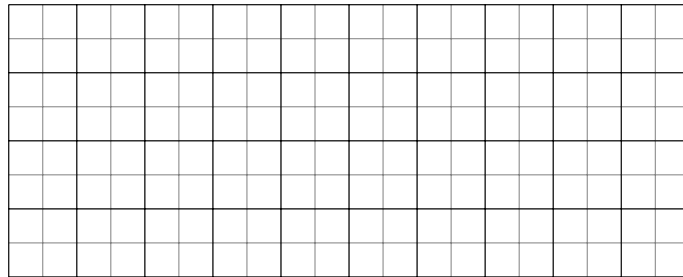

Tikz の練習

1 Tikz の練習

■グリッド

help lines で線の色と太さが補助線用に, step オプションでグリッドの間隔を変更.

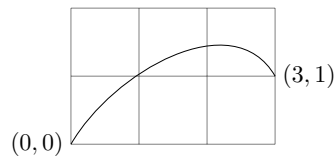
```
1 \begin{tikzpicture}
2   \draw[help lines, step=0.5cm] (0,0) grid (10,4);
3   \draw (0,0) grid (10,4);
4 \end{tikzpicture}
```



■簡単な曲線

(0,0) から出て (3,1) に入る曲線で, (0,0) における接線が x 軸の正の向きから反時計回りに 60° の方向を向き, (3,1) における接線の x 軸の正の向きから反時計回りに測った角度が 120° であるもの.

```
1 \begin{tikzpicture}
2   \draw[help lines] (0,0) grid (3,2);
3   \draw (0,0) to [out=60,in=120] (3,1);
4   \draw (-0.5cm,0) node [red] {$(0,0)$};
5   \draw (3, 1)+(0.5cm,0) node [red] {$(3,1)$};
6 \end{tikzpicture}
```



■ベジエ曲線

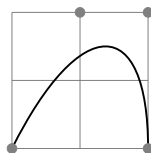
始点が (0,0), 終点が (2,0), 制御点が (1,2), (2,2) のベジエ曲線

```
1 \begin{tikzpicture}
2   \draw[help lines] (0,0) grid (2, 2);
3   \draw[thick] (0,0) .. controls (1,2) and (2,2) .. (2,0);
```

```

4 \filldraw[gray]
5 (0,0) circle (2pt)
6 (1,2) circle (2pt)
7 (2,2) circle (2pt)
8 (2,0) circle (2pt);
9 \end{tikzpicture}

```

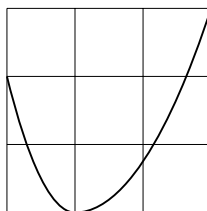


■放物線

```

1 \begin{tikzpicture}
2 \draw (0,0) grid (3,3);
3 \draw[thick] (0,2) parabola bend (1,0) (3,3);
4 \end{tikzpicture}

```



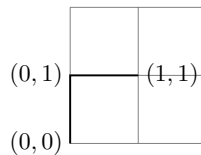
■+ と ++ の違い

(1) $+(a, b)$ は元の点に (a, b) を足した点を与えるが、この点を新たな点として定義し直さない。

```

1 \begin{tikzpicture}
2 \draw[thick] (0,0) -- +(0,1) -- +(1,1);
3 \end{tikzpicture}

```



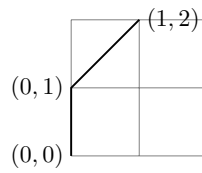
実際に、2 番目の $+(1, 1)$ で表されている点は $(0, 0) + (1, 1) = (1, 1)$ になっている。

(2) $++(a, b)$ は元の点に (a, b) を足した点を新たな点として定義し直す。

```

1 \begin{tikzpicture}
2 \draw[thick] (0,0) -- ++(0,1) -- ++(1,1);
3 \end{tikzpicture}

```



2 番目の $++(1, 1)$ で表される点は $\{(0,0) + (0,1)\} + (1,1) = (1,2)$ になっている.

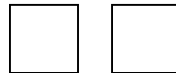
その他の例:

```

1 \begin{tikzpicture}
2   \def\rectanglepath{-- ++(1,0) -- ++(0,1) -- ++(-1,0) --cycle}
3   \draw[thick] (0,0)\rectanglepath (1.5,0)\rectanglepath;
4 \end{tikzpicture}

```

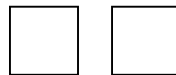
path を定義したいときには `\def` を使えば良さそう.



```

1 \begin{tikzpicture}
2   \def\rectanglepath{-- +(1,0) -- +(1,1) -- +(0,1) --cycle}
3   \draw[thick] (0,0)\rectanglepath (1.5,0)\rectanglepath;
4 \end{tikzpicture}

```



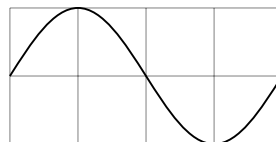
■三角関数

$\pi/2$ ずつしか描けない. π も定義されていない.

```

1 \begin{tikzpicture}
2   \draw[help lines] (0,-1) grid (4,1);
3   \draw[thick] (0,0) sin ++(1,1) cos ++(1,-1) sin ++(1,-1) cos ++(1,1);
4 \end{tikzpicture}

```

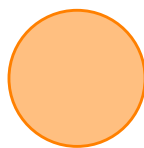


■円

```

1 \begin{tikzpicture}
2   \filldraw[very thick,fill=orange!50,draw=orange] (0,0) circle (1);
3 \end{tikzpicture}

```



■弧

```

1 \begin{tikzpicture}
2   \filldraw[very thick,draw=blue!50,fill=blue!20,opacity=0.8]
3   (0,0) -- (90:1) arc (90:360:1) arc (0:30:1) --cycle
4   (60:5pt) -- +(30:1) arc (30:90:1) --cycle;
5 \end{tikzpicture}

```

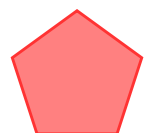


■正五边形

```

1 \begin{tikzpicture}
2   \filldraw[very thick,fill=red!50,draw=red!80]
3   (0,0) +(18:1) -- +(90:1) -- +(162:1) -- +(234:1) -- +(306:1)--cycle;
4 \end{tikzpicture}

```



```

1 \begin{tikzpicture}[even odd rule,rounded corners=2pt,x=10pt,y=10pt]
2   \filldraw[thick,draw=orange,fill=yellow!70,scale=1.5]
3   (0,0) rectangle (1,1)
4   [xshift=5pt,yshift=5pt]
5   (0,0) rectangle (1,1)
6   [rotate =30] (-1,-1) rectangle (2,2);
7 \end{tikzpicture}

```

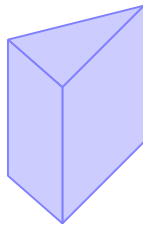


■三角柱

```

1 \begin{tikzpicture}[thick,draw=blue!50,fill=blue!20,line join=bevel]
2 \def\triangle{+(0,0) -- +(2,0.5)-- +(0.8,-0.7) --cycle}
3 \filldraw (0,0)\triangle;
4 \filldraw (0.8,-0.7) -- (2,0.5) -- (2,-1.5) -- (0.8,-2.7)--cycle;
5 \filldraw (0,0) -- (0.8,-0.7)-- ++(0,-2) -- ++(-0.8,0.7)--cycle;
6 \end{tikzpicture}

```

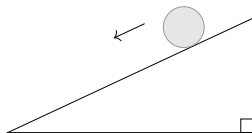


■斜面と球

```

1 \begin{tikzpicture}
2 \draw (0,0) -- +(25:4) -- +(25:4 |- 0,0) --cycle;
3 \filldraw[draw=gray!80,fill=gray!20] (25:3)++(115:3.11mm) circle (3mm);
4 \draw[->] (25:2.5)++(115:6mm) -- +(205:5mm);
5 \draw (25:4 |- 0,0) rectangle +(-2mm,2mm);
6 \end{tikzpicture}

```



```

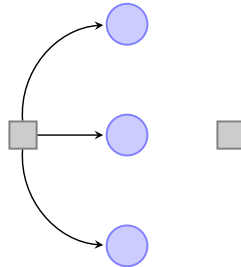
1 \begin{tikzpicture}
2 [place/.style={circle,draw=blue!50,fill=blue!20,thick,
3 inner sep=0pt,minimum size=6mm},
4 transition/.style={rectangle,draw=black!50,fill=black!20,thick,
5 inner sep=0pt,minimum size=4mm},
6 pre/.style={<- ,shorten <=1pt,>=stealth,semithick},
7 post/.style={-> ,shorten >=1pt,>=stealth,semithick},
8 bend angle=45]
9 \node[place] (waiting) {};
10 \node[place] (critical) [below=of waiting] {};
11 \node[place] (semaphore) [below=of critical] {};
12 \node[transition] (leave critical) [right=of critical] {};
13 \node[transition] (enter critical) [left=of critical] {}
14 edge [post] (critical)
15 edge [post,bend left] (waiting)
16 edge [post,bend right] (semaphore);
17 % \draw [->] (enter critical.east) to (critical.west);

```

```

18 % \draw [->] (waiting) to [bend right=45] (enter critical);
19 % \draw [->] (enter critical) to [bend right=45] (semaphore);
20 \end{tikzpicture}

```

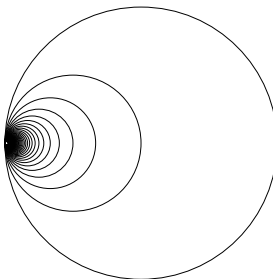


■ハワイの耳飾り

```

1 % %tikzpicture 環境の内部のみで定義されるマクロを作る
2 % \newcommand*{\pgfmathsetnewmacro}[2]{%
3 %     \newcommand*{#1}{}% Error if already defined
4 %     \pgfmathsetmacro{#1}{#2}%
5 % }%
6 \begin{tikzpicture}
7 \foreach \i in {1, 2, ..., 80}
8 {\pgfmathdivide{2}{\i}
9 \pgfmathsetnewmacro{\radius}{\pgfmathresult}
10 \draw (\radius,0) circle [radius=\radius];
11 }
12 \end{tikzpicture}

```



■plot with gnuplot

```

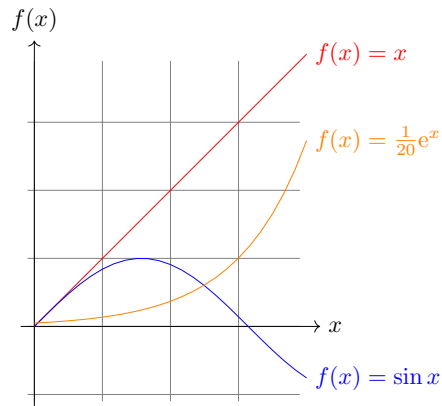
1 \begin{tikzpicture}[domain=0:4]
2 \draw[very thin,color=gray] (-0.1,-1.1) grid (3.9,3.9);
3 \draw[->] (-0.2,0) -- (4.2,0) node[right] {$x$};
4 \draw[->] (0,-1.2) -- (0,4.2) node[above] {$f(x)$};
5 \draw[color=red] plot[id=x,prefix=figures/tikz/plots/] function{x} node[right] {$f(x) = x$};
6 \draw[color=blue] plot[id=sin,prefix=figures/tikz/plots/] function{sin(x)}
7 node[right] {$f(x) = \sin x$};
8 \draw[color=orange] plot[id=exp,prefix=figures/tikz/plots/] function{0.05*exp(x)}

```

```

9   node[right] {$f(x) = \frac{1}{20} \mathrm{e}^x$};
10 \end{tikzpicture}

```

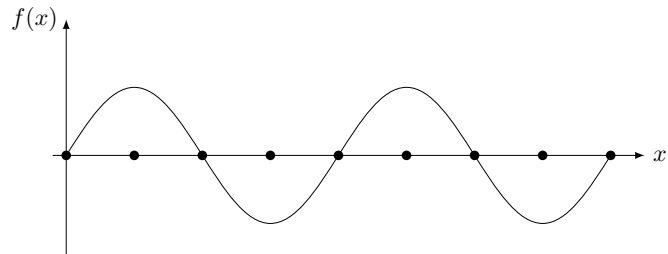


■ $\sin x$ のグラフ

```

1 \begin{tikzpicture}
2   \draw[-latex] (-0.2,0) -- (8.5,0) node[right] {$x$};
3   \draw[-latex] (0,-1.5) -- (0,2) node[left] {$f(x)$};
4   \foreach \n in {0, 1, 2, ..., 8} \fill (\n,0) circle (2pt);
5   \def\sincurve{sin ++(1, 1) cos ++(1, -1) sin ++(1, -1) cos ++(1, 1)}
6   \draw (0, 0)\sincurve \sincurve ;
7 \end{tikzpicture}

```



■ 電圧計

```

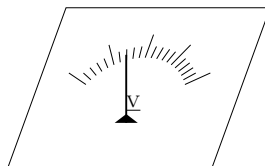
1 \begin{tikzpicture}
2   \draw (0,0)--(3,0)-- ++(70:2.5)-- ++(-3,0)--cycle; %外枠
3   \coordinate (p) at ($(1.5,0)+(70:0.7)$);
4   \draw[thick] (p)--($(p)+(0,1)$);
5   \node (V) at ($(p)+(70:0.3)$){\scriptsize $\underline{\mathrm{V}}$};
6   \fill ($(p)+(-0.17,0)$) -- ($(p)+(0.17,0)$) -- ($(p)+(0,0.13)$)--cycle;
7
8   \coordinate (q) at ($(70:0.4)+(0.65,0)$);
9   \begin{scope}[shift=(q),scale=1.2]
10    %%%%%%%%%%%%%%%

```

```

11  %%% 電圧計の目盛り
12  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
13  \renewcommand*{\r}{0.7}%円の半径
14  \renewcommand*{\l}{0.3}%長い目盛りの長さ
15  \renewcommand*{\t}{0.15}%短い目盛りの長さ
16
17  \pgfmathparse{cos(70)}
18  \let\c\pgfmathresult
19
20  \pgfmathparse{sin(70)}
21  \let\d\pgfmathresult
22
23  \pgftransformcm{1}{0}{\c}{\d}{(p3)}%座標軸の回転とシフト
24
25  \foreach \i in {0,1,2,..., 20}
26  {
27    \pgfmathparse{30+6*\i}
28    \let\th\pgfmathresult
29
30    % 変数\i が 5 の倍数のときのみ長い目盛りを使う.
31    \pgfmathparse{int(mod(\i,5))}
32    \let\imod\pgfmathresult
33    \ifnum\imod=0
34      \pgfmathparse{\r+\l}
35      \let\length\pgfmathresult
36      \draw[thin] (\th:\r)--(\th:\length);
37    \else
38      \pgfmathparse{\r+\t}
39      \let\length\pgfmathresult
40      \draw[thin] (\th:\r)--(\th:\length);
41    \fi
42  }
43  \end{scope}
44  \end{tikzpicture}

```



```

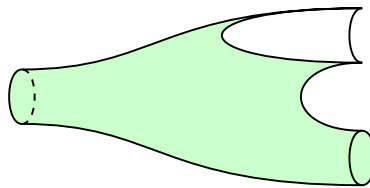
1  \begin{tikzpicture}[thick]
2    \filldraw[fill=green!25, fill opacity=0.8]
3      (1,2.6) .. controls (0.75,2.6) and (0.75,3.4) .. (1,3.4) ..
4      controls (3,3.4) and (3,4.3) .. (6,4.3) ..
5      controls (3.25,4.3) and (3.25,3.5) .. (6,3.5) ..

```

```

6      controls (4.8,3.5) and (4.8,2.5) .. (6,2.5) ..
7      controls (6.25,2.5) and (6.25,1.7) .. (6,1.7) ..
8      controls (3,1.7) and (3,2.6) .. (1,2.6);
9      \draw[dashed]
10     (1,2.6) .. controls (1.25,2.6) and (1.25,3.4) .. (1,3.4);
11     \draw
12     (6,4.3) .. controls (5.75,4.3) and (5.75,3.5) .. (6,3.5);
13     \draw
14     (6,2.5) .. controls (5.75,2.5) and (5.75,1.7) .. (6,1.7);
15     \end{tikzpicture}

```



■△ OAB の内心を求める

```

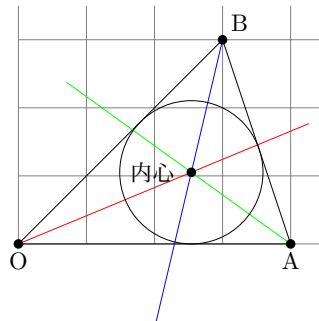
1  \begin{tikzpicture}
2  % △ OAB の内心を求める
3  \draw [help lines] (0,0) grid (4.5,3.5); % (0,0) から (4.5,3.5) までの "細線の方眼"
4
5  % 三角形の頂点を設定し、三角形を描く
6  \coordinate (O) at (0,0) node [below] at (O) {O};
7  \coordinate (A) at (4,0) node [below] at (A) {A};
8  \coordinate (B) at (3,3) node [above right] at (B) {B};
9  \draw (O)--(A)--(B)--cycle;
10
11 % 各辺上で一定の長さの点を設定する
12 \coordinate (s) at ($ (O)!1cm!(A) $);
13 \coordinate (t) at ($ (O)!1cm!(B) $);
14 \coordinate (u) at ($ (A)!1cm!(O) $);
15 \coordinate (v) at ($ (A)!1cm!(B) $);
16 \coordinate (w) at ($ (B)!1cm!(O) $);
17 \coordinate (z) at ($ (B)!1cm!(A) $);
18
19 % 内角の二等分線
20 \draw (O)--($ (s)!0.5!(t) $) [name path=line O, red];
21 \draw (A)--($ (u)!0.5!(v) $) [name path=line A, green];
22 \draw (B)--($ (z)!0.5!(w) $) [name path=line B, blue];
23
24 % 角の二等分線の交点 (=内心)
25 \fill [name intersections={of=line O and line B}]
26 (intersection-1) circle (2pt) node (P) [label=left:内心] {};
27

```

```

28 %各点に黒丸をつける
29 \foreach \P in {O,A,B} \fill (\P) circle (2pt);
30
31 %内心円 (半径は P から OA に下ろした垂線の長さ)
32 \draw let \p1=($ (O)! (P)! (A)-(P)$), \n1={veclen(\x1,\y1)} in circle
33 [at=(P), radius=\n1];
34 \end{tikzpicture}

```



■△ OAB の外心を求める

```

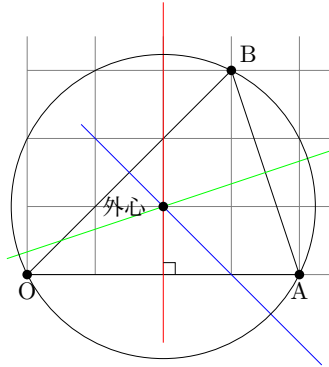
1 \begin{tikzpicture}
2 %△ OAB の外心を求める
3 \draw [help lines] (0,0) grid (4.5,3.5);%(0,0) から (4.5,3.5) までの "細線の方眼"
4
5 %三角形の頂点を設定し、三角形を描く
6 \coordinate (O) at (0,0) node [below] at (O) {O};
7 \coordinate (A) at (4,0) node [below] at (A) {A};
8 \coordinate (B) at (3,3) node [above right] at (B) {B};
9 \draw (O)--(A)--(B)--cycle;
10
11 %各辺の垂直二等分線およびその交点 (=外心)
12 \draw ($ (O)! .5! (A)! 1cm! 90: (O)$)--($ (O)! .5! (A)! 4cm! 90: (A)$)
13 [name path=line 1, red];
14
15 \draw ($ (A)! .5! (B)! 1cm! 90: (A)$)--($ (A)! .5! (B)! 4cm! 90: (B)$)
16 [name path=line 2, green];
17
18 \draw ($ (B)! .5! (O)! 1cm! 90: (B)$)--($ (B)! .5! (O)! 4cm! 90: (O)$)
19 [name path=line 3, blue];
20
21 \fill [name intersections={of=line 1 and line 2}]
22 (intersection-1) circle (2pt) node (P) [label=left:外心] {};
23
24 \draw ($ (O)! .5! (A)! 5pt! (A)$) |- ($ (O)! .5! (A)! 5pt! 90: (A)$);%直角記号
25
26 %各点に黒丸をつける

```

```

27 \foreach \P in {O,A,B} \fill (\P) circle (2pt);
28
29 %外心円 (半径は OP の距離)
30 \node [draw, circle through=(O)] at (P) {};
31 \end{tikzpicture}

```



■曲線上に矢印

```

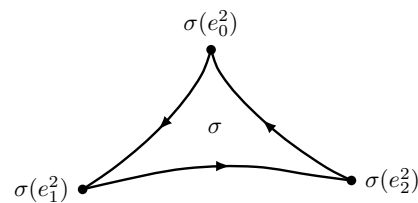
1 \begin{tikzpicture}[y=0.60pt, x=0.6pt,yscale=-1, inner sep=0pt,
2   outer sep=0pt]
3 \tikzset{->/.style={decoration={markings,
4   mark=at position #1 with {\arrow[latex]}},postaction={decorate}}}
5
6 \coordinate (A) at (342.0,213.5);
7 \coordinate (B) at (252.5,310.8);
8 \coordinate (C) at (439.8,304.6);
9 \coordinate (D) at ($(B)!.5!(C)$);
10 \coordinate (E) at ($(C)!.5!(A)$);
11 \path[name path=line1] (A) -- (D);
12 \path[name path=line2] (B) -- (E);
13 \path[name intersections={of=line1 and line2,by=G}];
14 \node[above=0.1cm] at (G){$\sigma$};
15
16 \node[above=0.2cm] at (A){$\sigma(e^2_0)$};
17 \node[left=0.2cm] at (B){$\sigma(e^2_1)$};
18 \node[right=0.2cm] at (C){$\sigma(e^2_2)$};
19
20 \fill (A) circle (2pt) (B) circle (2pt) (C) circle (2pt);
21
22 \path[draw=black,line join=bevel,line cap=butt,line width=1pt,->=.5]
23   (A) .. controls (A) and (338.6,225.1) ..
24   (335.7,230.3) .. controls (328.6,243.1) and (319.0,254.6) ..
25   (309.0,265.3) .. controls (299.0,276.1) and (287.6,285.6) ..
26   (276.0,294.6) .. controls (268.5,300.5) and (252.5,310.8) ..
27   (B) ;

```

```

28
29 \path[draw=black,line join=bevel,line cap=butt,line width=1pt,->=.55]
30 (B) .. controls (B) and (262.6,308.3) ..
31 (267.7,307.2) .. controls (286.6,303.1) and (305.4,298.2) ..
32 (324.7,296.2) .. controls (340.8,294.5) and (357.2,294.1) ..
33 (373.3,295.1) .. controls (387.6,296.0) and (401.6,299.5) ..
34 (415.7,301.4) .. controls (423.7,302.5) and (439.8,304.6) ..
35 (C);
36
37 \path[draw=black,line join=bevel,line cap=butt,line width=1pt,->=.55]
38 (C) .. controls (C) and (428.0,299.1) ..
39 (422.5,295.7) .. controls (406.9,285.9) and (391.6,275.2) ..
40 (378.1,262.7) .. controls (366.6,252.2) and (355.2,241.0) ..
41 (347.2,227.7) .. controls (344.6,223.4) and (342.0,213.5) ..
42 (342.0,213.5);
43 \end{tikzpicture}

```



■関数のグラフに矢印

```

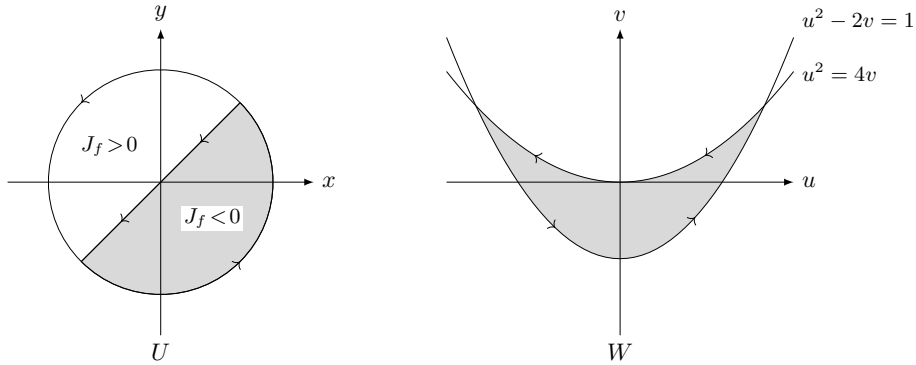
1 \begin{tikzpicture}
2 \tikzset{->/.style={decoration={markings,
3 mark=at position #1 with {\arrow{>}}},postaction={decorate}}}
4 \filldraw[fill=gray!30] (45:1.1) -- (225:1.1) arc (225:405:1.1);
5 \draw[-latex] (-1.5,0) -- (1.5,0) node[right,at end]{$x$};
6 \draw[-latex] (0,-1.5) node[below]{$U$} -- (0,1.5) node[above,at end]{$y$};
7 \draw[->=.5] (45:1.1) arc (45:225:1.1);
8 \draw[->=.5] (225:1.1) arc (225:405:1.1);
9 \draw[->=.5] (45:1.1)--(0,0); \draw[->=.5] (0,0)--(225:1.1);
10 \node at ($(135:0.5)+(-0.15,0)$){\small$J_f!>!0$};
11 \node[fill=white,inner sep=1pt] at ($(315:0.5)+(0.15,0)$){\small$J_f!<!0$};
12 \begin{scope}[xshift=4.5cm,yscale=1.5]
13 \tikzset{->/.style={decoration={markings,
14 mark=at position #1 with {\arrow{>}}},postaction={decorate}}}
15 \tikzset{<-.style={decoration={markings,
16 mark=at position #1 with {\arrow{<}}},postaction={decorate}}}
17 \fill[gray!30] plot[domain=-1.414:1.414] (\x, 0.5*\x*\x-0.5)--cycle;
18 \fill[white] plot [domain=-1.5:1.5] (\x, 0.25*\x*\x)--cycle;
19 \draw[domain=0:1.7,<-=0.45] plot (\x, 0.25*\x*\x)
20 node[right] {\small$u^2=4v$};
21 \draw[domain=-1.7:0,<-=0.6] plot (\x, 0.25*\x*\x);

```

```

22 \draw[domain=0:1.7,->=0.3] plot (\x, 0.5*\x*\x-0.5)
23   node[above right]{\small  $u^2-2v=1$ };
24 \draw[domain=-1.7:0,->=0.75] plot (\x, 0.5*\x*\x-0.5);
25 \draw[-latex] (-1.7,0) -- (1.7,0) node[right,at end]{ $u$ };
26 \draw[-latex] (0,-1) node[below]{ $W$ } -- (0,1) node[above,at end]{ $v$ };
27 \end{scope}
28 \end{tikzpicture}

```

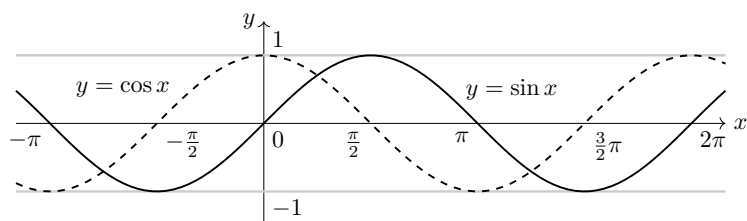


■三角関数 with gnuplot

```

1 \begin{tikzpicture}
2   \draw[->] (-pi-0.5,0)--(2*pi+0.5,0) node[right] { $x$ };
3   \draw[->] (0,-1.5)--(0,1.5) node[left] { $y$ };
4   \draw[gray!40,line width=1pt] (-pi-0.5,1)--(2*pi+0.5,1)
5   (-pi-0.5,-1)--(2*pi+0.5,-1);
6   \draw[thick] plot[id=sine,prefix=figures/tikz/plots/,raw gnuplot]
7   function{set samples 100;plot [-pi-0.5:2*pi+0.5] sin(x)} ;
8   \node at (pi+0.5,0.5){ $y=\sin x$ };
9   \draw[thick,dashed] plot[id=cosine,prefix=figures/tikz/plots/,raw gnuplot]
10  function{set samples 100;plot [-pi-0.5:2*pi+0.5] cos(x)} ;
11  \node at (-0.5*pi-0.5,0.5){ $y=\cos x$ };
12  \node at (0,0)[below right]{ $0$ };
13  \node at (-0.5*pi,0)[below right]{ $-\frac{\pi}{2}$ };
14  \node at (0.5*pi,0)[below left]{ $\frac{\pi}{2}$ };
15  \node at (-pi,0)[below left]{ $-\pi$ };
16  \node at (pi,0)[below left]{ $\pi$ };
17  \node at (1.5*pi,0)[below right]{ $\frac{3}{2}\pi$ };
18  \node at (2*pi,0)[below right]{ $2\pi$ };
19  \node at (0,1)[above right]{ $1$ };
20  \node at (0,-1)[below right]{ $-1$ };
21 \end{tikzpicture}

```

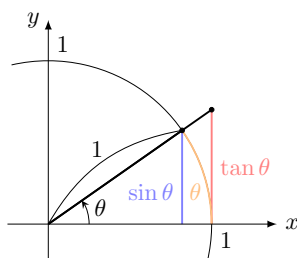


■三角関数と弧長の関係

```

1 \begin{tikzpicture}[scale=1.5]
2 \coordinate (A) at (35:2);
3 \draw[thick] (0,0) -- (A);
4 \draw[auto,bend left=25,pos=0.45] (0,0) to node[above]{$1$} (A);
5 \pgfmathparse{2*cos(35)}
6 \coordinate (X) at (\pgfmathresult,0);
7 \pgfmathparse{2*tan(35)}
8 \coordinate (B) at (2,\pgfmathresult);
9 \draw[thick,red!50] (B) -- (2,0);
10 \draw[thick,blue!50] (A) -- (X);
11 \draw[thick] (0,0) -- (B);
12 \draw[-stealth] (0.5,0) arc [start angle=0, end angle=35,radius=0.5] node[right] at (23:0.5){$\theta$};
13 \draw (-13:2) arc [start angle=-13, end angle=103, radius=2];
14 \draw[thick,orange!50] (0:2) arc (0:35:2);
15 \filldraw (A) circle (0.8pt);
16 \filldraw (B) circle (0.8pt);
17
18 \node[below right] at (2,0){$1$};
19 \node[above right] at (0,2){$1$};
20 \node[left,blue!50] at ($(X)! .35!(A)$) {$\sin \theta$};
21 \node[right,red!50] at ($(B)! .5!(2,0)$) {$\tan \theta$};
22 \node[orange!50] at (1.8,0.4) {$\theta$};
23
24 \draw[-latex] (-0.5,0) -- (2.8,0) node [at end, right]{$x$};
25 \draw[-latex] (0,-0.5) -- (0,2.5) node [at end, left]{$y$};
26 \end{tikzpicture}

```

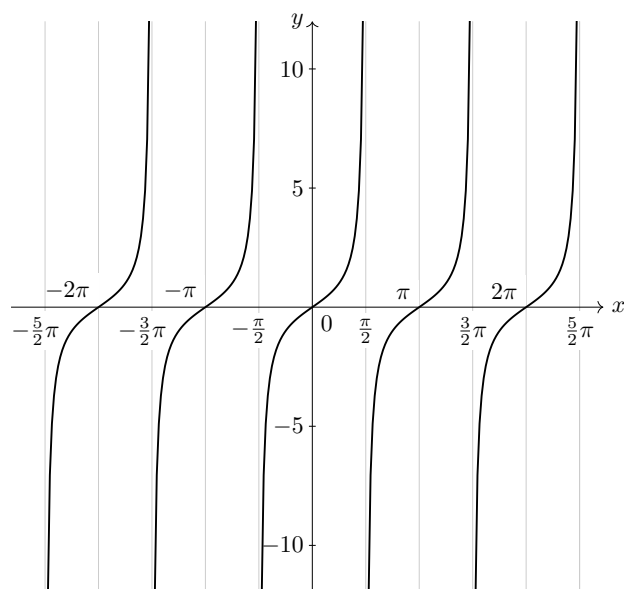


■正接関数のグラフ

```

1 \begin{tikzpicture}[xscale=0.5,yscale=0.35]
2 \begin{scope}
3   \clip (-2.5*pi-1,-12) rectangle (2.5*pi+0.5,12);
4   \draw[gray!40] (2.5*pi,12)--(2.5*pi,-12);
5   \foreach \n/\ntext in
6     {-4/-2\pi,-2/-\pi,2/\pi,4/2\pi,-5/-\frac{5}{2}\pi,-3/-\frac{3}{2}\pi,-1/-\frac{\pi}{2},%
7     1/\hphantom{-}\frac{\pi}{2},3/\hphantom{-}\frac{3}{2}\pi,5/\hphantom{-}\frac{5}{2}\pi}{%
8     \tikzmath{
9       real \x1,\x2;
10      \x1=0.5*\n*pi;
11      \x2=(0.5*\n+1)*pi;
12    };
13    \draw[gray!40] (\x1,12)--(\x1,-12);
14    \pgfmathparse{mod(\n,2)==0?1:0}
15    \ifnum\pgfmathresult > 0
16      \node[fill=white,above left] at (\x1,0){$\ntext$};
17    \else
18      \node[fill=white,inner sep=2pt] at ($(\x1,0)+(-0.28,-1)$){$\ntext$};
19    \ifnum\n < 5
20      \draw[thick] plot[id=tangent\n,prefix=figures/tikz/plots/,raw gnuplot]
21        function{set samples 50;plot [\x1+0.08:\x2-0.08] tan(x)} ;
22      \fi
23      \fi
24    }
25    \node[below right] at (0,0){$0$};
26
27    \foreach \n in {-10, -5, 5, 10}{
28      \draw (-0.1,\n)--(0.1,\n);
29      \node[left] at (0,\n){$\n$};
30    }
31  \end{scope}
32  \draw[->] (-2.5*pi-1,0)--(2.5*pi+0.7,0) node[right] {$x$};
33  \draw[->] (0,-12)--(0,12) node[left] {$y$};
34 \end{tikzpicture}

```

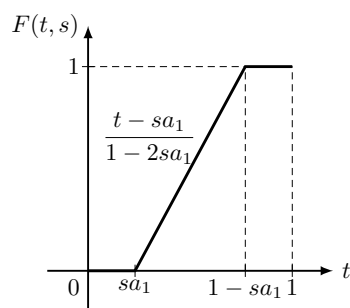


■ホモトピー関係 1

```

1 \begin{tikzpicture}[x=3cm,y=3cm]
2   \draw[thick,-latex] (-0.2,0)--(1.2,0)node[right] {$t$};
3   \draw[thick,-latex] (0,-0.2)--(0,1.2)node[left] {$F(t, s)$};
4   \tikzmath{
5     real \t;
6     \t1=0.23;
7     \t2=1-\t1;
8     \t3=1;
9   }
10  \draw[very thick] (0,0)--(\t1, 0)--(\t2,1)--(1,1);
11  \node[below]at(\t1,0){$s_1$};
12  \node[below]at(\t2,0){$1-s_1$};
13  \node[below]at(1,0){$1$};
14  \draw(-0.03,1)--(0.03,1);
15
16  \foreach \i in {1, 2, 3}{
17    \draw(\t\i,-0.03)--(\t\i,0.03);};
18
19  \foreach \i in {2, 3}{
20    \draw[densely dashed](\t\i,0)--(\t\i,1);};
21  \draw[densely dashed](0,1)--(1,1);
22
23  \node[left]at(0,1){$1$};
24  \node[below left]at(0,0){$0$};
25  \node at(0.3,0.65){$\dfrac{t-s_1}{1-2s_1}$};
26 \end{tikzpicture}

```



■ホモトピー関係 2

```

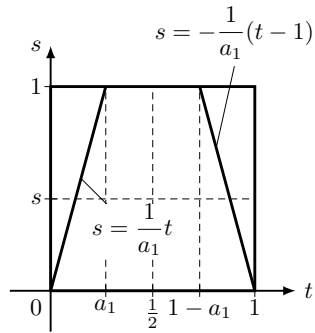
1  \begin{tikzpicture}[x=3cm,y=3cm]
2  \draw[thick,-latex](-0.2,0)--(1.2,0)node[right] {$t$};
3  \draw[thick,-latex](0,-0.2)--(0,1.2)node[left] {$s$};
4  \tikzmath{
5    real \t, \s;
6    \t1=0.27;
7    \t2=1-\t1;
8    \t3=0.5;
9    \t4=1;
10   \s=0.45;
11   coordinate \A, \B, \C, \D;
12   \A=(0,0);
13   \B=(\t1,1);
14   \C=(\t2,1);
15   \D=(1,0);
16 }
17 \draw[very thick](\A)--(\B);
18 \draw[very thick](\C)--(\D);
19 \draw[very thick](0,0)--(1,0)--(1,1)--(0,1)--cycle;
20 \node[below]at(\t1,0){$a_1$};
21 \node[below]at(\t2,0){$1-a_1$};
22 \node[below]at(\t3,0){$\frac{1}{2}$};
23 \node[below]at(1,0){$1$};
24 \draw(-0.03,1)--(0.03,1);
25
26 \foreach \i in {1, 2, 3, 4}{
27   \draw(\t\i,-0.03)--(\t\i,0.03);};
28
29 \foreach \i in {1, 2, 3}{
30   \draw[densely dashed](\t\i,0)--(\t\i,1);};
31
32 \draw[densely dashed](0,\s)--(1,\s);
33 \draw(-0.03,\s)--(0.03,\s);
34
35 \node[left]at(0,1){$1$};

```

```

36 \node[below left]at(0,0){$0$};
37 \node[left]at(0,\s){$s$};
38 \draw (0.4,0.3)node[fill=white,inner sep=0pt]{ $s=\frac{1}{a_1}t$ }--($(\A)!0.55!(\B)$);
39 \draw (0.9,1.1)node[fill=white,inner sep=3pt,above]{ $s=-\frac{1}{a_1}(t-1)$ }
40 --($(\C)!0.3!(\D)$);
41 \end{tikzpicture}

```



■ホモトピー関係 3

```

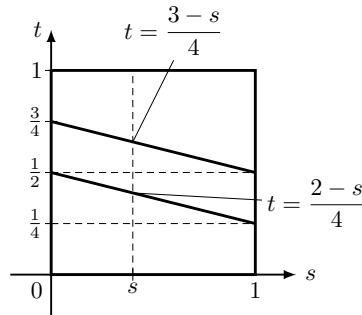
1 \begin{tikzpicture}[x=3cm,y=3cm]
2 \draw[thick,-latex](-0.2,0)--(1.2,0)node[right]{$s$};
3 \draw[thick,-latex](0,-0.2)--(0,1.2)node[left]{$t$};
4 \tikzmath{
5   real \t, \s;
6   \t1=0;
7   \t2=0.25;
8   \t3=0.5;
9   \t4=0.75;
10  \t5=1;
11  \s=0.4;
12  coordinate \A, \B, \C, \D;
13  \A=(0,\t3);
14  \B=(0,\t4);
15  \C=(1,\t2);
16  \D=(1,\t3);
17 }
18 \draw[very thick](\A)--(\C);
19 \draw[very thick](\B)--(\D);
20 \draw[very thick](0,0)--(1,0)--(1,1)--(0,1)--cycle;
21 \node[left]at(0,\t2){ $\frac{1}{4}$ };
22 \node[left]at(0,\t3){ $\frac{1}{2}$ };
23 \node[left]at(0,\t4){ $\frac{3}{4}$ };
24 \node[left]at(0,\t5){1};
25 \draw(-0.03,1)--(0.03,1);
26
27 \foreach \i in {1, 2, 3, 4}{

```

```

28 \draw(-0.03,\t\i)--(0.03,\t\i);};
29
30 \foreach \i in {1, 2, 3}{
31 \draw[densely dashed](0,\t\i)--(1,\t\i);};
32
33 \draw[densely dashed](\s,0)--(\s,1);
34 \draw(\s,-0.03)--(\s,0.03);
35
36 \node[below]at(1,0){$1$};
37 \node[below left]at(0,0){$0$};
38 \node[below]at(\s,0){$s$};
39 \draw (1.3,0.35)node[fill=white,inner sep=2pt]{$t=\dfrac{2-s}{4}$}--($(\A)!0.4!(\C)$);
40 \draw (0.6,1.05)node[fill=white,inner sep=2pt,above]{$t=\dfrac{3-s}{4}$}
41 --($(\B)!0.4!(\D)$);
42 \end{tikzpicture}

```



■ホモトピー関係 4

```

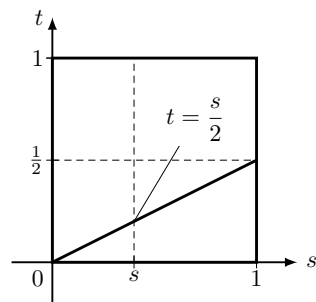
1 \begin{tikzpicture}[x=3cm,y=3cm]
2 \draw[thick,-latex](-0.2,0)--(1.2,0)node[right] {$s$};
3 \draw[thick,-latex](0,-0.2)--(0,1.2)node[left]{$t$};
4 \tikzmath{
5 real \t, \s;
6 \t1=0.5;
7 \t2=1;
8 \s=0.4;
9 coordinate \A, \B;
10 \A=(0,0);
11 \B=(1,0.5);
12 }
13 \draw[very thick](\A)--(\B);
14 \draw[very thick](0,0)--(1,0)--(1,1)--(0,1)--cycle;
15 \node[left]at(0,1){$1$};
16 \node[left]at(0,\t1){$\frac{1}{2}$};
17 \draw(-0.03,1)--(0.03,1);
18
19 \foreach \i in {1, 2}{

```

```

20 \draw(-0.03,\t\i)--(0.03,\t\i);};
21
22 \draw[densely dashed](0,\t1)--(1,\t1);
23
24 \draw[densely dashed](\s,0)--(\s,1);
25 \draw(\s,-0.03)--(\s,0.03);
26 \draw(1,-0.03)--(1,0.03);
27
28 \node[below]at(1,0){$1$};
29 \node[below left]at(0,0){$0$};
30 \node[below]at(\s,0){$s$};
31 \draw (0.7,0.7)node[fill=white,inner sep=2pt]{$t=\dfrac{s}{2}$}--($(\A)!0.4!(\B)$);
32 \end{tikzpicture}

```



■ホモトピー関係 5

```

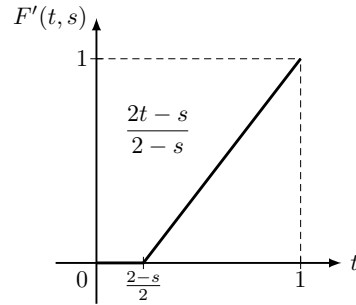
1 \begin{tikzpicture}[x=3cm,y=3cm]
2 \draw[thick,-latex](-0.2,0)--(1.2,0)node[right] {$t$};
3 \draw[thick,-latex](0,-0.2)--(0,1.2)node[left] {$F'(t, s)$};
4 \tikzmath{
5 real \t;
6 \t1=0.23;
7 %\t2=1-\t1;
8 \t2=1;
9 }
10 \draw[very thick](0,0)--(\t1, 0)--(\t2,1)--(1,1);
11 \node[below]at(\t1,0){$\frac{2-s}{2}$};
12 %\node[below]at(\t2,0){$1-s_1$};
13 \node[below]at(1,0){$1$};
14 \draw(-0.03,1)--(0.03,1);
15
16 \foreach \i in {1, 2}{
17 \draw(\t\i,-0.03)--(\t\i,0.03);};
18
19 \foreach \i in {2}{
20 \draw[densely dashed](\t\i,0)--(\t\i,1);};
21 \draw[densely dashed](0,1)--(1,1);

```

```

22
23 \node[left] at (0,1){$1$};
24 \node[below left] at (0,0){$0$};
25 \node at (0.3,0.65){$\dfrac{2t-s}{2-s}$};
26 \end{tikzpicture}

```



■ホモトピー関係 6

```

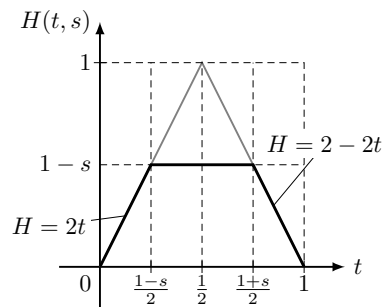
1 \begin{tikzpicture}[x=3cm,y=3cm]
2 \draw[thick,-latex](-0.2,0)--(1.2,0)node[right] {$t$};
3 \draw[thick,-latex](0,-0.2)--(0,1.2)node[left] {$H(t, s)$};
4 \tikzmath{
5   real \t, \s, \h;
6   \s=0.5;
7   \h=1-\s;
8   \t1=0;
9   \t2=0.5*(1-\s);
10  \t3=0.5*(1+\s);
11  \t4=1;
12  \t5=0.5;
13  coordinate \A, \B, \C, \D;
14  \A=(\t1, 0);
15  \B=(\t2, \h);
16  \C=(\t3, \h);
17  \D=(\t4, 0);
18 }
19 \draw[thick,gray](0,0)--(0.5,1)--(1,0);
20
21 \draw[very thick](\t1,0)--(\t2, \h)--(\t3, \h)--(\t4,0);
22 \node[below] at (\t2,0){$\frac{1-s}{2}$};
23 \node[below] at (\t3,0){$\frac{1+s}{2}$};
24 \node[below] at (\t5,0){$\frac{1}{2}$};
25 \node[below] at (1,0){$1$};
26 \draw(-0.03,1)--(0.03,1);
27
28 \foreach \i in {2, 3, 4, 5}{
29 \draw(\t\i,-0.03)--(\t\i,0.03);};

```

```

30
31 \foreach \i in {2, 3, 5}{
32 \draw[densely dashed](\t\i,0)--(\t\i,1)};
33
34 \foreach \i in {2, 3}{
35 \draw[densely dashed](\t\i,\h)--(\t\i,\h)};
36 \draw[densely dashed](0,1)--(1,1)--(1,0);
37 \draw[densely dashed](0,\h)node[left]{ $1-s$ }--(1,\h);
38
39 \node[left]at(0,1){ $1$ };
40 \node[below left]at(0,0){ $0$ };
41 \draw(-0.25,0.2)node[fill=white, inner sep=2pt]{ $H=2t$ }--($(\A)!0.5!(\B)$);
42 \draw(1.1,0.6)node[fill=white, inner sep=2pt]{ $H=2-2t$ }--($(\C)!0.4!(\D)$);
43 \end{tikzpicture}

```



■ホモトピー関係 7

```

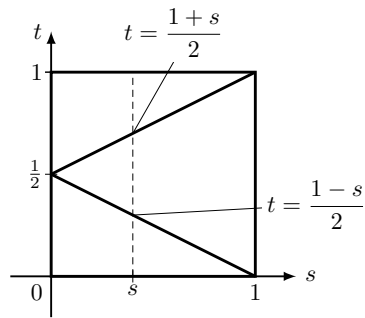
1 \begin{tikzpicture}[x=3cm,y=3cm]
2 \draw[thick,-latex](-0.2,0)--(1.2,0)node[right]{ $s$ };
3 \draw[thick,-latex](0,-0.2)--(0,1.2)node[left]{ $t$ };
4 \tikzmath{
5   real \t, \s;
6   \t1=0;
7   \t2=0.5;
8   \t3=1;
9   \s=0.4;
10  coordinate \A, \B, \C;
11   \A=(0,\t2);
12   \B=(1,1);
13   \C=(1,0);
14 }
15 \draw[very thick](\A)--(\B);
16 \draw[very thick](\A)--(\C);
17 \draw[very thick](0,0)--(1,0)--(1,1)--(0,1)--cycle;
18 \node[left]at(0,\t2){ $\frac{1}{2}$ };
19 \node[left]at(0,\t3){ $1$ };
20 \draw(-0.03,1)--(0.03,1);

```

```

21
22 \foreach \i in {2, 3}{
23 \draw(-0.03,\t\i)--(0.03,\t\i)};
24
25 \draw[densely dashed](\s,0)--(\s,1);
26 \draw(\s,-0.03)--(\s,0.03);
27
28 \node[below]at(1,0){$1$};
29 \node[below left]at(0,0){$0$};
30 \node[below]at(\s,0){$s$};
31 \draw (1.3,0.35)node[fill=white,inner sep=2pt]{$t=\dfrac{1-s}{2}$}--($(\A)!0.4!(\C)$);
32 \draw (0.6,1.05)node[fill=white,inner sep=2pt,above]{$t=\dfrac{1+s}{2}$}
33 --($(\A)!0.4!(\B)$);
34 \end{tikzpicture}

```



■可換図

```

1 %要 \usetikzlibrary{cd}
2 \begin{equation*}
3 \begin{tikzcd}[column sep=small]
4 H_{n+1}(S_{\ast}(U)+S_{\ast}(V))
5 \arrow[r]
6 \arrow[d]
7 &(\Sigma^{-1}\mathbb{Z})_n
8 \arrow[r]
9 \arrow[d,equal]
10 &H_n(\tilde{S}_{\ast}(U)+\tilde{S}_{\ast}(V))
11 \arrow[d]
12 \arrow[ddd,phantom,"{coordinate,name=Z}]
13 \arrow[dd,rounded corners,
14 to path={ --([xshift=2ex]\tikztostart.east)
15 |-(\Z)+(0,-1ex)\tikztonodes
16 -|([xshift=-2ex]\tikztotarget.west)
17 --(\tikztotarget)}]
18 \\
19 H_{n+1}(X)
20 \arrow[r]

```

```

21 &(\Sigma^{-1}\mathbb{Z})_n
22 \arrow[r]
23 &\tilde{H}_n(X)
24 \arrow[dd,rounded corners,
25 to path={ --([xshift=2ex]\tikztostart.east)
26 |-(\$(Z)+(0,+1ex)\$)\tikztonodes
27 -|([xshift=-10ex]\tikztotarget.west)
28 --(\tikztotarget)}]
29 \\
30 &H_n(S_*\ast(U)+S_*\ast(V))
31 \arrow[r]
32 \arrow[d]
33 &(\Sigma^{-1}\mathbb{Z})_{n-1}
34 \arrow[d,equal]
35 \\
36 &H_n(X)
37 \arrow[r]
38 &(\Sigma^{-1}\mathbb{Z})_{n-1}
39 \end{tikzcd}
40 \end{equation*}

```

$$\begin{array}{ccccc}
H_{n+1}(S_*(U) + S_*(V)) & \rightarrow & (\Sigma^{-1}\mathbb{Z})_n & \rightarrow & H_n(\tilde{S}_*(U) + \tilde{S}_*(V)) \\
\downarrow & & \parallel & & \downarrow \\
H_{n+1}(X) & \longrightarrow & (\Sigma^{-1}\mathbb{Z})_n & \longrightarrow & \tilde{H}_n(X) \\
& & & \searrow & \\
& & & & H_n(S_*(U) + S_*(V)) \rightarrow (\Sigma^{-1}\mathbb{Z})_{n-1} \\
& & & \searrow & \parallel \\
& & & & H_n(X) \longrightarrow (\Sigma^{-1}\mathbb{Z})_{n-1}
\end{array}$$

■手書きの図を svg2tikz で変換したもの

```

1 \begin{tikzpicture}[y=0.9pt, x=0.9pt,yscale=-1,inner sep=0pt, outer sep=0pt]
2 \tikzset{->/.style={decoration={markings,
3 mark=at position #1 with {\arrow{latex}}},postaction={decorate}}}
4 \tikzset{-</.style={decoration={markings,
5 mark=at position #1 with {\arrowreversed{latex}}},postaction={decorate}}}
6
7 %U_{i-1}
8 \def\myfirstpath{ (157.0067,389.7258) .. controls (165.7034,368.3085)
9 and (190.1796,347.4348) .. (209.5294,337.0207) .. controls (233.4684,324.0812)
10 and (254.2961,317.9895) .. (278.0767,314.1725) .. controls (295.2475,311.4164)
11 and (313.3788,310.8893) .. (330.2480,314.3518) .. controls (347.5000,318.4966)
12 and (368.1742,327.6396) .. (371.4851,346.6381) .. controls (374.9547,362.9230)
13 and (365.7111,379.5047) .. (351.7498,387.7360) .. controls (336.8479,396.9542)

```

```

14 and (318.3773,400.1960) .. (301.0813,398.2222) .. controls (291.8272,396.8369)
15 and (279.8109,396.1909) .. (273.4585,404.2524) .. controls (264.7832,416.4780)
16 and (276.6443,427.9286) .. (287.5522,432.3663) .. controls (297.5718,437.9447)
17 and (310.4415,445.9577) .. (309.1202,459.1847) .. controls (307.0599,473.7413)
18 and (292.4327,482.4913) .. (278.7745,483.7576) .. controls (263.8668,485.1863)
19 and (241.3976,486.0999) .. (223.4505,481.8097) .. controls (204.4384,477.2650)
20 and (188.0595,472.2329) .. (170.2461,457.1453) .. controls (158.0723,446.5051)
21 and (149.0181,430.8106) .. (151.0625,414.1707) .. controls (151.5808,405.7588)
22 and (153.5254,397.4117) .. (157.0067,389.7258) -- cycle};
23
24 %U_i
25 \def\mysecondpath{(315.3049,342.7099) .. controls (325.9853,334.1596)
26 and (339.5588,330.5938) .. (353.0448,330.0850) .. controls (371.4057,328.7153)
27 and (390.4800,333.2682) .. (404.9620,345.0059) .. controls (428.7134,362.7247)
28 and (444.1578,388.6888) .. (461.0534,412.4660) .. controls (468.6126,423.1932)
29 and (469.6883,438.5854) .. (461.2734,449.1408) .. controls (452.7792,460.2858)
30 and (438.9689,465.5604) .. (426.1605,470.0463) .. controls (399.0619,477.9140)
31 and (371.4184,485.3901) .. (342.9587,485.1084) .. controls (323.6240,485.1759)
32 and (304.0299,484.5658) .. (285.1250,480.2935) .. controls (276.6889,477.5333)
33 and (269.0397,469.7868) .. (270.3613,460.3429) .. controls (271.0749,446.2362)
34 and (280.6862,434.7188) .. (290.0482,425.0042) .. controls (298.8432,416.8357)
35 and (301.0736,403.6369) .. (297.1839,392.5335) .. controls (293.2223,374.9014)
36 and (298.2189,354.0886) .. (313.9713,343.6827) -- (315.3049,342.7099) --
37 (315.3049,342.7099) -- cycle};
38
39 %U_{i+1}
40 \def\mythirdpath{(500.3243,357.2544) .. controls (481.1539,356.3190)
41 and (460.6839,357.4454) .. (443.9737,367.9254) .. controls (427.3045,378.5248)
42 and (416.0032,395.7235) .. (408.1408,413.4949) .. controls (401.7973,428.2880)
43 and (399.6152,445.9552) .. (407.1679,460.7552) .. controls (413.5666,475.5372)
44 and (427.5444,485.6884) .. (442.7412,490.0386) .. controls (457.9402,494.5285)
45 and (473.8684,495.5226) .. (489.3917,498.3569) .. controls (493.8515,499.3566)
46 and (498.2766,500.5058) .. (502.6920,501.6845)};
47
48 \begin{scope}
49 \clip \myfirstpath ; \fill[gray!40] \mysecondpath ;
50 \fill[white](280,450) circle (1.5cm);
51 \end{scope}
52
53 \begin{scope}
54 \clip \mysecondpath ; \fill[gray!40] \mythirdpath ;
55 \end{scope}
56
57 \draw[draw=black,line width=1pt] \myfirstpath \mysecondpath \mythirdpath;
58
59 %\ell_i
60 \path[draw=black,line join=miter,line cap=butt,miter limit=4.00,even odd rule,line width=1pt,->=0.65]

```

```

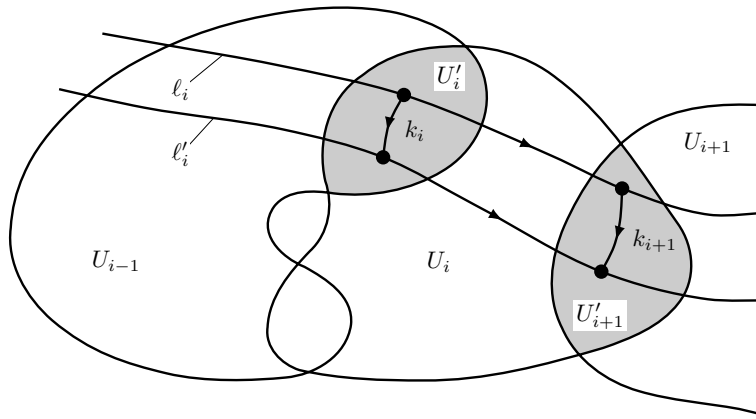
61 (193.6181,323.9866) .. controls (193.6181,323.9866)
62 and (214.9852,327.8088) .. (225.6675,329.7268) .. controls (241.6137,332.5900)
63 and (257.6394,335.0439) .. (273.5024,338.3371) coordinate[pos=.5,name=L]{}
64 .. controls (293.6835,342.5267)
65 and (314.0670,346.2056) .. (333.6898,352.5119) .. controls (357.3591,360.1187)
66 and (379.8821,370.9394) .. (402.6567,380.9101) .. controls (413.5649,385.6857)
67 and (423.9252,391.7278) .. (435.0573,395.9551) .. controls (448.3256,400.9936)
68 and (461.7638,406.3931) .. (475.8441,408.1760) .. controls (483.9178,409.1984)
69 and (500.2399,407.2194) .. (500.2399,407.2194) ;
70
71 %\ell'_i
72 \path[draw=black,line join=miter,line cap=butt,miter limit=4.00,even odd
73 rule,line width=1pt,->-=0.63] (173.5275,349.8175) .. controls (173.5275,349.8175)
74 and (199.9183,355.9433) .. (213.2304,358.4277) .. controls (234.4904,362.3955)
75 and (256.1931,363.8914) .. (277.3292,368.4731) coordinate[pos=.5,name=M]{}
76 .. controls (293.1232,371.8967)
77 and (308.9977,375.5557) .. (324.0358,381.4741) .. controls (338.8038,387.2862)
78 and (352.2392,396.0368) .. (366.3022,403.3926) .. controls (386.0390,413.7160)
79 and (404.6333,426.5260) .. (425.4032,434.5713) .. controls (441.2929,440.7263)
80 and (458.0062,445.0795) .. (474.8874,447.4007) .. controls (482.9451,448.5086)
81 and (499.2832,447.8790) .. (499.2832,447.8790);
82
83 \draw (230,350)node[fill=white]{\ell_i} --(L);
84 \draw (230,380)node[fill=white]{\ell'_i} --(M);
85
86 \coordinate (A) at (333.6898,352.5119);
87 \coordinate (B) at (435.0573,395.9551);
88 \coordinate (C) at (324.0358,381.4741);
89 \coordinate (D) at (425.4032,434.5713);
90 \fill (A)circle (3pt) (B) circle (3pt) (C) circle (3pt) (D)circle (3pt);
91 \node at ($(A)!.5!(C)+(10,2)$){\k_i};
92 \node at ($(B)!.5!(D)+(20,+5)$){\k_{i+1}};
93
94 %\k_i
95 \path[draw=black,line join=miter,line cap=butt,miter limit=4.00,even odd
96 rule,line width=1pt,->-=0.6] (333.6898,352.5119) .. controls (333.6898,352.5119)
97 and (328.3527,361.1910) .. (326.7417,365.9783) coordinate[name=P]
98 .. controls (325.0694,370.9479) and (324.0358,381.4741) .. (324.0358,381.4741);
99
100 %\k'_i
101 \path[draw=black,line join=miter,line cap=butt,miter limit=4.00,even odd
102 rule,line width=1pt,->-=0.6] (435.0573,395.9551) .. controls (435.0573,395.9551)
103 and (434.8075,406.1678) .. (434.0426,411.2043) .. controls (433.4412,415.1635)
104 and (432.6157,419.1251) .. (431.2450,422.8878) coordinate[pos=0.5,name=Q]
105 .. controls (429.7547,426.9790)
106 and (425.4033,434.5713) .. (425.4033,434.5713);
107

```

```

108 \coordinate (X) at (200,430);
109 \coordinate (Y) at (350,430);
110 \coordinate (Z) at (475,375);
111 \coordinate(XY) at (355,344);
112 \coordinate(YZ) at (425,455);
113 \node at (X){ $U_{i-1}$ };
114 \node at (Y){ $U_i$ };
115 \node at (Z){ $U_{i+1}$ };
116 \node[fill=white,inner sep=1pt] at (XY){ $U'_i$ };
117 \node[fill=white,inner sep=1pt] at (YZ){ $U'_{i+1}$ };
118 \end{tikzpicture}

```



■被覆空間

```

1 \begin{tikzpicture}[y=0.70pt, x=0.70pt, yscale=1.000000, xscale=1.000000, inner sep=0pt, outer sep=0pt]
2 \tikzset{->/.style={decoration={markings,
3   mark=at position #1 with {\arrow{latex}}},postaction={decorate}}}
4 \tikzset{<-/.style={decoration={markings,
5   mark=at position #1 with {\arrowreversed{latex}}},postaction={decorate}}}
6
7 %底空間
8 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
9   width=0.55pt] (121.7900,34.7100) .. controls (129.4699,33.7134) and
10   (137.2230,33.2738) .. (144.9658,33.4858) .. controls (151.1520,33.5812) and
11   (157.3269,34.1118) .. (163.4499,34.9838) .. controls (167.9372,35.7712) and
12   (172.4532,36.5160) .. (176.7722,38.0058) .. controls (179.9229,39.0369) and
13   (183.0531,40.2638) .. (185.7365,42.2505) .. controls (187.1066,43.2428) and
14   (188.2353,44.6511) .. (188.8310,46.2317) .. controls (188.9693,47.2196) and
15   (189.0289,48.1949) .. (188.4684,49.0712) .. controls (187.7969,50.5781) and
16   (186.5119,51.7061) .. (185.1793,52.6393) .. controls (184.2748,53.3518) and
17   (183.1765,53.7818) .. (182.1900,54.3700)%;
18 (158.1500,60.2000) .. controls (151.1650,60.8803) and
19   (144.1436,61.2315) .. (137.1265,60.9667) .. controls (130.1383,60.7578) and
20   (123.1416,60.1556) .. (116.2710,58.8355) .. controls (112.0407,58.0174) and

```

```

21 (107.8204,57.0060) .. (103.7972,55.4554) .. controls (101.0122,54.2356) and
22 (98.1354,52.9151) .. (96.0490,50.6479) .. controls (95.3159,49.8176) and
23 (94.7529,48.9022) .. (94.5761,47.7934) .. controls (94.4872,46.7104) and
24 (94.7489,45.5451) .. (95.4151,44.6486) .. controls (96.0496,43.5286) and
25 (97.1482,42.7157) .. (98.1705,41.9599) .. controls (101.0723,39.8963) and
26 (104.4734,38.7001) .. (107.8382,37.6228) .. controls (112.3900,36.2160) and
27 (117.0938,35.4544) .. (121.7900,34.7100)%;
28 (91.8300,15.9200) .. controls (115.1417,12.9461) and
29 (138.7044,12.0806) .. (162.1739,13.2604) .. controls (178.2734,14.1191) and
30 (194.3578,15.9437) .. (210.1645,19.1419) .. controls (223.1220,21.9311) and
31 (236.1009,25.5184) .. (247.7242,32.0260) .. controls (251.5044,34.5786) and
32 (255.5303,37.2396) .. (257.8644,41.2385) .. controls (259.4511,43.6355) and
33 (260.0680,46.6344) .. (259.4884,49.4154) .. controls (258.5988,52.8928) and
34 (256.3184,55.7543) .. (253.7062,58.1132) .. controls (247.7652,63.2883) and
35 (240.7376,66.1295) .. (233.4978,68.9989)%;
36 (175.2977,80.2200) .. controls (167.1557,80.9239) and
37 (159.8385,81.3539) .. (151.6701,81.5807) .. controls (144.2787,81.8041) and
38 (136.8877,81.8174) .. (129.4973,81.5430) .. controls (122.3851,81.3787) and
39 (115.2818,80.8431) .. (108.1917,80.2841) .. controls (100.6143,79.5880) and
40 (93.0542,78.7506) .. (85.5371,77.5595) .. controls (79.9541,76.7439) and
41 (74.4219,75.5673) .. (68.9059,74.3956) -- (68.6970,74.3408) --
42 (68.5800,74.3100)%;
43 (65.0500,73.3800) .. controls (60.8145,72.3845) and
44 (56.6323,71.2065) .. (52.5323,69.7467) .. controls (48.0910,68.4336) and
45 (43.9025,66.4266) .. (39.6778,64.5624) .. controls (36.6739,62.7399) and
46 (33.3693,61.3525) .. (30.8001,58.9011) .. controls (29.2253,57.6538) and
47 (27.6580,56.3994) .. (26.6015,54.6586) .. controls (25.6594,53.4130) and
48 (24.5596,52.2446) .. (24.3962,50.6178) .. controls (24.0223,49.1878) and
49 (23.3902,47.7734) .. (23.8867,46.2912) .. controls (24.0965,44.7631) and
50 (24.1800,43.1904) .. (25.2110,41.9524) .. controls (26.1185,40.3691) and
51 (26.9467,38.7218) .. (28.4771,37.6422) .. controls (30.2135,35.9556) and
52 (32.0202,34.3599) .. (34.1480,33.1802) .. controls (36.4821,31.5438) and
53 (38.9700,30.1854) .. (41.5917,29.0688) .. controls (46.0084,26.7879) and
54 (50.7825,25.3627) .. (55.4331,23.6523) .. controls (61.1252,22.0944) and
55 (66.7833,20.3972) .. (72.5950,19.3316) .. controls (78.9450,17.8519) and
56 (85.4059,17.0028) .. (91.8300,15.9200);
57
58 %ファイバー 1
59 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
60 width=0.55pt,densely dashed]
61 (66.7800,57.4600)coordinate[name=FPAA] .. controls (66.7800,70.9267) and
62 (66.7800,84.3933) .. (66.7800,97.8600)%;
63 (66.7800,125.2200)coordinate[name=FPAB] .. controls (66.7800,131.1233) and
64 (66.7800,137.0267) .. (66.7800,142.9300)%;
65 (66.7800,170.4300)coordinate[name=FPAC] .. controls (66.7800,185.4800) and
66 (66.7800,200.5300) .. (66.7800,215.5800)coordinate[name=FPAD];
67

```

```

68 \fill (FPAA) circle [x radius=2.7,y radius=1.4];
69 \fill (FPAB) circle [x radius=2.7,y radius=1.1];
70 \fill (FPAC) circle [x radius=2.7,y radius=1.1];
71 \node at (FPAA)[right=5]{\textcolor{red}{b}_0};
72 \node at (FPAC)[right=5]{\textcolor{red}{e}};
73
74
75 %ファイバー 2
76 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
77 width=0.55pt,densely dashed]
78 (216.6800,37.0200)coordinate[name=FPBA] .. controls (216.6800,45.5400) and
79 (216.6800,54.0600) .. (216.6800,62.5800)%;
80 (216.6800,82.2300)coordinate[name=FPBB] .. controls (216.6800,90.7267) and
81 (216.6800,99.2233) .. (216.6800,107.7200)%;
82 (216.6800,127.3800)coordinate[name=FPBC] .. controls (216.6800,135.9000) and
83 (216.6800,144.4200) .. (216.6800,152.9400)%;
84 (216.6800,172.5900)coordinate[name=FPBD] .. controls (216.6800,180.1033) and
85 (216.6800,187.6167) .. (216.6800,195.1300)coordinate[name=FPBE];
86
87 \fill (FPBA) circle [x radius=2.7,y radius=1.4];
88 \fill (FPBB) circle [x radius=2.7,y radius=1.2];
89 \fill (FPBC) circle [x radius=2.7,y radius=1.2];
90 \fill (FPBD) circle [x radius=2.7,y radius=1.2];
91 \node at (FPBA)[right=5]{\textcolor{red}{b}_1};
92 \node at ($ (FPBD)+(18,6)$){\textcolor{red}{ell}_\textcolor{blue}{sharp}(e)};
93
94
95 %全空間
96 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
97 width=0.55pt] (164.2700,51.7800) .. controls (179.9613,53.7115) and
98 (195.5999,56.3735) .. (210.7988,60.7926) .. controls (220.5089,63.6070) and
99 (230.1200,66.9296) .. (239.0606,71.7018) .. controls (243.6323,74.1180) and
100 (248.0505,76.9606) .. (251.8380,80.4952) .. controls (254.9407,83.3555) and
101 (257.6684,86.8107) .. (259.0284,90.8329) .. controls (260.0306,93.9826) and
102 (259.9541,97.3820) .. (258.9295,100.5162) .. controls (257.8230,103.8144) and
103 (255.6884,106.7189) .. (253.2994,109.2207) .. controls (249.7786,112.7929) and
104 (245.6512,115.6746) .. (241.3100,118.1600);
105 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
106 width=0.55pt] (187.5900,135.8000) .. controls (182.7711,136.6728) and
107 (177.9371,137.4656) .. (173.1013,138.2363) .. controls (168.0256,138.8673) and
108 (162.9560,139.5518) .. (157.8625,140.0284) .. controls (155.3657,140.2832) and
109 (152.8712,140.5606) .. (150.3700,140.7700);
110 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
111 width=0.55pt] (85.1400,140.7000) -- (85.1400,140.7000) -- (81.9700,140.4800)
112 -- (73.1100,139.4000) -- (68.5800,138.7500);
113 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
114 width=0.55pt] (65.0500,138.1800) .. controls (52.4050,135.6448) and

```

```

115 (38.9681,133.3493) .. (28.2973,125.6380) .. controls (24.2763,123.0680) and
116 (21.8353,117.1684) .. (25.5788,113.3073) .. controls (32.6698,105.5701) and
117 (43.5507,103.1404) .. (53.3201,100.4758) .. controls (86.8997,93.0420) and
118 (121.7011,93.0405) .. (155.8208,96.0510) .. controls (182.1876,98.7792) and
119 (208.8127,103.2819) .. (233.2121,114.0355) .. controls (243.1027,118.5954) and
120 (253.7364,124.4562) .. (258.5354,134.7187) .. controls (262.2053,143.0311) and
121 (257.0225,152.0473) .. (250.3572,157.0643) .. controls (247.5706,159.4123) and
122 (244.5554,161.5185) .. (241.3800,163.3000);
123 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
124 width=0.55pt] (187.8800,180.9400) .. controls (174.8107,183.2401) and
125 (161.6422,185.1299) .. (148.3936,186.0614) .. controls (129.7803,187.4724) and
126 (111.0588,187.7269) .. (92.4293,186.4832) .. controls (84.4502,185.9476) and
127 (76.4996,185.0740) .. (68.5800,183.9700);
128 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
129 width=0.55pt] (65.0500,183.3200) .. controls (52.2639,180.9554) and
130 (38.8413,178.3846) .. (28.0400,170.7200) .. controls (24.3242,168.0092) and
131 (22.0057,162.6089) .. (25.3800,158.7000) .. controls (32.8151,150.6030) and
132 (44.1618,148.0637) .. (54.4123,145.4097) .. controls (85.4573,138.7021) and
133 (117.5632,138.2602) .. (149.1300,140.6686) .. controls (176.7525,142.9486) and
134 (204.6034,147.3712) .. (230.3713,157.9462) .. controls (241.0143,162.7364) and
135 (252.7196,168.4260) .. (258.2199,179.3142) .. controls (262.4674,187.4068) and
136 (257.3561,196.7760) .. (250.7865,201.8917) .. controls (237.9805,212.4664) and
137 (221.7335,217.6822) .. (205.9363,221.9945) .. controls (201.2113,223.3056) and
138 (196.4110,224.2907) .. (191.6300,225.3700);
139 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
140 width=0.55pt] (150.7300,72.0800) .. controls (154.9632,73.0373) and
141 (159.2029,73.9974) .. (163.3179,75.3921) .. controls (167.8574,76.8131) and
142 (172.2435,78.6941) .. (176.4825,80.8424) .. controls (179.6038,82.5644) and
143 (182.5773,84.5995) .. (185.0869,87.1459) .. controls (186.4699,88.6800) and
144 (187.7286,90.3903) .. (188.4150,92.3575) .. controls (188.7357,93.2496) and
145 (188.9395,94.2219) .. (188.9420,95.1698) .. controls (188.9430,96.7793) and
146 (188.6592,98.3999) .. (187.9321,99.8454) .. controls (187.8681,99.9969) and
147 (187.8040,100.1485) .. (187.7400,100.3000);
148 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
149 width=0.55pt] (154.6200,118.1600) .. controls (149.3916,119.3857) and
150 (144.1010,120.3696) .. (138.7751,121.1037) .. controls (127.4839,122.4807) and
151 (116.0191,123.1346) .. (104.6824,121.9232) .. controls (101.3908,121.3475) and
152 (97.7975,121.0932) .. (95.0000,119.1000) .. controls (93.6508,117.8294) and
153 (95.6291,116.5396) .. (96.7780,116.1495) .. controls (102.7946,113.9839) and
154 (109.3083,113.9279) .. (115.6293,113.7211) .. controls (131.0300,113.7215) and
155 (146.4894,115.6365) .. (161.2909,119.9523) .. controls (168.9395,122.3199) and
156 (176.6156,125.2649) .. (182.9298,130.3073) .. controls (186.2489,133.0737) and
157 (189.3395,137.0100) .. (188.8931,141.5787) .. controls (188.8225,143.0220) and
158 (188.3029,144.4150) .. (187.5900,145.6600);
159 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
160 width=0.55pt] (154.6200,163.3000) .. controls (142.6125,166.3051) and
161 (130.2058,167.5463) .. (117.8479,167.7700) .. controls (111.4879,167.7167) and

```

```

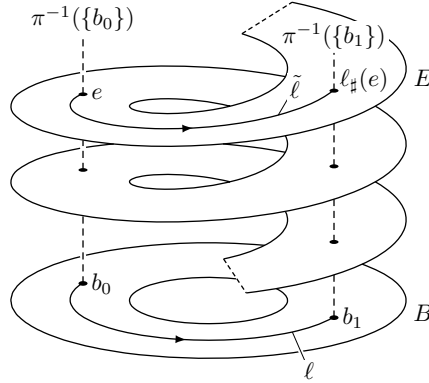
162 (105.0352,167.5644) .. (98.8418,165.9871) .. controls (97.2795,165.4425) and
163 (95.1287,165.1316) .. (94.5000,163.3800) .. controls (95.0561,161.4662) and
164 (97.4926,161.1050) .. (99.1665,160.5871) .. controls (107.0229,158.7187) and
165 (115.1908,158.8109) .. (123.2185,159.0161) .. controls (139.3530,159.8634) and
166 (155.6086,162.3321) .. (170.6548,168.4266) .. controls (176.7087,171.1082) and
167 (182.9971,174.2793) .. (186.9500,179.7900) .. controls (189.4702,183.2978) and
168 (189.6814,188.3557) .. (187.0076,191.8426) .. controls (183.3209,197.3147) and
169 (177.2170,200.4775) .. (171.3422,203.0904) .. controls (168.1792,204.4173) and
170 (164.9360,205.5364) .. (161.6700,206.5800);
171
172 %全空間の端
173 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
174 width=0.55pt,dash pattern=on 2 off 1.2 on 2 off 1.5]
175 (161.6700,206.5800) .. controls (168.3857,210.7740) and
176 (175.1000,214.9703) .. (181.7865,219.2103) .. controls (185.0754,221.2511) and
177 (188.3635,223.2934) .. (191.6300,225.3700)%;
178 (150.7300,72.0800) .. controls (155.2782,65.3383) and
179 (159.7263,58.5188) .. (164.2700,51.7800);
180
181 \coordinate (A) at (191.7957,28.4428);
182 \draw[white,line width=2] ($(A)+(10,-23)$) --(A);
183 \draw ($(A)+(10,-23)$)node [fill=white,inner sep=1pt]{$\tilde{\ell}$}--(A);
184
185 %パス
186 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
187 width=0.55pt,->=0.5]
188 (66.7800,57.9000) .. controls (62.7687,55.3206) and (58.0064,51.2055) ..
189 (59.2900,45.8700) .. controls (61.5092,39.5170) and (68.2134,36.4643) ..
190 (73.9325,33.8971) .. controls (88.2860,28.0080) and (103.8501,25.9345) ..
191 (119.1900,24.4200) .. controls (143.4111,22.6264) and (167.9826,23.4274) ..
192 (191.7957,28.4428) .. controls (200.3968,30.4418) and (209.0188,32.9456) .. (216.6800,37.4500);
193
194
195 \coordinate (B) at (183.3695,157.9951);
196 \draw[white,line width=2] ($(B)+(10,17)$) --(B);
197 \draw ($(B)+(10,17)$)node [fill=white,inner sep=1pt]{$\tilde{\ell}$}--(B);
198
199 %リフト
200 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
201 width=0.55pt,->=0.5]
202 (66.7800,170.8600) .. controls (63.7874,169.4857) and (60.0056,167.8190) ..
203 (59.1264,164.3512) .. controls (58.9342,160.3734) and (63.2953,158.3322) ..
204 (66.3638,156.8875) .. controls (80.1601,151.4941) and (95.1761,150.5555) ..
205 (109.8293,149.9010) .. controls (134.5358,149.4627) and (159.4359,151.6692) ..
206 (183.3695,157.9951) .. controls (195.0747,161.3216) and (207.0429,165.3379) .. (216.6800,173.0200);
207
208 \node[above=1,fill=white,inner sep=1pt] at (FPBE){$\pi^{-1}(\{b_1\})$};

```

```

209 \node[fill=white,inner sep=2pt] at (FPAD){ $\pi^{-1}(\{b_0\})$ };
210
211 \node at (270,40){ $B$ };
212 \node at (270,180){ $E$ };
213 \end{tikzpicture}

```



■被覆空間 2 (ketpic で描いた図を inkscape で処理してパスを簡略化し, svg2tikz で tikz コードにしたもの)

```

1 %要 \usetikzlibrary{decorations.pathreplacing}
2 \begin{tikzpicture}[y=0.70pt, x=0.70pt, yscale=1.000000, xscale=1.000000, inner sep=0pt, outer sep=0pt]
3 %base space
4 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
5 width=0.464pt] (125.6000,35.7200) .. controls (142.4087,34.3575) and
6 (159.5398,34.7421) .. (175.9773,38.7994) .. controls (180.1472,40.1646) and
7 (184.7687,41.3156) .. (187.8071,44.6888) .. controls (189.2497,46.0412) and
8 (189.1998,48.3816) .. (187.8393,49.7750) .. controls (186.3255,51.5901) and
9 (184.0679,52.7070) .. (181.9224,53.6402) .. controls (174.9060,56.4707) and
10 (167.3630,57.6632) .. (159.8874,58.5401) .. controls (145.8827,59.9648) and
11 (131.6927,59.7714) .. (117.7587,57.7399) .. controls (111.2587,56.6981) and
12 (104.6350,55.4195) .. (98.7795,52.2875) .. controls (96.7852,51.0911) and
13 (94.2837,49.4268) .. (94.5700,46.7814) .. controls (95.0563,44.2113) and
14 (97.6605,42.8176) .. (99.7845,41.6618) .. controls (105.3492,38.9299) and
15 (111.5156,37.7458) .. (117.5889,36.7461) .. controls (120.2458,36.3014) and
16 (122.9271,36.0458) .. (125.6000,35.7200) -- cycle%;
17 (101.3400,18.5100) .. controls (120.1743,16.8631) and
18 (139.0962,16.3129) .. (157.9919,16.9977) .. controls (178.3401,17.7169) and
19 (198.7014,19.7536) .. (218.6090,24.1105) .. controls (229.8211,26.6514) and
20 (241.0682,29.8009) .. (251.0420,35.6733) .. controls (254.1459,37.8654) and
21 (257.2526,40.3344) .. (259.0212,43.7481) .. controls (259.5714,45.8355) and
22 (260.1171,47.9228) .. (259.1351,49.9794) .. controls (258.4575,52.3193) and
23 (256.6067,54.3258) .. (254.7891,55.9132) .. controls (248.9617,60.8774) and
24 (241.6686,63.6331) .. (234.5119,66.0811) .. controls (230.1030,67.4000) and
25 (225.7190,68.7924) .. (221.2200,69.7800)%;
26 (217.6200,70.5700) -- (217.6200,70.5700) -- (215.0300,71.2200)
27 -- (202.5700,73.4500)%;

```

```

28 (119.7000,77.1900) .. controls (112.5497,77.0098) and
29 (105.4199,76.3045) .. (98.3015,75.6415) .. controls (90.9830,74.8761) and
30 (83.6888,73.9353) .. (76.4431,72.6437) .. controls (69.1704,71.3589) and
31 (61.9200,69.8828) .. (54.8142,67.8526) .. controls (50.2666,66.6878) and
32 (45.8463,65.0344) .. (41.4821,63.3267) .. controls (37.9966,61.7465) and
33 (34.4651,60.2502) .. (31.3691,57.9618) .. controls (29.1001,56.6967) and
34 (27.3807,54.6621) .. (25.6419,52.7960) .. controls (24.9150,50.9949) and
35 (23.4839,49.3542) .. (23.8700,47.2994) .. controls (23.6531,45.7758) and
36 (24.0577,44.4032) .. (24.9090,43.1393) .. controls (25.8494,40.6756) and
37 (28.1649,39.1993) .. (29.9609,37.3984) .. controls (33.0729,35.3737) and
38 (36.1645,33.3117) .. (39.6472,31.9690) .. controls (43.9684,29.8616) and
39 (48.6226,28.5533) .. (53.1832,27.0777) .. controls (59.2170,25.3724) and
40 (65.3018,23.8830) .. (71.4665,22.7315) .. controls (77.7955,21.4897) and
41 (84.1892,20.5438) .. (90.5881,19.7399) .. controls (94.1720,19.3299) and
42 (97.7560,18.9200) .. (101.3400,18.5100);
43
44 %fiber1
45 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
46 width=0.464pt,densely dashed]
47 (219.4200,39.9000)coordinate[name=FPAA] .. controls (219.4200,52.4733) and
48 (219.4200,65.0467) .. (219.4200,77.6200)%;
49 (219.4200,96.9900)coordinate[name=FPAB] .. controls (219.4200,105.7500) and
50 (219.4200,114.5100) .. (219.4200,123.2700)%;
51 (219.4200,142.6400)coordinate[name=FPAC] .. controls (219.4200,151.3267) and
52 (219.4200,160.0133) .. (219.4200,168.7000)%;
53 (219.4200,188.2200)coordinate[name=FPAD] .. controls (219.4200,197.0033) and
54 (219.4200,205.7867) .. (219.4200,214.5700)%;
55 (219.4200,233.8600)coordinate[name=FPAE] .. controls (219.4200,245.2600) and
56 (219.4200,256.6600) .. (219.4200,268.0600);
57
58 \fill (FPAA) circle [x radius=1.7pt,y radius=1pt];
59 \fill (FPAB) circle [x radius=1.7pt,y radius=0.9pt];
60 \fill (FPAC) circle [x radius=1.7pt,y radius=0.9pt];
61 \fill (FPAD) circle [x radius=1.7pt,y radius=0.9pt];
62 \fill (FPAE) circle [x radius=1.7pt,y radius=0.9pt];
63
64
65 %fiber2
66 \coordinate(FPBA) at (64.0400,54.5800);
67 \coordinate(FPBB) at (64.0400,134.4300);
68 \coordinate(FPBC) at (64.0400,180.0800);
69 \coordinate(FPBD) at (64.0400,225.6600);
70 \coordinate(FPBE) at (64.0400,271.3000);
71
72 \node at (FPBA)[below=8]{$U$};
73 \node at (FPBB)[below=6]{$V$};
74

```

%evenly covered set boundary

```
\path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
width=0.464pt] (72.1100,60.2700) .. controls (69.1166,60.6704) and
(66.0936,60.6149) .. (63.0812,60.6954) .. controls (59.4561,60.5414) and
(55.8235,60.4144) .. (52.2347,59.8383) .. controls (48.7005,59.3396) and
(45.1097,58.5884) .. (42.0018,56.7595) .. controls (41.1482,56.1918) and
(40.1647,55.2460) .. (40.5316,54.1278) .. controls (40.8407,53.0171) and
(41.9745,52.3739) .. (42.9376,51.8661) .. controls (45.5811,50.5433) and
(48.4845,49.8442) .. (51.3965,49.4108) .. controls (56.5203,48.5632) and
(61.7296,48.3898) .. (66.9137,48.4851) .. controls (70.6099,48.6124) and
(74.2930,48.9964) .. (77.9396,49.6042) .. controls (80.9222,50.2677) and
(84.0433,50.9204) .. (86.5766,52.7131) .. controls (87.3385,53.3801) and
(87.9771,54.5207) .. (87.3466,55.4809) .. controls (86.4996,56.8654) and
(84.8476,57.4611) .. (83.3974,58.0325) .. controls (80.4943,59.1693) and
(77.3875,59.6010) .. (74.3200,60.0411) .. controls (73.5833,60.1174) and
(72.8467,60.1937) .. (72.1100,60.2700) -- cycle%;
(72.1100,138.1800) .. controls (66.8380,138.7193) and
(61.5284,139.0211) .. (56.2295,138.8482) .. controls (53.1404,138.7128) and
(50.0464,138.5468) .. (47.0032,137.9637) .. controls (44.9920,137.5934) and
(42.8780,137.2526) .. (41.1500,136.0900) .. controls (40.6601,135.7198) and
(40.2090,135.0878) .. (40.5954,134.4831) .. controls (41.2742,133.4366) and
(42.6145,133.1184) .. (43.7061,132.6439) .. controls (46.6001,131.7140) and
(49.6362,131.3328) .. (52.6449,130.9861) .. controls (59.4179,130.3518) and
(66.2371,130.2116) .. (73.0266,130.6587) .. controls (77.2170,130.8926) and
(81.4331,131.1935) .. (85.5356,132.1176) .. controls (86.2637,132.3771) and
(87.2862,132.5114) .. (87.5900,133.3072) .. controls (87.6738,134.2840) and
(86.5110,134.6221) .. (85.8225,135.0264) .. controls (84.4757,135.6598) and
(83.0133,136.0360) .. (81.5919,136.4705) .. controls (78.4748,137.2505) and
(75.2770,137.6570) .. (72.1100,138.1800) -- cycle%;
(72.1100,183.7500) .. controls (67.8608,184.3373) and
(63.5620,184.5283) .. (59.2756,184.5193) .. controls (56.4001,184.4735) and
(53.5263,184.3944) .. (50.6646,184.0912) .. controls (48.6434,183.9402) and
(46.6289,183.5967) .. (44.6600,183.1306) .. controls (43.2473,182.6107) and
(41.6011,182.3489) .. (40.5700,181.1600) .. controls (40.1284,180.2312) and
(41.0590,179.4626) .. (41.8000,179.0745) .. controls (43.6023,178.1581) and
(45.6207,177.7175) .. (47.5997,177.3426) .. controls (51.1676,176.7239) and
(54.7693,176.3094) .. (58.3908,176.2139) .. controls (63.2968,175.9554) and
(68.2176,176.0215) .. (73.1220,176.2582) .. controls (75.4959,176.4660) and
(77.8821,176.4995) .. (80.2401,176.8695) .. controls (82.6119,177.1063) and
(85.0677,177.3502) .. (87.2300,178.4200) .. controls (87.7747,178.8073) and
(87.6685,179.5610) .. (87.1480,179.9122) .. controls (84.9251,181.3287) and
(82.2864,181.8333) .. (79.7844,182.5473) .. controls (77.2381,183.0235) and
(74.6844,183.4561) .. (72.1100,183.7500) -- cycle%;
(72.1100,229.4000) .. controls (68.3992,229.7997) and
(64.6811,230.1580) .. (60.9453,230.1716) .. controls (58.4055,230.1636) and
(55.8589,230.1339) .. (53.3246,229.9619) .. controls (50.8131,229.7767) and
(48.3009,229.5746) .. (45.8331,229.0483) .. controls (44.4230,228.7821) and
```

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122 (43.0414,228.2971) .. (41.7391,227.7031) .. controls (41.0597,227.3953) and
123 (40.1333,226.7011) .. (40.5644,225.8652) .. controls (41.1922,224.7443) and
124 (42.5508,224.3319) .. (43.7061,223.9439) .. controls (46.9142,222.9154) and
125 (50.2648,222.4599) .. (53.6098,222.1575) .. controls (57.5664,221.7256) and
126 (61.5528,221.7307) .. (65.5281,221.7000) .. controls (71.7034,221.7622) and
127 (77.9088,221.9445) .. (84.0043,223.0136) .. controls (85.1308,223.3497) and
128 (86.4245,223.4657) .. (87.3548,224.2190) .. controls (87.9537,224.7242) and
129 (87.3698,225.4519) .. (86.8366,225.7252) .. controls (85.7745,226.4398) and
130 (84.5083,226.8215) .. (83.3018,227.2301) .. controls (79.6403,228.2702) and
131 (75.8920,228.9782) .. (72.1100,229.4000) -- cycle%;
132 (72.1100,275.0500) .. controls (66.0048,275.6946) and
133 (59.8454,275.9549) .. (53.7122,275.6439) .. controls (51.1439,275.4162) and
134 (48.5593,275.2055) .. (46.0311,274.6908) .. controls (44.3111,274.2743) and
135 (42.4695,273.9440) .. (41.0114,272.8938) .. controls (40.3314,272.4944) and
136 (40.2732,271.4869) .. (40.9172,271.0276) .. controls (42.1128,269.8708) and
137 (43.8395,269.5937) .. (45.3697,269.0980) .. controls (47.8867,268.4771) and
138 (50.4491,268.0966) .. (53.0292,267.8641) .. controls (56.9520,267.4214) and
139 (60.9016,267.2799) .. (64.8475,267.3400) .. controls (67.7059,267.3059) and
140 (70.5620,267.3545) .. (73.4145,267.5480) .. controls (77.0844,267.7670) and
141 (80.7742,268.0212) .. (84.3813,268.7578) .. controls (85.4881,269.1087) and
142 (86.8746,269.0934) .. (87.5900,270.1500) .. controls (87.6763,271.0458) and
143 (86.6737,271.5224) .. (85.9859,271.8570) .. controls (83.0612,273.1815) and
144 (79.8742,273.7689) .. (76.7431,274.3868) .. controls (75.2070,274.6665) and
145 (73.6584,274.8535) .. (72.1100,275.0500) -- cycle;
146
147 %evenly covered set inner
148 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
149 width=0.464pt] (40.4300,54.5800) -- (40.4300,54.5800) -- (48.8500,49.9000);
150 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
151 width=0.464pt] (43.3100,57.4600) -- (43.3100,57.4600) -- (59.3600,48.6100);
152 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
153 width=0.464pt] (48.4900,59.1200) -- (48.4900,59.1200) -- (67.5700,48.5400);
154 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
155 width=0.464pt] (54.7500,60.2000) -- (54.7500,60.2000) -- (74.7000,49.1100);
156 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
157 width=0.464pt] (62.0300,60.6300) -- (62.0300,60.6300) -- (80.7500,50.2600);
158 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
159 width=0.464pt] (70.5900,60.4200) -- (70.5900,60.4200) -- (85.6400,52.0600);
160 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
161 width=0.464pt] (82.4000,58.4000) -- (82.4000,58.4000) -- (87.2300,55.7400);
162 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
163 width=0.464pt] (40.4300,135.0100) -- (40.4300,135.0100) -- (48.8500,131.4800);
164 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
165 width=0.464pt] (43.3100,137.1000) -- (43.3100,137.1000) -- (59.3600,130.5400);
166 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
167 width=0.464pt] (48.4900,138.1800) -- (48.4900,138.1800) -- (67.5700,130.4000);
168 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line

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```

169     width=0.464pt] (54.7500,138.7500) -- (54.7500,138.7500) -- (74.7000,130.7600);
170 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
171     width=0.464pt] (62.0300,138.8200) -- (62.0300,138.8200) -- (80.7500,131.2600);
172 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
173     width=0.464pt] (70.5900,138.3200) -- (70.5900,138.3200) -- (85.6400,132.1300);
174 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
175     width=0.464pt] (82.4000,136.2300) -- (82.4000,136.2300) -- (87.2300,134.1400);
176 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
177     width=0.464pt] (40.4300,180.5800) -- (40.4300,180.5800) -- (48.8500,177.1300);
178 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
179     width=0.464pt] (43.3100,182.7400) -- (43.3100,182.7400) -- (59.3600,176.1200);
180 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
181     width=0.464pt] (48.4900,183.8200) -- (48.4900,183.8200) -- (67.5700,176.0500);
182 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
183     width=0.464pt] (54.7500,184.4000) -- (54.7500,184.4000) -- (74.7000,176.3400);
184 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
185     width=0.464pt] (62.0300,184.4700) -- (62.0300,184.4700) -- (80.7500,176.9100);
186 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
187     width=0.464pt] (70.5900,183.9700) -- (70.5900,183.9700) -- (85.6400,177.7800);
188 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
189     width=0.464pt] (82.4000,181.8800) -- (82.4000,181.8800) -- (87.2300,179.7900);
190 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
191     width=0.464pt] (40.4300,226.2300) -- (40.4300,226.2300) -- (48.8500,222.7800);
192 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
193     width=0.464pt] (43.3100,228.3900) -- (43.3100,228.3900) -- (59.3600,221.7700);
194 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
195     width=0.464pt] (48.4900,229.4700) -- (48.4900,229.4700) -- (67.5700,221.7000);
196 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
197     width=0.464pt] (54.7500,230.0500) -- (54.7500,230.0500) -- (74.7000,221.9800);
198 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
199     width=0.464pt] (62.0300,230.1200) -- (62.0300,230.1200) -- (80.7500,222.5600);
200 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
201     width=0.464pt] (70.5900,229.5400) -- (70.5900,229.5400) -- (85.6400,223.4200);
202 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
203     width=0.464pt] (82.4000,227.5300) -- (82.4000,227.5300) -- (87.2300,225.4400);
204 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
205     width=0.464pt] (40.4300,271.8800) -- (40.4300,271.8800) -- (48.8500,268.4200);
206 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
207     width=0.464pt] (43.3100,274.0400) -- (43.3100,274.0400) -- (59.3600,267.4200);
208 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
209     width=0.464pt] (48.4900,275.1200) -- (48.4900,275.1200) -- (67.5700,267.3400);
210 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
211     width=0.464pt] (54.7500,275.7000) -- (54.7500,275.7000) -- (74.7000,267.6300);
212 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
213     width=0.464pt] (62.0300,275.7700) -- (62.0300,275.7700) -- (80.7500,268.2100);
214 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
215     width=0.464pt] (70.5900,275.1900) -- (70.5900,275.1900) -- (85.6400,269.0700);

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216 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
217 width=0.464pt] (82.4000,273.1000) -- (82.4000,273.1000) -- (87.2300,271.0900);
218
219 %covering space
220 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
221 width=0.464pt] (101.3400,64.1600) .. controls (129.3435,63.4125) and
222 (157.4454,65.1718) .. (185.0931,69.7154) .. controls (205.7707,73.4946) and
223 (226.7950,78.0306) .. (245.2659,88.4723) .. controls (251.0352,92.1202) and
224 (256.9835,96.5447) .. (259.2819,103.2406) .. controls (260.6217,108.1547) and
225 (258.7677,113.3974) .. (255.3751,117.0447) .. controls (250.3178,122.7351) and
226 (243.4263,126.5201) .. (236.5500,129.6100)%;
227 (184.4300,144.0100) .. controls (148.2961,149.8242) and
228 (111.3784,151.2782) .. (74.9299,147.7789) .. controls (60.1021,145.9296) and
229 (44.7860,144.2552) .. (31.1702,137.7035) .. controls (27.3783,135.8923) and
230 (21.9586,132.0322) .. (24.3539,127.2517) .. controls (28.6742,120.9591) and
231 (36.8431,119.2363) .. (43.6700,116.8600) .. controls (70.6693,110.1989) and
232 (98.7229,109.1751) .. (126.4143,109.8098) .. controls (158.4622,110.8642) and
233 (190.7110,114.4521) .. (221.4639,123.8629) .. controls (234.2171,128.3292) and
234 (247.9184,133.1088) .. (256.7900,143.8600) .. controls (260.6117,148.8972) and
235 (260.7288,156.1825) .. (256.6104,161.0810) .. controls (251.6909,167.6858) and
236 (243.8891,171.8479) .. (236.5500,175.2600)%;
237 (184.4300,189.6600) .. controls (146.6433,195.5952) and
238 (108.0187,197.1483) .. (69.9737,192.8205) .. controls (56.3968,191.0170) and
239 (42.3895,189.1006) .. (30.0770,182.7638) .. controls (26.5062,180.9290) and
240 (21.7756,176.8340) .. (24.5887,172.5330) .. controls (28.8085,166.7262) and
241 (36.4596,164.9531) .. (42.9610,162.7723) .. controls (68.6869,156.0361) and
242 (95.5243,155.1031) .. (121.9886,155.3245) .. controls (152.6419,156.0407) and
243 (183.4520,159.1311) .. (213.1234,167.1072) .. controls (227.2388,171.1625) and
244 (241.9086,175.7757) .. (253.1572,185.6025) .. controls (258.3807,189.9771) and
245 (261.9028,197.6933) .. (258.2470,204.1151) .. controls (253.6359,212.3563) and
246 (244.7987,217.0257) .. (236.5500,220.9000)%;
247 (184.3500,235.3000) .. controls (147.3831,241.2152) and
248 (109.6031,242.6598) .. (72.3483,238.7570) .. controls (58.1896,236.9161) and
249 (43.5868,235.0967) .. (30.6397,228.7349) .. controls (26.9422,226.8115) and
250 (21.7454,222.8196) .. (24.5305,218.1944) .. controls (29.5627,211.7428) and
251 (38.2666,209.8510) .. (45.7829,207.6598) .. controls (73.2423,201.0775) and
252 (101.7425,200.4102) .. (129.8474,201.2074) .. controls (162.2451,202.5428) and
253 (194.9296,206.2459) .. (225.7914,216.6182) .. controls (236.7445,220.7520) and
254 (248.4064,225.2954) .. (256.1484,234.4504) .. controls (260.7726,239.5771) and
255 (260.8785,247.7899) .. (256.2011,252.9126) .. controls (248.5062,262.0610) and
256 (236.9364,266.7200) .. (225.9751,270.7333) .. controls (198.8577,280.0428) and
257 (170.1610,283.7406) .. (141.6660,285.6639) .. controls (110.9580,287.4381) and
258 (79.8316,286.9479) .. (49.6109,280.7435) .. controls (41.2350,278.5180) and
259 (31.9507,276.7218) .. (25.5071,270.5373) .. controls (21.6705,267.0839) and
260 (24.8733,261.7588) .. (28.6908,259.8891) .. controls (40.0100,253.4498) and
261 (53.2220,251.3894) .. (65.9443,249.4679) .. controls (77.6761,247.8308) and
262 (89.5117,247.1525) .. (101.3400,246.6800)%;

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263 (125.6000,81.3700) .. controls (134.0026,81.9715) and
264 (142.3741,83.1025) .. (150.6252,84.8007) .. controls (157.6587,86.2924) and
265 (164.6636,88.0843) .. (171.3343,90.7970) .. controls (176.4111,92.9206) and
266 (181.5055,95.4010) .. (185.4313,99.3408) .. controls (187.1578,101.2388) and
267 (188.7934,103.4756) .. (188.8902,106.1351) .. controls (189.1576,108.7019) and
268 (187.9965,111.2206) .. (186.3912,113.1626) .. controls (185.7439,113.9040) and
269 (185.1143,114.6537) .. (184.3500,115.2800)%;
270 (146.5500,129.6100) .. controls (139.3601,131.0302) and
271 (132.0361,131.7093) .. (124.7390,132.3206) .. controls (115.8164,132.7105) and
272 (106.7472,133.2044) .. (97.9420,131.3977) .. controls (96.7830,130.9864) and
273 (94.7776,130.9077) .. (94.5546,129.4850) .. controls (95.4248,128.1910) and
274 (97.3690,128.0227) .. (98.8271,127.6672) .. controls (108.0164,126.1042) and
275 (117.4096,126.4820) .. (126.6701,127.1160) .. controls (138.9075,128.0280) and
276 (151.0968,130.0414) .. (162.8789,133.4948) .. controls (169.8969,135.6801) and
277 (176.9370,138.3176) .. (182.8754,142.7403) .. controls (185.9617,145.1628) and
278 (189.1031,148.5554) .. (188.9017,152.7377) .. controls (188.7910,155.9883) and
279 (186.6746,158.8227) .. (184.3500,160.9300)%;
280 (146.7000,175.2600) .. controls (138.2675,176.6923) and
281 (129.7717,177.7900) .. (121.2180,178.1229) .. controls (113.2204,178.5087) and
282 (105.1090,178.4907) .. (97.2300,176.9100) .. controls (96.3342,176.4148) and
283 (94.3429,176.3472) .. (94.5700,174.9700) .. controls (96.5290,173.2747) and
284 (99.3905,173.2889) .. (101.8400,172.8100) .. controls (113.7373,171.6282) and
285 (125.7558,172.3594) .. (137.5909,173.8739) .. controls (148.7206,175.3148) and
286 (159.7987,177.6887) .. (170.3010,181.6944) .. controls (176.0838,184.0635) and
287 (182.0732,186.7602) .. (186.2511,191.5648) .. controls (188.7394,194.3656) and
288 (189.8459,198.6513) .. (187.9308,202.0522) .. controls (187.1296,203.7769) and
289 (185.7903,205.1963) .. (184.4300,206.5000)%;
290 (146.5500,220.9000) .. controls (133.4634,223.2826) and
291 (120.1039,224.3348) .. (106.8079,223.7849) .. controls (103.0394,223.4437) and
292 (99.1168,223.3051) .. (95.5679,221.9089) .. controls (94.0742,221.5310) and
293 (94.4926,220.0524) .. (95.7900,219.7500) .. controls (102.0143,217.8262) and
294 (108.6403,217.8916) .. (115.0945,217.8988) .. controls (127.2508,218.0141) and
295 (139.3914,219.3742) .. (151.2895,221.8526) .. controls (161.7904,224.1787) and
296 (172.4611,227.0689) .. (181.5392,233.0376) .. controls (185.2711,235.5840) and
297 (189.0667,239.3032) .. (188.9600,244.1600) .. controls (188.5300,248.7520) and
298 (184.8771,252.1241) .. (181.2850,254.5801) .. controls (173.6845,259.6059) and
299 (164.8266,262.2756) .. (156.0828,264.5475) .. controls (140.5849,268.2205) and
300 (124.6032,269.9131) .. (108.6800,269.5000) .. controls (104.1584,269.1168) and
301 (99.3974,269.2395) .. (95.1893,267.3561) .. controls (93.5804,266.4548) and
302 (95.5624,265.2568) .. (96.6030,265.1094) .. controls (102.0220,263.6535) and
303 (107.7098,263.6133) .. (113.2869,263.4638) .. controls (117.3942,263.5116) and
304 (121.4988,263.6623) .. (125.6000,263.8900);
305
306 \path[draw=black,line join=round,line cap=butt,miter limit=1.40,line
307 width=0.464pt,dash pattern=on 2pt off 1.2pt on 2pt off 1.5pt]
308 (125.6000,81.3700) .. controls (121.8743,78.8316) and
309 (118.2685,76.1224) .. (114.5586,73.5612) .. controls (110.1557,70.4237) and

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310      (105.7559,67.2797) .. (101.3400,64.1600)%;
311      (125.6000,263.8900) .. controls (122.6714,261.9505) and
312      (119.8855,259.8062) .. (116.9918,257.8159) .. controls (111.8428,254.1503) and
313      (106.6820,250.5007) .. (101.5381,246.8284) -- (101.4390,246.7543) --
314      (101.3400,246.6800);
315
316      %fiber2 label
317      \draw[white,line width=2pt] (FPBA)--($ (FPBA)+(21,12)$);
318      \draw (FPBA)--($ (FPBA)+(21,12)$)node[fill=white,inner sep=1pt]{$\mathbf{b}$};
319      \fill (FPBA) circle [x radius=1.7pt,y radius=1pt];
320
321
322      \draw[thick,decorate,decoration={brace,amplitude=7}]
323      ($ (FPBB)-(45,0)$)--($ (FPBE)-(45,0)$)node[midway,xshift=-25]{$\pi^{-1}(U)$};
324
325      \draw[white,line width=2] ($ (FPBB)-(25,0)$) to [bend right] ($ (FPBA)-(25,0)$);
326      \draw[-latex] ($ (FPBB)-(25,0)$) to [bend right] node [left=2,midway]{$\pi|_V$}($ (FPBA)-(25,0)$);
327
328      \node at (FPAE)[above=30,fill=white,inner sep=1pt]{$\pi^{-1}(\mathbf{b}_0)$};
329      \node at (FPAA)[above right=3]{$\mathbf{b}_0$};
330
331      \coordinate (B) at (270,45);
332      \coordinate (E) at (270,240);
333      \draw[-latex]($ (E)-(0,13)$)--($ (B)+(0,13)$)node [right=3,midway,fill=white,inner sep=1]{$\pi$};
334      \node at (B){$\mathbf{B}$};
335      \node at (E){$\mathbf{E}$};
336      \end{tikzpicture}

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