

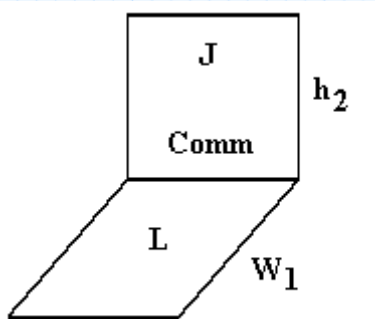
## CHAPTER 6 RADIATION HEAT TRANSFER IN BUILDINGS

### 6.1 Calculation of View Factors in a Rectangular Room with One Window

The view factor, or shape factor,  $F_{ij}$  from surface  $i$  to surface  $j$  is equal to the fraction of diffuse radiation leaving surface  $i$  which is directly incident on surface  $j$ . There are three main types of view factors between room surfaces:

1. between surfaces at right angle,
2. between parallel surfaces, and
3. between the window and another surface.

The view factors for the room below are determined after first calculating the view factor between two rectangular finite surfaces inclined at 90 degrees to each other with one common surface as follows:



Define the following intermediate variables:

$$w = \frac{w_1}{comm}$$

$$h = \frac{h_2}{comm}$$

$$A(h, w) := h^2 + w^2$$

$$B(w) := 1 + w^2$$

$$C(h) := 1 + h^2$$

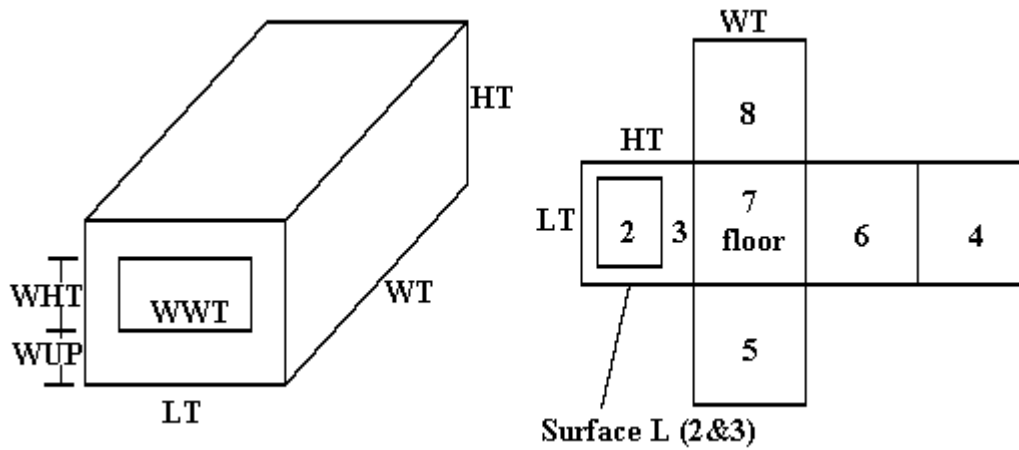
$$D(h, w) := 1 + (h^2 + w^2)$$

$$E(w) := w^2$$

$$G(h) := h^2$$

View factor  $F_{ij}$  from  $i$  to  $j$ :

$$F_{ij}(w, h) := \frac{\left( w \cdot \operatorname{atan}\left(\frac{1.}{w}\right) + h \cdot \operatorname{atan}\left(\frac{1}{h}\right) + \sqrt{A(h, w)} \cdot \operatorname{atan}\left(\frac{1}{\sqrt{A(h, w)}}\right) + 0.25 \cdot \ln\left(\frac{E(w) \cdot D(h, w)}{B(w) \cdot A(h, w)}\right)^{E(w)} \cdot \frac{G(h) \cdot L}{C(h) \cdot A} \right)}{\pi \cdot w}$$



The other view factors between the room surfaces are calculated by applying the following principles:

1. Reciprocity:  $A_i \cdot F_{i,j} = A_j \cdot F_{j,i}$

2. Symmetry, e.g.:  $F_{7,5} = F_{7,8}$

3. Energy conservation:  $\sum_j F_{i,j} = 1$  (for any surface  $i$ )

$i := 1, 2..8$        $j := 1, 2..8$       indices for surfaces

First, calculate  $F_{6,7}$  and other related view factors:

$HT := 2.4 \text{ m}$        $LT := 4.0 \text{ m}$        $WT := 6.0 \text{ m}$

$WWT := 3.0 \text{ m}$        $WHT := 1.6 \text{ m}$        $WUP := 0.4 \text{ m}$

Areas of surfaces:

$$A1 := LT \cdot HT \quad A2 := WWT \cdot WHT \quad A3 := A1 - A2$$

$$A4 := LT \cdot WT \quad A5 := WT \cdot HT \quad A6 := A1$$

$$A7 := A4 \quad A8 := A5$$

Calculate view factors for all surfaces except 2, 3 (window and wall around window):

$$w1 := HT \quad h2 := WT \quad comm := LT$$

$$w := \frac{w1}{comm} \quad h := \frac{h2}{comm}$$

$$F_{6,7} := F_{ij}(w, h) \quad F_{7,6} := A6 \cdot \frac{F_{6,7}}{A7} \quad F_{6,7} = 0.287$$

$$F_{4,6} := A6 \cdot \frac{F_{6,7}}{A4} \quad F_{6,4} := F_{6,7} \quad \dots \text{ from symmetry}$$

$$F_{1,4} := A4 \cdot \frac{F_{4,6}}{A1} \quad F_{1,7} := F_{1,4} \quad F_{4,1} := A1 \cdot \frac{F_{1,4}}{A4}$$

$$w1 := LT \quad h2 := WT \quad comm := HT$$

$$w := \frac{w1}{comm} \quad h := \frac{h2}{comm}$$

$$F_{6,5} := F_{ij}(w, h) \quad F_{5,6} := A6 \cdot \frac{F_{6,5}}{A5} \quad F_{6,8} := F_{6,5}$$

$$F_{8,6} := F_{5,6} \quad F_{1,5} := F_{6,8} \quad F_{5,1} := F_{8,6}$$

$$F_{1,8} := F_{6,8} \quad F_{8,1} := F_{8,6}$$

$$w1 := HT \quad h2 := LT \quad comm := WT$$

$$w := \frac{w1}{comm} \quad h := \frac{h2}{comm}$$

$$F_{8,4} := F_{ij}(w, h) \quad F_{4,8} := A8 \cdot \frac{F_{8,4}}{A4} \quad F_{5,7} := F_{8,4}$$

$$F_{7,5} := F_{4,8} \quad F_{4,5} := F_{4,8} \quad F_{5,4} := F_{8,4}$$

$$F_{7,8} := F_{7,5} \quad F_{8,7} := F_{5,7} \quad F_{4,8} := F_{7,8}$$

$$F_{8,4} := F_{8,7}$$

Determine the view factors for parallel opposite surfaces using the fact that

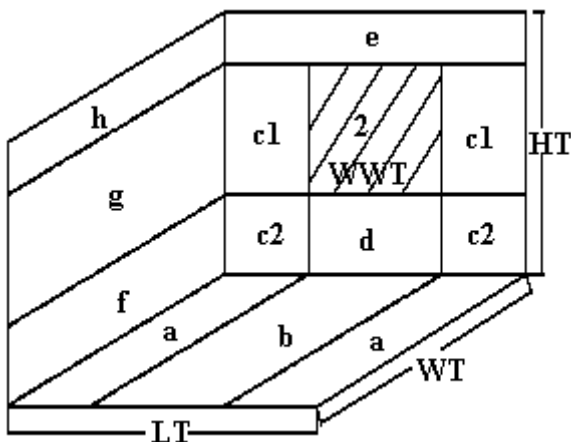
$$\sum_j F_{i,j} = 1$$

$$F_{1,6} := 1 - 2 \cdot F_{6,8} - 2 \cdot F_{6,4} \quad F_{6,1} := F_{1,6}$$

$$F_{5,8} := 1 - 2 \cdot F_{5,4} - 2 \cdot F_{5,6} \quad F_{8,5} := F_{5,8}$$

$$F_{4,7} := 1 - 2 \cdot F_{4,8} - 2 \cdot F_{4,6} \quad F_{7,4} := F_{4,7}$$

Determine the view factor between the window and the floor. Note that the same equations may be used to determine the view factor between the window and all other surfaces except the back wall (6).  $F_{2,6}$  can be calculated from the fact that the sum of the view factors to all surfaces is equal to 1.



$$Ab := WWT \cdot WT \quad A2 := WWT \cdot WHT$$

$$Ad := WWT \cdot WUP \quad DIS := \frac{LT - WWT}{2}$$

$$Ac1 := WHT \cdot DIS \quad Ac2 := WUP \cdot DIS$$

$$Aa := DIS \cdot WT$$

$$Aab := WT \cdot (DIS + WWT)$$

$$w1 := WT$$

$$h2 := WHT + WUP$$

$$comm := WWT$$

$$w := \frac{w1}{comm}$$

$$h := \frac{h2}{comm}$$

$$Fb\_2d := Fij(w, h)$$

... F from Ab to A2+Ad

$$w1 := WT$$

$$h2 := WUP$$

$$comm := WWT$$

$$w := \frac{w1}{comm}$$

$$h := \frac{h2}{comm}$$

$$Fb\_d := Fij(w, h)$$

$$Fb\_d = 0.028$$

$$w1 := WT$$

$$h2 := WUP$$

$$comm := DIS$$

$$w := \frac{w1}{comm}$$

$$h := \frac{h2}{comm}$$

$$Fa\_c2 := Fij(w, h)$$

$$Fa\_c2 = 0.018$$

$$w1 := WT$$

$$h2 := WHT + WUP$$

$$comm := DIS$$

$$w := \frac{w1}{comm}$$

$$h := \frac{h2}{comm}$$

$$Fa\_c1c2 := Fij(w, h)$$

... F from Aa to Ac1+Ac2

$$w1 := WT$$

$$h2 := WHT + WUP$$

$$comm := WWT + DIS$$

$$w := \frac{w1}{comm}$$

$$h := \frac{h2}{comm}$$

$$F_{ab\_c1c2d2} := F_{ij}(w, h) \quad \dots \text{ F from } A_{ab} \text{ to } A_{c1+A_{c2}+A_d+A_2}$$

$$w1 := WT \quad h2 := WUP$$

$$comm := WWT + DIS$$

$$w := \frac{w1}{comm} \quad h := \frac{h2}{comm}$$

$$F_{ab\_c2d} := F_{ij}(w, h)$$

$$F_{2\_b} := (F_{b\_2d} - F_{b\_d}) \cdot \frac{A_b}{A_2}$$

$$F_{a\_2d} := \frac{A_{ab} \cdot F_{ab\_c1c2d2} - A_a \cdot F_{a\_c1c2} - A_b \cdot F_{b\_2d}}{2 \cdot A_a}$$

$$F_{a\_d} := \frac{A_{ab} \cdot F_{ab\_c2d} - A_a \cdot F_{a\_c2} - A_b \cdot F_{b\_d}}{2 \cdot A_a}$$

$$F_{2\_a} := (F_{a\_2d} - F_{a\_d}) \cdot \frac{A_a}{A_2}$$

$$F_{2,7} := 2 \cdot F_{2\_a} + F_{2\_b} \quad F_{7,2} := A_2 \cdot \frac{F_{2,7}}{A_7}$$

To calculate  $F_{2,4}$ , interchange WUP with HT - WHT - WUP in the above calculations.

In this case, because the window is in the center of surface 1,  $F_{2,4} = F_{2,7}$ .

Also

$$F_{3,7} := F_{1,7} - F_{2,7}$$

Important view factors:

$$F_{6,4} = 0.287 \quad \text{back wall to ceiling (or floor)}$$

$$F_{5,6} = 0.118 \quad \text{right wall (or left wall) to back wall}$$

$$F_{2,7} = 0.295 \quad \text{window to floor}$$

$$F_{4,7} = 0.415$$

ceiling to floor

$$F_{4,8} = 0.178$$

$$F_{4,6} = 0.115$$

$$F_{5,8} = 0.171$$