Fundamentals of Heat Transfer-CHE 216
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Muhammad Rashid Usman

Institute of Chemical Engineering and Technology

University of the Punjab, Lahore.

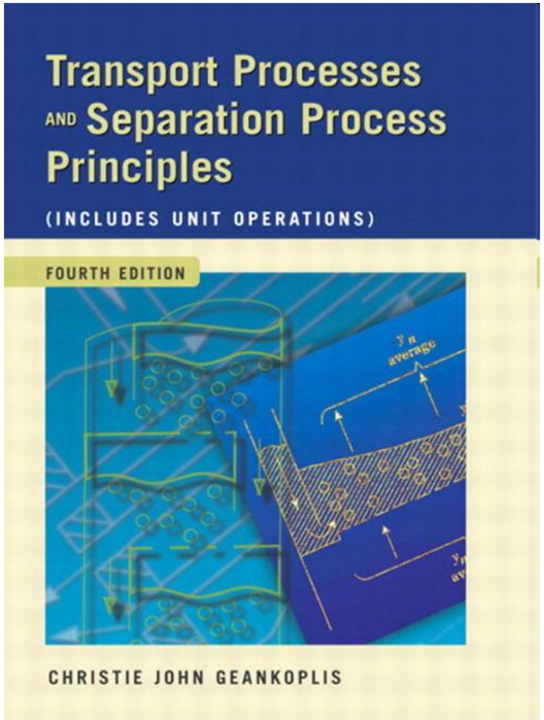
Figure taken from: http://heatexchanger-design.com/2011/10/06/heat-exchangers-6/ Accessed on: 17-Jan-2012

Course contents mid term

Introduction to transfer processes. Definition, applications, and various units of heat transfer. Modes of heat transfer: Conduction, convection, and radiation heat transfer. Fourier's law of heat conduction. Thermal conductivity of gasses, liquids, and solids. Units of thermal conductivity. Effect of temperature, pressure, and composition on thermal conductivity of materials. Estimation of thermal conductivity of gases, liquids, and solids. Introduction to steady-state heat transfer. Heat conduction through plane wall, hollow cylinder, and hollow sphere. Numerical problems related to heat conduction through plane wall, hollow cylinder, and hollow sphere. Thermal resistances in series: Composite plane wall, composite hollow cylinder, and composite hollow sphere. Numerical problems related to heat conduction through composite plane wall, composite hollow cylinder, and composite hollow sphere. Free and forced convection. Rate equation for convective heat transfer coefficient. Brief description of hydrodynamic boundary layer and heat transfer coefficient. Units of heat transfer coefficient. Individual and overall heat transfer coefficients: plane wall and hollow cylinder. Numerical problems regarding overall heat transfer coefficient. Determination of heat transfer coefficient. Description of various heat transfer correlations. Heat transfer in coiled and jacketed agitated vessels.

The text book

Please read and consult to know and learn.



Geankoplis, C.J. (2003). Transport processes and separation process principles: includes unit operations. 4^{th} ed. Prentice-Hall International, Inc.

Transfer processes

For a transfer or rate process

$$Rate\ of\ a\ quantity \propto driving\ force$$

$$Rate\ of\ a\ quantity \propto area\ for\ the\ flow\ of\ the\ quantity$$

$$Rate\ of\ a\ quantity = \left(\frac{1}{resistance}\right) \times Area \times driving\ force$$

$$Rate\ of\ a\ quantity = conductance \times Area \times driving\ force$$

$$Flux\ of\ a\ quantity = conductance \times driving\ force$$

Driving force is the corresponding gradient and conductance is a transport property.

Compare the above equations with Ohm's law of electrical conductance.

Transfer processes

$$Rate\,of\;a\,quantity = \frac{change\,in\,the\,quanity}{change\,in\,time}$$

$$Flux\,of\;a\,quantity = \frac{rate\,of\;the\,quantity}{area\;for\;flow\,of\;the\,quantity}$$

$$Gradient\,of\;a\,quantity = \frac{change\,in\,the\,quanity}{change\,in\,distance}$$

The gradient is defined in differential form, i.e., it is the change in a quantity with respect to change in distance when distance approaches to zero.

Transfer processes

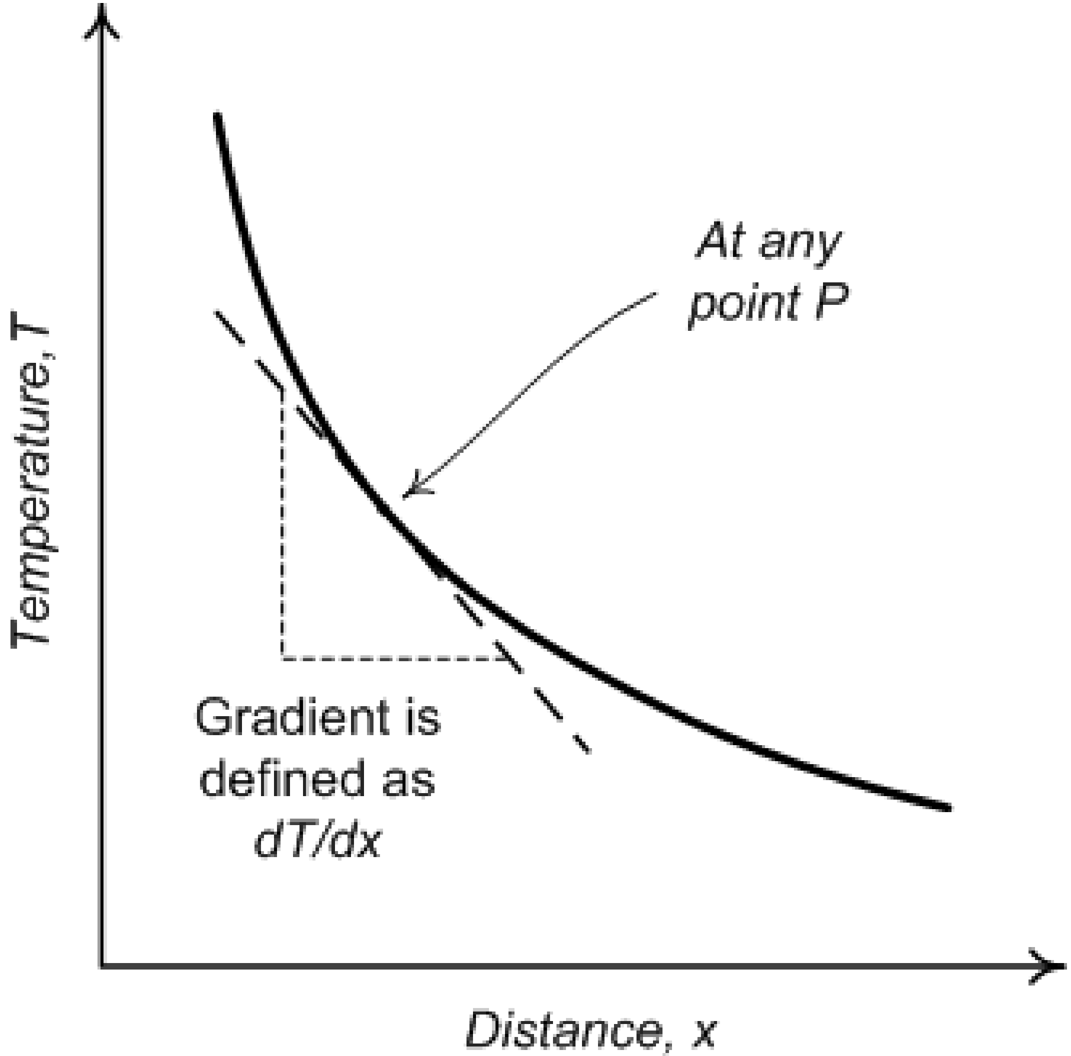
In chemical engineering, we study three transfer processes (rate processes), namely

- Momentum transfer or Fluid flow
- Heat transfer
- Mass transfer

Transfer processes

Rate Process	Driving force	Conductance (Transport property)	Law for molecular transfer
Momentum transfer	Velocity gradient	Viscosity	Newton's law of viscosity
Heat transfer	Temperature gradient	Thermal conductivity	Fourier's law
Mass transfer	Concentration gradient (chemical potential gradient)	Mass diffusivity	Fick's law

Temperature gradient



Transfer processes

Transfer processes are either:

- Molecular (rate of transfer is only a function of molecular activity), or
- Convective (rate of transfer is mainly due to fluid motion or convective currents)

We now start "principles of heat transfer".

Introduction to heat transfer

- Heat transfer is a science which deals with the energy transfer between two given locations as a result of temperature difference.
- First law of thermodynamics says energy can neither be created nor be destroyed. However, energy can be transformed from one from to the other and can be transferred from one point (location) to the other. For an open system, energy can be transferred by mass, heat, and work. Though for a closed system (no mass enters or leaves the system) energy can only be transferred by heat and work. It is important to mention here that heat and work are forms of energy by which energy is transferred from one point to the other or from one body to the other. These two forms are not properties and therefore not possessed by a body. These are energies in transit and vehicles or conveyances to transport energy from one point to the other and unlike properties such as temperature, pressure, and specific volume they do depend on the path followed by energy for its transference. When energy is transferred by a temperature gradient (difference), heat is said to be transferred while transfer of energy by work does not require any kind of such temperature difference. Work is considered a high quality energy compared to heat energy and that leads us to define second law of thermodynamics. An introductory thermodynamics course in the next semesters will hopefully make your concepts of heat and work and their interrelationships more clear.

Introduction to heat transfer

- Thermodynamics encompasses systems at equilibrium and does not give any information about rate of a quantity, say, rate of heat transfer. Time is not a thermodynamic variable. Thermodynamics predicts only the maximum (or minimum) possible amount of a quantity that can be transferred. Heat transfer, on the other hand, deals with rates and predicts how fast or slow the heat will flow from one point to the other. Heat transfer, therefore, helps in sizing the heat transfer equipment.
- Chemical kinetics determines rate of a chemical reaction while heat transfer deals with rate of heat transfer where rate of transfer is a physical phenomenon.

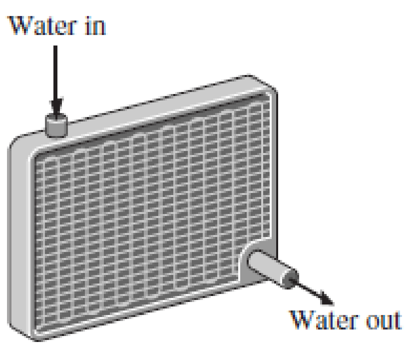
Introduction to heat transfer: Applications

Knowledge of heat transfer is important in designing refrigeration systems, power plants, motor vehicles, major pieces of equipment for petroleum refinery and chemical plants, etc.

Think of daily life examples!!!

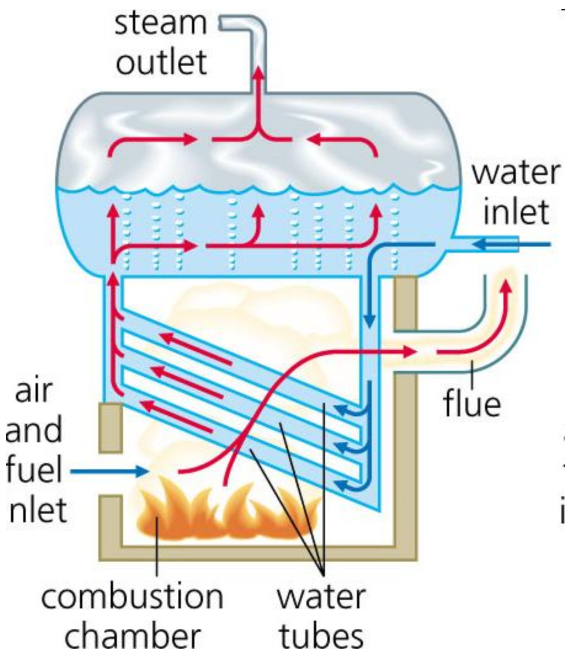
What about wearing warm cloths in winter?

Introduction to heat transfer: Applications

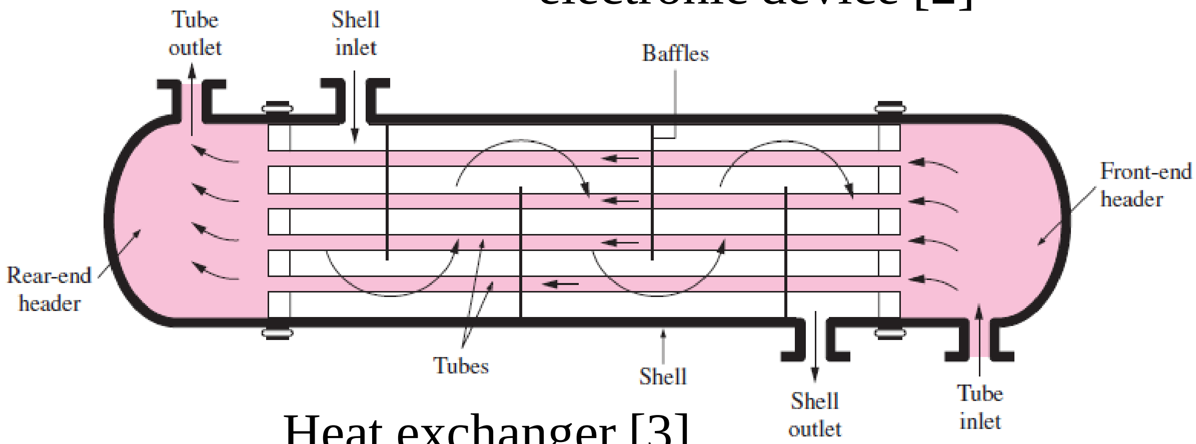


Car radiator [3]

Cooling fins in an electronic device [2]



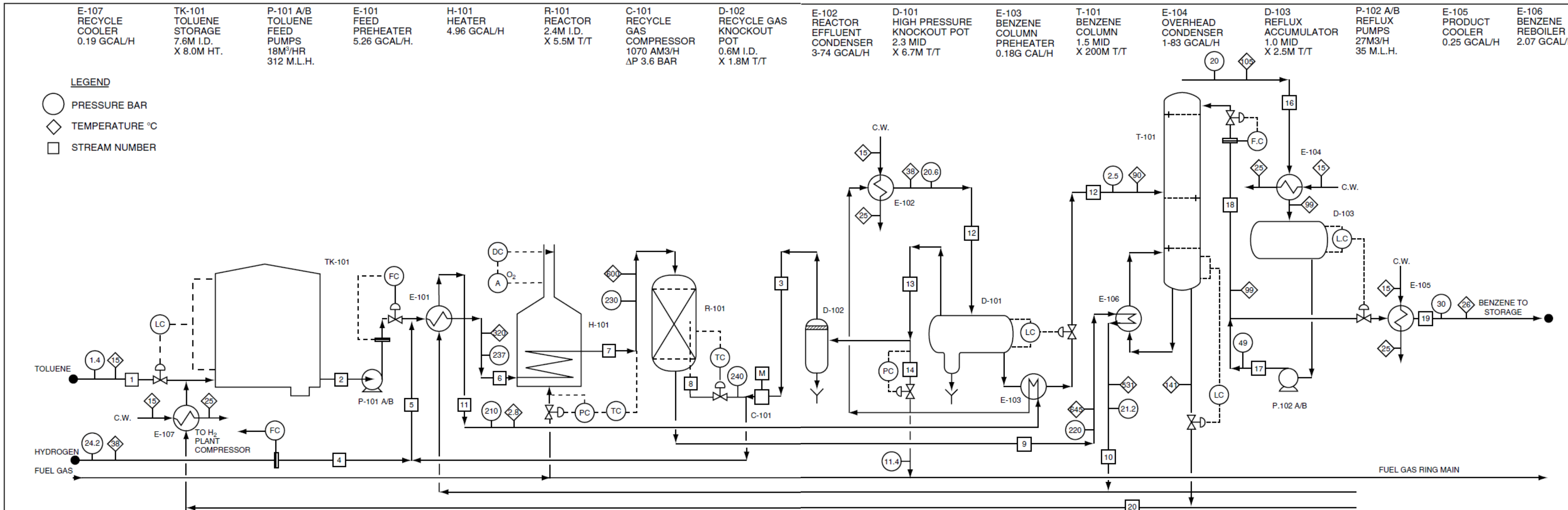
Boiler



Heat exchanger [3]

Figure on far right is taken from http://www.lenntech.com/applications/process/boiler/boiler-feed-water.htm

Introduction to heat transfer: Applications



MATERIAL BALANCE																					
STREAM NUMBER		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
HYDROGEN	KMOL/H	0.0	0.0	470.80	285.00	730.80	730.80	730.80	25.00	647.30	647.30	647.30	647.30	647.30	176.50	0.00	0.00	0.00	0.00	0.00	0.00
METHANE	KMOL/H	0.0	0.0	329.40	15.00	326.90	326.90	326.90	17.50	452.90	452.90	452.90	452.90	452.90	123.50	0.00	0.00	0.00	0.00	0.00	0.00
BENZENE	KMOL/H	0.0	0.40	6.10	0.00	5.80	6.20	6.20	0.30	115.00	115.00	115.00	115.00	8.40	2.30	106.60	245.70	245.70	139.50	106.20	0.40
TOLUENE	KMOL/H	108.70	143.90	0.43	0.00	0.41	144.31	144.31	0.02	35.83	35.83	35.83	35.83	0.59	0.16	3524	0.09	0.09	0.05	0.04	35.00
TOTAL MOLAR FLOW	KMOL/H	108.70	144.30	806.73	300.00	1063.91	1208.21	1208.21	42.82	1251.03	1251.03	1251.03	1251.03	1109.19	302.46	14184	245.79	245.79	139.55	106.24	35.60
TOTAL MASS FLOW	KG H	10.000	13.270	6727	810	7.132	20452	20452	355	20807	20807	20.807	20.807	9.250	2523	11.557	19173	19173	10.836	8.287	3270
TEMPERATURE	°C	15	18	38	38	38	320	600	58	649	531	278	38	38	38	90	105	99	99	30	1.11
PRESSURE	BAR	14	1.1	20.4	24.0	24.0	23.7	230	240	220	212	21.0	20.6	20.6	20.6	2.5	2.0	2.9	2.9	26	0.3
TOTAL HEAT FLOW	GCALS/H	1.33	1.77	-3.36	0.40	-257	4.46	942	-017	913	7.24	198	-194	-462	-126	286	718	539	3.06	206	0.63

XYZ ENGINEERING LTD.
TITLE: PROCESS FLOW DIAGRAM
BENZENE PLANT
Drawn By F.I.T. | Date | DRG. No A-1001 | Rs

Source: Couper, J.R. et al. 2005. Chemical process equipment: Selection and design. 2nd ed. Gulf professional publishing.

Units of energy and heat transfer

- SI units of heat is J (Joule), while in English system units are British thermal unit (Btu).
- SI units of rate of heat transfer = $J \cdot s^{-1}$, while in English system units are $Btu \cdot h^{-1}$.

1.0 cal (thermochemical) = 4.1840 J

1.0 cal (IT) = 4.1868 J

1.0 Btu = 1055.06 J = 252.16 cal (TC)

1.0 $J \cdot s^{-1}$ = 1.0 W (Watt)

1.0 $Btu \cdot h^{-1}$ = 0.29307 W

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