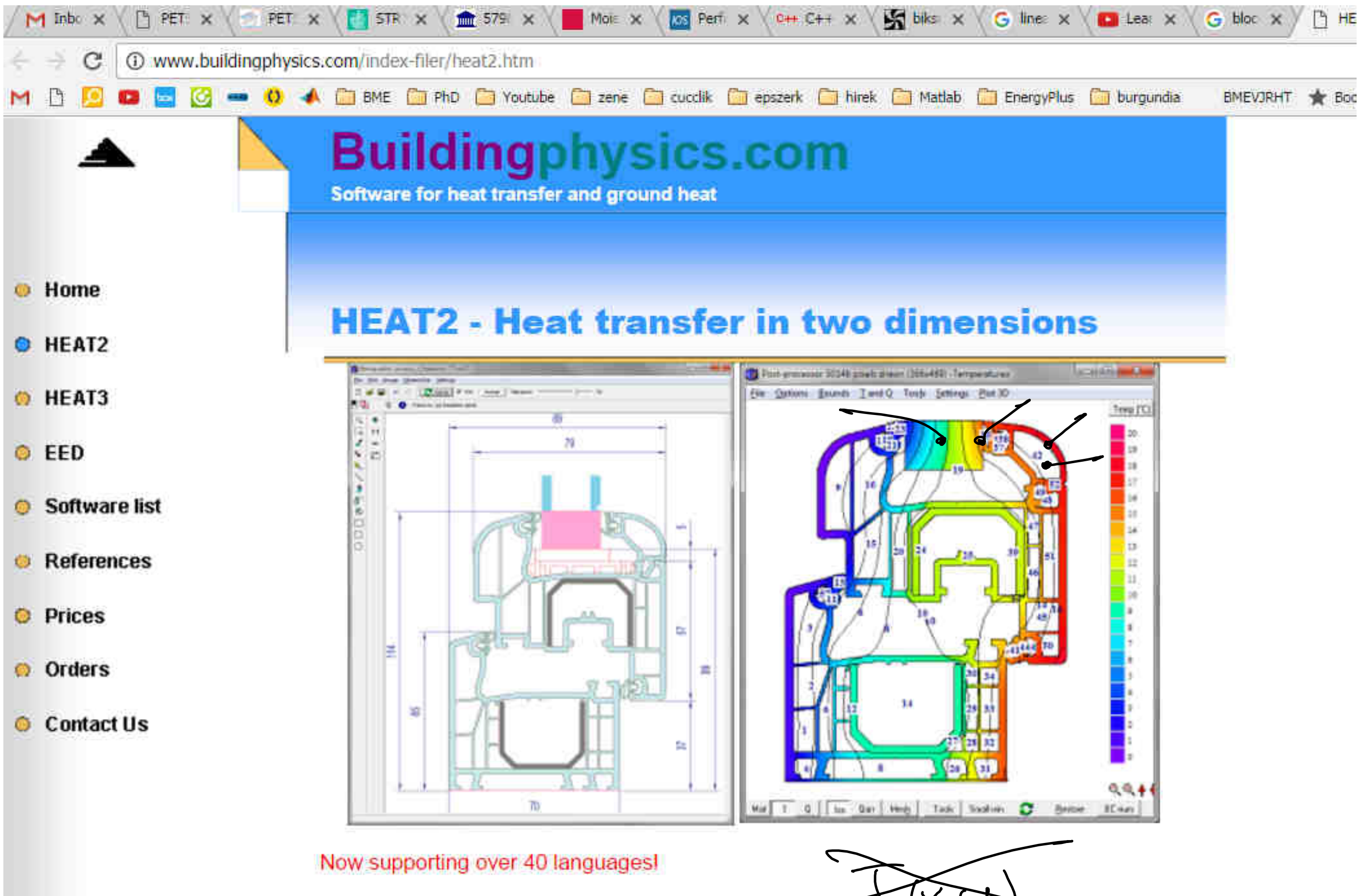
Heat 2D - free light version

www.buildingphysics.com



~~f(x,y)~~

...

DIN (Deutsches Institut für Normung, DIN V 4108-4) is also available.

· Extensive window frame analysis has been implemented according to ISO 10077.

Support and manuals also available in German, see www.buildingphysics.de

For sales and support in the CIS-countries, Latvia, Lithuania, and Estonia, see www.buildingphysics.ru

Click here for current version update info

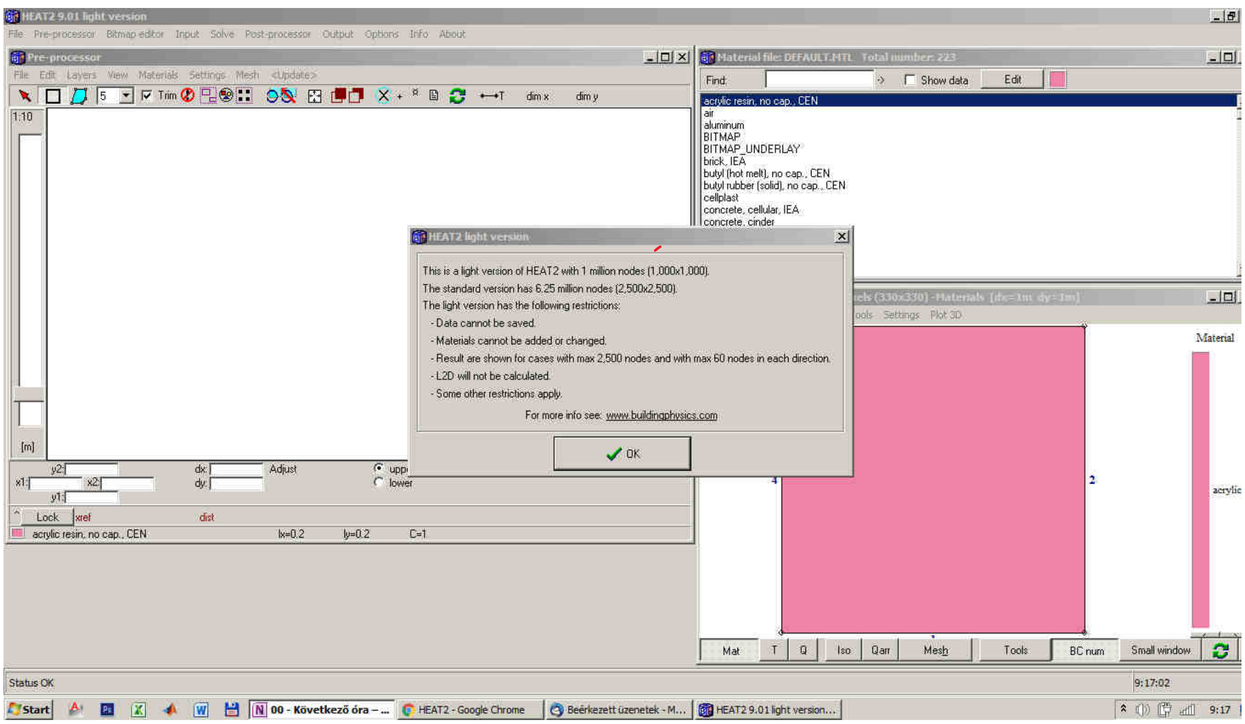
Free light version: Click here to download a free light version

YouTube clips:

· Input example using rectangles, polygons, and bitmaps

· Input example using bitmaps. Also shows a bitmap of a window frame that is imported and filled with different materials.

Tips for reading for beginners: For a quick start read Chapter 4 (pages 23-27) in Manual HEAT2 5.0. The example in chapter 8 (pages 117-121) would also give a short introduction. After this, look at the update manuals for HEAT2 6.0, HEAT2 7.0, etc. Also see the EN ISO test cases: **[ISO 10211 & 10077-2**



00b - LBNL Therm

2016. szeptember 23.
9:18

LBNL Therm

https://windows.lbl.gov/software/therm/therm.html

Inbo PET PET STR 579 Mois Perf C++ biks line Lear lbnl LBN

https://windows.lbl.gov/software/therm/therm.html

BME PhD Youtube zene cucclik epszerk hirek Matlab EnergyPlus burgundia BMEVJRHT Bookmarks Munkak space

THERM

THERM 6.3 For NFRC Certification and modeling complex glazing systems	**THERM 7.4** For modeling vacuum glazing, deflected glass, vertical venetian blinds, cellular shades and perforated screens
Forum For questions about THERM	**Forum** For questions about THERM
Knowledge Base (Check here first if you are experiencing a problem with the software)	**Knowledge Base** (Check here first if you are experiencing a problem with the software)
Documentation	**Documentation**
Tutorials	**Tutorials**

Two-Dimensional Building Heat-Transfer Modeling

THERM is a state-of-the-art computer program developed at Lawrence Berkeley National Laboratory (LBNL) for use by building component manufacturers, engineers, educators, students, architects, and others interested in heat transfer. Using THERM, you can model two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of concern. THERM's heat-transfer analysis allows you to evaluate a product's energy efficiency and local temperature patterns, which may relate directly to problems with condensation, moisture damage, and structural integrity.

THERM's two-dimensional conduction heat-transfer analysis is based on the finite-element method, which can model the complicated geometries of building products. See Components for more details.

THERM can be used with the Berkeley Lab WINDOW program. THERM's results can be used with WINDOW's center-of-glass optical and thermal models to determine total window product U-factors and Solar Heat Gain Coefficients. These values can be used, in turn, with the RESFEN program, which calculates total annual energy requirements in typical residences throughout the United States.

Components

...

THERM 7.4

Last Updated: 10/03/2015

If you find bugs, or have comments about this version, we now have an online forum where you can ask questions and respond to questions by others. Getting feedback from users is how we improve the program.

THERM 7 contains many new modeling features, including:

- Deflection Model
- Vacuum Glazing
- Vertical Louvered Blinds
- Perforated Screens
- Honeycomb shades
- Dynamic Glazing (Thermochromic and Electrochromic)

Latest Version

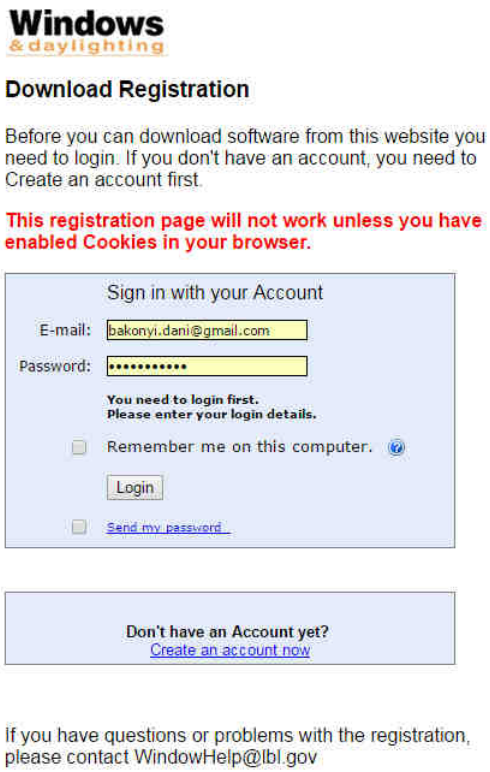
THERM 7.4.3
(7.4.3)
(10/03/2015)

Release Notes -- *Please read these before running this version !*

This version is compatible with WINDOW 7.4.6.

- **If you try to import THERM 7.4.3 files into earlier versions of WINDOW 7.3, WINDOW may crash; in this case upgrade to this latest version of WINDOW 7.4**

...


Windows
& daylighting
Download Registration
Before you can download software from this website you need to login. If you don't have an account, you need to Create an account first.
This registration page will not work unless you have enabled Cookies in your browser.
Sign in with your Account
E-mail:
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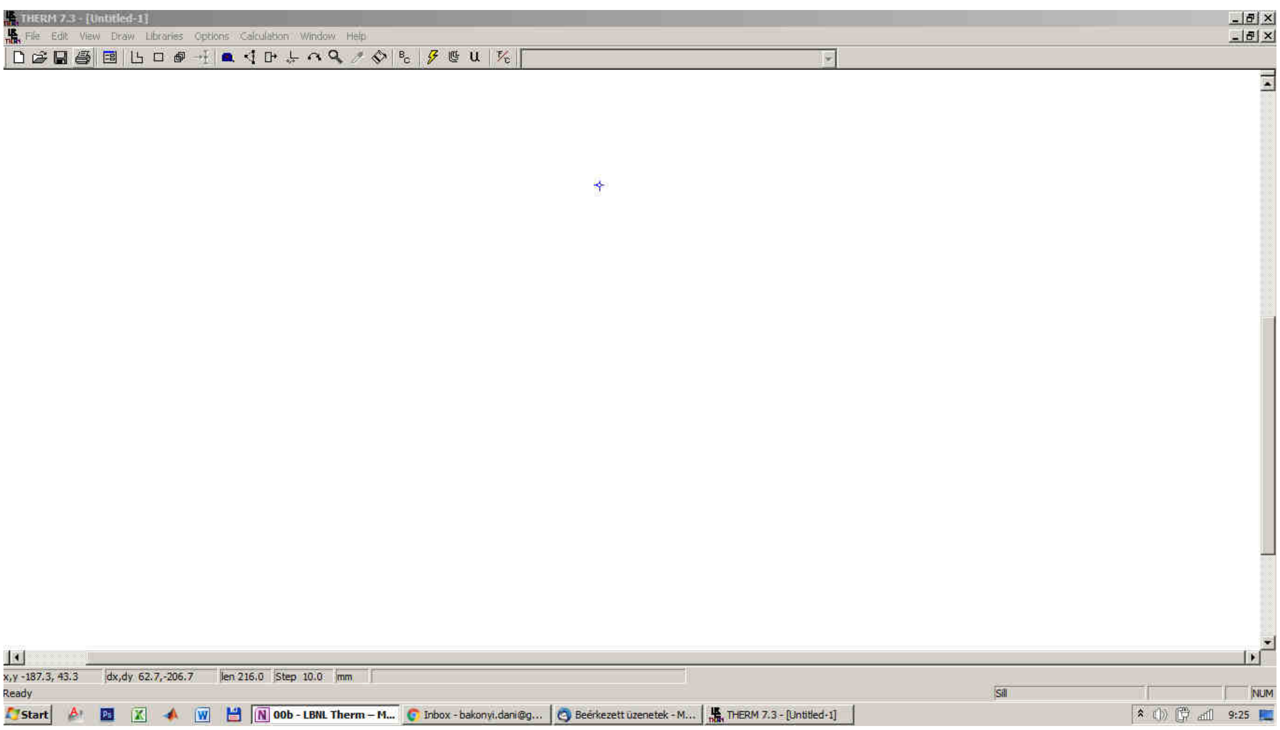
Password:
You need to login first.
Please enter your login details.
Remember me on this computer.
Login
Send my password
Don't have an Account yet?
Create an account now
If you have questions or problems with the registration, please contact WindowHelp@lbl.gov


THERM 7.3 - [Untitled-1]
File Edit View Draw Libraries Options Calculation Window Help
x,y -187.3, 43.3
dx,dy 62.7,-206.7
len 216.0
Step 10.0
mm
Ready
NUM
Start
00b - LBNL Therm – M...
Inbox - bakonyi.dani@g...
Beérkezett üzenetek - M...
THERM 7.3 - [Untitled-1]
9:25

01 - lineáris algebra

2016. szeptember 23.
11:52

$$\frac{\partial}{\partial x}\lambda\frac{\partial T}{\partial x}+\frac{\partial}{\partial y}\lambda\frac{\partial T}{\partial y}+\frac{\partial}{\partial z}\lambda\frac{\partial T}{\partial z}=\emptyset$$

$T = x \cdot \sin \ldots$

Lineáris algebra

vektor $\vec{v} = \bar{v} = (v_1, v_2, v_3) = \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} \in \mathbb{R}^3$

mátrix $A = m\left\{\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \\ a_{31} & a_{32} \end{bmatrix}\right. = \in \mathbb{R}^{m \times n}$

index

$A_{m \times n} = A_{3 \times 2}$

vektorműveletek

$\oplus$ $\vec{u} + \vec{v} = (u_1+v_1, u_2+v_2, u_3+v_3)$

$\ominus$ $\vec{u} - \vec{v} = (u_1-v_1, u_2-v_2, u_3-v_3)$

skalárral szorz. $\alpha \cdot \vec{u} = (\alpha u_1, \alpha u_2, \alpha u_3)$

skalár

} vektor

$\|\vec{u}\| = \sqrt{u_1^2 + u_2^2 + u_3^2}$ (norm) $\to$ skalár

$\vec{u}\cdot\vec{v} = u_1v_1 + u_2\cdot v_2 + u_3\cdot v_3 = \|\vec{u}\|\|\vec{v}\|\cos\Theta$

pont szorzás v. skaláris szorzás

$$\vec{u}\times\vec{v} = (\underbrace{u_2v_3 - u_3v_2}_{\cdot i},\ \underbrace{u_3v_1 - u_1v_3}_{\cdot j},\ \underbrace{u_1v_2 - u_2v_1}_{\cdot k}) \rightarrow \text{vektor}$$

$\|\vec{u}\times\vec{v}\| = \|\vec{u}\|\|\vec{v}\|\sin\Theta$

$\neq$

$\|\vec{v}\times\vec{u}\|$

---

mátrix műveletek

elemei a_{ij} b_{ij}

(+) $C = A + B$ ~ $c_{ij} = a_{ij} + b_{ij}$

$$\begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix} + \begin{vmatrix} 4 & 6 \\ 7 & 9 \end{vmatrix} = \begin{vmatrix} 5 & 8 \\ 10 & 13 \end{vmatrix}$$

(−) $c_{ij} = a_{ij} - b_{ij}$

mátrix szorzás

$A \in \mathbb{R}^{m\times n}$ $B \in \mathbb{R}^{n\times l}$ $\rightarrow C = A\cdot B \in \mathbb{R}^{m\times l}$

sor oszlop

$$a_{ij} = \sum_{k=1}^{n} a_{ik} b_{kj}$$

l

$$\begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix}$$

$$\begin{vmatrix} 1 & 2 \end{vmatrix} \begin{vmatrix} 7 & 10 \end{vmatrix}$$

$$m\left\{\begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix}\right. \begin{vmatrix} 7 & 10 \\ 15 & 22 \end{vmatrix}$$

$$\begin{vmatrix} 1 \\ 2 \end{vmatrix} \qquad v_{2\times 1}^{n \; l}$$

$$A_{2\times 2} \;\; \begin{vmatrix} 1 & 2 \\ 3 & 4 \end{vmatrix} \qquad A \cdot v = u$$

$m \;\; n$

$$\begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \\ a_{31} & a_{32} \end{vmatrix} \begin{vmatrix} x_1 \\ x_2 \end{vmatrix} = \begin{vmatrix} a_{11}x_1 + a_{12}x_2 \\ a_{21}x_1 + a_{22}x_2 \\ a_{31}x_1 + a_{32}x_2 \end{vmatrix} = x_1 \begin{vmatrix} a_{11} \\ a_{21} \\ a_{31} \end{vmatrix} + x_2 \begin{vmatrix} a_{12} \\ a_{22} \\ a_{32} \end{vmatrix}$$

$$A_{3\times 2} \cdot x_{2\times 1} = y_{3\times 1}$$

$$\vec{y} = T_1(\vec{x}) = A \cdot \vec{x}$$

$$f \;\; \mathbb{R} \to \mathbb{R} \qquad \Leftrightarrow T_r \quad \mathbb{R}^n \to \mathbb{R}^n$$

$$f(x) \qquad \Leftrightarrow T_r(\vec{x}) = A\vec{x}$$

$$g \cdot f = g(f(x)) \Leftrightarrow T_2(T_1(\vec{x})) = B \cdot A \cdot \vec{x}$$

$$g \cdot f = g(f(x)) \Leftrightarrow T_B(T_A(\vec{x})) = B \cdot A \cdot \vec{x}$$

$$f^{-1} \Leftrightarrow A^{-1}$$

$$\ln(x) \quad e^x$$

$$\cancel{\ln(x)\ e}$$

$$\ln(e^x) = 1$$

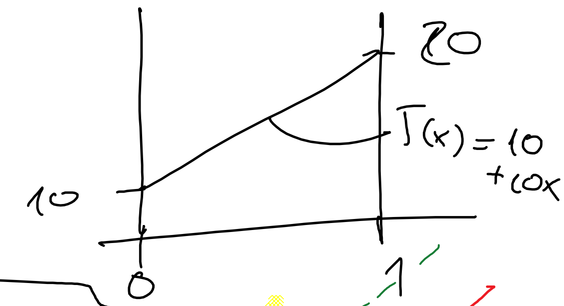
$$A^{-1} A = \mathbb{I} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix} = \begin{pmatrix} 1+0 \\ 2+0 \\ 3+0 \end{pmatrix} = \begin{pmatrix} 1 \\ 2 \\ 3 \end{pmatrix}$$

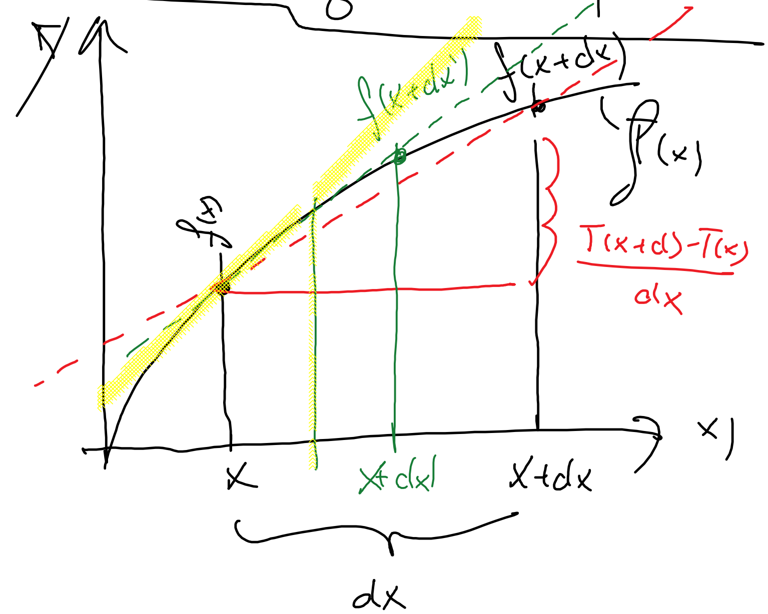
$$\frac{\partial}{\partial x}\lambda_x\frac{\partial T}{\partial x}+\frac{\partial}{\partial y}\lambda_y\frac{\partial T}{\partial y}+\frac{\partial}{\partial z}\lambda_z\frac{\partial T}{\partial z}=0$$

$$\frac{\partial^2 T}{\partial x^2}=0$$

- 1D
- $\lambda = 1$



$$\underbrace{\underbrace{\lim_{dx\to 0}\frac{T(x+dx)-T(x)}{dx}}_{\text{differencia-hányados}}}_{\text{differenciál-hányados}}=T'(x)$$



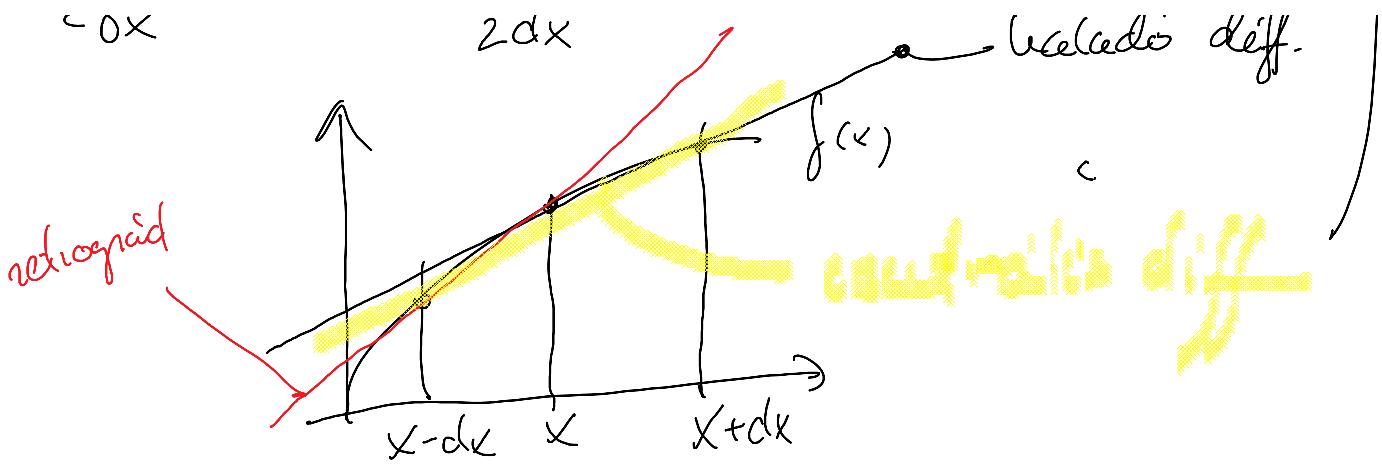
$$\frac{\partial T}{\partial x}\cong\frac{T(x+dx)-T(x)}{dx}$$ haladó-differencia (forward difference)

$$\frac{\partial T}{\partial x}\cong\frac{T(x)-T(x-dx)}{dx}$$ retrográd-differencia (backward-difference)

$$\frac{\partial T}{\partial x}\cong\frac{T(x+dx)-T(x-dx)}{2dx}$$ centrális differencia

véges differencia

haladó diff.



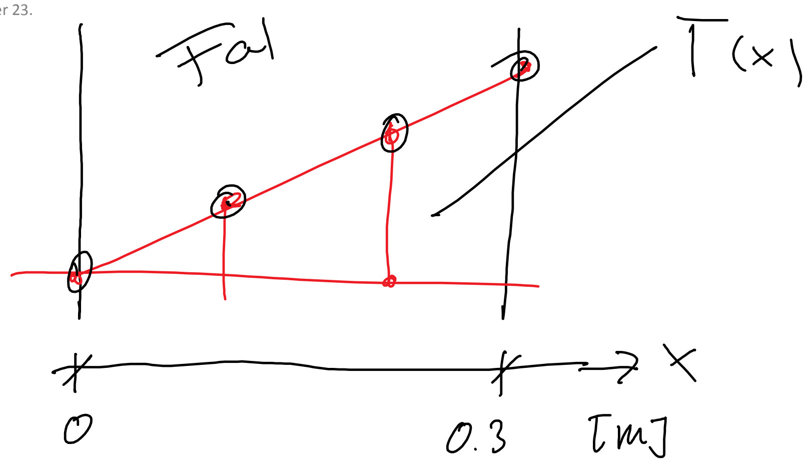
2. rendű véges differencia

$$\frac{\partial^2 T}{\partial x^2} \cong \frac{T'(x) - T'(x-dx)}{dx} = \frac{\frac{T(x+dx)-T(x)}{dx} - \frac{T(x)-T(x-dx)}{dx}}{dx} =$$

$$= \frac{T(x+dx) - 2T(x) + T(x-dx)}{dx^2}$$

03 - egy konkrét példa

2016. szeptember 23.
13:13



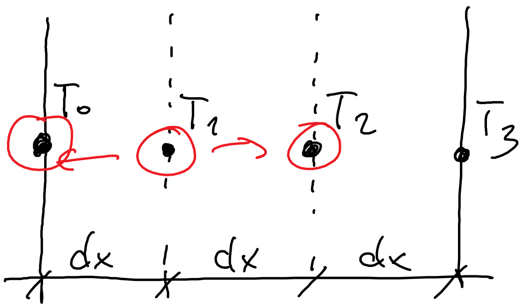
BC:

$T(x=0) = 10\,[^\circ C]$

$T(x=0.3) = 20\,[^\circ C]$

$$\lambda \frac{\partial^2 T}{\partial x^2} = \varnothing$$

1.



$dx = 0.1\,[m]$

$\boxed{\text{diszkretizáció}}$

2. diszkretizált egyenletek felírása

$$\lambda \frac{\partial^2 T}{\partial x^2} = 0$$

$$\frac{\lambda T_{(x-dx)} - 2\lambda T_{(x)} + \lambda T_{(x+dx)}}{dx^2} = 0$$

$x = 1$

$$T_1 = \frac{\lambda T_0 - 2\lambda T_1 + \lambda T_2}{dx^2} = 0$$

$$T_1: \quad \boxed{\frac{\lambda}{dx^2} T_0 - \frac{2\lambda}{dx^2} T_1 + \frac{\lambda}{dx^2} T_2 = \varnothing}$$

$$T_2: \quad \boxed{\frac{\lambda}{dx^2} T_1 - \frac{2\lambda}{dx^2} T_2 + \frac{\lambda}{dx^2} T_3 = \varnothing}$$

$T_0 = 10$

$T(x)$

lineáris egyenletrendszer

$\lambda = 1$

$\lambda = 0.01$

$T_0 = 10$

$T_3 = 20$

$\lambda = 0.01$

$dx = 0.1$

③. peremfeltételek behelyettesítése

$$\left.\begin{aligned} -\frac{2\lambda}{dx^2}T_1 + \frac{\lambda}{dx^2}T_2 &= -\frac{\lambda}{dx^2}10 \\ \frac{\lambda}{dx^2}T_1 - \frac{2\lambda}{dx^2}T_2 &= -\frac{\lambda}{dx^2}20 \end{aligned}\right\}$$

a.G.

$$\begin{vmatrix} -\frac{2\lambda}{dx^2} & \frac{\lambda}{dx^2} \\ \frac{\lambda}{dx} & -\frac{2\lambda}{dx^2} \end{vmatrix} \begin{vmatrix} T_1 \\ T_2 \end{vmatrix} = \begin{vmatrix} -\frac{\lambda}{dx^2}10 \\ -\frac{\lambda}{dx^2}20 \end{vmatrix}$$

$$A \cdot \vec{x} = \vec{b}$$

A: mátrix

$\vec{x}$: ismeretlenek vektora

$\vec{b}$: konstansok vektora

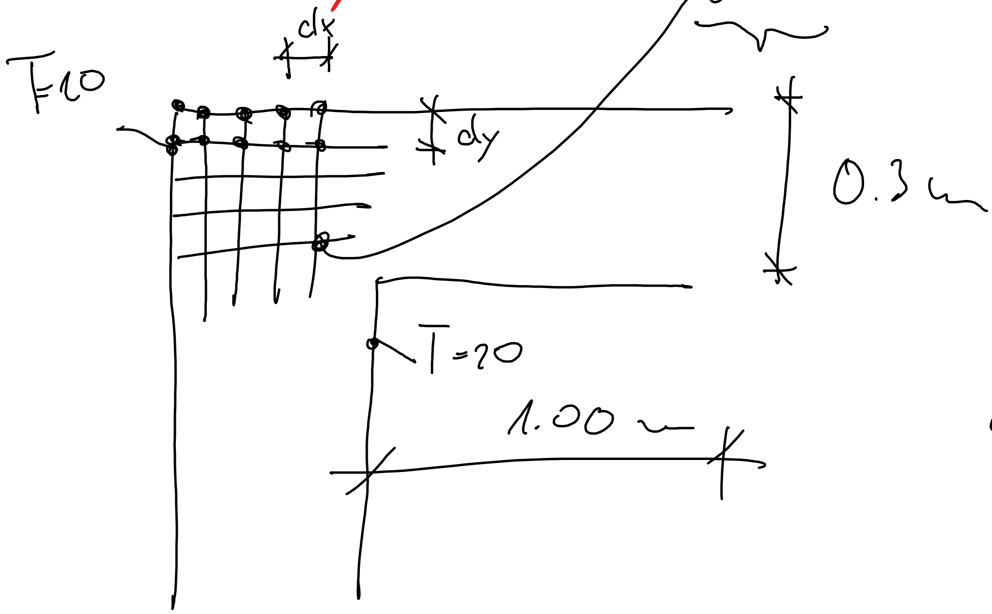
...

$$\vec{x} = \begin{vmatrix} T_1 \\ T_2 \end{vmatrix} = \begin{vmatrix} 13.33 \\ 16.66 \end{vmatrix} \iff T(x) = 10x + 10$$

analitikus megoldás

Numerikus megoldás

$$\underbrace{\frac{\partial}{\partial x}\lambda_x\frac{\partial T}{\partial x}}+\underbrace{\frac{\partial}{\partial y}\lambda_y\frac{\partial T}{\partial y}}=0$$



100 × 100

$$\begin{array}{ccc} A & \bar{x} & \underline{b} \\ \begin{pmatrix} 1 & 0 & 0 & 0 \\ \frac{\lambda}{dx^2} & -\frac{2\lambda}{dx^2} & \frac{\lambda}{dx^2} & 0 \\ 0 & \frac{\lambda}{dx^2} & -\frac{2\lambda}{dx^2} & \frac{\lambda}{dx^2} \\ 0 & 0 & 0 & 1 \end{pmatrix} & \begin{pmatrix} T_0 \\ T_1 \\ T_2 \\ T_3 \end{pmatrix} = & \begin{pmatrix} 10 \\ 0 \\ 0 \\ 20 \end{pmatrix} \end{array}$$

04 - az egyenletrendszer megoldása

2016. szeptember 23.
13:36

$$A \, \bar{x} = b$$

1 mátrix inverz

$$\underbrace{A^{-1} A}\cdot \bar{x} = A^{-1}\cdot b$$

$$I \cdot \bar{x} = A^{-1} \cdot b$$

$$\bar{x} = A^{-1} \cdot b$$

gépidő !!!

2. Gauss-Jordan elimináció

direkt módszer

műveletek
- egyik sor n-szeresét +/− másik sorhoz
- kicserélhetek két sort
- sor skalár szorosa

$$A \cdot \bar{x} = b$$

$$\begin{bmatrix} 1 & 2 \\ 3 & 9 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 21 \end{bmatrix}$$

cél:

$$\begin{bmatrix} 1 & x & x & \cdots \\ 0 & 1 & \cdots & \\ 0 & 0 & 1 & \cdots \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \vdots \end{bmatrix} = \begin{bmatrix} b'_1 \\ b'_2 \\ b'_2 \end{bmatrix}$$

$$\begin{bmatrix} \cdots & \cdots \\ 3 & 9 \end{bmatrix} \begin{bmatrix} \vdots \\ x_2 \end{bmatrix} \begin{bmatrix} \vdots \\ 21 \end{bmatrix}$$

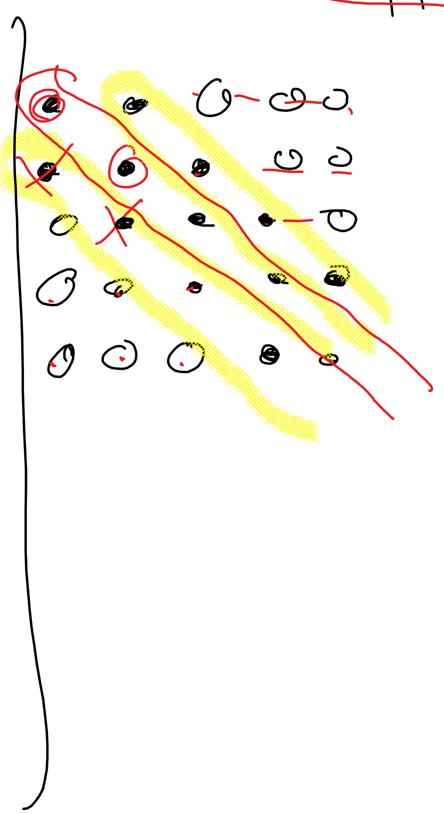
$$\begin{bmatrix} \cdots & & & & \\ 0 & 0 & 1 & & \\ 0 & 0 & 0 & \ddots & 1 \end{bmatrix} \begin{bmatrix} \vdots \\ x_3 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} \vdots \\ b'_2 \\ b'_3 \\ \vdots \\ b'_n \end{bmatrix}$$

2.sor − 3x 1.sor

$$\begin{bmatrix} 1 & 2 \\ 0 & 3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 6 \end{bmatrix}$$

2. sor / 3

$$\begin{bmatrix} 1 & 2 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 2 \end{bmatrix} \rightarrow x_2 = 2$$

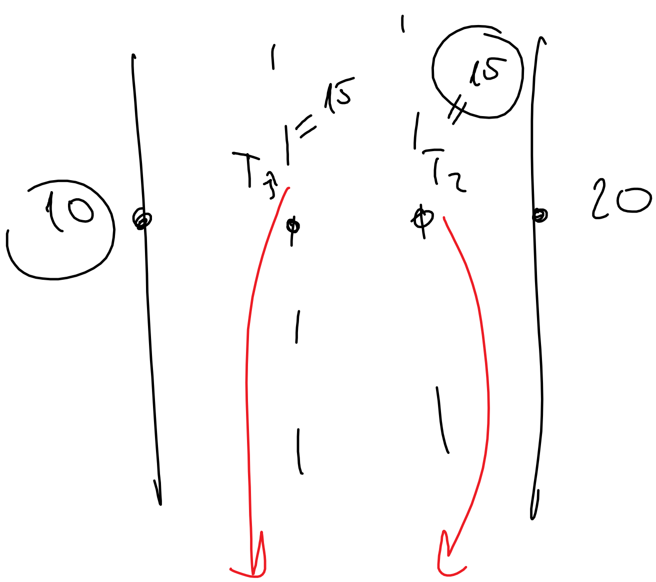


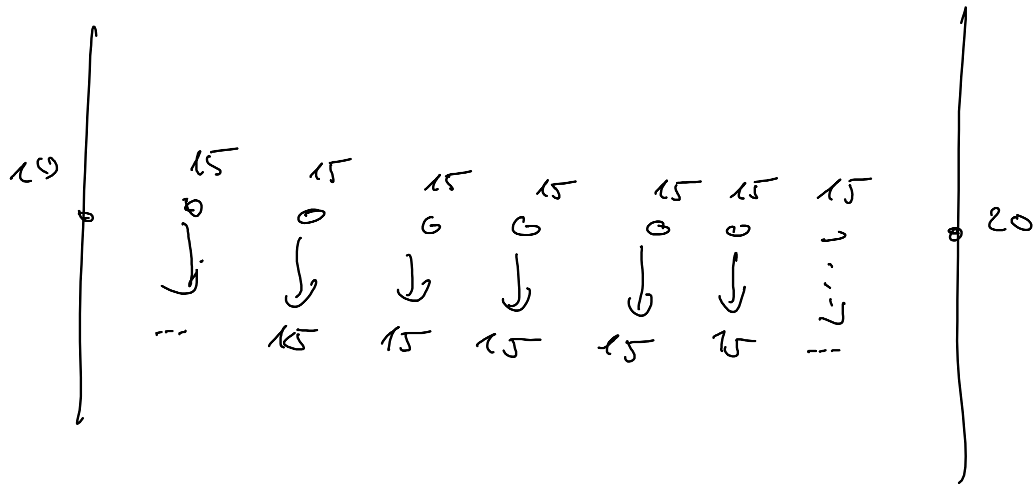
$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ \vdots \\ b_n \end{bmatrix}$$

(3.) iteratív szolver

$$\bar{X}_{\xi} = \begin{vmatrix} 10 \\ 10 \end{vmatrix}$$

$$\begin{vmatrix} 1 & 2 \\ 3 & 9 \end{vmatrix} \begin{vmatrix} \overset{=10}{x_1} \\ \underset{=10}{x_2} \end{vmatrix} = \begin{vmatrix} 5 \\ 21 \end{vmatrix} \to \begin{vmatrix} x_1' \\ x_2' \end{vmatrix} = \bar{x}'$$





$$\Delta T_{max} = 0.0001 \ [K]$$