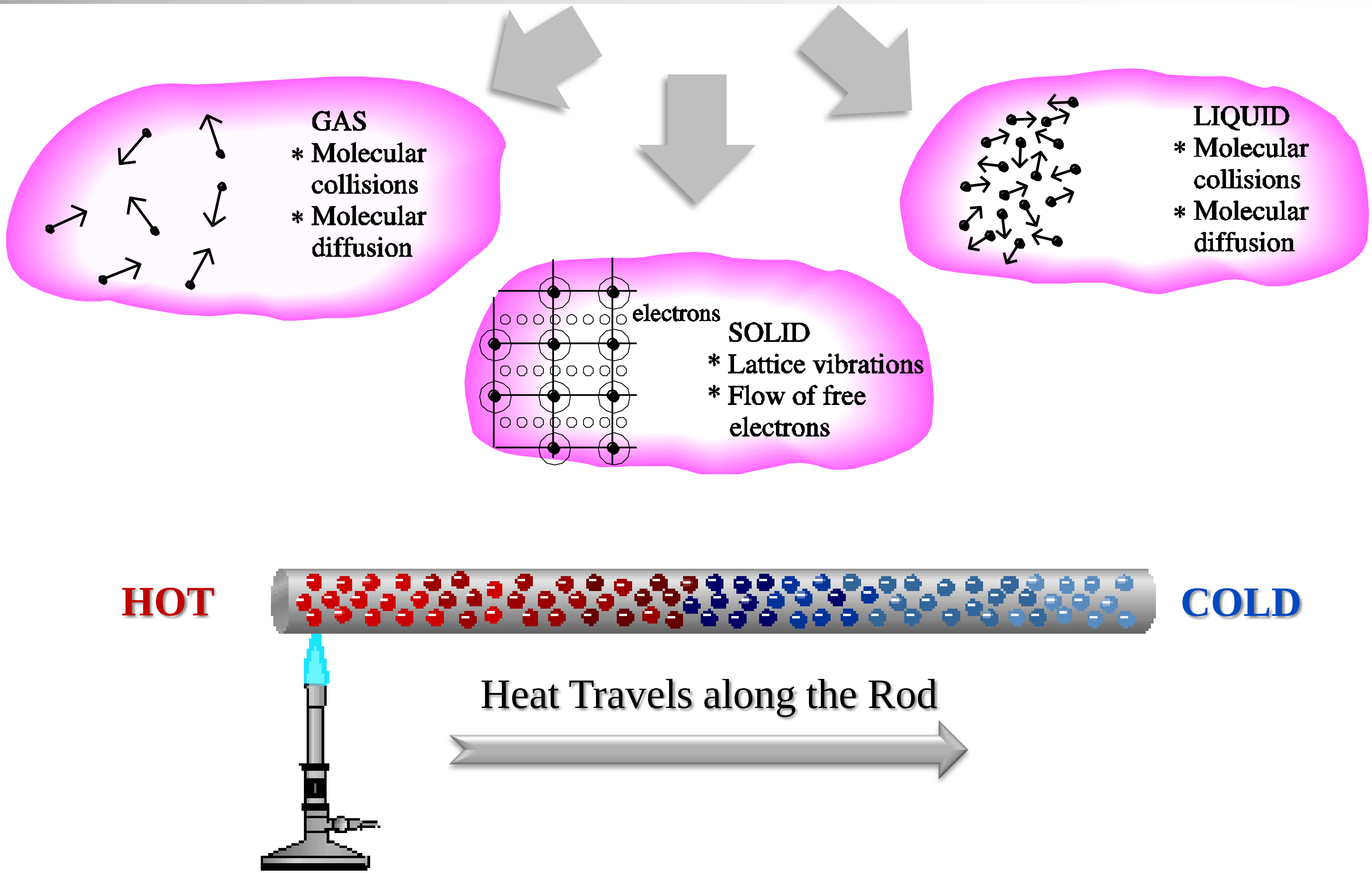
北京科技大学
University of Science and Technology Beijing

Heat and Mass Transfer
传热传质学

主讲：冯妍卉 教授

北京市本科优秀教学团队“传热传质学教学团队”
张欣欣 冯妍卉 夏德宏 温治 于帆 姜泽毅 乐恺 任玲 尹少武 包成

Heat Conduction



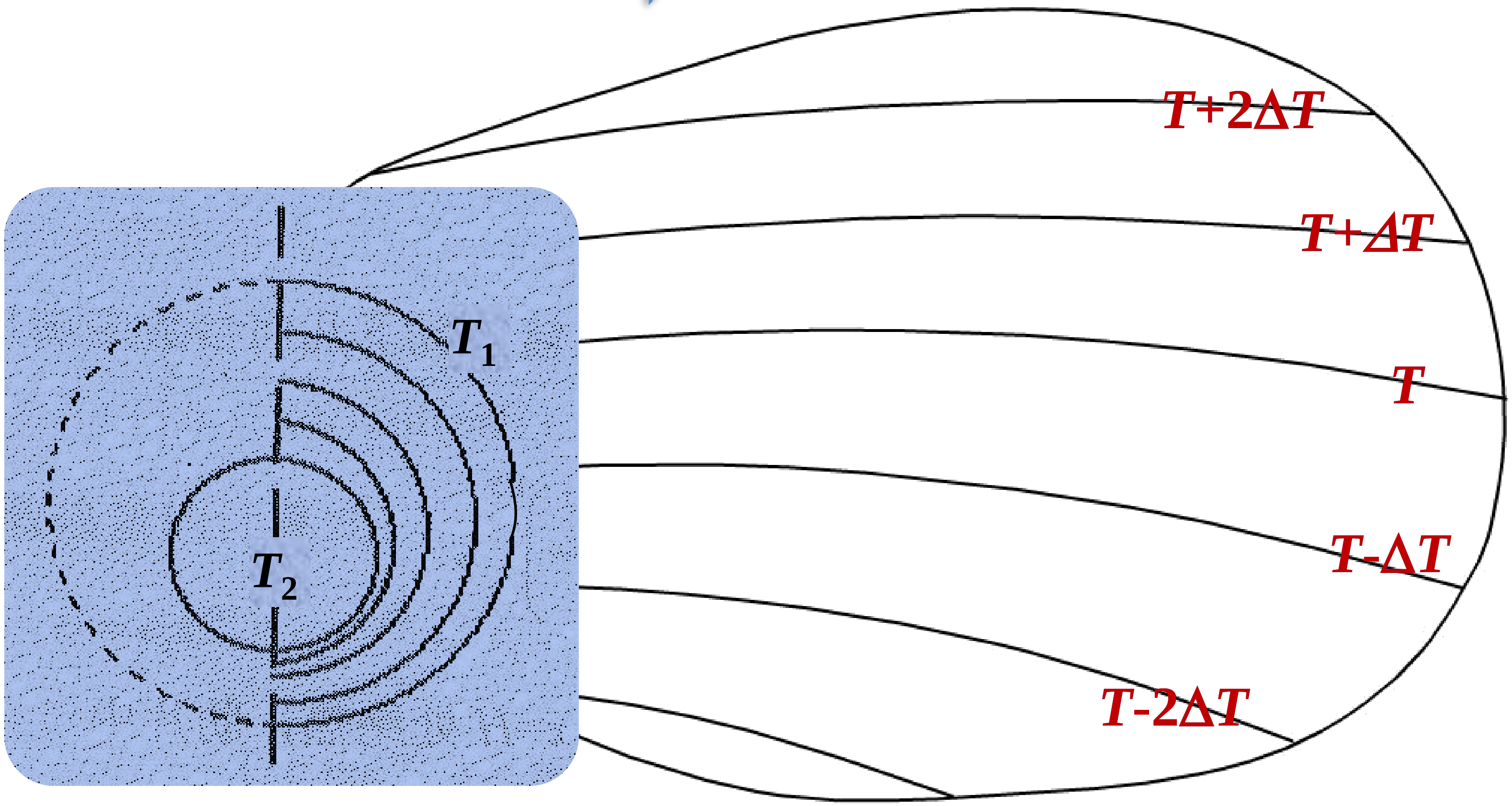
§ 2-1 Basic Concepts

Temperature Field (温度场)

$T = f(x, y, z, t)$ → 图示

Isothermal Surfaces (等温面) : 3-D

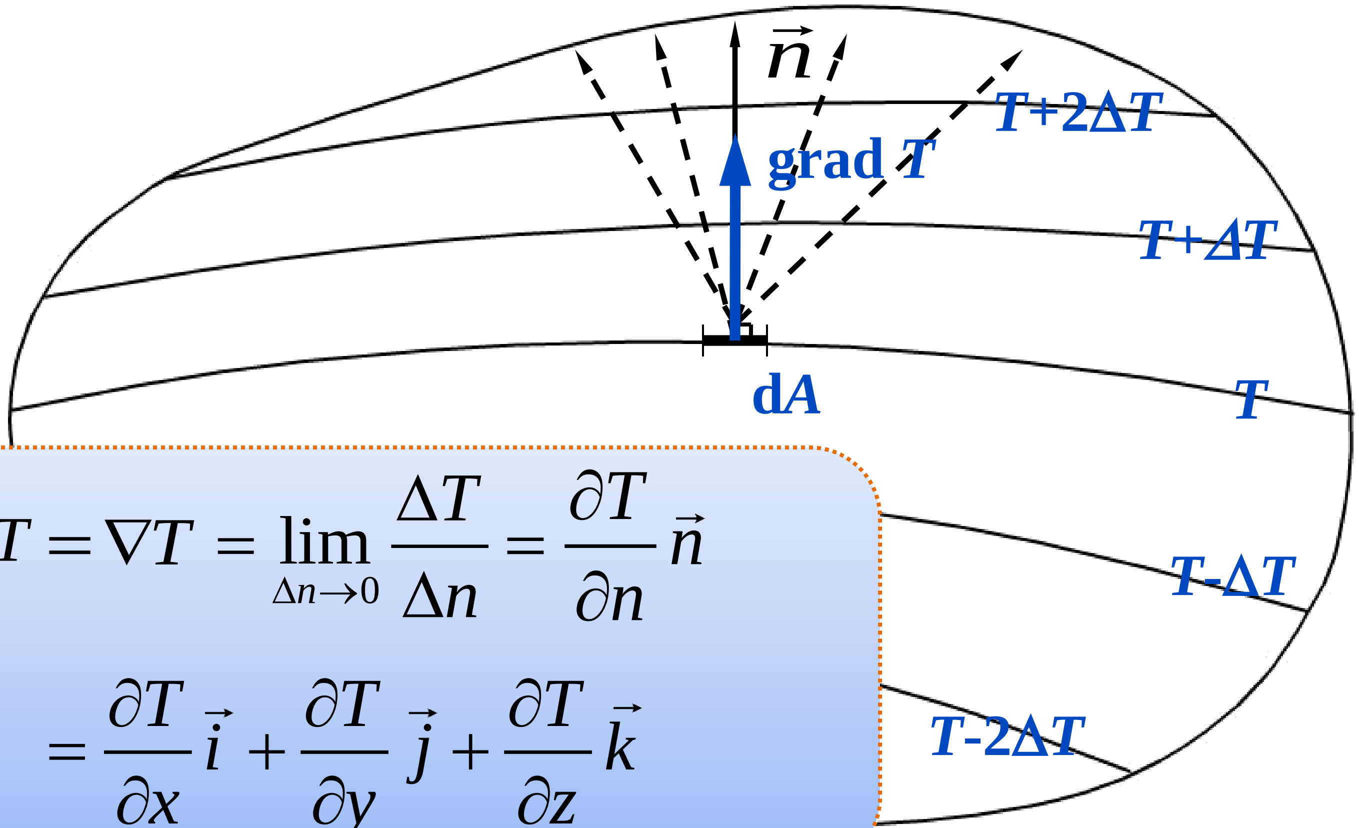
Isotherms (等温线) : 2-D



§ 2-1 Basic Concepts

Temperature Gradient (温度梯度)

Direction: **of temperature ascent**



$$\mathrm{grad}T = \nabla T = \lim_{\Delta n \to 0} \frac{\Delta T}{\Delta n} = \frac{\partial T}{\partial n}\vec{n}$$

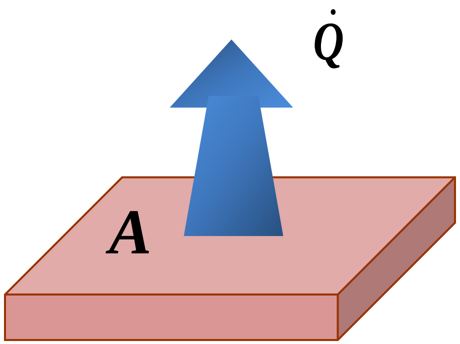
$$= \frac{\partial T}{\partial x}\vec{i} + \frac{\partial T}{\partial y}\vec{j} + \frac{\partial T}{\partial z}\vec{k}$$

§ 2-1 Basic Concepts

1) Heat Flux (热流密度) $\dot{q}$

$$\dot{q} = \frac{dQ}{dtdA} \quad (\mathrm{W/m^2})$$

2) Heat Transfer Rate (热流量) $\dot{Q}$



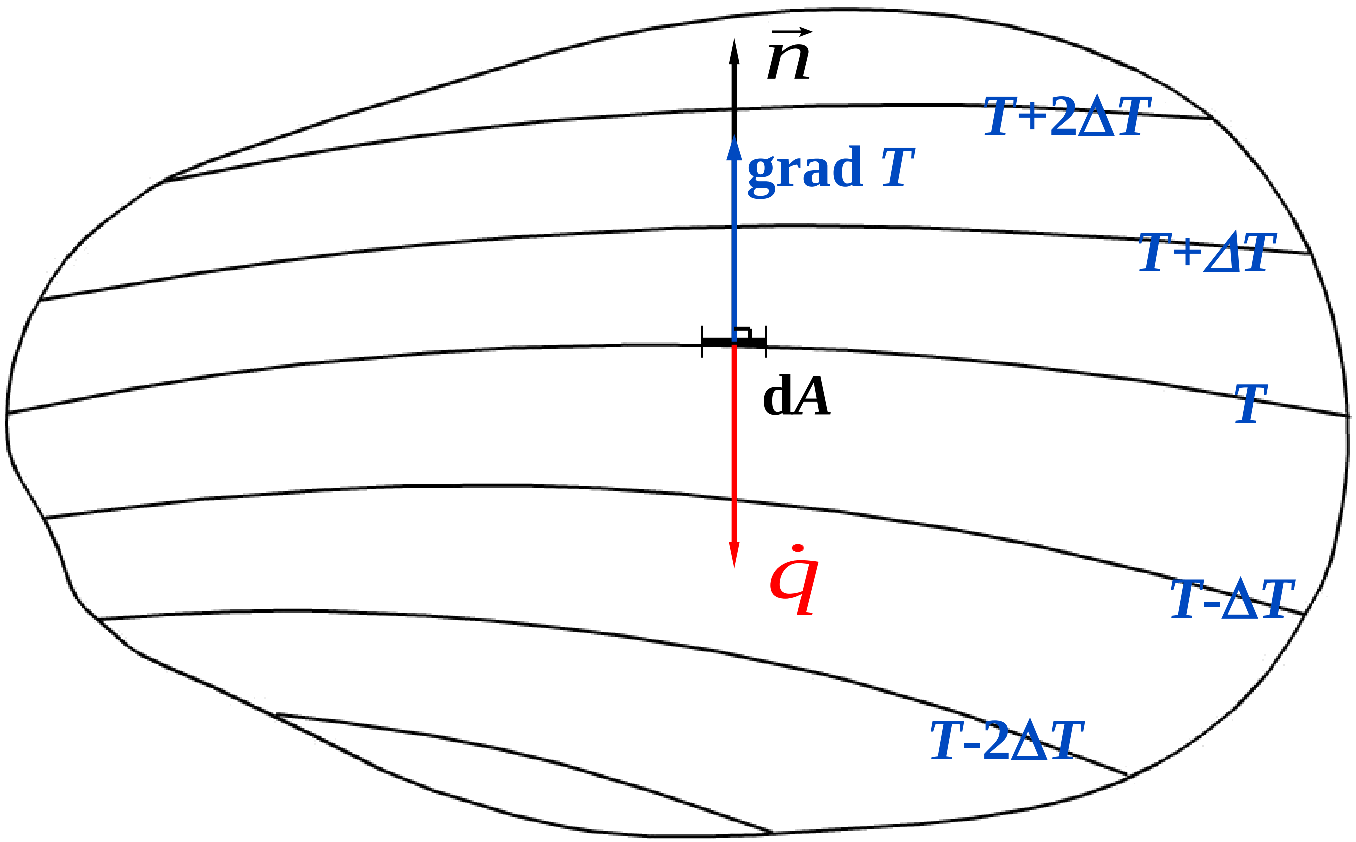
$$\dot{Q} = \frac{dQ}{dt} = \int_A \dot{q}dA \quad (\mathrm{W})$$

If $\dot{q} = \dot{q}_o$, then $\dot{Q} = \dot{q}_o A$ (W)

3) Total Amount of Heat Transfer (总热量) Q

$$Q = \int_0^t \dot{Q}dt = \int_0^t \int_A \dot{q}dAdt \quad (\mathrm{J})$$

§ 2-1 Basic Concepts



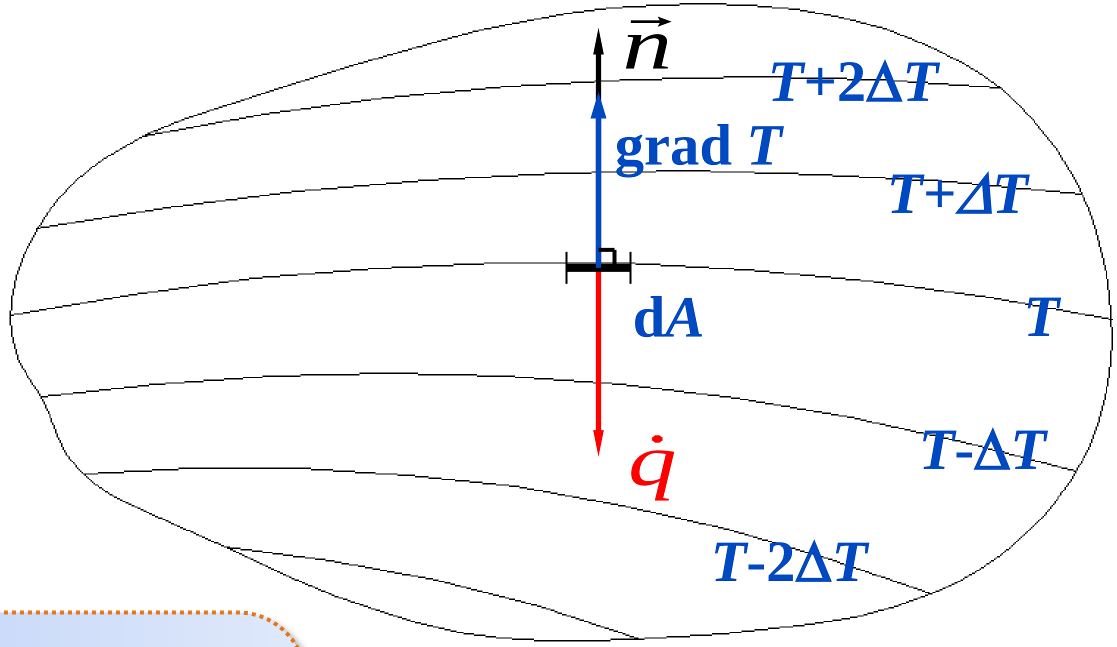
Heat Transfer Direction: **of temperature descent**

§ 2-2 Fourier's Law of Heat Conduction (傅立叶导热定律)

$$\dot{Q} \propto A \cdot \text{grad}T$$

Introduce ***k***

$$\dot{Q} = -kA \cdot \text{grad}T$$
$$= -kA_x \frac{\partial T}{\partial x}\vec{i} - kA_y \frac{\partial T}{\partial y}\vec{j} - kA_z \frac{\partial T}{\partial z}\vec{k}$$
$$= \dot{Q}_x \vec{i} + \dot{Q}_y \vec{j} + \dot{Q}_z \vec{k} \quad \text{(W)}$$

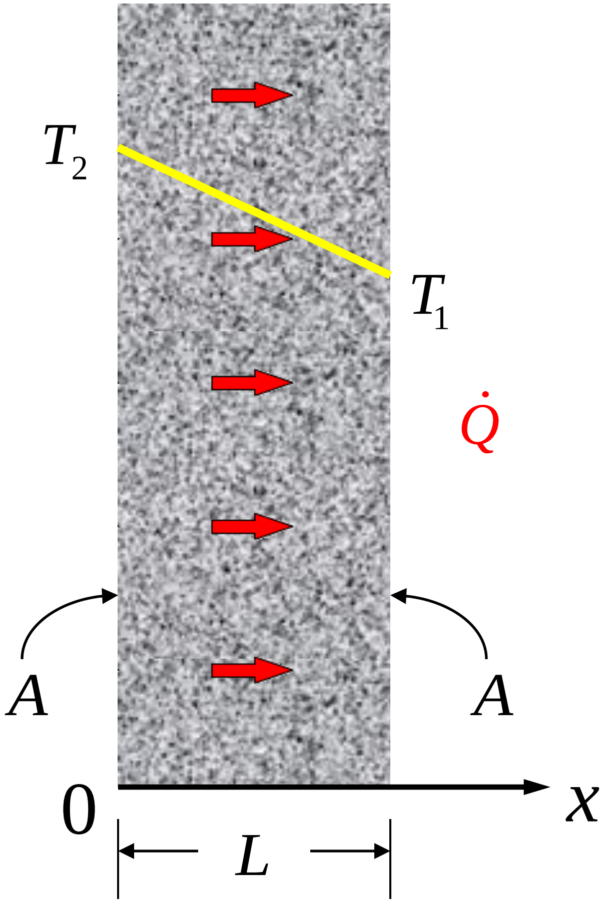


Jean Baptiste Fourier (1768-1830)

§ 2-2 Fourier's Law of Heat Conduction (傅立叶导热定律)

e.g. Heat Conduction Through a Large Plate **(Steady, 1-D)**

$$\dot{Q} = \textbf{?}$$



Solution:

$$\frac{T(x)-T_2}{T_1-T_2} = \frac{x}{L}$$

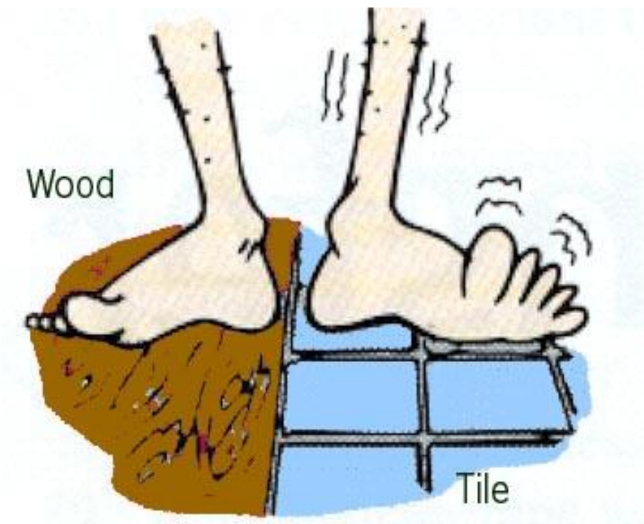
$$\dot{Q} = -k\,A \cdot \mathrm{grad}T = -kA\frac{dT(x)}{dx}$$

$$= \frac{T_2 - T_1}{L/(kA)} \quad \text{(W)}$$

§ 2-3 Thermal Conductivity *k* (热导率)

$$k = -\frac{\dot{Q}}{A \cdot \mathrm{grad}T} \quad \mathrm{W/(m \cdot K)}$$

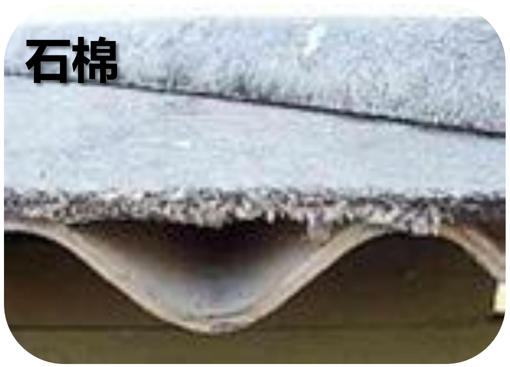
Thermophysical Parameters
(热物性参数)

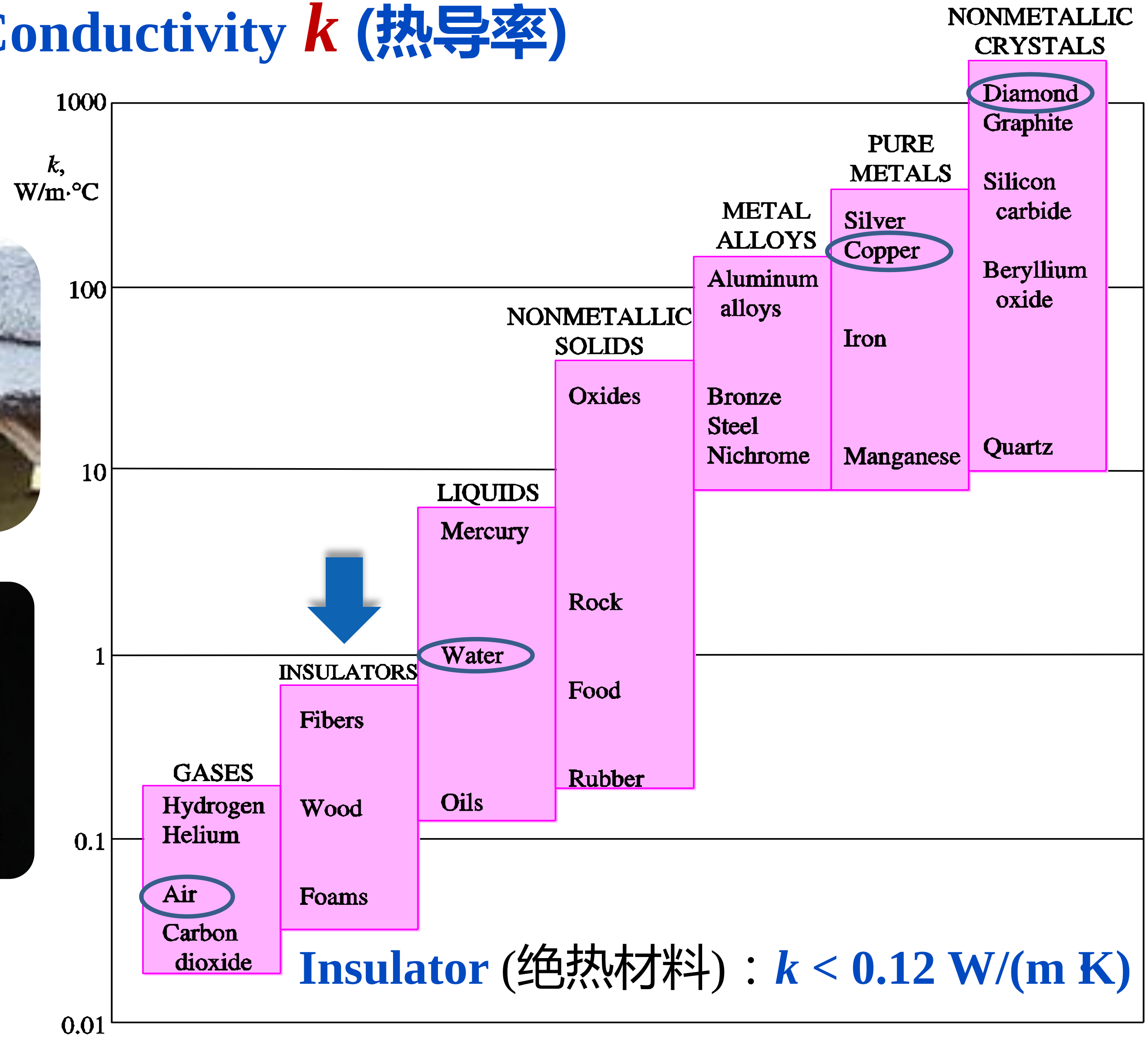


$$k_{\text{tile}} = 1.2\ \mathrm{W/(m \cdot K)}$$
$$k_{\text{wood}} = 0.1 \sim 0.5\mathrm{W/(m \cdot K)}$$

A measurement of a material's **ability to conduct heat**.

§ 2-3 Thermal Conductivity *k* (热导率)

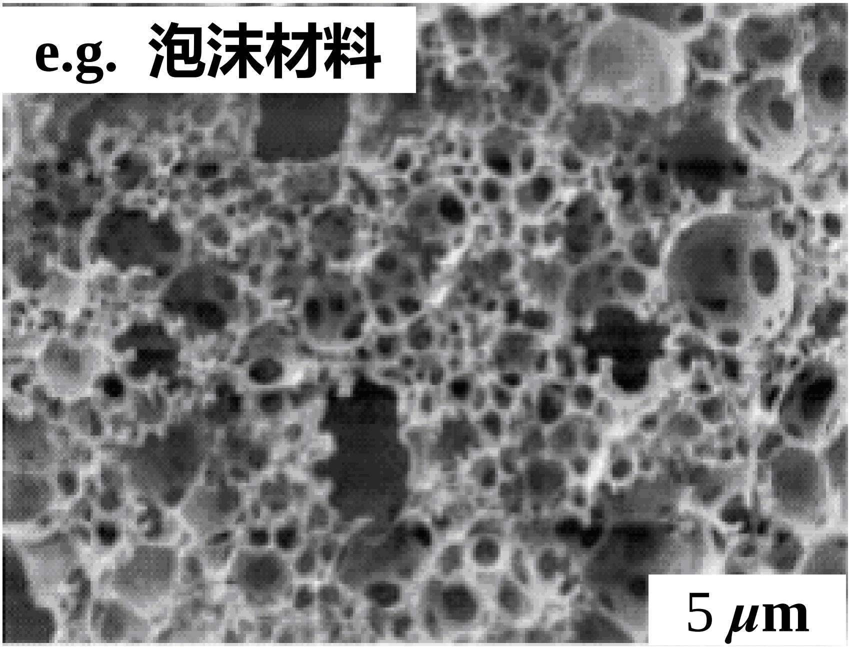




Insulator (绝热材料)：k < 0.12 W/(m K)

Insulator (绝热材料)

多 孔 结 构



绝热性能好

1. 孔隙中气相 导热

——占 50% ~ 80%

2. 固体骨架 导热

↑ **Porosity** (孔隙率)

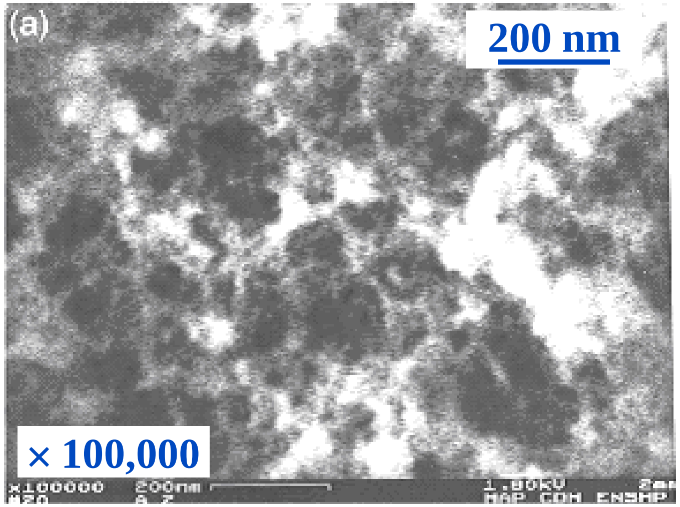
↓ **Pore Size** (孔隙尺寸)

$$k_{\text{常规绝热材料}} > k_{\text{气体}}$$

Nano Porous Super Insulator (纳米孔超级绝热材料)

?

e.g. 气凝胶材料



热导率低于静止空气的热导率(20°C):

$k_{aerogel}$ ： 0.017-0.021 W/(m K)

k_{air} = 0.026 W/(m K)

孔径大部分为 20 nm，孔隙率 > 95%

Key Words: Porous Medium, Insulator, Thermal Conductivity, Aerogel
（关键词: 多孔介质 绝热材料 热导率 气凝胶 ）

Summary

§2-1 Basic Concepts

- Temperature Field: $T=f\,(x, y, z, t)$
- Temperature Gradient : grad T
- Heat Flux $\dot{q}$

  Heat Transfer Rate $\dot{Q}$

  Total Amount Heat Transfer Q

§2-2 Fourier's Law of Heat Conduction

$$\dot{Q} = -\,k\,A \cdot \mathrm{grad}T$$

§2-3 Thermal Conductivity k

致　谢

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北京科技大学“传热传质学教学团队”

（2010年北京市本科优秀教学团队）

张欣欣 冯妍卉 夏德宏 温治 于帆 姜泽毅 乐恺 任玲 尹少武 包成

Thank You for Your Attention

谢 谢

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