```
> restart;
> A__req := Q/(F*U*DeltaT__LM);
  DeltaT__LM := ((T__hot2 - T__cold1)-(T__hot1 - T__cold2))/ln(
  (T__hot2-T__cold1)/(T__hot1-T__cold2));
  T__hot2 := -(Q-m__hot*c__hot*T__hot1)/(m__hot*c__hot); #Kelvin
  T__cold2 := (c__cold*m__cold*T__cold1 + Q)/(m__cold*c__cold)
```

$$A_{req} := \frac{Q}{F\, U\, DeltaT_{LM}}$$

$$DeltaT_{LM} := \frac{T_{hot2} - T_{cold1} - T_{hot1} + T_{cold2}}{\ln\left(\frac{T_{hot2} - T_{cold1}}{T_{hot1} - T_{cold2}}\right)}$$

$$T_{hot2} := -\frac{-m_{hot}\, c_{hot}\, T_{hot1} + Q}{m_{hot}\, c_{hot}}$$

$$T_{cold2} := \frac{c_{cold}\, m_{cold}\, T_{cold1} + Q}{m_{cold}\, c_{cold}} \tag{1}$$

```
> #1 is in
  #2 is out
  print("====Specifications====");
  Q := 10*1000; #W
  m__hot := 90/1.204/60; #kg/s
  c__hot := 1.006*1000; #J/kg/K (Isobaric)
  T__hot1 := 20 + 273.15; #Kelvin
  c__cold := 4.2*1000; #J/kg/K (Isobaric)
  T__cold1 := 8 + 273.15; #Kelvin


  print("=====Estimated=====");
  m__cold := 1.5; #kg/s
  U__o_ass := 78.82; #W/m2/K
  F := 1;
```

"====Specifications===="

$$Q := 10000$$

$$m_{hot} := 1.245847176$$

$$c_{hot} := 1006.000$$

$$T_{hot1} := 293.15$$

$$c_{cold} := 4200.0$$

$$T_{cold1} := 281.15$$

"=====Estimated====="

$$m_{cold} := 1.5$$

$$U_{o\_ass} := 78.82$$

$$F := 1 \quad \textbf{(2)}$$

```
> U := U__o_ass;
```

$$U := 78.82 \quad \textbf{(3)}$$

```
> DeltaT__LM;
  A__req;
```

$$6.717674465$$

$$18.88620133 \quad \textbf{(4)}$$

```
> #Tube parameters
  D__internal := 0.022; #m
  D__external := 0.025; #m
  #Fin type, Helical
  l__f := 0.002; #m
  t__f := 0.001; #m
  p__f := 0.002; #m
```

$$D_{internal} := 0.022$$

$$D_{external} := 0.025$$

$$l_f := 0.002$$

$$t_f := 0.001$$

$$p_f := 0.002 \quad \textbf{(5)}$$

```
> r__f1 := D__external/2;
  l__fc := l__f + t__f/2; #corrected fin hight to account for
  transfer in tip
  r__f2c := r__f1 + l__fc;
  A__f := 2*Pi*(r__f2c^2 - r__f1^2);
  N__fin := 1/p__f;
  A__b := Pi*D__external*(1 - N__fin*t__f);
  A__o_one_meter := A__f*N__fin + A__b
```

$$r_{f1} := 0.01250000000$$

$$l_{fc} := 0.002500000000$$

$$r_{f2c} := 0.01500000000$$

$$A_f := 0.0004319689900$$

$$N_{fin} := 500.0000000$$

$$A_b := 0.03926990818$$

$$A_{o\_one\_meter} := 0.2552544032 \qquad \textbf{(6)}$$

```
> L := A__req/A__o_one_meter;
```

$$L := 73.98971807 \qquad \textbf{(7)}$$

```
> #properties of water, tube side
  rho__t := 999.70; #kg/m3
  mu__t := 1.308*10^(-3); #Pa*s
  k__t := 0.58; #W/m/K
  C__pt := 4200; #J/kg/K
```

$$\rho_t := 999.70$$

$$\mu_t := 0.001308000000$$

$$k_t := 0.58$$

$$C_{pt} := 4200 \qquad \textbf{(8)}$$

```
> #Calculating Tube side cross-sectional flow area
  N__per_pass := 1;
  A__internal := (3.14159/4)*D__internal^2; #m2
  A__t := N__per_pass * A__internal; #m2
```

$$N_{per\_pass} := 1$$

$$A_{internal} := 0.0003801323900$$

$$A_t := 0.0003801323900 \qquad \textbf{(9)}$$

```
> #Water key equations
  v__t := m__cold/(rho__t*A__t);
  Re__t := (rho__t*v__t*D__internal)/mu__t;
  Pr__t := (C__pt*mu__t)/k__t;
  mu__corr := 1;
  Nu__t := 0.023*Re__t^0.8*Pr__t^0.4*(mu__corr);
  h__i := (Nu__t *k__t)/D__internal; #W/m^2/K
```

$$v_t := 3.947177811$$

$$\Re_t := 66369.92391$$

$$Pr_t := 9.471724138$$

$$\mu_{corr} := 1$$

$$\mathrm{N}_t := 407.2644555$$

(10)

$$h_i := 10736.97201 \quad (10)$$

```
> #properties of air, shell side
  rho__s := 1.204; #kg/m3 (air at 20C)
  mu__s := 1.825*10^(-5); #kg/m/s
  k__s := 0.02514; #W/m/K
  C__ps := 1007;
```

$$\rho_s := 1.204$$

$$\mu_s := 0.00001825000000$$

$$k_s := 0.02514$$

$$C_{ps} := 1007 \quad (11)$$

```
> #Shell side
  D__i := 0.2;
  d__e := D__i - (D__external + 2*l__f);
  A__outer := Pi/4*D__i^2;
  A__inner := Pi/4*(D__external+2*l__f)^2;
  u__s := m__hot/(rho__s*(A__outer - A__inner));
  Re__s := (rho__s*u__s*d__e)/mu__s;
```

$$\mathrm{D}_i := 0.2$$

$$d_e := 0.171$$

$$A_{outer} := 0.03141592655$$

$$A_{inner} := 0.0006605198555$$

$$u_s := 33.64471169$$

$$\Re_s := 379556.5929 \quad (12)$$

```
> Pr__s := C__ps*mu__s/k__s;
  Nu__s := 0.023*Re__s^0.8*Pr__s^0.33;
  h__s := Nu__s * k__s/d__e;
```

$$Pr_s := 0.7310163087$$

$$\mathrm{N}_s := 602.8996051$$

$$h_s := 88.63681912 \quad (13)$$

```
> #Defining Thermal Conductivity Variables
  k__tube := 50; #W/m/K
  k__fin := 205; #W/m/K
  Rf__o := 0.0003526; #m2*K/W
  Rf__i := 0.00018; #m2*K/W
```

$$k_{tube} := 50$$

$$k_{fin} := 205$$

$$Rf_{o} := 0.0003526$$

$$Rf_{i} := 0.00018 \qquad (14)$$

```
> #Fin equations
  m := simplify(((2*h__s)/(k__fin * t__f))^(1/2));
  eta__f := tanh(m * l__f) / (m * l__f);
  N__fin := L/p__f;
```

$$m := 29.40662263$$

$$\eta_{f} := 0.9988485935$$

$$N_{fin} := 36994.85904 \qquad (15)$$

```
> #Outside area calculations
  A__f := A__f;
  A__b := A__b;
  A__f_total := A__f * N__fin;
  A__b_total := A__b *L;
  A__o := A__f_total + A__b_total;
```

$$A_{f} := 0.0004319689900$$

$$A_{b} := 0.03926990818$$

$$A_{f\_total} := 15.98063189$$

$$A_{b\_total} := 2.905569435$$

$$A_{o} := 18.88620132 \qquad (16)$$

```
> #Internal Area calculations
  A__i := 3.14159 * D__internal * L;
```

$$A_{i} := 5.113797886 \qquad (17)$$

```
> eta__o := (eta__f *  A__f_total + A__b_total)/A__o
```

$$\eta_{o} := 0.9990257331 \qquad (18)$$

```
> #Calculating all thermal resistances
  R__shell_conv := 1/eta__o/h__s; #Air side convection
  R__tube_conv := 1/(h__i*(A__i/A__o)); #Water side convection
  R__wall_cond := (D__external * ln(D__external/D__internal))/(2*
  k__tube);
  R__fouling := (Rf__i * (A__o/A__i))+(Rf__o /eta__o);
```

$$R_{shell\_conv} := 0.01129299570$$

$$R_{tube\_conv} := 0.0003439689452$$

$$R_{wall\_cond} := 0.00003195834280$$

$$R_{fouling} := 0.001017717150 \quad (19)$$

```
> #Calculating U
  R__total := R__shell_conv + R__tube_conv + R__wall_cond +
  R__fouling;
```

$$R_{total} := 0.01268664014 \quad (20)$$

```
> print("=============================");
  U__o_calc := 1/R__total; #W/m2/K
  print("=============================");
```

"============================="

$$U_{o\_calc} := 78.82307600$$

"=============================" (21)

```
> #Pressure losses
  f__t := 0.0035 + 0.264/Re__t^0.42;
  f__s := 0.0035 + 0.264/Re__t^0.42;
  DP__t := 4*f__t*(L/D__internal)*(rho__t*v__t^2/2);
  DP__s := 4*f__s*(L/D__external)*(rho__s*u__s^2/2);
```

$$f_t := 0.005991012877$$

$$f_s := 0.005991012877$$

$$DP_t := 627656.4756$$

$$DP_s := 48330.54826 \quad (22)$$

```
> DP__t/1000;
  DP__s/1000;
```

$$627.6564756$$

$$48.33054826 \quad (23)$$