C

PRASEODYMIUM

```
60TO 900
    325 IF(IH.6T.NHS) 60T0 900
         IF(IH.GT.50) GOTO 900
FIH=FLOAT(IH-1)
CALCULATE APPLIED MAGNETIC FIELD RHA
RHA=RHL+FIH#RHS
IF(ID.EQ.0) GOTO 330
C
CONSTRUCT THE HAMILTONIAN MATRICES FOR THE ENERGY OF THE IONS
 CONSIDERING THE INTERNAL MAGNETIC FIELD AND THE
 CRYSTAL FIELD ENERGY LEVELS. UNITS ARE KELUIN.
C
          HZC=0.0
          HZH=0.0
HXC=(RHA+PM1#RMAGC+RM2#RMAGH)#CU#0.50
          HXH=(RHA+RM1*RMAGH+RM2*RMAGC)*CU#0.50
          GOTO 340 34 (1997) 1997 1997 1997 1997 1997 1997
    330 HXC=0.0
          HXH=0.0
          HZC=(RHA+RM1#RMAGC+RM2#RMAGH)#CU
          HZH=(RHA+RM1#RMAGH+RM2#RMAGC)#CU
    340 CALL PRHCRHH, 0, HXH, HZH, BH2, BH4, BH6)
          CALL PRHCRHC, 1, HXC, HZC, BC2, BC4, BC6)
 C
CALCULATE THE EIGENVALUES AND EIGENVECTORS OF THE TWO MATRICES
C
C
            ROUTINES F01AJF+F02AMF ARE STANDARD LIBRARY ROUTINES(NAG)
r.
            WHICH CALCULATE EIGENVALUES AND EIGENVECTORS OF REAL
C
            SYMMETRIC MATRICES BY HOUSEHOLDER REDUCTION TO TRI-
C
            DIAGONAL FORM FOLLOWED BY THE OR ALGORITHM TO COMPLETE
C
            THE DIAGONALISATION.
            FOR DETAILS OF HOUSEHOLDER AND OP ALGORITHMS SEE BOOKS ON
C
            NUMERICAL METHODS, FOR EXAMPLE ACTON R.S. "NUMERICAL METHODS
С
            THAT WORK" PUBLISHED BY HARPER, N.Y. (1970) PAGE 347
C
C
C
     THE PARAMETER LIST OF FØ1AJF(N, TOL, A, IA, D, E, Z, IZ) IS
C
C
            N=INTEGER, THE OPDER OF MATRIX A
C
            TOL=REAL, MACHINE DEPENDENT CONSTANT, FOR ICL 1900 TOL=2.0mm(-218)
C
            A=REAL ARRAY, OF DIMENSION AT LEAST(N, N) CONTAINING THE SYMMETRIC
C
                     MATRIX, THE LOWER TRIANGLE ONLY IS REQUIRED. THE ARRAY IS THE ARRAY IS
C
                     NOT OVERWRITTEN BY THE ROUTINE.
c
            IA=INTEGER, THE FIRST DIMENSION OF A AS DEFINED IN THE CALLING.
C
           D=REAL ARRAY, OF DIMENSION AT LEAST (N), ON EXIT IT CONTAINS THE
С
                     DIAGONAL ELEMENIS OF IRIDIAGONAL MATRIX.
С
            E=REAL ARRAY, OF DIMENSION A! LEAST (N), ON EXIT IT CONTAINS THE
c
                     N-1 OFF DIAGONAL ELEMENTS OF TPIDIAGONAL MATRIX.
С
           Z=REAL ARRAY, OF DIMENSION AT LEAST (N, N). ON EXIT IT CONTAINS
С
                     THE ORTHOGONAL MATRIX Q THE PRODUCT OF THE HOUSEHOLDER
С
C
            IZ=INTEGER, THE FIRST DIMENSION OF Z AS DEFINED IN CALLING SEG.
С
C
```

THE PARAMETER LIST OF F02AMF(N, ACC, D, E, Z, 1Z, 1FAIL) IS
N=INTEGER, THE ORDER OF TRIDIAGONAL MATRIX T.

```
ACC=REAL, SMALLEST NUMBER ON THE COMPUTER SUCH THAT 1+ACC=1
 r
                     (ON ICL 1900 ACC=2.0mm(-37))
            D=REAL ARRAY, OF DIMENSION AT LEAST (N), CONTAINING DIAGONAL
 C
 C
                     ELEMENTS OF T.
            E=REAL ARRAY.OF DIMENSION AT LEAST (N) CONTAINING THE SUB-
 C
 C
                     DIAGONAL ELEMENTS OF T STORED IN E(2)-=E(N). IT IS
 C
                     OVERHRITTEN BY THE ROUTINE.
           Z=REAL ARRAY, DIMENSION AT LEAST (N,N), IF ELGENVECTORS OF THE
 C
                     FULL SYMMETRIC MATRIX ARE REQUIRED IT SHOULD CONTAIN THE
 C
                     Q (SEE F01AJF). ON EXIT IT CONTAINS THE NORMALIZED
 C
 C
                     EIGENVECTORS SUCH THAT 2(1, J), I=1, N CORRESPONDS TO
 C
                     EIGENVALUE J.
           IZ=INTEGER, THE FIRST DIMENSION OF Z AS DECLARED.
 C
 C IFAIL=INTEGER FLAG, GOVERNS ON ENTRY THE TYPES OF FAILURE
                     THAT WILL BE DETECTED. ON EXIT THE TYPE OF FAILURE.
C
                     IFAIL-0 ON EXIT FOR SUCCESSFUL COMPLETION.
 C
 C
CDEMENTERMENT CONTRACT OF THE PROPERTY OF THE 
C
C NOTE THAT IF NAG LIBRARY ROUTINES ARE NOT AVAILABLE THEN THESE
           ROUTINES HAVE THEIR EXACT EQUIVALENTS IN MOST SCIENTIFIC
C
C
           LIBRARIES UNDER DIFFERENT NAMES AND WITH, POSSIBLY, DIFFERENT
           ARGUMENT LISTS)
C THOSE INTERESTED IN NUMERICAL EIGENVALUE PROBLEMS SHOULD CONSULT
C MARTIN R.S., REINSCH C., WILKINSON J.H., NUM. MATH. BAND(11)181-95(1968)
C BOUDLER H, MARTIN R.S., REINSCH C., WILKINSON J.H,
          NUM MATH BAND(11) 293-306 (1968)
IFAIL=0
          CALL F01AJF(9,2.0**(-218), RHH, 9, EVALH, USE, PHH, 9)
          CALL F02AMF(9,2.0mm(-37),EUALH,USE,PHH,9,IFAIL)
          IF(IFAIL.EQ.0) GOTO 345
         WRITE(2,2000)
          IFAIL=0
   345 CONTINUE
          CALL F01AJF(9,2.0mm(-218),RHC,9,EVALC,USE,RHC,9)
          CALL F02RMF(9,2.0mm(-37),EVALC,USE,RHC,9,IFAIL)
          IF(IFAIL.EQ.0) GOTO 346
         WRITE(2,2000)
         IFAIL=0
   346 CONTINUE
         IF(IP.EQ.0) GOTO 349
         IF(IT.GT.1) GOTO 349
         WRITE(2,2005)
         IF(ID.EQ.0) GOTO 347
         URITE(2,2006) RHA
         GOTO 348
   347 URITE(2,2007)RHA
   348 CONTINUE
         WRITE(2,2001)
C
C PRINT EIGENVALUES AND EIGENVECTORS IF REQUIRED
C
         IE=1
         IU=9
```

```
CALL PRINTM(EVALH,1,9,IE)
    HRITE(2:2002)
CALL PRINTH(RHH:9:9:IV)
         WRITE(2,2003)
         CALL PRINTM(EVALC:1:9:IE)
         WRITE(2,2002)
         CALL PRINTM(RHC, 9, 9, IU)
   CHLL PRINTING HES 3, 3, 10)
349 CONTINUE
CALCULATE THE MAGNETIZATION ON BOTH SITES
                               je dangana kalangan kalangan kalangan kanangan kanangan kanangan kanangan kanangan kanangan kanangan kanangan k
C
         IF(ID.EQ.0) 60TO 350
         CALL PRT(9,RHC,EVALC, 1,RX0,USE1)
         CALL PRICS, RHH, EVALH, T, RXO, USE2)
                                                            esta esta esta de la composição dos comos de esta de la como de esta de la como de esta de la como de la como de esta de la como dela como de la como dela como de la como dela como de la como dela como de la como dela 
   350 CALL PRT(9,RHC,EUALC,T,RZO,USE1)
         CALL PRT(9,RHH,EVALH,T,RZO,USE2)
   360 USE1=-0.80#USE1
         USE2=-0.80*USE2
                    С
CHECK FOR CONVERGENCE OF MAGNETIZATION
         XX=ABS(USE1-RMAGC)
С
         YY=ABS(USE2-RMAGH)
         IF(XX.GT.0.20) GOTO 390
         IF(YY.LE.0.20) GOTO 400
   390 RMAGC=USE1
         RMAGH=USE2
         GOTO 320
   100 CONTINUE
C
C STORE RESULTS IN ARRAY RES
Ç
         RES(IH:1)=T
         RES(IH, 2)=RHA
         RES(IH,3 >=USE1
         RES(IH, 4)=USE2
         RES( IH, 5 )=0.50#(USE1+USE2)
CHECK WHETHER REQUISITE NUMBER OF FIELD STEPS HAVE BEEN
COMPLETED AND IF SO OUTPUT THE RESULTS TO LINEPRINTER
         IF(IH.LT.NHS) GOTO 310 .
   900 CONTINUE
CONSTRUCT A TABLE OF RESULTS
С
         WRITE(2,2004)
         WRITE(2,2008)
         CALL PRINTM(RES, 50, 5, NHS)
C
CONSTRUCT A GRAPHICAL DISPLAY ON THE LINEPRINTER
C
         CALL PRG(RES, 50, 5, 1H, 2, 3, 1, 84)
         CALL PRG(RES, 50, 5, 1H, 2, 4, T, 84)
         CALL PRG(PES, 50, 5, IH, 2, 5, T, 84)
```

```
60TO 300 ,
 948 STOP
 1009 FORMAT(II)
 1010 FORMAT(2F6.2)
 1012 FORMAT(F7.2)
 1008 FORMAT(13)
 1011 FORMAT(2F7.2)
 2008 FORMAT(1H0,3X,6HTEMP K,SX,SHFIELD,SX,SHMAG C,SX,SHMAG H,SX
   A, 7HAVERAGE )
 2000 FORMAT(1H0, 22HFAILURE IN NAG FOZ AMF)
 2001 FORMAT(1H0,37HE1GENUALUES HEXAGONAL SITES IN KELUIN)
 2002 FORMAT(1H0,26HCORRESPONDING EIGENVECTORS)
 2003 FORMAT(1H0,33HE16ENVALUES CUBIC SITES IN KELUIN)
 2004 FORMAT(1H1,11HRESULTS ARE)
 2005 FORMAT(1H0, 25HAPPLIED FIELD IN TESLA IS)
 2006 FORMAT(1HI, 28X, F8.2, 14HIN X DIRECTION)
 2007 FORMAT(1H+,28X,F8.2,14HIN 2 DIPECTION)
 2900 FORMAT(1H0,31HMAGNETIZATION IS NOT CONVERGING)
2901 FORMAT(1H0,3HIH=,13,3HIT=,13,3HIM=,13)
 1200 FORMAT(1H1,27HINPUT DATA FOR PRASEODYMIUM)
1201 FORMA!(1H0,15HLOWEST FIELD IS,F8.2,6H TESLA)
1292 FORMAT(1H0,9HTHERE ARE,13,9H STEPS OF,F8.2,6H TESLA)
1203 FORMAT(1H+,40X,22HAPPLIED IN X DIRECTION)
1204 FORMAT(1H+,40X,22HAPPLIED IN 2 DIRECTION)
1205 FORMAT(1H0,32HMOLECULAR FIELD PARAMETERS USED=,2(F7.2,3X))
                                         SUBROUTINE PRG(ROUT, NN, MM, NP, IX, IY, TT, A4)
    DIMENSION ROUT(NN, MM), ILINE(120), ICHAR(3)
    LOGICAL A4
    DATA ICHAR(1), ICHAR(2), ICHAR(3)/1H, 1H,, 1H#/
    IF(NP.GT.NN) GOTO 900
C
CODE OUTPUTS A SIMPLE GRAPH OF ROUT ONTO LINEPRINTER
C
ILIM=120
    IF(A4) ILIM=71
    SMALL=10.0mm(-10)
RYM=ROUT(1,IY)
    RYS=0.0
DO 100 II=1,NP
IF(ROUT(II,IY).GT.RYM) RYM=ROUT(II,IY)
    IF(POUT(II,IY).LT.RYS) RYS=ROUT(II,IY)
 100 CONTINUE
    YB=RYS
    AYB=ABS(YB)
    IF(AYB.LT.SMALL) YB=0.0
AYB=ARS(RYM-YR)
    AYB=ABS(RYM-YB)
    IF(AYB.LT.SMALL) 6010 900
    IF(.NOT.A4) RYS=109.0/(RYM-YB)
    IF(A4) RYS=69.0/(RYM-YB)
    IF(IY.EQ.3) GOTO 110
    IF(IY.EQ.4) GOTO 112
    WRITE(2,1902)
    GOTO 116
```

```
110 URITE(2,1900)
    GOTO 116
 112 URITE(2,1901)
 116 CONTINUE
    WRITE(2,1903) TT
    IF(IX.EQ.2) GOTO 120
    IF(IX.EQ.1) 60T0 122
 GOTO 130
 120 WRITE(2,2000)
    60T0 130
 122 URITE(2,2002)
              130 CONTINUE
 140 WRITE(2,2003)
   DO 320 II=1. ILIM
 320 ILINE(II)=1CHAR(2)
 IF(.NOT.A4) WRITE(2,2500) YB,RYM
    IF(A4) WRITE(2,2503) YB,RYM
   WRITE(2,2501 X ILINE(II), II=1, ILIM)
    RX=55.0/FLOAT(NP)
    ILX=IFIX(RX-0.50)
   DO 400 II=1,NP
DO 360 JJ=1,ILIM
    ILINE(JJ)=ICHAR(1)
 360 CONTINUE
    ILINE(10)=ICHAR(2)
    Y=(ROUT(II,IY)-YB) MRYS
 Y=Y+0.50
    ILY=IFI/(Y)+10
    IF(ILY.GT.ILIM) ILY=ILIM
    ILINE(ILY)=ICHAR(3)
    WRITE(2,2501)(ILINE(JJ),JJ=1,ILIM)
    WRITE(2,2502) ROUT(11,1X)
    II INE(ILY)=ICHAR(1)
    ILINE(10)=ICHAR(2)
    IF(ILX.I.E.1) 6010 390
    DO 380 JJ=1, ILX
    WRITE(2,2501)(ILINE(KK),KK=1,ILIM)
 380 CONTINUE
 390 CONTINUE
 400 CONTINUE
1900 FORMAT(1H1,20X,11HCUBIC SITES)
1901 FORMAT(1H1,20X,15HHEXAGONAL SITES)
1902 FORMAT(1H1,20X,23HAVERAGE FROM BOTH SITES)
1903 FORMAT(1H ,40X,14HTEMPERATURE IS,F8.2,7H KELUIN)
2000 FORMAT(1H0,12H FIELD TESLA)
2002 FORMAT(1H0,11H TEM KELUIN)
2003 FORMAT(1H+,50X,17HMAGNETISATION(BM))
C BM=BOHR MAGNETONS
2500 FORMAT(1H ,10X,E10.2,90X,E10.2)
2501 FORMAT(1H ,120A1)
2502 FORMAT(1H+,F9.3)
2503 FORMAT(1H ,10X,E10.2,28X,E10.2)
 900 RETURN
    SUBROUTINE PRHCRH, CH, HX, HZ, B2, B4, B6)
```

```
DIMENSION RH(9,9)
    REAL B2,84,86,HX,HZ,H,G,X,XS,MU,SQP
    INTEGER CH
C
C
CONSTRUCTS THE HAMILTONIAN MATRICES FOR PRASEODYMIUM AND STORES IN RH
CH IS=0 FOR HEXAGONAL SITES AND=1 FOR CUBIC SITES
CONSTANTS B2 B4 B6 ARE THE THREE CRYSTAL FIELD PARAMETERS
CODE USES HX AND HZ FOR THE TOTAL MAGNETIC FIELDS IN X AND Z DIRE
CTIONS RESPECTIVELY.
C
    DO 100 I=1.9
    DO 100 J=1,9
 100 RH(I,J)=0.0
    RK(1:1)=28.0mB2+14.0mB4+4.0mB6+4.0mHZ
RK(1:2)=SOPT(8.0)mHY
    RH(1,2)=SQRT(8.0)=HX
RH(2,1)=RH(1,2)
    RH(8,9)=RH(1,2)
RH(9,8)=RH(8,9)
    RH(1,7)=SQRT(7.0)#5.50#B6
    RH(7x1)=RH(1x7)
    RH(3,9)=RH(1,7)
    RH(9,3)=RH(3,9)
    RH(2,2)=7.0xB2-21.0xB4-17.0xB6)3.0xHZ
    RH(3,2)=SQRf(14.0)>HX
    RH(2,3)=RH(3,2)
    RH(7,8)=RH(2,3)
    RH(8,7)=RH(7,8)
    RH(2,8)=(77.0mB6)/4.0
RH(8,2)=RH(2,8)
    RH(8,2)=RH(2,8)
RH(3,3)=-8.0mB2-11.0mB4+22.00mB6+2.0mH2
RH(3,4)=SQRT(18.0)mHX
    RH(3,1)=SQRT(18.0)=HX
RH(4,3)=RH(3,1)
    RH(6,7)=RH(3,4)
    RH(7,6)=RH(6,7)
    RH(1,1)=-17.0mB2:9.0mB4:B6+HZ
    RH(1,5)=SQRT(20.0)#HX
   RH(5,4)=RH(4,5)
RH(5,6)=RH(4,5)
    RH(6,5)=RH(5,6)
    RH(5,5)=-20.0#B2+18.0#B4-20.0#B6
    RH(6,6)=RH(4,4)-2.0#HZ
   RH(7,7)=RH(3,3)-1.0#HZ
   RH(8,8)=RH(2,2)-6.0*HZ
   RH(9,9)=RH(1,1)-8.0×HZ
   IF(CH.EQ.0) 60TO 900
C
CUBIC SYMMETRY TERMS ADDED NOW
   RH(1,4)=SQRT(7.0)=(10.0=B4-5.0=B6)
   RH(4,1)=RH(1,4)
   RH(2,5)=SQRT(70.0)x(3.0xB4+1.250xB6)
   RH(5,2)=RH(2,5)
   RH(3,6)=10.0\B4+8.750\B6
   RH(6,3)=RH(3,6)
```

```
RH(6,9)=-RH(1,4)
    RH(9,6)=RH(6,9)
    RH(5,8)=-RH(2,5)
    RH(8,5)=RH(5,8)
    RH(4,7)=-RH(3,6)
    RH(7,4)=RH(4,7)
 900 RETURN
    END
    SUBROUTINE PRINTMCRMAT, 11, 12, 1POH)
    DIMENSION PMAI(11,12)
C
COLUMNS OF MATRIX RMAT(11,12) PRINTED BY SUBROUTINE (MAX 12 COLS)
C
    LIM=I2
    IF(I2.GT.LIM) LIM-12
    IF(IROW.GT.11) G010 910
    WRITE(2,2001)
    DO 100 II=1, IRON
    URITE(2,2000)(RMAT(11,JJ),JJ=1,LIM)
 100 CONTINUE
    GOTO 900
 910 WRITE(2,2003) IROW,11
2000 FORMAT(1H ,12F10.4)
2001 FORMAT(1H0)
2003 FORMAT(1H0,24HPRINTM CALLED WITH IROW=,16,5H I1=,16)
 900 RETURN
    END
    SUBROUTINE PRT(NN, EVEC, EVAL, TEM, ROP, RES)
                                                可以的 网络神经 多足能 加强管
    DIMENSION EVEC(NN, NN), EVAL(NN), ROP(NN, NN)
    DIMENSION RMOM(20), RU(20)
                                           4、1、1、4000年,2005年高兴高兴的
    REAL NUM, DEN
    INTEGER RR
    IF(NN.GT.20) GOTO 900
CALCULATES THE THERMAL AVERAGE OF AN OPERATOR ROP GIVEN THE
CORECT EIGENVALUES STORED IN ASCENDING ORDER IN EVAL AND THE
CORRESPONDING EIGENVECTORS STORED IN EVEC. TEM IS THE TEMPERATURE.
NUM=0.0
    DEN=0.0
    IF(TEM.LT.0.000000001) GOTO 800
    DO 100 II=1,20
    0.0=(II)MOMS
    RU( II )=0.0
 100 CONTINUE
    DO 200 KK=1.NN
    DO 110 II=1,NN
 110 RU(II)=0.0
    DO 160 II=1,NN
    DO 140 JJ=1,NN
    RU(II)=RU(II)+ROP(II, JJ)*EUEC(JJ, KK)
 140 CONTINUE
 160 CONTINUE
    DO 170 II=1,NN
```

```
RMOM(KK)=RMOM(KK)+EUEC(II, KK) **RU(II)
170 CONTINUE
200 CONTINUE
   NUM=EVAL(1)/TEM
    IF(NUM.LE.-60.0) GOTO 400
   DO 210 II=1,NN
   M3T\(11)/AN3-=YX
   DEN=DEN+EXP(XX)
   (YX)9X3#(11)MOM9+MUN=MUN
210 CONTINUE
   RES=NUM/DEN
   GO FO 900
100 RR=0
   NUM=0.0
   DO 420 II=1,NN
420 IF(EUAL(II).EQ.EUAL(I)) RR=RR+1
   DO 430 II=1,RR
430 NUM=NUM | RMOM(11)
   JJ=RR+1
   XX=EUAL(RR)-EUAL(JJ)
   XX=EXP(XX/TEM)
   NUM=NUM+XX
   DEN=1.0+XX
   PES=NUM/DEN
   GOTO 900
800 DO 820 II=1,20
   RMOM(II)=0.0
820 RU(II)=0.0
   DO 830 II=1,NN
   DO 825 JJ=1,NN
825 RUCII>=RUCII>+ROPCII; JJ) **EVECCJJ; 1>
830 CONTINUE
   DO 840 II=1,NN
   RMOM(1)=RMOM(1)+EUEC(II,1)*RU(II)
840 CONTINUE
   RES=RMOM(1)
END
```

X DIRECTION RESULTS

INPUT DATA FOR PRASEODYMIUM
LOWEST FIELD IS 0.00 TESLA
THERE ARE 40 STEPS OF 2.00 TESLA

APPLIED IN X DIRECTION MOLECULAR FIELD PARAMETERS USED= -1.20 4.14 RESULTS ARE TEMP K FIELD MAG C MAG H AVERAGE 4.2000 0.0000 0.0000 -0.0000 0.0000 4.2000 2.0000 0.2789 0.5438 0.4113 4.2000 4.0000 0.5092 1.2042 0.8567 4.2000 6.0000 0.7421 1.6494 1.1957 4.2000 8.0000 0.9151 1.9961 1.4556 4.2000 10.0000 1.0634 2.2234 1.6434 4.2000 12.0000 1.1603 2.3644 1.7624 4.2000 14.0000 1.2907 2.5025 1.8966 4.2000 16.0000 1.3748 2.5829 1.9788 4.2000 18.0000 1.4722 2.6660 2.0691 20.0000 4.2000 1.5455 2.7167 2.1311 4.2000 22.0000 1.6143 2.7593 2.1868 4.2000 24.0000 1.6897 2.8080 2.2488 4.2000 26.0000 1.7500 2.8376 2.2938 4.2000 28.0000 1.8067 2.8635 2.3351 4.2000 30.0000 1.8601 2.8862 2.3732 4.2000 32.0000 1.9149 2.9141 2.4145 4.2000 34.0000 1.9622 2.9313 2.4467 4.2000 36.0000 2.0069 2.9467 2.4768 4.2000 38.0000 2.0493 2.9607 2.5050 4.2000 40.0000 2.0895 2.9734 2.5315 4.2000 42.0000 2.1289 2.9894 2.5591 4.2000 44.0000 2.1651 2.9996 2.5824 4.2000 46.0000 2.1997 3.0090 2.6044 4.2000 48.0000 2.2327 2.6252 3.0177 4.2000 50.0000 2.2642 3.0257 2.6449 4.2000 52.0000 2.2943 3.0332 2.6637 4.2000 54.0000 2.3232 3.0401 2.6816 4.2000 56.0000 2.3507 3.0492 2.6999 4.2000 58.0000 2.3773 3.0550 2.7162 4.2000 60.0000 2.4028 3.0605 2.7317 4.2000 62.0000 2.4275 3.0657 2.7466 4.2000 64.0000 2.4511 3.0705 2.7608 4.2000 66.0000 2.4740 3.0751 2.7745 4.2000 68.0000 2.4960 3.0794 2.7877 4.2000 70.0000 2.5173 3.0834 2.8004 4.2000 72.0000 2.5378 3.0873 2.8125 4.2000 74.0000 2.5570 3.0923 2.8247 4.2000 76.0000 2.5762 3.0957 2.8360 4.2000 78.0000 2.5948 3.0989 2.8468

X DIRECTION RESULTS

CUBIC SITES

FIELD TESLA		TEMPERATURE I	S 4.20 KELVIN	
		MAG	NETISATION(BM)	
	.00E 00	9.2	6E 01	
8.000		••••••••••		
10.000				
12.000				
14.000		*		
16.000				
18.000				
20.000				
22.000				
21.000				
26.000				
28.000				
30.000				
32.000				
34.000				
36.000			경기 : 1 : 1 : 1 : 1 : 1 : 1 : 1 : 1 : 1 :	
38.000				
10.000				
1 2.000				
11.000				
+6.000				
18.000				
50.000				
52.000				
54.000				1
56.000				

				그 내가 있다. 내 시설 휴가 있는 것 같다.	
	HEXAGON	AL SITES	TEMPEDATI DE	IS 4.20 KELVIN	
FIELD TESLA					
a aa	E 00			AGNETISATION(BM) .31E 01	
• • • • • • • • • • • • • • •				.31E 01	
0.000	.				
2.000				A Sept. A Sept.	
4.000					
T.000			***	an Region	
6.000		图 海原			
8.000				· · · · · · · · · · · · · · · · · · ·	
				· · · · · · · · · · · · · · · · · · ·	
10.000				- 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1	
12.000					
14.000					
16.000			\$100 to	a bolik	
	46.054			Tara Bee	
18.000	o de la compania de La compania de la co		i sistema in a second		
20.000		verijas Rojenski		i da bar Tarangan	
e j•lest					*
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24.000				was fire.	×
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Z DIRECTION RESULTS

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APPLIED IN Z DIRECTION

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4.2000 34.0000 1.5706 0.1907 0.8807 4.2000 36.0000 1.6360 0.3154 0.9757 4.2000 38.0000 1.6818 0.4683 1.0751 4.2000 40.0000 1.7556 0.6820 1.2188 4.2000 42.0000 1.8109 0.9649 1.3879 4.2000 42.0000 1.8628 1.2676 1.5652 4.2000 46.0000 1.9970 1.5664 1.7367 4.2000 48.0000 1.9440 1.8201 1.8821 4.2000 50.0000 1.9669 2.0170 1.9919 4.2000 52.0000 2.0003 2.1381 2.0692 4.2000 52.0000 2.0192 2.2203 2.1198 4.2000 54.0000 2.0369 2.2700 2.1535 4.2000 58.0000 2.0535 2.3003 2.1769 4.2000 58.0000 2.0689 2.3191 2.1940 4.2000 62.0000 2.0834 2.3312 2.2073 4.2000 64.0000 2.0970 <t< td=""><td></td><td>30.0000</td><td>1 . 1555</td><td>0.0988</td><td></td><td></td></t<>		30.0000	1 . 155 5	0.0988		
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PART 3

Solid State and Quantum Physics

CHAPTER 7

Elastic Waves in Crystalline Solids

B. W. JAMES

1. INTRODUCTION

Several fundamental physical properties are related to the propagation of sound waves in solids and an understanding of these processes has led to the development of a number of devices. For example ultrasonic delay lines are widely used in colour television receivers, and diffraction grating dispersive filters are used in radar systems for pulse compression.

The behaviour of sound waves in gases, liquids, amorphous solids, and crystalline solids has been widely investigated. The study of the propagation of sound waves in crystalline solids is the most complex and most interesting of the forms of sound wave to investigate since account must be taken of the anisotropic elastic properties of crystalline solids (Love, 1 Musgrave, 2 and Pollard3). In each direction in a crystalline solid there will be three modes of propagation which will, in general, all have different phase velocities, particle motion directions, and energy flow directions. The largest velocity is associated with a longitudinal or nearly longitudinal wave and the other two velocities with transverse or nearly transverse waves. The particle motion directions of the three waves always form an orthogonal set. Pure longitudinal and transverse modes occur in high symmetry directions and in some accidental directions which may be obtained from the known physical properties.

2. TENSOR FORMULATION

2.1 Hooke's law

In order to discuss the elastic properties of anisotropic materials and hence the propagation of sound waves it is necessary to use a tensor formulation of Hooke's law as the stress and strain at a point are given by two second-rank tensors. Hence if σ_{ij} is the stress tensor and e_{kl} is the strain tensor then Hooke's law is written as

$$\sigma_{ij} = c_{ijkl}e_{kl}$$
 (i, j, k, l = 1, 2, 3), (1)

where c_{ijkl} is a fourth-rank tensor of 81 elements relating 9 stress components to 9 strain components. (Note that summation is assumed for repeated suffices, see Nye⁴.)

2.2 The strain tensor

The particle displacements U of the strained material determine the nine elements of the general strain tensor E_{kl} and

$$E_{kl} = \frac{\partial U_k}{\partial x_l},\tag{2}$$

where $\mathbf{U} = \mathbf{i}_1 U_1 + \mathbf{i}_2 U_2 + \mathbf{i}_3 U_3 = \mathbf{i}_i U_i$ and $\mathbf{i}_1, \mathbf{i}_2$, and \mathbf{i}_3 are unit vectors along the Cartesian axes x_1, x_2 , and x_3 respectively.

The general tensor E_{kl} consists of a symmetrical part e_{kl} and an antisymmetrical part w_{kl} , where

$$e_{kl} = \frac{1}{2} \left(\frac{\partial U_k}{\partial x_l} + \frac{\partial U_l}{\partial x_k} \right), \tag{3}$$

and

$$w_{kl} = -\frac{1}{2} \left(\frac{\partial U_k}{\partial x_l} - \frac{\partial U_l}{\partial x_k} \right) = -w_{lk}. \tag{4}$$

Now if we first consider a rotation of the material about the origin of the axes without any deformation of the material, then in this rotation the displacement of any point is perpendicular to its radius vector so that

$$U_i x_i = 0$$
 (scalar product), (5)

or

$$E_{ij}x_ix_j=0. (6)$$

Since this is true for all x_i the coefficients on the left-hand side must all be zero. Hence

$$E_{ij} = 0 \quad \text{if } i = j; \qquad E_{ij} = -E_{ji} \quad \text{if } i \neq j, \tag{7}$$

which is just the condition for E_{ij} to be antisymmetrical. So that in the special case of a rotation of the material about the origin of the axes without deformation, the general strain tensor E_{kl} becomes antisymmetrical, with the rotation of the material about the origin of the axes given by the