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PRODUCTS.**

**An Interactive Program for the
Analysis and Design of
Advanced Laser Targets***

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Introduction

Experiments are currently in progress testing the optical quality of cryogenic targets made using the β -layering process. This process uses the heat liberated from decaying tritium to sublimate thick parts of the DT layer. This sublimated DT is subsequently condensed on a thinner part of the shell thereby tending to equalize the layer thickness. The uniformity and stability of the ice layer formed on the inside of these capsules is of fundamental importance.

The experiments now being performed simply photograph a capsule through a pair of transparent windows in the dewar as the temperature is lowered below the triple point and finally the sublimation point of the DT mixture. The analysis of these photographs is made difficult by the strong refraction and multiple reflections of the light by the sapphire shell (index of refraction 1.8) and the relatively weak refraction at the vacuum solid DT interface (index of refraction 1.1). Photographs thus far obtained show very little difference between an empty shell and a shell which is believed to be uniformly layered with hydrogen ice. The difficulty in interpreting these data has led to the establishment of an effort to simulate these measurements by direct computational methods.

The code which is the subject of this report is a simple ray tracing routine which allows the operator the freedom to enter as many as 50 different objects - light sources, opaque solids or surfaces, or transparent objects, placed anywhere in space. The program is written in Absoft Fortran for the Amiga, but the source code (except for the graphics subroutines) should compile without any major changes and run on any Macintosh.

The next section gives a brief outline of how the calculation proceeds. This is followed by a presentation of some of the results obtained and a description of some additional features being implemented for future use. A listing of the source deck is added as an appendix. This source can be downloaded from the LEAF where it resides in my file space.

How it Works and What it Does

The code is divided into three main sections.

- 1) Geometry definition and bookkeeping

- 2) Transport
- 3) Calculation of polarization and intensity

The geometry can be defined interactively or through a user supplied input file. In either case, the user must specify the size of the picture to be generated in pixels. The screen on the Amiga made the maximum size of 300 x 500 convenient, but larger arrays may be specified if the corresponding dimension is increased. This part was made interactive so that the user may obtain a quick low resolution look at the calculation. Next the user must supply the actual format of the picture and the distance from the origin along the z- axis. For example, the pictures I had made at TID as a check on these calculations were taken with the target 450 mm from the camera. Since the shell is about 1.6 cm in diameter, a rectangular screen 20 x 20 mm at 450 mm was used in these simulations.

Next the code queries as to the polarization of the light source and/or detector. Finally, the user is requested to input a file name for determining the objects. Alternatively, the user may input objects at the console.

Objects are specified as a ten element vector. The meaning of each of the ten elements is dependent on the specific object: but, for all objects, the first eight elements specify the geometry, the ninth element is the relative (outside relative to interior) index of refraction, and the tenth is the brightness (for sources).

With the objects specified, the calculation commences. The calculation proceeds with the execution of a pair of nested do loops starting two statements above the statement labeled 97. Initially, the code calculates the direction cosines for a given pixel for a ray starting at the origin. For polarized light the code also calculates the correct polarization for this ray.

Control is then passed to subroutine transport to see which object, if any, the ray intercepts first. This subroutine solves analytically for the intersection of the ray with each object and checks to see which has the shortest path. It then checks to see if the object is a source. If it is, it returns to the main program and adds the intensity to the intensity of that pixel. If the object was not a source, the new direction cosines of both the refracted and reflected ray are calculated along with the angle of incidence and angle of refraction and passed back to the main program. In the main program, if the object was not a source or a sink, the subroutine fresnel is called to calculate the intensities of the refracted and reflected rays.

Fresnel calculates the reflectivity and the transmission by calculating the fresnel coefficients and squaring them. In order to accomplish this, the s and p polarization directions must first be determined. Once these directions are determined, the s and p intensity is determined and hence the amount of s and p reflected and refracted intensity are calculated. These intensities are all determined for incoherent light.

After fresnel, the intensities of the refracted and reflected beams are check, and a decision is made. If either reflected or refracted ray is less than .001 its original intensity, that beam is dropped. If both are still brighter than this limit, a pointer is incremented so that the refracted ray will be traced at a later time. Then the reflected ray is sent to transport and the process is repeated until the reflected intensity is weaker than the above limit or the reflected ray hits a source. At this point control is passed to statement label 98. This part of the program picks up the next refracted ray and sends it through transport. As it does, the code still follows only the reflected rays but keeps track of any of the refracted rays that are sufficiently bright. Eventually, the intensity of all the rays that don't hit a source or sink will reach an intensity level lower then .001. If this doesn't happen before the index reaches 200, the loop is automatically terminated.

Finally, if a trace flag were set, a file is opened which keeps track of all the reflected and refracted rays and a graphics window is opened that plots these rays as viewed in the x-z plane. This routine is for diagnostic purposes.

Results

Figures 1 - 3 show the results of three measurements and the corresponding calculations. The measurements were taken at a studio at TID using an f/19 4 x 5 camera with $t_{\max}$ 1000 film. Unfortunately, the wedge made for these exposures was considerably over exposed and useless for calibration purposes. Therefore, wedges from NSCS were used to get exposure levels. The three figures were made with different sized backlighters. In each case, the distance from camera to target was 45 cm and the backlighter was 8.5 cm behind the target. The backlighter consisted of a black piece of cardboard with a circular aperture cut into it. Behind this cardboard was placed a white sheet of paper which was

illuminated with a studio light. Considerable care was taken in order to keep the backlighter as flat as possible.

The calculations were made with a resolution of 300×300 pixels. The photographs were digitized with a $12 \mu\text{m}$ square slit. The calculated image was sent to the LEAF where it was stretched (IDL congrid) to the same size as the digitized photograph. The digitized photograph had been adjusted in exposure so that the background was at the same intensity as the calculated image. No other normalizations were done.

The first three figures show not only these images, but also horizontal lineouts at corresponding locations. The only difference in these three pictures is the size of the backlighter - 25, 50, and 100 mm diameter for Figs. 1 - 3, respectively. Inspections of these images reveal reasonable agreement between calculations and data - especially in the limb of the target. Many of the features in the photographs appear to be reproduced extremely well by the calculation. A discrepancy between calculation and data exists primarily in the region of the sphere directly inside the dark band. The photographs show a smooth increase in intensity from the dark band to the bright center. The calculations show a region of increased brightness due to some reflections between the inner wall and the outer wall followed by a noticeable decrease in intensity and finally a monotonic increase in intensity to a maximum at the center. The sudden decrease in intensity corresponds to imaging the edge of the backlighter. A trace of this region was done to show that this is indeed the case. The results of this trace are presented in Figs. 4 and 5. These two figures show the rays as seen in the x-z plane, and represent two rays that are separated by only a single pixel. Appendix B is a printout of the positions and intensities of each ray at each surface. It is not known at this time why the data disagree so strongly with the calculation. It may be the result of nonspecular reflection smoothing out the sharp image, but this is pure speculation. It would point out that I assembled these targets myself and did not do a very good job. The hemishells were adhered to each other with optical grease and fingerprints were deposited on both the inside and outside surfaces.

Several other calculations were done. In order to try to optimize the measurements and determine how much anisotropy could be detected, the calculations shown in Figs. 6 - 11 were done. Figure 6 is a lineout of a sapphire shell which a 1 mm thick layer of hydrogen ice inside it. The shell

is 375 mm from the origin and the backlighter is at 410 mm. The diameter that the backlighter is 50 mm. Figures 7 and 8 are similar to Fig. 6 except that the backlighter is 20 mm and 250 mm in diameter, respectively. Figures 9 and 10 are lineouts of a geometry identical to Fig. 6 except that the ice is geometry similar to Fig. 7 and the ice offset by 250 μ m.

Finally Figs. 12 and 13 are calculations for geometry similar to that of Fig. 6, except that the sapphire was replaced by quartz ($n=1.56$) and LiF ($n=1.42$), respectively. These calculations lead me to believe that probably the sapphire gives the best contrast for observing the DT ice layer and that irregularities as small as 100 should be very easy to spot.

Conclusions

A code capable of synthesizing the images obtained from backlighting transparent shells has been written and appears to be in moderate agreement with actual photographs. This code, however, neglects birefringence and has no method of introducing scattering. Subroutines are currently being written which will allow the introduction of different geometries-cylinders and prisms with spherical voids which may offer better diagnostics for the β -layering process.

Figure Captions

- 1-3) Photographs and simulations of an empty sapphire shell backlight within a ^{2.5, 50 and 100} 10, 20 or 50 mm diameter backlight. The shell-camera distance was 45.0 cm and the camera-backlight distance was 53.5 cm.
- 4) "Trace" of the region around coll. 103, i.e., $r = 3$ mm. ^{lit} This figure shows how each ray branches into reflected and refracted components. In this figure, the light source is off the edge of the plot so rays that would have intercepted it were not plotted.
- 5a) Traces similar to Fig. 4 but with a much expanded scale. Two rays are shown intercepting the source.
- 5b) Same as Fig. 5a, except the incident ray is shifted by one pixel. Now only one ray hits the source. A complete printout of this trace is in Appendix B.
- 6) Lineout of a full sapphire shell. Index of refraction $n = 1.8$, ^{$6.35 < r < 7.6$} ~~$n = 1.1$~~ , $5.35 < r < 6.35$, $n = 1$, $r < 5.35$. The scale is 8 mm = 500 pixels. Backlighter is a disk $r = 50$ mm at $z = 410$ mm. Shell is 375 mm from argon.
- 7) Similar to Fig. 6 except backlighter radius is 20 mm.
- 8) Similar to Fig. 6 except backlighter radius is 250 mm.
- 9) Similar to Fig. 6 except DT ($n=1.1$) is centered at $z=410$, $y=0$, $x=0.1$ mm.
- 10) Similar to Fig. 6 except DT is centered at $z=410$, $y=0$, $x=0.25$ mm.
- 11) Similar to Fig. 7 except DT is centered at $z=410$, $y=0$, $x=0.25$ mm.
- 12) Similar to Fig. 6 except that quartz ($n=1.56$) was used instead of sapphire.
- 13) Similar to Fig. 6 except that LiF ($n=1.42$) was used instead of sapphire.

Figure 1

00501

Figure 2

Figure 3

Figure 4

Figure 5a

Figure 5b

KClO₄ 10
 Bk₁ 10 10 410
 Shell 76 10 6.35 10 21.8
 6.35 10 5.35 10 11

Figure 6

TITANIUM
Full Target
Backlight $r=30$ at 410

Figure 7

im
full target
pak(gut r=150 @ 410

Figure 8

image 110
full target offset 0.1 mm
BL: 844 x=50 @ 410

Figure 9

Full target offset 0.25
Backlight R=50 at -110

Figure 10

Filter: V10
 Full target ice offset 0.25
 Backscattered R=20 of 410

Figure 11

Picture 410
Bright $\tau=50$ @ 410
Full shell quartz $n=1.56$

Figure 12

PIVOT
 BKlight R=50 @ 410
 LIF N=1.72

Figure 13

Appendix A

FORTRAN Compiler Listing

03/14/90

Source File: picture.p10

Program Unit: PICTUR Entry: 00000612 Options: 1

```

00001
00002 *      program picture.p10 03/17/90
00003      program picture
00004
00005      implicit none
00006
00007
00008
00009      integer*1 i(512,300)
00010      integer ind(200),cold,nrow,ncol
00011      integer i,j,k,col,row,tcol,trow,l,m,n,nob,blk1,blk2
00012      integer trap,tlim,cntr,cnt,cntt,kntt,tim
00013      real geo(50,10),ray(200,23),10,flag,pol
00014      real temp,scalex,scaley,xl,xh,y1,yh,z0,scale(16),r,x,y
00015
00016      character*20 shape(50),titl(10),filnam
00017      character*1 trace
00018
00019
00020      common / blk1 /flag,ray(200,23)
00021      common /blk2/geo(50,10),shape(50),nob
00022
00023
00024
00025
00026      do(k=1,10);do(j=1,10);geo(k,j)=0;repeat;repeat
00027
00028      do(i=1,50);shape(i)= ' ';repeat
00029      do(j=1,200)
00030      do(l=1,23);ray(j,k)=0;repeat
00031      repeat
00032      filnam=
00033
00034 * ray(*,1-3)=current x,y,z
00035 * ray(*,4-6)= reflected(current) dir cos
00036 * ray(*,7-9)= refracted dir cos
00037 * ray(*,10-12) polarization vector dir cosines
00038 * ray(*,13) current index of refraction
00039 * ray(*,14) angle of incidence, reflection coeff
00040 * ray(*,15) angle of ref,transmiss coeff
00041 * ray(*,16) detector polarization
00042 * ray(*,17) not used
00043 * ray(*,18-20)surface normal dir cosines
00044 * ray(*,21-23)trans pol dir cosines
00045
00046 * at surfaces reflected ray are all followed first
00047 * refracted rays are done next but only until the next surf where the
00048 * reflected branch is again chosen
00049
00050
00051      write(9,*) 'stack set to 200000? or or ctrl-c'
00052      pause
00053      write(9,*) 'input no of horizontal pix,vertical pix=500,300 max'
00054      read(9,*)ncol,nrow

```

Source File: picture.p10

```

00056
00057      write(9,*) 'input window limits-xlow,xh,ylow,yh'
00058      read(9,*)xl,xh,y1,yh
00059      write(9,*) 'input zposition of window'
00060      read(9,*)z0
00061      write(9,*) 'input 0,1,2 for no,x,y,polarization'
00062      read(9,*)pol
00063      scale=(xh-xl)/ncol;scale=(yh-y1)/nrow
00064      scale(16)=0
00065      call obj(k)
00066      do(k=1,nob)
00067          if(scale(16).lt.abs(qeo(k,10)))scale(16)=abs(qeo(k,10))
00068      repeat
00069
00070      *****
00071      *****
00072      *****
00073      *      start main loop here      *****
00074      *      *****
00075      *      scan over objects a row at a time *****
00076      *      *****
00077      *****
00078
00079      xh=ncol*scale+xl;yh=nrow*scale+y1
00080
00081
00082
00083
00084      scale(1)=xl;scale(3)=xh;scale(2)=y1;scale(4)=yh
00085      scale(7)=scale(3)-scale(1);scale(8)=scale(4)-scale(2)
00086      scale(5)=scale(7)/50;scale(6)=scale(8)/50
00087      scale(14)=nrow;scale(15)=ncol
00088
00089
00090      scale(11)=5;scale(12)=5
00091      *      no o+x,y hash marks
00092
00093      titl(1)= ' dimension'
00094      titl(2)= 'y-dimension'
00095      titl(7)= 'qo'
00096      *      title of picture
00097      titl(3)=shape(1)
00098      titl(4)= 'window'
00099
00100      lo=0.;tlim=4;trap=0
00101
00102      call time(tim)
00103      write(9,*) 'starting calculation'
00104      do(row=1,nrow)
00105
00106          do (col=1,ncol)
00107              x=col*scale+xl;y=row*scale+y1
00108              r=sqrt(z0*z0+x*x+y*y)
00109

```



```

00110      ray(1,4)=x/r;ray(1,5)=y/r;ray(1,6)=z0/r
00111      ray(1,10)=0;ray(1,11)=0;ray(1,12)=0
00112      ray(1,16)=pol;ray(1,17)=1
00113      if(pol=1)then

```

FORTRAN Compiler Listing

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Source File: picture.p10

```

00114      ray(1,10)=ray(1,6)
00115      ray(1,12)=sqrt(1-ray(1,6)**2)
00116      endif
00117      if(pol=2)then
00118      ray(1,11)=ray(1,6)
00119      ray(1,12)=sqrt(1-ray(1,6)**2)
00120      endif
00121      *
00122      * we will always follow reflected rays first keeping track of
00123      * transmitted rays
00124      *
00125      *
00126
00127      cntr=1;cntr=1;kntr=0
00128
00129      *****
00130
00131      **          continue
00132
00133      call transport(cntr)
00134      if (titl(7)='trace')then
00135      if (flag.ne.0)then
00136      k=cntr
00137      write(9,*) cntr,flag=1,flag
00138      call trace(10,k,row,col,titnam)
00139      endif
00140      open(unit=2,file='+tinam,status='old',position='append')
00141      write(2,*)
00142      write(2,*)
00143      write(2,*) '*** back from transport ***'
00144      write(2,*) cntr, flag=cntr,flag
00145      if flag=0 write(2,*) '*****intensity=,10
00146      flag*(ray(cntr,10)**2+ray(cntr,11)**2+ray(cntr,12)**2)
00147      write(2,*) position initial-final
00148      write(2,*) ray(cntr,k),k=1,3,ray(cntr+1,k),k=1,3)
00149      write(2,*) initial direction
00150      write(2,*) ray(cntr,k),k=4,6)
00151      write(2,*) reflected refracted dir
00152      write(2,*) ray(cntr,k),k=4,9)
00153
00154      close(2)
00155      endif
00156      *****
00157      if(cntr>195)goto1001 'enough is enough
00158
00159

```

```

00161         if(flag=0)goto98      !hit dark boundary
00162
00163     ** here we need to change this part to enable the
00164     *   probably use flag=source to
00165
00166         if(flag=0)then
00167
00168
00169
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00176
00177
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00179
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00219
00220

```

angle of incm ray(13),angle of refl=ray(14)

call freene1(cnt1) ! calculate n&d ray(13),ray(14)

open(unit=3,file="trace",position="append")
write(3,*) 10= ray(cnt1,10),ray(cnt1,11),ray(cnt1,12)
write(3,*) 21= ray(cnt1,21),ray(cnt1,22),ray(cnt1,23)
close(3)

if(titi(7)='trace')then

open(unit=2,file='filnam stat5'old,position='append')
write(2,*) n&f from freene1
write(2,*) intensity
write(2,*) ray(cnt1,k),k=10,12)
write(2,*) ray(cnt1,k),k=21,23)

close(2)
write(9,0) int= sqrt(ray(cnt1,10)*ray(cnt1,11)*ray(cnt1,12)*ray(cnt1,21)*ray(cnt1,22)*ray(cnt1,23))
if((abs(ray(cnt1,10))>.03).and.(abs(ray(cnt1,11))>.03).and.(abs(ray(cnt1,21))>.03))write(9,0)int to 100
endif

if((abs(ray(cnt1,21))>.1).or.(abs(ray(cnt1,22))>.1).or.(abs(ray(cnt1,23))>.1))then
ind(cnt1)=cnt1
cnt1=cnt1+1
endif

if((ray(cnt1,21)=0).and.(ray(cnt1,22)=0).and.(ray(cnt1,23)=0))then
trap=trap+1
if(trap.ge.3)then
trap=0
goto98
endif

```

00221      else
00222      trap 0
00223      endif
00224
00225      if ((abs(ray(cntr,10))<.1).and.(abs(ray(cntr,11))<.1)
00226      + .and.(abs(ray(cntr,12))<.1)) goto 98
00227
00228
00229      goto 99

```

FORTRAN Compiler Listing 03/14/90

Source File: picture.p10

```

00230
00231
00232
00233  *****
00234
00235  98:      kntr=cntr+1
00236          cntr=cntr+1
00237          if (kntr.ge.cntr) goto 1001  ! one with his pazed
00238  *      set up to do a retracted ray
00239
00240
00241          m=ind(kntr)
00242  *      write(9,*) 't-ray# ',m
00243
00244          ray(cntr,1)=ray(m,1); ray(cntr,2)=ray(m,2); ray(cntr,3)=ray(m,3)
00245          ray(cntr,4)=ray(m,7); ray(cntr,5)=ray(m,8); ray(cntr,6)=ray(m,9)
00246
00247          ray(cntr,10)=ray(m,21); ray(cntr,11)=ray(m,22)
00248          ray(cntr,12)=ray(m,23)
00249          ray(cntr,16)=ray(ind(kntr),17)
00250          ray(cntr,17)=0
00251
00252          kntr=(9,9) ray(cntr,17),K=1,9)
00253
00254          goto 99  ! transport to next surface
00255
00256  *****
00257
00258
00259
00260
00261
00262  1001  i(col,row)=int(10)
00263  *****
00264  *      open unit=3, file="trace", position="append"
00265  *      write(3,*) col,row,cntr x 10= ,col,row,cntr x 10
00266  *      write(9,*) col,row,cntr x 10= ,col,row,cntr x 10, i(col,row)
00267  *      pause "hit cr"
00268  *      write(9,*) *****
00269  *      close(3)
00270  *****
00271      if (titi(7)='trace') then
00272          call tracer+19,cntr,row,col,i then
00273          goto 96
00274      endif
00275

```

```

00276      10=0
00277      trap=0
00278      cnt=1
00279
00280      repeat      ! main inside(coll) loop
00281
00282      scale(13)=float(row)
00283
00284      call imager(1,scale,tit1)
00285      if(tit1(7)='quit')goto999
00286      repeat      ! main row loop
00287

```

FORTRAN Compiler Listing

03/14/90

Source File: picture.p10

```

00288      * all done with calculation
00289      call time(k)
00290      flag=float(k-time)/60
00291      write(9,*)'total elapsed time= ',flag, ' minutes'
00292      96 tit1(7)='end'
00293      call imager(1,scale,tit1)      ! close screen
00294      if(tit1(7)='trace') then
00295      write(9,*)'input row col'
00296      read(9,*)row,col
00297      call trace2(10,cnt,row,col,finer)
00298      goto97
00299      endif
00300      999 continue
00301      end

```

Source File: picture.p10

Symbol and Label Tables for: PICTURE

SYMBOL	TYPE	ADDRESS	COMMON
i	INTEGER*1	00000160	
ind	INTEGER	00454160	
ncol	INTEGER	00455620	
nrow	INTEGER	00455624	
ncol	INTEGER	00455630	
i	INTEGER	00455634	
j	INTEGER	00455640	
k	INTEGER	00455644	
col	INTEGER	00455650	
row	INTEGER	00455654	
lcol	INTEGER	00455660	
lrow	INTEGER	00455664	
i	INTEGER	00455670	
m	INTEGER	00455674	
n	INTEGER	00455680	
nob	INTEGER	00005674	BLK2
blk1	INTEGER	00455704	
blk2	INTEGER	00455710	
trap	INTEGER	00455714	
tlim	INTEGER	00455720	
cntr	INTEGER	00455724	
cnt	INTEGER	00455730	
cnit	INTEGER	00455734	
bnit	INTEGER	00455740	
tim	INTEGER	00455744	
geo	REAL	00000004	BLK2
ray	REAL	00000010	BLK1
lo	REAL	00455750	
flag	REAL	00000004	BLK1
pol	REAL	00455754	
temp	REAL	00455760	
scalx	REAL	00455764	
scaly	REAL	00455770	
sh	REAL	00455774	
sh	REAL	00456000	
sh	REAL	00456004	
sh	REAL	00456010	
zo	REAL	00456014	
scale	REAL	00456020	
r	REAL	00456120	
r	REAL	00456124	
r	REAL	00456130	
shape	CHARACTER*20	00003124	BLK2
title	CHARACTER*20	00456134	
filnam	CHARACTER*20	00456444	
trace	CHARACTER*1	00456470	

STORAGE

MEMORY

LOCAL

154938

BLK1

18408

Source File: picture.p10

BLK2

3008

LABEL	ADDRESS	LABEL	ADDRESS
87	0000005046	99	0000006038
98	0000014634	1001	0000015754
96	0000017046	999	0000017622

Source File: picture.p10

Program Unit: TRANSP Entry: 00017662 Options: L

```

00302
00303
00304
00305
00306
00307
00308 *****
00309
00310 *
00311 *
00312 *   from here on attach the subs for finding the inter-
00313 *   sections of a ray with a surface. note that
00314 *   this surface can be used for image surfaces also
00315 *
00316 *
00317
00318
00319 *****
00320   subroutine transport(cntr)
00321
00322   implicit none
00323   integer cntr
00324
00325   real in,ray(200,23),flag,geo(50,10)
00326
00327   real aa,bb,cc,kr,rp,r(50),zp,zm,rmin
00328   real x1,y1,z1
00329
00330   real an,bn,cn,ap,bp,cp,temp,temp1
00331   integer i,j,k,l,m,n,kp,km,nob,nob,blk1,blk2
00332   real sqn(50)
00333   character*20 shape(50)
00334
00335   common /blk1 /flag,ray(200,23)
00336   common /blk2/geo(50,10),shape(50),nob
00337
00338
00339   data r /50*0/
00340
00341   nob=0;zp=0
00342
00343
00344
00345
00346 *   if refract -on surf cc=0,zp=0,zm=-bb/aa
00347   do (m=1,nob)
00348
00349
00350
00351       select case(shape(m))
00352       case('sphere')
00353           x1=ray(cntr,1)-geo(m,1)
00354           y1=ray(cntr,2)-geo(m,2)
00355           z1=ray(cntr,3)-geo(m,3)
00356       if(ray(cntr,6).ne.0)then

```

Source File: picture.p10

```

00357      aa=1/ray(cntr,6)/ray(cntr,6)
00358      bb=((x1*ray(cntr,4)+y1*ray(cntr,5))/ray(cntr,6)+z1)*2
00359      cc=x1*x1+y1*y1+z1*z1-geo(m,4)*geo(m,4)
00360      sgn(m)=sign(1.,cc)
00361      if(cc.lt.0001) sgn(m)=-1
00362      kr=bb*bb-4*aa*cc
00363      if(kr.lt.0)cycle
00364      zp=(-bb+sqrt(kr))/2/aa
00365      zm=(-bb-sqrt(kr))/2/aa
00366
00367      *      open(unit=3,file="trace",position="append")
00368      *      write(3,*) '*****'
00369      *      write(3,*) 'in transport zm,zp,sgn(m)=',cntr,zp,zm,sgn(m)
00370      *      write(3,*) 'aa,bb,cc,kr=',aa,bb,cc,kr
00371      *      write(3,*) 'z,geo(z)z1=',ray(cntr,3),geo(m,3),z1
00372      *      close(3)
00373
00374      if(abs(zp)<.001)zp=0
00375      if(abs(zm)<.001)zm=0
00376
00377      *      zp & zm = incremental z e
00378      *
00379      if(zp=0)then
00380
00381          if(ray(cntr,6)<0)then
00382              r(m)=zm/ray(cntr,6)
00383              rmin=rmin+r(m)
00384          endif
00385          cycle
00386      endif
00387
00388      if(zm=0)then
00389          if(ray(cntr,6)>0)then
00390              r(m)=zp/ray(cntr,6)
00391              rmin=rmin+r(m)
00392          endif
00393          cycle
00394      endif
00395
00396      if(zp=0)then
00397          if(ray(cntr,6)<0)then
00398              r(m)=zm/ray(cntr,6)
00399              rmin=rmin+r(m)
00400          endif
00401          cycle
00402      endif
00403
00404      if(zm=0)then
00405          if(ray(cntr,6)>0)then
00406              r(m)=zm/ray(cntr,6)
00407              rmin=r(m)+rmin
00408          endif
00409          cycle
00410      endif
00411
00412      if(zm=0)then
00413          if(ray(cntr,6)<0)then
00414              r(m)=zm/ray(cntr,6)
00415          else

```


Source File: picture.p10

```

00415         r(m)=zp/ray(cntr,6)
00416     endif
00417     endif
00418     rmin=r(m)+rmin
00419 else      !      c=0 ray normal to z direction
00420     if(ray(cntr,4).ne.0)then
00421         aa=1/ray(cntr,4)/ray(cntr,4)
00422         bb=((y1*ray(cntr,5))/ray(cntr,4)+z1)*2
00423         cc=y1*y1+z1*z1-geo(m,4)*geo(m,4)
00424
00425
00426         sqn(m)=sign(1.,cc)
00427         if(cc.lt.0001) sqn(m)=-1
00428         kr=bb*bb-4*aa*cc
00429         if(kr.lt.0)cycle
00430         zp=(-bb+sqrt(kr))/2/aa
00431         zm=(-bb-sqrt(kr))/2/aa
00432         if(abs(zp)<.001)zp=0
00433         if(abs(zm)<.001)zm=0
00434
00435 *      zp & zm = incremental z's
00436
00437         if(zp=0)then
00438
00439             if(ray(cntr,4)<0)then
00440                 r(m)=zm/ray(cntr,4)
00441                 rmin=rmin+r(m)
00442             endif
00443             cycle
00444         endif
00445
00446         if(rm=0)then
00447             if(ray(cntr,4)>0)then
00448                 r(m)=zp/ray(cntr,4)
00449                 rmin=rmin+r(m)
00450             endif
00451             cycle
00452         endif
00453
00454         if(zp>0)then
00455             if(ray(cntr,4)<0)then
00456                 r(m)=zp/ray(cntr,4)
00457                 rmin=rmin+r(m)
00458             endif
00459             cycle
00460         endif
00461         if(zm=0)then
00462             if(ray(cntr,4)>0)then
00463                 r(m)=zm/ray(cntr,4)
00464                 rmin=r(m)+rmin
00465             endif
00466             cycle
00467         endif
00468
00469         if(zm<0)then
00470             if(ray(cntr,4)<0)then
00471                 r(m)=zm/ray(cntr,4)
00472             else

```

Source File: picture.p10

```

00473       r(m)=zp/ray(cntr,4)
00474       endif
00475       endif
00476       else      ! c & a=0, b=1
00477       zp=2*abs(ray(cntr,2)-y1)
00478       if (zp*ray(cntr,5)>0) cycle
00479       r(m)=zp
00480       endif
00481       endif
00482
00483       case( disk )
00484       aa=geo(m,5)*ray(cntr,4)+geo(m,6)*ray(cntr,5)+
00485 + geo(m,7)*ray(cntr,6)
00486       if (aa=0) cycle
00487       zp=(ray(cntr,6)+geo(m,5)*(ray(cntr,4)*ray(cntr,5)-ray(cntr,5)*
00488 + ray(cntr,1))+geo(m,6)*(ray(cntr,5)*ray(cntr,3)-ray(cntr,6)*
00489 + ray(cntr,4)))/aa
00490       zm=(zp-ray(cntr,3))/ray(cntr,6)      ! distance-r(m)
00491       if (zm<0) cycle
00492       aa=zm*ray(cntr,4)+ray(cntr,1)      ! x-intercept
00493       bb=zm*ray(cntr,5)+ray(cntr,2)      ! y-intercept
00494       cc=(aa-geo(m,1))**2+(bb-geo(m,2))**2+(zp-geo(m,3))**2
00495 + -geo(m,4)**2
00496       if (cc>.0) cycle
00497       r(m)=zm
00498       rmin=rmin+r(m)
00499
00500       case( z-rect )
00501       if (ray(cntr,4)=0) cycle
00502       bb=(geo(m,1)-ray(cntr,1))/ray(cntr,4)
00503       if (bb<0) cycle
00504       cc=bb*ray(cntr,5)+ray(cntr,2)
00505       if (cc<geo(m,2)) cycle
00506       if (cc>geo(m,3)) cycle
00507       cc=bb*ray(cntr,6)+ray(cntr,3)
00508       if (cc<geo(m,4)) cycle
00509       if (cc>geo(m,5)) cycle
00510       r(m)=bb
00511       rmin=rmin+r(m)
00512
00513       case( y-rect )
00514       if (ray(cntr,5)=0) cycle
00515       bb=(geo(m,1)-ray(cntr,2))/ray(cntr,5)
00516       if (bb<0) cycle
00517       cc=bb*ray(cntr,4)+ray(cntr,1)
00518       if (cc<geo(m,2)) cycle
00519       if (cc>geo(m,3)) cycle
00520       cc=bb*ray(cntr,6)+ray(cntr,3)
00521       if (cc<geo(m,4)) cycle
00522       if (cc>geo(m,5)) cycle
00523       r(m)=bb
00524       rmin=rmin+r(m)
00525
00526       case( z-rect )
00527       if (ray(cntr,6)=0) cycle
00528       bb=(geo(m,1)-ray(cntr,3))/ray(cntr,6)
00529       if (bb<0) cycle
00530       cc=bb*ray(cntr,4)+ray(cntr,1)

```

Source File: picture.p10

```

00531      if (cc < geo(m,2)) cycle
00532      if (cc > geo(m,3)) cycle
00533      cc = bb * ray(cntr,5) + ray(cntr,2)
00534      if (cc < geo(m,4)) cycle
00535      if (cc > geo(m,5)) cycle
00536      r(m) = bb
00537      rmin = rmin + r(m)
00538
00539      case default
00540      write(9,*) 'surface not determined'
00541      end select
00542      repeat
00543
00544
00545      if (rmin = 0) then
00546          flag = 0
00547      *      write(9,*) 'hit dark boundary'
00548          return
00549      endif
00550
00551
00552      rmin = 9999; nnob = 0
00553      do (k=1, nob)
00554          if ((r(k) < rmin).and. (r(k).ne.0)) then
00555              rmin = r(k)
00556              nnob = k
00557          endif
00558      repeat
00559
00560      if (ray(1,10) = -999) write(9,*) 'hit ', shape(nnob)
00561  *      check to see if object is a source
00562      if (geo(nnob,9) = 0) then
00563  *      write(9,*) '*****hit source no ,nnob'
00564
00565          flag = -geo(nnob,10)
00566          kp = cntr + 1
00567          ray(kp,1) = rmin * ray(cntr,4) + ray(cntr,1)
00568          ray(kp,2) = rmin * ray(cntr,5) + ray(cntr,2)
00569          ray(kp,3) = rmin * ray(cntr,6) + ray(cntr,3)
00570          return
00571      else
00572          flag = geo(nnob,10)
00573      endif
00574
00575  *      now we have found the next surface write it in ray
00576
00577      kp = cntr + 1
00578      ray(kp,1) = rmin * ray(cntr,4) + ray(cntr,1)
00579      ray(kp,2) = rmin * ray(cntr,5) + ray(cntr,2)
00580      ray(kp,3) = rmin * ray(cntr,6) + ray(cntr,3)
00581      temp = ray(kp,3) - geo(nnob,3)
00582      aa = (geo(nnob,4)**2 - (ray(kp,1) - geo(nnob,1))**2
00583  + (ray(kp,2) - geo(nnob,2))**2)
00584
00585      if (aa.ge.0) then
00586          ray(kp,3) = sign(sqrt(aa), temp) + geo(nnob,3)
00587      endif
00588

```

Source File: picture.p10

```

00589 * index of refraction-watch out
00590
00591      if (sgn(nnob).le.0)then !internal ref
00592          in=geo(nnob,9)
00593      else
00594          in=1/geo(nnob,9)
00595      endif
00596
00597 * now find new dir cos for ref and trans rays
00598
00599      an=sgn(nnob)*(geo(nnob,1)-ray(kp,1))/geo(nnob,4)
00600      bn=sgn(nnob)*(geo(nnob,2)-ray(kp,2))/geo(nnob,4)
00601      if (an**2+bn**2.ge. 1)then
00602          cn=0
00603      else
00604          temp=sgn(nnob)*(geo(nnob,3)-ray(kp,3))/geo(nnob,4)
00605          cn=sgn(sqrt(1.-an*an-bn*bn),temp)
00606      endif
00607      ray(kp,18)=an; ray(kp,19)=bn; ray(kp,20)=cn
00608
00609
00610
00611
00612      ray(kp,13)=in
00613      k=0
00614 * next remember angle of inc and refraction
00615      3004 ray(kp,14)=ray(cntr,6)*cn+ray(cntr,5)*bn+ray(cntr,4)*an
00616          if (abs(ray(kp,14)).lt.1.0001)then
00617              write(9,*) 'angle of inc>1*****' ,ray(kp,14)
00618              write(9,*) an,ray(cntr,4),bn,ray(cntr,5),cn,ray(cntr,6)
00619          endif
00620
00621      if (cn.ge.0)then
00622          ray(kp,15)=(1.-in*in*(1.-ray(kp,14)*ray(kp,14)))
00623          if (ray(kp,15).ge.0)then
00624              ray(kp,15)=sqrt(ray(kp,15))
00625          else
00626              ray(kp,15)=0
00627          endif
00628          aa=ray(kp,15)-ray(kp,14)*in
00629          ray(kp,7)=ray(cntr,4)*in+aa*an
00630          ray(kp,8)=ray(cntr,5)*in+aa*bn
00631          ray(kp,9)=ray(cntr,6)*in+aa*cn
00632          temp=ray(kp,7)**2+ray(kp,8)**2+ray(kp,9)**2
00633          if (temp>.0005)then
00634              * write(9,*) 'refracted ray bad-redo ,temp
00635                  temp=ray(cntr,4)**2+ray(cntr,5)**2+ray(cntr,6)**2-1
00636              * write(9,*) 'inc ray**2-1,ray(4)= ,temp,ray(cntr,4)
00637                  ray(cntr,4)=sgn(1.,ray(cntr,4))/sqrt(abs(1.-ray(cntr,5)**2
00638                      -ray(cntr,6)**2))
00639              * write(9,*) 'new ray(4)= ,ray(cntr,4)
00640                  k=k+1
00641                  if (k.lt.2)goto3004
00642          endif
00643
00644      else
00645          ray(kp,15)=0
00646          ray(kp,7)=0; ray(kp,8)=0; ray(kp,9)=0

```

Source File: picture.p10

```
00647
00648      endif
00649
00650
00651
00652 *   now get dir cosines of refl ray
00653
00654
00655      ray(kp,4)=-2*ray(kp,14)*an+ray(cntr,4)
00656      ray(kp,5)=-2*ray(kp,14)*bn+ray(cntr,5)
00657      ray(kp,6)=-2*ray(kp,14)*cn+ray(cntr,6)
00658      temp=ray(kp,4)**2+ray(kp,5)**2+ray(kp,6)**2-1
00659      if (abs(temp)>.00005)then
00660          temp=1-ray(kp,5)**2-ray(kp,6)**2
00661          if (temp<0)then
00662              ray(kp,4)=0
00663 *          write(9,*) 'refl ray(yxz) sum=',ray(kp,5),ray(kp,6),temp
00664          else
00665              ray(kp,4)=sign(1.,ray(kp,4))*sqrt(temp)
00666          endif
00667      endif
00668      if (ray(kp,4)>1.000)then
00669 *          write(9,*) '***ray(*,4)=',kp,ray(kp,4)
00670          ray(kp,4)=1; ray(kp,5)=0; ray(kp,6)=0
00671      endif
00672      if (ray(kp,5)>1.)then
00673 *          write(9,*) '***ray(*,5)=',kp,ray(kp,5)
00674          ray(kp,5)=1; ray(kp,4)=0; ray(kp,6)=0
00675      endif
00676      if (ray(kp,6)>1.00)then
00677 *          write(9,*) '***ray(*,6)=',kp,ray(kp,6)
00678          ray(kp,6)=1; ray(kp,5)=0; ray(kp,4)=0
00679      endif
00680      if (ray(kp,7)>1.00)then
00681 *          write(9,*) '***ray(*,7)=',kp,ray(kp,7)
00682          ray(kp,7)=1; ray(kp,8)=0; ray(kp,9)=0
00683      endif
00684      if (ray(kp,8)>1.000)then
00685 *          write(9,*) '***ray(*,8)=',kp,ray(kp,8)
00686          ray(kp,8)=1; ray(kp,7)=0; ray(kp,9)=0
00687      endif
00688      if (ray(kp,9)>1.00)then
00689 *          write(9,*) '***ray(*,9)=',kp,ray(kp,9)
00690          ray(kp,9)=1; ray(kp,8)=0; ray(kp,7)=0
00691      endif
00692
00693      return
00694  end
```

Source File: picture.p10

Symbol and Label Tables for: TRANSF

SYMBOL	TYPE	ADDRESS	COMMON
cntr	INTEGER	DUMMY	
in	REAL	00000010	
rav	REAL	00000010	BLK1
flag	REAL	00000004	BLK1
geo	REAL	00000004	BLK2
aa	REAL	00000024	
bb	REAL	00000030	
cc	REAL	00000034	
kr	REAL	00000040	
rp	REAL	00000044	
r	REAL	00000050	
zp	REAL	00000360	
zm	REAL	00000364	
radn	REAL	00000370	
x1	REAL	00000374	
y1	REAL	00000400	
z1	REAL	00000404	
an	REAL	00000410	
bn	REAL	00000414	
cn	REAL	00000420	
ap	REAL	00000424	
bp	REAL	00000430	
cp	REAL	00000434	
temp	REAL	00000440	
temp1	REAL	00000444	
i	INTEGER	00000450	
j	INTEGER	00000454	
k	INTEGER	00000460	
l	INTEGER	00000464	
m	INTEGER	00000470	
n	INTEGER	00000474	
kp	INTEGER	00000500	
km	INTEGER	00000504	
nnob	INTEGER	00000510	
nob	INTEGER	00000514	BLK2
blk1	INTEGER	00000514	
blk2	INTEGER	00000520	
sqh	REAL	00000524	
shape	CHARACTER*20	00000574	BLK2

STORAGE MEMORY

LOCAL 540
BLK2 3008
BLK1 18408

LABEL	ADDRESS	LABEL	ADDRESS
3004	000005530		

Source File: picture.p10

Program Unit: OBJ Entry: 00042412 Options: L

```

00695 *****
00696
00697 *****
00698 *****
00699 *
00700     subroutine obj(k)
00701
00702     implicit none
00703     real geo(50,10)
00704     integer nob,k,j,l,m,n,blk2
00705     character*20 shape(50),filenam
00706
00707
00708     common /blk2/geo(50,10),shape(50),nob
00709
00710
00711
00712     * object are defined as a (10,10) array
00713     * geo(*,1-8) geometry
00714     * geo(*,9) index of refraction inside object,0= boundry
00715     * geo(*,10) source brightness
00716
00717
00718     write(9,*) 'for file input type filename,h= else hand inp'
00719     read(9,*)filenam
00720     if(filenam.ne.'h')then
00721         open(unit=2,file=filenam,status='old',action='read')
00722         read(2,*)nob
00723         do(k=1,nob)
00724             read(2,*)shape(k)
00725             read(2,*)(geo(k,j),j=1,10)
00726             repeat
00727         close(2)
00728         write(9,*)nob, ' objects'
00729         do(k=1,nob)
00730             write(9,*)shape(k)
00731             write(9,*)(geo(k,j),j=1,10)
00732             repeat
00733         else
00734             write(9,*) 'input total no of objects-sources'
00735             read(9,*)nob
00736             write(9,*) 'allowable shapes-spheres,disk,x,y,z-rect'
00737             do(l=1,nob)
00738                 write(9,*) 'l=',l, ' input object shape'
00739                 read(9,*)shape(k)
00740                 select case (shape(k))
00741                     case ('x-rect');call rect(x)
00742                     case ('y-rect');call rect(y)
00743                     case ('z-rect');call rect(z)
00744                     case ('disk');call disk(k)
00745                     case ('prism');call prism(k)
00746                     case ('cylinder');call cylinder(k)
00747                     case default
00748                         shape(k)= 'sphere'
00749                         call sphere(k)

```

Source File: picture.p10

```
00750      end select
00751      repeat
00752      k=nob+1
00753      geo(1,9)=1; geo(k,10)=-999
00754      endif
00755      return
00756      end
```


Source File: picture.plt

Symbol and Label Tables for: OBJ

SYMBOL	TYPE	ADDRESS	COMMON
k	INTEGER	DUMMY	
geo	REAL	00000004	BLK2
nob	INTEGER	00005874	BLK2
j	INTEGER	00000050	
l	INTEGER	00000054	
m	INTEGER	00000060	
n	INTEGER	00000064	
blk2	INTEGER	00000070	
shape	CHARACTER*20	00003724	BLK2
filenam	CHARACTER*20	00003074	

STORAGE

MEMORY

LOCAL

80

BLK2

3008

LABEL

ADDRESS

LABEL

ADDRESS

Source File: picture.p10

Program Unit: SPHERE Entry: 00046154 Options: L

```
00757
00758 *****
00759      subroutine sphere(k)
00760
00761      implicit none
00762      real geo(50,10)
00763      integer k,m,blk2,nob
00764      character*20 shape(50)
00765
00766
00767
00768      common /blk2/geo(50,10),shape(50),nob
00769
00770      do(m=6,8);geo(k,m)=0;repeat
00771
00772      write(9,*) input x0,y0,z0,radius
00773      read(9,*)(geo(k,m),m=1,4)
00774      write(9,*) input index of refraction, 0 if boundary
00775      read(9,*)geo(k,9)
00776      if(geo(k,9)=0)then
00777         write(9,*) if object is source input intensity
00778         read(9,*)geo(k,10)
00779      else
00780         geo(k,10)=1
00781      endif
00782      return
00783      end
```

Source File: picture.p10

Symbol and Label Tables for: SPHERE

SYMBOL	TYPE	ADDRESS	COMMON
i	INTEGER	DUMMY	
geo	REAL	00000004	BLK2
m	INTEGER	00000020	
blk2	INTEGER	00000024	
nob	INTEGER	00005674	BLK2
shape	CHARACTER*20	00003724	BLK2

STORAGE	MEMORY
---------	--------

LOCAL	24
BLK2	3008

LABEL	ADDRESS	LABEL	ADDRESS
-------	---------	-------	---------

Source File: picture.p10

Program Unit: PRISM Entry: 00047356 Options: L

```
00784 *****
00785      subroutine prism(k)
00786
00787      implicit none
00788      real geo(50,10)
00789      integer k,m,blk2,nob
00790      character*20 shape(50)
00791
00792
00793
00794      common /blk2/geo(50,10),shape(50),nob
00795
00796      do(m=6,8); geo(k,m)=0; repeat
00797
00798      write(9,*) 'input x0,y0,z0,radius'
00799      read(9,*)(geo(k,m),m=1,4)
00800      write(9,*) 'input index of refraction. 0 if boundry'
00801      read(9,*) geo(k,9)
00802      if(geo(k,9)=0) then
00803      write(9,*) 'if object is source input intensity'
00804      read(9,*) geo(k,10)
00805      else
00806      geo(k,10)=1
00807      endif
00808      return
00809      end
```

Source File: picture.p10

Symbol and Label Tables for: PRISM

SYMBOL	TYPE	ADDRESS	COMMON
k	INTEGER	DUMMY	
qeo	REAL	00000004	BLK2
m	INTEGER	00000020	
blk2	INTEGER	00000024	
nob	INTEGER	00005674	BLK2
shape	CHARACTER*20	00003724	BLK2

STORAGE	MEMORY
---------	--------

LOCAL	24
BLK2	3008

LABEL	ADDRESS	LABEL	ADDRESS
-------	---------	-------	---------

Source File: picture.p10

Program Unit: DISK Entry: 00050560 Options: 1

```
00810
00811 *****
00812      subroutine disk(k)
00813
00814      implicit none
00815      real geo(50,10)
00816      integer i,j,k,m,blk2,nob
00817      character*20 shape(50)
00818
00819
00820
00821      common /blk2/geo(50,10),shape(50),nob
00822
00823      do(m=6,8); geo(k,m)=0; repeat
00824
00825      write(9,*) disk-input :0,0,0, radius
00826      read(9,*)(geo(k,j),j=1,4)
00827
00828      write(9,*) input miller indices
00829      read(9,*) geo(k,5),geo(k,6),geo(k,7)
00830      if(geo(k,5).ne.0) geo(k,5)=1/geo(k,5)
00831      if(geo(k,6).ne.0) geo(k,6)=1/geo(k,6)
00832      if(geo(k,7).ne.0) geo(k,7)=1/geo(k,7)
00833      geo(k,9)=0
00834      write(9,*) input source intensity
00835      read(9,*) geo(k,10)
00836
00837
00838      return
00839      end
```

Source File: picture.p10

Symbol and Label Tables for: DISK

SYMBOL	TYPE	ADDRESS	COMMON
l	INTEGER	DUMMY	
geo	REAL	00000004	BLK2
i	INTEGER	00000020	
i	INTEGER	00000024	
m	INTEGER	00000030	
blk2	INTEGER	00000034	
nob	INTEGER	00005674	BLK2
shape	CHARACTER*20	00003724	BLK2

STORAGE

MEMORY

LOCAL

32

BLK2

3008

LABEL

ADDRESS

LABEL

ADDRESS

Program Unit: RECI Entry: 00052356 Options: L

```

00840
00841 *****
00842      subroutine rect(k)
00843
00844      implicit none
00845      real geo(50,10)
00846      integer k,m,blk2,nob
00847      character*20 shape(50)
00848
00849      common /blk2/geo(50,10),shape(50),nob
00850
00851      geo(k,7)=0; geo(k,7)=0
00852      select case (shape(k))
00853      case ('rect')
00854        write(9,*) 'input x0,y0,yh1,z0,zh1'
00855        read(9,*)(geo(k,m),m=1,5)
00856        write(9,*) 'input index of refraction'
00857        read(9,*)geo(k,9)
00858        write(9,*) 'if object is source input intensity'
00859        read(9,*)geo(k,10)
00860        case ('vrect')
00861        write(9,*) 'input x0, y0, y1, z0, z1'
00862        read(9,*)(geo(k,m),m=1,5)
00863        write(9,*) 'input index of refraction'
00864        read(9,*)geo(k,9)
00865

```

[illegible]

Source File: picture.plt

Symbol and Label Tables for: RECI

SYMBOL	TYPE	ADDRESS	COMMON
r	INTEGER	DUMMY	
geo	REAL	00000004	BLK1
m	INTEGER	00000010	
blk2	INTEGER	00000004	
nob	INTEGER	00000674	BLK2
shape	CHARACTER*20	00003724	BLK2

STORAGE

MEMORY

LOCAL

32

BLK2

8008

LABEL	ADDRESS	LABEL	ADDRESS
-------	---------	-------	---------

Source File: picture.plt

Program Unit: FRESNEL Entry: 00055632 Options: L

```

00879
00880
00881 *****
00881 *****
00883
00884
00885      subroutine fresnel (cntr)      ! calculate r&t ray (10), ray (14)
00886
00887      implicit none
00888      real ray(200,23), flag
00889      real ds,rs,ts,dp,rp,ip,c1,c2,p,s
00890      real as,ap,bs,bp,cs,cp,np,ns,nk,io,eqin
00891      real ar,br,cr,at,bt,ct
00892      real p1,p2,p3,s1,s2,s3,s,b,c,d,m,n3,sinr,sintr
00893      integer blk1,cntr,cntm
00894
00895
00896      cntm=blk1+flag,ray,(200,23)
00897
00898
00899
00900      cntm=cntr-1
00901      in=ray(cntr,13)      ! index of refraction
00902      cl=ray(cntr,14)      ! cos(angle of inc)
00903      cr=ray(cntr,15)      ! cos(angle of ref)
00904
00905 *****
00906 ***
00907
00908      normal incidence
00909
00910      if (abs(cl).gt..9999) then normal incidence
00911      if (cntm==0) then
00912          ray(1,10)=ray(1,6)*.707107
00913          ray(1,11)=ray(1,6)*.707107
00914          ray(1,12)=sign(eqin*ray(1,4)+.25*ray(1,5),ray(1,4)+.25*ray(1,5))
00915
00916
00917      end if
00918
00919
00920      if (cl>.99) then creque
00921          ray(cntr,10)=s*ray(cntm,10)
00922          ray(cntr,11)=s*ray(cntm,11)
00923          ray(cntr,12)=s*ray(cntm,12)
00924          ray(cntr,21)=0
00925          ray(cntr,22)=0
00926          ray(cntr,23)=0
00927          return
00928      end if
00929
00930      eqin=sqrt(1-in**2)
00931      ns=1/n3      ! n1/n2
00932      ts=eqin*10-10*in
00933      ray(cntr,10)=rs*ray(cntm,10)
00934      ray(cntr,11)=rs*ray(cntm,11)
00935      ray(cntr,12)=rs*ray(cntm,12)
00936      ray(cntr,21)=ts*ray(cntm,10)

```

Source File: picture.p10

```

00934      ray(cntr,22)=ts*ray(cntr,11)
00935      ray(cntr,23)=ts*ray(cntr,12)
00936      return
00937  endif
00938  *****
00939  *
00940
00941
00942
00943      if(c1*c1>1)write(9,*)'c1**2>1',c1
00944      if(c2*c2>1)write(9,*)'c2**2>1',c2
00945      sin=sqrt(1-c1*c1)
00946      sin=sqrt(1-c2*c2)
00947      ar=ray(cntr,4)
00948      br=ray(cntr,5)
00949      cr=ray(cntr,6)
00950      ar=ray(cntr,4)
00951      br=ray(cntr,5)
00952      cr=ray(cntr,6)
00953      at=ray(cntr,7)
00954      bt=ray(cntr,8)
00955      ct=ray(cntr,9)
00956      n1=ray(cntr,18) ! normal points away from L
00957      n2=ray(cntr,19)
00958      n3=ray(cntr,20)
00959
00960
00961
00962  *****
00963  *   for the first ray it is necessary to cal the s & p components
00964  *   explicitly for unpolarized radiation
00965  *   to do this use the vector equation (see 11)
00966  *   then  $\cos \theta = \hat{r} \cdot \hat{N}$  &  $E_s = E \times \hat{r}$ 
00967  *   or  $E_p = E - E_s$ 
00968
00969  *   test for first ray unpolarized light
00970  *****
00971  *****
00972
00973      if (u=0.1,10=0, and, u=0.1,11=0, and, u=0.1,12=0) then
00974
00975          a1=b*cos(n2)/sin1
00976          a2=a*cos(2*0.5/sin1)
00977          a3=a*cos(2-b*n1)/sin1
00978

```

```

00975
00980 p1=a1*a2+b1*b2
00981 p2=a1*a3+c1*c2
00982 p3=a1*b2-a*b2
00983
* 00984 p=.20/100; s=p
00985 as=a1*s; bs=a2*p; cs=a3*p
00986 ap=p1*p; bp=p2*p; cp=p3*p
00987 ray(1,10)=as+ap
00988 ray(1,11)=bs+bp
00989 ray(1,12)=cs+cp
00990 write(1,80,"100",p1,"100",p2,"100",p3)
00991 write(1,80,"100",ray(1,10),ray(1,11),ray(1,12)

```


01046

01047 * the new polarization vector is the sum of the two (S & P) components

01048 * these must be added incoherently at each bounce

01049 * the reflected polarizations are stored in ray(2,10-12)

Source File: picture.p10

```

01050 *   the transmitted polarizations are in ray(*,18-20)
01051   if (c2=0) then
01052     rs=.9;rp=.9
01053   else
01054     sqin=sqrt(abs(c2/in/c1))
01055     ds=in*c1+c2
01056     rs=((in*c1-c2)/ds)
01057     ts=2*sqin*in*c1/ds
01058
01059     dp=c1+in*c2
01060     rp=((c1-in*c2)/dp)
01061     tp=2*sqin*in*c1/dp
01062   endit
01063
01064 *****
01065 *****
01066 *   write(3,*) rs,rp,ts,tp,c1,c2 ,rs,rp,ts,tp,c1,c2
01067 *   write(3,*) r+t(rs,p)= ,rs**2+ts**2,rp**2+tp**2
01068 *   we now have the amplitudes of the p and s components
01069
01070
01071 *   now the direction s remains the same so reflected components are:
01072
01073
01074 *   p component changes so that P=S x K before and after reflection
01075 *   Ep=E(P*E) Es=S(S*E)
01076
01077
01078   p1=(s1*c1-s2*br)
01079   p2=(s1*ar-s1*cr)
01080   p3=(s1*br-s2*ar)
01081   np=p*rp
01082   ap=p1*np
01083   bp=p2*np
01084   cp=p3*np
01085 *   write(3,*) ap,bp,cp= ,ap,bp,cp
01086
01087   ns=s*rs
01088   as=s1*ns
01089   bs=s1*ns
01090   cs=s2*ns
01091 *   write(3,*) as,bs,cs= ,as,bs,cs
01092
01093
01094   ray(ctr,10)=ap/as
01095   ray(ctr,11)=bp/ba
01096   ray(ctr,12)=cp/cs
01097 *   write(3,*) 1/ray(ctr,10)+*2/ray(ctr,11)+*3/ray(ctr,12)**
01098 *   write(3,*) er=ns,ray(ctr,10),ray(ctr,11),ray(ctr,12)
01099
01100
01101   if (c2=0) then
01102     ray(ctr,21)=0
01103     ray(ctr,22)=0
01104     ray(ctr,23)=0
01105     return
01106   endit
01107

```

Source File: picture.p10

```

01108 *      transmitted ray similar
01109
01110      p1=(s2*ct-s3*bt)
01111      p2=(s3*at-s1*ct)
01112      p3=(s1*bt-s2*at)
01113 *      np=(p1*ray(cntm,10)+p2*ray(cntm,11)+p3*ray(cntm,12))*tp
01114      np=p*tp
01115      ap=p1*np
01116      bp=p2*np
01117      cp=p3*np
01118
01119      ns=s*ts
01120      as=s1*ns;bs=s2*ns;cs=s3*ns
01121
01122
01123      ray(cntn,21)=ap+as
01124      ray(cntn,22)=bp+bs
01125      ray(cntn,23)=cp+cs
01126
01127
01128 *      write(3,*) 11*+2 ,ray(cntn,21)**2+ray(cntn,22)**2+ray(cntn,23)**2
01129
01129 *      write(3,*) 11*+2 ,ray(cntn,21),ray(cntn,22),ray(cntn,23)
01130 *      close(3)
01131      return
01132      end

```


Source File: picture.p10

Symbol and Label Tables for: FRESNE

SYMBOL	TYPE	ADDRESS	COMMON
entr	INTEGER	DUMMY	
ra,	REAL	00000010	BLK1
flag	REAL	00000004	BLK1
ds	REAL	00000000	
rs	REAL	00000004	
ls	REAL	00000010	
dp	REAL	00000014	
rp	REAL	00000020	
tp	REAL	00000024	
c1	REAL	00000030	
c2	REAL	00000034	
p	REAL	00000040	
s	REAL	00000044	
as	REAL	00000050	
ap	REAL	00000054	
bs	REAL	00000060	
bp	REAL	00000064	
cs	REAL	00000070	
cd	REAL	00000074	
np	REAL	00000100	
ns	REAL	00000104	
nk	REAL	00000110	
nn	REAL	00000114	
eqin	REAL	00000120	
er	REAL	00000124	
or	REAL	00000130	
ol	REAL	00000134	
ot	REAL	00000140	
of	REAL	00000144	
pf	REAL	00000150	
p1	REAL	00000154	
p2	REAL	00000160	
p3	REAL	00000164	
s1	REAL	00000170	
s2	REAL	00000174	
s3	REAL	00000200	
s4	REAL	00000204	
t	REAL	00000210	
t1	REAL	00000214	
t2	REAL	00000220	
t3	REAL	00000224	
t4	REAL	00000230	
t5	REAL	00000234	
nm	REAL	00000240	
nl1	INTEGER	00000244	
nlm	INTEGER	00000250	

STORAGE

MEMBERS

LOCAL

172

BLK1

18400

Source File: picture.p10

Program Unit: TRACE Entry: 00054500 Options: L

```

01133
01134 *****
01135 *****
01136
01137     subroutine trace2(jo,cntr,row,col,filnam)
01138     implicit none
01139     real x(200),y(200),lo,temp,geo(50,10),ra,(200,25),flag
01140     real x0,y0
01141     character*20 shape(50),tit(jo),filnam
01142     integer m,n,k,j,nob,blk1,blk2,cntr,row,col
01143
01144     common / blk1 /+flag,ray(200,25)
01145     common /blk2/geo(50,10),shape(50),nob
01146
01147     save tit
01148     k=cntr+1;n=2
01149     x(1)=ray(cntr,3);y(1)=ray(cntr,1)
01150     x(2)=ray(k,3);y(2)=ray(k,1)
01151     tit(7)='cycle'
01152     tit(6)='one'
01153     if(flag) tit(5)='two'
01154     call qraff(x,y,n,tit)
01155
01156     return
01157
01158 *****
01159     entry trace2(jo,cntr,row,col,filnam)
01160
01161     tit(1)=' r-axis ;tit(2)=' x-axis ;tit(3)='shape('
01162     tit(4)='linlin ;tit(5)='line ;tit(6)='one
01163     tit(7)=' ;tit(8)=' ;tit(9)=' ;tit(10)='
01164
01165     write(9,*) 'input filename'
01166     read(9,*) filnam
01167     filnam=filnam//'.dat'
01168
01169
01170     do k=1,nob
01171         a=200;lo=0
01172         temp=3.1415926
01173         select case (shape(k))
01174         case ('sphere')
01175             do j=1,m
01176                 x(1)=geo(k,4)*sin(temp*j)+geo(k,5)
01177                 y(1)=geo(k,4)*cos(temp*j)+geo(k,6)
01178             repeat
01179             case ('disk')
01180                 y0=geo(k,7)*sqrt(geo(k,5)**2+geo(k,6)**2+geo(k,7)**2)
01181                 x0=geo(k,5)*sqrt(geo(k,5)**2+geo(k,6)**2+geo(k,7)**2)
01182                 do j=1,m
01183                     x(1)=x0*geo(k,4)*cos(temp*j)+geo(k,5)
01184                     y(1)=y0*geo(k,4)*sin(temp*j)+geo(k,6)
01185             repeat
01186             case ('c rect')
01187                 m=4

```

Source File: picture.plt

```

01188      y(1)=geo(k,2);y(2)=geo(k,3)
01189      x(1)=geo(k,1);x(2)=geo(k,1)
01190      x(3)=geo(k,1);y(3)=0
01191      x(4)=0;y(4)=0
01192
01193      case (v=rect)
01194      m=0
01195      y(1)=geo(k,1);y(2)=geo(k,1)
01196      x(1)=geo(k,4);x(2)=geo(k,5)
01197      y(3)=geo(k,1)-1;x(3)=geo(k,5)
01198      case default
01199      write(9,*)'no surface'
01200      pause hit ret
01201      return
01202      end select
01203
01204      call grafit(v,m,tit)
01205      tit(7)='cycle'
01206      repeat
01207      open(unit=2,file='+ilnam,status='new)
01208      write(2,*)'trace row= ,row, col= ,col'
01209      write(2,*)'cntr a b c d'
01210      + c a b c d
01211      close(2)
01212      return
01213
01214      entr, trace(10,cntr,row,col,ilnam)
01215      tit(7)='stop'
01216      open(unit=2,file='+ilnam,status='old,position='append)
01217      write(2,*)'cntr,10= ,cntr,10'
01218      write(2,*)'ray(cntr,k,l=1,9)'
01219      write(2,*)'ray(cntr,k,k=10,12),ray(cntr,k,k=21,23)'
01220      m=cntr+1
01221      write(2,*)'ray(m,l,l=1,9)'
01222      write(2,*)'ray(m,l,k=10,12),ray(m,l,l=21,23)'
01223
01224      call grafit(v,m,tit)
01225      close(2)
01226      return
01227      end

```

Source File: picture.plt

Symbol and Label Tables for: TRACE

SYMBOL	TYPE	ADDRESS	COMMON
io	REAL	DUMMY	
cmh	INTEGER	DUMMY	
row	INTEGER	DUMMY	
col	INTEGER	DUMMY	
filnam	CHARACTER*20	DUMMY	
z	REAL	00000110	
z	REAL	00001550	
temp	REAL	00003210	
geo	REAL	00000004	BLK2
res	REAL	00000010	BLK1
slaq	REAL	00000004	BLK1
z0	REAL	00003214	
z0	REAL	00003220	
shape	CHARACTER*20	00003724	BLK2
xit	CHARACTER*20	00003724	
m	INTEGER	00003534	
n	INTEGER	00003540	
l	INTEGER	00003544	
a	INTEGER	00003550	
nob	INTEGER	00005674	BLK2
blk1	INTEGER	00003554	
blk2	INTEGER	00003560	

STORAGE

MEMORY

LOCAL	1908
BLK1	18408
BLK2	1008

LABEL	ADDRESS	LABEL	ADDRESS
01232			
01233			
01230			
01231			
01232			
01233			
01234			
01235			
01236			
01237			
01238			
01239			
01240			
01241			
01242			

*** END OF FILE ***

Appendix B

trace row= 1 coll= 104

cntr x y z a b c a b c di

**** back from transport ****

cntr, flag= 1 1.000

position initial-final

.0000 .0000 .0000 -5.162 3.2920E-02 -444.4

initial direction

-1.1614E-02 7.4069E-05 -.9999

reflected refracted dir

-1.1614E-02 7.4069E-05 -.9999 .0000 .0000 .0000

back from fresnel

intensity

6.2070E-03 -.2775 .1210

-.6491 .6546 -.2419

**** back from transport ****

cntr, flag= 2 .0000

position initial-final

-5.162 3.2920E-02 -444.4 -5.162 3.2920E-02 -444.4

initial direction

-.9978 6.3636E-03 6.5763E-02

reflected refracted dir

-.9978 6.3636E-03 6.5763E-02 .3473 -2.2148E-03 -.9378

**** back from transport ****

cntr, flag= 3 1.000

position initial-final

-5.162 3.2920E-02 -444.4 -4.684 2.9872E-02 -445.7

initial direction

.3473 -2.2148E-03 -.9378

reflected refracted dir

.3473 -2.2148E-03 -.9378 .0000 .0000 .0000

back from fresnel

intensity

-1.0779E-02 .3098 -4.6755E-02

-.6847 .5763 9.5036E-02

**** back from transport ****

cntr, flag= 4 1.000

position initial-final

-4.684 2.9872E-02 -445.7 -6.012 3.8340E-02 -445.4

initial direction

-.9647 6.1526E-03 .2632

reflected refracted dir

-.9647 6.1526E-03 .2632 -.1368 8.7214E-04 -.9906

back from fresnel

intensity

-6.4371E-03 .1216 -4.1339E-03

6.5824E-03 .2849 -4.7507E-02

**** back from transport ****
cntr, flag= 5 1.000
position initial-final
-6.012 3.8340E-02 -445.4 -5.327 3.3975E-02 -446.5
initial direction
.4973 -3.1714E-03 -.8676
reflected refracted dir
.4973 -3.1714E-03 -.8676 -.9950 6.3456E-03 -9.9809E-02
back from fresnel
intensity
3.1103E-04 5.7871E-02 -5.7544E-04
-7.6077E-03 .1069 -2.3725E-04

**** back from transport ****
cntr, flag= 7 1.000
position initial-final
-4.684 2.9872E-02 -445.7 -5.670 3.6163E-02 -452.9
initial direction
-.1368 8.7214E-04 -.9906
reflected refracted dir
-.1368 8.7214E-04 -.9906 2.2326E-03 2.7908E-03 -1.000
back from fresnel
intensity
-2.4912E-02 -.2722 -4.2430E-02
-.5573 .5065 .4079

**** back from transport ****
cntr, flag= 8 1.000
position initial-final
-5.670 3.6163E-02 -452.9 .6599 -4.2088E-03 -456.3
initial direction
.8776 -5.5970E-03 -.4794
reflected refracted dir
.8776 -5.5970E-03 -.4794 -.5884 3.7523E-03 -.8086
back from fresnel
intensity
3.0149E-03 .1297 -2.5548E-03
-4.1895E-02 -.2392 -2.6392E-02

**** back from transport ****
cntr, flag= 9 1.000
position initial-final
.6599 -4.2088E-03 -456.3 6.139 -3.9150E-02 -451.6
initial direction
.7595 -4.8441E-03 .6504
reflected refracted dir
.7595 -4.8441E-03 .6504 .5472 -3.4898E-03 -.8370
back from fresnel
intensity
-1.7377E-04 -6.1771E-02 7.9228E-05
1.4475E-03 .1140 -3.2771E-03

**** back from transport ****

cntr, flag= 11 1.0000

position initial-final

-6.012 3.8340E-02 -445.4 -5.327 3.3975E-02 -446.5

initial direction

-.9950 6.3456E-03 -9.9809E-02

reflected refracted dir

-.9950 6.3456E-03 -9.9809E-02 6.7316E-04 8.4144E-04 -1.000

**** back from transport ****

cntr, flag= 12 1.000

position initial-final

-5.327 3.3975E-02 -446.5 -5.121 3.2659E-02 -453.8

initial direction

2.8608E-02 -1.8245E-04 -.9996

reflected refracted dir

2.8608E-02 -1.8245E-04 -.9996 -7.9975E-03 -9.9968E-03 .9999

back from fresnel

intensity

-5.1373E-04 -5.0885E-02 -5.4505E-04

-6.8014E-03 9.4006E-02 3.6966E-03

**** back from transport ****

cntr, flag= 14 1.000

position initial-final

-5.670 3.6163E-02 -452.9 -6.480 4.1327E-02 -454.0

initial direction

-.5884 3.7523E-03 -.8086

reflected refracted dir

-.5884 3.7523E-03 -.8086 -9.0718E-03 -1.1340E-02 .9999

back from fresnel

intensity

-1.7420E-02 .1974 .1174

-.6566 .4668 .1774

**** back from transport ****

cntr, flag= 15 1.000

position initial-final

-6.480 4.1327E-02 -454.0 -5.121 3.2659E-02 -453.8

initial direction

.9876 -6.2983E-03 .1571

reflected refracted dir

.9876 -6.2983E-03 .1571 -.2597 1.6565E-03 -.9657

back from fresnel

intensity

-6.8011E-03 9.4007E-02 3.6966E-03

4.0008E-02 .1732 .1121

**** back from transport ****

cntr, flag= 17 1.000

position initial-final

.6599 -4.2088E-03 -456.3 1.413 -9.0115E-03 -457.5

initial direction

.5472 -3.4898E-03 -.8370

reflected refracted dir

.5472 -3.4898E-03 -.8370 -9.8638E-03 -1.2330E-02 .9999

back from fresnel

intensity

-8.6985E-03 -9.3908E-02 1.6840E-03

-2.9224E-02 -.2201 -3.8519E-02

**** back from transport ****
cntr, flag= 19 1.000
position initial-final
6.139 -3.9150E-02 -451.6 7.483 -4.7722E-02 -451.3
initial direction
.9767 -6.2288E-03 .2146
reflected refracted dir
.9767 -6.2288E-03 .2146 .9032 -1.9355E-02 -.4287
back from fresnel
intensity
-2.4099E-05 4.4748E-02 -4.8525E-04
2.4877E-03 .1049 -2.7603E-03

**** back from transport ****
cntr, flag= 21 -255.0
*****intensity= 173.5
position initial-final
-6.480 4.1327E-02 -454.0 -26.93 .1717 -530.0
initial direction
-.2597 1.6565E-03 -.9657
reflected refracted dir
-.2597 1.6565E-03 -.9657 .9958 -2.1712E-02 -8.8392E-02

**** back from transport ****
cntr, flag= 22 1.000
position initial-final
-5.121 3.2659E-02 -453.8 1.693 -1.0798E-02 -456.1
initial direction
.9447 -6.0247E-03 -.3279
reflected refracted dir
.9447 -6.0247E-03 -.3279 .9913 -2.1243E-02 -.1296
back from fresnel
intensity
-6.8548E-03 -8.2581E-02 5.2963E-03
8.7974E-02 .1520 8.0212E-02

**** back from transport ****
cntr, flag= 24 .0000
position initial-final
1.413 -9.0115E-03 -457.5 7.483 -4.7722E-02 -451.3
initial direction
.8107 -5.1700E-03 -.5855
reflected refracted dir
.8107 -5.1700E-03 -.5855 .9696 -1.9868E-02 -.2440

**** back from transport ****
cntr, flag= 25 .0000
position initial-final
7.483 -4.7722E-02 -451.3 1.693 -1.0798E-02 -456.1
initial direction
.8350 -5.3254E-03 .5502
reflected refracted dir
.8350 -5.3254E-03 .5502 -.1970 3.4050E-03 -.9804

**** back from transport ****

cntr, flag= 26 1.000

position initial-final

1.693 -1.0798E-02 -456.1 2.626 -1.6747E-02 -457.1

initial direction

.6778 -4.3228E-03 -.7352

reflected refracted dir

.6778 -4.3228E-03 -.7352 .9476 -1.8901E-02 -.3190

back from fresnel

intensity

2.0663E-02 5.9721E-02 -7.9595E-04

5.2619E-02 .1400 .1045

**** back from transport ****

cntr, flag= 28 .0000

position initial-final

2.626 -1.6747E-02 -457.1 99.60 -1.822 -530.0

initial direction

.8962 -5.7153E-03 -.4437

reflected refracted dir

.8962 -5.7153E-03 -.4437 .2196 -3.7946E-03 -.9756

cntr, I0= 29 173.5

99.60 -1.822 -530.0 .9758 -1.7764E-02 .2178 .1236 -2.1074E-03 -.9923

2.1338E-03 .1155 -1.4134E-04 8.1904E-02 .1114 9.9680E-03

.1260 -2.2943E-03 -456.3 .4979 -9.0634E-03 -.8672 -2.2317E-02 3.7361E-04 -.9998

9.4560E-02 .1398 5.2829E-02 7.2098E-02 9.8299E-02 -1.5727E-03

Appendix B

```

trace row= 1    coll= 103
cntr  x      y      z      a      b      c      a      b      c      di

```

**** back from transport ****

```

cntr, flag= 1 1.000
position initial-final
.0000 .0000 .0000 -5.189 3.2922E-02 -444.4
initial direction
-1.1673E-02 7.4069E-05 -.9999
reflected refracted dir
-1.1673E-02 7.4069E-05 -.9999 .0000 .0000 .0000
back from fresnel
intensity
4.9721E-03 -.2786 .1198
-.6487 .6541 -.2437

```

**** back from transport ****

```

cntr, flag= 2 .0000
position initial-final
-5.189 3.2922E-02 -444.4 -5.189 3.2922E-02 -444.4
initial direction
-.9984 6.3350E-03 5.6160E-02
reflected refracted dir
-.9984 6.3350E-03 5.6160E-02 .3498 -2.2194E-03 -.9368

```

**** back from transport ****

```

cntr, flag= 3 1.000
position initial-final
-5.189 3.2922E-02 -444.4 -4.707 2.9864E-02 -445.7
initial direction
.3498 -2.2194E-03 -.9368
reflected refracted dir
.3498 -2.2194E-03 -.9368 .0000 .0000 .0000
back from fresnel
intensity
-9.5665E-03 .3120 -4.3685E-02
-.6850 .5746 9.6566E-02

```

**** back from transport ****

```

cntr, flag= 4 1.000
position initial-final
-4.707 2.9864E-02 -445.7 -6.039 3.8316E-02 -445.4
initial direction
-.9668 6.1344E-03 .2555
reflected refracted dir
-.9668 6.1344E-03 .2555 -.1389 8.8112E-04 -.9903
back from fresnel
intensity
-5.8592E-03 .1229 -3.8379E-03
6.7352E-03 .2866 -4.4257E-02

```

**** back from transport ****
cntr, flag= 5 1.000
position initial-final
-6.039 3.8316E-02 -445.4 -5.349 3.3941E-02 -446.6
initial direction
.5005 -3.1756E-03 -.8657
reflected refracted dir
.5005 -3.1756E-03 -.8657 -.9939 6.3063E-03 -.1104
back from fresnel
intensity
3.2864E-04 5.8959E-02 -4.9510E-04
-6.9653E-03 .1078 -2.1034E-04

**** back from transport ****
cntr, flag= 7 1.000
position initial-final
-4.707 2.9864E-02 -445.7 -5.697 3.6151E-02 -452.8
initial direction
-.1389 8.8112E-04 -.9903
reflected refracted dir
-.1389 8.8112E-04 -.9903 2.2326E-03 2.7908E-03 -1.000
back from fresnel
intensity
-2.4019E-02 -.2735 -3.9198E-02
-.5551 .5038 .4122

**** back from transport ****
cntr, flag= 8 1.000
position initial-final
-5.697 3.6151E-02 -452.8 .5055 -3.2075E-03 -456.3
initial direction
.8693 -5.5161E-03 -.4942
reflected refracted dir
.8693 -5.5161E-03 -.4942 -.5940 3.7687E-03 -.8045
back from fresnel
intensity
2.6631E-03 .1313 -2.2801E-03
-3.9710E-02 -.2398 -2.3794E-02

**** back from transport ****
cntr, flag= 9 1.000
position initial-final
.5055 -3.2075E-03 -456.3 6.070 -3.8516E-02 -451.9
initial direction
.7799 -4.9485E-03 .6259
reflected refracted dir
.7799 -4.9485E-03 .6259 .5288 -3.3555E-03 -.8487
back from fresnel
intensity
-2.1868E-04 -6.3018E-02 5.5786E-05
1.2522E-03 .1152 -2.8705E-03

**** back from transport ****
cntr, flag= 11 1.0000
position initial-final
-6.039 3.8316E-02 -445.4 -5.349 3.3941E-02 -446.6
initial direction
-.9939 6.3063E-03 -.1104
reflected refracted dir
-.9939 6.3063E-03 -.1104 6.7316E-04 8.4144E-04 -1.000

**** back from transport ****
cntr, flag= 12 1.000
position initial-final
-5.349 3.3941E-02 -446.6 -5.153 3.2696E-02 -453.7
initial direction
2.7487E-02 -1.7441E-04 -.9996
reflected refracted dir
2.7487E-02 -1.7441E-04 -.9996 -7.9975E-03 -9.9968E-03 .9999
back from fresnel
intensity
-4.9838E-04 -5.1725E-02 -4.6604E-04
-6.2108E-03 9.4606E-02 3.4527E-03

**** back from transport ****
cntr, flag= 14 1.000
position initial-final
-5.697 3.6151E-02 -452.8 -6.516 4.1344E-02 -453.9
initial direction
-.5940 3.7687E-03 -.8045
reflected refracted dir
-.5940 3.7687E-03 -.8045 -9.0718E-03 -1.1340E-02 .9999
back from fresnel
intensity
-1.5949E-02 .1972 .1165
-.6567 .4640 .1804

**** back from transport ****
cntr, flag= 15 1.000
position initial-final
-6.516 4.1344E-02 -453.9 -5.153 3.2696E-02 -453.7
initial direction
.9893 -6.2770E-03 .1460
reflected refracted dir
.9893 -6.2770E-03 .1460 -.2638 1.6738E-03 -.9646
back from fresnel
intensity
-6.2112E-03 9.4606E-02 3.4528E-03
4.1403E-02 .1726 .1104

**** back from transport ****
cntr, flag= 17 1.000
position initial-final
.5055 -3.2075E-03 -456.3 1.234 -7.8303E-03 -457.5
initial direction
.5288 -3.3555E-03 -.8487
reflected refracted dir
.5288 -3.3555E-03 -.8487 -9.8638E-03 -1.2330E-02 .9999
back from fresnel
intensity
-8.0332E-03 -9.4516E-02 1.7485E-03
-2.8042E-02 -.2205 -3.5445E-02

**** back from transport ****
cntr, flag= 19 1.000
position initial-final
6.070 -3.8516E-02 -451.9 7.426 -4.7117E-02 -451.6
initial direction
.9839 -6.2430E-03 .1787
reflected refracted dir
.9839 -6.2430E-03 .1787 .9032 -1.9355E-02 -.4287
back from fresnel
intensity
4.8727E-06 4.5382E-02 -4.0622E-04
2.1713E-03 .1059 -2.4531E-03

**** back from transport ****
cntr, flag= 21 -255.0
*****intensity= 173.2
position initial-final
-6.516 4.1344E-02 -453.9 -27.32 .1734 -530.0
initial direction
-.2638 1.6738E-03 -.9646
reflected refracted dir
-.2638 1.6738E-03 -.9646 .9958 -2.1712E-02 -8.8392E-02

**** back from transport ****
cntr, flag= 22 1.000
position initial-final
-5.153 3.2696E-02 -453.7 1.550 -9.8321E-03 -456.2
initial direction
.9393 -5.9602E-03 -.3430
reflected refracted dir
.9393 -5.9602E-03 -.3430 .9913 -2.1243E-02 -.1296
back from fresnel
intensity
-6.2165E-03 -8.7927E-02 5.0685E-03
8.8814E-02 .1511 7.7684E-02

**** back from transport ****
cntr, flag= 24 -255.0
*****intensity= 186.1
position initial-final
1.234 -7.8303E-03 -457.5 97.69 -.6199 -530.0
initial direction
.7994 -5.0720E-03 -.6008
reflected refracted dir
.7994 -5.0720E-03 -.6008 .9696 -1.9868E-02 -.2440

**** back from transport ****
cntr, flag= 25 .0000
position initial-final
7.426 -4.7117E-02 -451.6 1.550 -9.8321E-03 -456.2
initial direction
.8532 -5.4138E-03 .5215
reflected refracted dir
.8532 -5.4138E-03 .5215 -.1970 3.4050E-03 -.9804

**** back from transport ****

cntr, flag= 26 1.000

position initial-final

1.550 -9.8321E-03 -456.2 2.462 -1.5623E-02 -457.2

initial direction

.6624 -4.2031E-03 -.7491

reflected refracted dir

.6624 -4.2031E-03 -.7491 .9476 -1.8901E-02 -.3190

back from fresnel

intensity

2.0241E-02 5.9618E-02 -1.2768E-03

5.4019E-02 .1391 .1026

**** back from transport ****

cntr, flag= 28 .0000

position initial-final

2.462 -1.5623E-02 -457.2 99.60 -1.822 -530.0

initial direction

.8880 -5.6347E-03 -.4598

reflected refracted dir

.8880 -5.6347E-03 -.4598 .2196 -3.7946E-03 -.9756

cntr, IO= 29 186.1

99.60 -1.822 -530.0 .9758 -1.7764E-02 .2178 .1236 -2.1074E-03 -.9923

2.1338E-03 .1155 -1.4134E-04 8.1904E-02 .1114 9.9680E-03

.1260 -2.2943E-03 -456.3 .4979 -9.0634E-03 -.8672 -2.2317E-02 3.7361E-04 -.9998

9.4560E-02 .1398 5.2829E-02 7.2098E-02 9.8299E-02 -1.5727E-03

- END -

DATE FILMED

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