

INPUT DATA CARDS FOR PROGRAM CHUCK3.

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J. COMFORT EXTENDED VERSION 25 JUNE 1979
K.V.I. VERSION LAST MODIFIED 1 JANUARY 1982

CHUCK3 IS A COUPLED-CHANNEL, DISTORTED-WAVE BORN-APPROXIMATION (CCBA) PROGRAM WRITTEN BY P.D.KUNZ OF THE UNIVERSITY OF COLORADO. IT IS AN EXTENSION OF THE WELL-KNOWN PROGRAM DWUCK4 INTO A COUPLED-CHANNELS FORMAT. THE FORMALISM ALLOWS MULTISTEP CALCULATIONS THROUGH DIFFERENT MASS PARTITIONS SO THAT IT IS ALSO A COUPLED-REACTION-CHANNEL (CRC) PROGRAM. THE COUPLINGS MAY BE HANDLED IN A ONE-WAY MANNER (SECOND-ORDER DWBA) OR, AT SOME LARGE EXPENSE IN EXECUTION TIME, IN A TWO-WAY MANNER (FULL CCBA/CRC).

ESSENTIALLY ALL OF THE FEATURES THAT ARE IN DWUCK4 ARE ALSO IN CHUCK3. A BRIEF OUTLINE OF THE FORMALISM AND OPTIONS IS PROVIDED IN A WRITEUP DISTRIBUTED WITH THE PROGRAM BY THE AUTHOR. THIS STANDARD VERSION IS DATED 01/JULY/1978. THE PRESENT DOCUMENT IS INTENDED TO SUPPLEMENT, AND NOT REPLACE, THE ORIGINAL WRITEUP. HOWEVER, THERE ARE A FEW MINOR CHANGES AND EXTENSIONS FROM THE STANDARD VERSION THAT ARE DOCUMENTED.

DUE TO THE COMPLEXITY OF COUPLED-CHANNELS CALCULATIONS, CHUCK3 HAS SOME PROGRAM LIMITS THAT WILL RESTRICT ITS APPLICATION. THERE MAY NOT BE MORE THAN 400 POINTS OF INTEGRATION AND THERE ARE NO IMAGINARY SPIN-ORBIT POTENTIALS. THE TOTAL NUMBER OF CHANNELS MAY NOT EXCEED 8 AND THE TOTAL NUMBER OF TRANSITIONS MAY NOT EXCEED 16. THERE ARE OTHER LIMITATIONS THAT ARE DETAILED IN AN APPENDIX. THE INTEGRATION TECHNIQUE IS DIFFERENT FROM THAT IN DWUCK4. THE QUANTITY TO WATCH IS $K*DR = 'DRHOC'$. THIS SHOULD BE WELL LESS THAN 0.5 FOR BEST RESULTS.

KVI ADDITIONS TO THE PROGRAM ARE EXTRA FORM FACTORS INCLUDING A FOLDING FORM FACTOR AND BETA, GAMMA AND OCTUPOLE BANDS COLLECTIVE MODEL FORM FACTORS.

COLUMN	VARIABLE	VALUE	USAGE
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CARD 1. CONTROL PARAMETERS AND TITLE

(ICON(I), I=1, 20), TITLE
 FORMAT(20I1, 15A4)

1	ICON(1)	= 0	REPEAT THE SAME SET OF ANGLES AS FOR THE LAST CASE. FOR THE FIRST CASE, THE DEFAULT ANGLE SET IS 0 TO 180 DEG. IN STEPS OF 5 DEG.
		= 1	READ ANGLE DATA FROM CARD 2 FOR THE VALUES OF--
		= 2	NUMBER OF ANGLES, INITIAL ANGLE, STEP SIZE.
		= 9	READ ANGLE DATA FROM CARD 2 FOR THE VALUES OF--
			INITIAL ANGLE, FINAL ANGLE (OR FINAL ANGLE AND
			INITIAL ANGLE) AND STEP SIZE.
			TERMINATE THE CALCULATIONS. (THIS IS NOT NEEDED
			SINCE THE PROGRAM WILL TERMINATE ON AN EOF CARD.)
2	ICON(2)	= 0	PRINT ALL FORM-FACTOR INFORMATION.
		= 1	SAME.
		= 2	SUPPRESS SINGLE-PARTICLE WAVE FUNCTIONS. USED WHEN
			ICODE = 2.
		= 3	SUPPRESS ALL SINGLE-PARTICLE F.F. PARAMETERS. USED
			FOR ANY ICODE.
3	ICON(3)		NOT USED.
4	ICON(4)		NOT USED.
5	ICON(5)	= 0	DO NOT WRITE SCAT. AMPLITUDES ONTO SCRATCH FILE.
		= 1	WRITE SCATTERING AMPLITUDES ONTO SCRATCH FILE
			"TAPE4" FOR EXTERNAL USE.
6	ICON(6)	= 0	DO NOT PRINT ELASTIC T-MATRIX ELEMENTS.
		= 1	PRINT.
		= 2	ALSO PRINT IN FORM OF S-MATRIX ELEMENTS.
7	ICON(7)	= 0	DO NOT PRINT ALL T-MATRIX ELEMENTS.
		= 1	PRINT.
8	ICON(8)	= 0	DO NOT PRINT TRANSITION AMPLITUDES, D.
		= 1	PRINT.
		= N	WRITE TRANSITION AMPLITUDES OF STATE "N" ONTO
			SCRATCH FILE "TAPE2" TO BE READ BY PROGRAM ANGCR.
9	ICON(9)	= 0	PLOT 3-CYCLE SEMILOG GRAPHS OF CROSS SECTIONS.
		= N	(N=1 TO 5) PLOT ALL DIFFERENTIAL CROSS SECTIONS,
			N-CYCLE SEMILOG.
		> 5	NO GRAPHS.
10	ICON(10)	= 0	USE NON-RELATIVISTIC KINEMATICS.
		= 1	COMPUTE K AND ETA FROM RELATIVISTIC KINEMATICS.
			CAUTION: SINCE OPTICAL POTENTIALS HAVE USUALLY BEEN OBTAINED
			FROM ANALYSES WITH NON-RELATIVISTIC KINEMATICS, THE
			RELATIVISTIC FEATURE SHOULD BE USED WITH CARE.
			CHANGES IN CROSS SECTIONS OF 20 PERCENT HAVE BEEN
			SEEN IN PATHOLOGICAL CASES.
11	ICON(11)	= 0	DO NOT PRINT DIAGONAL $K^2 - 2M^2 U(R) / \hbar^2$ OF
		= 1	DISTORTED WAVES.
			PRINT.
12	ICON(12)	= 0	DO NOT PRINT OFF-DIAGONAL $-2AMU \cdot BETA \cdot FF(R) / \hbar^2$,
			WHERE $FF(R)$ IS THE FORM FACTOR, $BETA$ IS THE
			STRENGTH, AND AMU IS THE MASS UNIT.
		= 1	PRINT.

13 ICON(13) = 0 DO NOT PUNCH CROSS SECTIONS AND POLARIZATIONS.
 = N PUNCH CROSS SECTION AND POLARIZATION FOR CHANNEL N.
 = 9 PUNCH CROSS SECTIONS AND POLARIZATIONS FOR ALL
 CHANNELS.

Scheint keine weitere Scheit zu machen

STABILITY-CHECK CONTROLS (FOR TEST PURPOSES)

18 ICON(18) = 0 USE STORMER INTEGRATION.
 = 1 USE NUMEROV INTEGRATION.

19 ICON(19) = 0 NORMAL STARTING POINTS.
 = N SHIFT L-VALUE IN CALCULATION OF STARTING POINTS
 BY -N.

20 ICON(20) = 0 NORMAL STARTING VALUES = $10.0^{**}(-8)$.
 = N STARTING VALUES = $10.0^{**}(-2*N)$.

21-80 TITLE = ANY ALPHANUMERIC TITLE.

CARD 2. ANGLE SET CARD (USE ONLY IF ICON(1) > 0)

ANGLE(I), I=1,3
FORMAT(3F8.4)

1-8 ANGLE(1) = NUMBER OF ANGLES (ICON(1) = 1)
= INITIAL ANGLE (ICON(1) = 2)

9-16 ANGLE(2) = INITIAL ANGLE (ICON(1) = 1)
= FINAL ANGLE (ICON(1) = 2)

NOTE: IF ICON(1) = 2, THESE TWO VARIABLES MAY ALSO BE FINAL ANGLE AND
INITIAL ANGLE, RESPECTIVELY. THE PROGRAM REARRANGES THEM.

17-24 ANGLE(3) = ANGLE STEP SIZE.

CARD 3. ANGULAR-MOMENTUM CARD

LMAX, NCHANN, JC(1), JC(2), ..., JC(NCHANN), KC(1), KC(2), ..., KC(NCHANN),
JP(1), JP(2), ..., JP(NCHANN)
FORMAT(26I3)

1-3 LMAX = THE MAXIMUM NUMBER OF PARTIAL WAVES TO BE USED.
NOTE: THE MAXIMUM UPPER LIMIT ON LMAX IS 600/NCHANN.
SEE ALSO APPENDIX I.

4-6 NCHANN = THE TOTAL NUMBER OF INTRINSIC CHANNELS, INCLUDING THE
ELASTIC CHANNEL. (NCHANN .LE. 8)

7-9, JC(I) = THE VALUE OF 2*(PARITY)*(SPIN) FOR THE I-TH CHANNEL, WHERE
10-12, PARITY IS THE PARITY OF THE NUCLEUS IN THE I-TH CHANNEL AND
SPIN IS THE TOTAL ANGULAR MOMENTUM OF THE NUCLEUS. FOR
MOST COMPUTERS, -0 WILL BE READ AS +0.

ETC. KC(I) = TWICE THE VALUE OF THE SPIN PROJECTION FOR THE BANDHEAD OF
----- A COLLECTIVE ROTATIONAL BAND. ONE VALUE FOR EACH
APPLICABLE CHANNEL.

ETC. JP(I) = 1 (OR -1 OR ANY ODD VALUE) CHANGE THE PARITY OF JC(I).
= 0 (OR BLANK OR EVEN VALUE) DO NOT CHANGE THE PARITY.
NOTE: THIS ARRAY IS INTENDED FOR USE WITH 0- STATES.

CARD 4. INTEGRATION CONTROLS CARD

DR, RMAX, FLCO
FORMAT(3F8.4)

1-8 DR = THE INTEGRATION STEP SIZE (DEFAULT IS 0.1 FERMI).

9-16 RMAX = THE UPPER CUT-OFF ON THE RADIAL INTEGRATIONS (DEFAULT VALUE
IS 20 FERMI). THE PROGRAM WILL INSURE A REASONABLE MINIMUM
VALUE IF RMAX > 0. IF RMAX < 0, THE ABSOLUTE VALUE WILL BE
USED AND WILL NOT BE INCREASED.
NOTE: THE RATIO RMAX/DR MAY NOT EXCEED 400 POINTS.

17-24 FLCO = LOWER-L CUTOFF ON ALL TRANSFER COUPLINGS.

THERE ARE TO BE NCHANN SETS OF THE FOLLOWING CARD SET 5, ONE FOR EACH CHANNEL.

CARD SET 5. SCATTERING-CHANNEL OPTICAL PARAMETERS

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CARD 5A. CHANNEL DEFINITION

E, FMP, ZP, FMT, ZT, RC, AC, PNLOC, FS, QCD
FORMAT(10F8.4)

1-8	E	= THE LAB ENERGY (MEV) OF THE INCIDENT PROJECTILE. (NZ=1)
	OR	= Q VALUE (MEV) RELATIVE TO ELASTIC CHANNEL. (NZ>1)
9-16	FMP	= THE MASS OF THE PROJECTILE (U, 12C = 12.000000).
17-24	ZP	= THE CHARGE NUMBER OF THE PROJECTILE.
25-32	FMT	= THE MASS OF THE TARGET NUCLEUS.
33-40	ZT	= THE CHARGE NUMBER OF THE TARGET NUCLEUS.
41-48	RC	= THE RADIUS PARAMETER FOR THE COULOMB POTENTIAL (UNIFORM DISTRIBUTION), TO BE MULTIPLIED BY FMT**1/3 (PLUS FMP**1/3 IF RC IS NEGATIVE).
49-56	AC	NOT USED.
57-64	PNLOC	= THE NON-LOCALITY PARAMETER FOR THE PROJECTILE-- = 0 NO NON-LOCALITY CORRECTIONS. > 0 USE HULTHEN FORM. < 0 USE GAUSSIAN FORM.
65-72	FS	= TWICE THE SPIN VALUE OF THE INCIDENT PROJECTILE. -----
73-80	QCD	= AN ENERGY OFFSET TO BE ADDED ALGEBRAICALLY TO THE ENTRY E (Q VALUE, NZ>1 ONLY). NORMALLY USED TO COMPENSATE GROUND-STATE Q VALUES FOR EXCITATION ENERGY.

CARD 5B. CHANNEL SPECIFICATION CARD

NZ, NZ, LDFRM, BETA, BETA2, BETA4
FORMAT(2I3, 12X, I3, 3X, 3F8.4)

3, 6	NZ	= THE NUMBER OF THE CHANNEL. (ACTUALLY THESE ARE NOT USED; THE PROGRAM ASSIGNS NUMBERS SEQUENTIALLY.)
21	LDFRM	= THE ORDER OF DEFORMATION OF THE OPTICAL POTENTIALS, IF DEFORMATION IS BEING SPECIFIED.
25-32	BETA	= THE DEFORMATION PARAMETER FOR ORDER LDFRM. THIS IS USED ONLY FOR OPTIONS 11 AND 12 OF THE POTENTIALS. THE PROGRAM EXTRACTS THE MONOPOLE PART OF THE POTENTIAL.
33-40	BETA2	= THE DEFORMATION PARAMETER FOR ORDER LDFRM+2.
41-48	BETA4	= THE DEFORMATION PARAMETER FOR ORDER LDFRM+4.

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FX,VR,RR,AR,VSOR,VI,RI,AI,VSOI,PWR  
FORMAT(10F8.4)
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* FX=9, 14, OR 15 REQUIRE EXTRA CARDS.

9-16 VR = REAL WELL DEPTH (MEV).

17-24 RR = REAL WELL RADIUS PARAMETER R0 (FERMI), TO BE MULTIPLIED BY
FMT**1/3 (PLUS FMP**1/3 IF RR IS NEGATIVE).

25-32 AR = REAL WELL DIFFUSENESS (FERMI).

33-40 VSOR = REAL WELL THOMAS SPIN-ORBIT FACTOR FOR THE REAL GEOMETRY.

41-48 VI = IMAGINARY WELL DEPTH.

49-56 RI = IMAGINARY WELL RADIUS PARAMETER. (SAME CONVENTIONS AS RR.)

57-64 AI = IMAGINARY WELL DIFFUSENESS.

65-72 VSOI NOT USED. (NO IMAG. SPIN-ORBIT POTENTIALS IN CHUCK3.)

73-80 PWR = THE POWER TO WHICH THE RADIUS COORDINATE WILL BE RAISED IN
CALCULATING THE POTENTIAL. (USE ONLY FOR FX = 6, 7, OR 10.)

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VSOR   = 0.      OAK-RIDGE (SECOND-DERIVATIVE) FORM OF POTENTIAL 5.
        = 1.      GLASHAUSSEY FORM OF POTENTIAL 5 (FULL DERIVATIVE OF
                   SPIN-ORBIT POTENTIAL 4).

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NOTE: USE THESE ONLY FOR FX = 5. THE SPIN-ORBIT
POTENTIAL CANNOT BE DEFORMED IN CHUCK3.

NOTE: CARDS 5C WILL CONTINUE TO BE READ SEQUENTIALLY, WITH ANY EXTRA CARDS THAT ARE NEEDED INTERSPERSED, UNTIL FX IS NEGATIVE. THIS SIGNALS THE LAST POTENTIAL, FOR THE ABSOLUTE VALUE OF FX. THE TOTAL POTENTIAL IS FORMED FROM THE SUM OF ALL POTENTIALS READ. $FX = 0$ ALSO TERMINATES AND $FX > 16$ WILL BE IGNORED (EXCEPT THAT THE RADIUS VALUES CAN INCREASE RMAX).

CARD 5D. HARMONIC OSCILLATOR PARAMETERS (REQUIRED IF FX = 9)

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FN, FL  
FORMAT (2F8.4)
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1-8 FN = THE PRINCIPLE HARMONIC-OSCILLATOR QUANTUM NUMBER.

9-16 FL = THE ORBITAL ANGULAR MOMENTUM.

NOTE: FX = 9 SHOULD NOT BE USED IN THE SCATTERING CHANNELS AS IT GENERATES A SINGLE-PARTICLE WAVE FUNCTION.

CARD 5E(1). EXTERNAL FORM FACTOR PARAMETERS (REQUIRED IF FX = 14)
----- TO BE READ FROM SCRATCH FILE "TAPE2"
F1,F2
FORMAT(2F8.4)

1-8 F1 = THE NUMBER OF POINTS IN THE FORM FACTOR TO BE READ IN.
9-16 F2 = 0. CENTRAL REAL FORM FACTOR.
= 1. CENTRAL IMAGINARY FORM FACTOR.
= 2. SPIN-ORBIT REAL FORM FACTOR.

CARD 5E(2). FORM FACTOR CARDS (REQUIRED IF FX = 14)
----- TO BE READ FROM SCRATCH FILE "TAPE2"
U(I),I=1,F1
FORMAT(5E16.7)

1-16, U(I) = THE I-TH VALUE OF THE FORM FACTOR. THE ENTIRE FORM FACTOR
17-32, ETC. WILL BE MULTIPLIED BY THE VALUE OF VR OR VI ON CARD 5B
(DEFAULT VALUE IS 1). THUS THE FORM FACTOR MAY BE SCALED
BY A POTENTIAL DEPTH OR A SPECTROSCOPIC AMPLITUDE.

NOTE: CARDS 5E(2) WILL BE READ SEQUENTIALLY UNTIL THE VALUE OF F1 IS EXHAUSTED. THE CARDS 5E ARE IDENTICAL WITH THE PUNCHED OUTPUT FROM DWUCK.

CARD 5F. TRANSITION DENSITY AND PROJECTILE-NUCLEON INTERACTION (FOLDING
----- -- POTENTIAL) PARAMETERS. (REQUIRED IF FX = 15)

F1,QCODE,FMUV,OPT
FORMAT(4F8.4)

1-8 F1 = THE NUMBER OF POINTS IN THE FORM FACTOR TO BE CONSTRUCTED.
9-16 QCODE = 1, 2, 4, OR 6 (SEE CARD 7A FOR MORE DETAILS)
17-24 FMUV = THE INVERSE RANGE OF THE INTERACTION, MU (IN INVERSE
FERMIS), IF QCODE = 1, OR 4.
25-32 OPT = THE STRENGTH OF THE POTENTIAL IN MEV.

NOTE: THE TRANSITION DENSITY SUBROUTINE FMN SHOULD BE COMPILED AND LINKED
FOR EACH FOLDING MODEL CALCULATION.

CARD 6. CHANNEL-COUPLING SPECIFICATION CARD

NJ, NI, LTR, 2*STR, 2*JTR, ICODE, LDFRM, ICOUEX, BETA, BETA2, BETA4,
 ROCX, FNRNG, AGAMMA, VBETA
 FORMAT(8I3, 7F8.4)

- 1-3 NJ = THE FINAL-CHANNEL SPECIFICATION NUMBER FOR THE TRANSITION.
 ----- THE CHANNELS ARE DESCRIBED ON CARD SET 5. IF NJ
 IS NEGATIVE, THE COUPLING IS ONE-WAY, NI --> NJ;
 IF POSITIVE, IT WILL BE TWO-WAY, NI <--> NJ.
- 6 NI = THE INITIAL-CHANNEL SPECIFICATION NUMBER.

- 7-9 LTR = THE ORBITAL-ANGULAR-MOMENTUM TRANSFER FOR THE COUPLING.
- 10-12 2*STR = TWICE THE SPIN TRANSFER FOR THE COUPLING.
- 13-15 2*JTR = TWICE THE TOTAL-ANGULAR-MOMENTUM TRANSFER FOR THE COUPLING.
- 16-18 ICODE = 0 COLLECTIVE FORM FACTOR FOR ROTATIONS.
 = 1 SINGLE-PARTICLE-TRANSFER FORM FACTOR.
 = 2 TWO-NUCLEON MICROSCOPIC FORM FACTOR.
 = 3 COLLECTIVE F.F., NOT-STRONG-COUPLING MODEL; K IS
 NOT A GOOD QUANTUM NUMBER (E.G., VIBRATIONS).
 = 4 'CLUSTER' (COLLECTIVE) COMPLEX F.F., HANDLED
 AS STRIPPING.
 = 5 SIMPLY MULTIPLY LAST F.F. BY NEW STRENGTH BETA.
 = 6 PARTICLE TRANSFER IN STRONG-COUPLING COLLECTIVE
 MODEL.
 = 7 GAMMA BAND COLLECTIVE FORM FACTOR
 = -7 BETA BAND COLLECTIVE FORM FACTOR
 = 8 OCTUPOLE BAND COLLECTIVE FORM FACTOR.
 NOTE: FOR ICODE.EQ.-7.AND.ICODE.EQ.8 CORRECTION TERMS FOR
 BETA AND OCTUPOLE VIBRATIONS WHICH TAKE CARE OF
 CONSERVATION OF NUMBER OF PARTICLES AND REMOVE CENTER
 OF MASS MOTION, RESPECTIVELY, SHOULD BE CONSIDERED (SEE
 FOR FURTHER DETAILS INTERNAL REPORT KVI77 BY M.N.
 HARAKEH)
 NOTE: CARE SHOULD BE EXERCISED IN THE USE OF ICODE=3 FOR
 VIBRATIONAL EXCITATIONS IN THE GENERAL CASE OF ARBITRA-
 RY SPINS. INSPECTION OF THE PROGRAM MAY BE NECESSARY.
 CF. ALSO T.TAMURA, REV.MOD.PHYS. 37,679 (1965).
- 19-21 LDFRM = THE ORDER OF DEFORMATION FOR A COLLECTIVE FORM FACTOR.
 USED WITH ICODE = 0, 3, 4, 7, -7, OR 8, AND ONLY WITH
 POTENTIAL OPTIONS 11, 12 AND 13.
- 22-24 ICOUEX = 0 DO NOT COMPUTE COULOMB-EXCITATION CORRECTIONS TO
 INELASTIC SCATTERING.
 = 1 COMPUTE.
- 25-32 BETA = THE COUPLING STRENGTH FOR THE TRANSITION.
 (SEE APPENDIX II.)
- 33-40 BETA2 = THE DEFORMATION PARAMETER OF ORDER LDFRM+2.
- 41-48 BETA4 = THE DEFORMATION PARAMETER OF ORDER LDFRM+4.
- 49-56 ROCX = THE RADIUS PARAMETER (FERMIS) FOR THE COULOMB-EXCITATION
 CALCULATIONS, TO BE MULTIPLIED BY FMT(NJ)**1/3 (PLUS
 FMP(NJ)**1/3 IF ROCX IS NEGATIVE).
- 57-64 FNRNG = FINITE-RANGE CORRECTION PARAMETER--
 FOR ICODE = -7 OR 8 SEE NOTES 1 AND 2.
 = 0 NO FINITE-RANGE CORRECTIONS.
 > 0 USE HULTHEN FORM.

CARD SET 7. FORM FACTOR PARAMETER CARDS (ICODE = 2)

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CARD 7A. MICROSCOPIC FORM FACTOR CONTROL

CNTROL, QCODE, FMUV, OPT, FJC, FJI, FJF
FORMAT(7F8.4)

1-8 CNTROL = 0. TERMINATE THIS FORM FACTOR WITHOUT FURTHER ADO.
= 1. BOTH SINGLE-PARTICLE FORM FACTORS ARE IDENTICAL
AND DATA ARE TO BE READ FOR ONLY ONE OF THEM.
= 2. READ DATA FOR 2 SINGLE-PARTICLE FORM FACTORS.
NOTE: FORM-FACTOR DATA WILL CONTINUE TO BE READ SEQUENTIALLY, BEGINNING
WITH CARD 7A, AS LONG AS CNTROL > 0. THIS IS USEFUL FOR OBTAIN-
ING A FORM FACTOR OF MANY MICROSCOPIC COMPONENTS. A MINUS SIGN
PRECEEDING THE 1. OR 2. WILL SIGNAL THE LAST COMPONENT.

9-16 QCODE = 1. YUKAWA INTERACTION.
= 2. COULOMB INTERACTION.
= 3. OPEP TENSOR INTERACTION.
= 4. GAUSSIAN INTERACTION.
= 5. TWO-NUCLEON TRANSFER.
= 6. ZERO-RANGE KNOCKOUT.
= 11.-16. SAME AS FOR 1.-6., EXCEPT CONSTRUCT IMAGINARY FORM
FACTOR INSTEAD OF REAL FORM FACTOR.
= 0. DO NOT READ DATA OR CONSTRUCT F.F.
< 0. USE THE SAME 2 SINGLE-PARTICLE WAVE FUNCTIONS AS IN
THE PRECEEDING F.F. CONSTRUCTION, WITH THE INTER-
ACTION GIVEN BY ABS(QCODE). NOTE THAT THE SINGLE-
PARTICLE WAVE FUNCTIONS ARE RETAINED BETWEEN SUC-
CESSIVE REQUESTS FOR FORM FACTORS. THE READING OF
CARDS 7B - 7D WILL BE BYPASSED.

17-24 FMUV = THE INVERSE RANGE OF THE INTERACTION, MU (IN INVERSE
FERMIS), IF QCODE = 1, 3, OR 4.
= THE R.M.S. RADIUS OF THE LARGER-MASS PROJECTILE (IN FERMI)
FOR TWO-NUCLEON TRANSFER, QCODE = 5. IF LEFT BLANK, A
DEFAULT VALUE OF 1.70 FERMI IS ASSUMED.
NOTE: DUE TO A CODING OVERSIGHT, THE INPUT VALUE OF RMS FOR
(ALPHA,D) REACTIONS (OR THE INVERSE) MUST BE CHANGED
FROM THE PHYSICAL VALUE. USE
$$RMS(CHUCK INPUT) = RMS(PHYSICAL) * \sqrt{8/9}.$$

25-32 OPT = THE STRENGTH OF THE POTENTIAL (MEV) TIMES THE SPECTROSCOPIC
AMPLITUDES FOR THE PROJECTILE AND THE TARGET, FOR
QCODE = 1 - 4.
= THE SPECTROSCOPIC AMPLITUDE FOR THE TWO-NUCLEON-TRANSFER
COMPONENT, FOR QCODE = 5.
= VOLUME INTEGRAL OF TWO-BODY POTENTIAL FOR QCODE = 6,
WHERE V.I. = INTEGRAL OF $V(R) * \exp(I * K * R) * DR$.

33-40 FJC = TWICE THE TOTAL ANGULAR MOMENTUM OF THE CORE TO WHICH EACH
SINGLE-PARTICLE IS ATTACHED. NOT USED FOR QCODE = 5.

41-48 FJI = TWICE THE TOTAL ANGULAR MOMENTUM OF THE INITIAL STATE. NOT
USED FOR QCODE = 5.

49-56 FJF = TWICE THE TOTAL ANGULAR MOMENTUM OF THE FINAL STATE. NOT
USED FOR QCODE = 5.

NOTE: IF FJC = 0., THE REDUCED MATRIX ELEMENT IS ONLY FOR THE SINGLE-PARTICLE
TRANSITION J1 TO J2. ALSO FJF WILL NOT BE USED. OTHERWISE, THE R.M.E.
WILL INCLUDE THE COUPLING TO THE CORE.

MENTALLY SET ICODE TO 1 AND ENTER GROUPS OF CARDS SETS 7 FOR ICODE=1. THE
NUMBER OF SUCH SETS WILL BE EQUAL TO THE VALUE OF CNTROL ON CARD 7A HERE.

CARD SET 7. FORM FACTOR PARAMETER CARDS (ICODE = 1 AND 6)

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CARD 7A. CHANNEL DEFINITION CARD

THIS CARD IS THE SAME AS CARD 5A, EXCEPT FOR THE MEANING OF THREE PARAMETERS, NAMELY E, FS, AND QCD.

1-8	E	= 0.	DO NOT USE; ICODE=4 IS USED FOR THIS DWUCK OPTION.
		< 0.	E IS THE BINDING ENERGY (MEV) OF THE SINGLE PARTICLE TO THE CORE.
		> 0.	UNBOUND FORM FACTOR. E IS THE ENERGY ABOVE BINDING.
65-72	FS	= NOT USED.	
73-80	QCD	= THE VALUE TO BE ADDED TO THE VALUE OF E. TYPICALLY, E IS	

			THE BINDING ENERGY FOR THE GROUND STATE AND QCD IS AN OFFSET FOR EXCITATION ENERGY.

CARD 7B. FORM-FACTOR POTENTIALS

THIS CARD IS THE SAME AS CARD 5C. NOTE, HOWEVER, THAT 'IMAGINARY' PORTIONS ARE TREATED AS REAL POTENTIALS, BUT ARE NOT VARIED DURING A SEARCH FOR WELL DEPTH OR BINDING ENERGY. ALSO, THE POTENTIAL STRENGTH VR WILL BE MULTIPLIED BY VTRIAL (CARD 7C).

CARD 7C. SINGLE-PARTICLE QUANTUM NUMBERS

FN, FL, FJ2, FSS, VTRIAL, FISW, DAMP
FORMAT(7F8.4)

1-8	FN	= THE PRINCIPLE QUANTUM NUMBER, OR THE NUMBER OF NODES. (DO NOT COUNT ORIGIN AND INFINITY--HENCE START AT ZERO.)
9-16	FL	= THE ORBITAL ANGULAR MOMENTUM.
17-24	FJ2	= TWICE THE TOTAL ANGULAR MOMENTUM.
25-32	FSS	= TWICE THE SPIN ANGULAR MOMENTUM.

		NOTE: THE SPIN-ORBIT CONTRIBUTIONS OF THE FORM FACTOR ARE TREATED PROPERLY EVEN IF THERE ARE NO SPIN-DEPENDENT EFFECTS IN THE OPTICAL CHANNELS.
33-40	VTRIAL	= AN INITIAL SCALE FACTOR THAT MULTIPLIES THE REAL POTENTIAL PRIOR TO THE SEARCH ON BINDING ENERGY OR WELL DEPTH. IF LEFT BLANK, A DEFAULT VALUE OF +60. IS ASSUMED.
41-48	FISW	= 0. USE BINDING ENERGY TO SEARCH FOR WELL DEPTH. = 1. USE WELL DEPTH TO SEARCH FOR BINDING ENERGY. = 2. INTEGRATE FROM ORIGIN TO RMAX AND NORMALIZE TO $\sin(K \cdot R + \Delta TAC) / (K \cdot R)$. DO NOT USE FOR $E < 0$.
49-56	DAMP	= THE VALUE OF A DAMPING FACTOR $\exp(-DAMP \cdot R \cdot R)$ TO BE APPLIED TO THE SINGLE-PARTICLE WAVE FUNCTION.

CARD SET 7. FORM FACTOR PARAMETER CARDS (ICODE = 4)
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CARD 7A. CHANNEL DEFINITION CARD

THIS CARD IS THE SAME AS CARD 5A, EXCEPT FOR THE MEANING OF TWO
PARAMETERS, NAMELY E AND FS.

1-8 E = 0. SET THIS VALUE.

65-72 FS = NOT USED.

CARD 7B. FORM-FACTOR POTENTIALS

THIS CARD IS THE SAME AS CARD 5C.

RETURN TO CARD 7A HERE IF CNTROL > 0.

THE CHOICE FOR CARD SET 7 DEPENDS ON THE VALUE OF ICODE ON CARD 6. THE
OPTIONS ARE DETAILED SEPARATELY. THERE WILL BE NO CARD SET 7 FOR ICODE = 5.

CARD SET 7. FORM FACTOR PARAMETER CARDS (ICODE = 0, 3, 7, -7 AND 8)
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CARD 7A. FORM-FACTOR POTENTIALS

THIS CARD IS THE SAME AS CARD 5C. THE CONVENTIONS ARE NOW THE SAME AS
DWUCK4. THE VARIABLE PWR SHOULD NOT BE USED FOR FX = 1-3. THE OPTIONS
WITH FX = 4 OR 5 MAY NOT BE USED AS FORM FACTORS.

NOTE: IF ICODE = -7 OR 8 AND MORE THAN ONE OPTICAL POTENTIAL IS READ, THEN
CORRECTION TERM COUPLING PARAMETERS SHOULD BE READ ONCE MORE (SEE NOTES
OF CARD 6). IN THIS CASE THE FOLLOWING CARD SHOULD BE READ.

CARD 7B. ADDITIONAL CARD FOR CORRECTION TERMS

BETAR, BETAI
FORMAT(2F8.4)

1-8 BETAR = BETA0R FOR BETA VIBRATION COUPLING TERMS.
= BETA1R FOR OCTUPOLE VIBRATION COUPLING TERMS.

9-16 BETAI = BETA0I FOR BETA VIBRATION COUPLING TERMS.
= BETA1I FOR OCTUPOLE VIBRATION COUPLING TERMS.

NOTE: SEE NOTE3 OF PREVIOUS CARD. HOWEVER, THE TRANSITION MATRIX ELEMENTS
PRINTED ARE NOT CORRECT BECAUSE OF PROBLEMS WITH INTERNAL NORMALIZA-
TION. IF ONE IS STILL INTERESTED IN MATRIX ELEMENTS, THE PROGRAM
SHOULD BE RUN SEPARATELY FOR EACH POTENTIAL.

< 0 USE GAUSSIAN FORM.
NOTE: THE HULTHEN FORM MAY BE APPLIED TO CLUSTER DESCRIPTIONS OF MULTI-NUCLEON-TRANSFER REACTIONS. HOWEVER, FOR MICROSCOPIC TREATMENTS (ICODE = 2; VIZ., TWO-NUCLEON-TRANSFER REACTIONS), THE GAUSSIAN FORM WILL BE INVOKED AUTOMATICALLY.

65-72 AGAMMA = GAMMA BAND COUPLING PARAMETER.

73-80 VBETA = BETA BAND COUPLING PARAMETER, IF ICODE.EQ.-7.
= OCTUPOLE BAND COUPLING PARAMETER, IF ICODE.EQ.8.

IMPORTANT
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NOTE1: IF(ICODE.EQ.-7) THE PARAMETERS BETA0R AND BETA0I ARE READ IN PLACE OF FNRNG AND AGAMMA, RESPECTIVELY. BETA0R AND BETA0I ARE NECESSARY TO CONSERVE THE NUMBER OF PARTICLES FOR A BETA VIBRATION WHICH INDUCES A CHANGE IN VOLUME. THEY ARE BOTH READ TO ENSURE THAT VOLUME REAL AND IMAGINARY MONOPOLE MATRIX ELEMENTS COULD SEPARATELY BE SET TO ZERO OR PRACTICALLY TO A VERY SMALL NUMBER.

NOTE2: IF(ICODE.EQ.8) THE PARAMETERS BETA1R AND BETA1I ARE READ IN PLACE OF FNRNG AND AGAMMA, RESPECTIVELY. BETA1R AND BETA1I ARE NECESSARY TO REMOVE SPURIOUS CENTER OF MASS MOTION FOR AN OCTUPOLE VIBRATION WHICH INDUCES SUCH A MOTION. THEY ARE BOTH READ TO ENSURE THAT CENTER OF MASS REAL AND IMAGINARY MATRIX ELEMENTS COULD SEPARATELY BE SET TO ZERO OR PRACTICALLY TO A VERY SMALL NUMBER.
THESE CORRECTION PARAMETERS CAN BE CALCULATED WITH THE PROGRAM BECOR WHICH RUNS ON THE VAX.

NOTE3: FOR INELASTIC SCATTERING THE PROGRAM PRINTS THE ISOSCALAR TRANSITION MATRIX ELEMENTS DEFINED WITH RESPECT TO THE OPERATOR $R^{*}L^{*}Y_L$ ($L > 1$) AS DERIVED FROM BOTH THE REAL GEOMETRY AND THE IMAGINARY GEOMETRY. IF MONOPOLE AND DIPOLE TRANSITIONS ARE CONSIDERED THE PROGRAM PRINTS IN ADDITION TO THE MATRIX ELEMENTS DEFINED WITH RESPECT TO THE OPERATORS $(1/2)R^{*}2$ (MONOPOLE) AND $(1/2)R^{*}3Y_1$ (DIPOLE), RESPECTIVELY, THE CORRECTION TERMS MATRIX ELEMENTS WHICH SHOULD BE NEGLIGIBLE.

NOTE: THERE WILL BE AS MANY CARDS 6 AS THERE ARE TRANSITIONS TO CONSIDER. EACH CARD 6 WILL BE FOLLOWED BY AN APPROPRIATE CARD SET 7 (BELOW). THIS SEQUENCE WILL TERMINATE, AND CALCULATIONS WILL BEGIN, WHEN NJ=0 (I.E., ONE EXTRA BLANK CARD 6).

APPENDIX I. THE LIMITS ON THE SIZE OF THE CASES.
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THE LIMITS ON THE DIAGONAL POTENTIALS AND COUPLINGS ARE--
THERE MAY BE NO MORE THAN 8 (NUCLEUS+PROJECTILE) CHANNELS.
THE POTENTIALS MAY NOT CONTAIN MORE THAN 400 POINTS.
THERE MAY BE NO IMAGINARY SPIN-ORBIT POTENTIALS.
LMAX MAY NOT EXCEED 600/NCHANN.
THE TOTAL NUMBER OF COUPLING TRANSITIONS MAY NOT EXCEED 16.
THE LAST CONDITION PRODUCES THE MESSAGE 'TOO MANY CHANNEL COUPLINGS'
AND ALL CALCULATIONS CEASE.

THE MESSAGE 'NO TRANSITION STRENGTH' WILL BE PRODUCED IF
BETA (CARD 6) IS ZERO.
KC(I) .NE. KC(J) FOR ICODE=0.
JC(I) AND KC(I) DO NOT MATCH PROPERLY FOR ICODE = 0 AND 6.
SEARCH FOR SINGLE PARTICLE W.F. EXCEEDS 16 ITERATIONS.
THE CASE WILL NOT BE PROCESSED.

DEFINE JC = THE TOTAL ANGULAR MOMENTUM OF THE TARGET NUCLEUS
IN A CHANNEL.
SC = THE SPIN OF THE PROJECTILE IN A CHANNEL.
J1 = JC FOR CHANNEL 1.
S1 = SC FOR CHANNEL 1.
LMAX = THE MAXIMUM NUMBER OF PARTIAL WAVES.
NDIAG= THE NUMBER OF (NUCLEUS+PROJECTILE) CHANNELS.
NFF = THE NUMBER OF FORM FACTORS SPECIFIED.

ALSO; MC = THE PRODUCT $(2*JC+1)*(2*SC+1)$ FOR EACH CHANNEL.
M1 = $(2*J1+1)*(2*S1+1)$.
SUM = SUM OF MC OVER ALL CHANNELS.
NC = SUM OF $(MC+1)/2$ OVER ALL CHANNELS.
IDBL = 2 FOR DOUBLE PRECISION.

THE PROGRAM PRINTS THE FOLLOWING INFORMATION--
NCHAN IS NC, THE LARGEST NUMBER OF COUPLED EQUATIONS.
THE UPPER LIMIT IS 100.
NDAMPL IS THE NUMBER OF TRANSITION AMPLITUDES 'BETAS'.
NDAMPL = IDBL*SUM*M1*LMAX.
NTR1 IS THE LARGEST NUMBER OF CROSS-SECTION AMPLITUDES.
NTR1 = IDBL*M1*MAX(MC).
NYLM IS THE NUMBER OF SPHERICAL HARMONIC TERMS.
NYLM = LMAX*MAX((J1+JC+S1+SC)+1).

THE BASE SIZE OF THE PROGRAM IS ABOUT 28K. THE ADDITIONAL CORE NEEDED
IS THE MAXIMUM OF--

NEED1 = $1200*NDIAG + 800*NFF + 14*IDBL*NC$
NEED2 = $4*IDBL*NC*NC + NDAMPL$
NEED3 = $NDAMPL + 2*NTR1 + NYLM$.

FINALLY, THERE ARE SOME COMPLEX RELATIONS INVOLVING THE PARTIAL-WAVE
COUPLINGS. WITHOUT DETAIL, THESE MAY BE STATED AS--
FOR ANY VALUE OF THE SYSTEM TOTAL ANGULAR MOMENTUM, THE TOTAL
NUMBER OF ALL NON-ZERO OFF-DIAGONAL COUPLING POTENTIALS MAY
NOT EXCEED 510.
IF EXCEEDED, THE PROGRAM STOPS WITH STOP CODE 111.

APPENDIX II. THE TRANSITION COUPLING STRENGTHS, BETA
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COUPLING TRANSITIONS WILL HAVE ZERO FORM FACTORS UNLESS VALUES ARE ENTERED FOR BETA ON CARD 6. THE MEANING OF BETA DEPENDS ON THE VALUE OF ICODE.

DEFINE SAMP = A SPECTROSCOPIC AMPLITUDE, DEFINED IN THE USUAL CONVENTION. THERE ARE SEPARATE AMPLITUDES BETWEEN (RELATIVE-S) STATES OF THE LIGHT PROJECTILES AND BETWEEN STATES OF THE TARGET AND RESIDUAL NUCLEI. EACH SHOULD PROPERLY BE MULTIPLIED BY THE CORRESPONDING ISOSPIN CLEBSCH-GORDON COEFFICIENT. VALUES OF THE AMPLITUDES AND ISOSPIN COEFFICIENTS ARE GIVEN IN APPENDIX III.

D0 = THE ZERO-RANGE NORMALIZATION AMPLITUDE FOR THE REACTION. UNLIKE DWUCK, THIS MUST INCLUDE A FACTOR OF 100 (I.E., 10^{*4} IN $D0^{*2}$).

ICODE = 0, 3, 7, -7 AND 8

BETA IS THE DEFORMATION PARAMETER OF ORDER LDFRM FOR COLLECTIVE STATES.

ICODE = 7

AGAMMA IS THE GAMMA BAND COUPLING PARAMETER.

ICODE = -7

VBETA IS THE BETA BAND COUPLING PARAMETER.

BETA0R IS THE REAL BETA VIBRATION CORRECTION TERM COUPLING PARAMETER.

BETA0I IS THE IMAGINARY BETA VIBRATION CORRECTION TERM COUPLING PARAMETER.

ICODE = 8

VBETA IS THE OCTUPOLE BAND COUPLING PARAMETER.

BETA1R IS THE REAL OCTUPOLE VIBRATION CORRECTION TERM COUPLING PARAMETER.

BETA1I IS THE IMAGINARY OCTUPOLE VIBRATION CORRECTION TERM COUPLING PARAMETER.

ICODE = 1 AND 4

BETA = SAMP(LIGHT)*SAMP(TARGET)*D0

ICODE = 2

BETA = SAMP(LIGHT)*D0

FOR 2-NUCLEON TRANSFER.

BETA = SAMP(LIGHT)*SAMP(TARGET)

FOR INELASTIC SCATTERING OR CHARGE EXCHANGE.

EACH OF THESE WILL BE MULTIPLIED BY THE ENTRY OPT ON CARD 7A. DO NOT DUPLICATE.

ICODE = 6

BETA = SAMP(LIGHT)*D0*G*CORE*CLJ WHERE
 G = SQRT(2.) IF KC(I) OR KC(J) IS ZERO.
 = 1. OTHERWISE.
 CORE = OVERLAPS OF CORE STATES.

APPENDIX III. LIGHT-PARTICLE SPECTROSCOPIC AMPLITUDES
 =====

VALUES HAVE BEEN GIVEN BY KUNZ FOR THE SPECTROSCOPIC AMPLITUDES AND COUPLING STRENGTHS FOR VARIOUS LIGHT-ION TRANSFER REACTIONS. THE OVERALL FACTOR IS A PRODUCT OF THE INTRINSIC SPECTROSCOPIC AMPLITUDE, AN ISOSPIN CLEBSCH-GORDON COEFFICIENT, AND A ZERO-RANGE NORMALIZATION FACTOR D0. THE VALUES ARE TABULATED HERE.

REACTION -----	ISOSPIN C -----	C*SAMP -----	C*SAMP*D0 -----
P(N)D	-1./SQRT(2)	-1.	122.5
N(P)D	1./SQRT(2)	1.	-122.5
D(N)T	1.	SQRT(3/2)	-225
D(P)HE3	1.	SQRT(3/2)	-225
P(2N)T	-SQRT(2/3)	1.	-1560
P(NP)HE3 (S=0/T=1)	-1./SQRT(3)	1./SQRT(2)	-1100
P(NP)HE3 (S=1/T=0)	1.	SQRT(3/2)	-1920
N(2P)HE3	SQRT(2/3)	-1.	1560
N(NP)T (S=0/T=1)	1./SQRT(3)	-1./SQRT(2)	1100
N(NP)T (S=1/T=0)	1.	SQRT(3/2)	-1920
HE3 (N) ALPHA	-1./SQRT(2)	-SQRT(2.)	678
T(P) ALPHA	1./SQRT(2)	SQRT(2)	-678
D(NP) ALPHA	1.	2.	(-4800)

CLJ = COEFFICIENT OF CORE-COUPPLING EXPANSION.