1. **Modes of Heat Transfer**
   1. Conductive Heat Transfer
      1. Intro to Conductive Heat Transfer
         1. Movement of thermal energy through a medium from more energetic particles to the less energetic
         2. Temperature associated with energy of molecules
         3. Energy transferred from higher to lower temperature
            1. Diffusion of energy
            2. Solid: molecules cannot move, so energy diffuses between them.
            3. Liquid: space larger than in solid, so less effective flow
         4. Conduction heat equation
            1. **qx/A = -k dT/dx**

Qx = rate of heat flow in x direction

A = area perpendicular to x direction

K = thermal conductivity of the medium

Units = W/mK

T = temperature at location x

qx/A = heat flux = qx’’

* + - * 1. Fourir’s Law: **qx/A = -k dT/dx**

Algebraic: **qx’’ = -k ΔT/Δx**

* + - 1. Example: Heat Flux through a Wall
    1. Thermal Conductivity of Biological and Other Materials
       1. Mostly water
       2. Close to values for water
       3. Dry biomaterials conductivity less than water
    2. Thermal Diffusivity
       1. Fourier’s Law rewrite: **qx’’ = - k dT/dx = -k/⍴cp \* d(⍴cpT)/dx = -α dU/dx**
          1. **U/⍴cpT**
          2. **α = k/⍴cp**

Units: m2/s

* + - * 1. Energy flux = α \* gradient in energy
    1. Density and Specific Heat
       1. Density and specific heat are parts of thermal mass of system
       2. Affect temperature change in system
       3. Higher density and specific heat = larger is energy it takes to change temperature by one degree
       4. Two types of density
          1. Solid and bulk
          2. Important when material i porous
          3. Porosity = volume of pores / total volume of solid
  1. Convective Heat Transfer
     1. Movement of heat through medium as result of net motion in medium
     2. Forced convection driven by density difference
     3. Convection over a surface:
        1. **Q1-2 = hA(T1-T2)**
           1. Q1-2 is heat flow rate from 1 - 2 in W
           2. A is area normal to direction of heat flow in m2
           3. T1 - T2 is temperature difference between surface and fluid
           4. H is convective heat transfer coefficient

W/m2 °C

Includes effect of conduction in fluid and bulk flow

Function of system geometry, fluid and flow properties, and magnitude of ΔT

* 1. Radiative Heat Transfer
     1. All matter emits radiative energy
     2. Changes in electron configuration of atoms within matter
     3. Emitted as electronic waves
     4. Does not require a medium
     5. Maximum flux of radiation: Stefan-Boltzmann Law
        1. **q/A = σT4**
           1. σ = 5.676 \* 10-8 W/m2K4
     6. Energy transfer depends on surface and geometric factors