One-tube

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1 UCN LD2 Calculations

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Modeling a HEX as a single straight tube with fluid flowing down the middle using https://uspas.fnal.gov/materials/10MIT/Lecture_3.2.pdf as a reference. A fixed Reynolds number of 10,000 is used.

```
[4]: #!/usr/bin/python3

     from math import *
     import matplotlib.pyplot as plt
     import matplotlib.patches as patches

     import numpy as np
     from scipy import interpolate
     from scipy.integrate import odeint
```

The flow perimeter is found from:

$$P = \frac{4\dot{m}}{Re\mu} \tag{1}$$

```
[5]: mdot=0.004 # kg/s
     mu=3.5e-5 # Pa*s
     Re=10000.
     p=4*mdot/(Re*mu) # m
     print('Flow perimeter %f m'%p)
     diameter=p/pi
     print('Diameter of tube %f m'%diameter)

     rho=163.0 # kg/m^3

     Cp=6565.4 # J/(kg*K)
```

```
Flow perimeter 0.045714 m
Diameter of tube 0.014551 m
```

The Colburn Factor is found from:

$$jH = 0.023Re^{-0.2}B1 \tag{2}$$

The Nusselt Number is found from:

$$Nu = jHRePr^{1/3} \tag{3}$$

```
[6]: Pr=2.209513 # taken from d2-hex-drawing.py
     B1=1.174*((3.7e-5)/(3.68e-5))**(0.14) #viscosity taken from cams sheets
     print('This is B1 %f.' %B1)
     jh=0.023*Re**(-0.2)*B1
     Nu=jh*Re*Pr**(1./3.)
     print('According to correlations, Nu=%f'%Nu)
```

```
This is B1 1.174891.
According to correlations, Nu=55.781604
```

The heat transfer coefficient is found from:

$$hc = \frac{Nukt}{D} \tag{4}$$

```
[7]: kt=0.104 # W/(m*K)
     Ntu=3.0
     hc=Nu*kt/diameter
     print('The heat transfer coefficient is %f W/m^2-K'%hc)
```

```
The heat transfer coefficient is 398.678003 W/m^2-K
```

The length of the tube needed is found from:

$$L = \frac{Ntu\dot{m}C_p}{Nukt\pi} \tag{5}$$

The friction factor is found from:

$$f = 0.316Re^{-0.25} \tag{6}$$

```
[8]: L=Ntu/(Nu*kt*pi/(mdot*Cp))
     print('Tube length needed for sufficient heat transfer %f m'%L)

     f=0.316*Re**(-0.25)
     print('The turbulent friction factor is %f.' %f)
```

```
Tube length needed for sufficient heat transfer 4.322831 m
The turbulent friction factor is 0.031600.
```

The pressure drop is found from:

$$dp = \frac{8f\dot{m}^2 L}{\rho\pi^2 D^5} \tag{7}$$

```
[9]: dp=(8*f*mdot**2/(rho*pi**2))*L/diameter**5 # tube
     print('The pressure drop is %f Pa'%dp)
```

The pressure drop is 16.659716 Pa

```
[10]: dcoil=4.*0.0254 # m diameter of coiled tube
      turns=L/(pi*dcoil)
      print('Coiling around a Cu rod of diameter %f m would require %f␣
      ↪turns'%(dcoil,turns))
      print('This Cu rod would need to be at least %f m long (for zero Cu wall␣
      ↪thickness)'%(turns*diameter))
```

Coiling around a Cu rod of diameter 0.101600 m would require 13.543305 turns
This Cu rod would need to be at least 0.197073 m long (for zero Cu wall
thickness)

In the above calculations, Reynolds number was fixed at 10,000 and the diameter at 0.014551 m, to find what the pressure drop would be. Now, the pressure drop is fixed at 10 Pa and the Ntu is fixed at 3, to determine what the diameter of the tube, the Reynolds number, and the heat transfer coefficient would be at 10 Pa.

Finding the optimal pipe diameter for a pressure drop of 10 Pa by:

$$D = \frac{8f\dot{m}^2 L}{(dp\rho\pi^2)^{1/5}} \tag{8}$$

```
[11]: dp2=10 #Pa
      mdot=0.004 # kg/s
      mu=3.5e-5 # Pa*s
      Ntu=3.0
      f=0.03 # following along in the example, have to guess an f

      D=((8*f*mdot**2*L)/(rho*pi**2*dp2))**(1/5)

      print('The diameter is %f m'%D)
```

The diameter is 0.015949 m

The Reynolds Number is found from:

$$Re = \frac{4\dot{m}}{\pi D \mu} \tag{9}$$

3

The Nusselt Number is found from:

$$Nu = jHRePr^{1/3} \tag{10}$$

```
[12]: Re2=(4*mdot)/(pi*D*mu)
      print('This is Re based on optimal diameter %f' %Re2)

      Pr2=(mu*Cp)/(kt) # yes still dimensionless
      jh2=0.023*Re2**(-0.2)*B1
      Nu2=jh2*Re2*Pr2**(1./3.)
      print('According to correlations, Nu=%f'%Nu2)
```

```
This is Re based on optimal diameter 9123.881703
According to correlations, Nu=51.836360
```

The length of the tube needed is found from:

$$L = \frac{Ntu\dot{m}C_p}{Nukt\pi} \tag{11}$$

```
[13]: L2=Ntu/(Nu2*kt*pi/(mdot*Cp))
      print('Tube length needed for sufficient heat transfer %f m'%L)

      turns2=L2/(pi*D)
      print('Coiling around a HEX of diameter %f m would require %f turns'%(D,turns2))
      print('This Cu rod would need to be at least %f m long (for zero Cu wall␣
       ↪thickness)'%(turns2*D))
```

```
Tube length needed for sufficient heat transfer 4.322831 m
Coiling around a HEX of diameter 0.015949 m would require 92.843700 turns
This Cu rod would need to be at least 1.480727 m long (for zero Cu wall
thickness)
```

The heat transfer coefficient is found from:

$$hc = \frac{Nukt}{D} \tag{12}$$

The Nusselt number from the example is found from:

$$Nu = 0.023Re^{0.8}Pr^{0.3} \tag{13}$$

```
[14]: hc2=Nu2*kt/D
      print('The heat transfer coefficient is %f W/m^2-K'%hc2)

      Nu3=0.023*Re2**(0.8)*Pr2**(0.3)
      print('From example Nu=%f'%Nu3)
```

```
The heat transfer coefficient is 338.022348 W/m^2-K
From example Nu=42.969502
```

The heat transfer per temperature is found from:

$$Q = hc\pi DL \tag{14}$$

```
[15]: QL=hc2*pi*D*L
      print('The heat transfer per temp is %f W/K' %QL)
```

```
The heat transfer per temp is 73.212617 W/K
```

```
[ ]:
```