Model question answer

Subject-Pharmaceutical engineering

unit-1

10 Marks

1) **Derive Bernoulli's equation stating the assumptions? Discuss the various applications of Bernoulli's theorem?**

BERNOULLI'S THEOREM

*** INTRODUCTION**

•A fluid in motion is subjected to several forces, which result in the variation of the acceleration and the energies in the flow phenomenon.

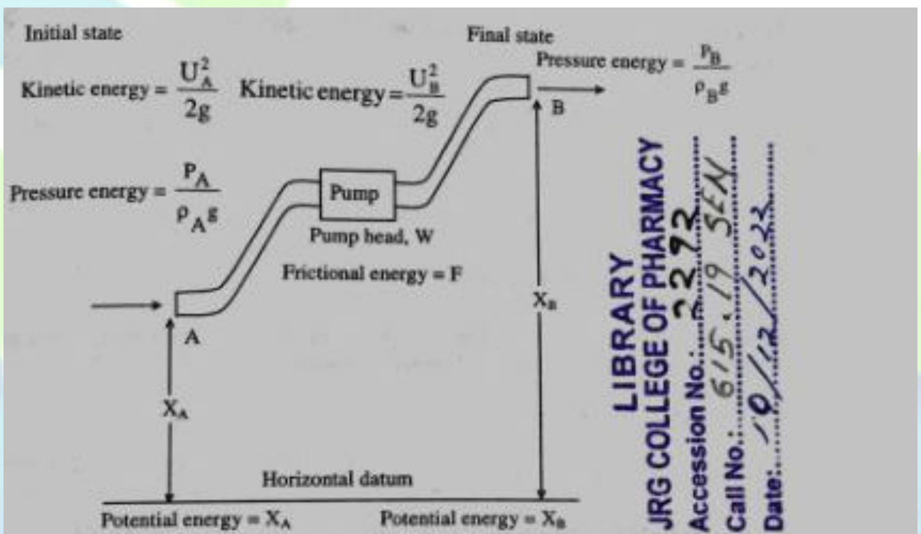

Figure 1.10: Bernoulli's Theorem

PRINCIPLE

* When the principle of conservation of energy is applied to the flow of fluids, tie resulting equation is called Bernoulli's theorem.

Pumps generally supply energy for conveying liquids from one point to another.

Consider such a pump working under isothermal conditions between points A and B

Bernoulli's theorem states that in a steady state ideal flow of an mompr the total energy pre unit mass, which consists of pressure energy, kinetic energy and datum energy, at any point of the fluid is constant.

* At point A one kilogram of liquid is assumed to be entering.

At this point, liquid experiences pressure energy, kinetic energy and potential energy in joules may be written as,

$\text{Pressure energy} = \frac{P_A}{g\rho_A}$ **-------------(1)**

Where

P_A = pressure at point A, P_A

g = acceleration due to gravity, m/s

PA = density of liquid, kg/m3

The point A is considered at a hight of X, meters above the horizontal datum plane. ©

•The potential energy for one kilogram of liquid may be written as:

potential energy = X_A ------------------(2)

Since liquid is under motion, the velocity of liquid may be designated as u, meter per second at point A.

The kinetic energy may be expressed as

$\text{Kinetic Energy} = \frac{U_A^2}{2g}$ **------------------(3)**

Total energy = Pressure energy + Potential energy + Kinetic energy

Total energy at point

$\text{Total energy at point A} = \frac{P_A}{g\rho_A} + X_A + \frac{U_A^2}{2g}$ **---------------(4)**

According to the Bernoulli's theorem the total energy at point A is constant.

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$$\text{Total energy at point A} = \frac{P_A}{g\rho_A} + X_A + \frac{U_A^2}{2g}$$ ----------------(4)

After the system reaches the steady state, whenever one kilogram of liquid enters at point A, another kilogram of liquid leaves at point.

$$\text{Total energy at point A} = \frac{P_A}{g\rho_A} + X_A + \frac{U_A^2}{2g} = \text{Constant}$$ ----------------(5)

* Therefore energy content of one kilogram liquid that is being displaced at point B may be written as;

be written as.

$$\text{Total energy at point B} = \frac{P_B}{g\rho_B} + X_B + \frac{U_B^2}{2g} = \text{Constant}$$ --------------------(6)

constant

* Where Xg = height from the datum to the pipe, m

Ug = velocity at point B, m/s

PB = pressure at point B, Pa

Pr = density at point B, kg/m3

* The principle of conservation of energy may be applied to the two points A and B

INPUT = OUTPUT

Total energy at point A = total energy at point B

Total energy at point A = Total energy at point B

$$\frac{P_A}{g\rho_A} + X_A + \frac{U_A^2}{2g} = \frac{P_B}{g\rho_B} + X_B + \frac{U_B^2}{2g}$$ ----------------(7)

•In the transportation of fluid, the pump has added certain amount of energy,which

can be written as

Energy added by the pump = +WJ ------------------(8)

The energy loss may be written as

Loss of energy due to friction in the line = $-FJ$ ---------------------(9)

•The energy balance between points A and B dan be accounted by including equation

7 and 8 in equation 9.

* This complete equation representing such energy may be written as:

$$\frac{P_A}{g\rho_A} + X_A + \frac{U_A^2}{2g} - F + W \frac{P_B}{g\rho_B} + X_B + \frac{U_B^2}{2g}$$ -------------------------(10)

APPLICATION

1. Bernoulli's theorem is applied in the measurement of the rate of fluid flow usir © orifice meter, venturi meter.

2. Bernoulli's theorem is applied in the working of centrifugal pumps. In these pumps, the kinetic energy is converted into pressure head, which helps in pumping the liquids.

3. It is easy to measure heights and apply them as energy terms, which is a contribution of Bernoulli's theorem.

2) Describe about flow of fluid.

FLOW OF FLUID

A fluid is a substance that continually deforms (flows)under an applied shear stress.

* Fluids are a subset of the phases of matter and include

> liquids, gases.

•Fluid flow may be defined as the flow of substances that do not permanently resist distortion.

* The subject of fluid flow can be divided into fluid static's and fluid dynamiss.

IMPORTANCE

* Manufacture of dosage forms.

•Handling of drugs for administration.

The flow of fluid through a pipe can be viscous or turbulent and it can be determined by

Reynolds number.

FLUID STATICS

Also known as Hydrostatics.

There is no shear stress when fluid at rest - stable equilibrium.

•Any force developed will be only due to its pressure and pressure variation is simply due to weight of liquid.

* In simple words, in fluid statics we are studying nature of pressure exerting by fluid and variation of pressure at different levels when the flow rate is zero.

PRINCIPLES OF FLUID STATICS

A fluid, like water or air exerts a pressure on its surroundings.

This pressure applies a distributed load on surfaces surrounding the fluid, like the face of a dam, an irrigation control gate a teakettle or the drum of boiler.

When you dive underwater the pressure you feel in your ears in depth.

At the surface, the gage pressure is zero no matter which unit system you descend, the fluid pressure P increases with depth according to the equation.

P = p.g.h

where:

p is the density of a fluid,

g is gravitational acceleration and

h is the height of fluid above the point of interest

FLUID DYNAMICS

Fluid dynamics deals with the study of fluids in motion.

This knowledge is important for (liquids, gels, ointments which will change their flow behavior when exposed to different stress conditions.

PRINCIPLE

* Conservation of Mass Basic fluid mechanics Jaws dictate that mass is conserve within a control volume for constant density fluids. _

* Thus, the total mass entering the control volume must equal the total mass € the control volume.

3) Discuss thoroughly about energy losses.

Energy Losses

INTRODUCTION

When energy is transformed from one form to another, or moved from one place to another, or from one system to another there is energy loss.

Types of Energy Losses

1. Heat energy

2. Light energy

3. Sound energy

1**. Heat energy**

Potentially as a result of air drag or friction, heat energy is the most easily dissipated form of energy.

2. Light energy

It is frequently energy seen in combustion, and is a type of wave motion.

3. Sound energy

It is another type of wave motion caused by the vibration of molecules in the air.

Like heat energy, sound is a type of energy that is generally lost.

PRINCIPLE

Bernoulli's equation includes the term 'loss of energy' in the pipe.

According to law of conservation of energy, energy balances have to be properly accounted.

Therefore, it is necessary to calculate the energy losses.

Fluids experience energy losses in several ways while flowing through a pipe.

Some of them are energy losses

1. Friction losses

2. Losses in fittings

3. Enlargement losses

4. Contraction Losses

Friction Losses

- Energy loss due to **friction** between fluid layers and pipe walls.
- Happens all along the length of the pipe.

- Because fluid has viscosity (internal resistance).
- Pipe roughness adds to friction.

hf=f×DL×2gV2

Where:

- _h_f= head loss due to friction (m)
- f = friction factor (depends on flow type and pipe surface)
- L = pipe length (m)
- D = pipe diameter (m)
- V = fluid velocity (m/s)
- g = acceleration due to gravity (9.81 m/s²)

. Losses in Fittings

- Energy loss caused by pipe fittings like **elbows, valves, bends**.
- These cause flow disturbances and turbulence.

- Flow changes direction or speed suddenly.
- Turbulence and eddies form.

Formula:

hf=K×2gV2

Where:

- hf= head loss due to fitting (m)
- K = loss coefficient for the fitting (given in handbooks)
- V = velocity before the fitting (m/s)

Enlargement Losses

Definition:

Energy loss occurring when fluid flows from a pipe with smaller diameter to a pipe with larger diameter suddenly.

Cause:

- Sudden increase in pipe area causes fluid velocity to drop abruptly.
- Flow separation and turbulence occur downstream.

Equation:

he=Ke×2gV12

Where:

- heh_ehe = head loss due to enlargement (m)
- Ke= Ke= (1- A2-A1)^2
- V1 = velocity in smaller pipe (m/s)

A1,A2 = cross-sectional areas of smaller and larger pipes respectively

Contraction Losses

Definition:

Energy loss that occurs when fluid flows from a pipe with larger diameter to a smaller diameter suddenly.

Cause:

- Fluid velocity increases suddenly.
- Flow separation and turbulence happen at the contraction point.

Equation:
hc=Kc×2gV2

Where:

- hc = head loss due to contraction (m)
- Kc=0.5×(1−A2/A1)
- V = velocity in smaller pipe (m/s)
- A1,A2 = cross-sectional areas of larger and smaller pipes respectively

4) Discuss about size reduction in detail.

Introduction

Size reduction (also called comminution or diminution) is the process of reducing the particle size of solids into smaller pieces. It is an essential operation in pharmaceutical manufacturing to enhance the performance and handling of solid dosage forms.

Objectives of Size Reduction

- **Increase surface area** for better dissolution and absorption.
- **Improve uniform mixing** of powders in formulation.
- **Enhance bioavailability** of poorly soluble drugs.
- **Improve flow properties** and compressibility.
- **Facilitate drying and extraction** by breaking cell walls.
- **Achieve desired particle size** for dosage uniformity.

Principles of Size Reduction

Size reduction involves applying force to break down particles. Common mechanisms include:

- **Cutting** – using sharp edges (e.g., cutter mills).
- **Compression** – crushing between heavy surfaces (e.g., roller mills).
- **Impact** – striking particles against a surface (e.g., hammer mills).
- **Attrition** – rubbing or friction (e.g., fluid energy mill).

Laws Governing Size Reduction

Several empirical laws describe the energy required for size reduction:

a. Kick's Law-Useful for coarse size reduction.
b. Rittinger's Law-Applicable to fine grinding.
c. Bond's Law-More accurate over a wide range of sizes.

5. Factors Affecting Size Reduction

- **Hardness** of the material
- **Moisture content**
- **Stickiness or elasticity**
- **Material structure** (fibrous, crystalline, etc.)
- **Machine type and mechanism**

6. Equipment for Size Reduction

a. Cutter Mill

- Suitable for fibrous materials.
- Cutting action by rotating knives.

b. Ball Mill

- Uses impact and attrition.
- Ideal for brittle materials.

c. Hammer Mill

- High-speed rotating hammers crush the particles.
- Used for intermediate and fine grinding.

d. Fluid Energy Mill (Jet Mill)

- Uses high-velocity air jets.
- Ideal for ultra-fine powders.

e. Edge Runner and End Runner Mills

- Use heavy wheels to crush and grind materials.
- Suitable for ointments and soft solids.

7. Advantages of Size Reduction

- Enhances **uniformity** of drug content.
- Improves **processing and mixing** efficiency.
- Increases **bioavailability**.
- Reduces **settling time** in suspensions.

Disadvantages

- **Heat generation** may degrade sensitive drugs.
- **Dust formation** is a risk.
- May require **energy-intensive operations**.
- Possible **equipment wear and tear**.

Applications in Pharmacy

- Tablet and capsule formulation.
- Suspension and emulsion preparation.
- Extraction of plant constituents.
- Granule preparation for dry powders.

5) Explain about air separator or bag filter.

Introduction

In pharmaceutical and chemical industries, **air separators and bag filters** are used in powder processing units for:

- Classifying particles by size
- Recovering fine powders
- Removing dust or airborne particles from exhaust gases
- Maintaining a clean and safe working environment

Air Separator

Definition

An **air separator** is a device used to separate fine particles from coarser particles in a stream of gas (usually air), based on particle size, shape, and density.

Principle

- Works on the principle of **centrifugal force** and **air classification**.
- Finer particles are carried upward by airflow; heavier particles fall downward by gravity.

Construction

- **Feeder**: Introduces the mixture of particles.
- **Centrifugal chamber**: A rotating wheel or blades create a vortex.
- **Classifier blades**: Help classify particles based on size.
- **Fine outlet**: Finer particles escape with the air.
- **Coarse outlet**: Heavier particles are collected below.

Working

1. The powdered mixture is fed into the air separator.
2. A stream of air flows through the chamber.
3. Particles are subjected to:
   - **Drag force** (by air) — moves lighter particles upward.
   - **Gravitational force** — pulls heavier particles down.
4. The fine particles are collected from the top; coarse ones from the bottom.

Advantages

- Suitable for **dry powder classification**
- Provides **controlled particle size**
- **Energy efficient** compared to sieving

Applications

- Common in **closed-loop grinding systems**
- Used with **ball mills and hammer mills**
- Classifies powders for **tablet and capsule** formulation

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Bag Filter

Definition

A **bag filter** is an air pollution control device that removes **dust particles** from air or gas using **fabric filter bags**.

Principle

- Operates on the principle of **filtration**.
- Dust-laden air is passed through a **fabric filter** that traps solid particles while allowing clean air to pass.

Construction

- **Inlet chamber**: Receives dusty air.
- **Filter bags**: Cylindrical fabric bags arranged vertically.
- **Cage**: Supports the fabric from collapsing.
- **Dust collector**: Base where filtered dust collects.
- **Outlet**: Clean air exits here.

Working

1. Dust-laden air enters the bag filter.
2. Air passes through the filter fabric.
3. **Dust particles get trapped** on the outer surface of the bags.
4. Periodically, the bags are cleaned by:
    - **Shaking**
    - **Reverse air flow**
    - **Pulse jet cleaning**
5. Collected dust is removed from the bottom hopper.

Advantages

- High **dust collection efficiency** (up to 99%)
- Works on **dry particles**
- Handles **large volumes** of gas
- Improves **air quality** in the plant

Disadvantages

- Regular **maintenance** needed
- Filters may get **damaged by moisture or corrosive dust**
- Requires **space and cleaning mechanisms**

Applications

- **Pharmaceutical plants** – during granulation, grinding
- **Chemical and cement industries**
- **Dust control** in fluid bed dryers, mills, blenders

6) **Write an exhaustive note on size separation.**

Introduction

Size separation, also known as **sieving** or **screening**, is the process of separating particles based on their **individual particle size**. It is an essential step in many pharmaceutical manufacturing processes to ensure **uniformity**, **consistency**, and **efficacy** of dosage forms.

Objectives of Size Separation

- To achieve **uniform particle size** in formulations.
- To ensure **quality control** of raw materials and final products.
- To remove **oversized or undersized particles**.
- To improve **flow properties**, **compressibility**, and **dissolution rate**.
- To **enhance the appearance** and **stability** of products like tablets and capsules.

Principle of Size Separation

The principle is based on the **passage of particles** through a series of **sieves or screens** with defined mesh sizes.

- Larger particles are **retained**.
- Smaller particles **pass through** to the next sieve.

4. Standard Sieves

Pharmaceutical size separation follows **IP/BP/USP standard sieves**, made of wire mesh with specific **aperture sizes**.

Mesh Number:

- Indicates the number of openings per linear inch.
- **Higher mesh number → finer sieve**.

Mesh No.	Aperture Size (mm)
10	2.00
22	0.710
44	0.355
80	0.180
120	0.125

Methods of Size Separation

a) Sieving Method

- Uses a stack of standard sieves arranged in descending order of mesh size.
- Material is placed on top, and the whole assembly is shaken.

b) Cyclone Separator

- Uses centrifugal force to separate fine and coarse particles.

c) Air Separator

- Separates particles based on their size using air as the separating medium.

d) Elutriation

- Based on the velocity of an upward-flowing stream of air or liquid to separate particles.

Equipment Used

Sieve Shaker

- Mechanically shakes the sieves to facilitate separation.
- Can be **rotary, vibratory, or tapping type**.

Cyclone Separator

- Particles are fed tangentially into a cylindrical chamber; fine particles rise with air while coarse ones settle.

Elutriation Tank

- Based on terminal settling velocity; finer particles are carried away by upward-moving fluid.

Factors Affecting Size Separation

- **Shape and density** of particles
- **Moisture content** of the material
- **Screen loading** and capacity
- **Sieve agitation method**
- **Time of sieving**

Pharmaceutical Applications

- Ensuring **uniformity in powder blending**
- Preparing **granules for tablet compression**
- Removing **foreign particles**
- Classifying **bulk drugs** and **excipients**
- Enhancing **bioavailability** by ensuring consistent particle size

Advantages

- Simple and economical method
- Requires no solvents or chemicals
- Can handle a wide range of materials
- Helps in **quality control** and **batch consistency**

Disadvantages

- Not suitable for very **fine powders**
- Sieve clogging can occur
- Not suitable for **sticky** or **moist** materials
- Labor and time-intensive for large-scale production

7) Discuss in detail about manometer.

MANOMETERS

INTRODUCTION

The manometer is a device used to measure pressure at a point in a fluid via balancing the column of fluid by the same or another fluid.

It is commonly known as a U-shaped tube that is filled with a liquid, gas, steam, etc. ‹

TYPES OF MANOMETERS

Simple manometer

Differential U-tube manometers

Small manometer

Simple Manometer

Enlarged Leg Manometer

A simple manometer has a glass tube that's one end is connected to a point where pressure is to be measured and the other end remains open to the atmosphere.

The simple manometer is further classified into four types.

Piezometer

U-tube manometer

Single Column Manometer

Inclined tube manometer or Sensitive Manometer.

Piezometer

For measuring the pressure inside a vessel or pipe in which liquid is there a tube is attached to the walls of the container or pipe in which the liquid remains so liquid can rise in the tube.

•By determining the height to which liquid rises and using the relation.

•P= pgh, a gauge pressure of the liquid can be determined.

U-tube Manometer

It consists of a glass tube bent in V-shape with one end is connected to a point at which pressure is to be measured and the other end remaining open to the atmosphere.

•The tube carries mercury or any other liquid or fluid whose specific gravity is much higher than the specific gravity of the liquid whose pressure is to be measured.

For gauge pressure

For vacuum pressure

Single Column Manometer

•the Consider a vertical tube micromanometer connected to a pipe containing light liquid under very high pressure.

The pressure in the pipe will force the lighter liquid in the basin to push heavier liquid downwards

Due to the larger area of the basin, the fall of a heavy liquid level will be very small.

This downward movement of heavy liquid into the basin will result in a significant rise of heavy liquid in the right limb.

Due to the larger area of the basin the fall of a heavy liquid level will be very small.

This downward movement of heavy liquid into the basin will result in a significant

rise of heavy liquid in the right limb.

Inclined Tube Manometer

If the vertical tube of the micromanometer is made inclined as shown in the figure then it is called an inclined tube micromanometer.

This type of inclined micromanometer is more sensitive than the vertical tube type.

Due to inclination, the distance moved by the heavy liquid in the right limb is comparatively more.

Thus, it can give a higher reading for the given pressure.

Differential Manometer

The differential manometer is a device used to measure the pressure difference between two points in a pipe or in two different pipes.

A differential manometer consists of a U-tube, containing a heavy liquid, with two ends connected by points whose pressure difference is to be measured.

The differential manometer is further classified into three types:

Two piezometer manometers

U-tube differential manometer

Inverted differential manometer

Two Piezometer Manometer

It consists of two piezometers mounted at two different gauge points where the pressure difference is to be measured.

The pressure difference-between the two points can be simply measured by the difference in the level of liquid between the two tubes.

It possesses some limitations in the form of piezometers.

U-tube Differential Manometer

It is a device that is used to measure the pressure difference between two points in a pipe or between two different pipes.

This manometer is consists of a U-shaped tube containing a heavy liquid.

The two ends are connected to the two desired points in the pipe whose difference of pressure is required.

Let pressure at point A be more than at point B.

Then the greater pressure at A will force the heavy liquid in U-tube to move downwards.

This downwards movement of the heavy liquid in the left limb will cause a corresponding rise of the heavy liquid in the right limb.

Inverted Differential Manometer

In these types of manometers, the U-tube is inverted and contains a light liquid.

The two ends of the tube are connected to the points whose pressure difference is to be measured

It is used for measuring the difference in low pressures.

The figure shows an inverted U-tube a differential manometer connected to th two points A and B.

Let the pressure at point A is more than the pressure at point B.

Small Manometer

These are types of a manometer in that it works based on the principle of an inclined tube manometer.

Small manometers or pressure gauges are used to measure very small pressure variations or very small pressure variations.

These manometers are also known as micro-manometer, which is a modified variant of a simple manometer whose part is formed by a large cross-sectional space.

It is a highly precise instrument capable of observing very small pressure variations with high accuracy.

Advantages

It is simple to construct.

It has great accuracy.

Used to measure pressure, temperature, flow and other process variables.

It has a low cost.

It has better sensitivity

Disadvantages

1. The manometer has a smaller dynamic response

2. They are fragile and therefore provide low portability.

3. They have small operational limits which are on the order of 1000 kN/m2.

4. The density of manometric fluid depends on temperature Therefore errors may occur due to change in temperature.

Application

1. Used in the maintenance of heating, ventilation and air conditioning (HVAC systems and gas systems.

2. It is used to construct bridges, swimming pools and other engineering purposes.

3. Used in climate forecasting.

4. In clinical applications such as blood pressure measuring and physiotherapy.

5Marks

a) Enumerate the differences between orifice and venture meter.

Introduction

Both **Venturimeter** and **Orifice Meter** are **devices used to measure the flow rate of fluid** in a pipeline. They operate on **Bernoulli's principle**, which states that the total mechanical energy of the flowing fluid remains constant. However, these two differ in terms of construction, pressure loss, accuracy, cost, and applications.

1. Principle

Aspect	Venturimeter	Orifice Meter
Principle	Based on Bernoulli's equation (energy conservation)	Same principle, measures pressure difference across orifice
Flow behavior	Smooth and streamlined	Turbulent with vortex formation after orifice

. Construction

Venturimeter

- It has **three parts**: converging section, throat, and diverging section.
- Designed to reduce friction and energy loss.
- Typically longer in size and needs more space for installation.

Orifice Meter

- A thin plate with a sharp-edged **circular hole** in the middle.
- Compact and easy to install.
- Causes abrupt contraction of flow.

. Pressure Loss

Venturimeter	Orifice Meter
Low permanent pressure loss due to gradual expansion	High permanent pressure loss due to sudden contraction

Explanation:

Venturimeter has a **diverging section**, which allows the pressure to recover after the throat, while the orifice meter lacks this, causing **more energy dissipation** due to turbulence.

Accuracy and Sensitivity

Venturimeter	Orifice Meter
High accuracy (±1%)	Lower accuracy (±2–4%) due to energy loss
Less sensitive to flow disturbances	Highly sensitive to upstream flow irregularities

Cost and Maintenance

Venturimeter	Orifice Meter
Expensive due to complex shape and longer length	Cheaper and widely used in industries
Maintenance is minimal	Plate edges wear out with time, reducing accuracy

Space Requirement

- **Venturimeter**: Requires more space for installation because of the long gradual tapering sections.
- **Orifice Meter**: Compact and suitable for tight spaces.

Head Loss Comparison

Parameter	Venturimeter	Orifice Meter
Head loss	~10–15% of differential head	~40–90% of differential head

This shows that orifice meters waste more energy in the form of pressure drop.

Applications in Pharmaceutical Industry

Venturimeter	Orifice Meter
Suitable for clean liquids, gases, and steam where low head loss is required	Used for temporary flow measurement in fluid transport systems
Often used in air handling units, cleanroom air ducts	Used in **pilot plants** and water treatment areas for flow checks

b) What is Reynolds number? Describe its importance.

REYNOLDS NUMBER

INTRODUCTION

In Reynolds experiment, the flow conditions are affected by four factors.

Diameter of pipe, m (D)
Average velocity; m/s (u)
Density of liquid, kg/m° (p)
Viscosity of the fluid, Pa.s (n)
These factors are grouped into an expression as given below.

$$\mathrm{Re} = \frac{\rho \times v \times d}{\mu}$$

ρ = Desity of fluid
v = velocity of the fluid
d = Diameter of the pipe, if pipe flow.
μ = viscosity of the flowing fluid

Reynolds number; Re =Dup

Reynolds number is obtained by the following equation.

Reynolds number, Re= Inertial forces / Viscous forces

=

Mass **x** Acceleration of liquid flowing / shear stress **x** area

Inertial forces are due to mass and the velocity of the fluid particles trying to diffuse the fluid particles

Viscous force if the frictional force due to the viscosity of the fluid which make the motion of the fluid in parallel.

At low velocities the inertial forces are less when compared to the frictional forces.

Resulting flow will be viscous in nature.

Other hand when inertial forces are predominant the fluid layers break up due to the increase in velocity hence turbulent flow takes place.

If Re < 2000 the flow I said to be laminar.

If Re > 4000 the flow is said to be turbulent.

If Re lies between 2000 to 4000 the flow change between laminar to turbulent

Types of flow

Laminar flow

It is one in which the fluid particles move in layers or laminar with one layer sliding with other

There is no exchange of fluid particles from one layer to other

Avg. velocity = 0.5V max

Re < 2000

Turbulent flow

It is when velocity of the water is increased the thread of the colored watt disappears and mass of the water gets uniformly colored

There is complete mixing of the solution and the flow of the fluid is called a° turbulent flow

Avg velocity = 0.8 Vmax

Re > 4000

The velocity at which the fluid changes from laminar flow to turbulent flow that velocity is called as critical velocity.

Applications

* Reynolds number is used to predict the nature of flow in a particular set of experimental conditions.

* Study of sedimentation of particles, stokes law is used.

* The rate of heat transfer in liquids also depends on the flow, whether viscous or turbulent.

c) Differentiate between fluid statics and fluid dynamics?

Fluids in engineering are studied under two main branches:

- **Fluid Statics**: Deals with fluids **at rest**.
- **Fluid Dynamics**: Deals with fluids **in motion**.

Both branches are essential in pharmaceutical engineering for applications like pressure measurements, fluid transport systems, and process equipment design.

2. Definition

Term	Definition
Fluid Statics	Study of fluids when they are not in motion.
Fluid Dynamics	Study of fluids in motion and the forces that act on them.

4. Key Differences

Aspect	Fluid Statics	Fluid Dynamics
Nature of Fluid	Fluid at rest	Fluid in motion
Velocity	Zero	Finite (non-zero)
Forces Considered	Only pressure and gravity	Pressure, gravity, viscous, and inertial forces
Pressure Variation	Only due to height (hydrostatic)	Due to height, velocity, frictional losses
Governing Equation	Pascal's and Hydrostatic Law	Bernoulli's Equation, Continuity Equation
Applications	Manometers, pressure vessels, tanks	Flow meters, pumps, fluid transport systems
Energy Consideration	Potential energy only	Potential + kinetic + pressure energy

Applications in Pharmaceutical Engineering

Fluid Statics Applications:

- **Manometers**: Used to measure pressure of gases and vapors.
- **Storage Vessels**: Used for formulation liquids where pressure due to depth is considered.

Fluid Dynamics Applications:

- **Flow measurement** using Venturimeter, Orifice meter, Rotameter.
- **Design of pumps and pipelines** for transferring solutions and suspensions.
- **Mixers and agitators** where velocity profile is important.

d) Discuss in detail about the edge runner mill.

Introduction

The **Edge Runner Mill** is a size reduction machine primarily used in the pharmaceutical, chemical, and food industries. It reduces solid materials into fine powders through **compression and shear forces** between rollers and a solid bed.

It is especially useful for **crushing fibrous, gummy, and tough materials** that are difficult to reduce using impact or cutting alone.

Principle

The Edge Runner Mill works on the principle of:

- **Crushing**: Applying compressive force via heavy rollers.
- **Shearing**: As the rollers rotate over the material, shear forces assist in breaking it down further.

Construction of Edge Runner Mill

The main components are:

Component	Description
Grinding Bed (Pan)	Circular, shallow, heavy cast-iron or granite pan where material is placed.
Rollers (Runners)	Two or more heavy granite or steel wheels mounted vertically on a horizontal shaft.
Shaft	Attached to a drive mechanism that rotates the rollers.
Scraper Arm	Fixed arm that ensures the material is evenly distributed under the wheels.

Working of Edge Runner Mill

1. **Loading**: Material to be crushed is placed in the circular pan.
2. **Rolling Action**: The rollers are rotated either by hand or motor.
3. **Crushing and Grinding**:
   - The rollers rotate and revolve around the pan.
   - Material is crushed by the **weight of the rollers**.
   - **Shear force** acts as the rollers move over the material.
4. **Scraping and Mixing**: Scraper arms keep the material under the rollers and ensure uniform size reduction.

The mill continues until the material reaches the desired fineness.

Uses in Pharmaceutical Engineering

- Used for **crushing roots, barks, and hard resins**.
- Suitable for **mixing semi-solid materials** such as ointments.
- Effective for **triturating insoluble powders** with liquids (levigation).
- Ideal for **wet grinding** processes in formulation preparation.

Advantages

- **Simple and easy to operate**.
- **High crushing efficiency** due to rolling and shearing action.
- Suitable for **wet grinding and mixing** simultaneously.
- Durable and **low maintenance cost**.

Disadvantages

- **Not suitable for fine size reduction**.
- Occupies **more floor space**.
- **Not suitable for heat-sensitive materials**.
- Cleaning can be difficult due to crevices.

Pharmaceutical Examples

- Used for grinding **guar gum**, **resins**, **roots**, and **herbs**.
- Preparation of **herbal extracts** and **ayurvedic powders**.

Maintenance and Cleaning

- Regular inspection of roller wear and lubrication is necessary.
- Should be cleaned thoroughly to avoid cross-contamination between batches.

e) Discuss in detail about the ball mill.

Introduction

The **Ball Mill** is a widely used equipment for **size reduction** of materials in solid dosage formulation. It operates on the principle of **impact and attrition** and is commonly used in pharmaceutical, chemical, and mineral industries for both **dry and wet grinding**.

. Principle

The **Ball Mill works on the principle of impact and attrition**:

- When the cylinder rotates, the balls are lifted on the rising side of the shell and then they cascade down.

- The material inside is crushed between the balls and the inner surface of the mill.

Impact: Balls fall from a height and break the particles.

Attrition: Rubbing action between balls and particles causes size reduction.

Construction of Ball Mill

The major components of a ball mill include:

Component	Description
Cylindrical Shell	Made of steel, rubber-lined, mounted horizontally on a supporting frame.
Rotating Shaft	Supports the rotation of the shell, connected to a motor.
Grinding Balls	Steel, ceramic, or rubber balls used as grinding media.
Inlet and Outlet	For loading raw materials and collecting the ground product.
Gear Mechanism	Controls the speed of rotation.

Working of Ball Mill

1. The material to be ground and the grinding balls are loaded into the rotating cylindrical chamber.
2. As the cylinder rotates:
   - Balls are lifted up on the side of the cylinder due to centrifugal force.
   - At a certain height, the balls fall, crushing the material by **impact**.
   - As they roll over the material, they also produce **attrition**.
3. The operation can be:
   - **Dry grinding**: No liquid is added.
   - **Wet grinding**: A small amount of water or liquid binder is added.

Types of Ball Mill

1. **Batch Ball Mill** – Operates for a fixed time, then emptied.
2. **Continuous Ball Mill** – Materials are fed continuously, product collected at the other end.
3. **Planetary Ball Mill** – Small scale, used in labs for ultra-fine grinding.

Pharmaceutical Applications

- Preparation of fine powders like magnesium carbonate, calcium carbonate.
- Grinding of **active pharmaceutical ingredients (APIs)**.
- Milling of **herbal powders** and **natural drugs**.
- Used in **pigment and colorant** production.
- Suitable for **dispersion of solid in liquids** (wet milling).

Advantages

- Efficient and versatile for both dry and wet grinding.
- Can handle both **hard and soft materials**.
- Simple and easy to operate.
- Available in various sizes (lab scale to industrial).

Disadvantages

- High energy consumption.
- Time-consuming operation.
- Not suitable for **heat-sensitive materials** due to frictional heat.
- Possibility of **contamination** from grinding media or liners.

Factors Affecting Efficiency

- Size and weight of balls.
- Speed of rotation (critical speed).
- Type of feed (dry/wet).
- Ball to powder ratio.
- Time of milling.

Maintenance and Cleaning

- Balls and liner should be checked regularly for wear.
- Proper cleaning is essential to prevent **cross-contamination**.
- Bearings and motor should be lubricated as per schedule.

f) Explain working construction merits and demerits of ball mill.

Introduction

The **Ball Mill** is a widely used equipment for **size reduction** (milling) in pharmaceutical and industrial processes. It is ideal for **grinding solid materials into fine powders** using mechanical forces like **impact and attrition**.

. Construction of Ball Mill

The Ball Mill consists of the following key components:

Component	Description
Cylindrical Shell	Horizontal, hollow cylinder made of stainless steel or ceramic. It rotates on its axis.
Grinding Media	Steel, ceramic, or glass balls that are used to crush the material.
Shaft and Bearings	Shaft is connected to a motor; supports the rotating shell.
Inlet/Outlet Ports	For loading materials and collecting the finished product.
Liner (Optional)	Inside wall of the cylinder is lined with rubber or metal to minimize wear.
Motor & Gear System	Used to rotate the cylinder at a controlled speed.

Working of Ball Mill

1. **Loading**: The raw material and grinding balls are loaded into the cylinder.
2. **Rotation**: The shell rotates on its axis using a motor.
3. **Impact and Attrition**:
   - Balls are lifted by friction and centrifugal force to a certain height.
   - They fall under gravity and impact the material.
   - While rolling, they also cause **attrition**, grinding the material into fine powder.
4. **Collection**: After sufficient grinding, the material is discharged.

Ball Mill can be operated in:

- **Dry mode**: No liquid used.
- **Wet mode**: Liquid (e.g., water, ethanol) is added to aid dispersion and grinding.

4. Merits (Advantages)

- **Simple and easy to use** – no complex mechanisms.
- **Efficient for both dry and wet grinding**.
- **Handles both hard and soft materials**.
- **Uniform particle size** can be achieved.
- **Available in small (lab) and large (industrial) sizes**.
- Suitable for mixing and homogenization.

Demerits (Disadvantages)

- **Time-consuming process**.
- **High energy consumption**.
- **Not suitable for heat-sensitive materials** due to heat generation by friction.
- **Wear and contamination** from grinding media and liners.
- Requires frequent **cleaning and maintenance**.
- Bulky equipment; not suitable for continuous high-volume processes.

. Applications in Pharmaceutical Industry

- Size reduction of **API (Active Pharmaceutical Ingredients)**.
- Grinding **natural and synthetic drugs**.
- Preparation of **pigments and colorants**.
- **Wet milling** of suspensions and emulsions.
- Milling of **herbal and plant-based formulations**.

. Conclusion

The **Ball Mill** remains a reliable, simple, and versatile equipment for pharmaceutical and industrial milling. Its ability to grind materials with **uniform particle size** and ease of operation makes it widely preferred, despite a few operational limitations.

g) Explain in detail about size separation.

. Introduction

Size separation, also known as **sieving or sifting**, is the process of separating particles into different size fractions using screens or sieves. It is an essential operation in pharmaceutical industries to ensure **uniformity in particle size**, which affects the **flowability, mixing, dissolution, and bioavailability** of the final product.

Objectives of Size Separation

- To obtain **uniform particle size** for better product quality.
- To separate **coarse particles from fine powders**.
- To remove **undesired large or foreign particles**.
- To ensure **dose uniformity** in solid dosage forms (e.g., tablets, capsules).
- To improve **packing and flow properties** of powders.

Principle of Size Separation

Size separation is based on the **particle size and shape**. A material is passed through **screens or sieves** of known mesh size. Particles smaller than the mesh size **pass through**, while larger particles are retained.

Mesh size: Number of openings per linear inch of screen.
Example: A 10-mesh screen has 10 openings per inch.

Equipment Used for Size Separation

Equipment	Description
Sieve Shaker	Vibrating mechanism to facilitate sieving through different mesh sizes.
Cyclone Separator	Uses centrifugal force to classify particles based on size/density.
Air Separator	Uses airflow to separate fine and coarse particles.
Elutriation Tank	Uses rising air or liquid to separate particles of different size/weight.
Bag Filter	Uses fabric bags to separate fine particles from air or gas streams.

Method of Sieve Analysis (For Powders)

1. **A stack of sieves** (coarse to fine) is arranged.
2. A known quantity of powder is placed on the top sieve.
3. The sieve stack is placed in a **sieve shaker**.
4. The material is sieved for a fixed time (typically 15–20 minutes).
5. The **weight of material retained** on each sieve is measured.
6. **Particle size distribution** is calculated as % retained on each sieve.

Standards of Sieves (I.P. Specification)

The Indian Pharmacopoeia (I.P.) and other pharmacopeias define sieve sizes based on mesh numbers and aperture size.

Mesh Number (I.P.)	Aperture Size (mm)
10	2.00
22	0.710
44	0.355
85	0.180
120	0.125
240	0.063

Advantages of Size Separation

- Ensures **uniform mixing** in solid dosage forms.
- Helps achieve **uniform drug release**.
- Eliminates **oversized particles or contaminants**.
- Useful in **grading powders** for different pharmaceutical applications.

Limitations of Size Separation

- **Not suitable for sticky or wet powders**.
- Sieves may get **clogged or damaged** over time.
- Not very effective for **irregularly shaped particles**.
- Requires **frequent calibration and cleaning**.

Applications in Pharmaceutical Industry

- Grading of **granules for tableting**.
- Separation of **fine dust from compressed powders**.
- Preparation of **uniform powders** for capsule filling.
- Used in **powder blending, granulation**, and **coating processes**.

h) What are the factors affecting size reduction?

Introduction

Size reduction (also known as comminution or milling) is a crucial unit operation in pharmaceutical manufacturing. It involves breaking down large particles into smaller ones to improve **flow properties, dissolution rate, uniformity**, and **bioavailability**. The efficiency of this process is influenced by several factors.

Factors Influencing Size Reduction

1. Hardness of the Material

- Defined using **Mohs scale**.
- Hard materials (e.g., quartz, alumina) are difficult to grind and require more energy.
- Soft materials (e.g., talc, chalk) are easier to reduce in size.

2. Toughness

- Tough materials absorb energy before breaking (e.g., rubber, resins).
- They are more **resistant to fracture**, making size reduction less efficient.
- May need to be **chilled or frozen** before milling.

3. Abrasiveness

- Abrasive materials (e.g., silica, sand) cause **wear and tear** on milling equipment.
- Leads to contamination and equipment damage.

4. Moisture Content

- High moisture materials may become **sticky and clog screens**.
- Low moisture content improves powder flow and reduces adhesion.
- **Optimum moisture** is important for efficiency.

5. Feed Size of the Material

- Larger particles require **preliminary crushing** before fine grinding.
- Very large particles can overload the mill, reducing efficiency.

6. Material Structure

- **Crystalline** materials break more easily than **fibrous or amorphous** ones.
- **Cellulose and starches** are fibrous and resist grinding.
- Brittle materials fracture more readily than plastic ones.

7. Temperature Sensitivity

- Some drugs and excipients are **heat-sensitive**.
- Size reduction generates **heat due to friction**, which may degrade the product.
- Solutions:
  - Use **cooling jackets**.
  - Perform **cryogenic grinding** (liquid nitrogen).

8. Mill Type and Operating Conditions

- Different mills (ball mill, hammer mill, fluid energy mill) have different mechanisms (impact, attrition, shear).
- Parameters like:
  - Speed of rotation
  - Feed rate
  - Ball size (in ball mill)
  - Air pressure (in fluid energy mill)
  - Duration of milling
  - Screen size

9. Product Requirements

- Desired **fineness or particle size range** affects the choice of equipment and energy input.
- For example:
  - **Tablets** need finer particles for compressibility.
  - **Suspensions** need uniform particle size to prevent settling.

i) Write the mechanism and objective of size reduction.

1. Introduction

Size reduction (also called **comminution or diminution**) is the mechanical process of breaking down solid materials into smaller particles using external forces. It is a **key operation in pharmaceutical manufacturing**, used to improve drug formulation and product quality.

Objectives of Size Reduction

Size reduction is performed for several important reasons in pharmaceutical processing:

Improve Bioavailability

- Finer particles have a **greater surface area**.
- Enhances **solubility** and **dissolution rate** of poorly soluble drugs.

Improve Uniform Mixing

- Ensures **homogeneous mixing** of powders for tablet or capsule formulation.

Enhance Flow Properties

- Uniform and fine powders improve **powder flow**, essential for tablet compression and capsule filling.

Facilitate Drug Absorption

- Smaller particles lead to **faster absorption** in the gastrointestinal tract.

Facilitate Extraction

- Increased surface area helps in **faster solvent penetration** during extraction processes.

Improve Stability

- Helps in the preparation of **uniform emulsions and suspensions**, reducing sedimentation.

Dose Uniformity

- Uniform particle size ensures each dosage form contains the correct amount of drug.

. Mechanisms of Size Reduction

Size reduction occurs by applying **mechanical forces** such as impact, attrition, cutting, or compression. These are the primary mechanisms:

Cutting (Shearing)

- Material is reduced by **sharp blades or knives**.
- Used for **fibrous and soft materials**.
- Example: Cutter mill.

Compression (Crushing)

- Particles are compressed between **two rigid surfaces**.
- Common for **brittle materials**.
- Example: Roller mill, jaw crusher.

Impact

- Particles are thrown against hard surfaces or collide with moving hammers.
- Sudden force causes fracture.
- Suitable for **brittle or moderately hard materials**.
- Example: Hammer mill, ball mill.

. Attrition (Rubbing or Friction)

- Material is **scraped or rubbed** between two surfaces.
- Causes **fine powder formation**.
- Example: Fluid energy mill, edge runner mill.

Combined Mechanisms

- Most equipment uses a **combination** of forces.
- Example: Ball mill uses both **impact and attrition**.

Laws Governing Size Reduction

Several theoretical laws explain energy requirements:

Law	Concept
Rittinger's Law	Energy required is **proportional to new surface area**.
Kick's Law	Energy is **proportional to size reduction ratio**.
Bond's Law	Intermediate between Kick's and Rittinger's laws.

j) Explain in detail about cyclone separation.

Introduction

Cyclone separation is a method of separating particles from an air or gas stream using **centrifugal force**. It is a type of mechanical dust collector used in **size separation** and **air pollution control** systems.

In pharmaceutical industries, it is commonly used to remove **powder particles** from process air and for separating **fine dust** from powdered products.

Construction of Cyclone Separator

A cyclone separator is a **vertical cylindrical vessel** with the following components:

Main Parts:

1. **Inlet Duct** – Tangential entry to introduce the dust-laden air.
2. **Cylindrical Body** – Upper portion where air spirals downward.
3. **Conical Base** – Lower section to collect particles.
4. **Dust Collection Chamber** – At the bottom to collect separated solids.
5. **Vortex Finder (Outlet pipe)** – For the exit of cleaned air.
6.

3. Working Principle of Cyclone Separator

Cyclone separator operates based on **centrifugal action**.

1. **Dust-laden air or gas** enters tangentially at the top of the cyclone.
2. This generates a **spiral vortex** (whirl) in the downward direction.
3. **Heavier particles** are thrown toward the wall due to **centrifugal force**.
4. These particles **lose momentum**, slide down the wall, and collect in the dust chamber.
5. The **clean air or gas** moves up through the **vortex finder** and exits at the top.

Centrifugal force inside a cyclone is **5 to 10 times greater** than gravity, leading to efficient separation.

Factors Affecting Efficiency

- **Particle size** (larger particles separate more easily).
- **Density** of particles.
- **Air flow rate** and **velocity**.
- **Cyclone dimensions** (height, diameter, inlet size).
- **Operating pressure**.

Applications of Cyclone Separator in Pharmacy

- Separation of **dust or fines** in tablet, powder, and granule production.
- Used in **tablet coating and granulation** areas to remove excess particles.
- **Pre-cleaning air** before HEPA filtration.
- **Environmental control** – collecting airborne drug particles.

Merits (Advantages)

- **No moving parts** – low maintenance.
- **Continuous operation** possible.
- Handles **large volumes of air**.
- **Cost-effective** and **energy-efficient**.
- Can be operated under **high-temperature** and **pressure** conditions.

Demerits (Disadvantages)

- **Less efficient** for particles <5 µm (microns).
- **Not suitable** for sticky or highly electrostatic powders.
- May require **secondary filtration** for complete air purification.
- Efficiency depends on **design and operating conditions**.

k) Explain working construction merits and demerits of end runner mill.

1. Introduction

The **End Runner Mill** is a type of size reduction equipment that uses **compression and shear forces** to crush and grind solid materials. It is traditionally used in the pharmaceutical, chemical, and food industries to process **sticky, pasty, or soft substances**, and also for **wet grinding**.

. Construction of End Runner Mill

The end runner mill consists of the following key components:

Main Parts:

1. **Heavy Circular Mortar (Pan or Trough):**
   - Made of granite or cast iron.
   - It is the base where materials are placed for grinding.
2. **Roller or Runner (Heavy Wheel):**
   - Mounted vertically on a central shaft.
   - Made of stone or metal.
   - The roller rotates on its axis and revolves around the central shaft.
3. **Scraper (optional):**
   - Helps in mixing and collecting the material.
4. **Driving Mechanism:**
   - Usually driven by **electric motor** or **manual labor**.
   - Connects to the shaft to rotate the runner.

Working Principle

The operation of the End Runner Mill is based on the **rolling and crushing** action of the wheel.

1. The material to be ground is placed in the **pan**.
2. The **heavy runner wheel** is rotated either manually or using an electric motor.
3. As the wheel rolls over the material:
   - **Compression** (crushing) occurs due to the weight of the wheel.
   - **Shear** force is generated due to rotation and movement across the surface.
4. Continuous **mixing and grinding** occur until the desired consistency or particle size is achieved.
5. Ground material is collected manually or via an outlet.

. Uses / Applications

- Used for **wet grinding** of pastes, ointments, and emulsions.
- Suitable for **sticky, oily**, and **semi-solid** materials.
- Used in **herbal** and **traditional medicine** formulations.
- Used in the **cosmetic** industry for mixing creams and pastes.

Merits (Advantages)

- **Simple construction** and easy to use.
- Suitable for **wet grinding** of difficult materials.
- No **overheating** – suitable for **heat-sensitive** drugs.
- Requires **low maintenance** due to minimal moving parts.
- Ensures **uniform mixing and grinding**.

Demerits (Disadvantages)

- **Bulky and heavy**; occupies large floor space.
- **Manual operation** is labour-intensive and time-consuming.
- **Low speed** and not suitable for high-volume production.
- **Not ideal for dry grinding** of hard or brittle materials.
- Cleaning may be difficult for sticky substances.

l) Write a note on detail about elutriation tank.

1. Introduction

Elutriation is a process of **size separation** based on the **sedimentation velocity** of particles in a **fluid medium** (usually water or air). An **Elutriation Tank** is a size separation device used in the pharmaceutical and chemical industries to **separate fine particles from coarse particles** by using a rising stream of fluid.

Principle of Elutriation

The process works on **Stoke's Law**, which states:

Heavier and larger particles settle faster in a fluid, whereas smaller and lighter particles are carried upward by the flowing fluid.

So, if a stream of water (or gas) is passed **upward** through a powder mixture:

- **Fine particles** get carried upward by the fluid.
- **Coarse or heavier particles** settle at the bottom.

This forms the basis of **separation by elutriation**.

Construction of Elutriation Tank

An elutriation tank consists of:

Main Parts:

1. **Vertical Tank (or Column):**
   - Cylindrical or conical shape.
   - Made of glass, stainless steel, or acrylic.
2. **Fluid Inlet:**
   - At the **bottom**, connected to a pump or water source.
   - Allows controlled upward flow of fluid.
3. **Powder Feed Port:**
   - Where the **powder mixture** is introduced, usually at the top or side.
4. **Overflow Outlet / Collection Zone:**
   - Fine particles rise with the fluid and are collected through an overflow outlet at the top.
5. **Sediment Collection Area:**
   - Coarse particles settle and collect at the bottom.

Working of Elutriation Tank

1. A mixture of powders (with various particle sizes) is introduced into the tank.
2. A **controlled upward flow of fluid** (usually water) is started.
3. **Fine and light particles** are carried upward by the fluid.
4. These fine particles exit through the **overflow outlet** at the top.
5. **Coarse and heavy particles** cannot be carried and thus settle at the **bottom** of the tank.
6. Separation is complete when all desired fractions are removed.

Factors Affecting Elutriation Efficiency

- **Density and size** of particles.
- **Viscosity and velocity** of the fluid.
- **Shape** of the particles.
- **Time** allowed for settling.
- **Design of the tank** (height, diameter).

Advantages of Elutriation Tank

- Simple, **non-mechanical** method.
- **Low cost** and **energy-efficient**.
- Effective for **separating very fine particles**.
- Can be used for **heat-sensitive** powders.
- Minimal **wear and tear**, since no moving parts.

Disadvantages

- Limited to materials that are **insoluble** in the working fluid.
- Not suitable for separating particles of **similar sizes or densities**.
- Separation is **slow and batch-wise**.
- Requires **drying** after wet elutriation.

Applications in Pharmacy

- Used for separation of **powders and granules** in formulation development.
- Preparation of **fine fractions** of crude drugs or excipients.
- Separation of **abrasive** or **non-uniform** particles from mixtures.
- Used in **herbal extraction** and **natural product isolation**.

m) Explain in detail about sieve shaker.

Introduction

A **sieve shaker** is a laboratory instrument used for **size analysis** of granular or powdered materials. It helps to separate particles into different size fractions by mechanically shaking a stack of standard test sieves.

In pharmaceutical industries, sieve shakers are essential for quality control to determine **particle size distribution** in powders, granules, and capsules.

Construction of Sieve Shaker

A typical sieve shaker consists of the following parts:

Main Components:

1. **Stack of Sieves:**
   - A set of sieves with progressively smaller mesh sizes.
   - Sieves are placed one over another with the largest mesh size on top.
2. **Sieve Holder or Clamp:**
   - Holds the stack of sieves firmly during shaking.
3. **Shaker Mechanism:**
   - Usually an **electric motor** connected to an eccentric shaft.
   - The shaft imparts **vibratory** or **rotary motion** to the sieve stack.
4. **Base or Frame:**
   - Rigid structure that supports the motor and sieve holder.
5. **Timer and Control Panel:**
   - Allows setting shaking duration and intensity.

Working Principle

The sieve shaker works on the principle of **mechanical vibration or shaking**, which facilitates the passage of particles through the sieve mesh.

1. A representative sample of powder or granules is placed in the **top sieve**.
2. The sieve stack is assembled with sieves arranged in decreasing mesh size order.
3. The stack is secured in the shaker holder.
4. The shaker is switched on, causing the stack to **vibrate or rotate**.
5. Particles smaller than the mesh size pass through the respective sieve to the next lower sieve.
6. After the set time, the shaker stops, and each sieve is weighed to determine the mass retained.
7. Particle size distribution is calculated based on mass retained on each sieve.

Types of Sieve Shakers

- **Mechanical or Electromechanical Shakers:** Use motor-driven vibration.
- **Rotary Shakers:** Impart rotational motion.
- **Ultrasonic Sieve Shakers:** Use ultrasonic waves to prevent mesh clogging and enhance separation.

Applications

- Determination of **particle size distribution** in powders.
- Quality control in pharmaceutical manufacturing.
- Testing granules for uniformity.
- Separation of fine and coarse particles.

- Research and development in formulation science.

Advantages

- Provides **accurate and reproducible** particle size analysis.
- Reduces **manual effort** and time compared to manual sieving.
- Prevents **mesh clogging** (especially with ultrasonic shakers).
- Allows testing of large sample sizes.
- Easy to operate and clean.

Limitations

- Not suitable for **very fine particles** (below 45 microns) unless ultrasonics are used.
- Vibrations may cause **particle breakage** in fragile materials.
- Requires **calibrated standard sieves** for accurate results.
- Initial cost can be high for ultrasonic models.

2Marks

1. **Write the Difference between laminar flow and Turbulent flow.**

S. No	Turbulent flow	Streamline Flow
1.	The velocity of liquid is high and unsteady.	The velocity of liquid is low and steady.
2.	Velocity of liquid is greater than the critical velocity.	Velocity of liquid is below its critical velocity.
3.	The velocity of every particle of liquid keeps on changing at every instant.	The velocity of every particle of liquid crossing a particular point is same.

2. **What are the advantages of size reduction?**

Increases **surface area** for better drug dissolution.

Improves **uniform mixing** of drug and excipients.

Enhances **bioavailability** of poorly soluble drugs.

Facilitates **uniform dosage** form manufacturing.

Improves **flow properties** and **compressibility** of powders.

Useful in preparing **micronized or nano-sized particles**.

3. **Difference between size reduction and size separation?**

Feature	Size Reduction	Size Separation
Definition	Reducing particle size	Classifying particles based on size
Principle	Cutting, impact, or compression	Sieving, air classification
Equipment Used	Ball mill, hammer mill	Sieve shaker, air separator
Purpose	Reduce bulk size	Obtain uniform particle distribution

4. **Define manometer.**
A **manometer** is a U-shaped tube filled with liquid (usually mercury or water) used to measure **pressure differences** between two points in a fluid system.
It is commonly used to determine **static pressure**, **vacuum pressure**, or **differential pressure** in pipelines or fluid equipment.
5. **Name the type of sieve used.**

In pharmaceutical industries, **standard test sieves** conforming to **Indian Pharmacopoeia (IP), British Pharmacopoeia (BP), or USP** specifications are used.
They are made of **woven wire mesh** with specific **mesh numbers** such as:

- 10 (2 mm)
- 22 (710 µm)
- 44 (355 µm)
- 85 (180 µm)
- 120 (125 µm)

These sieves are used in **size separation** and **quality control** of powders.

6. Discuss the objective of size separation.

The main objectives of size separation are:

- To achieve **uniform particle size** for consistent drug formulation.
- To remove **oversized or undersized particles**.
- To improve **flow properties** of powders.
- To prepare powders suitable for **compression or encapsulation**.
- To ensure **quality control** of raw and finished products.

ALL DIAGRAM RELATED TO UNIT -1

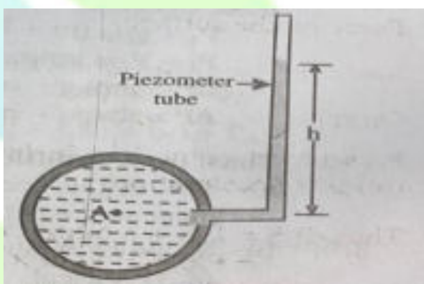


Figure 1.3: Piezometer

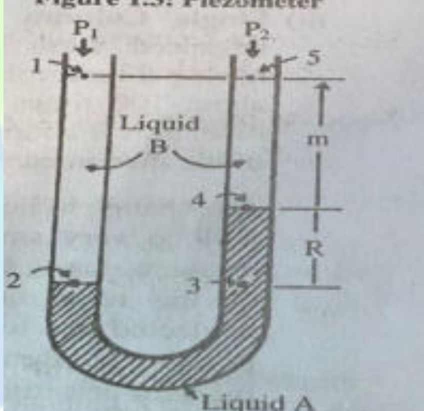


Figure 1.4: Simple Manometer

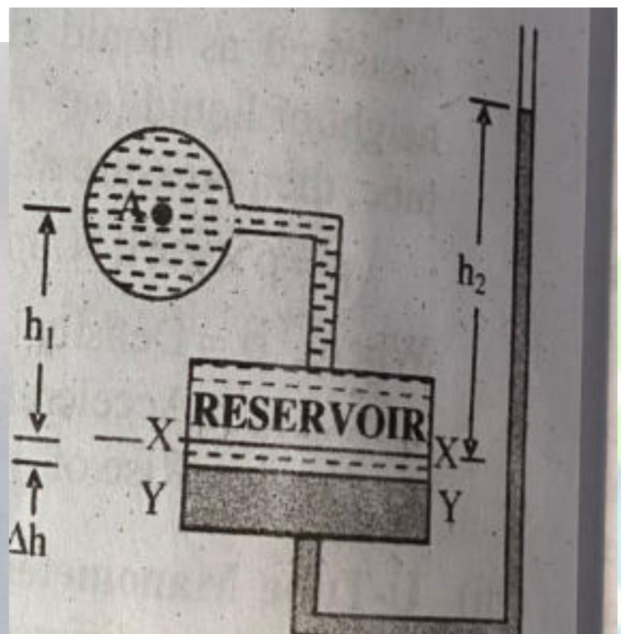


Figure 1.5: Vertical Single Column Manometer

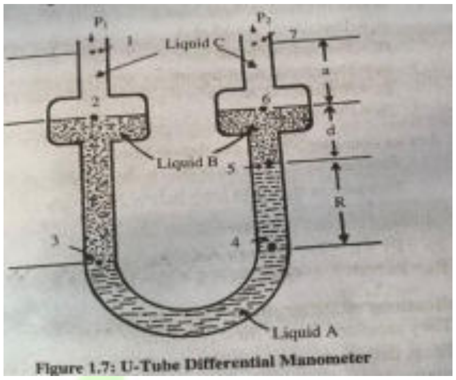


Figure 1.7: U-Tube Differential Manometer

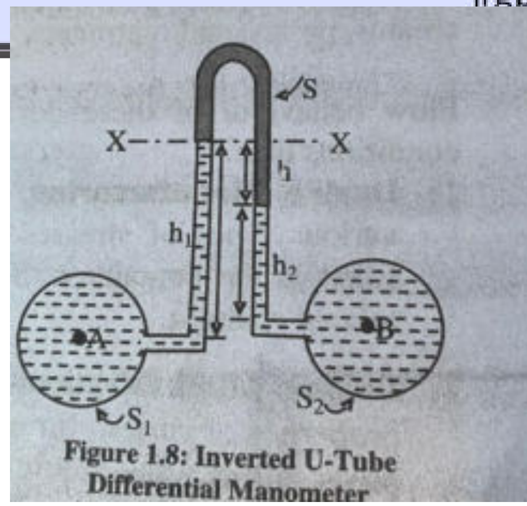


Figure 1.8: Inverted U-Tube Differential Manometer

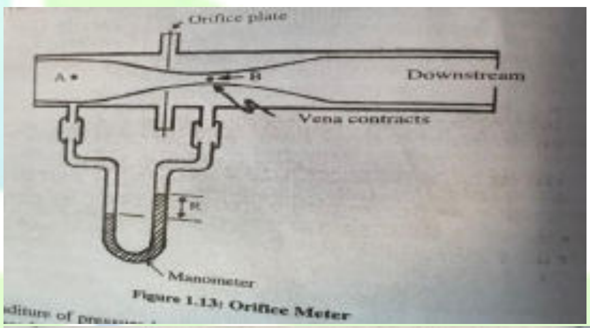


Figure 1.13: Orifice Meter

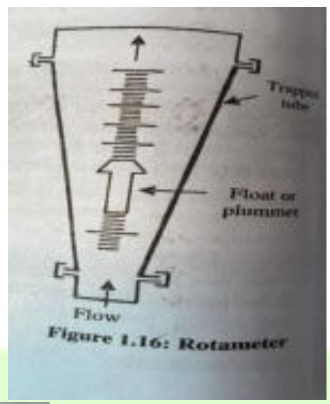


Figure 1.16: Rotameter

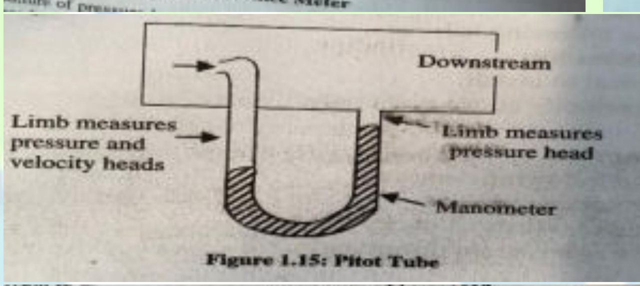


Figure 1.15: Pitot Tube

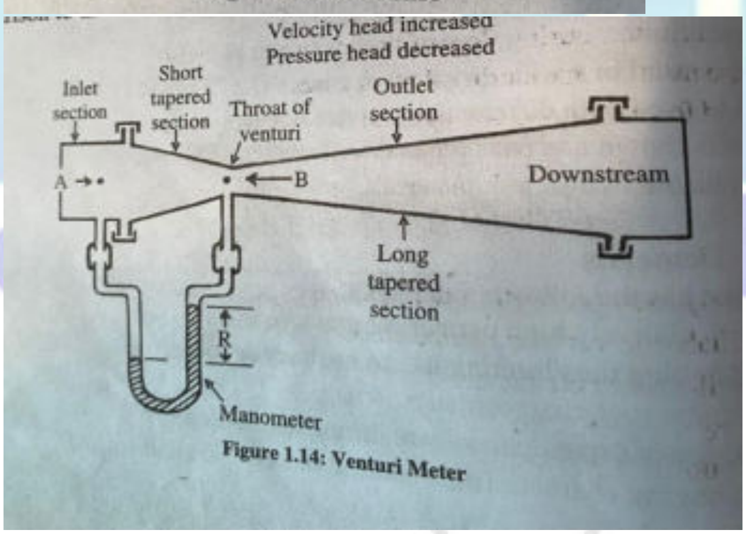


Figure 1.14: Venturi Meter

Prepared by- Kiranmayee Bhatra

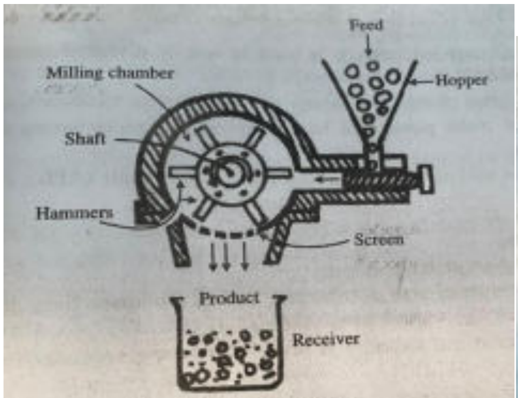


Figure 2.4: Hammer Mill

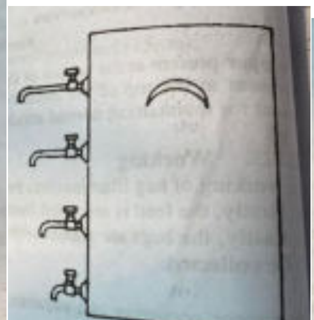


Figure 3.7: Elutriating Tank

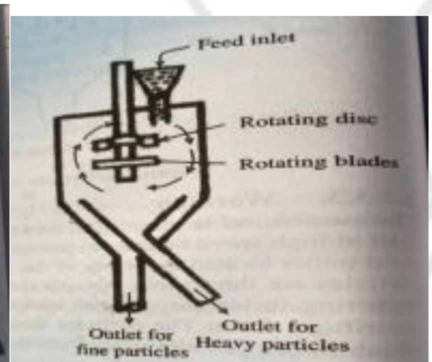


Figure 3.5: Air Separator

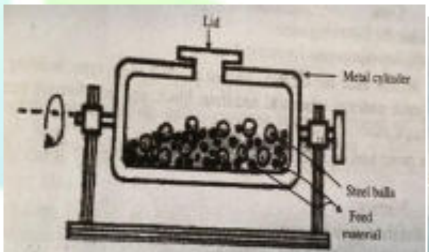


Figure 2.5: Ball Mill

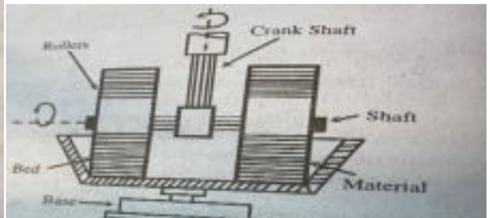


Figure 2.8: Edge Runner Mill

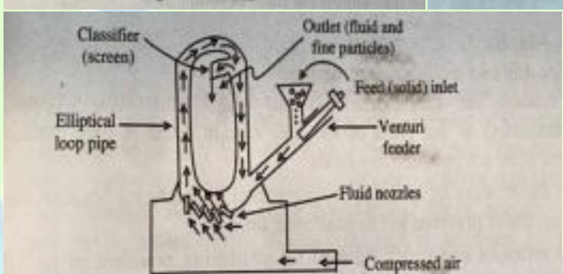


Figure 2.7: Fluid Energy Mill

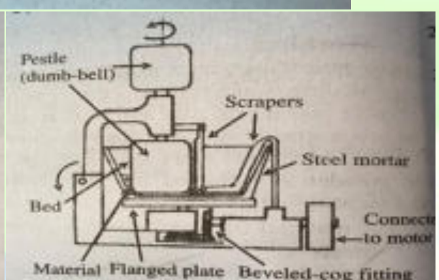


Figure 2.9: End Runner Mill

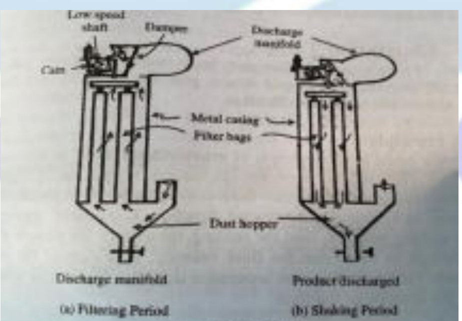


Figure 3.6: Bag Filter

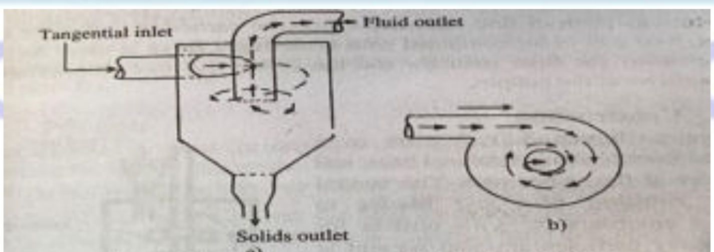


Figure 3.4: Cyclone Separator (a) Elevation (b) Plan

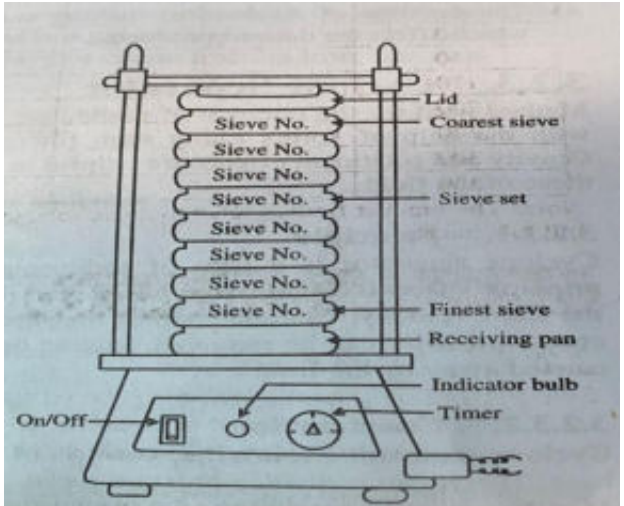


Figure 3.3: Sieve Shaker

10 marks

Question 1:

Explain in detail the mechanisms of heat transfer with pharmaceutical applications and examples.

Answer:

Introduction to Heat Transfer:
Heat transfer is the process by which thermal energy moves from a region of higher temperature to a region of lower temperature. In pharmaceutical processes, controlling heat transfer is crucial for product stability, safety, and quality.

1. Conduction

Definition:
Conduction is the transfer of heat through solids without the movement of the material. It occurs when high-energy particles collide with low-energy ones, transferring heat molecule by molecule.

Mechanism:

- Heat moves from one end of a solid to the other via direct contact.
- Metals are good conductors due to free electrons.

Pharmaceutical Applications:

- **Tray drying:** Heat from the tray is conducted to the wet granules or powders.
- **Dry heat sterilization:** Metallic surgical tools placed in ovens receive heat through conduction.

2. Convection

Definition:
Convection is the heat transfer in fluids (liquids or gases) due to the movement of the fluid itself.

Types:

- **Natural Convection:** Occurs due to natural differences in temperature and density (e.g., hot air rising).
- **Forced Convection:** Involves external devices like fans or pumps to circulate fluid.

Pharmaceutical Applications:

- **Fluidized bed dryers:** Hot air is forced through the powder bed.
- **Evaporators:** Hot fluids like steam transfer heat to the product via convection.

3. Radiation

Definition:
Radiation is the transfer of heat in the form of electromagnetic waves, especially infrared radiation. It does not require a medium.

Mechanism:

- Objects emit radiation based on their temperature.
- Does not need contact or material medium.

Pharmaceutical Applications:

- **Infrared dryers:** Dry products using emitted heat waves.
- **Dry heat sterilizers:** Radiated heat helps sterilize instruments.

4. Fourier's Law of Conduction:

Formula:
$$q = -kA\frac{dT}{dx}$$

Where:

- *q* = heat transfer rate
- *k* = thermal conductivity
- *A* = area of heat flow
- *dT/dx* = temperature gradient

Explanation:

- Greater temperature difference and conductivity = more heat flow.
- Greater thickness = slower heat flow.

Question 2:

Describe the process, types, and applications of Horizontal Tube Evaporator and Climbing Film Evaporator (Rising Film)?

Ans:

Horizontal Tube Evaporator

Principle:

Heat is transferred indirectly by steam surrounding horizontal tubes that carry the liquid. As heat is applied, the liquid evaporates inside the tubes.

Construction:

- A horizontal shell containing multiple straight tubes.
- Steam jacket surrounds the outside of the tubes.
- Inlet and outlet for the feed and evaporated vapors.
- Baffles may be used to direct flow and improve heat transfer.

Working:

- The feed liquid enters and flows inside the horizontal tubes.
- Steam circulates outside the tubes in the jacket.
- Heat transfers through the tube walls, causing evaporation of the liquid inside.
- Vapors exit and are separated from the concentrated liquid.

Uses:

- Concentrating fruit juices, brine, chemical, and pharmaceutical solutions.

Advantages:

- Simple and compact design.
- Low headroom requirement (horizontal orientation).
- Good heat transfer for moderate-viscosity liquids.

Disadvantages:

- Prone to fouling and scaling inside tubes.
- Lower heat transfer rate compared to vertical types.
- Batch-type operation (less continuous processing efficiency).

Climbing Film (Rising Film) Evaporator

Principle:

Uses the boiling of liquid to form vapor, which pushes the liquid upwards, creating a thin climbing film on the inner tube surface, promoting high heat transfer.

Construction:

- A set of long vertical tubes enclosed in a steam jacket.
- Feed enters at the bottom, and vapors and concentrated liquid exit at the top.
- Separator at the top removes vapors from the liquid.

Working:

- Liquid feed enters the bottom of the vertical tubes.
- As it gets heated by the surrounding steam, vapor forms and moves upward.
- The vapor movement carries the liquid upward, forming a thin film on the inner walls.
- Evaporation continues as the film climbs; vapors and residue are separated at the top.

Uses:

- Evaporation of milk, fruit juices, pharmaceutical syrups, and heat-sensitive liquids.

Advantages:

- High heat transfer efficiency due to thin film.
- Low residence time (ideal for heat-sensitive products).
- Suitable for continuous operation.
- Efficient energy use with lower liquid hold-up.

Disadvantages:

- Not suitable for highly viscous or foaming liquids.
- More complex construction.
- Maintenance can be challenging due to vertical design.

5 Mark:

Q1. Explain the different modes of heat transfer with pharmaceutical applications.

Answer:

Heat transfer occurs through three primary modes: conduction, convection, and radiation. Each has distinct mechanisms and pharmaceutical applications:

1. Conduction:
   - It is the transfer of heat through solids without any movement of the material.
   - Heat flows from a region of higher temperature to a lower temperature via molecular vibration.

- Pharma Application: In tray dryers, heat from the hot trays is conducted to the wet granules. In dry heat sterilization, metallic surfaces conduct heat to sterilize instruments.

2. Convection:
   - Heat is transferred through fluids (liquids or gases) due to the movement of the fluid itself.
   - It can be natural (due to density differences) or forced (via fans or pumps).
   - Pharma Application: In fluidized bed dryers, hot air carries heat to powder particles. In evaporators, convection helps circulate the heating fluid.
3. Radiation:
   - Transfer of heat through electromagnetic waves, mostly infrared, without any medium.
   - Pharma Application: In infrared dryers, radiation is used to dry pharmaceuticals. In dry heat sterilizers, radiation assists in killing microbes on instruments.

Q2. Describe the process of evaporation and the factors influencing it.

Answer:

Evaporation is the process where a liquid changes into vapor, usually below its boiling point. It's widely used in the pharmaceutical and food industries to concentrate solutions.

Principle:
Heat energy causes surface molecules to gain kinetic energy and escape as vapor.

Applications:

- Concentrating syrups, herbal extracts.
- Solvent recovery.
- Producing dry formulations after concentration.

Factors Influencing Evaporation:

1. Temperature: Higher temperatures provide more energy for molecules to evaporate.
2. Surface Area: A larger surface increases the rate as more molecules can escape.
3. Vapor Pressure: Liquids with higher vapor pressure (e.g., alcohol) evaporate faster.
4. Humidity: Low humidity increases evaporation as dry air absorbs more vapor.
5. Wind Speed: Wind removes vapor, enhancing evaporation — similar to clothes drying faster on windy days.

Understanding these factors helps optimize the evaporation process for better efficiency and product quality.

Q3. Explain the construction, working, and merits/demerits of a Steam Jacketed Kettle.

Answer:

The Steam Jacketed Kettle is a widely used evaporator in food and pharmaceutical industries.

Principle:
It works on indirect heating, where steam circulates around a jacketed vessel to heat the product inside.

Construction:

- A hemispherical vessel, usually made of stainless steel.
- Surrounded by a jacket where steam is passed.
- May include agitators or scrapers for uniform heating and to prevent sticking.

Working:

- Steam is introduced into the jacket.
- Heat is transferred through the vessel wall to the product inside.
- The condensate from steam is removed through an outlet.
- The product is stirred for even heating.

Merits:

- Simple to use and clean.
- Good temperature control.
- Suitable for viscous materials like syrups and pastes.

Demerits:

- Batch operation, not continuous.
- Lower efficiency compared to other evaporators.
- Limited capacity and requires steam supply.

This kettle is effective for making jams, sauces, and concentrating pharmaceutical liquids.

Q4. Write a short note on Multiple Effect Evaporator (MEE) with working and economy.

Answer:

A Multiple Effect Evaporator (MEE) is a system used to increase evaporation efficiency by reusing steam multiple times.

Principle:

- It uses the vapor from one effect (stage) as the heating medium for the next, saving energy.
- Each effect operates at a lower pressure and temperature than the previous one.

Construction:

- Composed of 2–7 evaporators in series.
- Steam is supplied to the first effect.
- Vapors from one effect are used to heat the next.

Working:

- In the first effect, steam heats the liquid.
- The vapor produced goes to the second effect as a heat source.
- This process continues across all effects.

Economy:

- It is defined as the amount of water evaporated per kg of steam used.
- Example: If 1 kg steam evaporates 3 kg water, economy = 3.
- More effects → higher economy → better energy savings.

Applications:

- Used in sugar, pharmaceutical, and chemical industries.

Advantages:

- Reduces steam usage and fuel cost.
- Suitable for large-scale continuous operations.

Disadvantages:

- High initial cost and complex control.

1-mark questions:

Which of the following is NOT a mode of heat transfer?
a) Conduction
b) Convection
c) Compression
d) Radiation

In pharmaceutical drying, heat is primarily transferred to:

a) Increase the solubility of drug

b) Remove moisture from solids

c) Increase tablet size

d) Convert liquid to gas for separation

Which method uses electromagnetic waves to transfer heat?

a) Conduction

b) Convection

c) Radiation

d) Evaporation

What type of heat exchanger has fluids entering from opposite ends and flowing in opposite directions?

a) Parallel flow

b) Counter flow

c) Cross flow

d) Circular flow

Which process is used to separate components based on their boiling points?

a) Drying

b) Distillation

c) Crystallization

d) Sublimation

In multiple effect evaporators, the term "economy" refers to:

a) Heat loss per unit area

b) Cost of installation

c) Amount of solvent evaporated per kg of steam

d) Time taken for each stage

What principle does steam distillation work on?

a) Molecular weight

b) Solubility differences

c) Co-distillation with steam at lower temperature

d) Viscosity of liquid

Which of the following is an example of indirect heating?

a) Infrared dryer

b) Steam jacketed kettle

c) Sun drying

d) Direct flame

The process of converting liquid to vapor at any temperature below boiling point is called:

a) Evaporation

b) Sublimation

c) Boiling

d) Condensation

What is the main advantage of a counterflow heat exchanger over parallel flow?

a) Simpler construction

b) Lower temperature difference

c) Higher efficiency due to constant temperature gradient

d) Requires more space

MODEL QUESTION AND ANSWER

B. Pharm - 3rd Sem

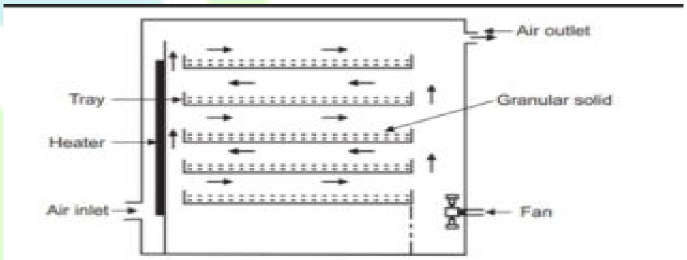
Subject- Pharma Engineering

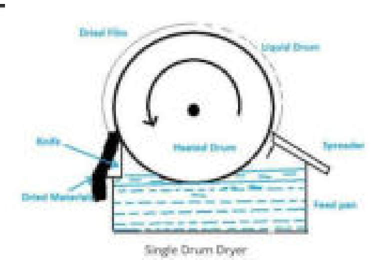
Unit- 3

10 Mark

Q1) Briefly discuss about tray dryer and drum dryer.

Drying is one of the most essential unit operations in the pharmaceutical and chemical industry. It is defined as the removal of small amounts of water or other liquids from solids, semisolids, or liquids by evaporation. Among the various drying methods, tray dryers and drum dryers are two widely used techniques. Each has its unique construction, working principle, applications, and advantages depending upon the type of material to be dried.





Tray Dryer

1. Construction
   - The tray dryer is a cabinet-like structure that consists of an insulated chamber.
   - Inside the chamber, trays are arranged in multiple shelves. The trays are usually made of stainless steel to resist corrosion and contamination.
   - The dryer is provided with a heating system (electric heaters or steam coils) and a blower fan to circulate hot air uniformly throughout the chamber.
   - A control panel regulates temperature, air flow, and drying time.
   - The door of the dryer is airtight to prevent heat loss.

2. Working Principle

- The material to be dried is placed in trays.

- Heated air is circulated using blowers, which transfers heat to the wet material by conduction and convection.
- Moisture from the material evaporates and is removed from the dryer through a moist air outlet.
- Drying continues until the desired moisture content is achieved.

3. Uses

- Drying of crystalline, granular, or coarse powders.
- Used in pharmaceuticals for drying crude drugs, chemicals, and intermediates.
- Also used in food industries for drying fruits, vegetables, and spices.

4. Merits

- Simple in construction and operation.
- Uniform drying due to controlled hot air circulation.
- Economical for batch drying of solid materials.
- Easy maintenance and cleaning.

5. Demerits

- Drying rate is slow compared to fluidized bed dryers.
- Labor-intensive (loading and unloading trays).
- Not suitable for thermolabile materials.
- Risk of uneven drying if trays are overloaded.

Drum Dryer

1. Construction

- A drum dryer consists of one or two large, hollow cylindrical drums that are heated internally by steam.
- The outer surface of the drum serves as the drying surface.
- A feed system spreads the liquid or slurry material on the drum surface.
- A doctor blade or scrapper is fitted to continuously scrape off the dried material from the drum surface.
- The entire system is mounted with appropriate drives for drum rotation.

2. Working Principle

- The wet material (slurry or solution) is applied as a thin film on the heated rotating drum.
- Heat from the drum causes rapid evaporation of moisture from the film.

- As the drum rotates, the dried material forms a solid layer which is continuously scrapped off by the doctor blade.
- The product is collected in a hopper and further processed (milled or ground) if needed.

3. Uses

- Drying of liquid extracts, pastes, and slurries.
- Used in pharmaceuticals for drying yeast, starches, vitamins, and enzymes.
- In food industry for drying milk (milk powder), baby food, and fruit pulp.

4. Merits

- Very rapid drying due to large heat transfer area.
- Continuous operation possible (higher productivity than tray dryer).
- Suitable for heat-resistant slurries or viscous materials.

5. Demerits

- Not suitable for heat-sensitive drugs (product may get charred).
- Higher installation and maintenance cost.
- Dried product is usually in the form of flakes, which may require size reduction.
- Cleaning and sterilization are difficult compared to tray dryers.

Comparison Between Tray Dryer and Drum Dryer

Feature	Tray Dryer	Drum Dryer
Mode	Batch	Continuous
Material	Solids, granules	Liquids, slurries
Heat Transfer	Convection	Conduction
Drying Speed	Moderate	High
Product Form	Dry powder/granules	Flakes/powder
Suitability	Thermostable solids	Non-thermolabile liquids

Q2) Give a brief review on the mechanism of drying process.

Introduction.

Drying is a fundamental unit operation in pharmaceutical, chemical, and food industries. It involves the removal of moisture or solvents from wet solids, liquids, or semi-solids through evaporation or sublimation, ultimately producing a stable solid product. The mechanism of drying is not simply the removal of water; it is a complex phenomenon involving simultaneous heat transfer and mass transfer processes.

To design and optimize drying equipment, one must understand the mechanism of drying, which explains how moisture is removed, at what rate, and under which conditions.

Definition of Drying

Drying can be defined as a process by which water or any other solvent is removed by evaporation from a solid, semi-solid, or liquid by supplying heat, thereby producing a dry solid product.

Basic Principle of Drying

- Heat transfer: Heat is supplied to the wet material either by conduction, convection, or radiation.
- Mass transfer: Moisture migrates from the interior of the solid to its surface and evaporates into the surrounding drying medium (usually hot air).
- The driving force for drying is the difference in vapor pressure of the liquid on the solid surface and in the surrounding air.

Thus, the drying mechanism involves a coupled process of heat transfer and mass transfer.

Stages in Drying Mechanism

The drying process typically takes place in two main periods:

1. Constant Rate Period

- At the beginning of drying, the surface of the wet material is fully saturated with water.
- Heat supplied evaporates water from the surface at a constant rate.
- The drying rate during this period is controlled by the rate of heat transfer to the surface.
- Surface water is easily removed, similar to evaporation from a free liquid surface.
- In this stage, the material temperature remains close to the wet bulb temperature of the drying air.

2. Falling Rate Period

- After the surface moisture is removed, the rate of drying decreases.
- Moisture must now diffuse from the interior of the material to the surface before evaporation can occur.
- The drying rate is controlled by the rate of internal mass transfer of moisture.

- Movement of water molecules occurs by mechanisms like liquid diffusion, vapor diffusion, or capillary action.
- As drying continues, the material temperature rises toward the dry bulb temperature of the drying air.
- This stage continues until the desired final moisture content is achieved.

Mechanisms of Moisture Movement within Solids

During the falling rate period, different mechanisms govern how water moves within the material:

1. Liquid Diffusion
- Occurs when moisture is present in the form of liquid inside pores.
- Moisture diffuses due to concentration gradients (from high to low moisture regions).

2. Capillary Action
- Moisture moves through fine capillary spaces in porous solids.
- Capillary forces drive liquid water toward the drying surface.

3. Vapor Diffusion
- If liquid water evaporates inside pores, vapor diffuses toward the surface.
- This occurs in hygroscopic materials or at low moisture levels.

5. Surface Diffusion
- Moisture migrates along the surface of solid particles.
- Important in materials with high surface area.

6. Hydrodynamic Flow
- When material shrinks due to water removal, a pressure gradient is created that forces water movement.

Factors Affecting Drying Mechanism

1. Nature of material – Porous vs. non-porous, crystalline vs. amorphous.
2. Moisture content – Free moisture is removed faster than bound moisture.
3. Air temperature and humidity – High drying air temperature and low humidity increase drying rate.
4. Air velocity – Faster airflow removes evaporated moisture more effectively.
5. Surface area – Smaller particle size increases surface exposure, enhancing drying.
6. Heat sensitivity – Thermolabile substances require gentle drying (e.g., freeze drying).

Theoretical Models of Drying

Several models explain the drying mechanism mathematically:

1. Newton's Law of Cooling Analogy
   $Dm/dt = -k(M - M_e)$
- Where M= moisture content,
  M_e = equilibrium moisture content,
  k= drying rate constant.
2. Diffusion Models
- Based on Fick's Law of Diffusion, moisture flux is proportional to concentration gradient.
3. Capillary Flow Models
- Based on movement of liquid through porous media under capillary forces.

Graphical Representation of Drying

A typical drying rate curve helps visualize the drying mechanism:

- X-axis: Moisture content (dry basis)
- Y-axis: Drying rate

Stages:

1. Warm-up period (initial heating).
2. Constant rate period (surface evaporation).
3. Falling rate period (internal diffusion-controlled).
4. Equilibrium moisture content (no further drying possible).

Practical Examples

1. Tray Dryer – Exhibits clear constant and falling rate periods when drying granules.
2. Fluidized Bed Dryer – Higher drying rates due to increased surface contact with air.
3. Freeze Dryer – Follows sublimation drying mechanism (no constant rate).
4. Spray Dryer – Droplet drying shows an extremely short constant rate period.

Importance in Pharmaceutical Industry

Understanding the mechanism is crucial for:

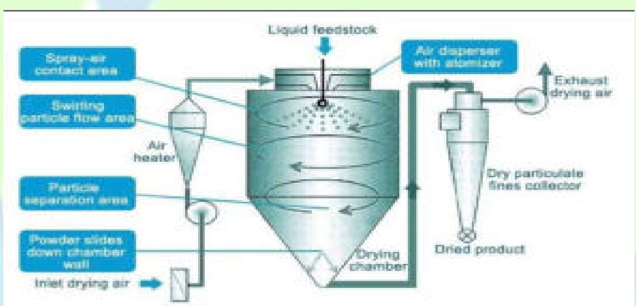
- Selection of drying equipment (tray dryer, drum dryer, spray dryer, freeze dryer).
- Optimization of drying conditions to avoid drug degradation.
- Controlling product quality (particle size, flow properties, stability).
- Energy efficiency in large-scale drying processes.

Q3) Discuss the construction, working, uses, merits, and demerits of freeze dryer and spray dryer.

Introduction

Drying of pharmaceuticals is an essential step in drug formulation and manufacturing. However, many active pharmaceutical ingredients (APIs), enzymes, proteins, and vaccines are thermolabile (heat-sensitive) and cannot be dried using conventional high-temperature dryers like tray or drum dryers. For such cases, freeze drying (lyophilization) and spray drying are the preferred techniques.

Both dryers are widely used in the pharmaceutical, food, and biotechnology industries, but their construction, principle, and applications differ greatly.



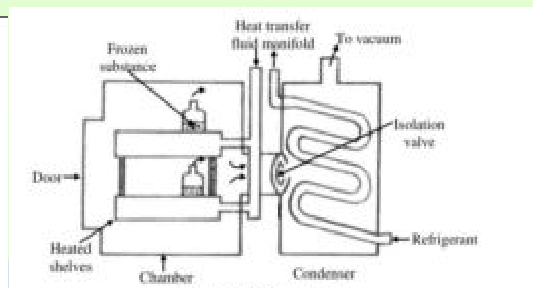


Figure 7.15: Freeze Dryer

1. Freeze Dryer (Lyophilizer)

Construction

A freeze dryer consists of the following main parts:

- Drying chamber – A vacuum-tight chamber fitted with shelves where product containers (vials, ampoules, or trays) are placed.
- Shelves with temperature control – Equipped with heating/cooling systems to first freeze the material and then supply heat for sublimation.
- Condenser (cold trap) – A separate chamber maintained at very low temperature (−40°C to −80°C) to collect the water vapor sublimed from the product.

- Vacuum system – High-capacity vacuum pumps to reduce chamber pressure (typically below 1 torr), enabling sublimation.

5. Refrigeration unit – Provides low temperatures for freezing and condenser operation.
6. Control system – Monitors temperature, pressure, and drying cycle.

Working Principle

- Freeze drying works on the principle of sublimation, i.e., direct conversion of ice (frozen water) to vapor without passing through the liquid state.
- At low pressure and temperature, water molecules gain enough energy to escape directly from solid to vapor phase.
- Stages of Freeze Drying
- Freezing – The material (solution/suspension) is frozen at very low temperatures (−40°C or lower).
- Primary drying (sublimation phase) – Under vacuum, heat is gently supplied to cause sublimation of ice. Water vapor is collected in the condenser.
- Secondary drying (desorption phase) – Removes bound moisture at slightly higher temperatures to achieve final dryness.

Uses

- Preservation of heat-sensitive drugs, antibiotics, and vaccines (e.g., penicillin, insulin ,biologicals).
- Drying of blood plasma, hormones, enzymes.
- Used in biotechnology for long-term storage of cultures and microorganisms.
- Food industry: preservation of coffee, fruits, and vegetables.

Merits

- Suitable for thermolabile materials.
- Products retain their biological activity and original structure.
- Final product is porous and easily reconstituted (important for injections).
- Very low residual moisture (<1–2%), improving stability.

Demerits

- Very expensive equipment and operation cost.
- Long drying time (several hours to days).
- Requires skilled personnel and strict control of parameters.
- Not suitable for large-scale drying of inexpensive bulk materials.

2. Spray Dryer

Construction

A spray dryer consists of:

1. Drying chamber – Large cylindrical or conical chamber.
- Atomizer/Nozzle – Converts feed liquid into small droplets (pressure nozzle, rotary disc, or two-fluid nozzle).
- Hot air system – Heated air is introduced into the chamber (co-current or counter-current flow).
4. Cyclone separator – Collects dried product particles.
5. Exhaust system – Removes moist air.
6. Control panel – Regulates inlet air temperature, feed rate, and air flow.

Working Principle

- The liquid feed (solution, suspension, or emulsion) is atomized into fine droplets inside the drying chamber.
- Hot air is introduced, which rapidly evaporates moisture from the droplets.
- Dry particles are separated from exhaust air in a cyclone separator and collected.
- Moist air is vented out.

Uses

- Drying of heat-sensitive pharmaceutical products such as antibiotics, enzymes, and vitamins.
- Preparation of powders from liquid feeds (milk powder, coffee powder).
- Microencapsulation of flavors, oils, and drugs.
- Used in ceramics, detergents, and polymers.

Merits

- Very rapid drying (seconds).
- Suitable for continuous large-scale production.
- Can process heat-sensitive materials (short exposure time).
- Produces uniform, fine, free-flowing powders.
- Direct conversion from liquid feed to dry powder in one step.

Demerits

- High initial and operational costs.
- Low thermal efficiency (large heat losses).
- Bulky equipment, requiring large space.

- Not suitable for highly viscous liquids or slurries.
- Particle size sometimes difficult to control.

Comparison Between Freeze Dryer and Spray Dryer

Feature	Freeze Dryer	Spray Dryer
Principle	Sublimation (solid → vapor)	Atomization + hot air drying
Operation	Batch	Continuous
Suitable for	Heat-sensitive injectables, vaccines, proteins	Powders from solutions/suspensions
Product	Porous, easily reconstituted cake	Free-flowing powder
Cost	Very high	High but lessthan freeze
Time	Hours to days	Seconds minutes

Q4) Briefly discuss about liquid–liquid mixing

Introduction

Mixing is a fundamental unit operation in pharmaceutical, chemical, food, and biotechnology industries. It involves bringing together two or more substances to form a homogeneous product. Among the different types of mixing, liquid–liquid mixing is of great importance, as many pharmaceutical formulations and chemical processes involve liquids as the main phase. Liquid–liquid mixing refers to the combination of two immiscible or miscible liquids to achieve uniformity. Depending on the system, it may result in a true solution, emulsion, or dispersion. Examples include mixing of solvents in extraction, preparation of emulsions, and formulation of syrups, lotions, and injectables.

Objectives of Liquid–Liquid Mixing

1. To achieve uniform distribution of one liquid into another.
2. To prepare true solutions (completely miscible liquids).
3. To prepare emulsions (immiscible liquids stabilized by emulsifiers).
4. To improve heat and mass transfer in chemical reactions.

- To enable pharmaceutical manufacturing such as suspensions, emulsions, syrups, and oral liquids.

Types of Liquid–Liquid Mixing

Liquid–liquid systems can be classified as:

1. Miscible Liquids
   - Example: Mixing ethanol and water.
   - Results in a single-phase solution.
   - Mixing is relatively easy.
2. Immiscible Liquids
   - Example: Oil and water.
   - Results in a two-phase system that requires agitation and stabilizers.
   - Forms emulsions (oil-in-water or water-in-oil).

Mechanism of Liquid–Liquid Mixing

The mechanism depends on whether liquids are miscible or immiscible:

1. Miscible Liquids
   - Governed by molecular diffusion and convection currents created by agitation.
   - The process is relatively fast due to low resistance.
2. Immiscible Liquids
   - Mixing involves dispersion of one liquid into another in the form of droplets.
   - Droplet formation occurs due to shear forces generated by impellers or agitators.
   - Stabilization requires emulsifying agents or surfactants.
   - Mechanism involves:
   - Drop breakage (large drops broken into smaller ones).
   - Drop coalescence (small drops merging to form larger ones).
   - Mass transfer across droplets.

Factors Affecting Liquid–Liquid Mixing

1. Viscosity of liquids – High viscosity increases resistance to mixing.
2. Density difference – Large differences make dispersion more difficult.
3. Interfacial tension – Higher tension makes droplet formation harder.
4. Agitation speed – Higher speeds improve dispersion but may cause instability.
5. Type of agitator – Propellers, turbines, and paddles are commonly used.
6. Presence of emulsifiers – Reduces interfacial tension and stabilizes the mixture.

Equipment for Liquid–Liquid Mixing

1. Propeller Mixers – Suitable for low-viscosity liquids (solutions, syrups).
2. Turbine Mixers – Suitable for viscous and immiscible systems (emulsions).
3. Paddle Agitators – Used in tanks for gentle mixing of large liquid volumes.
4. Homogenizers – High-shear devices used for fine emulsions.
5. Colloid Mills – Reduce droplet size for stable emulsions.

Applications in Pharmaceuticals

- Preparation of emulsions (ointments, creams, lotions).
- Mixing of syrups and oral liquids.
- Solvent extraction processes (separation of compounds).
- Parenteral formulations (oil-based injections).
- Microencapsulation and sustained-release drug formulations.

Merits

- Ensures uniform product quality.
- Enables mixing of both miscible and immiscible liquids.
- Improves reaction rates in chemical processes.
- Provides stable dosage forms (emulsions, suspensions).

Demerits

- Requires specialized equipment for immiscible liquids.
- Energy-intensive for viscous or high-density systems.
- Emulsions may be unstable without surfactants.
- Scale-up from lab to industrial level is sometimes difficult.

Q5) Discuss the construction, working, uses, merits, and demerits of double cone and twin shell blender.

Introduction

Blending is a critical step in pharmaceutical manufacturing to ensure uniform distribution of drug and excipients in solid dosage forms like tablets and capsules. Two widely used equipment for solid-solid mixing are the Double Cone Blender and the Twin Shell Blender (V-Blender). Both operate on the principle of tumbling motion and are designed for gentle mixing of free-flowing powders.

Mixing (Chapter 8)

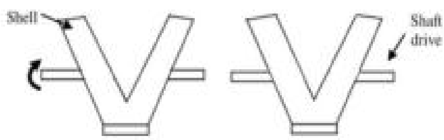


Figure 8.2: Twin Shell Blender without Mixing Blade

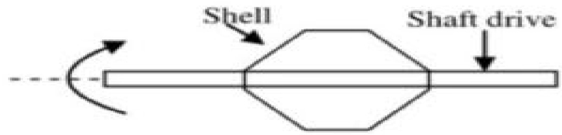


Figure 8.1: Double Cone Blender without Mixing Blade

1. Double Cone Blender

Construction

- A double cone-shaped vessel mounted on a horizontal axis.
- Vessel made of stainless steel for pharmaceutical use.
- Supported by trunnions, which allow rotation.
- Charging port provided at the top, discharge valve at the bottom.
- Sometimes fitted with intensifier bars for better mixing.

Working

- The vessel rotates slowly around its axis.
- Powder particles continuously cascade and intermix due to tumbling action.
- Mixing occurs by diffusion and shear.
- After desired time, material is discharged through the bottom valve.

Uses

- Blending of dry powders and granules.
- Mixing excipients with active pharmaceutical ingredients.
- Used in food, chemical, and cosmetic industries.

Merits

- Simple design, easy to operate.
- Gentle mixing, no degradation of particles.
- Uniform mixing with minimal dead spots.
- Easy to clean and maintain.

Demerits

- Not suitable for cohesive or sticky powders.
- Requires longer mixing time than high-shear mixers.
- Cannot handle wet granules or pastes.
- Overfilling reduces efficiency.

2. Twin Shell Blender (V-Blender)

Construction

- Vessel consists of two cylindrical shells joined at an angle (~75° to 90°) forming a "V" shape.
- Mounted on a horizontal shaft for rotation.
- Charging port at the top, discharge valve at the bottom.
- Optionally equipped with intensifier bar.

Working

- Vessel rotates slowly, causing powders to cascade between the two arms of the "V".
- Repeated dividing and recombining of powders ensure mixing.
- Diffusion and convection are the main mechanisms.

Uses

- Blending of free-flowing powders and granules.
- Widely used for pharmaceutical tablet and capsule formulations.
- Suitable for fragile materials as mixing is gentle.

Merits

- More efficient mixing than double cone blender.
- Shorter mixing time due to V-shape.
- Minimal attrition of particles.
- Can be scaled up for large batches.

Demerits

- High initial cost compared to double cone blender.
- Not suitable for cohesive or sticky powders.
- Dead zones may exist if not rotated properly.
- Requires precise filling (50–70% volume).

Comparison Between Double Cone and Twin Shell Blender

Feature	Double Cone Blender	Twin Shell Blender
Shape	Double cone	V-shaped twin shell

Efficiency	Moderate	Higher
Mixing Time	Longer	Shorter
Cost	Lower	Higher
Suitable For	Dry free-flowing powders	Fragile, sensitive powders

Q6) Give a brief review on propellers and turbines.

Introduction

In liquid mixing operations, agitators play a crucial role in achieving homogeneity, enhancing heat and mass transfer, and dispersing immiscible liquids. Among the different types of agitators, propellers and turbines are the most widely used in pharmaceutical and chemical industries. Both differ in design, flow pattern, and applications.

hapter 8)

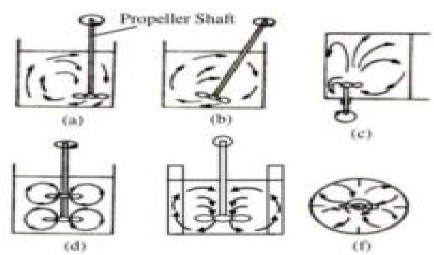


Figure 8.6: Different Positions of Propellers

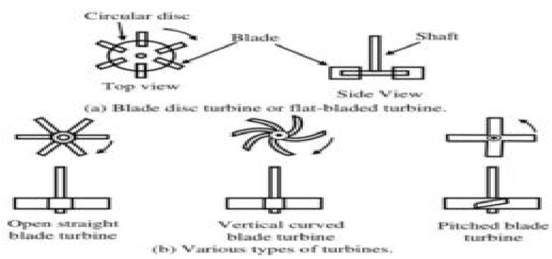


Figure 8.7: Turbine Impeller

Propellers

Construction

- Consist of 2–4 blades attached to a central hub.
- Blades are narrow, tapered, and resemble a marine propeller.
- Mounted on a shaft connected to a motor.

Working

- When rotated at high speed (400–1500 rpm), propellers create an axial flow pattern.
- Liquid moves parallel to the shaft, resulting in top-to-bottom circulation.
- Suitable for low-viscosity liquids.

Uses

- Mixing of solutions, syrups, and suspensions.
- Preparation of emulsions in low-viscosity media.

- Fermentation processes (aeration and mixing).

Merits

- High pumping capacity.
- Efficient mixing at high speeds.
- Produces good top-to-bottom circulation.

Demerits

- Not suitable for very viscous liquids.
- May cause vortex formation if not baffled.
- Requires high power input at large scale.

Turbines

Construction

- Consist of a central hub with 4–8 flat or curved blades.
- Blades are mounted vertically or at angles.
- Shaft connected to motor drives the turbine.

Working

- Operates at moderate speeds (50–200 rpm).
- Produces a radial flow pattern (liquid moves outward from shaft to walls).
- Suitable for high-viscosity liquids and gas-liquid dispersions.

Uses

- Mixing of viscous emulsions and suspensions.
- Fermenters for aeration and agitation.
- Crystallization and extraction processes.

Merits

- Effective in dispersing immiscible liquids.
- Works well in viscous systems.
- Promotes good gas-liquid mixing.

Demerits

- Higher power consumption than propellers.
- May cause localized high shear, damaging sensitive materials.
- Cleaning can be difficult in large reactors.

Comparison Between Propellers and Turbines

Feature	Propeller	Turbine
Speed	High (400–1500 rpm)	Low–moderate (50–200 rpm)
Flow	Axial	Radial
Suitable for	Low-viscosity liquids	Medium-to-high viscosity
Efficiency	High circulation	Good dispersion
Applications	Solutions, syrups, low-viscosity emulsions	Fermentation, emulsions, crystallization

Q7) **Explain in detail the principle, construction, working, uses, merits, and demerits of Plate and Frame Filter.**

Answer:
The **Plate and Frame Filter Press** is one of the oldest and widely used filtration equipment in the pharmaceutical and chemical industries.

- **Principle:**
  It works on the principle of **mechanical separation** of solids from liquids using pressure-driven filtration. A slurry (suspension) is pumped into chambers formed between plates and frames; liquid passes through filter media while solids are retained as a cake.
- **Construction:**
  - Consists of a **series of plates and frames** arranged alternately.
  - Plates have grooved surfaces and filter cloths attached.
  - Frames form empty chambers for holding the slurry.
  - Tightened by a screw mechanism or hydraulic press.
  - A filtrate outlet collects the liquid.
- **Working:**
  - Slurry is pumped into the frames under pressure.
  - Liquid passes through filter cloth (acting as medium).
  - Filtrate comes out through channels, while solids remain as a **filter cake**.
  - After filtration, frames are dismantled to remove cake.

- **Uses:**
    - Used in pharmaceutical industries for separating drugs from mother liquors.
    - In chemical industries for separating catalysts.
    - In food industry (sugar, juices, oils).
- **Merits:**
    - Simple in design and operation.
    - Gives clear filtrate.
    - Can handle corrosive materials (with suitable construction).
    - Filter cake can be recovered easily.
- **Demerits:**
    - Batch process (not continuous).
    - Labor-intensive (requires dismantling).
    - Not suitable for dilute slurries.
    - High operation time.

Q8) **Describe the principle, construction, working, uses, merits, and demerits of Rotary Drum Filter.**

Answer:
The **Rotary Drum Filter** is a continuous filtration device widely used in large-scale industries.

- **Principle:**
  It works on the principle of **continuous vacuum filtration**. A rotating drum covered with filter cloth is partially immersed in slurry. Due to vacuum, filtrate passes through the filter cloth, leaving solids as a filter cake.
- **Construction:**
    - A large hollow cylindrical drum, mounted horizontally.
    - Outer surface covered with filter cloth.
    - Drum is divided into compartments connected to a vacuum system.
    - A trough at the bottom contains slurry.
    - Cake removal device (scraper, belt discharge, or roll discharge).

- **Working:**
  - Drum rotates slowly in slurry.
  - Vacuum applied → liquid passes inside through filter cloth → filtrate collected.
  - Solids deposit as cake on drum surface.
  - Cake is dried by air flow as drum rotates out of slurry.
  - Cake removed mechanically by scraper or belt.
  - Continuous process repeats.
- **Uses:**
  - In pharmaceutical industries (antibiotics, fermentation products).
  - In sewage treatment plants.
  - In food industry (sugar, starch, juices).
- **Merits:**

1. Continuous operation → high throughput.
2. Suitable for slurries with moderate solid content.
3. Easy recovery of filtrate and cake.

- **Demerits:**

1. High cost and bulky design.
2. Not suitable for dilute suspensions.
3. Filter cloth requires frequent cleaning.
4. Not ideal for highly compressible solids.

5 marks

Q1) Discuss the factors affecting drying

Introduction

Drying is a critical unit operation in the pharmaceutical and chemical industry. It refers to the removal of moisture or solvent from solids, liquids, or semisolids through evaporation or sublimation, leading to a stable solid product. The efficiency of drying is not uniform—it depends on various factors related to the material, equipment, and environment. Understanding these factors is essential for selecting the right drying method and achieving consistent product quality.

Factors Affecting Drying

1. Nature of the Material
- Porosity: Porous materials dry faster as moisture migrates easily through voids. Non porous materials show slower drying.
- Crystallinity/Amorphous nature: Crystalline substances release moisture more readily, while amorphous solids may retain bound water.
- Hygroscopicity: Hygroscopic materials (e.g., gelatin) absorb atmospheric moisture, complicating drying.

2. Moisture Content
- Free moisture: Easily removed during the constant rate period.
- Bound moisture: Strongly attached to solid matrix, requires higher energy (falling rate period).
- Equilibrium Moisture Content (EMC): Drying cannot reduce moisture below EMC.

3. Surface Area of Material
- Larger surface area (small particles, granules) → faster drying due to increased exposure to air.
- Bulk materials with less surface area dry slower.

4. Air Temperature
- Higher drying air temperature increases vapor pressure difference, accelerating drying.
- But excessive heat may degrade thermolabile drugs (vitamins, proteins).

5. Air Humidity
- Drying is faster when surrounding air has low humidity.
- High relative humidity reduces driving force for evaporation.

6. Air Velocity
- Faster airflow removes evaporated moisture quickly from material surface, preventing saturation.
- Too high velocity may cause attrition or dust formation.

7. Type of Heat Transfer

- Conduction (tray, drum dryers) – moderate drying, surface-limited.
- Convection (fluidized bed, spray dryers) – faster drying due to continuous hot air flow.
- Radiation (infrared, microwave dryers) – rapid heating, but limited control.

8. Equipment Design

- Tray dryers: slow, batch-wise.
- Fluidized bed dryers: fast, uniform drying.
- Freeze dryers: suitable for thermolabile materials, but very slow.
- Spray dryers: rapid, continuous drying of liquids.

9. Product Properties

- Shape and density of granules affect drying rate.
- Sticky or viscous materials are difficult to dry (require specialized dryers like vacuum dryers)

Q2) Write a short note on EMC

Introduction

During drying, moisture is progressively removed from the material until a stage is reached when no further drying occurs under given conditions. This moisture content is called the Equilibrium Moisture Content (EMC). It is a crucial parameter in drying operations, as it determines the limit of drying achievable for a material.

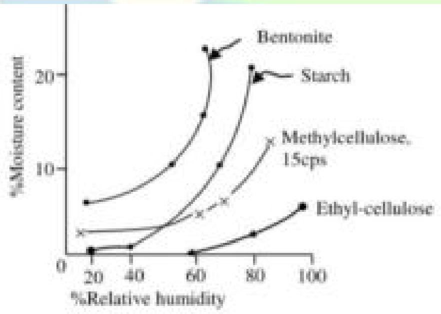


Figure 7.2: EMC Curves for Tableting Material

Definition

Equilibrium Moisture Content (EMC):

The moisture content of a material at which it is in equilibrium with the surrounding air, i.e., the rate of moisture removal equals the rate of moisture absorption from air.

Importance of EMC

- Limit of Drying: Drying cannot reduce moisture below EMC under specified air temperature and humidity.
- Stability of Product: Products stored above EMC tend to absorb moisture, leading to degradation (e.g., caking, microbial growth).
- Drying Efficiency: Knowledge of EMC helps determine when to stop drying to avoid unnecessary energy use.
- Design of Equipment: EMC values guide engineers in selecting suitable dryers and operating conditions.

Factors Affecting EMC

1. Relative Humidity of Air
- EMC increases with increase in relative humidity.
- At higher humidity, material tends to absorb water until equilibrium is reached.
2. Temperature of Air
- As temperature increases, EMC decreases (air can hold more moisture).
- Lower EMC at high temperature makes drying more effective.
3. Nature of Material
- Hygroscopic substances (gelatin, gums, starch) have higher EMC.
- Crystalline solids exhibit lower EMC.
4. Porosity and Surface Area
- Porous substances adsorb more water vapor, increasing EMC.
- Fine powders have higher EMC due to greater surface exposure.

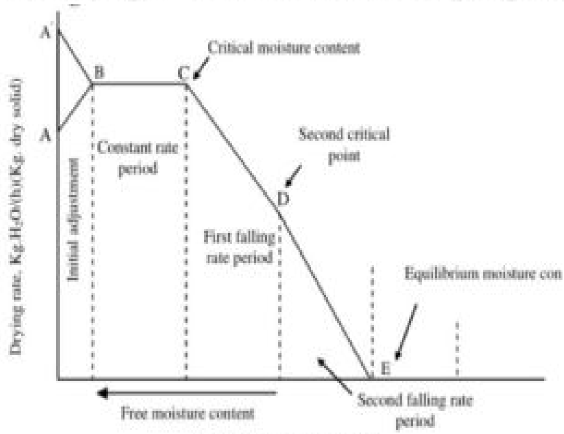
Practical Examples

- Tablets: If dried below EMC, they may become brittle; if stored above EMC, they may swell or disintegrate.
- Food Products: Milk powder and coffee require storage below EMC to prevent caking.
- Biological Products: Enzymes and proteins need strict EMC control for stability.

Q3) Discuss the different periods of the drying curve.

Introduction

The drying of a material does not occur at a constant rate throughout the process. Instead, the drying rate changes depending on the moisture content, heat transfer, and mass transfer involved. The relationship between drying rate and moisture content can be represented graphically as the drying rate curve. Understanding the different periods of this curve helps optimize drying methods and avoid drug degradation in pharmaceuticals.



7.3: Drying Rate Curve

Stages of Drying Rate Curve

1. Initial Adjustment (Warm-up Period)
   - At the beginning of drying, the material is at room temperature.
   - When hot air or heat is applied, the material first undergoes a heating phase.
   - Moisture evaporation is minimal at this stage.
   - Duration depends on the nature of material and initial temperature difference.
2. Constant Rate Period
   - Once the surface becomes saturated with water, evaporation occurs at a constant rate.
   - Heat supplied is used entirely for vaporization of surface moisture.
   - Drying rate is constant and controlled by external conditions like air temperature, air velocity, and humidity.
   - Mechanism is similar to evaporation from a free water surface.
   - The temperature of the material remains close to the wet bulb temperature.
   - Most free water is removed in this stage.
3. First Falling Rate Period
   - Begins when surface moisture is depleted.

- Moisture must now diffuse from interior to surface before evaporation.
- Drying rate decreases as internal diffusion is slower than surface evaporation.
- Material temperature begins to rise toward the dry bulb temperature.
- Moisture movement occurs by capillary action, diffusion, and vapor migration.

4. Second Falling Rate Period

- At this stage, most of the moisture present is bound water (held by adsorption, chemical bonds, or within pores).
- Removing this moisture requires higher energy.
- Drying rate falls sharply.
- Product may undergo physical or chemical changes (browning, crystallization).
- Care is needed to avoid degradation of thermolabile drugs.

5. Equilibrium Moisture Content Stage

- Drying continues until the material reaches EMC.
- At EMC, the moisture content of material equals that of the surrounding air.
- No further drying occurs unless conditions (temperature, humidity) are changed.

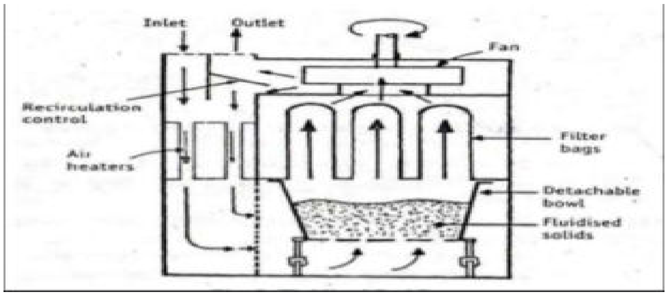
Graphical Representation

- X-axis: Moisture content (dry basis).
- Y-axis: Drying rate.
- Curve shows: Initial heating → Constant rate → Falling rate(s) → EMC

Q4) Give the construction and working of fluidized bed dryer

Introduction

The Fluidized Bed Dryer (FBD) is one of the most widely used dryers in the pharmaceutical industry. It is preferred due to its rapid drying, uniform heat transfer, and efficiency. The principle involves suspending solid particles in an upward moving stream of hot air, creating a "fluidized state." This ensures excellent contact between air and particles, resulting in faster drying compared to tray dryers.



Construction

1. Drying Chamber
   - A vertical, cylindrical chamber with a perforated bottom plate (air distributor).
   - Made of stainless steel to maintain hygienic conditions.
2. Air Handling System
   - Blower fan supplies air.
   - Air heater (electric coils or steam) raises temperature.
   - Filter removes dust and contaminants.
3. Perforated Plate
   - Supports material bed.
   - Allows passage of hot air, which fluidizes particles.
4. Product Container
   - Removable bowl for charging and discharging material.
5. Bag Filters/Expansion Chamber
   - Prevents powder loss by trapping fine particles in air stream.
6. Control Panel
   - Regulates temperature, airflow, and drying time.

Working

1. Wet granules or powders are loaded into the product container.
2. A stream of hot air is passed through the perforated plate.
3. At appropriate velocity, particles become suspended and behave like a fluidized bed.
4. Hot air provides uniform heat transfer to each particle, causing rapid evaporation of surface moisture.
5. Moist air is carried away through exhaust filters.

6. Once desired moisture content is reached, the dryer is stopped, and dried material is discharged.

Uses

- Drying of granules before compression into tablets.
- Drying powders, intermediates, and crystalline products.
- Used in food, chemical, and agricultural industries.

Advantages

- Very rapid drying due to high surface area exposure.
- Uniform drying without hot spots.
- Short drying time compared to tray dryer.
- Easy loading and unloading.
- Can handle large batch sizes.

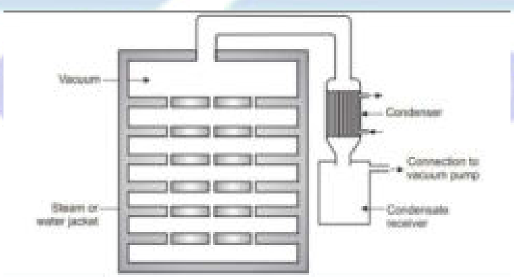
Disadvantages

- Not suitable for thermolabile drugs (due to high air temperature).
- Particle attrition may occur due to turbulence.
- High installation cost compared to tray dryers.
- Requires careful control of airflow to avoid elutriation (loss of fine particles)

Q5) Write a note on vacuum dryer

Introduction

In pharmaceutical and chemical industries, many substances are thermolabile (sensitive to heat) and cannot be dried at high temperatures. Conventional dryers (tray dryer, drum dryer, FBD) may cause degradation, oxidation, or loss of potency in such products. To overcome this, the vacuum dryer is used. By reducing pressure inside the chamber, water boils at a lower temperature, allowing drying at mild heat.



Construction

1. Drying Chamber – Large, airtight vessel (cylindrical or rectangular) that can withstand vacuum.
2. Shelves/Trays – Material spread in stainless steel trays; shelves may be heated by steam, hot water, or electric coils.
3. Vacuum Pump – Reduces pressure to facilitate evaporation at low temperature.
4. Condenser – Collects and condenses vapors removed from material.
5. Heating System – Provides controlled heat (conduction or radiation).
6. Control System – Monitors temperature, pressure, and drying time.

Working

1. Material loaded onto trays in chamber.
2. Chamber sealed, vacuum pump activated to reduce pressure.
3. Heat applied to shelves/trays, causing moisture to evaporate at lower temperature.
4. Water vapor drawn out and condensed.
5. Drying continues until desired moisture content achieved.
6. Finally, vacuum released and dried material collected.

Applications

- Drying of thermolabile drugs (antibiotics, vitamins).
- Drying of hygroscopic and toxic materials.
- Preparation of sterile products (under aseptic conditions).
- Drying plant extracts, enzymes, and biological products.

Advantages

- Suitable for heat-sensitive materials.
- Prevents oxidation since drying occurs in absence of air.
- Energy efficient (less heat required).
- Produces high-quality product with minimal decomposition.

Disadvantages

- High cost of equipment and maintenance.
- Drying time longer than FBD or spray dryer.
- Batch process (not continuous).
- Limited capacity compared to large-scale dryers.

Q6) Discuss the factors affecting mixing

Introduction

Mixing is the process of achieving homogeneity by reducing the physical differences (concentration, particle size, temperature) between materials. In pharmaceuticals, mixing ensures uniform distribution of active drug and excipients. However, mixing efficiency depends on several factors related to material, equipment, and process.

Factors Affecting Mixing

1. Nature of Materials
   - Solid–solid mixing depends on particle size, shape, density, and cohesiveness.
   - Liquid–liquid mixing depends on miscibility, viscosity, and interfacial tension.
   - Semisolids require high shear due to stickiness.
2. Particle Size & Size Distribution
   - Uniform sizes mix better.
   - Wide size variation may cause segregation (larger particles settle).
3. Particle Shape
   - Spherical particles flow and mix better.
   - Irregular or fibrous particles may entangle and resist mixing.
4. Density Differences
   - Materials with large density differences segregate easily after mixing.
   - Example: Talc and granules.
5. Moisture Content
   - Excess moisture → clumping, poor mixing.
   - Very dry powders → electrostatic charges, leading to segregation.
6. Mixing Equipment
   - Tumbling mixers (double cone, V-blender) – gentle mixing.
   - High shear mixers – rapid, effective for cohesive powders.
   - Propellers/turbines – effective for liquids.
7. Mixing Speed & Time
   - Too little time → incomplete mixing.
   - Too long → risk of demixing or segregation.
8. Batch Size/Fill Level
   - Overfilling reduces tumbling efficiency.

- Under-filling leads to poor contact between particles.

Q7) Write a short note on mechanism of solid mixing

Introduction

Solid–solid mixing is vital in pharmaceuticals for producing uniform blends of drugs and excipients. Since powders tend to segregate, understanding the mechanisms of mixing helps in selecting the correct equipment and process.

Mechanisms of Solid Mixing

1. Diffusion Mixing
- Occurs when particles randomly move and spread over each other.
- Dominates in tumbling mixers (double cone, V-blender).
- Effective for free-flowing powders.
2. Convection Mixing
- Large groups of particles move together from one part of the mix to another.
- Achieved in paddle mixers, ribbon blenders.
- Provides faster mixing than diffusion.
3. Shear Mixing
- Layers of particles slide over each other due to shear forces.
- Common in high-shear mixers.
- Effective for cohesive or sticky powders.

Factors Influencing Mechanism

- Particle size and density.
- Degree of cohesion.
- Speed of impeller or tumbler.
- Moisture content.

Q8) Discuss the mechanism of semisolids mixing

Introduction

Semisolid dosage forms (ointments, creams, gels, pastes) require mixing to ensure uniform distribution of drug and excipients. Unlike powders, semisolids are viscous, sticky, and resistant to flow, requiring special mixing mechanisms.

Mechanism of Semisolid Mixing

1. Shear Mixing

- Dominant mechanism.
- High shear forces break down lumps and distribute drug uniformly.
- Achieved using sigma blade mixers, planetary mixers.

2. Convective Mixing

- Bulk movement of semisolid mass.
- Helps distribute excipients evenly.
- Achieved by paddles or planetary blades.

3. Diffusion Mixing

- Limited due to low mobility of molecules in semisolids.
- Plays minor role.

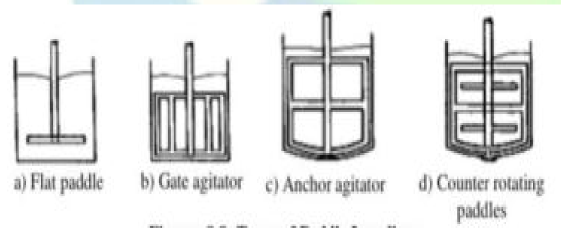
Equipment Used

- Sigma Blade Mixer – High shear for pastes.
- Planetary Mixer – Both shear and convective forces.
- Colloid Mill – For emulsions and creams.

Q9) Write a short note on paddles

Introduction

Paddle agitators are simple mixing devices used in liquid mixing operations. They consist of flat blades attached to a central shaft and are widely used in tanks and reactors.



Figurer 8.8: Types of Paddle Impellers

Construction

- Flat blades (2–4) mounted on a shaft.
- Shaft connected to motor.
- Tank may have baffles to improve mixing.

- Blades can be straight or pitched.

Working

- Operates at low speed (20–150 rpm).
- Produces a radial flow pattern in the tank.
- Suitable for mixing low-viscosity liquids and suspensions.

Applications

- Mixing syrups, solutions.
- Dissolving solids in liquids.
- Heat transfer in tanks.
- Suspension of particles in liquids.

Advantages

- Simple, economical.
- Gentle mixing without foaming.
- Suitable for heat transfer processes.

Limitations

- Inefficient for high-viscosity liquids.
- Poor top-to-bottom circulation.

Q10) Give the construction, working, and uses of sigma blade mixer

Introduction

The Sigma Blade Mixer is a high-shear mixer designed for semisolids, pastes, and dough-like materials. It is named after its sigma-shaped blades.

Construction

- Horizontal trough divided into two sections.
- Two heavy sigma-shaped blades mounted on parallel shafts.
- Blades rotate in opposite directions at different speeds.
- Jacketed trough for heating/cooling.
- Discharge door or bottom screw for unloading.

Working

- Material loaded into trough.
- Blades rotate, creating intense shear and kneading action.
- Material continuously folded, stretched, and sheared.
- Heat can be applied for melting or fusion.

- Mixing continues until uniform product obtained.

Uses

- Preparation of ointments, pastes, creams.
- Mixing rubber, plastics, chewing gum.
- Heavy dough in food industry.
- Adhesives and resins.

Q11) Write a note on ribbon blender

Introduction

The Ribbon Blender is a widely used mixer for powders and granules in pharmaceutical, food, and chemical industries. It works on the principle of convective mixing.

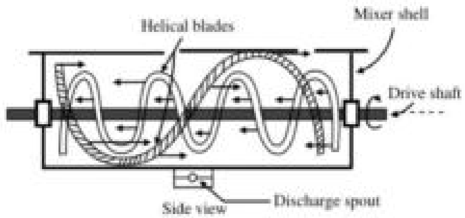


Figure 8.3: Ribbon Mixer

Construction

- U-shaped horizontal trough.
- Shaft fitted with inner and outer helical ribbons.
- Outer ribbon moves material in one direction; inner ribbon moves it in opposite direction.
- End plates prevent leakage.
- Central discharge valve.

Working

- Material loaded into trough (40–70% volume).
- When shaft rotates, ribbons move powders in opposite directions.
- Continuous movement causes convective mixing.
- After desired time, material discharged through central valve.

Applications

- Mixing dry powders for tablets and capsules.

- Blending nutraceuticals, spices, fertilizers.
- Adding small amounts of liquid to powder blends.

Advantages

- Short mixing time.
- Handles large volumes.
- Produces fairly uniform mix.

Limitations

- Not suitable for sticky or cohesive powders.
- Risk of overmixing leading to segregation.

Q12) **Explain the factors influencing filtration?**

Ans: Introduction:
Filtration efficiency depends on several factors related to the properties of the suspension, filter medium, and operational conditions. Understanding these helps in achieving faster and effective separation.

Factors:

1. **Particle size and shape:** Large particles filter more easily, while fine particles clog pores and slow down filtration.
2. **Viscosity of liquid:** Higher viscosity reduces flow rate. Heating may reduce viscosity and improve filtration.
3. **Temperature:** Increase in temperature decreases viscosity, enhancing flow.
4. **Filter medium:** Pore size, thickness, and surface area affect filtration speed and clarity.
5. **Pressure difference:** Greater pressure difference (by vacuum or pump) accelerates filtration.
6. **Concentration of solids:** More solids increase resistance to flow and cause clogging.

Use of filter aids: Substances like kieselguhr form a porous precoat, improving rate and clarity

Q13) **Write short notes on Filter Aids with examples.**

Ans:

Introduction:
During filtration, fine particles often clog pores of filter medium, reducing efficiency. To overcome this, **filter aids** are used.

Definition:
Filter aids are inert, porous, and insoluble materials added to the liquid before or during filtration to improve flow rate and prevent clogging.

Examples:

- **Kieselguhr (diatomaceous earth)**
- **Asbestos fibers**
- **Perlite**
- **Cellulose**

Functions:

1. Form a porous precoat on the filter medium, preventing clogging.
2. Improve clarity of filtrate.
3. Increase rate of filtration by reducing resistance.
4. Useful in sterilizing filtration where clarity is essential.

Q14) **Describe the working of a Filter Leaf?**

Ans:

Introduction:
The **filter leaf** is a simple filtration device used mainly in laboratory and small-scale operations. It consists of a rigid support covered with filter medium.

Construction:

- A metal frame with perforations.
- Covered with filter cloth or mesh.
- Connected to a filtrate outlet tube.

Working:

- The filter leaf is immersed in slurry.
- A vacuum is applied, drawing liquid through the cloth into the perforations.

- Solids deposit as a cake on the cloth surface.
- After filtration, cake is removed by washing or shaking.

Uses:

- Useful for testing filter media performance.
- Applied in small-scale filtration operations.

Q15) **Explain the objectives and applications of centrifugation.**

Answer:
Introduction:
Centrifugation is an advanced separation method based on density differences, widely used in pharmaceutical, chemical, and biological fields.

Objectives:

1. To separate solids from liquids (e.g., plasma from blood).
2. To separate immiscible liquids of different densities.
3. To concentrate suspensions or emulsions.
4. To purify biomolecules like proteins and DNA.

Applications:

- **Pharmaceuticals:** Separation of vaccines, plasma, antibiotics.
- **Biochemistry:** Isolation of subcellular organelles, nucleic acids, proteins.
- **Food industry:** Cream separation from milk.
- **Environmental:** Sludge dewatering in wastewater treatment.

Q16) **Compare perforated and non-perforated basket centrifuges.**

Ans:

Introduction:
Basket centrifuges are common separation equipment. They are classified as **perforated** and **non-perforated** types, depending on basket design.

Perforated Basket Centrifuge:

- Has perforated walls lined with filter cloth.
- Works by filtration principle.
- Solids remain inside basket, liquid passes out.
- Used for crystal separation in pharmaceuticals.

Non-Perforated Basket Centrifuge:

- Basket without holes.
- Works by sedimentation principle.
- Separation occurs due to settling of denser particles at walls.
- Used mainly for liquid–liquid separation.

Comparison:

- **Perforated:** Solid-liquid separation (filtration type).
- **Non-perforated:** Liquid-liquid separation (sedimentation type).

Q17) **Explain Corrosion theory?**

Ans:

Acid Theory

- **Idea:** Corrosion occurs because of the direct chemical action of acids present in the environment.
- **How:** Acids attack the metal surface, dissolving the metal to form salts.
- **Example:** Iron in hydrochloric acid → forms iron chloride.
- **Limitation:** This theory cannot explain corrosion in neutral solutions (like pure water) where no free acid is present.

2. Dry Chemical Theory (Chemical / Oxidation Theory)

- **Idea:** Corrosion happens due to direct chemical reaction between metal and dry gases (especially oxygen).

- **How:** Metal reacts with oxygen in the environment to form an oxide layer.
- **Example:** Iron forms Fe_2O_3 (rust) in dry air.
- **Limitation:** Does not explain corrosion in the presence of moisture or electrolytes (wet corrosion).

3. Electrochemical Theory

- **Idea:** Most corrosion occurs by an electrochemical process in the presence of **water or moisture**.
- **How:**
    - Metal surface has tiny anodic and cathodic regions.
    - **Anode reaction:** Metal atoms lose electrons (oxidation) → form metal ions. Example: $Fe \rightarrow Fe^{2+} + 2e^-$
    - **Cathode reaction:** Electrons are consumed by reduction (usually oxygen + water → OH^-).
    - This leads to gradual metal loss and rust formation.
- **Example:** Rusting of iron in moist air.
- **Limitation:** Cannot explain corrosion in completely dry conditions.

2 Marks

Q1) Define mixing

Mixing is a unit operation in which two or more components are intermingled to achieve a homogeneous system. It reduces differences in concentration, particle size, or temperature between components. In pharmaceuticals, mixing ensures uniform distribution of the active drug with excipients, which is essential for dose accuracy, stability, and patient safety. Mixing may involve solids, liquids, or semisolids, and requires different mechanisms (diffusion, convection, shear) depending on the material.

Q2) Give the objectives of mixing

The main objectives of mixing are:

1. To achieve uniform distribution of components in dosage forms.
2. To improve drug stability by preventing segregation.
3. To enhance bioavailability by ensuring dose uniformity.
4. To improve process efficiency (e.g., drying, granulation).
5. To prepare solutions, emulsions, suspensions, creams, and ointments.
6. To ensure therapeutic effectiveness by maintaining consistency in formulations.

Q3) Mention the applications of mixing

- Solid mixing: Powder blends for tablets, capsules.
- Liquid mixing: Solutions, emulsions, syrups.
- Semisolid mixing: Ointments, creams, gels, pastes.
- Chemical processes: Crystallization, dissolution, fermentation.
- Food industry: Mixing of spices, powders, beverages.
- Cosmetics: Creams, lotions, shampoos.

Q4) What are the selection criteria for mixing equipment?

1. Nature of material – solid, liquid, or semisolid.
2. Viscosity and density of the product.
3. Batch size and scale of operation.
4. Desired degree of homogeneity.
5. Sensitivity of material (heat, shear).
6. Cleaning and sterilization requirements.
7. Cost and maintenance of equipment.

Q5) Differentiate between solid and liquid mixing

Feature	Solid Mixing	Liquid Mixing
Mechanism	Diffusion, convection, shear	Axial or radial flow
Equipment	Double cone, V-blender, ribbon blender	Propellers, turbines, paddles
Challenges	Segregation, cohesion	Viscosity, miscibility
Applications	Powders for tablets, capsules	Solutions, syrups, emulsions

Q6) Mention the uses of planetary mixers

- Mixing semisolid preparations like ointments, creams, gels.
- Preparation of dough, pastes, adhesives.
- Used in food industry for bakery doughs.
- Suitable for viscous and sticky materials.
- Provides both shear and convective mixing due to planetary blade movement.

Q7) Draw a well labelled diagram of a Silverson emulsifier

I cannot directly draw here in text, but I'll describe the labelled diagram:

A Silverson emulsifier has:

- Motor drive connected to a shaft.
- High-speed rotor (impeller) at the bottom.
- Stator surrounding the rotor with perforations.
- Mixing head submerged in liquid.
- Container/vessel holding liquid

Fill the blanks

1 Marks

1) Drying can also be defined as a process of_____which removes the liquid

moisture from the other solvent by means of evaporation in a solid, semi-solid, or liquid resulting in a solid end product.

ANS- Mass Transfer

2)In the__ Period the replacement of surface water occurs at a slower rate, thus fails to maintain a continuous film on the surface.

ANS- First falling rate

3) ____is the moisture content present at the end of the falling rate period.

ANS- Equilibrium moisture content

4) The principle of freeze drying involves removal of water from the frozen material by____.

ANS- Sublimation

5) In_____the fluid to be dried is atomized into fine droplets.

ANS- Spray dryer

6) ___ is used for reducing particle size and mixing powders.

ANS-Trituration

7)___ refers to the movement of a large amount of material to be mixed from one position to another in the system.

ANS- Bulk transport

8) Sigma blade mixer works on the principle of___and__.

ANS- Shearing and Convective action

9)____ are mechanical devices used for mixing different types of fluids with different types of blades and impellers.

ANS- Turbine

10) Paddles work on the principle of_____and they apply shearing forces for mixing liquids.

ANS- Kneading action

11) Plate and Frame Filter works on the principle of __________.

Answer: Pressure-driven filtration

12) The main advantage of Plate and Frame Filter is that it provides a very __________.

Answer: Clear filtrate

13) Rotary Drum Filter is a __________ filtration device.
Answer: Continuous vacuum

14) Rotary Drum Filters are commonly used in the __________ industry.
Answer: Pharmaceutical

15) Higher viscosity of liquid __________ the flow rate during filtration.

Answer: Reduces

16) Kieselguhr (diatomaceous earth) is an example of a __________.

Answer: Filter aid

17) In a Filter Leaf, the force applied during operation is __________.

Answer: Vacuum

18) The main objective of centrifugation is to separate particles based on __________ differences.

Answer: Density

19) __________ basket centrifuge works by filtration principle.
Answer: Perforated

20) Non-perforated basket centrifuges work by __________ method.

Answer: Sedimentation

10-Mark Questions:

Q1. Define filtration. Explain the objectives of filtration in pharmacy with examples.

Answer:
Definition:
Filtration is a **mechanical or physical separation process** used to separate solids from liquids or gases by passing the mixture through a porous medium. The medium (filter paper, cloth, membrane, etc.) allows the liquid or gas (filtrate) to pass, while the solid particles are retained as residue or cake.

Objectives of Filtration in Pharmacy:
Filtration is essential in the pharmaceutical industry for ensuring **clarity, purity, and safety** of products. The key objectives include:

1. **Clarification of liquids:**
    - Removes suspended solids and insoluble impurities.
    - Ensures that syrups, elixirs, and tinctures are clear, appealing, and stable.
    - *Example:* Syrup clarification before bottling.
2. **Sterilization (removal of microorganisms):**
    - Used for heat-sensitive liquids like antibiotics, eye drops, vaccines, and injections.
    - Membrane filters of **0.22 µm pore size** remove bacteria and fungi without heat damage.
3. **Recovery of solids:**
    - Used after crystallization/precipitation to collect valuable **Active Pharmaceutical Ingredients (APIs)**.
    - *Example:* Recovery of antibiotic crystals from fermentation broth.
4. **Purification:**
    - Removes contaminants to improve drug **safety and shelf life**.
    - *Example:* Removing dust and foreign particles during formulation.
5. **Preparation of sterile products:**
    - Ensures injectables, ophthalmic solutions, and parenteral nutrition fluids are sterile.
6. **Enhancing product quality:**
    - Clear, impurity-free solutions improve **therapeutic efficiency, appearance, and stability**.

Conclusion:
Filtration is not just a separation process but a **critical pharmaceutical operation** for producing **safe, effective, and quality-controlled medicines**.

Q2. Explain Darcy's Law of filtration with theory, equation, and applications.

Answer:
Theory:
The flow of liquid during filtration is governed by the balance between **driving force** (pressure difference) and **resistance** (filter medium + cake).

Darcy's Law (Equation):

$$Rate\ of\ Filtration(Q) = \frac{K \cdot A \cdot \Delta P}{\mu \cdot L}$$

Where:

- **K** = permeability coefficient of cake
- **A** = surface area of filter medium
- **ΔP** = pressure difference across filter
- **μ** = viscosity of filtrate
- **L** = thickness of filter cake

Explanation:

- Filtration rate **increases** with:
  - Higher permeability
  - Larger filter area
  - Higher pressure difference
- Filtration rate **decreases** with:
  - Thicker filter cake
  - Higher viscosity liquids

Applications in Pharmacy:

1. Used to design **membrane filters, filter press, Seitz filter**.
2. Helps calculate **time required for sterile filtration** of injectables.
3. Used in **production planning** of filtration systems in bulk drug manufacturing.

Conclusion:
Darcy's Law is fundamental for predicting and optimizing **industrial and laboratory filtration processes**.

Q3. Discuss filter media and filter cake with their characteristics and pharmaceutical importance.

Answer:
Filter Media:
The material used to separate solids from liquids.

Ideal Characteristics:

- **Porous** enough to pass fluids but trap solids.
- **Chemically resistant** (non-reactive with drugs).
- **Mechanically strong** (resist tearing).
- **Thermally stable** (can withstand hot liquids).
- **Low adsorption** (should not absorb the drug).
- **Reusable or disposable** depending on use.

Examples:

- Cloth (cotton, nylon), filter paper, stainless steel mesh, glass wool, ceramic discs, sand beds.

Filter Cake:
Layer of solid particles deposited on the filter medium during filtration.

Characteristics:

- **Permeability** – affects rate of flow.
- **Compressibility** – compressible cakes reduce efficiency.
- **Removability** – should be easy to remove.
- Sometimes acts as a **secondary filter (precoat)**, improving clarity.

Pharmaceutical Importance:

- Filter media → used in **sterile filtration of injectables, eye drops**.

- Filter cake → important in **recovery of APIs** from crystallization/fermentation.

Conclusion:
Both filter media and filter cake directly influence **filtration efficiency, cost, and product quality**.

Q4. Describe the construction, working, advantages, and disadvantages of filter press.

Answer:
Principle:
Filter press works on **pressure filtration** – slurry is forced into chambers under pressure.

Construction:

- **Plates:** Arranged in series, made of plastic or metal.
- **Filter cloths:** Cover plates to trap solids.
- **Hydraulic system:** Applies pressure to force liquid through the cloth.

Working:

1. Slurry is pumped into chambers.
2. Pressure forces liquid through cloth → filtrate collected.
3. Solids remain on cloth → form filter cake.
4. Cake is removed after process completion.

Advantages:

- Effective for **high-solids content**.
- Produces **clear filtrate**.
- Can be **automated** for large-scale use.

Disadvantages:

- **Expensive equipment.**
- Requires **frequent maintenance**.
- Relatively **slow for very large volumes**.

Pharmaceutical Uses:

- Recovery of **APIs** after crystallization.
- **Wastewater treatment** in pharma industries.

- Filtration of **fermentation broths**.

Q5. Explain centrifugation, its principle, and pharmaceutical applications.

Answer:
Definition:
Centrifugation is a **separation technique** based on density differences using centrifugal force.

Principle:
When a sample is rotated at high speed:

- Heavier particles (greater density) move outward.
- Lighter components remain closer to the center.
  This separation is due to **centrifugal force**.

Applications in Pharmacy:

1. **Solid-liquid separation:** Removes solids from solutions during API manufacturing.
2. **Purification of medicines:** Removes unwanted by-products after synthesis.
3. **Cell harvesting:** Collects bacterial or yeast cells for antibiotics, enzymes, vaccines.
4. **Blood separation:** Separates plasma, RBCs, WBCs, platelets in medical labs.
5. **Research:** Used for DNA, RNA, protein, organelle separation.
6. **Wastewater treatment:** Removes suspended solids before discharge.

Conclusion:
Centrifugation is a versatile technique, widely used in **drug production, biotechnology, diagnostics, and research**.

📘 **5-Mark Questions with Elaborative Answers**

Q1. Differentiate between Darcy's Law, Carman-Kozeny Equation, and Poiseuille's Law.

Answer:

- **Darcy's Law:** Deals with flow in porous media. Factors: pressure, viscosity, surface area, cake thickness.
- **Carman-Kozeny Equation:** More detailed; considers **porosity, particle size, bed depth**.
- **Poiseuille's Law:** Explains laminar flow through **capillaries**; strongly dependent on $radius^4$.

Table:

Law	Used For	Key Factors
Darcy	General filtration	Pressure, viscosity, thickness
Carman-Kozeny	Packed beds	Porosity, particle size
Poiseuille	Capillaries	Radius, viscosity, length

Each law applies to **different filtration systems** in pharma.

Q2. Explain membrane filters with construction, working, advantages, and uses.

Answer:
Construction:

- Made from cellulose acetate, nitrocellulose, or nylon.
- Available in various pore sizes (0.22 µm for sterilization).
- Supported by grids for strength.

Working:

- Fluid passed through under vacuum/pressure.
- Particles larger than pore size retained on membrane.
- Filtrate collected as clear, sterile liquid.

Advantages:

- High precision.
- Sterilization of heat-sensitive liquids.
- Available in various grades.

Disadvantages:

- Easily clogged.
- Costly.
- Limited chemical resistance.

Uses in Pharmacy:

- Sterile filtration of **antibiotics, injectables, ophthalmic solutions**.

Q3. What are the factors influencing filtration?

Answer:

1. **Filter medium:** Pore size & thickness → clarity vs flow rate.
2. **Viscosity of liquid:** High viscosity slows filtration. Heating reduces viscosity.
3. **Particle size/shape:** Fine particles clog pores.
4. **Pressure difference:** Higher pressure increases rate (via vacuum or pump).
5. **Temperature:** Higher temperature lowers viscosity.
6. **Filter area:** Larger surface area → faster rate.
7. **Cake thickness:** Thicker cake → more resistance, slower filtration.

Thus, both **liquid properties and equipment design** affect efficiency.

Q4. Explain the working and uses of rotary drum filter.

Answer:
Working:

- A rotating drum covered with filter cloth is partly submerged in slurry.
- As drum rotates → liquid passes through cloth → solids deposited as cake.
- Scraper removes cake continuously.

Uses:

- Wastewater treatment.
- Clarification of **juices, syrups, chemicals**.
- Recovery of minerals and APIs.

Advantages: Continuous, efficient, versatile.
Disadvantages: Expensive, high maintenance, complex operation.

Q5. Write a short note on Seitz filter.

Answer:

- **Principle:** Depth filtration using asbestos-cellulose pads.
- **Working:** Fluid passed under pressure → impurities trapped in pad → sterile filtrate collected.

- **Advantages:** Effective sterilization, easy to use, filters large volumes.
- **Disadvantages:** Non-reusable, pad shedding, not suitable for viscous liquids, asbestos hazard.
- **Uses:** Sterile filtration of **sera, vaccines, antibiotics**.

1-Mark Fill in the Blanks with Answers

1. Filtration is the process of separating ______ from liquids or gases using a porous medium.
   Answer: solids
2. The clear liquid obtained after filtration is called ______.
   Answer: filtrate
3. The solid material retained on the filter medium during filtration is called ______.
   Answer: filter cake
4. The principle of filtration is based on the movement of fluids through a ______ medium.
   Answer: porous
5. Darcy's Law describes the relationship between filtration rate and ______.
   Answer: pressure difference (ΔP)
6. The pore size of membrane filters used for sterilization is ______ µm.
   Answer: 0.22
7. The filter medium should be chemically ______ with the liquid being filtered.
   Answer: inert
8. Seitz filter is made of ______ and cellulose.
   Answer: asbestos
9. The method used for separation of particles based on density difference is called ______.
   Answer: centrifugation
10. In centrifugation, heavier particles move ______ from the axis of rotation.
    Answer: away (outward)
11. Rotary drum filter works on the principle of ______ filtration.
    Answer: vacuum
12. The equation that describes laminar flow through a capillary is ______ Law.
    Answer: Poiseuille's
13. Increasing the temperature of liquid generally ______ its viscosity.
    Answer: decreases

14. The hydraulic pressure applied in a filter press helps to form the ______.
    Answer: filter cake

15. The centrifugal force applied in centrifugation is directly proportional to the square of ______.
    Answer: speed (RPM)

16. The first filtrate layer that improves clarity of liquid is known as ______.
    Answer: precoat

17. Depth filtration is achieved by ______ filters.
    Answer: Seitz

18. Centrifugation used for separating cell organelles is called ______ centrifugation.
    Answer: differential

19. Glass wool and cotton plugs are examples of ______ filter media.
    Answer: fibrous

20. The flow rate of filtration is inversely proportional to the ______ of filtrate.
    Answer: viscosity

MODEL QUESTION AND ANSWER

Sub- Ph. Engineering

Unit-5

Q7) Explain in detail the principle, construction, working, uses, merits, and demerits of Plate and Frame Filter.

Answer: The Plate and Frame Filter Press is one of the oldest and widely used filtration equipment in the pharmaceutical and chemical industries.

• **Principle:**

It works on the principle of mechanical separation of solids from liquids using pressuredriven filtration. A slurry (suspension) is pumped into chambers formed between plates and frames; liquid passes through filter media while solids are retained as a cake.

• **Construction:**

Consists of a series of plates and frames arranged alternately. o Plates have grooved surfaces and filter cloths attached. Frames form empty chambers for holding the slurry. Tightened by a screw mechanism or hydraulic press. A filtrate outlet collects the liquid.

• **Working:**

Slurry is pumped into the frames under pressure. o Liquid passes through filter cloth (acting as medium). Filtrate comes out through channels, while solids remain as a filter cake. After filtration, frames are dismantled to remove cake.

- **Uses:**
    - Used in pharmaceutical industries for separating drugs from mother liquors.
    - In chemical industries for separating catalysts.
    - In food industry (sugar, juices, oils).
- **Merits:**
    - Simple in design and operation.
    - Gives clear filtrate.
    - Can handle corrosive materials (with suitable construction).
    - Filter cake can be recovered easily.
- **Demerits:**
        - Batch process (not continuous).
        - Labor-intensive (requires dismantling).
        - Not suitable for dilute slurries.
        - High operation time.

Q8) **Describe the principle, construction, working, uses, merits, and demerits of Rotary Drum Filter.**

Answer:
The **Rotary Drum Filter** is a continuous filtration device widely used in large-scale industries.

- **Principle:**
  It works on the principle of **continuous vacuum filtration**. A rotating drum covered with filter cloth is partially immersed in slurry. Due to vacuum, filtrate passes through the filter cloth, leaving solids as a filter cake.
- **Construction:**
    - A large hollow cylindrical drum, mounted horizontally.
    - Outer surface covered with filter cloth.
    - Drum is divided into compartments connected to a vacuum system.
    - A trough at the bottom contains slurry.
    - Cake removal device (scraper, belt discharge, or roll discharge).

- **Working:**
    - Drum rotates slowly in slurry.
    - Vacuum applied → liquid passes inside through filter cloth → filtrate collected.
    - Solids deposit as cake on drum surface.
    - Cake is dried by air flow as drum rotates out of slurry.
    - Cake removed mechanically by scraper or belt.
    - Continuous process repeats.
- **Uses:**
    - In pharmaceutical industries (antibiotics, fermentation products).
    - In sewage treatment plants.
    - In food industry (sugar, starch, juices).
- **Merits:**

1. Continuous operation → high throughput.
2. Suitable for slurries with moderate solid content.
3. Easy recovery of filtrate and cake.

- **Demerits:**

1. High cost and bulky design.
2. Not suitable for dilute suspensions.
3. Filter cloth requires frequent cleaning.
4. Not ideal for highly compressible solids.

5 marks

Q1) Discuss the factors affecting drying

Introduction

Drying is a critical unit operation in the pharmaceutical and chemical industry. It refers to the removal of moisture or solvent from solids, liquids, or semisolids through evaporation or sublimation, leading to a stable solid product. The efficiency of drying is not uniform—it depends on various factors related to the material, equipment, and environment. Understanding these factors is essential for selecting the right drying method and achieving consistent product quality.

Factors Affecting Drying

1. Nature of the Material
- Porosity: Porous materials dry faster as moisture migrates easily through voids. Non porous materials show slower drying.
- Crystallinity/Amorphous nature: Crystalline substances release moisture more readily, while amorphous solids may retain bound water.
- Hygroscopicity: Hygroscopic materials (e.g., gelatin) absorb atmospheric moisture, complicating drying.

2. Moisture Content
- Free moisture: Easily removed during the constant rate period.
- Bound moisture: Strongly attached to solid matrix, requires higher energy (falling rate period).
- Equilibrium Moisture Content (EMC): Drying cannot reduce moisture below EMC.

3. Surface Area of Material
- Larger surface area (small particles, granules) → faster drying due to increased exposure to air.
- Bulk materials with less surface area dry slower.

4. Air Temperature
- Higher drying air temperature increases vapor pressure difference, accelerating drying.
- But excessive heat may degrade thermolabile drugs (vitamins, proteins).

5. Air Humidity
- Drying is faster when surrounding air has low humidity.
- High relative humidity reduces driving force for evaporation.

6. Air Velocity
- Faster airflow removes evaporated moisture quickly from material surface, preventing saturation.
- Too high velocity may cause attrition or dust formation.

7. Type of Heat Transfer

- Blending nutraceuticals, spices, fertilizers.
- Adding small amounts of liquid to powder blends.

Advantages

- Short mixing time.
- Handles large volumes.
- Produces fairly uniform mix.

Limitations

- Not suitable for sticky or cohesive powders.
- Risk of overmixing leading to segregation.

Q12) **Explain the factors influencing filtration?**

Ans: Introduction:

Filtration efficiency depends on several factors related to the properties of the suspension, filter medium, and operational conditions. Understanding these helps in achieving faster and effective separation.

Factors:

1. **Particle size and shape:** Large particles filter more easily, while fine particles clog pores and slow down filtration.
2. **Viscosity of liquid:** Higher viscosity reduces flow rate. Heating may reduce viscosity and improve filtration.
3. **Temperature:** Increase in temperature decreases viscosity, enhancing flow.
4. **Filter medium:** Pore size, thickness, and surface area affect filtration speed and clarity.
5. **Pressure difference:** Greater pressure difference (by vacuum or pump) accelerates filtration.
6. **Concentration of solids:** More solids increase resistance to flow and cause clogging.

Use of filter aids: Substances like kieselguhr form a porous precoat, improving rate and clarity

Q13) **Write short notes on Filter Aids with examples.**

Ans:

Introduction:

During filtration, fine particles often clog pores of filter medium, reducing efficiency. To overcome this, **filter aids** are used.

- **How:** Metal reacts with oxygen in the environment to form an oxide layer.
- **Example:** Iron forms Fe_2O_3 (rust) in dry air.
- **Limitation:** Does not explain corrosion in the presence of moisture or electrolytes (wet corrosion).

3. Electrochemical Theory

- **Idea:** Most corrosion occurs by an electrochemical process in the presence of **water or moisture**.
- **How:**
  - Metal surface has tiny anodic and cathodic regions.
  - **Anode reaction:** Metal atoms lose electrons (oxidation) → form metal ions. Example: $Fe \rightarrow Fe^{2+} + 2e^-$
  - **Cathode reaction:** Electrons are consumed by reduction (usually oxygen + water → OH^-).
  - This leads to gradual metal loss and rust formation.
- **Example:** Rusting of iron in moist air.
- **Limitation:** Cannot explain corrosion in completely dry conditions.

2 Marks

Q1) Define mixing

Mixing is a unit operation in which two or more components are intermingled to achieve a homogeneous system. It reduces differences in concentration, particle size, or temperature between components. In pharmaceuticals, mixing ensures uniform distribution of the active drug with excipients, which is essential for dose accuracy, stability, and patient safety. Mixing may involve solids, liquids, or semisolids, and requires different mechanisms (diffusion, convection, shear) depending on the material.

1)Plate and Frame Filter works on the principle of __________.

Answer: Pressure-driven filtration

2) The main advantage of Plate and Frame Filter is that it provides a very __________

Answer: Clear filtrate

3) Rotary Drum Filter is a __________ filtration device.

Answer: Continuous vacuum

4) Rotary Drum Filters are commonly used in the __________ industry. Answer: Pharmaceutical

5) Higher viscosity of liquid __________ the flow rate during filtration. Answer: Reduces

6) Kieselguhr (diatomaceous earth) is an example of a __________.

Answer: Filter aid

7) In a Filter Leaf, the force applied during operation is __________.

Answer: Vacuum

8) The main objective of centrifugation is to separate particles based on __________ differences.

Answer: Density

9) __________ basket centrifuge works by filtration principle.

Answer: Perforated

10) Non-perforated basket centrifuges work by __________ method.

Answer: Sedimentation