Design Problem

In [ ]:
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import matplotlib.pyplot as plt
import numpy as np

# battery specifications
diameterBattery = 21.55/1000  # mm ->m
lengthBattery = 70.15/1000  # mm -> m
massBattery = 70/1000  # g -> kg
voltageBattery = 4.0  # V
resistanceBattery = .015  # Ω (ohms)

batteryArea = (np.pi*diameterBattery**2/2) + \
    (np.pi*diameterBattery*lengthBattery)


safeOpCurr = 45  # amps
safeOpTemp = 75  # C

# problem requirements
reqAmps = 225  # amps
reqVolts = 28  # volts

# fan specifications
fanDia = 140/1000  # mm -> m
flowRate = 270/3600  # m^3/h -> m^3/s
staticGagePressure = 65  # Pa

# other specifications
# properties of air pg 935
airTemp = 25  # C
p = 1.217  # kg/m^3 #density
cp = 1007  # J/KgK
v = 14.82e-6  # m^2/s
k = 26.3e-3  # W/mK
Pr = .707

# ----------------Chosen Variables--------------
# number and type of batteries
numSeries = 7  # reqVolts/voltageBattery
numParellel = 4  # reqAmps/safeOpCurr  # fixed

# battery spacing
sL = 27/1000  # mm ->m
sT = 27/1000  # mm ->m
sD = sT

# -----calculated values-----
totalNumBatteries = numSeries * numParellel

# power
arrVoltage = voltageBattery*numSeries  # volts
arrCurrent = reqAmps  # amps
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arrPower = arrVoltage*arrCurrent  # W
arrHeatGen = arrVoltage**2 / (resistanceBattery*totalNumBatteries)

currentBattery = reqAmps/numParellel
power_heatBattery = (currentBattery**2) * \
    resistanceBattery  # watts this is also heat

# box dimensions
# spacing
minCell_WallSpace = sT - diameterBattery
height = (2*minCell_WallSpace) + (diameterBattery *
                                  numParellel) + (minCell_WallSpace*(numParellel-1)
width = lengthBattery
length = (2*minCell_WallSpace) + \
    (diameterBattery * numSeries) + (minCell_WallSpace*(numSeries-1))


def findPowerDensity():
    volPowerDensity = arrPower/(length*width*height)
    return volPowerDensity


def findU():
    area = height*width
    u = flowRate/area
    return u


# pressure drop
def findUMax():
    '''#### Based on eq 7.60
    '''
    uMax = (sT/(sT-diameterBattery))*findU()  # m/s
    return uMax


def findRe():
    Re = (diameterBattery*findUMax()) / v
    return Re


def findPressureDrop():
    # we looked up these values in the table 7.14
    x = 1  # correction factor
    f = .7  # friction factor
    NL = numSeries

    PT = sT/diameterBattery
    PL = sL/diameterBattery
    ratioPTPL = PT/PL

    deltaP = NL*x * ((p*findUMax()**2) / 2)*f
    return deltaP


def findBatteryTemp(Tinf=25):
```

```
    # from table 7.2 from the Re
    # pg 444
    Re = findRe()
    C = .027
    m = .805

    NuD = C*Re**m*Pr**(1/3)  # eq 7.52
    h = NuD*(k/diameterBattery)

    q = power_heatBattery
    Ts = (q/(h*batteryArea)) + Tinf
    return Ts


def findVDotAir():
    return (width*height*length) * findU()


def findNextAirTemp(Tprev=25):
    # gets q generated by the col of batteries
    qBatteryColumn = power_heatBattery*numParellel

    areaAir = (width*height)
    massAir = areaAir*p*findU()

    Tout_air = (qBatteryColumn / (massAir*cp)) + Tprev
    return Tout_air


def findTempsPack(T0=airTemp):
    '''
    This will iterate through the colums of batteries that we have
    and update that cols battery temp and resultant air temp based on the previosu
    '''
    Tair_prev = T0
    for _ in range(int(numSeries)):  # go through cols
        batteryTemp = findBatteryTemp(Tair_prev)
        Tair_prev = findNextAirTemp(Tair_prev)
    return batteryTemp, Tair_prev


def plot():
    inletAirTemps = np.linspace(20, 40, (40-20)+1)
    batteryTemps = []
    maxTemp = []
    for temp in inletAirTemps:
        batteryTemps.append(findTempsPack(temp)[0])
        maxTemp.append(safeOpTemp)

    # Create a line plot
    plt.plot(inletAirTemps, batteryTemps, label='Cell Temperature (C)')
    plt.plot(inletAirTemps, maxTemp, linestyle='--',
             color='r', label='Max Operating Temperature (C)')

    # Add labels and a title
    plt.xlabel('Inlet Air Temp (C)')
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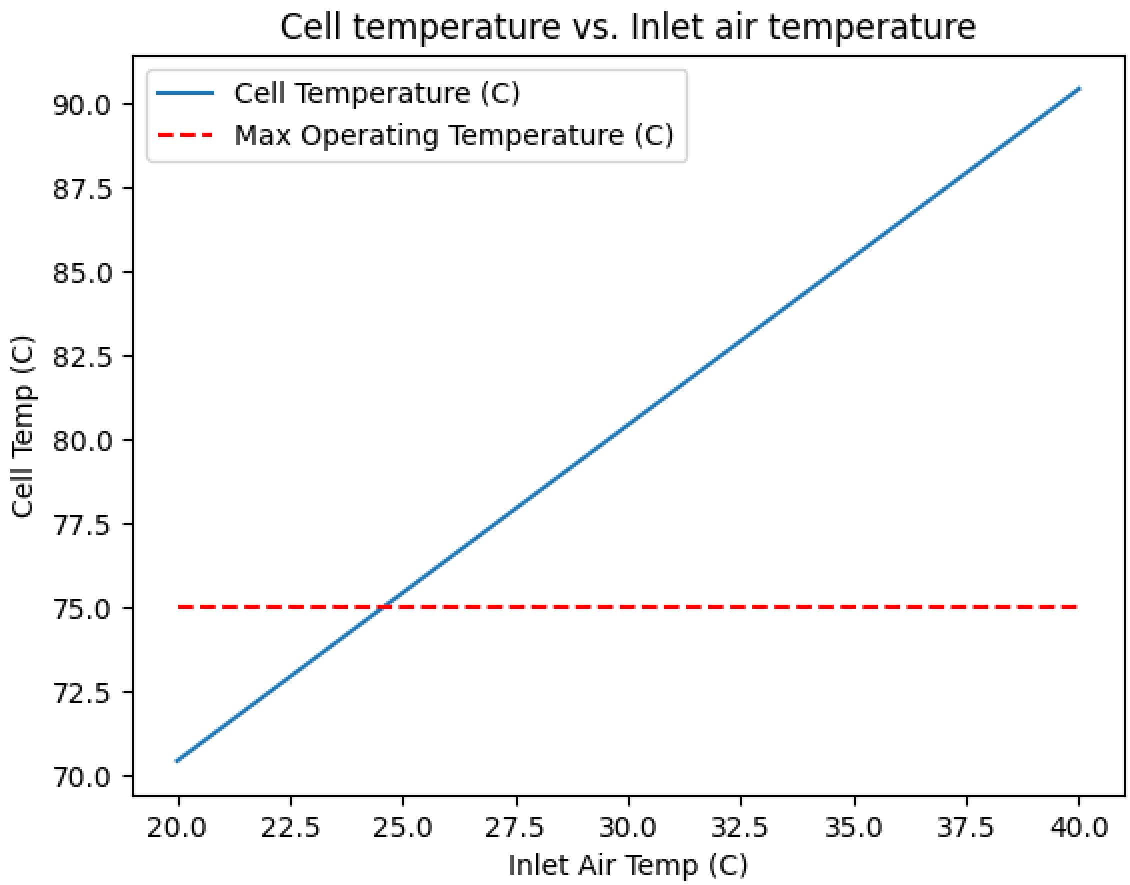
```
    plt.ylabel('Cell Temp (C)')
    plt.title('Cell temperature vs. Inlet air temperature')

    # Add a legend
    plt.legend()

    # save the figure
    plt.savefig('plot.png')

    # Display the plot
    plt.show()


print()

print("Reynolds number:\t", findRe())
print("\nNum series:\t\t", numSeries, "\nnum parallel:\t\t",  numParellel)

print("\n-------------These are the table Values-------------")
print("Height\t\t\t", height, "\t(m)\nLength \t\t\t", length, "\t(m)")
print("Voltage of Pack\t\t", arrVoltage,
      "\t\t\tVolts\nI of cell\t\t", currentBattery, "\t\t\tAmps")
print("Power Density\t\t", findPowerDensity(), "\tW/m^3")
print("VDot of air\t\t", findVDotAir(), "\t\tm^3/s")
print("Pressure Drop\t\t", findPressureDrop(), "\tPa")
t = findTempsPack()
print("output air temp\t\t", t[1], "\tC\nbattery temp\t\t", t[0], "\tC")
plot()
```

```
Reynolds number:         67888.37612059906

Num series:              7
num parallel:            4

-------------These are the table Values-------------
Height                   0.11345        (m)
Length                   0.19444999999999998    (m)
Voltage of Pack          28.0                   Volts
I of cell                56.25                  Amps
Power Density            4070993.663350305      W/m^3
VDot of air              0.01458375             m^3/s
Pressure Drop            6499.042274925521      Pa
output air temp          39.45816017540323      C
battery temp             75.44514211146901      C
```


Cell temperature vs. Inlet air temperature
Cell Temperature (C)
Max Operating Temperature (C)
90.0
87.5
85.0
82.5
80.0
77.5
75.0
72.5
70.0
Cell Temp (C)
20.0
22.5
25.0
27.5
30.0
32.5
35.0
37.5
40.0
Inlet Air Temp (C)