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Appendix 1. Computer program listings

NIKZX


```
      PROGRAM NIKZX
C--------FINDS ZEROES IN Z-PLANE;  POZ.FOR
          IMPLICIT COMPLEX (Z)
  6       FORMAT(2F6.3,4F11.4,4F6.3)
          WRITE(1,100)
  100 FORMAT('ENTER R,ZP,ZDP,ZX')
  7       READ(1,*)R,ZP,ZDP,ZX
          L=0
  2         ZY=ZX*R
          CALL RAT(ZP,ZX,ZU,ZUD)
          CALL RAT(ZP,ZY,ZV,ZVD)
          ZPP=ZP*ZP
          ZYY=ZY*ZY
            ZUE=ZPP-ZX*ZX-ZU*ZU
          ZPQ=ZPP-1.
          ZVE=ZPP-ZYY-ZV*ZV
          ZM=ZV*ZU*ZPQ-(ZV+ZU)*ZYY/2. + ZPP*(ZYY-ZPP)+ZPP-ZYY*ZYY/4.
          ZME=ZPQ*(ZU*ZVE+ZV*ZUE)-ZYY*(ZV+ZU+.5*ZVE+.5*ZUE-2.*ZPP+ZYY)
          ZME=ZME/ZX
          ZMD=ZVD*(ZU*ZPQ-ZYY/2)+ZUD*(ZV*ZPQ-ZYY/2)+
     .    2.*ZP*(ZV*ZU+ZYY-2.*ZPQ-1.)
       ZDZ=-ZM/ZME
       ZX=ZX+ZDZ
       IF(CABS(ZDZ).LE..0008)GOTO 3
          GOTO 2
  3       CONTINUE
          WRITE(6,6)ZP,ZX,ZME
          ZP=ZP+ZDP
            Z=Z2
          Z2=ZX-Z1
          Z1=ZX
          Z3=Z2-Z
          L=L+1
          IF(L.GT.2) ZX=Z1+Z2+Z3
          IF(REAL(ZX).LE.0.)GOTO 7
          IF(CABS(ZP-5.).LE.5.001) GOTO 2
          GOTO 7
          END
          SUBROUTINE RAT(ZP,ZX,ZF,ZFD)
          IMPLICIT COMPLEX (Z)
          ZI=(0.,1.)
          ZA=ZP+.5
          N=55
          ZN=1.+CSQRT(-2.*ZI*ZX/N)
          DO 1 J=1,N
            I=N+1-J
          ZZ=I-ZA+1.0E-09
        ZK=(I+1)*I/(ZA+I-1)/ZZ
        ZND=ZK/ZN/ZN*ZND-ZN/(ZA+I-1)+ZN/ZZ
   1    ZN=((-2.*ZI*ZX+I+I)/(I+1)-1/ZN)*ZK
        ZF=-.5+ZI*ZX+1./ZN
        ZFD=-ZND/ZN/ZN
        END
```

```
      PROGRAM LLD2
C       CALCULATES GREENS FUNCTIONS OF THETA FOR RANGE OF X.
C       THE PHASE RESPONSE IS UN-WRAPPED AND WRITTEN TO LLPH:TS
        IMPLICIT COMPLEX (Z)
        DIMENSION PHA(500)
        WRITE(1,200)
        READ(1,*) R,X,DX,XMAX
        WRITE(1,300)
        READ(1,*) NN,KK,RT
        OPEN(2,STATUS='UN',FILE='LOUT:TS')
        ZII=(0.,1.)
        J=0
        X=X-DX
    2   X=X+DX
        J=J+1
    4   Y=R*X
        YY=Y*Y
        XX=X*X
        RR=XX/YY
        DO 9 K=1,KK
        TH=3.14159*RT
        TH=TH*FLOAT(K/KK)
        CALL RAT(X,ZU)
        CALL RAT(Y,ZV)
        P=0.
        ZW=CEXP(TH*ZII)
        ZP=(.5,0.)
        ZSUM=P
        ZSUN=P
        DO 1 I=1,NN
        P=I-1
        PP=P*P
        ZQ=CONJG(ZP)
        ZT=ZV*ZU*(PP-1.)-(ZV+ZU)*YY/2. + PP*(YY-PP)+PP-YY*YY/4.
        ZMM=ZM
        ZM=(ZV*ZU+ZU*YY/2. -PP)/ZT
        ZSUM=ZSUM+ZM*(ZP+ZQ)
        ZNN=ZN
        ZN=ZII*P*(ZU*ZV+YY/2-PP)/ZT
        ZSUN=ZSUN+ZN*(ZP-ZQ)
        ZU=((P+1)*ZU+X*X-PP-P)/(P-ZU)
        IF(I.EQ.1)ZP=ZP+ZP
        ZP=ZP*ZW
    1   ZV=((P+1)*ZV+YY-PP-P)/(P-ZV)
    3   ZSUM=ZSUM+ZM*ZM*ZP/(ZMM-ZM*ZW)
        ZSUN=ZSUN+ZN*ZN*ZP/(ZNN-ZN*ZW)
        ZSUM=ZSUM+ZM*ZM/ZP/(ZMM-ZM/ZW)
        ZSUN=ZSUN-ZN*ZN/ZP/(ZNN-ZN*ZW)
        YPHA=AIMAG(ZSUM)/REAL(ZSUM)
        YPHA=ATAN(YPHA)
        PHA(J) = 57.295795*YPHA
        YMAG=CABS(ZSUM)
    9   WRITE(2,100) TH,X,ZSUM,YMAG,YPHA
        IF(X.LE.XMAX) GOTO 2
        NP=INT(XMAX/DX)
        PI=180.
        TOL=0.4*PI
        K=2
   19   CONTINUE
        DO 20 I=K,NP
        IF((PHA(I-1)-PHA(I)).GT.TOL) GO TO 25
   20   CONTINUE
   25   K=I
        IF(K.GE.NP) GO TO 27
```

```
      DO 26 J=K,NP
      PHA(J)=PHA(J)+PI
 26   CONTINUE
      IF(I.LT.NP) GO TO 19
 27   CONTINUE
      OPEN(3,STATUS='UN',FILE='LLPH:TS')
      X=0.
      DO 30 I=1,NP
      X=X+DX
      WRITE(3,400) X,PHA(I)
 30   CONTINUE
100   FORMAT(2F10.4,4E12.5)
200   FORMAT('ENTER R,X,DX,XMAX')
300   FORMAT('ENTER NO.OF TERMS IN SUM, NO.OF INTERVALS 0-PI,
     .FRACTION OF PI')
400   FORMAT(F10.2,5X,E12.5)
      END
      SUBROUTINE RAT(Y,ZF)
      IMPLICIT COMPLEX (Z)
      ZI=(0.,1.)
      Z1=(1.,0.)
      Z0=(0.,0.)
      ZA0=Z0
      ZA1=.5
      ZB0=Z1
      ZB1=Y
      DO 1 J=1,150
      ZC=Z1
      ZD=.5*ZI*(J-.5)
      DO2 K=1,2
      ZB2=ZB1*ZC+ZB0*ZD
      ZA2=ZA1*ZC+ZA0*ZD
      ZB0=ZB1/ZA1
      ZA0=Z1
      ZB1=ZB2/ZA1
      ZA1=ZA2/ZA1
      ZD=ZD+ZI*(.5)
  2   ZC=Y
      ZF=ZA2/ZB2
      ZF=Y*(ZI-ZF)
      C=CABS(ZF-ZF1)
      IF(C.LT.1.0E-06)RETURN
  1   ZF1=ZF
      END
```

```
      PROGRAM LLDISP(TAPE1,INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION X(200), SUMR(500), SUMS(500), SUMP(500), SUMT(500),
     *ITIT(4)
      COMMON /PART1/ R, TPT, VP, VS, PCA, PCB, AA, BB, CC
      COMMON /PART2/ TIM(500), XLEN, NPLOTS, SCL
      EXTERNAL FUN1
      EXTERNAL FUN2
      EXTERNAL FUN3
      DATA ITIT /9HDISP.R X=,9HDISP.S X=,9HDISP.P X=,9HDISP.T X=/
      XLEN = 0.0
      NPLOTS = 0
      READ (5,99999) NPTS1, NPTS2, SCL, VS, PCA, PCB, TSTEP, PTYP,
     *NPRINT
      IF(PTYP.EQ.2H  )PTYP=2HPK
      CALL SETPLOT(PTYP, 0, 0, 1)
      XHI = 52.0
      SCL = FLOAT(INT(SCL+0.5))
      IF (SCL.GT.4.0) SCL = 4.0
      IF (SCL.LT.1.0) SCL = 1.0
      CALL PLOT(SCL, SCL, 0)
      XHI = 52.0
      PRINT 99996, NPTS1, NPTS2, SCL, VS, PCA, PCB, TSTEP, PTYP, NPRINT
      READ (5,99998) A, B, PSCL
C NPTS1=NO. OF X VALUES,NPTS2=NO. OF T STEPS
C VP=P WAVE VELOCITY,VS=SHEAR W.V.,PCA,PCB ARE CONSTANTS
C DEFINING LOAD-TIME FUNCTION
      READ (5,99997) (X(I),I=1,NPTS1)
      VP = VS*(SQRT(3.0))
      WAVNP = 1.0/VP
      WAVNS = 1.0/VS
      WAVNR = 1.0/(0.9194*VS)
C CALCULATION OF CONSTANTS IN DISP. FUNCTION
      CALL CON1(WAVNP, WAVNS, WAVNR, R, AA)
      CALL CON2(WAVNP, WAVNS, WAVNR, R, BB)
      CALL CON3(WAVNP, WAVNS, WAVNR, R, CC)
      TIM(1) = 0.0
      DO 10 I=2,NPTS2
         TIM(I) = TIM(I-1) + TSTEP
   10 CONTINUE
      DO 30 K=1,NPTS1
         R = X(K)
      ENCODE(10,300,FRED)R
         PRINT (6,99995) R
         PRINT (6,99994)
         DO 20 J=1,NPTS2
            TPT = TIM(J)
            RELACC = 1.0E-5
            ABSACC = 0.0
            IFAIL = 0
C INTEGRATION OF RAYLEIGH WAVE TERM
            CALL D01ACF(A, B, FUN1, RELACC, ABSACC, ACC, ANS, NPTS,
     *      IFAIL)
            SUMR(J) = ANS*0.282095/(PCA**3)
            IF(NPRINT.EQ.1)PRINT(6,1600) ACC,NPTS
C INTEGRATION OF SHEAR WAVE TERM
            CALL D01ACF(A, B, FUN2, RELACC, ABSACC, ACC, ANS, NPTS,
     *      IFAIL)
            SUMS(J) = ANS*0.282095/(PCA**3)
            IF(NPRINT.EQ.1)PRINT(6,1600) ACC,NPTS
C INTEGRATION OF P-WAVE TERM
            CALL D01ACF(A, B, FUN3, RELACC, ABSACC, ACC, ANS, NPTS,
```

```
          IFAIL)
          SUMP(J) = ANS*0.282095/(PCA**3)
          IF(NPRINT.EQ.1)PRINT(6,1600) ACC,NPTS
          SUMT(J) = SUMR(J) + (SUMS(J) + SUMP(J))/PSCL
          PRINT (6,99993) TIM(J), SUMR(J), SUMS(J), SUMP(J), SUMT(J)
   20    CONTINUE
         CALL WPLT(SUMR, NPTS2, FRED, ITIT(1))
         CALL WPLT(SUMS, NPTS2, FRED, ITIT(2))
         CALL WPLT(SUMP, NPTS2, FRED, ITIT(3))
         CALL WPLT(SUMT, NPTS2, FRED, ITIT(4))
   30 CONTINUE
      YHI = FLOAT(NPLOTS)/4.0
      YHI = YHI*SCL*13.0
      IF (PTYP.NE.2HZP) CALL DISPOZ(1, PTYP, XHI, YHI, 2HMS)
      STOP
99999 FORMAT (2I5, F5.0, 4F10.0, 3X, A2, I5)
99998 FORMAT (3F10.0)
99997 FORMAT (8F10.0)
  300 FORMAT (F10.3)
99996 FORMAT (21H1CSIRO PROGRAM LLDISP, /, 21H --------------------, /,
     *21H NO.OF X VALUES------, I12, /, 21H NO.OF TIME STEPS----, I12,
     */, 21H SCALE PARAMETER-----, F12.2, /, 21H SHEAR WAVE VELOCITY-,
     *1PE12.4, /, 21H PCA-----------------, 1PE12.4, /, 12H PCB--------,
     *9H---------, E12.4, /, 21H TIME STEP SIZE------, E12.4, /,
     *21H PLOTTER TYPE--------, 10X, A2, /, 21H PRINT-OUT PARAMETER-,
     *I12)
99995 FORMAT (///, 1H , 131(1H-), /, 10X, 2HX=, F10.4, /, 1H , 131(1H-))
99994 FORMAT (15X, 9HTIME(SEC), 5X, 11HDISP.(RAYL), 8X, 12HDISP.(SHEAR),
     *8X, 12HDISP.(COMP.), 8X, 12HDISP.(TOTAL))
 1600 FORMAT (10X, 6HACC = , E11.4, 5X, 7HNPTS = , I3)
99993 FORMAT (10X, F10.5, 4(5X, 1PE15.8))
      END
      FUNCTION FUN1(OMEGA)
      COMMON /PART1/ R, TPT, VP, VS, PCA, PCB, AA, BB, CC
      WAVNR = OMEGA/(0.9194*VS)
      THETA1 = OMEGA*(TPT-PCB)-WAVNR*R
      CALL FTLF(OMEGA, PCA, FTL)
      DPR = -AA*SIN(THETA1)
      FUN1 = FTL*DPR
      RETURN
      END
      FUNCTION FUN2(OMEGA)
      COMMON /PART1/ R, TPT, VP, VS, PCA, PCB, AA, BB, CC
      WAVNS = OMEGA/VS
      THETA2 = OMEGA*(TPT-PCB)-WAVNS*R+ATAN(1.)
      CALL FTLF(OMEGA, PCA, FTL)
      BBN = BB/((R/VS)**1.5)
      DPS = (BBN*SIN(THETA2))/(OMEGA**1.5)
      FUN2 = FTL*DPS
      RETURN
      END
      FUNCTION FUN3(OMEGA)
      COMMON /PART1/ R, TPT, VP, VS, PCA, PCB, AA, BB, CC
      WAVNP = OMEGA/VP
      THETA3 = OMEGA*(TPT-PCB)-WAVNP*R+ATAN(1.)
      CALL FTLF(OMEGA, PCA, FTL)
      CCN = CC/((R/VP)**1.5)
      DPP = (CCN*SIN(THETA3))/(OMEGA**1.5)
      FUN3 = FTL*DPP
      RETURN
      END
      SUBROUTINE WPLT(SUMX, NPTS2, FRED, ITITLE)
```

```
      COMMON /PART2/ TIM(500), XLEN, NPLOTS, SCL
      DIMENSION SUMX(500)
      CALL AUTPLOT(TIM, SUMX, NPTS2, 1, 11H*TIME(SEC)*,
     *14H*DISPLACEMENT*)
      NPLOTS = NPLOTS + 1
      CALL PLOT(3.5, 10.5, 3)
      CALL TEXT(ITITLE, 9, 7)
      CALL TEXT(FRED, 10, 7)
      CALL PLOT(13.0, 13.0, 3)
      CALL PLOT(0.0, 0.0, 1)
      XLEN = XLEN + 13.0
      X = 52.0/SCL
      IF (XLEN.LT.X) GO TO 10
      CALL PLOT(-14.0, -X, 3)
      XLEN = 0.0
      CALL PLOT(0.0, 0.0, 1)
   10 CONTINUE
      RETURN
      END
      SUBROUTINE CON1(W1, W2, W3, R, AA)
      BETA1 = (W3**2) - (W1**2)
      BETA2 = (W3**2) - (W2**2)
      DELRF1 = 2*(W3**2) - W2**2
      DELRF2 = SQRT(BETA1*BETA2)
      DELRF3 = 0.5*(W3**2)*(SQRT(BETA2/BETA1))
      DELRF4 = 0.5*(W3**2)*(SQRT(BETA1/BETA2))
      DELRF = (8*W3)*(DELRF1-DELRF2-DELRF3-DELRF4)
      AA = -(W2**2)*(SQRT(BETA1))/(DELRF)
      RETURN
      END
      SUBROUTINE CON2(W1, W2, W3, X, BB)
      BB = 1.0 - (W1**2)/(W2**2)
      BB = 1.59577*BB
      RETURN
      END
      SUBROUTINE CON3(W1, W2, W3, X, CC)
      CC = (W1*W2)**2
      CC = CC/(((W2**2)-2*(W1**2))**2)
      CC = 0.39894*CC
      RETURN
      END
      SUBROUTINE DISPOZ(LUN, PTYP, XSIZE, YSIZE, ST)
      DIMENSION ID(3)
C
C     THIS ROUTINE CALL SYSTEM ROUTINE DISPOSE TO
C     DISPOSE THE PLOT ON FILE LUNTO THE NETWORKWITH THE
C     SIZE IN CM. SPECIFIED IN THE 'FID' PARAMETER
C     ALL PARAMETERS NEED TO BE IN L FORMAT(LEFT JUSTIFIED ZERO FILLED)
C     THE COLON (:) IS THE CHARACTER CODE FOR ZERO
      IX = INT(XSIZE)
      IY = INT(YSIZE)
      PRINT 99999, IX, IY
      CALL JOBID(ID)
      ENCODE(10,1,STAT)ST
      ENCODE(10,2,ATYP)PTYP
      ENCODE(10,3,FID)ID(2),IX,IY
      CALL DISPOSE(LUN, STAT, ATYP, 0, FID)
      CALL PLOCHOP(1)
      CALL REMARK(19H PLOT FILE DISPOSED)
      RETURN
    1 FORMAT (3HRIO, A2, 5H:::::)
    2 FORMAT (1H*, A2, 7H:::::::)
```

```
    3 FORMAT (A1, I2, 1H*, I3, 3H:::)
99999 FORMAT (///, 10X, 24H PLOT DIMENSIONS WILL BE, I5, 6H CM BY, I5,
     *3H CM)
      END
      SUBROUTINE FTLF(OMEGA, PCA, FTL)
C     FOURIER TRANSFORM OF LOAD TIME FUNCTION
      FTL = EXP(-3.*((OMEGA/(2.0*PCA))**2))
      FTL = -(OMEGA**3)*FTL
      RETURN
      END
```

Appendix 2. Relevant pulications by the author

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RECEIVED 29/5/87
A/Chief 29/5
GGS
L Hunt 1/6
A.S 1/6
GGS 2/6 2/6
GGS 5/6 7/6
TW1/111/9

TW2506/AU
PK/PK

May 27, 1987

The Chief
CSIRO
Division of Geomechanics
PO Box 54
MOUNT WAVERLY Vic 3149

ATTENTION: Mr G.G. Shorten

Dear Sir

Australian Provisional Patent Application No PI1967/87
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION
"FORCE TRANSDUCER"

We are pleased to report that the abovementioned application was lodged in the Australian Patent Office on 18 May 1987 and was allocated the number PI1967/87.

As you may be aware, it is essential that any applicant(s) for the grant of Letters Patent have a clear title to the invention from the actual inventor(s).

We enclose (in duplicate) an acknowledgement that the invention, the subject of this patent application, is the property of the CSIRO.

Would you please arrange for each inventor to insert his full name, nationality and complete residential address, and to execute the acknowledgements in the presence of a witness.

Please return one of the executed acknowledgements to Sirotech Limited at your earliest convenience. The second acknowledgement can be retained for your file.

Yours faithfully

[redacted]

Paul Kilborn
CORPORATE PATENT ATTORNEY
Intellectual Property Group

encl.:

TW2506/AU

IN THE MATTER OF an invention entitled:

"FORCE TRANSDUCER"

as described in the specification of Australian Patent Application No: PI1967/87

We*/I (Insert full name of each Inventor)

LEIGH DAVID HUNT

ANTHONY FREDERICK SIGGINS

Citizen(s*) of (Insert Nationality of each Inventor)

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AUSTRALIAN, respectively*

of (Insert full residential address of each Inventor)

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VICTORIA 3150, respectively*

HEREBY ACKNOWLEDGE AND DECLARE that the above invention was made by ~~me~~/us* in the course of ~~my~~/our* official duties with the Commonwealth Scientific and Industrial Research Organisation and is, by virtue of Section 54 (1) of the Science and Industry Research Act 1949, the property of the said Organisation.

DATED this FIRST day of JUNE 1987

Witness: [redacted]

Witness: [redacted]

* Delete where appropriate

Circumferential propagation of elastic waves on boreholes and cylindrical cavities

A. F. Siggins and A. N. Stokes

GEOPHYSICS, VOL. 52, NO. 4 (APRIL 1987); P. 514–529, 15 FIGS., 2 TABLES.