Exercises on Load and Energy Calculations

1. What are the major components of space cooling load? Draw a flow-chart diagram to explain the basic principles of cooling load calculation.

<u>Solution</u>: (outline only)

Major components of space cooling load are:

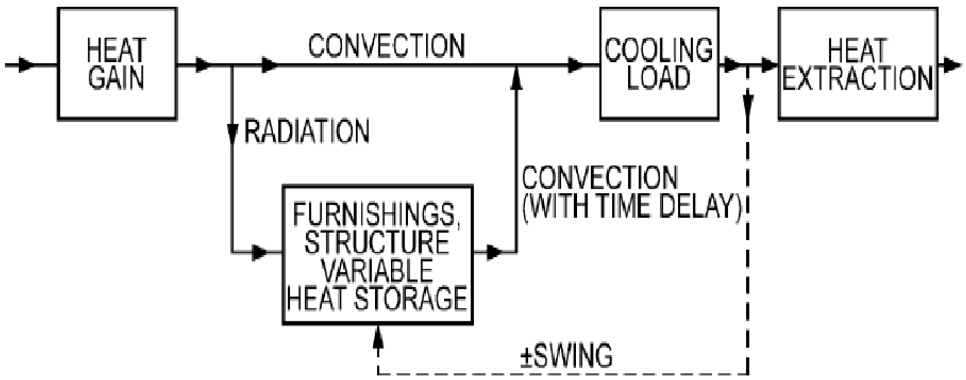
1. External loads

    - Heat gain through exterior walls and roofs
    - Solar heat gain through fenestrations (windows)
    - Conductive heat gain through fenestrations
    - Heat gain through partitions & interior doors
    - Infiltration of outdoor air

2. Internal loads

    - People
    - Electric lights
    - Equipment and appliances

A flow-chart diagram to show the basic principles of cooling load calculation:



2. Determine the cooling load due to sensible and latent heat gains from the occupants for an office building as described below.

• Office building:
 	
- Floor area = 150 m x 70 m
- Working time = 8 hours
- Occupant density = 12.5 m^2/person
	• Cooling load estimation data:
	
	- Cooling load factor (CLF) = 0.84
	- Heat gain from occupants:-
	  - Total heat = 115 W per person
	  - Sensible heat = 70 W per person

Solution: (outline only)

Total floor area, A = 150 m x 70 m = 10,500 m^2

With an occupant density 12.5 m^2/person, the number of occupants is = 10,500 / 12.5 = 840 persons

Given cooling load factor (CLF) = 0.84 for occupants, thus the cooling load due to the occupants is:

Sensible = 840 x 70 x 0.84 = 49,392 W = 49.392 kW

Latent = 840 x (115 – 70) = 37,800 W = 37.8 kW

3. Explain the three common steady-state methods for energy calculation in buildings. What is the major limitation of these methods?

Solution: (outline only)

Three common steady-state methods for energy calculation in buildings are:

(a) Degree-day method

- A degree-day = the sum of the number of degrees that the average daily temperature is above (for cooling) or below (for heating) a base temperature times the duration in days
- Summed over a period or a year for indicating climate severity
- t_{bal} = base temperature (or balance point temperature) e.g. 18.3 °C

Heating degree-day:

$$DD_h(t_{bal}) = (1 \text{ day}) \sum_{\text{days}} (t_{bal} - t_o)^+$$

Cooling degree-day:

$$DD_c(t_{bal}) = (1 \text{ day}) \sum_{\text{days}} (t_o - t_{bal})^+$$

(b) Variable base degree-day (VBDD) method

- Degree-day with variable reference temperatures
- To account for different building conditions and variation between daytime and nighttime
- First calculate the balance point temperature of a building and then the heating and cooling degree hours at that base temperature

(c) Bin and modified bin methods

- They evolve from VBDD methods and derive building annual heating/cooling loads by calculating its loads for a set of temperature "bins" and multiplying the calculated loads by nos. of hours represented by each bin (e.g. 18-20, 20-22, 22-24 °C)
- Totaling the sums to obtain the loads (cooling/heating energy)
- Original bin method: not account of solar/wind effects; modified bin method: account for solar/wind effects

The major limitation of these methods is they cannot cater for dynamic behaviours of the buildings.

4. An engineer has performed load and energy calculations for a building using a building energy simulation program. A brief summary of the results is given below.

- Design space cooling load:

  - Total sensible cooling load = 75.9 kW
  - Total latent cooling load = 52.5 kW

- Building energy performance:

  - Annual energy consumption = 589,000 MJ
    - Lighting = 204,000 MJ - Fans = 84,000 MJ
    - Equipment = 77,000 MJ - Heat reject = 5,000 MJ
    - Space heat = 55,000 MJ - Pumps & miscell. = 3,000 MJ
    - Space cool = 141,000 MJ - Domestic hot water = 20,000 MJ

Calculate the sensible heat ratio and the design flow of the cooling supply air if the temperature difference between the supply air and room air is 11 ºC. Assume air density is 1.2 kg/m^3 and specific heat of air is 1.02 kJ/kg.K.

If the total floor area of the building is 929 m^2, determine the energy utilization index (kWh/m^2/year) of the building energy consumption and calculate the percentage of energy use due to HVAC systems.

Solution: (outline only)

Sensible heat ratio = 75.9 / (75.9 + 52.5) = 0.59

Design flow of the cooling supply air = 75.9 / (1.2 x 1.02 x 11) = 5.6 m^3/s

Energy utilization index (kWh/m^2/year) of the building energy consumption is:

= 589,000 / 3.6 / 929 = 176 kWh/m^2/year

The percentage of energy use due to HVAC systems is

= Space heat + Space cool + Fans + Heat reject + Pumps & miscall.

= (55,000 + 141,000 + 84,000 + 5,000 + 3,000) / 589,000

= 48.9 %