Marginally stable thermal equilibria of Rayleigh-Bénard convection

Liam O'Connor

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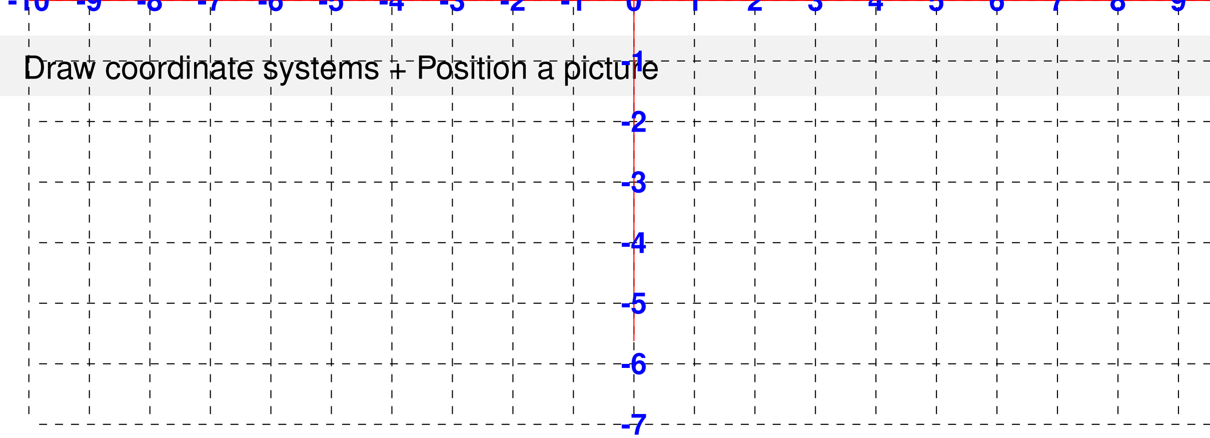
Compilation: requires LaTeX environment

1. Just compile like an ordinary Beamer/LaTeX:
   `pdflatex+biber+pdflatex+pdflatex`
2. Or use compilation script:
   - Linux or MacOS: run in terminal
     - `./artratex.sh pb`: full compilaiton with reference cited in biblatex format
     - `./artratex.sh p`: run pdflatex only, no biber for reference
3. Switch to Chinese: just add the "CJK" option in "artrabeamer.tex":
   `\usepackage[CJK,biber,authoryear,tikz,table,xlink]{Style/artrabeamer}`
4. Many other functionalities: check the available options below the line
   `\usepackage[biber,authoryear,tikz,table,xlink]{Style/artrabeamer}` in "artrabeamer.tex"

Useful commands added to generic $\LaTeX$

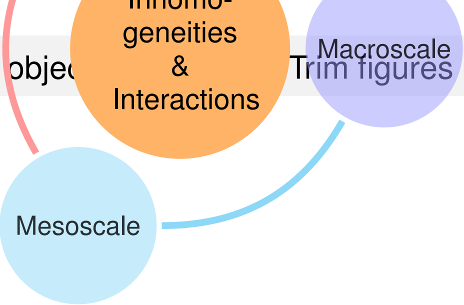
- `\enorcn{English}{Chinese}`: automatically switch between English and Chinese versions
- `\tikzart[t=m]{}`: draw coordinate system to help you position contents
- `\tikzart[t=p,x=-7,y=3,w=4]"comments"{figname}`: position a picture named "figname" at location "(x,y)" with width "w=4" and comments below the picture.
- `\tikzart[t=o,x=0,y=-0.8,s=0.8]{objects-such-as-tikz-diagrams}`: position objects at location "(x,y)" with scaling "s=0.8"
- `\tikzart[t=v,x=9.5,y=-6.5,w=0.5]{Video/vortex_preserve_geo.mp4}[\includegraphics{cover_image}]`: position a video at location "(x,y)" with a cover image of width "w=0.5"
- `\lolt{lowlight}`, `\hilt{highlight}`: make the item show in different color when in different state

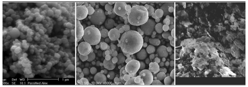
Draw coordinate systems + Position a picture



Smart diagrams + Position objec Trim figures + Low/Hi

(reed2008transient)



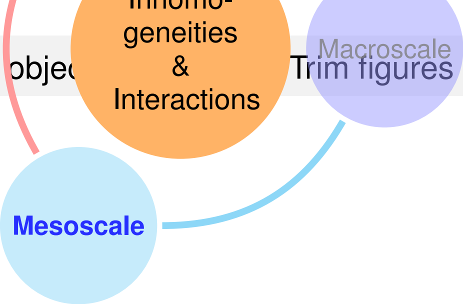


(zhang2009reaction)

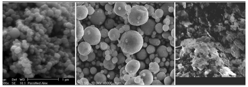
(zhang2010hybrid)

Smart diagrams + Position objec Trim figures + Low/Hi

(reed2008transient)



(zhang2010hybrid)



(zhang2009reaction)

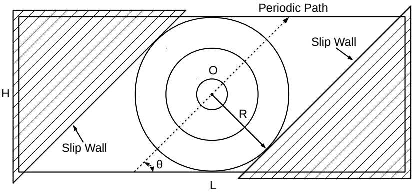
Math + Position text + Full citation + Notes

$\psi_I = f(\{\psi_N\}, \psi_O)$

1. Prediction step: $\psi_I^* = \left[\sum w(d_N)\psi_N\right] / \left[\sum w(d_N)\right]$
2. Boundary condition enforcement step: $\psi_O = C\psi_I + \mathrm{RRHS}$
3. Correction step: $\psi_I = \left[\psi_I^* + \frac{w(d_O)}{\sum w(d_N)}\psi_O\right] / \left[1 + \frac{w(d_O)}{\sum w(d_N)}\right]$

Type	Example form	C	RRHS
Dirichlet	$\psi_O = g$	0	g
Neumann	$\left.\frac{\partial \psi}{\partial n}\right\vert_O = \frac{\partial \psi_O}{\partial n}$	1	$-\vert\vert \boldsymbol{x}_I - \boldsymbol{x}_O \vert\vert \frac{\partial \psi_O}{\partial n}$
Robin	$\alpha\psi_O + \beta \left.\frac{\partial \psi}{\partial n}\right\vert_O = g$	$\frac{\beta}{\beta - \vert\vert \boldsymbol{x}_I - \boldsymbol{x}_O \vert\vert \alpha}$	$\frac{-\vert\vert \boldsymbol{x}_I - \boldsymbol{x}_O \vert\vert g}{\beta - \vert\vert \boldsymbol{x}_I - \boldsymbol{x}_O \vert\vert \alpha}$
Cauchy	$(\boldsymbol{V} \cdot \mathbf{n})\vert_{\boldsymbol{x}=\boldsymbol{x}_O} = \boldsymbol{V}_S \cdot \mathbf{n}$ $\left.\frac{\partial(\boldsymbol{V} \cdot \hat{\boldsymbol{t}})}{\partial n}\right\vert_{\boldsymbol{x}=\boldsymbol{x}_O} = 0$ $\left.\frac{\partial(\boldsymbol{V} \cdot \tilde{\boldsymbol{t}})}{\partial n}\right\vert_{\boldsymbol{x}=\boldsymbol{x}_O} = 0$	$\begin{bmatrix} n_x & n_y & n_z \\ \hat{t}_x & \hat{t}_y & \hat{t}_z \\ \tilde{t}_x & \tilde{t}_y & \tilde{t}_z \end{bmatrix}^{\mathrm{T}} \begin{bmatrix} 0 & 0 & 0 \\ \hat{t}_x & \hat{t}_y & \hat{t}_z \\ \tilde{t}_x & \tilde{t}_y & \tilde{t}_z \end{bmatrix}$	$\begin{bmatrix} n_x & n_y & n_z \\ \hat{t}_x & \hat{t}_y & \hat{t}_z \\ \tilde{t}_x & \tilde{t}_y & \tilde{t}_z \end{bmatrix}^{\mathrm{T}} \begin{bmatrix} n_x & n_y & n_z \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \cdot \boldsymbol{V}_S$

Position animation + Make Table



To play the video, the compiled PDF should be moved out from the "Tmp" directory

$m_x \times m_y$	L_1 error	L_1 order	L_2 error	L_2 order	L_∞ error	L_∞ order
40×20	3.536e−2	–	6.097e−2	–	4.105e−1	–
80×40	9.113e−3	1.956	2.497e−2	1.288	1.997e−1	1.039
160×80	2.034e−3	2.163	6.548e−3	1.931	5.236e−2	1.931
320×160	5.114e−4	1.992	1.640e−3	1.997	1.278e−2	2.035
640×320	1.287e−4	1.990	4.097e−4	2.001	3.119e−3	2.034
1280×640	3.233e−5	1.993	1.024e−4	2.000	7.818e−4	1.996

Ordinary text

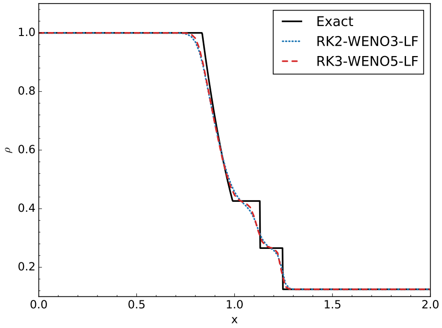
- **A 3D, high-resolution, parallelized, gas-solid flow solver**
  - Establishes a numerical framework for the direct simulation of gas-solid flows.
  - Solves coupled and interface-resolved fluid-fluid, fluid-solid, and solid-solid interactions.
  - Addresses shocked flow conditions, irregular and moving geometries, and multibody contact and collisions.
- **Advancement in understanding particle clustering and jetting**
  - Demonstrates a valid statistical dissipative property in solving explosively dispersed granular materials with respect to Gurney velocity.
  - Extends the time range of the velocity scaling law with regard to Gurney energy in the Gurney theory from the steady-state termination phase to the unsteady evolution phase.
  - Proposes an explanation for particle clustering and jetting instabilities to increase the understanding of experimental observations.

Thank you for your attention!

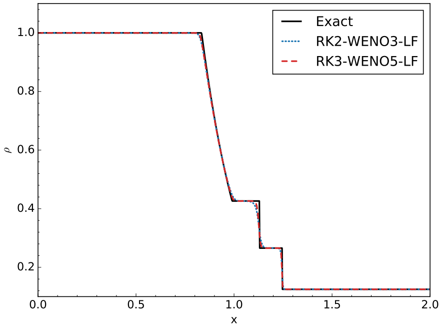
Part I

Appendix

Sod's problem (**sod1978survey**)



$n = 100$



$n = 500$

$$\begin{array}{llll} \rho = 1; & u = 0; & p = 1 & \text{if } 0 \leq x < 1 \\ \rho = 0.125; & u = 0; & p = 0.1 & \text{if } 1 < x \leq 2 \end{array}$$

References I