Section-II
L-22
Particulate control
Air Pollution and Control
(Elective-I)

Contents of - Unit VII

L-22 → Control of pollutant emission at source, alternative fuels, process change, removal methods of particulate, principals of particulate removals.

Various types of particulate control equipments(Theory and problems),

L-23 → Gravity Setting chamber,

L- 25→ Cyclone separators,

L- 26→ Fabric filters,

L-27→ Electrostatic precipitators and

L-28→ Scrubbers

Air Pollution Control Techniques Without Using Emissions Control Devices

- **Process Change or modification**

- Use of low volatile coal instead of high volatile coal

-Wind, Geothermal, Hydroelectric, or Solar Unit instead of Fossil fired Unit.

- **Change in Fuel or changes in operational practices** - e.g. Use of Low Sulfur Fuel, instead of High Sulfur fuel.

- **Good Operating Practices**
  - Good Housekeeping
  - Maintenance
- **Plant Shutdown**.
- **Replacement or modification of the process equipment.**

-***Use of vapour recovery system*:-** use of absorbers, condensers and compressors may be used to control vapour losses

Particulate removal mechanisms

- The control of particulate matter is an important aspect of industrial air pollution engineering.
- Particles are collected by a combination of several mechanisms.

- The six available mechanisms are

1) **GRAVITATIONAL SETTLING,**
2) **CENTRIFUGAL IMPACTION,**
3) **INERTIAL IMPACTION,**
4) **DIRECT INTERCEPTION,**
5) **DIFFUSION AND**
6) **THE ELECTROSTATIC ATTRACTION.**

1. Gravitational settling

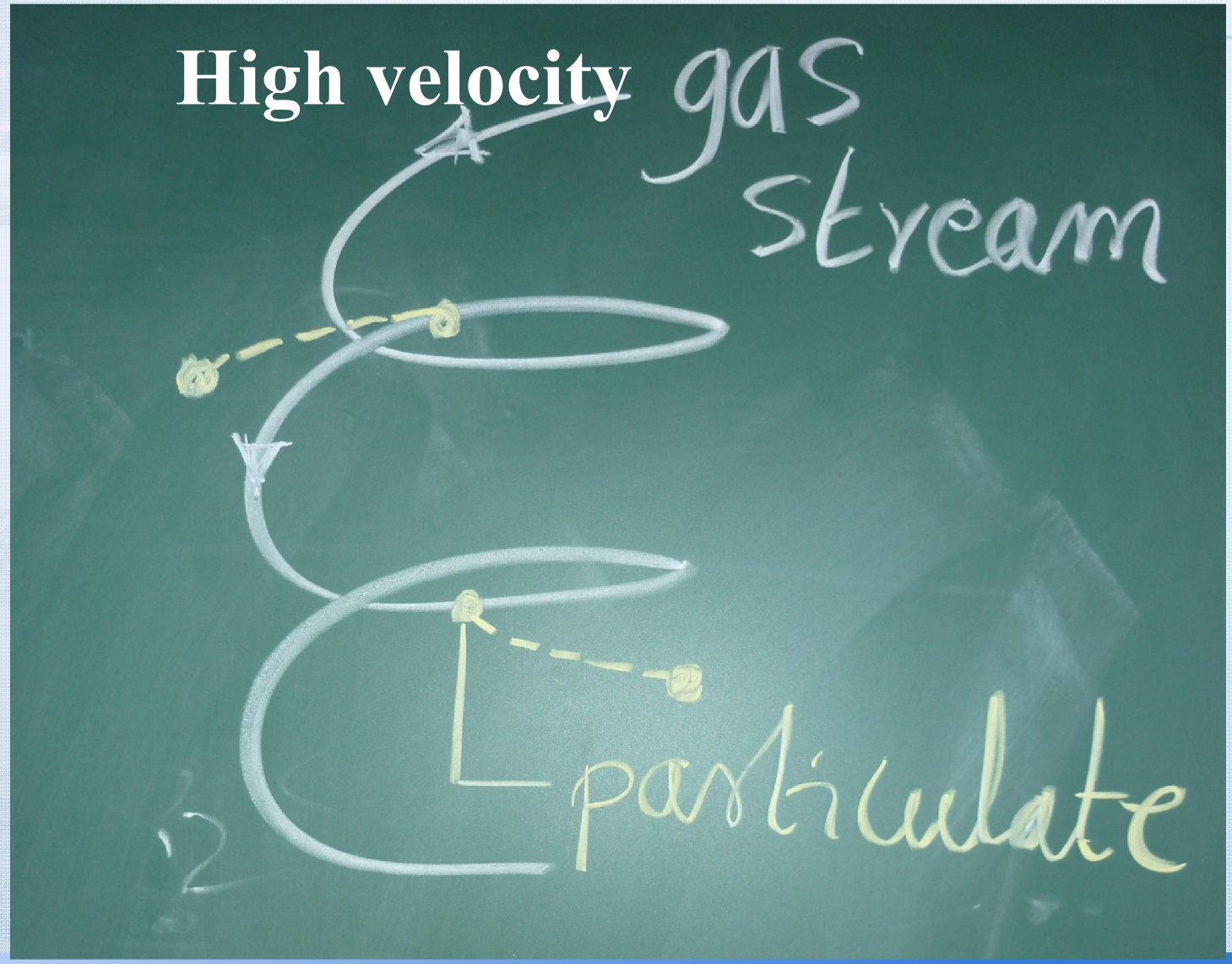
- Particles in still air have two forces acting on them;

(1) a gravitational force downward and

(2) the air resistance (or drag) force upward.

- When particles begin to fall, they quickly reach a **terminal settling velocity**, which represents the constant velocity of a falling particle when the gravitational force downward is balanced by the air resistance (or drag) force upward.

2. Centrifugal impaction

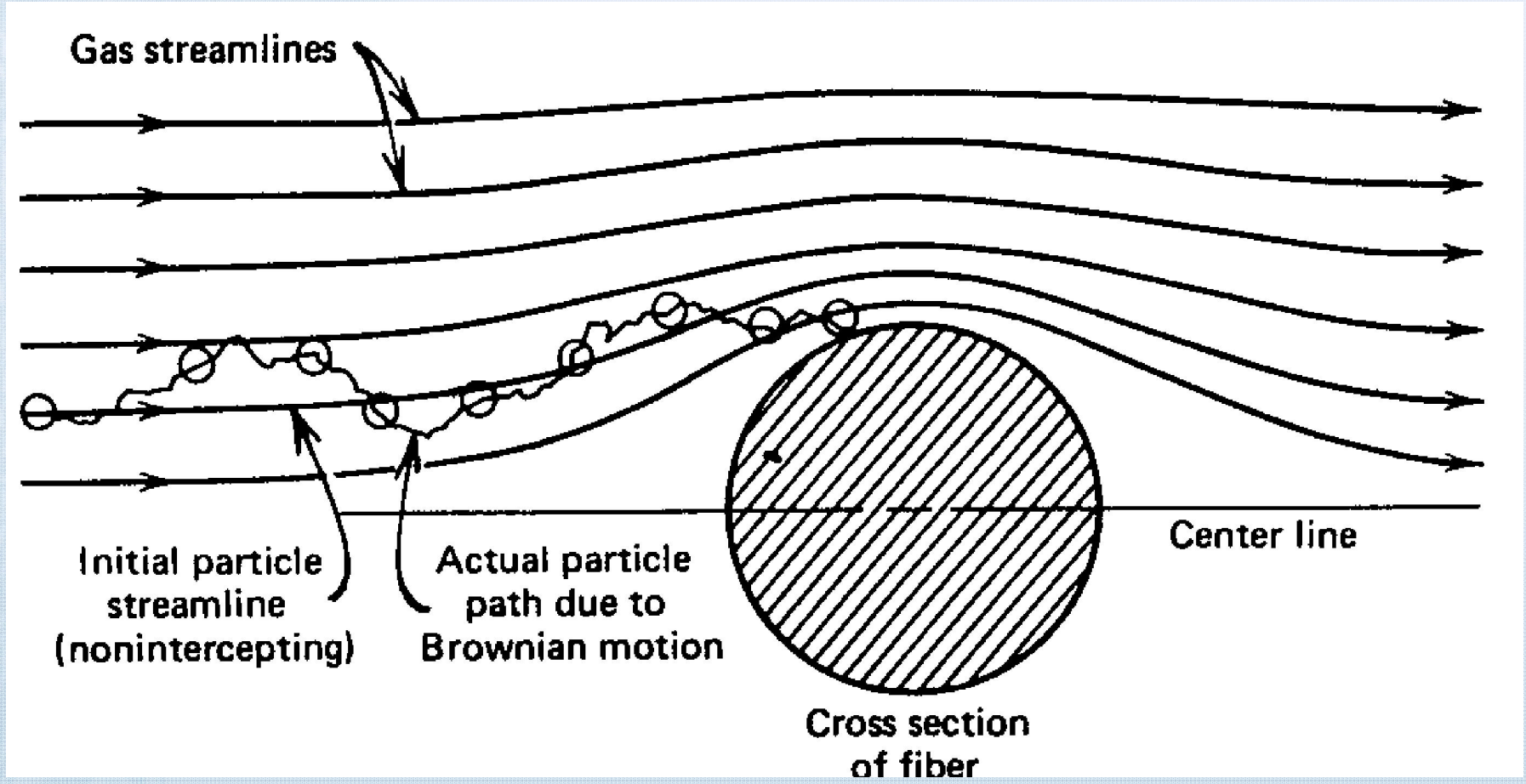


- Consider a high velocity gas stream revolving, because of centrifugal action particulates are separated from gas stream as their self weight is more than that of gas molecules.

3. Electrostatic attraction

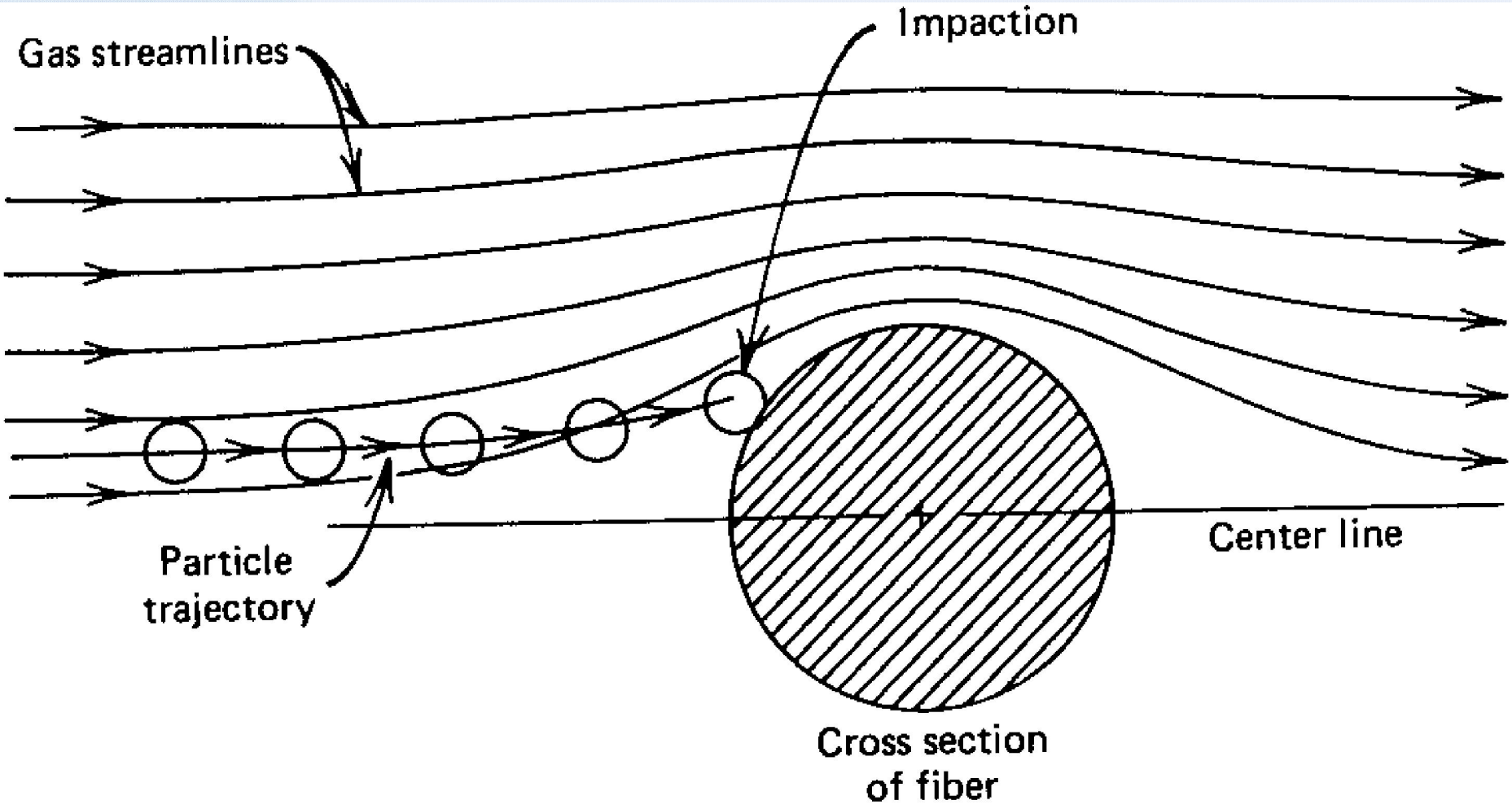
Migration of charged particle in an electric field. The particle-containing gas stream is introduced into a device in which the particles are charged and then subjected to an electric field. The resulting electrostatic force on the particles causes them to migrate to one of the surfaces of the device, where they are held and collected. Devices of this type are called electrostatic precipitators.

4 .Diffusion


Gas streamlines
Initial particle streamline (nonintercepting)
Actual particle path due to Brownian motion
Center line
Cross section of fiber

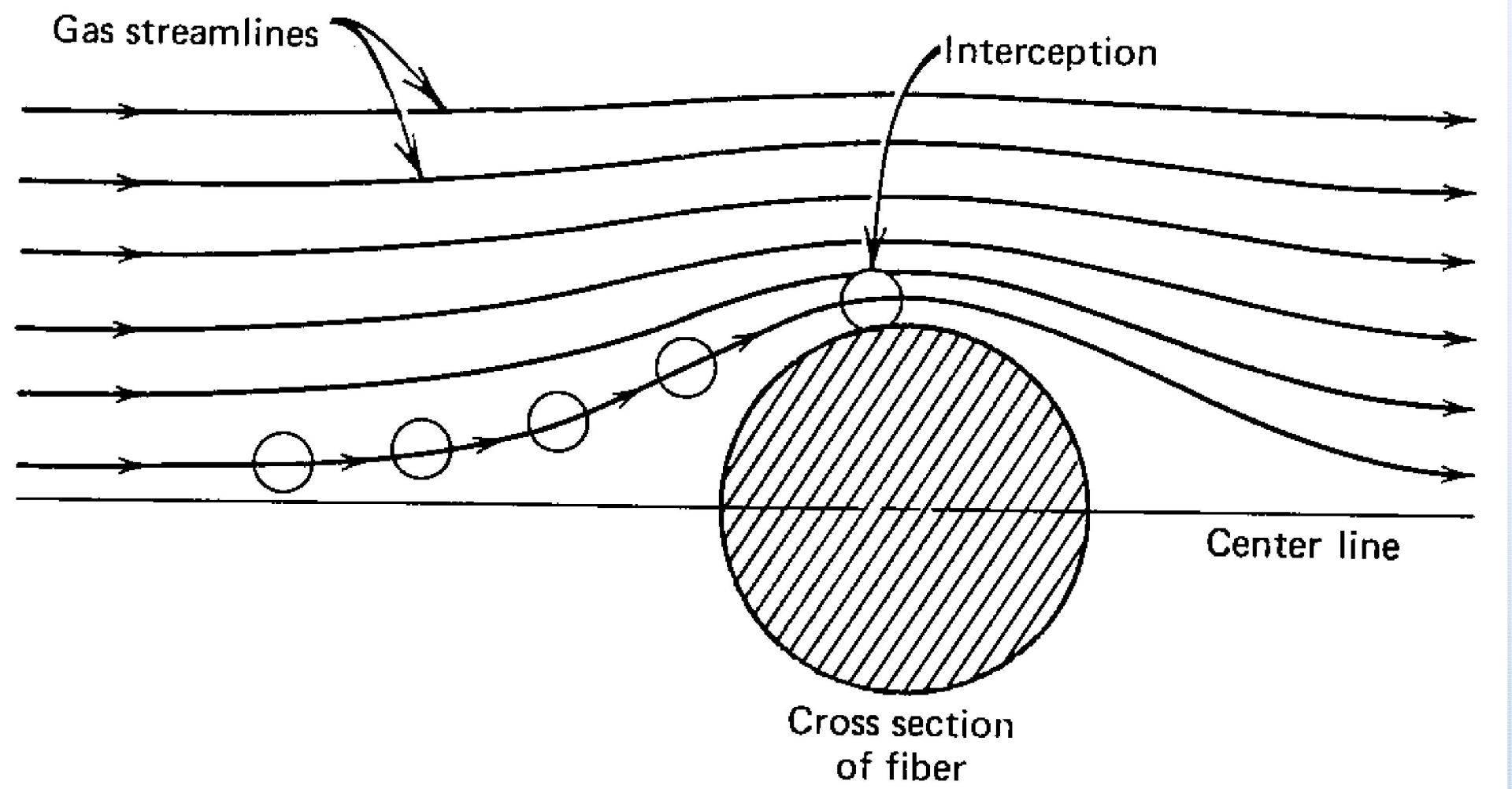
- Brownian diffusion becomes the dominant collection mechanism for **particles less than 0.3 micrometer and is especially significant for particles in the 0.01 to 0.1 micrometer size range.**
- Very small particles in a gas stream deflect slightly when gas molecules strike them. Transfer of kinetic energy from the rapidly moving gas molecule to the small particle causes this deflection, called **Brownian diffusion**. These small particles are captured when they impact a target (e.g. liquid droplet) as a result of this random movement.

5. Inertial Impaction

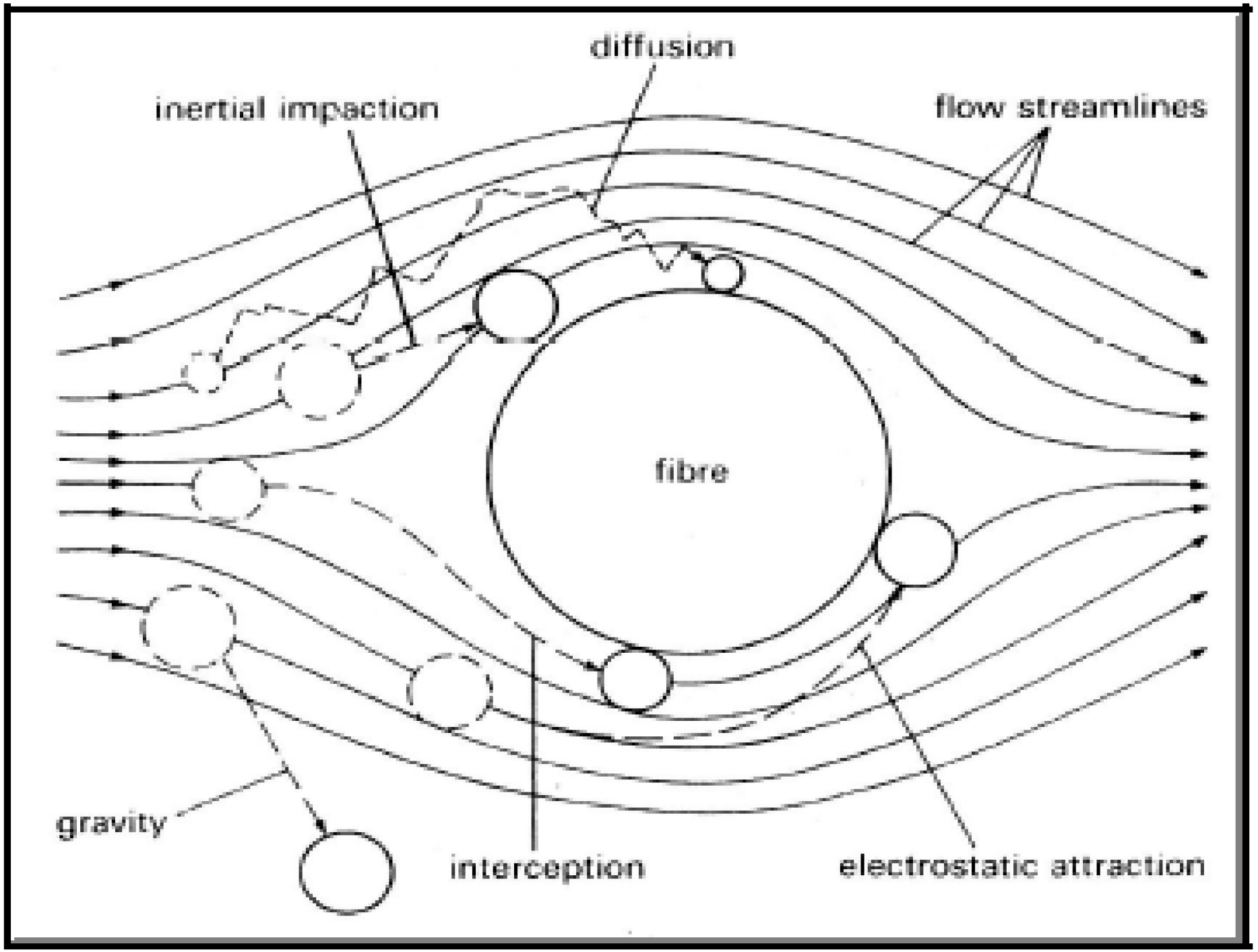


- Due to inertia, a particle moving in a gas stream can strike slowly moving or stationary obstacles (targets) in its path. As the gas stream deflects around the obstacle, the particle continues toward the object and impacts it. The obstacle may be a water droplet as shown in the Figure above.

6. Interception



- Inertial impaction occurs when obstacles (e.g. water droplets) are *directly* in the path of the particle moving in the gas stream. Sometimes the obstacle or target is offset slightly from the direct path of the moving particle. In this instance, as the particle approaches the edge of the obstacle, the obstacle may collect the particle through a process called **interception**.


diffusion
inertial impaction
flow streamlines
fibre
gravity
interception
electrostatic attraction

Types of particulate control equipments

- There are five basic types of dust collectors in use and forces/mechanisms responsible are:

i) gravity settling chambers - Gravity force

ii) cyclones – Centrifugal separation

iii) fabric filters- Combination of many mechanisms

iv) electrostatic precipitators- electrostatic action

v) Scrubbers - Combination of many mechanisms

Control of particles

- **Wall collection devices**

***Gravity settlers**

***Centrifugal separators (cyclones)**

***Electrostatic precipitators**

- **Dividing collection devices**

***Bag house filter**

***Scrubbers**

Control Efficiency

- In all cases, the efficiency of PM control is based on the mass percent of the incoming PM that is collected or removed from the gas stream. That is, collection efficiency is calculated as:

$$\eta = \frac{\text{Mass rate of particles collected}}{\text{Mass input rate of particles}} \times 100\%$$

where: η = particle collection efficiency, percent

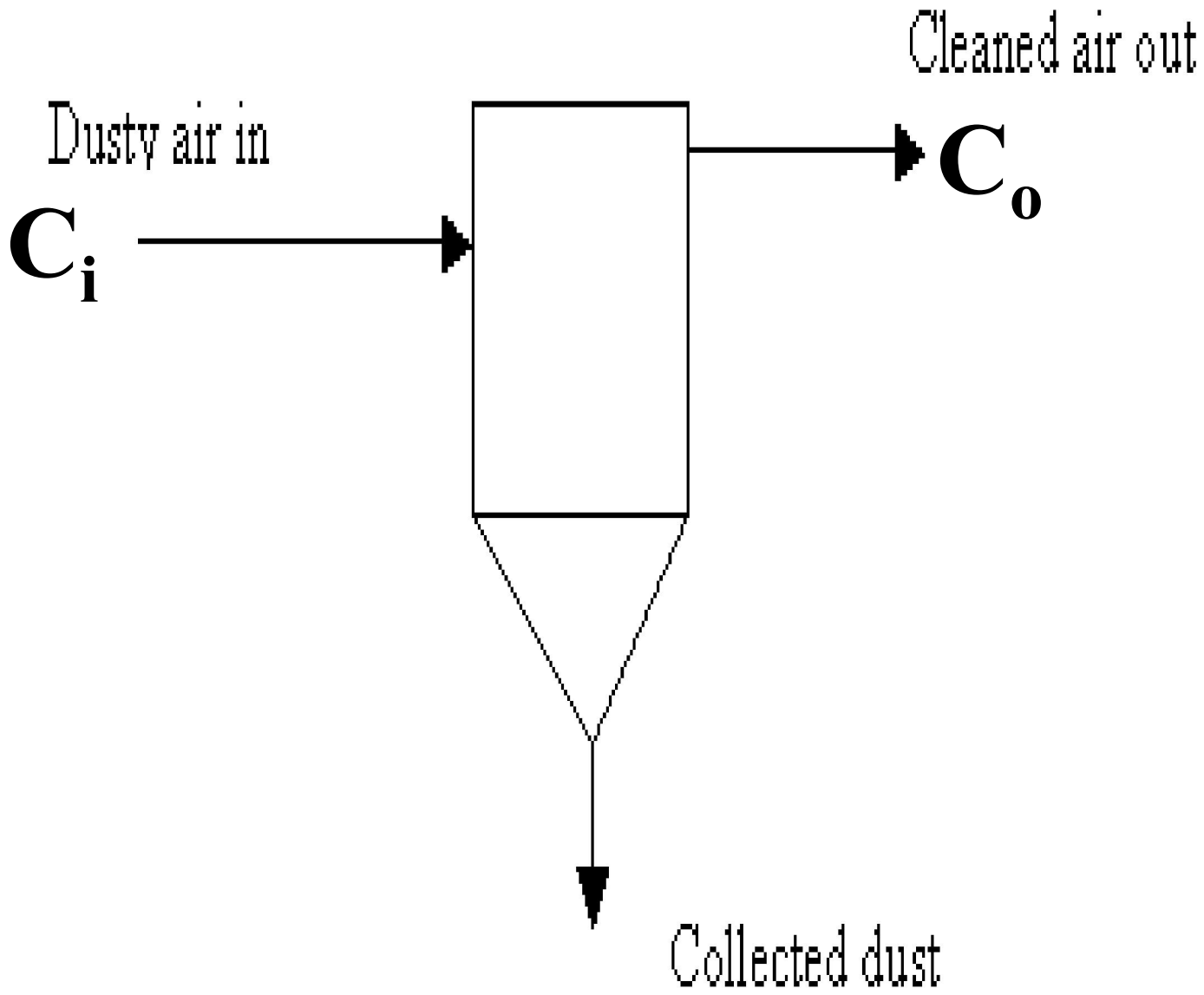


Figure 2. Schematic diagram of particulate matter air pollution control device

Overall Collection η

$$\eta(\%) = \frac{C_i - C_o}{C_i}$$

C_i = Inlet concentration

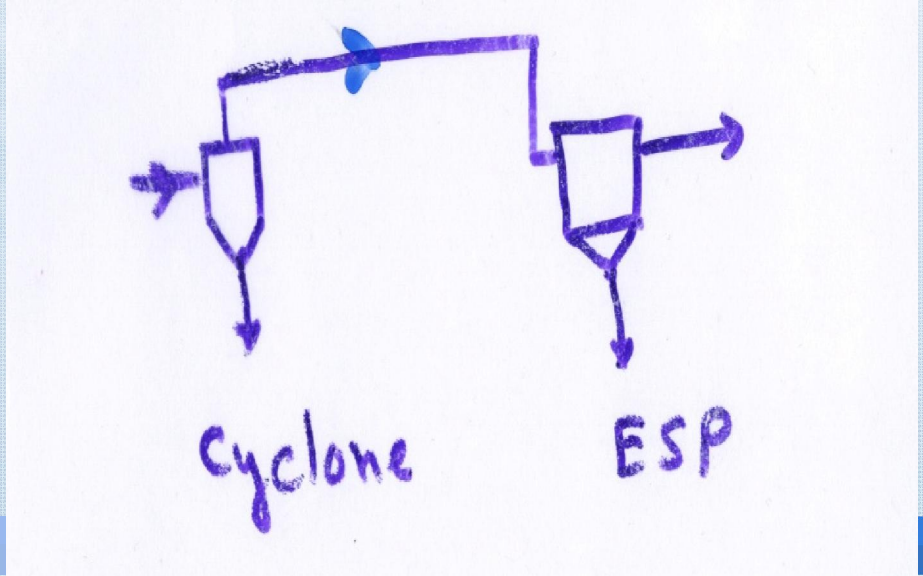
C_o = Outlet concentration

Note: The smaller the particle, the lower is efficiency of removal.

- Air pollution control devices operate on a continuously flowing stream of contaminated air or exhaust gas.
- The dusty gas flows into the device, and most of the particles are separated from the gas stream and collected as solids, while the entire air flow continues through the equipment

Problem

- A cyclone operates removes 75% of particulate matter fed to it. The filter is then fed to an ESP which operates with 90% efficiency. What is the overall efficiency of this particulate system?



- *Step 1*:

Assuming an initial feed of 100%, determine the percentage of the stream fed to the ESP.

100% - (100% x 0.75) = 25%

- *Step 2*:

Determine final composition after ESP.

25% - (25% x 0.9) = 2.5%

- *Step 3*:

Determine overall efficiency

$\eta_{overall}$ = (initial – final)/ initial

= [(100% - 2.5%)/100%] = 97.5%

Objective Questions

Q1. Match the pairs

Equipment	Force responsible
Gravity settler	Electrostatic
Cyclone	Gravity
ESP	Interception, Impaction and diffusion
Fabric filter	Centrifugal

Q2. Use of Low Sulfur Fuel, instead of High Sulfur fuel is example of _____.

Q3. In general efficiency of particulate control equipment is given by _____.

Q4. If particulate control equipments are connected in series , overall efficiency _____.

Theory Questions

Q1. Explain different particulate collection mechanisms with neat sketches.

Q2. Write a short note on *'Air pollution control Techniques Without Using Emissions Control Devices'*