

Definitions

Conduction	It is the transfer of heat through a material
Radiation	It is energy transmitted directly through space
Convection	It is the transfer of heat by the movement of fluids such as air or water
Emissivity(ϵ)	ratio of the radiation emitted by the surface at a given temperature to the radiation emitted by a blackbody at the same temperature.
blackbody	The idealized surface that emits radiation at this maximum rate
Kirchhoff's Law (1860)	At the thermal equilibrium, the power radiated by an object must be equal to the power absorbed.
Heat	It is the form of energy that can be transferred from one system to another as a result of temperature difference.

Definitions (cont)

Thermo dynamics	We can determine the amount of heat transferred using a Thermodynamic analysis alone. It deals with equilibrium states and changes from one to another.
Heat Transfer	It deals with systems that lack thermal equilibrium. It is the science that deals with the determination of the rates of such energy transfers is called heat transfer. Unit is Btu/hr, or Watt (1 W = 3.41 Btu/hr)
Infiltration	is the accidental heat loss/gain due to air leaking through the envelope, doors, windows etc.
Ventilation	is the deliberate, designed introduction of air into/out of a space required for healthy buildings
Heat Loss(Btu/hr)	The heat transfer through each element to outdoor in winter season.

Definitions (cont)

Peak Heating Loads(-Btu/hr)	the amount of heat lost to the outdoor environment at design outdoor and indoor conditions, which must be made up by the HVAC system to maintain occupant comfort.
Annual Heating Energy-(Btu)	The energy consumption during winter heating season. It will consider the heat gains from lights, human activities, appliances, etc.
When will the peak heating loads happen?	Lowest weather temperature • At night (no solar) • No internal gains • Ignore thermal mass
When will the peak cooling loads happen?	Highest weather temperature • Maximum solar gains (window orientation) • Maximum internal heat gains • Ignore thermal mass

Appropriate terms and questions

The heat (loss or gain) during a day is about #___?	B. Btu, D. Joule
The heat flow rate in this situation is # ___?	C. Btu/hr



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Appropriate terms and questions (cont)

____ (heating or cooling) loads for a year will be needed
B. MBtu, D. Joule

____ peak heating loads are documented.
B. MBtu, D. Joule

R_{subt} Total thermal resistance - Ability of a construction assembly to insulate heat, including air films

U Overall coefficient of heat transmission - Ability of a construction assembly to transfer heat, including air films

When will the peak heating loads happen?
• Lowest weather temperature • At night (no solar) • No internal gains • Ignore thermal mass

When will the peak cooling loads happen?
• Highest weather temperature • Maximum solar gains (window orientation) • Maximum internal heat gains • Ignore thermal mass

Why do we need to calculate Peak heating/cooling loads
To size the heating/cooling equipment, ducts, etc.

Appropriate terms and questions (cont)

Why do we need to calculate these Annual heating/cooling energy
To estimate the annual energy use by a system so we can tell the building owners how much it will cost to operate a building with a proposed system.

Thermal Gradient

Thermal Gradient Calculation Example

Here's an example of a simple wall section with the thickness of each material provided (Outdoor = 0 C; and Indoor = 20 C):



- Step 1: Determine what units are being used.
- Step 2: Make a chart of all the materials in the assembly. In the chart include columns for Resistance of each layer.
 - Find out air space Resistance - effective emissivity
 - Find out interior and exterior surface coefficient
- Step 3: Calculate the total R value and U value.
- Step 4: Calculate the overall heat flow Q.
- Step 5: Calculate the temperature change for each layer.
- Step 6: Draw or sketch a section for thermal gradient

Calculations

U value calculation $U = 1 / \sum \langle R \rangle = \text{Btu/h ft}^2 \text{ OF}$

Calculations

U value calculation [Btu/hr ft² OF]
 $U = 1 / \sum \langle R \rangle$

U value with frames [Btu/hr ft² OF]
 $U = 1 / \sum \langle R \rangle$ where $R = R_{stud} \% \text{ area stud of sample} + R_{insulation} \% \text{ area ins of sample}$

Emissivity $Q_{emit} = \epsilon \delta AT^4$ where $\epsilon =$ emissivity of surface

Air Space $1/E = 1/\epsilon_{sub1} + 1/\epsilon_{sub2} - 1$

Heat Flow (q) [BTU/hr]
 $q = u \times A \times \text{deltaT}$

Thermal Gradient [BTU/hr]
 $q = u \times A \times \text{deltaT}$

Calculations (cont)

Heat loss through slab-on-grade floors
 $q = F2 \times P \times \text{deltaT}$

Heat flow through windows
 $q = UA(T_{in} - T_{out})$

Heat flow through windows pt2
 $q = ASHGC E_t$

Heat flow by infiltration
 $q_v = V \times 1.08 \times \Delta T$

Latent Heat by Infiltration or Ventilation
 $q_{latent} = 4840 \times V \times \Delta W$

Simple heat loss calculation
total heat loss = $Q_{win} + Q_{walls} + Q_{door} + \dots + Q_{infiltration}$

Annual Energy Estimation
 $E_{heating} = UA_{ref} \times (HDD) \times (24) / k$ where $UA_{ref} = Q_{heat loss} / \Delta T$

Annual Energy Estimation pt2
 $E_{fuel} = E_{heating} / V$

F2 (this is not U-value)
heat loss coefficient from above (Btu/h-ft-F)

Eheating:
Annual heating energy in Btu

UA_{ref} : average heat loss rate from a building
HDD: the degree days at the reference temperature
k: heating system efficiency
 $U =$ U-factors of window assemblies (Btu/h ft² F)
 $Q =$ rate of heat flow (Btu/hr)
SHGC= solar heat gain coefficient
 $E_t =$ total incident irradiance
 deltaW is found on the psychometric chart in-out (right side)
 E_{fuel} : Amount of fuel
 V : heat value of fuel