Handbook of CLShanFigures

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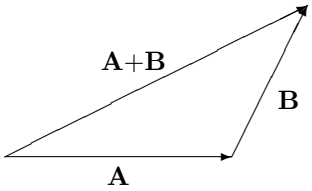
Contents

Chapter 1

Fundamental Mathematics

1.1 Vector analysis

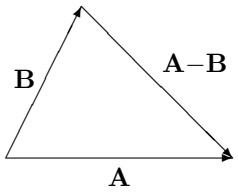
Fig. 1.1.1: Vector addition



Definition

```
\begin{picture}(4,2.5)
\put(0,0){\makebox(4,2.5){}}
% Draw the vectors.
  \put(0   ,0.5){\vector (1  ,0  ){3    }}      % {\bf A}
  \put(3   ,0.5){\vector (1  ,2  ){1    }}      % {\bf B}
  \put(0   ,0.5){\vector (2  ,1  ){4    }}      % {\bf A}+{\bf B}
% Label the vectors.
  \put(1.25,0  ){\makebox(0.5,0.5){\bf A}}
  \put(3.5 ,1  ){\makebox(0.5,0.5){\bf B}}
  \put(1.2 ,1.5){\makebox(1  ,0.5){{\bf A}+{\bf B}}}
\end{picture}
```

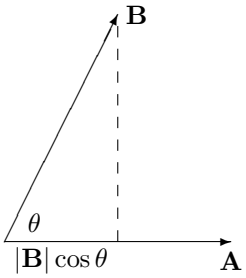
Fig. 1.1.2: Vector subtraction



Definition

```
\begin{picture}(3,2.5)
\put(0,0){\makebox(3,2.5){}}
% Draw the vectors.
  \put(0   ,0.5){\vector (1  , 0  ){3    }}      % {\bf A}
  \put(0   ,0.5){\vector (1  , 2  ){1    }}      % {\bf B}
  \put(1   ,2.5){\vector (1  ,-1  ){2    }}      % {\bf A}-{\bf B}
% Label the vectors.
  \put(1.25,0  ){\makebox(0.5, 0.5){\bf A}}
  \put(0   ,1.3){\makebox(0.5, 0.5){\bf B}}
  \put(2   ,1.5){\makebox(1  , 0.5){{\bf A}$-${\bf B}}}
\end{picture}
```

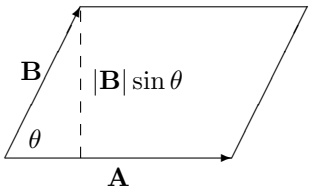
Fig. 1.1.3: Dot or scalar product



Definition

```
\begin{picture}(3.25,3.75)
\put(0,0){\makebox(3.25,3.75){}}
% Draw the vectors.
  \put(0   ,0.5 ){\vector (1  ,0  ){3       }}            % {\bf A}
  \put(0   ,0.5 ){\vector (1  ,2  ){1.5     }}            % {\bf B}
% Label the vectors, the projection and the angle.
  \put(2.75,0   ){\makebox(0.5,0.5){$\bf A $}}
  \put(1.5 ,3.25){\makebox(0.5,0.5){$\bf B $}}
  \put(0.15,0.5 ){\makebox(0.5,0.5){$\theta$}}
  \put(0   ,0   ){\makebox(1.5,0.5){$|\bf B| \cos\theta$}}
  \multiput(1.5,0.5)(0,0.3){10}{\line(0,1){0.15}}
\end{picture}
```

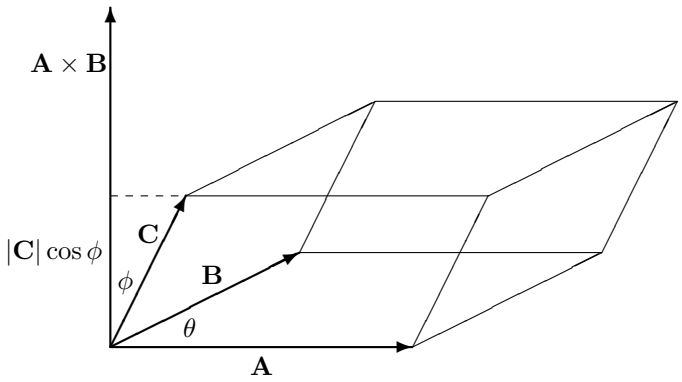
Fig. 1.1.4: Cross or vector product



Definition

```
\begin{picture}(4,2.5)
\put(0,0){\makebox(4,2.5){}}
% Draw the vectors and the parallelogram.
  \put(0   ,0.5 ){\vector (1  ,0  ){3       }}      % {\bf A}
  \put(0   ,0.5 ){\vector (1  ,2  ){1       }}      % {\bf B}
  \put(1   ,2.5 ){\line   (1  ,0  ){3       }}
  \put(3   ,0.5 ){\line   (1  ,2  ){1       }}
% Label the vectors and the angle.
  \put(1.25,0   ){\makebox(0.5,0.5){$\bf A $}}
  \put(0.1 ,1.4 ){\makebox(0.5,0.5){$\bf B $}}
  \put(0.15,0.5 ){\makebox(0.5,0.5){$\theta$}}
% Label the altitude of the parallelogram.
  \put(1   ,1.25){\makebox(1.5,0.5){$|\bf B| \sin\theta$}}
  \multiput(1,0.5)(0,0.3){7}{\line(0,1){0.15}}
\end{picture}
```

Fig. 1.1.5: Triple product



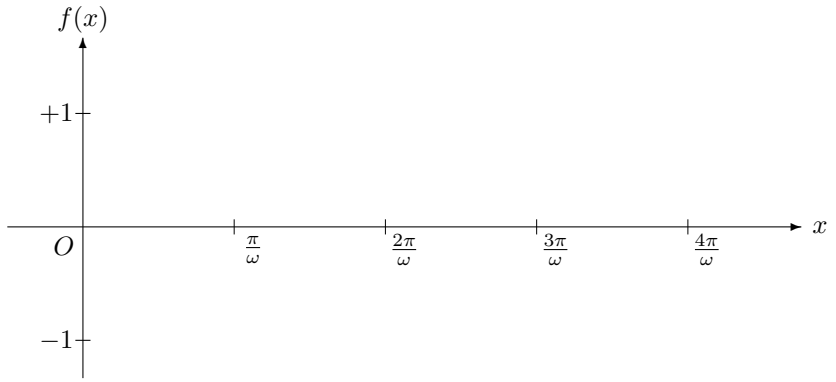
Definition

```
\begin{picture}(9,5)
\put(0,0){\makebox(9,5){}}
% Draw the vectors and the parallelepiped.
  \thicklines
  \put(1.5 ,0.5 ){\vector (1  ,0  ){4       }}  % Vector A
  \thinlines
  \put(4   ,1.75){\line   (1  ,0  ){4       }}  % parallel to vector A
  \put(2.5 ,2.5 ){\line   (1  ,0  ){4       }}  % parallel to vector A
  \put(5   ,3.75){\line   (1  ,0  ){4       }}  % parallel to vector A
  \thicklines
  \put(1.5 ,0.5 ){\vector (2  ,1  ){2.5     }}  % Vector B
  \thinlines
  \put(5.5 ,0.5 ){\line   (2  ,1  ){2.5     }}  % parallel to vector B
  \put(2.5 ,2.5 ){\line   (2  ,1  ){2.5     }}  % parallel to vector B
  \put(6.5 ,2.5 ){\line   (2  ,1  ){2.5     }}  % parallel to vector B
  \thicklines
  \put(1.5 ,0.5 ){\vector (1  ,2  ){1       }}  % Vector C
  \thinlines
  \put(4   ,1.75){\line   (1  ,2  ){1       }}  % parallel to vector C
  \put(5.5 ,0.5 ){\line   (1  ,2  ){1       }}  % parallel to vector C
  \put(8   ,1.75){\line   (1  ,2  ){1       }}  % parallel to vector C
% Label the vectors and the angles.
  \put(3.25,0   ){\makebox(0.5,0.5){$\bf A $}}
  \put(2.6 ,1.2 ){\makebox(0.5,0.5){$\bf B $}}
  \put(1.75,1.75){\makebox(0.5,0.5){$\bf C $}}
  \put(2.3 ,0.5 ){\makebox(0.5,0.5){$\theta$}}
  \put(1.45,1.1 ){\makebox(0.5,0.5){$\phi  $}}
```

```
% Draw and label the vector A x B.
  \thicklines
  \put(1.5 ,0.5 ){\vector (0  ,1  ){4.5     }}
  \thinlines
  \put(0.4 ,4   ){\makebox(1.1,0.5){${\bf A} \times {\bf B}$}}
% Label the projection of vector C on the vector A x B.
  \put(0   ,1.5 ){\makebox(1.5,0.5){$|\bf C| \cos\phi$}}
  \multiput(1.5,2.5)(0.2,0){5}{\line(1,0){0.1}}
\end{picture}
```

1.2 Fourier series

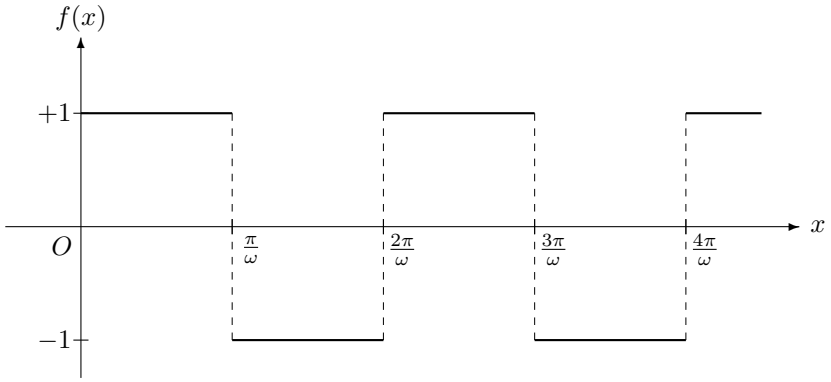
Fig. 1.2.1: Savebox: Fourierfx



Savebox: Fourierfx

```
\newsavebox{\Fourierfx}
\savebox{\Fourierfx}(11,5){
\begin{picture}(11,5)
% Draw the axes.
  \put( 0  ,2   ){\vector (1  ,0  ){10.5  }}  % x
  \put( 1  ,0   ){\vector (0  ,1  ){ 4.5  }}  % f(x)
% Label the axes.
  \put(10.5,1.75){\makebox(0.5,0.5){$  x $}}
  \put( 0.5,4.5 ){\makebox(1  ,0.5){$f(x)$}}
  \put( 0.5,1.5 ){\makebox(0.5,0.5){$0   $}}
% Label +1 and -1 on the f(x)-axis.
  \put( 0.9,3.5 ){\line   (1  ,0  ){0.2   }}
  \put( 0.9,0.5 ){\line   (1  ,0  ){0.2   }}
  \put( 0.4,3.25){\makebox(0.5,0.5){$+1  $}}
  \put( 0.4,0.25){\makebox(0.5,0.5){$-1  $}}
% Label n \pi / \omega on the x-axis.
  \linethickness{0.2pt}
  \put( 3  ,1.9 ){\line   (0  ,1  ){0.2   }}
  \put( 5  ,1.9 ){\line   (0  ,1  ){0.2   }}
  \put( 7  ,1.9 ){\line   (0  ,1  ){0.2   }}
  \put( 9  ,1.9 ){\line   (0  ,1  ){0.2   }}
  \thinlines
  \put( 3  ,1.45){\makebox(0.5,0.5){$\frac{  \pi}{\omega}$}}
  \put( 5  ,1.45){\makebox(0.5,0.5){$\frac{2 \pi}{\omega}$}}
  \put( 7  ,1.45){\makebox(0.5,0.5){$\frac{3 \pi}{\omega}$}}
  \put( 9  ,1.45){\makebox(0.5,0.5){$\frac{4 \pi}{\omega}$}}
\end{picture}}
```

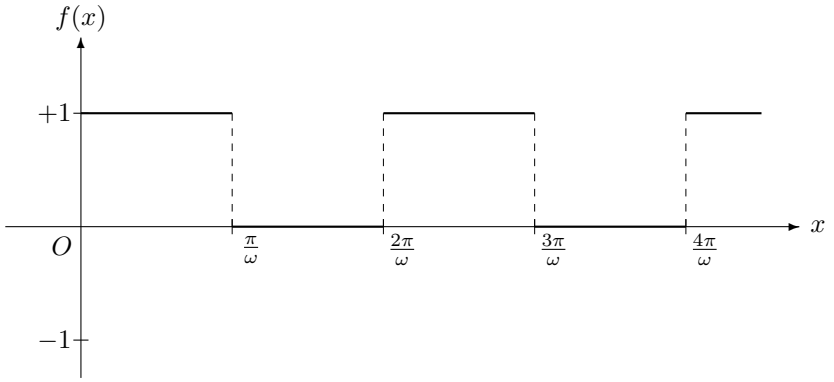
Fig. 1.2.2: Periodic square function



Definition

```
\begin{picture}(11,5)
\put(0,0){\makebox(11,5){}}
% Draw and label the axes.
% Use the savebox: Fourierfx.
  \put(0,0  ){\usebox{\Fourierfx}}
% Draw the periodic square function.
  \thicklines
  \put(1,3.5){\line(1,0){2}}
  \put(3,0.5){\line(1,0){2}}
  \put(5,3.5){\line(1,0){2}}
  \put(7,0.5){\line(1,0){2}}
  \put(9,3.5){\line(1,0){1}}
% Draw the connecting lines.
  \linethickness{0.2pt}
  \multiput(3,2)(0, 0.2){8}{\line(0, 1){0.1}}
  \multiput(3,2)(0,-0.2){8}{\line(0,-1){0.1}}
  \multiput(5,2)(0, 0.2){8}{\line(0, 1){0.1}}
  \multiput(5,2)(0,-0.2){8}{\line(0,-1){0.1}}
  \multiput(7,2)(0, 0.2){8}{\line(0, 1){0.1}}
  \multiput(7,2)(0,-0.2){8}{\line(0,-1){0.1}}
  \multiput(9,2)(0, 0.2){8}{\line(0, 1){0.1}}
  \multiput(9,2)(0,-0.2){8}{\line(0,-1){0.1}}
  \thinlines
\end{picture}
```

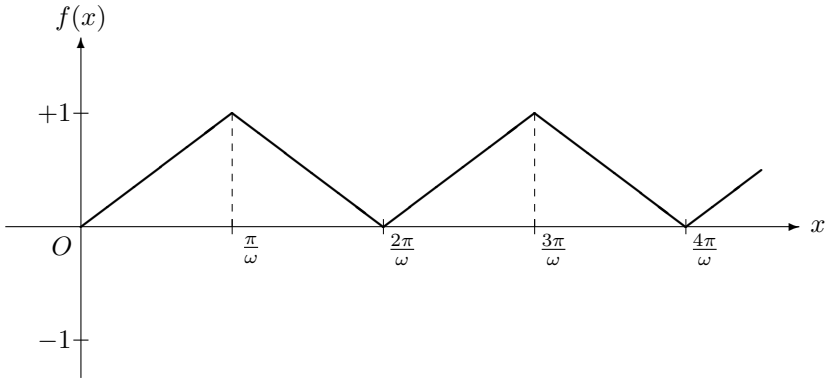
Fig. 1.2.3: Rectangular pulse



Definition

```
\begin{picture}(11,5)
\put(0,0){\makebox(11,5){}}
% Draw and label the axes.
% Use the savebox: Fourierfx.
  \put(0,0  ){\usebox{\Fourierfx}}
% Draw the rectangular pulse.
  \thicklines
  \put(1,3.5){\line(1,0){2}}
  \put(3,2  ){\line(1,0){2}}
  \put(5,3.5){\line(1,0){2}}
  \put(7,2  ){\line(1,0){2}}
  \put(9,3.5){\line(1,0){1}}
% Draw the connecting lines.
  \linethickness{0.2pt}
  \multiput(3,2)(0,0.2){8}{\line(0,1){0.1}}
  \multiput(5,2)(0,0.2){8}{\line(0,1){0.1}}
  \multiput(7,2)(0,0.2){8}{\line(0,1){0.1}}
  \multiput(9,2)(0,0.2){8}{\line(0,1){0.1}}
  \thinlines
\end{picture}
```

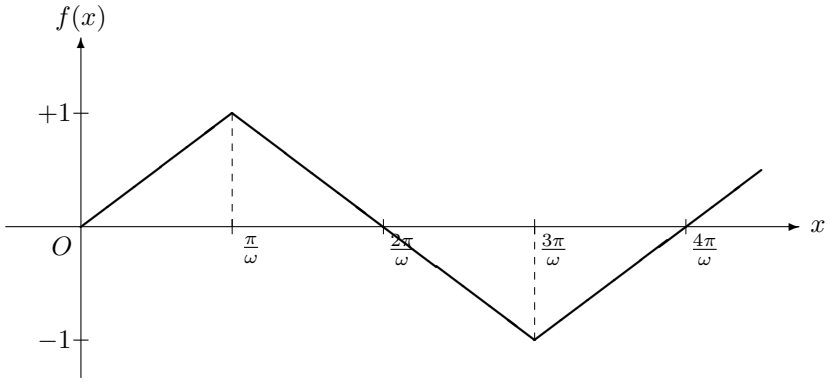
Fig. 1.2.4: Periodic triangle function



Definition

```
\begin{picture}(11,5)
\put(0,0){\makebox(11,5){}}
% Draw and label the axes.
% Use the savebox: Fourierfx.
  \put(0,0  ){\usebox{\Fourierfx}}
% Draw the periodic triangle function.
  \thicklines
  \put(1,2  ){\line(4, 3){2}}
  \put(3,3.5){\line(4,-3){2}}
  \put(5,2  ){\line(4, 3){2}}
  \put(7,3.5){\line(4,-3){2}}
  \put(9,2  ){\line(4, 3){1}}
% Draw the connecting lines.
  \linethickness{0.2pt}
  \multiput(3,2)(0,0.2){8}{\line(0,1){0.1}}
  \multiput(7,2)(0,0.2){8}{\line(0,1){0.1}}
  \thinlines
\end{picture}
```

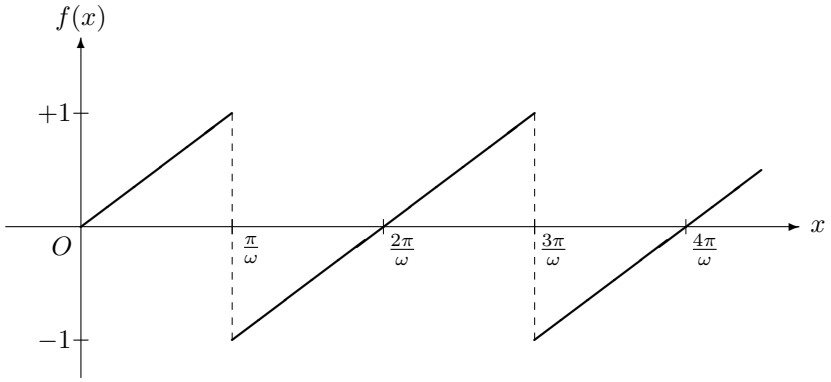
Fig. 1.2.5: Odd periodic expansion of the triangle function



Definition

```
\begin{picture}(11,5)
\put(0,0){\makebox(11,5){}}
% Draw and label the axes.
% Use the savebox: Fourierfx.
  \put(0,0  ){\usebox{\Fourierfx}}
% Draw the odd periodic expansion of the triangle function.
  \thicklines
  \put(1,2  ){\line(4, 3){2}}
  \put(3,3.5){\line(4,-3){2}}
  \put(5,2  ){\line(4,-3){2}}
  \put(7,0.5){\line(4, 3){2}}
  \put(9,2  ){\line(4, 3){1}}
% Draw the connecting lines.
  \linethickness{0.2pt}
  \multiput(3,2)(0, 0.2){8}{\line(0, 1){0.1}}
  \multiput(7,2)(0,-0.2){8}{\line(0,-1){0.1}}
  \thinlines
\end{picture}
```

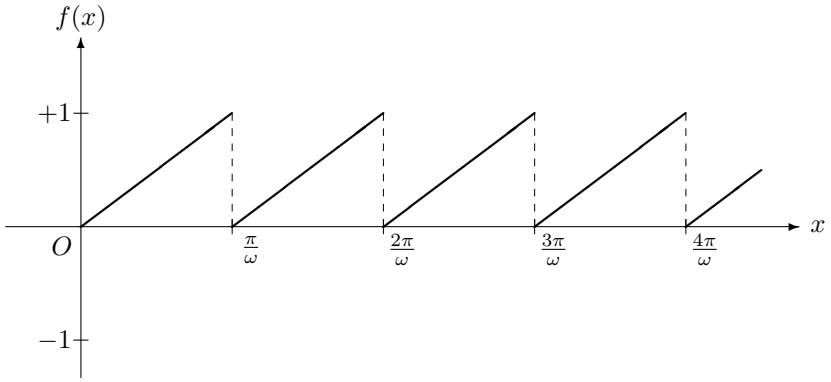
Fig. 1.2.6: Long saw-toothed function



Definition

```
\begin{picture}(11,5)
\put(0,0){\makebox(11,5){}}
% Draw and label the axes.
% Use the savebox: Fourierfx.
  \put(0,0  ){\usebox{\Fourierfx}}
% Draw the long saw-toothed function.
  \thicklines
  \put(1,2  ){\line(4,3){2}}
  \put(3,0.5){\line(4,3){2}}
  \put(5,2  ){\line(4,3){2}}
  \put(7,0.5){\line(4,3){2}}
  \put(9,2  ){\line(4,3){1}}
% Draw the connecting lines.
  \linethickness{0.2pt}
  \multiput(3,2)(0, 0.2){8}{\line(0, 1){0.1}}
  \multiput(3,2)(0,-0.2){8}{\line(0,-1){0.1}}
  \multiput(7,2)(0, 0.2){8}{\line(0, 1){0.1}}
  \multiput(7,2)(0,-0.2){8}{\line(0,-1){0.1}}
  \thinlines
\end{picture}
```

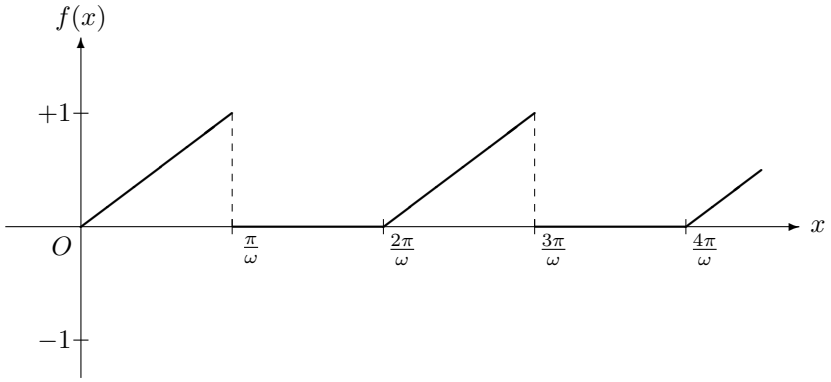
Fig. 1.2.7: Saw-toothed function



Definition

```
\begin{picture}(11,5)
\put(0,0){\makebox(11,5){}}
% Draw and label the axes.
% Use the savebox: Fourierfx.
  \put(0,0  ){\usebox{\Fourierfx}}
% Draw the saw-toothed function.
  \thicklines
  \put(1,2){\line(4,3){2}}
  \put(3,2){\line(4,3){2}}
  \put(5,2){\line(4,3){2}}
  \put(7,2){\line(4,3){2}}
  \put(9,2){\line(4,3){1}}
% Draw the connecting lines.
  \linethickness{0.2pt}
  \multiput(3,2)(0,0.2){8}{\line(0,1){0.1}}
  \multiput(5,2)(0,0.2){8}{\line(0,1){0.1}}
  \multiput(7,2)(0,0.2){8}{\line(0,1){0.1}}
  \multiput(9,2)(0,0.2){8}{\line(0,1){0.1}}
  \thinlines
\end{picture}
```

Fig. 1.2.8: Saw-toothed pulse

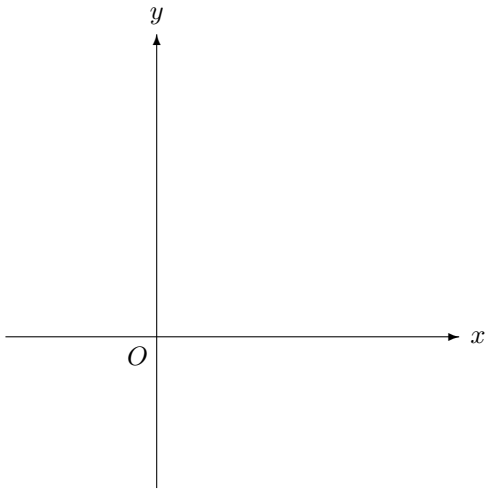


Definition

```
\begin{picture}(11,5)
\put(0,0){\makebox(11,5){}}
% Draw and label the axes.
% Use the savebox: Fourierfx.
  \put(0,0  ){\usebox{\Fourierfx}}
% Draw the saw-toothed pulse.
  \thicklines
  \put(1,2){\line(4,3){2}}
  \put(3,2){\line(1,0){2}}
  \put(5,2){\line(4,3){2}}
  \put(7,2){\line(1,0){2}}
  \put(9,2){\line(4,3){1}}
% Draw the connecting lines.
  \linethickness{0.2pt}
  \multiput(3,2)(0,0.2){8}{\line(0,1){0.1}}
  \multiput(7,2)(0,0.2){8}{\line(0,1){0.1}}
  \thinlines
\end{picture}
```

1.3 Coordinate systems

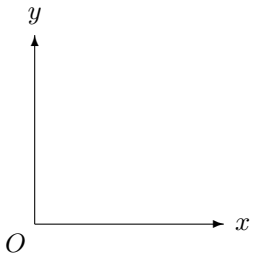
Fig. 1.3.1: Cartesian coordinates (2D)



Definition

```
\begin{picture}(6.5,6.5)
\put(0,0){\makebox(6.5,6.5){}}
% Draw the coordinate axes.
  \put(0   ,2   ){\vector (1  ,0  ){6  }}  % x-axis
  \put(2   ,0   ){\vector (0  ,1  ){6  }}  % y-axis
% Label the coordinate axes.
  \put(6   ,1.75){\makebox(0.5,0.5){$x$}}  % x-axis
  \put(1.75,6   ){\makebox(0.5,0.5){$y$}}  % y-axis
  \put(1.5 ,1.5 ){\makebox(0.5,0.5){$O$}}  % origin
\end{picture}
```

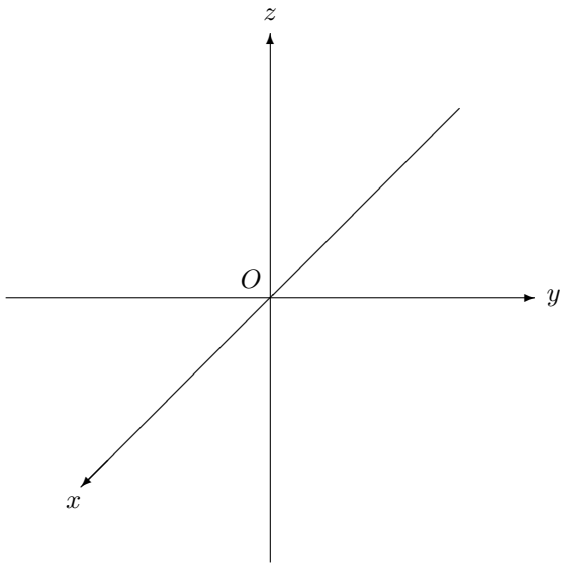
Fig. 1.3.2: Cartesian coordinates (2D)



Definition

```
\begin{picture}(3.5,3.5)
\put(0,0){\makebox(3.5,3.5){}}
% Draw the coordinate axes.
  \put(0.5 ,0.5 ){\vector (1  ,0  ){2.5}}  % x-axis
  \put(0.5 ,0.5 ){\vector (0  ,1  ){2.5}}  % y-axis
% Label the coordinate axes.
  \put(3   ,0.25){\makebox(0.5,0.5){$x$}}  % x-axis
  \put(0.25,3   ){\makebox(0.5,0.5){$y$}}  % y-axis
  \put(0   ,0   ){\makebox(0.5,0.5){$O$}}  % origin
\end{picture}
```

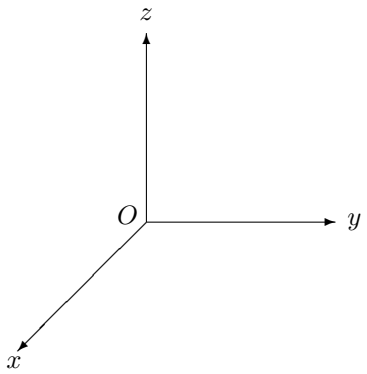
Fig. 1.3.3: Cartesian coordinates (3D)



Savebox: CartesianXYZ

```
\newsavebox{\CartesianXYZ}
\savebox{\CartesianXYZ}(7.5,7.5){
\begin{picture}(7.5,7.5)
% Draw the coordinate axes.
  \put(6   ,6   ){\vector (-1  ,-1  ){5  }}  % x-axis
  \put(0   ,3.5 ){\vector ( 1  , 0  ){7  }}  % y-axis
  \put(3.5 ,0   ){\vector ( 0  , 1  ){7  }}  % z-axis
% Label the coordinate axes.
  \put(0.65,0.55){\makebox( 0.5, 0.5){$x$}}  % x-axis
  \put(7   ,3.25){\makebox( 0.5, 0.5){$y$}}  % y-axis
  \put(3.25,7   ){\makebox( 0.5, 0.5){$z$}}  % z-axis
  \put(3   ,3.5 ){\makebox( 0.5, 0.5){$O$}}  % origin
\end{picture}}
```

Fig. 1.3.4: Cartesian coordinates (3D)

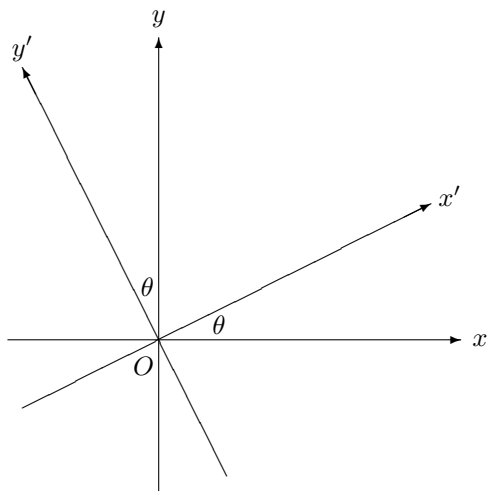


Definition

```
\begin{picture}(5,5.1)
\put(0,0){\makebox(5,5.1){}}
% Draw the coordinate axes.
  \put(2   ,2.1 ){\vector (-1  ,-1  ){1.7}}  % x-axis
  \put(2   ,2.1 ){\vector ( 1  , 0  ){2.5}}  % y-axis
  \put(2   ,2.1 ){\vector ( 0  , 1  ){2.5}}  % z-axis
% Label the coordinate axes.
  \put(0   ,0   ){\makebox( 0.5, 0.5){$x$}}  % x-axis
  \put(4.5 ,1.85){\makebox( 0.5, 0.5){$y$}}  % y-axis
  \put(1.75,4.6 ){\makebox( 0.5, 0.5){$z$}}  % z-axis
  \put(1.5 ,1.95){\makebox( 0.5, 0.5){$O$}}  % origin
\end{picture}
```

1.4 Transformations of coordinate systems

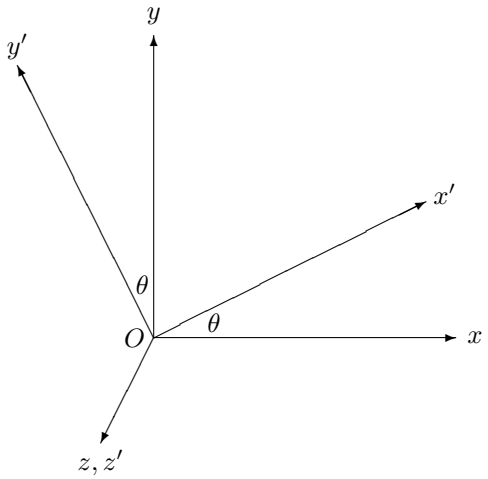
Fig. 1.4.1: Rotation with respect to the z-axis (2D)



Definition

```
\begin{picture}(6.5,6.5)
\put(0,0){\makebox(6.5,6.5){}}
% Draw the coordinate axes.
  \put(0   ,2   ){\vector ( 1  ,0  ){6       }}  % x -axis
  \put(2   ,0   ){\vector ( 0  ,1  ){6       }}  % y -axis
  \put(0.2 ,1.1 ){\vector ( 2  ,1  ){5.4     }}  % x'-axis
  \put(2.9 ,0.2 ){\vector (-1  ,2  ){2.7     }}  % y'-axis
% Label the coordinate axes.
  \put(6   ,1.75){\makebox( 0.5,0.5){$x      $}}  % x -axis
  \put(1.75,6   ){\makebox( 0.5,0.5){$y      $}}  % y -axis
  \put(5.6 ,3.65){\makebox( 0.5,0.5){$x'     $}}  % x'-axis
  \put(0   ,5.6 ){\makebox( 0.4,0.5){$y'     $}}  % y'-axis
  \put(1.55,1.4 ){\makebox( 0.5,0.5){$O      $}}  % origin
% Label the angles.
  \put(2.6 ,2   ){\makebox( 0.4,0.4){$\theta$}}  % between x- and x'-axes
  \put(1.65,2.5 ){\makebox( 0.4,0.4){$\theta$}}  % between y- and y'-axes
\end{picture}
```

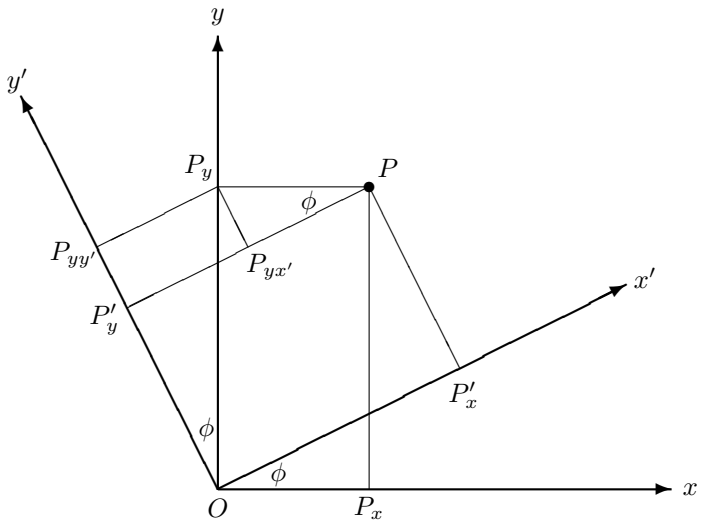
Fig. 1.4.2: Rotation with respect to the z-axis (3D)



Definition

```
\begin{picture}(6.5,6.5)
\put(0,0){\makebox(6.5,6.5){}}
% Draw the coordinate axes.
  \put(2   ,2   ){\vector ( 1  , 0  ){4       }}  % x -axis
  \put(2   ,2   ){\vector ( 0  , 1  ){4       }}  % y -axis
  \put(2   ,2   ){\vector ( 2  , 1  ){3.6     }}  % x'-axis
  \put(2   ,2   ){\vector (-1  , 2  ){1.8     }}  % y'-axis
  \put(2   ,2   ){\vector (-1  ,-2  ){0.7     }}  % z- and z'-axes
% Label the coordinate axes.
  \put(6   ,1.75){\makebox( 0.5, 0.5){$x     $}}  % x -axis
  \put(1.75,6   ){\makebox( 0.5, 0.5){$y     $}}  % y -axis
  \put(5.6 ,3.65){\makebox( 0.5, 0.5){$x'    $}}  % x'-axis
  \put(0   ,5.6 ){\makebox( 0.4, 0.5){$y'    $}}  % y'-axis
  \put(0.95,0.1 ){\makebox( 0.7, 0.5){$z, z' $}}  % z- and z'-axes
  \put(1.5 ,1.75){\makebox( 0.5, 0.5){$O     $}}  % origin
% Label the angles.
  \put(2.6 ,2   ){\makebox( 0.4, 0.4){$\theta$}}  % between x- and x'-axes
  \put(1.65,2.5 ){\makebox( 0.4, 0.4){$\theta$}}  % between y- and y'-axes
\end{picture}
```

Fig. 1.4.3: Transformation matrix

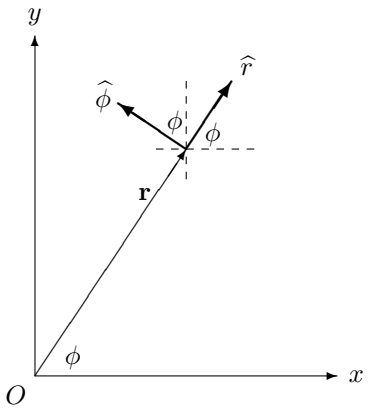


Definition

```
\begin{picture}(9.5,7)
\put(0,0){\makebox(9.5,7){}}
% Draw the coordinate axes and the point P.
  \thicklines
  \put(3   ,0.5 ){\vector ( 1  , 0  ){6        }}  % x -axis
  \put(3   ,0.5 ){\vector ( 0  , 1  ){6        }}  % y -axis
  \put(3   ,0.5 ){\vector ( 2  , 1  ){5.4      }}  % x'-axis
  \put(3   ,0.5 ){\vector (-1  , 2  ){2.6      }}  % y'-axis
  \put(5   ,4.5 ){\circle*           {0.15     }}  % point P
  \thinlines
% Label the coordinate axes and the point P.
  \put(9   ,0.25){\makebox( 0.5, 0.5){$x      $}}  % x -axis
  \put(2.75,6.5 ){\makebox( 0.5, 0.5){$y      $}}  % y -axis
  \put(8.4 ,3.05){\makebox( 0.5, 0.5){$x'     $}}  % x'-axis
  \put(0.1 ,5.65){\makebox( 0.5, 0.5){$y'     $}}  % y'-axis
  \put(2.75,0   ){\makebox( 0.5, 0.5){$O      $}}  % origin
  \put(5   ,4.5 ){\makebox( 0.5, 0.5){$P      $}}  % point P
% Draw the auxiliary lines.
  \put(5   ,4.5 ){\line   ( 0  ,-1  ){4        }}  % P-P_x
  \put(5   ,4.5 ){\line   (-1  , 0  ){2        }}  % P-P_y
  \put(5   ,4.5 ){\line   ( 1  ,-2  ){1.2      }}  % P-P_x'
  \put(5   ,4.5 ){\line   (-2  ,-1  ){3.2      }}  % P-P_y'
  \put(3   ,4.5 ){\line   (-2  ,-1  ){1.6      }}  % P_y-P_{yx'}
  \put(3   ,4.5 ){\line   ( 1  ,-2  ){0.4      }}  % P_y-P_{yy'}
```

```
% Label the points.
  \put(4.75,0   ){\makebox( 0.5, 0.5){$P_x    $}}  % point P_x
  \put(2.5 ,4.5 ){\makebox( 0.5, 0.5){$P_y    $}}  % point P_y
  \put(6   ,1.5 ){\makebox( 0.5, 0.5){$P_x'   }$}  % point P_x'
  \put(1.25,2.5 ){\makebox( 0.5, 0.5){$P_y'   $}}  % point P_y'
  \put(3.4 ,3.2 ){\makebox( 0.6, 0.5){$P_{yx'}$}}  % point P_{yx'}
  \put(0.8 ,3.35){\makebox( 0.6, 0.5){$P_{yy'}$}}  % point P_{yy'}
% Label the angles.
  \put(3.6 ,0.5 ){\makebox( 0.4, 0.4){$\phi   $}}  % between x- and x'-axes
  \put(2.65,1.1 ){\makebox( 0.4, 0.4){$\phi   $}}  % between y- and y'-axes
  \put(4   ,4.1 ){\makebox( 0.4, 0.4){$\phi   $}}  % between P-P_y and P-P_y'
\end{picture}
```

Fig. 1.4.4: Transformation from the cartesian coordinates to the cylindrical coordinates

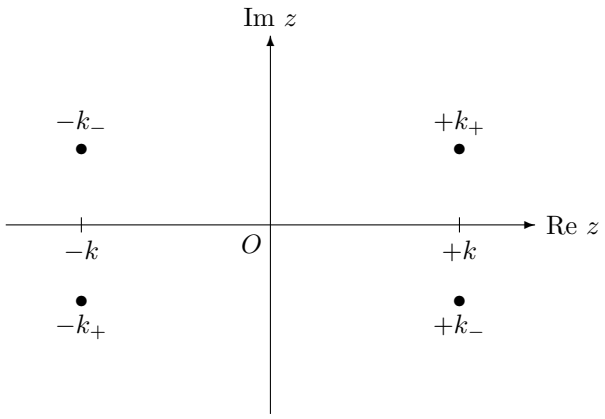


Definition

```
\begin{picture}(5,5.5)
\put(0,0){\makebox(5,5.5){}}
% Draw the coordinate axes and the vector.
  \put(0.5 ,0.5 ){\vector ( 1  ,0  ){4         }}  % x-axis
  \put(0.5 ,0.5 ){\vector ( 0  ,1  ){4.5       }}  % y-axis
  \put(0.5 ,0.5 ){\vector ( 2  ,3  ){2         }}  % {\bf r}
% Label the coordinate axes and the vector.
  \put(4.5 ,0.25){\makebox( 0.5,0.5){$x       $}}  % x-axis
  \put(0.25,5   ){\makebox( 0.5,0.5){$y       $}}  % y-axis
  \put(0   ,0   ){\makebox( 0.5,0.5){$0       $}}  % origin
  \put(1.7 ,2.65){\makebox( 0.5,0.5){$\bf r   $}}  % {\bf r}
% Draw the cylindrical coordinate axes.
  \thicklines
  \put(2.5 ,3.5 ){\vector ( 2  ,3  ){0.6       }}  % \h{r}   -axis
  \put(2.5 ,3.5 ){\vector (-3  ,2  ){0.9       }}  % \h{\phi}-axis
  \thinlines
% Label the cylindrical coordinate axes.
  \put(3.05,4.35){\makebox( 0.5,0.5){$\h{r}   $}}  % \h{r}   -axis
  \put(1.15,3.95){\makebox( 0.5,0.5){$\h{\phi}$}}  % \h{\phi}-axis
% Label the angles.
  \multiput(2.1,3.5)(0.2,0  ){7}{\line(1,0){0.1}}  % horizontal dashed line
  \multiput(2.5,3.1)(0  ,0.2){7}{\line(0,1){0.1}}  % vertical dashed line
  \put(0.8 ,0.55){\makebox( 0.4,0.4){$\phi    $}}
  \put(2.7 ,3.5 ){\makebox( 0.4,0.4){$\phi    $}}
  \put(2.2 ,3.65){\makebox( 0.4,0.4){$\phi    $}}
\end{picture}
```

1.5 Complex analysis

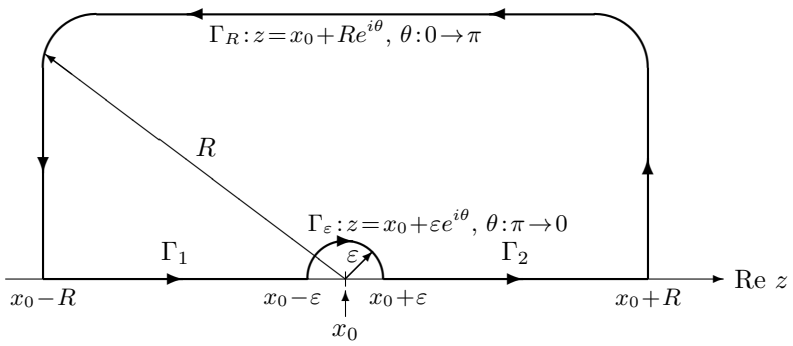
Fig. 1.5.1: Poles on the imaginary plane



Definition

```
\begin{picture}(8,5.5)
\put(0,0){\makebox(8,5.5){}}
% Draw and label the Re- and Im-axes.
  \put(0  ,2.5 ){\vector (1  ,0  ){7       }}
  \put(3.5,0   ){\vector (0  ,1  ){5       }}
  \put(7  ,2.25){\makebox(1  ,0.5){Re $z  $}}
  \put(3  ,5   ){\makebox(1  ,0.5){Im $z  $}}
  \put(3  ,2   ){\makebox(0.5,0.5){$0     $}}
% Draw and label k and -k.+
  \put(6  ,2.4 ){\line   (0  ,1  ){0.2     }}
  \put(1  ,2.4 ){\line   (0  ,1  ){0.2     }}
  \put(5.7,1.9 ){\makebox(0.6,0.5){$+k    $}}
  \put(0.7,1.9 ){\makebox(0.6,0.5){$-k    $}}
% Draw and label +k_{+}, -k_{+}, +k_{-} and -k_{-}.
  \put(6  ,3.5 ){\circle*         {0.15    }}
  \put(6  ,1.5 ){\circle*         {0.15    }}
  \put(1  ,3.5 ){\circle*         {0.15    }}
  \put(1  ,1.5 ){\circle*         {0.15    }}
  \put(5.6,3.6 ){\makebox(0.8,0.5){$+k_{+}$}}
  \put(5.6,0.9 ){\makebox(0.8,0.5){$+k_{-}$}}
  \put(0.6,3.6 ){\makebox(0.8,0.5){$-k_{-}$}}
  \put(0.6,0.9 ){\makebox(0.8,0.5){$-k_{+}$}}
\end{picture}
```

Fig. 1.5.2: Contour integral

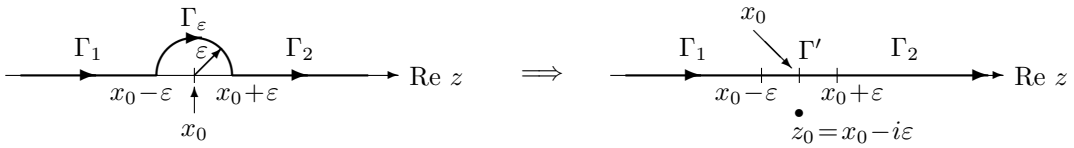


Definition

```
\begin{picture}(10.5,4.5)
\put(0,0){\makebox(10.5,4.5){}}
% Draw and label the Re-axis.
  \put(0   ,0.9 ){\vector ( 1  , 0  ){9.5   }}
  \put(9.5 ,0.65){\makebox( 1  , 0.5){Re $z$}}
% Draw and label x_0.
  \put(4.5 ,0.8 ){\line   ( 0  , 1  ){0.2   }}
  \put(4.5 ,0.4 ){\vector ( 0  , 1  ){0.35  }}
  \put(4.25,0   ){\makebox( 0.5, 0.4){$x_0 $}}
% Draw the contour and indicate the direction of integral.
  \thicklines
  \put(0.5 ,0.9 ){\line   ( 1  , 0  ){3.5   }}  % Gamma_{1}
  \put(2.15,0.9 ){\vector ( 1  , 0  ){0.2   }}  % Gamma_{1}
  \put(4.5 ,0.9 ){\oval   ( 1  , 1  )[t     ]}  % Gamma_{\varepsilon}
  \put(4.4 ,1.4 ){\vector ( 1  , 0  ){0.2   }}  % Gamma_{\varepsilon}
  \put(5   ,0.9 ){\line   ( 1  , 0  ){3.5   }}  % Gamma_{2}
  \put(6.65,0.9 ){\vector ( 1  , 0  ){0.2   }}  % Gamma_{2}
  \put(4.5 ,0.9 ){\oval   ( 8  , 7  )[t     ]}  % Gamma_{R}
  \put(8.5 ,2.3 ){\vector ( 0  , 1  ){0.2   }}  % Gamma_{R}
  \put(6.6 ,4.4 ){\vector (-1  , 0  ){0.2   }}  % Gamma_{R}
  \put(2.6 ,4.4 ){\vector (-1  , 0  ){0.2   }}  % Gamma_{R}
  \put(0.5 ,2.5 ){\vector ( 0  ,-1  ){0.2   }}  % Gamma_{R}
  \thinlines
% Label the lines, Gamma_{1} and Gamma_{2}.
  \put(2   ,1   ){\makebox( 0.5, 0.5){$\Gamma_{1} $}}
  \put(6.5 ,1   ){\makebox( 0.5, 0.5){$\Gamma_{2} $}}
% Label the inner circle, Gamma_{\varepsilon}.
  \put(4.5 ,0.9 ){\vector ( 1  , 1  ){0.36         }}
  \put(4.45,1.05){\makebox( 0.3, 0.3){$\varepsilon$}}
```

```
  \put(4   ,1.4 ){\makebox( 2  , 0.5)[l]
                {\small$\Gamma_{\varepsilon}\!:\!z\!=\!x_0\!+\!
                        \varepsilon e^{i\theta}$,
                       $\theta\!:\!\pi\!\to\!0$}}
  \put(3.4 ,0.4 ){\makebox( 0.8, 0.5){\small$x_0\!-\!\varepsilon$}}
  \put(4.8 ,0.4 ){\makebox( 0.8, 0.5){\small$x_0\!+\!\varepsilon$}}
% Label the outer circle, Gamma_{R}.
  \put(4.5 ,0.9 ){\vector (-4  , 3  ){3.97}}
  \put(2.4 ,2.4 ){\makebox( 0.5, 0.5){$R $}}
  \put(2.5 ,3.9 ){\makebox( 4  , 0.5)
                {\small$\Gamma_{R}\!:\!z\!=\!x_0\!+\!R e^{i\theta}$,
                       $\theta\!:\!0\!\to\!\pi$}}
  \put(8   ,0.4 ){\makebox( 1  , 0.5){\small$x_0\!+\!R$}}
  \put(0   ,0.4 ){\makebox( 1  , 0.5){\small$x_0\!-\!R$}}
\end{picture}
```

Fig. 1.5.3: Shift of a pole located on the real axis



Definition

```
\begin{picture}(14.2,2)
\put(0,0){\makebox(14.2,2){}}
\put(0,0){\makebox( 6.2,2){}}
\put(8,0){\makebox( 6.2,2){}}
% Draw and label the Re-axis.
  \put( 0   ,1   ){\vector (1  , 0  ){5.2                  }}
  \put( 5.2 ,0.75){\makebox(1  , 0.5){Re $z                $}}
% Draw and label x_0.
  \put( 2.5 ,0.9 ){\line   (0  , 1  ){0.2                  }}
  \put( 2.5 ,0.5 ){\vector (0  , 1  ){0.35                 }}
  \put( 2.25,0   ){\makebox(0.5, 0.5){$x_0                 $}}
% Draw the integral path and indicate the direction.
  \thicklines
  \put( 0.2 ,1   ){\line   (1  , 0  ){1.8                  }}
  \put( 1   ,1   ){\vector (1  , 0  ){0.2                  }}
  \put( 2.5 ,1   ){\oval   (1  , 1  )[t                    ]}
  \put( 2.4 ,1.5 ){\vector (1  , 0  ){0.2                  }}
  \put( 3   ,1   ){\line   (1  , 0  ){1.8                  }}
  \put( 3.8 ,1   ){\vector (1  , 0  ){0.2                  }}
  \thinlines
% Label the lines, Gamma_{1} and Gamma_{2}.
  \put( 0.85,1.1 ){\makebox(0.5, 0.5){$\Gamma_{1}          $}}
  \put( 3.65,1.1 ){\makebox(0.5, 0.5){$\Gamma_{2}          $}}
% Label the circle, Gamma_{\varepsilon}.
  \put( 2.5 ,1   ){\vector (1  , 1  ){0.36                 }}
  \put( 2.45,1.15){\makebox(0.3, 0.3){$\varepsilon         $}}
  \put( 2.2 ,1.5 ){\makebox(0.6, 0.5){$\Gamma_{\varepsilon}$}}
  \put( 1.3 ,0.5 ){\makebox(1  , 0.5){$x_0\!-\!\varepsilon $}}
  \put( 2.7 ,0.5 ){\makebox(1  , 0.5){$x_0\!+\!\varepsilon $}}
%
% Draw the arrow.
  \put( 6.6 ,0.75){\makebox(1  , 0.5){$\lTo                $}}
%
```

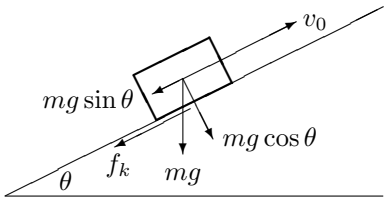
```
% Draw and label the Re-axis.
  \put( 8   ,1   ){\vector (1  , 0  ){5.2                  }}
  \put(13.2 ,0.75){\makebox(1  , 0.5){Re $z                $}}
% Draw and label x_0.
  \put(10.5 ,0.9 ){\line   (0  , 1  ){0.2                  }}
  \put( 9.9 ,1.6 ){\vector (1  ,-1  ){0.5                  }}
  \put( 9.65,1.6 ){\makebox(0.5, 0.4){$x_0                 $}}
% Draw the integral path and indicate the direction.
  \thicklines
  \put( 8.2 ,1   ){\line   (1  , 0  ){4.6                  }}
  \put( 9   ,1   ){\vector (1  , 0  ){0.2                  }}
  \put(12.8 ,1   ){\vector (1  , 0  ){0.2                  }}
  \thinlines
% Label the lines, Gamma_{1} and Gamma_{2}.
  \put( 8.85,1.1 ){\makebox(0.5, 0.5){$\Gamma_{1}          $}}
  \put(11.65,1.1 ){\makebox(0.5, 0.5){$\Gamma_{2}          $}}
% Label the line Gamma'.
  \put(10.4 ,1.1 ){\makebox(0.5, 0.5){$\Gamma'             $}}
  \put(10   ,0.9 ){\line   (0  , 1  ){0.2                  }}
  \put(11   ,0.9 ){\line   (0  , 1  ){0.2                  }}
  \put( 9.3 ,0.5 ){\makebox(1  , 0.5){$x_0\!-\!\varepsilon $}}
  \put(10.7 ,0.5 ){\makebox(1  , 0.5){$x_0\!+\!\varepsilon $}}
% Draw and label z_0.
  \put(10.5 ,0.5 ){\circle*          {0.1                  }}
  \put(10.4 ,0   ){\makebox(1.6, 0.5){$z_0\!=\!x_0\!-\!i\varepsilon$}}
\end{picture}
```

Chapter 2

Classical Mechanics

2.1 Motions on the inclined plane

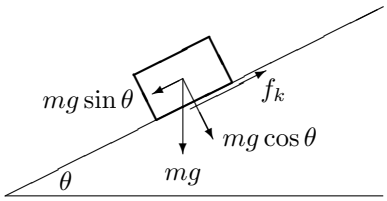
Fig. 2.1.1: Upward motion of a block



Definition

```
\begin{picture}(5,2.5)
\put(0,0){\makebox(5,2.5){}}
% Draw the inclined plane.
  \put(0   ,0   ){\line   ( 1  , 0  ){5    }}
  \put(0   ,0   ){\line   ( 2  , 1  ){5    }}
% Draw the block.
  \thicklines
  \put(2   ,1   ){\line   ( 2  , 1  ){1    }}
  \put(2   ,1   ){\line   (-1  , 2  ){0.3  }}
  \put(1.7 ,1.6 ){\line   ( 2  , 1  ){1    }}
  \put(3   ,1.5 ){\line   (-1  , 2  ){0.3  }}
  \thinlines
% Draw the components of the gravitational force.
  \put(2.35,1.55){\vector ( 0  ,-1  ){1    }}            % mg
  \put(2.35,1.55){\vector ( 1  ,-2  ){0.4  }}            % mg \cos\theta
  \put(2.35,1.55){\vector (-2  ,-1  ){0.4  }}            % mg \sin\theta
% Label the angle and the components of the gravitational force.
  \put(0.6 ,0   ){\makebox( 0.4, 0.4){$\theta       $}}
  \put(2.1 ,0   ){\makebox( 0.5, 0.5){$mg           $}}
  \put(2.9 ,0.5 ){\makebox( 1.2, 0.5){$mg \cos\theta$}}
  \put(0.5 ,1   ){\makebox( 1.2, 0.5){$mg \sin\theta$}}
% Draw and label the velocity.
  \put(2.35,1.55){\vector ( 2  , 1  ){1.5  }}
  \put(3.85,2.05){\makebox( 0.5, 0.5){$v_0$}}
% Draw and label the frictional force.
  \put(2.45,1.15){\vector (-2  ,-1  ){1    }}
  \put(1.25,0.15){\makebox( 0.5, 0.5){$f_k$}}
\end{picture}
```

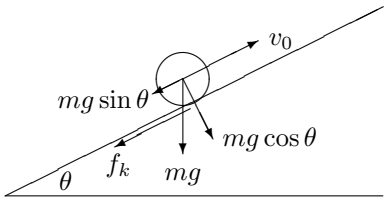
Fig. 2.1.2: Downward motion of a block



Definition

```
\begin{picture}(5,2.5)
\put(0,0){\makebox(5,2.5){}}
% Draw the inclined plane.
  \put(0   ,0   ){\line   ( 1  , 0  ){5    }}
  \put(0   ,0   ){\line   ( 2  , 1  ){5    }}
% Draw the block.
  \thicklines
  \put(2   ,1   ){\line   ( 2  , 1  ){1    }}
  \put(2   ,1   ){\line   (-1  , 2  ){0.3  }}
  \put(1.7 ,1.6 ){\line   ( 2  , 1  ){1    }}
  \put(3   ,1.5 ){\line   (-1  , 2  ){0.3  }}
  \thinlines
% Draw the components of the gravitational force.
  \put(2.35,1.55){\vector ( 0  ,-1  ){1    }}            % mg
  \put(2.35,1.55){\vector ( 1  ,-2  ){0.4  }}            % mg \cos\theta
  \put(2.35,1.55){\vector (-2  ,-1  ){0.4  }}            % mg \sin\theta
% Label the angle and the components of the gravitational force.
  \put(0.6 ,0   ){\makebox( 0.4, 0.4){$\theta       $}}
  \put(2.1 ,0   ){\makebox( 0.5, 0.5){$mg           $}}
  \put(2.9 ,0.5 ){\makebox( 1.2, 0.5){$mg \cos\theta$}}
  \put(0.5 ,1   ){\makebox( 1.2, 0.5){$mg \sin\theta$}}
% Draw and label the frictional force.
  \put(2.45,1.15){\vector ( 2  , 1  ){1    }}
  \put(3.3 ,1.15){\makebox( 0.5, 0.5){$f_k$}}
\end{picture}
```

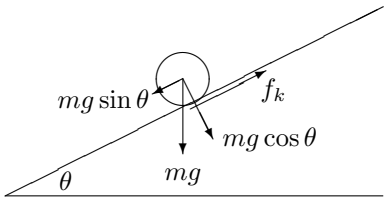
Fig. 2.1.3: Upward motion of a ball or a cylinder



Definition

```
\begin{picture}(5,2.5)
\put(0,0){\makebox(5,2.5){}}
% Draw the inclined plane.
  \put(0   ,0   ){\line   ( 1  , 0  ){5    }}
  \put(0   ,0   ){\line   ( 2  , 1  ){5    }}
% Draw the ball.
  \put(2.35,1.55){\circle            {0.65 }}
% Draw the components of the gravitational force.
  \put(2.35,1.55){\vector ( 0  ,-1  ){1    }}           % mg
  \put(2.35,1.55){\vector ( 1  ,-2  ){0.4  }}           % mg \cos\theta
  \put(2.35,1.55){\vector (-2  ,-1  ){0.4  }}           % mg \sin\theta
% Label the angle and the components of the gravitational force.
  \put(0.6 ,0   ){\makebox( 0.4, 0.4){$\theta       $}}
  \put(2.1 ,0   ){\makebox( 0.5, 0.5){$mg           $}}
  \put(2.9 ,0.5 ){\makebox( 1.2, 0.5){$mg \cos\theta$}}
  \put(0.7 ,1   ){\makebox( 1.2, 0.5){$mg \sin\theta$}}
% Draw and label the velocity.
  \put(2.35,1.55){\vector ( 2  , 1  ){1    }}
  \put(3.4 ,1.8 ){\makebox( 0.5, 0.5){$v_0$}}
% Draw and label the frictional force.
  \put(2.45,1.15){\vector (-2  ,-1  ){1    }}
  \put(1.25,0.15){\makebox( 0.5, 0.5){$f_k$}}
\end{picture}
```

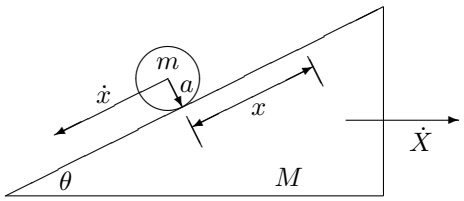
Fig. 2.1.4: Downward motion of a ball or a cylinder



Definition

```
\begin{picture}(5,2.5)
\put(0,0){\makebox(5,2.5){}}
% Draw the inclined plane.
  \put(0   ,0   ){\line   ( 1  , 0  ){5    }}
  \put(0   ,0   ){\line   ( 2  , 1  ){5    }}
% Draw the ball.
  \put(2.35,1.55){\circle            {0.65 }}
% Draw the components of the gravitational force.
  \put(2.35,1.55){\vector ( 0  ,-1  ){1    }}           % mg
  \put(2.35,1.55){\vector ( 1  ,-2  ){0.4  }}           % mg \cos\theta
  \put(2.35,1.55){\vector (-2  ,-1  ){0.4  }}           % mg \sin\theta
% Label the angle and the components of the gravitational force.
  \put(0.6 ,0   ){\makebox( 0.4, 0.4){$\theta       $}}
  \put(2.1 ,0   ){\makebox( 0.5, 0.5){$mg           $}}
  \put(2.9 ,0.5 ){\makebox( 1.2, 0.5){$mg \cos\theta$}}
  \put(0.7 ,1   ){\makebox( 1.2, 0.5){$mg \sin\theta$}}
% Draw and label the frictional force.
  \put(2.45,1.15){\vector ( 2  , 1  ){1    }}
  \put(3.3 ,1.15){\makebox( 0.5, 0.5){$f_k$}}
\end{picture}
```

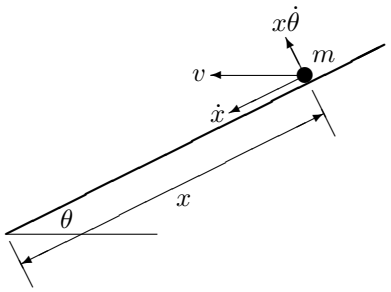
Fig. 2.1.5: Downward motion on a movable wedge



Definition

```
\begin{picture}(6,2.5)
\put(0,0){\makebox(6,2.5){}}
% Draw the wedge.
  \put(0   ,0   ){\line   ( 1  , 0  ){5        }}
  \put(0   ,0   ){\line   ( 2  , 1  ){5        }}
  \put(5   ,0   ){\line   ( 0  , 1  ){2.5      }}
% Label the angle, the mass, and the velocity of the wedge.
  \put(0.6 ,0   ){\makebox( 0.4, 0.4){$\theta $}}
  \put(3.5 ,0   ){\makebox( 0.5, 0.5){$M      $}}
  \put(4.5 ,1   ){\vector ( 1  , 0  ){1.5      }}
  \put(5.25,0.5 ){\makebox( 0.5, 0.5){$\dot{X}$}}
% Draw the ball and label its mass, radius and velocity.
  \put(2.15,1.55){\circle            {0.9      }}
  \put(1.9 ,1.55){\makebox( 0.5, 0.4){$m      $}}
  \put(2.15,1.55){\vector ( 1  ,-2  ){0.19     }}
  \put(2.15,1.2 ){\makebox( 0.5, 0.5){$a      $}}
  \put(2.15,1.55){\vector (-2  ,-1  ){1.5      }}
  \put(1.05,1.1 ){\makebox( 0.5, 0.5){$\dot{x}$}}
% Label the generalized coordinate x.
  \put(2.4 ,1.05){\line   ( 1  ,-2  ){0.2      }}
  \put(4   ,1.85){\line   ( 1  ,-2  ){0.2      }}
  \put(3.27,1.31){\vector (-2  ,-1  ){0.8      }}
  \put(3.27,1.31){\vector ( 2  , 1  ){0.8      }}
  \put(3.1 ,0.9 ){\makebox( 0.5, 0.5){$x      $}}
\end{picture}
```

Fig. 2.1.6: Motion on an elevating plane



Definition

```
\begin{picture}(5,3.8)
\put(0,0){\makebox(5,3.8){}}
% Draw the inclined plane.
  \thicklines
  \put(0   ,0.7 ){\line   ( 2  , 1  ){5               }}
  \thinlines
% Label the angle.
  \put(0   ,0.7 ){\line   ( 1  , 0  ){2               }}
  \put(0.6 ,0.7 ){\makebox( 0.4, 0.4){$\theta        $}}
% Draw the particle and label its mass and velocity.
  \put(3.95,2.8 ){\circle*           {0.22            }}
  \put(3.95,2.8 ){\makebox( 0.5, 0.5){$m             $}}
  \put(3.95,2.8 ){\vector (-2  ,-1  ){1               }}
  \put(2.55,2.05){\makebox( 0.5, 0.5){$\dot{x}       $}}
  \put(3.95,2.8 ){\vector (-1  , 2  ){0.25            }}
  \put(3.45,3.3 ){\makebox( 0.5, 0.5){$x \dot{\theta}$}}
  \put(3.95,2.8 ){\vector (-1  , 0  ){1.25            }}
  \put(2.3 ,2.55){\makebox( 0.5, 0.5){$v             $}}
% Label the generalized coordinate x.
  \put(0.05,0.6 ){\line   ( 1  ,-2  ){0.3             }}
  \put(4.05,2.6 ){\line   ( 1  ,-2  ){0.3             }}
  \put(2.2 ,1.3 ){\vector ( 2  , 1  ){2               }}
  \put(2.2 ,1.3 ){\vector (-2  ,-1  ){2               }}
  \put(2.1 ,0.9 ){\makebox( 0.5, 0.5){$x             $}}
\end{picture}
```

2.2 Collisions and scatterings

Fig. 2.2.1: Scattering in the laboratory (LAB) system

Before collision After collision

Definition

```
\begin{picture}(11.5,4)
\put(0,0){\makebox(11.5,4){}}
% Before collision:
% Draw the incident and the target particles.
  \put(0.5 ,2.5){\circle*          {0.2         }}
  \put(0.5 ,2.5){\vector (1  , 0  ){2           }}
  \put(4.5 ,2.5){\circle*          {0.3         }}
  \multiput(2.7,2.5)(0.4,0){ 7}{\line(1,0){0.2  }}
% Label the masses and the velocity.
  \put(0.25,1.9){\makebox(0.5, 0.5){$m         $}}
  \put(4.25,1.8){\makebox(0.5, 0.5){$M         $}}
  \put(1.75,1.9){\makebox(0.5, 0.5){${\bf v}_i $}}
  \put(1.15,0  ){\makebox(3  , 0.5){Before collision}}
% After collision:
% Draw the incident and the target particles.
  \put(8.1 ,2.6){\circle*          {0.2         }}
  \put(8.1 ,2.6){\vector (1  , 1  ){1.2         }}
  \put(8   ,2.4){\circle*          {0.3         }}
  \put(8   ,2.4){\vector (1  ,-2  ){0.3         }}
  \multiput(7.2,2.5)(0.4,0){11}{\line(1,0){0.2  }}
% Label the masses, the velocities and the angles.
  \put(7.7 ,2.6){\makebox(0.5, 0.5){$m         $}}
  \put(7.5 ,1.8){\makebox(0.5, 0.5){$M         $}}
  \put(9.2 ,3.2){\makebox(0.5, 0.5){${\bf v}_f'$}}
  \put(8.2 ,1.3){\makebox(0.5, 0.5){${\bf V}'  $}}
  \put(8.3 ,2,5){\makebox(0.5, 0.5){$\theta    $}}
  \put(8.1 ,2  ){\makebox(0.5, 0.5){$\phi      $}}
  \put(7.8 ,0  ){\makebox(3  , 0.5){After collision}}
\end{picture}
```

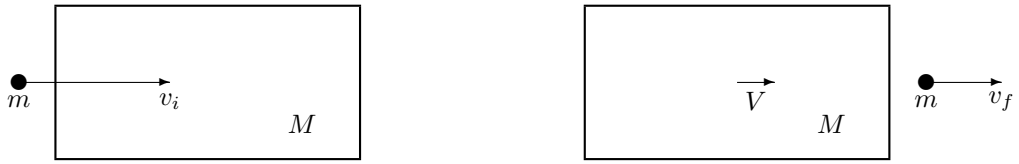
Fig. 2.2.2: Scattering in the center-of-mass (CM) system

Before collision After collision

Definition

```
\begin{picture}(11.5,4)
\put(0,0){\makebox(11.5,4){}}
% Before collision:
% Draw the incident and the target particles.
  \put( 0.5 ,2.5){\circle*           {0.2         }}
  \put( 0.5 ,2.5){\vector ( 1  , 0  ){1.5         }}
  \put( 4.5 ,2.5){\circle*           {0.3         }}
  \put( 4.5 ,2.5){\vector (-1  , 0  ){1           }}
  \multiput(2.05,2.5)(0.4,0){ 4}{\line(1,0){0.2   }}
% Label the masses and the velocities.
  \put( 0.25,1.9){\makebox( 0.5, 0.5){$m         $}}
  \put( 4.25,1.8){\makebox( 0.5, 0.5){$M         $}}
  \put( 1.75,1.9){\makebox( 0.5, 0.5){${\bf v}_i $}}
  \put( 3.4 ,1.9){\makebox( 0.5, 0.5){${\bf V}_i $}}
  \put( 1.15,0  ){\makebox( 3  , 0.5){Before collision}}
% After collision:
% Draw the incident and the target particles.
  \put( 9.2 ,2.7){\circle*           {0.2         }}
  \put( 9.2 ,2.7){\vector ( 1  , 1  ){1.05        }}
  \put( 8.8 ,2.2){\circle*           {0.3         }}
  \put( 8.8 ,2.2){\vector (-1  ,-1  ){0.7         }}
  \multiput(7.2 ,2.5)(0.4,0){11}{\line(1,0){0.2   }}
% Label the masses, the velocities and the angles.
  \put( 8.7 ,2.7){\makebox( 0.5, 0.5){$m         $}}
  \put( 9   ,1.7){\makebox( 0.5, 0.5){$M         $}}
  \put(10.2 ,3.2){\makebox( 0.5, 0.5){${\bf v}_f'$}}
  \put( 7.6 ,1.4){\makebox( 0.5, 0.5){${\bf V}_f'$}}
  \put( 9.3 ,2,5){\makebox( 0.5, 0.5){$\theta    $}}
  \put( 8.2 ,1.9){\makebox( 0.5, 0.5){$\theta    $}}
  \put( 7.8 ,0  ){\makebox( 3  , 0.5){After collision}}
\end{picture}
```

Fig. 2.2.3: A bullet passes through a block



Before collision

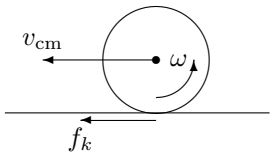
After collision

Definition

```
\begin{picture}(14,3)
\put(0,0){\makebox(14,3){}}
% Before collision:
% Draw the block and the bullet.
  \thicklines
  \put( 1   ,1.5){\framebox(4  ,2  ){     }}
  \thinlines
  \put( 0.5 ,2.5){\circle*          {0.2  }}
  \put( 0.5 ,2.5){\vector  (1  ,0  ){2    }}
% Label the masses and the velocity.
  \put( 0.25,2  ){\makebox (0.5,0.5){$m  $}}
  \put( 2.25,2  ){\makebox (0.5,0.5){$v_i$}}
  \put( 4   ,1.7){\makebox (0.5,0.5){$M  $}}
  \put( 1.5 ,0  ){\makebox (3  ,0.5){Before collision}}
% After collision:
% Draw the block and the bullet.
  \thicklines
  \put( 8   ,1.5){\framebox(4  ,2  ){     }}
  \thinlines
  \put(12.5 ,2.5){\circle*          {0.2  }}
  \put(12.5 ,2.5){\vector  (1  ,0  ){1    }}
  \put(10   ,2.5){\vector  (1  ,0  ){0.5  }}
% Label the masses and the velocities.
  \put(12.25,2  ){\makebox (0.5,0.5){$m  $}}
  \put(13.25,2  ){\makebox (0.5,0.5){$v_f$}}
  \put(11   ,1.7){\makebox (0.5,0.5){$M  $}}
  \put(10   ,2  ){\makebox (0.5,0.5){$V  $}}
  \put( 8.5 ,0  ){\makebox (3  ,0.5){After collision}}
\end{picture}
```

2.3 Balls and cylinders

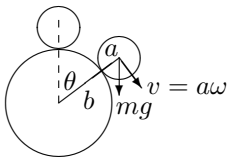
Fig. 2.3.1: A billiard ball rolls on the table



Definition

```
\begin{picture}(3.5,2)
\put(0,0){\makebox(3.5,2){}}
% Draw the ground.
  \put(0   ,0.6 ){\line   ( 1  ,0  ){3.5         }}
% Draw the billiard ball and label its angular velocity.
  \put(2   ,1.3 ){\circle           {1.4         }}
  \put(2   ,1.3 ){\circle*          {0.1         }}
  \put(2   ,1.3 ){\oval   ( 1  ,1  )[rb          ]}
  \put(2.5 ,1.3 ){\vector ( 0  ,1  ){0           }}
  \put(2.1 ,1.05){\makebox( 0.4,0.5){$\omega    $}}
% Label the velocity.
  \put(2   ,1.3 ){\vector (-1  ,0  ){1.5         }}
  \put(0.2 ,1.3 ){\makebox( 0.6,0.5){$v_{\rm cm}$}}
% Label the frictional force.
  \put(2   ,0.5 ){\vector (-1  ,0  ){1           }}
  \put(0.75,0   ){\makebox( 0.5,0.5){$f_k       $}}
\end{picture}
```

Fig. 2.3.2: A thin cylinder rolls on a thick cylinder

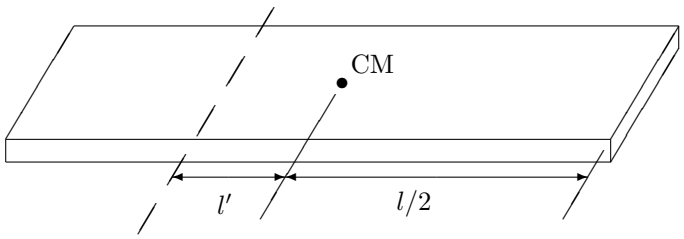


Definition

```
\begin{picture}(3,2)
\put(0,0){\makebox(3,2){}}
% Draw two cylinders.
  \put(0.7 ,1.7 ){\circle           {0.6           }}
  \put(0.7 ,0.7 ){\circle           {1.4           }}
% Draw the rolling cylinder and label its weight and velocity.
  \put(1.5 ,1.3 ){\circle           {0.6           }}
  \put(1.5 ,1.3 ){\vector (0  ,-1  ){0.5           }}
  \put(1.45,0.35){\makebox(0.5, 0.5){$mg          $}}
  \put(1.5 ,1.3 ){\vector (3  ,-4  ){0.3           }}
  \put(1.8 ,0.65){\makebox(1.2, 0.5){$v = a \omega$}}
% Label the radius of each cylinder and the angle.
  \put(0.7 ,0.7 ){\line   (4  , 3  ){0.8           }}
  \put(1.25,1.25){\makebox(0.3, 0.3){$a           $}}
  \put(0.95,0.6 ){\makebox(0.3, 0.3){$b           $}}
  \put(0.7 ,0.75){\makebox(0.3, 0.5){$\theta      $}}
  \multiput(0.7,0.7)(0,0.2){6}{\line(0,1){0.1      }}
\end{picture}
```

2.4 Rods, planes, and planks

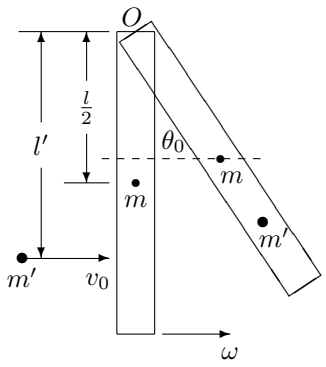
Fig. 2.4.1: A rotating plank



Definition

```
\begin{picture}(8.9,3)
\put(0,0){\makebox(8.9,3){}}
% Draw the rectangular plank.
  \put(0   ,1.25){\line   ( 1  , 0  ){8    }}
  \put(0   ,1.25){\line   ( 3  , 5  ){0.9  }}
  \put(8   ,1.25){\line   ( 3  , 5  ){0.9  }}
  \put(0.9 ,2.75){\line   ( 1  , 0  ){8    }}
  \put(0   ,1.25){\line   ( 0  ,-1  ){0.3  }}
  \put(8   ,1.25){\line   ( 0  ,-1  ){0.3  }}
  \put(8.9 ,2.75){\line   ( 0  ,-1  ){0.3  }}
  \put(0   ,0.95){\line   ( 1  , 0  ){8    }}
  \put(8   ,0.95){\line   ( 3  , 5  ){0.9  }}
% Draw the center of mass of the rectangular plank.
  \put(4.45,2   ){\circle*           {0.15 }}
  \put(4.6 ,2   ){\makebox( 0.5, 0.5){CM}}
% Draw the axis of rotation.
  \multiput(1.75,0  )(0.39,0.65){5}{\line(3,5){0.24}}
% Label the length.
  \put(4.36,1.85){\line   (-3  ,-5  ){0.99 }}
  \put(7.91,1.1 ){\line   (-3  ,-5  ){0.54 }}
  \put(2.95,0.75){\vector ( 1  , 0  ){0.75 }}
  \put(2.95,0.75){\vector (-1  , 0  ){0.75 }}
  \put(5.7 ,0.75){\vector ( 1  , 0  ){2    }}
  \put(5.7 ,0.75){\vector (-1  , 0  ){2    }}
  \put(2.65,0.15){\makebox( 0.5, 0.5){$l' $}}
  \put(5.1 ,0.15){\makebox( 0.6, 0.5){$l/2$}}
\end{picture}
```

Fig. 2.4.2: A bullet knocks into a rod

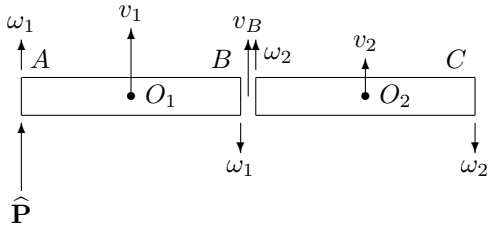


Definition

```
\begin{picture}(4.2,5)
\put(0,0){\makebox(4.2,5){}}
% Draw the rod before the collision.
  \put(1.5 ,0.5 ){\line   (1  , 0  ){0.5          }}
  \put(1.5 ,0.5 ){\line   (0  , 1  ){4            }}
  \put(2   ,0.5 ){\line   (0  , 1  ){4            }}
  \put(1.5 ,4.5 ){\line   (1  , 0  ){0.5          }}
  \put(1.75,2.5 ){\circle*          {0.1          }}
  \put(1.5 ,2   ){\makebox(0.5, 0.5){$m          $}}
% Draw the bullet and label its mass and velocity.
  \put(0.25,1.5 ){\circle*          {0.15         }}
  \put(0.25,1.5 ){\vector (1  , 0  ){1.15         }}
  \put(0   ,1   ){\makebox(0.5, 0.5){$m'         $}}
  \put(1   ,1   ){\makebox(0.5, 0.4){$v_0        $}}
% Label the distances l'.
  \put(0.2 ,4.5 ){\line   (1  , 0  ){1.2          }}
  \put(0.5 ,3.3 ){\vector (0  , 1  ){1.2          }}
  \put(0.5 ,2.7 ){\vector (0  ,-1  ){1.2          }}
  \put(0.25,2.7 ){\makebox(0.5, 0.6){$l'         $}}
% Label the distance l/2.
  \put(0.8 ,2.5 ){\line   (1  , 0  ){0.6          }}
  \put(1.1 ,3.85){\vector (0  , 1  ){0.65         }}
  \put(1.1 ,3.15){\vector (0  ,-1  ){0.65         }}
  \put(0.85,3.15){\makebox(0.5, 0.7){$\frac{l}{2}$}}
% Label the angular velocity omega.
  \put(2.1 ,0.5 ){\vector (1  , 0  ){0.9          }}
  \put(2.75,0   ){\makebox(0.5, 0.5){$\omega     $}}
```

```
% Draw the rod at the angle theta_0 and the bullet inside the rod.
  \put(1.54,4.36){\line   (3  , 2  ){0.42         }}
  \put(1.54,4.36){\line   (2  ,-3  ){2.24         }}
  \put(1.96,4.64){\line   (2  ,-3  ){2.24         }}
  \put(3.78,1   ){\line   (3  , 2  ){0.42         }}
  \put(2.87,2.82){\circle*          {0.1          }}
  \put(2.77,2.32){\makebox(0.5, 0.5){$m          $}}
  \put(3.43,1.98){\circle*          {0.15         }}
  \put(3.33,1.53){\makebox(0.5, 0.5){$m'         $}}
% Label the point O and the angle theta_0.
  \put(1.5 ,4.5 ){\makebox(0.4, 0.4){$O          $}}
  \put(2   ,2.8 ){\makebox(0.5, 0.5){$\theta_0   $}}
  \multiput(1.3,2.82)(0.2,0){11}{\line(1,0){0.1   }}
\end{picture}
```

Fig. 2.4.3: Two rods joined smoothly and struck by an impulse

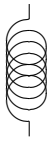


Definition

```
\begin{picture}(6.5,3.1)
\put(0,0){\makebox(6.5,3.1){}}
% Draw two rods.
  \multiput(0.25,1.5 )(3.1,0  ){2}{\line(1,0){2.9}}
  \multiput(0.25,2   )(3.1,0  ){2}{\line(1,0){2.9}}
  \multiput(0.25,1.5 )(3.1,0  ){2}{\line(0,1){0.5}}
  \multiput(3.15,1.5 )(3.1,0  ){2}{\line(0,1){0.5}}
% Label every points of this system.
  \multiput(1.7 ,1.75)(3.1,0  ){2}{\circle*  {0.1}}
  \put(1.85,1.5 ){\makebox(0.5, 0.5){$O_1       $}}
  \put(4.95,1.5 ){\makebox(0.5, 0.5){$O_2       $}}
  \put(0.25,2   ){\makebox(0.5, 0.5){$A         $}}
  \put(2.65,2   ){\makebox(0.5, 0.5){$B         $}}
  \put(5.75,2   ){\makebox(0.5, 0.5){$C         $}}
% Label the velocities.
  \put(1.7 ,1.75){\vector (0  , 1  ){0.9         }}
  \put(1.45,2.65){\makebox(0.5, 0.4){$v_1       $}}
  \put(4.8 ,1.75){\vector (0  , 1  ){0.5         }}
  \put(4.55,2.25){\makebox(0.5, 0.4){$v_2       $}}
  \put(3.25,1.75){\vector (0  , 1  ){0.75        }}
  \put(3   ,2.5 ){\makebox(0.5, 0.4){$v_B       $}}
% Label the angular velocities.
  \put(0.25,2.1 ){\vector (0  , 1  ){0.4         }}
  \put(0   ,2.5 ){\makebox(0.5, 0.4){$\omega_1  $}}
  \put(3.15,1.4 ){\vector (0  ,-1  ){0.4         }}
  \put(2.9 ,0.6 ){\makebox(0.5, 0.4){$\omega_1  $}}
  \put(3.35,2.1 ){\vector (0  , 1  ){0.4         }}
  \put(3.4 ,2.1 ){\makebox(0.5, 0.4){$\omega_2  $}}
  \put(6.25,1.4 ){\vector (0  ,-1  ){0.4         }}
  \put(6   ,0.6 ){\makebox(0.5, 0.4){$\omega_2  $}}
% Label the impulse.
  \put(0.25,0.5 ){\vector (0  , 1  ){0.9         }}
  \put(0   ,0   ){\makebox(0.5, 0.5){$\Hbf{P}   $}}
\end{picture}
```

2.5 Springs

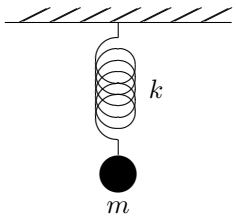
Fig. 2.5.1: Savebox: springv



Savebox: springv

```
\newsavebox{\springv}
\savebox{\springv}(0.6,1.75){
\begin{picture}(0.6,1.75)
  \put(0.3,1.55){\line(0, 1   ){0.2}}
  \multiput(0.3,1.25 )(0,-0.15){6}{\oval(0.6 ,0.6 )[l]}
  \multiput(0.3,1.175)(0,-0.15){5}{\oval(0.45,0.45)[r]}
  \put(0.3,0   ){\line(0, 1   ){0.2}}
\end{picture}}
```

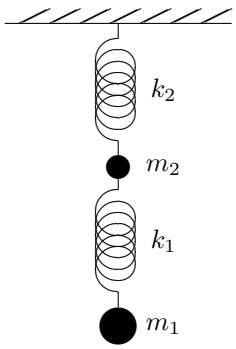
Fig. 2.5.2: A single vertical spring



Definition

```
\begin{picture}(3,3)
\put(0,0){\makebox(3,3){}}
% Draw the roof.
  \put(0   ,2.7  ){\line    (1  , 0  ){3     }}
  \multiput(0.2,2.7)(0.4,0){7}{\line(2,1){0.4}}
% Draw and label the spring.
% Use the savebox: springv.
  \put(1.2 ,0.95 ){\usebox{\springv}}
  \put(1.75,1.575){\makebox (0.5, 0.5){$k   $}}
% Draw the ball and label its mass.
  \put(1.5 ,0.7  ){\circle*           {0.5   }}
  \put(1.25,0    ){\makebox (0.5, 0.5){$m   $}}
\end{picture}
```

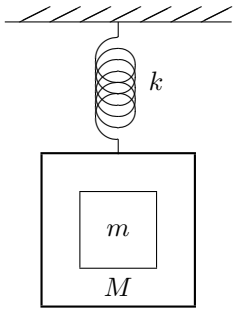
Fig. 2.5.3: Two vertical springs (with two masses)



Definition

```
\begin{picture}(3,4.5)
\put(0,0){\makebox(3,4.5){}}
% Draw the roof.
  \put(0   ,4.3  ){\line   (1  , 0  ){3      }}
  \multiput(0.2,4.3)(0.4,0){7}{\line(2,1){0.4}}
% Draw and label the upper spring.
% Use the savebox: springv.
  \put(1.2 ,2.55 ){\usebox{\springv}}
  \put(1.85,3.175){\makebox(0.5, 0.5){$k_2  $}}
% Draw the upper ball and label its mass.
  \put(1.5 ,2.4  ){\circle*          {0.3    }}
  \put(1.85,2.15 ){\makebox(0.5, 0.5){$m_2  $}}
% Draw and label the lower spring.
% Use the savebox: springv.
  \put(1.2 ,0.55 ){\usebox{\springv}}
  \put(1.85,1.175){\makebox(0.5, 0.5){$k_1  $}}
% Draw the lower ball and label its mass.
  \put(1.5 ,0.3  ){\circle*          {0.5    }}
  \put(1.85,0.05 ){\makebox(0.5, 0.5){$m_1  $}}
\end{picture}
```

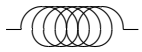
Fig. 2.5.4: A single vertical spring with a block



Definition

```
\begin{picture}(3,4)
\put(0,0){\makebox(3,4){}}
% Draw the roof.
  \put(0   ,3.8  ){\line    (1  , 0  ){3     }}
  \multiput(0.2,3.8)(0.4,0){7}{\line(2,1){0.4}}
% Draw and label the spring.
% Use the savebox: springv.
  \put(1.2 ,2.05 ){\usebox{\springv}}
  \put(1.75,2.775){\makebox (0.5, 0.5){$k   $}}
% Draw the box and label its mass.
  \thicklines
  \put(0.5 ,0.05 ){\framebox(2  , 2  ){      }}
  \thinlines
  \put(1.25,0.05 ){\makebox (0.5, 0.5){$M   $}}
% Draw the block and label its mass.
  \put(1   ,0.55 ){\framebox(1  , 1  ){$m   $}}
\end{picture}
```

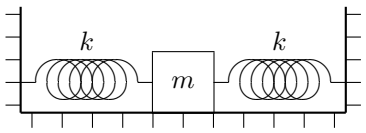
Fig. 2.5.5: Savebox: springh



Savebox: springh

```
\newsavebox{\springh}
\savebox{\springh}(1.75,0.6){
  \begin{picture}(1.75,0.6)
  \put(0   ,0.3){\line(1   ,0){0.2}}
  \multiput(0.5  ,0.3)(0.15,0){6}{\oval(0.6 ,0.6 )[t]}
  \multiput(0.575,0.3)(0.15,0){5}{\oval(0.45,0.45)[b]}
  \put(1.55,0.3){\line(1   ,0){0.2}}
\end{picture}}
```

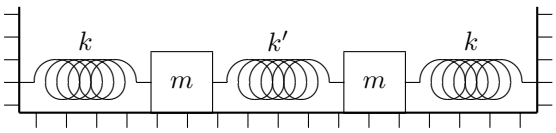
Fig. 2.5.6: Two horizontal springs with a block



Definition

```
\begin{picture}(4.7,1.6)
\put(0,0){\makebox(4.7,1.6){}}
% Draw the walls and the ground.
  \thicklines
  \put(0.2  ,0.2 ){\line    (0  ,1  ){1.4}}
  \put(0.2  ,0.2 ){\line    (1  ,0  ){4.3}}
  \put(4.5  ,0.2 ){\line    (0  ,1  ){1.4}}
  \thinlines
  \multiput(0   ,0.3)(0  , 0.3){5 }{\line(1,0){0.2}}
  \multiput(0.35,0  )(0.4, 0  ){11}{\line(0,1){0.2}}
  \multiput(4.5 ,0.3)(0  , 0.3){5 }{\line(1,0){0.2}}
% Draw and label the spring.
% Use the savebox: springh.
  \put(0.2  ,0.3 ){\usebox  {\springh    }}
  \put(0.825,0.9 ){\makebox (0.5,0.5){$k$}}
  \put(2.75 ,0.3 ){\usebox  {\springh    }}
  \put(3.375,0.9 ){\makebox (0.5,0.5){$k$}}
% Draw the block and label its mass.
  \put(1.95 ,0.2 ){\framebox(0.8,0.8){$m$}}
\end{picture}
```

Fig. 2.5.7: Three horizontal springs with two blocks

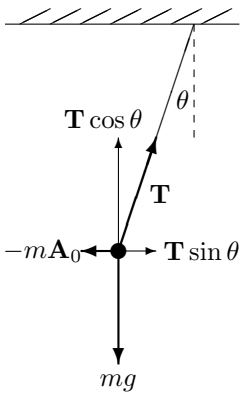


Definition

```
\begin{picture}(7.25,1.6)
\put(0,0){\makebox(7.25,1.6){}}
% Draw the walls and the ground.
  \thicklines
  \put(0.2  ,0.2 ){\line    (0  ,1  ){1.4 }}
  \put(0.2  ,0.2 ){\line    (1  ,0  ){6.85}}
  \put(7.05 ,0.2 ){\line    (0  ,1  ){1.4 }}
  \thinlines
  \multiput(0    ,0.3)(0  , 0.3){5 }{\line(1,0){0.2}}
  \multiput(0.425,0  )(0.4, 0  ){17}{\line(0,1){0.2}}
  \multiput(7.05 ,0.3)(0  , 0.3){5 }{\line(1,0){0.2}}
% Draw and label the spring.
% Use the savebox: springh.
  \put(0.2  ,0.3 ){\usebox  {\springh     }}
  \put(0.825,0.9 ){\makebox (0.5,0.5){$k $}}
  \put(2.75 ,0.3 ){\usebox  {\springh     }}
  \put(3.375,0.9 ){\makebox (0.5,0.5){$k'$}}
  \put(5.3  ,0.3 ){\usebox  {\springh     }}
  \put(5.925,0.9 ){\makebox (0.5,0.5){$k $}}
% Draw the blocks and label their masses.
  \put(1.95 ,0.2 ){\framebox(0.8,0.8){$m $}}
  \put(4.5  ,0.2 ){\framebox(0.8,0.8){$m $}}
\end{picture}
```

2.6 Pendulums

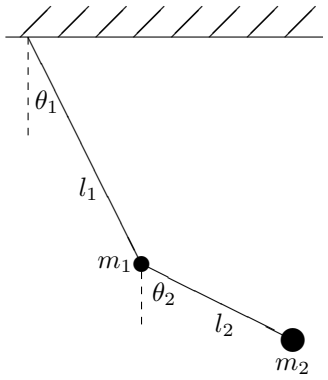
Fig. 2.6.1: A simple pendulum



Definition

```
\begin{picture}(3.1,5.2)
\put(0,0){\makebox(3.1,5.2){}}
% Draw the roof.
  \put(0   ,5   ){\line   ( 1  , 0  ){3.1     }}
  \multiput(0.2,5)(0.4,0){7}{\line(2,1){0.4   }}
% Draw the plumb bob.
  \put(1.5 ,2   ){\line   ( 1  , 3  ){1       }}
  \put(1.5 ,2   ){\circle*           {0.2     }}
% Draw the forces acting upon the plumb bob.
  \thicklines
  \put(1.5 ,2   ){\vector ( 1  , 3  ){0.5     }}
  \put(1.5 ,2   ){\vector (-1  , 0  ){0.5     }}
  \put(1.5 ,2   ){\vector ( 0  ,-1  ){1.5     }}
  \thinlines
% Label the forces acting upon the plumb bob.
  \put(1.5 ,2   ){\vector ( 1  , 0  ){0.5     }}
  \put(1.5 ,2   ){\vector ( 0  , 1  ){1.5     }}
  \put(1.8 ,2.5 ){\makebox( 0.5, 0.5){$\bf T $}}
  \put(2.1 ,1.75){\makebox( 1  , 0.5){$\bf T \sin\theta$}}
  \put(0.8 ,3.5 ){\makebox( 1  , 0.5){$\bf T \cos\theta$}}
  \put(0   ,1.75){\makebox( 1  , 0.5){$-m {\bf A}_0    $}}
  \put(1.25,0   ){\makebox( 0.5, 0.5){$mg    $}}
% Label the deflection angle.
  \multiput(2.5,5)(0,-0.2){8}{\line(0,-1){0.1 }}
  \put(2.1 ,3.75){\makebox( 0.5 ,0.5){$\theta$}}
\end{picture}
```

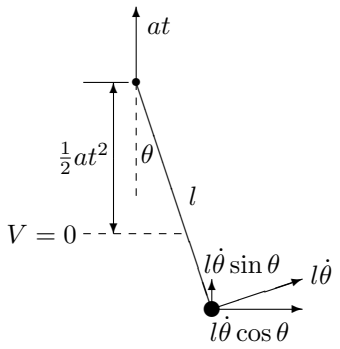
Fig. 2.6.2: A double pendulum



Definition

```
\begin{picture}(4.2,5)
\put(0,0){\makebox(4.2,5){}}
% Draw the roof.
  \put(0   ,4.6 ){\line   (1  , 0  ){4.2       }}
  \multiput(0.2,4.6)(0.5,0){8}{\line(1,1){0.4  }}
% Draw the upper pendulum.
  \put(0.3 ,4.6 ){\line   (1  ,-2  ){1.5       }}
  \put(1.8 ,1.6 ){\circle*          {0.2       }}
% Label the mass, the length and the angle of the upper pendulum.
  \put(1.2 ,1.35){\makebox(0.5, 0.5){$m_1     $}}
  \put(0.85,2.35){\makebox(0.5, 0.5){$l_1     $}}
  \put(0.3 ,3.5 ){\makebox(0.5, 0.5){$\theta_1$}}
  \multiput(0.3,4.6)(0,-0.2){7}{\line(0,-1){0.1}}
% Draw the lower pendulum.
  \put(1.8 ,1.6 ){\line   (2  ,-1  ){2         }}
  \put(3.8 ,0.6 ){\circle*          {0.3       }}
% Label the mass, the length and the angle of the lower pendulum.
  \put(3.55,0   ){\makebox(0.5, 0.5){$m_2     $}}
  \put(2.65,0.55){\makebox(0.5, 0.5){$l_2     $}}
  \put(1.85,0.95){\makebox(0.5, 0.5){$\theta_2$}}
  \multiput(1.8,1.5)(0,-0.2){4}{\line(0,-1){0.1}}
\end{picture}
```

Fig. 2.6.3: A simple pendulum moving upwards

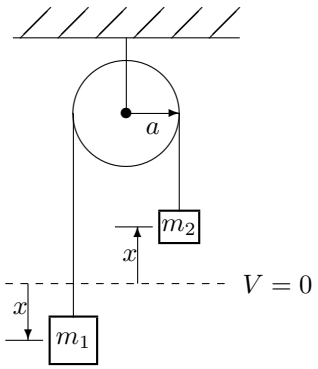


Definition

```
\begin{picture}(4.5,4.5)
\put(0,0){\makebox(4.5,4.5){}}
% Draw the plumb bob.
  \put(1.8 ,3.5 ){\line   (1  ,-3  ){1       }}
  \put(1.8 ,3.5 ){\circle*          {0.1     }}
  \put(2.8 ,0.5 ){\circle*          {0.2     }}
  \put(2.3 ,1.75){\makebox(0.5, 0.5){$l     $}}
% Label the angle.
  \multiput(1.8,3.5)(0  ,-0.2){8}{\line(0,-1){0.1}}
  \put(1.8 ,2.3 ){\makebox(0.3, 0.5){$\theta$}}
% Label the displacement and the velocity of the support point and the potential.
  \put(1.8 ,3.5 ){\vector (0  , 1  ){1       }}
  \put(1.1 ,3.5 ){\line   (1  , 0  ){0.6     }}
  \multiput(1.1,1.5)(0.2, 0  ){7}{\line(1, 0){0.1}}
  \put(1.5 ,2.5 ){\vector (0  , 1  ){1       }}
  \put(1.5 ,2.5 ){\vector (0  ,-1  ){1       }}
  \put(1.8 ,4   ){\makebox(0.6, 0.5){$at    $}}
  \put(0.7 ,2.25){\makebox(0.8, 0.5){$\frac{1}{2} a t^2$}}
  \put(0   ,1.25){\makebox(1.1, 0.5){$V = 0 $}}
% Draw and label the components of the velocity of the plumb bob.
  \put(2.8 ,0.5 ){\vector (3  , 1  ){1.2     }}
  \put(2.8 ,0.5 ){\vector (1  , 0  ){1.2     }}
  \put(2.8 ,0.5 ){\vector (0  , 1  ){0.4     }}
  \put(4   ,0.75){\makebox(0.5, 0.5){$l \dot{\theta}$}}
  \put(2.8 ,0   ){\makebox(1  , 0.5){$l \dot{\theta} \cos\theta$}}
  \put(2.7 ,0.9 ){\makebox(1  , 0.5){$l \dot{\theta} \sin\theta$}}
\end{picture}
```

2.7 Pulleys

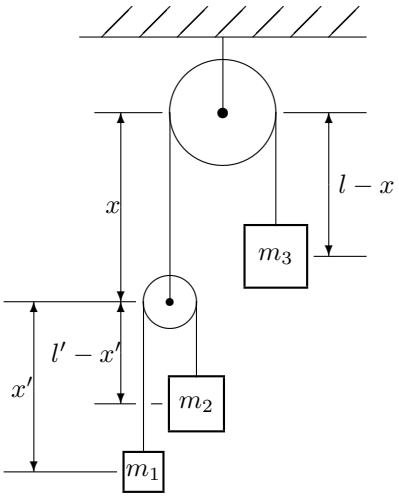
Fig. 2.7.1: Atwood's machine



Definition

```
\begin{picture}(4.5,5)
\put(0,0){\makebox(4.5,5){}}
% Draw the roof.
  \put(0.5 ,4.5  ){\line    (1  , 0  ){3       }}
  \multiput(0.6,4.5)(0.5,0){6}{\line(1,1){0.4  }}
% Draw the pulley.
  \put(2   ,3.5  ){\line    (0  , 1  ){1       }}
  \put(2   ,3.5  ){\circle            {1.4     }}
  \put(2   ,3.5  ){\circle*           {0.15    }}
  \put(2   ,3.5  ){\vector  (1  , 0  ){0.7     }}
  \put(2.1 ,3.1  ){\makebox (0.5, 0.4){$a     $}}
% Draw the blocks and label their weights.
  \put(1.3 ,3.5  ){\line    (0  ,-1  ){2.7     }}
  \put(2.7 ,3.5  ){\line    (0  ,-1  ){1.3     }}
  \thicklines
  \put(1   ,0.2  ){\framebox(0.6, 0.6){$m_1   $}}
  \put(2.45,1.8  ){\framebox(0.5, 0.4){$m_2   $}}
  \thinlines
  \put(0.4 ,0.5  ){\line    (1  , 0  ){0.5     }}
  \put(0.7 ,1.25 ){\vector  (0  ,-1  ){0.75    }}
  \put(0.4 ,0.675){\makebox (0.4, 0.5){$x     $}}
% Draw and label the displacement of m_2.
  \put(1.85,2    ){\line    (1  , 0  ){0.5     }}
  \put(2.15,1.25 ){\vector  (0  , 1  ){0.75    }}
  \put(1.85,1.425){\makebox (0.4, 0.4){$x     $}}
% Label the potential V = 0.
  \multiput(0.4,1.25)(0.2,0){15}{\line(1,0){0.1}}
  \put(3.5 ,1    ){\makebox (1  , 0.5){$V = 0 $}}
\end{picture}
```

Fig. 2.7.2: Double Atwood's machine

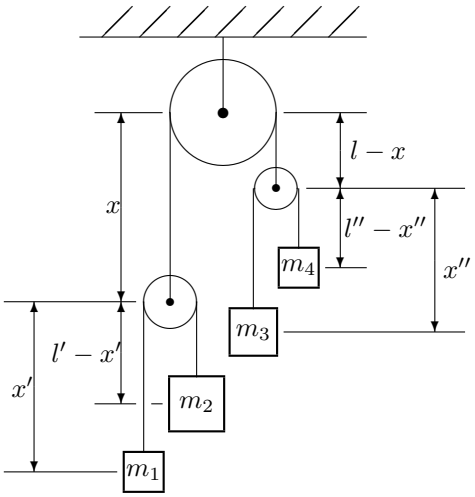


Definition

```
\begin{picture}(5.2,6.4)
\put(0,0){\makebox(5.2,6.4){}}
% Draw the roof.
  \put(1   ,6    ){\line    (1  , 0  ){3.8    }}
  \multiput(1.3,6)(0.5,0){7}{\line(1,1){0.4   }}
% Draw the fixed pulley.
  \put(2.9 ,5    ){\line    (0  , 1  ){1      }}
  \put(2.9 ,5    ){\circle             {1.4    }}
  \put(2.9 ,5    ){\circle*            {0.15   }}
  \put(2.2 ,5    ){\line    (0  ,-1  ){2.5    }}
  \put(3.6 ,5    ){\line    (0  ,-1  ){1.5    }}
% Draw the movable pulley on the left-hand side.
  \put(2.2 ,2.5  ){\circle             {0.7    }}
  \put(2.2 ,2.5  ){\circle*            {0.1    }}
  \put(1.85,2.5  ){\line    (0  ,-1  ){2      }}
  \put(2.55,2.5  ){\line    (0  ,-1  ){1      }}
% Draw the blocks and label their masses.
  \thicklines
  \put(1.6 ,0    ){\framebox(0.5, 0.5){$m_1  $}}
  \put(2.2 ,0.8  ){\framebox(0.7, 0.7){$m_2  $}}
  \put(3.2 ,2.7  ){\framebox(0.8, 0.8){$m_3  $}}
  \thinlines
```

```
% Lable the displacements on the left-hand side.
  \put(1.2 ,5    ){\line    (1  , 0  ){0.9    }}
  \put(0   ,2.5  ){\line    (1  , 0  ){1.75   }}
  \put(1.2 ,1.15 ){\line    (1  , 0  ){0.55   }}
  \put(1.95,1.15 ){\line    (1  , 0  ){0.15   }}
  \put(0   ,0.25 ){\line    (1  , 0  ){1.5    }}
  \put(1.55,3.75 ){\vector  (0  , 1  ){1.25   }}
  \put(1.55,3.75 ){\vector  (0  ,-1  ){1.25   }}
  \put(1.55,1.825){\vector  (0  , 1  ){0.675  }}
  \put(1.55,1.825){\vector  (0  ,-1  ){0.675  }}
  \put(0.4 ,1.375){\vector  (0  , 1  ){1.125  }}
  \put(0.4 ,1.375){\vector  (0  ,-1  ){1.125  }}
  \put(1.2 ,3.5  ){\makebox (0.5, 0.5){$   x $}}
  \put(0.6 ,1.575){\makebox (1  , 0.5){$l'-x'$}}
  \put(0   ,1.125){\makebox (0.5, 0.5){$   x'$}}
% Lable the displacement on the right-hand side.
  \put(3.7 ,5    ){\line    (1  , 0  ){1.1    }}
  \put(4.1 ,3.1  ){\line    (1  , 0  ){0.7    }}
  \put(4.3 ,4.05 ){\vector  (0  , 1  ){0.95   }}
  \put(4.3 ,4.05 ){\vector  (0  ,-1  ){0.95   }}
  \put(4.4 ,3.8  ){\makebox (0.8, 0.5){$l -x $}}
\end{picture}
```

Fig. 2.7.3: Double-double Atwood's machine

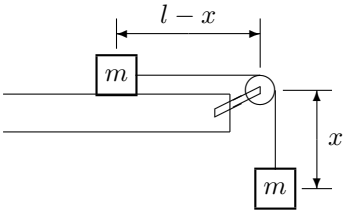


Definition

```
\begin{picture}(6.2,6.4)
\put(0,0){\makebox(6.2,6.4){}}
% Draw the roof.
  \put(1   ,6    ){\line    (1  , 0  ){3.8      }}
  \multiput(1.3,6)(0.5,0){7}{\line(1,1){0.4     }}
% Draw the fixed pulley.
  \put(2.9 ,5    ){\line    (0  , 1  ){1        }}
  \put(2.9 ,5    ){\circle             {1.4      }}
  \put(2.9 ,5    ){\circle*            {0.15     }}
  \put(2.2 ,5    ){\line    (0  ,-1  ){2.5      }}
  \put(3.6 ,5    ){\line    (0  ,-1  ){1        }}
% Draw the movable pulley on the left-hand side.
  \put(2.2 ,2.5  ){\circle             {0.7      }}
  \put(2.2 ,2.5  ){\circle*            {0.1      }}
  \put(1.85,2.5  ){\line    (0  ,-1  ){2        }}
  \put(2.55,2.5  ){\line    (0  ,-1  ){1        }}
% Draw the movable pulley on the right-hand side.
  \put(3.6 ,4    ){\circle             {0.6      }}
  \put(3.6 ,4    ){\circle*            {0.1      }}
  \put(3.3 ,4    ){\line    (0  ,-1  ){1.6      }}
  \put(3.9 ,4    ){\line    (0  ,-1  ){0.8      }}
% Draw the blocks and label their masses.
  \thicklines
  \put(1.6 ,0    ){\framebox(0.5, 0.5){$m_1    $}}
  \put(2.2 ,0.8  ){\framebox(0.7, 0.7){$m_2    $}}
  \put(3   ,1.8  ){\framebox(0.6, 0.6){$m_3    $}}
  \put(3.65,2.7  ){\framebox(0.5, 0.5){$m_4    $}}
  \thinlines
```

```
% Lable the displacements on the left-hand side.
  \put(1.2 ,5    ){\line    (1  , 0  ){0.9      }}
  \put(0   ,2.5  ){\line    (1  , 0  ){1.75     }}
  \put(1.2 ,1.15 ){\line    (1  , 0  ){0.55     }}
  \put(1.95,1.15 ){\line    (1  , 0  ){0.15     }}
  \put(0   ,0.25 ){\line    (1  , 0  ){1.5      }}
  \put(1.55,3.75 ){\vector  (0  , 1  ){1.25     }}
  \put(1.55,3.75 ){\vector  (0  ,-1  ){1.25     }}
  \put(1.55,1.825){\vector  (0  , 1  ){0.675    }}
  \put(1.55,1.825){\vector  (0  ,-1  ){0.675    }}
  \put(0.4 ,1.375){\vector  (0  , 1  ){1.125    }}
  \put(0.4 ,1.375){\vector  (0  ,-1  ){1.125    }}
  \put(1.2 ,3.5  ){\makebox (0.5, 0.5){$   x   $}}
  \put(0.6 ,1.575){\makebox (1  , 0.5){$l'-x'  $}}
  \put(0   ,1.125){\makebox (0.5, 0.5){$   x'  $}}
% Lable the displacements on the right-hand side.
  \put(3.7 ,5    ){\line    (1  , 0  ){1.1      }}
  \put(4   ,4    ){\line    (1  , 0  ){2.1      }}
  \put(4.25,2.95 ){\line    (1  , 0  ){0.55     }}
  \put(3.7 ,2.1  ){\line    (1  , 0  ){2.4      }}
  \put(4.45,4.5  ){\vector  (0  , 1  ){0.5      }}
  \put(4.45,4.5  ){\vector  (0  ,-1  ){0.5      }}
  \put(4.45,3.475){\vector  (0  , 1  ){0.525    }}
  \put(4.45,3.475){\vector  (0  ,-1  ){0.525    }}
  \put(5.7 ,3.05 ){\vector  (0  , 1  ){0.95     }}
  \put(5.7 ,3.05 ){\vector  (0  ,-1  ){0.95     }}
  \put(4.45,4.25 ){\makebox (1  , 0.5){$l  -x  $}}
  \put(4.45,3.225){\makebox (1.2, 0.5){$l''-x''$}}
  \put(5.7 ,2.7  ){\makebox (0.6, 0.5){$    x''$}}
\end{picture}
```

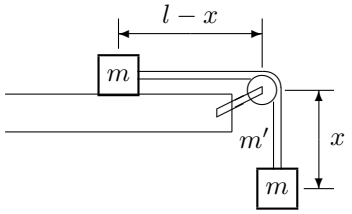
Fig. 2.7.4: Two blocks connected by a massless rope



Definition

```
\begin{picture}(4.5,2.8)
\put(0,0){\makebox(4.5,2.8){}}
% Draw the table.
  \put(0   ,1.5 ){\line    ( 1  , 0  ){3    }}
  \put(0   ,1   ){\line    ( 1  , 0  ){3    }}
  \put(3   ,1   ){\line    ( 0  , 1  ){0.5  }}
% Draw the pulley.
  \put(2.8 ,1.3 ){\line    ( 2  , 1  ){0.6  }}
  \put(2.8 ,1.2 ){\line    ( 2  , 1  ){0.6  }}
  \put(2.8 ,1.2 ){\line    ( 0  , 1  ){0.1  }}
  \put(3.4 ,1.5 ){\line    ( 0  , 1  ){0.1  }}
  \put(3.4 ,1.55){\circle             {0.4  }}
% Draw the blocks.
  \thicklines
  \put(1.25,1.5 ){\framebox( 0.5, 0.5){$m  $}}
  \put(3.35,0   ){\framebox( 0.5, 0.5){$m  $}}
  \thinlines
% Draw the cord.
  \put(1.75,1.75){\line    ( 1  , 0  ){1.65 }}
  \put(3.6 ,1.55){\line    ( 0  ,-1  ){1.05 }}
% Label the generalized coordinate l-x.
  \put(1.5 ,2.1 ){\line    ( 0  , 1  ){0.4  }}
  \put(3.4 ,1.85){\line    ( 0  , 1  ){0.65 }}
  \put(2.45,2.3 ){\vector  ( 1  , 0  ){0.95 }}
  \put(2.45,2.3 ){\vector  (-1  , 0  ){0.95 }}
  \put(1.95,2.3 ){\makebox ( 1  , 0.5){$l-x$}}
% Label the generalized coordinate x.
  \put(3.7 ,1.55){\line    ( 1  , 0  ){0.65 }}
  \put(3.95,0.25){\line    ( 1  , 0  ){0.4  }}
  \put(4.15,0.9 ){\vector  ( 0  , 1  ){0.65 }}
  \put(4.15,0.9 ){\vector  ( 0  ,-1  ){0.65 }}
  \put(4.15,0.65){\makebox ( 0.5, 0.5){$  x$}}
\end{picture}
```

Fig. 2.7.5: Two blocks connected by a massive rope



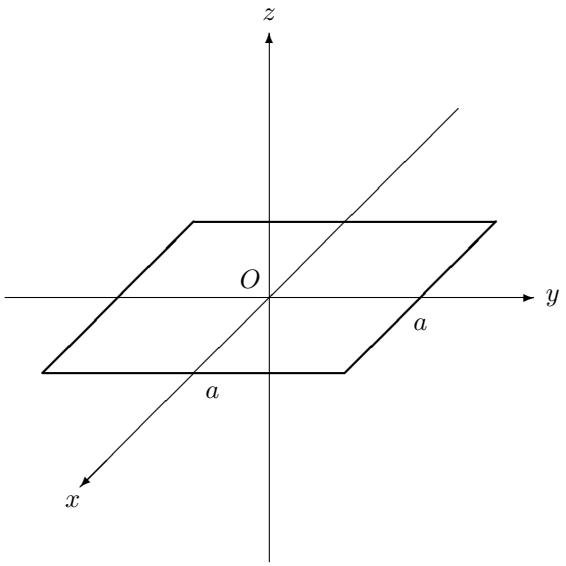
Definition

```
\begin{picture}(4.5,2.8)
\put(0,0){\makebox(4.5,2.8){}}
% Draw the table.
  \put(0   ,1.5  ){\line    ( 1  , 0  ){3    }}
  \put(0   ,1    ){\line    ( 1  , 0  ){3    }}
  \put(3   ,1    ){\line    ( 0  , 1  ){0.5  }}
% Draw the pulley.
  \put(2.8 ,1.3  ){\line    ( 2  , 1  ){0.6  }}
  \put(2.8 ,1.2  ){\line    ( 2  , 1  ){0.6  }}
  \put(2.8 ,1.2  ){\line    ( 0  , 1  ){0.1  }}
  \put(3.4 ,1.5  ){\line    ( 0  , 1  ){0.1  }}
  \put(3.4 ,1.55 ){\circle             {0.4  }}
% Draw the blocks.
  \thicklines
  \put(1.25,1.5  ){\framebox( 0.5, 0.5){$m  $}}
  \put(3.35,0    ){\framebox( 0.5, 0.5){$m  $}}
  \thinlines
% Draw the cord and label its weight.
  \put(1.75,1.8  ){\line    ( 1  , 0  ){1.65 }}
  \put(1.75,1.7  ){\line    ( 1  , 0  ){1.5  }}
  \put(3.65,1.55 ){\line    ( 0  ,-1  ){1.05 }}
  \put(3.55,1.4  ){\line    ( 0  ,-1  ){0.9  }}
  \put(3.4 ,1.55 ){\oval    ( 0.5, 0.5)[rt]   }
  \put(3.05,0.675){\makebox ( 0.5, 0.5){$m' $}}
% Label the generalized coordinate l-x.
  \put(1.5 ,2.1  ){\line    ( 0  , 1  ){0.4  }}
  \put(3.4 ,1.85 ){\line    ( 0  , 1  ){0.65 }}
  \put(2.45,2.3  ){\vector  ( 1  , 0  ){0.95 }}
  \put(2.45,2.3  ){\vector  (-1  , 0  ){0.95 }}
  \put(1.95,2.3  ){\makebox ( 1  , 0.5){$l-x$}}
```

```
% Label the generalized coordinate x.
  \put(3.7 ,1.55 ){\line    ( 1  , 0  ){0.65 }}
  \put(3.95,0.25 ){\line    ( 1  , 0  ){0.4  }}
  \put(4.15,0.9  ){\vector  ( 0  , 1  ){0.65 }}
  \put(4.15,0.9  ){\vector  ( 0  ,-1  ){0.65 }}
  \put(4.15,0.65 ){\makebox ( 0.5, 0.5){$  x$}}
\end{picture}
```

2.8 Simple symmetric rigid bodies

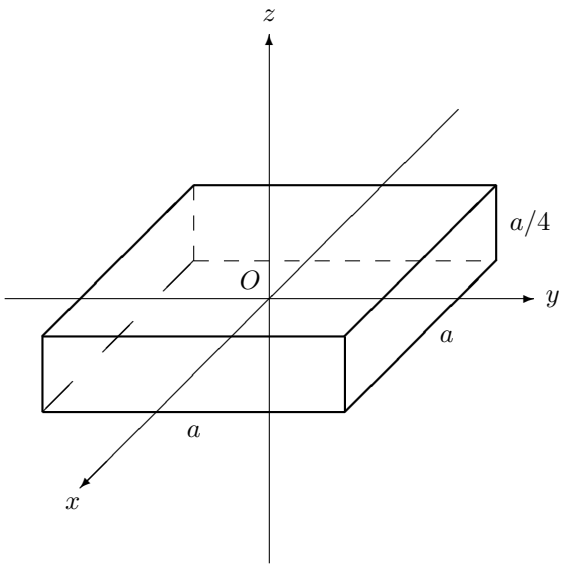
Fig. 2.8.1: Thin square plate



Definition

```
\begin{picture}(7.5,7.5)
\put(0,0){\makebox(7.5,7.5){}}
% Draw and label the coordinate axes.
% Use the savebox: CartesianXYZ.
  \put(0   ,0   ){\usebox {\CartesianXYZ }}
% Draw the square.
  \thicklines
  \put(0.5 ,2.5 ){\line   ( 1  , 0  ){4  }}
  \put(0.5 ,2.5 ){\line   ( 1  , 1  ){2  }}
  \put(2.5 ,4.5 ){\line   ( 1  , 0  ){4  }}
  \put(4.5 ,2.5 ){\line   ( 1  , 1  ){2  }}
  \thinlines
% Label the dimension.
  \put(2.5 ,2   ){\makebox( 0.5, 0.5){$a$}}
  \put(5.25,2.9 ){\makebox( 0.5, 0.5){$a$}}
\end{picture}
```

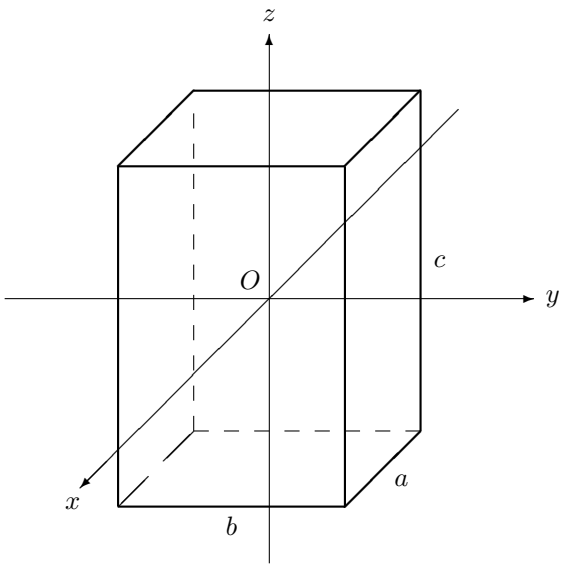
Fig. 2.8.2: Thick square plate



Definition

```
\begin{picture}(7.5,7.5)
\put(0,0){\makebox(7.5,7.5){}}
% Draw and label the coordinate axes.
% Use the savebox: CartesianXYZ.
  \put(0   ,0   ){\usebox {\CartesianXYZ   }}
% Draw the upper square.
  \thicklines
  \put(0.5 ,3   ){\line   ( 1  , 0  ){4    }}
  \put(0.5 ,3   ){\line   ( 1  , 1  ){2    }}
  \put(4.5 ,3   ){\line   ( 1  , 1  ){2    }}
  \put(2.5 ,5   ){\line   ( 1  , 0  ){4    }}
% Draw the lower square.
  \put(0.5 ,2   ){\line   ( 1  , 0  ){4    }}
  \put(4.5 ,2   ){\line   ( 1  , 1  ){2    }}
% Draw the pillars between two squares.
  \put(0.5 ,2   ){\line   ( 0  , 1  ){1    }}
  \put(4.5 ,2   ){\line   ( 0  , 1  ){1    }}
  \put(6.5 ,4   ){\line   ( 0  , 1  ){1    }}
  \thinlines
% Draw the lines which we can not see.
  \multiput(0.5,2  )(0.8,0.8){ 3}{\line(1,1){0.4}}
  \multiput(2.5,4  )(0.4,0  ){10}{\line(1,0){0.2}}
  \multiput(2.5,4  )(0  ,0.4){ 3}{\line(0,1){0.2}}
% Label the dimensions.
  \put(2.25,1.5 ){\makebox( 0.5, 0.5){$a  $}}
  \put(5.6 ,2.75){\makebox( 0.5, 0.5){$a  $}}
  \put(6.6 ,4.25){\makebox( 0.7, 0.5){$a/4$}}
\end{picture}
```

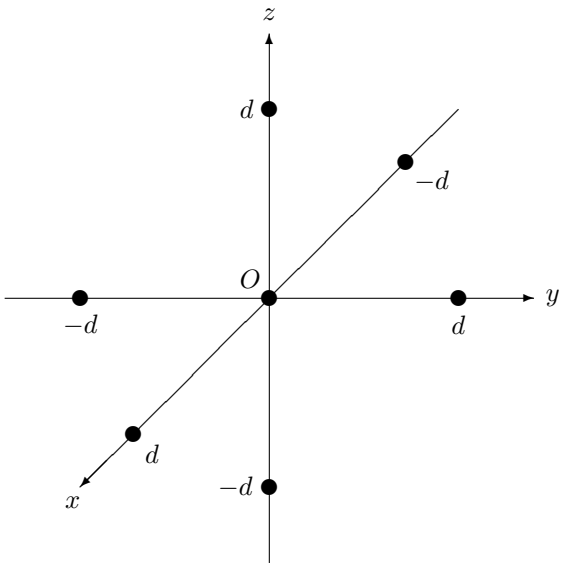
Fig. 2.8.3: Cubic block



Definition

```
\begin{picture}(7.5,7.5)
\put(0,0){\makebox(7.5,7.5){}}
% Draw and label the coordinate axes.
% Use the savebox: CartesianXYZ.
  \put(0   ,0   ){\usebox {\CartesianXYZ }}
% Draw the upper square.
  \thicklines
  \put(1.5 ,5.25){\line   ( 1  , 0  ){3  }}
  \put(1.5 ,5.25){\line   ( 1  , 1  ){1  }}
  \put(4.5 ,5.25){\line   ( 1  , 1  ){1  }}
  \put(2.5 ,6.25){\line   ( 1  , 0  ){3  }}
% Draw the lower square.
  \put(1.5 ,0.75){\line   ( 1  , 0  ){3  }}
  \put(4.5 ,0.75){\line   ( 1  , 1  ){1  }}
% Draw the pillars between two squares.
  \put(1.5 ,0.75){\line   ( 0  , 1  ){4.5}}
  \put(4.5 ,0.75){\line   ( 0  , 1  ){4.5}}
  \put(5.5 ,1.75){\line   ( 0  , 1  ){4.5}}
  \thinlines
% Draw the lines which we can not see.
  \multiput(1.5,0.75)(0.6,0.6){ 2}{\line(1,1){0.4}}
  \multiput(2.5,1.75)(0.4,0  ){ 8}{\line(1,0){0.2}}
  \multiput(2.5,1.75)(0  ,0.4){11}{\line(0,1){0.2}}
% Label the dimensions
  \put(5   ,0.85){\makebox( 0.5, 0.5){$a$}}
  \put(2.75,0.25){\makebox( 0.5, 0.5){$b$}}
  \put(5.5 ,3.75){\makebox( 0.5, 0.5){$c$}}
\end{picture}
```

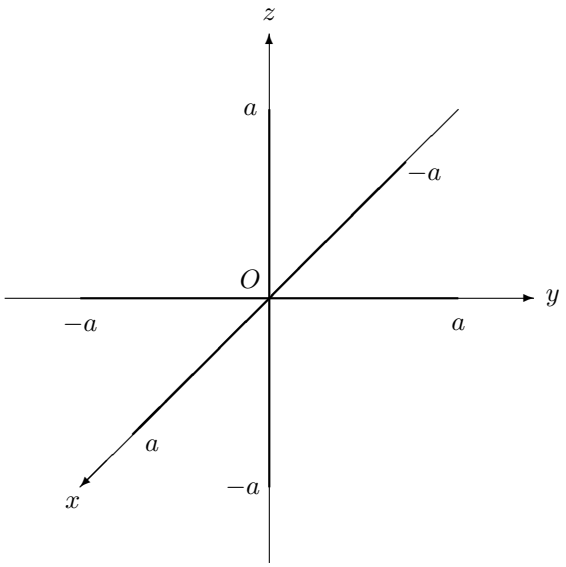
Fig. 2.8.4: Particles



Definition

```
\begin{picture}(7.5,7.5)
\put(0,0){\makebox(7.5,7.5){}}
% Draw and label the coordinate axes.
% Use the savebox: CartesianXYZ.
  \put(0   ,0   ){\usebox {\CartesianXYZ  }}
% Draw the atoms.
  \put(1.7 ,1.7 ){\circle*           {0.2 }}  % on x-axis,  d
  \put(5.3 ,5.3 ){\circle*           {0.2 }}  % on x-axis, -d
  \put(6   ,3.5 ){\circle*           {0.2 }}  % on y-axis,  d
  \put(1   ,3.5 ){\circle*           {0.2 }}  % on y-axis, -d
  \put(3.5 ,6   ){\circle*           {0.2 }}  % on z-axis,  d
  \put(3.5 ,1   ){\circle*           {0.2 }}  % on z-axis, -d
  \put(3.5 ,3.5 ){\circle*           {0.2 }}  % on origin
% Label the locations of the atoms.
  \put(1.7 ,1.2 ){\makebox( 0.5, 0.5){$ d$}}  % on x-axis
  \put(5.3 ,4.8 ){\makebox( 0.7, 0.5){$-d$}}  % on x-axis
  \put(5.75,2.9 ){\makebox( 0.5, 0.5){$ d$}}  % on y-axis
  \put(0.65,2.9 ){\makebox( 0.7, 0.5){$-d$}}  % on y-axis
  \put(2.95,5.75){\makebox( 0.5, 0.5){$ d$}}  % on z-axis
  \put(2.7 ,0.75){\makebox( 0.7, 0.5){$-d$}}  % on z-axis
\end{picture}
```

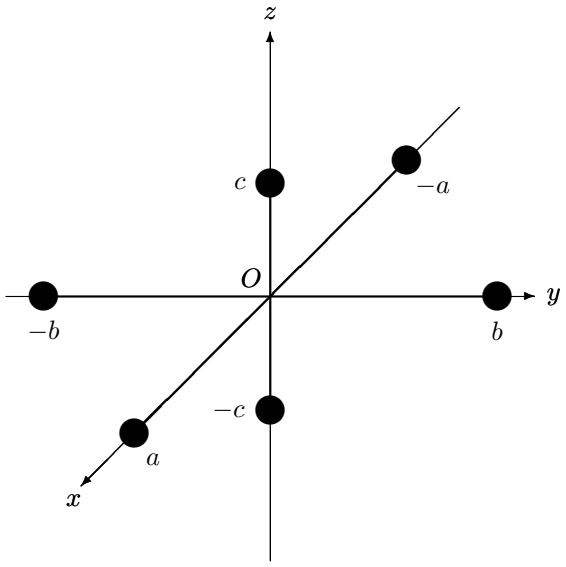
Fig. 2.8.5: Rods



Definition

```
\begin{picture}(7.5,7.5)
\put(0,0){\makebox(7.5,7.5){}}
% Draw and label the coordinate axes.
% Use the savebox: CartesianXYZ.
  \put(0   ,0   ){\usebox {\CartesianXYZ  }}
% Draw the rods.
  \thicklines
  \put(5.3 ,5.3 ){\line   (-1  ,-1  ){3.6 }}  % on x-axis
  \put(1   ,3.5 ){\line   ( 1  , 0  ){5   }}  % on y-axis
  \put(3.5 ,1   ){\line   ( 0  , 1  ){5   }}  % on z-axis
  \thinlines
% Label the locations of the ends of the rods.
  \put(1.7 ,1.3 ){\makebox( 0.5, 0.5){$ a$}}  % on x-axis
  \put(5.2 ,4.9 ){\makebox( 0.7, 0.5){$-a$}}  % on x-axis
  \put(5.75,2.9 ){\makebox( 0.5, 0.5){$ a$}}  % on y-axis
  \put(0.65,2.9 ){\makebox( 0.7, 0.5){$-a$}}  % on y-axis
  \put(3   ,5.75){\makebox( 0.5, 0.5){$ a$}}  % on z-axis
  \put(2.8 ,0.75){\makebox( 0.7, 0.5){$-a$}}  % on z-axis
\end{picture}
```

Fig. 2.8.6: Rods with particles

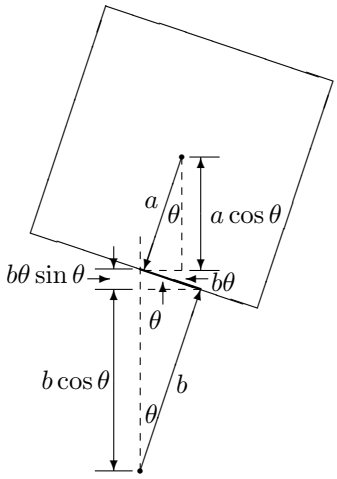


Definition

```
\begin{picture}(7.5,7.5)
\put(0,0){\makebox(7.5,7.5){}}
% Draw and label the coordinate axes.
% Use the savebox: CartesianXYZ.
  \put(0   ,0   ){\usebox {\CartesianXYZ  }}
% Draw the rods.
  \thicklines
  \put(5.3 ,5.3 ){\line   (-1  ,-1  ){3.6 }}  % on x-axis
  \put(0.5 ,3.5 ){\line   ( 1  , 0  ){6   }}  % on y-axis
  \put(3.5 ,2   ){\line   ( 0  , 1  ){3   }}  % on z-axis
  \thinlines
% Draw the balls.
  \put(1.7 ,1.7 ){\circle*           {0.4 }}  % on x-axis,  a
  \put(5.3 ,5.3 ){\circle*           {0.4 }}  % on x-axis, -a
  \put(6.5 ,3.5 ){\circle*           {0.4 }}  % on y-axis,  b
  \put(0.5 ,3.5 ){\circle*           {0.4 }}  % on y-axis, -b
  \put(3.5 ,5   ){\circle*           {0.4 }}  % on z-axis,  c
  \put(3.5 ,2   ){\circle*           {0.4 }}  % on z-axis, -c
% Label the locations of the balls.
  \put(1.7 ,1.1 ){\makebox( 0.5, 0.5){$ a$}}  % on x-axis
  \put(5.3 ,4.7 ){\makebox( 0.7, 0.5){$-a$}}  % on x-axis
  \put(6.25,2.8 ){\makebox( 0.5, 0.5){$ b$}}  % on y-axis
  \put(0.15,2.8 ){\makebox( 0.7, 0.5){$-b$}}  % on y-axis
  \put(2.85,4.75){\makebox( 0.5, 0.5){$ c$}}  % on z-axis
  \put(2.6 ,1.75){\makebox( 0.7, 0.5){$-c$}}  % on z-axis
\end{picture}
```

2.9 Hemispheres and bowls

Fig. 2.9.1: A cubic block oscillates on a hemisphere



Definition

```
\begin{picture}(6,6.2)
\put(0,0){\makebox(6,6.2){}}
% Draw and label the bowl below and label the angle theta.
  \put(3   ,0   ){\circle*           {0.06                }}
  \put(3   ,0   ){\vector ( 1  , 3  ){0.8                 }}
  \multiput(3   ,0   )( 0  , 0.2){16}{\line(0, 1){0.1     }}
  \put(3.3 ,0.9 ){\makebox( 0.5, 0.5){$b                 $}}
  \put(3   ,0.5 ){\makebox( 0.3, 0.5){$\theta            $}}
% Draw the cubical block titling on the right-hand side.
  \put(1.55,3.15){\line   ( 3  ,-1  ){3                   }}
  \put(1.55,3.15){\line   ( 1  , 3  ){1                   }}
  \put(4.55,2.15){\line   ( 1  , 3  ){1                   }}
  \put(2.55,6.15){\line   ( 3  ,-1  ){3                   }}
% Label the size of the cubic and the angle theta.
  \put(3.55,4.15){\circle*           {0.06                }}
  \put(3.55,4.15){\vector (-1  ,-3  ){0.5                 }}
  \multiput(3.55,4.15)( 0  ,-0.2){8 }{\line( 0,-1){0.1    }}
  \put(2.9 ,3.3 ){\makebox( 0.5, 0.5){$a                 $}}
  \put(3.3 ,3.15){\makebox( 0.3, 0.5){$\theta            $}}
% Label the height: a cos theta.
  \multiput(3.05,2.65)( 0.2, 0  ){3 }{\line( 1, 0){0.1    }}
  \put(3.65,4.15){\line   ( 1  , 0  ){0.4                 }}
  \put(3.65,2.65){\line   ( 1  , 0  ){0.4                 }}
  \put(3.8 ,3.4 ){\vector ( 0  , 1  ){0.75                }}
  \put(3.8 ,3.4 ){\vector ( 0  ,-1  ){0.75                }}
  \put(3.9 ,3.15){\makebox( 1  , 0.5){$a \cos\theta       $}}
```

```
% Label the track of the arc on the cubic: b theta.
  \thicklines
  \put(3   ,2.67){\line   ( 3  ,-1  ){0.8                  }}
  \thinlines
  \put(3.9 ,2.54){\vector (-1  , 0  ){0.3                  }}
  \put(3.9 ,2.25){\makebox( 0.4, 0.5){$b \theta           $}}
  \put(3.3 ,2.2 ){\vector ( 0  , 1  ){0.3                  }}
  \put(3.1 ,1.75){\makebox( 0.2, 0.5){$\theta             $}}
% Label the heights: b theta sin theta and b cos theta.
  \put(2.4 ,2.67){\line   ( 1  , 0  ){0.5                  }}
  \put(2.4 ,2.4 ){\line   ( 1  , 0  ){0.5                  }}
  \multiput(3.8 ,2.4 )(-0.2, 0  ){4 }{\line(-1, 0){0.1     }}
  \put(2.9 ,0   ){\line   (-1  , 0  ){0.5                  }}
  \put(2.65,2.97){\vector ( 0  ,-1  ){0.3                  }}
  \put(2.65,1.2 ){\vector ( 0  , 1  ){1.2                  }}
  \put(2.65,1.2 ){\vector ( 0  ,-1  ){1.2                  }}
  \put(2.3 ,2.54){\vector ( 1  , 0  ){0.3                  }}
  \put(1.25,2.35){\makebox( 1  , 0.5){$b \theta \sin\theta$}}
  \put(1.65,0.95){\makebox( 1  , 0.5){$b \cos\theta       $}}
\end{picture}
```

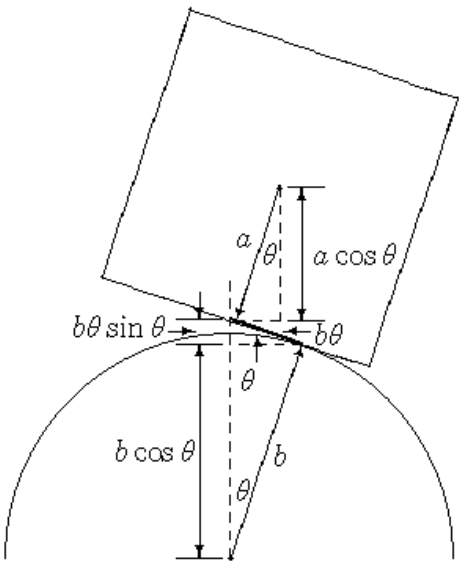
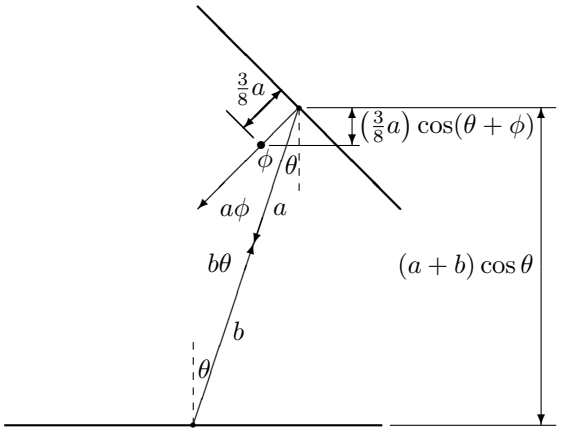


Fig. 2.9.2: A bowl oscillates on a hemisphere



Definition

```
\begin{picture}(7.3,5.6)
\put(0,0){\makebox(7.3,5.6){}}
  \thicklines
% Draw the baseline of the lower hemisphere with radius b.
  \put(2.5 ,0   ){\circle*           {0.06              }}
  \put(0   ,0   ){\line   ( 1  , 0  ){5                 }}
% Draw the baseline of the upper hemisphere with radius a.
  \put(3.9 ,4.2 ){\circle*           {0.06              }}
  \put(3.9 ,4.2 ){\line   ( 1  ,-1  ){1.34              }}
  \put(3.9 ,4.2 ){\line   (-1  , 1  ){1.34              }}
  \thinlines
% Label the radius b and, angle theta, and the arc b theta.
  \multiput(2.5,0  )(0, 0.2){6}{\line(0, 1){0.1         }}
  \put(2.5 ,0   ){\vector ( 1  , 3  ){0.8               }}
  \put(2.85,1   ){\makebox( 0.5, 0.5){$b               $}}
  \put(2.5 ,0.5 ){\makebox( 0.3, 0.5){$  \theta        $}}
  \put(2.7 ,1.9 ){\makebox( 0.3, 0.5){$b \theta        $}}
% Label the radius a and the angle theta.
  \multiput(3.9,4.2)(0,-0.2){6}{\line(0,-1){0.1         }}
  \put(3.9 ,4.2 ){\vector (-1  ,-3  ){0.6               }}
  \put(3.5 ,2.6 ){\makebox( 0.3, 0.5){$a               $}}
  \put(3.65,3.2 ){\makebox( 0.3, 0.5){$\theta          $}}
% Label the angle phi and the arc a phi.
  \put(3.9 ,4.2 ){\vector (-1  ,-1  ){1.34              }}
  \put(3.25,3.25){\makebox( 0.4, 0.5){$  \phi          $}}
  \put(2.8 ,2.6 ){\makebox( 0.5, 0.5){$a \phi          $}}
```

```
% Label the center of mass of the hemisphere of radius a.
  \put(3.4 ,3.7 ){\circle*           {0.09              }}
  \put(3.3 ,3.8 ){\line   (-1  , 1  ){0.36              }}
  \put(3.17,3.94){\vector ( 1  , 1  ){0.5               }}
  \put(3.67,4.43){\vector (-1  ,-1  ){0.5               }}
  \put(3   ,4.2 ){\makebox( 0.5, 0.5){$\T \frac{3}{8} a$}}
% Label the heights.
  \put(4   ,4.2 ){\line   (1  , 0  ){3.3               }}
  \put(3.5 ,3.7 ){\line   (1  , 0  ){1.2               }}
  \put(4.6 ,3.95){\vector (0  , 1  ){0.25              }}
  \put(4.6 ,3.95){\vector (0  ,-1  ){0.25              }}
  \put(4.6 ,3.7 ){\makebox(2.5, 0.5)
                {$\T \left(\frac{3}{8} a\right) \cos(\theta+\phi)$}}
  \put(5.1 ,0   ){\line   (1   ,0  ){2.2               }}
  \put(7.1 ,2.1 ){\vector (0  , 1  ){2.1               }}
  \put(7.1 ,2.1 ){\vector (0  ,-1  ){2.1               }}
  \put(5.1 ,1.9 ){\makebox(2  , 0.4){$(a+b) \cos\theta $}}
\end{picture}
```

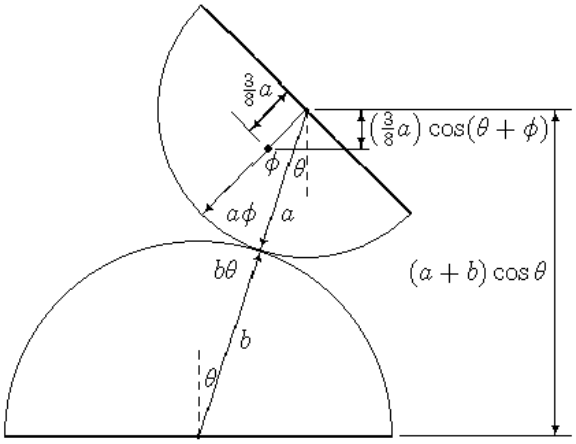
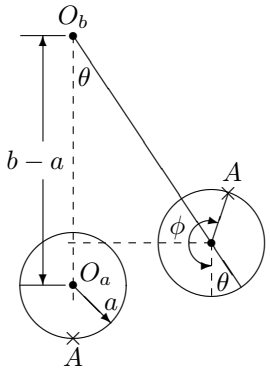


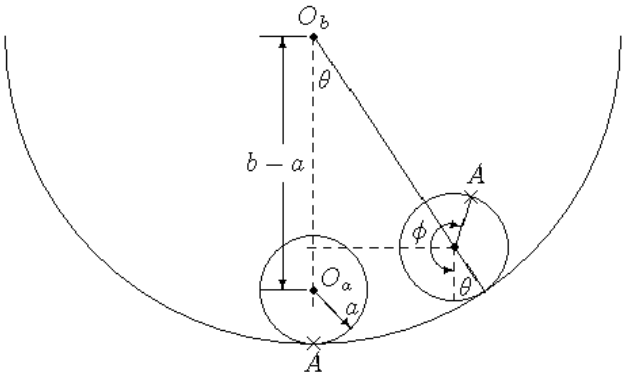
Fig. 2.9.3: A ball rolls in a bowl



Definition

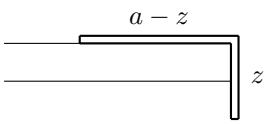
```
\begin{picture}(8,5)
\put(0,0){\makebox(8,5){}}
% Draw the steel ball and label its radius and center.
  \put(4   ,1.2 ){\circle           {1.4     }}
  \put(4   ,1.2 ){\circle*          {0.1     }}
  \put(4   ,1.2 ){\vector (1  ,-1  ){0.5     }}
  \put(4.25,0.7 ){\makebox(0.5, 0.5){$a     $}}
  \put(4.05,1.1 ){\makebox(0.5, 0.5){$O_a   $}}
% Draw and label the point O_b.
  \put(4   ,4.5 ){\circle*          {0.1     }}
  \put(3.75,4.5 ){\makebox(0.5, 0.5){$O_b   $}}
% Drew the moving ball.
  \put(4   ,4.5 ){\line   (2  ,-3  ){2.22    }}
  \put(5.83,1.76){\circle           {1.4     }}
  \put(5.83,1.76){\circle*          {0.1     }}
% Label the angle theta.
  \multiput(4   ,4.5 )(0,-0.2){18}{\line(0,-1){0.1}}
  \multiput(5.83,1.76)(0,-0.2){4 }{\line(0,-1){0.1}}
  \put(3.95,3.7 ){\makebox(0.4, 0.5){$\theta$}}
  \put(5.78,1   ){\makebox(0.4, 0.5){$\theta$}}
% Label the angle phi.
  \put(3.8 ,0.3 ){\makebox(0.4, 0.4){$\times$}}
  \put(3.75,0   ){\makebox(0.5, 0.5){$A     $}}
  \put(5.85,2.22){\makebox(0.4, 0.4){$\times$}}
  \put(5.85,2.45){\makebox(0.5, 0.5){$A     $}}
  \put(5.83,1.76){\line   (1  , 3  ){0.22    }}
  \put(5.83,1.76){\oval   (0.6, 0.6)[l       ]}
  \put(5.78,2.06){\vector (4  ,-1  ){0.15    }}
  \put(5.73,1.46){\vector (1  , 0  ){0.1     }}
  \put(5.23,1.76){\makebox(0.3, 0.4){$\phi  $}}
```

```
% Label the length b-a.
  \multiput(5.83,1.76)(-0.2,0){10}{\line(-1,0){0.1}}
  \put(3.3 ,1.2 ){\line   (1  , 0  ){0.6     }}
  \put(3.3 ,4.5 ){\line   (1  , 0  ){0.6     }}
  \put(3.6 ,3.1 ){\vector (0  , 1  ){1.4     }}
  \put(3.6 ,2.6 ){\vector (0  ,-1  ){1.4     }}
  \put(3   ,2.6 ){\makebox(1  , 0.5){$b-a   $}}
\end{picture}
```



2.10 Miscellaneous

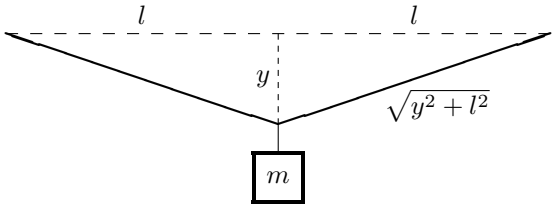
Fig. 2.10.1: A heavy chain hangs partly on the table



Definition

```
\begin{picture}(3.6,1.6)
\put(0,0){\makebox(3.6,1.6){}}
% Draw the table.
  \put(0   ,1  ){\line   (1  , 0  ){3    }}
  \put(0   ,0.5){\line   (1  , 0  ){3    }}
  \put(3   ,0.5){\line   (0  , 1  ){0.5  }}
% Draw the chain.
  \thicklines
  \put(1   ,1.1){\line   (1  , 0  ){2.1  }}
  \put(1   ,1  ){\line   (1  , 0  ){2    }}
  \put(1   ,1  ){\line   (0  , 1  ){0.1  }}
  \put(3   ,1  ){\line   (0  ,-1  ){1    }}
  \put(3.1 ,1.1){\line   (0  ,-1  ){1.1  }}
  \put(3   ,0  ){\line   (1  , 0  ){0.1  }}
  \thinlines
% Label the chain.
  \put(1.55,1.1){\makebox(1  , 0.5){$a-z$}}
  \put(3.1 ,0.3){\makebox(0.5, 0.5){$  z$}}
\end{picture}
```

Fig. 2.10.2: A block suspends from an elastic cord



Definition

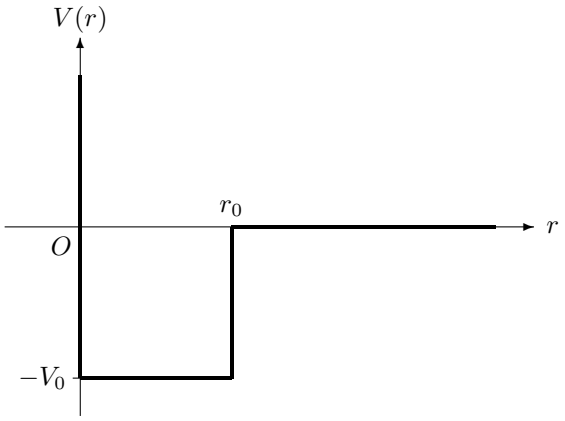
```
\begin{picture}(7.2,2.7)
\put(0,0){\makebox(7.2,2.7){}}
% Draw the cord that suspends the block.
  \thicklines
  \put(3.6,1   ){\line    ( 3  , 1  ){3.6}}
  \put(3.6,1   ){\line    (-3  , 1  ){3.6}}
  \thinlines
% Draw the block and label its mass.
  \put(3.6,1   ){\line    ( 0  ,-1  ){0.4}}
  \linethickness{1.5pt}
  \put(3.3,0   ){\framebox( 0.6, 0.6){$m$}}
  \thinlines
% Label the length of the cord.
  \multiput(0  ,2.2)(0.32,0   ){23}{\line(1,0){0.16}}
  \multiput(3.6,1  )(0   ,0.16){ 8}{\line(0,1){0.08}}
  \put(1.6,2.2 ){\makebox ( 0.4, 0.5){$l$}}
  \put(5.2,2.2 ){\makebox ( 0.4, 0.5){$l$}}
  \put(3.2,1.35){\makebox ( 0.4, 0.5){$y$}}
  \put(5  ,1   ){\makebox ( 1.4, 0.5){$\sqrt{y^2+l^2}$}}
\end{picture}
```

Chapter 3

Quantum Mechanics

3.1 Potential wells

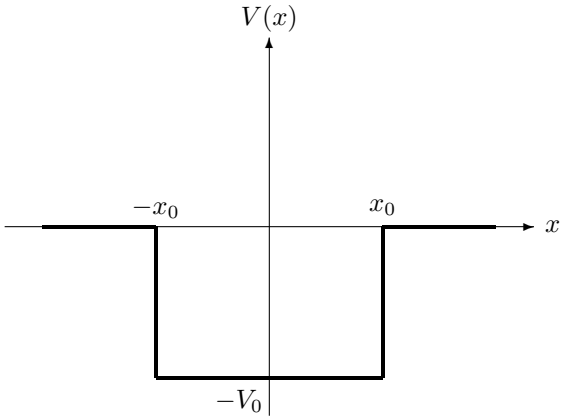
Fig. 3.1.1: Spherical square potential well



Definition

```
\begin{picture}(7.5,5.5)
\put(0,0){\makebox(7.5,5.5){}}
% Draw and label the axes.
  \put(0   ,2.5 ){\vector (1  ,0  ){7     }}
  \put(1   ,0   ){\vector (0  ,1  ){5     }}
  \put(7   ,2.25){\makebox(0.5,0.5){$  r $}}
  \put(0.5 ,5   ){\makebox(1  ,0.5){$V(r)$}}
  \put(0.5 ,2   ){\makebox(0.5,0.5){$  0 $}}
% Draw the potential.
  \linethickness{1.5pt}
  \put(1   ,0.5 ){\line   (0  ,1  ){4     }}
  \put(1   ,0.5 ){\line   (1  ,0  ){2     }}
  \put(3   ,0.5 ){\line   (0  ,1  ){2     }}
  \put(3   ,2.5 ){\line   (1  ,0  ){3.5   }}
  \thinlines
% Label the potential.
  \put(0.9 ,0.5 ){\line   (1  ,0  ){0.2   }}
  \put(0.1 ,0.25){\makebox(0.8,0.5){$-V_0$}}
  \put(2.75,2.5 ){\makebox(0.5,0.5){$ r_0$}}
\end{picture}
```

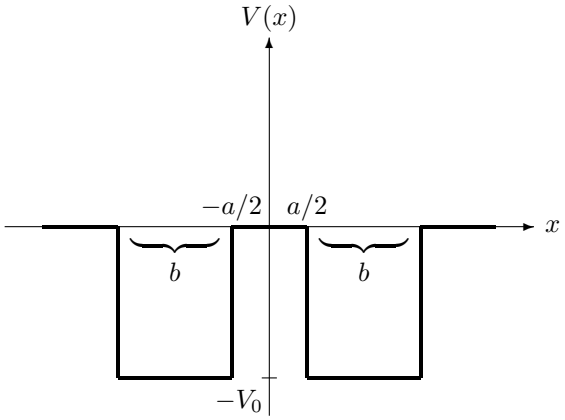
Fig. 3.1.2: Finite square potential well



Definition

```
\begin{picture}(7.5,5.5)
\put(0,0){\makebox(7.5,5.5){}}
% Draw and label the axes.
  \put(0   ,2.5 ){\vector (1  ,0  ){7     }}
  \put(3.5 ,0   ){\vector (0  ,1  ){5     }}
  \put(7   ,2.25){\makebox(0.5,0.5){$  x $}}
  \put(3   ,5   ){\makebox(1  ,0.5){$V(x)$}}
% Draw the potential.
  \linethickness{1.5pt}
  \put(0.5 ,2.5 ){\line   (1  ,0  ){1.5   }}
  \put(2   ,0.5 ){\line   (0  ,1  ){2     }}
  \put(2   ,0.5 ){\line   (1  ,0  ){3     }}
  \put(5   ,0.5 ){\line   (0  ,1  ){2     }}
  \put(5   ,2.5 ){\line   (1  ,0  ){1.5   }}
  \thinlines
% Label the potential.
  \put(2.7 ,0   ){\makebox(0.8,0.4){$-V_0$}}
  \put(4.75,2.5 ){\makebox(0.5,0.5){$ x_0$}}
  \put(1.65,2.5 ){\makebox(0.7,0.5){$-x_0$}}
\end{picture}
```

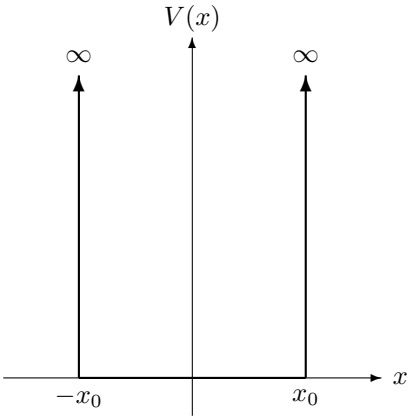
Fig. 3.1.3: Double finite square potential well



Definition

```
\begin{picture}(7.5,5.5)
\put(0,0){\makebox(7.5,5.5){}}
% Draw and label the axes.
  \put(0  ,2.5 ){\vector (1  ,0  ){7     }}
  \put(3.5,0   ){\vector (0  ,1  ){5     }}
  \put(7  ,2.25){\makebox(0.5,0.5){$  x $}}
  \put(3  ,5   ){\makebox(1  ,0.5){$V(x)$}}
% Draw the potential.
  \linethickness{1.5pt}
  \put(0.5,2.5 ){\line   (1  ,0  ){1     }}
  \put(1.5,0.5 ){\line   (0  ,1  ){2     }}
  \put(1.5,0.5 ){\line   (1  ,0  ){1.5   }}
  \put(3  ,0.5 ){\line   (0  ,1  ){2     }}
  \put(3  ,2.5 ){\line   (1  ,0  ){1     }}
  \put(4  ,0.5 ){\line   (0  ,1  ){2     }}
  \put(4  ,0.5 ){\line   (1  ,0  ){1.5   }}
  \put(5.5,0.5 ){\line   (0  ,1  ){2     }}
  \put(5.5,2.5 ){\line   (1  ,0  ){1     }}
  \thinlines
% Label the potential.
  \put(3.4,0.5 ){\line   (1  ,0  ){0.2   }}
  \put(2.7,0   ){\makebox(0.8,0.4){$-V_0$}}
  \put(3.7,2.5 ){\makebox(0.6,0.5){$ a/2$}}
  \put(2.6,2.5 ){\makebox(0.8,0.5){$-a/2$}}
  \put(1.6,2   ){\makebox(1.3,0.5){$\underbrace{~~~~~~~~~~}$}}
  \put(2  ,1.65){\makebox(0.5,0.5){$ b  $}}
  \put(4.1,2   ){\makebox(1.3,0.5){$\underbrace{~~~~~~~~~~}$}}
  \put(4.5,1.65){\makebox(0.5,0.5){$ b  $}}
\end{picture}
```

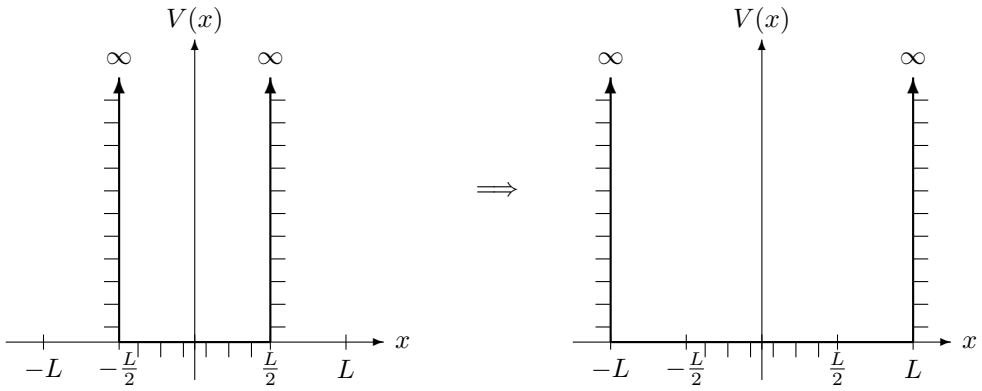
Fig. 3.1.4: Infinite square potential well



Definition

```
\begin{picture}(5.5,5)
% Draw and label the axes.
  \put(0  ,0.5 ){\vector (1  ,0  ){5       }}
  \put(2.5,0   ){\vector (0  ,1  ){5       }}
  \put(5  ,0.25){\makebox(0.5,0.5){$  x   $}}
  \put(2  ,5   ){\makebox(1  ,0.5){$V(x)  $}}
% Draw the potential.
  \thicklines
  \put(1  ,0.5 ){\line   (1  ,0  ){3       }}
  \put(1  ,0.5 ){\vector (0  ,1  ){4       }}
  \put(4  ,0.5 ){\vector (0  ,1  ){4       }}
  \thinlines
% Label the potential.
  \put(0.7,4.5 ){\makebox(0.6,0.5){$\infty$}}
  \put(3.7,4.5 ){\makebox(0.6,0.5){$\infty$}}
  \put(0.7,0   ){\makebox(0.6,0.5){$-x_0  $}}
  \put(3.7,0   ){\makebox(0.6,0.5){$ x_0  $}}
\end{picture}
```

Fig. 3.1.5: Expansion of an infinite square potential well



Before expansion

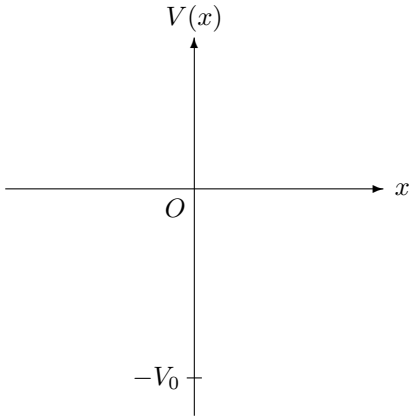
After expansion

Definition

```
\begin{picture}(13  ,6.5)
\put(0  ,0){\makebox(13  ,6.5){}}
\put(0  ,0){\makebox( 5.5,6.5){}}
\put(7.5,0){\makebox( 5.5,6.5){}}
% Before expansion:
% Draw and label the axes.
  \put( 0   ,2   ){\vector (1  ,0  ){5                }}
  \put( 2.5 ,1.5 ){\vector (0  ,1  ){4.5              }}
  \put( 5   ,1.75){\makebox(0.5,0.5){$  x            $}}
  \put( 2   ,6   ){\makebox(1  ,0.5){$V(x)           $}}
% Draw the well.
  \thicklines
  \put( 1.5 ,2   ){\line   (1  ,0  ){2                }}
  \put( 1.5 ,2   ){\vector (0  ,1  ){3.5              }}
  \put( 3.5 ,2   ){\vector (0  ,1  ){3.5              }}
  \thinlines
% Draw the walls and the floor of the well.
  \multiput( 1.3 ,2.2 )(0  ,0.3){11}{\line(1,0){0.2    }}
  \multiput( 1.75,1.8 )(0.3,0  ){ 6}{\line(0,1){0.2    }}
  \multiput( 3.5 ,2.2 )(0  ,0.3){11}{\line(1,0){0.2    }}
% Label the potential.
  \put( 1.25,5.5 ){\makebox(0.5,0.5){$\infty          $}}
  \put( 3.25,5.5 ){\makebox(0.5,0.5){$\infty          $}}
```

```
% Label the dimension of the well.
  \multiput( 0.5 ,1.9 )(1  ,0  ){ 5}{\line(0,1){0.2    }}
  \put( 0.2 ,1.4 ){\makebox(0.6,0.5){$   -      L     $}}
  \put( 1.2 ,1.4 ){\makebox(0.6,0.5){$\T{-\frac{L}{2}}$}}
  \put( 3.2 ,1.4 ){\makebox(0.6,0.5){$\T{ \frac{L}{2}}$}}
  \put( 4.2 ,1.4 ){\makebox(0.6,0.5){$          L     $}}
  \put( 1   ,0   ){\makebox(3  ,0.5){Before   expansion}}
%
% Draw the arrow.
  \put( 6   ,3.75){\makebox(1  ,0.5){$\lTo            $}}
%
% After expansion:
% Draw and label the axes.
  \put( 7.5 ,2   ){\vector (1  ,0  ){5                }}
  \put(10   ,1.5 ){\vector (0  ,1  ){4.5              }}
  \put(12.5 ,1.75){\makebox(0.5,0.5){$  x             $}}
  \put( 9.5 ,6   ){\makebox(1  ,0.5){$V(x)            $}}
% Draw the well.
  \thicklines
  \put( 8   ,2   ){\line   (1  ,0  ){4                }}
  \put( 8   ,2   ){\vector (0  ,1  ){3.5              }}
  \put(12   ,2   ){\vector (0  ,1  ){3.5              }}
  \thinlines
% Draw the walls and the floor of the well.
  \multiput( 7.8 ,2.2 )(0  ,0.3){11}{\line(1,0){0.2    }}
  \multiput( 9.25,1.8 )(0.3,0  ){ 6}{\line(0,1){0.2    }}
  \multiput(12   ,2.2 )(0  ,0.3){11}{\line(1,0){0.2    }}
% Label the potential.
  \put( 7.75,5.5 ){\makebox(0.5,0.5){$\infty          $}}
  \put(11.75,5.5 ){\makebox(0.5,0.5){$\infty          $}}
% Label the dimension of the well.
  \multiput( 8   ,1.9 )(1  ,0  ){ 5}{\line(0,1){0.2    }}
  \put( 7.7 ,1.4 ){\makebox(0.6,0.5){$   -      L     $}}
  \put( 8.7 ,1.4 ){\makebox(0.6,0.5){$\T{-\frac{L}{2}}$}}
  \put(10.7 ,1.4 ){\makebox(0.6,0.5){$\T{ \frac{L}{2}}$}}
  \put(11.7 ,1.4 ){\makebox(0.6,0.5){$          L     $}}
  \put( 8.5 ,0   ){\makebox(3  ,0.5){After    expansion}}
\end{picture}
```

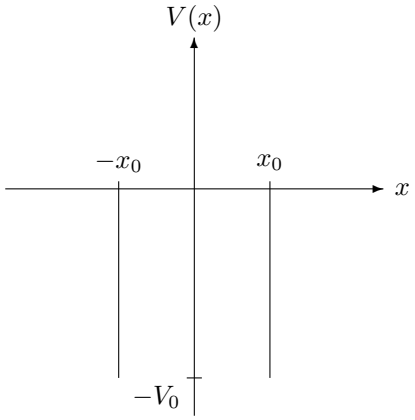
Fig. 3.1.6: Delta-function potential well



Definition

```
\begin{picture}(5.5,5.5)
\put(0,0){\makebox(5.5,5.5){}}
% Draw and label the axes.
  \put(0  ,3   ){\vector (1  ,0  ){5     }}
  \put(2.5,0   ){\vector (0  ,1  ){5     }}
  \put(5  ,2.75){\makebox(0.5,0.5){$  x $}}
  \put(2  ,5   ){\makebox(1  ,0.5){$V(x)$}}
  \put(2  ,2.5 ){\makebox(0.5,0.5){$  O $}}
% Label the potential -V_0.
  \put(2.4,0.5 ){\line   (1  ,0  ){0.2   }}
  \put(1.6,0.25){\makebox(0.8,0.5){$-V_0$}}
\end{picture}
```

Fig. 3.1.7: Double delta-function potential well

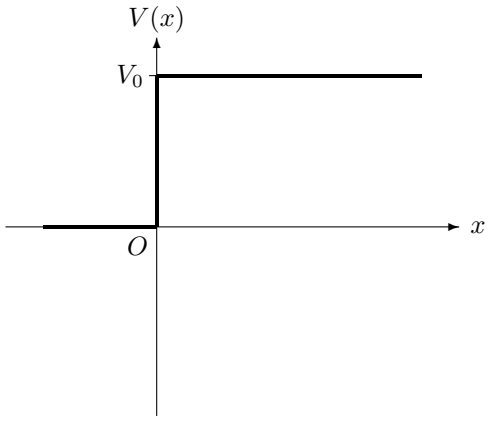


Definition

```
\begin{picture}(5.5,5.5)
\put(0,0){\makebox(5.5,5.5){}}
% Draw and label the axes.
  \put(0   ,3   ){\vector (1   , 0  ){5     }}
  \put(2.5,0    ){\vector (0   , 1  ){5     }}
  \put(5   ,2.75){\makebox(0.5, 0.5){$  x $}}
  \put(2   ,5   ){\makebox(1   , 0.5){$V(x)$}}
% Label the potential -V_0.
  \put(2.4,0.5 ){\line   (1   , 0  ){0.2   }}
  \put(1.6,0    ){\makebox(0.8, 0.5){$-V_0$}}
% Label the positions of the wells.
  \put(1.5,3.1 ){\line   (0   ,-1  ){2.6   }}
  \put(3.5,3.1 ){\line   (0   ,-1  ){2.6   }}
  \put(1.2,3.1 ){\makebox(0.6, 0.5){$-x_0$}}
  \put(3.2,3.1 ){\makebox(0.6, 0.5){$ x_0$}}
\end{picture}
```

3.2 Potential barriers

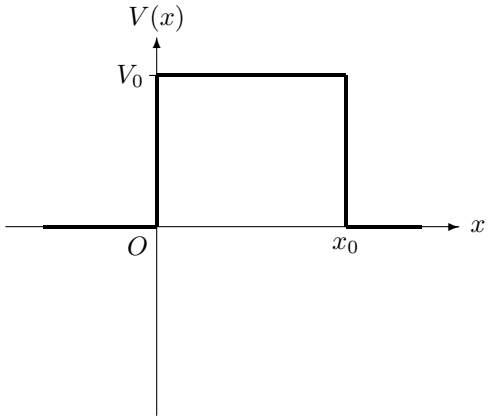
Fig. 3.2.1: Step-function potential barrier



Definition

```
\begin{picture}(6.5,5.5)
\put(0,0){\makebox(6.5,5.5){}}
% Draw and label the axes.
  \put(0   ,2.5 ){\vector (1  ,0  ){6     }}
  \put(2   ,0   ){\vector (0  ,1  ){5     }}
  \put(6   ,2.25){\makebox(0.5,0.5){$  x $}}
  \put(1.5 ,5   ){\makebox(1  ,0.5){$V(x)$}}
  \put(1.5 ,2   ){\makebox(0.5,0.5){$  O $}}
% Draw the potential.
  \linethickness{1.5pt}
  \put(0.5 ,2.5 ){\line   (1  ,0  ){1.5   }}
  \put(2   ,2.5 ){\line   (0  ,1  ){2     }}
  \put(2   ,4.5 ){\line   (1  ,0  ){3.5   }}
  \thinlines
% Label the potential.
  \put(1.9 ,4.5 ){\line   (1  ,0  ){0.2   }}
  \put(1.4 ,4.25){\makebox(0.5,0.5){$V_0 $}}
\end{picture}
```

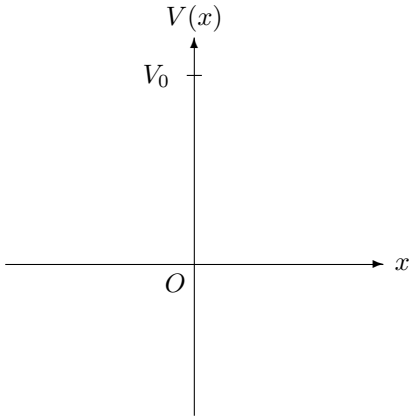
Fig. 3.2.2: Square potential barrier



Definition

```
\begin{picture}(6.5,5.5)
\put(0,0){\makebox(6.5,5.5){}}
% Draw and label the axes.
  \put(0   ,2.5 ){\vector (1  ,0  ){6     }}
  \put(2   ,0   ){\vector (0  ,1  ){5     }}
  \put(6   ,2.25){\makebox(0.5,0.5){$  x $}}
  \put(1.5 ,5   ){\makebox(1  ,0.5){$V(x)$}}
  \put(1.5 ,2   ){\makebox(0.5,0.5){$  O $}}
% Draw the potential.
  \linethickness{1.5pt}
  \put(0.5 ,2.5 ){\line   (1  ,0  ){1.5   }}
  \put(2   ,2.5 ){\line   (0  ,1  ){2     }}
  \put(2   ,4.5 ){\line   (1  ,0  ){2.5   }}
  \put(4.5 ,2.5 ){\line   (0  ,1  ){2     }}
  \put(4.5 ,2.5 ){\line   (1  ,0  ){1     }}
  \thinlines
% Label the potential.
  \put(1.9 ,4.5 ){\line   (1  ,0  ){0.2   }}
  \put(1.4 ,4.25){\makebox(0.5,0.5){$V_0 $}}
  \put(4.25,2   ){\makebox(0.5,0.5){$x_0 $}}
\end{picture}
```

Fig. 3.2.3: Delta-function potential barrier

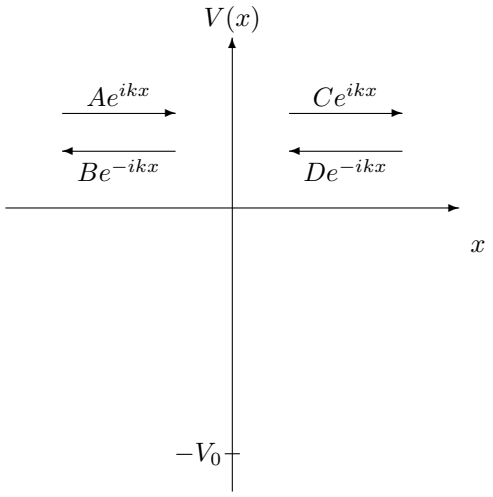


Definition

```
\begin{picture}(5.5,5.5)
\put(0,0){\makebox(5.5,5.5){}}
% Draw and label the axes.
  \put(0  ,2   ){\vector (1  ,0  ){5     }}
  \put(2.5,0   ){\vector (0  ,1  ){5     }}
  \put(5  ,1.75){\makebox(0.5,0.5){$  x $}}
  \put(2  ,1.5 ){\makebox(1  ,0.5){$V(x)$}}
  \put(2  ,1.5 ){\makebox(0.5,0.5){$  O $}}
% Label the potential V_0.
  \put(2.4,4.5 ){\line   (1  ,0  ){0.2   }}
  \put(1.7,4.25){\makebox(0.6,0.5){$V_0 $}}
\end{picture}
```

3.3 Scattering

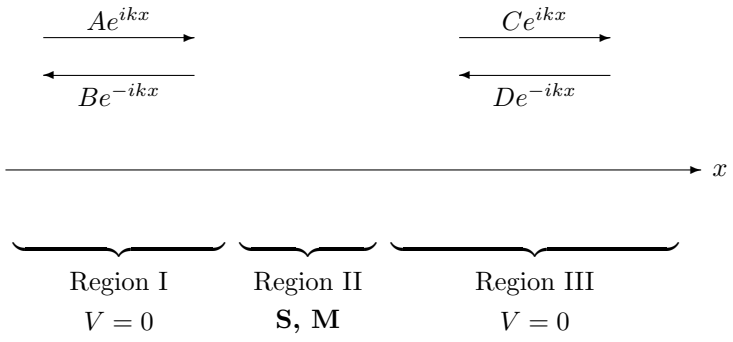
Fig. 3.3.1: From a delta-function potential well



Definition

```
\begin{picture}(6.5,6.5)
\put(0,0){\makebox(6.5,6.5){}}
% Draw and label the axes.
  \put(0   ,3.75){\vector ( 1  ,0  ){6          }}
  \put(3   ,0   ){\vector ( 0  ,1  ){6          }}
  \put(6   ,3.5 ){\makebox( 0.5,0.5){$x         $}}
  \put(2.5 ,6   ){\makebox( 1  ,0.5){$V(x)      $}}
% Draw and label the wave functions at x < 0.
  \put(0.75,5   ){\vector ( 1  ,0  ){1.5        }}
  \put(2.25,4.5 ){\vector (-1  ,0  ){1.5        }}
  \put(1   ,5   ){\makebox( 1  ,0.5){$A e^{ ikx}$}}
  \put(0.9 ,4   ){\makebox( 1.2,0.5){$B e^{-ikx}$}}
% Draw and label the wave functions at x > 0.
  \put(3.75,5   ){\vector ( 1  ,0  ){1.5        }}
  \put(5.25,4.5 ){\vector (-1  ,0  ){1.5        }}
  \put(4   ,5   ){\makebox( 1  ,0.5){$C e^{ ikx}$}}
  \put(3.9 ,4   ){\makebox( 1.2,0.5){$D e^{-ikx}$}}
% Label the potential -V_0.
  \put(2.9 ,0.5 ){\line   ( 1  ,0  ){0.2        }}
  \put(2.2 ,0.25){\makebox( 0.7,0.5){$-V_0      $}}
\end{picture}
```

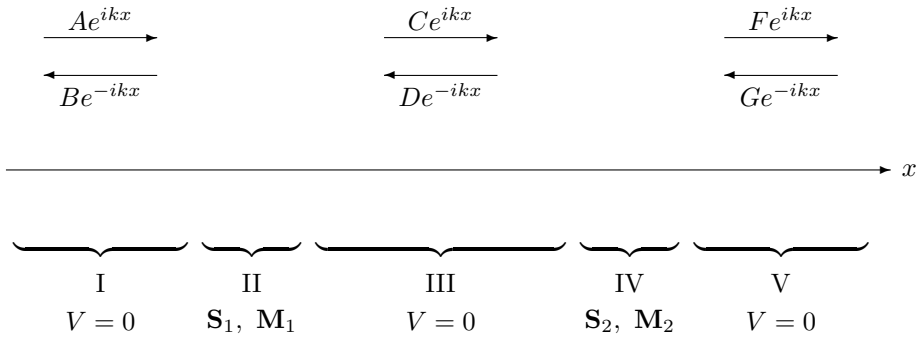
Fig. 3.3.2: From an arbitrary localized potential



Definition

```
\begin{picture}(9.7,4.5)
\put(0,0){\makebox(9.7,4.5){}}
% Draw and label the axes.
  \put(0  ,2.25){\vector ( 1  ,0  ){9.2         }}
  \put(9.2,2   ){\makebox( 0.5,0.5){$x         $}}
% Draw and label the wave functions at region I.
  \put(0.5,4   ){\vector ( 1  ,0  ){2           }}
  \put(2.5,3.5 ){\vector (-1  ,0  ){2           }}
  \put(1  ,4   ){\makebox( 1  ,0.5){$A e^{ ikx}$}}
  \put(0.9,3   ){\makebox( 1.2,0.5){$B e^{-ikx}$}}
% Draw and label the wave functions at region III.
  \put(6  ,4   ){\vector ( 1  ,0  ){2           }}
  \put(8  ,3.5 ){\vector (-1  ,0  ){2           }}
  \put(6.5,4   ){\makebox( 1  ,0.5){$C e^{ ikx}$}}
  \put(6.4,3   ){\makebox( 1.2,0.5){$D e^{-ikx}$}}
% Label the region I.
  \put(0.1,1   ){\makebox( 2.8,0.5){$\underbrace{\makebox(2.8,0.1){}}$}}
  \put(0.6,0.5 ){\makebox( 1.8,0.5){Region I}}
  \put(0.9,0   ){\makebox( 1.2,0.5){$V = 0 $}}
% Label the region II.
  \put(3.1,1   ){\makebox( 1.8,0.5){$\underbrace{\makebox(1.8,0.1){}}$}}
  \put(3.1,0.5 ){\makebox( 1.8,0.5){Region II}}
  \put(3.4,0   ){\makebox( 1.2,0.5){\bf S,  M}}
% Label the region III.
  \put(5.1,1   ){\makebox( 3.8,0.5){$\underbrace{\makebox(3.8,0.1){}}$}}
  \put(6.1,0.5 ){\makebox( 1.8,0.5){Region III}}
  \put(6.4,0   ){\makebox( 1.2,0.5){$V = 0   $}}
\end{picture}
```

Fig. 3.3.3: From an arbitrary potential consisting of two isolated pieces

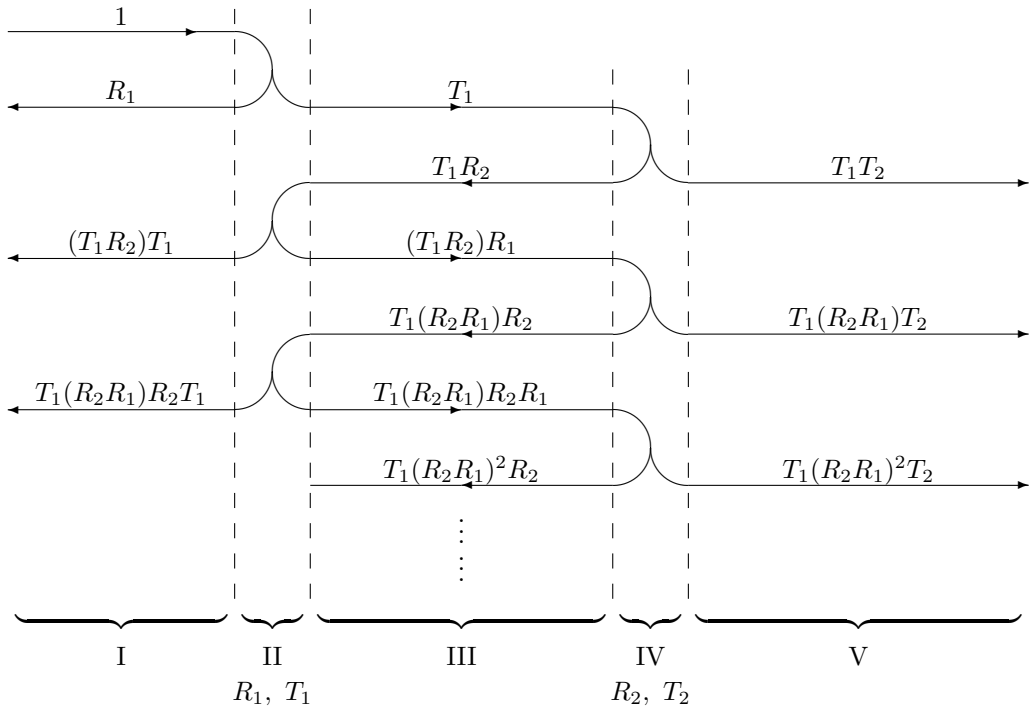


Definition

```
\begin{picture}(12.2,4.5)
\put(0,0){\makebox(12.2,4.5){}}
% Draw and label the axes.
  \put( 0   ,2.25){\vector ( 1  ,0  ){11.7        }}
  \put(11.7 ,2   ){\makebox( 0.5,0.5){$x         $}}
% Draw and label the wave functions at regions I.
  \put( 0.5 ,4   ){\vector ( 1  ,0  ){1.5         }}
  \put( 2   ,3.5 ){\vector (-1  ,0  ){1.5         }}
  \put( 0.75,4   ){\makebox( 1  ,0.5){$A e^{ ikx}$}}
  \put( 0.65,3   ){\makebox( 1.2,0.5){$B e^{-ikx}$}}
% Draw and label the wave functions at regions III.
  \put( 5   ,4   ){\vector ( 1  ,0  ){1.5         }}
  \put( 6.5 ,3.5 ){\vector (-1  ,0  ){1.5         }}
  \put( 5.25,4   ){\makebox( 1  ,0.5){$C e^{ ikx}$}}
  \put( 5.15,3   ){\makebox( 1.2,0.5){$D e^{-ikx}$}}
% Draw and label the wave functions at regions V.
  \put( 9.5 ,4   ){\vector ( 1  ,0  ){1.5         }}
  \put(11   ,3.5 ){\vector (-1  ,0  ){1.5         }}
  \put( 9.75,4   ){\makebox( 1  ,0.5){$F e^{ ikx}$}}
  \put( 9.65,3   ){\makebox( 1.2,0.5){$G e^{-ikx}$}}
% Label the region I.
  \put( 0.1 ,1   ){\makebox( 2.3,0.5){$\underbrace{\makebox(2.3,0.1){}}$}}
  \put( 1   ,0.5 ){\makebox( 0.5,0.5){$\rm I     $}}
  \put( 0.7 ,0   ){\makebox( 1.1,0.5){$V = 0     $}}
% Label the region II.
  \put( 2.6 ,1   ){\makebox( 1.3,0.5){$\underbrace{\makebox(1.3,0.1){}}$}}
  \put( 3   ,0.5 ){\makebox( 0.5,0.5){$\rm II    $}}
  \put( 2.5 ,0   ){\makebox( 1.5,0.5){${\bf S}_1,~{\bf M}_1$}}
% Label the region III.
  \put( 4.1 ,1   ){\makebox( 3.3,0.5){$\underbrace{\makebox(3.3,0.1){}}$}}
  \put( 5.5 ,0.5 ){\makebox( 0.5,0.5){$\rm III   $}}
  \put( 5.2 ,0   ){\makebox( 1.1,0.5){$V = 0     $}}
```

```
% Label the region IV.
  \put( 7.6 ,1   ){\makebox( 1.3,0.5){$\underbrace{\makebox(1.3,0.1){}}$}}
  \put( 8   ,0.5 ){\makebox( 0.5,0.5){$\rm IV    $}}
  \put( 7.5 ,0   ){\makebox( 1.5,0.5){${\bf S}_2,~{\bf M}_2$}}
% Label the region V.
  \put( 9.1 ,1   ){\makebox( 2.3,0.5){$\underbrace{\makebox(2.3,0.1){}}$}}
  \put(10   ,0.5 ){\makebox( 0.5,0.5){$\rm V     $}}
  \put( 9.7 ,0   ){\makebox( 1.1,0.5){$V = 0     $}}
\end{picture}
```

Fig. 3.3.4: Schematic illustration of the total transmission coefficient



Definition

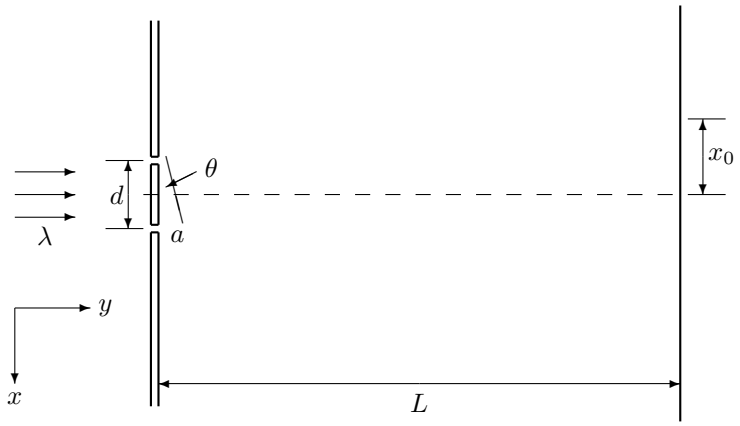
```
\begin{picture}(13.5,9.5)
\put(0,0){\makebox(13.5,9.5){}}
% Draw and label the incident wave.
  \put( 0   ,9  ){\vector ( 1  ,0  ){2.5  }}     % 1
  \put( 2.5 ,9  ){\line   ( 1  ,0  ){0.5  }}     % 1
  \put( 1.25,9  ){\makebox( 0.5,0.4){$1  $}}
% Draw and label the refraction and transmission in region II.
  \put( 3   ,8.5){\oval   ( 1  ,1  )[r    ]}     % 1 to R_1
  \put( 4   ,8.5){\oval   ( 1  ,1  )[lb   ]}     % 1 to T_1
  \put( 3   ,8  ){\vector (-1  ,0  ){3    }}     % R_1
  \put( 1.25,8  ){\makebox( 0.5,0.4){$R_1$}}     % R_1
  \put( 4   ,8  ){\vector ( 1  ,0  ){2    }}     % T_1
  \put( 6   ,8  ){\line   ( 1  ,0  ){2    }}     % T_1
  \put( 5.75,8  ){\makebox( 0.5,0.4){$T_1$}}     % T_1
% Draw and label the refraction and transmission in region IV.
  \put( 8   ,7.5){\oval   ( 1  ,1  )[r    ]}     % T_1 to T_1 R_2
  \put( 9   ,7.5){\oval   ( 1  ,1  )[lb   ]}     % T_1 to T_1 T_2
  \put( 8   ,7  ){\vector (-1  ,0  ){2    }}     % T_1 R_2
  \put( 6   ,7  ){\line   (-1  ,0  ){2    }}     % T_1 R_2
  \put( 5.5 ,7  ){\makebox( 1  ,0.4){$T_1 R_2$}}
  \put( 9   ,7  ){\vector ( 1  ,0  ){4.5  }}     % T_1 T_2
  \put(10.75,7  ){\makebox( 1  ,0.4){$T_1 T_2$}}
```

```
% Draw and label the refraction and transmission in region II.
  \put( 4   ,6.5){\oval   ( 1  ,1  )[l    ]}     % T_1 R_2 to T_1 R_2 R_1
  \put( 3   ,6.5){\oval   ( 1  ,1  )[rb   ]}     % T_1 R_2 to T_1 R_2 T_1
  \put( 4   ,6  ){\vector ( 1  ,0  ){2    }}     % T_1 R_2 R_1
  \put( 6   ,6  ){\line   ( 1  ,0  ){2    }}     % T_1 R_2 R_1
  \put( 5.25,6  ){\makebox( 1.5,0.4){$(T_1 R_2) R_1$}}
  \put( 3   ,6  ){\vector (-1  ,0  ){3    }}     % T_1 R_2 T_1
  \put( 0.75,6  ){\makebox( 1.5,0.4){$(T_1 R_2) T_1$}}
% Draw and label the refraction and transmission in region IV.
  \put( 8   ,5.5){\oval   ( 1  ,1  )[r    ]}     % (T_1 R_2)R_1 to T_1(R_2 R_1)R_2
  \put( 9   ,5.5){\oval   ( 1  ,1  )[lb   ]}     % (T_1 R_2)R_1 to T_1(R_2 R_1)T_2
  \put( 8   ,5  ){\vector (-1  ,0  ){2    }}     % T_1(R_2 R_1)R_2
  \put( 6   ,5  ){\line   (-1  ,0  ){2    }}     % T_1(R_2 R_1)R_2
  \put( 5   ,5  ){\makebox( 2  ,0.4){$T_1 (R_2 R_1) R_2$}}
  \put( 9   ,5  ){\vector ( 1  ,0  ){4.5  }}     % T_1(R_2 R_1)T_2
  \put(10.25,5  ){\makebox( 2  ,0.4){$T_1 (R_2 R_1) T_2$}}
% Draw and label the refraction and transmission in region II.
  \put( 4   ,4.5){\oval   ( 1  ,1  )[l    ]}
  \put( 3   ,4.5){\oval   ( 1  ,1  )[rb   ]}
  \put( 4   ,4  ){\vector ( 1  ,0  ){2    }}
  \put( 6   ,4  ){\line   ( 1  ,0  ){2    }}
  \put( 4.75,4  ){\makebox( 2.5,0.4){$T_1 (R_2 R_1) R_2 R_1$}}
  \put( 3   ,4  ){\vector (-1  ,0  ){3    }}
  \put( 0.25,4  ){\makebox( 2.5,0.4){$T_1 (R_2 R_1) R_2 T_1$}}
% Draw and label the refraction and transmission in region IV.
  \put( 8   ,3.5){\oval   ( 1  ,1  )[r    ]}
  \put( 9   ,3.5){\oval   ( 1  ,1  )[lb   ]}
  \put( 8   ,3  ){\vector (-1  ,0  ){2    }}
  \put( 6   ,3  ){\line   (-1  ,0  ){2    }}
  \put( 4.75,3  ){\makebox( 2.5,0.4){$T_1 (R_2 R_1)^2 R_2$}}
  \put( 9   ,3  ){\vector ( 1  ,0  ){4.5  }}
  \put(10   ,3  ){\makebox( 2.5,0.4){$T_1 (R_2 R_1)^2 T_2$}}
% Draw the vertical points.
  \put( 5.75,2.25){\makebox( 0.5,0.5){$\vdots  $}}
  \put( 5.75,1.75){\makebox( 0.5,0.5){$\vdots  $}}
% Draw the seperations between the regions
  \multiput(3  ,1.5)(0  ,0.4){20}{\line(0,1){0.2}}
  \multiput(4  ,1.5)(0  ,0.4){20}{\line(0,1){0.2}}
  \multiput(8  ,1.5)(0  ,0.4){18}{\line(0,1){0.2}}
  \multiput(9  ,1.5)(0  ,0.4){18}{\line(0,1){0.2}}
```

```
% Label the regions.
  \put( 0.1 ,1  ){\makebox(2.8,0.5){$\underbrace{\makebox(2.8,0.1){}}$}}
  \put( 1.25,0.5){\makebox(0.5,0.5){I}}
  \put( 3.1 ,1  ){\makebox(0.8,0.5){$\underbrace{\makebox(0.8,0.1){}}$}}
  \put( 3.25,0.5){\makebox(0.5,0.5){II}}
  \put( 3   ,0  ){\makebox(1  ,0.5){$R_1,~T_1$}}
  \put( 4.1 ,1  ){\makebox(3.8,0.5){$\underbrace{\makebox(3.8,0.1){}}$}}
  \put( 5.75,0.5){\makebox(0.5,0.5){III}}
  \put( 8.1 ,1  ){\makebox(0.8,0.5){$\underbrace{\makebox(0.8,0.1){}}$}}
  \put( 8.25,0.5){\makebox(0.5,0.5){IV}}
  \put( 8   ,0  ){\makebox(1  ,0.5){$R_2,~T_2$}}
  \put( 9.1 ,1  ){\makebox(4.3,0.5){$\underbrace{\makebox(4.3,0.1){}}$}}
  \put(11   ,0.5){\makebox(0.5,0.5){V}}
\end{picture}
```

3.4 Interference and diffraction

Fig. 3.4.1: Two-slits interference (without magnetic field)

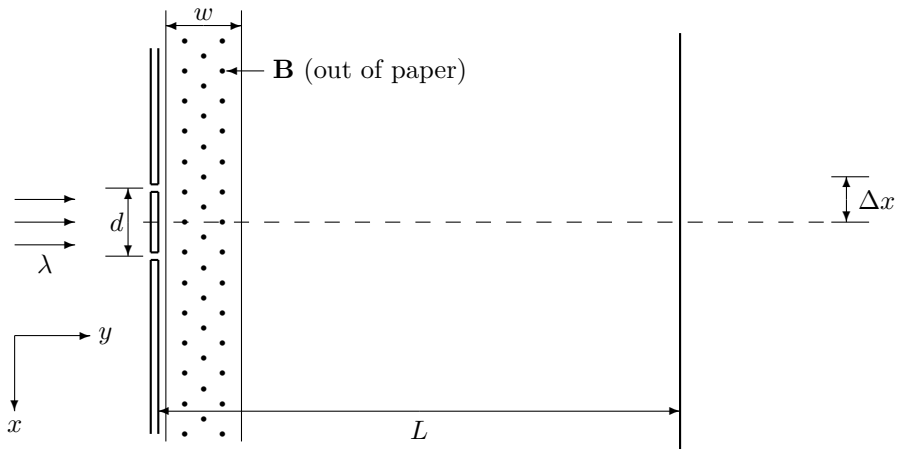


Definition

```
\begin{picture}(9.8,5.5)
\put(0,0){\makebox(9.8,5.5){}}
% Draw the two-slits.
  \thicklines
  \put(2   ,0.2 ){\line   ( 0  , 1  ){2.3      }}
  \put(2.1 ,0.2 ){\line   ( 0  , 1  ){2.3      }}
  \put(2   ,2,6 ){\line   ( 0  , 1  ){0.8      }}
  \put(2.1 ,2,6 ){\line   ( 0  , 1  ){0.8      }}
  \put(2   ,3.5 ){\line   ( 0  , 1  ){1.8      }}
  \put(2.1 ,3.5 ){\line   ( 0  , 1  ){1.8      }}
  \put(2   ,2.5 ){\line   ( 1  , 0  ){0.1      }}
  \put(2   ,2.6 ){\line   ( 1  , 0  ){0.1      }}
  \put(2   ,3.4 ){\line   ( 1  , 0  ){0.1      }}
  \put(2   ,3.5 ){\line   ( 1  , 0  ){0.1      }}
% Draw the screen.
  \put(9   ,0   ){\line   ( 0  , 1  ){5.5      }}
  \thinlines
% Draw the central line.
  \multiput(1.9,3  )(0.4,0){18}{\line(1,0){0.2 }}
% Draw and label the incident wave length.
  \put(0.2 ,2.7 ){\vector ( 1  , 0  ){0.8      }}
  \put(0.2 ,3   ){\vector ( 1  , 0  ){0.8      }}
  \put(0.2 ,3.3 ){\vector ( 1  , 0  ){0.8      }}
  \put(0.35,2.2 ){\makebox( 0.5, 0.5){$\lambda$}}
% Draw and label the coordinate axes.
  \put(0.2 ,1.5 ){\vector ( 0  ,-1  ){1        }}
  \put(0.2 ,1.5 ){\vector ( 1  , 0  ){1        }}
  \put(0   ,0.1 ){\makebox( 0.4, 0.4){$x      $}}
  \put(1.2 ,1.3 ){\makebox( 0.4, 0.4){$y      $}}
```

```
% Label the width of two slits d.
  \put(1.4 ,2.55){\line   ( 1  , 0  ){0.5      }}
  \put(1.4 ,3.45){\line   ( 1  , 0  ){0.5      }}
  \put(1.7 ,3   ){\vector ( 0  ,-1  ){0.45     }}
  \put(1.7 ,3   ){\vector ( 0  , 1  ){0.45     }}
  \put(1.3 ,2.75){\makebox( 0.5, 0.5){$d      $}}
% Draw and label the path difference a and the angle theta.
  \put(2.2 ,3.5 ){\line   ( 1  ,-4  ){0.22     }}
  \put(2.6 ,3.3 ){\vector (-2  ,-1  ){0.4      }}
  \put(2.7 ,3.1 ){\makebox( 0.2, 0.5){$\theta $}}
  \put(2.1 ,2.2 ){\makebox( 0.5, 0.5){$a      $}}
% Label the distance between the two-slits and the screen L.
  \put(5.55,0.5 ){\vector (-1  , 0  ){3.45     }}
  \put(5.55,0.5 ){\vector ( 1  , 0  ){3.45     }}
  \put(5.3 ,0   ){\makebox( 0.5, 0.5){$L      $}}
% Label x_0.
  \put(9.1 ,4   ){\line   ( 1  , 0  ){0.5      }}
  \put(9.1 ,3   ){\line   ( 1  , 0  ){0.5      }}
  \put(9.3 ,3.5 ){\vector ( 0  ,-1  ){0.5      }}
  \put(9.3 ,3.5 ){\vector ( 0  , 1  ){0.5      }}
  \put(9.3 ,3.25){\makebox( 0.5, 0.5){$x_0    $}}
\end{picture}
```

Fig. 3.4.2: Two-slits interference (with a magnetic field)

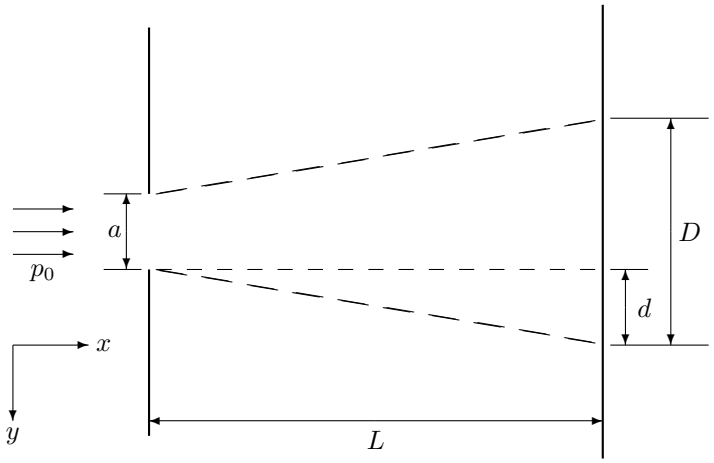


Definition

```
\begin{picture}(12,6)
\put(0,0){\makebox(12,6){}}
% Draw the two-slits.
  \thicklines
  \put( 2   ,0.2 ){\line   ( 0  , 1  ){2.3      }}
  \put( 2.1 ,0.2 ){\line   ( 0  , 1  ){2.3      }}
  \put( 2   ,2,6 ){\line   ( 0  , 1  ){0.8      }}
  \put( 2.1 ,2,6 ){\line   ( 0  , 1  ){0.8      }}
  \put( 2   ,3.5 ){\line   ( 0  , 1  ){1.8      }}
  \put( 2.1 ,3.5 ){\line   ( 0  , 1  ){1.8      }}
  \put( 2   ,2.5 ){\line   ( 1  , 0  ){0.1      }}
  \put( 2   ,2.6 ){\line   ( 1  , 0  ){0.1      }}
  \put( 2   ,3.4 ){\line   ( 1  , 0  ){0.1      }}
  \put( 2   ,3.5 ){\line   ( 1  , 0  ){0.1      }}
% Draw the screen.
  \put( 9   ,0   ){\line   ( 0  , 1  ){5.5      }}
  \thinlines
% Draw the central line.
  \multiput(1.9,3  )(0.4,0){18}{\line(1, 0){0.2}}
% Draw and label the incident wave length.
  \put( 0.2 ,2.7 ){\vector ( 1  , 0  ){0.8      }}
  \put( 0.2 ,3   ){\vector ( 1  , 0  ){0.8      }}
  \put( 0.2 ,3.3 ){\vector ( 1  , 0  ){0.8      }}
  \put( 0.35,2.2 ){\makebox( 0.5, 0.5){$\lambda$}}
% Draw and label the coordinate axes.
  \put( 0.2 ,1.5 ){\vector ( 0  ,-1  ){1        }}
  \put( 0.2 ,1.5 ){\vector ( 1  , 0  ){1        }}
  \put( 0   ,0.1 ){\makebox( 0.4, 0.4){$x      $}}
  \put( 1.2 ,1.3 ){\makebox( 0.4, 0.4){$y      $}}
```

```
% Label the width of two slits d.
  \put( 1.4 ,2.55){\line   ( 1  , 0  ){0.5      }}
  \put( 1.4 ,3.45){\line   ( 1  , 0  ){0.5      }}
  \put( 1.7 ,3   ){\vector ( 0  ,-1  ){0.45     }}
  \put( 1.7 ,3   ){\vector ( 0  , 1  ){0.45     }}
  \put( 1.3 ,2.75){\makebox( 0.5, 0.5){$d      $}}
% Label the distance between the two-slits and the screen L.
  \put( 5.55,0.5 ){\vector (-1  , 0  ){3.45     }}
  \put( 5.55,0.5 ){\vector ( 1  , 0  ){3.45     }}
  \put( 5.3 ,0   ){\makebox( 0.5, 0.5){$L      $}}
% Draw and label the strip of the magnetic field.
  \put( 2.2 ,0.1 ){\line   ( 0  , 1  ){5.7       }}
  \put( 3.2 ,0.1 ){\line   ( 0  , 1  ){5.7       }}
  \multiput(2.45,0.2 )(0  ,0.4){14}{\circle*{0.08}}
  \multiput(2.7 ,0.4 )(0  ,0.4){13}{\circle*{0.08}}
  \multiput(2.95,0.2 )(0  ,0.4){14}{\circle*{0.08}}
  \put( 3.5 ,5   ){\vector (-1  , 0  ){0.5       }}
  \put( 3.5 ,4.75){\makebox( 2.8, 0.5){${\bf B}$ (out of paper)}}
% Label the width of the strip w.
  \put( 2.7 ,5.6 ){\vector ( 1  , 0  ){0.5       }}
  \put( 2.7 ,5.6 ){\vector (-1  , 0  ){0.5       }}
  \put( 2.45,5.5 ){\makebox( 0.5, 0.5){$w       $}}
% Label Delta x.
  \put(11   ,3.6 ){\line   ( 1  , 0  ){0.5       }}
  \put(11   ,3   ){\line   ( 1  , 0  ){0.5       }}
  \put(11.2 ,3.3 ){\vector ( 0  ,-1  ){0.3       }}
  \put(11.2 ,3.3 ){\vector ( 0  , 1  ){0.3       }}
  \put(11.2 ,3   ){\makebox( 0.8, 0.6){$\Delta x$}}
\end{picture}
```

Fig. 3.4.3: Diffraction



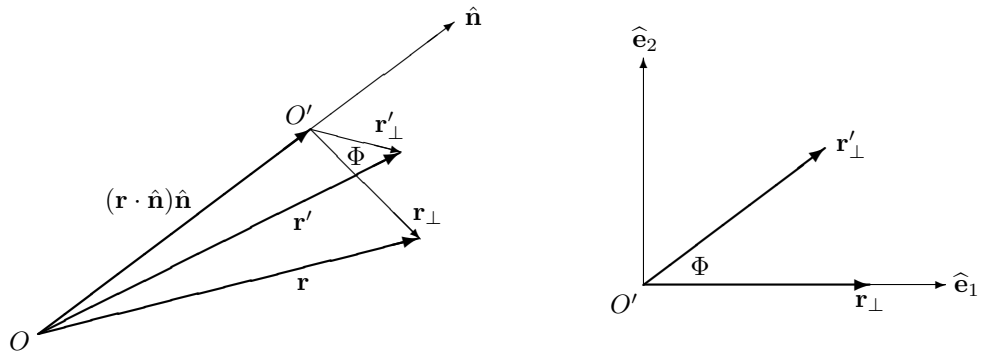
Definition

```
\begin{picture}(9.4,6)
\put(0,0){\makebox(9.4,6){}}
% Draw the apparatus.
  \thicklines
  \put(2   ,0.3 ){\line   ( 0  , 1  ){2.2         }}
  \put(2   ,3.5 ){\line   ( 0  , 1  ){2.2         }}
  \put(8   ,0   ){\line   ( 0  , 1  ){6           }}
  \thinlines
% Draw the dotted lines.
  \multiput(2.1,2.5)(0.4, 0  ){15}{\line(1, 0){0.2}}
  \multiput(2.1,2.5)(0.6,-0.1){10}{\line(6,-1){0.4}}
  \multiput(2.1,3.5)(0.6, 0.1){10}{\line(6, 1){0.4}}
% Draw and label the incident momentum.
  \put(0.2 ,2.7 ){\vector ( 1  , 0  ){0.8         }}
  \put(0.2 ,3   ){\vector ( 1  , 0  ){0.8         }}
  \put(0.2 ,3.3 ){\vector ( 1  , 0  ){0.8         }}
  \put(0.3 ,2.2 ){\makebox( 0.6, 0.5){$p_0       $}}
% Draw and label the coordinate axes.
  \put(0.2 ,1.5 ){\vector ( 1  , 0  ){1           }}
  \put(0.2 ,1.5 ){\vector ( 0  ,-1  ){1           }}
  \put(1.2 ,1.3 ){\makebox( 0.4, 0.4){$x         $}}
  \put(0   ,0.1 ){\makebox( 0.4, 0.4){$y         $}}
% Label the width a.
  \put(1.4 ,2.5 ){\line   ( 1  , 0  ){0.5         }}
  \put(1.4 ,3.5 ){\line   ( 1  , 0  ){0.5         }}
  \put(1.7 ,3   ){\vector ( 0  ,-1  ){0.5         }}
  \put(1.7 ,3   ){\vector ( 0  , 1  ){0.5         }}
  \put(1.3 ,2.75){\makebox( 0.5, 0.5){$a          $}}
```

```
% Label the distance L.
  \put(5   ,0.5 ){\vector (-1  , 0  ){3           }}
  \put(5   ,0.5 ){\vector ( 1  , 0  ){3           }}
  \put(4.75,0   ){\makebox( 0.5, 0.5){$L          $}}
% Label d and D.
  \put(8.1 ,1.5 ){\line   ( 1  , 0  ){1.3         }}
  \put(8.1 ,4.5 ){\line   ( 1  , 0  ){1.3         }}
  \put(8.1 ,2.5 ){\line   ( 1  , 0  ){0.5         }}
  \put(8.3 ,2   ){\vector ( 0  ,-1  ){0.5         }}
  \put(8.3 ,2   ){\vector ( 0  , 1  ){0.5         }}
  \put(8.9 ,3   ){\vector ( 0  ,-1  ){1.5         }}
  \put(8.9 ,3   ){\vector ( 0  , 1  ){1.5         }}
  \put(8.3 ,1.75){\makebox( 0.5, 0.5){$d          $}}
  \put(8.9 ,2.75){\makebox( 0.5, 0.5){$D          $}}
\end{picture}
```

3.5 Rotations of vectors

Fig. 3.5.1: Through a finite angle

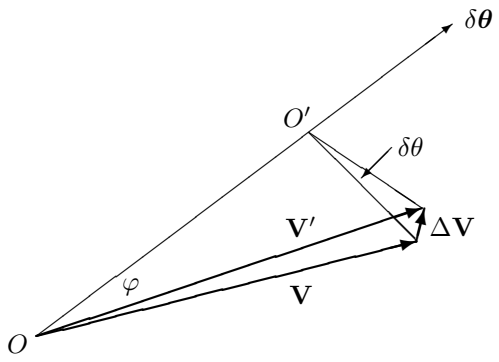


Definition

```
\begin{picture}(13,4.8)
\put(0,0){\makebox(x,y){}}
% Draw the axis of rotation.
  \put( 0.5 ,0.35){\vector (4  , 3  ){5.5              }}
  \put( 6   ,4.3 ){\makebox(0.5, 0.5){$\hbf{n}         $}}
  \put( 0   ,0   ){\makebox(0.5, 0.5){$O               $}}
% Draw and label two vectors.
  \thicklines
  \put( 0.5 ,0.35){\vector (4  , 1  ){5.03             }}  % r
  \put( 0.5 ,0.35){\vector (2  , 1  ){4.78             }}  % r'
  \thinlines
  \put( 3.75,0.75){\makebox(0.5, 0.5){${\bf r}         $}}
  \put( 3.75,1.6 ){\makebox(0.5, 0.5){${\bf r}'        $}}
% Draw two vectors perpendicular to the axis of rotation and label the angle.
  \put( 4.1 ,3.05){\vector (1  ,-1  ){1.45             }}  % r _{\perp}
  \put( 4.1 ,3.05){\vector (4  ,-1  ){1.2              }}  % r'_{\perp}
  \put( 5.4 ,1.65){\makebox(0.5, 0.5){${\bf r} _{\perp}$}}
  \put( 4.9 ,2.85){\makebox(0.5, 0.5){${\bf r}'_{\perp}$}}
  \put( 4.45,2.45){\makebox(0.5, 0.5){$\Phi            $}}
% Draw and label the projection of two vectors on the axis of rotation.
  \thicklines
  \put( 0.5 ,0.35){\vector (4  , 3  ){3.6              }}
  \thinlines
  \put( 1.2 ,1.85){\makebox(1.5, 0.5){$({\bf r} \cdot \hbf{n}) \hbf{n}$}}
  \put( 3.7 ,3   ){\makebox(0.5, 0.5){$O'              $}}
% Draw and label the auxiliary coordinate axes.
  \put( 8.5 ,1   ){\vector (1  , 0  ){4                }}
  \put( 8.5 ,1   ){\vector (0  , 1  ){3                }}
  \put(12.5 ,0.75){\makebox(0.5, 0.5){$\Axis{1}        $}}
  \put( 8.25,4   ){\makebox(0.5, 0.5){$\Axis{2}        $}}
  \put( 8   ,0.5 ){\makebox(0.5, 0.5){$O'              $}}
```

```
% Draw two vectors perpendicular to the axis of rotation and label the angle.
  \thicklines
  \put( 8.5 ,1   ){\vector (1  , 0  ){3                }}  % r _{\perp}
  \put( 8.5 ,1   ){\vector (4  , 3  ){2.4              }}  % r'_{\perp}
  \thinlines
  \put(11.25,0.5 ){\makebox(0.5, 0.5){${\bf r} _{\perp}$}}
  \put(11   ,2.6 ){\makebox(0.5, 0.5){${\bf r}'_{\perp}$}}
  \put( 9   ,1   ){\makebox(0.5, 0.5){$\Phi            $}}
\end{picture}
```

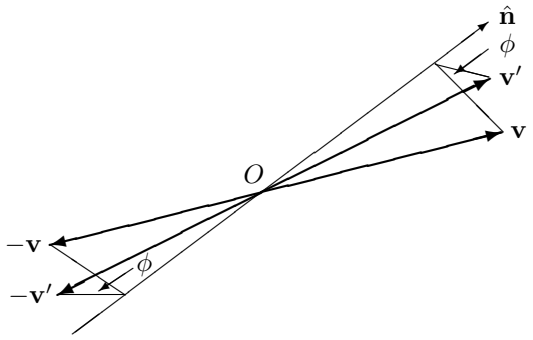
Fig. 3.5.2: Through an infinitesimal angle



Definition

```
\begin{picture}(6.6,4.8)
\put(0,0){\makebox(6.6,4.8){}}
% Draw the axis of rotation.
  \put(0.5 ,0.35){\vector ( 4  , 3  ){5.5                 }}
  \put(6.1 ,4.3 ){\makebox( 0.5, 0.5){$\delta\bfG{\theta}$}}
  \put(0   ,0   ){\makebox( 0.5, 0.5){$O                $}}
% Draw and label two vectors.
  \thicklines
  \put(0.5 ,0.35){\vector ( 4  , 1  ){5.03                }}  % V
  \put(0.5 ,0.35){\vector ( 3  , 1  ){5.1                 }}  % V'
  \put(5.52,1.6 ){\vector ( 1  , 4  ){0.11                }}  % Delta V
  \thinlines
  \put(3.75,0.65){\makebox( 0.5, 0.5){${\bf V}           $}}
  \put(3.75,1.55){\makebox( 0.5, 0.5){${\bf V}'          $}}
  \put(5.65,1.55){\makebox( 0.7, 0.5){$\Delta{\bf V}     $}}
% Draw two lines perpendicular to the axis of rotation and label the angle.
  \put(4.1 ,3.05){\line   ( 1  ,-1  ){1.42                }}  % V
  \put(4.1 ,3.05){\line   ( 3  ,-2  ){1.5                 }}  % V'
  \put(5.2 ,2.85){\vector (-1  ,-1  ){0.4                 }}
  \put(5.2 ,2.6 ){\makebox( 0.5, 0.5){$\delta\theta      $}}
% Label the angle between the vector V and the axis of rotation.
  \put(1.5 ,0.75){\makebox( 0.5, 0.5){$\varphi           $}}
  \put(3.7 ,3   ){\makebox( 0.5, 0.5){$O'                $}}
\end{picture}
```

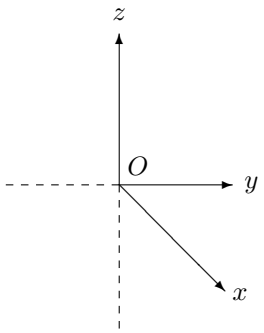
Fig. 3.5.3: Rotations of the reflections of vectors



Definition

```
\begin{picture}(7.15,4.6)
\put(0,0){\makebox(7.15,4.6){}}
% Draw the axis of rotation.
  \put(3.5 ,2   ){\vector ( 4  , 3  ){3          }}
  \put(3.5 ,2   ){\line   (-4  ,-3  ){2.5        }}
  \put(6.5 ,4.1 ){\makebox( 0.5, 0.5){$\hbf{n}  $}}
  \put(3.15,2   ){\makebox( 0.5, 0.5){$0        $}}
% Draw and label two vectors.
  \thicklines
  \put(3.5 ,2   ){\vector ( 4  , 1  ){3.18       }}  %  v
  \put(3.5 ,2   ){\vector ( 2  , 1  ){3.02       }}  %  v'
  \thinlines
  \put(5.8 ,3.7 ){\line   ( 1  ,-1  ){0.9        }}  %  v
  \put(5.8 ,3.7 ){\line   ( 4  ,-1  ){0.71       }}  %  v'
  \put(6.65,2.55){\makebox( 0.5, 0.5){${\bf v}  $}}
  \put(6.55,3.3 ){\makebox( 0.5, 0.5){${\bf v}' $}}
% Draw and label two vectors.
  \thicklines
  \put(3.5 ,2   ){\vector (-4  ,-1  ){2.8        }}  % -v
  \put(3.5 ,2   ){\vector (-2  ,-1  ){2.7        }}  % -v'
  \thinlines
  \put(1.7 ,0.65){\line   (-3  , 2  ){1          }}  % -v
  \put(1.7 ,0.65){\line   (-1  , 0  ){0.9        }}  % -v'
  \put(0.1 ,1.05){\makebox( 0.5, 0.5){$-{\bf v} $}}
  \put(0.2 ,0.4 ){\makebox( 0.5, 0.5){$-{\bf v}'$}}
% Label the angle of rotation, phi.
  \put(6.5 ,3.9 ){\vector (-4  ,-3  ){0.45       }}
  \put(6.5 ,3.7 ){\makebox( 0.5, 0.5){$\phi     $}}
  \put(1.8 ,1   ){\vector (-3  ,-2  ){0.45       }}
  \put(1.7 ,0.8 ){\makebox( 0.5, 0.5){$\phi     $}}
\end{picture}
```

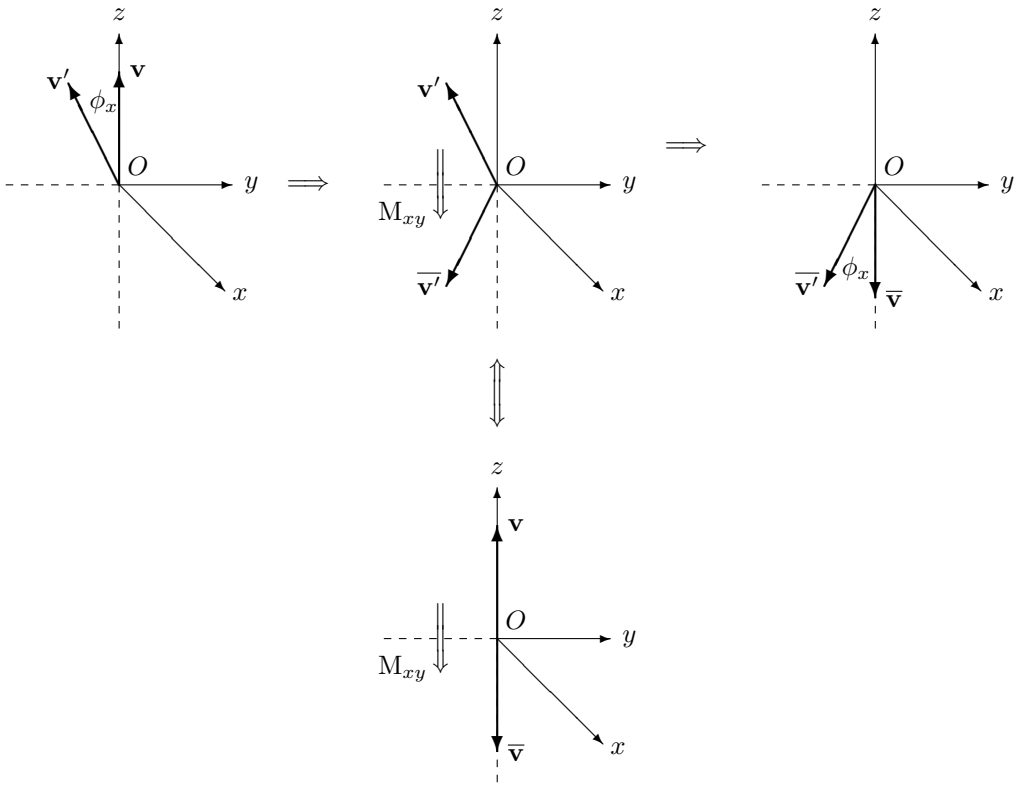
Fig. 3.5.4: Savebox: XmYZ



Savebox: XmYZ

```
\newsavebox{\XmYZ}
\savebox{\XmYZ}(4  ,4.5){
\begin{picture}(4  ,4.5)
% Draw the coordinates.
  \put(2  ,2  ){\vector(1,-1){1.4}}                    % x-axis
  \put(2  ,2  ){\vector(1, 0){1.5}}                    % y-axis
  \put(2  ,2  ){\vector(0, 1){2  }}                    % z-axis
  \multiput(2  ,2  )(-0.2, 0  ){8 }{\line(-1, 0){0.1}}
  \multiput(2  ,2  )( 0  ,-0.2){10}{\line( 0,-1){0.1}}
% Label the coordinates.
  \put(3.35,0.3 ){\makebox(0.5,0.5){$x$}}
  \put(3.5 ,1.75){\makebox(0.5,0.5){$y$}}
  \put(1.75,4   ){\makebox(0.5,0.5){$z$}}
  \put(2   ,2   ){\makebox(0.5,0.5){$O$}}
\end{picture}}
```

Fig. 3.5.5: Rotation and Mirror operators



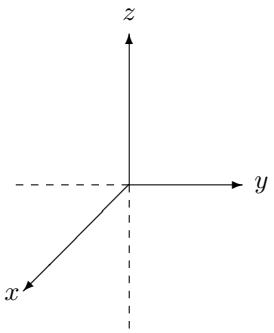
Definition

```
\begin{picture}(14,10.5)
\put(0,0){\makebox(14,10.5){}}
% Rotation operator R_x:
% Draw and label the coordinate axes.
% Use the savebox: XmYZ.
  \put( 0   ,6   ){\usebox {\XmYZ}}
% Draw and label the vectors before and after the rotation operator R_x.
  \thicklines
  \put( 2   ,8   ){\vector ( 0  , 1  ){1.5             }}
  \put( 2   ,8   ){\vector (-1  , 2  ){0.67            }}
  \thinlines
  \put( 2   ,9.25){\makebox( 0.5, 0.5){${\bf v}        $}}
  \put( 0.95,9.15){\makebox( 0.5, 0.5){${\bf v}'       $}}
% Label the angle of rotation phi_x.
  \put( 1.55,8.9 ){\makebox( 0.5, 0.4){$\phi_x         $}}
%
% Draw the arror.
  \put( 4   ,7.5 ){\makebox( 1  , 1  ){$\lTo           $}}
%
```

```
% Mirror operator M_xy:
% Draw and label the coordinate axes.
% Use the savebox: XmYZ.
  \put( 5   ,6   ){\usebox {\XmYZ}}
% Draw and label the vectors before and after the mirror operator M_xy.
  \thicklines
  \put( 7   ,8   ){\vector (-1  , 2  ){0.67             }}
  \put( 7   ,8   ){\vector (-1  ,-2  ){0.67             }}
  \thinlines
  \put( 5.85,9.05){\makebox( 0.5, 0.5){${\bf v}'       $}}
  \put( 5.85,6.45){\makebox( 0.5, 0.5){$\Line{{\bf v}'}$}}
% Draw and label the mirror operator.
  \put( 6   ,8.15){\makebox( 0.5, 0.5){$\parallel      $}}
  \put( 6   ,7.75){\makebox( 0.5, 0.5){$\parallel      $}}
  \put( 6   ,7.35){\makebox( 0.5, 0.5){$\Downarrow     $}}
  \put( 5.5 ,7.35){\makebox( 0.5, 0.5){${\rm M}_{xy}   $}}
%
% Draw the arror.
  \put( 9   ,8   ){\makebox( 1  , 1  ){$\lTo           $}}
%
% Rotation operator R_x:
% Draw and label the coordinate axes.
% Use the savebox: XmYZ.
  \put(10   ,6   ){\usebox {\XmYZ}}
% Draw and label the vectors before and after the rotation operator R_x.
  \thicklines
  \put(12   ,8   ){\vector (-1  ,-2  ){0.67             }}
  \put(12   ,8   ){\vector ( 0  ,-1  ){1.5              }}
  \thinlines
  \put(10.85,6.45){\makebox( 0.5, 0.5){$\Line{{\bf v}'}$}}
  \put(12   ,6.25){\makebox( 0.5, 0.5){$\Line{{\bf v}} $}}
% Label the angle of rotation phi_x.
  \put(11.5 ,6.7 ){\makebox( 0.5, 0.4){$\phi_x         $}}
%
% Draw the arror.
  \put( 6   ,5.4 ){\makebox( 2  , 0.5){$\Uparrow       $}}
  \put( 6   ,5   ){\makebox( 2  , 0.5){$\parallel      $}}
  \put( 6   ,4.6 ){\makebox( 2  , 0.5){$\Downarrow     $}}
%
```

```
% Mirror operator M_xy:
% Draw and label the coordinate axes.
% Use the savebox: XmYZ.
  \put( 5   ,0   ){\usebox {\XmYZ}}
% Draw and label the vectors before and after the mirror operator M_xy.
  \thicklines
  \put( 7   ,2   ){\vector ( 0  , 1  ){1.5              }}
  \put( 7   ,2   ){\vector ( 0  ,-1  ){1.5              }}
  \thinlines
  \put( 7   ,3.3 ){\makebox( 0.5, 0.4){${\bf v}        $}}
  \put( 7   ,0.3 ){\makebox( 0.5, 0.4){$\Line{{\bf v}} $}}
% Draw and label the mirror operator.
  \put( 6   ,2.15){\makebox( 0.5, 0.5){$\parallel      $}}
  \put( 6   ,1.75){\makebox( 0.5, 0.5){$\parallel      $}}
  \put( 6   ,1.35){\makebox( 0.5, 0.5){$\Downarrow     $}}
  \put( 5.5 ,1.35){\makebox( 0.5, 0.5){${\rm M}_{xy}   $}}
\end{picture}
```

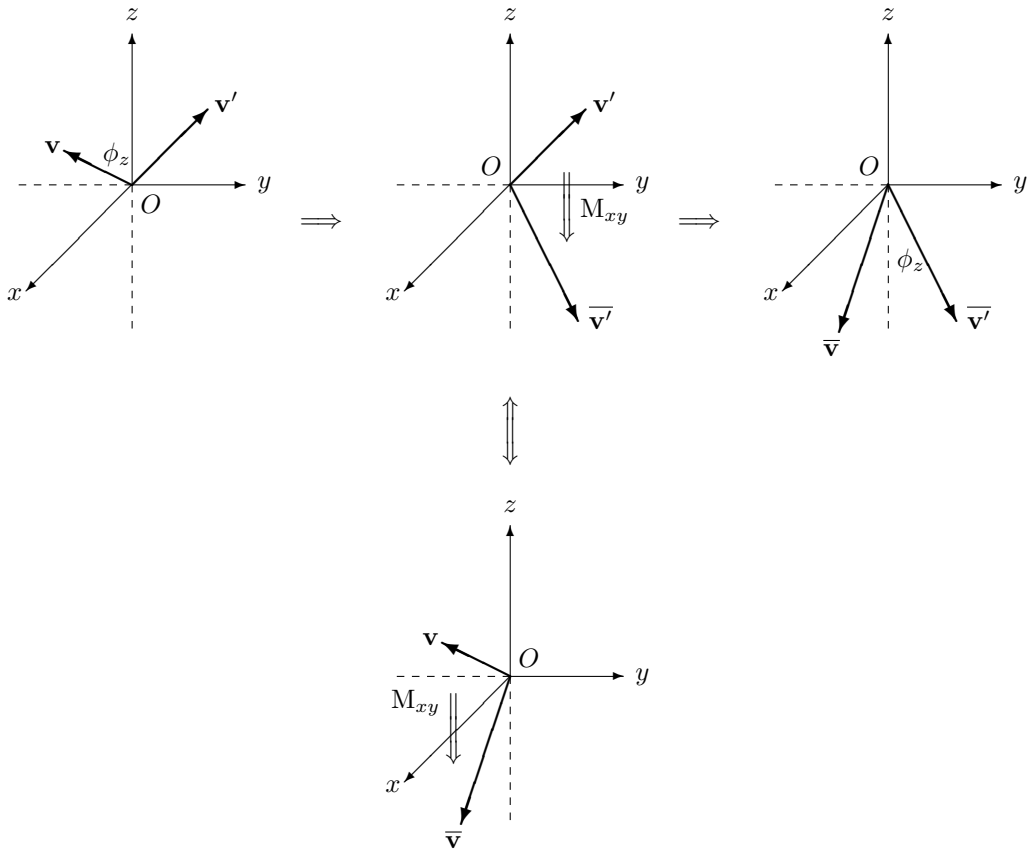
Fig. 3.5.6: Savebox: XpYZ



Savebox: XpYZ

```
\newsavebox{\XpYZ}
\savebox{\XpYZ}(4  ,4.5){
\begin{picture}(4  ,4.5)
% Draw the coordinates.
  \put(2  ,2  ){\vector(-1,-1){1.4}}                    % x-axis
  \put(2  ,2  ){\vector( 1, 0){1.5}}                    % y-axis
  \put(2  ,2  ){\vector( 0, 1){2  }}                    % z-axis
  \multiput(2  ,2  )(-0.2, 0  ){8 }{\line(-1, 0){0.1}}
  \multiput(2  ,2  )( 0  ,-0.2){10}{\line( 0,-1){0.1}}
% Label the coordinates.
  \put(0.2 ,0.3 ){\makebox(0.5,0.5){$x$}}
  \put(3.5 ,1.75){\makebox(0.5,0.5){$y$}}
  \put(1.75,4   ){\makebox(0.5,0.5){$z$}}
\end{picture}}
```

Fig. 3.5.7: Rotation and Mirror operators



Definition

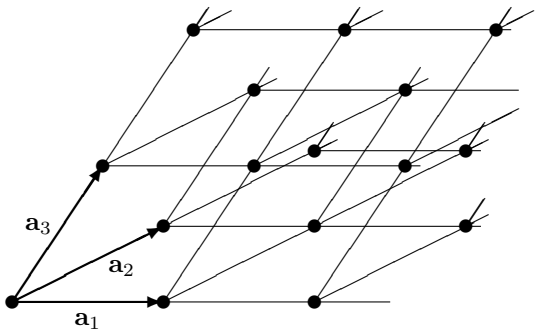
```
\begin{picture}(14,11.5)
\put(0,0){\makebox(14,11.5){}}
% Rotation operator R_z:
% Draw and label the coordinate axes.
% Use the savebox: XpYZ.
  \put( 0   ,7   ){\usebox {\XpYZ}}
% Draw the origin O.
  \put( 2   ,8.5 ){\makebox( 0.5, 0.5){$O              $}}
% Draw and label the vectors before and after the rotation operator R_z.
  \thicklines
  \put( 2   ,9   ){\vector (-2  , 1  ){0.9              }}
  \put( 2   ,9   ){\vector ( 1  , 1  ){1                }}
  \thinlines
  \put( 0.7 ,9.25){\makebox( 0.5, 0.5){${\bf v}        $}}
  \put( 3   ,9.85){\makebox( 0.5, 0.5){${\bf v}'       $}}
% Label the angle of rotation phi_z.
  \put( 1.55,9.2 ){\makebox( 0.5, 0.4){$\phi_z         $}}
```

```
%
% Draw the arror.
  \put( 4   ,8   ){\makebox( 1   , 1  ){$\lTo           $}}
%
% Mirror operator M_xy:
% Draw and label the coordinate axes.
% Use the savebox: XpYZ.
  \put( 5   ,7   ){\usebox {\XpYZ}}
% Draw the origin O.
  \put( 6.5 ,9   ){\makebox( 0.5, 0.5){$O              $}}
% Draw and label the vectors before and after the mirror operator M_xy.
  \thicklines
  \put( 7   ,9   ){\vector ( 1  , 1  ){1               }}
  \put( 7   ,9   ){\vector ( 1  ,-2  ){0.9             }}
  \thinlines
  \put( 8   ,9.85){\makebox( 0.5, 0.5){${\bf v}'       $}}
  \put( 7.95,7   ){\makebox( 0.5, 0.5){$\Line{{\bf v}'}$}}
% Draw and label the mirror operator.
  \put( 7.5 ,8.75){\makebox( 0.5, 0.5){$\parallel      $}}
  \put( 7.5 ,8.45){\makebox( 0.5, 0.5){$\parallel      $}}
  \put( 7.5 ,8.15){\makebox( 0.5, 0.5){$\Downarrow     $}}
  \put( 8   ,8.4 ){\makebox( 0.5, 0.5){${\rm M}_{xy}   $}}
%
% Draw the arror.
  \put( 9   ,8   ){\makebox( 1   , 1  ){$\lTo           $}}
%
% Rotation operator R_z:
% Draw and label the coordinate axes.
% Use the savebox: XpYZ.
  \put(10   ,7   ){\usebox {\XpYZ}}
% Draw the origin O.
  \put(11.5 ,9   ){\makebox( 0.5, 0.5){$O              $}}
% Draw and label the vectors before and after the rotation operator R_z.
  \thicklines
  \put(12   ,9   ){\vector ( 1  ,-2  ){0.9             }}
  \put(12   ,9   ){\vector (-1  ,-3  ){0.65            }}
  \thinlines
  \put(12.95,7   ){\makebox( 0.5, 0.5){$\Line{{\bf v}'}$}}
  \put(11   ,6.6 ){\makebox( 0.5, 0.5){$\Line{{\bf v}} $}}
% Label the angle of rotation phi_z.
  \put(12.05,7.8 ){\makebox( 0.5, 0.4){$\phi_z         $}}
```

```
%
% Draw the arror.
  \put( 6   ,5.8 ){\makebox( 2  , 0.5){$\Uparrow       $}}
  \put( 6   ,5.5 ){\makebox( 2  , 0.5){$\parallel      $}}
  \put( 6   ,5.2 ){\makebox( 2  , 0.5){$\Downarrow     $}}
%
% Mirror operator M_xy:
% Draw and label the coordinate axes.
% Use the savebox: XpYZ.
  \put( 5   ,0.5 ){\usebox {\XpYZ}}
% Draw the origin O.
  \put( 7   ,2.5 ){\makebox( 0.5, 0.5){$O              $}}
% Draw and label the vectors before and after the mirror operator M_xy.
  \thicklines
  \put( 7   ,2.5 ){\vector (-2  , 1  ){0.9              }}
  \put( 7   ,2.5 ){\vector (-1  ,-3  ){0.65             }}
  \thinlines
  \put( 5.7 ,2.75){\makebox( 0.5, 0.5){${\bf v}        $}}
  \put( 6   ,0.1 ){\makebox( 0.5, 0.5){$\Line{{\bf v}} $}}
% Draw and label the mirror operator.
  \put( 6   ,1.85){\makebox( 0.5, 0.5){$\parallel      $}}
  \put( 6   ,1.55){\makebox( 0.5, 0.5){$\parallel      $}}
  \put( 6   ,1.25){\makebox( 0.5, 0.5){$\Downarrow     $}}
  \put( 5.5 ,1.9 ){\makebox( 0.5, 0.5){${\rm M}_{xy}   $}}
\end{picture}
```

3.6 Miscellaneous

Fig. 3.6.1: Lattice points

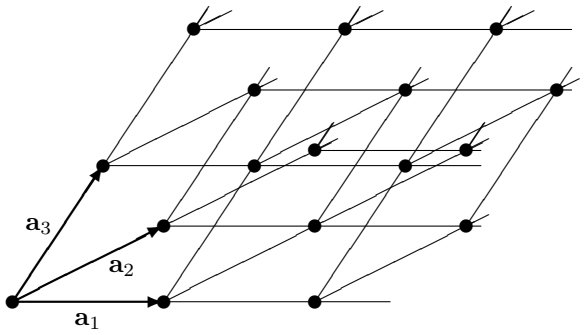


Definition

```
\begin{picture}(7,4.4)
\put(0,0){\makebox(7,4.4){}}
% Draw and label three primitive vectors.
  \thicklines
  \put(0.1 ,0.5 ){\vector (1  ,0  ){2   }}  % {\bf a_1}
  \put(0.1 ,0.5 ){\vector (2  ,1  ){2   }}  % {\bf a_2}
  \put(0.1 ,0.5 ){\vector (2  ,3  ){1.2 }}  % {\bf a_3}
  \thinlines
  \put(0.85,0   ){\makebox(0.5,0.5){${\bf a}_1$}}
  \put(1.3 ,0.7 ){\makebox(0.5,0.5){${\bf a}_2$}}
  \put(0.2 ,1.25){\makebox(0.5,0.5){${\bf a}_3$}}
% Draw lines parallel to the vector a_1.
  \put(0.1 ,0.5 ){\line   (1  ,0  ){5   }}  % (0,0,0)
  \put(1.3 ,2.3 ){\line   (1  ,0  ){4.2 }}  % (0,0,1)
  \put(2.5 ,4.1 ){\line   (1  ,0  ){4.2 }}  % (0,0,2)
  \put(2.1 ,1.5 ){\line   (1  ,0  ){4.2 }}  % (0,1,0)
  \put(3.3 ,3.3 ){\line   (1  ,0  ){3.5 }}  % (0,1,1)
  \put(4.1 ,2.5 ){\line   (1  ,0  ){2.2 }}  % (0,2,0)
% Draw lines parallel to the vector a_2.
  \put(0.1 ,0.5 ){\line   (2  ,1  ){4.3 }}  % (0,0,0)
  \put(2.1 ,0.5 ){\line   (2  ,1  ){4.3 }}  % (1,0,0)
  \put(4.1 ,0.5 ){\line   (2  ,1  ){2.3 }}  % (2,0,0)
  \put(1.3 ,2.3 ){\line   (2  ,1  ){2.3 }}  % (0,0,1)
  \put(3.3 ,2.3 ){\line   (2  ,1  ){2.3 }}  % (1,0,1)
  \put(5.3 ,2.3 ){\line   (2  ,1  ){1.5 }}  % (2,0,1)
  \put(2.5 ,4.1 ){\line   (2  ,1  ){0.5 }}  % (0,0,2)
  \put(4.5 ,4.1 ){\line   (2  ,1  ){0.5 }}  % (1,0,2)
  \put(6.5 ,4.1 ){\line   (2  ,1  ){0.5 }}  % (2,0,2)
```

```
% Draw lines parallel to the vector a_3.
  \put(0.1 ,0.5 ){\line   (2  ,3  ){2.6 }}  % (0,0,0)
  \put(2.1 ,0.5 ){\line   (2  ,3  ){2.6 }}  % (1,0,0)
  \put(4.1 ,0.5 ){\line   (2  ,3  ){2.6 }}  % (2,0,0)
  \put(2.1 ,1.5 ){\line   (2  ,3  ){1.4 }}  % (0,1,0)
  \put(4.1 ,1.5 ){\line   (2  ,3  ){1.4 }}  % (1,1,0)
  \put(6.1 ,1.5 ){\line   (2  ,3  ){0.25}}  % (2,1,0)
  \put(4.1 ,2.5 ){\line   (2  ,3  ){0.25}}  % (0,2,0)
  \put(6.1 ,2.5 ){\line   (2  ,3  ){0.25}}  % (1,2,0)
% Draw the lattice points on the first layer.
  \put(0.1 ,0.5 ){\circle*         {0.18}}  % (0,0,0)
  \put(2.1 ,0.5 ){\circle*         {0.18}}  % (1,0,0)
  \put(4.1 ,0.5 ){\circle*         {0.18}}  % (2,0,0)
  \put(2.1 ,1.5 ){\circle*         {0.18}}  % (0,1,0)
  \put(4.1 ,1.5 ){\circle*         {0.18}}  % (1,1,0)
  \put(6.1 ,1.5 ){\circle*         {0.18}}  % (2,1,0)
  \put(4.1 ,2.5 ){\circle*         {0.18}}  % (0,2,0)
  \put(6.1 ,2.5 ){\circle*         {0.18}}  % (1,2,0)
% Draw the lattice points on the second layer.
  \put(1.3 ,2.3 ){\circle*         {0.18}}  % (0,0,1)
  \put(3.3 ,2.3 ){\circle*         {0.18}}  % (1,0,1)
  \put(5.3 ,2.3 ){\circle*         {0.18}}  % (2,0,1)
  \put(3.3 ,3.3 ){\circle*         {0.18}}  % (0,1,1)
  \put(5.3 ,3.3 ){\circle*         {0.18}}  % (1,1,1)
% Draw the lattice points on the third layer.
  \put(2.5 ,4.1 ){\circle*         {0.18}}  % (0,0,2)
  \put(4.5 ,4.1 ){\circle*         {0.18}}  % (1,0,2)
  \put(6.5 ,4.1 ){\circle*         {0.18}}  % (2,0,2)
\end{picture}
```

Fig. 3.6.2: Lattice points

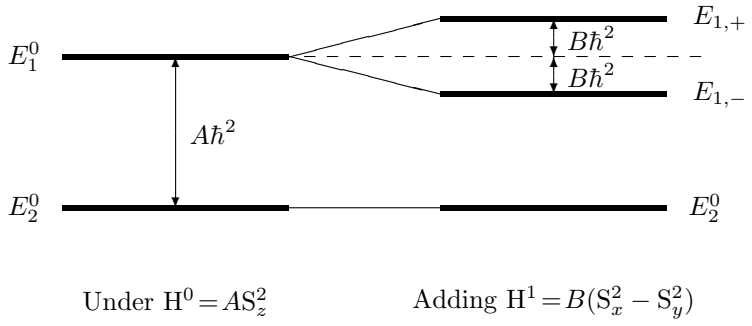


Definition

```
\begin{picture}(7.6,4.4)
\put(0,0){\makebox(7.6,4.4){}}
% Draw and label three primitive vectors.
  \thicklines
  \put(0.1 ,0.5 ){\vector (1  ,0  ){2                   }}  % {\bf a_1}
  \put(0.1 ,0.5 ){\vector (2  ,1  ){2                   }}  % {\bf a_2}
  \put(0.1 ,0.5 ){\vector (2  ,3  ){1.2                 }}  % {\bf a_3}
  \thinlines
  \put(0.85,0   ){\makebox(0.5,0.5){${\bf a}_1          $}}
  \put(1.3 ,0.7 ){\makebox(0.5,0.5){${\bf a}_2          $}}
  \put(0.2 ,1.25){\makebox(0.5,0.5){${\bf a}_3          $}}
% Draw lines parallel to the vector a_1.
  \multiput(0.1 ,0.5 )(1.2,1.8){3}{\line   (1  ,0  ){5   }}
  \multiput(2.1 ,1.5 )(1.2,1.8){2}{\line   (1  ,0  ){4.2 }}
  \put     (4.1 ,2.5 )            {\line   (1  ,0  ){2.2 }}  % (0,2,0)
% Draw lines parallel to the vector a_2.
  \multiput(0.1 ,0.5 )(2  ,0  ){2}{\line   (2  ,1  ){4.3 }}
  \put     (4.1 ,0.5 )            {\line   (2  ,1  ){2.3 }}  % (2,0,0)
  \multiput(1.3 ,2.3 )(2  ,0  ){3}{\line   (2  ,1  ){2.3 }}
  \multiput(2.5 ,4.1 )(2  ,0  ){3}{\line   (2  ,1  ){0.5 }}
% Draw lines parallel to the vector a_3.
  \multiput(0.1 ,0.5 )(2  ,0  ){3}{\line   (2  ,3  ){2.6 }}
  \multiput(2.1 ,1.5 )(2  ,0  ){3}{\line   (2  ,3  ){1.4 }}
  \multiput(4.1 ,2.5 )(2  ,0  ){2}{\line   (2  ,3  ){0.25}}
% Draw the lattice points on the first layer.
  \multiput(0.1 ,0.5 )(2  ,0  ){3}{\circle*         {0.18}}
  \multiput(2.1 ,1.5 )(2  ,0  ){3}{\circle*         {0.18}}
  \multiput(4.1 ,2.5 )(2  ,0  ){2}{\circle*         {0.18}}
```

```
% Draw the lattice points on the second layer.
  \multiput(1.3 ,2.3 )(2  ,0  ){3}{\circle*         {0.18}}
  \multiput(3.3 ,3.3 )(2  ,0  ){3}{\circle*         {0.18}}
% Draw the lattice points on the third layer.
  \multiput(2.5 ,4.1 )(2  ,0  ){3}{\circle*         {0.18}}
\end{picture}
```

Fig. 3.6.3: Splitting of the energy level

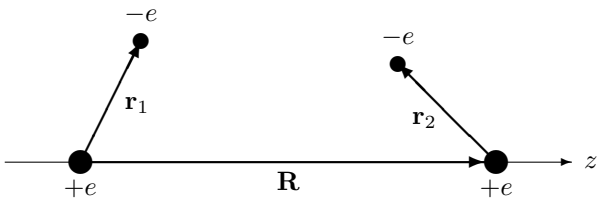


Definition

```
\begin{picture}(10.2,4.25)
\put(0,0){\makebox(10.2,4.25){}}
% Draw the unperturbed energies E_1^0 and E_2^0.
  \linethickness{2pt}
  \put(1  ,3.5 ){\line   (1  , 0  ){3            }}
  \put(1  ,1.5 ){\line   (1  , 0  ){3            }}
  \thinlines
% Draw internal lines.
  \put(4  ,3.5 ){\line   (4  , 1  ){2            }}
  \put(4  ,3.5 ){\line   (4  ,-1  ){2            }}
  \put(4  ,1.5 ){\line   (1  , 0  ){2            }}
% Draw the perturbed energies E_{1,+}, E_{2,+} and E_2.
  \linethickness{2pt}
  \put(6  ,4   ){\line   (1  , 0  ){3            }}
  \put(6  ,3   ){\line   (1  , 0  ){3            }}
  \put(6  ,1.5 ){\line   (1  , 0  ){3            }}
  \thinlines
% Label E_1^0, E_2^0 and the energy difference between them.
  \put(0  ,3.25){\makebox(1  , 0.5){$E_1^0      $}}
  \put(0  ,1.25){\makebox(1  , 0.5){$E_2^0      $}}
  \put(2.5,2.5 ){\vector (0  , 1  ){1            }}
  \put(2.5,2.5 ){\vector (0  ,-1  ){1            }}
  \put(2.5,2.25){\makebox(1  , 0.5){$A \hbar^2  $}}
% Label the energies E_{1,+}, E_{1,-} and E_2^0.
  \put(9.2,3.75){\makebox(1  , 0.5){$E_{1,+}    $}}
  \put(9.2,2.75){\makebox(1  , 0.5){$E_{1,-}    $}}
  \put(9  ,1.25){\makebox(1  , 0.5){$E_2^0      $}}
```

```
% Label the energy differences between E_{1,+}, E_{1,-}, and E_1^0.
  \multiput(4.2,3.5)(0.3 ,0){18}{\line(1,0){0.15 }}
  \put(7.5,3.75){\vector (0  , 1  ){0.25         }}
  \put(7.5,3.75){\vector (0  ,-1  ){0.25         }}
  \put(7.5,3.25){\vector (0  , 1  ){0.25         }}
  \put(7.5,3.25){\vector (0  ,-1  ){0.25         }}
  \put(7.5,3.5 ){\makebox(1  , 0.5){$B \hbar^2  $}}
  \put(7.5,3   ){\makebox(1  , 0.5){$B \hbar^2  $}}
% Label the cases.
  \put(1  ,0   ){\makebox(3  , 0.5)
                 {Under  ${\rm H}^0\!=\!A {\rm S}_z^2              $}}
  \put(5.5,0   ){\makebox(4  , 0.5)
                 {Adding ${\rm H}^1\!=\!B ({\rm S}_x^2-{\rm S}_y^2)$}}
\end{picture}
```

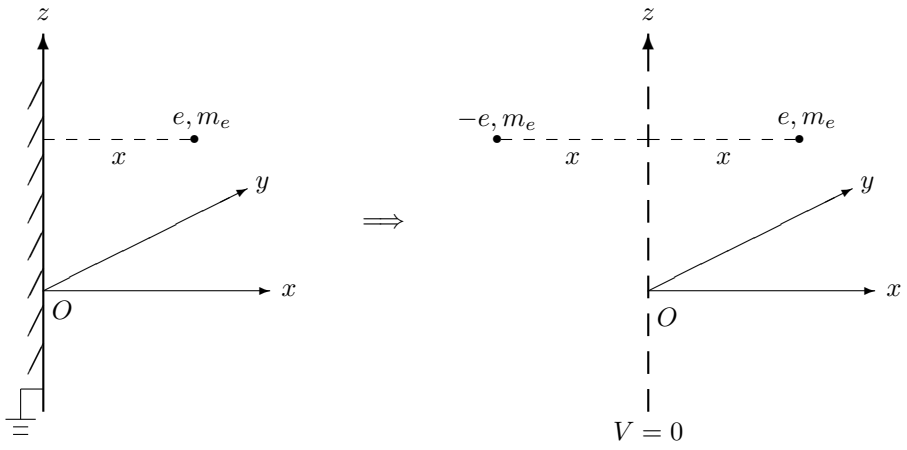
Fig. 3.6.4: Two hydrogen atoms



Definition

```
\begin{picture}(8,2.8)
\put(0,0){\makebox(8,2.8){}}
% Draw and label the z-axis.
  \put(0   ,0.6 ){\vector ( 1  ,0  ){7.5        }}
  \put(7.5 ,0.35){\makebox( 0.5,0.5){$z        $}}
% Draw and label two protons.
  \put(1   ,0.6 ){\circle*          {0.3        }}
  \put(6.5 ,0.6 ){\circle*          {0.3        }}
  \put(0.7 ,0   ){\makebox( 0.6,0.5){$+e       $}}
  \put(6.2 ,0   ){\makebox( 0.6,0.5){$+e       $}}
% Draw and label the vector between the protons.
  \thicklines
  \put(1.15,0.6 ){\vector ( 1  ,0  ){5.2        }}
  \thinlines
  \put(3.5 ,0.1 ){\makebox( 0.5,0.5){$\bf R    $}}
% Draw and label two electrons.
  \put(1.8 ,2.2 ){\circle*          {0.2        }}
  \put(5.2 ,1.9 ){\circle*          {0.2        }}
  \put(1.5 ,2.3 ){\makebox( 0.6,0.5){$-e       $}}
  \put(4.9 ,2   ){\makebox( 0.6,0.5){$-e       $}}
% Draw and label the vectors from the protons to the electrons.
  \thicklines
  \put(1   ,0.6 ){\vector ( 1  ,2  ){0.8        }}
  \put(6.5 ,0.6 ){\vector (-1  ,1  ){1.3        }}
  \thinlines
  \put(1.5 ,1.1 ){\makebox( 0.5,0.5){${\bf r}_1$}}
  \put(5.3 ,0.9 ){\makebox( 0.5,0.5){${\bf r}_2$}}
\end{picture}
```

Fig. 3.6.5: Method of imaging charge



Definition

```
\begin{picture}(12,6)
\put(0,0){\makebox(x,y){}}
\put(0,0){\makebox(12,6){}}
\put(0,0){\makebox( 4,6){}}
\put(6,0){\makebox( 6,6){}}
% Draw the plane.
  \thicklines
  \put( 0.5 ,0.5 ){\vector (0  ,1  ){5            }}
  \thinlines
  \multiput(0.3,1  )( 0  ,0.5){8}{\line( 1,2){0.2 }}
% Label the plane to be grounded.
  \put( 0.2 ,0.8 ){\line   (1  , 0  ){0.3         }}
  \put( 0.2 ,0.8 ){\line   (0  ,-1  ){0.4         }}
  \put( 0   ,0.4 ){\line   (1  , 0  ){0.4         }}
  \put( 0.1 ,0.3 ){\line   (1  , 0  ){0.2         }}
  \put( 0.1 ,0.2 ){\line   (1  , 0  ){0.2         }}
% Draw and label the coordinate axes.
  \put( 0.5 ,2.1 ){\vector (1  , 0  ){3           }}
  \put( 0.5 ,2.1 ){\vector (2  , 1  ){2.7         }}
  \put( 3.5 ,1.85){\makebox(0.5, 0.5){$x         $}}
  \put( 3.15,3.25){\makebox(0.5, 0.5){$y         $}}
  \put( 0.25,5.5 ){\makebox(0.5, 0.5){$z         $}}
  \put( 0.5 ,1.6 ){\makebox(0.5, 0.5){$O         $}}
% Draw and label the electron.
  \multiput(0.5,4.1)( 0.3,0  ){7}{\line( 1,0){0.15}}
  \put( 2.5 ,4.1 ){\circle*          {0.12        }}
  \put( 2.2 ,4.1 ){\makebox(0.8, 0.5){$e,m_e     $}}
  \put( 1.25,3.6 ){\makebox(0.5, 0.5){$x         $}}
```

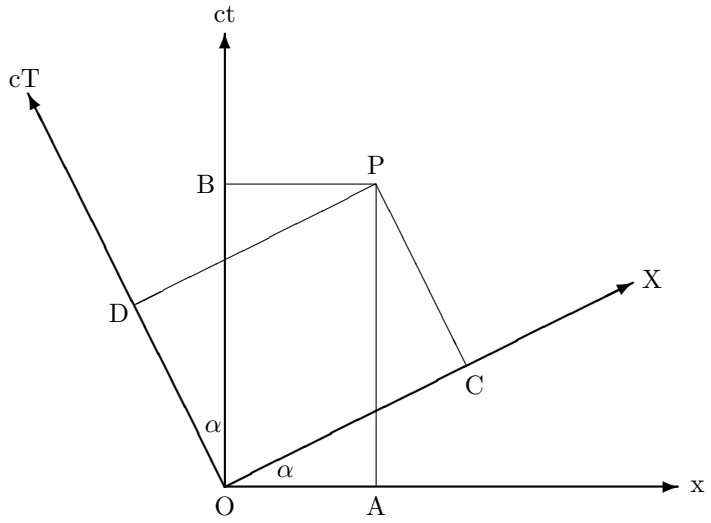
```
%
% Draw the arrow.
  \put( 4.5 ,2.75){\makebox(1   , 0.5){$\lTo      $}}
%
% Draw and label the potential.
  \thicklines
  \multiput(8.5,0.5)( 0  ,0.5){9}{\line( 0,1){0.3 }}
  \put( 8.5 ,5   ){\vector (0  ,1  ){0.5          }}
  \thinlines
  \put( 8.1 ,0   ){\makebox(0.8 ,0.5){$V = 0     $}}
% Draw and label the coordinate axes.
  \put( 8.5 ,2.1 ){\vector (1  , 0  ){3           }}
  \put( 8.5 ,2.1 ){\vector (2  , 1  ){2.7         }}
  \put(11.5 ,1.85){\makebox(0.5, 0.5){$x         $}}
  \put(11.15,3.25){\makebox(0.5, 0.5){$y         $}}
  \put( 8.25,5.5 ){\makebox(0.5, 0.5){$z         $}}
  \put( 8.5 ,1.5 ){\makebox(0.5, 0.5){$O         $}}
% Draw and label the electron.
  \multiput(8.5,4.1)( 0.3,0  ){7}{\line( 1,0){0.15}}
  \put(10.5 ,4.1 ){\circle*          {0.12        }}
  \put(10.2 ,4.1 ){\makebox(0.8, 0.5){$ e,m_e    $}}
  \put( 9.25,3.6 ){\makebox(0.5, 0.5){$ x        $}}
% Draw and label the image charge.
  \multiput(8.5,4.1)(-0.3,0  ){7}{\line(-1,0){0.15}}
  \put( 6.5 ,4.1 ){\circle*          {0.12        }}
  \put( 6   ,4.1 ){\makebox(1  , 0.5){$-e,m_e    $}}
  \put( 7.25,3.6 ){\makebox(0.5, 0.5){$ x        $}}
\end{picture}
```

Chapter 4

Miscellaneous

4.1 Special Relativity

Fig. 4.1.1: Lorentz transformation



Definition

```
\begin{picture}(9.5,7)
\put(0,0){\makebox(9.5,7){}}
% Draw the x-ct and X-cT coordinate axes.
  \thicklines
  \put(3   ,0.5 ){\vector ( 1  , 0  ){6  }}       % x -axis
  \put(3   ,0.5 ){\vector ( 0  , 1  ){6  }}       % ct-axis
  \put(3   ,0.5 ){\vector ( 2  , 1  ){5.4}}       % X -axis
  \put(3   ,0.5 ){\vector (-1  , 2  ){2.6}}       % cT-axis
  \thinlines
% Label the coordinate axes.
  \put(9   ,0.25){\makebox( 0.5, 0.5){x}}         % x -axis
  \put(2.75,6.5 ){\makebox( 0.5, 0.5){ct}}        % ct-axis
  \put(8.4 ,3.  ){\makebox( 0.5, 0.5){X}}         % X -axis
  \put(0.1 ,5.65){\makebox( 0.5, 0.5){cT}}        % cT-axis
  \put(2.75,0   ){\makebox( 0.5, 0.5){O}}         % origin
% Draw the auxiliary lines.
  \put(5   ,4.5 ){\line   ( 0  ,-1  ){4  }}       % P-A
  \put(5   ,4.5 ){\line   (-1  , 0  ){2  }}       % P-B
  \put(5   ,4.5 ){\line   ( 1  ,-2  ){1.2}}       % P-C
  \put(5   ,4.5 ){\line   (-2  ,-1  ){3.2}}       % P-D
```

```
% Label the points.
  \put(4.75,4.5 ){\makebox( 0.5, 0.5){P}}         % point P
  \put(4.75,0   ){\makebox( 0.5, 0.5){A}}         % point A
  \put(2.5 ,4.25){\makebox( 0.5, 0.5){B}}         % point B
  \put(6.05,1.6 ){\makebox( 0.5, 0.5){C}}         % point C
  \put(1.35,2.55){\makebox( 0.5, 0.5){D}}         % point D
% Label the angles.
  \put(3.6 ,0.5 ){\makebox( 0.4, 0.4){$\alpha$}}  % between x - and X -axes
  \put(2.65,1.1 ){\makebox( 0.4, 0.4){$\alpha$}}  % between ct- and cT-axes
\end{picture}
```