

KIAS L^AT_EX특강

TikZ: 기초부터 심화까지

권현우

2018년 11월 16일

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TikZ 기본기 다지기

그래서 TikZ가 무엇인고?

- “TikZ ist kein Zeichenprogramm”
 - “TikZ is not a drawing program”
 - “마우스/태블릿으로 그리는 것이 아니다!”

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- diagram 그리기가 쉬워요

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- 이걸, 공짜예요

기존의 xymatrix로 diagram 그리기

$$\begin{array}{ccc}
 HF(L, L) & \xrightarrow{OC} & QH^*(M) \\
 \downarrow \mathcal{F}^{\mathbb{L}} & \searrow B & \downarrow \mathfrak{ks} \\
 & & Jac(W_{\mathbb{L}}) \\
 & & \downarrow I \\
 MF(\mathcal{F}^{\mathbb{L}}(L), \mathcal{F}^{\mathbb{L}}(L)) & \xrightarrow{\text{boundary-bulk}} & Jac(W_{\mathbb{L}}) dx_1 \cdots dx_n
 \end{array} \tag{1}$$

```

\begin{equation}\label{diagram7}
\begin{xymatrix}
HF(L, L) \ar[dd]^{\mathcal{F}^{\mathbb{L}}} \ar[rr]^{-OC} \ar@{-->}[ddrr]^{-B} & & QH^*(M) \\
\downarrow & & \downarrow \mathfrak{ks} \\
& & Jac(W_{\mathbb{L}}) \\
& & \downarrow I \\
MF(\mathcal{F}^{\mathbb{L}}(L), \mathcal{F}^{\mathbb{L}}(L)) \ar[rr]_{\text{boundary-bulk}} & & Jac(W_{\mathbb{L}}) dx_1 \cdots dx_n
\end{xymatrix}
\end{equation}

```

기존의 xymatrix로 diagram 그리기 (*gathered 환경으로 둘러싸야 수식번호 문제가 해결됩니다.)

$$\begin{array}{ccc}
 HF(L, L) & \xrightarrow{OC} & QH^*(M) \\
 \downarrow \mathcal{F}^L & \dashrightarrow B & \downarrow \mathbb{E}_S \\
 & & Jac(W_L) \\
 & & \downarrow I \\
 MF(\mathcal{F}^L(L), \mathcal{F}^L(L)) & \xrightarrow{\text{boundary-bulk}} & Jac(W_L) dx_1 \cdots dx_n
 \end{array} \tag{1}$$

```

\begin{equation}
\begin{gathered}
\begin{xymatrix}
...
\end{xymatrix}
\end{gathered}
\end{equation}

```



```
\usepackage{tikz-cd}
```

$$\begin{array}{ccc}
 HF(L, L) & \xrightarrow{OC} & QH^*(M) \\
 \downarrow \mathcal{F}^L & \searrow B & \downarrow \mathfrak{ks} \\
 & & Jac(W_L) \\
 & & \downarrow I \\
 MF(\mathcal{F}^L(L), \mathcal{F}^L(L)) & \xrightarrow{\text{boundary-bulk}} & Jac(W_L) dx_1 \cdots dx_n
 \end{array} \tag{2}$$

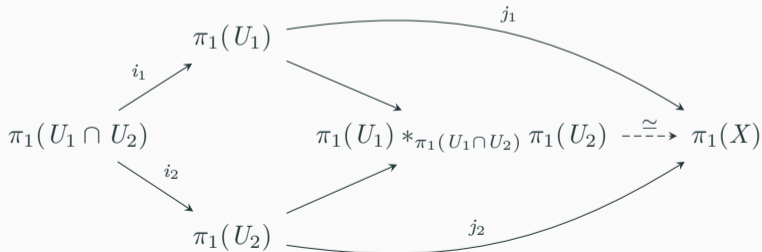
```

\tikzcdset{arrow style=tikz, diagrams={>=stealth}}
\begin{tikzcd}[row sep={large},column sep={huge}]
HF(L,L)\arrow[r,"OC"]\arrow[ddr,"B",dashed]\arrow[dd,"\mathcal{F}^{\mathbb{L}}"]
\arrow[<-]{\hspace{2cm}} QH^*(M)\arrow[d,"\mathfrak{ks}"] \\
& & \&Jac(W_{\mathbb{L}})\arrow[d,"I"] \\
MF(\mathcal{F}^{\mathbb{L}}(L),\mathcal{F}^{\mathbb{L}}(L)) & \arrow[r,"\text{boundary-bulk}"] & Jac(W_{\mathbb{L}}) dx_1 \cdots dx_n
\end{tikzcd}

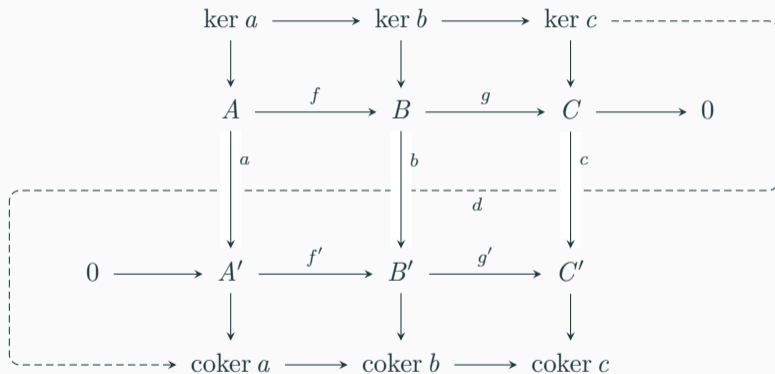
```

tikz-cd로 다이어그램 이쁘게 그리기

```
\usetikzlibrary{arrows,arrows.meta} %preamble
\tikzcdset{arrow style=tikz, diagrams={>=stealth}}
\begin{tikzcd}[column sep=tiny]
& \pi_1(U_1) \arrow[dr] \arrow[dr, "j_1", bend left=20] & \& \& [1.5em] \\\
\pi_1(U_1 \cap U_2) \arrow[ur, "i_1"] \arrow[dr, "i_2"] & \pi_1(U_1) \arrow[ur, "i_1"] \arrow[dr, "i_2"] & \& \& \pi_1(U_1) \last_{\rightarrow} \\
& \pi_1(U_2) \arrow[r, dashed, "\simeq"] & \& \& \pi_1(X) \\\
& \pi_1(U_2) \arrow[ur] \arrow[urr, "j_2", bend right=20] & \& \& 
\end{tikzcd}
```



tikz-cd 예시 하나 더

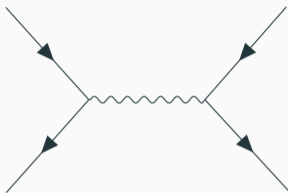


<https://tikzcd.yichuanshen.de/>

- tikz-cd 사용법 자료는 <http://wiki.ktug.org/wiki/wiki.php/LaTeXWorkshop/2017> 에서 “TikZ와 수학” 참고

TikZ-Feynman (compile it via Lua^AT_EX)

TikZ-Feynman: Feynman diagrams with TikZ (<https://arxiv.org/abs/1601.05437>)



```
\feynmandiagram [horizontal=a to b] {  
  i1 -- [fermion] a -- [fermion] i2,  
  a -- [photon] b,  
  f1 -- [fermion] b -- [fermion] f2,  
};
```

직관적인 설명서: <https://www.overleaf.com/learn/latex/TikZ-Feynman>

TikZ-Feynman: when someone uses Lua \LaTeX

현재 Lua \LaTeX 버전과 호환이 완전하지 않은 상태

```
\usepackage{luacode}  
\usepackage{tikz}  
\usetikzlibrary{graphdrawing}  
\usepackage{tikz-feynman}
```

some codes..

See the codes

[https://tex.stackexchange.com/questions/455001/
updated-lualatex-vs-tikz-feynman?noredirect=1](https://tex.stackexchange.com/questions/455001/updated-lualatex-vs-tikz-feynman?noredirect=1)

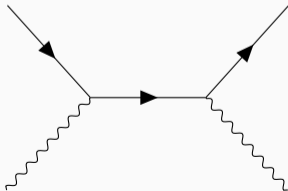
standalone 클래스

- 그림 컴파일을 매번 하는 것이 문제가 되는 상황이라면(TikZ-Feynman), standalone 클래스가 유용
- TikZ 작업을 할 때 유용
- 그림 크기에 맞게 알아서 잘라줌
- 이 파일을 graphicx 패키지로 그림으로 부름

```
\documentclass[tikz]{standalone}
```

...

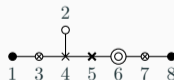
예시:



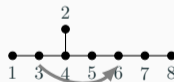
```
\usepackage{dynkin-diagrams}
```

...

```
\[ \dynkin{A}{} \quad \dynkin{C}{} \quad \dynkin{D}{} \]  
\[ \dynkin[label]{E}{*otxXOt*} \]
```




```
\begin{tikzpicture}
\dynkin[label]{E}{8}
\draw[very thick, black!50,-latex]
(root 3.south) to [out=-45, in=-135] (root 6.south);
\end{tikzpicture}
```



그런고로... 오늘의 목표는

- TikZ 기본명령어를 익힌다.
- 미적분학이나 몇몇 학술논문에 나오는 간단한 그림들을 그린다.

```
\documentclass[tikz]{standalone}

\usepackage{tikz}

\begin{document}
\begin{tikzpicture}
    \draw (0,0) -- (1,1);
    \draw (0,0) rectangle (2,1);
    \draw (0,0) circle [radius=0.5];
    \node at (0,0) {Some text};
    \draw (0,0) -- (120:2); %극좌표
\end{tikzpicture}
\end{document}
```

- tikzpicture에서 명령은 반드시 세미콜론(;)으로 종결해야 함.
- `\draw`, `\node`

도형 그리기 (shape.tex)



```
\draw (0,0) -- (1,1);  
\draw (0,0) -- (1,-1) -- (2,-2);  
\draw (0,0) -- (2,0) -- (2,3) -- (0,3) -- cycle;  
\draw (3,0) arc (0:120:3) -- cycle;%(start angle:end angle:radius)
```

- cycle: 첫번째/마지막 점을 이어 폐곡선을 만들
- visualtikz 2장 참조 (>texdoc visualtikz)

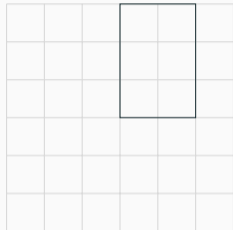
도형 그리기 (shape.tex)



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\draw (0,0) -- (1,1);  
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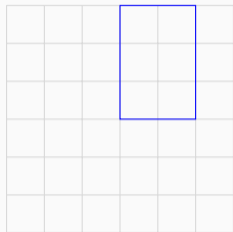
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\draw (0,0) -- (1,1);  
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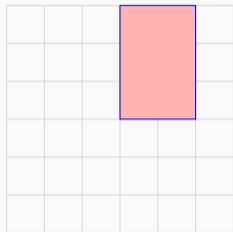
색깔좀 칠해봅시다! (decoration.tex)



```
\draw[draw=blue] (0,0) -- (2,0) -- (2,3) -- (0,3) -- cycle;
```

- 선 색깔 칠하기 (draw=색깔), 면 색깔 칠하기 (fill=색깔)
- 두께: line width = 2pt, thick,...
- 선의 형태: dashed, dotted,...
- 화살표 축: ->, <->, ... (visualltikz 4.10 참고)

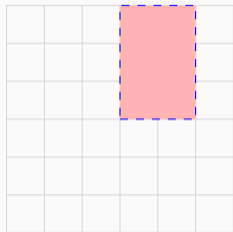
색깔좀 칠해봅시다! (decoration.tex)



```
\draw[draw=blue,fill=red!30] (0,0) -- (2,0) -- (2,3) -- (0,3) -- cycle;
```

- 선 색깔 칠하기 (draw=색깔), 면 색깔 칠하기 (fill=색깔)
- 두께: line width = 2pt, thick,...
- 선의 형태: dashed, dotted,...
- 화살표 축: ->, <->, ... (visualltikz 4.10 참고)

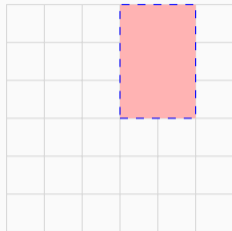
색깔좀 칠해봅시다! (decoration.tex)



```
\draw[draw=blue,fill=red!30,dashed] (0,0) -- (2,0) -- (2,3) -- (0,3) --
```

- 선 색깔 칠하기 (draw=색깔), 면 색깔 칠하기 (fill=색깔)
- 두께: line width = 2pt, thick,...
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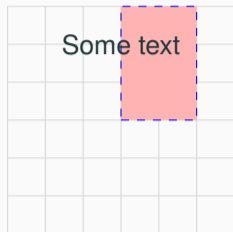
색깔좀 칠해봅시다! (decoration.tex)



```
\filldraw[draw=blue,fill=red!30,dashed] (0,0) -- (2,0) -- (2,3) --  
↪ (0,3) -- cycle;
```

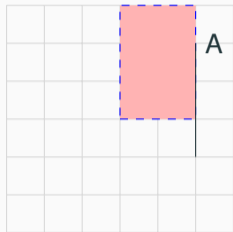
- 선 색깔 칠하기 (draw=색깔), 면 색깔 칠하기 (fill=색깔)
- 두께: line width = 2pt, thick,...
- 선의 형태: dashed, dotted,...
- 화살표 축: →, <->, ... (visualltikz 4.10 참고)

텍스트도 넣어봅시다! (decoration-text.tex)



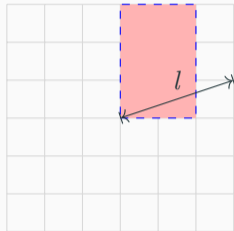
```
\filldraw[draw=blue,fill=red!30,dashed] (0,0) -- (2,0) -- (2,3) --  
  ↪ (0,3) -- cycle;  
\node at (0,2) {Some text};  
\draw (2,-1) -- (2,2) node[right] {A};  
\draw[|<->|] (0,0) -- node[midway, above] {$ \ l $} (3,1);
```

텍스트도 넣어봅시다! (decoration-text.tex)



```
\filldraw[draw=blue,fill=red!30,dashed] (0,0) -- (2,0) -- (2,3) --  
  ↪ (0,3) -- cycle;  
\node at (0,2) {Some text};  
\draw (2,-1) -- (2,2) node[right] {A};  
\draw[|<->|] (0,0) -- node[midway, above] {$ l $} (3,1);
```

텍스트도 넣어봅시다! (decoration-text.tex)



```
\filldraw[draw=blue,fill=red!30,dashed] (0,0) -- (2,0) -- (2,3) --  
  ↪ (0,3) -- cycle;  
\node at (0,2) {Some text};  
\draw (2,-1) -- (2,2) node[right] {A};  
\draw[|<->|] (0,0) -- node[midway, above] {$ l $} (3,1);
```

조금 더 똑똑하게! 상대위치 쓰기

아래 셋은 모두 같은 결과를 낸다.

```
\draw (10,10) -- (10,11) -- (11,11);
```

```
\draw (10,10) -- +(0,1) -- +(1,1);
```

```
\draw (10,10) -- ++(0,1) -- ++(1,0);
```

- ‘+’ 1개: 임시적. 뒤의 상대좌표에 영향을 끼치지 않는다.
 - 가지처럼 뻗어나가는 그림
- ‘+’ 2개: 구한 좌표를 뒤의 상대좌표 계산에 사용
 - 계속 이어지는 경로

텍스트 상대위치 (text-relative.tex)

above left ●

above ●

● above right

left ●

●
right

below left ●

●
below

●
below right

원하는 위치에 node 찍게 만들기 (overlay.tex)

글 위에서도 써지네!

```
\begin{tikzpicture}[overlay]  
\draw (0,10) -- (5,-20);  
\end{tikzpicture}
```

글 위에서도 써지네!

overlay 사용 용례

```
\usepackage{tikz}
\usetikzlibrary{shapes.callouts}
\begin{tikzpicture}[overlay]
\node[fill=red!50, rectangle callout, callout relative pointer={(-2,-1)}] at (12,1)
{Nonlinear Schrödinger equation};
\node[fill=red!50, rectangle callout, callout relative pointer={(-2,1)}] at (12,-3)
{Hartree equation};
\end{tikzpicture}
```

$$i\partial_t u + \Delta u = |u|^{p-1}u$$

Nonlinear Schrödinger equation

$$i\partial_t u + \Delta u = V(u)u$$

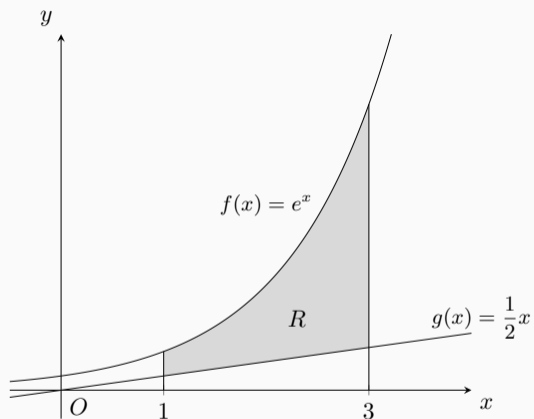
Hartree equation

where $V(u) = |x|^{-n} * |u|^2$.

- [pgfmanual](#) (무려 1161페이지..)
- [VisualTikZ](#)
- 급한 사람들을 위하여
- [Texample.net](#) (다양한 TikZ예시 수록)

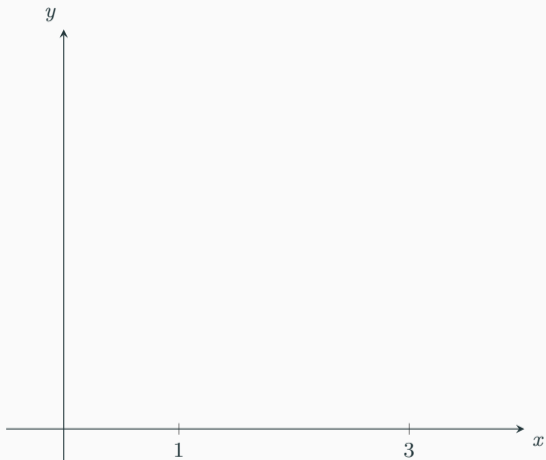
TikZ 그래프 그리기

첫번째 예: 미적분학



김현석, 이영란, 조성희 저 / “대학수학”, 청문각

첫번째 예: 미적분학 / Step 1: 좌표축 그리기



```
\usepackage{tikz,pgfplots,amssymb}
```

```
\begin{tikzpicture}[>=stealth]
```

```
\begin{axis}[
```

```
axis x line=center,
```

```
axis y line=center,
```

```
xlabel={ $x$ },
```

```
ylabel={ $y$ },
```

```
xtick={1,3},
```

```
ytick={.},
```

```
xlabel style={below right},
```

```
ylabel style={above left},
```

```
xmin=-0.5,
```

```
xmax=4,
```

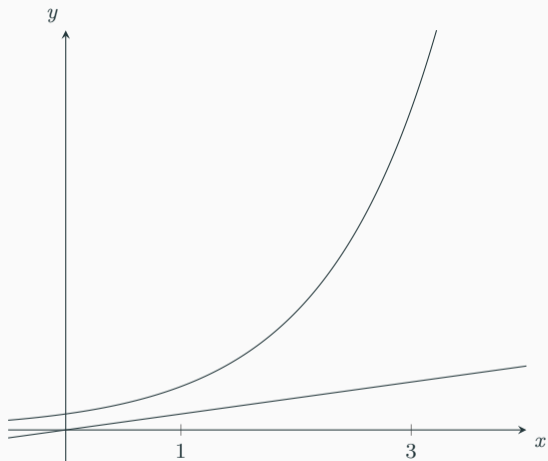
```
ymin=-2,
```

```
ymax=25]
```

```
\end{axis}
```

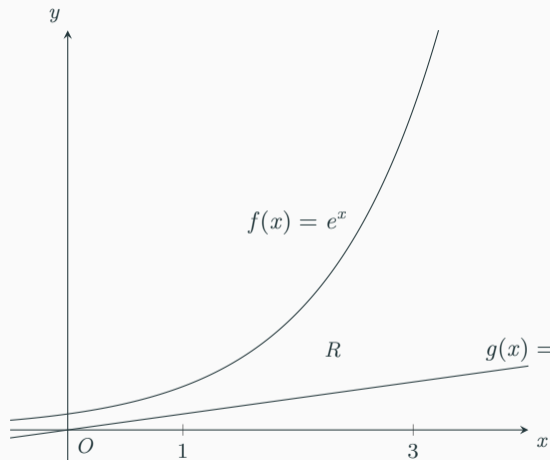
```
\end{tikzpicture}
```

첫번째 예: 미적분학 / Step 2: 그래프 그리기



```
\begin{axis}
....
\addplot [mark=none,domain=-
↪ 0.5:4,samples=201]
↪ {e^x};
\addplot [mark=none,domain=-
↪ 0.5:4,samples=201]
↪ {x};
\end{axis}
```

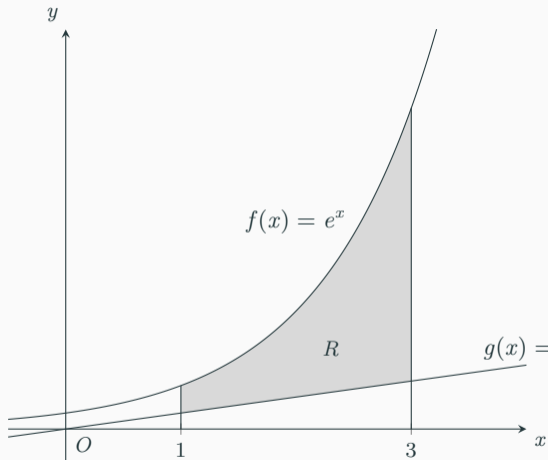
첫번째 예: 미적분학 / Step 3: 글씨 쓰기



```
\begin{axis}
....
\node at (axis cs:2.3,5) {$R$};
\node[below right] at (axis cs:0,0)
  \to {$0$};

\node at (axis cs:2,13) {\small
  \to $f(x)=e^x$};
\end{axis}
\node at (7,1.5) {\small
  \to $\displaystyle
  \to g(x)=\frac{1}{2}x$};
```

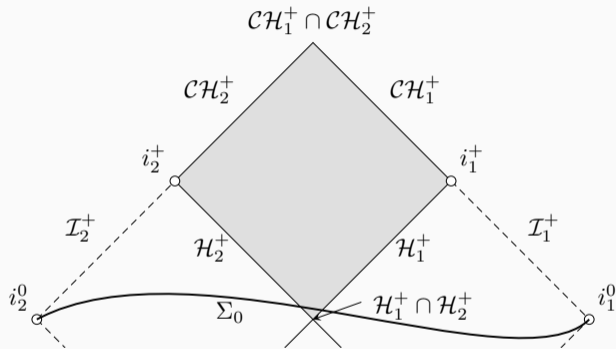

첫번째 예: 미적분학 / Step 4: 색칠하기



```
\begin{axis}
....
\addplot [mark=none,domain=-
↪ 0.5:4,samples=201,name path=f]
↪ {e^x};
\addplot [mark=none,domain=-
↪ 0.5:4,samples=201,name path=l]
↪ {x};

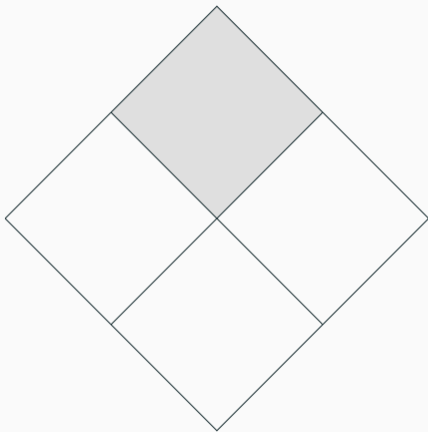
\addplot[gray!30] fill between[of=f
↪ and l,soft clip={(axis cs:1,0)
↪ rectangle (axis cs:3,e^3)}];
\draw (axis cs:1,0) -- (axis
↪ cs:1,e^1);
\draw (axis cs:3,0) -- (axis
↪ cs:3,e^3);
\end{axis}
```

두번째 예: Penrose diagram of Reissner-Nordström spacetime



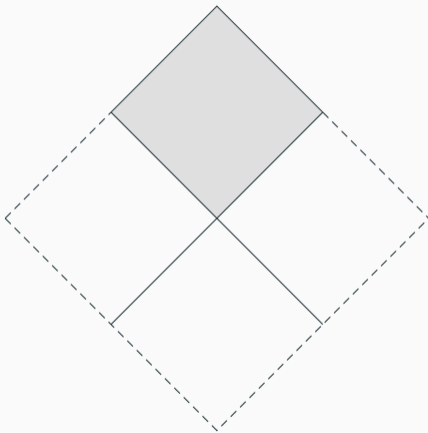
J. Luk and S.-J. Oh, arXiv:1702.05715 (originally drawn by inkscape)

두번째 예 / Step 1: 틀부터 짜기



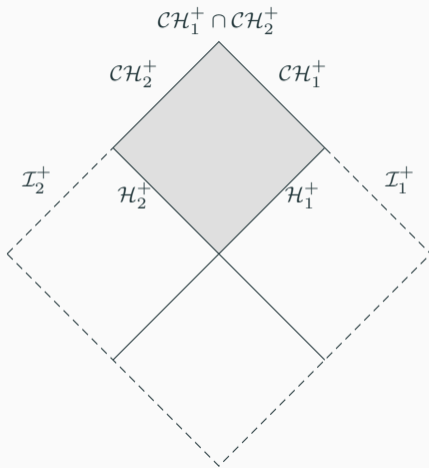
```
\begin{tikzpicture}[>=stealth]
\draw (0,0) -- (-2,-2);
\draw (0,0) -- (2,-2);
\draw(-4,0) -- (-2,2);
\fill[gray!25] (-2,2) -- (0,4) --
  \to (2,2) -- (0,0) --cycle;
\draw (-2,2) -- (0,4) -- (2,2);
\draw (2,2) -- (0,0) -- (-2,2);
\draw (2,2) -- (4,0);
\draw (-4,0) -- (0,-4) -- (4,0);
\end{tikzpicture}
```

두번째 예 / Step 2: 선 바꾸기



```
\begin{tikzpicture}[>=stealth]
\draw (0,0) -- (-2,-2);
\draw (0,0) -- (2,-2);
\draw(-4,0) -- (-2,2);
\fill[gray!25] (-2,2) -- (0,4) --
→ (2,2) -- (0,0) --cycle;
\draw (-2,2) -- (0,4) -- (2,2);
\draw (2,2) -- (0,0) -- (-2,2);
\draw (2,2) -- (4,0);
\draw (-4,0) -- (0,-4) -- (4,0);
\end{tikzpicture}
```

두번째 예 / Step 3: 글씨 넣기

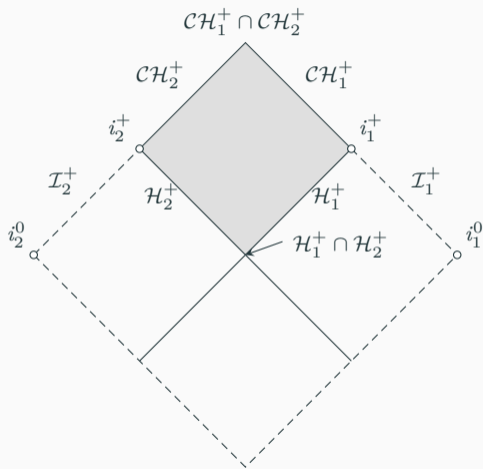


```

\begin{tikzpicture}[>=stealth]
\draw[densely dashed] (-4,0) --node[above left]
↪  $\{\mathcal{I}_2^+\}$  (-2,2);
\fill[gray!25] (-2,2) -- (0,4) -- (2,2) -- (0,0) --cycle;
\draw[very thin] (-2,2) --node[above left]
↪  $\{\mathcal{CH}_2^+\}$  (0,4) node[above]
↪  $\{\mathcal{CH}_1^+\} \cap \{\mathcal{CH}_2^+\}$ 
↪ --node[above right]  $\{\mathcal{CH}_1^+\}$  (2,2);
\draw (2,2) --node[below right,xshift=2pt,yshift=10pt]
↪  $\{\mathcal{H}_1^+\}$  (0,0) --node[below
↪ left,xshift=-2pt,yshift=10pt]  $\{\mathcal{H}_2^+\}$ 
↪ (-2,2);
\draw[densely dashed] (2,2) --node[above right]
↪  $\{\mathcal{I}_1^+\}$  (4,0);
\draw[densely dashed] (-4,0) -- (0,-4) -- (4,0);
\end{tikzpicture}

```

두번째 예 / Step 4: 점 표시하기



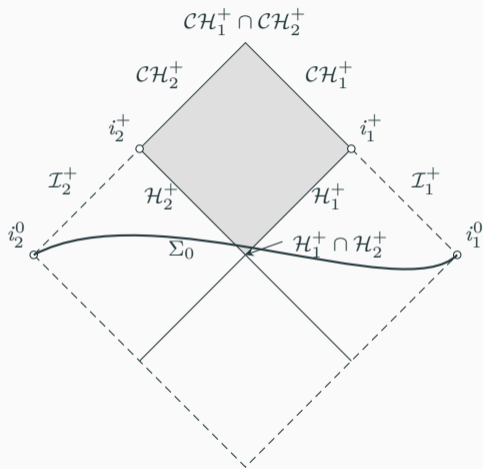
```

\begin{tikzpicture}[>=stealth]
\draw[fill=white] (-4,0) circle (2pt)
  \rightarrow node[above left] {$i_2^{\{0\}}$};
\draw[fill=white] (4,0) circle (2pt)
  \rightarrow node[above right] {$i_1^{\{0\}}$};
\draw[fill=white] (2,2) circle (2pt)
  \rightarrow node[above right] {$i_1^{\{+\}}$};
\draw[fill=white] (-2,2) circle (2pt)
  \rightarrow node[above left] {$i_2^{\{+\}}$};

\draw[->] (0.7,0.25) -- (0,0);
\node[overlay] at (1.6,0.2)
  \rightarrow {\mathcal{H}_1^+ \cap \mathcal{H}_2^+};
\end{tikzpicture}

```

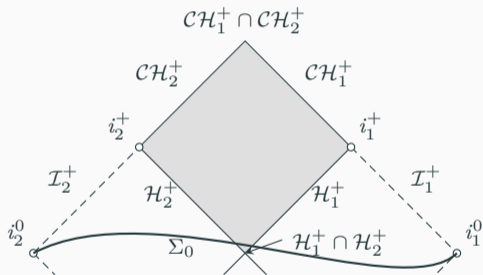
두번째 예 / Step 5: Cauchy Horizon 그리기



```
\begin{tikzpicture}[>=stealth]
\draw[rounded corners,thick] (-4,0)
↪ .. controls (-1.75,1.2) and
↪ (3,-1) .. (4,0);
```

```
\node[overlay] at (-1.2,0.1)
↪ {\Sigma_0};
\end{tikzpicture}
```

두번째 예 / Step 6: Clipping



```
\begin{tikzpicture}[>=stealth]  
\clip (-4.6,-0.4) rectangle  
  \to (4.6,4.8); % 맨 상단에  
\end{tikzpicture}
```


이건 좀 신기한 것

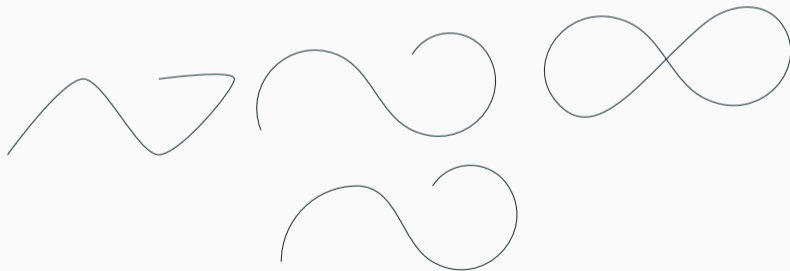
```
\usetikzlibrary{hobby}
```

```
\tikz[smooth] \draw plot coordinates {(0,0) (1,1) (2,0) (3,1) (2,1)};
```

```
\tikz[hobby] \draw plot coordinates {(0,0) (1,1) (2,0) (3,1) (2,1)};
```

```
\tikz[closed hobby] \draw plot coordinates {(0,0) (1,1) (2,0) (3,1) (2,1)};
```

```
\tikz[quick hobby] \draw plot coordinates {(0,0) (1,1) (2,0) (3,1) (2,1)};
```



숙제! (안 할거 다 알지만...)

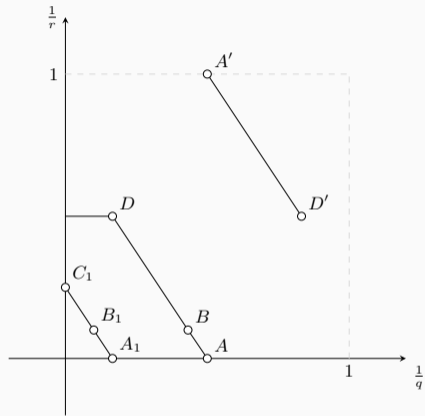







Figure 1: The Strichartz “game board” for Schrödinger equations in $\dot{H}^1(\mathbb{R}^3)$ (T. Tao, Nonlinear dispersive equations)

- 많이 연습해야 늘어요.
- 잘 안되는 것 있으면 ktug에 문의하시고 (with Minimal Working Example!)
- 공개하기 곤란한게 있으면 저한테 연락주세요.

References

-  권현우, TikZ와 수학, 2017 문서작성워크숍
-  박승원, TikZ기초, 2017 문서작성워크숍
-  PGFplots project, <http://pgfplots.sourceforge.net/>
-  F. Neves, tikzcd: commutative diagrams with TikZ
-  Overleaf, <https://www.overleaf.com/learn/latex/TikZ-Feynman>