

# Workshop 11: Distribution of residence time

Lecture notes for chemical reaction engineering

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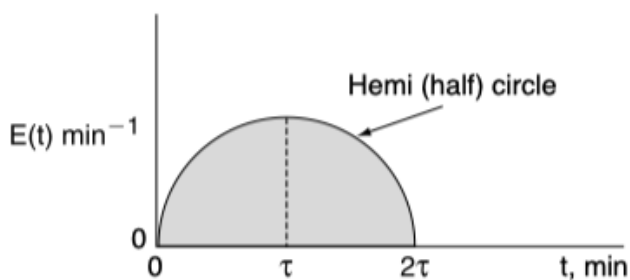
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Try following problems from Fogler 5e (Fogler (2016)) P 16-3, P 16-6, P 16-11

We will go through some of these problems in the workshop.

## P 16-3

Consider the  $E(t)$  curve below.



Mathematically this hemi circle is described by these equations:

For  $2\tau \geq t \geq 0$ , then  $E(t) = \sqrt{\tau^2 - (t - \tau)^2} \text{ min}^{-1}$  (hemi circle)

For  $t > 2\tau$ , then  $E(t) = 0$

- What is the mean residence time?
- What is the variance?

## P 16-6

An RTD experiment was carried out in a nonideal reactor that gave the following results:

$E(t) = 0$	for $t < 1 \text{ min}$
$E(t) = 1.0 \text{ min}^{-1}$	for $1 \leq t \leq 2 \text{ min}$
$E(t) = 0$	for $t > 2 \text{ min}$

- What are the mean residence time,  $t_m$ , and variance  $\sigma^2$ ?

- (b) What is the fraction of the fluid that spends a time 1.5 minutes or longer in the reactor?
- (c) What fraction of fluid spends 2 minutes or less in the reactor?
- (d) What fraction of fluid spends between 1.5 and 2 minutes in the reactor?

## P 16-11

The volumetric flow rate through a reactor is  $10 \text{ dm}^3/\text{min}$ . A pulse test gave the following concentration measurements at the outlet:

t (min)	$c \times 10^5$	t (min)	$c \times 10^5$
0	0	15	238
0.4	329	20	136
1.0	622	25	77
2	812	30	44
3	831	35	25
4	785	40	14
5	720	45	8
6	650	50	5
8	523	60	1
10	418		

- (a) Plot the external-age distribution  $E(t)$  as a function of time.
- (b) Plot the external-age cumulative distribution  $F(t)$  as a function of time.
- (c) What are the mean residence time  $t_m$  and the variance,  $\sigma^2$ ?
- (d) What fraction of the material spends between 2 and 4 minutes in the reactor?
- (e) What fraction of the material spends longer than 6 minutes in the reactor?
- (f) What fraction of the material spends less than 3 minutes in the reactor?
- (g) Plot the normalized distributions  $E(\Phi)$  and  $F(\Phi)$  as a function of  $(\Phi)$ .
- (h) What is the reactor volume?
- (i) Plot the internal-age distribution  $I(t)$  as a function of time.
- (j) What is the mean internal age  $\alpha_m$ ?

## References

Fogler, H. Scott. 2016. *Elements of Chemical Reaction Engineering*. Fifth edition. Boston: Prentice Hall.