left(\frac{{}^4T_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^4T_2}{M_2c^2}\right)}} \sin\theta$$

(5) $$\sin\varphi = \frac{{}^4T_1}{{}^4T_2} \sin\theta$$

(6) $$^4\gamma_2' = \frac{2M_2^2 {}^1\gamma_2'^2 + m_1^2 - m_2^2 + M_2^2 + 2m_2 {}^1\gamma_2' \sqrt{m_2^2({}^1\gamma_2'^2 - 1) + m_1^2}}{2M_2 \left[\sqrt{m_2^2({}^1\gamma_2'^2 - 1) + m_1^2} + m_2 {}^1\gamma_2' \right]}$$

(7) $$J(\varphi) = \frac{({}^1\gamma_2'^2 - 1)^{\frac{1}{2}} \left[\cos\varphi ({}^1\gamma_2'^2 - 1)^{\frac{1}{2}} \left(\frac{{}^4T_2}{M_2c^2} + 1\right) - {}^1\gamma_2' \right]}{\sqrt{\left(\frac{{}^4T_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^4T_2}{M_2c^2}\right)}}$$

(8) $$\cos\varphi = \frac{{}^4\gamma_2' ({}^1\gamma_2'^2 - 1)^{\frac{1}{2}} - {}^1\gamma_2' ({}^4\gamma_2'^2 - 1)^{\frac{1}{2}} \cos\Omega}{\sqrt{\left(\frac{{}^4T_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^4T_2}{M_2c^2}\right)}}$$

(9) $$\sin\varphi = \frac{\left(\frac{{}^{f}T_1}{M_2c^2}\right)\sin\theta}{\sqrt{\left(\frac{{}^{f}T_2}{M_2c^2}\right)^2 + 2\left(\frac{{}^{f}T_2}{M_2c^2}\right)}}$$

(10) $$\cos\varphi = \frac{{}^{f}E'\left[\left({}^{f}\gamma_2'^2-1\right)^{\frac{1}{2}} - {}^{f}\gamma_2'\cos\Omega\right]}{{}^{f}T_2}$$

(11) $${}^{f}\gamma_1' = \frac{m_2^2\left[1+2\left(\frac{T_0}{m_2c^2}\right)\right] + M_1^2 - M_2^2}{2m_2M_1\sqrt{1+2\left(\frac{T_0}{m_2c^2}\right)}}$$

Chapter VI Geometrical Interpretation of Relativistic Kinematics.

In classical mechanics it was possible to construct a vector diagram for velocities and hence represent the relationship between the center-of-mass and lab angles. Relativistically, it can be shown that an analogous situation exists; however it is no longer valid to add velocities or momenta vectorially; rather we must find a proper expression for the relative momenta (or velocity) of the two frames. to utilize the vector method.

Using the Lorents transformations we can first transform ${}^{f}p_{x_1}$ and ${}^{f}p_{y_1}$ to the center-of-mass frame as in Eqs. 80) and 81), obtaining

$$ {}^{f}p_{x_1} = \left[{}^{f}p_1' \cos\Omega + u_{cg} \frac{{}^{f}E_1'}{c^2} \right] {}^{i}\gamma_2' $$

$$ {}^{f}p_{y_1} = {}^{f}p_1' \sin\Omega $$

Then noting that ${}^{i}\beta_2' = \frac{u_{cg}}{c}$ and, from Eq. 11)

$$ {}^{i}\gamma_2' = \frac{1}{\left[1 - {}^{i}\beta_2'^2 \right]^{\frac{1}{2}}} $$

we can easily derive the identity

$$ 197) \quad \frac{\left({}^{f}p_{x_1} - \epsilon_1 \right)^2}{{}^{f}p_1'^2 \, {}^{i}\gamma_2'^2} + \frac{{}^{f}p_{y_1}^2}{{}^{f}p_1'^2} = 1 $$

where

$$ 198) \quad \epsilon_1 = M_1 c \, {}^{f}\gamma_1' \left({}^{i}\gamma_2'^2 - 1 \right)^{1/2} $$

and use has been made of Eq. 74) for ${}^{f}E_1'$.

If we set ${}^{f}p_1' = b_1$ and ${}^{i}\gamma_2' \, {}^{f}p_1' = a_1$ and note that ${}^{f}p_1' = {}^{f}p_2'$ from the properties of the center-of-mass frame, then $a_1 = a_2 = a$ and $b_1 = b_2 = b$. In a completely analogous fashion we might write an expression for the momentum of particle M_2 by merely replacing subscript "1" in Eqs. 197) and 198) by sub-

script "2". Generalising by using the subscript "n" where n = 1, 2 we can rewrite 197) and 198) as:

$$199) \qquad \frac{\left({}^{f}p_{n_x} - \epsilon_n\right)^2}{a^2} + \frac{{}^{f}p_{n_y}{}^2}{b^2} = 1$$

$$200) \qquad \epsilon_n = M_n c\, {}^{f}\gamma_n' \left({}^{i}\gamma_2'^2 - 1\right)^{1/2}$$

Eq. 199) is the equation of a rectangular ellipse displaced a distance ϵ_n along the ${}^{f}p_{n_x}$ axis with semi-major axis a, semi-minor axis b, and with eccentricity

$$e = 1 - \frac{b^2}{a^2}$$

and foci located a distance

$$f = ae$$

to the right and left of the center of the ellipse. Hence the locus of points described by the vector ${}^{f}\vec{p}_n$ is an ellipse in momentum space, the result 199) being easily generalized to three dimensions where the locus is an ellipsoid of revolution.

There are clearly three possible situations,

(1) $\epsilon_n > a$, (2) $\epsilon_n < a$ and (3) $\epsilon_n = a$. Or, if we set $a_n = \frac{\epsilon_n}{a}$ these three cases become $a_n > 1$; $a_n < 1$, and $a_n = 1$ respectively. From the definition of the quantities ϵ_n and "a" it is readily demonstrated that a_n is identical to the a_n introduced previously in Eq. 82). The case for $a_n > 1$ is illustrated graphically in Fig. 17 and for $a_n < 1$ in Fig. 18.

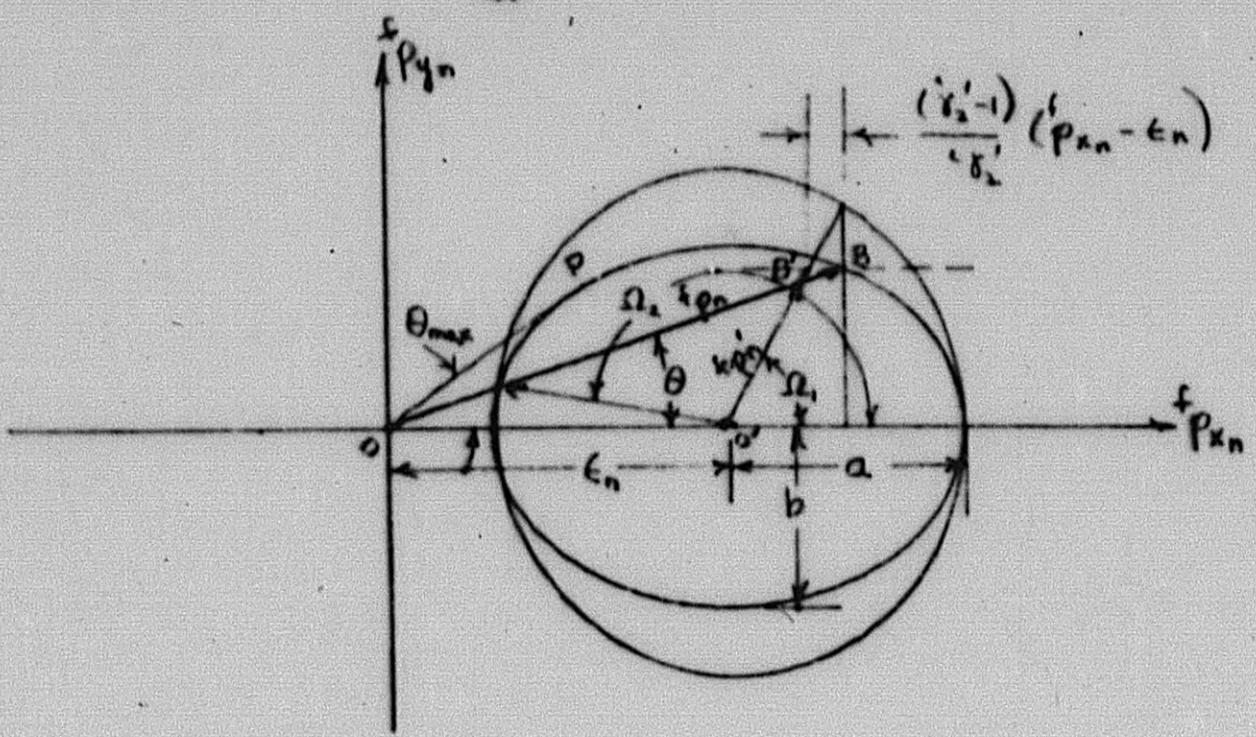
$f\rho_{yn}$
$\frac{(\gamma_2'-1)}{\gamma_2'}(f\rho_{xn}-\epsilon_n)$
P
B'
B
Ω_2
$i\rho_n$
θ_{max}
θ
$i\rho_n'$
Ω_1
$f\rho_{xn}$
o
o'
ϵ_n
a
b

Fig. 17

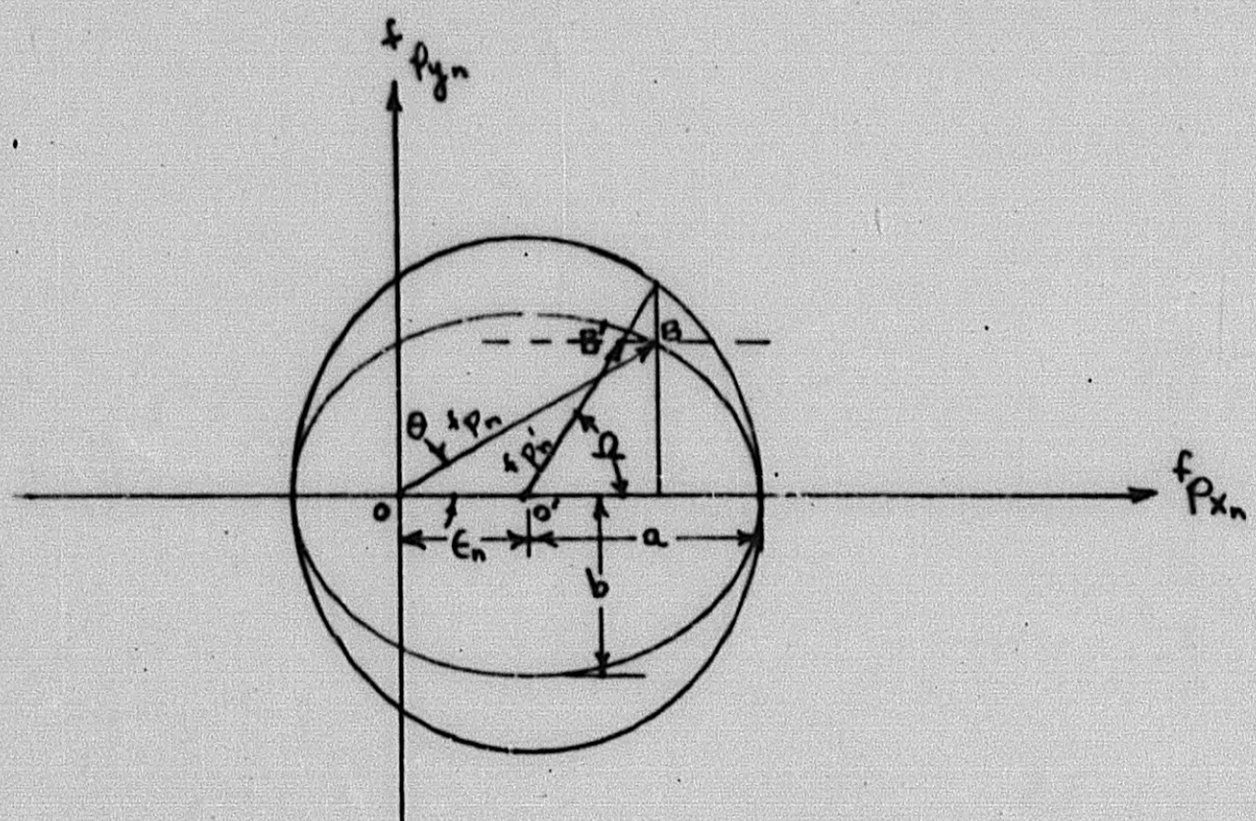
$f\rho_{yn}$
B'
B
θ
$i\rho_n$
$i\rho_n'$
Ω
$f\rho_{xn}$
o
o'
ϵ_n
a
b

Fig. 18

In Fig. 17 it is evident that θ will have a maximum value less than $\frac{\pi}{2}$ and further that there are two possible orientations of ${}^{f}P_{n}'$ and hence of Ω for a given θ. The vector $\vec{BB}'$ will diminish to zero in the classical limit as ${}^{i}\gamma_{2}' \to 1$ and the points B and B' will coalesce on the circle of radius "a" which is the classical locus when $b \to a$. The magnitude of $\vec{BB}'$ may be computed directly from the known lengths ${}^{f}p_{n_x}$ and ${}^{f}p_{n_x}'$ as

$$201) \qquad \left|\vec{BB}'\right| = \frac{({}^{i}\gamma_{2}' - 1)}{{}^{i}\gamma_{2}'} \left({}^{f}p_{n_x} - \delta_{n}\right) \quad .$$

TABLE IX

MASSES OF ELEMENTARY PARTICLES AND LIGHT NUCLEI

(ALL VALUES IN AMU*)

	MASS		MASS		MASS
e	$5.48760\ 10^{-4}$	O^{9}	9.0346	Ne^{20}	19.998769
H^{1}	1.008145	C^{10}	10.020240	Ne^{21}	21.000499
n	1.008986	C^{11}	11.014922	Ne^{22}	21.998354
H^{2}	2.014740	C^{12}	12.003803	Ne^{23}	23.001764
H^{3}	3.017005	C^{13}	13.007478	Na^{20}	20.01536
He^{3}	3.016986	C^{14}	14.007687	Na^{21}	21.004281
He^{4}	4.003873	C^{15}	15.014162	Na^{22}	22.001404
He^{5}	5.013888	N^{12}	12.022776	Na^{23}	22.997053
He^{6}	6.02083	N^{13}	13.009864	Na^{24}	23.998565
He^{7}	7.0338	N^{14}	14.007520	Mg^{23}	23.001453
Li^{5}	5.013948	N^{15}	15.004862	Mg^{24}	23.992640
Li^{6}	6.017034	N^{16}	16.011171	Mg^{25}	24.993752
Li^{7}	7.018232	N^{17}	17.013984	Mg^{26}	25.990798
Li^{8}	8.025033	O^{14}	14.013069	Mg^{27}	26.992868
Li^{9}	9.0302	O^{15}	15.007767	Mg^{28}	27.992714
Be^{6}	6.0223	O^{16}	16.000000	Al^{24}	24.007691
Be^{7}	7.019159	O^{17}	17.004534	Al^{25}	24.998312
Be^{8}	8.007849	O^{18}	18.004855	Al^{26}	25.995120
Be^{9}	9.015046	O^{19}	19.009591	Al^{27}	26.990080
Be^{10}	10.016716	O^{20}	20.0143	Al^{28}	27.990771
Be^{11}	11.0251	F^{16}	16.0171	Al^{29}	28.989925
B^{8}	8.026768	F^{17}	17.007506		
B^{9}	9.016195	F^{18}	18.006646		
B^{10}	10.016119	F^{19}	19.004448		
B^{11}	11.012795	F^{20}	20.006340		
B^{12}	12.018168	Ne^{18}	18.011185		
B^{13}	13.0204	Ne^{19}	19.007945		

* In converting from AMU to MEV the factor = 931.160 MEV/AMU is used, based on the best values for Avegadro's number A, the velocity of light in vacuum c, and the charge on the electron e.

$A = 6.02472\ 10^{23}$ particles/mole at STP

$c = 2.997929\ 10^{10}$ cm/sec

$e = 1.60207\ 10^{-19}$ coulombs (MKS)

TABLE I

LIGHT MESON DATA

PARTICLE	MASS (in electron mass)	MASS (in AMU)	REFERENCE	POSSIBLE DECAY SCHEMES
μ^+	207.0 ± 0.4	0.11359	12	$\mu^+ \rightarrow \beta^+ + 2\nu$
μ^-	209.8 ± 2.2	0.11513	14	$\mu^- \rightarrow \beta^- + 2\nu$
π^0	264.6 ± 3.2	0.14520	5	$\pi^0 \rightarrow 2\gamma$
π^-	272.5 ± 0.3	0.14954	12	$\pi^- \rightarrow \mu^- + \nu$
				$\pi^- \rightarrow \mu^- + \nu + \gamma$
π^+	273.4 ± 0.2	0.15003	12	$\pi^+ \rightarrow \mu^+ + \nu$
				$\pi^+ \rightarrow \mu^+ + \nu + \gamma$

HEAVY MESON DATA

S^+	914 ± 20	0.5016	8	$S^+ \rightarrow \mu^+ + \nu + \gamma$
S^-	914 ± 20	0.5016	8	$S^- \rightarrow \mu^- + \nu + \gamma$
K_μ^+	950 ± 15	0.5213	13	$K_\mu^+ \rightarrow \mu^+ + \nu$
τ^+	965.5 ± 0.7	0.52983	8	$\tau^+ \rightarrow 2\pi^+ + \pi^-$
				$\tau^+ \rightarrow \pi^+ + 2\pi^0$
				$\tau^+ \rightarrow \pi^+ + \gamma$
τ^-	965.5 ± 0.7	0.52983	8	$\tau^- \rightarrow 2\pi^- + \pi^+$
				$\tau^- \rightarrow \pi^- + 2\pi^0$
				$\tau^- \rightarrow \pi^- + \gamma$
θ^0	966 ± 10	0.5301	8	$\theta^0 \rightarrow \pi^+ + \pi^-$
				$\theta^0 \rightarrow \pi^\pm + \mu^\mp$
χ^+	966 ± 12	0.5301	13	$\chi^+ \rightarrow \pi^+ + \pi^0$
χ^-	966 ± 12	0.5301	13	$\chi^- \rightarrow \pi^- + \pi^0$
χ^+	974 ± 42	0.5345	11	$\chi^+ \rightarrow \mu^+ + \nu + \gamma$
				$\chi^+ \rightarrow \mu^+ + N^0$
χ^-	974 ± 42	0.5345	11	$\chi^- \rightarrow \mu^- + \nu + \gamma$
				$\chi^- \rightarrow \mu^- + N^0$
V^+	1000	0.54876	8	$V^+ \rightarrow \pi^+ + 2N^0$
V^-	1000	0.54876	8	$V^- \rightarrow \pi^- + 2N^0$
V_3^0			8	$V_3^0 \rightarrow \tau^\pm + \pi^\mp$
K_B^+	1000 ± 150	0.54876	5	$K_B^+ \rightarrow \beta^+ + 2N^0$
K_B^-	1000 ± 150	0.54876	5	$K_B^- \rightarrow \beta^- + 2N^0$

HYPERON DATA

PARTICLE	MASS (in electron masses)	MASS (in AMU)	REFERENCE	POSSIBLE DECAY SCHEMES
Λ^0	2181 ± 1	1.1968	13	$\Lambda^0 \rightarrow p^+ + \pi^-$
Σ^+	2327 ± 3	1.2770	13	$\Sigma^+ \rightarrow p^+ + \pi^0$
				$\Sigma^+ \rightarrow n^0 + \pi^+$
Σ^-	2327 ± 3	1.2770	13	$\Sigma^- \rightarrow n^0 + \pi^-$
H^+	2540 ± 30	1.3938	13	$H^+ \rightarrow \Lambda^0 + \pi^+$
H^-	2540 ± 30	1.3938	13	$H^- \rightarrow \Lambda^0 + \pi^-$

Bibliography

1. Experimental Nuclear Physics. Segre, E. ed. Vol. 2. John Wiley and Sons, Inc. (1953)

Chapter I by P. Morrison contains most of the derivations and formulae used in section II of this report on elastic scattering. Morrison's notation is also adopted in this report. Further, the momentum four-vector used in this report is presented by Morrison.

2. Quantum Mechanics. Schiff, L.I. McGraw-Hill (1949)

The non-relativistic limit for the Jacobian from the center-of-mass to lab system is given on page 99.

3. The Classical Theory of Fields. Landau, L. and Lifschuts, E. tr. by M. Hamermesh. Addison-Wesley (1951)

Relativistic kinematics is summarized here in chapter The examples of the formulations of the relativistic decay problem on page were useful in deriving the formulae of section V of this report.

4. Introduction to the Theory of Relativity. Bergmann, P. Prentice-Hall

This work was used as background material only. Use of the Lorentz transformation is illustrated as well as the fundamental relativistic formulae for energy and momentum in inertial frames of reference.

5. Meson Physics. Marshak, R. McGraw-Hill (1952)

The relativistic kinematics of simple meson production is presented, as well as a chapter on multiple meson production. The pertinent formulae of sections IV and V of this report are found in Marshak with slightly different notation.

6. LA-723. Los Alamos Scientific Laboratory. Semes, A., Carlson, B., Goldstein, M., Rosen, L., and Sweeney, D. (1949)

All of the formulae of sections II and III of this report may be reduced in the classical limit to those in LA-723 providing that the following corrections are made:

(1) replace equation D on page 10 by

$$m = \frac{\sqrt{m_2 M_2}\sqrt{2 M_1 E_T}}{M_1 + M_2}\sqrt{\frac{M_1+M_2-m_1}{m_2} + \frac{m_1}{m_2}\frac{Q}{E_T}}$$

(2) replace equation 2.10, page 12 by

$$\sin\theta = \sqrt{\frac{M_2}{M_1}\frac{E_2/E_T}{(A_1+B_1+A_2+B_2-E_2/E_T)}}\ \sin\varphi$$

(3) replace equation 2.1 for B_1 and B_2 by

$$B_1 = \frac{m_2 M_2}{(M_1+M_2)^2}\left[\frac{M_1+M_2-m_1}{m_2} + \frac{m_1}{m_2}\frac{Q}{E_T}\right]$$

$$B_2 = \frac{m_2 M_1}{(M_1+M_2)^2}\left[\frac{M_1+M_2-m_1}{m_2} + \frac{m_1}{m_2}\frac{Q}{E_T}\right]$$

In equation 2.1 the expressions for A_1 and A_2 remain unchanged. Otherwise, LA-723 presents the correct classical formulation of the two-body problem and the general outline of that report has been adopted for the relativistic formulation.

The notation corresponds to the notation adopted for angles in this report, but the inherent difference between total energy and kinetic energy in relativistic dynamics required the adoption of T for the kinetic energy. Furthermore, it was not found necessary in the present work, as in LA-723 to restrict M_1 to being the heavy particle produced in a reaction; rather, the formulation here is sufficiently general so that M_1 may be either the heavy or light particle, depending on which distribution is desired. In the present work, the tables are computed only on intervals of θ.

Finally, the formulation of the Rutherford scattering problem in LA-723 was omitted in the present work since, with the exception of electron-electron scattering, the usefulness of the coulomb cross-section diminishes at relativistic energies.

7. On a Geometrical Interpretation of Energy and Momentum Conservation in Atomic Collisions and Disintegration Processes. Blaton, J., Danske Videnskab. Selskab Mat.-Fys Medd. Bind XXIV, Nr. 20 (1950).

Section VI of this report is based on Blaton's geometrical representation of the reaction process using the momentum ellipsoid for the vector additions. The results given here are specialised to two dimensions and use different notation than Blaton.

8. Heavy Mesons. Delvorth, Occhialini, and Scarsi. Annual Reviews of Nuclear Science. Vol. 4, p. 271. Annual Reviews, Inc., Stanford, California (1954).

Many of the mass values of the heavy mesons in Table I are taken from this review article. Also the decay schemes presented were helpful in formulating Sections IV and V.

9. Mesons and Heavy Unstable Particles in Cosmic Rays. Leprince-Ringuet. Annual Review of Nucl. Sci., Vol. 3, p. 39. Annual Reviews, Inc., Stanford, California (1953).

The decay schemes for hyperons were useful in Section V of this report, as well as mass values for the heavy mesons.

10. Energy Levels of Light Nuclei. V. Ajzenberg, F. and Lauritsen, T., Rev. Mod. Phys., Vol. 27, No. 1, 77 (1955).

Table IX is taken partly from p. 157 of this article.

11. An Improved Method for Determining the Mass of Particles from Scattering Versus Range and its Applications to the Mass of K Mesons. Biswas, S., George, E., and Peters, B. Proceedings of the Indian Academy of Science 38A (1953).

12. Measurement of Meson Masses and Related Quantities. Smith, F., Birnbaum, W., and Barkas, W. Phys. Rev. 91, 765(1953).

13. Observations on Heavy Mesons and Hyperons. Nature, June 4, 1955, p. 971.

14. On the Lifetime of the Negative Pi-Meson. Lederman, L., Booth, E., Byfield, H., and Kessler, J. Phys. Rev. 83, 685(1951).

15. Isotopic Masses I. A 34. Wapstra, A.H. Physica, Deel XXI, No. 5, 367(1955).

This is the primary reference for Table IX.

Chapter VII. Computations

The calculation as outlined on page 39 has been coded for the I.B.M. Electronic Data Processing Machine, Type 701. The input data consist of the quantities T_0, m_1, m_2, M_1, M_2, and $\Delta\theta$ with scaling and units as illustrated on the key-punch form, page.[56] The logic of deciding which case to compute and whether or not the quantities involved are double-valued is written into the code. The results are illustrated in Tables XI-LXVI; a complete calculation and listing for a case of $0 \leq \theta \leq \pi$ and $\Delta\theta = 5^\circ$ requires 37 seconds of machine time. The input data are printed out at the top of each listing in the order they appear on the key-punch form.

The significance of the results for ${}^{f}T_1(\theta)$ and ${}^{f}T_2(\theta)$ may be evaluated from the conservation of energy in the laboratory frame as

$$202) \qquad {}^{f}T_1 + {}^{f}T_2 = (m_1 + m_2 - M_1 - M_2)c^2 + T_0$$

It is assumed that ${}^{f}T_1$ and ${}^{f}T_2$ are known to the same significance as is the sum ${}^{f}T_1 + {}^{f}T_2$. Using this procedure it has been observed that the accuracy is a function both of T_0 and θ but in no case are the results less significant than $\pm$ 100 ev. When the sum ${}^{f}T_1 + {}^{f}T_2 \geq$ 20 Mev and relativistic effects become significant to the order of 0.5%, it has been noted that the signficance of the results improve to the order of $\pm$ 10 ev. This loss of significance at low energies is due to the dropping of significant digits inherent in the relativistic quantity $(\gamma^2 - 1)^{\frac{1}{2}}$ when γ is on the order of unity.

It has been found necessary to limit the output of the

Jacobian transformations $J(\theta)$ and $J(\varphi)$ to the decimal scaling (3,7). When they exceed this amount the quantity *999.9999999 is printed. Further, only the absolute values of these transformations are tabulated.

The code has not been designed to handle cases where the bombarding energy T_0 is less than the threshold energy T_{TH} of an endothermic reaction. To obtain a relativistic expression for T_{TH}, we can first write the expression for the conservation of total energy in the center-of-mass frame as

$$203) \quad m_1c^2\gamma_1' + m_2c^2\gamma_2' = M_1c^2 + M_2c^2$$

for the case when the kinetic energies of both reaction products M_1 and M_2 vanish. Substitution of eq. 196) for γ_1' in terms of γ_2' and of eq. 9) for γ_1 we obtain for the threshold

$$204) \quad T_{TH} = \left[\frac{(M_1+M_2)^2 - (m_1+m_2)^2}{2m_2}\right] c^2$$

Upon substitution of the reaction "Q" defined as

$$205) \quad Q = (m_1+m_2)c^2 - (M_1+M_2)c^2$$

we can write eq. 204) in the more convenient form

$$206) \quad T_{TH} = -Q\left[\frac{m_1+m_2+M_1+M_2}{2m_2}\right]$$

The significance of the ratio $\frac{T}{Mc^2}$ has been investigated and, for the special case of elastic scattering may be shown to depend only on the ratio $\frac{m_2}{m_1}$. Further, in this case, the

quantities $J(\theta)$, $J(\varphi)$, φ and Ω also depend only on this mass ratio. Hence a listing for proton-proton scattering at a given bombarding energy is also valid for deuteron-deuteron scattering, etc. with the qualification that the quantities $\frac{4T_1}{M_1c^2}$ and $\frac{4T_2}{M_2c^2}$ are formed.

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RELATIVISTIC TWO-BODY PROBLEM

(Always punch zero in columns 61-63 and 67-70)

T_0 (MEV)										m_1 (AMU)										m_2 (AMU)										M_1 (AMU)										M_2 (AMU)										$\Delta\theta$ (DEG)		
10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	64	65	66

	5.00000	1.0089861	1.0081450	1.0089861	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	5.00006	0.00001	0.2491304	*999.9999999	0.0000000	179.9999997
	0.00002	5.00001	*999.9999999	0.2493360	179.9999997	0.0000000
2.50	4.99051	0.00956	0.2493703	4.0311297	5.0087329	86.7474396
	0.00002	5.00001	*999.9999999	0.2493360	179.9860038	0.0000000
5.00	4.96194	0.03813	0.2500922	2.7939045	10.0173905	84.8561019
	0.00002	5.00001	*999.9999999	0.2493360	179.9914204	0.0098771
7.50	4.91457	0.08549	0.2513030	1.9072848	15.0259748	82.4488238
	0.00002	5.00001	*999.9999999	0.2493360	179.9901240	0.0148274
10.00	4.84877	0.15130	0.2530143	1.4374967	20.0344361	79.9592640
	0.00002	5.00001	*999.9999999	0.2493360	179.9869165	0.0191542
12.50	4.76503	0.23503	0.2552429	1.1539875	25.0427306	77.4575635
	0.00002	5.00001	*999.9999999	0.2493360	179.9851730	0.0237224
15.00	4.66401	0.33606	0.2580108	0.9652299	30.0508205	74.9535252
	0.00002	5.00001	*999.9999999	0.2493360	179.9843609	0.0284138
17.50	4.54646	0.45360	0.2613463	0.8307890	35.0586738	72.4478088
	0.00002	5.00001	*999.9999999	0.2493360	179.9802296	0.0331760
20.00	4.41330	0.58676	0.2652843	0.7304028	40.0662545	69.9418292
	0.00002	5.00001	*999.9999999	0.2493360	179.9808443	0.0376671
22.50	4.26555	0.73451	0.2698672	0.6527598	45.0735364	67.4363874
	0.00002	5.00001	*999.9999999	0.2493360	179.9802296	0.0422575
25.00	4.10433	0.89574	0.2751466	0.5910262	50.0804972	64.9306350
	0.00002	5.00001	*999.9999999	0.2493361	179.9757779	0.0466536
27.50	3.93087	1.06919	0.2811842	0.5408941	55.0871145	62.4255248
	0.00002	5.00001	*999.9999999	0.2493361	179.9724735	0.0559547
30.00	3.74652	1.25355	0.2880542	0.4994649	60.0933753	59.9206135
	0.00002	5.00001	*999.9999999	0.2493361	179.9715869	0.0605708
32.50	3.55266	1.44739	0.2958456	0.4647450	65.0992736	57.4162834
	0.00002	5.00001	*999.9999999	0.2493362	179.9679510	0.0650506
35.00	3.35079	1.64926	0.3046653	0.4353032	70.1048072	54.9121667
	0.00002	5.00001	*999.9999999	0.2493362	179.9646877	0.0694140
37.50	3.14245	1.85760	0.3146422	0.4100982	75.1099840	52.4086248
	0.00002	5.00001	*999.9999999	0.2493362	179.9626611	0.0736870
40.0	2.92922	2.07083	0.3259328	0.3883451	80.1148217	49.9055009
	0.00002	5.00001	*999.9999999	0.2493362	179.9592152	0.0777254
42.50	2.71274	2.28731	0.3387279	0.3694467	85.1193469	47.4028386
	0.00002	5.00001	*999.9999999	0.2493362	179.9563207	0.0817158
45.00	2.49464	2.50541	0.3532625	0.3529388	90.1236002	44.9005663
	0.00002	5.00001	*999.9999999	0.2493362	179.9520552	0.0855156
47.50	2.27660	2.72345	0.3698280	0.3384564	95.1276369	42.3986863
	0.00002	5.00001	*999.9999999	0.2493363	179.9478978	0.0892922
50.0	2.06026	2.93979	0.3887904	0.3257087	100.1315303	39.8971811
	0.00002	5.00001	*999.9999999	0.2493363	179.9431816	0.0926530
52.50	1.84728	3.15277	0.4106144	0.3144613	105.1353775	37.3959866
	0.00002	5.00001	*999.9999999	0.2493363	179.9380332	0.0960255
55.00	1.63927	3.36077	0.4358991	0.3045237	110.1393029	34.8950274
	0.00002	5.00001	*999.9999999	0.2493364	179.9321882	0.0991583
57.50	1.43781	3.56223	0.4654292	0.2957397	115.1434779	32.3941965
	0.00002	5.00001	*999.9999999	0.2493364	179.9254864	0.1020734
60.00	1.24444	3.75561	0.5002525	0.2879807	120.1481186	29.8934467
	0.00002	5.00001	*999.9999999	0.2493364	179.9176894	0.1047938
62.50	1.06060	3.93944	0.5417990	0.2811399	125.1535267	27.3925323
	0.00002	5.00001	*999.9999999	0.2493364	179.9088083	0.1073296
65.00	0.88771	4.11233	0.5920724	0.2751284	130.1601157	24.8912502
	0.00002	5.00001	*999.9999999	0.2493364	179.8981652	0.1096981
67.50	0.72707	4.27297	0.6539682	0.2698726	135.1684742	22.3893680
	0.00003	5.00001	*999.9999999	0.2493365	179.8853949	0.1207352
70.0	0.57989	4.42015	0.7318309	0.2653103	140.1794814	19.8863540
	0.00003	5.00001	*999.9999999	0.2493366	179.8695289	0.1228455
72.50	0.44729	4.55275	0.8324887	0.2613904	145.1945081	17.3815168
	0.00003	5.00001	*999.9999999	0.2493366	179.8496693	0.1332541
75.00	0.33026	4.66977	0.9673209	0.2580704	150.2158269	14.8737002
	0.00003	5.00000	*999.9999999	0.2493368	179.8220947	0.1431668
77.50	0.22971	4.77033	1.1568017	0.2553154	155.2475877	12.3608891
	0.00004	4.99999	*999.9999999	0.2493369	179.7845401	0.1525120
80.00	0.14637	4.85367	1.4418286	0.2530972	160.2982283	9.8387426
	0.00005	4.99999	*999.9999999	0.2493371	179.7279939	0.1754807
82.50	0.08088	4.91916	1.9174445	0.2513935	165.3883271	7.2971404
	0.00007	4.99996	*999.9999999	0.2493377	179.6314940	0.2135209
85.00	0.03368	4.96635	2.8629306	0.2501867	170.5872156	4.7014856
	0.00015	4.99989	657.0189409	0.2493396	179.4261597	0.3073834
87.50	0.00443	4.99561	4.5048732	0.2494473	176.5973233	1.7031545
	0.00098	4.99905	19.7557799	0.2493607	178.4093902	0.8021678
87.6703781	0.00204	5.00208	24.8894319	0.2493357	179.9999997	0.0000000
	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.1103662

	10.00000	1.0089861	1.0081450	1.0089861	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	10.00004	0.00001	0.2484690	*999.9999999	0.0000000	179.9999997
	0.00002	10.00005	*999.9999999	0.2486755	179.9999997	0.0000000
2.50	9.98089	0.01916	0.2487107	4.6302064	5.0153831	87.0026458
	0.00002	10.00005	*999.9999999	0.2486755	179.9879037	0.0000000
5.00	9.92361	0.07644	0.2494383	2.8364037	10.0306451	84.9173922
	0.00002	10.00005	*999.9999999	0.2486755	179.9999997	0.0000000
7.50	9.82863	0.17142	0.2506585	1.9100498	15.0457334	82.4403059
	0.00002	10.00005	*999.9999999	0.2486755	179.9914204	0.0098771
10.00	9.69669	0.30336	0.2523831	1.4377814	20.0605486	79.9359754
	0.00002	10.00005	*999.9999999	0.2486755	179.9836121	0.0130815
12.50	9.52880	0.47125	0.2546287	1.1539467	25.0749908	77.4264688
	0.00002	10.00005	*999.9999999	0.2486755	179.9901240	0.0171295
15.00	9.32628	0.67378	0.2574176	0.9650231	30.0889917	74.9148589
	0.00002	10.00005	*999.9999999	0.2486755	179.9821630	0.0203891
17.50	9.09066	0.90939	0.2607780	0.8305615	35.1024602	72.4035129
	0.00002	10.00005	*999.9999999	0.2486755	179.9796112	0.0231050
20.00	8.82378	1.17627	0.2647448	0.7301548	40.1153218	69.8922992
	0.00002	10.00005	*999.9999999	0.2486755	179.9836121	0.0266276
22.50	8.52769	1.47236	0.2693606	0.6524787	45.1275151	67.3816133
	0.00002	10.00005	*999.9999999	0.2486755	179.9778827	0.0296855
25.00	8.20467	1.79538	0.2746770	0.5907270	50.1389738	64.8715563
	0.00002	10.00005	*999.9999999	0.2486755	179.9743026	0.0328011
27.50	7.85721	2.14285	0.2807560	0.5405690	55.1496442	62.3622764
	0.00002	10.00005	*999.9999999	0.2486755	179.9747907	0.0360072
30.00	7.48797	2.51209	0.2876719	0.4991176	60.1594862	59.8538801
	0.00002	10.00005	*999.9999999	0.2486756	179.9699180	0.0389405
32.50	7.09979	2.90027	0.2955137	0.4643741	65.1684612	57.3464315
	0.00002	10.00005	*999.9999999	0.2486756	179.9683385	0.0419637
35.00	6.69565	3.30441	0.3043886	0.4349113	70.1765485	54.8399266
	0.00002	10.00005	*999.9999999	0.2486756	179.9650304	0.0447833
37.50	6.27863	3.72143	0.3144259	0.4096839	75.1837354	52.3343835
	0.00002	10.00005	*999.9999999	0.2486756	179.9620166	0.0474355
40.00	5.85193	4.14812	0.3257824	0.3879095	80.1900249	49.8298712
	0.00002	10.00005	*999.9999999	0.2486756	179.9592152	0.0501942
42.50	5.41882	4.58124	0.3386494	0.3689903	85.1954345	47.3263686
	0.00002	10.00005	*999.9999999	0.2486756	179.9563207	0.0528018
45.00	4.98257	5.01748	0.3532623	0.3524624	90.1999984	44.8238473
	0.00002	10.00004	*999.9999999	0.2486756	179.9517944	0.0550692
47.50	4.54653	5.45352	0.3699133	0.3379608	95.2037692	42.3222907
	0.00002	10.00004	*999.9999999	0.2486756	179.9474247	0.0574625
50.00	4.11401	5.88605	0.3889697	0.3251948	100.2068259	39.8216732
	0.00002	10.00004	*999.9999999	0.2486756	179.9427532	0.0597537
52.50	3.68830	6.31176	0.4108960	0.3139302	105.2092724	37.3219609
	0.00002	10.00004	*999.9999999	0.2486756	179.9374409	0.0619673
55.00	3.27261	6.72745	0.4362942	0.3039761	110.2112457	34.8230127
	0.00002	10.00004	*999.9999999	0.2486756	179.9314730	0.0639104
57.50	2.87011	7.12996	0.4659505	0.2951767	115.2129322	32.3247429
	0.00002	10.00004	*999.9999999	0.2486757	179.9248382	0.0720082
60.0-	2.48382	7.51624	0.5009154	0.2874033	120.2145703	29.8270322
	0.00002	10.00004	*999.9999999	0.2486757	179.9171008	0.0740169
62.50	2.11668	7.88338	0.5426226	0.2805497	125.2164878	27.3296807
	0.00002	10.00004	*999.9999999	0.2486757	179.9080074	0.0758144
65.00	1.77146	8.22860	0.5930810	0.2745256	130.2191280	24.8324450
	0.00003	10.00004	*999.9999999	0.2486757	179.8973307	0.0836946
67.50	1.45074	8.54932	0.6551936	0.2692585	135.2231205	22.3349597
	0.00003	10.00004	*999.9999999	0.2486758	179.8843332	0.0852302
70.00	1.15696	8.84310	0.7333164	0.2646862	140.2293779	19.8367644
	0.00003	10.00004	*999.9999999	0.2486758	179.8684038	0.0927870
72.50	0.89231	9.10775	0.8342955	0.2607575	145.2393234	17.3371181
	0.00003	10.00003	*999.9999999	0.2486759	179.8476465	0.0998970
75.00	0.65879	9.34127	0.9695401	0.2574298	150.2552964	14.8347951
	0.00004	10.00002	*999.9999999	0.2486760	179.8205897	0.1117944
77.50	0.45815	9.54191	1.1595777	0.2546682	155.2815214	12.3276442
	0.00005	10.00001	*999.9999999	0.2486761	179.7829568	0.1274378
80.00	0.29188	9.70818	1.4454117	0.2524446	160.3265479	9.8113742
	0.00007	9.99999	*999.9999999	0.2486764	179.7255762	0.1537101
82.50	0.16122	9.83884	1.9223190	0.2507367	165.4112227	7.2755433
	0.00012	9.99994	*999.9999999	0.2486770	179.6281897	0.1987490
85.00	0.06708	9.93299	2.8700952	0.2495270	170.6056893	4.6852288
	0.00027	9.99979	705.1216736	0.2486789	179.4207096	0.2969826
87.50	0.00865	9.99141	4.4337955	0.2487848	176.6319908	1.6810937
	0.00201	9.99805	18.8756723	0.2487009	178.3813499	0.8101626
87.6588308	0.00414	10.00420	24.6748749	0.2486749	179.9999997	0.0000000
	0.00002	10.00005	*999.9999999	0.2486757	179.9999991	0.0778845

		20.00000	1.0089861	1.0081450	1.0089861	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	19.99998	0.00001	0.2471618	*999.9999999	0.0000000	179.9999997
	0.00003	19.99996	*999.9999999	0.2473658	179.9999997	0.0000000
2.50	19.96149	0.03850	0.2474073	5.1739731	5.0285962	87.2272358
	0.00003	19.99996	*999.9999999	0.2473658	179.9999997	0.0000000
5.00	19.84632	0.15367	0.2481460	2.8514757	10.0570071	84.9174447
	0.00003	19.99996	*999.9999999	0.2473658	179.9860038	0.0000000
7.50	19.65539	0.34460	0.2493850	1.9124686	15.0850099	82.4110370
	0.00003	19.99996	*999.9999999	0.2473658	179.9859032	0.0085777
10.00	19.39018	0.60982	0.2511359	1.4382747	20.1124445	79.8888966
	0.00003	19.99996	*999.9999999	0.2473658	179.9860038	0.0120944
12.50	19.05277	0.94722	0.2534155	1.1538768	25.1391079	77.3644406
	0.00003	19.99996	*999.9999999	0.2473658	179.9901240	0.0148274
15.00	18.64581	1.35418	0.2562460	0.9647968	30.1648337	74.8405729
	0.00003	19.99996	*999.9999999	0.2473658	179.9821630	0.0178372
17.50	18.17250	1.82750	0.2596558	0.8302177	35.1894412	72.3174404
	0.00003	19.99996	*999.9999999	0.2473658	179.9836121	0.0209872
20.00	17.63651	2.36349	0.2636800	0.7297266	40.2127773	69.7953310
	0.00003	19.99996	*999.9999999	0.2473659	179.9796112	0.0237224
22.50	17.04203	2.95796	0.2683613	0.6519828	45.2346891	67.2746912
	0.00003	19.99996	*999.9999999	0.2473659	179.9796112	0.0266276
25.00	16.39370	3.60629	0.2737516	0.5901727	50.2550438	64.7556942
	0.00003	19.99996	*999.9999999	0.2473659	179.9773462	0.0292585
27.50	15.69655	4.30344	0.2799129	0.5399581	55.2737199	62.2383229
	0.00003	19.99996	*999.9999999	0.2473659	179.9729131	0.0320497
30.0	14.95600	5.04399	0.2869200	0.4984530	60.2906112	59.7228173
	0.00003	19.99996	*999.9999999	0.2473659	179.9703352	0.0349706
32.50	14.17777	5.82222	0.2948623	0.4636578	65.3056301	57.2092597
	0.00003	19.99996	*999.9999999	0.2473659	179.9687222	0.0395612
35.00	13.36787	6.63212	0.3038474	0.4341457	70.3187082	54.6977375
	0.00003	19.99996	*999.9999999	0.2473659	179.9668223	0.0422575
37.50	12.53255	7.46745	0.3140052	0.4088715	75.3297966	52.1883197
	0.00003	19.99996	*999.9999999	0.2473659	179.9636595	0.0450587
40.00	11.67821	8.32179	0.3254932	0.3870518	80.3388685	49.6810082
	0.00003	19.99996	*999.9999999	0.2473659	179.9598262	0.0474355
42.50	10.81140	9.18859	0.3385036	0.3680895	85.3459202	47.1758705
	0.00003	19.99996	*999.9999999	0.2473659	179.9566038	0.0499471
45.00	9.93875	10.06125	0.3532729	0.3515206	90.3509755	44.6728781
	0.00003	19.99996	*999.9999999	0.2473659	179.9520552	0.0521004
47.50	9.06690	10.93309	0.3700948	0.3369800	95.3540813	42.1720143
	0.00003	19.99996	*999.9999999	0.2473659	179.9478978	0.0543971
50.00	8.20249	11.79751	0.3893377	0.3241771	100.3553234	39.6732394
	0.00004	19.99996	*999.9999999	0.2473660	179.9431816	0.0595528
52.50	7.35206	12.64794	0.4114701	0.3128774	105.3548194	37.1764679
	0.00004	19.99996	*999.9999999	0.2473660	179.9380332	0.0617665
55.00	6.52203	13.47797	0.4370954	0.3028906	110.3527285	34.6815903
	0.00004	19.99995	*999.9999999	0.2473660	179.9321882	0.0637157
57.50	5.71866	14.28133	0.4670045	0.2940607	115.3492867	32.1884830
	0.00004	19.99995	*999.9999999	0.2473660	179.9254864	0.0656070
60.00	4.94801	15.05199	0.5022530	0.2862588	120.3447133	29.6969660
	0.00004	19.99995	*999.9999999	0.2473660	179.9178421	0.0706351
62.50	4.21583	15.78417	0.5442823	0.2793785	125.3394373	27.2067856
	0.00004	19.99995	*999.9999999	0.2473660	179.9088083	0.0756511
65.00	3.52761	16.47239	0.5951115	0.2733309	130.3339377	24.7176673
	0.00004	19.99995	*999.9999999	0.2473661	179.8981652	0.0772507
67.50	2.88848	17.11151	0.6576591	0.2680421	135.3288926	22.2291902
	0.00005	19.99994	*999.9999999	0.2473661	179.8853949	0.0850843
70.00	2.30321	17.69678	0.7363039	0.2634503	140.3252855	19.7407965
	0.00006	19.99994	*999.9999999	0.2473661	179.8695289	0.0895895
72.50	1.77614	18.22385	0.8379281	0.2595044	145.3245953	17.2517054
	0.00006	19.99993	*999.9999999	0.2473662	179.8489355	0.0967881
75.00	1.31119	18.68881	0.9740013	0.2561617	150.3292285	14.7606086
	0.00008	19.99991	*999.9999999	0.2473663	179.8220947	0.1089153
77.50	0.91178	19.08821	1.1651602	0.2533874	155.3434432	12.2653082
	0.00010	19.99989	*999.9999999	0.2473664	179.7845401	0.1248207
80.00	0.58087	19.41912	1.4526266	0.2511535	160.3758186	9.7614742
	0.00014	19.99985	*999.9999999	0.2473667	179.7277667	0.1493533
82.50	0.32087	19.67913	1.9321908	0.2494376	165.4471047	7.2386099
	0.00024	19.99976	*999.9999999	0.2473673	179.6313971	0.1951469
85.00	0.13354	19.86645	2.8852391	0.2482220	170.6268378	4.6623999
	0.00053	19.99946	720.6571312	0.2473692	179.4257350	0.2931700
87.50	0.01739	19.98260	4.4987760	0.2474768	176.6233183	1.6808245
	0.00391	19.99608	19.7923366	0.2473908	178.4031503	0.7971053
87.6655116	0.00819	20.00818	24.8729907	0.2473647	179.9999997	0.0000000
	0.00003	19.99996	*999.9999999	0.2473660	179.9999997	0.0695920

		50.00000	1.0089861	1.0081450	1.0089861	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	50.00006	0.00001	0.2433170	*999.9999999	0.0000000	179.9999997
	0.00003	50.00005	*999.9999999	0.2435149	179.9999997	0.0000000
2.50	49.90232	0.09776	0.2435735	5.5191446	5.0681259	87.3384461
	0.00003	50.00005	*999.9999999	0.2435149	179.9914204	0.0000000
5.00	49.60990	0.39017	0.2443453	2.8610951	10.1357393	84.8554645
	0.00003	50.00005	*999.9999999	0.2435149	179.9879037	0.0000000
7.50	49.12520	0.87487	0.2456394	1.9128389	15.2023464	82.2962310
	0.00003	50.00005	*999.9999999	0.2435149	179.9860038	0.0000000
10.00	48.45220	1.54787	0.2474676	1.4376975	20.2674564	79.7335520
	0.00003	50.00005	*999.9999999	0.2435149	179.9851730	0.0140971
12.50	47.59641	2.40366	0.2498469	1.1530147	25.3305916	77.1718081
	0.00003	50.00005	*999.9999999	0.2435149	179.9828708	0.0098771
15.00	46.56482	3.43525	0.2527999	0.9637225	30.3912885	74.6124089
	0.00003	50.00005	*999.9999999	0.2435149	179.9815036	0.0110587
17.50	45.36583	4.63424	0.2563552	0.8289554	35.4491036	72.0556494
	0.00003	50.00005	*999.9999999	0.2435149	179.9860038	0.0130815
20.0	44.00917	5.99090	0.2605484	0.7282965	40.5036271	69.5022766
	0.00003	50.00005	*999.9999999	0.2435149	179.9808443	0.0148274
22.50	42.50583	7.49425	0.2654228	0.6503859	45.5544651	66.9526167
	0.00003	50.00005	*999.9999999	0.2435149	179.9790114	0.0163881
25.00	40.86789	9.13219	0.2710307	0.5884142	50.6012645	64.4071523
	0.00003	50.00005	*999.9999999	0.2435149	179.9762771	0.0184972
27.50	39.10849	10.89159	0.2774353	0.5380441	55.6437015	61.8661277
	0.00003	50.00005	*999.9999999	0.2435149	179.9724735	0.0203891
30.00	37.24165	12.75842	0.2847119	0.4963884	60.6814921	59.3298034
	0.00003	50.00005	*999.9999999	0.2435149	179.9729131	0.0215509
32.50	35.28218	14.71789	0.2929515	0.4614478	65.7143951	56.7986842
	0.00003	50.00005	*999.9999999	0.2435149	179.9691208	0.0231050
35.00	33.24552	16.75455	0.3022630	0.4317956	70.7422085	54.2726927
	0.00003	50.00005	*999.9999999	0.2435149	179.9660958	0.0266276
37.50	31.14763	18.85245	0.3127781	0.4063870	75.7647771	51.7520946
	0.00003	50.00005	*999.9999999	0.2435149	179.9623333	0.0279750
40.0	29.00483	20.99525	0.3246563	0.3844391	80.7819940	49.2369905
	0.00003	50.00005	*999.9999999	0.2435149	179.9598262	0.0296655
42.50	26.83370	23.16638	0.3380927	0.3653545	85.7938007	46.7274580
	0.00003	50.00005	*999.9999999	0.2435149	179.9563207	0.0312786
45.00	24.65090	25.34917	0.3533272	0.3486695	90.8001926	44.2235041
	0.00004	50.00005	*999.9999999	0.2435149	179.9523048	0.0346151
47.50	22.47311	27.52697	0.3706576	0.3340192	95.8012156	41.7251002
	0.00004	50.00005	*999.9999999	0.2435149	179.9481288	0.0360072
50.0-	20.31680	29.68328	0.3904579	0.3211130	100.7969752	39.2321842
	0.00004	50.00005	*999.9999999	0.2435149	179.9433976	0.0392569
52.50	18.19822	31.80186	0.4132034	0.3097164	105.7876423	36.7445652
	0.00004	50.00004	*999.9999999	0.2435149	179.9382344	0.0407848
55.00	16.13319	33.86688	0.4395068	0.2996392	110.7734516	34.2621073
	0.00004	50.00004	*999.9999999	0.2435150	179.9323708	0.0439542
57.50	14.13705	35.86303	0.4701707	0.2907253	115.7547124	31.7845467
	0.00005	50.00004	*999.9999999	0.2435150	179.9256541	0.0469180
60.00	12.22452	37.77556	0.5062671	0.2828460	120.7318269	29.3115806
	0.00005	50.00003	*999.9999999	0.2435150	179.9179876	0.0499471
62.50	10.40962	39.59046	0.5492596	0.2758946	125.7053092	26.8428270
	0.00006	50.00003	*999.9999999	0.2435150	179.9090765	0.0548511
65.00	8.70558	41.29451	0.6011987	0.2697824	130.6758188	24.3778125
	0.00007	50.00002	*999.9999999	0.2435150	179.8985265	0.0593447
67.50	7.12472	42.87536	0.6650484	0.2644352	135.6442161	21.9159525
	0.00008	50.00001	*999.9999999	0.2435150	179.8857152	0.0654240
70.00	5.67846	44.32163	0.7452562	0.2597915	140.6116858	19.4564942
	0.00009	49.99999	*999.9999999	0.2435151	179.8699014	0.0725165
72.50	4.37714	45.62294	0.8488124	0.2557998	145.5789229	16.9984125
	0.00012	49.99997	*999.9999999	0.2435151	179.8494235	0.0820133
75.00	3.23007	46.77002	0.9873675	0.2524176	150.5515575	14.5402260
	0.00015	49.99994	*999.9999999	0.2435152	179.8231304	0.0931820
77.50	2.24538	47.75471	1.1818837	0.2496100	155.5310898	12.0794937
	0.00020	49.99988	*999.9999999	0.2435154	179.7854491	0.1117944
80.00	1.43002	48.57007	1.4742330	0.2473489	160.5273224	9.6116793
	0.00031	49.99978	*999.9999999	0.2435156	179.7286235	0.1385648
82.50	0.78966	49.21042	1.9617131	0.2456118	165.5612178	7.1262058
	0.00054	49.99954	*999.9999999	0.2435163	179.6325594	0.1843851
85.00	0.32846	49.67162	2.9300574	0.2443811	170.7024574	4.5884796
	0.00127	49.99881	754.7788844	0.2435182	179.4274412	0.2844899
87.50	0.04240	49.95768	4.5306953	0.2436262	176.6635068	1.6468698
	0.00975	49.99033	19.6465101	0.2435404	178.4017645	0.7894431
87.6601862	0.02029	50.02038	25.1493026	0.2435123	179.9999997	0.0000000
	0.00003	50.00005	*999.9999999	0.2435149	179.9999997	0.0407848

	100.00000	1.0089861	1.0081450	1.0089861	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	99.99998	0.00001	0.2371698	*999.9999999	0.0000000	179.9999997
	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0000000
2.50	99.79945	0.20055	0.2374438	5.6396274	5.1333065	87.3250943
	0.00002	100.00002	*999.9999999	0.2373577	179.9879037	0.0000000
5.00	99.19960	0.80040	0.2382684	2.8628289	10.2655642	84.7271428
	0.00002	100.00002	*999.9999999	0.2373577	179.9860038	0.0000000
7.50	98.20573	1.79426	0.2396507	1.9122440	15.3957661	82.1004394
	0.00002	100.00002	*999.9999999	0.2373577	179.9914204	0.0000000
10.00	96.82659	3.17341	0.2416027	1.4365471	20.5229223	79.4741269
	0.00002	100.00002	*999.9999999	0.2373577	179.9889393	0.0000000
12.50	95.07425	4.92577	0.2441419	1.1514690	25.6460480	76.8510807
	0.00002	100.00002	*999.9999999	0.2373577	179.9851730	0.0000000
15.00	92.96395	7.03603	0.2472915	0.9618361	30.7642039	74.2331732
	0.00002	100.00002	*999.9999999	0.2373577	179.9815036	0.0000000
17.50	90.51409	9.48590	0.2510806	0.8267657	35.8764920	71.6213915
	0.00002	100.00002	*999.9999999	0.2373577	179.9828708	0.0085777
20.00	87.74571	12.25427	0.2555457	0.7258121	40.9820736	69.0165784
	0.00002	100.00002	*999.9999999	0.2373577	179.9815036	0.0085777
22.50	84.68256	15.31745	0.2607311	0.6476208	46.0801631	66.4196163
	0.00002	99.99998	*999.9999999	0.2373577	179.9784489	0.0098771
25.00	81.35055	18.64945	0.2666905	0.5853766	51.1700422	63.8311673
	0.00002	99.99998	*999.9999999	0.2373577	179.9784489	0.0110587
27.50	77.77773	22.22227	0.2734883	0.5347467	56.2510651	61.2519398
	0.00002	99.99998	*999.9999999	0.2373577	179.9733713	0.0120944
30.00	73.99381	26.00618	0.2812019	0.4928421	61.3226611	58.6824637
	0.00003	99.99998	*999.9999999	0.2373577	179.9699180	0.0139954
32.50	70.02998	29.97004	0.2899241	0.4576650	66.3843423	56.1232585
	0.00003	99.99998	*999.9999999	0.2373577	179.9691208	0.0156394
35.00	65.91842	34.08158	0.2997666	0.4277881	71.4357078	53.5746321
	0.00003	99.99998	*999.9999999	0.2373577	179.9657345	0.0163881
37.50	61.69226	38.30775	0.3108640	0.4021673	76.4764413	51.0369386
	0.00003	99.99998	*999.9999999	0.2373577	179.9636595	0.0184072
40.0	57.38501	42.61500	0.3233799	0.3800195	81.5063231	48.5103306
	0.00003	99.99998	*999.9999999	0.2373577	179.9607426	0.0197703
42.50	53.03046	46.96955	0.3375138	0.3607474	86.5252223	45.9949266
	0.00003	99.99998	*999.9999999	0.2373577	179.9568906	0.0221174
45.00	48.66227	51.33774	0.3535114	0.3438873	91.5331073	43.4907295
	0.00004	99.99998	*999.9999999	0.2373577	179.9528264	0.0242226
47.50	44.31379	55.68621	0.3716777	0.3290741	96.5300422	40.9976497
	0.00004	99.99998	*999.9999999	0.2373577	179.9488440	0.0252082
50.0	40.01776	59.98225	0.3923960	0.3160168	101.5161909	38.5155100
	0.00004	99.99998	*999.9999999	0.2373577	179.9440458	0.0275272
52.50	35.80608	64.19394	0.4161532	0.3044808	106.4918153	36.0440377
	0.00005	99.99998	*999.9999999	0.2373577	179.9390279	0.0308807
55.00	31.70963	68.29038	0.4435771	0.2942756	111.4572957	33.5828949
	0.00005	99.99998	*999.9999999	0.2373577	179.9330972	0.0331760
57.50	27.75800	72.24202	0.4754906	0.2852446	116.4131165	31.1316036
	0.00006	99.99994	*999.9999999	0.2373577	179.9266450	0.0363387
60.00	23.97942	76.02058	0.5129926	0.2772589	121.3598847	28.6896501
	0.00007	99.99994	*999.9999999	0.2373578	179.9190342	0.0395612
62.50	20.40051	79.59951	0.5575838	0.2702113	126.2983531	26.2563702
	0.00008	99.99994	*999.9999999	0.2373578	179.9102947	0.0439542
65.00	17.04620	82.95383	0.6113672	0.2640128	131.2294602	23.8310240
	0.00009	99.99994	*999.9999999	0.2373578	179.8998602	0.0489609
67.50	13.93958	86.06043	0.6773824	0.2585889	136.1543648	21.4127272
	0.00012	99.99990	*999.9999999	0.2373578	179.8872240	0.0555098
70.0	11.10180	88.89820	0.7601916	0.2538776	141.0745718	19.0003898
	0.00015	99.99987	*999.9999999	0.2373579	179.8715107	0.0633922
72.50	8.55199	91.44802	0.8669655	0.2498271	145.9921040	16.5926605
	0.00019	99.99983	*999.9999999	0.2373579	179.8513047	0.0726817
75.00	6.30718	93.69284	1.0096557	0.2463946	150.9099491	14.1877122
	0.00025	99.99975	*999.9999999	0.2373580	179.8249371	0.0858000
77.50	4.38223	95.61777	1.2097677	0.2435450	155.8329500	11.7827937
	0.00036	99.99964	*999.9999999	0.2373582	179.7882058	0.1036202
80.00	2.78975	97.21026	1.5102592	0.2412498	160.7702114	9.3730589
	0.00057	99.99946	*999.9999999	0.2373584	179.7321141	0.1308480
82.50	1.54001	98.46002	2.0109529	0.2394864	165.7428518	6.9478048
	0.00102	99.99901	*999.9999999	0.2373591	179.6372496	0.1769389
85.00	0.64040	99.35960	3.0049948	0.2382371	170.8201170	4.4728637
	0.00245	99.99756	785.2858342	0.2373610	179.4349216	0.2754916
87.50	0.08264	99.91739	4.6465276	0.2374707	176.7056808	1.6050072
	0.01897	99.98105	20.2372439	0.2373836	178.4223020	0.7686904
87.6602715	0.03959	100.03962	25.7775161	0.2373529	179.9999997	0.0000000
	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0242226

	1000.00000	1.0089861	1.0081450	1.0089861	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	1000.0 009	0.00000	0.1630299	*999.9999999	0.0000000	179.9999997
	0.00012	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
2.50	997.08539	2.91472	0.1635162	5.7138635	6.1895805	86.1669540
	0.00015	999.99990	*999.9999999	0.1631187	179.9851730	0.0000000
5.00	988.39865	11.60146	0.1649796	2.8468330	12.3666510	82.3603485
	0.00015	999.99990	*999.9999999	0.1631187	179.9851730	0.0000000
7.50	974.10929	25.89082	0.1674346	1.8843356	18.5189992	78.5891186
	0.00015	999.99990	*999.9999999	0.1631187	179.9843609	0.0000000
10.00	954.49143	45.50867	0.1709052	1.3996131	24.6348601	74.8732667
	0.00014	999.99994	*999.9999999	0.1631187	179.9860038	0.0000000
12.50	929.91215	70.08795	0.1754254	1.1065241	30.7031628	71.2284103
	0.00014	999.99994	*999.9999999	0.1631187	179.9889393	0.0000000
15.00	900.81636	99.18373	0.1810398	0.9097073	36.7137171	67.6676042
	0.00015	999.99990	*999.9999999	0.1631187	179.9843609	0.0000000
17.50	867.70971	132.29038	0.1878040	0.7683119	42.6573500	64.2014772
	0.00015	999.99990	*999.9999999	0.1631187	179.9828708	0.0000000
20.00	831.13995	168.86014	0.1957855	0.6618979	48.5260300	60.8378917
	0.00015	999.99990	*999.9999999	0.1631187	179.9815036	0.0000000
22.50	791.67903	208.32107	0.2050646	0.5790892	54.3129347	57.5822745
	0.00015	999.99990	*999.9999999	0.1631187	179.9836121	0.0000000
25.00	749.90575	250.09431	0.2157364	0.5130297	60.0124814	54.4376872
	0.00016	999.99990	*999.9999999	0.1631187	179.9802296	0.0140971
27.50	706.39078	293.60931	0.2279122	0.4593250	65.6203263	51.4051374
	0.00017	999.99990	*999.9999999	0.1631187	179.9768060	0.0085777
30.00	661.68357	338.31652	0.2417223	0.4150163	71.1333335	48.4838813
	0.00017	999.99990	*999.9999999	0.1631187	179.9762771	0.0098771
32.50	616.30253	383.69756	0.2573194	0.3780290	76.5495200	45.6717357
	0.00017	999.99990	*999.9999999	0.1631187	179.9757779	0.0098771
35.00	570.72737	429.27273	0.2748829	0.3468594	81.8679791	42.9653663
	0.00019	999.99987	*999.9999999	0.1631187	179.9724735	0.0110587
37.50	525.39427	474.60582	0.2946249	0.3203874	87.0887913	40.3605673
	0.00020	999.99987	*999.9999999	0.1631187	179.9695082	0.0120944
40.00	480.69343	519.30666	0.3167976	0.2977596	92.2129326	37.8529082
	0.00021	999.99987	*999.9999999	0.1631187	179.9668223	0.0130954
42.50	436.96843	563.03166	0.3417044	0.2783134	97.2421691	35.4359359
	0.00023	999.99983	*999.9999999	0.1631187	179.9639910	0.0148274
45.00	394.51715	605.48294	0.3697131	0.2615264	102.1789648	33.1053279
	0.00025	999.99983	*999.9999999	0.1631187	179.9607426	0.0163881
47.50	353.59405	646.40604	0.4012758	0.2469816	107.0263907	30.8550443
	0.00026	999.99979	*999.9999999	0.1631187	179.9574606	0.0178372
50.00	314.41328	685.58682	0.4369553	0.2343424	111.7880195	28.6794189
	0.00029	999.99976	*999.9999999	0.1631187	179.9536049	0.0191542
52.50	277.15210	722.84705	0.4774623	0.2233347	116.4678782	26.5728299
	0.00032	999.99976	*999.9999999	0.1631187	179.9493209	0.0209872
55.00	241.95511	758.04494	0.5237093	0.2137341	121.0703403	24.5297659
	0.00036	999.99972	*999.9999999	0.1631187	179.9447052	0.0226130
57.50	208.93794	791.06216	0.5768891	0.2053551	125.6000996	22.5448497
	0.00041	999.99964	*999.9999999	0.1631187	179.9392328	0.0252082
60.0	178.19133	821.80876	0.6385929	0.1980444	130.0621070	20.6128582
	0.00047	999.99961	*999.9999999	0.1631187	179.9329184	0.0275272
62.50	149.78487	850.21518	0.7109927	0.1916743	134.4615919	18.7287267
	0.00055	999.99953	*999.9999999	0.1631188	179.9256541	0.0304900
65.00	123.77061	876.22944	0.7971336	0.1861384	138.8038322	16.8875467
	0.00065	999.99942	*999.9999999	0.1631188	179.9169481	0.0339040
67.50	100.18610	899.81400	0.9014206	0.1813481	143.0945992	15.0845341
	0.00079	999.99927	*999.9999999	0.1631188	179.9064241	0.0379841
70.0-	79.05726	920.94280	1.0304711	0.1772294	147.3397873	13.3149840
	0.00100	999.99908	*999.9999999	0.1631186	179.8931248	0.0433964
72.50	60.40104	939.59902	1.1946958	0.1737210	151.5457891	11.5741920
	0.00129	999.99879	*999.9999999	0.1631189	179.8767596	0.0499471
75.00	44.22756	955.77251	1.4114613	0.1707721	155.7197571	9.8573121
	0.00173	999.99834	*999.9999999	0.1631190	179.8548847	0.0589328
77.50	30.54188	969.45819	1.7120369	0.1683412	159.9703861	8.1590108
	0.00247	999.99759	*999.9999999	0.1631191	179.8244491	0.0711540
80.0	19.34555	980.65451	2.1589156	0.1663950	164.0098654	6.4726600
	0.00388	999.99618	*999.9999999	0.1631193	179.7779426	0.0898411
82.50	10.63733	989.36275	2.8973612	0.1649068	168.1603380	4.7877152
	0.00701	999.99305	*999.9999999	0.1631198	179.6992533	0.1215437
85.00	4.41109	995.58897	4.3540707	0.1638563	172.3837890	3.0776091
	0.01684	999.98321	*999.9999999	0.1631215	179.5314960	0.1892042
87.50	0.56849	999.43157	8.7590065	0.1632134	177.2678383	1.1039476
	0.13030	999.86978	29.4905957	0.1631404	178.6925383	0.5280922
87.6605618	0.27205	1000.27211	37.5060801	0.1631033	179.9999997	0.0000000
	0.00012	999.99994	*999.9999999	0.1631187	179.9999997	0.0163881

	10000.00000	1.0089861	1.0081450	1.0089861	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	9999.99948	0.00010	0.0395126	*999.9999999	0.0000000	179.9999997
	0.00019	9999.99914	*999.9999999	0.0395178	179.9999997	0.0000000
2.50	9880.82446	119.17494	0.0403559	5.2520799	12.5346348	74.5583460
	0.00019	9999.99914	*999.9999999	0.0395178	179.9999997	0.0000000
5.00	9538.07354	461.92564	0.0429380	2.1034531	24.8222057	61.0348172
	0.00028	9999.99914	*999.9999999	0.0395178	179.9914204	0.0000000
7.50	9011.72508	988.27429	0.0474147	1.0606703	36.6453688	50.2080739
	0.00030	9999.99914	*999.9999999	0.0395178	179.9901240	0.0000000
10.00	8356.15601	1643.84335	0.0540448	0.6037941	47.8378318	41.8728903
	0.00019	9999.99914	*999.9999999	0.0395178	179.9999997	0.0000000
12.50	7627.87703	2372.12233	0.0631883	0.3791292	58.2930073	35.4870059
	0.00038	9999.99914	*999.9999999	0.0395178	179.9860038	0.0000000
15.00	6876.19302	3123.80631	0.0753041	0.2587699	67.9609347	30.5351961
	0.00028	9999.99914	*999.9999999	0.0395178	179.9914204	0.0000000
17.50	6138.54337	3861.45599	0.0909476	0.1893459	76.8377870	26.6238555
	0.00030	9999.99914	*999.9999999	0.0395178	179.9901240	0.0000000
20.00	5439.89144	4560.10792	0.1107685	0.1466582	84.9526871	23.4726109
	0.00019	9999.99914	*999.9999999	0.0395178	179.9999997	0.0000000
22.50	4794.51779	5205.48158	0.1355087	0.1189395	92.3553146	20.8850958
	0.00030	9999.99914	*999.9999999	0.0395178	179.9901240	0.0000000
25.00	4208.69410	5791.30527	0.1660007	0.1000923	99.1059825	18.7231325
	0.00032	9999.99914	*999.9999999	0.0395178	179.9889393	0.0000000
27.50	3683.28035	6316.71898	0.2031683	0.0867707	105.2685715	16.8881491
	0.00034	9999.99914	*999.9999999	0.0395178	179.9879037	0.0000000
30.0	3215.82399	6784.17537	0.2480281	0.0770423	110.9059602	15.3086308
	0.00034	9999.99914	*999.9999999	0.0395178	179.9879037	0.0000000
32.50	2802.07727	7197.92210	0.3016951	0.0697391	116.0773784	13.9317680
	0.00036	9999.99914	*999.9999999	0.0395178	179.9869165	0.0000000
35.00	2437.00828	7562.99105	0.3653920	0.0641271	120.8370589	12.7178859
	0.00038	9999.99914	*999.9999999	0.0395178	179.9860038	0.0000000
37.50	2115.42849	7884.57088	0.4404649	0.0597280	125.2338029	11.6366927
	0.00041	9999.99914	*999.9999999	0.0395178	179.9843609	0.0000000
40.0	1832.35332	8167.64604	0.5284060	0.0562209	129.3109953	10.6647004
	0.00043	9999.99877	*999.9999999	0.0395178	179.9836121	0.0000000
42.50	1583.18903	8416.81033	0.6308890	0.0533839	133.1069395	9.7834441
	0.00047	9999.99877	*999.9999999	0.0395178	179.9821630	0.0000000
45.00	1363.81060	8636.18873	0.7498187	0.0510607	136.6553344	8.9782100
	0.00053	9999.99877	*999.9999999	0.0395178	179.9802296	0.0000000
47.50	1170.57655	8829.42282	0.8874034	0.0491379	139.9857625	8.2371341
	0.00056	9999.99877	*999.9999999	0.0395178	179.9790114	0.0000000
50.0	1000.30847	8999.69090	1.0462576	0.0475326	143.1242153	7.5505357
	0.00064	9999.99877	*999.9999999	0.0395178	179.9768060	0.0000000
52.50	850.25319	9149.74634	1.2295516	0.0461822	146.0935399	6.9104368
	0.00077	9999.99877	*999.9999999	0.0395178	179.9733713	0.0000000
55.00	718.03805	9281.96136	1.4412278	0.0450397	148.9139050	6.3101808
	0.00071	9999.99877	*999.9999999	0.0395178	179.9747907	0.0000000
57.50	601.62690	9398.37258	1.6863205	0.0440686	151.6031437	5.7441765
	0.00095	9999.99840	*999.9999999	0.0395178	179.9691208	0.0000000
60.00	499.27552	9500.72382	1.9714425	0.0432404	154.1771255	5.2076569
	0.00101	9999.99840	*999.9999999	0.0395178	179.9679510	0.0000000
62.50	409.49483	9590.50443	2.3055355	0.0425332	156.6500328	4.6965404
	0.00129	9999.99803	*999.9999999	0.0395178	179.9628611	0.0140971
65.00	331.01548	9668.98401	2.7010773	0.0419291	159.0346433	4.2072751
	0.00148	9999.99803	*999.9999999	0.0395178	179.9595207	0.0085777
67.50	262.75933	9737.23989	3.1760925	0.0414141	161.3425812	3.7367465
	0.00181	9999.99765	*999.9999999	0.0395178	179.9544021	0.0085777
70.00	203.81377	9796.18553	3.7576735	0.0409770	163.5844447	3.2821752
	0.00229	9999.99691	*999.9999999	0.0395178	179.9478978	0.0098771
72.50	153.41044	9846.58908	4.4885157	0.0406087	165.7702737	2.8410380
	0.00300	9999.99654	*999.9999999	0.0395178	179.9396351	0.0120944
75.00	110.90774	9889.09166	5.4399777	0.0403019	167.9096408	2.4109871
	0.00410	9999.99542	*999.9999999	0.0395178	179.9286716	0.0139954
77.50	75.77576	9924.22376	6.7407788	0.0400510	170.0122617	1.9897131
	0.00600	9999.99318	*999.9999999	0.0395178	179.9129248	0.0171295
80.00	47.58376	9952.41564	8.6485362	0.0398514	172.0890962	1.5747198
	0.00928	9999.99020	*999.9999999	0.0395179	179.8909754	0.0215509
82.50	25.99022	9974.00928	11.7626727	0.0396995	174.1555445	1.1626741
	0.01690	9999.98238	*999.9999999	0.0395179	179.8520461	0.0292585
85.00	10.72644	9989.27292	17.8451385	0.0395926	176.2463525	0.7464119
	0.04074	9999.95854	*999.9999999	0.0395181	179.7693521	0.0458583
87.50	1.37801	9998.62153	27.8563526	0.0395274	178.6549054	0.2673817
	0.31595	9999.68324	121.5763278	0.0395200	179.3561205	0.1280134
87.6804039	0.65937	10000.65878	154.7226980	0.0395156	179.9999997	0.0000000
	0.00019	9999.99914	*999.9999999	0.0395178	179.9999997	0.0000000

		5.00000	1.0081450	1.0081450	1.0081450	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	5.00002	0.00001	0.2493360	*999.9999999	0.0000000	179.9999997
2.50	4.99048	0.00955	0.2495761	3.9627343	5.0066618	86.7180282
5.00	4.96194	0.03809	0.2502985	2.8024458	10.0132469	84.8711889
7.50	4.91461	0.08542	0.2515103	1.9074707	15.0197420	82.4495822
10.00	4.84886	0.15117	0.2532231	1.4374905	20.0260892	79.9592298
12.50	4.76519	0.23484	0.2554535	1.1542984	25.0322364	77.4609953
15.00	4.66425	0.33578	0.2582237	0.9655044	30.0381370	74.9579016
17.50	4.54680	0.45323	0.2615620	0.8310580	35.0437489	72.4536702
20.00	4.41375	0.58628	0.2655032	0.7306674	40.0490254	69.9493980
22.50	4.26612	0.73391	0.2700899	0.6529989	45.0539291	67.4450152
25.00	4.10503	0.89500	0.2753736	0.5912540	50.0584237	64.9409417
27.50	3.93172	1.06831	0.2814162	0.5411040	55.0624721	62.4371028
30.00	3.74752	1.25251	0.2882920	0.4996620	60.0660443	59.9336874
32.50	3.55383	1.44620	0.2960898	0.4649284	65.0691148	57.4306794
35.00	3.35213	1.64790	0.3049167	0.4354777	70.0716555	54.9282406
37.50	3.14396	1.85607	0.3149019	0.4102631	75.0736565	52.4262890
40.0	2.93091	2.06912	0.3262018	0.3885021	80.0750941	49.9249030
42.50	2.71460	2.28543	0.3390076	0.3695962	85.0759603	47.4240400
45.00	2.49669	2.50334	0.3535542	0.3530824	90.0762480	44.9238289
47.50	2.27883	2.72121	0.3701335	0.3385946	95.0759575	42.4241442
50.00	2.06267	2.93756	0.3891115	0.3258420	100.0750884	39.9250343
52.50	1.84987	3.15017	0.4109537	0.3145904	105.0736494	37.4265183
55.00	1.64203	3.35800	0.4362594	0.3046488	110.0716479	34.9285193
57.50	1.44074	3.55929	0.4658142	0.2958616	115.0691062	32.4311171
60.00	1.24752	3.75251	0.5006666	0.2880995	120.0660355	29.9341783
62.50	1.06385	3.93619	0.5422480	0.2812561	125.0624619	27.4378106
65.00	0.89110	4.10894	0.5925640	0.2752423	130.0584152	24.9418616
67.50	0.73059	4.26944	0.6545129	0.2699844	135.0539252	22.4464081
70.00	0.58353	4.41650	0.7324438	0.2654204	140.0490291	19.9513365
72.50	0.45104	4.54899	0.8331930	0.2614990	145.0437568	17.4566340
75.00	0.33412	4.66591	0.9681563	0.2581778	150.0381529	14.9622653
77.50	0.23365	4.76638	1.1578484	0.2554218	155.0322585	12.4682661
80.00	0.15040	4.84964	1.4433018	0.2532030	160.0261219	9.9745416
82.50	0.08498	4.91505	1.9202628	0.2514992	165.0197841	7.4809406
85.00	0.03790	4.96214	2.8759773	0.2502938	170.0132973	4.9878923
87.50	0.00950	4.99053	5.7467049	0.2495752	175.0066876	2.4953614
90.0	0.00002	5.00001	259.4539449	0.2493364	179.9860038	0.1104748
92.50	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.1103662
95.00	0.00002	5.00001	*999.9999999	0.2493364	179.9901240	0.1100324
97.50	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.1094753
100.0	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.1088017
102.50	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.1077866
105.00	0.00002	5.00001	*999.9999999	0.2493364	179.9914204	0.1066460
107.50	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.1053757
110.0	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.1037595
112.50	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.1020734
115.00	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.1001405
117.50	0.00002	5.00001	*999.9999999	0.2493364	179.9999997	0.0979172
120.0	0.00002	5.00001	*999.9999999	0.2493363	179.9999997	0.0956417
122.50	0.00002	5.00001	*999.9999999	0.2493363	179.9999997	0.0931820
125.00	0.00002	5.00001	*999.9999999	0.2493363	179.9914204	0.0905191
127.50	0.00002	5.00001	*999.9999999	0.2493363	179.9859032	0.0876345
130.0	0.00002	5.00001	*999.9999999	0.2493362	179.9999997	0.0846560
132.50	0.00002	5.00001	*999.9999999	0.2493362	179.9999997	0.0814117
135.00	0.00002	5.00001	*999.9999999	0.2493362	179.9999997	0.0780383
137.50	0.00002	5.00001	*999.9999999	0.2493362	179.9889393	0.0746781
140.0	0.00002	5.00001	*999.9999999	0.2493362	179.9914204	0.0709791
142.50	0.00002	5.00001	*999.9999999	0.2493362	179.9901240	0.0672672
145.00	0.00002	5.00001	*999.9999999	0.2493361	179.9901240	0.0633322
147.50	0.00002	5.00001	*999.9999999	0.2493361	179.9901240	0.0593447
150.0	0.00002	5.00001	*999.9999999	0.2493361	179.9999997	0.0552933
152.50	0.00002	5.00001	*999.9999999	0.2493361	179.9914204	0.0509133
155.00	0.00002	5.00001	*999.9999999	0.2493361	179.9999997	0.0466536
157.50	0.00002	5.00001	*999.9999999	0.2493360	179.9879037	0.0422575
160.0	0.00002	5.00001	*999.9999999	0.2493360	179.9999997	0.0376671
162.50	0.00002	5.00001	*999.9999999	0.2493360	179.9999997	0.0331760
165.00	0.00002	5.00001	*999.9999999	0.2493360	179.9999997	0.0284138
167.50	0.00002	5.00001	*999.9999999	0.2493360	179.9869165	0.0237224
170.0	0.00002	5.00001	*999.9999999	0.2493360	179.9999997	0.0191542
172.50	0.00002	5.00001	*999.9999999	0.2493360	179.9999997	0.0148274
175.00	0.00002	5.00001	*999.9999999	0.2493360	179.9889393	0.0098771
177.50	0.00002	5.00001	*999.9999999	0.2493360	179.9999997	0.0000000
180.0	0.00002	5.00001	*999.9999999	0.2493360	179.9999997	0.0000000

		10.00000	1.0081450	1.0081450	1.0081450	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	10.00004	0.00001	0.2486755	*999.9999999	0.0000000	179.9999997
2.50	9.98091	0.01914	0.2489174	4.8118283	5.0132927	87.0828619
5.00	9.92368	0.07638	0.2496456	2.8374410	10.0284885	84.9192801
7.50	9.82877	0.17128	0.2508668	1.9108601	15.0394489	82.4427586
10.0	9.69694	0.30311	0.2525928	1.4383183	20.0521302	79.9412800
12.50	9.52920	0.47085	0.2548403	1.1544374	25.0644089	77.4318045
15.00	9.32683	0.67322	0.2576316	0.9634257	30.0761994	74.9212887
17.50	9.09141	0.90863	0.2609947	0.8309161	35.0874070	72.4112528
20.00	8.82476	1.17529	0.2649648	0.7304602	40.0979452	69.9010477
22.50	8.52891	1.47124	0.2695845	0.6527510	45.1077394	67.3913579
25.00	8.20618	1.79389	0.2749034	0.5909735	50.1167107	64.8827251
27.50	7.85899	2.14107	0.2809894	0.5407958	55.1247908	62.3748060
30.00	7.49005	2.51000	0.2879110	0.4993268	60.1319205	59.8677471
32.50	7.10220	2.89785	0.2957593	0.4645689	65.1380438	57.3617524
35.00	6.69839	3.30167	0.3046416	0.4350933	70.1431152	54.8568898
37.50	6.28172	3.71839	0.3146873	0.4098556	75.1470957	52.3527871
40.00	5.85537	4.14468	0.3260533	0.3880720	80.1499584	49.8499516
42.50	5.42261	4.57744	0.3389310	0.3691450	85.1516754	47.3482896
45.00	4.98674	5.01332	0.3535361	0.3526101	90.1522417	44.8477388
47.50	4.55106	5.44899	0.3702210	0.3381026	95.1516475	42.3483647
50.00	4.11890	5.88115	0.3892928	0.3253313	100.1498997	39.8501555
52.50	3.69353	6.30652	0.4112379	0.3140619	105.1470155	37.3550414
55.00	3.27819	6.72186	0.4366574	0.3041037	110.1430098	34.8570757
57.50	2.87602	7.12403	0.4661387	0.2953008	115.1379198	32.3621929
60.00	2.49006	7.50999	0.5013330	0.2875241	120.1317832	29.8683334
62.50	2.12323	7.87682	0.5430756	0.2806872	125.1248445	27.3754932
65.00	1.77828	8.22177	0.5935771	0.2746411	130.1169596	24.8835839
67.50	1.45784	8.54221	0.6557434	0.2693719	135.1079880	22.3925780
70.00	1.16430	8.83575	0.7339352	0.2647979	140.0978044	19.9027868
72.50	0.89988	9.10017	0.8350068	0.2608676	145.0872757	17.4129039
75.00	0.66656	9.33349	0.9703842	0.2575385	150.0760913	14.9240699
77.50	0.46610	9.53395	1.1606384	0.2547760	155.0643258	12.4358423
80.00	0.29999	9.70006	1.4489048	0.2525517	160.0520760	9.9481066
82.50	0.16949	9.83056	1.9251898	0.2508438	165.0394276	7.4607457
85.00	0.07557	9.92449	2.8835006	0.2496354	170.0264849	4.9736950
87.50	0.01893	9.98112	5.7619145	0.2489140	175.0133522	2.4869149
90.0	0.00000	10.00005	821.9343796	0.2486755	179.9999997	0.0349706
92.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0349706
95.00	0.00000	10.00005	*999.9999999	0.2486755	179.9901240	0.0346151
97.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0346151
100.0	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0342670
102.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0339040
105.00	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0335355
107.50	0.00000	10.00005	*999.9999999	0.2486755	179.9901240	0.0331760
110.0	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0328011
112.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0320497
115.00	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0316597
117.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0308807
120.0	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0300814
122.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0292585
125.00	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0284138
127.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0275272
130.00	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0266276
132.50	0.00000	10.00005	*999.9999999	0.2486755	179.9901240	0.0256984
135.00	0.00000	10.00005	*999.9999999	0.2486755	179.9889393	0.0247280
137.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0237224
140.0	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0226530
142.50	0.00000	10.00005	*999.9999999	0.2486755	179.9914204	0.0209872
145.00	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0197703
147.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0184972
150.0	0.00000	10.00005	*999.9999999	0.2486755	179.9914204	0.0171295
152.50	0.00000	10.00005	*999.9999999	0.2486755	179.9901240	0.0163881
155.00	0.00000	10.00005	*999.9999999	0.2486755	179.9901240	0.0148274
157.50	0.00000	10.00005	*999.9999999	0.2486755	179.9859032	0.0130815
160.0	0.00000	10.00005	*999.9999999	0.2486755	179.9889393	0.0120944
162.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0098771
165.00	0.00000	10.00005	*999.9999999	0.2486755	179.9859032	0.0085777
167.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0140971
170.0	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0000000
172.50	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0000000
175.00	0.00000	10.00005	*999.9999999	0.2486755	179.9914204	0.0000000
177.50	0.00000	10.00005	*999.9999999	0.2486755	179.9889393	0.0000000
180.0	0.00000	10.00005	*999.9999999	0.2486755	179.9999997	0.0000000

		20.00000	1.0081450	1.0081450	1.0081450	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	20.00004	0.00001	0.2473649	*999.9999998	0.0000000	0.0000000
2.50	19.96158	0.03847	0.2476106	5.2416158	5.0265235	87.2573130
5.00	19.84651	0.15354	0.2483500	2.8530972	10.0528828	84.9203497
7.50	19.65573	0.34432	0.2495900	1.9126470	15.0787763	82.4117791
10.00	19.39074	0.60931	0.2513423	1.4387892	20.1040964	79.8925813
12.50	19.05381	0.94644	0.2536238	1.1543027	25.1286164	77.3692150
15.00	18.64698	1.35307	0.2564366	0.9651592	30.1521476	74.8464580
17.50	18.17405	1.82600	0.2598693	0.8305389	35.1745140	72.3245420
20.00	17.63850	2.36155	0.2638967	0.7300143	40.1955456	69.8038738
22.50	17.04451	2.95554	0.2685819	0.6522439	45.2150799	67.2843214
25.00	16.39671	3.60334	0.2739766	0.5904080	50.2329681	64.7664689
27.50	15.70013	4.29992	0.2801430	0.5401759	55.2490737	62.2504763
30.00	14.96018	5.03987	0.2871559	0.4986544	60.2632757	59.7363025
32.50	14.18259	5.81746	0.2951047	0.4638464	65.2754872	57.2242107
35.00	13.37336	6.62669	0.3040972	0.4343228	70.2855548	54.7141724
37.50	12.53871	7.46134	0.3142634	0.4090385	75.2934835	52.2063408
40.00	11.68507	8.31498	0.3257609	0.3872106	80.2991346	49.7007612
42.50	10.81897	9.18108	0.3387820	0.3682407	85.3025265	47.1974513
45.00	9.94704	10.05302	0.3535635	0.3516053	90.3036166	44.6964208
47.50	9.07591	10.92415	0.3703962	0.3371191	95.3023937	42.1977337
50.00	8.21220	11.78785	0.3896581	0.3243111	100.2988704	39.7013251
52.50	7.36246	12.63759	0.4118088	0.3130071	105.2930802	37.2071825
55.00	6.53311	13.46694	0.4374554	0.3030164	110.2850623	34.7152643
57.50	5.73041	14.26964	0.4673893	0.2941829	115.2748801	32.2255045
60.00	4.96038	15.03967	0.5026672	0.2863781	120.2626154	29.7378123
62.50	4.22880	15.77125	0.5447317	0.2794951	125.2483577	27.2521086
65.00	3.54115	16.45890	0.5956039	0.2734451	130.2322187	24.7682650
67.50	2.90255	17.09750	0.6582050	0.2681543	135.2143250	22.2861823
70.00	2.31777	17.68229	0.7369184	0.2635607	140.1948072	19.8056929
72.50	1.79113	18.20892	0.8386347	0.2596132	145.1738141	17.3266713
75.00	1.32657	18.67348	0.9748400	0.2562694	150.1515135	14.8489639
77.50	0.92752	19.07253	1.1662123	0.2534942	155.1280618	12.3724122
80.00	0.59692	19.40313	1.4541106	0.2512597	160.1036489	9.8968092
82.50	0.33722	19.66283	1.9350438	0.2495436	165.0784463	7.4219782
85.00	0.15035	19.84970	2.8985466	0.2483295	170.0526588	4.9478172
87.50	0.03761	19.96238	5.7923254	0.2476056	175.0264578	2.4742556
90.0	0.00002	20.00003	521.0818276	0.2473650	179.9889393	0.0550692
92.50	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0548511
95.00	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0548511
97.50	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0546250
100.0	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0541762
102.50	0.00002	20.00003	*999.9999999	0.2473650	179.9859032	0.0537247
105.00	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0530355
107.50	0.00002	20.00003	*999.9999999	0.2473650	179.9901240	0.0525742
110.0	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0516508
112.50	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0509133
115.00	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0499471
117.50	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0487075
120.0	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0476956
122.50	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0463959
125.00	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0450587
127.50	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0436805
130.0	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0422575
132.50	0.00002	20.00003	*999.9999999	0.2473650	179.9901240	0.0404803
135.00	0.00002	20.00003	*999.9999999	0.2473650	179.9901240	0.0389405
137.50	0.00002	20.00003	*999.9999999	0.2473650	179.9879037	0.0370029
140.0	0.00002	20.00003	*999.9999999	0.2473650	179.9914204	0.0353118
142.50	0.00002	20.00003	*999.9999999	0.2473650	179.9901240	0.0335355
145.00	0.00002	20.00003	*999.9999999	0.2473650	179.9859032	0.0316597
147.50	0.00002	20.00003	*999.9999999	0.2473650	179.9879037	0.0296655
150.0	0.00002	20.00003	*999.9999999	0.2473650	179.9914204	0.0275272
152.50	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0252082
155.00	0.00002	20.00003	*999.9999999	0.2473650	179.9869165	0.0231950
157.50	0.00002	20.00003	*999.9999999	0.2473650	179.9869165	0.0209872
160.0	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0184972
162.50	0.00002	20.00003	*999.9999999	0.2473650	179.9879037	0.0163881
165.00	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0139954
167.50	0.00002	20.00003	*999.9999999	0.2473649	179.9859032	0.0120944
170.0	0.00002	20.00003	*999.9999999	0.2473649	179.9999997	0.0098771
172.50	0.00002	20.00003	*999.9999999	0.2473650	179.9999997	0.0140971
175.00	0.00002	20.00003	*999.9999999	0.2473649	179.9999997	0.0000000
177.50	0.00002	20.00003	*999.9999999	0.2473649	179.9999997	0.0000000
180.0	0.00002	20.00003	*999.9999999	0.2473649	179.9999997	0.0000000

		50.00000	1.0081450	1.0081450	1.0081450	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	50.00000	0.00001	0.2435152	*999.9999999	0.0000000	179.9999997
2.50	49.90234	0.09768	0.2437719	5.5561617	5.0660597	87.3551108
5.00	49.61016	0.38985	0.2445443	2.8619826	10.1316050	84.8570574
7.50	49.12585	0.87416	0.2458394	1.9136298	15.1961263	82.2994176
10.00	48.45340	1.54661	0.2476691	1.4383467	20.2591214	79.7382072
12.50	47.59831	2.40170	0.2500504	1.1535114	25.3201105	77.1773789
15.00	46.56756	3.43245	0.2530058	0.9641338	30.3786170	74.6190671
17.50	45.36955	4.63047	0.2565640	0.8293046	35.4341980	72.0633600
20.0	44.01400	5.98601	0.2607606	0.7286024	40.4864211	69.5111308
22.50	42.51187	7.48814	0.2656390	0.6506588	45.5348860	66.9626452
25.00	40.87527	9.12474	0.2712515	0.5886605	50.5792208	64.4183785
27.50	39.11731	10.88271	0.2776613	0.5387700	55.6190916	61.8788510
30.00	37.25199	12.74802	0.2849439	0.4965969	60.6541969	59.3437370
32.50	35.29412	14.70589	0.2931902	0.4616418	65.6842765	56.8139102
35.00	33.25912	16.74089	0.3025093	0.4319777	70.7091026	54.2894073
37.50	31.16294	18.83708	0.3130329	0.4065587	75.7284977	51.7709679
40.00	29.02188	20.97813	0.3249208	0.3846019	80.7423189	49.2569413
42.50	26.85252	23.14749	0.3383682	0.3655097	85.7504718	46.7492077
45.00	24.67151	25.32850	0.3536151	0.3488180	90.7529045	44.2472055
47.50	22.49549	27.50453	0.3709597	0.3341619	95.7496054	41.7509280
50.0	20.34094	29.65907	0.3907762	0.3212506	100.7406116	39.2603330
52.50	18.22439	31.77593	0.4135404	0.3098495	105.7259999	36.7753256
55.00	16.16075	33.83927	0.4398653	0.2997684	110.7058898	34.2957780
57.50	14.16623	35.83378	0.4705545	0.2908510	115.6804413	31.8215162
60.00	12.25527	37.74475	0.5066807	0.2829686	120.6498556	29.3523342
62.50	10.44185	39.55817	0.5497088	0.2760145	125.6143712	26.8879868
65.00	8.73920	41.26081	0.6016915	0.2698999	130.5742562	24.4281910
67.50	7.15964	42.84037	0.6655953	0.2645507	135.5298236	21.9726458
70.00	5.71457	44.28544	0.7458725	0.2599052	140.4814087	19.5210051
72.50	4.41434	45.58567	0.8495218	0.2559120	145.4293765	17.0729075
75.00	3.26824	46.73178	0.9882104	0.2525286	150.3741182	14.6279722
77.50	2.28440	47.71561	1.1829426	0.2497201	155.3160399	12.1857721
80.00	1.46980	48.53021	1.4757306	0.2474583	160.2555062	9.7459157
82.50	0.83021	49.16980	1.9646087	0.2457212	165.1931182	7.3079680
85.00	0.37011	49.62990	2.9436887	0.2444920	170.1290719	4.8715178
87.50	0.09277	49.90725	5.8835661	0.2437590	175.0634313	2.4364654
90.0	0.00006	49.99995	450.3137171	0.2435154	179.9042299	0.0637157
92.50	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0407848
95.00	0.00003	49.99998	*999.9999999	0.2435153	179.9901240	0.0407848
97.50	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0404803
100.00	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0401722
102.50	0.00003	49.99998	*999.9999999	0.2435153	179.9859032	0.0425403
105.00	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0395612
107.50	0.00003	49.99998	*999.9999999	0.2435153	179.9901240	0.0389405
110.00	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0383084
112.50	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0376671
115.00	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0370029
117.50	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0363387
120.00	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0353118
122.50	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0346151
125.00	0.00003	49.99998	*999.9999999	0.2435153	179.9859032	0.0356619
127.50	0.00003	49.99998	*999.9999999	0.2435153	179.9859032	0.0346151
130.0	0.00003	49.99998	*999.9999999	0.2435153	179.9901240	0.0312786
132.50	0.00003	49.99998	*999.9999999	0.2435153	179.9999997	0.0300814
135.00	0.00003	49.99998	*999.9999999	0.2435153	179.9914204	0.0288327
137.50	0.00003	49.99998	*999.9999999	0.2435153	179.9859032	0.0296655
140.00	0.00003	49.99998	*999.9999999	0.2435152	179.9999997	0.0261734
142.50	0.00003	49.99998	*999.9999999	0.2435152	179.9901240	0.0247280
145.00	0.00003	49.99998	*999.9999999	0.2435152	179.9999997	0.0231950
147.50	0.00003	49.99998	*999.9999999	0.2435152	179.9869165	0.0231950
150.00	0.00003	49.99998	*999.9999999	0.2435152	179.9999997	0.0203891
152.50	0.00003	49.99998	*999.9999999	0.2435152	179.9914204	0.0191542
155.00	0.00003	49.99998	*999.9999999	0.2435152	179.9879037	0.0184972
157.50	0.00003	49.99998	*999.9999999	0.2435152	179.9879037	0.0163881
160.00	0.00003	49.99998	*999.9999999	0.2435152	179.9999997	0.0139954
162.50	0.00003	49.99998	*999.9999999	0.2435152	179.9999997	0.0120944
165.00	0.00003	49.99998	*999.9999999	0.2435152	179.9999997	0.0110587
167.50	0.00003	49.99998	*999.9999999	0.2435152	179.9914204	0.0085777
170.00	0.00003	49.99998	*999.9999999	0.2435152	179.9889393	0.0140971
172.50	0.00003	49.99998	*999.9999999	0.2435152	179.9828708	0.0000000
175.00	0.00003	49.99998	*999.9999999	0.2435152	179.9859032	0.0000000
177.50	0.00003	49.99998	*999.9999999	0.2435152	179.9901240	0.0000000
180.0	0.00003	49.99998	*999.9999999	0.2435152	179.9999997	0.0000000

		100.00000	1.0081450	1.0081450	1.0081450	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	100.00002	0.00001	0.2373577	*999.9999999	0.0000000	179.9999997
2.50	99.79963	0.20039	0.2376320	5.6271456	5.1312665	87.3193883
5.00	99.20027	0.79976	0.2384572	2.8639961	10.2614854	84.7292941
7.50	98.20718	1.79284	0.2398405	1.9131041	15.3896313	82.1040005
10.00	96.82912	3.17090	0.2417941	1.4371192	20.5147069	79.4783981
12.50	95.07816	4.92187	0.2443354	1.1519341	25.6357193	76.8584799
15.00	92.96957	7.03046	0.2474874	0.9622258	30.7517208	74.2396788
17.50	90.52161	9.47840	0.2512795	0.8270998	35.8618032	71.6289269
20.00	87.75543	12.24457	0.2557482	0.7261070	40.9651168	69.0252770
22.50	84.69470	15.30532	0.2609377	0.6475842	46.0608857	66.4294849
25.00	81.36533	18.63468	0.2669018	0.5856162	51.1483178	63.8422459
27.50	77.79535	22.20468	0.2737050	0.5349666	56.2268119	61.2642732
30.00	74.01444	25.98559	0.2814248	0.4930481	61.2957623	58.6961503
32.50	70.05371	29.94631	0.2901539	0.4578551	66.3546603	56.1382655
35.00	65.94542	34.05459	0.3000042	0.4279670	71.4030828	53.5911072
37.50	61.72262	38.27742	0.3111104	0.4023365	76.4406875	51.0549512
40.00	57.41877	42.58125	0.3236362	0.3801803	81.4672232	48.5299744
42.50	53.06767	46.93235	0.3377814	0.3609010	86.4825204	46.0163291
45.00	48.70294	51.29708	0.3537917	0.3440346	91.4865036	43.5140289
47.50	44.35791	55.64211	0.3719725	0.3292158	96.4791793	41.0230178
50.00	40.06528	59.93474	0.3927073	0.3161537	101.4606394	38.5431509
52.50	35.85693	64.14309	0.4164834	0.3046135	106.4310633	36.0742029
55.00	31.76373	68.23629	0.4439292	0.2944045	111.3907099	33.6158816
57.50	27.81523	72.18480	0.4758683	0.2853702	116.3399182	31.1677907
60.00	24.03965	75.96038	0.5134004	0.2773816	121.2790944	28.7295040
62.50	20.46358	79.53644	0.5580277	0.2703315	126.2087300	26.3001089
65.00	17.11195	82.88808	0.6118548	0.2641308	131.1293691	23.8802932
67.50	14.00780	85.99221	0.6779245	0.2587050	136.0416263	21.4680608
70.00	11.17230	88.82772	0.7608035	0.2539920	140.9461759	19.0633159
72.50	8.62455	91.37548	0.8676709	0.2499401	145.8437331	16.6652817
75.00	6.38159	93.61844	1.0104954	0.2465065	150.7350728	14.2732125
77.50	4.45827	95.54174	1.2108248	0.2436560	155.6210071	11.8863132
80.00	2.86725	97.13277	1.5117601	0.2413602	160.5023742	9.5037893
82.50	1.61895	98.38108	2.0138770	0.2395969	165.3800537	7.1247380
85.00	0.72148	99.27854	3.0189153	0.2383490	170.2549455	4.7483657
87.50	0.18068	99.81934	6.0356163	0.2376050	175.1279533	2.3738292
90.0	0.00002	100.00002	*999.9999999	0.2373577	179.9860038	0.0261734
92.50	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0242228
95.00	0.00002	100.00002	*999.9999999	0.2373577	179.9901240	0.0242228
97.50	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0237224
100.0	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0237224
102.50	0.00002	100.00002	*999.9999999	0.2373577	179.9859032	0.0256984
105.00	0.00002	100.00002	*999.9999999	0.2373577	179.9859032	0.0256984
107.50	0.00002	100.00002	*999.9999999	0.2373577	179.9901240	0.0231950
110.0	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0226530
112.50	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0221174
115.00	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0215509
117.50	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0215509
120.0	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0209872
122.50	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0203891
125.00	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0197703
127.50	0.00002	100.00002	*999.9999999	0.2373577	179.9859032	0.0209872
130.0	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0184972
132.50	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0178372
135.00	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0171295
137.50	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0163881
140.0	0.00002	100.00002	*999.9999999	0.2373577	179.9879037	0.0171295
142.50	0.00002	100.00002	*999.9999999	0.2373577	179.9914204	0.0148274
145.00	0.00002	100.00002	*999.9999999	0.2373577	179.9889393	0.0139954
147.50	0.00002	100.00002	*999.9999999	0.2373577	179.9869165	0.0139954
150.0	0.00002	100.00002	*999.9999999	0.2373577	179.9869165	0.0130815
152.50	0.00002	100.00002	*999.9999999	0.2373577	179.9879037	0.0120944
155.00	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0098771
157.50	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0085777
160.0	0.00002	100.00002	*999.9999999	0.2373577	179.9901240	0.0085777
162.50	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0140971
165.00	0.00002	100.00002	*999.9999999	0.2373577	179.9901240	0.0000000
167.50	0.00002	100.00002	*999.9999999	0.2373577	179.9889393	0.0000000
170.0	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0000000
172.50	0.00002	100.00002	*999.9999999	0.2373577	179.9859032	0.0000000
175.00	0.00002	100.00002	*999.9999999	0.2373577	179.9859032	0.0000000
177.50	0.00002	100.00002	*999.9999999	0.2373577	179.9869165	0.0000000
180.0	0.00002	100.00002	*999.9999999	0.2373577	179.9999997	0.0000000

	1000.00000	1.0081450	1.0081450	1.0081450	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	999.99994	0.00000	0.1631187	*999.9999999	0.0000000	179.9999997
2.50	997.08680	2.91312	0.1636052	5.7164074	6.1878917	86.1686528
5.00	988.40479	11.59514	0.1650694	2.8476258	12.3632710	82.3624365
7.50	974.12322	25.87672	0.1675257	1.8848724	18.5139142	78.5922401
10.00	954.51605	45.48391	0.1709982	1.4000205	24.6280510	74.8773761
12.50	929.95014	70.04984	0.1755208	1.1068552	30.6946017	71.2334771
15.00	900.87019	99.12975	0.1811384	0.9099924	36.7033694	67.6736925
17.50	867.78153	132.21841	0.1879063	0.7685620	42.6451746	64.2085064
20.00	831.23170	168.76824	0.1958920	0.6621227	48.5119749	60.8458750
22.50	791.79224	208.20770	0.2051762	0.5792941	54.2969391	57.5911846
25.00	750.04172	249.95822	0.2158539	0.5132185	59.9944741	54.4475205
27.50	706.55041	293.44954	0.2280363	0.4595008	65.6002231	51.4158964
30.00	661.86752	338.13242	0.2418539	0.4151810	71.1110372	48.4955728
32.50	616.51118	383.48876	0.2574596	0.3781843	76.5249163	45.6843794
35.00	570.96083	429.03911	0.2750327	0.3470065	81.8409361	42.9789897
37.50	525.65243	474.34751	0.2947853	0.3205274	87.0591540	40.3752115
40.00	480.97592	519.02402	0.3169702	0.2978933	92.1805218	37.8682241
42.50	437.27472	562.72522	0.3418905	0.2784416	97.2067736	35.4527909
45.00	394.84654	605.15341	0.3699145	0.2616497	102.1403372	33.1234079
47.50	353.94575	646.05419	0.4014945	0.2471005	106.9842279	30.8744583
50.00	314.78632	685.21362	0.4371935	0.2344574	111.7419749	28.7002981
52.50	277.54545	722.45449	0.4777226	0.2234463	116.4175197	26.5953355
55.00	242.36765	757.63229	0.5239950	0.2138425	121.0151464	24.5541040
57.50	209.36847	790.63147	0.5772041	0.2054608	125.5394258	22.5712728
60.00	178.63806	821.36128	0.6389420	0.1981478	129.9951412	20.6416894
62.50	150.24777	849.75217	0.7113820	0.1917753	134.3872622	18.7603824
65.00	124.24778	875.75216	0.7975713	0.1862375	138.7208663	16.9225659
67.50	100.67619	899.32375	0.9019180	0.1814455	143.0011503	15.1236404
70.00	79.55905	920.44089	1.0310442	0.1773254	147.2333595	13.3591838
72.50	60.91329	939.08664	1.1953703	0.1738158	151.4228024	11.6249323
75.00	44.74905	955.25090	1.4122830	0.1708659	155.5748023	9.9167744
77.50	31.07157	968.92838	1.7131048	0.1684343	159.6947052	8.2307300
80.00	19.88274	980.11721	2.1605181	0.1664875	163.7878567	6.5629380
82.50	11.18238	988.81755	2.9008363	0.1649993	167.8596176	4.9096309
85.00	4.96935	995.03059	4.3730890	0.1639500	171.9153263	3.2671205
87.50	1.24225	998.75771	8.7726399	0.1633258	175.9603359	1.6317760
90.0	0.00002	999.99994	*999.9999999	0.1631187	179.9860038	0.0000000
92.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
95.00	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
97.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
100.0	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
102.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
105.00	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
107.50	0.00001	999.99994	*999.9999999	0.1631187	179.9914204	0.0000000
110.0	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
112.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
115.00	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
117.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
120.00	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
122.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
125.00	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
127.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
130.0	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
132.50	0.00002	999.99994	*999.9999999	0.1631187	179.9859032	0.0000000
135.00	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
137.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
140.0	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
142.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
145.00	0.00001	999.99994	*999.9999999	0.1631187	179.9914204	0.0000000
147.50	0.00002	999.99994	*999.9999999	0.1631187	179.9859032	0.0000000
150.00	0.00002	999.99994	*999.9999999	0.1631187	179.9869165	0.0000000
152.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
155.00	0.00002	999.99994	*999.9999999	0.1631187	179.9879037	0.0000000
157.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
160.0	0.00002	999.99994	*999.9999999	0.1631187	179.9859032	0.0000000
162.50	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
165.00	0.00002	999.99994	*999.9999999	0.1631187	179.9879037	0.0000000
167.50	0.00002	999.99994	*999.9999999	0.1631187	179.9879037	0.0000000
170.0	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000
172.50	0.00002	999.99994	*999.9999999	0.1631187	179.9869165	0.0000000
175.00	0.00001	999.99994	*999.9999999	0.1631187	179.9901240	0.0000000
177.50	0.00001	999.99994	*999.9999999	0.1631187	179.9889393	0.0000000
180.0	0.00000	999.99994	*999.9999999	0.1631187	179.9999997	0.0000000

	10000.00000	1.0081450	1.0081450	1.0081450	1.0081450
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	9999.99952	0.00007	0.0395178	*999.9999999	0.0000000	179.9999997
2.50	9880.84052	119.15922	0.0403612	5.2524934	12.5338029	74.6593399
5.00	9538.13467	461.86471	0.0429436	2.1036739	24.8205412	61.0364933
7.50	9011.85561	988.14398	0.0474209	1.0608128	36.6428655	50.2101377
10.00	8356.37286	1643.62673	0.0540520	0.6038897	47.8344809	41.8751355
12.50	7628.19003	2371.80959	0.0631967	0.3791961	58.2887921	35.4893476
15.00	6876.60515	3123.39451	0.0753140	0.2588190	67.9558404	30.5376008
17.50	6139.05270	3860.94697	0.0909596	0.1893836	76.8317930	26.6263209
20.00	5440.49289	4559.50677	0.1107831	0.1466884	84.9457677	23.4751478
22.50	4795.20436	5204.79530	0.1355266	0.1189648	92.3474398	20.8877213
25.00	4209.45801	5790.54166	0.1660226	0.1001139	99.0971159	18.7258627
27.50	3684.11351	6315.88619	0.2031951	0.0867897	105.2586734	16.8910019
30.00	3216.71877	6783.28093	0.2480608	0.0770593	110.8949855	15.3116234
32.50	2803.02666	7196.97304	0.3017349	0.0697547	116.0652637	13.9349200
35.00	2438.00588	7561.99382	0.3654403	0.0641415	120.8237447	12.7212159
37.50	2116.46851	7883.53119	0.4405230	0.0597415	125.2192110	11.6402224
40.00	1833.43072	8166.56899	0.5284758	0.0562336	129.2950362	10.6684517
42.50	1584.29932	8415.70042	0.6309723	0.0533961	133.0895126	9.7874414
45.00	1364.94990	8635.04983	0.7499178	0.0510724	136.6363131	8.9824817
47.50	1171.74137	8828.25837	0.8875206	0.0491492	139.9650052	8.2417124
50.00	1001.49579	8998.50395	1.0463961	0.0475435	143.1015432	7.5554576
52.50	851.46036	9148.53934	1.2297146	0.0461929	146.0687444	6.9157461
55.00	719.26292	9280.73686	1.4414189	0.0450501	148.8867253	6.3159322
57.50	602.86697	9397.13281	1.6865450	0.0440787	151.5732706	5.7504301
60.00	500.52945	9499.47026	1.9717058	0.0432504	154.1441493	5.2145002
62.50	410.76072	9589.23895	2.3058456	0.0425430	156.6134505	4.7040734
65.00	332.29198	9667.70772	2.7014441	0.0419388	158.9937918	4.2156312
67.50	264.04515	9735.95467	3.1765312	0.0414237	161.2965465	3.7460983
70.00	205.10782	9794.89174	3.7582082	0.0409865	163.5320447	3.2927720
72.50	154.71186	9845.28784	4.4891904	0.0406181	165.7097191	2.8532331
75.00	112.21584	9887.78372	5.4408877	0.0403113	167.8382680	2.4253086
77.50	77.09019	9922.90948	6.7421786	0.0400604	169.9257679	2.0070173
80.00	48.90555	9951.09428	8.6513382	0.0398607	171.9797738	1.5965413
82.50	27.32239	9972.67749	11.7718048	0.0397088	174.0074679	1.1921743
85.00	12.08441	9987.91542	17.9152355	0.0396021	176.0156825	0.7923192
87.50	3.01229	9996.98762	36.1429285	0.0395388	178.0110374	0.3954314
90.0	0.00000	9999.99989	*999.9999999	0.0395178	179.9914204	0.0000000
92.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
95.00	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
97.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
100.0	0.00000	9999.99989	*999.9999999	0.0395178	179.9914204	0.0000000
102.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
105.00	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
107.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
110.0	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
112.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
115.00	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
117.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
120.00	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
122.50	0.00009	9999.99952	*999.9999999	0.0395178	179.9859032	0.0000000
125.00	0.00000	9999.99989	*999.9999999	0.0395178	179.9914204	0.0000000
127.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
130.0	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
132.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
135.00	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
137.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
140.0	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
142.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
145.00	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
147.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
150.0	0.00000	9999.99989	*999.9999999	0.0395178	179.9914204	0.0000000
152.50	0.00000	9999.99989	*999.9999999	0.0395178	179.9914204	0.0000000
155.00	0.00000	9999.99989	*999.9999999	0.0395178	179.9914204	0.0000000
157.50	0.00000	9999.99989	*999.9999999	0.0395178	179.9914204	0.0000000
160.0	0.00002	9999.99989	*999.9999999	0.0395178	179.9901240	0.0000000
162.50	0.00002	9999.99989	*999.9999999	0.0395178	179.9901240	0.0000000
165.00	0.00004	9999.99989	*999.9999999	0.0395178	179.9889393	0.0000000
167.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
170.0	0.00002	9999.99989	*999.9999999	0.0395178	179.9901240	0.0000000
172.50	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000
175.00	0.00002	9999.99989	*999.9999999	0.0395178	179.9901240	0.0000000
177.50	0.00007	9999.99952	*999.9999999	0.0395178	179.9869165	0.0000000
180.0	0.00009	9999.99989	*999.9999999	0.0395178	179.9999997	0.0000000

	5.00000	1.0081450	2.0147400	1.0081450	2.0147400
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	5.00000	0.00004	0.4431700	*999.9999999	0.0000000	0.0000000
2.50	4.99523	0.00481	0.4434890	5.1426125	3.7551172	84.9504832
5.00	4.98094	0.01[illegible]	0.4444474	3.6158620	7.5083702	86.0420518
7.50	4.95722	0.04280	0.4460505	2.4910291	11.2580430	84.2364315
10.00	4.92422	0.07581	0.4483065	1.8984765	15.0022563	82.4249655
12.50	4.88214	0.11791	0.4512275	1.5266292	18.7392056	80.5645175
15.00	4.83124	0.16879	0.4548285	1.2810079	22.4670462	78.7335701
17.50	4.77184	0.22817	0.4591289	1.1038910	26.1838913	76.8964030
20.00	4.70429	0.29575	0.4641514	0.9691119	29.8878621	75.0347599
22.50	4.62900	0.37104	0.4699229	0.8654248	33.5770488	73.1922936
25.00	4.54644	0.45359	0.4764743	0.7829559	37.2494981	71.3610269
27.50	4.45707	0.54296	0.4838411	0.7156150	40.9032404	69.5333168
30.00	4.36145	0.63859	0.4920634	0.6598771	44.5362691	67.7172057
32.50	4.26011	0.73992	0.5011861	0.6130492	48.1465451	65.9132119
35.00	4.15363	0.84639	0.5112593	0.5731827	51.7319959	64.1204245
37.50	4.04263	0.95740	0.5223388	0.5388998	55.2905191	62.3401813
40.00	3.92770	1.07232	0.5344861	0.5091819	58.8199832	60.5749417
42.50	3.80948	1.19053	0.5477690	0.4832272	62.3182248	58.8259462
45.00	3.68860	1.31141	0.5622613	0.4603945	65.7830641	57.0930530
47.50	3.56568	1.43435	0.5780443	0.4401999	69.2123029	55.3778145
50.00	3.44133	1.55870	0.5952058	0.4222555	72.6037316	53.6818806
52.50	3.31615	1.68387	0.6138414	0.4062386	75.9551425	52.0060234
55.00	3.19075	1.80926	0.6340537	0.3918897	79.2643365	50.3515564
57.50	3.06586	1.93436	0.6559534	0.3789866	82.5291392	48.7187855
60.00	2.94145	2.05856	0.6796589	0.3673578	85.7474107	47.1098438
62.50	2.81859	2.18142	0.7052962	0.3568448	88.9170654	45.5248337
65.00	2.69757	2.30245	0.7329975	0.3473222	92.0360852	43.9651508
67.50	2.57882	2.42118	0.7629039	0.3386829	95.1025386	42.4322665
70.00	2.46272	2.53730	0.7951603	0.3308273	98.1145997	40.9261357
72.50	2.34963	2.65036	0.8299186	0.3236787	101.0705680	39.4485868
75.00	2.23984	2.76014	0.8673344	0.3171620	103.9688922	37.9995957
77.50	2.13362	2.86639	0.9075645	0.3112158	106.8081744	36.5799878
80.00	2.03118	2.96883	0.9507683	0.3057866	109.5872037	35.1906657
82.50	1.93269	3.06729	0.9971017	0.3008260	112.3049706	33.8322263
85.00	1.83829	3.16169	1.0467164	0.2962896	114.9606742	32.5047150
87.50	1.74805	3.25195	1.0997567	0.2921388	117.5537333	31.2083803
90.00	1.66204	3.33797	1.1563587	0.2883402	120.0838014	29.9436781
92.50	1.58026	3.41974	1.2166399	0.2848625	122.5507744	28.7106257
95.00	1.50270	3.49730	1.2807038	0.2816773	124.9547824	27.5090009
97.50	1.42931	3.57069	1.3486278	0.2787595	127.2961907	26.3387043
100.00	1.36003	3.63998	1.4204662	0.2760860	129.5755990	25.1993824
102.50	1.29475	3.70525	1.4962417	0.2736363	131.7938343	24.0906820
105.00	1.23339	3.76660	1.5759371	0.2713913	133.9519247	23.0121322
107.50	1.17579	3.82420	1.6595035	0.2693336	136.0511072	21.9629880
110.00	1.12183	3.87818	1.7468473	0.2674474	138.0927861	20.9425040
112.50	1.07136	3.92862	1.8378251	0.2657188	140.0785409	19.9501291
115.00	1.02423	3.97574	1.9322494	0.2641343	142.0100890	18.9847793
117.50	0.98030	4.01970	2.0298743	0.2626821	143.8892670	18.0456046
120.00	0.93940	4.06060	2.1304197	0.2613515	145.7180195	17.1316471
122.50	0.90137	4.09860	2.2335360	0.2601325	147.4983841	16.2419345
125.00	0.86608	4.13392	2.3388235	0.2590159	149.2324471	15.3752893
127.50	0.83337	4.16663	2.4458381	0.2579938	150.9223618	14.5307641
130.00	0.80310	4.19687	2.5540837	0.2570585	152.5703110	13.7072485
132.50	0.77513	4.22485	2.6630147	0.2562034	154.1784965	12.9035730
135.00	0.74934	4.25063	2.7720597	0.2554223	155.7491273	12.1186789
137.50	0.72560	4.27440	2.8805934	0.2547095	157.2844200	11.3513954
140.00	0.70379	4.29619	2.9879566	0.2540601	158.7865651	10.6007572
142.50	0.68382	4.31616	3.0934876	0.2534696	160.2577418	9.8655810
145.00	0.66558	4.33441	3.1964994	0.2529338	161.7001072	9.1447710
147.50	0.64898	4.35099	3.2962832	0.2524491	163.1157883	8.4373465
150.00	0.63393	4.36604	3.3921408	0.2520121	164.5068787	7.7421833
152.50	0.62035	4.37964	3.4833823	0.2516198	165.8754461	7.0582556
155.00	0.60819	4.39178	3.5693165	0.2512698	167.2235094	6.3846276
157.50	0.59736	4.40262	3.6493056	0.2509596	168.5530581	5.7202119
160.00	0.58782	4.41216	3.7227263	0.2506872	169.8660515	5.0640749
162.50	0.57952	4.42047	3.7889920	0.2504508	171.1644344	4.4152481
165.00	0.57241	4.42758	3.8475575	0.2502489	172.4500917	3.7727919
167.50	0.56646	4.43354	3.8979640	0.2500803	173.7248674	3.1357597
170.00	0.56163	4.43835	3.9398086	0.2499437	174.9906503	2.5032272
172.50	0.55789	4.44207	3.9727091	0.2498383	176.2492619	1.8742906
175.00	0.55525	4.44475	3.9964040	0.2497636	177.5025018	1.2480282
177.50	0.55366	4.44632	4.0107193	0.2497189	178.7520796	0.6235588
180.00	0.55313	4.44684	4.0154893	0.2497041	179.9999997	0.0000000

	10.00000	1.0081450	2.0147400	1.0081450	2.0147400
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.00	9.99999	0.00004	0.4421262	*999.9999999	0.0000000	179.9999997
2.50	9.99042	0.00961	0.4424466	1.3262267	3.7595241	85.8971570
5.00	9.96176	0.03826	0.4434096	3.4974021	7.5172101	85.9200101
7.50	9.91420	0.08583	0.4450202	2.4924660	11.2712238	84.2326760
10.00	9.84803	0.15199	0.4472867	1.9059717	15.0197510	82.4456733
12.50	9.76365	0.23637	0.4502210	1.5319630	18.7609218	80.5865664
15.00	9.66161	0.33840	0.4538386	1.2824663	22.4928737	78.7338503
17.50	9.54251	0.45750	0.4581585	1.1032517	26.2137149	76.8742971
20.00	9.40709	0.59292	0.4632036	0.9692258	29.9215443	75.0206050
22.50	9.25618	0.74383	0.4690008	0.8653504	33.6144298	73.1734757
25.00	9.09067	0.90934	0.4755811	0.7825678	37.2904088	71.3329453
27.50	8.91157	1.08845	0.4829799	0.7152382	40.9474950	69.5026047
30.00	8.71993	1.28009	0.4912374	0.6595199	44.5836678	67.6843386
32.50	8.51685	1.48315	0.5003986	0.6126681	48.1968798	65.8766873
35.00	8.30352	1.69650	0.5105138	0.5727929	51.7850514	64.0807446
37.50	8.08114	1.91890	0.5216386	0.5385267	55.3460684	62.2987233
40.00	7.85093	2.14908	0.5338348	0.5088299	58.8777922	60.5323486
42.50	7.61416	2.38586	0.5471700	0.4828751	62.3780593	58.7811559
45.00	7.37207	2.62797	0.5617186	0.4600477	65.8446837	57.0466176
47.50	7.12592	2.87410	0.5775617	0.4398667	69.2754667	55.3307325
50.00	6.87696	3.12306	0.5947873	0.4219286	72.6681993	53.6338106
52.50	6.62638	3.37366	0.6134912	0.4059134	76.0206763	51.9568149
55.00	6.37536	3.62467	0.6337764	0.3915679	79.3307040	50.3014896
57.50	6.12503	3.87501	0.6557537	0.3786702	82.5961128	48.6684088
60.00	5.87646	4.12356	0.6795415	0.3670442	85.8147681	47.0590844
62.50	5.63065	4.36939	0.7052660	0.3565341	88.9845930	45.4738855
65.00	5.38855	4.61146	0.7330603	0.3470166	92.1035789	43.9146396
67.50	5.15101	4.84902	0.7630650	0.3383773	95.1698031	42.3815142
70.00	4.91882	5.08122	0.7954264	0.3305247	98.1814522	40.8759080
72.50	4.69265	5.30738	0.8302962	0.3233764	103.1368372	39.3985104
75.00	4.47313	5.52692	0.8678298	0.3168612	104.0344164	37.9500780
77.50	4.26076	5.73929	0.9081855	0.3109170	106.8728082	36.5312982
80.00	4.05597	5.94407	0.9515216	0.3054892	109.6508130	35.1428561
82.50	3.85910	6.14092	0.9979955	0.3005292	112.3674326	33.7851912
85.00	3.67041	6.32964	1.0477595	0.2959931	115.0218770	32.4584931
87.50	3.49008	6.50994	1.1009587	0.2918438	117.6135801	31.1634064
90.00	3.31819	6.68183	1.1577275	0.2880458	120.1422103	29.8998143
92.50	3.15479	6.84526	1.2181863	0.2845682	122.6076707	28.6677878
95.00	2.99982	7.00023	1.2824365	0.2813834	125.0100993	27.4673462
97.50	2.85321	7.14682	1.3505576	0.2784661	127.3498796	26.2983259
100.00	2.71481	7.28522	1.4226039	0.2757930	129.6276152	25.1602959
102.50	2.56443	7.41560	1.4985954	0.2733435	131.8441480	24.0528781
105.00	2.46185	7.53820	1.5785189	0.2710985	134.0005063	22.9755476
107.50	2.34681	7.65324	1.6623243	0.2690410	136.0979378	21.9277013
110.00	2.23904	7.76101	1.7499158	0.2671550	138.1378546	20.9086020
112.50	2.13826	7.86178	1.8411503	0.2654265	140.1218437	19.9175205
115.00	2.04416	7.95588	1.9358419	0.2638421	142.0516185	18.9535122
117.50	1.95643	8.04361	2.0337463	0.2623901	143.9290307	18.0156987
120.00	1.87476	8.12527	2.1345728	0.2610596	145.7560249	17.1031028
122.50	1.79884	8.20119	2.2379776	0.2598405	147.5346349	16.2146673
125.00	1.72837	8.27167	2.3435633	0.2587241	149.2669582	15.3493509
127.50	1.66307	8.33698	2.4508784	0.2577020	150.9551480	14.5061258
130.00	1.60263	8.39740	2.5594287	0.2567668	152.6013874	13.6838690
132.50	1.54680	8.45324	2.6686717	0.2559117	154.2078778	12.8814570
135.00	1.49531	8.50473	2.7780219	0.2551306	155.7768360	12.0978180
137.50	1.44792	8.55211	2.8868552	0.2544178	157.3104635	11.3318417
140.00	1.40439	8.59566	2.9945324	0.2537685	158.8109694	10.5823774
142.50	1.36452	8.63552	3.1003644	0.2531779	160.2805294	9.8484148
145.00	1.32811	8.67192	3.2036605	0.2526422	161.7212892	9.1288507
147.50	1.29497	8.70507	3.3037284	0.2521574	163.1353833	8.4225831
150.00	1.26493	8.73510	3.3998562	0.2517204	164.5249017	7.7286138
152.50	1.23783	8.76222	3.4913512	0.2513282	165.8919044	7.0458737
155.00	1.21354	8.78651	3.5775365	0.2509782	167.2384292	6.3733776
157.50	1.19194	8.80811	3.6577489	0.2506680	168.5664468	5.7101295
160.00	1.17290	8.82715	3.7313716	0.2503956	169.8779240	5.0551419
162.50	1.15633	8.84373	3.7978158	0.2501592	171.1747870	4.4074587
165.00	1.14214	8.85792	3.8565539	0.2499573	172.4589467	3.7661265
167.50	1.13025	8.86981	3.9071080	0.2497887	173.7322547	3.1302141
170.00	1.12062	8.87942	3.9490545	0.2496521	174.9965474	2.4988005
172.50	1.11317	8.88687	3.9820589	0.2495467	176.2536913	1.8709660
175.00	1.10788	8.89216	4.0058300	0.2494720	177.5054187	1.2458212
177.50	1.10472	8.89532	4.0201732	0.2494273	178.7535101	0.6224591
180.00	1.10367	8.89637	4.0249626	0.2494124	179.9999997	0.0000000

	20.00000	1.0081450	2.0147400	1.0081450	2.0147400
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	20.00001	0.00004	0.4400482	+999.9999999	0.0000000	179.9999997
2.50	19.98076	0.01926	0.4403716	5.4502856	3.7683973	87.5726484
5.00	19.92314	0.07689	0.4413435	3.6634675	7.5348980	86.0746451
7.50	19.82752	0.17252	0.4429689	2.5231297	11.2976469	84.2875172
10.00	19.69449	0.30555	0.4452562	1.9075938	15.0547706	82.4347842
12.50	19.52488	0.47516	0.4482173	1.5315363	18.8043803	80.5627436
15.00	19.31977	0.68028	0.4518677	1.2808892	22.5445680	78.6949940
17.50	19.08040	0.91962	0.4562264	1.1019437	26.2734056	76.8302631
20.00	18.80828	1.19176	0.4613165	0.9679174	29.9889501	74.9686670
22.50	18.50506	1.49496	0.4671648	0.8642098	33.6892352	73.1167350
25.00	18.17259	1.82744	0.4738024	0.7815445	37.3722747	71.2714873
27.50	17.81286	2.18719	0.4812650	0.7142714	41.0360485	69.4357149
30.00	17.42801	2.57202	0.4895926	0.6586009	44.6785156	67.6123362
32.50	17.02031	2.97975	0.4988305	0.6117780	48.2976042	65.7994032
35.00	16.59210	3.40793	0.5090291	0.5719702	51.8912126	64.0005209
37.50	16.14582	3.85422	0.5202441	0.5377413	55.4572124	62.2149870
40.00	15.68395	4.31608	0.5325376	0.5080639	58.9934569	60.4446981
42.50	15.20903	4.79102	0.5459774	0.4821331	62.4977708	58.6904559
45.00	14.72358	5.27646	0.5606381	0.4593323	65.9679625	56.9537439
47.50	14.23011	5.76995	0.5766011	0.4391636	69.4018316	55.2351300
50.00	13.73112	6.26892	0.5939548	0.4212415	72.7971721	53.5363820
52.50	13.22903	6.77101	0.6127952	0.4052414	76.1517819	51.8580139
55.00	12.72619	7.27385	0.6332258	0.3909052	79.4634759	50.2013508
57.50	12.22487	7.77517	0.6553578	0.3780180	82.7300943	48.5675290
60.00	11.72720	8.27287	0.6793102	0.3663980	85.9495171	46.9573535
62.50	11.23519	8.76486	0.7052096	0.3558963	89.1196832	45.3721590
65.00	10.75073	9.24934	0.7331900	0.3463833	92.2386013	43.8127477
67.50	10.27551	9.72454	0.7633923	0.3377502	95.3043699	42.2801673
70.00	9.81110	10.18897	0.7959634	0.3299018	98.3151969	40.7751519
72.50	9.35886	10.64118	0.8310559	0.3227577	101.2694165	39.2987061
75.00	8.92000	11.08006	0.8688261	0.3162457	104.1655093	37.8513865
77.50	8.49555	11.50452	0.9094329	0.3103046	107.0021242	36.4339951
80.00	8.08633	11.91374	0.9530360	0.3048790	109.7780801	35.0470401
82.50	7.69303	12.30702	0.9997926	0.2999211	112.4924086	33.6910818
85.00	7.31615	12.68391	1.0498564	0.2953873	115.1443422	32.3663913
87.50	6.95602	13.04403	1.1033733	0.2912394	117.7333444	31.0732767
90.00	6.61283	13.38724	1.1604787	0.2874427	120.2590987	29.8118267
92.50	6.28663	13.71343	1.2212932	0.2839665	122.7215379	28.5821576
95.00	5.97733	14.02274	1.2859193	0.2807828	125.1208186	27.3840908
97.50	5.68475	14.31532	1.3544376	0.2778663	127.4573468	26.2174584
100.00	5.40860	14.59148	1.4269003	0.2751940	129.7317483	25.0819489
102.50	5.14848	14.85158	1.5033302	0.2727452	131.9446687	23.9771191
105.00	4.90396	15.09610	1.5837144	0.2705010	134.0977699	22.9024030
107.50	4.67452	15.32555	1.6680002	0.2684440	136.1917034	21.8571931
110.00	4.45961	15.54046	1.7560919	0.2665585	138.2281035	20.8407659
112.50	4.25864	15.74144	1.8478485	0.2648303	140.2085535	19.8523075
115.00	4.07102	15.92904	1.9430786	0.2632464	142.1347894	18.8909851
117.50	3.89611	16.10395	2.0415428	0.2617947	144.0086663	17.9558169
120.00	3.73330	16.26678	2.1429438	0.2604644	145.8321400	17.0458402
122.50	3.58198	16.41810	2.2469366	0.2592456	147.6072446	16.1600512
125.00	3.44153	16.55854	2.3531225	0.2581294	149.3360884	15.2973734
127.50	3.31137	16.68870	2.4610495	0.2571075	151.0208286	14.4567330
130.00	3.19093	16.80914	2.5702170	0.2561725	152.6636444	13.6370424
132.50	3.07967	16.92042	2.6800813	0.2553175	154.2667486	12.8371816
135.00	2.97706	17.02301	2.7900537	0.2545365	155.8323503	12.0560635
137.50	2.88263	17.11745	2.8995096	0.2538239	157.3626623	11.2925697
140.00	2.79592	17.20414	3.0077934	0.2531747	158.8598825	10.5456188
142.50	2.71648	17.28359	3.1142313	0.2525843	160.3261828	9.8140782
145.00	2.64394	17.35613	3.2181185	0.2520486	161.7637314	9.0969218
147.50	2.57792	17.42214	3.3187559	0.2515639	163.1746367	8.3930594
150.00	2.51807	17.48200	3.4154307	0.2511270	164.5610109	7.7014496
152.50	2.46410	17.53598	3.5074512	0.2507349	165.9248956	7.0210621
155.00	2.41572	17.58434	3.5941254	0.2503849	167.2683209	6.3509011
157.50	2.37268	17.62740	3.6747949	0.2500747	168.5932763	5.6899544
160.00	2.33475	17.66533	3.7488399	0.2498024	169.9017137	5.0372553
162.50	2.30175	17.69833	3.8156649	0.2495660	171.1955480	4.3918412
165.00	2.27348	17.72657	3.8747394	0.2493642	172.4767163	3.7527699
167.50	2.24981	17.75026	3.9255833	0.2491955	173.7470217	3.1191011
170.00	2.23061	17.76945	3.9677712	0.2490590	175.0083566	2.4899236
172.50	2.21579	17.78427	4.0009618	0.2489537	176.2625054	1.8643186
175.00	2.20525	17.79482	4.0248676	0.2488789	177.5113344	1.2413857
177.50	2.19895	17.80111	4.0392929	0.2488342	178.7565164	0.6202354
180.0-	2.19685	17.80320	4.0441165	0.2488194	179.9999997	0.0000000

	50.00000	1.0081450	2.0147400	1.0081490	2.0147400
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	49.99995	0.00004	0.4339419	+999.9999999	0.0000000	0.0000000
2.50	49.95107	0.04891	0.4342741	5.2964761	3.7947923	87.5129618
5.00	49.80477	0.19521	0.4352721	3.7536080	7.5875511	86.1366704
7.50	49.56197	0.43802	0.4369412	2.5246779	11.3763437	84.2508435
10.00	49.22426	0.77572	0.4392897	1.9038925	15.1590969	82.3677041
12.50	48.79381	1.20617	0.4423297	1.5273608	18.9338446	80.4725897
15.00	48.27339	1.72660	0.4460767	1.2767412	22.6985447	78.5825748
17.50	47.66630	2.33367	0.4505500	1.0981085	26.4511582	76.6980350
20.00	46.97639	3.02359	0.4557726	0.9644518	30.1896427	74.8188041
22.50	46.20799	3.79197	0.4617717	0.8609883	33.9119248	72.9490947
25.00	45.36589	4.63407	0.4685786	0.7785872	37.6159314	71.0884139
27.50	44.45525	5.54472	0.4762292	0.7115268	41.2995555	69.2381993
30.00	43.48159	6.51838	0.4847640	0.6559884	44.9606799	67.3999373
32.50	42.45074	7.54923	0.4942285	0.6093036	48.5971667	65.5742131
35.00	41.36876	8.63120	0.5046736	0.5695902	52.2068835	63.7626201
37.50	40.24190	9.75806	0.5161558	0.5354526	55.7875935	61.9660404
40.00	39.07654	10.92341	0.5287373	0.5058516	59.3371723	60.1857700
42.50	37.87910	12.12087	0.5424869	0.4799847	62.8534019	58.4225804
45.00	36.65603	13.34391	0.5574798	0.4572369	66.3340777	56.6779033
47.50	35.41374	14.58623	0.5737984	0.4371153	69.7769929	54.9526051
50.00	34.15852	15.84142	0.5915319	0.4192312	73.1799480	53.2480184
52.50	32.89650	17.10344	0.6107776	0.4032652	76.5407585	51.5650533
55.00	31.63360	18.36635	0.6316401	0.3889580	79.8572622	49.9047957
57.50	30.37548	19.62446	0.6542319	0.3760953	83.1273340	48.2683655
60.00	29.12752	20.87243	0.6786734	0.3644976	86.3488954	46.6567226
62.50	27.89473	22.10520	0.7050931	0.3540145	89.5199347	45.0709194
65.00	26.68175	23.31819	0.7336264	0.3445176	92.6385161	43.5118083
67.50	25.49284	24.50712	0.7644164	0.3358982	95.7027994	41.9803392
70.00	24.33180	25.66814	0.7976120	0.3280622	98.7110589	40.4773634
72.50	23.20201	26.79791	0.8333678	0.3209284	101.6617008	39.0036140
75.00	22.10642	27.89352	0.8718426	0.3144258	104.5532711	37.5597719
77.50	21.04749	28.95244	0.9131974	0.3084926	107.3844992	36.1464891
80.00	20.02727	29.97268	0.9575943	0.3030740	110.1542823	34.7642336
82.50	19.04733	30.95262	1.0051933	0.2981220	112.8617227	33.4134616
85.00	18.10885	31.89109	1.0561503	0.2935935	115.5061312	32.0944701
87.50	17.21261	32.78732	1.1106136	0.2894502	118.0870384	30.8074705
90.00	16.35900	33.64093	1.1687209	0.2856576	120.6042059	29.5525357
92.50	15.54807	34.45186	1.2305948	0.2821850	123.0576299	28.3296566
95.00	14.77955	35.22038	1.2963400	0.2790044	125.4475378	27.1386757
97.50	14.05291	35.94700	1.3660376	0.2760906	127.7743839	25.9793620
100.00	13.36736	36.63257	1.4397420	0.2734208	130.0388612	24.8513233
102.50	12.72190	37.27801	1.5174762	0.2709741	132.2418638	23.7541065
105.00	12.11537	37.88456	1.5992272	0.2687317	134.3845017	22.6871189
107.50	11.54647	38.45345	1.6849414	0.2666763	136.4680640	21.6497261
110.00	11.01378	38.98613	1.7745230	0.2647924	138.4940259	20.6411548
112.50	10.51581	39.48409	1.8678286	0.2630655	140.4640079	19.6605798
115.00	10.05104	39.94890	1.9646638	0.2614826	142.3797719	18.7071089
117.50	9.61790	40.38203	2.0647840	0.2600319	144.2431957	17.7798033
120.00	9.21482	40.78511	2.1678905	0.2587026	146.0562572	16.8776583
122.50	8.84027	41.15965	2.2736304	0.2574846	147.8210166	15.9996454
125.00	8.49271	41.50722	2.3815991	0.2563691	149.5395862	15.1446819
127.50	8.17068	41.82924	2.4913366	0.2553478	151.2141339	14.3117025
130.00	7.87276	42.12715	2.6023364	0.2544134	152.8468579	13.4995915
132.50	7.59760	42.40233	2.7140437	0.2535589	154.4399634	12.7072401
135.00	7.34389	42.65603	2.8258613	0.2527784	155.9956744	11.9335465
137.50	7.11042	42.88949	2.9371547	0.2520662	157.5162038	11.1773979
140.00	6.89607	43.10384	3.0472572	0.2514174	159.0037458	10.4376894
142.50	6.69973	43.30017	3.1554797	0.2508273	160.4604796	9.7133559
145.00	6.52045	43.47946	3.2611132	0.2502918	161.8885510	9.0032959
147.50	6.35729	43.64263	3.3634391	0.2498074	163.2900946	8.3064639
150.00	6.20942	43.79049	3.4617406	0.2493707	164.6671891	7.6218133
152.50	6.07607	43.92385	3.5553052	0.2489788	166.0218872	6.9483183
155.00	5.95655	44.04336	3.6434363	0.2486290	167.3562191	6.2849783
157.50	5.85022	44.14968	3.7254633	0.2483190	168.6721481	5.6308022
160.00	5.75654	44.24337	3.8007528	0.2480468	169.9716412	4.9848129
162.50	5.67501	44.32488	3.8687033	0.2478106	171.2566055	4.3460642
165.00	5.60521	44.39469	3.9287718	0.2476088	172.5289263	3.7136121
167.50	5.54675	44.45318	3.9804693	0.2474402	173.7904511	3.0865253
170.00	5.49933	44.50057	4.0233705	0.2473037	175.0430614	2.4638955
172.50	5.46271	44.53719	4.0571165	0.2471985	176.2885153	1.8448228
175.00	5.43669	44.56323	4.0814268	0.2471238	177.5286198	1.2284018
177.50	5.42114	44.57876	4.0960950	0.2470791	178.7651926	0.6137537
180.00	5.41596	44.58394	4.1009970	0.2470643	179.9999997	0.0000000

	100.00000	1.0081450	2.0147400	1.0081450	2.0147400
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	100.00002	0.00004	0.4241312	*999.9999999	0.0000000	0.0000000
2.50	99.89973	0.10032	0.4244773	6.3849750	3.8384154	87.7575364
5.00	99.59955	0.40047	0.4255175	3.7637284	7.6745464	86.1014135
7.50	99.10155	0.89850	0.4272567	2.5187657	11.5062848	84.1703408
10.00	98.40902	1.59100	0.4297038	1.8945614	15.3313681	82.2421506
12.50	97.52672	2.47333	0.4328706	1.5191470	19.1475727	80.3130004
15.00	96.46047	3.53958	0.4367731	1.2694056	22.9526803	78.3895955
17.50	95.21741	4.78264	0.4414308	1.0915902	26.7444708	76.4741115
20.00	93.80571	6.19430	0.4468670	0.9586847	30.5207096	74.5671466
22.50	92.23465	7.76541	0.4531093	0.8556977	34.2791684	72.6692565
25.00	90.51427	9.48578	0.4601896	0.7736961	38.0176075	70.7823243
27.50	88.65554	11.34448	0.4681443	0.7069600	41.7337909	68.9075224
30.00	86.67014	13.32987	0.4770144	0.6516737	45.4254750	67.0459025
32.50	84.57035	15.42970	0.4868461	0.6052036	49.0904167	65.1988134
35.00	82.36874	17.63128	0.4976914	0.5656630	52.7263712	63.3673560
37.50	80.07847	19.92155	0.5096073	0.5316712	56.3310914	61.5527805
40.00	77.71272	22.28733	0.5226575	0.5021885	59.9023364	59.7560540
42.50	75.28480	24.71521	0.5369118	0.4764254	63.4378720	57.9785045
45.00	72.80804	27.19197	0.5524468	0.4537637	66.9354748	56.2211502
47.50	70.29556	29.70446	0.5693461	0.4337172	70.3929368	54.4851337
50.00	67.76016	32.23985	0.5877011	0.4158955	73.8080736	52.7714774
52.50	65.21434	34.78568	0.6076106	0.3999838	77.1787282	51.0812812
55.00	62.67004	37.32998	0.6291814	0.3857236	80.5027880	49.4155552
57.50	60.13869	39.86135	0.6525282	0.3729015	83.7781869	47.7753323
60.00	57.63098	42.36907	0.6777741	0.3613392	87.0029189	46.1615499
62.50	55.15690	44.84314	0.7050502	0.3508867	90.1750594	44.5751332
65.00	52.72564	47.27438	0.7344950	0.3414169	93.2927665	43.0169575
67.50	50.34554	49.65447	0.7662546	0.3328210	96.3543046	41.4878163
70.00	48.02405	51.97600	0.8004815	0.3250056	99.3580606	39.9884392
72.50	45.76770	54.23233	0.8373338	0.3178900	102.3025550	38.5195505
75.00	43.58212	56.41792	0.8769742	0.3114035	105.1864624	37.0817121
77.50	41.47202	58.52800	0.9195677	0.3054846	108.0086306	35.6754672
80.00	39.44118	60.55884	0.9652804	0.3000788	110.7680835	34.3012042
82.50	37.49254	62.50746	1.0142763	0.2951381	113.4640463	32.9592683
85.00	35.62818	64.37186	1.0667155	0.2906196	116.0959564	31.6498574
87.50	33.84939	66.15065	1.1227507	0.2864853	118.6634637	30.3731087
90.00	32.15671	67.84331	1.1825218	0.2827008	121.1664416	29.1290138
92.50	30.55004	69.44999	1.2461565	0.2792355	123.6050017	27.9174581
95.00	29.02862	70.97140	1.3137618	0.2760.14	125.9794720	26.7382257
97.50	27.59120	72.40884	1.3854215	0.2731535	128.2904148	25.5909868
100.00	26.23604	73.76399	1.4611919	0.2704890	130.5385977	24.4753163
102.50	24.96100	75.03901	1.5410967	0.2680471	132.7250116	23.3906735
105.00	23.76362	76.23639	1.6251233	0.2658090	134.8508373	22.3364234
107.50	22.64119	77.35882	1.7132174	0.2637576	136.9174346	21.3118568
110.00	21.59080	78.40924	1.8052807	0.2618772	138.9263347	20.3161739
112.50	20.60939	79.39063	1.9011658	0.2601535	140.8792138	19.3485185
115.00	19.69385	80.30616	2.0006751	0.2585736	142.7778825	18.4079569
117.50	18.84101	81.15903	2.1035566	0.2571256	144.6242593	17.4935091
120.00	18.04770	81.95232	2.2095045	0.2557987	146.4203522	16.6041575
122.50	17.31081	82.68919	2.3181571	0.2545830	148.1682435	15.7388464
125.00	16.62730	83.37270	2.4290973	0.2534695	149.8700790	14.8964912
127.50	15.99421	84.00582	2.5418556	0.2524500	151.5280381	14.0759915
130.00	15.40869	84.59132	2.6559099	0.2515173	153.1443335	13.2762425
132.50	14.86805	85.13197	2.7706913	0.2506643	154.7211818	12.4961220
135.00	14.36971	85.63030	2.8855858	0.2498852	156.2608071	11.7345225
137.50	13.91124	86.08878	2.9999429	0.2491743	157.7654332	10.9903295
140.00	13.49038	86.50962	3.1130773	0.2485266	159.2372432	10.2624498
142.50	13.10501	86.89500	3.2242797	0.2479375	160.6784202	9.5497919
145.00	12.75315	87.24686	3.3328234	0.2474030	162.0911174	8.8512868
147.50	12.43300	87.56701	3.4379697	0.2469195	163.4774394	8.1658810
150.00	12.14290	87.85713	3.5389802	0.2464835	164.8394763	7.4925370
152.50	11.88132	88.11869	3.6351243	0.2460923	166.1792696	6.8302376
155.00	11.64690	88.35312	3.7256862	0.2457431	167.4988270	6.1779828
157.50	11.43838	88.56162	3.8099777	0.2454336	168.8001230	5.5347919
160.00	11.25469	88.74532	3.8873427	0.2451619	170.0850986	4.8997049
162.50	11.09483	88.90521	3.9571698	0.2449261	171.3556387	4.2717705
165.00	10.95796	89.04207	4.0188970	0.2447247	172.6136319	3.6500636
167.50	10.84335	89.15666	4.0720225	0.2445564	173.8609336	3.0336677
170.00	10.75041	89.24961	4.1161070	0.2444202	175.0993431	2.4216743
172.50	10.67862	89.32140	4.1507855	0.2443151	176.3307117	1.8131907
175.00	10.62762	89.37239	4.1757661	0.2442405	177.5567010	1.2073328
177.50	10.59712	89.40290	4.1908399	0.2441959	178.7791699	0.6032219
180.00	10.58698	89.41304	4.1958788	0.2441811	179.9999997	0.0000000

		1000.00000	1.0081450	2.0147400	1.0081450	2.0147400
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	999.99994	0.00004	0.3014567	*999.9999999	0.0000000	0.0000000
2.50	998.54134	1.45864	0.3019781	6.9583384	4.5522025	87.4354966
5.00	994.18346	5.81652	0.3035454	3.5099973	9.0975967	84.9224061
7.50	986.97927	13.02067	0.3061669	2.3399506	13.6295363	82.4002288
10.00	977.01568	22.98430	0.3098564	1.7542341	18.1414098	79.8934166
12.50	964.41094	35.58900	0.3146339	1.4027530	22.6268292	77.4089445
15.00	949.31185	50.68809	0.3205246	1.1684154	27.0796258	74.9514721
17.50	931.88983	68.11015	0.3275599	1.0010734	31.4939521	72.5255244
20.00	912.33689	87.66305	0.3357771	0.8756668	35.8642455	70.1354496
22.50	890.86130	109.13867	0.3452195	0.7782593	40.1853394	67.7848268
25.00	867.68284	132.31710	0.3559371	0.7004981	44.4524262	65.4769898
27.50	843.02861	156.97136	0.3679860	0.6370639	48.6611124	63.2147037
30.00	817.12846	182.87148	0.3814296	0.5844109	52.8074130	61.0003393
32.50	790.21130	209.78868	0.3963381	0.5400815	56.8877455	58.8357810
35.00	762.50132	237.49866	0.4127893	0.5023187	60.8989384	56.7225274
37.50	734.21512	265.78486	0.4308688	0.4698318	64.8382101	54.6616893
40.00	705.55892	294.44106	0.4506707	0.4416504	68.7031612	52.6540093
42.50	676.72674	323.27324	0.4722974	0.4170304	72.4917438	50.6999400
45.00	647.89854	352.10144	0.4958607	0.3953910	76.2022533	48.7996344
47.50	619.23936	380.76062	0.5214822	0.3762717	79.8332933	46.9530139
50.00	590.89843	409.10151	0.5492932	0.3593024	83.3837606	45.1597869
52.50	563.00905	436.99093	0.5794357	0.3441817	86.8528161	43.4194774
55.00	535.68844	464.31154	0.6120626	0.3306622	90.2398627	41.7314749
57.50	509.03808	490.96186	0.6473379	0.3185376	93.5445256	40.0950398
60.00	483.14434	516.85561	0.6854371	0.3076356	96.7666335	38.5093361
62.50	458.07894	541.92100	0.7265466	0.2978101	99.9062002	36.9734530
65.00	433.89991	566.10003	0.7708642	0.2889369	102.9634103	35.4864121
67.50	410.65242	589.34756	0.8185981	0.2809093	105.9386027	34.0471916
70.00	388.36971	611.63023	0.8699663	0.2736354	108.8322699	32.6547298
72.50	367.07424	632.92570	0.9251952	0.2670355	111.6450466	31.3079376
75.00	346.77852	653.22142	0.9845178	0.2610400	114.3776961	30.0057046
77.50	327.48613	672.51381	1.0481720	0.2555877	117.0311160	28.7468947
80.00	309.19287	690.80711	1.1163973	0.2506250	119.6063347	27.5303658
82.50	291.88745	708.11249	1.1894319	0.2461043	122.1044995	26.3549533
85.00	275.55272	724.44722	1.2675083	0.2419833	124.5268881	25.2194866
87.50	260.16634	739.83364	1.3508493	0.2382246	126.8748939	24.1227794
90.00	245.70163	754.29835	1.4396626	0.2347944	129.1500330	23.0636332
92.50	232.12843	767.87151	1.5341353	0.2316625	131.3539296	22.0408350
95.00	219.41386	780.58608	1.6344273	0.2288019	133.4883347	21.0531674
97.50	207.52292	792.47702	1.7406656	0.2261882	135.5550773	20.0993996
100.00	196.41910	803.58084	1.8529370	0.2237994	137.5561133	19.1782892
102.50	186.06499	813.93495	1.9712819	0.2216154	139.4934654	18.2885896
105.00	176.42282	823.57716	2.0956866	0.2196182	141.3692457	17.4290523
107.50	167.45470	832.54524	2.2260786	0.2177916	143.1856342	16.5984187
110.00	159.12339	840.87659	2.3623180	0.2161206	144.9448615	15.7954417
112.50	151.39211	848.60783	2.5041956	0.2145918	146.6492191	15.0188688
115.00	144.22528	855.77466	2.6514253	0.2131930	148.3010165	14.2674621
117.50	137.58849	862.41149	2.8036420	0.2119131	149.9025933	13.5399917
120.00	131.44869	868.55125	2.9604000	0.2107420	151.4562964	12.8352400
122.50	125.77444	874.22554	3.1211697	0.2096706	152.9644728	12.1520139
125.00	120.53583	879.46415	3.2853410	0.2086906	154.4294663	11.4891328
127.50	115.70468	884.29529	3.4522224	0.2077946	155.8535993	10.8454429
130.00	111.25449	888.74545	3.6210470	0.2069756	157.2391540	10.2198105
132.50	107.16055	892.83939	3.7909730	0.2062276	158.5883982	9.6111385
135.00	103.39975	896.60019	3.9610955	0.2055450	159.9035487	9.0183468
137.50	99.95073	900.04925	4.1304498	0.2049227	161.1867845	8.4403877
140.00	96.79369	903.20628	4.2980234	0.2043562	162.4402367	7.8762455
142.50	93.91043	906.08954	4.4627652	0.2038413	163.6659913	7.3249262
145.00	91.28429	908.71569	4.6235944	0.2033746	164.8660712	6.7854747
147.50	88.89999	911.09995	4.7794179	0.2029525	166.0424657	6.2569531
150.00	86.74376	913.25618	4.9291356	0.2025723	167.1971045	5.7384604
152.50	84.80307	915.19691	5.0716598	0.2022312	168.3318578	5.2291157
155.00	83.06660	916.93338	5.2059301	0.2019269	169.4485769	4.7280662
157.50	81.52429	918.47565	5.3309204	0.2016574	170.5490537	4.2344799
160.00	80.16728	919.83270	5.4456526	0.2014208	171.6350205	3.7475452
162.50	78.98763	921.01231	5.5492201	0.2012155	172.7082171	3.2664762
165.00	77.97863	922.02131	5.6407819	0.2010403	173.7703085	2.7904976
167.50	77.13448	922.86546	5.7195889	0.2008939	174.8229153	2.3188519
170.00	76.45029	923.54968	5.7849908	0.2007754	175.8676916	1.8508002
172.50	75.92216	924.07782	5.8364407	0.2006840	176.9062281	1.3856098
175.00	75.54706	924.45288	5.8735051	0.2006191	177.9400595	0.9225440
177.50	75.32283	924.67710	5.8958716	0.2005804	178.9707914	0.4609234
180.00	75.24826	924.75172	5.9033470	0.2005675	179.9999997	0.0000000

		10000.00000	1.0081450	2.0147400	1.0081450	2.0147400
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	9999.99989	0.00019	0.0774481	*999.9999999	0.0000000	179.9999997
2.50	9940.06667	59.93299	0.0782915	5.9362122	8.9674424	81.5214515
5.00	9764.20094	235.79881	0.0808480	2.7970590	17.8409744	73.3860932
7.50	9483.57370	516.42575	0.0851954	1.7067310	26.5328068	65.8584844
10.0-	9114.90072	885.09906	0.0914630	1.1513470	34.9661760	59.0887625
12.50	8678.12507	1321.87452	0.0998306	0.8231292	43.0789422	53.1182956
15.00	8194.04703	1805.95260	0.1105269	0.6142545	50.8251421	47.9130954
17.50	7682.33214	2317.66742	0.1238282	0.4751183	58.1748582	43.3987752
20.00	7160.15436	2839.84523	0.1400562	0.3792430	65.1127249	39.4865599
22.50	6641.49817	3358.50142	0.1595766	0.3112812	71.6356713	36.0885747
25.00	6137.01444	3862.98515	0.1827960	0.2618855	77.7503047	33.1252128
27.50	5654.25389	4345.74570	0.2101605	0.2251639	83.4703714	30.5276577
30.00	5198.11072	4801.88887	0.2421530	0.1972995	88.8144694	28.2379471
32.50	4771.34153	5228.65806	0.2792910	0.1757602	93.8041706	26.2079071
35.00	4375.07342	5624.92613	0.3221252	0.1588287	98.4625250	24.3977621
37.50	4009.25078	5990.74881	0.3712368	0.1453167	102.8129756	22.7747198
40.00	3673.00466	6326.99493	0.4272368	0.1343859	106.8785675	21.3117235
42.50	3364.94066	6635.05893	0.4907645	0.1254346	110.6814332	19.9863818
45.00	3083.35599	6916.64361	0.5624866	0.1180232	114.2424569	18.7800985
47.50	2826.39571	7173.60389	0.6430969	0.1118258	117.5811179	17.6773574
50.00	2592.16234	7407.83725	0.7333161	0.1065974	120.7154095	16.6651506
52.50	2378.78907	7621.21048	0.8338921	0.1021510	123.6618310	15.7325219
55.00	2184.48620	7815.51339	0.9456000	0.0983423	126.4354438	14.8701951
57.50	2007.56867	7992.43089	1.0692433	0.0950587	129.0499568	14.0702791
60.00	1846.47016	8153.52954	1.2056536	0.0922112	131.5177940	13.3260295
62.50	1699.74819	8300.25159	1.3556910	0.0897287	133.8502169	12.6316570
65.00	1566.08265	8433.91687	1.5202443	0.0875543	136.0574178	11.9821634
67.50	1444.27158	8555.72790	1.7002294	0.0856415	138.1486244	11.3732204
70.00	1333.22358	8666.77582	1.8965878	0.0839523	140.1321962	10.8010594
72.50	1231.95022	8768.04933	2.1102826	0.0824554	142.0157030	10.2623861
75.00	1139.55725	8860.44249	2.3422940	0.0811247	143.8060142	9.7543110
77.50	1055.23594	8944.76369	2.5936119	0.0799384	145.5093920	9.2742811
80.00	978.25512	9021.74458	2.8652276	0.0788782	147.1315362	8.8200389
82.50	907.95383	9092.04565	3.1581199	0.0779285	148.6776508	8.3895755
85.00	843.73362	9156.26593	3.4732437	0.0770759	150.1525268	7.9810917
87.50	785.05270	9214.94708	3.8115107	0.0763092	151.5605524	7.5929725
90.00	731.42029	9268.57934	4.1737696	0.0756184	152.9057920	7.2237643
92.50	682.39093	9317.60863	4.5607848	0.0749952	154.1920044	6.8721440
95.00	637.56027	9362.43914	4.9732118	0.0744322	155.4226950	6.5369080
97.50	596.56128	9403.43820	5.4115678	0.0739228	156.6011161	6.2169583
100.00	559.05979	9440.93958	5.8762085	0.0734615	157.7303372	5.9112794
102.50	524.75244	9475.24727	6.3672930	0.0730433	158.8132232	5.6189406
105.00	493.36262	9506.63693	6.8847622	0.0726638	159.8524898	5.3390727
107.50	464.63896	9535.36078	7.4283046	0.0723191	160.8506888	5.0708748
110.00	438.35238	9561.64718	7.9973347	0.0720059	161.8102491	4.8135894
112.50	414.29445	9585.70510	8.5909675	0.0717210	162.7334692	4.5665168
115.00	392.27564	9607.72380	9.2079952	0.0714617	163.6225283	4.3289931
117.50	372.12346	9627.87613	9.8468744	0.0712257	164.4795090	4.1004042
120.00	353.68063	9646.31893	10.5057228	0.0710107	165.3064005	3.8801582
122.50	336.80499	9663.19449	11.1822896	0.0708148	166.1050729	3.6677068
125.00	321.36671	9678.63284	11.8739866	0.0706364	166.8773443	3.4625283
127.50	307.24835	9692.75132	12.5778705	0.0704737	167.6249281	3.2641266
130.00	294.34320	9705.65647	13.2906716	0.0703258	168.3494672	3.0720343
132.50	282.55470	9717.44478	14.0088040	0.0701907	169.0525264	2.8858028
135.00	271.79543	9728.20416	14.7283986	0.0700679	169.7356105	2.7050207
137.50	261.98648	9738.01322	15.4453259	0.0699562	170.4001389	2.5292811
140.00	253.05636	9746.94312	16.1552541	0.0698548	171.0474938	2.3581994
142.50	244.94097	9755.05866	16.8536667	0.0697628	171.6789752	2.1914186
145.00	237.58236	9762.41723	17.5359357	0.0696795	172.2958460	2.0285919
147.50	230.92870	9769.07097	18.1973577	0.0696044	172.8993095	1.8693833
150.00	224.93355	9775.06608	18.8332129	0.0695368	173.4905206	1.7134860
152.50	219.55557	9780.44391	19.4388207	0.0694763	174.0705855	1.5605899
155.00	214.75785	9785.24171	20.0096116	0.0694223	174.6405810	1.4104034
157.50	210.50785	9789.49189	20.5411684	0.0693746	175.2015539	1.2626423
160.00	206.77730	9793.22240	21.0292693	0.0693327	175.7544577	1.1170412
162.50	203.54092	9796.45856	21.4700162	0.0692964	176.3003282	0.9733502
165.00	200.77754	9799.22198	21.8597852	0.0692654	176.8400632	0.8312925
167.50	198.46916	9801.53054	22.1953299	0.0692396	177.3745641	0.6906350
170.0	196.60052	9803.39915	22.4738527	0.0692187	177.9047512	0.5511409
172.50	195.15928	9804.84046	22.6930115	0.0692025	178.4315929	0.4125346
175.00	194.13676	9805.86268	22.8508796	0.0691911	178.9556816	0.2746474
177.50	193.52555	9806.47400	22.9461759	0.0691843	179.4782691	0.1372345
180.00	193.32226	9806.67740	22.9780320	0.0691820	179.9999997	0.0000000

	5.00000	1.0081450	4.0038730	1.0081450	4.0038730
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	4.99993	0.00007	0.6370862	*999.9999999	0.0000000	0.0000000
2.50	4.99753	0.00246	0.6373548	32.2031114	3.1319413	81.1545339
5.00	4.99033	0.00965	0.6381612	1.6185488	6.2627865	84.8282669
7.50	4.97837	0.02161	0.6395066	2.5768836	9.3913278	84.5651154
10.00	4.96170	0.03830	0.6413934	2.1247954	12.5164967	83.7761664
12.50	4.94040	0.05957	0.6438247	1.8074463	15.6371437	82.0483617
15.00	4.91456	0.08542	0.6468049	1.5202615	18.7521655	80.5318937
17.50	4.88428	0.11571	0.6503389	1.3104612	21.8604334	78.9980725
20.00	4.84971	0.15028	0.6544327	1.1531929	24.9608368	77.4746224
22.50	4.81098	0.18898	0.6590928	1.0304207	28.0522771	75.9533752
25.00	4.76827	0.23171	0.6643268	0.9305244	31.1336618	74.4092371
27.50	4.72176	0.27820	0.6701430	0.8499128	34.2039079	72.8872698
30.00	4.67163	0.32835	0.6765505	0.7822747	37.2619450	71.3557929
32.50	4.61810	0.38188	0.6835567	0.7254601	40.3067138	69.8351603
35.00	4.56138	0.43858	0.6911780	0.6770798	43.3371782	68.3245551
37.50	4.50170	0.49826	0.6994192	0.6352488	46.3523090	66.8173403
40.00	4.43930	0.56066	0.7082933	0.5988735	49.3511099	65.3188773
42.50	4.37442	0.62555	0.7178119	0.5669502	52.3325931	63.8276998
45.00	4.30729	0.69268	0.7279871	0.5387735	55.2958045	62.3460181
47.50	4.23817	0.76178	0.7388302	0.5137635	58.2398120	60.8750619
50.00	4.16731	0.83264	0.7503534	0.4914127	61.1637123	59.4131958
52.50	4.09497	0.90498	0.7625680	0.4713562	64.0666381	57.9618093
55.00	4.02138	0.97856	0.7754858	0.4532875	66.9477511	56.5218121
57.50	3.94679	1.05318	0.7891174	0.4369195	69.8062573	55.0911263
60.00	3.87145	1.12850	0.8034724	0.4220826	72.6413943	53.6741030
62.50	3.79559	1.20435	0.8185603	0.4085705	75.4524484	52.2689451
65.00	3.71943	1.28049	0.8343886	0.3962302	78.2387506	50.8759268
67.50	3.64321	1.35671	0.8509643	0.3849325	80.9996791	49.4954649
70.00	3.56712	1.43282	0.8682914	0.3745623	83.7346632	48.1273580
72.50	3.49138	1.50856	0.8863728	0.3650331	86.4431854	46.7732325
75.00	3.41617	1.58377	0.9052090	0.3562541	89.1247824	45.4323452
77.50	3.34167	1.65824	0.9247979	0.3481569	91.7790513	44.1056699
80.00	3.26805	1.73185	0.9451341	0.3406717	94.4056455	42.7923918
82.50	3.19548	1.80445	0.9662100	0.3337425	97.0042821	41.4926160
85.00	3.12408	1.87583	0.9880123	0.3273259	99.5747397	40.2076464
87.50	3.05400	1.94591	1.0105269	0.3213731	102.1168604	38.9366384
90.00	2.98536	2.01456	1.0337330	0.3158451	104.6305522	37.6796313
92.50	2.91827	2.08165	1.0576064	0.3107089	107.1157828	36.4370953
95.00	2.85281	2.14711	1.0821178	0.3059320	109.5725968	35.2087535
97.50	2.78908	2.21081	1.1072341	0.3014872	112.0010875	33.9947674
100.00	2.72716	2.27276	1.1329153	0.2973468	114.4014224	32.7944331
102.50	2.66710	2.33281	1.1591169	0.2934906	116.7738326	31.6083644
105.00	2.60896	2.39093	1.1857892	0.2898973	119.1186085	30.4362316
107.50	2.55278	2.44711	1.2128756	0.2865471	121.4361005	29.2775687
110.00	2.49861	2.50131	1.2403163	0.2834231	123.7267256	28.1321812
112.50	2.44646	2.55342	1.2680436	0.2805114	125.9909496	27.0003654
115.00	2.39635	2.60353	1.2959856	0.2777961	128.2292940	25.8812785
117.50	2.34831	2.65159	1.3240640	0.2752649	130.4423362	24.7748058
120.00	2.30233	2.69756	1.3521954	0.2729064	132.6307021	23.6807902
122.50	2.25842	2.74148	1.3802924	0.2707094	134.7950660	22.5987002
125.00	2.21657	2.78331	1.4082641	0.2686643	136.9361505	21.5283424
127.50	2.17678	2.82310	1.4360127	0.2667619	139.0547156	20.4692270
130.00	2.13902	2.86087	1.4634394	0.2649937	141.1515586	19.4208540
132.50	2.10330	2.89660	1.4904401	0.2633526	143.2275176	18.3830149
135.00	2.06959	2.93028	1.5169116	0.2618317	145.2834643	17.3552908
137.50	2.03787	2.96202	1.5427435	0.2604242	147.3203003	16.3369779
140.00	2.00812	2.99174	1.5678323	0.2591246	149.3389606	15.3278559
142.50	1.98032	3.01957	1.5920685	0.2579274	151.3403952	14.3272202
145.00	1.95445	3.04542	1.6153433	0.2568281	153.3255875	13.3348379
147.50	1.93047	3.06942	1.6375546	0.2558219	155.2955359	12.3499725
150.00	1.90839	3.09151	1.6585953	0.2549052	157.2512686	11.3722734
152.50	1.88816	3.11173	1.6783678	0.2540742	159.1938101	10.4011733
155.00	1.86977	3.13010	1.6967768	0.2533258	161.1242220	9.4361728
157.50	1.85320	3.14668	1.7137308	0.2526569	163.0435698	8.4766602
160.00	1.83842	3.16147	1.7291447	0.2520651	164.9529301	7.5221325
162.50	1.82543	3.17443	1.7429387	0.2515480	166.8533757	6.5721140
165.00	1.81420	3.18568	1.7550456	0.2511038	168.7460318	5.6259361
167.50	1.80473	3.19514	1.7654009	0.2507307	170.6319712	4.6831456
170.00	1.79699	3.20289	1.7739473	0.2504273	172.5123078	3.7431406
172.50	1.79099	3.20889	1.7806427	0.2501926	174.3881702	2.8053907
175.00	1.78670	3.21317	1.7854510	0.2500255	176.2606651	1.8693178
177.50	1.78413	3.21575	1.7883478	0.2499255	178.1308986	0.9343595
180.00	1.78327	3.21660	1.7893154	0.2498922	179.9999997	0.0000000

	10.00000	1.0081450	4.0038730	1.0081450	4.0038730
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	9.99990	0.00007	0.6359988	*999.9999999	0.0000000	179.9999997
2.50	9.99508	0.00488	0.6362687	20.2677779	3.1346514	83.3085976
5.00	9.98066	0.01930	0.6370784	2.9523692	6.2681140	85.7479751
7.50	9.95668	0.04329	0.6384296	2.7603119	9.3993296	84.8461818
10.00	9.92325	0.07670	0.6403246	2.2301833	12.5271101	83.5626431
12.50	9.88054	0.11943	0.6427666	1.8125064	15.6503554	82.0662826
15.00	9.82871	0.17125	0.6457597	1.5253994	18.7679134	80.5592500
17.50	9.76800	0.23197	0.6493089	1.3129237	21.8786687	79.0137895
20.00	9.69868	0.30130	0.6534201	1.1537137	24.9815039	77.4747867
22.50	9.62104	0.37893	0.6581001	1.0297995	28.0753057	75.9386607
25.00	9.53541	0.46454	0.6633564	0.9307340	31.1589822	74.4062420
27.50	9.44216	0.55782	0.6691972	0.8492787	34.2314348	72.8670556
30.00	9.34167	0.65830	0.6756315	0.7819848	37.2915950	71.3411689
32.50	9.23437	0.76562	0.6826692	0.7250940	40.3383922	69.8167253
35.00	9.12068	0.87928	0.6903202	0.6767074	43.3707848	68.3039170
37.50	9.00107	0.99890	0.6985953	0.6348951	46.3877447	66.7953313
40.00	8.87600	1.12400	0.7075059	0.5984951	49.3882649	65.2937249
42.50	8.74595	1.25401	0.7170636	0.5666397	52.3713559	63.8036601
45.00	8.61144	1.38853	0.7272799	0.5384819	55.3360611	62.3211272
47.50	8.47294	1.52703	0.7381667	0.5134661	58.2814470	60.8479842
50.00	8.33097	1.66901	0.7497359	0.4911319	61.2066071	59.3853675
52.50	8.18602	1.81395	0.7619993	0.4710878	64.1106740	57.9331186
55.00	8.03860	1.96140	0.7749681	0.4530195	66.9928089	56.4914141
57.50	7.88919	2.11079	0.7886529	0.4366861	69.8522128	55.0621327
60.00	7.73829	2.26170	0.8030638	0.4218533	72.6881299	53.6440380
62.50	7.58634	2.41365	0.8182100	0.4083453	75.4998434	52.2378523
65.00	7.43383	2.56617	0.8340993	0.3960131	78.2866877	50.8443493
67.50	7.28119	2.71879	0.8507378	0.3847261	81.0480409	49.4638678
70.00	7.12884	2.87116	0.8681305	0.3743671	83.7833349	48.0960306
72.50	6.97719	3.02281	0.8862801	0.3648439	86.4920545	46.7416361
75.00	6.82661	3.17339	0.9051867	0.3560722	89.1737398	45.4008162
77.50	6.67748	3.32251	0.9248485	0.3479791	91.8279909	44.0738276
80.00	6.53012	3.46988	0.9452598	0.3404992	94.4544636	42.7605487
82.50	6.38485	3.61517	0.9664125	0.3335774	97.0528793	41.4613068
85.00	6.24196	3.75804	0.9882950	0.3271656	99.6230196	40.1765041
87.50	6.10171	3.89829	1.0108912	0.3212171	102.1647304	38.9056910
90.00	5.96435	4.03564	1.0341810	0.3156946	104.6779267	37.6492877
92.50	5.83009	4.16990	1.0581403	0.3105622	107.1625762	36.4071060
95.00	5.69913	4.30089	1.0827396	0.3057888	109.6187271	35.1791244
97.50	5.57163	4.42840	1.1079451	0.3013466	112.0464802	33.9653641
100.00	5.44775	4.55227	1.1337173	0.2972107	114.4460104	32.7658966
102.50	5.32760	4.67241	1.1600119	0.2933574	116.8175451	31.5803602
105.00	5.21131	4.78871	1.1867779	0.2897864	119.1613823	30.4086644
107.50	5.09894	4.90107	1.2139600	0.2864191	121.4778759	29.2506963
110.00	4.99059	5.00944	1.2414967	0.2832981	123.7674467	28.1061377
112.50	4.88629	5.11374	1.2693207	0.2803881	126.0305643	26.9748319
115.00	4.78609	5.21395	1.2973595	0.2776751	128.2677539	25.8565020
117.50	4.69002	5.31003	1.3255350	0.2751462	130.4795966	24.7508925
120.00	4.59807	5.40197	1.3537641	0.2727896	132.6667219	23.6576464
122.50	4.51027	5.48977	1.3819592	0.2705945	134.8298118	22.5764189
125.00	4.42659	5.57344	1.4100269	0.2685510	136.9695812	21.5068772
127.50	4.34703	5.65302	1.4378716	0.2666501	139.0867978	20.4485841
130.00	4.27155	5.72849	1.4653922	0.2648836	141.1822662	19.4011975
132.50	4.20014	5.79990	1.4924860	0.2632439	143.2568245	18.3642745
135.00	4.13274	5.86729	1.5190474	0.2617241	145.3113481	17.3373770
137.50	4.06934	5.93070	1.5449687	0.2603178	147.3467387	16.3200576
140.00	4.00986	5.99016	1.5701434	0.2590193	149.3639275	15.3118432
142.50	3.95430	6.04574	1.5944616	0.2578232	151.3638757	14.3122274
145.00	3.90258	6.09744	1.6178167	0.2567247	153.3475667	13.3207705
147.50	3.85466	6.14539	1.6401034	0.2557195	155.3160027	12.3368926
150.00	3.81052	6.18953	1.6612163	0.2548035	157.2702006	11.3601823
152.50	3.77008	6.22995	1.6810570	0.2539733	159.2112072	10.3900742
155.00	3.73332	6.26672	1.6995282	0.2532254	161.1400656	9.4260231
157.50	3.70020	6.29984	1.7165390	0.2525571	163.0578451	8.4675257
160.00	3.67067	6.32938	1.7320059	0.2519658	164.9656370	7.5140116
162.50	3.64470	6.35535	1.7458478	0.2514492	166.8645181	6.5649677
165.00	3.62227	6.37777	1.7579952	0.2510053	168.7555797	5.6198343
167.50	3.60333	6.39670	1.7683854	0.2506326	170.6399359	4.6780528
170.00	3.58787	6.41216	1.7769622	0.2503294	172.5186892	3.7390679
172.50	3.57587	6.42419	1.7836808	0.2500949	174.3929647	2.8023233
175.00	3.56731	6.43272	1.7885052	0.2499279	176.2638539	1.8672751
177.50	3.56217	6.43786	1.7914107	0.2498280	178.1325005	0.9333378
180.00	3.56046	6.43957	1.7923808	0.2497947	179.9999997	0.0000000

	20.00000	1.0081450	4.0038730	1.0081450	4.0038730
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	19.99992	0.00007	0.6338288	*999.9999999	0.0000000	0.0000000
2.50	19.99023	0.00976	0.6341009	12.0079722	3.1399905	84.7567063
5.00	19.96122	0.03874	0.6349176	3.8070652	6.2788044	86.3327667
7.50	19.91300	0.08699	0.6362805	2.8709352	9.4153184	85.0126643
10.00	19.84581	0.15415	0.6381918	2.2649425	12.5483766	83.6528581
12.50	19.75992	0.24006	0.6406546	1.8220853	15.6767849	82.1009692
15.00	19.65573	0.34425	0.6436733	1.5262100	18.7994417	80.5567552
17.50	19.53370	0.46626	0.6472528	1.3147400	21.9151870	79.0205646
20.00	19.39435	0.60562	0.6513990	1.1537985	25.0228964	77.4662230
22.50	19.23830	0.76167	0.6561186	1.0291845	28.1214330	75.9197105
25.00	19.06621	0.93378	0.6614192	0.9295587	31.2096890	74.3748441
27.50	18.87881	1.12116	0.6673090	0.8484757	34.2865657	72.8384372
30.00	18.67689	1.32307	0.6737971	0.7810856	37.3509690	71.3063847
32.50	18.46130	1.53866	0.6808931	0.7243173	40.4018298	69.7811335
35.00	18.23291	1.76705	0.6886074	0.6758633	43.4380848	68.2620656
37.50	17.99265	2.00733	0.6969506	0.6340930	46.4586984	66.7506397
40.00	17.74146	2.25853	0.7059340	0.5977685	49.4626597	65.2479552
42.50	17.48032	2.51964	0.7155691	0.5659382	52.4489708	63.7550362
45.00	17.21023	2.78976	0.7258678	0.5378083	55.4166671	62.2699831
47.50	16.93219	3.06778	0.7368419	0.5128388	58.3648097	60.7957356
50.00	16.64722	3.35276	0.7485033	0.4905317	61.2924926	59.3312308
52.50	16.35631	3.64367	0.7608635	0.4705162	64.1988397	57.8775119
55.00	16.06049	3.93949	0.7739341	0.4524799	67.0830142	56.4350132
57.50	15.76073	4.23923	0.7877256	0.4361663	69.9442182	55.0042693
60.00	15.45801	4.54195	0.8022482	0.4213558	72.7816921	53.5852440
62.50	15.15326	4.84671	0.8175109	0.4078676	75.5947244	52.1782320
65.00	14.84742	5.15256	0.8335215	0.3955533	78.3826497	50.7840037
67.50	14.54137	5.45859	0.8502863	0.3842822	81.1448507	49.4028654
70.00	14.23596	5.76403	0.8678103	0.3739391	83.8807631	48.0346765
72.50	13.93198	6.06798	0.8860958	0.3644315	86.5898762	46.6801893
75.00	13.63022	6.36976	0.9051434	0.3556723	89.2717362	45.3391250
77.50	13.33139	6.66857	0.9249506	0.3475916	91.9259485	44.0121550
80.00	13.03616	6.96380	0.9455123	0.3401237	94.5521765	42.6991034
82.50	12.74517	7.25478	0.9668201	0.3332134	97.1501481	41.4002716
85.00	12.45899	7.54099	0.9888618	0.3268102	99.7196529	40.1155878
87.50	12.17815	7.82181	1.0116216	0.3208719	102.2605449	38.8454590
90.00	11.90312	8.09685	1.0350795	0.3153577	104.7727428	37.5895809
92.50	11.63435	8.36563	1.0592107	0.3102336	107.2562300	36.3481309
95.00	11.37221	8.62777	1.0839859	0.3054681	109.7110547	35.1210512
97.50	11.11703	8.88292	1.1093707	0.3010335	112.1373363	33.9083530
100.00	10.86913	9.13083	1.1353257	0.2969039	114.5352460	32.7097893
102.50	10.62874	9.37123	1.1618056	0.2930569	116.9050261	31.5253459
105.00	10.39607	9.60391	1.1887601	0.2894717	119.2469820	30.3548194
107.50	10.17131	9.82866	1.2161331	0.2861299	121.5614788	29.1981086
110.00	9.95458	10.04539	1.2438624	0.2830141	123.8489412	28.0548994
112.50	9.74600	10.25397	1.2718806	0.2801091	126.1098422	26.9250203
115.00	9.54564	10.45432	1.3001145	0.2774008	128.3447221	25.8081969
117.50	9.35353	10.64643	1.3284859	0.2748761	130.5541657	24.7040667
120.00	9.16972	10.83024	1.3569108	0.2725234	132.7388138	23.6123845
122.50	8.99420	11.00577	1.3853005	0.2703319	134.8993406	22.5327585
125.00	8.82694	11.17304	1.4135624	0.2682919	137.0364837	21.4648425
127.50	8.66792	11.33204	1.4415985	0.2663943	139.1510107	20.4082917
130.00	8.51708	11.48291	1.4693087	0.2646308	141.2437297	19.3625972
132.50	8.37436	11.62562	1.4965888	0.2629939	143.3154829	18.3274336
135.00	8.23969	11.76029	1.5233324	0.2614767	145.3671493	17.3023239
137.50	8.11299	11.88699	1.5494321	0.2600728	147.3996416	16.2868146
140.00	7.99417	12.00579	1.5747790	0.2587765	149.4138949	15.2804427
142.50	7.88315	12.11680	1.5992637	0.2575825	151.4108703	14.2827146
145.00	7.77983	12.22015	1.6227788	0.2564859	153.3915550	13.2931210
147.50	7.68412	12.31585	1.6452172	0.2554825	155.3569548	12.3111922
150.00	7.59592	12.40402	1.6664748	0.2545681	157.3080868	11.3364022
152.50	7.51516	12.48479	1.6864505	0.2537393	159.2460051	10.3682205
155.00	7.44174	12.55822	1.7050484	0.2529928	161.1717679	9.4061220
157.50	7.37558	12.62437	1.7221758	0.2523256	163.0864292	8.4495775
160.00	7.31661	12.68335	1.7377471	0.2517353	164.9910696	7.4980463
162.50	7.26475	12.73520	1.7516845	0.2512196	166.8868065	6.5509790
165.00	7.21994	12.78002	1.7639144	0.2507766	168.7747054	5.6078249
167.50	7.18212	12.81783	1.7743748	0.2504044	170.6558876	4.6680344
170.00	7.15125	12.84871	1.7830101	0.2501019	172.5314595	3.7310468
172.50	7.12728	12.87270	1.7897743	0.2498677	174.4025499	2.7963095
175.00	7.11018	12.88980	1.7946321	0.2497011	176.2702577	1.8632555
177.50	7.09993	12.90005	1.7975570	0.2496013	178.1356595	0.9313310
180.0	7.09652	12.90344	1.7985340	0.2495681	179.9999997	0.0000000

		50 00000	1 0081450	4 0038730	1 0081450	4 0038730
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	50.00000	0.00007	0.6274283	*999.9999999	0.0000000	179.9999997
2.50	49.97540	0.02466	0.6277073	0.8240016	3.1559575	86.6881080
5.00	49.90172	0.09835	0.6285446	4.0585583	6.3106973	86.4946053
7.50	49.77929	0.22076	0.6299418	2.9845482	9.4630177	85.1757769
10.00	49.60867	0.39138	0.6319011	2.2683579	12.6117002	83.6456914
12.50	49.39064	0.60942	0.6344259	1.8231354	15.7555480	82.0852499
15.00	49.12617	0.87388	0.6375202	1.5246374	18.8933726	80.5232160
17.50	48.81646	1.18360	0.6411891	1.3104762	22.0239688	78.9573681
20.00	48.46288	1.53717	0.6454386	1.1502257	25.1461651	77.3964226
22.50	48.06700	1.93305	0.6502754	1.0257159	28.2587893	75.8379269
25.00	47.63054	2.36951	0.6557070	0.9264230	31.3606851	74.2847379
27.50	47.15541	2.84463	0.6617419	0.8454939	34.4507098	72.7377966
30.00	46.64363	3.35641	0.6683890	0.7783099	37.5277329	71.1969599
32.50	46.09736	3.90269	0.6756581	0.7217147	40.5906524	69.6630590
35.00	45.51887	4.48119	0.6835595	0.6734470	43.6383739	68.1368079
37.50	44.91052	5.08953	0.6921041	0.6318495	46.6698390	66.6190259
40.00	44.27477	5.72529	0.7013030	0.5956641	49.6840015	65.1099142
42.50	43.61409	6.38597	0.7111680	0.5639362	52.6798520	63.6099648
45.00	42.93106	7.06900	0.7217108	0.5359285	55.6564018	62.1199306
47.50	42.22823	7.77185	0.7329434	0.5110488	58.6127006	60.6399864
50.00	41.50818	8.49187	0.7448778	0.4888348	61.5478300	59.1710318
52.50	40.77349	9.22657	0.7575256	0.4688993	64.4609098	57.7130266
55.00	40.02671	9.97335	0.7708982	0.4509362	67.3510961	56.2667284
57.50	39.27036	10.72973	0.7850065	0.4346854	70.2175912	54.8322864
60.00	38.50669	11.49319	0.7998604	0.4199361	73.0596379	53.4103721
62.50	37.73870	12.26138	0.8154690	0.4065062	75.8765292	52.0011347
65.00	36.96810	13.03196	0.8318402	0.3942441	78.6676075	50.6049939
67.50	36.19735	13.80272	0.8489804	0.3830193	81.4322665	49.2221531
70.00	35.42856	14.57151	0.8668941	0.3727210	84.1699541	47.8529531
72.50	34.66379	15.33628	0.8855839	0.3632534	86.8801750	46.4976691
75.00	33.90492	16.09515	0.9050501	0.3545325	89.5624924	45.1563962
77.50	33.15379	16.84628	0.9252901	0.3464864	92.2165301	43.8294392
80.00	32.41208	17.58799	0.9462986	0.3390514	94.8419720	42.5169323
82.50	31.68133	18.31874	0.9680670	0.3321714	97.4385671	41.2189405
85.00	30.96299	19.03709	0.9905827	0.3257971	100.0061296	39.9355877
87.50	30.25836	19.74173	1.0138295	0.3198849	102.5445312	38.6669245
90.00	29.56863	20.43147	1.0377869	0.3143956	105.0537229	37.4129828
92.50	28.89486	21.10522	1.0624298	0.3092948	107.5337045	36.1737687
95.00	28.23799	21.76210	1.0877281	0.3045510	109.9845581	34.9491973
97.50	27.59885	22.40125	1.1136468	0.3001364	112.4064177	33.7392204
100.00	26.97815	23.02192	1.1401455	0.2960260	114.7994846	32.5437576
102.50	26.37650	23.62359	1.1671783	0.2921968	117.1640269	31.3626002
105.00	25.79441	24.20567	1.1946937	0.2886284	119.5003763	30.1956486
107.50	25.23228	24.76782	1.2226343	0.2853021	121.8089126	29.0426504
110.00	24.69044	25.30966	1.2509371	0.2822010	124.0900904	27.9034119
112.50	24.16914	25.83094	1.2795333	0.2793097	126.3444051	26.7776862
115.00	23.66853	26.33155	1.3083483	0.2766142	128.5724156	25.6651573
117.50	23.18872	26.81136	1.3373022	0.2741015	130.7747327	24.5655239
120.00	22.72974	27.27035	1.3663094	0.2717600	132.9520084	23.4784603
122.50	22.29158	27.70852	1.3952799	0.2695791	135.1049431	22.4036146
125.00	21.87418	28.12590	1.4241185	0.2675490	137.2342892	21.3406209
127.50	21.47743	28.52265	1.4527262	0.2656605	139.3408328	20.2890635
130.00	21.10118	28.89890	1.4810004	0.2639055	141.4253972	19.2485224
132.50	20.74527	29.25482	1.5088348	0.2622706	143.4888430	18.2185769
135.00	20.40951	29.59058	1.5361216	0.2607668	145.5320604	17.1987757
137.50	20.09367	29.90641	1.5627505	0.2593698	147.5559734	16.1886532
140.00	19.79755	30.20253	1.5886108	0.2580799	149.5615281	15.1877336
142.50	19.52091	30.47917	1.6135915	0.2568917	151.5497044	14.1955268
145.00	19.26350	30.73659	1.6375822	0.2558006	153.5214968	13.2115293
147.50	19.02508	30.97501	1.6604743	0.2548021	155.4779150	12.2352336
150.00	18.80543	31.19465	1.6821612	0.2538922	157.4200019	11.2661250
152.50	18.60431	31.39578	1.7025404	0.2530675	159.3488008	10.3036698
155.00	18.42150	31.57861	1.7215133	0.2523247	161.2653844	9.3473353
157.50	18.25678	31.74331	1.7389862	0.2516609	163.1708220	8.3965902
160.00	18.10997	31.89012	1.7548722	0.2510735	165.0661938	7.4508796
162.50	17.98087	32.01920	1.7690900	0.2505604	166.9526026	6.5096600
165.00	17.86934	32.13078	1.7815669	0.2501195	168.8311622	5.5723697
167.50	17.77521	32.22488	1.7922377	0.2497493	170.7029864	4.6384641
170.00	17.69837	32.30173	1.8010469	0.2494482	172.5691520	3.7073752
172.50	17.63872	32.36137	1.8079478	0.2492152	174.4308397	2.7785469
175.00	17.59617	32.40392	1.8129033	0.2490494	176.2891337	1.8514146
177.50	17.57066	32.42943	1.8158873	0.2489501	178.1450994	0.9254160
180.00	17.56216	32.43793	1.8168837	0.2489171	179.9999997	0.0000000

		100.00000	1.0081450	4.0038730	1.0081450	4.0038730
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	99.99990	0.00004	0.6170450	*999.9999999	0.0000000	179.9999997
2.50	99.94943	0.05052	0.6173351	4.9431121	3.1824003	87.6763612
5.00	99.79825	0.20169	0.6182059	4.3794197	6.3634676	86.7022369
7.50	99.54709	0.45285	0.6196588	3.0030732	9.5419254	85.1833895
10.00	99.19710	0.80283	0.6216962	2.2617237	12.7165102	83.5992858
12.50	98.74996	1.24998	0.6243213	1.8149831	15.8858798	82.0154913
15.00	98.20770	1.79224	0.6275385	1.5160405	19.0487783	80.4288935
17.50	97.57291	2.42703	0.6313527	1.3031367	22.2039297	78.8485087
20.00	96.84842	3.15152	0.6357700	1.1434353	25.3500734	77.2690423
22.50	96.03761	3.96237	0.6407972	1.0196361	28.4859583	75.6954361
25.00	95.14406	4.85592	0.6464420	0.9209301	31.6103655	74.1278026
27.50	94.17176	5.82818	0.6527129	0.8404785	34.7220749	72.5668121
30.00	93.12503	6.87491	0.6596190	0.7737048	37.8199007	71.0127197
32.50	92.00837	7.99161	0.6671700	0.7174531	40.9026846	69.4660153
35.00	90.82652	9.17345	0.6753765	0.6694886	43.9692810	67.9278556
37.50	89.58444	10.41550	0.6842495	0.6281529	47.0185760	66.3987879
40.00	88.28726	11.71272	0.6938002	0.5921938	50.0494964	64.8789555
42.50	86.94011	13.05986	0.7040405	0.5606689	53.0609894	63.3691438
45.00	85.54835	14.45163	0.7149824	0.5328399	56.0520437	61.8698891
47.50	84.11724	15.88270	0.7266381	0.5081228	59.0216823	60.3816401
50.00	82.65220	17.34778	0.7390193	0.4860499	61.9689744	58.9047808
52.50	81.15847	18.84151	0.7521382	0.4662458	64.8930240	57.4399080
55.00	79.64134	20.35864	0.7660059	0.4484012	67.7929867	55.9874643
57.50	78.10593	21.89405	0.7806338	0.4322593	70.6680611	54.5477062
60.00	76.55729	23.44269	0.7960316	0.4176080	73.5174965	53.1210955
62.50	75.00030	24.99968	0.8122087	0.4042684	76.3405956	51.7079566
65.00	73.43970	26.56028	0.8291727	0.3920893	79.1367158	50.3086347
67.50	71.88000	28.11998	0.8469302	0.3809413	81.9052689	48.9233777
70.00	70.32551	29.67447	0.8654858	0.3707138	84.6457258	47.5524545
72.50	68.78033	31.21965	0.8848417	0.3613115	87.3576172	46.1961012
75.00	67.24834	32.75163	0.9049979	0.3526517	90.0405355	44.8545378
77.50	65.73312	34.26686	0.9259521	0.3446621	92.6941358	43.5278829
80.00	64.23805	35.76197	0.9476981	0.3372796	95.3181382	42.2162883
82.50	62.76619	37.23383	0.9702271	0.3304486	97.9123272	40.9198552
85.00	61.32040	38.67961	0.9935261	0.3241702	100.4765555	39.6386601
87.50	59.90324	40.09675	1.0175783	0.3182506	103.0107364	38.3727186
90.00	58.51704	41.48297	1.0423622	0.3128013	105.5148542	37.1220075
92.50	57.16387	42.83614	1.0678519	0.3077377	107.9889610	35.8865246
95.00	55.84554	44.15449	1.0940164	0.3030289	110.4331687	34.6661814
97.50	54.56365	45.43636	1.1208195	0.2986471	112.8476597	33.4609021
100.00	53.31954	46.68046	1.1482195	0.2945673	115.2326763	32.2705265
102.50	52.11438	47.88566	1.1761689	0.2907667	117.5885275	31.0948841
105.00	50.94908	49.05094	1.2046145	0.2872253	119.9155822	29.9338181
107.50	49.82443	50.17560	1.2334973	0.2839242	122.2142614	28.7870742
110.00	48.74098	51.25906	1.2627520	0.2808467	124.4850531	27.6544075
112.50	47.69914	52.30088	1.2923079	0.2779776	126.7284974	26.5355472
115.00	46.69920	53.30082	1.3220879	0.2753027	128.9451830	25.4301783
117.50	45.74128	54.25874	1.3520094	0.2728095	131.1357543	24.3379734
120.00	44.82540	55.17454	1.3819845	0.2704863	133.3008967	23.2585784
122.50	43.95146	56.04859	1.4119199	0.2683224	135.4413480	22.1916206
125.00	43.11927	56.88075	1.4417178	0.2663081	137.5578828	21.1367130
127.50	42.32859	57.67144	1.4712756	0.2644345	139.6513134	20.0934261
130.00	41.57907	58.42097	1.5004877	0.2626934	141.7224966	19.0613337
132.50	40.87033	59.12971	1.5292446	0.2610773	143.7723078	18.0399895
135.00	40.20195	59.79810	1.5574346	0.2595795	145.8016708	17.0289278
137.50	39.57345	60.42659	1.5849444	0.2581937	147.8115246	16.0276718
140.00	38.98436	61.01567	1.6116594	0.2569141	149.8028375	15.0357343
142.50	38.43417	61.56586	1.6374651	0.2557354	151.7766044	14.0526097
145.00	37.92239	62.07764	1.6622476	0.2546530	153.7338383	13.0777907
147.50	37.44848	62.55157	1.6858947	0.2536626	155.6755714	12.1107511
150.00	37.01198	62.98806	1.7082968	0.2527601	157.6028466	11.1509729
152.50	36.61238	63.38768	1.7293476	0.2519421	159.5167369	10.1979118
155.00	36.24923	63.75082	1.7489455	0.2512053	161.4183113	9.2510326
157.50	35.92209	64.07797	1.7669940	0.2505468	163.3086689	8.3097846
160.00	35.63055	64.36952	1.7834028	0.2499643	165.1888900	7.3736193
162.50	35.37424	64.62582	1.7980886	0.2494553	167.0600846	6.4419804
165.00	35.15280	64.84725	1.8109761	0.2490181	168.9233854	5.5143060
167.50	34.96596	65.03411	1.8219982	0.2486508	170.7798839	4.5900375
170.00	34.81345	65.18662	1.8310972	0.2483522	172.6307273	3.6686108
172.50	34.69505	65.30501	1.8382249	0.2481211	174.4770184	2.7494576
175.00	34.61060	65.38946	1.8433436	0.2479567	176.3199382	1.8320151
177.50	34.55998	65.44009	1.8464258	0.2478583	178.1605482	0.9157045
180.00	34.54311	65.45693	1.8474550	0.2478255	179.9999997	0.0000000

	1000.00000	1.0081450	4.0038730	1.0081450	4.0038730
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	999.99994	0.00004	0.4754141	*999.9999999	0.0000000	179.9999997
2.50	999.26569	0.73429	0.4758562	8.0663808	3.6252969	88.0508121
5.00	997.06840	2.93158	0.4771832	4.1327779	7.2474135	86.1931737
7.50	993.42447	6.57551	0.4793978	2.7629398	10.8632676	84.3061239
10.00	988.36083	11.63915	0.4825043	2.0752842	14.4697558	82.4200656
12.50	981.91462	18.08535	0.4865087	1.6628825	18.0638377	80.5411328
15.00	974.13249	25.86745	0.4914186	1.3883143	21.6425628	78.6716178
17.50	965.07002	34.92996	0.4972433	1.1925584	25.2030317	76.8134207
20.00	954.79060	45.20934	0.5039936	1.0461058	28.7424982	74.9686625
22.50	943.36480	56.63518	0.5116817	0.9325141	32.2582919	73.1387645
25.00	930.86902	69.13092	0.5203215	0.8419394	35.7478846	71.3254333
27.50	917.38474	82.61524	0.5299278	0.7681052	39.2088938	69.5300110
30.0	902.99711	97.00287	0.5405169	0.7068329	42.6390741	67.7538905
32.50	887.79409	112.20585	0.5521062	0.6552269	46.0363299	65.9982644
35.00	871.86534	128.13464	0.5647139	0.6112186	49.3987333	64.2641928
37.50	855.30110	144.69884	0.5783591	0.5732924	52.7245116	62.5526961
40.00	838.19143	161.80854	0.5930616	0.5403104	56.0120527	60.8646162
42.50	820.62509	179.37485	0.6088416	0.5114027	59.2599105	59.2007168
45.00	802.68894	197.31101	0.6257197	0.4858919	62.4667995	57.5616058
47.50	784.46720	215.53274	0.6437164	0.4632439	65.6315904	55.9478391
50.00	766.04072	233.95918	0.6628522	0.4430304	68.7533155	54.3598246
52.50	747.48672	252.51318	0.6831471	0.4249049	71.8311533	52.7978968
55.00	728.87815	271.12175	0.7046202	0.4085836	74.8644281	51.2622911
57.50	710.28348	289.71642	0.7272900	0.3938319	77.8526098	49.7531529
60.00	691.76644	308.23346	0.7511732	0.3804541	80.7952982	48.2705483
62.50	673.38590	326.61401	0.7762852	0.3682853	83.6922266	46.8144592
65.00	655.19579	344.80412	0.8026390	0.3571864	86.5432475	45.3848112
67.50	637.24511	362.75480	0.8302451	0.3470382	89.3483289	43.9814560
70.00	619.57788	380.42203	0.8591114	0.3377307	92.1075508	42.6041801
72.50	602.23349	397.76642	0.8892421	0.3291997	94.8210921	41.2527352
75.00	585.24650	414.75341	0.9206377	0.3213446	97.4892285	39.9268013
77.50	568.64712	431.35278	0.9532942	0.3141068	100.1123302	38.6260260
80.00	552.46130	447.53861	0.9872029	0.3074277	102.6908420	37.3500161
82.50	536.71092	463.28895	1.0223498	0.3012559	105.2252948	36.0983435
85.00	521.41417	478.58574	1.0587148	0.2955456	107.7162921	34.8705407
87.50	506.58561	493.41425	1.0962716	0.2902568	110.1644970	33.6661190
90.00	492.23669	507.76321	1.1349870	0.2853533	112.5706397	32.4845608
92.50	478.37570	521.62416	1.1748203	0.2808031	114.9355099	31.3253246
95.00	465.00839	534.99147	1.2157230	0.2765774	117.2599457	30.1878516
97.50	452.13796	547.86194	1.2576386	0.2726504	119.5448302	29.0715668
100.00	439.76538	560.23449	1.3005018	0.2689990	121.7910983	27.9758792
102.50	427.88971	572.11015	1.3442384	0.2656021	123.9997186	26.9001827
105.00	416.50828	583.49159	1.3887651	0.2624407	126.1716969	25.8438628
107.50	405.61691	594.38296	1.4339893	0.2594976	128.3080727	24.8062983
110.00	395.21009	604.78978	1.4798089	0.2567573	130.4099150	23.7868555
112.50	385.28122	614.71865	1.5261128	0.2542055	132.4783117	22.7846966
115.00	375.82282	624.17701	1.5727803	0.2518293	134.5143802	21.7997808
117.50	366.82669	633.17318	1.6196816	0.2496170	136.5192644	20.8308641
120.00	358.28393	641.71594	1.6666788	0.2475577	138.4941079	19.8774964
122.50	350.18530	649.81453	1.7136252	0.2456416	140.4400840	18.9390302
125.00	342.52122	657.47865	1.7603670	0.2438598	142.3583701	18.0148155
127.50	335.28190	664.71793	1.8067433	0.2422041	144.2501619	17.1042040
130.00	328.45750	671.54233	1.8525870	0.2406668	146.1166553	16.2065472
132.50	322.03816	677.96167	1.8977265	0.2392412	147.9590572	15.3211989
135.00	316.01414	683.98569	1.9419855	0.2379210	149.7785747	14.4475151
137.50	310.37588	689.62399	1.9851851	0.2367005	151.5764296	13.5848526
140.00	305.11402	694.88585	2.0271449	0.2355743	153.3538327	12.7325729
142.50	300.21954	699.78032	2.0676842	0.2345378	155.1119983	11.8900411
145.00	295.68382	704.31605	2.1066229	0.2335865	156.8521559	11.0566236
147.50	291.49856	708.50130	2.1437840	0.2327165	158.5755050	10.2316942
150.00	287.65593	712.34390	2.1789944	0.2319242	160.2832787	9.4146242
152.50	284.14864	715.85119	2.2120856	0.2312064	161.9766764	8.6047961
155.00	280.96981	719.03002	2.2428973	0.2305603	163.6569202	7.8015887
157.50	278.11319	721.88668	2.2712764	0.2299831	165.3252095	7.0043891
160.00	275.57295	724.42692	2.2970804	0.2294726	166.9827476	6.2125851
162.50	273.34392	726.65595	2.3201774	0.2290267	168.6307527	5.4255708
165.00	271.42148	728.57834	2.3404479	0.2286438	170.2704057	4.6427380
167.50	269.80169	730.19814	2.3577857	0.2283223	171.9029173	3.8634841
170.00	268.48108	731.51879	2.3720993	0.2280609	173.5294834	3.0872111
172.50	267.45684	732.54302	2.3833126	0.2278587	175.1512699	2.3133221
175.00	266.72680	733.27303	2.3913656	0.2277147	176.7695062	1.5412132
177.50	266.28941	733.71042	2.3962147	0.2276286	178.3853434	0.7702954
180.00	266.14372	733.85611	2.3978340	0.2276000	179.9999997	0.0000000

	10000.00000	1.0081450	4.0038730	1.0081450	4.0038730
THETA	ENERGY 1	ENERGY 2	J OF THETA	J OF PHI	OMEGA	PHI
0.0	9999.99952	0.00011	0.1442702	*999.9999999	0.0000000	179.9999997
2.50	9969.76096	30.23829	0.1450684	6.4749069	6.5759210	85.0943707
5.00	9880.09397	119.90551	0.1474747	3.1935152	13.1161842	80.2527119
7.50	9734.05253	265.94680	0.1515246	2.0837791	19.5863448	75.5375326
10.00	9536.44525	463.55430	0.1572765	1.5196285	25.9542864	70.9989186
12.50	9293.45425	706.54508	0.1648118	1.1763392	32.1911503	66.6757733
15.00	9012.18381	987.81556	0.1742337	0.9455749	38.2720273	62.5939663
17.50	8700.19365	1299.80572	0.1856665	0.7806566	44.1763353	58.7676037
20.00	8365.06579	1634.93361	0.1992541	0.6579334	49.8879854	55.2004963
22.50	8014.04577	1985.95364	0.2151594	0.5639865	55.3952597	51.8885568
25.00	7653.77190	2346.22747	0.2335622	0.4905407	60.6905490	48.8219665
27.50	7290.10094	2709.89846	0.2546580	0.4321687	65.7699335	45.9871881
30.00	6928.02027	3071.97914	0.2786560	0.3851438	70.6326880	43.3686040
32.50	6571.63125	3428.36812	0.3057774	0.3468183	75.2807654	40.9497008
35.00	6224.18560	3775.81380	0.3362536	0.3152618	79.7182884	38.7139384
37.50	5888.15752	4111.84188	0.3703237	0.2890384	83.9510661	36.6453186
40.00	5565.33653	4434.66291	0.4082330	0.2670629	87.9861571	34.7287613
42.50	5256.92701	4743.07239	0.4502303	0.2485041	91.8315064	32.9501785
45.00	4963.64795	5036.35146	0.4965662	0.2327180	95.4956237	31.2967625
47.50	4685.82619	5314.17321	0.5474904	0.2192007	98.9873268	29.7567844
50.0	4423.47914	5576.52030	0.6032498	0.2075540	102.3155414	28.3196550
52.50	4176.38760	5823.61184	0.6640859	0.1974611	105.4891348	26.9758329
55.00	3944.15636	6055.84309	0.7302329	0.1886675	108.5167974	25.7167466
57.50	3726.26454	6273.73487	0.8019151	0.1809674	111.4069596	24.5347064
60.00	3522.10600	6477.89344	0.8793443	0.1741933	114.1677201	23.4228201
62.50	3331.02141	6668.97811	0.9627182	0.1682077	116.8068200	22.3749060
65.00	3152.32355	6847.67582	1.0522176	0.1628975	119.3316057	21.3854246
67.50	2985.31607	7014.68356	1.1480040	0.1581686	121.7490360	20.4493999
70.00	2829.30802	7170.69127	1.2502174	0.1539425	124.0656599	19.5623655
72.50	2683.62399	7316.37545	1.3589741	0.1501533	126.2876466	18.7202990
75.00	2547.61156	7452.38804	1.4743637	0.1467455	128.4207739	17.9195788
77.50	2420.64610	7579.35338	1.5964478	0.1436720	130.4704696	17.1569347
80.00	2302.13393	7697.86567	1.7252565	0.1408927	132.4418038	16.4294109
82.50	2191.51378	7808.48555	1.8607870	0.1383733	134.3395263	15.7343291
85.00	2088.25767	7911.74166	2.0030009	0.1360843	136.1680776	15.0692582
87.50	1991.87059	8008.12870	2.1518220	0.1340002	137.9316151	14.4319888
90.0	1901.88955	8098.10974	2.3071344	0.1320991	139.6340206	13.8205037
92.50	1817.88303	8182.11653	2.4687803	0.1303617	141.2789375	13.2329635
95.00	1739.44935	8260.55028	2.6365580	0.1287714	142.8697631	12.6676869
97.50	1666.21488	8333.78464	2.8102208	0.1273135	144.4096975	12.1231292
100.00	1597.83289	8402.16644	2.9894753	0.1259751	145.9017321	11.5978692
102.50	1533.98193	8466.01755	3.1739799	0.1247450	147.3486796	11.0906009
105.00	1474.36395	8525.63560	3.3633444	0.1236132	148.7531811	10.6001191
107.50	1418.70301	8581.29628	3.5571296	0.1225708	150.1177289	10.1253055
110.00	1366.74359	8633.25589	3.7548470	0.1216099	151.4446661	9.6651263
112.50	1318.24948	8681.74985	3.9559589	0.1207236	152.7362019	9.2186187
115.00	1273.00207	8726.99760	4.1598802	0.1199056	153.9944299	8.7848873
117.50	1230.79933	8769.19992	4.3659789	0.1191503	155.2213281	8.3630977
120.00	1191.45468	8808.54495	4.5735784	0.1184528	156.4187743	7.9524676
122.50	1154.79577	8845.20367	4.7819601	0.1178086	157.5885415	7.5522638
125.00	1120.66343	8879.33590	4.9903664	0.1172136	158.7323123	7.1617965
127.50	1088.91088	8911.08878	5.1980043	0.1166643	159.8517522	6.7804182
130.0	1059.40286	8940.59681	5.4040500	0.1161573	160.9483398	6.4075161
132.50	1032.01479	8967.98477	5.6076529	0.1156899	162.0235667	6.0425137
135.00	1006.63193	8993.36741	5.8079419	0.1152592	163.0788371	5.6848606
137.50	983.14896	9016.85052	6.0040308	0.1148630	164.1154960	5.3340330
140.00	961.46911	9038.53022	6.1950247	0.1144990	165.1348509	4.9895393
142.50	941.50398	9058.49554	6.3800258	0.1141654	166.1381349	4.6509002
145.00	923.17246	9076.82695	6.5581421	0.1138605	167.1265624	4.3176647
147.50	906.40098	9093.59858	6.7284920	0.1135825	168.1012809	3.9893981
150.00	891.12234	9108.87711	6.8902148	0.1133303	169.0634228	3.6656808
152.50	877.27595	9122.72364	7.0424753	0.1131024	170.0140797	3.3461117
155.00	864.80696	9135.19256	7.1844740	0.1128978	170.9543131	3.0302941
157.50	853.66681	9146.33267	7.3154489	0.1127155	171.8851402	2.7178572
160.00	843.81171	9156.18792	7.4346904	0.1125546	172.8075817	2.4084335
162.50	835.20331	9164.79632	7.5415426	0.1124143	173.7226322	2.1016598
165.00	827.80853	9172.19103	7.6354083	0.1122940	174.6312343	1.7971934
167.50	821.59873	9178.40071	7.7157602	0.1121932	175.5343564	1.4946896
170.00	816.55018	9183.44923	7.7821409	0.1121113	176.4329076	1.1938145
172.50	812.64332	9187.35631	7.8341720	0.1120480	177.3278415	0.8942306
175.00	809.86325	9190.13612	7.8715541	0.1120030	178.2200933	0.5955119
177.50	808.19957	9191.79984	7.8940692	0.1119761	179.1104600	0.2976400
180.00	807.64562	9192.35379	7.9015895	0.1119671	179.9999997	0.0000000