1.020 Ecology II: Engineering for Sustainability
Spring 2008

Lectures 08_8 & 08_9 Outline: Basic Thermodynamic Concepts, Building Energy

Motivation/Objective
Develop a model to determine how construction materials affect inside temperature and heat loss in a small house.

Approach
1. Define system, identify unknown (interior temperature T_i)
2. Write energy balance equation (rate form)
3. Relate terms in balance eq to unknown temperature and other inputs
4. Specify heat capacities, thermal resistances, meteorological inputs, etc, solve energy balance eq. for unknown interior temperature (MATLAB)
5. Compute heat loss, examine impact of building material properties

Concepts and Definitions Needed:
Relevant thermodynamic properties: Mass, volume, internal energy, enthalpy, heat capacity, temperature
Energy balance, First Law of Thermodynamics for a closed system:
Increase in system energy = Energy in across system boundary = Heat in - Work out:

Incremental form: $\Delta U = \Delta Q - \Delta W$

Infinitesimal form: $dU = \delta Q - \delta W$

Rate form: $\frac{dU}{dt} = \dot{Q} - \dot{W}$

Internal energy term: Write in terms of constant volume heat capacity $\frac{dU}{dt} = C_{vh} \frac{dT_i}{dt}$

Heat mechanisms:

Conduction, convection into system: $\dot{Q}_{cond,conv} = \frac{A_h (T_{air} - T_i)}{R_{ia}}$

Outgoing radiation: $\dot{Q}_{rad} = \varepsilon \sigma T_i^4$

Work done: Assume zero for house problem

Complete balance eqs:
Consider only conduction & convection through walls & roof (no net radiation into house):
$C_{vh} \frac{dT_i}{dt} = \dot{Q}_{wall} + \dot{Q}_{roof} = A_w \frac{[T_{air} - T_i]}{R_{ia}} + A_r \frac{[T_{air} - T_i]}{R_{ia}}$, specify T_{air}

Model Results
Note energy saved as insulation is improved.