Course SH2774: Numerical Methods in Nuclear Engineering (NMiNE)

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KTH Reactor Physics

Overview

- 6 ECTS Credits
- Start: August 30, Week 35
- Finish: November 16, Week 46
- 19 Sessions
- Quizzes, HAs, 1 Exam, 1 Numerical Project
- Tick/Tock Times: Tue 10/ Thu 08

W	35	36	37	38	39	40	41	44	45	46	47	48	49	50
L	2	2	2	2	2	2	2	2	2	1	0	0	0	0

NMiNE, SH2774 HT2022

L	Wk	WD	Date	Time	Room	Lecturer	Topic
1)	35	Tue	30-aug	10-12	C3	*V. Arzhanov*	Course Overview; Numerical Experiment
2)	35	Thu	01-sep	08-10	C3	*V. Arzhanov*	Computer Arithmetics
3)	36	Tue	06-sep	10-12	C3	*V. Arzhanov*	Basic Concepts, Convergent Series
4)	36	Thu	08-sep	08-10	C3	*V. Arzhanov*	Polynomial/Spline Interpolation
5)	37	Tue	13-sep	10-12	C3	*V. Arzhanov*	Nonlinear Equations
6)	37	Thu	15-sep	08-10	C3	*V. Arzhanov*	Differentiation and Integration
7)	38	Tue	20-sep	10-12	C3	*V. Arzhanov*	Ordinary Differential Equations (ODE)
8)	38	Thu	22-sep	08-10	C3	*V. Arzhanov*	Boundary Value Problems (BVP)
9)	39	Tue	27-sep	10-12	C3	*V. Arzhanov*	Midterm Exam
10)	39	Thu	29-sep	08-10	C3	*V. Arzhanov*	Linear Algebraic Equations (LAE)
11)	40	Tue	04-okt	08-10	C3	*V. Arzhanov*	Direct Methods for LAE
12)	40	Thu	06-okt	08-10	C3	*V. Arzhanov*	FD for NDE
13)	41	Tue	11-okt	08-10	C3	*V. Arzhanov*	Basic Iterative Methods
14)	41	Thu	13-okt	08-10	C3	*V. Arzhanov*	Successive Over Relaxation
15)	44	Wed	02-nov	13-15	C3	*V. Arzhanov*	Gradient Methods
16)	44	Thu	03-nov	08-10	C3	*V. Arzhanov*	Power Method
17)	45	Wed	09-nov	14-16	C3	*V. Arzhanov*	Partial Differential Equations
18)	45	Thu	10-nov	08-10	C3	*V. Arzhanov*	Recapitulation
19)	46	Wed	16-nov	13-15	C3	*V. Arzhanov*	Reserved
20)	46	Thu	17-nov		C3		
21)	46	Fri	18-nov		C3		
22)	47	Mon	21-nov		C3		
23)	47	Thu	24-nov		C3		

Cancelations

- ?

Beginning of Lectures

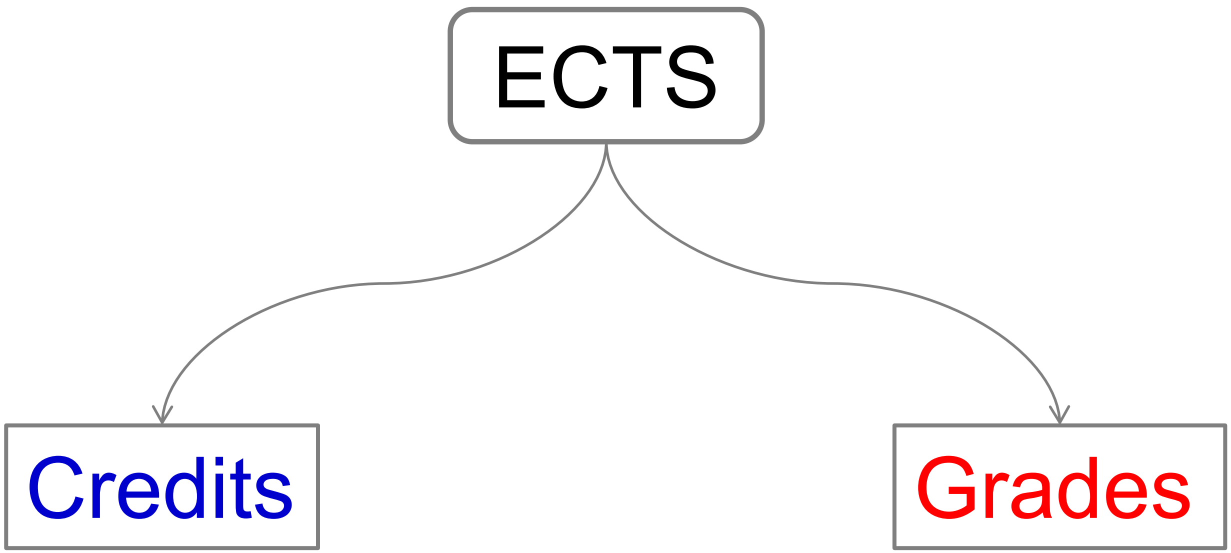
Example: A lecture is announced at 10 – 12.

This actually means:

- The lecture starts at 10:15
- The first (academic) hour runs 45 min (10:15 – 11:00)
- Break 15 min (11:00 – 11:15)
- The second hour runs another 45 min (11:15 – 12:00)

ECTS

European Credit Transfer and Accumulation System (ECTS) is a standard for comparing the study attainment and performance of students of higher education across the European Union and other collaborating European countries.



ECTS Credits

Sweden joined the Bologna declaration.

1 study year = 1500 ÷ 1800 hours = 60 ECTS credits

1 ECTS = 25 ÷ 30 hours

ECTS Grades

Since July 2007, ECTS is compulsory as grading system in KTH

ECTS	N	Verbal	Description
A	7	Excellent	(90 – 100)%
B	6	Very Good	(80 – 90)%
C	5	Good	(70 – 80)%
D	4	Satisfactory	(60 – 70)%
E	3	Sufficient	(50 – 60)%
Fx	2	Insufficient	(40 – 50)%
F	1	Insufficient	< 40%

Necessary Condition

Pass Midterm Written Exam

- Duration: 2 hours.
- Several (8-10) simple problems.
- Problems are theoretical or computational.
- Each problem is of multiple choice.
- Each problem brings 1 – 4 points.
- Totally 20 points.
- Passing: N ≥ 10.

Minimal Requirement

- Pass the midterm exam
- All HAs ≥ 50%
- Result = E
- No Project

Higher Grading Involves

• Quizzes (Q)	20%
• Home Assignments (HA)	40%
• Project (P)	40%

How It Works

20%	40%	40%		
Q	HA	P	Fin	Gr
90.0%	90.0%	90.0%	90.0%	A
100.0%	0.0%	100.0%	60.0%	D
100.0%	0.0%	99.0%	59.6%	E
0.0%	100.0%	100.0%	80.0%	B
0.0%	99.0%	100.0%	79.6%	C
90.0%	80.0%	80.0%	82.0%	B
50.0%	75.0%	75.0%	70.0%	C

Exam is a must !

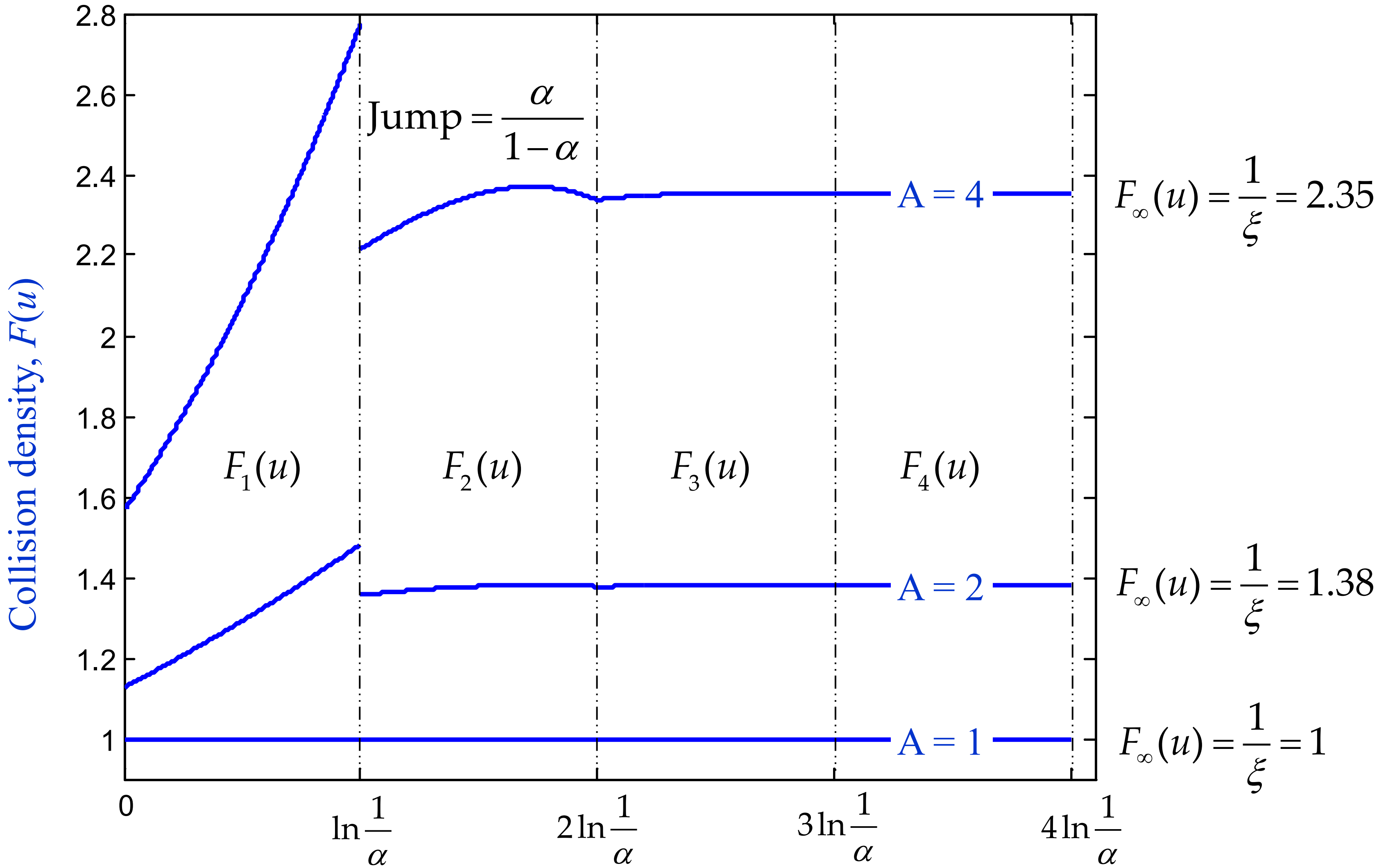
Project

- Larger numerical project
  - Analytic calculations
  - Numerical calculations (programming)
  - Answering questions
- Final report is in a form of scientific paper
- Topics
  - Neutron slowing down spectrum
  - Non-linear least squares fit

Project 1

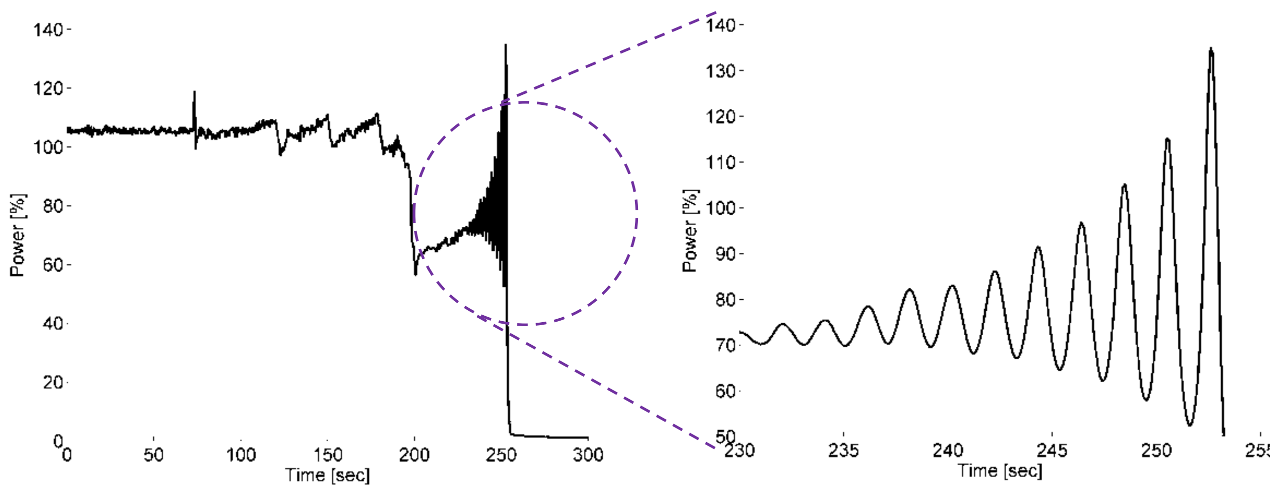
- Neutron slowing down spectrum
- Infinite homogenous medium
- Uniformly distributed neutron sources
- Equation: $\Sigma_t(E)\phi(E) = \int_0^\infty \Sigma_s(E' \to E)\phi(E')dE' + S(E)$
- Numerical inversion of Laplace transform

Collision Density in Lethargy



Project 2

- Non-Linear Model Fitting.
- Instability event at BWR in O-2, 1999.
- Model: $P(t) = ae^{-\gamma t}\cos\left(\omega t + \phi\right) + m$



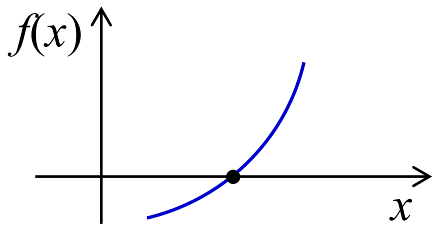
Topics

- Role of Numerical Modelling
- Computer Arithmetic
- Polynomial Interpolation, Splines
- Linear/Non-Linear Least Squares
- Linear Algebraic Equations, Eigenvalues
- Numerical Differentiation, Finite Differences
- Numerical Integration, Quadrature
- Solving (numerically) Neutron Diffusion Equation, NDE
- Numerical solution of ODE
- Numerical solution of PDE
- Equivalence Theorem, Spectral Stability

Major Numerical Methods

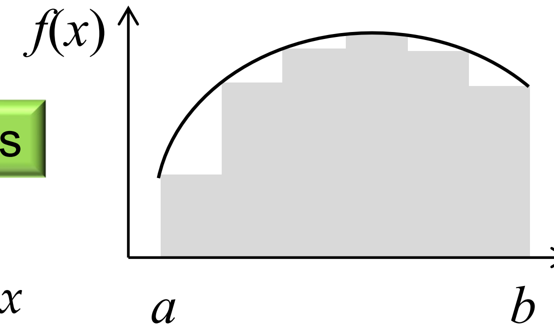
- Root finding

$$f(x) = 0$$



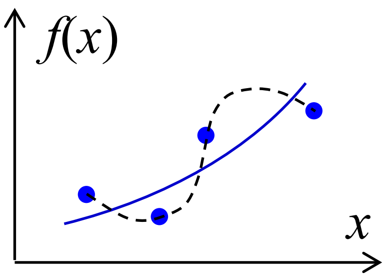
- Integrals

$$Q \approx \int_a^b f(x)dx$$



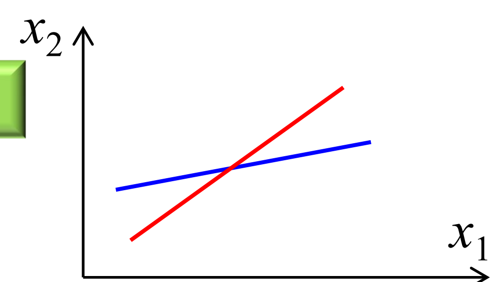
- Fitting/Interpol.

$$f(x_i) \approx y_i$$



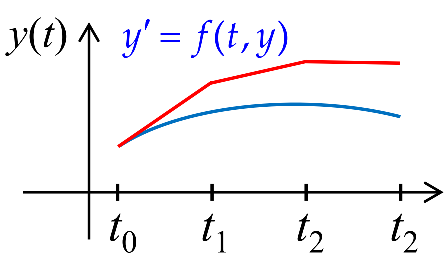
- LAE

$$\mathbf{Ax} = \mathbf{f}$$



- Discretization

$$y'(x_i) \approx \frac{y_{i+1} - y_i}{x_{i+1} - x_i}$$



- Eigenvalue

$$\mathbf{Ax} = \lambda \mathbf{x}$$

$$k = \frac{N_{n+1}}{N_n}$$

Prerequisites

- Basic course in Calculus
- Basic course in Linear Algebra
- Basic knowledge of Matlab/Python

Matlab/Python will be used for all class instructions and home assignments.

The amount of programming will increase after the first few weeks.

Literature

- Lecture presentations.
- Numerical Methods for Engineers by S.S.Chapra and R.P.Canale, 6th edition.
- Numerical Analysis by T.Sauer, 3^{d} edition.
- Computer Methods for Mathematical Computations by G.E.Forsythe M.E.Malcolm and C.B.Moler, 1977.
- Numerical Mathematics, A. Quarteroni, 2000.

Internet Resources

- https://www.python.org
- http://www.maths.dundee.ac.uk/software/matlab.shtml
- http://www.glue.umd.edu/~nsw/ench250/primer.htm
- https://www.sololearn.com/
  Learn to code for free
- ?? Open Courseware (MIT, etc.)

Numerical Methods

- Are techniques by which mathematical problems can be solved with elementary operations.
  - Arithmetic: addition, subtraction, multiplication, division;
  - Square, cubic etc. roots;
  - Elementary transcendental functions [e^x, $\log(x)$, $\sin(x)$, etc.];
  - Special functions: $J_n(x)$, $\Gamma(x) = (x\text{-}1)!$, hypergeometric, elliptic etc.
- Typically involve a large number of tedious calculations.
- Are characterized by its increasing role.
- Can be classified as: (a) Noncompurer and (b) Computer methods.
- Enhance your (mental, scientific) power
- Give direct (numerical) solution to complicated problems.

Why to Study NuMeth

- Explosion in use and development of Numerical Methods.
- Extremely effective in solving complicated problems.
- Intelligent use prepackaged computer programs heavily relies on the underlying theory. (Comsol, DIF3D, Serpent, SCALE etc.)
- Many problems cannot be solved by available packages.
- Numerical Methods are efficient in learning computers and thus understanding their strong and weak sides.
- Numerical Methods are efficient to reinforce your understanding of mathematics and physics.

The END

of the introductory lecture