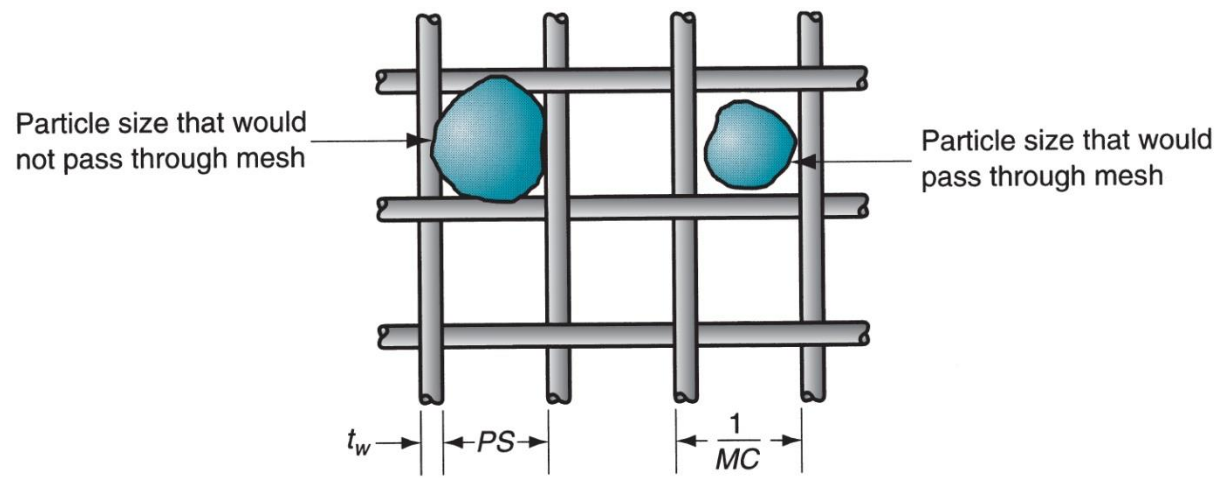
Lecture # 4

POWDER METALLURGY

Powder characterization

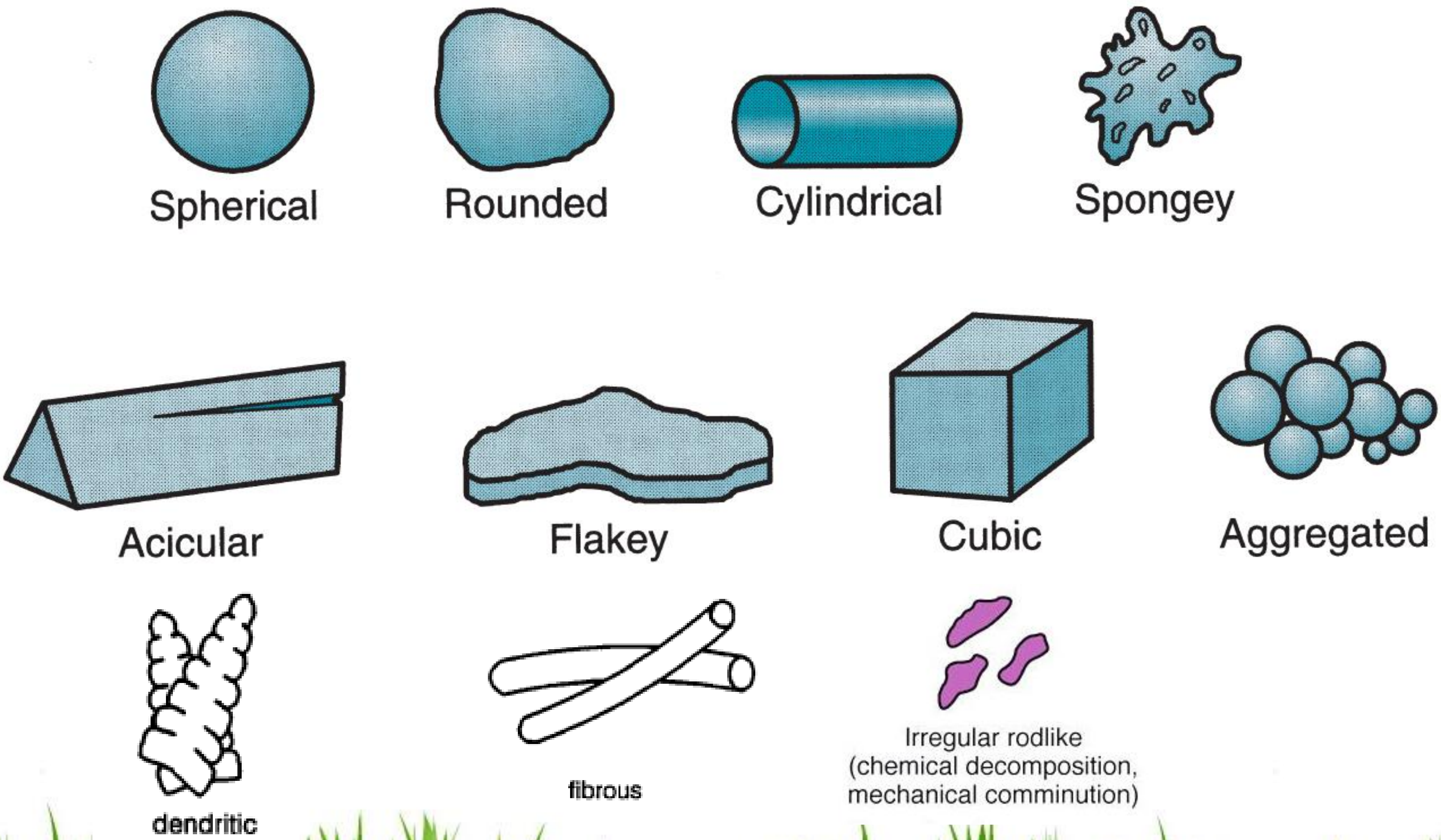


Dr. Mohammed Gamil

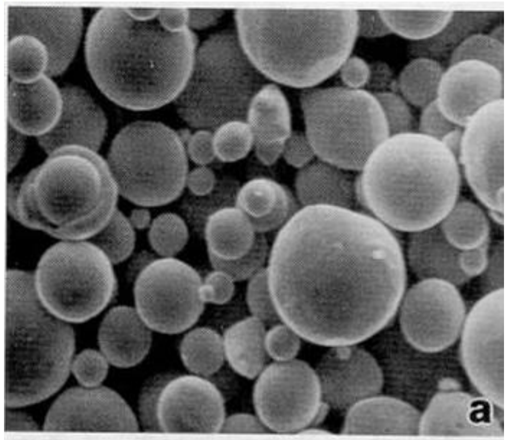
Geometric Features of Engineering Powders

- Particle shape and internal structure
- Particle size and distribution
- Interparticle Friction and Powder Flow
- Particle Density Measures
- Packing Factor
- Porosity

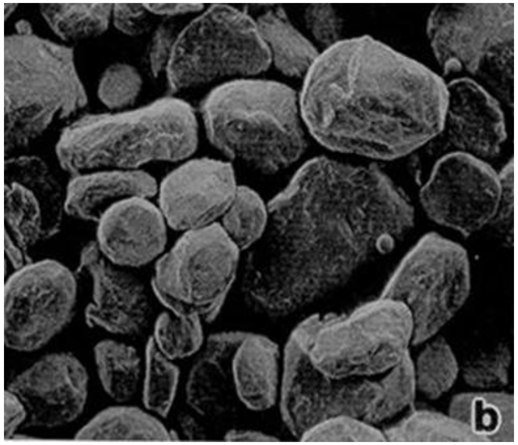
Particle Shapes in PM



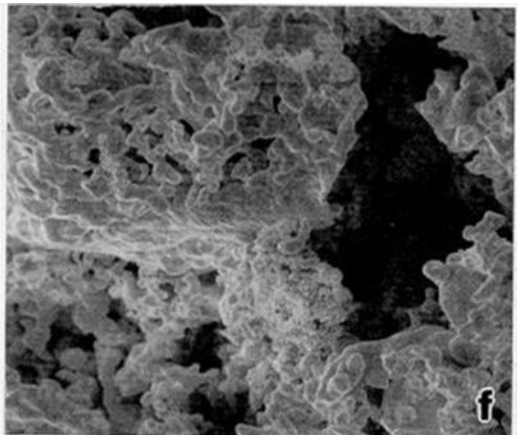
Particle Shapes in PM (Cont.)



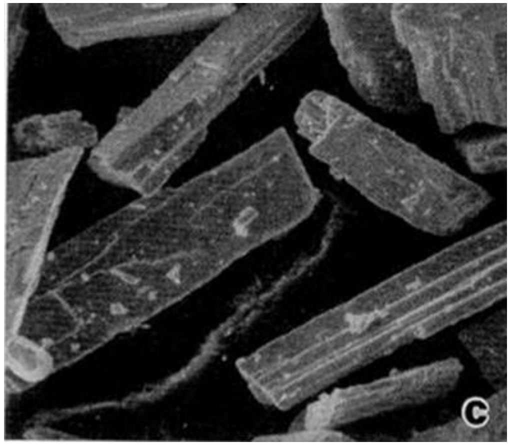
Spherical



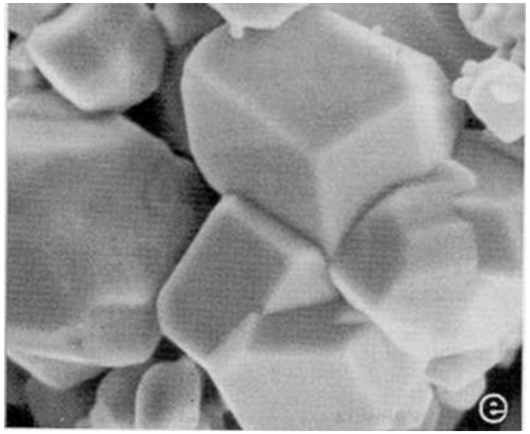
Rounded



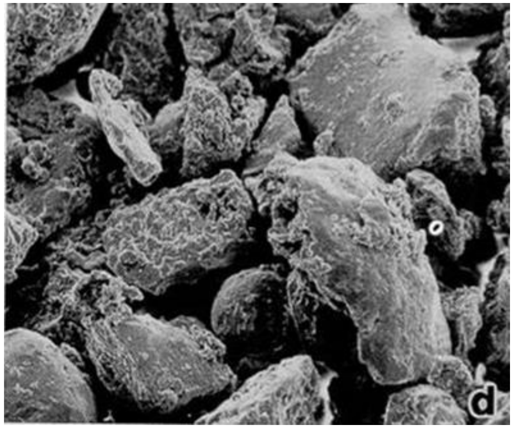
Spongy



Acicular

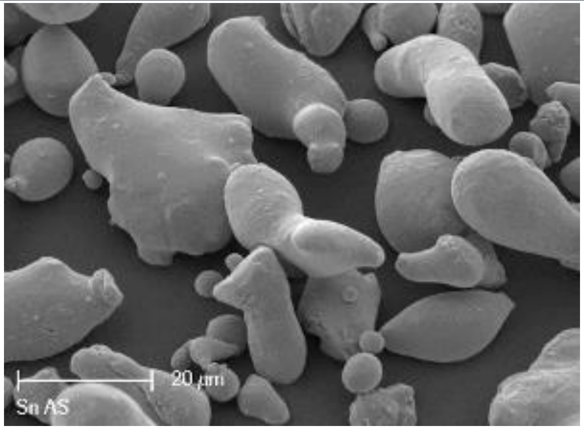


Cubic

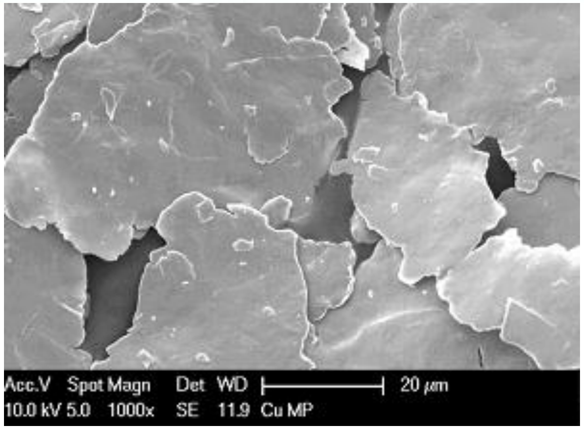


Irregular

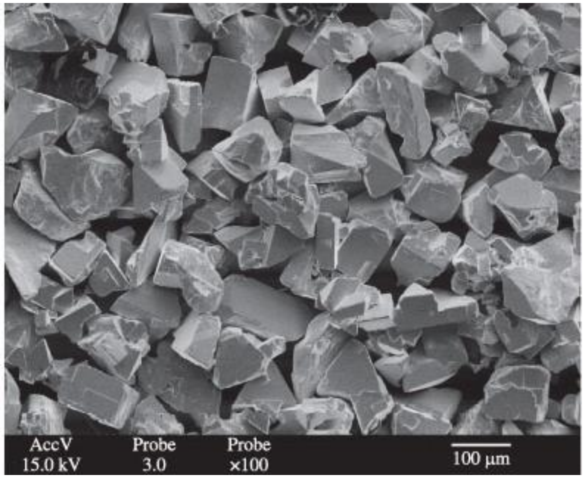
Particle Shapes in PM (Cont.)



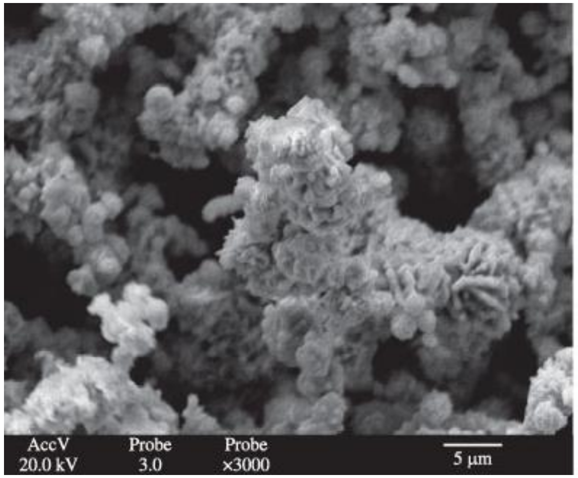
Flakey



Flakey

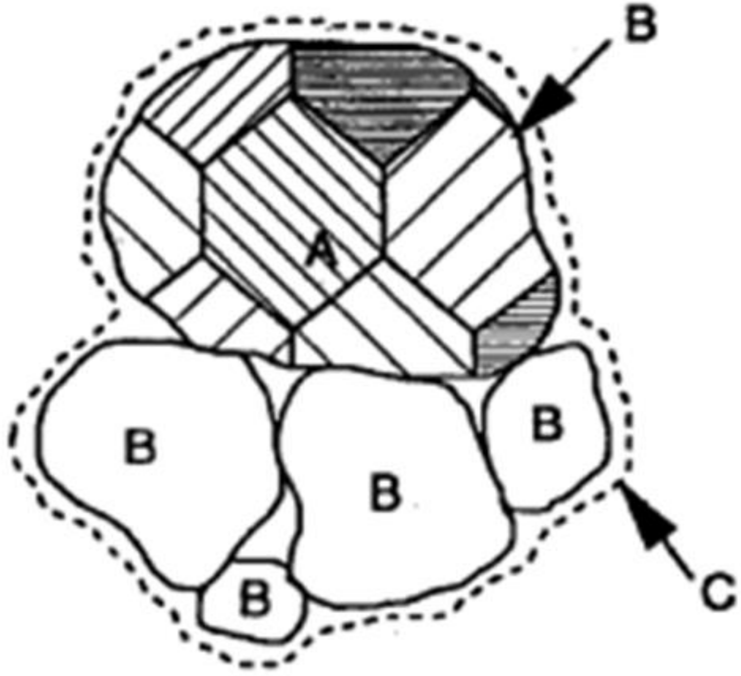


Polygonal



Aggregated

Internal structure

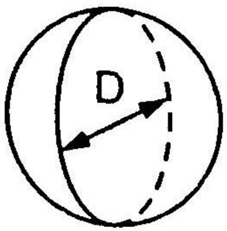


A = Grain

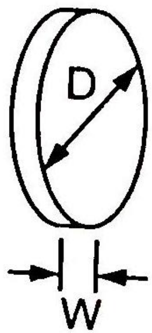
B = Powder Particle

C = Agglomerate

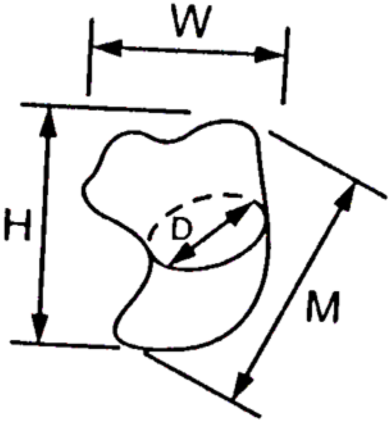
Particle Size



(a) Sphere



(b) Flake



(c) Rounded irregular

(d) Irregular

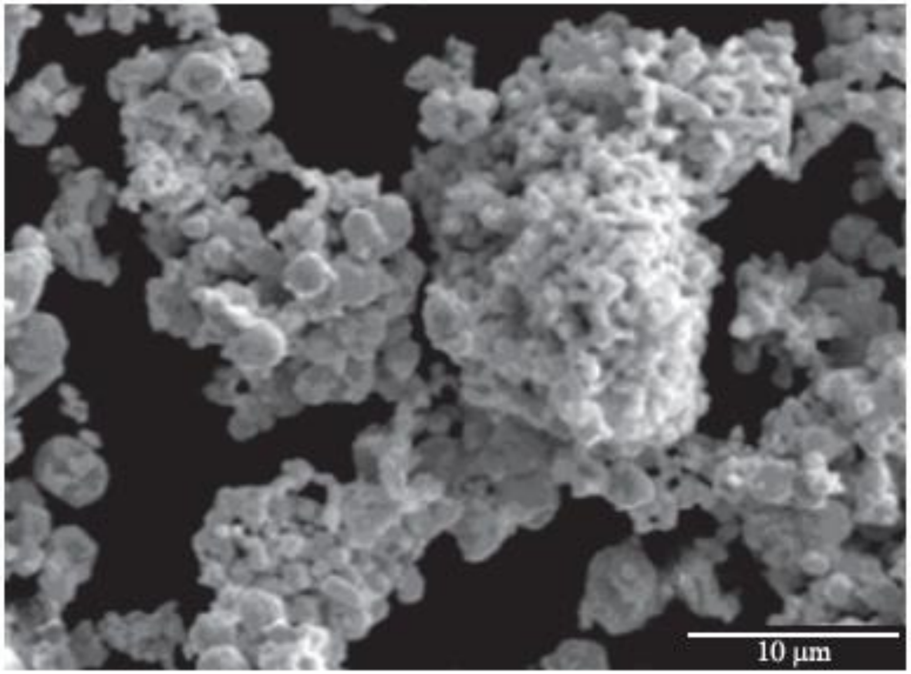
Measurement Techniques for Particle Size

1. Microscopy
2. Screening
3. Sedimentation
4. Light scattering
5. Electrical conductivity
6. Light blocking
7. X-Ray

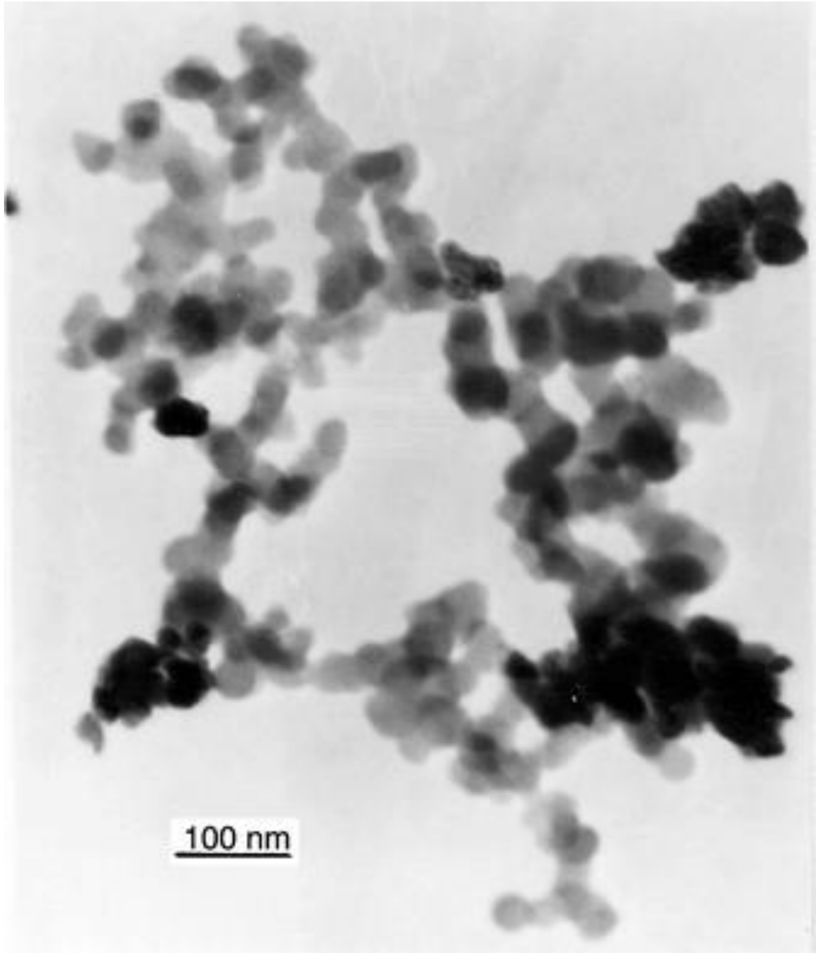
1. Microscopy

- A widely applied technique for particle sizing.
- Accurate technique.
- Need for automatic image analyzers.
- Optical, scanning electron or transmission electron microscopes are used.
- The choice of the instrument depend on the particle size.
- Problems with agglomeration, coincidence and particle orientation.

1. Microscopy (Cont.)

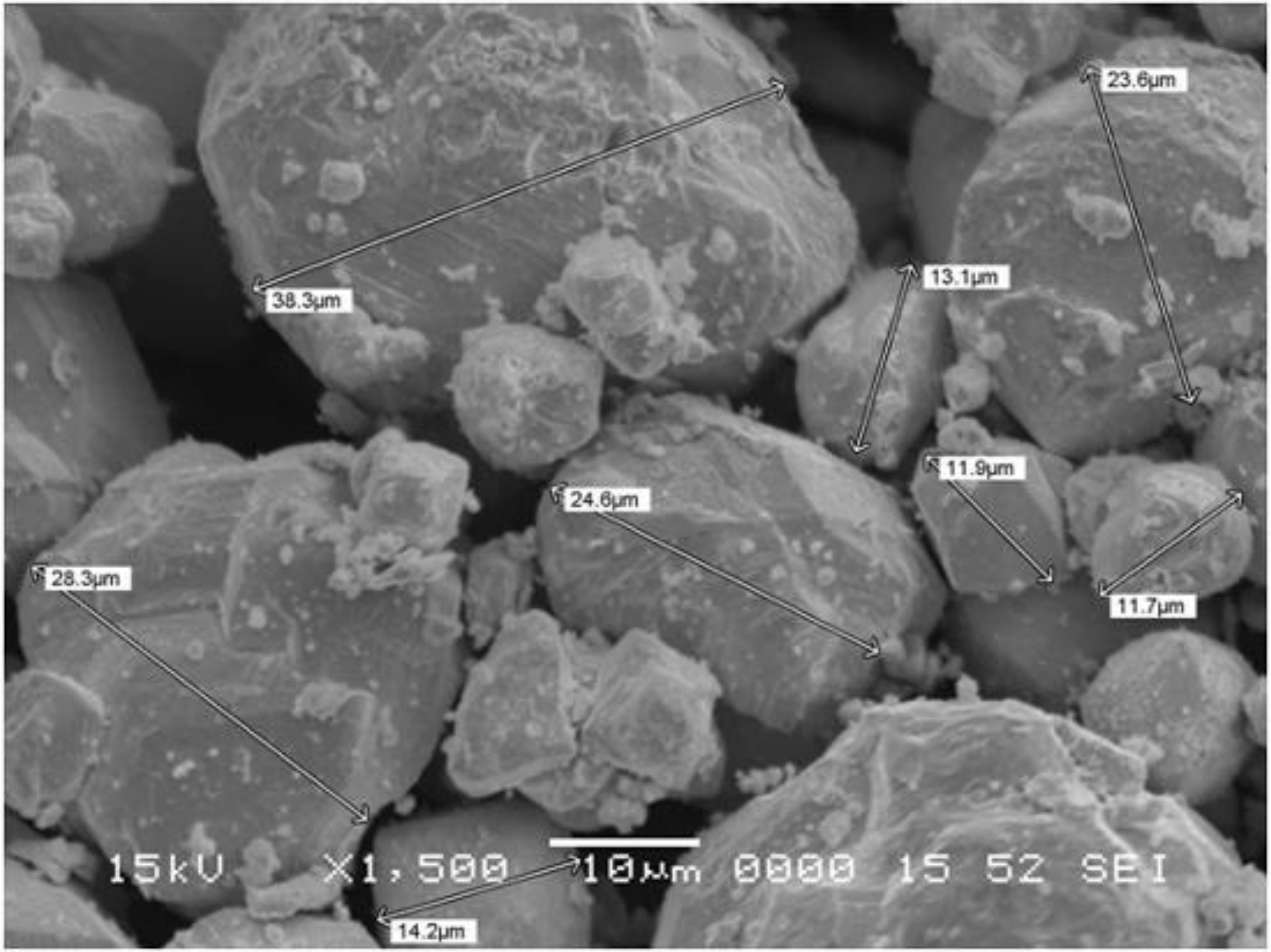


(a) SEM



(b) Transmission

1. Microscopy (Cont.)



2. Screening

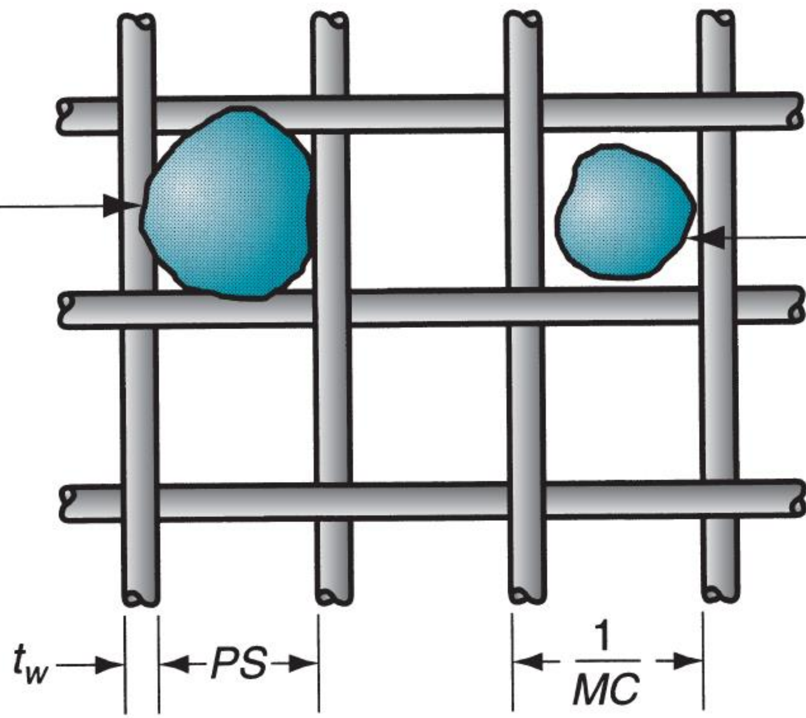
- Most common method uses screens of different mesh sizes
- *Mesh count* - refers to the number of openings per linear inch of screen
- A mesh count of 200 means there are 200 openings per linear inch
- Since the mesh is square, the count is equal in both directions, and the total number of openings per square inch is $200^2 = 40{,}000$
- Higher mesh count = smaller particle size

2. Screening (Cont.)

- Usually applied to particle size larger than 38 µm.
- Vibrating from 20 to 30 min.
- Sample size 200 gm when using 20 cm diameter screens.
- 8% error is occurred in screen analysis.

Particle size sorting machine

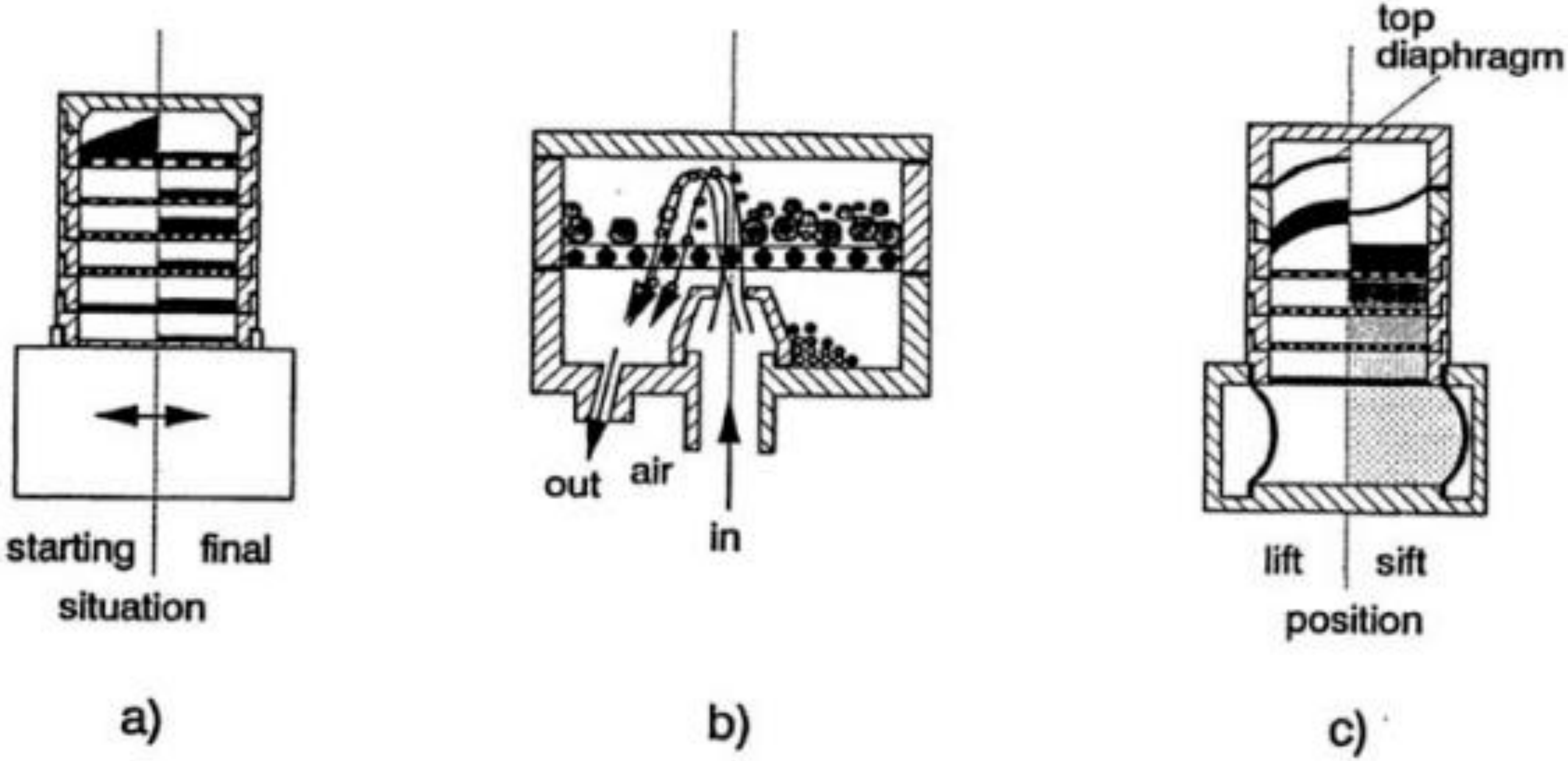
Screen Mesh for Sorting Particle Sizes



$$PS = \frac{1}{MC} - t_w$$

where *PS* = particle size, in; *MC* = mesh count, openings per linear inch; and t_w = wire thickness of screen mesh, in.

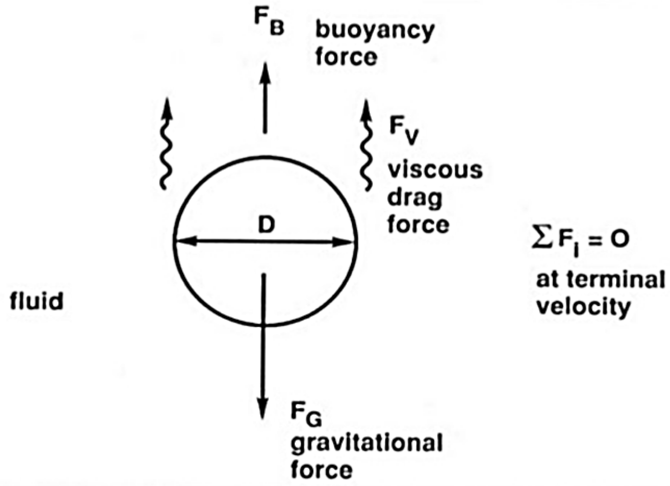
Sieving Methods



Sieving methods. a) vibrating sieving machine; b) air-jet sieving; c) sonic sifter

3. Sedimentation

- Applicable to finer powder.
- Particles setting in a fluid (liquid or gas).
- Reach a velocity dependent on the particle size and fluid viscosity.
- Applicable to particles in the 0.05 to 60 μm range.



3. Sedimentation for Spherical Particles

$$F_G = \left(\frac{\pi D^3}{6}\right)\rho_m g$$

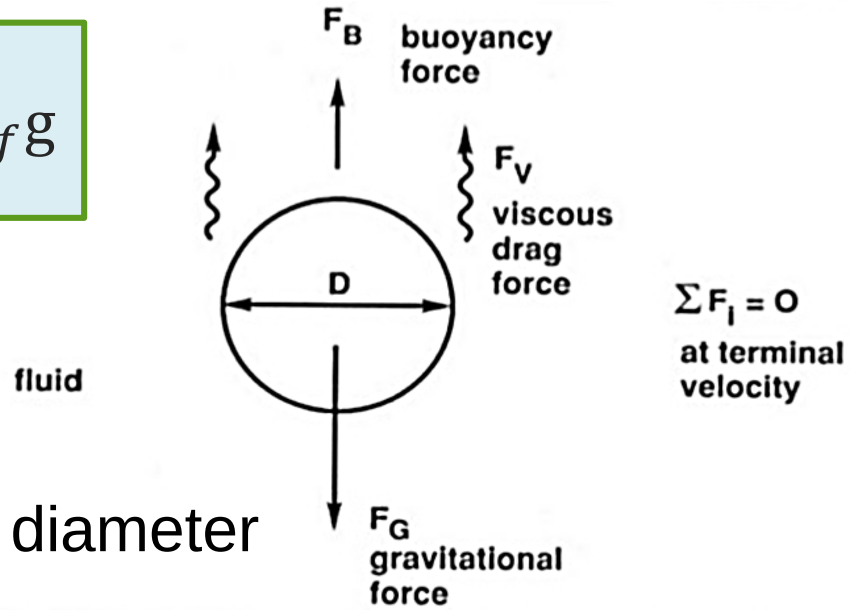
$$F_B = \left(\frac{\pi D^3}{6}\right)\rho_f g$$

$$F_V = 3DVU$$

$$\sum F = 0$$

$$V = \frac{gD^2(\rho_m - \rho_f)}{18U}$$

$$D = \left[\frac{18HU}{gt(\rho_m - \rho_f)}\right]^{1/2}$$



Where:

D : Particle diameter

ρ_m : Particle density

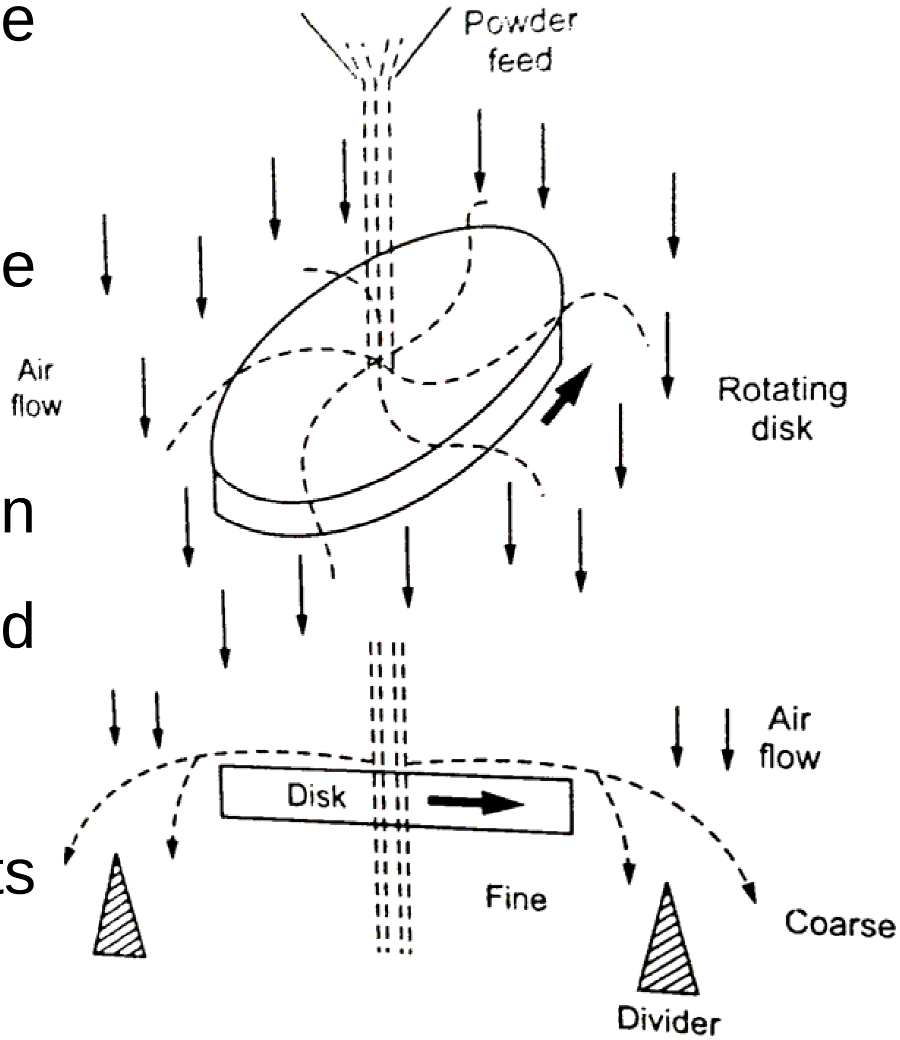
ρ_f : Fluid density

U : Fluid viscosity

V : Velocity

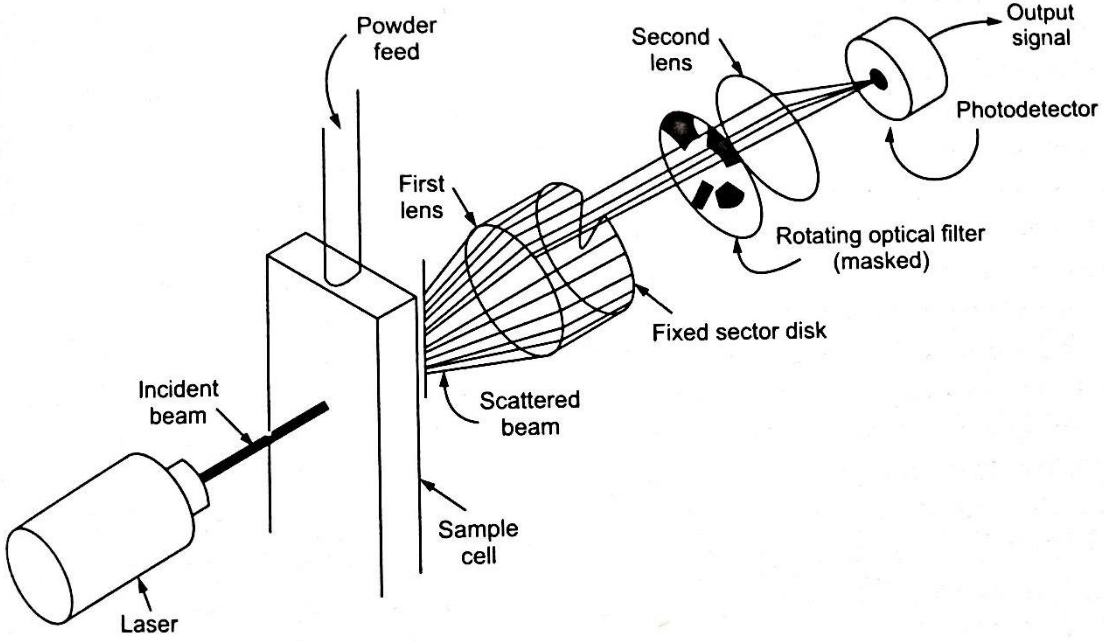
Air sedimentation

- Used for particle size classification.
- Spinning disc and air flow are used for the classification.
- Classification is done based on the spinning speed, air flow and masses of particles.
- Used for dividing powder lots into coarse and fine size.



4. Light scattering

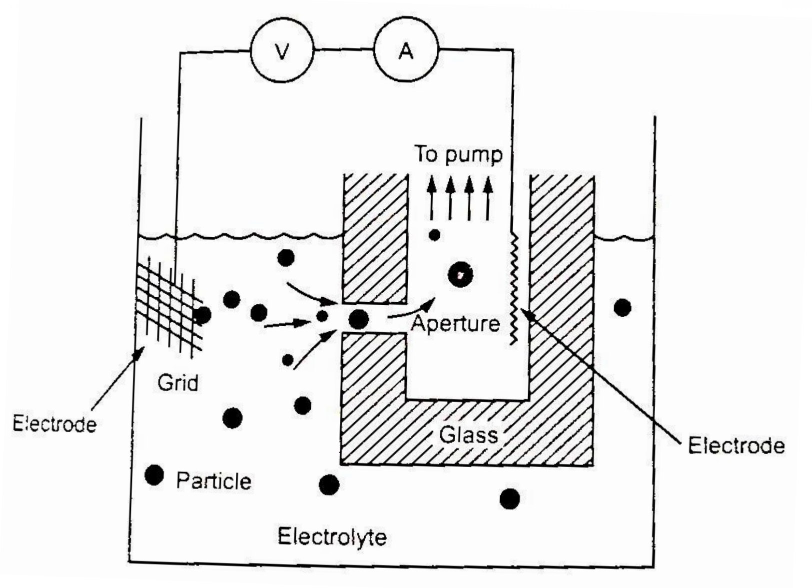
- This technique for particle sizing is based on light scattering.
- Laser beam is used as a light source



- Computer analysis is used for a quick determination of the particle size (ease data collection).
- Measuring range from 1 to 200 µm.

5. Electrical conductivity

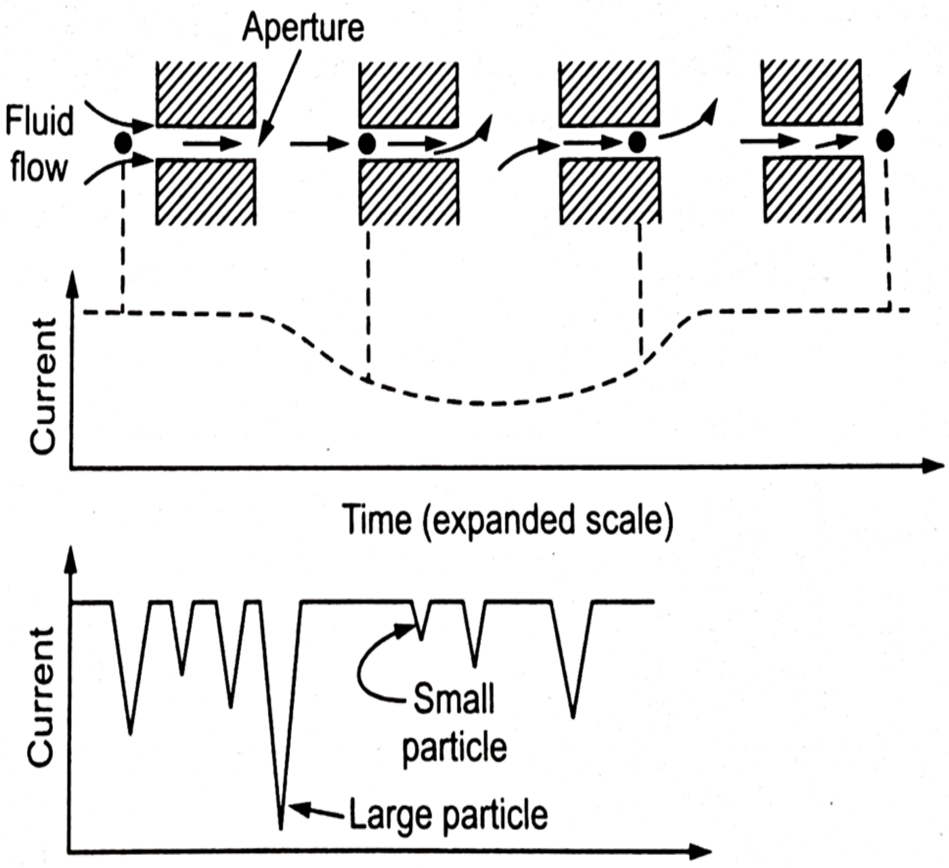
- This technique for particle sizing is based on the change in the electrical conductivity.



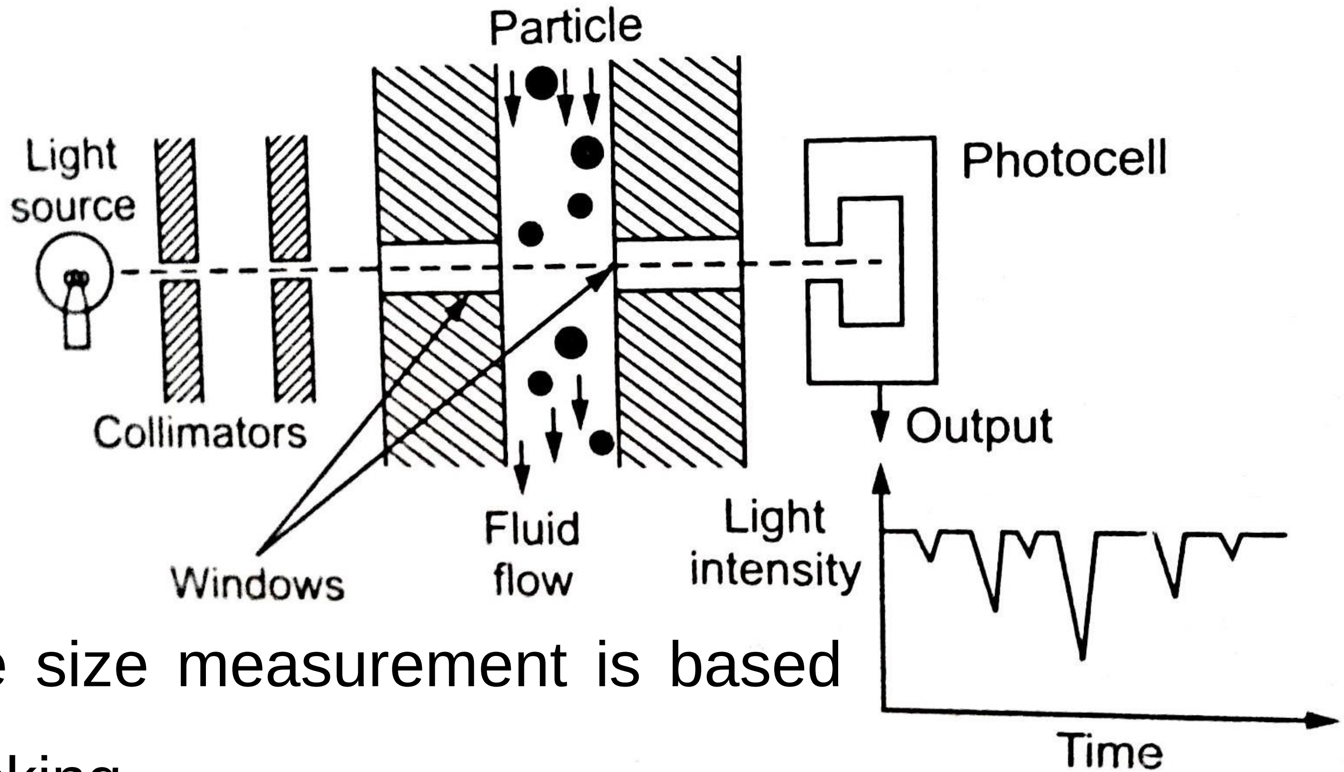
- A narrow hole in a non-conductive glass tube carries a flow of electrolyte.
- the decrease in the conductivity is proportional to the particle size.

5. Electrical conductivity (Cont.)

- The particle size is related to the intensity of the pulses.
- Minimum particle size to be measured is 0.5µm.
- Used for nonconductive powders like ceramics and polymers.
- The instrument is affected by noise.



6. Light blocking



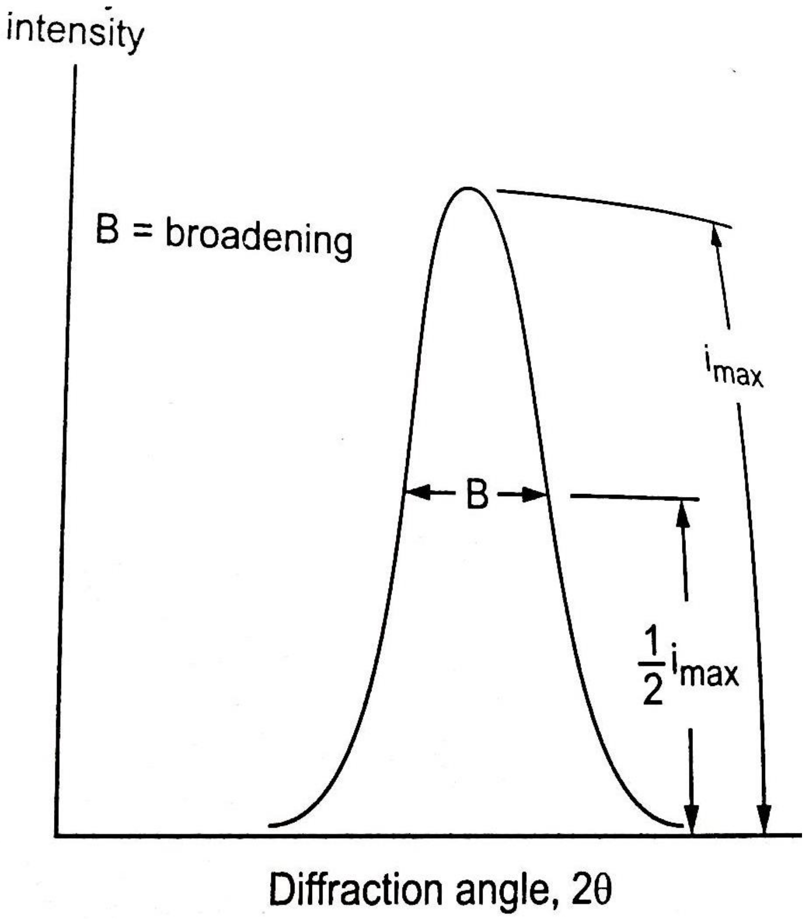
- The particle size measurement is based on light blocking.
- The minimum particle size to be measured is 2 µm.

7. X-Ray

- The particle size measurement is based on diffraction.

$$D = \frac{0.9\,\lambda}{B}$$

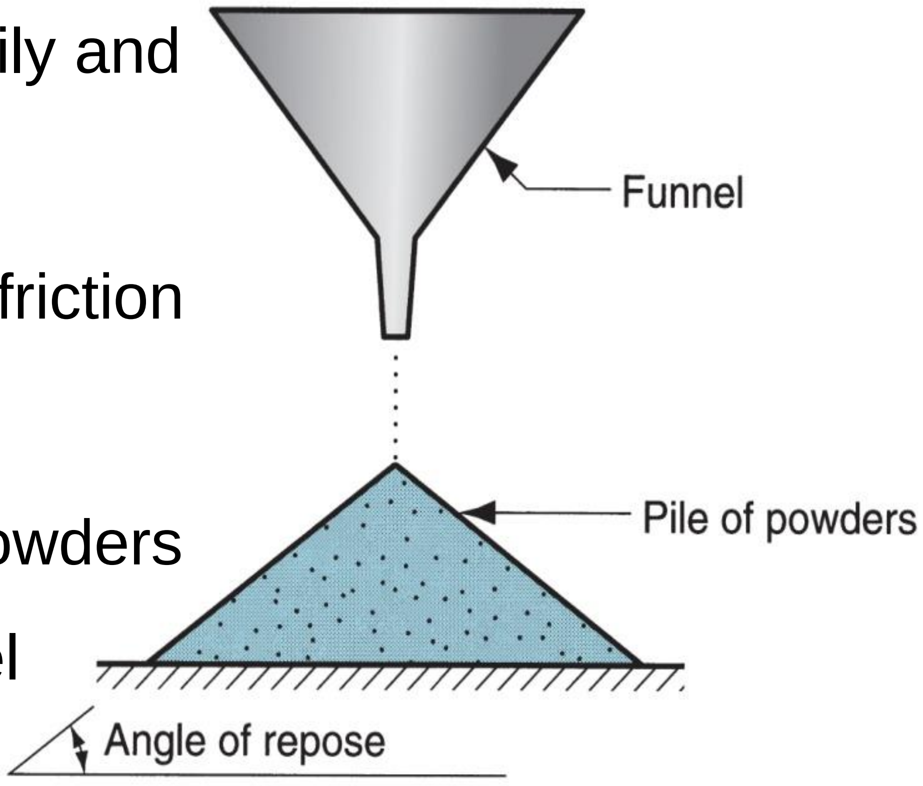
- The minimum particle size to be measured is 50 nm.
- This technique only gives a mean particle size with no shape formation.



Comparison between the different techniques

Interparticle Friction and Powder Flow

- Friction between particles affects ability of a powder to flow readily and pack tightly
- A common test of interparticle friction is the *angle of repose*
  - Angle formed by a pile of powders poured from a narrow funnel
- Larger angles mean greater interparticle friction



Observations About Interparticle Friction

- Smaller particle sizes generally show greater friction and steeper angles
- Spherical shapes have the lowest interpartical friction
- As shape deviates from spherical, friction between particles tends to increase
- Easier flow of particles correlates with lower interparticle friction
- Lubricants are often added to powders to reduce interparticle friction and facilitate flow during pressing

Particle Density Measures

- True density - density of the true volume of the material
  - The density of the material if the powders were melted into a solid mass
- Bulk density - density of the powders in the loose state after pouring
  - Because of pores between particles, bulk density is less than true density

Packing Factor

Bulk density divided by true density

- Typical values for loose powders are 0.5 to 0.7
- If powders of various sizes are present, smaller powders fit into spaces between larger ones, thus higher packing factor
- Packing can be increased by vibrating the powders, causing them to settle more tightly.
- Pressure applied during compaction greatly increases packing of powders.

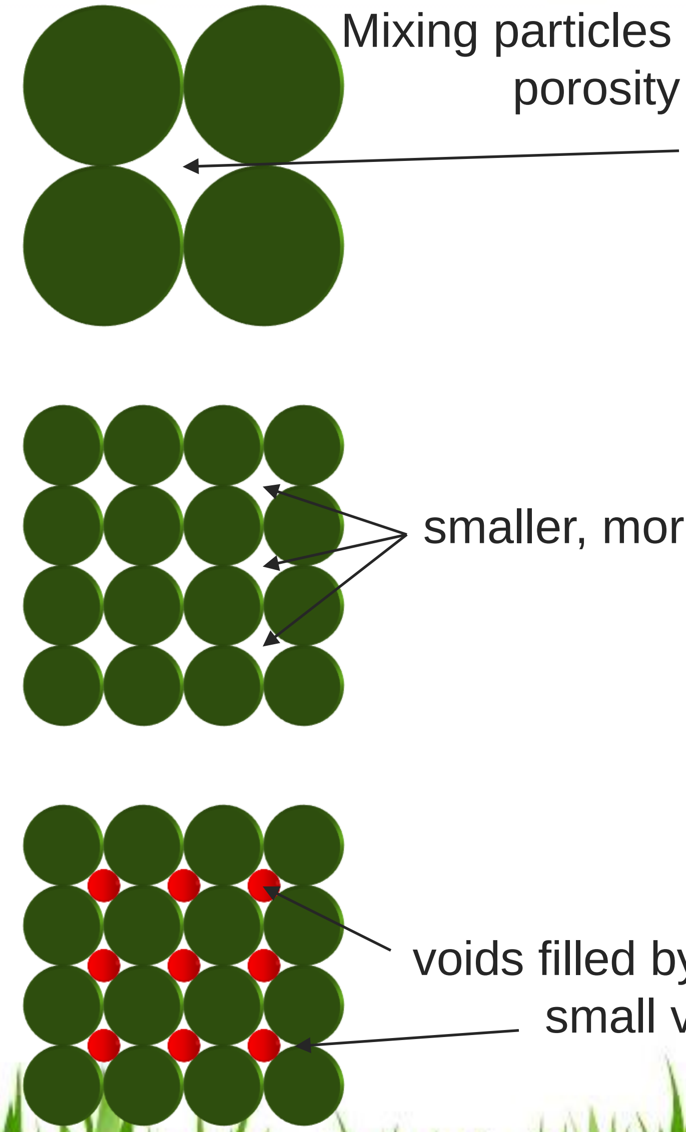
Porosity

Ratio of volume of the pores (empty spaces) in the powder to the bulk volume

- In principle, Porosity + Packing factor = 1.0
  - The issue is complicated by possible existence of closed pores in some of the particles
    - If internal pore volumes are included in above porosity, then equation is exact

Particle Size

Mixing particles of different sizes allows decreased porosity and a higher packing ratio



Thank You!