Energy

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Learning Outcomes

- This section supports to partially achieve the learning outcomes LO1 and LO2.
- Following areas will be covered
  - ✓ Heat and heat transfer
  - ✓ Work and Power
  - ✓ Heat transfer by mass transport (advection)

What is Energy?

- Energy may be viewed as the capacity to do work or the ability to cause changes
- Different forms of energy

Make a list yourself

Energy Categories

- Important energy categories in thermodynamic analysis:
- Macroscopic energy
  - ✓ The macroscopic energies are those which a system possesses as a whole with respect to some outside reference frame, such as kinetic energy (KE) and potential energy (PE).
- Microscopic energy
  - ✓ The microscopic forms of energy are those which are related to the molecular structure of a system and the degree of the molecular activity, and they are independent of outside reference frames. Sum of all the microscopic energies are called the internal energy of a system and is usually dented by U.

Total Energy

- Total Energy (E)
  - ✓ Sum of all the macroscopic and microscopic energies of a system

$E = U + KE + PE$

$E = U + ½\, mV^2 + mgh$

Energy per unit mass e can be given as

$e = u + ½\, V^2 + gh$

Heat and Work

- Both are forms of energies.
- Both are energy in transition.
- Can be detected when it crosses a system boundary

Heat Transfer

- Three Main Methods of Heat Transfer
  - ✓Conduction
  - ✓Convection
  - ✓Radiation
  - ✓Advection
- Advection is the mode of heat transfer with transport of mass

Convection

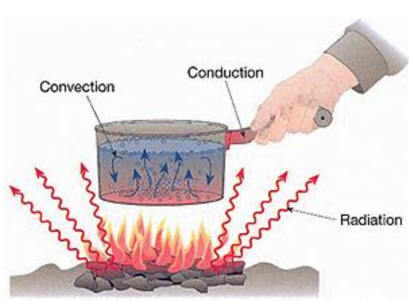
- This is the dominant method of heat transfer within fluids, unless the fluid is stagnant (like in the case of a boundary layer near a solid boundary).
- Convections flows are vertical.
- Fluid partials gain heat and expand as a consequence, thus, decreasing the density. Therefore, hot particles move up carrying heat while cold particles move down to gain heat.
- Convection heat transfer could either be natural convection or forced convection

Radiation

- All matter emits electro-magnetic radiation at temperatures above 0 K.
- Radiation does not require a medium to transfer heat. That's why we get heat from the sun

Conduction

- Heat transfer within solids is governed by conductions. (Heat transfer within stagnant fluid is also by conduction).
- There is no appreciable moment of matter in radiation (unlike in convection).



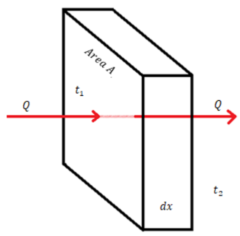
Fourier's Law of Conduction

- The Fourier's law describes how heat is conducted.
- It says, rate of heat transfer is:
  - ✓proportional to the cross-sectional area perpendicular to the direction of heat flow
  - ✓Proportional to the change of temperature with respect to the length of the path of heat transfer

$$\dot{Q} \propto A \qquad \dot{Q} \propto \frac{dt}{dx}$$

$$\boxed{\dot{Q} = -\lambda A \frac{dt}{dx}} \qquad \lambda - thermal\ conductivity$$

Fourier's Law of Conduction



$$\int_0^x \dot{Q}dx = -\int_{t1}^{t2} \lambda A dt$$

Thermal conductivity does not change significantly over a relatively a large temperature range.

$$\dot{Q}x = -\lambda A(t_2 - t_1)$$

Units of λ - W/mK

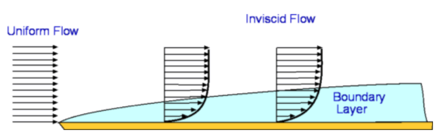
$$\boxed{\dot{Q} = \frac{\lambda A}{x}(t_1 - t_2)}$$

Newton's Law of Cooling

- In real-life applications heat transfer between solid and fluid is very common.
- Newton's law of cooling describes how heat transfer from solid to fluid and vice versa takes place.
- Newton's law does not count heat transfer due to radiation. However, when convection is facilitated with artificial means, thus, forced convection, the amount of heat transfer due to radiation is negligible compared to that by conduction and convection. Thus, Newton's law is best applicable under forced convection.

Newton's Law of Cooling

- What is boundary layer?
  - ✓ It is the stagnant fluid layer attached to a solid surface.
  - ✓ Because the boundary layer is stagnant, heat transfer within the boundary layer is by conduction.



Newton's Law of Cooling

- The rate of heat transfer from a solid surface of surface area A, which is at temperature t_1, to a fluid at temperature t_2 is given by:

$$\dot{Q} = \alpha A(t_1 - t_2)$$

α $-$ *heat transfer coefficient*

Units of α- W/m^{2}K

Overall Heat Transfer Coefficient (U)

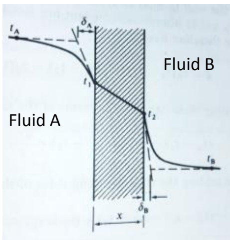
- In many real-world, applications are many where heat is transferred from a fluid to a solid and then back to another fluid.
- Examples:
  - ✓ Heat transfer through a wall: one side is air (may be outside air) and then the wall, and thereafter again air (may be inside a room).
  - ✓ Heat loss through a steam pipeline: Heat is transferred from steam to the pipe wall (solid) and then to the surrounding air.
  - ✓ Non-mixing heat exchangers

Overall Heat Transfer Coefficient (U)

- The overall heat transfer coefficient combines the heat transfer coefficients between solid and fluid, and the thermal conductivity of solid.

Overall Heat Transfer Coefficient (U)

- Consider the following example



Let's derive the equation together

Example

A mild steel tank of wall thickness 10 mm contains water at 90 ^{0}C when the atmospheric temperature is 15 ^{0}C. The thermal conductivity of mild steel is 50 W/mK, and the heat transfer coefficients for the inside and outside of the tank are 2800 and 11 W/m^{2}K respectively. Calculate:

1. The rate of heat loss per unit area of tank surface
2. The temperature of the outside surface of the tank