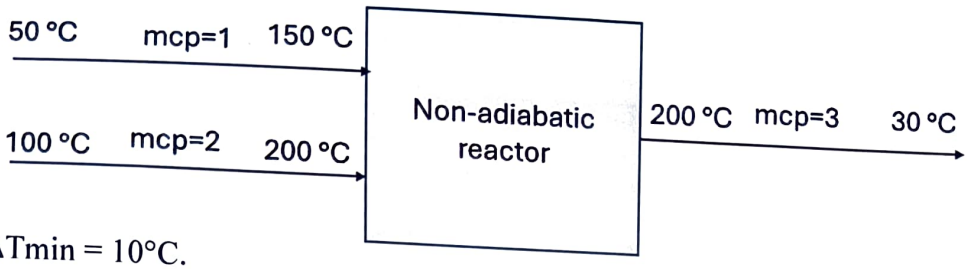
Name, Student number	

EXAM PART A: Answer part A questions on separate answer sheet

1. Pinch composite curves. [8 p]

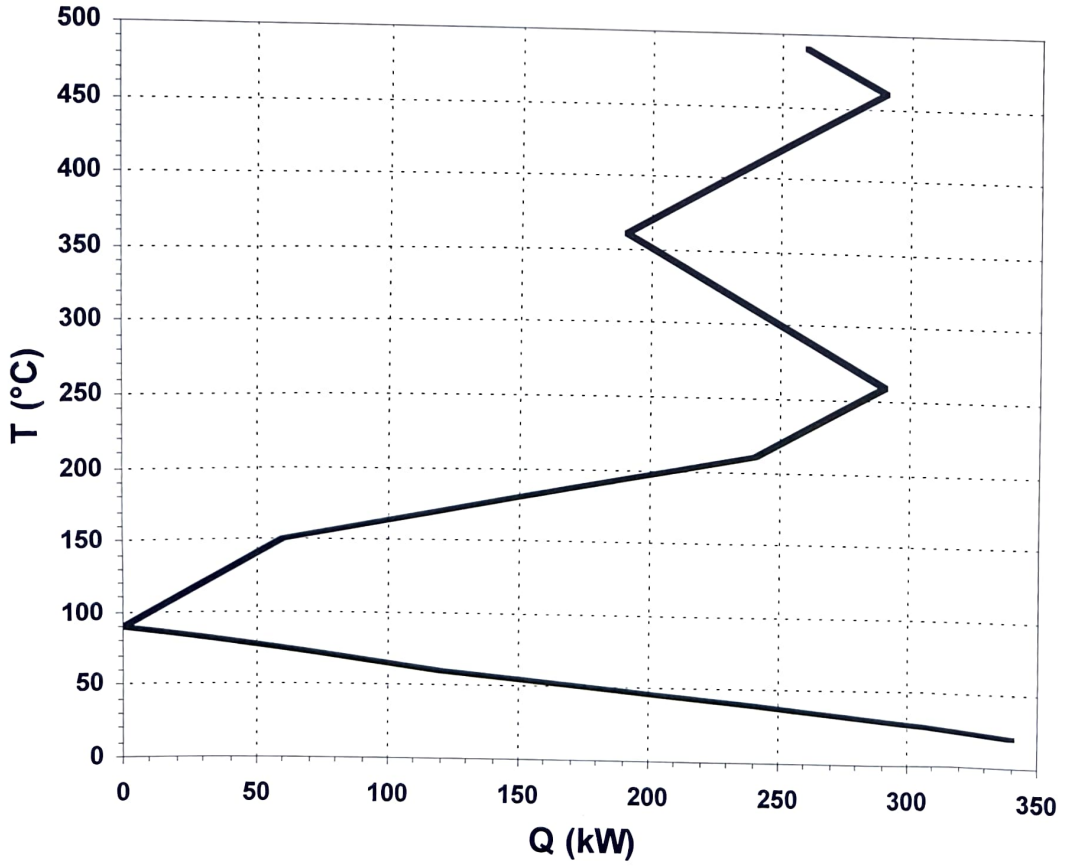
We have the following process:



ΔTmin = 10°C.

a) Extract the pinch streams (3p)
b) Draw the hot and cold composite curves. (2p)
c) What are the minimum hot and cold utility consumptions? (2p)
d) What is the pinch temperature? (1p)

2. Grand composite curve. [5 p]



ΔTmin = 20°C.

What are the minimum hot and cold utility consumptions, and what is the pinch temperature? (5p)

3. Transshipment model. [7 p]

Using the data below, formulate the problem as a LP TRANSSHIPMENT MODEL.

DATA

Stream	T_{start} (°C)	T_{target} (°C)	m*cp (kw/K)	Q (kW)
H1	120	80	4	
C1	50	90	1	
C2	40	150	1	
Steam	200	200		
Cooling water	20	20		
Δtmin	10 °C			

Name, Student number	

EXAM PART B: Answer part B questions on the question sheet

Use answer sheets only if you run out of space.

4. Mark the true statement in the following questions [0-6 points]

Each correct answer = +1 point, wrong answer = -0.5 points, no answer = 0 points.

a) Function f(x,y) = -x+y-1 is
- ☐ Convex but not concave
- ☐ Concave but not convex
- ☐ Both convex and concave

b) Static models in dynamic programming (DP) algorithm
- ☐ must be convex
- ☐ can be non-convex
- ☐ must be linear

c) For an optimization model
- ☐ -min f(**x**) = -max f(**x**)
- ☐ -max f(**x**) = min -f(**x**)
- ☐ max f(**x**) = min -f(**x**)

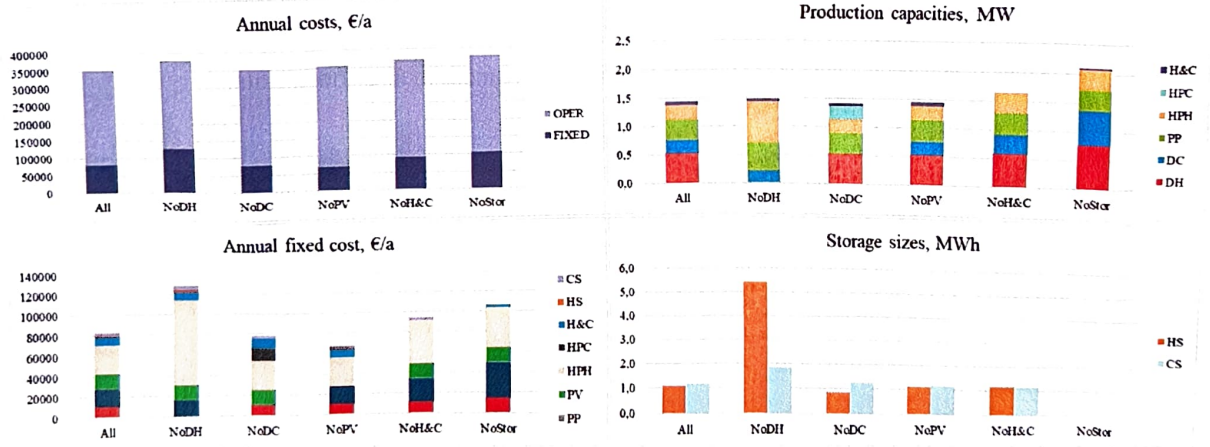
d) Optimization model min f(**x**) s.t. **g**(**x**)≥**0**, **h**(**x**)=**0** is a convex problem if
- ☐ f is a convex function, **g** is set of convex functions, and **h** is an empty set (vector) of functions
- ☐ f is a concave function, **g** is empty set, and **h** is a set of linear functions
- ☐ f is a convex function, **g** and **h** are sets of convex functions

e) A basic solution of an LP model
- ☐ can be infeasible
- ☐ can be unbounded
- ☐ is optimal

f) Dijkstra's shortest path algorithm can be applied for solving
- ☐ transshipment network flow problem
- ☐ unit commitment of power plants
- ☐ combined heat and power transmission problem

5. Energy supply and storage optimization for buildings [max 4 p]

Diagrams below show optimal annual operative and fixed costs and production/storage capacities for a building as described in course material. Answer the following questions briefly (one sentence).



5.a: Why are the fixed costs in the NoDH configuration higher than in the other scenarios? [2 p]

5.b: Why are the overall production capacities highest in the NoStor configuration? [2 p]

6. **An LP model has 4 variables and 5 inequality constraints. After converting the model into canonical format by introducing slack/surplus variables:**
   a) How many variables does the model contain? [1 p]
   b) How many basic solutions does the model potentially have? [2 p]

7. **Combined heat and power modelling [15 p]**
   A CHP plant can operate at the extreme points 1-4 shown in the following table and linearly between them.
   a) Draw the characteristic operating region in the PQ plane in the space to the right of the table [2 p]
   b) Compute the energy efficiency of the plant at each point and mark it in the table [1 p]
   c) Plant is producing 150MW power and 150MW heat. Compute fuel consumption and efficiency and mark them on **row c** of the table [2 p]

   Formulate the following problems as **LP** or **MILP** models. Tell if each model is **convex** or **non-convex**.
   d) Fuel price is C_F, market price for power is C_P and heat price is C_Q (€/MWh). Heat demand is Q. Using **extreme point formulation** for CHP, formulate a model for maximizing operative profit [5 p]
   e) If the plant is shut down, no fuel is consumed, and no power is generated. Extend the previous model to include the option of shutting down the plant. [5 p]

Point	Power generation P (MW)	Heat production Q (MW)	Fuel consumption F (MW)	4.b Efficiency (%)	4.a Picture
1	100	0	300		
2	200	0	500		
3	100	100	250		
4	200	200	440		
c	150	150			

7.**d**: Define model below: decision variables, objective function, and constraints.

7.**e**: Additional or modified model components: