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1982/31. A theoretical basis for gravity residual specification.

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Abstract

The aperture of the box-car filter required to produce a gravity residual corresponding to material within a specified depth range may be determined by comparing the theoretical gravity spectrum with the filter response.

INTRODUCTION

The interpretation of a gravity anomaly map normally requires the enhancement of particular features using a filtering process. The filtering may take the form of spectral truncation, running means, or visual smoothing of profiles. These techniques are frequently subjective, with the result that two interpreters rarely produce the same enhanced map.

It may be shown (Grant, 1974) that the phase angle of the spectrum of the gravity anomaly from one body depends only on the horizontal location of the body. The shape of the spectrum is determined by the body depth only. The spectrum of the anomaly from a body of finite dimensions declines more rapidly with increasing frequency than the spectrum from a point mass at the same depth of burial. Thus by calculating the spectrum of the anomaly from a point mass at a given depth, the maximum high frequency spectral content from any body at the same depth is defined.

APPLICATION

The normalised amplitude spectrum of the anomaly of a point mass at a depth z is

$$A = e^{-\pi z s}$$

where s is cycles per unit distance (Grant, 1974).

The high frequency cut-off is then defined as the point on the spectral curve at which the normalised amplitude is 0.707 (fig. 1). The high frequency cut-off at any desired body depth may be determined from a plot of this type.

The normalised amplitude response of a box-car low-pass filter is

$$A = \sin \frac{(D\pi s)}{D\pi s}$$

where D is the aperture
      s is cycles per unit distance (Leaman and Richardson, 1981).

The high frequency cut-off (fig. 2) is defined in the same way as the spectral cut-off. A plot for any desired aperture allows the cut-off to be measured.

It should be noted that by taking observations with finite spacing, the data is filtered with an aperture of the size of the nominal station spacing.

To select a filter aperture, plot the anomaly spectrum for a point

mass at the maximum depth of interest and measure the cut-off frequency.
Within the constraints imposed by the observation spacing, plot a series of
filter responses and select the one with a cut-off closest to the desired
cut-off. The plots may be made using FORTRAN program GRVRES (Appendix 1).

REFERENCES

GRANT, F.S. 1974. Geophysical data processing. *Unpublished course notes
from Macquarie University.*

LEAMAN, D.E.; RICHARDSON, R.G. 1981. Gravity survey of the East Coast
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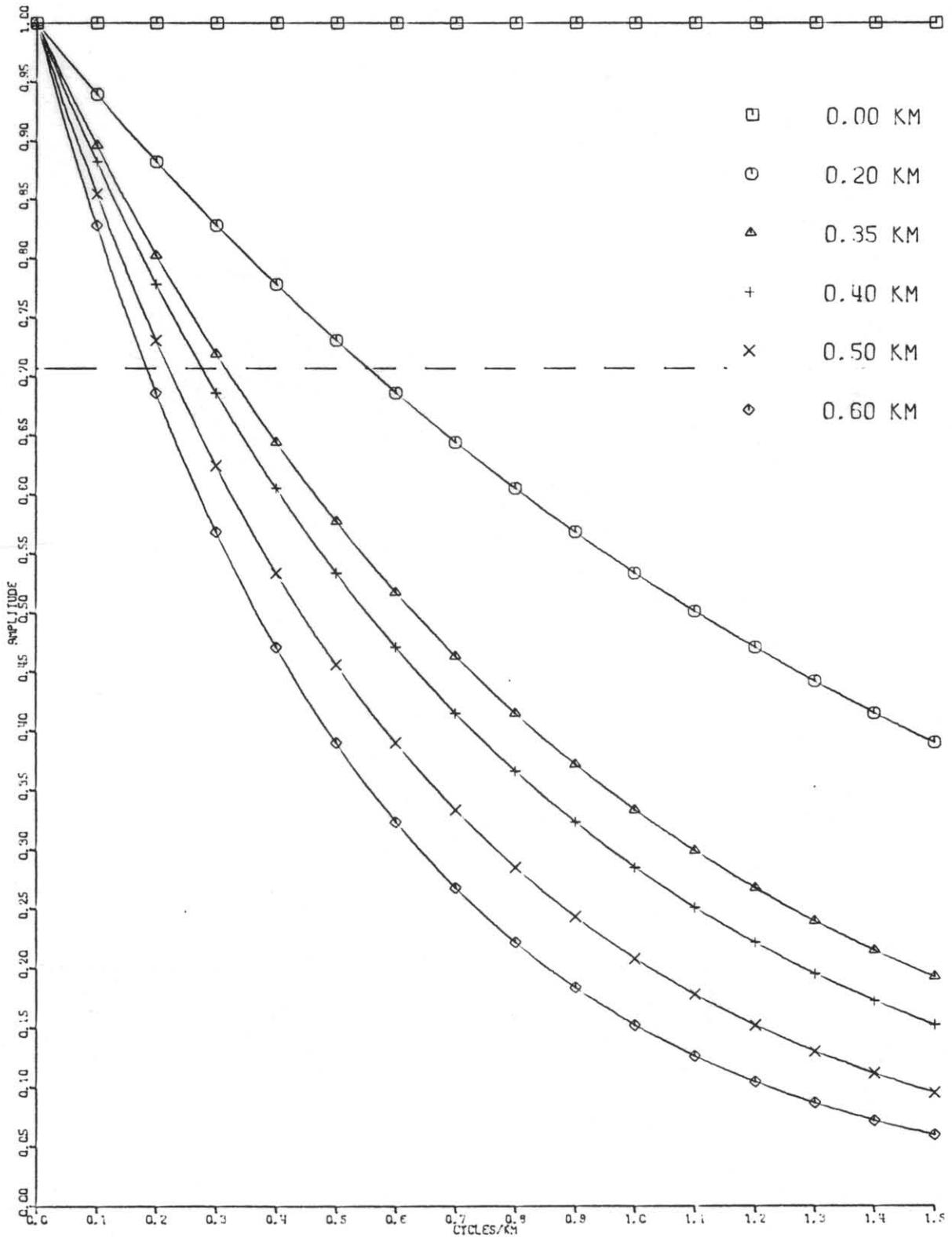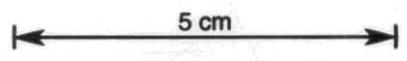
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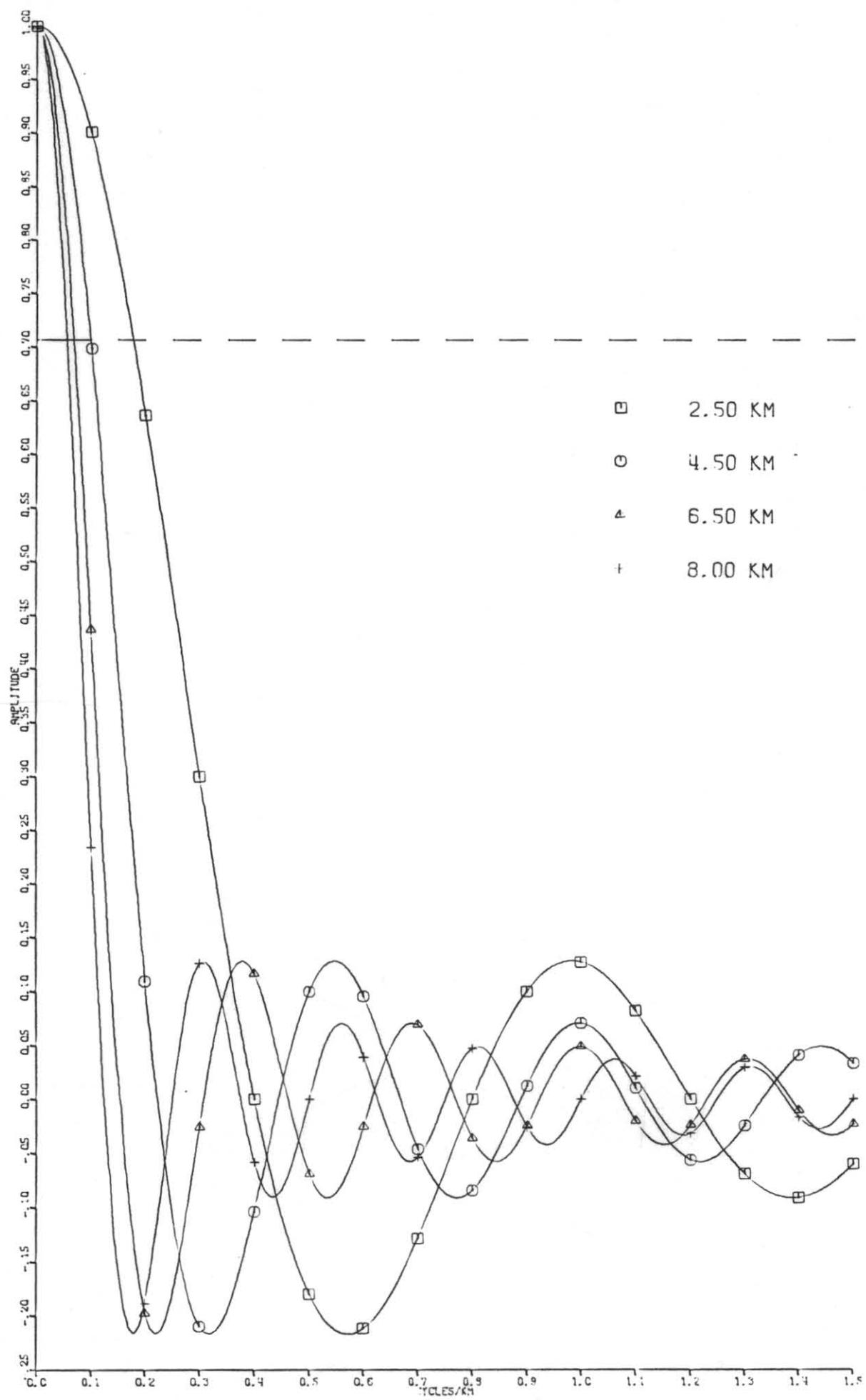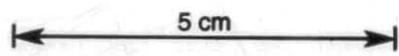
Figure 1. *Anomaly spectrum.*

Figure 2. *Moving average.*

5 cm

APPENDIX 1

Program GRVRES

The program issues prompts on logical unit 3 and reads the plot para-
meters from logical unit 5.

Input is:

    FI, AN or BO   - format A2
                      - choose a plot of filter responses, a plot of
                        anomaly spectra, or both

    CYCMAX   - free format
                      - the maximum number of cycles per kilometre to
                        which the plots are to extend.

If filter responses are to be plotted:

    AFILT   - free format one per line
                      - up to 14 aperture sizes (in kilometres) termin-
                        ated by a negative number

If spectra are to be plotted:

    AFREQ   - free format one per line
                      - up to 14 source depths (in kilometres) termin-
                        ated by a negative number

Non-standard subroutines are:

    FRINIT (ANUM, IER, ILUN) - read one real number in free format
                        from logical unit ILUN and store it in ANUM.
                        If there is an error IER is TRUE

    INITAL (ILUN, NSTEP, IW, I, I, I) - initiallises the plotter
                        as logical unit ILUN with NSTEP steps per inch
                        and a width of IW inches.

    PLOT (X, Y, I) - X and Y are the co-ordinates to which the
                        pen is to be moved (in inches) or the co-ordinate
                        value of the present position, depending on I.

                        I = 0 no pen movement. The present pen position
                          is redefined as (X, Y)
                        I = 1 the pen moves to (X, Y) in its present
                          condition
                        I = 2 the pen drops and moves to (X, Y)
                        I = 3 the pen lifts and moves to (X, Y)
                        I = -1, -2, -3. As for the positive values but
                          after (X, Y) is reached that point is re-
                          defined as (0., 0.)

    SYMBOL (X, Y, HT, IHOL, THETA, N) - writes an alphanumeric
                      string of N characters in IHOL starting at (X, Y).
                      The character height is HT and they are drawn at
                      an angle THETA counter-clockwise from the x-axis.

h

PWRITE (X, Y, HT, THETA) - copies the contents of the core
                buffer until an & is encountered then calls
                SYMBOL.

PENUP, PENDN - raise, lower the pen.

RSTR(2) - end the current plot.

MARKER(I) - draw a special symbol centred on the current pen
                positions. I has a value in the range 1 to 14.

FACTOR(FAC) - scale all following plotting commands by FAC.

SCALE (X, N, S, AMIN, DELTA) - AMIN and DELTA are determined
                such that the first N values of X can be plotted
                within a scale length S. The values of X are
                scaled to fit the plot.

        - AMIN is the minimum value on the axis.

        - DELTA is the increment per inch on the axis.

AXIS (X, Y, LBL, NC, S, THETA, AMIN, DELTA, NN) - draw and label
                an axis for a graph.

        - X, Y - the co-ordinates in inches of the
                  starting point of the axis.
        - LBL   - the identification label for the axis.
        - NC   - the number of characters in LBL.
                  - if NC is positive, all labelling is on
                    the counter-clockwise side of the axis.
                  - if NC is negative, all labelling is on
                    the clockwise side of the axis.
        - S   - the length of the axis.
        - THETA - the angle, in degrees, measured
                  counter-clockwise from the x-axis at
                  which the axis is to be drawn.
        - AMIN)
        - DELTA) calculated in SCALE
        - NN   - the number of digits to be drawn after
                  the decimal point.

```
.AB= GRVRES
ITL  GRVRES - PLOT MOVING AVERAGE FILTER RESPONSE OR ANOMALY SPECTRUM
     DIMENSION X(1000),Y(1000),AFILT(15),AFREQ(15)
     INTEGER*2 FI,AN,BO,IOPT
     IMPLICIT INTEGER*2 (I-N)
     LOGICAL FILT,DPTH,IER,IPN
     DATA FI/2HFI/,AN/2HAN/,BO/2HBO/
     YMAX=0.
  10 WRITE(3,100)
 100 FORMAT(' (FI)LTER RESPONSE,(AN)OMALY SPECTRUM OR (BO)TH?')
     READ(5,101) IOPT
 101 FORMAT(A2)
     IF (IOPT .NE. FI .AND. IOPT .NE. AN .AND. IOPT .NE. BO) GOTO 10
NEED VALID OPTION
     FILT=IOPT .EQ. FI .OR. IOPT .EQ. BO
     DPTH=IOPT .EQ. AN .OR. IOPT .EQ. BO
     CALL INITAL(9,200,36,0,0,0)
INITIALLISE PLOTTER
     CALL FACTOR(0.3937)
PLOT IN CENTIMETRES
     CALL PLOT(-5.,-5.,0)
SET ORIGIN
     WRITE(3,102)
 102 FORMAT(' MAXIMUM NO. OF CYCLES/KM?')
     CALL FRINIT(ANUM,IER,5)
     CYCMAX=ANUM
     NX=IFIX(CYCMAX*100.0+1.)
NO OF STEPS IN CURVE
     IF (.NOT. FILT) GOTO 12
DONT WANT FILTER
     IFILT=0
     WRITE(3,103)
 103 FORMAT(' ENTER APERTURE SIZES IN KM - TERMINATE BY NEGATIVE')
     DO 11 I=1,15
     CALL FRINIT(ANUM,IER,5)
     IF (ANUM .LT. 0.) GOTO 12
END OF INPUT
     IFILT=IFILT+1
     AFILT(IFILT)=ANUM
  11 CONTINUE
READ MOVING AVERAGE SIZES

NOW FOR VARIATION OF ANOMALY SPECTRUM WITH DEPTH
  12 IF (.NOT. DPTH) GOTO 15
DONT WANT FREQUENCY - DEPTH RELATION
     IFREQ=0
     WRITE(3,104)
 104 FORMAT(' ENTER DEPTH IN KM - TERMINATE BY NEGATIVE')
     DO 14 I=1,15
     CALL FRINIT(ANUM,IER,5)
     IF (ANUM .LT. 0.) GOTO 15
END OF INPUT
     IFREQ=IFREQ+1
     AFREQ(IFREQ)=ANUM
  14 CONTINUE
READ DEPTHS OF THE POINT SOURCE
  15 CONTINUE
     IF (.NOT. FILT) GOTO 19
DONT WANT FILTER RESPONSE
     CALL PLOT(0.,YMAX,-3)
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SET ORIGIN
      YMAX=25.
SAVE MAX VALUE IN Y DIRECTION FOR LATER
      CALL SYMBOL(2.,-4.,.28,'MOVING AVERAGE',0.,14)
LABEL FILTER GRAPH
NOW FORM AXES
      CALL PAXIS(CYCMAX,-0.25,25.)
      DO 17 J=1,IFILT
      X(1)=0.
      Y(1)=1.
SET THE FIRST VALUES
      DO 16 I=2,NX
      XTMP=FLOAT(I-1)*0.01
      X(I)=XTMP
      IF (AFILT(J) .GT. 0.) GOTO 18
      Y(I)=1.0
IF NO FILTER HAVE ALL PASS
      GOTO 16
  18 CONTINUE
      Y(I)=SIN(AFILT(J)*3.141592*XTMP)/(AFILT(J)*3.141592*XTMP)
  16 CONTINUE
      CALL LDRAW(X,Y,NX,CYCMAX*10.,25.0,YMAX,-0.25,AFILT(J),J)
  17 CONTINUE
NOW FOR THE -3 DB POINT WHICH IS THE CUT-OFF OF THE FILTER
      YVAL=0.707*20.0+5.0
      CALL CUTOFF(YVAL,NX)
  19 CONTINUE
NOW FOR THE SPECTRUM OF A POINT SOURCE WITH INCREASING
BURIAL
      IF (.NOT. DPTH) GOTO 22
ONLY WANTED FILTER
      CALL PLOT(0.,YMAX+5.0,-3)
SET ORIGIN AGAIN
      YMAX=20.
UPPER LIMIT OF Y
      CALL SYMBOL(2.,-2.,.28,'ANOMALY SPECTRUM',0.,16)
LABEL PLOT
      CALL PAXIS(CYCMAX,0.,20.)
      DO 21 J=1,IFREQ
      X(1)=0.
      Y(1)=1.
SET THE FIRST VALUES
      DO 20 I=2,NX
      XTMP=FLOAT(I-1)*0.01
      X(I)=XTMP
      Y(I)=EXP(-3.141592*AFREQ(J)*XTMP)
  20 CONTINUE
      CALL LDRAW(X,Y,NX,CYCMAX*10.,20.,YMAX,0.,AFREQ(J),J)
  21 CONTINUE
      YVAL=0.707*20.0
      CALL CUTOFF(YVAL,NX)
  22 CONTINUE
      CALL RSTR(2)
      STOP
      END
      SUBROUTINE LINE(X,Y,N,KODE,ISPACE)
      IMPLICIT INTEGER*2 (I-N)
      INTEGER*4 KODE,ISPACE,N,I,J
      DIMENSION X(N),Y(N)
      CALL PENUP
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      I=KODE
      IF (KODE .LT.  0) I=-I
      DO 10 J=1,N
      CALL PLOT(X(J),Y(J),1)
      IF (MOD(J-1,ISPACE) .NE.  0) GOTO 10
      CALL FACTOR(1. )
      IF (KODE .NE.  0) CALL MARKER(I)
      CALL FACTOR(0. 3937)
      IF (KODE .GE.  0) CALL PENDN
   10 CONTINUE
      CALL PENUP
      RETURN
      END
      SUBROUTINE CUTOFF(VAL,NX)
      LOGICAL IPN
      IPN=. TRUE.
      CALL PLOT(0. ,VAL,3)
      CALL PENDN
      DO 10 I=6,NX,5
      XTMP=FLOAT(I-1)*0. 01
      CALL PLOT(XTMP*10. ,VAL,1)
      IPN=. NOT.  IPN
      IF (. NOT.  IPN) CALL PENUP
      IF (IPN) CALL PENDN
   10 CONTINUE
      RETURN
      END
      SUBROUTINE PAXIS(XMAX,YMIN,YLNTH)
      DIMENSION X(2),Y(2)
      X(1)=0.
      Y(1)=1.
      X(2)=XMAX
      Y(2)=YMIN
      CALL SCALE(X,2,XMAX*10. ,FMIN,DELTA)
      CALL AXIS(0. ,0. ,'CYCLES/KM',-9,XMAX*10. ,0. ,FMIN,DELTA,1)
DRAW AND SCALE X AXIS
      CALL SCALE(Y,2,YLNTH,FMIN,DELTA)
      CALL AXIS(0. ,0. ,'AMPLITUDE',9,YLNTH,90. ,FMIN,DELTA,2)
      RETURN
      END
      SUBROUTINE LDRAW(X,Y,NX,XMAX,YLNTH,YMAX,YMIN,VAL,J)
      DIMENSION X(2),Y(2)
      X(NX+1)=XMAX*0. 1
      Y(NX+1)=YMIN
FORCE THE RANGE FOR SCALING
      CALL SCALE(X,NX+1,XMAX,FMIN,DELTA)
      CALL SCALE(Y,NX+1,YLNTH,FMIN,DELTA)
      CALL LINE(X,Y,NX,J,10)
      WRITE(8,200) VAL
  200 FORMAT(F5. 2,'  KM&')
      CALL PLOT(XMAX+1. ,YMAX-FLOAT(J+2),3)
      CALL FACTOR(1. )
      CALL MARKER(J)
      CALL FACTOR(0. 3937)
      CALL PWRITE(XMAX+2. 0,YMAX-FLOAT(J)-2. 14,0. 28,0. )
      RETURN
      END
```