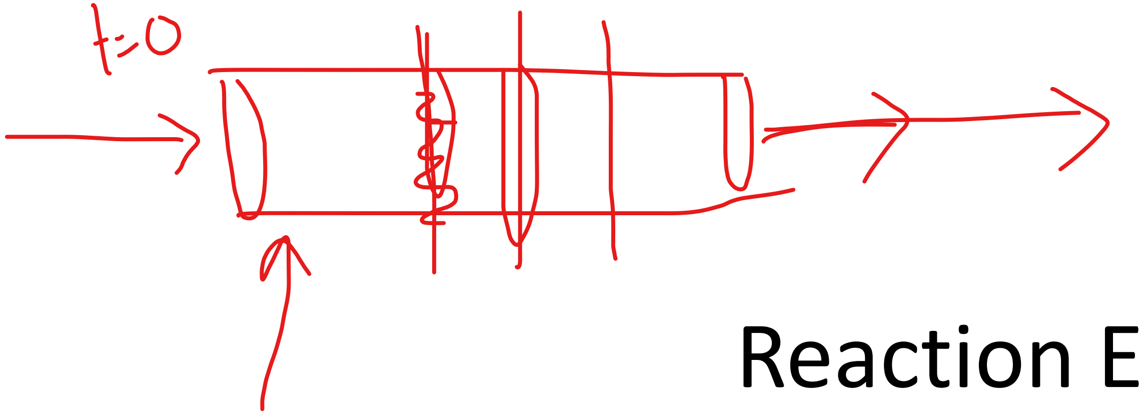
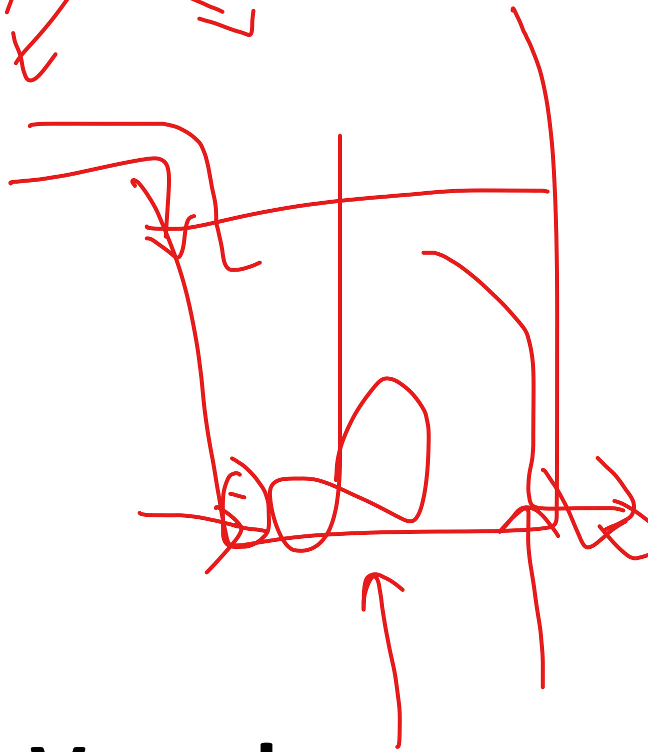


real

ideal



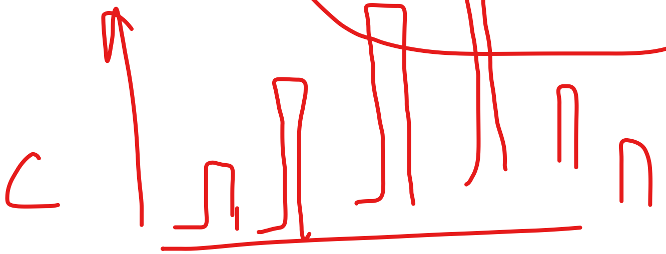
Reaction Engineering Lab

$\text{space time} = \frac{V_R}{v_0}$ $v_{in} = v_{out}$

Experiment No. 4

Residence time distribution in a Tubular Vessel

mean



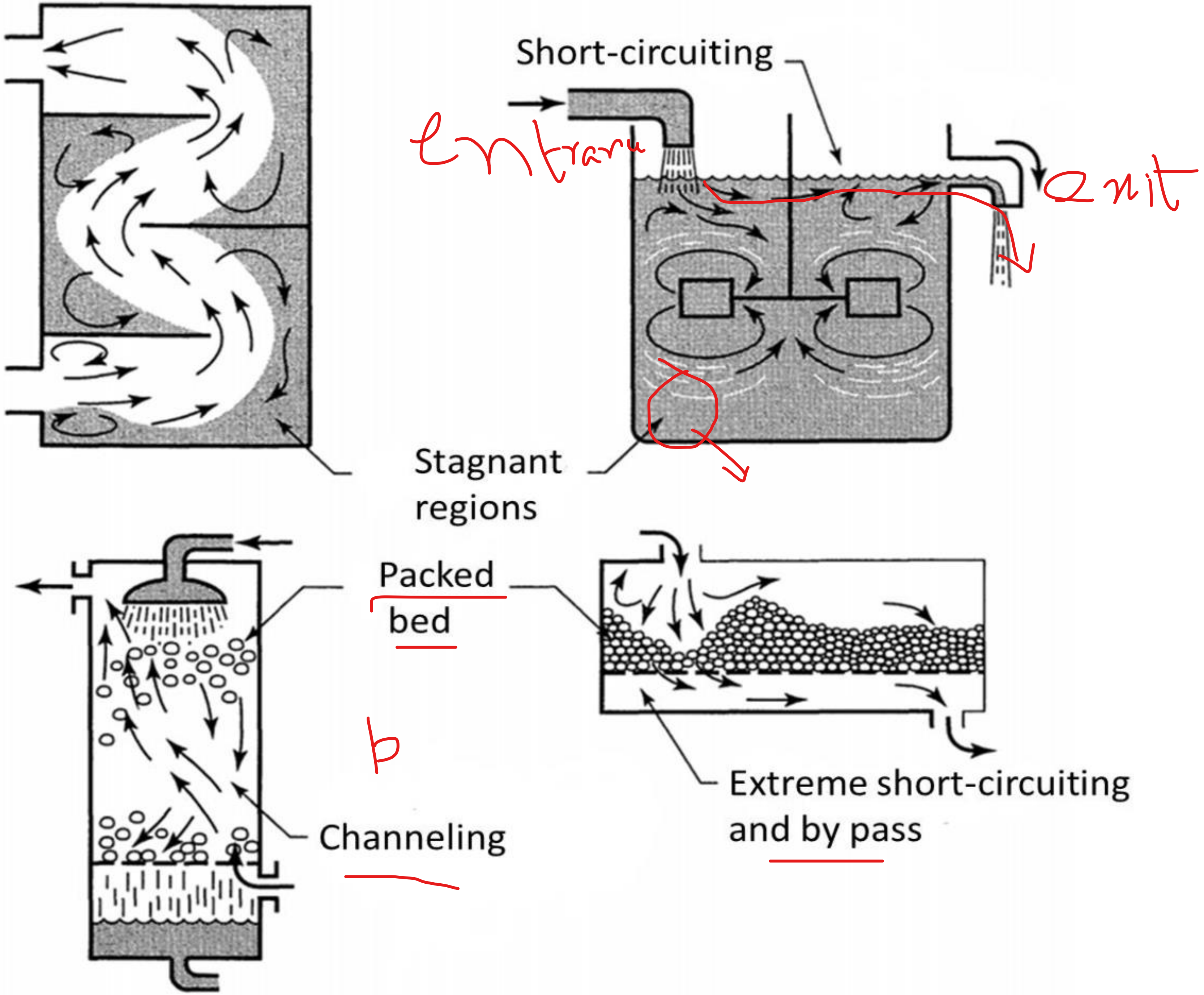
PFR

CSTR

LFR

Introduction

- In some cases the ideal reactor approach of the piston flow pattern for Tubular Reactors (PFR) or perfect mixing pattern for Continuous Stirred Tank Reactors (CSTR) or even laminar flow pattern in tubular reactors, can accurately describe the real reactors.
- Nevertheless, this is not the case for many other situations, especially when higher volumes and/or more viscous mixtures are involved.
- Several important modifications in the ideal flow pattern can effectively occur, such as the formation of stagnant regions inside the real reactor, channeling and short-circuiting, internal recycle flows, and so on.

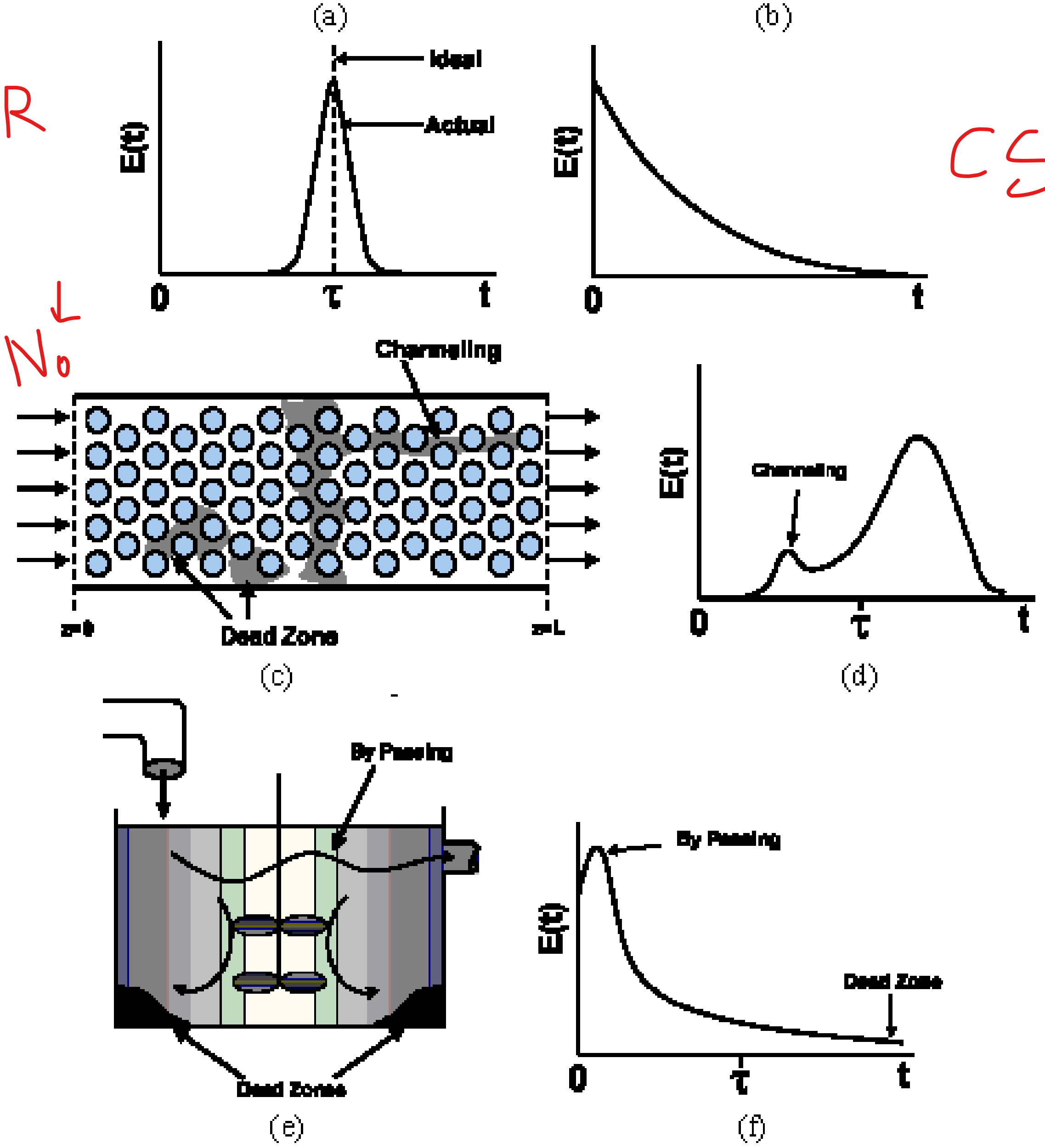

Short-circuiting
Stagnant regions
Packed bed
Channeling
Extreme short-circuiting and by pass
exit
b

$E =$

PF R

RTDs that are commonly observed

pulse N_0



CSTR

t	Conc.
t=0	0
1	
	max
	⋮
	0
	Σ Conc

Figure 13-10 (a) RTD for near plug-flow reactor; (b) RTD for near perfectly mixed CSTR; (c) Packed-bed reactor with dead zones and channeling; (d) RTD for packed-bed reactor in (c); (e) tank reactor with short-circuiting flow (bypass); (f) RTD for tank reactor with channeling (by-passing or short circuiting) and dead zone.

1. Schematic
2. calcultaion
3. Interpretation

Conc

time

❑ Objective:

- To construct C curve for pulse input
- To plot age-distribution curve (E vs t)
- To calculate average residence time
- To calculate the vessel dispersion number (D/uL) for different flow rates

PFR 0 →

CSTR 1

❑ Theory

- Real reactors never fully follow the two idealized flow patterns, plug flow and mixed flow.
- The deviation from the ideal flow patterns can be determined by the residence time distribution.
- Residence Time Distribution (RTD) analysis is a very efficient diagnosis tool that can be used to inspect the malfunction of chemical reactors.

- According to Fick's Law for molecular diffusion, in the x-direction the differential equation is

$$\frac{\partial C}{\partial t} = \mathrm{D}\frac{\partial^2 C}{\partial x^2}$$ where D is the axial dispersion coefficient

- In dimensionless form using z = x/L and θ = t / ṫ = tu/L, the above equation becomes

$$\frac{\partial C}{\partial \theta} = \left(\frac{D}{uL}\right)\frac{\partial^2 C}{\partial z^2} - \frac{\partial C}{\partial z}$$

- Where the dimensionless group D/uL is called vessel dispersion number, is the parameter which measures the extent of axial dispersion.
- For $\frac{D}{uL} \to 0$, negligible dispersion, plug flow
- For $\frac{D}{uL} \to \infty$, large dispersion, mixed flow

Cont.

- For closed vessel $\frac{D}{uL}$ can be determined by following equation-

$$\sigma_\theta^2 = 2\frac{D}{uL} - 2\left(\frac{D}{uL}\right)^2\left(1 - e^{-\frac{uL}{D}}\right)$$

Where $\sigma_\theta^2 = \frac{\theta^2}{\bar{t}^2}$, $\sigma_\theta^2 = \frac{\sum t_i^2 C_i}{\sum C_i} - \bar{t}^2$, and $\bar{t} = \frac{\sum t_i C_i}{\sum C_i}$

- **Apparatus**

- One tubular vessel (L= 81.5 cm) packed with Raschig rings
- Dye injection system
- Stop Watch and test tubes
- Colorimeter

t	C

Procedure

i. Start the water flow by adjusting the valve and metered by the calibrated rotameter.

ii. Inject the dye (about 5 ml of methylene blue) by the hypodermic syringe through the injection port near the inlet.

iii. Collect 10-12 samples from the outlet in different test tubes at one minute interval (approx.).

iv. Analyse the sample by a spectrophotometer at 664 nm. Conc.

v. Calculate vessel dispersion number from average residence time and variance.

vi. Plot E Curve and C curve

vii. Plot D/uL as a function of Reynold's Number (diameter - 5 cm)

$\bar{t} =$

$\sigma^2 =$