In[47]:=
```
Quiet@Remove["Global`*"];
$HistoryLength = 2;
Off[FindRoot::lstol];
SetDirectory[NotebookDirectory[]];
```

In[51]:=
```
mm = 0.001;
cm = 10. mm;
imax = 7;
jmax = 12;
TavstupZadane = 99.1;
TbvstupZAdane = 10.4;
msteckouA = 5.23;
msteckouB = 3.869;
delkaVymeniku = 5.5;
```

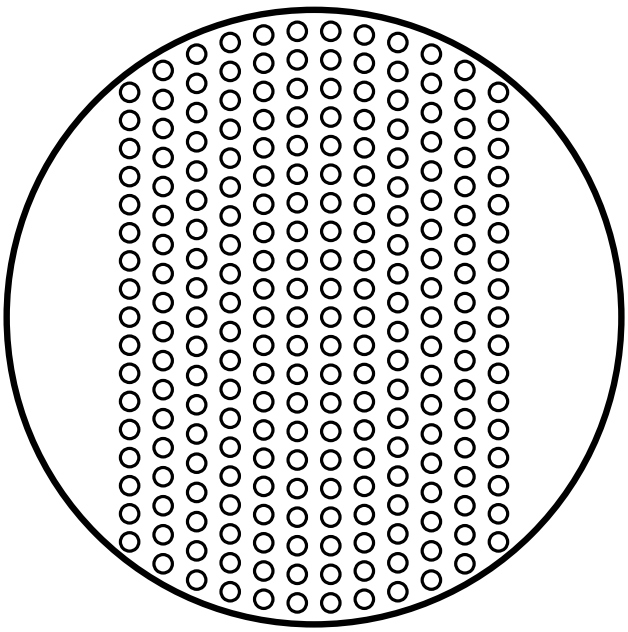
In[60]:=

```
ClearAll[yjm, x, rceKruh, yjmax, kmax, udaje, Δyj, km, Δyjm];
D1 = 0.5;(*vnitrni prumer trouby B*)
d1 = 1.5 cm;(*vnitrni prumer trubicky A*)
t = 2 mm;(*tloustka streny trubicky A*)
ξy = 1.2;(*Δytrubicka+mezera=ξy*Δytrubicka*)
ξyukr = 2;(*kolikrat je mezera u kraje mensi, nez mezera mezi trubkami*)
ξxj1 = 0.2;(*kolikrat je pocatecni x vuci prumeru*)
Δytrubicka = d1 + 2 t;
ΔyjZadane = ξy * Δytrubicka;
Δyukr = ξyukr * (ΔyjZadane - Δytrubicka);
xj1 = ξxj1 * D1;
Δx = (D1 - 2 xj1)/(jmax - 1);
x[j_Integer] := xj1 + (j - 1) * Δx;
rceKruh[x_, y_] := (x - 0.5 D1)^2 + y^2 == (0.5 D1)^2;
yjmax[j_Integer] := yjm /. Solve[rceKruh[x[j], yjm]][[2]];
kmax[j_Integer] := Floor[km /. Solve[
     2 * yjmax[j] == 2 * Δyukr + km * Δytrubicka + (km - 1) * (ΔyjZadane - Δytrubicka), km][[1]]]
udaje[j_Integer, k_Integer] := Module[{km, yjm, prutocnaDelka},
   km = kmax[j];
   yjm = yjmax[j];
   Δyj = Δyjm /.
     Solve[2 * yjm == 2 * Δyukr + km * Δytrubicka + (km - 1) * (Δyjm - Δytrubicka), Δyjm][[1]];
   prutocnaDelka = 2 * Δyukr + (km - 1) * (Δyj + -Δytrubicka);

   {{x[j], -yjm + Δyukr + 0.5 * Δytrubicka + (k - 1) * Δyj}, {km, yjm, prutocnaDelka}, {j, k}}

  ];
kruh[{{x_, y_}, r_}, tk_, barva_] := Graphics[{Thickness[tk], barva, Circle[{x, y}, r]}];
stredy = Union@Flatten[Table[udaje[j, k][[1]], {j, jmax}, {k, kmax[j]}], 1];
kruhy1 = kruh[{#, 0.5 d1}, 0.005, Black] & /@ stredy;
kruh2 = kruh[{{0.5 D1, 0}, 0.5 D1}, 0.01, Black];
grRez = Show[kruhy1, kruh2]
```

Out[81]=



In[82]:=
```
ClearAll[prutocnaDelka, SoutVrstva, SinVrstva,
  SkB, nyA, Tolej, gzA, nuA, vmaxB, αA, αB, nuB, kspom];
λTrubka = 41.5;
nTrubekA = Length[stredy];
SkA = nTrubekA * Pi * d1^2 / 4;
Δz = delkaVymeniku / imax;
RthTrubka = 1 / (2. * Pi * λTrubka * Δz) * Log[(d1 + 2 t) / d1];
SvitrniTrubka = 2. * Pi * Δz * d1;
SvnejsiTrubka = 2. * Pi * Δz * (d1 + 2 t);
SinVrstva[j_] := SvitrniTrubka * kmax[j];
SoutVrstva[j_] := SvnejsiTrubka * kmax[j];
prutocnaDelka[j_] := udaje[j, 1][[-2, -1]];
SkB[j_] := prutocnaDelka[j] * Δz;
nyA[Tolej_] = N[<< "nyA"];
nyB = 10^-6 * (<< "milionnyB")[#] &;(*funkce teploty A*)
cpA[T_] := 1988 + 0.01 T;
cpB[T_] := 4178 - 0.0478 T;
λA[T_] := 0.13141 + 0.0001 T;
λB = << "lambdaB";(*funkce teploty B*)
PrA[Tolej_] = << "prA";
PrB = << "prB";(*funkce teploty B*)
roA[T_] := 847 - 0.0000158 T;
roB[T_] := 1000 - 0.00047 T;
gzA[reA_, prA_, z_] := reA * prA * d1 / z;
nuA[gz_, PrA_, Prw_] :=
  (1 + 0.01 * (PrA / Prw)^0.25) * Which[0 ≤ gz < 667, 4.364 + 0.263 * gz^0.506 * Exp[-41. / gz],
    667 ≤ gz < 2 * 10^4, 1.302 * gz^0.333 - 0.5, gz ≥ 2 * 10^4, 1.302 * gz^0.333 - 1];
DcharB = d1 + 2 t;
vmaxB[j_, T_] := msteckouB / (roB[T] * SkB[j]);
vA[T_] := msteckouA / (roA[T] * SkA);
reA[T_] := vA[T] * d1 / nyA[T];
reB[T_, j_] := vmaxB[j, T] * (d1 + 2 t) / nyB[T];
```

```
αA[{{αAminule_, αBminule_}, {TAminule_, TBminule_}, z_}] :=
  Module[{Tstena, Tdef, nu, re, pr, prw, gz, λ},
   Tstena = (TAminule αAminule + TBminule αBminule)/(αAminule + αBminule);
   Tdef = 0.5 * (Tstena + TAminule);
   re = reA[Tdef];
   pr = PrA[Tdef];
   prw = PrA[Tstena];
   gz = gzA[re, pr, z];
   nu = nuA[gz, pr, prw];
   λ = λA[Tdef];
   (nu * λ)/d1
  ];
```

```
nuB[re_, PrB_, Prw_] := PrB^0.36 * (PrB/Prw)^0.25 * 0.52 re^0.5;
(*0.25 kapaliny, 0, plyny, HeatTransfer str. 382*)
αB[{{αAminule_, αBminule_}, {TAminule_, TBminule_}, j_}] :=
  Module[{Tstena, Dchar, Tdef, prB, prw, nu, re, λ},

   Tstena = (TAminule αAminule + TBminule αBminule)/(αAminule + αBminule);
   Dchar = d1 + 2 t;
   Tdef = 0.5 * (Tstena + TBminule);
   prB = PrB[Tdef];
   prw = PrB[Tstena];
   re = reB[Tdef, j];
   nu = nuB[re, prB, prw];
   λ = λB[Tdef];
   (nu * λ)/(d1 + 2 t)
  ];
```

```
kspom[{{αAminule_, αBminule_}, {TAminule_, TBminule_}, {j_, z_}}] :=
  Module[{α1, α2, S1, S2},
   α1 = αA[{{αAminule, αBminule}, {TAminule, TBminule}, z}];
   S1 = SinVrstva[j];
   S2 = SoutVrstva[j];
   α2 = αB[{{αAminule, αBminule}, {TAminule, TBminule}, j}];
```

$$\frac{1}{\text{RthTrubka} + \frac{1}{\alpha 1 * S1} + \frac{1}{\alpha 2 * S2}}$$

```
];

ClearAll[doskSij];
doskSij[{{i_Integer, j_Integer, res_}, dosalfas_}] :=
  Module[{αANew, αBNew, TAminule, TBminule, z, αAminule, αBminule},
   {αAminule, αBminule} = {αa[i, j], αb[i, j]} /. dosalfas;
   z = Δz * (0.5 + i - 1);
   TAminule = 0.5 * (Tain[i, j] + Taout[i, j]) /. res;
   TBminule = Tbin[i, j] /. res;
   αANew = αA[{{αAminule, αBminule}, {TAminule, TBminule}, z}];
   αBNew = αB[{{αAminule, αBminule}, {TAminule, TBminule}, j}];
   {{kS[i, j] -> kspom[{{αANew, αBNew}, {TAminule, TBminule}, {j, z}}],
     {mca[i, j] → msteckouA * kmax[j] / nTrubekA * cpA[TAminule],
      mcb[i, j] → msteckouB * cpB[TBminule]}}, {αa[i, j] → αANew, αb[i, j] → αBNew}}
  ];
```

In[117]:=

```
ClearAll[rcebilanceLn, rcebilance];
rcebilanceLn[i_Integer, j_Integer] := {mca[i, j] * (Tain[i, j] - Taout[i, j]) == Q[i, j],
   mcb[i, j] * (Tbout[i, j] - Tbin[i, j]) == Q[i, j],
   kS[i, j] * (Tain[i, j] - Taout[i, j]) *
     Log[Abs[((Tain[i, j] - Tbin[i, j]) / (Taout[i, j] - Tbin[i, j]))]]^-1 == Q[i, j]
  };
rcebilance[i_Integer, j_Integer] := {mca[i, j] * (Tain[i, j] - Taout[i, j]) == Q[i, j],
   mcb[i, j] * (Tbout[i, j] - Tbin[i, j]) == Q[i, j],
   kS[i, j] * (0.5 * (Tain[i, j] + Taout[i, j]) - Tbin[i, j]) == Q[i, j]
  };
rceSpojA[i_Integer, j_Integer] := {Taout[i, j] == Tain[i + 1, j]};
rceSpojB[i_?EvenQ, j_Integer] := {Tbout[i, j] == Tbin[i, j + 1]};
rceSpojB[i_?OddQ, j_Integer] := {Tbin[i, j] == Tbout[i, j + 1]};
rceSpojDole[i_?OddQ] := {Tbin[i, jmax] == Tbout[i + 1, jmax]};
rceSpojDole[i_?EvenQ] := {};
rceSpojNahore[i_?EvenQ] := {Tbin[i, 1] == Tbout[i + 1, 1]};
rceSpojNahore[i_?OddQ] := {};
rceVystupA = {Sum[mca[imax, j] * Taout[imax, j], {j, 1, jmax}] ==
    Tavystup * Sum[mca[imax, j], {j, 1, jmax}]};
rceVstupA[j_] := {Tain[1, j] == Tavstup};
rceVstupB = If[OddQ[imax], {Tbin[imax, jmax] == Tbvstup}, {Tbin[imax, 1] == Tbvstup}];
rceVystupB = {Tbout[1, 1] == Tbvystup};
```

In[131]:=
```
r1 = Flatten[Table[rcebilance[i, j], {i, imax}, {j, jmax}]];
r1Ln = Flatten[Table[rcebilanceLn[i, j], {i, imax}, {j, jmax}]];
r2 = Flatten[Table[rceSpojA[i, j], {i, imax - 1}, {j, jmax}]];
r3 = Flatten[Table[rceSpojB[i, j], {i, imax}, {j, jmax - 1}]];
r4 = Flatten[Table[rceSpojDole[i], {i, imax - 1}]];
r4 = Flatten[Table[rceSpojNahore[i], {i, imax - 1}]];
r5 = Flatten[Table[rceSpojDole[i], {i, imax - 1}]];
r6 = Flatten[Table[rceVstupA[j], {j, jmax}]];
r7 = rceVystupA;
r8 = rceVstupB;
r9 = rceVystupB;
rdohr =
  Union@DeleteCases[Flatten[Union[ToExpression["r" <> ToString[#]] & /@ Range[9]]], {}];
rdohrLn = Union[r1Ln, DeleteCases[
    Flatten[Union[ToExpression["r" <> ToString[#]] & /@ Range[2, 9, 1]]], {}]];
```

In[144]:=
```
mcbStart = msteckouB * cpB[TbvstupZAdane];
mcaStart = msteckouA * kmax[Round[0.5 * jmax]] / nTrubekA * cpA[TavstupZadane];
ksStart = kspom[{{100, 100},
    {TavstupZadane, TbvstupZAdane}, {Round[0.5 * jmax], 0.5 * delkaVymeniku}}];

dosalfasStart =
  Flatten[Table[{αa[i, j] → 2 * ksStart, αb[i, j] -> 2 * ksStart}, {i, imax}, {j, jmax}]];
```

In[148]:=
```
dosTry = {mcb[_, _] :↦ mcbStart, mca[_, _] :↦ mcaStart,
   kS[_, _] :↦ ksStart, Tavstup → TavstupZadane, Tbvstup → TbvstupZAdane};
rdos = rdohr /. dosTry;
nezname = Union[Cases[rdos, _[_Integer, _Integer], {0, ∞}], {Tavystup, Tbvystup}];
resStart = Solve[rdos, nezname][[1]];
```

In[152]:=
```
ClearAll[dos];
dos[{res_, doslast_}] := Union[{Tavstup → TavstupZadane, Tbvstup → TbvstupZAdane},
   Flatten[Table[doskSij[{{i, j, res}, doslast}], {i, imax}, {j, jmax}]]];
dosStart = dos[{resStart, dosalfasStart}];
```

In[155]:=
```
ClearAll[krokLin, krokLinLn, krokLn, krok];
krokLin[{doslast_, res_, iter_Integer}] := Module[{resNew},
   resNew = Solve[rdohr /. doslast, nezname][[1]];
   {dos[{resNew, doslast}], resNew, iter + 1}

  ];


krokLinLn[{doslast_, res_, iter_Integer}] :=
  Module[{resNew, dosNew, rdohrNew, obory, resLn},
   resNew = Solve[rdohr /. doslast, nezname][[1]];
   dosNew = dos[{resNew, doslast}];
   rdohrNew = rdohrLn /. dosNew;
   obory = resNew /. (a_ → b_) :> {a, b};
   resLn = FindRoot[rdohrNew, obory];
   {dos[{resLn, dosNew}], resLn, iter + 1}
  ];


krokLn[{doslast_, res_, iter_Integer}] :=
  Module[{resNew, dosNew, rdohrNew, obory, resLn},
   rdohrNew = rdohrLn /. doslast;
   obory = res /. (a_ → b_) :> {a, b};
   resLn = FindRoot[rdohrNew, obory];
   {dos[{resLn, doslast}], resLn, iter + 1}
  ];


krok[par : {doslast_, res_, iter_Integer}] :=
  Which[iter < 2, krokLin[par], 2 ≤ iter < 3, krokLinLn[par], iter ≥ 3, krokLn[par]];
```

In[160]:=
```
ClearAll[tav];
tav[{doslast_, res_, iter_Integer}] := Tavystup /. res;
dats = NestList[krok, {dosStart, resStart, 1}, 4];
{dosVys, resVys, iterVys} = dats[[-1]];
dosvys = Union[dosVys, resVys];
tav /@ dats
% - Last[%]
```

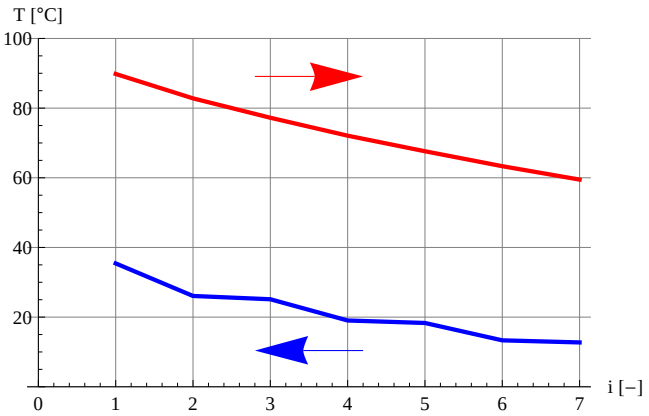
Out[165]= {61.9181, 59.4658, 59.5422, 59.5421, 59.5421}

Out[166]= $\{2.37605, -0.0762429, 0.000112176, 6.13069 \times 10^{-7}, 0.\}$

In[167]:=
```
pla = ListPlot[({#, Taout[#, 2]} & /@ Range[imax]) /. dosvys, PlotRange → All, Joined → True,
    PlotStyle → {Thick, Red}, GridLines → Automatic, AxesLabel → {"i [-]", "T [°C]"}];
plb = ListPlot[({#, Tbout[#, 2]} & /@ Range[imax]) /. dosvys, PlotRange → All,
    Joined → True, PlotStyle → {Thick, Blue}, GridLines → Automatic];

sipka[barva_, {{x1_, y1_}, {x2_, y2_}}] :=
  Graphics[{barva, {Arrowheads[Large], Arrow[{{x1, y1}, {x2, y2}}]}}];
s1 = sipka[Red, {{0.4 * imax, Tavstup - 10}, {0.6 imax, Tavstup - 10}}] /. dosvys;
s2 = sipka[Blue, {{0.6 * imax, Tbvstup}, {0.4 imax, Tbvstup}}] /. dosvys;
Show[pla, plb, s1, s2, PlotRange → {Automatic, {0, 100}}, AxesOrigin -> {0, 0}]
```

Out[172]=



In[173]:=
```
vykon1 = Plus @@ (Union[Cases[resVys, Q[_Integer, _Integer], {0, ∞}]] /. dosvys);
vykon2 = (Tavstup * msteckouA * cpA[Tavstup] - Tavystup * Sum[mca[imax, j], {j, 1, jmax}]) /.
    dosvys;
vykon3 = (mcb[1, jmax] * Tbvystup - msteckouB * cpB[Tbvstup] * Tbvstup) /. dosvys;
{vykon1, vykon2, vykon3}
{{Tavstup - Tavystup, Tbvystup - Tbvstup}, {Tavystup, Tbvystup}} /. dosvys
```

Out[176]= {411 457., 411 615., 411 388.}

Out[177]= {{39.5579, 25.4608}, {59.5421, 35.8608}}