

Computer-Aided Analyses of Heat Transfer (電腦輔助熱傳分析)

Part II

Chapter 1: Introduction to thermal analysis in ANSYS

Thomas Jin-Chee Liu (劉晉奇老師)
Department of Mechanical Engineering
Ming Chi University of Technology
Taiwan
Jun. 2009

Types

- Heat conduction (in solid) - main parts of this course ★
- Heat convection (CFD, fluid-solid) - not included in this course ▲
- Heat radiation - not included in this course

Types (cont.)

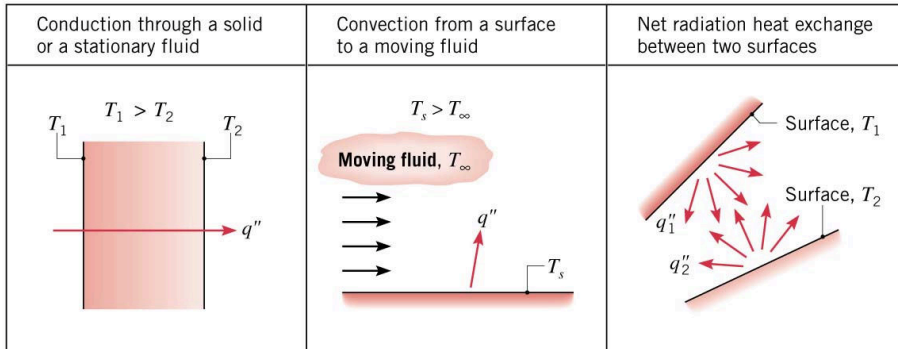


FIGURE 1.1 Conduction, convection, and radiation heat transfer modes.

F.P. Incropera, D.P. DeWitt, *Fundamentals of Heat and Mass Transfer*. 5th edition, John Wiley & Sons, 2002.

Types (cont.)

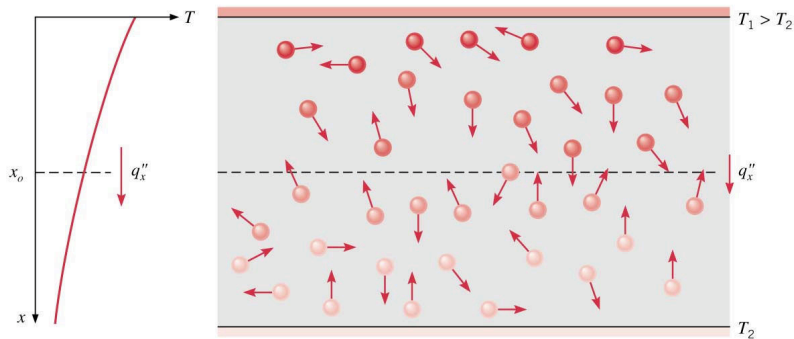


FIGURE 1.2 Association of conduction heat transfer with diffusion of energy due to molecular activity.

F.P. Incropera, D.P. DeWitt, *Fundamentals of Heat and Mass Transfer*. 5th edition, John Wiley & Sons, 2002.

Types (cont.)

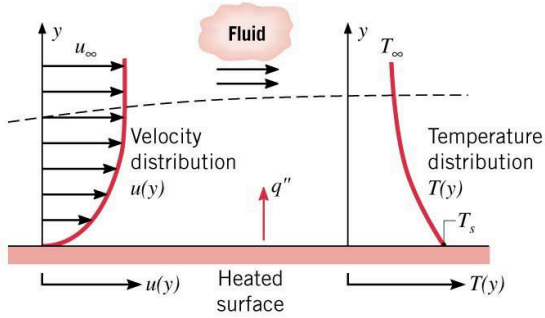


FIGURE 1.4
Boundary layer development in convection heat transfer.

F.P. Incropera, D.P. DeWitt, *Fundamentals of Heat and Mass Transfer*. 5th edition, John Wiley & Sons, 2002.

Types (cont.)

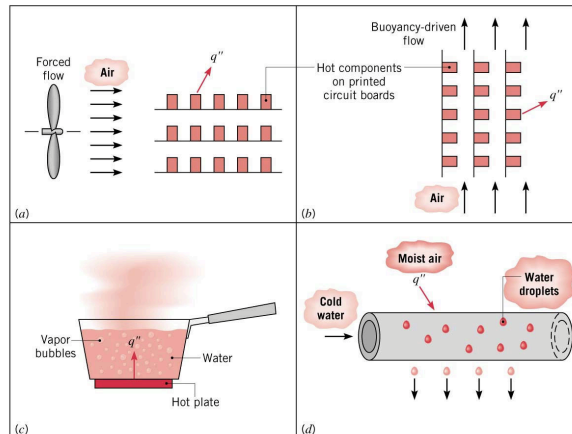


FIGURE 1.5 Convection heat transfer processes. (a) Forced convection. (b) Natural convection. (c) Boiling. (d) Condensation.

F.P. Incropera, D.P. DeWitt, *Fundamentals of Heat and Mass Transfer*. 5th edition, John Wiley & Sons, 2002.

Types (cont.)

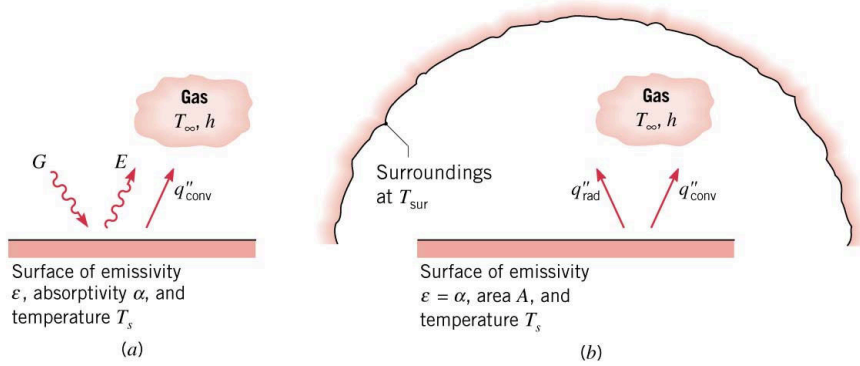
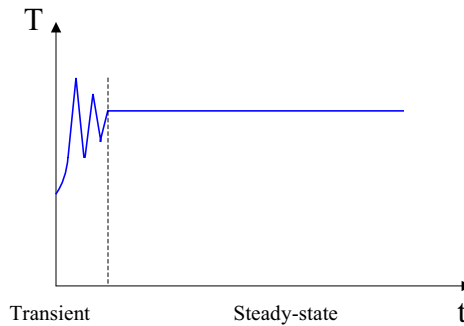


FIGURE 1.6 Radiation exchange: (a) at a surface and (b) between a surface and large surroundings.

F.P. Incropera, D.P. DeWitt, *Fundamentals of Heat and Mass Transfer*. 5th edition, John Wiley & Sons, 2002.

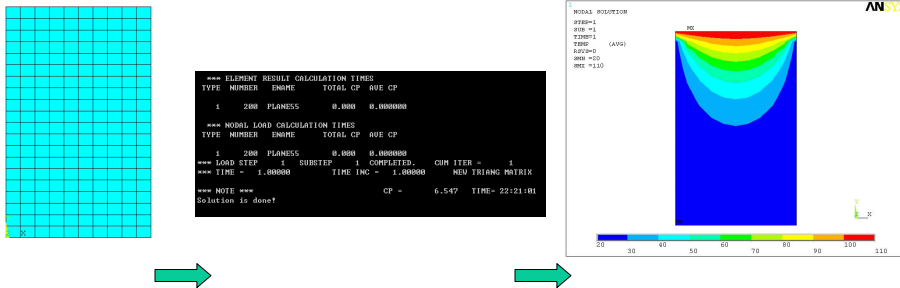
Analysis types

- Steady-state analysis
 - Time-independent
- Transient analysis
 - Time-dependent



FE Procedure

- Pre-processor
- Solver
- Post-processor



Units

Typical Units in ANSYS (SI)

ANSYS
Training Manual

- | | |
|----------------------------|---|
| • Temperature | • Degrees C (or K) |
| • Heat Flow | • Watts |
| • Thermal Conductivity | • Watts / (meter • degree C) |
| • Density | • kilogram/ (meter ³) |
| • Specific Heat | • (Watt • sec) / (kilogram • degree C) |
| • Film Coefficient | • Watts / (meter ² • degree C) |
| • Heat Flux | • Watts / (meter ²) |
| • Thermal Gradients | • degree C / meter |
| • Internal Heat Generation | • Watts / (meter ³) |

HEAT TRANSFER

Ref: ANSYS, Inc., ANSYS training manual.

Element types in ANSYS

- Plane 35
- Plane 55
- Plane 77

Conduction in solid

Figure 35.1 PLANE35 Geometry

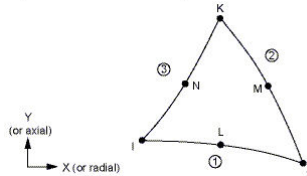


Figure 55.1 PLANE55 Geometry

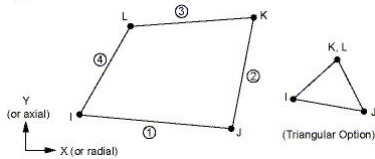
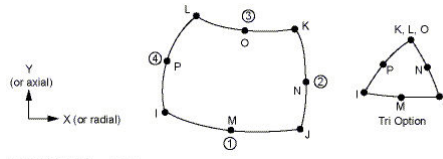


Figure 77.1 PLANE77 Geometry



Element types in ANSYS (cont.)

- Solid 70
- Solid 87
- Solid 90

Conduction in solid

Figure 87.1 SOLID87 Geometry

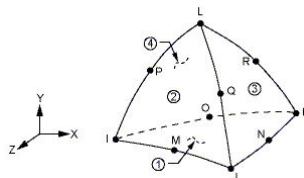


Figure 70.1 SOLID70 Geometry

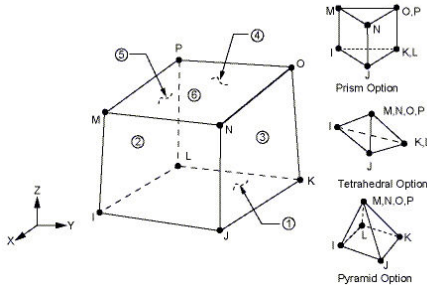
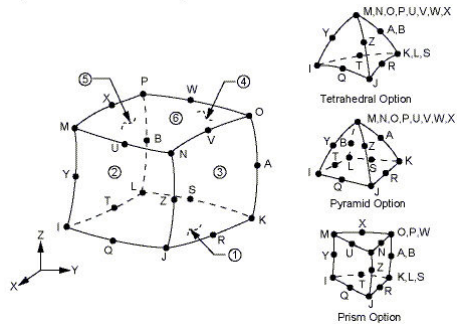
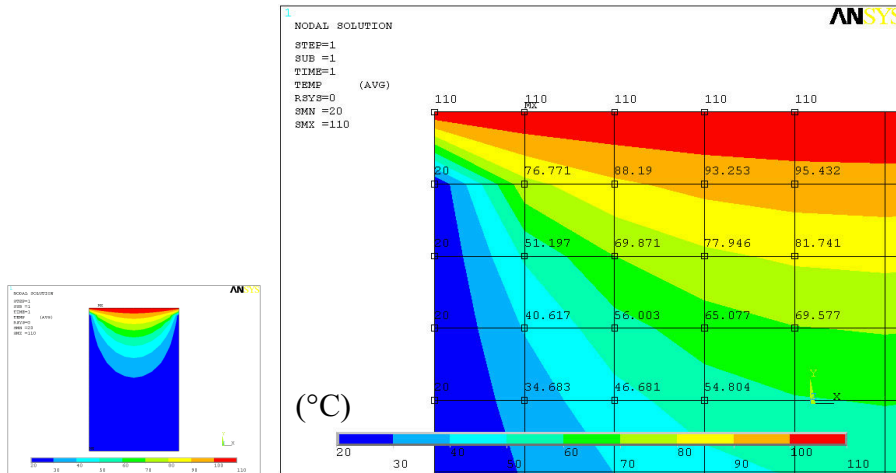


Figure 90.1 SOLID90 Geometry



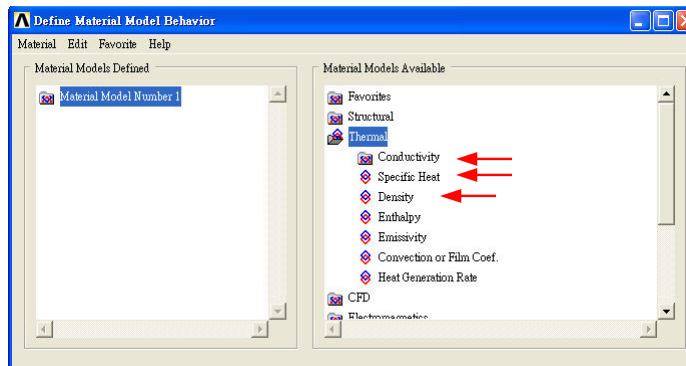
Nodal DOF

- DOF: Temperature (SI: K or °C)



Material properties

- Thermal conductivity (steady-state, transient conduction)
- Specific heat (only for transient conduction)
- Density (only for transient conduction)



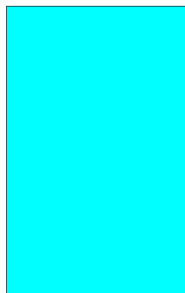
Modelling

- Geometry
- Mesh

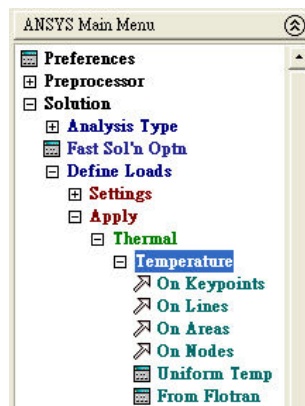
The same ways as structural analyses.

Boundary conditions

- First kind : prescribe a fixed temperature

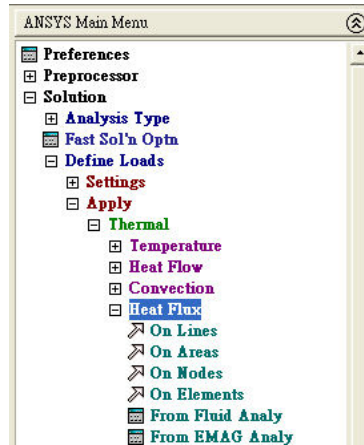
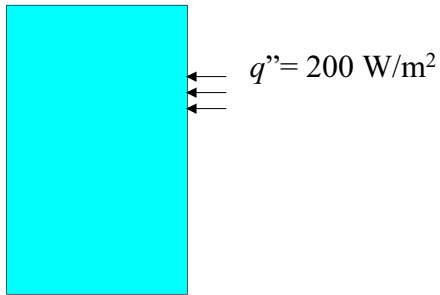


120 °C



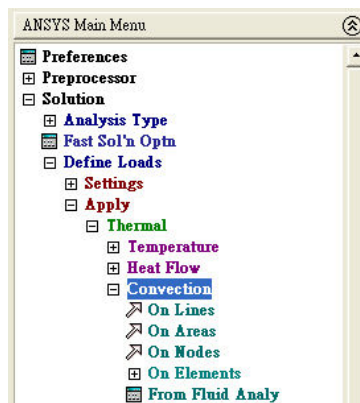
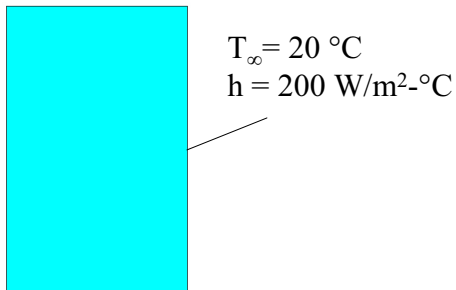
Boundary conditions (cont.)

- Second kind : prescribe a fixed heat flux



Boundary conditions (cont.)

- Third kind : prescribe a convection condition



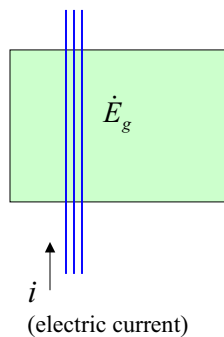
Boundary conditions (cont.)

✓ **TABLE 2.1** Boundary conditions for the heat diffusion equation at the surface ($x = 0$)

<p>1. Constant surface temperature</p> $T(0, t) = T_s \quad (2.24)$	
<p>2. Constant surface heat flux</p> <p>(a) Finite heat flux</p> $-k \frac{\partial T}{\partial x} \Big _{x=0} = q_s'' \quad (2.25)$	
<p>(b) Adiabatic or insulated surface</p> $\frac{\partial T}{\partial x} \Big _{x=0} = 0 \quad (2.26)$	
<p>3. Convection surface condition</p> $-k \frac{\partial T}{\partial x} \Big _{x=0} = h[T_\infty - T(0, t)] \quad (2.27)$	

F.P. Incropera, D.P. DeWitt, *Fundamentals of Heat and Mass Transfer*, 5th edition, John Wiley & Sons, 2002.

Heat generation



Analogy

Comparison to Structural Analysis

ANSYS
Training Manual

For those who feel more comfortable with structural analysis, the following table of analogies may be helpful:

$[M]\{\ddot{U}\} + [C]\{\dot{U}\} + [K]\{U\} = \{F\}$	$[C]\{\dot{T}\} + [K]\{T\} = \{Q\}$
Structural	Thermal
<ul style="list-style-type: none">• Displacement• Force• Pressure• Strain• Stress• Temperature Distribution• Inertial Loads• Elastic Foundation• None• Contact	<ul style="list-style-type: none">• Temperature• Heat Flow Rate• Heat Flux (applied)• Thermal Gradient• Heat Flux (calculated)• Internal Heat Generation (heat/volume)• None• Convection• Radiation• Thermostat

HEAT TRANSFER

Thanks to CADMEN, TADC, Taiwan (虎門科技)

Ref: ANSYS, Inc., ANSYS training manual.

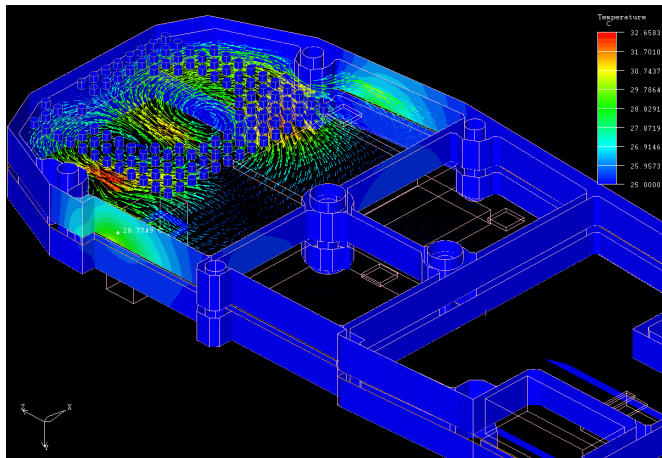
Department of Mechanical Engineering, Ming Chi University of Technology

Ch 1 21 / 23

CFD + thermal (convection) analysis

ANSYS Icepak

Thermal management of a cell phone using ANSYS Icepak



http://www.ansys.com/industries/electronics/consumer_electronics.asp

Department of Mechanical Engineering, Ming Chi University of Technology

Ch 1 22 / 23

