

# Lenses and Mirrors: PST-optic v0.9 Examples

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May 19, 2005

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## Introduction

`pstricks` writes pure PostScript[?] code, so it is not possible to run  $\text{\TeX}$  files with pdf $\text{\LaTeX}$  when there are `pstricks` macros in the document. If you still need a PDF output use the package `pdftricks.sty`[?] or the for Linux free available program `vlatex` (<http://www.micropress-inc.com/linux/>) or build the PDF with `ps2pdf` (`dvi`→`ps`→`pdf`).

If you need package `graphicx.sty` load it before any `pstricks` package. You do not need to load `pstricks.sty`, it will be done by `pst-optic` by default.

For more informations have a look into the documentations.

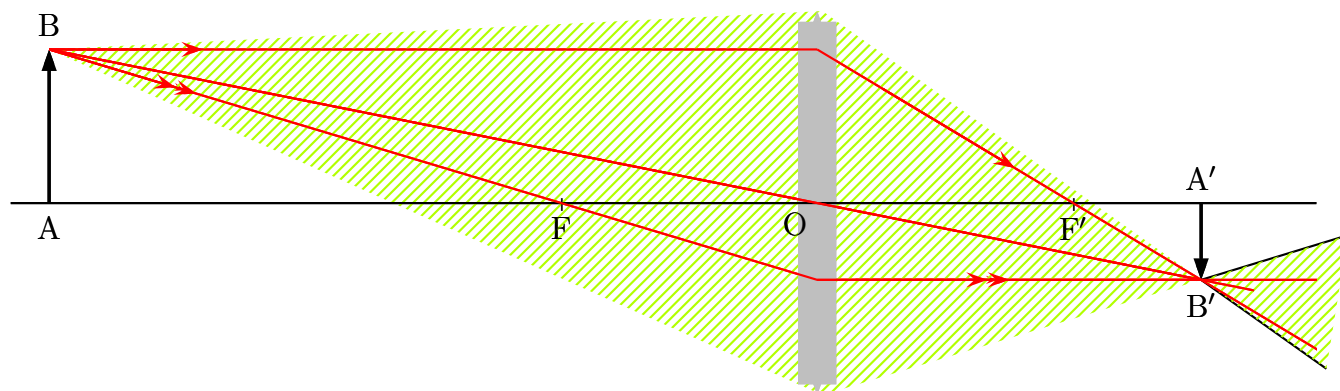
This PDF file was created with the `vlatex` program from the free available *VTeX/Lnx v7.530* - the *VTeX* distribution for Linux (x86).

## Part I

## Lenses

## 1 A simple colored System

- $\overline{AB} = 2 \text{ cm}$
- $\overline{OA} = -10 \text{ cm}$
- $\overline{OF'} = 3,333 \text{ cm}$
- $\overline{XO} = 2 \text{ cm}$

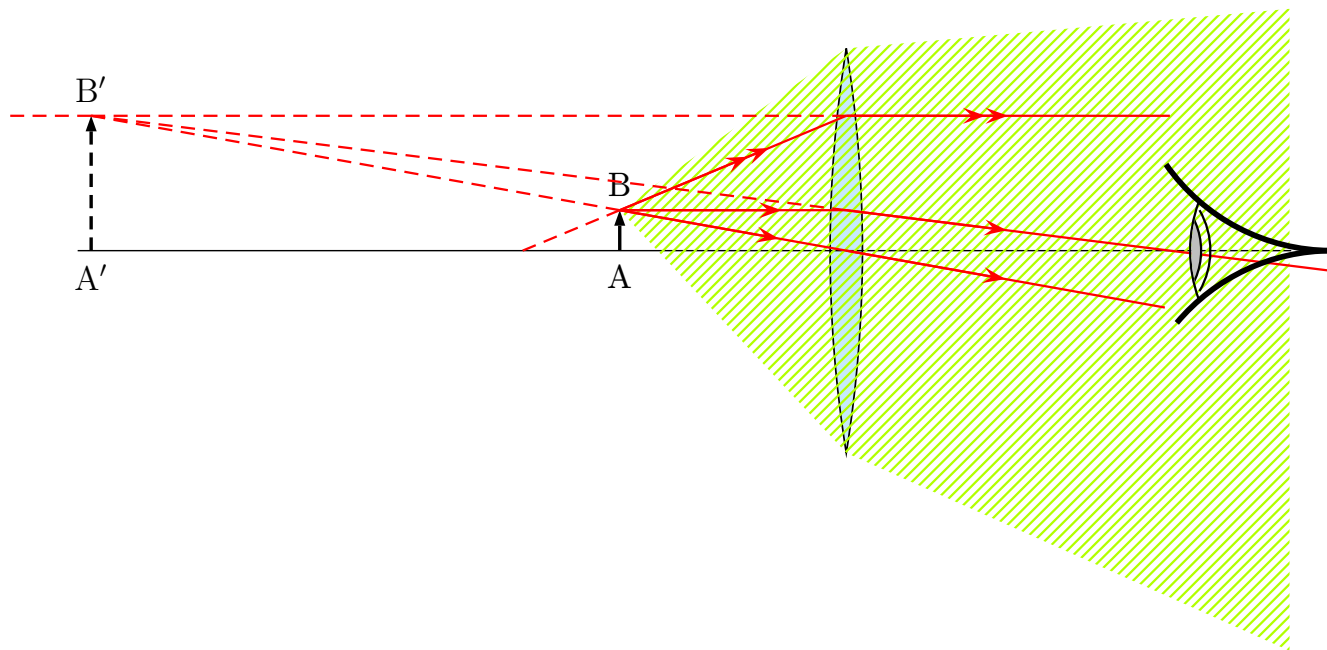


```

1 \begin{pspicture}(-8.5,-3)(8.5,3)
2 \rput(0,0){%
3 \lens[focus=3.333,%
4 OA=-10,AB=2,X0=2,%
5 xLeft=-8.5,xRight=8.5,%
6 rayColor=red]%
7 }
8 \pnode(!X0 2.5){L1}%extrémité supérieure de la lentille
9 \pnode(!X0 -2.5){L2}%extrémité inférieure de la lentille
10 \psOutLine[length=2](L1)(B'){END}
11 \psBeforeLine[length=2](B')(L2){START}
12 \pspolygon[style=rayuresJaunes,linestyle=none](B)(L1)(END)(START)(L2)
13 \rput(0,0){%
14 \lens[%
15 focus=3.333,%
16 OA=-10,AB=2,%
17 X0=2,%
18 xLeft=-8.5,xRight=8.5,%
19 rayColor=red,arrowsize=0.2]%
20 }
21 \end{pspicture}

```

## 2 A Magnifier



```

1 \begin{pspicture}(-8,-5)(8,3)
2 \rput(0,0){%
3   \lens[%
4     lensGlass=true,lensWidth=0.4,%
5     focus=4,AB=0.5,OA=-2.8,X0=2,drawing=false]%
6   \psline[linewidth=0.5pt](xLeft)(xRight)}
7 \pnode(!X0 2.5){L1}% extrmitsuprieuredelalentille
8 \pnode(!X0 -2.5){L2}% extrmitinfrieuredelalentille
9 \psOutLine[length=5.5,linestyle=none](B')(L1){END1}
10 \psBeforeLine[length=6,linestyle=none](L2)(B'){START}
11 \pspolygon[style=rayuresJaunes,linestyle=none](B)(L1)(END1)(START)(L2)
12 \psline[linewidth=1.5\pslinewidth,arrowinset=0]{->}(A)(B)
13 \uput[270](A){A}
14 \uput[90](B){B}
15 \psline[linewidth=1.5\pslinewidth,arrowinset=0,%
16   linestyle=dashed]{->}(A')(B')
17 \uput[270](A'){$\mathrm{A'}$}
18 \uput[90](B'){$\mathrm{B'}$}
19 \psset{linecolor=red,arrowsize=0.2}
20 \pcline[nodesepB=-4](B)(O)% Mittelpunktstrahl
21 \psline[linecolor=red,linestyle=dashed](B)(B')% ruckwaertige Verlaengerung
22 \Arrows(B)(O)% Mittelpunktstrahl
23 \psOutLine[length=2,arrows=->](B)(O){END6}% Mittelpunktstrahl
24 \psline(B)(I)(F')
25 \psOutLine(I)(F'){END2}
26 \Arrows(I)(F')
27 \Arrows(B)(I)
28 \psOutLine[length=1,linestyle=dashed](I')(B'){END3}
29 \psline[linestyle=dashed](B)(F)
30 \psline(B)(I')
31 \Arrows[arrows=->>](B)(I')

```

### 3 TWO LENSES

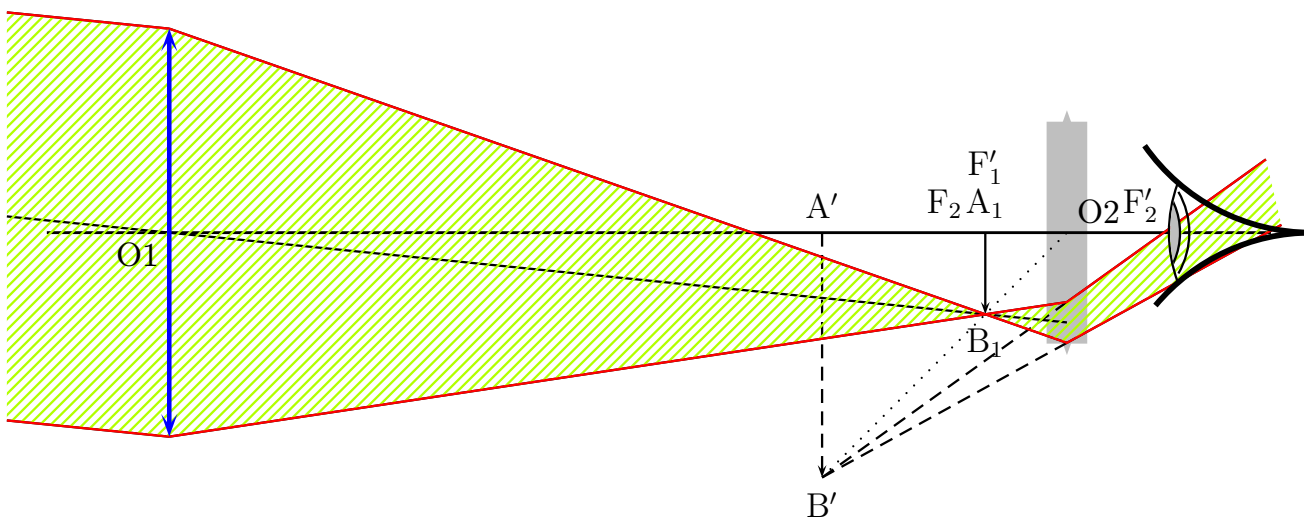
```

32 \psline[linestyle=dashed](B')(I')
33 \psline[linestyle=dashed](B')(I)
34 \psOutLine[length=2,arrows=->>](B')(I'){END4}
35 \psOutLine[length=4](B')(I'){END5}
36 \rput(8,0){\psset{linecolor=black}\eye}
37 \end{pspicture}

```

### 3 Two Lenses

This is a simple system with two lenses, where the `\lens` macro is used only once. The second lense (the left one) is drawn by the `\psline` macro.



```

1 \begin{pspicture}(-8,-3)(8,3)
2   %on place l'oculaire dès le début
3   \rput(0,0){%
4     \lens[%
5       lensScale=0.6,drawing=false,%
6       focus=1.5,OA=-1,X0=5,nameF={},nameFi={},AB=-1]%
7     \psline[linewidth=1pt](xLeft)(xRight)
8   }
9   %image intermédiaire A1B1 au foyer F'1
10  \psline{->}(4,0)(4,-1)
11  %lentille 2
12  % \psline[linewidth=2\pslinewidth,linestyle=blue]{<->}(5,1.5)(5,-1.5)
13  %On place les points essentiels
14  \pnode(-6,0){O1}
15  \pnode(-6,2.5){E1L1}%extrémité sup de L1
16  \pnode(-6,-2.5){E2L1}%extrémité inf de L1
17  \pnode(4,0){A1}
18  \pnode(4,-1){B1}
19  %intersection de O1 avec la lentille L2

```

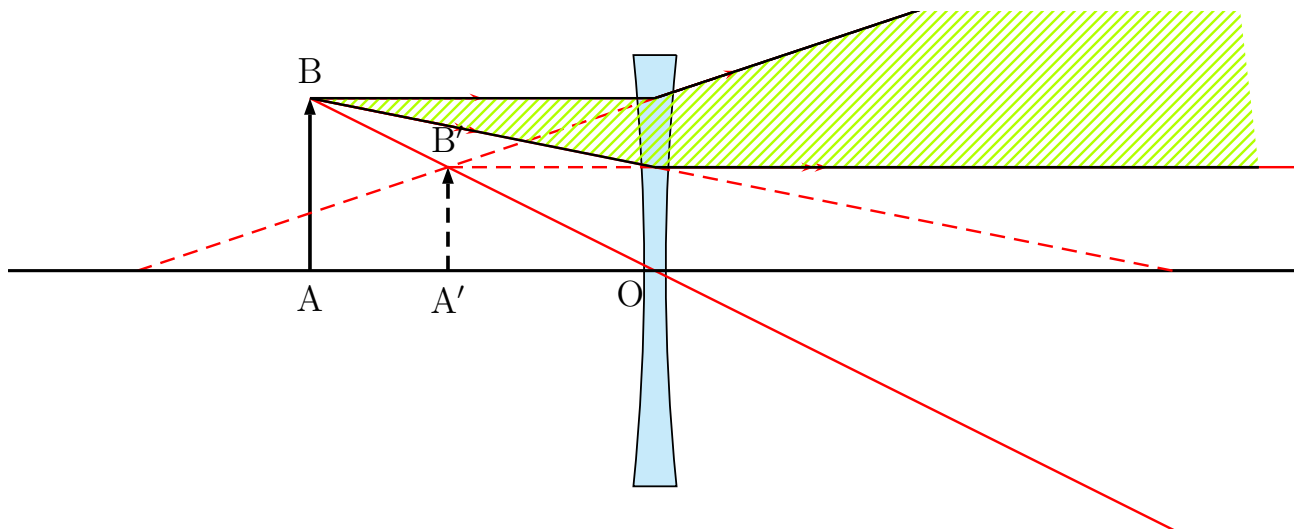
### 3 TWO LENSES

```

20 \rayInterLens(01)(B1){5}{Inter1L2}
21 %rayon venant de l'infini jusqu'à la lentille L2
22 \pcline[nodesepB=-2](Inter1L2)(01)
23 %rayon parallèle au précédent et passant par E1L1
24 \Parallel(B1)(01)(E1L1){B1infty}
25 %rayon parallèle au précédent et passant par E2L2
26 \Parallel(B1)(01)(E2L1){B2infty}
27 %intersection de la droite passant par E1L1 et B1 avec la lentille L2
28 \rayInterLens(E1L1)(B1){5}{InterE1B1L2}
29 \psline(E1L1)(InterE1B1L2)
30 %intersection de la droite passant par E2L2 et B1 avec la lentille L2
31 \rayInterLens(E2L1)(B1){5}{InterE2B1L2}
32 \psline(E2L1)(InterE2B1L2)
33 \psline[linestyle=dashed]{->}(A')(B')
34 \psline[linestyle=dashed](InterE1B1L2)(B')
35 \psline[linestyle=dashed](InterE2B1L2)(B')
36 \psline[linestyle=dotted](B')(0)
37 \psOutLine[length=3](B')(InterE1B1L2){END}
38 \psBeforeLine[length=3](InterE2B1L2)(B'){START}
39 \pspolygon[%
40 style=rayuresJaunes,%
41 linestyle=none]%
42 (B1infty)(E1L1)(InterE1B1L2)%
43 (END)(START)(InterE2B1L2)%
44 (E2L1)(B2infty)
45 \uput[90](A'){$\mathrm{A'}$}
46 \uput[270](B'){$\mathrm{B'}$}
47 \uput[90](A1){$\mathrm{A_1}$}
48 \uput[270](B1){$\mathrm{B_1}$}
49 \uput[225](01){01}
50 \uput[45](0){02}
51 \uput[90](F){$\mathrm{F_2}$}
52 \uput{0.4}[150](F'){$\mathrm{F'_2}$}
53 \uput{0.6}[90](A1){$\mathrm{F'_1}$}
54 \psline[linecolor=red](B1infty)(E1L1)(InterE1B1L2)(END)
55 \psline[linecolor=red](B2infty)(E2L1)(InterE2B1L2)(START)
56 \rput(8,0){\eye}
57 %lentille 1
58 \psline[%
59 linewidth=2\pslinewidth,%
60 linecolor=blue,%
61 arrowsize=0.2,arrowinset=0.5]{<->}(-6,-2.5)(-6,2.5)
62 \end{pspicture}

```

## 4 Real Image



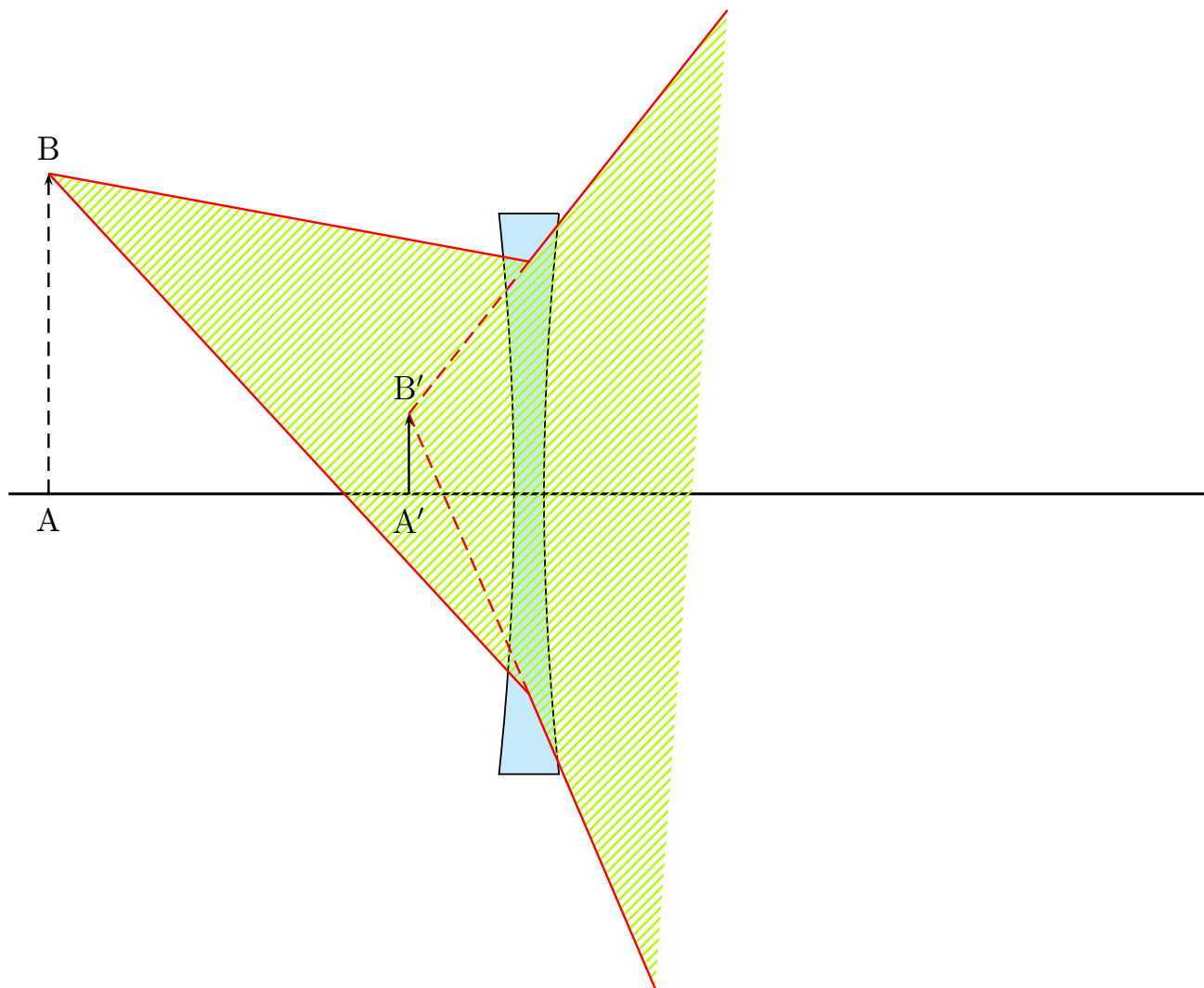
```

1 \begin{pspicture}*(-7.5,-3)(7.5,3)
2   \rput(0,0){%
3     \lens[lensGlass=true,lensWidth=0.5,lensType=DVG,%
4       X0=0,AB=2,OA=-4,focus=-6,spotAi=270,spotBi=90]%
5     \psline[linewidth=1pt](xLeft)(xRight)
6   }
7   \psline[linecolor=red,linestyle=dashed](I')(F)% Verlaengerung des Brennstrahls
8   \psOutLine[length=7](B')(I){END}
9   %pour prolonger au-delà de B' permet de définir END
10  \psBeforeLine[length=7](I')(B'){START}% permet de définir START
11  \pspolygon[style=rayuresJaunes,linestyle=none](B)(I)(END)(START)(I')
12  \psline(B)(I)(END)
13  \psline(B)(I')(START)
14 \end{pspicture}

```



## 5 Virtual Image



```

1 \begin{pspicture*}(-7.5,-6.5)(7.5,7.5)
2 \rput(0,0){%
3   \lens[lensType=DVG,lensWidth=0.75,
4     lensHeight=7,focus=-2,OA=-6,AB=4,X0=-1,lensGlass=true,%
5     rayColor=red,yBottom=-5,yTop=5,drawing=false]%
6   \psline[linewidth=1pt](xLeft)(xRight)}
7 \pnode(!X0 2.9){L1}% extrmitdelalentillesup
8 \pnode(!X0 -2.5){L2}% extrmitdelalentilleinf
9 {%
10  \psset{length=4,linestyle=none}
11  \psOutLine(B')(L1){A1}
12  \psOutLine(B')(L2){A2}
13  \pspolygon[style=rayuresJaunes,linestyle=none](B)(L1)(A1)(A2)(L2)

```

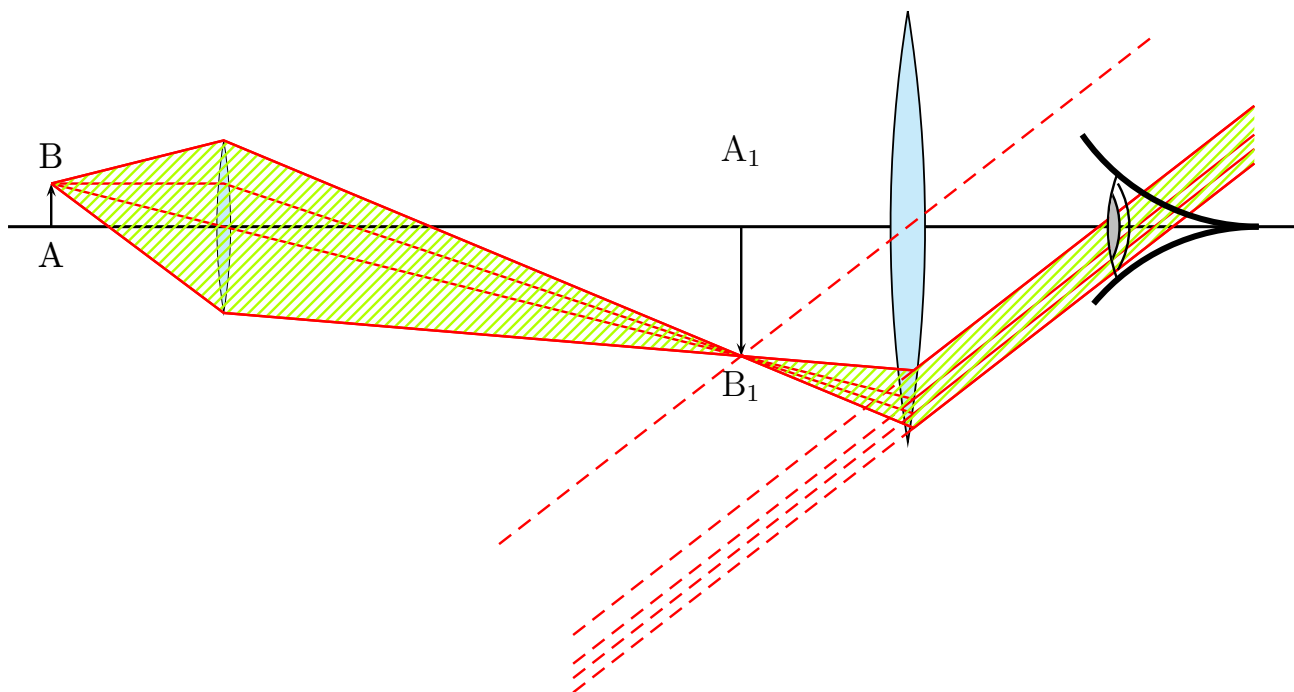
## 6 A MICROSCOPE

```

14 \psset{linecolor=red,linestyle=solid}
15 \psline(B)(L1)(A1)
16 \psline(B)(L2)(A2)%
17 \psline[linestyle=dashed](B')(L1)
18 \psline[linestyle=dashed](B')(L2)%
19 }
20 \psline[linestyle=dashed]{->}(A)(B)
21 \psline{-->}(A')(B')
22 \uput[90](B){B}
23 \uput[90](B'){$\mathrm{B'}$}
24 \uput[270](A){A}
25 \uput[270](A'){$\mathrm{A'}$}
26 \end{pspicture*}

```

## 6 A Microscope



```

1 \begin{pspicture}(-7.5,-5.5)(7.5,3)
2 \rput(0,0){%
3 \lens[focus=1.5,OA=-2,AB=0.5,X0=-5,lensGlass=true,lensWidth=0.4,%
4 yBottom=-4,yTop=4,drawing=false,lensScale=0.4,%
5 nameF=F_1,nameFi=F'_1]%
6 \psline[linewidth=1pt](xLeft)(xRight)
7 }
8 \pnode(! X0 1){UPlens1}
9 \pnode(! X0 -1){DOWNlens1}
10 \Transform
11 \rput(0,0){%
12 \lens[focus=2,X0=3,lensGlass=true,lensWidth=0.4,%

```

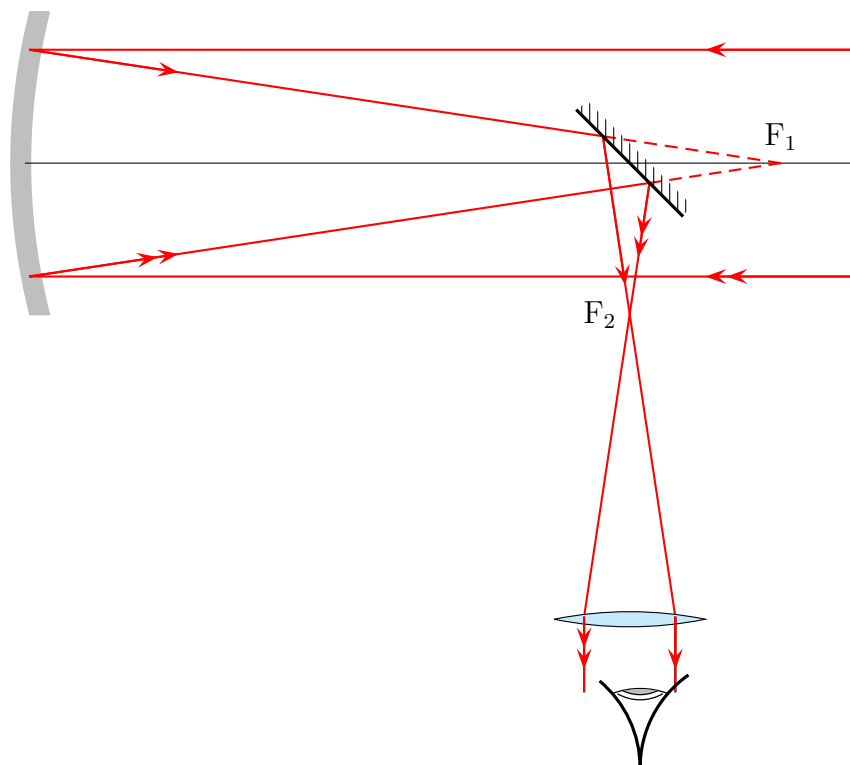
## 6 A MICROSCOPE

```

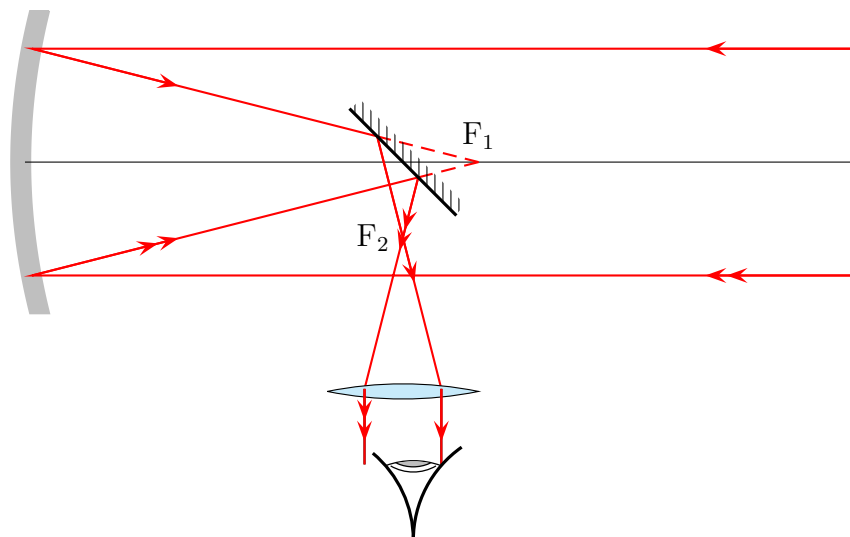
13   yBottom=-4,yTop=4,drawing=false,%
14   nameF=F_2,nameFi=F'_2,spotF=90,spotFi=90]%
15 }
16 \psline{->}(A1)(B1)
17 \psline{->}(A'1)(B'1)
18 \uput[270](A1){A}
19 \uput[90](B1){B}
20 \uput[270](B'1){$\mathrm{B}_1$}
21 \uput{0.7}[90](A'1){$\mathrm{A}_1$}
22 {\psset{linecolor=red}
23 \rayInterLens(I11)(B'1){3}{Inter1L2}
24 \rayInterLens(B1)(O1){3}{Inter2L2}
25 \rayInterLens(UPlens1)(B'1){3}{Inter3L2}
26 \rayInterLens(DOWNlens1)(B'1){3}{Inter4L2}
27 \psline(B1)(I11)(B'1)(Inter1L2)
28 \psline(B1)(Inter2L2)
29 \psline(B1)(UPlens1)(Inter3L2)
30 \psline(B1)(DOWNlens1)(Inter4L2)
31 \psset{length=5}
32 \Parallel(B'1)(O)(Inter3L2){B1inftyRigth}
33 \Parallel(B'1)(O)(Inter4L2){B2inftyRigth}
34 \Parallel(B'1)(O)(Inter2L2){B3inftyRigth}
35 \Parallel(B'1)(O)(Inter1L2){B3inftyRigth}
36 {\psset{length=-5,linestyle=dashed}
37 \Parallel(B'1)(O)(Inter3L2){B1inftyLeft}
38 \Parallel(B'1)(O)(Inter4L2){B2inftyLeft}
39 \Parallel(B'1)(O)(Inter2L2){B3inftyLeft}
40 \Parallel(B'1)(O)(Inter1L2){B3inftyLeft}
41 \pcline[nodesep=6](B'1)(O)}
42 \pspolygon[style=rayuresJaunes,linestyle=none]%
43   (B1)(UPlens1)(Inter3L2)%
44   (B1inftyRigth)(B2inftyRigth)(Inter4L2)(DOWNlens1)
45 \psline(B1)(UPlens1)(Inter3L2)(B1inftyRigth)
46 \psline(B2inftyRigth)(Inter4L2)(DOWNlens1)(B1)}
47 \rput(7,0){\eye}
48 \end{pspicture}

```

## 7 Telescope



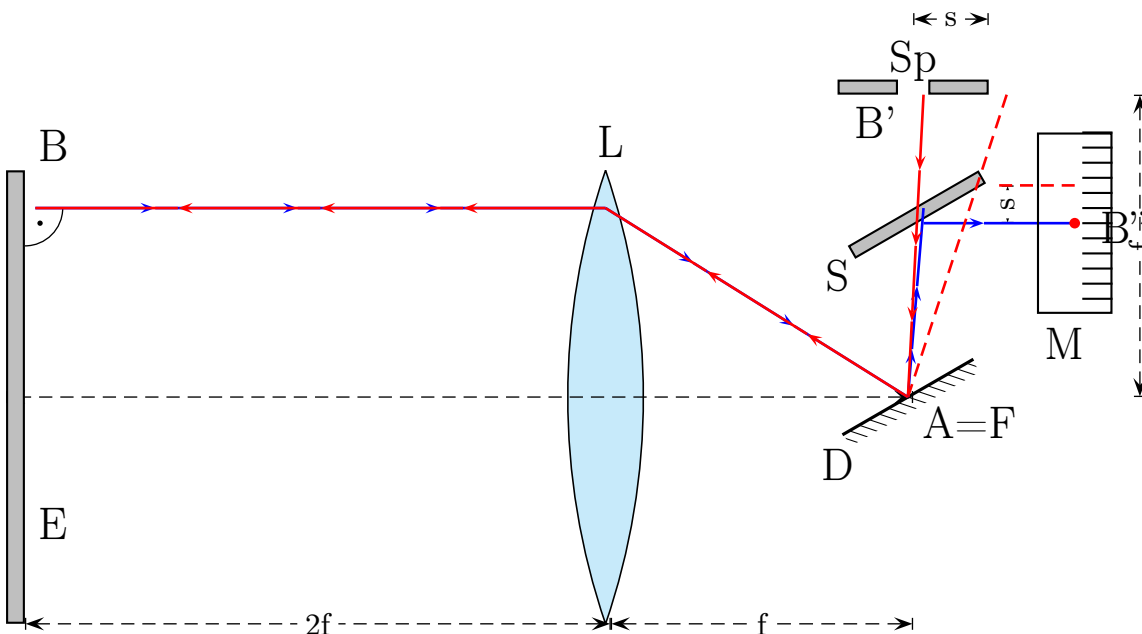
```
1 \telescope[mirrorFocus=10,posMirrorTwo=8,yBottom=-8]
```



```
1 \telescope[mirrorFocus=6,posMirrorTwo=5,yBottom=-5]
```

## 8 Lightspeed measured by Foucault

1849 Foucault (1819-1868) determines with the following configuration the speed of the light.



Sp chink;  
D rotating mirror;  
L collecting lens;  
E end mirror;  
S half diaphanous mirror;  
M scale

```

1 \begin{pspicture}(-8,-5)(7,6)
2   \rput(0,0){\lens[lensWidth=1,lensGlass=true,%
3     lensHeight=6,focus=4,drawing=false,AB=2.5]}
4   {%
5     \psset{linewidth=0.5pt,linestyle=dashed,arrowsize=5pt,arrows=|<->|}
6     \psline(-8,0)(4,0)
7     \pcline(-7.75,-3)(0,-3)
8     \lput*{:U}{2f}
9     \pcline(0,-3)(4,-3)
10    \lput*{:U}{f}
11    \pcline(7,0)(7,4)
12    \lput*{:U}{f}
13    \pcline(4,5)(5,5)
14    \lput*{:U}{s}
15    \pcline(5.25,2.3)(5.25,2.8)
16    \lput*{:U}{s}

```

## 8 LIGHTSPEED MEASURED BY FOUCAULT

```

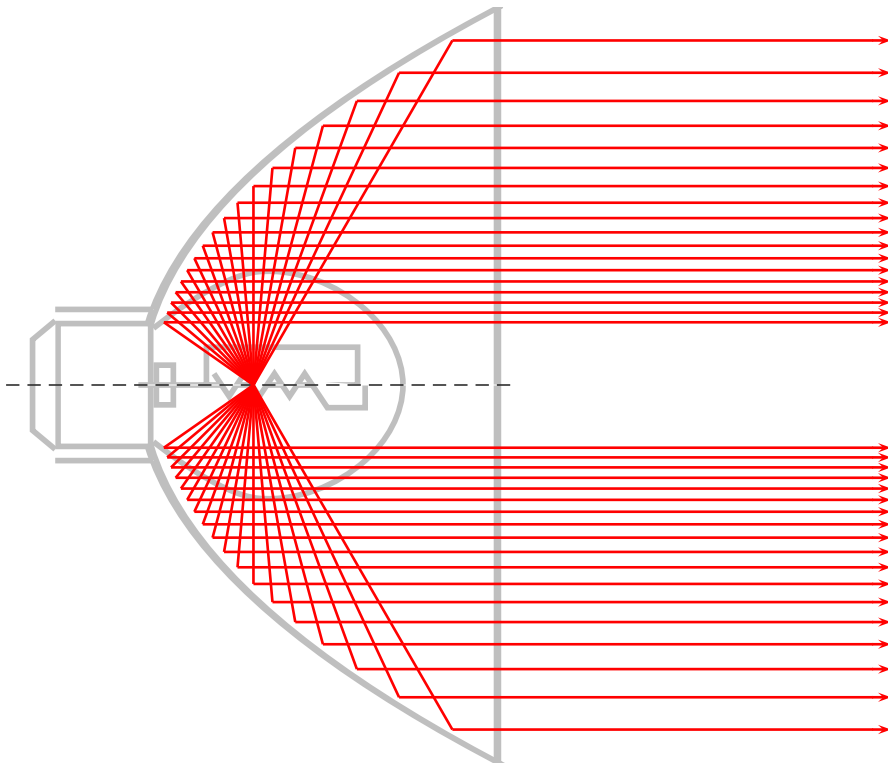
17 }
18 \uput[90](0,3){\Large L}
19 \uput[45](-7.7,3){\Large B}
20 \uput[45](-7.7,-2){\Large E}
21 \uput[270](3,-0.5){\Large D}
22 \uput[-45](4,0){\Large A=F}
23 \uput[270](3,2){\Large S}
24 \uput[90](4,4){\Large Sp}
25 \uput[90](3.5,3.25){\Large B'}
26 \uput[0](6.3,2.25){\Large B''}
27 \uput[-90](6,1.1){\Large M}
28 \psarc[linewidth=0.5pt](-7.75,2.5){0.5}{-90}{0}\qdisk(-7.55,2.3){1pt}
29 \rput{210}(F'){\mirrorTwo}
30 {%
31   \psset{fillstyle=solid,fillcolor=lightgray}
32   \rput{210}(4,2.5){\psframe(-1,0)(1,0.2)}
33   \psframe(-8,-3)(-7.75,3)
34   \psframe(3,4)(3.8,4.2)\psframe(4.2,4)(5,4.2)%
35 }{%
36   \psset{linewidth=1pt,linecolor=red,arrows=->,%
37     arrowsize=5pt}
38   \arrowLine[linecolor=blue,arrowOffset=-0.2](F')(4,2.5){2}
39   \arrowLine[linecolor=blue,arrowOffset=-0.2](4,2.3)(6,2.3){1}
40   \qdisk(6,2.3){2pt}
41   \psline[linestyle=dashed,arrows=-](F')(5.1,4)
42   \psline[linestyle=dashed,arrows=-](5,2.8)(6,2.8)
43   \arrowLine(4,4)(F'){3}
44   \arrowLine[linecolor=blue,arrowOffset=-0.2](I)(F'){2}
45   \arrowLine(F')(I){2}
46   \arrowLine[linecolor=blue,arrowOffset=-0.3](-7.75,2.5)(I){3}
47   \arrowLine(I)(-7.75,2.5){3}
48 }
49 \psframe(5.5,1.1)(6.5,3.5)
50 \multido{\r=1.3+0.2}{12}{%
51   \psline(6.1,\r)(6.5,\r)%
52 }
53 \end{pspicture}

```

## Part II

# Mirrors

## 9 High Beam Light



```

1 \begin{pspicture}(-1.5,-5.5)(10,5.5)
2 \rput(0,0){%
3   \beamLight[drawing=false,%
4     mirrorDepth=4.75,%
5     mirrorWidth=0.1,%
6     mirrorHeight=10,%
7     linecolor=lightgray]}
8 \makeatletter
9 \pst@getcoor{Focus}\pst@tempf
10 \psset{linewidth=1pt,linecolor=red}
11 \multido{\n=60+5}{18}{%
12   \mirrorCVGRay[linecolor=red,%
13     mirrorDepth=4.75,%
14     mirrorHeight=10,%
15     linewidth=1pt](Focus)(!%
16     /XF \pst@tempf pop \pst@number\psxunit div def
17     \n\space cos XF add \n\space sin neg){Endd1}
18   \psOutLine[arrows=->,length=.25](Endd1)(Endd1'){Endd2}%
19   \mirrorCVGRay[linecolor=red,%

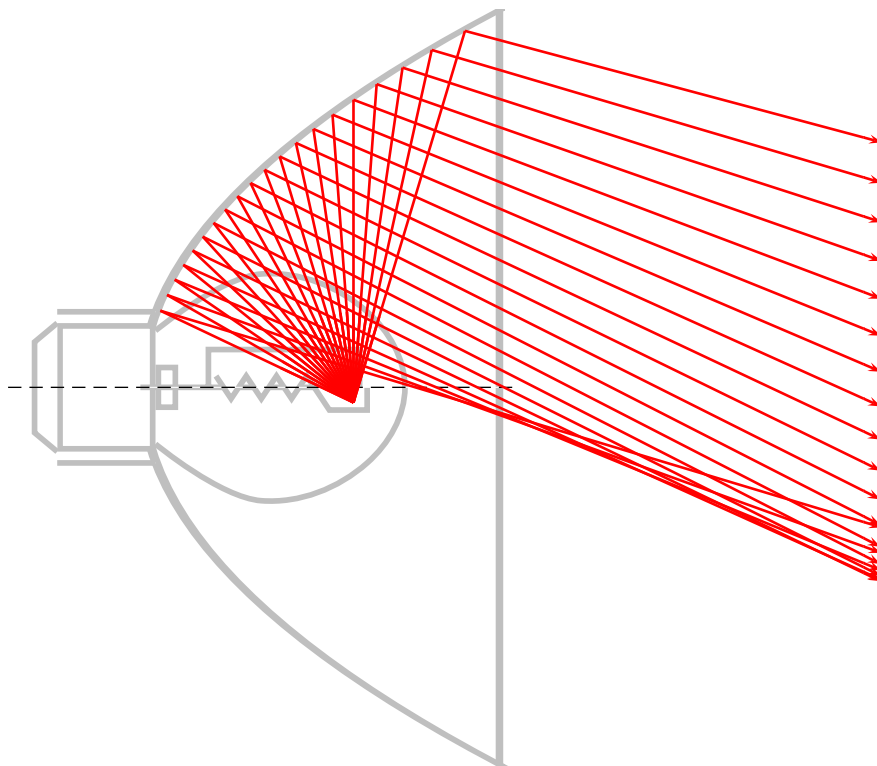
```

```

20     mirrorDepth=4.75,%
21     mirrorHeight=10,%
22     linewidth=1pt](Focus)(!%
23     /XF \pst@tempf pop \pst@number\psxunit div def
24     \n\space cos XF add \n\space sin ){End1}
25     \psOutLine[arrows=->,length=.25](End1)(End1''){End2}%
26 }
27 \makeatletter
28 \end{pspicture}

```

## 10 Low Beam Light



```

1 \begin{pspicture}(-1.5,-5)(10,5)
2   \rput(0,0){%
3     \beamLight[drawing=false,%
4       mirrorDepth=4.75,%
5       mirrorWidth=0.1,%
6       mirrorHeight=10,%
7       linecolor=lightgray]}
8   {%
9     \psset{linewidth=1pt,linecolor=red}
10    \multido{\n=70+5}{20}{%
11      \psline(2.75,-0.2)(! \n\space cos 2.75 add \n\space sin )
12      \mirrorCVGRay[linecolor=red,%
13        mirrorDepth=4.75,%
14        mirrorHeight=10,%
15        linewidth=1pt](2.75,-0.2)%

```



## 10 LOW BEAM LIGHT

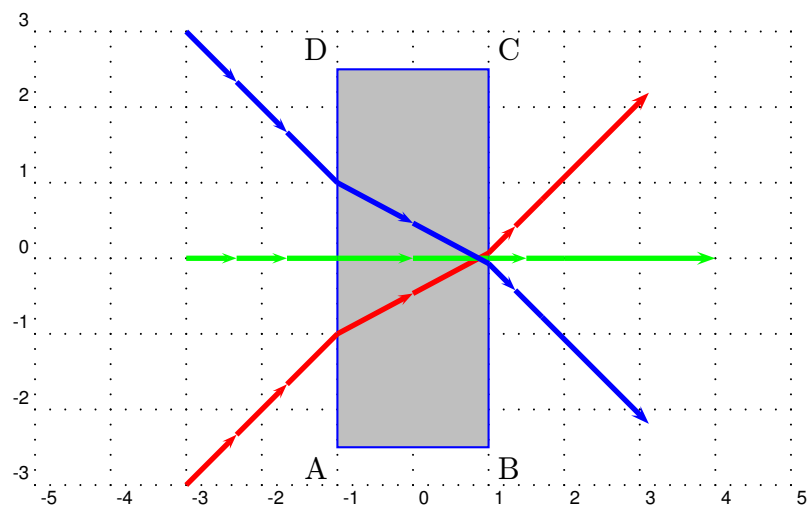
```
16      (! \n\space cos 2.75 add \n\space sin ){End1}  
17      \psOutLine[arrows=->,length=.25](End1)(End1'') {End2}%  
18      }  
19 \end{pspicture}
```

# Part III

## Refraction

### 11 Vertical Medium

Refraction numbers are  $n_1 = 1$  and  $n_2 = 1.5$ :



```

1 \begin{pspicture}(-5,-3)(5,3)
2 \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3 \pnode(-1,-2.5){A}
4 \pnode(1,-2.5){B}
5 \pnode(1,2.5){C}
6 \pnode(-1,2.5){D}
7 % \rotateFrame(A)(B)(C)(D){10}
8 \uput[-135](A){A}\uput[-45](B){B}
9 \uput[45](C){C}\uput[135](D){D}
10 \pspolygon[fillcolor=lightgray,fillstyle=solid,linecolor=blue](A)(B)(C)(D)
11 %
12 % 1.
13 %
14 \refractionRay(-3,-3)(-2,-2)(D)(A){1}{1.5}{END}
15 \psset{linecolor=red,linewidth=2pt,arrowsize=5pt,arrows=->}
16 \arrowLine(-3,-3)(END){2}
17 \ABinterCD(END)(END')(C)(B){Out}
18 \arrowLine(END)(Out){1}
19 \refractionRay(END)(Out)(C)(B){1.5}{1}{Q}
20 \arrowLine(Q)(Q'){1}
21 \psOutLine[length=2](Q)(Q'){End}
22 %
23 % 2.
24 \refractionRay(-3,0)(-2,0)(A)(D){1}{1.5}{END}
25 \psset{linecolor=green,linewidth=2pt,arrowsize=5pt,arrows=->}
26 \arrowLine(-3,0)(END){2}
27 \ABinterCD(END)(END')(C)(B){Out}
28 \arrowLine(END)(Out){1}

```

## 12 HORIZONTAL MEDIUM

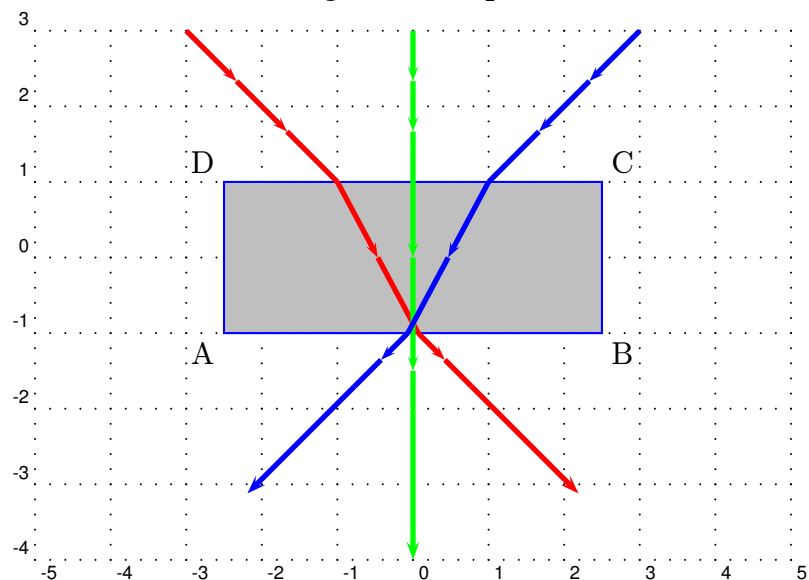
```

29 \refractionRay(END)(Out)(C)(B){1.5}{1}{Q}
30 \arrowLine(Q)(Q'){1}
31 \psOutLine[length=2](Q)(Q'){End}
32 %
33 % 3.
34 %
35 \refractionRay(-3,3)(-2,2)(D)(A){1}{1.5}{END}
36 \psset{linecolor=blue,linewidth=2pt,arrowsize=5pt,arrows=->}
37 \arrowLine(-3,3)(END){2}
38 \ABinterCD(END)(END')(C)(B){Out}
39 \arrowLine(END)(Out){1}
40 \refractionRay(END)(Out)(C)(B){1.5}{1}{Q}
41 \arrowLine(Q)(Q'){1}
42 \psOutLine[length=2](Q)(Q'){End}
43 \end{pspicture}

```

## 12 Horizontal Medium

Refraction numbers are  $n_1 = 1$  and  $n_2 = 1.5$ :



```

1 \begin{pspicture}(-5,-4)(5,3)
2 \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3 \pnode(-2.5,-1){A}
4 \pnode(2.5,-1){B}
5 \pnode(2.5,1){C}
6 \pnode(-2.5,1){D}
7 \uput[-135](A){A}\uput[-45](B){B}
8 \uput[45](C){C}\uput[135](D){D}
9 \pspolygon[fillcolor=lightgray,fillstyle=solid,linecolor=blue](A)(B)(C)(D)
10 %
11 % 1.
12 %
13 \refractionRay(-3,3)(-2,2)(C)(D){1}{1.5}{END}
14 \psset{linecolor=red,linewidth=2pt,arrowsize=5pt,arrows=->}
15 \arrowLine(-3,3)(END){2}

```

### 13 PARALLEL RAYS AND A SLOPING MEDIUM

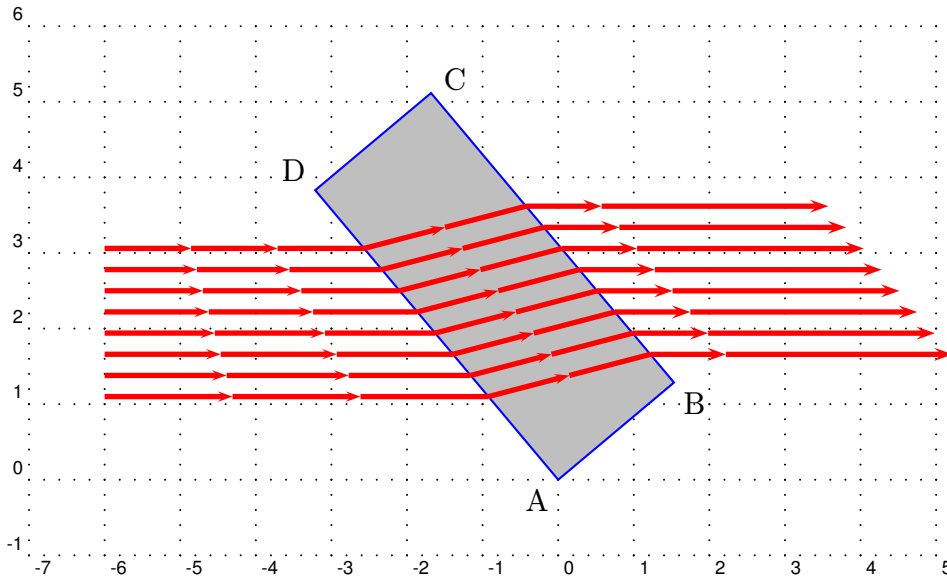
```

16 \ABinterCD(END)(END')(B)(A){Out}
17 \arrowLine(END)(Out){1}
18 \refractionRay(END)(Out)(B)(A){1.5}{1}{Q}
19 \arrowLine(Q)(Q'){1}
20 \psOutLine[length=2](Q)(Q'){End}
21 %
22 % 2.
23 %
24 \refractionRay(0,3)(0,1)(C)(D){1}{1.5}{END}
25 \psset{linecolor=green,linewidth=2pt,arrowsize=5pt,arrows=->}
26 \arrowLine(0,3)(END){2}
27 \ABinterCD(END)(END')(A)(B){Out}
28 \arrowLine(END)(Out){1}
29 \refractionRay(END)(Out)(B)(A){1.5}{1}{Q}
30 \arrowLine(Q)(Q'){1}
31 \psOutLine[length=2](Q)(Q'){End}
32 %
33 % 3.
34 %
35 \refractionRay(3,3)(2,2)(C)(D){1}{1.5}{END}
36 \psset{linecolor=blue,linewidth=2pt,arrowsize=5pt,arrows=->}
37 \arrowLine(3,3)(END){2}
38 \ABinterCD(END)(END')(B)(A){Out}
39 \arrowLine(END)(Out){1}
40 \refractionRay(END)(Out)(B)(A){1.5}{1}{Q}
41 \arrowLine(Q)(Q'){1}
42 \psOutLine[length=2](Q)(Q'){End}
43 \end{pspicture}

```

## 13 Parallel Rays and a sloping medium

Refraction numbers are  $n_1 = 1$  and  $n_2 = 1.5$ :



```

1 \begin{pspicture}(-7,-1)(5,6)
2 \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]

```

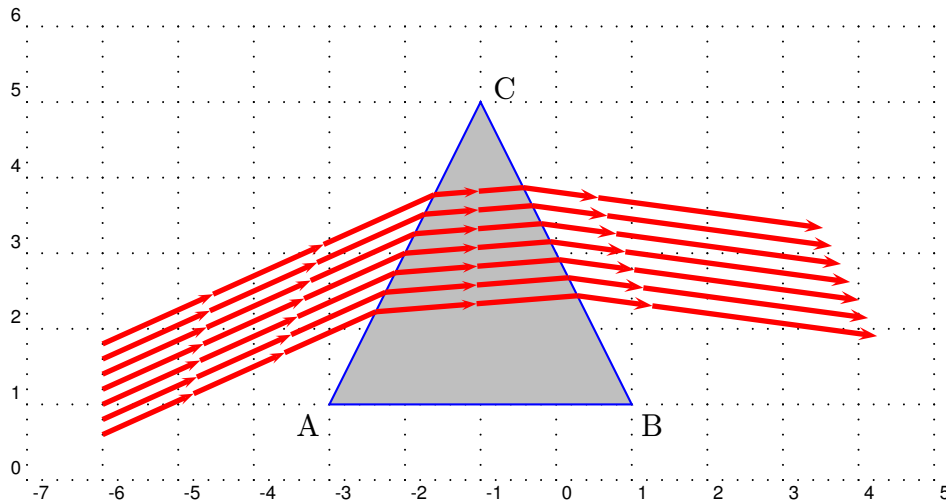
```

3 \pnode(0,0){A}
4 \pnode(2,0){B}
5 \pnode(2,5){C}
6 \pnode(0,5){D}
7 \rotateFrame(A)(B)(C)(D){45}
8 \uput[-135](A){A}\uput[-45](B){B}
9 \uput[30](C){C}\uput[135](D){D}
10 \pspolygon[fillcolor=lightgray,fillstyle=solid,linecolor=blue](A)(B)(C)(D)
11 \psset{linecolor=red,linewidth=2pt,arrowsize=5pt,arrows=->}
12 \multido{\r=3.0+-0.3}{8}{%
13   \refractionRay(-7,\r)(-4,\r)(D)(A){1}{1.25}{END}
14   \arrowLine(-7,\r)(END){2}
15   \ABinterCD(END)(END')(C)(B){Out}
16   \arrowLine(END)(Out){1}
17   \refractionRay(END)(Out)(C)(B){1.25}{1}{Q}
18   \psline(Q)(Q')}
19 \psOutLine[length=3](Q)(Q'){End}%
20 }
21 \end{pspicture}

```

## 14 A Prisma

Refractionnumbers are  $n_1 = 1$  and  $n_2 = 1.5$ :



```

1 \begin{pspicture}(-7,0)(5,6)
2   \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3   \pnode(-3,1){A}\pnode(1,1){B}\pnode(-1,5){C}
4   \uput[-135](A){A}\uput[-45](B){B}\uput[30](C){C}
5   \pspolygon[fillcolor=lightgray,fillstyle=solid,linecolor=blue](A)(B)(C)
6   \psset{linecolor=red,linewidth=2pt,arrowsize=5pt,arrows=->}
7   \multido{\rA=0.6+0.2,\rB=1.5+0.2}{7}{%
8     \refractionRay(-6,\rA)(-4,\rB)(C)(A){1}{1.5}{END}
9     \arrowLine(-6,\rA)(END){2}
10    \ABinterCD(END)(END')(C)(B){Out}
11    \arrowLine(END)(Out){1}
12    \refractionRay(END)(Out)(C)(B){1.5}{1}{Q}

```

```

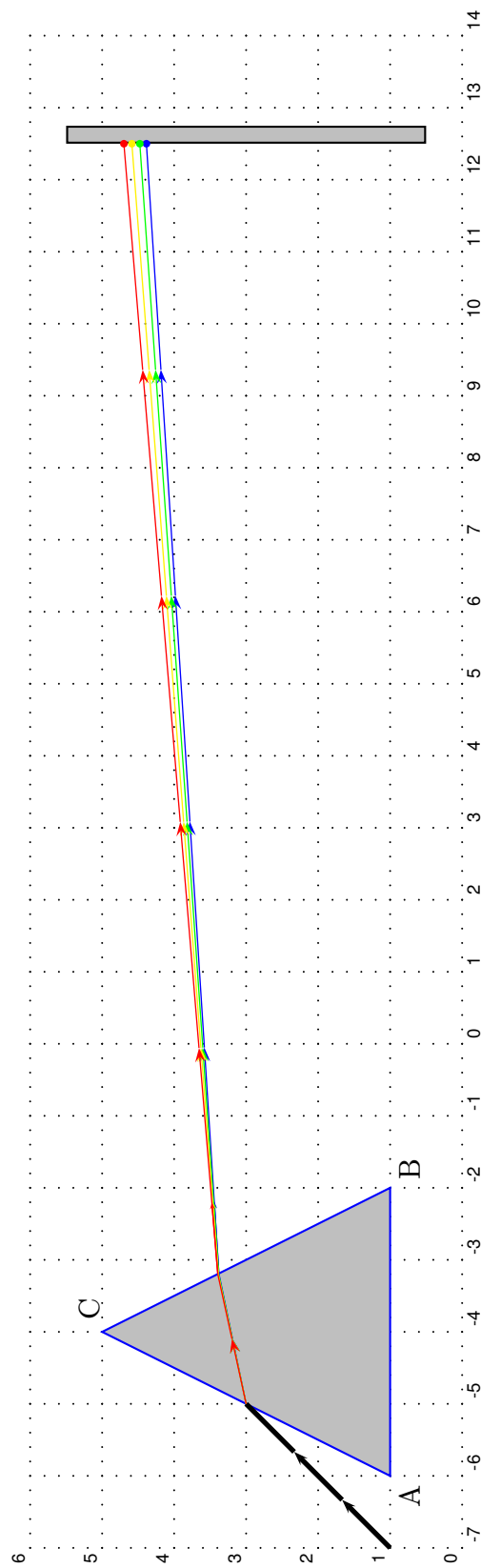
13   \psline(Q)(Q')
14   \psOutline[length=3](Q)(Q'){End}%
15   }
16 \end{pspicture}

```

## 15 A Prisma for Dispersion

The following figure shows the lioght dispersion with realistic values for the refractions numbers of the different light colors.

Color	Refraction number $n$ for glass
dark blue	1.528
bluegreen	1.523
yellow	1.517
red	1.514
darkred	1.511



```

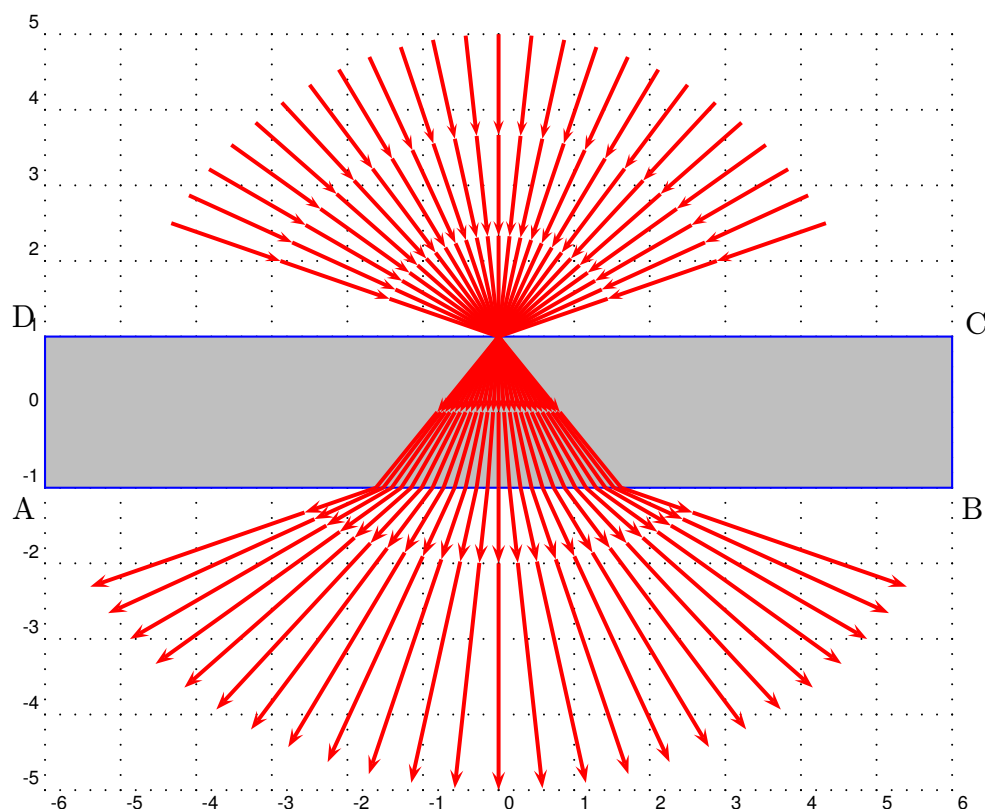
1 \begin{pspicture}(-7,0)(14,6)
2 \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3 \pnode(-6,1){A}\pnode(-2,1){B}\pnode(-4,5){C}
4 \uput[-135](A){A}\uput[-45](B){B}\uput[30](C){C}
5 \pnode(12.5,0.5){E1}\pnode(12.5,5.5){E2}
6 \psframe[fillcolor=lightgray,fillstyle=solid](E1)(12.75,5.5)
7 \pspolygon[fillcolor=lightgray,fillstyle=solid,linecolor=blue](A)(B)(C)
8 \psset{linecolor=black,linewidth=2pt,arrowsize=5pt,arrows=->}
9 \pnode(-7,1){P1}\pnode(-6,2){P2}
10 \ABinterCD(P1)(P2)(C)(A){END}
11 \arrowLine(P1)(END){2}
12 %
13 \psset{linecolor=blue,linewidth=0.5pt,arrowsize=2pt,}
14 \refractionRay(P1)(P2)(C)(A){1}{1.528}{END}
15 \ABinterCD(END)(END')(C)(B){Out}
16 \arrowLine(END)(Out){1}
17 \refractionRay(END)(Out)(C)(B){1.528}{1}{Q}
18 \psline(Q)(Q')
19 \ABinterCD(Q)(Q')(E1)(E2){END}
20 \arrowLine(Q)(END){4}\qdisk(END){1.5pt}
21 %
22 \psset{linecolor=green}
23 \refractionRay(P1)(P2)(C)(A){1}{1.523}{END}
24 \ABinterCD(END)(END')(C)(B){Out}
25 \arrowLine(END)(Out){1}
26 \refractionRay(END)(Out)(C)(B){1.523}{1}{Q}
27 \psline(Q)(Q')
28 \ABinterCD(Q)(Q')(E1)(E2){END}
29 \arrowLine(Q)(END){4}\qdisk(END){1.5pt}
30 %
31 \psset{linecolor=yellow}
32 \refractionRay(P1)(P2)(C)(A){1}{1.517}{END}
33 \ABinterCD(END)(END')(C)(B){Out}
34 \arrowLine(END)(Out){1}
35 \refractionRay(END)(Out)(C)(B){1.517}{1}{Q}
36 \psline(Q)(Q')
37 \ABinterCD(Q)(Q')(E1)(E2){END}
38 \arrowLine(Q)(END){4}\qdisk(END){1.5pt}
39 %
40 \psset{linecolor=red}
41 \refractionRay(P1)(P2)(C)(A){1}{1.511}{END}
42 \ABinterCD(END)(END')(C)(B){Out}
43 \arrowLine(END)(Out){1}
44 \refractionRay(END)(Out)(C)(B){1.511}{1}{Q}
45 \psline(Q)(Q')
46 \ABinterCD(Q)(Q')(E1)(E2){END}
47 \arrowLine(Q)(END){4}\qdisk(END){1.5pt}
48 \end{pspicture}

```



## 16 Refraction with different Angles

Refraction numbers are  $n_1 = 1$  and  $n_2 = 1.5$ :



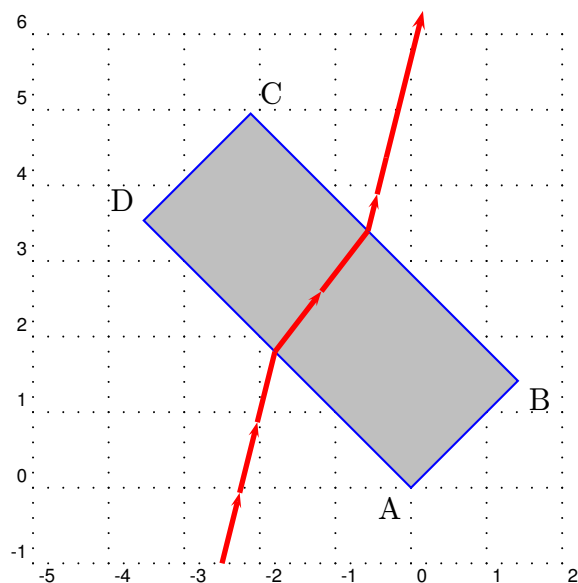
```

1 \begin{pspicture}(-6,-5)(6,5)
2   \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3   \pnode(-6,-1){A}\pnode(6,-1){B}\pnode(6,1){C}\pnode(-6,1){D}
4   \uput[-135](A){A}\uput[-45](B){B}
5   \uput[30](C){C}\uput[135](D){D}
6   \pspolygon[fillcolor=lightgray,fillstyle=solid,linecolor=blue](A)(B)(C)(D)
7   \psline[linewidth=0.5pt](0,-5)(0,5)
8   \psset{linecolor=red,linewidth=1.5pt,arrowsize=5pt,arrows=->}
9   \multido{\n=30+5}{25}{%
10    \refractionRay(5;\n)(0,1)(C)(D){1}{1.5}{END}
11    \arrowLine(5;\n)(END){2}
12    \ABinterCD(END)(END')(B)(A){Out}
13    \arrowLine(END)(Out){1}
14    \refractionRay(END)(Out)(B)(A){1.5}{1}{Q}
15    \psline(Q)(Q')
16    \psOutLine[length=3](Q)(Q'){End}%
17  }
18 \end{pspicture}

```

## 17 Great difference in the Refractionsnumbers

Refractionnumbers are  $n_1 = 1$  and  $n_2 = 4$ :



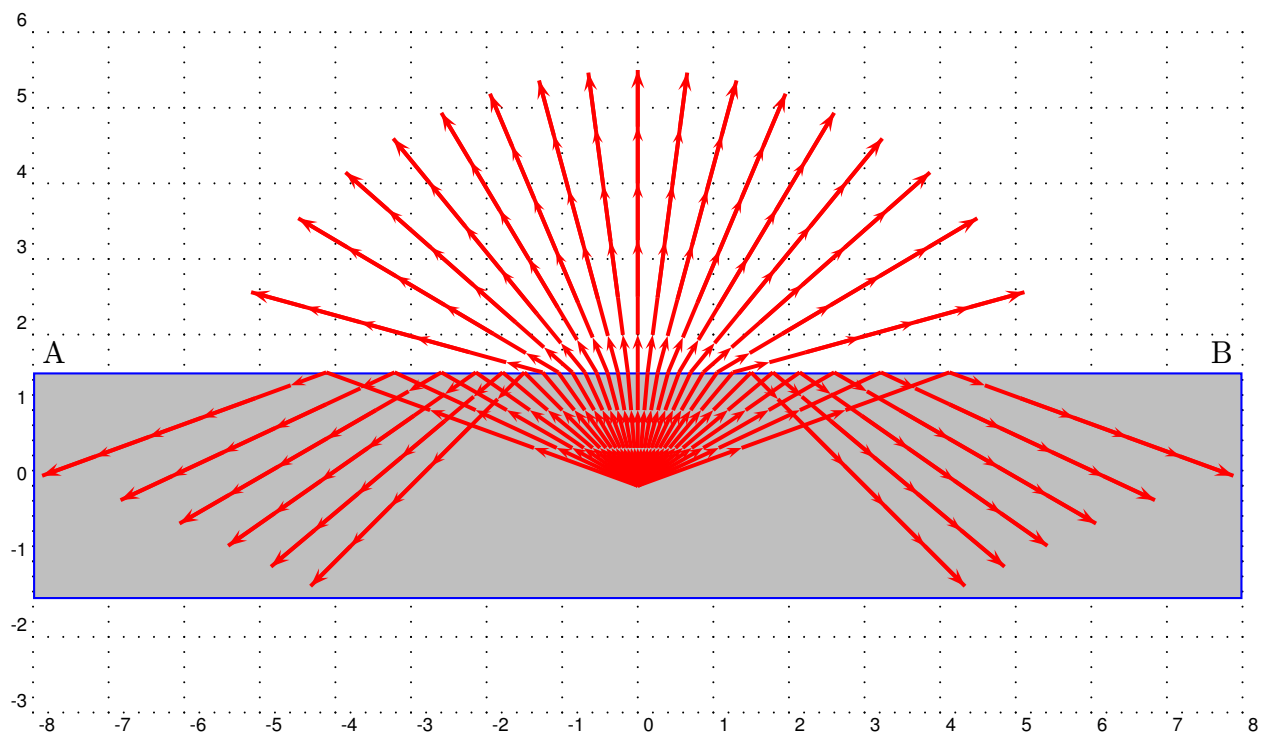
```

1 \begin{pspicture}(-5,-1)(2,6)
2   \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3   \pnode(0,0){A}
4   \pnode(2,0){B}
5   \pnode(2,5){C}
6   \pnode(0,5){D}
7   \rotateFrame(A)(B)(C)(D){45}
8   \uput[-135](A){A}\uput[-40](B){B}
9   \uput[45](C){C}\uput[135](D){D}
10  \pspolygon[fillcolor=lightgray,fillstyle=solid,linecolor=blue](A)(B)(C)(D)
11  \refractionRay(-2.5,-1)(-2,1)(D)(A){1}{4}{END}
12  \psset{linecolor=red,linewidth=2pt,arrowsize=5pt,arrows=->}
13  \arrowLine(-2.5,-1)(END){2}
14  \ABinterCD(END)(END')(C)(B){Out}
15  \arrowLine(END)(Out){1}
16  \refractionRay(END)(Out)(C)(B){4}{1}{Q}
17  \arrowLine(Q)(Q'){1}
18  \psOutLine[length=2](Q)(Q'){End}
19 \end{pspicture}

```

## 18 Total Reflection

Refraction numbers are  $n_1 = 2$  and  $n_2 = 1$ :



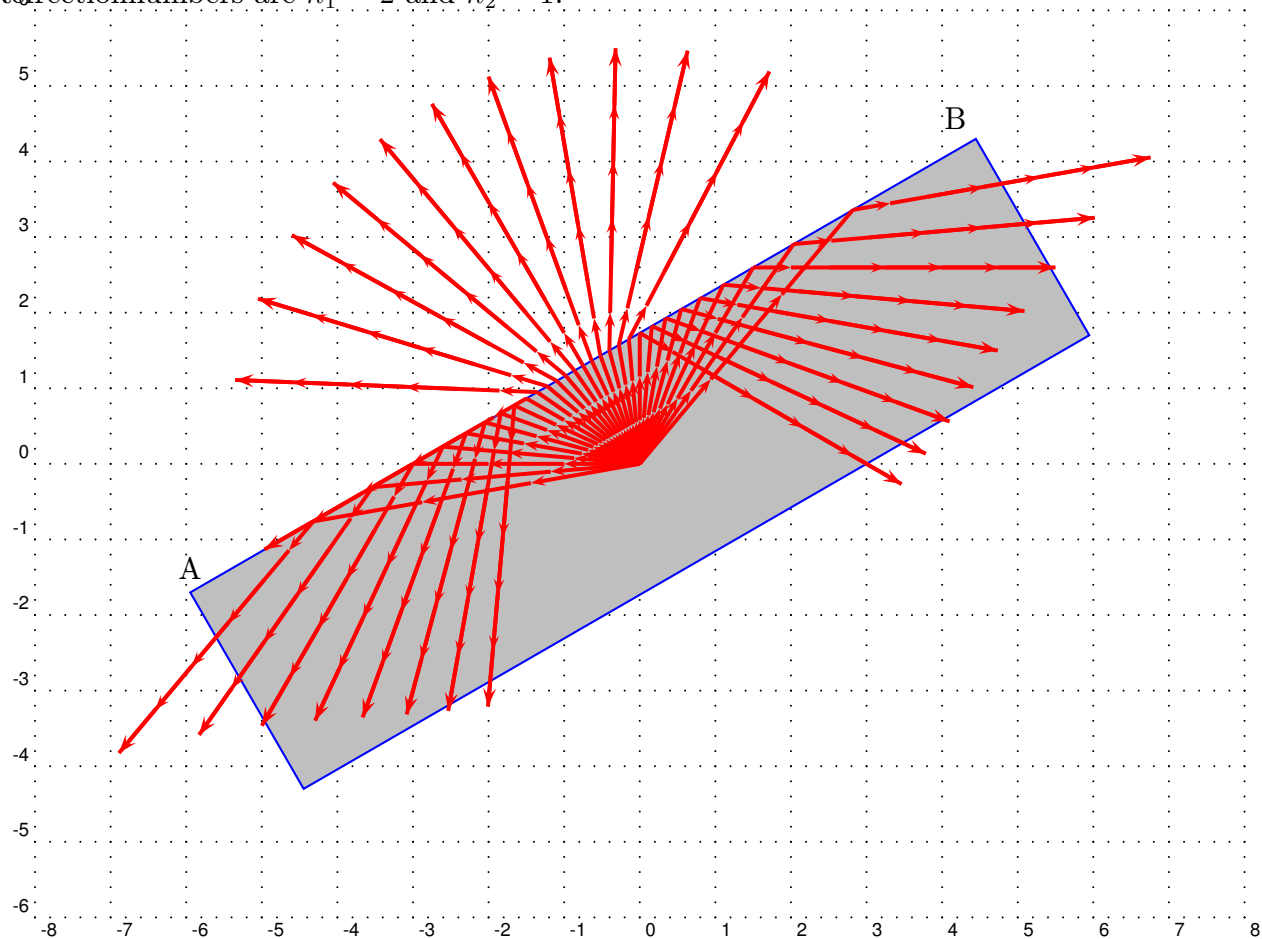
```

1 \begin{pspicture}(-8,-3)(8,6)
2 \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3 \pnode(-8,1.5){A}\pnode(8,1.5){B}
4 \uput[45](A){A}\uput[135](B){B}
5 \pnode(0,0){START}
6 \psframe[fillcolor=lightgray,fillstyle=solid,linecolor=blue](-8,-1.5)(B)
7 \psset[linecolor=red,linewidth=1.5pt,arrowsize=5pt,arrows=->}
8 \multido{\n=20+5}{29}{%
9 \refractionRay(START)(1;\n)(A)(B){2}{1}{END}
10 \arrowLine(START)(END){2}
11 \arrowLine(END)(END'){1}
12 \psOutLine[length=3](END)(END'){Q}
13 \arrowLine(END')(Q){3}
14 }
15 \end{pspicture}

```

## 19 Total Reflection with a sloping medium

Refraction numbers are  $n_1 = 2$  and  $n_2 = 1$ :



```

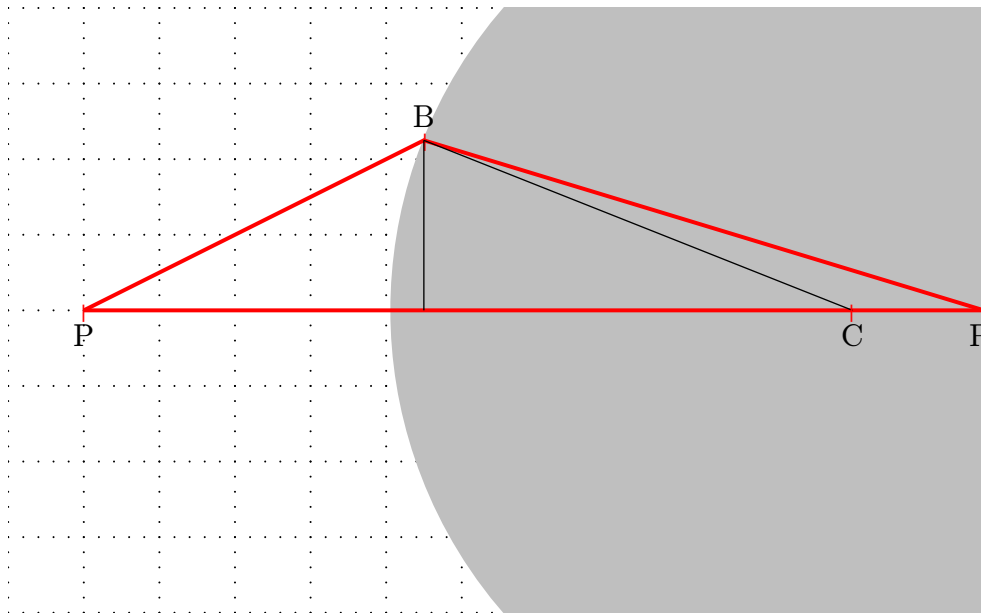
1 \begin{pspicture}(-8,-6)(8,6)
2 \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3 \pnode(-6,1.5){A}\pnode(6,1.5){B}
4 \pnode(6,-1.5){C}\pnode(-6,-1.5){D}
5 \rotateFrame(A)(B)(C)(D){30}
6 \uput[90](A){A}\uput[135](B){B}
7 \pnode(0,0){START}
8 \pspolygon[fillcolor=lightgray,fillstyle=solid,linecolor=blue](A)(B)(C)(D)
9 \psset{linecolor=red,linewidth=1.5pt,arrowsize=5pt,arrows=->}
10 \multido{\n=50+5}{29}{%
11 \refractionRay(START)(1;\n)(A)(B){2}{1}{END}
12 \arrowLine(START)(END){2}
13 \arrowLine(END)(END'){1}
14 \psOutLine[length=3](END)(END'){Q}
15 \arrowLine(END')(Q){3}
16 }
17 \end{pspicture}

```

## Part IV

## Spherical Optic

## 20 Refraction at a Spherical Surface

20.1 Construction for finding the position of the image point  $P'$  of a point object  $P$  formed by refraction at a spherical surface

```

1 \begin{pspicture}*(-10,-4)(3,4)
2 \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3 \rput(0,0){\lensSPH[%
4   lensType=CVG,%
5   lensHeight=12,%
6   lensWidth=10,%
7   yBottom=-4,yTop=4,xLeft=-5,xRight=5,%
8   drawing=false]}
9 \psset{linecolor=red,linewidth=1.5pt,dotstyle=|}
10 \pnode(-9,0){P}\psdots(P)\uput[-90](P){P}
11 \psline(P)(xRight)
12 \lensSPHray(P)(-5,2){1}{9}{Q}%
13 \psline(P)(Q)(Q')
14 \psdots(Q)\uput[90](Q){B}
15 \ABinterCD(Q)(Q')(0,0)(5,0){P'}
16 \psdots(Q')\uput[-90](P'){P'}
17 \psline[linewidth=0.5pt,linecolor=black](Center')(Q)
18 \psline[linewidth=0.5pt,linecolor=black](Q)(Q|0,0)
19 \psdots(Center')\uput[-90](Center'){C}
20 \end{pspicture}

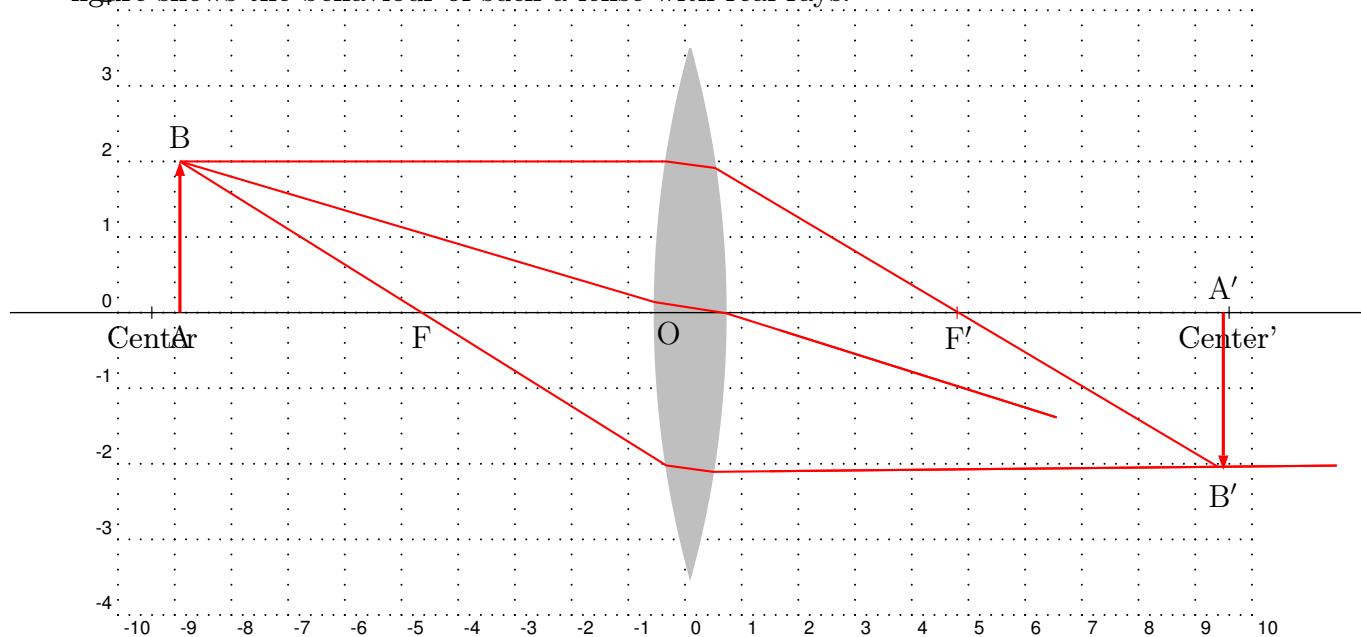
```

The diagram illustrates a geometric construction on a grid. A point  $Q$  is located at the top left. A vertical blue arrow points from a point  $P$  to  $Q$ . A horizontal red line segment extends from  $P$  to the right, passing through a point  $C$  and ending at a point  $P'$ . A red line segment connects  $Q$  to  $P'$ . Another red line segment connects  $Q$  to a point on the horizontal line between  $P$  and  $C$ . A gray shaded region, bounded by a circular arc, is located on the right side of the diagram. A red line segment connects  $Q$  to a point on the boundary of this gray region. A blue arrow points from  $P'$  down to a point  $Q'$ .

pst-optic-examples.tex

## 21 Thin Convergent Lenses

If the two spherical surfaces are close enough we can call such a lens a **thin lens**. The following figure shows the behaviour of such a lens with real rays.



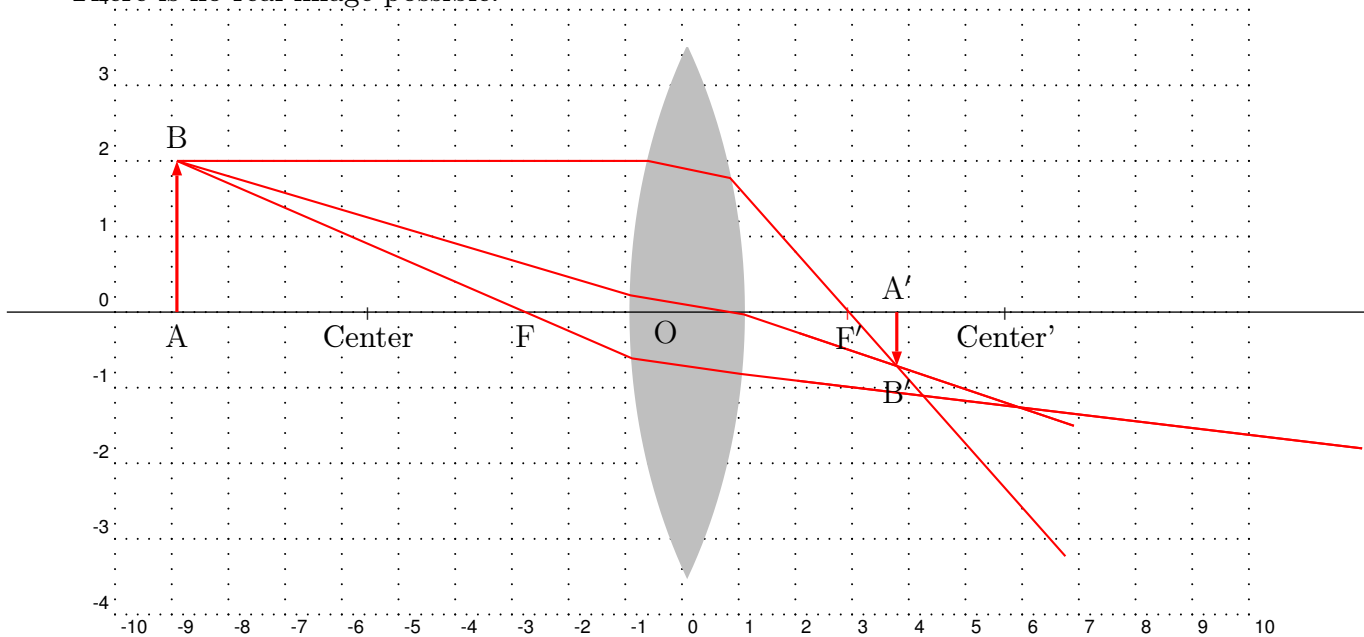
```

1 \psset{xunit=0.75cm}
2 \begin{pspicture}(-10,-4)(10,4)
3   \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
4   \rput(0,0){\lensSPH[%
5     lensType=CVG,%
6     lensHeight=7,%
7     lensWidth=1.25,%
8     yBottom=-5,yTop=5,xLeft=-12,xRight=12,%
9     AB=2,OA=-9,%
10    refractA=1,refractB=2,%
11    drawing=true,%
12    rayColor=red]}
13 \end{pspicture}

```

## 22 Thick Convergent Lenses

There is no real image possible.



```

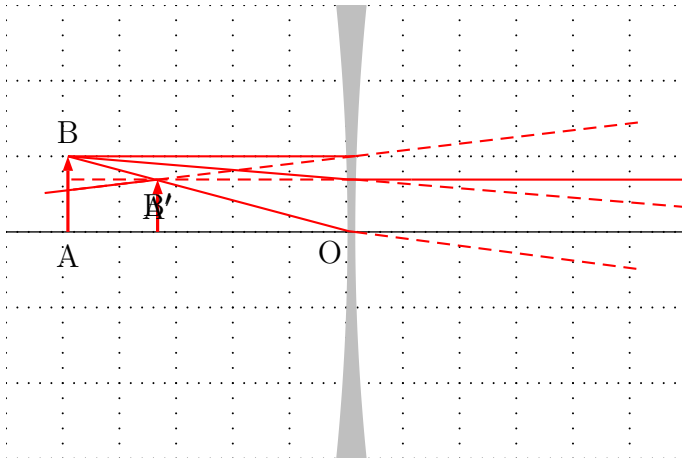
1 \begin{pspicture}(-10,-4)(10,4)
2   \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3   \rput(0,0){\lensSPH[%
4     lensType=CVG,%
5     lensHeight=7,%
6     lensWidth=2,%
7     yBottom=-5,yTop=5,xLeft=-12,xRight=12,%
8     AB=2,OA=-9,%
9     refractA=1,refractB=2,%
10    drawing=true,%
11    rayColor=red]}
12 \end{pspicture}

```



## 23 Thin Divergent Lenses

If the two spherical surfaces are close enough we can call such a lense a **thin lens**. The following figure shows the behaviour of such a lense with real rays.



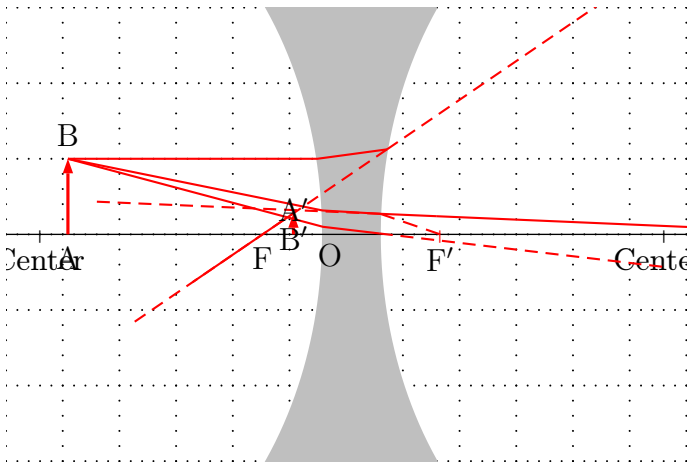
```

1 \begin{pspicture*}(-6,-3)(6,3)
2   \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3   \rput(0,0){\lensSPH[%
4     lensType=DVG,%
5     lensWidth=0.1,%
6     lensDepth=0.2,%
7     AB=1,OA=-5,%
8     drawing=true,%
9     rayColor=red]}
10 \end{pspicture*}

```

## 24 Thick Divergent Lenses

There is no real image possible.

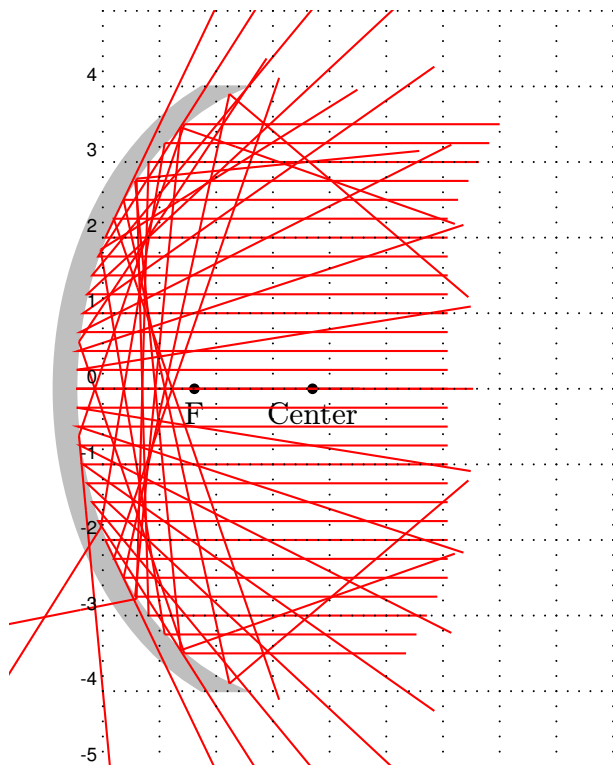


```

1 \begin{pspicture*}(-6,-3)(6,3)
2   \psgrid[subgriddiv=0,griddots=5,gridlabels=7pt]
3   \rput(0,0){\lensSPH[%
4     lensType=DVG,%
5     lensWidth=1,%
6     lensDepth=1,%
7     AB=1,OA=-5,%
8     drawing=true,%
9     rayColor=red]}
10 \end{pspicture*}

```

## 25 \mirrorCVG



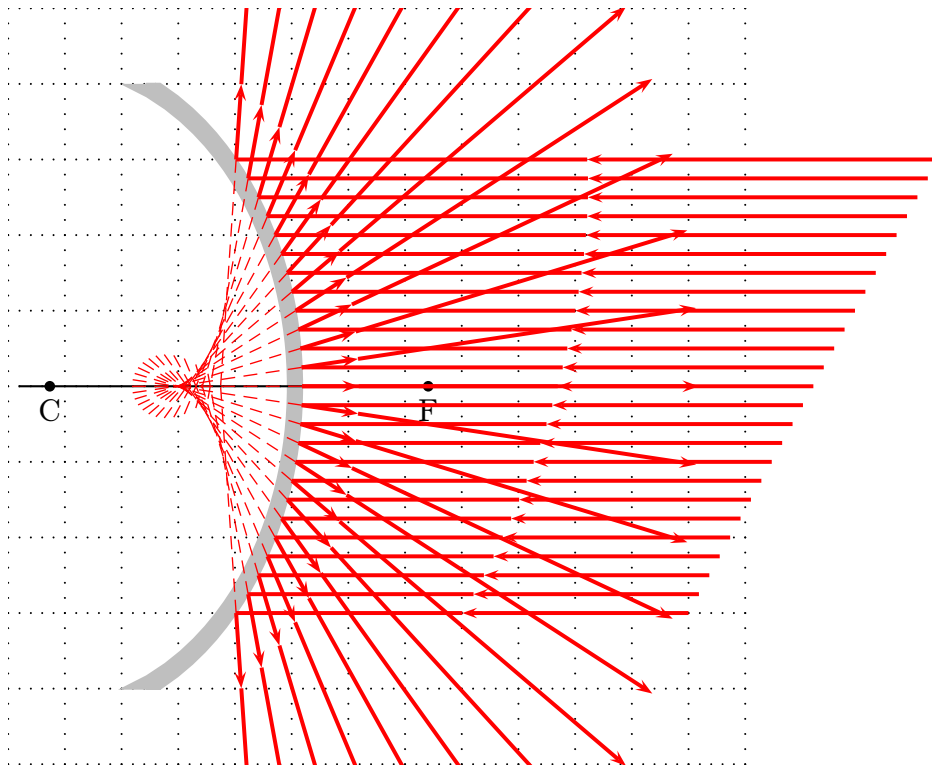
```

1 \begin{pspicture*}(-1,-5)(8,5)
2 \rput(0,0){%
3 \mirrorCVG[%
4 mirrorType=SPH,%
5 drawing=false,%
6 yBottom=-4,yTop=4,%
7 mirrorHeight=8,%
8 mirrorDepth=3]%
9 \qdisk(Center){2pt}\qdisk(Focus){2pt}
10 \uput[-90](Center){Center}\uput[-90](Focus){F}
11 \psline(0)(xRight)
12 }
13 \multido{\rA=-3.50+0.25}{5}{%
14 \mirrorCVGRay[mirrorType=SPH,linecolor=red](8,\rA)(4,\rA){E}
15 \psOutLine[linecolor=red,length=4](E')(E''){\EEnd}
16 }
17 \multido{\rA=-2.25+0.25}{19}{%
18 \ABinterSPHLens(8,\rA)(4,\rA)(Center){Ptemp}
19 \reflectionRay[mirrorType=CVG-SPH](5,\rA)(Ptemp){E}
20 \psline[linecolor=red](8,\rA)(Ptemp)(E)
21 \psOutLine[linecolor=red,length=6](Ptemp)(E){\EEnd}
22 }
23 \multido{\rA=2.50+0.25}{5}{%
24 \mirrorCVGRay[mirrorType=SPH,linecolor=red](8,\rA)(4,\rA){E}
25 \psOutLine[linecolor=red,length=4](E')(E''){\EEnd}
26 }
27 \psgrid

```

28 \end{pspicture\*}

## 26 \mirrorDVG



```

1 \begin{pspicture*}(-5,-5)(8,5)
2   \psgrid
3   \rput(0,0){%
4     \mirrorDVG[%
5       mirrorType=SPH,%
6       drawing=false,%
7       yBottom=-4,yTop=4,%
8       mirrorHeight=8,%
9       mirrorWidth=0.25,%
10      mirrorDepth=2.5]%
11   \qdisk(Center){2pt}\qdisk(Focus){2pt}
12   \uput[-90](Center){C}\uput[-90](Focus){F}
13   \psline(xLeft)(xRight)
14 }
15 \multido{\rA=-3.00+0.25}{25}{%
16   \ABinterSPHLens(7,\rA)(4,\rA)(Center){Ptemp}
17   \reflectionRay[mirrorType=SPH](5,\rA)(Ptemp){E}
18   \arrowLine[linecolor=red,linewidth=1.5pt](7,\rA)(Ptemp){1}
19   \psline[linecolor=red,arrows=->,linewidth=1.5pt](Ptemp)(E)
20   \psOutLine[linecolor=red,%
21     length=6,linewidth=1.5pt,%
22     arrows=->](Ptemp)(E){EEnd}
23   \psOutLine[linecolor=red,%
24     length=3,linestyle=dashed,%

```

```
25 linewidth=0.5pt](E)(Ptemp){EEnd}  
26 }  
27 \end{pspicture*}
```