جامعة ديالى
كلية الهندسة
قسم الهندسة الكيمياوية

Unit Operations

Lecturer

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Syllabus design:

3 hours lecture

1 hour tutorial per Week.

2 hours practical in the lab

Theoretical Lectures	Practical part
Boundary layer theory	sedimentation
Transfer of heat, mass. and momentum	cooling towers
Reynolds analogy	drying
Non Newtonian fluids	Reynolds analogy
Mixing	gas-solid and liquid-solid fluidization
Fluid flow through packed columns	pressure drop through packed towers
Fluidization	filtration
Flow of particles through fluids	free falling velocity.
Sedimentation	
Centrifuge	

Textbook:

- ❖ McCabe, W.L., Smith, J.C. and Harriott, P., 1993. Unit operations of chemical engineering (Vol. 5). New York: McGraw-Hill.

References:

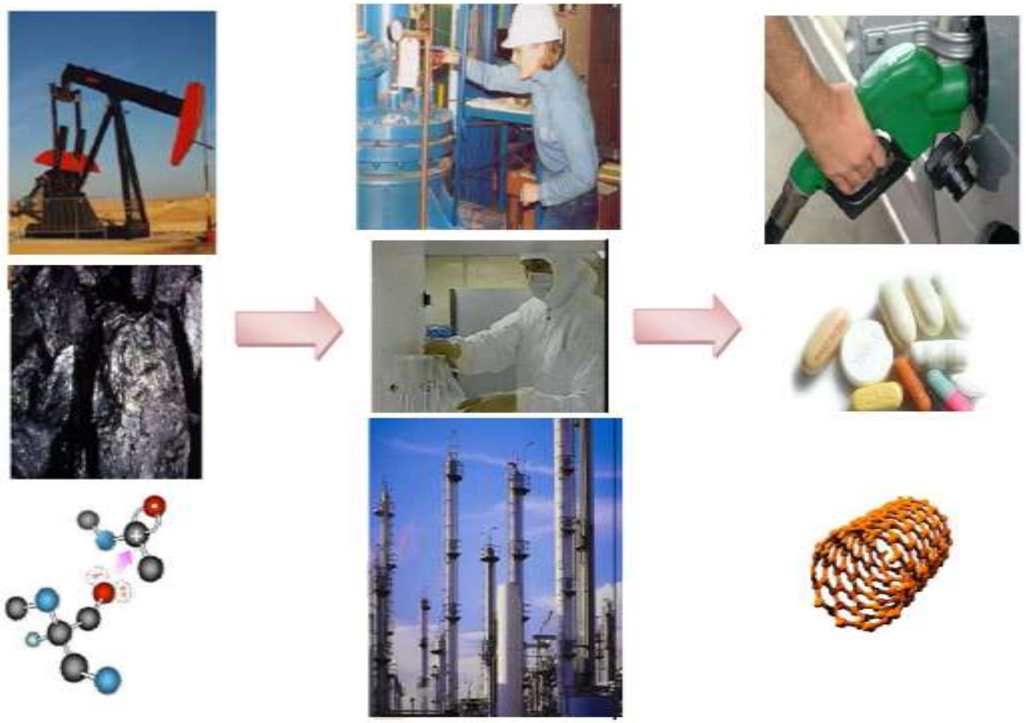
- ❖ Seader, J.D., Henley, E.J. and Roper, D.K., 1998. Separation process principles (Vol. 25). New York: Wiley.

- ❖ Richardson, J.F. and Harker, J.H., 1978. Coulson and Richardsons Chemical Engineering.

Preface:-

What is chemical engineering?

Chemical engineering is a branch of engineering that uses principles of chemistry, physics, mathematics, biology, and economics to efficiently use, produce, design, transport and transform energy and materials.



What are Unit Operations?

Every industrial chemical process is based on Unit Operations (physical treatment) and Unit Process (chemical treatment) to produce economically a desired product from specific raw materials. The raw materials are treated through physical steps to make it suitable for chemical reaction. So, knowledge of unit operations like 'Mixing and agitation of liquid' and' heat flow's very much necessary. The subject Unit Operations is based on fundamental laws, physicochemical principles. Unit Operations gives idea about science related to specific physical operation; different equipments-its design, material of construction and operation; and calculation of various physical parameters (mass flow, heat flow, mass balance, power and force etc.). Examples of Unit Operations are listed in Table 1.

Table 1: List of some unit operations

Heat flow, Fluid flow	**Mixing**	**Adsorption**
Drying	**Absorption**	**Distillation**
Evaporation	**Condensation**	**Crystallization**
Vaporization	**Leaching**	**Separation**
Extraction	**Sedimentation**	**Filtration**

Some examples of physical processes :

1) Sugar Manufacture:

Sugar cane crushing → sugar extraction → thickening of syrup →evaporation of water → sugar crystallization → filtration →drying →screening →packing

2) Salt Manufacture:

Brine transportation → evaporation → crystallization →drying → screening → conveying → packaging.

3) Pharmaceutical Manufacture:

Formulation of chemicals, mixing, granulation → drying of granules→ screening → pressing tablet → packaging.

Unit Operation

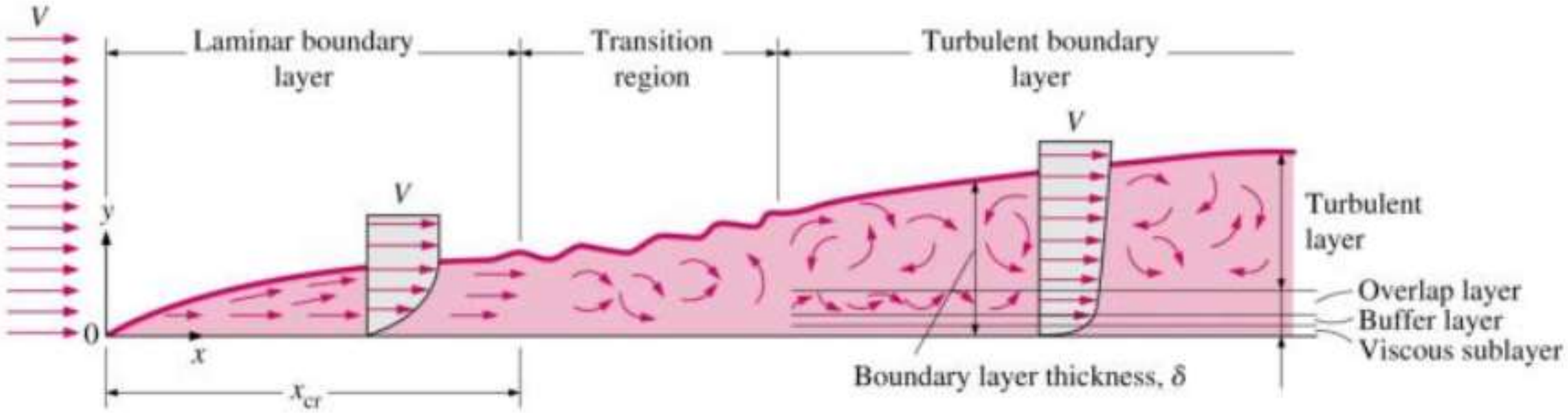
The equipment used in the chemical processes industries can be divided into two classes:.

1. Proprietary equipment,المعدات المسجلة الملكية such as pumps, compressors, filters, centrifuges and dryers, is designed and manufactured by specialist firms.

2. Non-proprietary equipment المعدات غير المسجلة الملكية designed as special , one-off , items for particular processes; for example, reactors, distillation columns and heat exchangers .

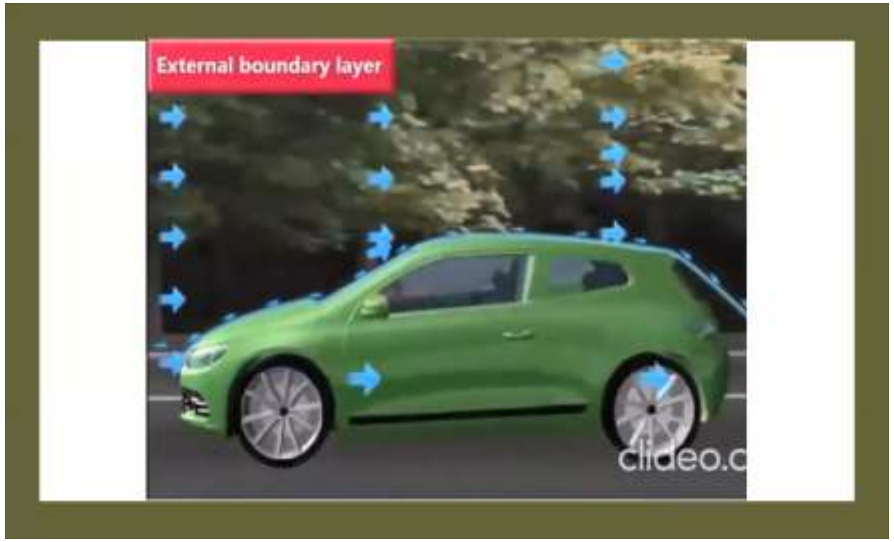
Momentum, Heat, and Mass Transfer

The processes of momentum, heat, and mass transfer is involved in most of the unit operations faced in the chemical and petroleum industries. In some cases , momentum , heat and mass transfer all occur simultaneously as , for example : In a water / cooling tower where transfer of sensible heat; evaporation both take place from the surface of the water droplets. When a fluid flows under turbulent conditions over a surface , the flow can conveniently be divided into three regions:



- At the surface , the viscus sublayer , in which the only motion at right angles to the surface is due to molecular diffusion .
- Next , the buffer layer , in which molecular diffusion and eddy motion are of comparable magnitude .
- Finally , over the greater part of the fluid the turbulent region in which eddy motion is large compared with molecular diffusion .

In addition to momentum , both heat and mass can be transferred either by molecular diffusion alone or by molecular diffusion combined with eddy diffusion . Generally, because the effects of eddy diffusion are more greater than those of the molecular diffusion , the main resistance to transfer lies in the region where the molecular diffusion is only occurring.



Notes:

- Along most of the length of the pipe, there is a constant velocity profile: there is a maximum at the centre-line and the velocity falls to zero at the pipe wall. In the case of laminar flow of a Newtonian liquid, the fully developed velocity profile has a parabolic shape. But for turbulent flow the profile is much flatter over most of the diameter.
- The Continuity Equation will be used most frequently but it is valid only when there is no accumulation ($\rho_1 u_1 V_1 = \rho_2 u_2 V_2$) or $\rho_1 Q_1 = \rho_2 Q_2$
- Where ρ, u, V, and Q are the density, velocity and volume, and volumetric flow rate of fluid at specific point respectively.

Notes:

- Consider two parallel plate of area ***A*** with dz distance between them, the space in between them is filled with a fluid. The lower plate travels with a velocity ***v*** and the upper plate with a velocity ***v***-d***v.*** The small difference in velocity dv between the plates results in resisting force **F** acting over plate area ***A*** due to the viscus frictional effects in the fluid.
- The force per unit area F/A is known as the shear stress **R**.
- Newton's law of viscosity states that the shear stress is proportional to the velocity gradient(-dv/dz) in the fluid.

- $R = -\mu \frac{dv}{dx}$ (1.1)

Where μ is known as the coefficient of dynamic viscosity

Notes:

- When fluid flow over a solid surface , the velocity gradient (du/dx) is organized, and a right angle to the direction of flow, this because viscus acting on the fluid (Newton law) at the leading edge.
- For greater distance from the surface the shear stress became small.
- The region close to the surface is known as boundary layer.
- The thickness of boundary layer will be a function of distance, when the velocity gradient is assumed to be constant.
- The drug force is maximum at the leading edge and the thickness is zero, then increase as the distance from the leading edge increase.
- The boundary layer thickness is small, the flow is streamline or laminar flow.
- At certain critical thickness the flow is changed from streamline to turbulent flow, except within a very thin layer near to surface in turbulent flow remains streamline, this layer is called laminar sub-layer.
- Between the laminar layer and turbulent layer a region of buffer layer is formed