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%% Steady one dimensional heat conduction program
clear all
close all
%Input data




L=1.5; %[m]
N=20; %number of grid points
N_list=4:4:N;

T_left=350.0; %Temperature left wall [K]
T_right=300.0; %Temperature right wall [K]
alpha=20.0; %thermal diffusivity [m^2/s]
Qt=50; %Heat source proportional to temperature, i.e.Qt*T, [1/s]
maxIter=1e6; %Maximum number of iterations for the solver
maxRes=1e-6; %Solver residual |Ax-b|<maxRes
Dt = 0.0001;
Error=zeros(1,length(N_list));
cas=1;



for N=N_list
%Mesh
%posX=0:L/(N-1):L;
x=linspace(0,L,N);

%Preallocate coefficients & mesh distances
ap=ones(1,N);
ae=zeros(1,N);
aw=zeros(1,N);
b=zeros(1,N);
Dxe=zeros(1,N);
Dxw=zeros(1,N);
Dx=zeros(1,N);

%Preallocate vector for local residual of solver
loc_res=zeros(1,N);

%Inner coefficients
for iX=2:N-1
  Dxe(iX)=(x(iX+1)-x(iX));
  Dxw(iX)=(x(iX)-x(iX-1));
  Dx(iX)=(Dxe(iX)+Dxw(iX))/2;
  ae(iX)=(alpha)/Dxe(iX);
  aw(iX)=(alpha)/Dxw(iX);
  ap(iX)=-(ae(iX)+aw(iX)+Qt*Dx(iX));
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  b(iX)=0;
end

%Boundary coefficients
b(1)=T_left;
b(end)=T_right;

%Initialize temperature vector
%T=ones(size(x))*((Tw+Te)*0.5);
T=zeros(size(x));
T(1)=T_left;
T(end)=T_right;

%Solver
res=maxRes+1;
ite=0;
tic;
A=50;
Bt=12;

k=sqrt(Qt/alpha);
C2 = (T(end)-T(1)*exp(k*L))/(exp(-k*L)-exp(k*L));
C1 = T(1)-C2;
T_initial = ones(size(x)).*(C1*exp(k*x)+C2*exp(-k*x)+A*sin(Bt*x));
T_initial(1) = T_left;
T_initial(end)= T_right;
t=0;
tend=1;
residue=1;
time=[];
T_plusone=[];
i=1;
%% while res>maxRes && ite<maxIter
  while t<tend && residue>maxRes
  %Gauss-Seidel iteration
  for iX=2:numel(T)-1
    T(iX)=T_initial(iX)+(Dt/Dx(iX))*(T_initial(iX)*ap(iX) + T_initial(iX +1)*ae(iX) + ↙
T_initial(iX - 1) * aw(iX));
  end
  residue=max(abs(T-T_initial));
  T_plusone(i,:)=[T];

  %Calculation of the solver residual res=|Ax-b|
%   for iX=2:numel(T)-1
%     loc_res(iX)=aw(iX)*T(iX-1)+ap(iX)*T(iX)+ae(iX)*T(iX+1)-b(iX);
%   end
%   res=max(abs(loc_res));
%
% res = max(abs(T -T_initial));
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```
T_initial = T;
time(i,1)=t;
t=t+Dt;
i=i+1;

  ite=ite+1;
  if mod(ite,10000)==0
    fprintf('ite: %d solver residual: %e\n',ite,res);
  end
end
if ite==maxIter
  warning(['Maximum number of iterations reached (lastRes=',num2str(res),').']);
end
end
figure
plot(x,T)

% %Matlab solver for systems of linear equations
% %A is the full matrix. Try full(A) to see the whole matrix
% A=spdiags([[aw(2:end)'; 0] ap(:) [0; ae(1:end-1)']],[-1 0 1],N,N);
% T2=A\b(:);
% toc;.;
%
%Tana=@(x) (-0.5*Q/lambda)*x.^2+((T_right-T_left+0.5*Q/lambda*L^2)/L)*x+T_left; %↙
analytic solution

figure
plot (x,T_plusone(662,:))
hold on

t=0.0661;
Ta= C1*exp(k*x)+C2*exp(-k*x)+A*exp(-(alpha*Bt^2+Qt)*t)*sin(Bt*x); %analytic↙
solutionfigure
plot (x,Ta)
legend ('Num','Ana')
hold off
```