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FACULTY OF ENGINEERING AND TECHNOLOGY

Department of Mechanical Engineering

BME504:Heat and Mass Transfer

Lecture 4

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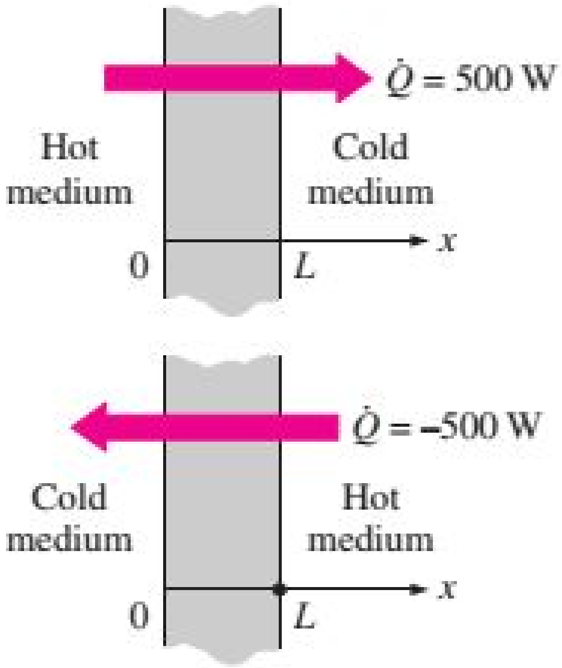
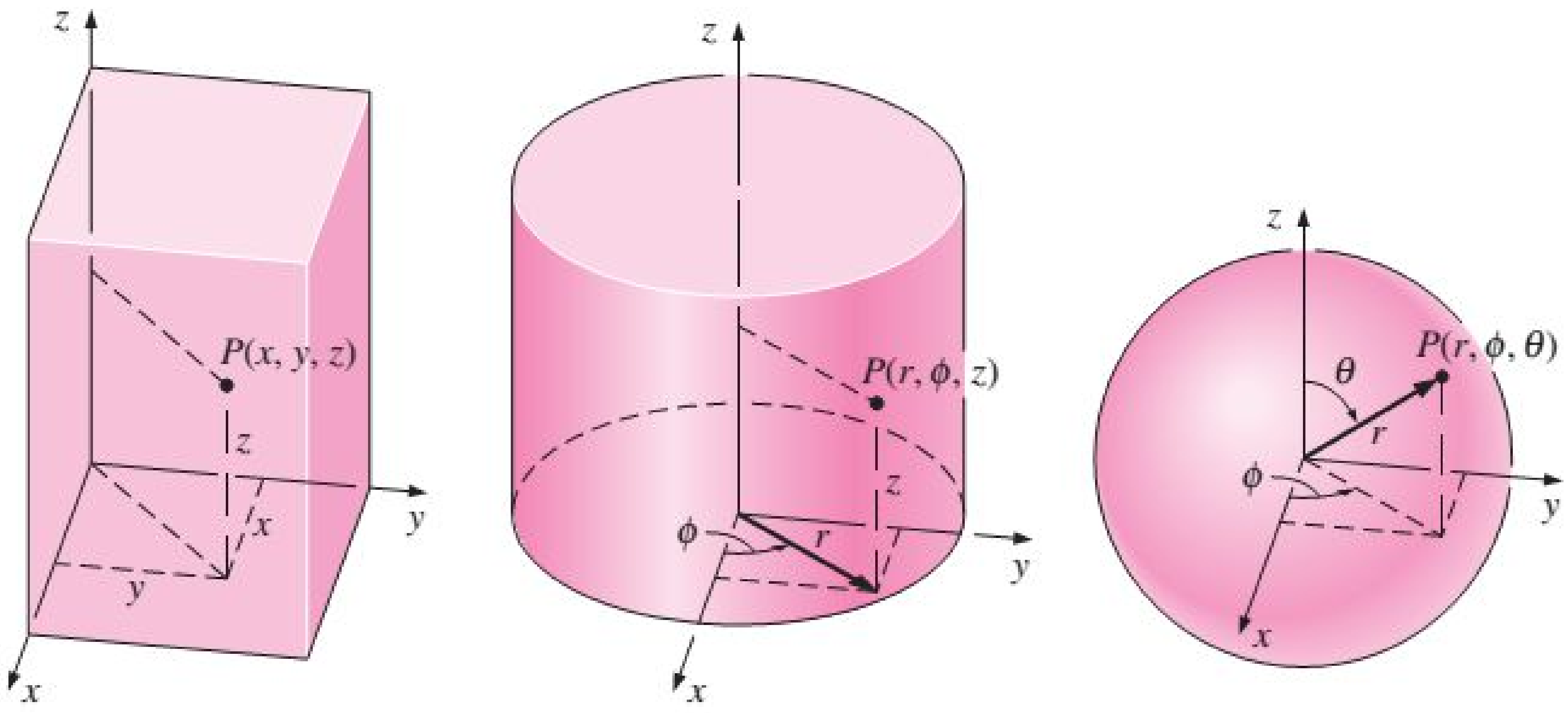
Conduction Introduction

- **Heat transfer** has direction as well as magnitude, and thus it is a **vector quantity**
  - Must specify **both direction and magnitude** in order to describe heat transfer completely at a point.
- Question: In the figure below tell us whether heat conduction is toward the inside (indicating heat gain) or toward the outside (indicating heat loss) or vice versa?
- To avoid such questions, a coordinate system and indicate direction with plus or minus signs can be developed



Different Kinds of Coordinate systems

- The notation T(x, y, z, t) implies that the temperature varies with the space variables x, y, and z as well as time.



(a) Rectangular coordinates (b) Cylindrical coordinates (c) Spherical coordinates

MULTIDIMENSIONAL HEAT TRANSFER

- Heat transfer problems are also classified as being
  - one-dimensional,
  - two dimensional, or
  - three dimensional,

depending on the relative magnitudes of heat transfer rates in different directions and the level of accuracy desired.

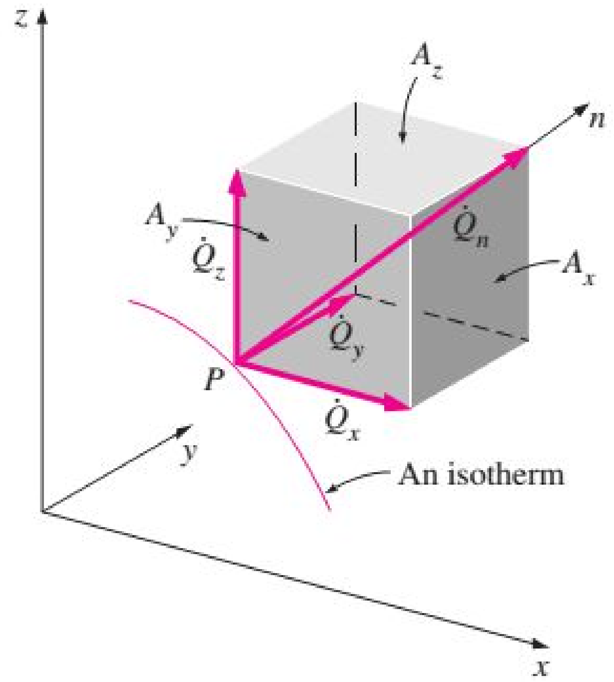
- A heat transfer problem is said to be one-dimensional if
  - the temperature in the medium varies in one direction only and thus heat is transferred in one direction,
  - the variation of temperature and thus heat transfer in other directions are negligible or zero.

MULTIDIMENSIONAL HEAT TRANSFER

- **Fourier's law** of heat conduction for one-dimensional heat conduction as
  - ***k*** is the thermal conductivity of the material, which is a measure of the ability of a material to conduct heat
  - ***dT/dx*** is the temperature gradient, which is the slope of the temperature curve on a T-x diagram
  - Heat is conducted in the direction of decreasing temperature, and thus the temperature gradient is negative when heat is conducted in the positive x-direction. The negative sign in equation ensures that heat transfer in the positive x-direction is a positive quantity

$$\dot{Q}_{\text{cond}} = -kA\frac{dT}{dx}$$

General relation for Fourier's law of heat conduction



$$\vec{\dot{Q}}_n = \dot{Q}_x \vec{i} + \dot{Q}_y \vec{j} + \dot{Q}_z \vec{k}$$

$$\dot{Q}_x = -kA_x \frac{\partial T}{\partial x}, \qquad \dot{Q}_y = -kA_y \frac{\partial T}{\partial y}, \qquad \text{and} \qquad \dot{Q}_z = -kA_z \frac{\partial T}{\partial z}$$

Questions

2–24 Consider a medium in which the heat conduction equation is given in its simplest form as

$$\frac{\partial^2 T}{\partial x^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

(*a*) Is heat transfer steady or transient?
(*b*) Is heat transfer one-, two-, or three-dimensional?
(*c*) Is there heat generation in the medium?
(*d*) Is the thermal conductivity of the medium constant or variable?

Questions

2–25 Consider a medium in which the heat conduction equation is given in its simplest form as

$$\frac{1}{r}\frac{d}{dr}\left(rk\frac{dT}{dr}\right) + \dot{g} = 0$$

(*a*) Is heat transfer steady or transient?
(*b*) Is heat transfer one-, two-, or three-dimensional?
(*c*) Is there heat generation in the medium?
(*d*) Is the thermal conductivity of the medium constant or variable?

Questions

2–26 Consider a medium in which the heat conduction equation is given in its simplest form as

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right) = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

(*a*) Is heat transfer steady or transient?
(*b*) Is heat transfer one-, two-, or three-dimensional?
(*c*) Is there heat generation in the medium?
(*d*) Is the thermal conductivity of the medium constant or variable?

Questions

2–27 Consider a medium in which the heat conduction equation is given in its simplest form as

$$r\frac{d^2T}{dr^2} + \frac{dT}{dr} = 0$$

(*a*) Is heat transfer steady or transient?
(*b*) Is heat transfer one-, two-, or three-dimensional?
(*c*) Is there heat generation in the medium?
(*d*) Is the thermal conductivity of the medium constant or variable?

Questions

2–33 Consider a medium in which the heat conduction equation is given in its simplest form as

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial t}\right) + \frac{1}{r^2 \sin^2\theta}\frac{\partial^2 T}{\partial \phi^2} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

(*a*) Is heat transfer steady or transient?
(*b*) Is heat transfer one-, two-, or three-dimensional?
(*c*) Is there heat generation in the medium?
(*d*) Is the thermal conductivity of the medium constant or variable?