An electrical wire of diameter D= 1 mm is suspended horizontally in air of temperature 20^0C. The Joule heating of the wire is responsible for the heat generation rate q'= 0.01 W/cm per unit length in the axial direction. The wire can be modeled as a cylinder with isothermal surface. Sufficiently far from the wire, the ambient air is motionless. Calculate the temperature difference that is established between the wire and the ambient air. [Note: This calculation requires a trial-and-error procedure; expect a relatively small Rayleigh number.]

In[1]:=

$$Nu_d = \left(0.6 + \frac{0.387\, Ra_d^{1/6}}{\left(1 + \left(\frac{0.559}{Pr}\right)^{9/16}\right)^{8/27}}\right)^2;\; Ra_d = \frac{g\,\beta\,(T_w - T_\infty)\, d^3}{\nu\,\alpha};$$

$$h = Nu_d \frac{\kappa}{d};\; q = h\,\pi\, d\,(T_w - T_\infty);$$

In[3]:=

```
SetDirectory[NotebookDirectory[]];
airProps = Import["../air_props.csv"];
airProps[[2 ;;, 5]] = airProps[[2 ;;, 5]] 10^-3;
airProps[[2 ;;, 6]] = airProps[[2 ;;, 6]] 10^-5;
airProps[[2 ;;, 7]] = airProps[[2 ;;, 7]] 10^-6;
airProps[[2 ;;, 8]] = airProps[[2 ;;, 8]] 10^-6;
νI = Interpolation[airProps[[2 ;;, {1, 7}]]];
βI = Interpolation[airProps[[2 ;;, {1, 5}]] ];
PrI = Interpolation[airProps[[2 ;;, {1, 9}]]];
αI = Interpolation[airProps[[2 ;;, {1, 8}]]];
κI = Interpolation[airProps[[2 ;;, {1, 4}]]];
μI = Interpolation[airProps[[2 ;;, {1, 6}]]];
TFilm = (Tw + T∞)/2;
propertyVals = {ν → νI[TFilm], α → αI[TFilm],
   β → βI[TFilm], Pr → PrI[TFilm], κ → κI[TFilm], g → 9.81};
```

In[17]:=

```
problem = {T∞ → 20, d → 0.001};
```

In[18]:=

```
solveRule = Join[propertyVals /. problem, problem];
```

In[19]:=

```
eqn = (q /. solveRule);
```

In[20]:=

```
FindRoot[eqn == 1, {Tw, 20}]
```

Out[20]=

$\{T_w \to 33.8795\}$