

**2007–09–25**

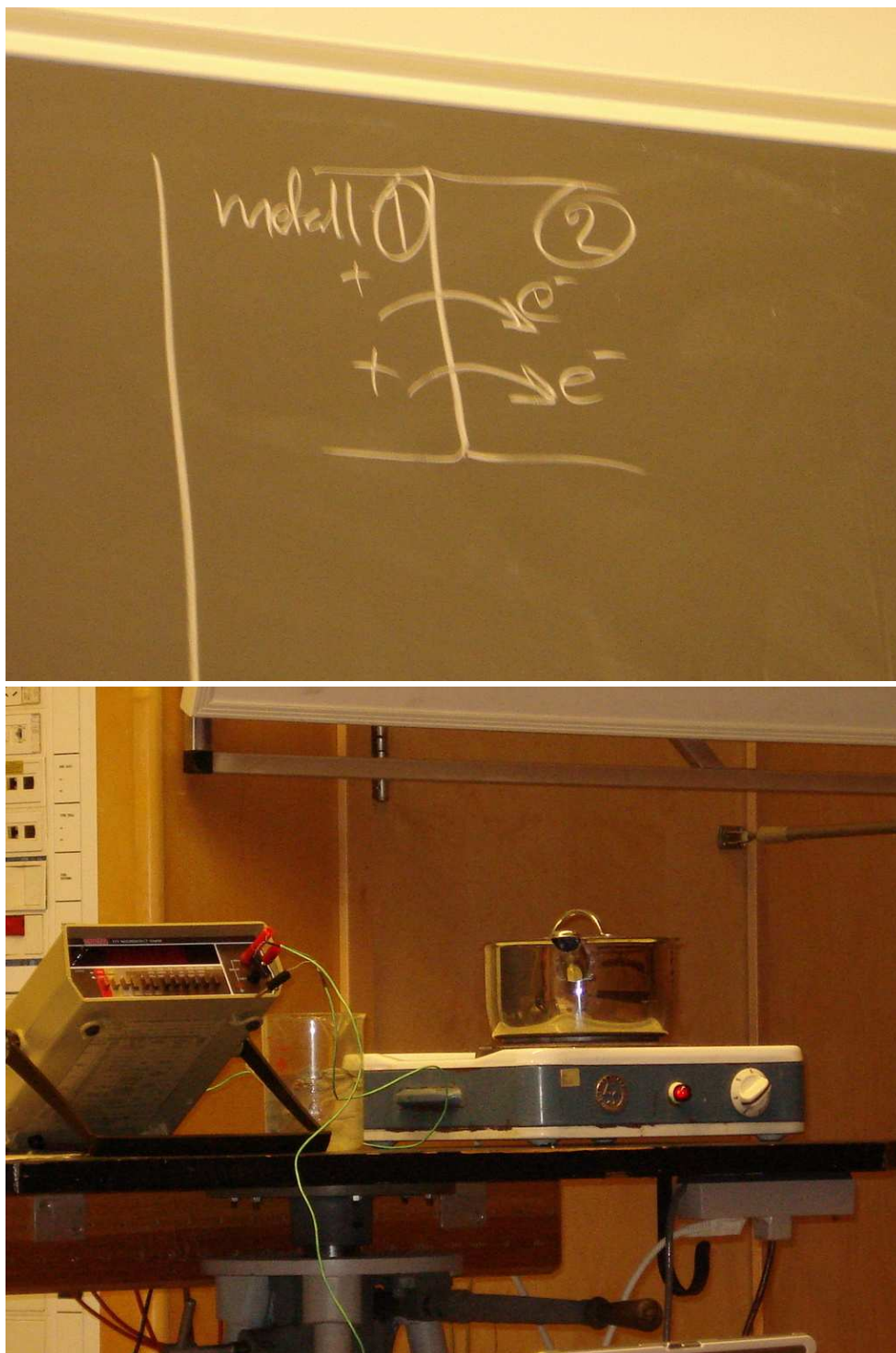
**Termodynamik**

0. Termisk jämvikt.
  1. Energiförhållanden.
  2. Entropi.  $\Delta S \geq 0$ .
  3. Ren kristalin substans:  $T = 0 \Rightarrow S = 0$ .
- Energiomvandlingsprocesser

**Temperaturmätningar**

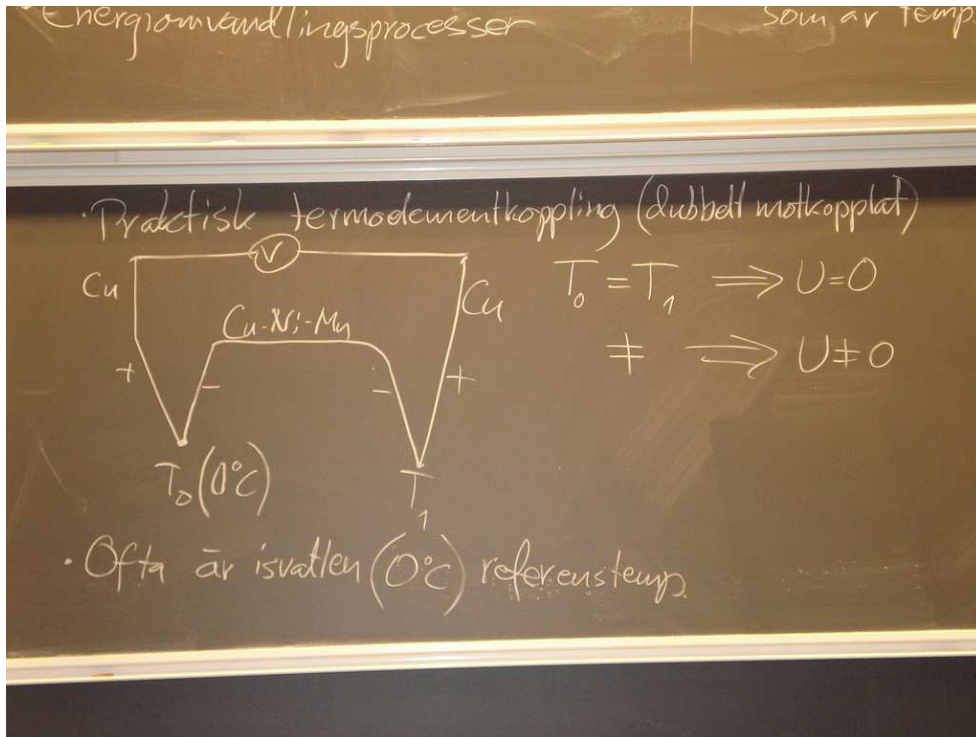
- Termoelementtekniken. (Seebeck-effekten).

Över en kontaktyta mellan två olika metaller uppstår en spänning (emk) som är temperaturberoende ( $\sim 10 - 50 \mu\text{V/K}$ ). (fig1)



Figur 1.

Praktisk termoelementkoppling (dubbelt motkopplat). (fig2)



Figur 2.

$T_0 = T_1 \Rightarrow U = 0.$

$T_0 \neq T_1 \Rightarrow U \neq 0.$

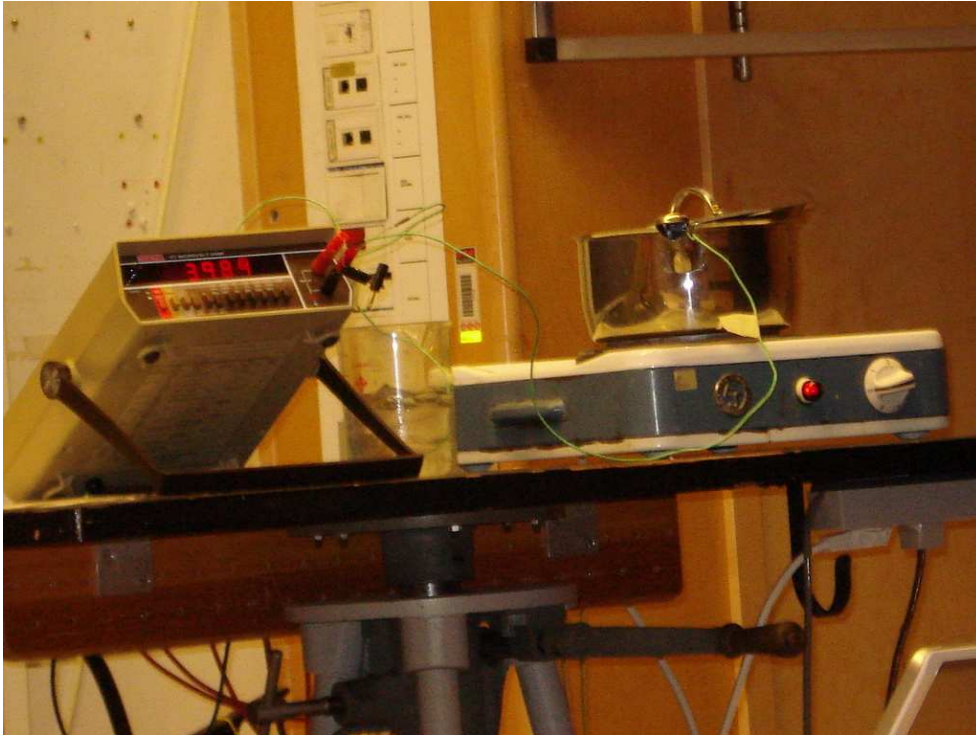
Ofta är isvatten ( $0^\circ\text{C}$ ) referenstemperatur.

Samtliga uppgifter berör termoelement. Typ K (Chromel-Alumel).

Nickel-Chromium vs. Nickel-Aluminum

TYPE K Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

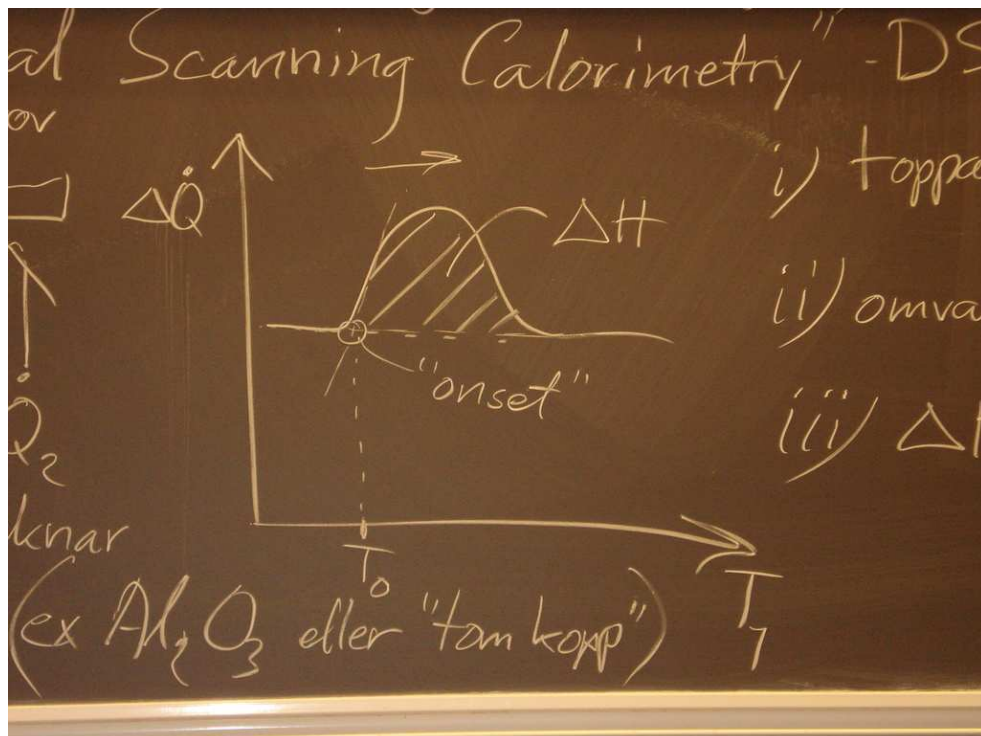
Temp. (°C)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	25	30	35	40	
-40	-1.889	-1.854	-1.818	-1.782	-1.745	-1.709	-1.673	-1.637	-1.600	-1.564	-1.527	-1.490	-1.453	-1.417	-1.380	-1.343	-1.306	-1.269	-1.231	-1.194	-1.156	-1.118	-1.080	-1.042	-1.004
-30	-1.527	-1.490	-1.453	-1.417	-1.380	-1.343	-1.306	-1.269	-1.231	-1.194	-1.156	-1.118	-1.080	-1.042	-1.004	-0.966	-0.928	-0.890	-0.852	-0.814	-0.776	-0.738	-0.700	-0.662	-0.624
-20	-1.156	-1.118	-1.080	-1.042	-1.004	-0.966	-0.928	-0.890	-0.852	-0.814	-0.776	-0.738	-0.700	-0.662	-0.624	-0.586	-0.548	-0.510	-0.472	-0.434	-0.396	-0.358	-0.320	-0.282	-0.244
-10	-0.778	-0.739	-0.701	-0.663	-0.624	-0.586	-0.548	-0.510	-0.472	-0.434	-0.396	-0.358	-0.320	-0.282	-0.244	-0.206	-0.168	-0.130	-0.092	-0.054	-0.016	0.022	0.060	0.098	0.136
0	-0.392	-0.353	-0.314	-0.275	-0.236	-0.197	-0.157	-0.118	-0.079	-0.039	0.000	0.039	0.079	0.118	0.157	0.197	0.236	0.275	0.314	0.353	0.392	0.431	0.470	0.509	0.548
0	0.000	0.039	0.079	0.119	0.158	0.198	0.238	0.277	0.317	0.357	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.717	0.757	0.797	0.837	0.877	0.917	0.957
10	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.717	0.757	0.797	0.837	0.877	0.917	0.957	0.997	1.037	1.077	1.117	1.157	1.197	1.237	1.277	1.317	1.357
20	0.798	0.838	0.879	0.919	0.960	1.000	1.041	1.081	1.122	1.163	1.203	1.244	1.284	1.325	1.365	1.406	1.446	1.487	1.527	1.568	1.608	1.649	1.689	1.730	1.770
30	1.203	1.244	1.285	1.326	1.366	1.407	1.448	1.489	1.530	1.571	1.612	1.653	1.694	1.735	1.776	1.817	1.858	1.899	1.941	1.982	2.023	2.064	2.105	2.146	2.187
40	1.612	1.653	1.694	1.735	1.776	1.817	1.858	1.899	1.941	1.982	2.023	2.064	2.105	2.146	2.187	2.228	2.269	2.310	2.351	2.392	2.433	2.474	2.515	2.556	2.597
50	2.023	2.064	2.105	2.146	2.187	2.228	2.269	2.310	2.351	2.392	2.433	2.474	2.515	2.556	2.597	2.638	2.679	2.720	2.761	2.802	2.843	2.884	2.925	2.966	3.007
60	2.436	2.478	2.519	2.561	2.602	2.644	2.685	2.727	2.768	2.810	2.851	2.892	2.934	2.975	3.017	3.058	3.100	3.141	3.183	3.224	3.265	3.307	3.348	3.389	3.430
70	2.851	2.893	2.934	2.976	3.017	3.059	3.100	3.142	3.184	3.225	3.267	3.308	3.350	3.391	3.433	3.474	3.516	3.557	3.599	3.640	3.682	3.723	3.765	3.806	3.848
80	3.267	3.308	3.350	3.391	3.433	3.474	3.516	3.557	3.599	3.640	3.682	3.723	3.765	3.806	3.848	3.889	3.931	3.972	4.014	4.055	4.097	4.138	4.179	4.221	4.262
90	3.682	3.723	3.765	3.806	3.848	3.889	3.931	3.972	4.014	4.055	4.097	4.138	4.179	4.221	4.262	4.303	4.345	4.386	4.428	4.469	4.510	4.552	4.593	4.635	4.676
100	4.099	4.138	4.179	4.220	4.262	4.303	4.344	4.385	4.427	4.468	4.509	4.550	4.591	4.633	4.674	4.715	4.756	4.797	4.838	4.879	4.920	4.961	5.002	5.043	5.084
110	4.509	4.550	4.591	4.633	4.674	4.715	4.756	4.797	4.838	4.879	4.920	4.961	5.002	5.043	5.084	5.124	5.165	5.206	5.247	5.288	5.329	5.370	5.411	5.452	5.493
120	4.920	4.961	5.002	5.043	5.084	5.124	5.165	5.206	5.247	5.288	5.329	5.370	5.411	5.452	5.493	5.534	5.575	5.616	5.657	5.698	5.739	5.780	5.821	5.862	5.903
130	5.328	5.369	5.410	5.450	5.491	5.532	5.573	5.614	5.655	5.696	5.737	5.778	5.819	5.860	5.901	5.942	5.983	6.024	6.065	6.106	6.147	6.188	6.229	6.270	6.311
140	5.735	5.775	5.815	5.856	5.896	5.937	5.978	6.019	6.060	6.101	6.142	6.183	6.224	6.265	6.306	6.347	6.388	6.429	6.470	6.511	6.552	6.593	6.634	6.675	6.716
150	6.138	6.179	6.219	6.259	6.299	6.339	6.380	6.420	6.460	6.501	6.541	6.582	6.623	6.663	6.704	6.744	6.785	6.825	6.866	6.906	6.947	6.987	7.028	7.068	7.109
160	6.540	6.580	6.620	6.660	6.701	6.741	6.781	6.821	6.861	6.901	6.941	6.981	7.021	7.061	7.101	7.141	7.181	7.221	7.261	7.301	7.341	7.381	7.421	7.461	7.501
170	6.941	6.981	7.021	7.061	7.101	7.141	7.181	7.221	7.261	7.301	7.341	7.381	7.421	7.461	7.501	7.541	7.581	7.621	7.661	7.701	7.741	7.781	7.821	7.861	7.901
180	7.342	7.382	7.422	7.462	7.502	7.542	7.582	7.622	7.662	7.702	7.742	7.782	7.822	7.862	7.902	7.942	7.982	8.022	8.062	8.102	8.142	8.182	8.222	8.262	8.302
190	7.743	7.783	7.823	7.863	7.903	7.943	7.983	8.023	8.063	8.103	8.143	8.183	8.223	8.263	8.303	8.343	8.383	8.423	8.463	8.503	8.543	8.583	8.623	8.663	8.703
200	8.144	8.184	8.224	8.264	8.304	8.344	8.384	8.424	8.464	8.504	8.544	8.584	8.624	8.664	8.704	8.744	8.784	8.824	8.864	8.904	8.944	8.984	9.024	9.064	9.104



“Convert Thermocouple Reading” (Labview).

### Uppgift 1: Fasomvandlingar — Värmelagring

- Differential Scanning Calorimetry — DSC (fig3)



Figur 3.



Referensmaterialet saknar fasomvandlingar (ex.  $\text{Al}_2\text{O}_3$  eller "tom kopp")

i) toppar  $\hat{=}$  fasomvandlingar (fast-fast, smältning)

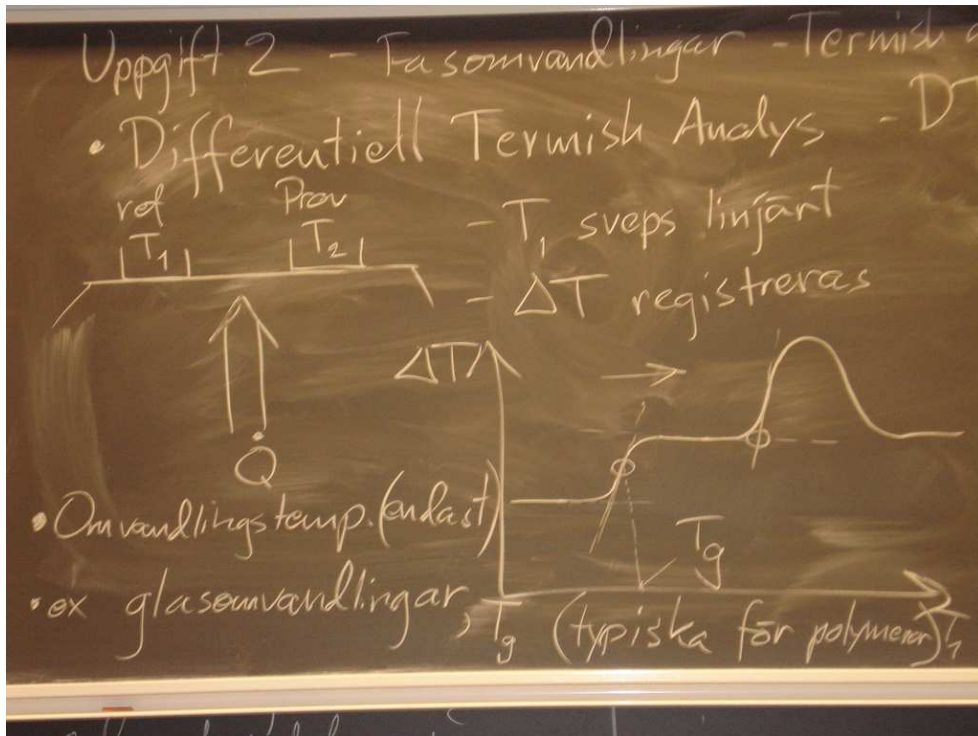
ii) omvandlingstemperatur = "onset".

iii)  $\Delta H$  = omvandlingsentalpin.

- Stor  $\Delta H$  vid lämplig temperatur  $T \Rightarrow$  Värmelager
- $\Delta H$  och  $T_{\text{fas}}$  kan påverkas (kemiskt/fysikaliskt)

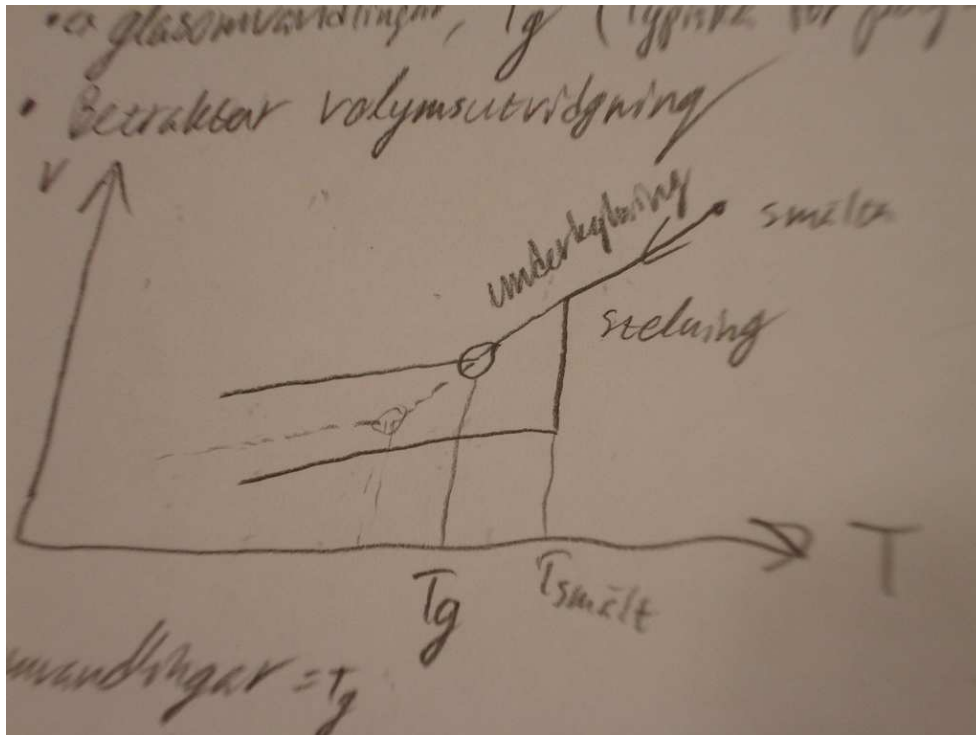
### Uppgift 2: Fasomvandlingar — Termisk analys

- Differentiell termisk analys — DTA. (fig4)



Figur 4.

- $T_1$  sveps linjärt
- $\Delta T$  registreras
- Omvandlingstemperatur (endast).
- Ex. glasomvandlingar,  $T_g$  (typiska för polymerer).
- Betraktar volymsutvidgning. (fig5)

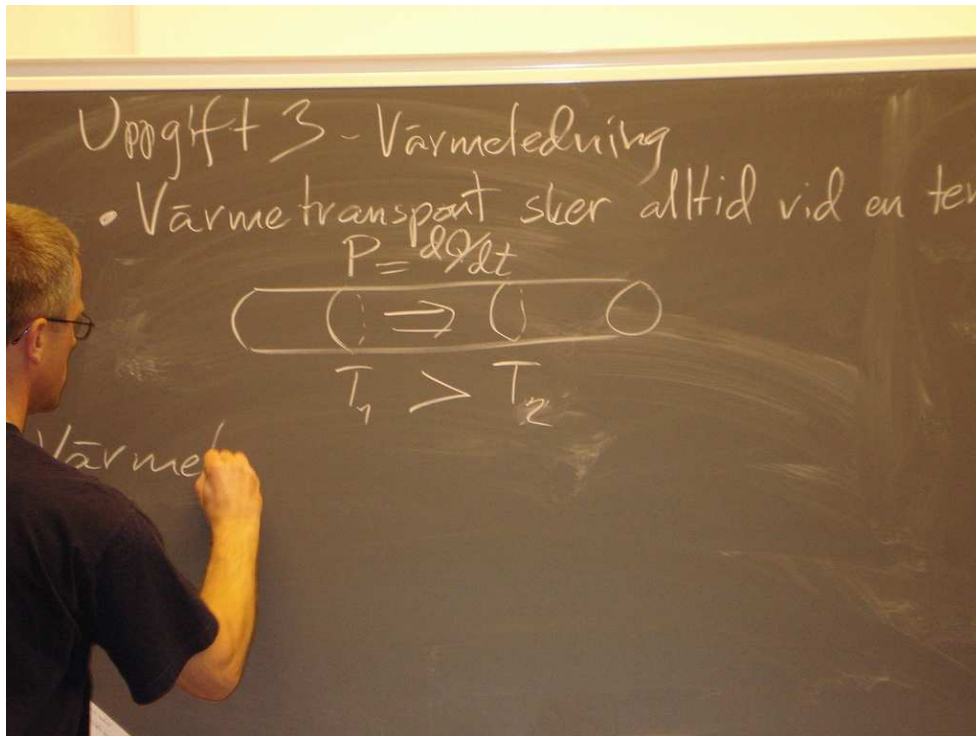


Figur 5.

- Glasomvandlingar:  $T_g$ . Dock ingen  $\Delta H$ .
- Studera  $T_g$ : Kryokonservering — nedkylning av organ. Isbildning förstör organ. Inblandning av alkoholer/glykol/glycerol.  $\Rightarrow$  Glasomvandling.

### Uppgift 3: Värmeledning

- Värmetransport sker alltid vid en temperatur-gradient. (fig6)



Figur 6.  $T_1 > T_2$

Värmeledningsekvationen:

$$\frac{\partial T}{\partial t} = a \frac{\partial^2 T}{\partial x^2}$$

- Endimensionella problem: halvoändlig stav. Pumpar in värme med en effekt  $P(t)$  i ena änden (enda änden).

— Termisk jämvikt:

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

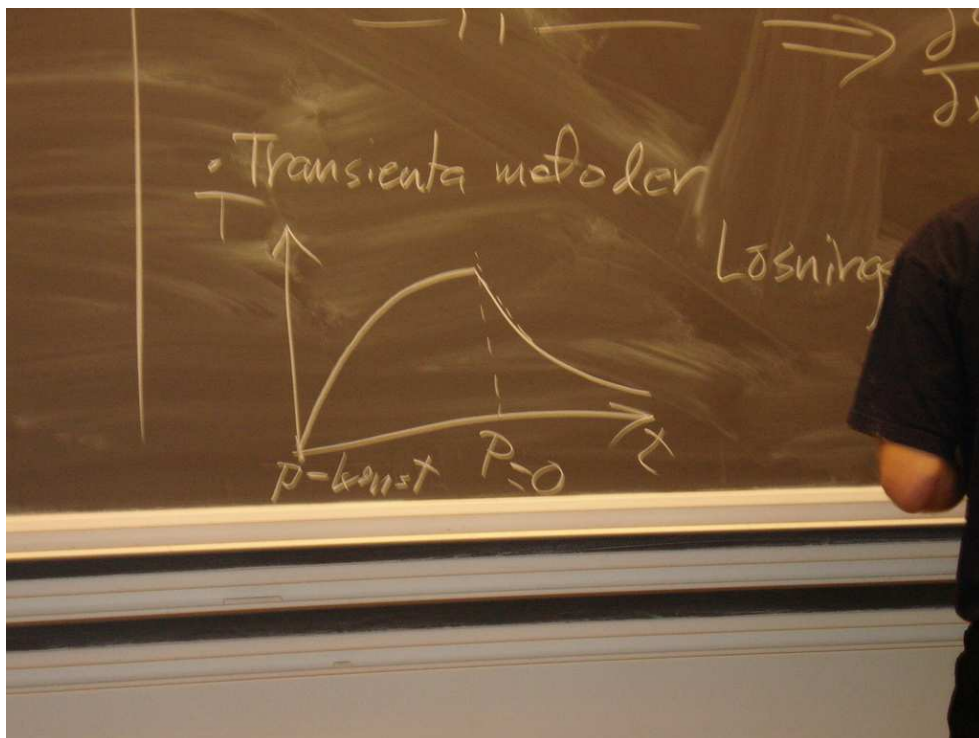
(inga förluster via mantelytan).

— Om staven avger värme längsmed sin yta:

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

(förluster!)

— Transienta metoder: (fig7)

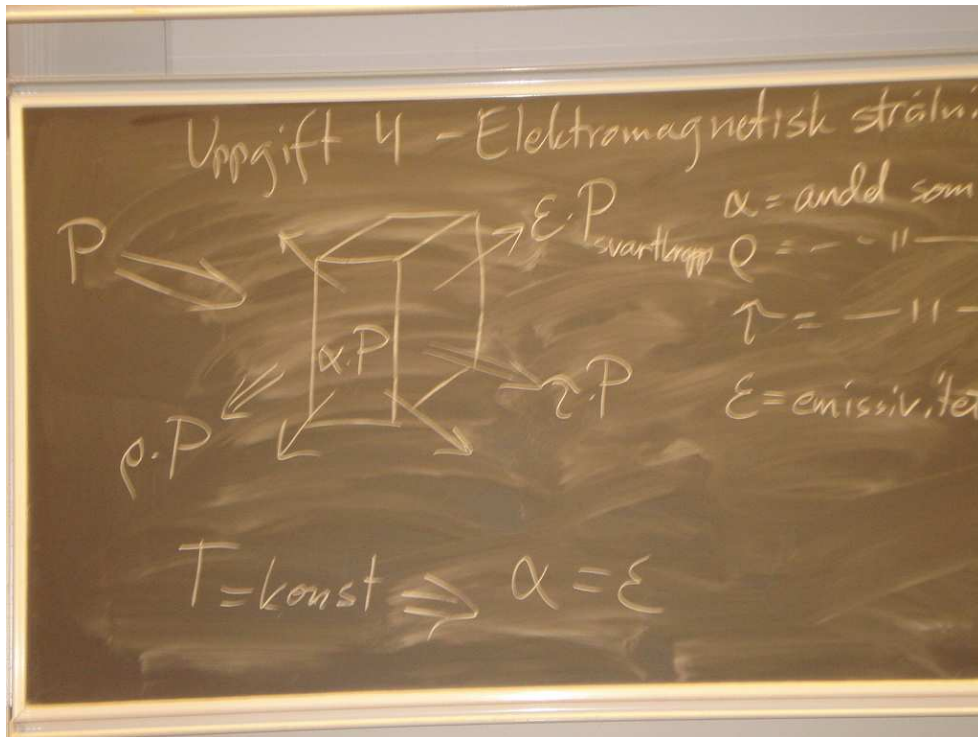


Figur 7.

Lösningsform:  $T = A + B e^{-Ct}$



#### Uppgift 4: Elektromagnetisk strålning



Figur 8.

$$\alpha + \rho + \tau = 1 \quad \text{där} \quad \begin{cases} \alpha = \text{andel som absorberas} \\ \rho = \text{andel som reflekteras} \\ \tau = \text{andel som transmitteras} \\ \epsilon = \text{emissivitet} \end{cases}$$

$T = \text{konstant} \Rightarrow \alpha = \epsilon.$

- Spektralt selektiva ytor (solfångarytor):  $\alpha(\lambda_1) \neq \epsilon(\lambda_2)$ . Dock gäller  $\int_0^\infty \alpha d\lambda = \int_0^\infty \epsilon d\lambda$ .
- Solstrålning (svartkropp - 6000°C):  $\lambda \approx 0,3 - 2 \mu\text{m}$ .

svartkropp på 200°C:  $\lambda \approx 2 - 20 \mu\text{m}$ .

Solfångare  $\alpha|_{\lambda \approx 0,3-2 \mu\text{m}} \approx 1$ ,  $\epsilon|_{\lambda \approx 2-20 \mu\text{m}} = 0$ .