Stuve diagram in LaTeX

Dry adiabats calculation

Given the following dry adiabats formula[1] [2]:

$$\phi = T \cdot \left(\frac{p_0}{p}\right)^k$$

We know that ϕ refers to the x axis, and p to the y axis, so we can rearrange to solve for p:

$$\frac{\phi}{T} = \left(\frac{p_0}{p}\right)^k$$

$$\left(\frac{\phi}{T}\right)^{\frac{1}{k}} = \frac{p_0}{p}$$

$$\left(\frac{T}{\phi}\right)^{\frac{1}{k}} = \frac{p}{p_0}$$

$$p_0 \cdot \left(\frac{T}{\phi}\right)^{\frac{1}{k}} = p$$

$$p = p_0 \cdot \left(\frac{T}{\phi}\right)^{\frac{1}{k}}$$

We know that ϕ refers to the x axis, and p to the y axis, while p_0 is the initial pressure with a standart value of 1000 hPa, and k the Poisson constant, the ratio of the gas constant to the specific heat capacity at constant pressure for an ideal diatomic gas[3].

$$\phi = x; \quad p = y; \quad p_0 = 1000; \quad k = 0.286$$

We can replace variables:

$$y = 1000 \cdot \left(\frac{T}{x}\right)^{\frac{1}{0.286}}$$

And knowing that temperature should be in Kelvin:

$$y = 1000 \cdot \left(\frac{T + 273.15}{x + 273.15}\right)^{\frac{1}{0.286}}$$

Which gives us a formula to use in the LaTeX diagram.

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1000 * ((x + 273.15) / (\T + 273.15))^(1/0.286)
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Also, we shoult take into account that in Stuve diagrams we want to draw the dry adiabats as straight lines. Thus y axis is not logarithmic, but progressing in a ratio of y^k, or $y^{0.286}$.

[1] Stull, Roland: *Practical Meteorology: An Algebra-based Survey of Atmospheric Science*, chapter 3, p. 61, equation 3.12, 2018

[2] www.igf.fuw.edu.pl/m/courses_materials.../thermodynamic_diagrams.pdf

[3] See https://resources.eumetrain.org/data/2/28/Content/theta.htm

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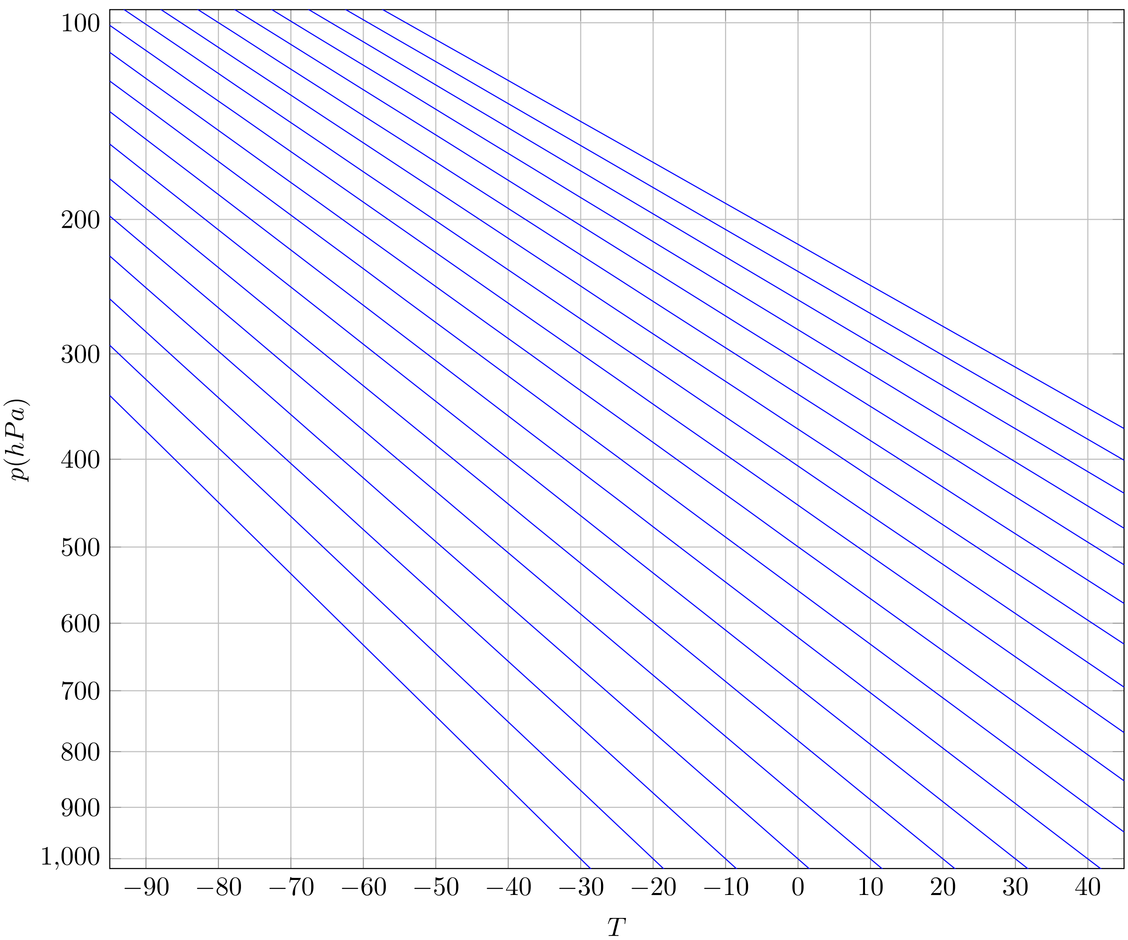
\begin{axis}[
  [...]
  y coord trafo/.code={\pgfmathparse{#1^0.286}},
  y coord inv trafo/.code={\pgfmathparse{#1^(1/0.286)}},
]
```



Isohumes calculation (Work in Progress)

First try

Given the following formula[4]:

$$r_s = \varepsilon \cdot \frac{e_s(T)}{p - e_s(T)}$$

And asuming that $e_s(T)$ is the Tetens equation[5]:

$$e_s(T) = 0.61078 \cdot \exp\left(\frac{12.27 \cdot T}{237.3 + T}\right)$$

We know that r_s refers to the x axis, and p to the y axis.

$$r_s = x; \quad p = y$$

$$x = \varepsilon \cdot \frac{e_s(T)}{y - e_s(T)}$$

Then we can solve for y:

$$x = \frac{\varepsilon \cdot e_s(T)}{y - e_s(T)}$$

$$y - e_s(T) = \frac{\varepsilon \cdot e_s(T)}{x}$$

$$y = \frac{\varepsilon \cdot e_s(T)}{x} + e_s(T)$$

$$y = \frac{(\varepsilon \cdot e_s(T)) + (x \cdot e_s(T))}{x}$$

$$y = \frac{(\varepsilon \cdot 0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3+T})) + (x \cdot 0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3+T}))}{x}$$

We also know that ε is a constant: the ratio between the gas constant for dry air and the gas constant for water vapor[6]:

$$\varepsilon = 0.622$$

We replace ε:

$$y = \frac{(0.622 \cdot 0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3+T})) + (x \cdot 0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3+T}))}{x}$$

$$y = \frac{(0.23620100952 \cdot \exp(\frac{12.27 \cdot T}{237.3+T})) + (x \cdot 0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3+T}))}{x}$$

Which we should be able to use in LaTeX:

[4] See www.igf.fuw.edu.pl/m/courses_materials.../thermodynamic_diagrams.pdf
[5] See en.wikipedia.org/wiki/Tetens_equation
[6] See pressbooks-dev.oer.hawaii.edu/atmo/chapter/chapter-4-water-vapor/

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((0.23620100952 * exp((12.27 * \T)/(237.3 + \T))) +
(x * 0.61078 * exp((12.27 * \T)/(237.3 + \T))) / x) * 10
```

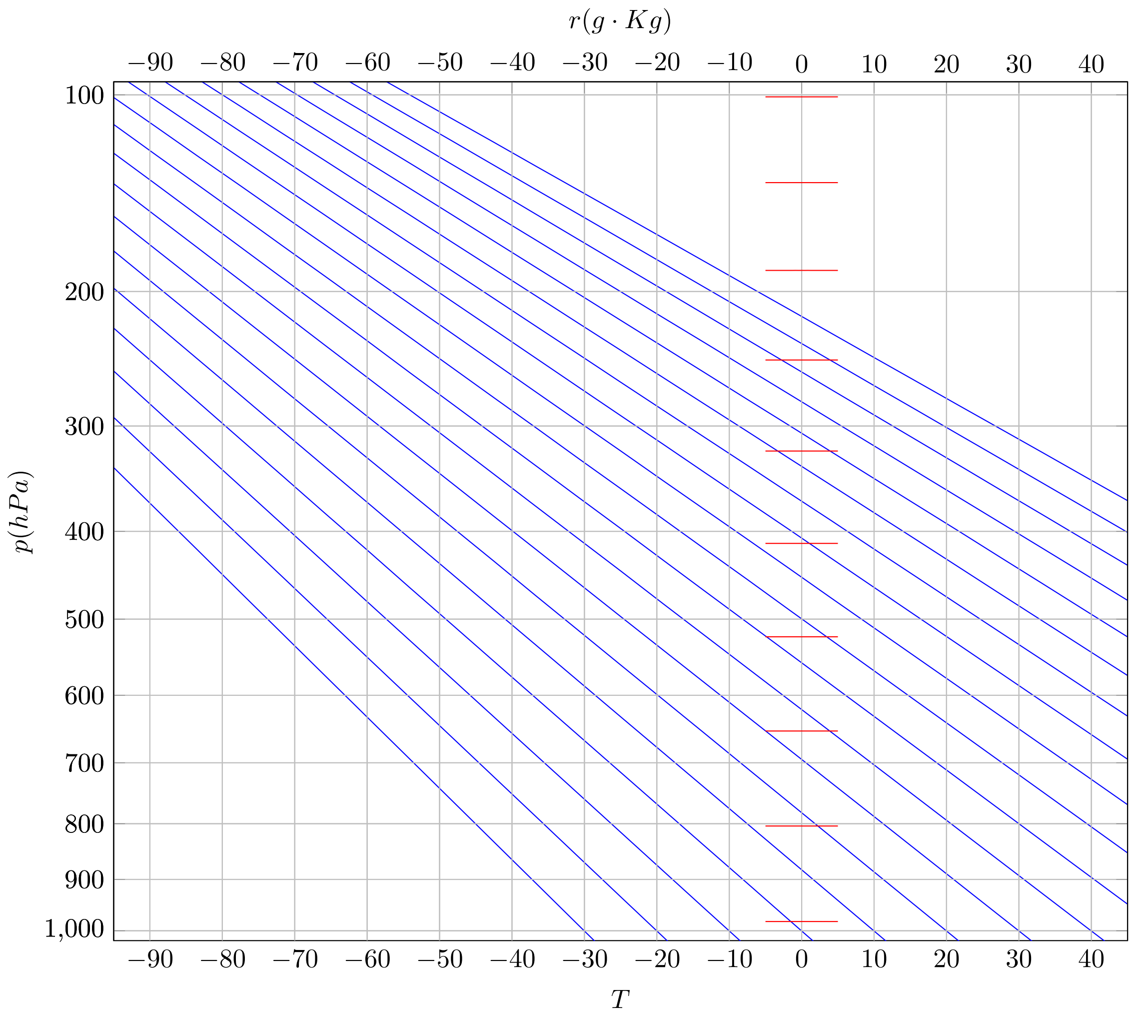

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Second try

Given the following formula[7]:

$$r_s = \frac{\varepsilon \cdot e_s(T)}{p - e_s(T)}$$

And asuming that $e_s(T)$ is the Tetens equation[8]:

$$e_s(T) = 0.61078 \cdot \exp\left(\frac{12.27 \cdot T}{237.3 + T}\right)$$

We know that T refers to the x axis, and p to the y axis, so the strategy would be to solve for p.

$$r_s = \frac{\varepsilon \cdot 0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3+T})}{p - \left(0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3+T})\right)}$$

We can solve for p:

$$r_s \cdot \left(p - \left(0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3 + T})\right)\right) = \varepsilon \cdot 0.61078 \cdot \exp\left(\frac{12.27 \cdot T}{237.3 + T}\right)$$

$$p - \left(0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3 + T})\right) = \frac{\varepsilon \cdot 0.61078 \cdot \exp\left(\frac{12.27 \cdot T}{237.3+T}\right)}{r_s}$$

$$p = \frac{\varepsilon \cdot 0.61078 \cdot \exp\left(\frac{12.27 \cdot T}{237.3+T}\right)}{r_s} + \left(0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3 + T})\right)$$

$$p = \frac{\left(\varepsilon \cdot 0.61078 \cdot \exp\left(\frac{12.27 \cdot T}{237.3+T}\right)\right) + \left(r_s \cdot 0.61078 \cdot \exp(\frac{12.27 \cdot T}{237.3+T})\right)}{r_s}$$

$$T = x \qquad p = y \qquad \varepsilon = 0.622$$

$$y = \frac{\left(0.622 \cdot 0.61078 \cdot \exp\left(\frac{12.27 \cdot x}{237.3+x}\right)\right) + \left(r_s \cdot 0.61078 \cdot \exp(\frac{12.27 \cdot x}{237.3+x})\right)}{r_s}$$

Which, we should be able to use in LaTeX when passing fixed values of r_s:

$$r_s = 2$$

[7]See www.igf.fuw.edu.pl/m/courses_materials.../thermodynamic_diagrams.pdf

[8]See en.wikipedia.org/wiki/Tetens_equation

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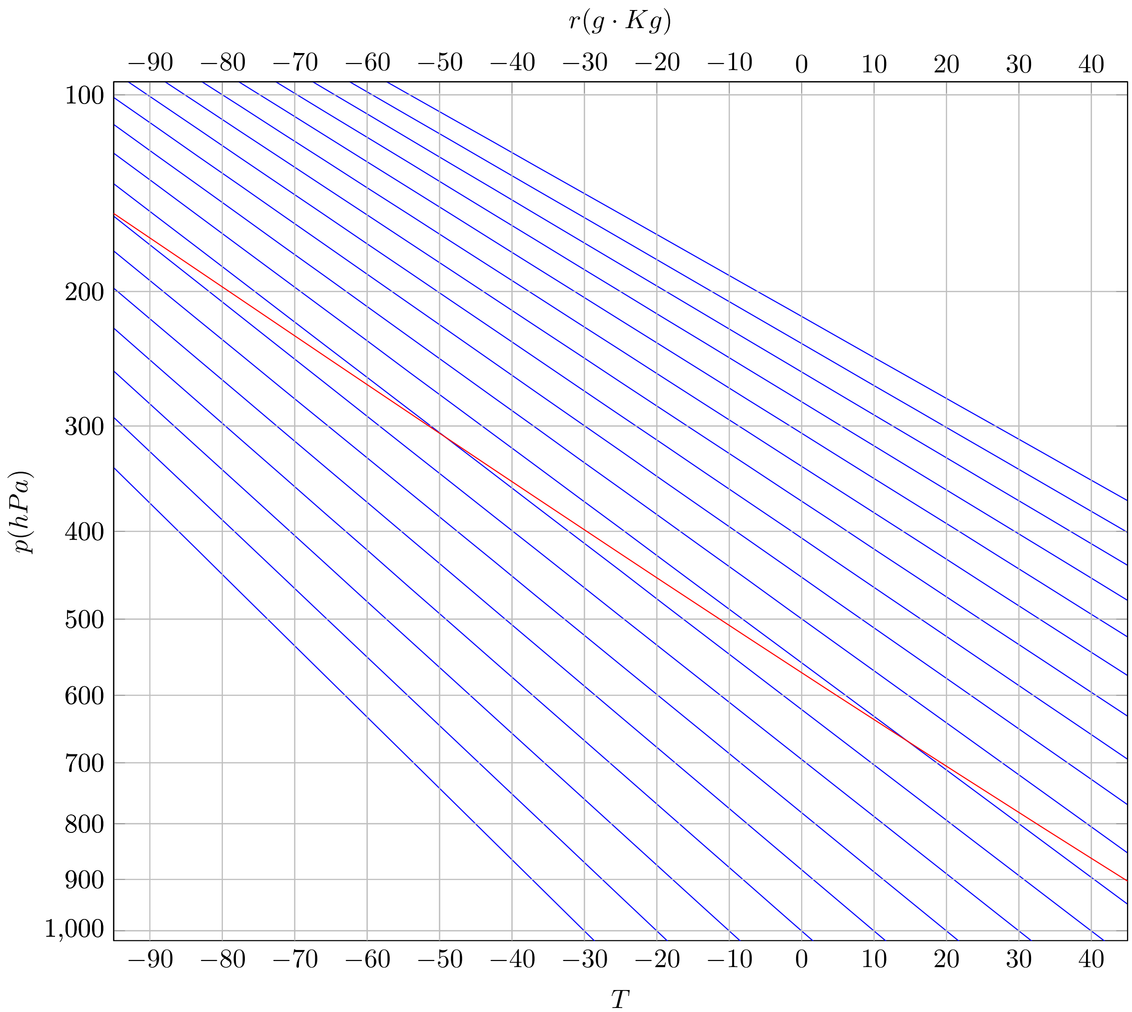
y = ( 0.622 * 0.61078 * exp( ( 12.27 * x ) / ( 237.3 + x )) + (2 * 0.61078 *
exp( ( 12.27 * x ) / ( 237.3 + x )) )) / ( 2 )
```



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Third try

Following the equation found on *Practical Meteorology: An Algebra-based Survey of Atmospheric Science*:[9]

$$T = \left[\frac{1}{T_0} - \frac{\mathfrak{R}_v}{L_v} \cdot \ln\left(\frac{r_s \cdot p}{e_0 \cdot (r_s + \varepsilon)}\right)\right]^{-1}$$

We should be able to solve for p:

$$\frac{1}{T} = \frac{1}{T_0} - \frac{\mathfrak{R}_v}{L_v} \cdot \ln\left(\frac{r_s \cdot p}{e_0 \cdot (r_s + \varepsilon)}\right)$$

$$\frac{1}{T} + \frac{\mathfrak{R}_v}{L_v} \cdot \ln\left(\frac{r_s \cdot p}{e_0 \cdot (r_s + \varepsilon)}\right) = \frac{1}{T_0}$$

$$\frac{\mathfrak{R}_v}{L_v} \cdot \ln\left(\frac{r_s \cdot p}{e_0 \cdot (r_s + \varepsilon)}\right) = \frac{1}{T_0} - \frac{1}{T}$$

$$\frac{\mathfrak{R}_v}{L_v} \cdot \ln\left(\frac{r_s \cdot p}{e_0 \cdot (r_s + \varepsilon)}\right) = \frac{T - T_0}{T \cdot T_0}$$

$$\ln\left(\frac{r_s \cdot p}{e_0 \cdot (r_s + \varepsilon)}\right) = \frac{T - T_0}{T \cdot T_0 \cdot \frac{\mathfrak{R}_v}{L_v}}$$

$$\frac{r_s \cdot p}{e_0 \cdot (r_s + \varepsilon)} = exp\left(\frac{T - T_0}{T \cdot T_0 \cdot \frac{\mathfrak{R}_v}{L_v}}\right)$$

$$r_s \cdot p = exp\left(\frac{T - T_0}{T \cdot T_0 \cdot \frac{\mathfrak{R}_v}{L_v}}\right) \cdot e_0 \cdot (r_s + \varepsilon)$$

$$p = \frac{exp\left(\frac{T - T_0}{T \cdot T_0 \cdot \frac{\mathfrak{R}_v}{L_v}}\right) \cdot e_0 \cdot (r_s + \varepsilon)}{r_s}$$

$$T_0 = 273.15 \qquad e_0 = 0.6113 \qquad \frac{\mathfrak{R}_v}{L_v} = 0.0001844 \qquad \varepsilon = 0.622$$

$$p = \frac{exp\left(\frac{T - 273.15}{T \cdot 273.15 \cdot 0.0001844}\right) \cdot 0.6113 \cdot (r_s + 0.622)}{r_s}$$

$$T = x \qquad p = y$$

[9] Stull, Roland: *Practical Meteorology: An Algebra-based Survey of Atmospheric Science*, chapter 4, p. 101, equation 4.36, 2018

$$y = \frac{exp\left(\frac{x-273.15}{x \cdot 273.15 \cdot 0.0001844}\right) \cdot 0.6113 \cdot (r_s + 0.622)}{r_s}$$

Which, we should be able to use in LaTeX when passing fixed values of r_s and converting T to Kelvin:

$$r_s = 2$$

$$y = \frac{exp\left(\frac{(x+273.15)-273.15}{(x+273.15) \cdot 273.15 \cdot 0.0001844}\right) \cdot 0.6113 \cdot (2 + 0.622)}{2}$$

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(exp(((x + 273.15) - 273.15) / ((x + 273.15) * 273.15 * 0.0001844))
* 0.6113 * (2 + 0.622 ) ) / (2)
```

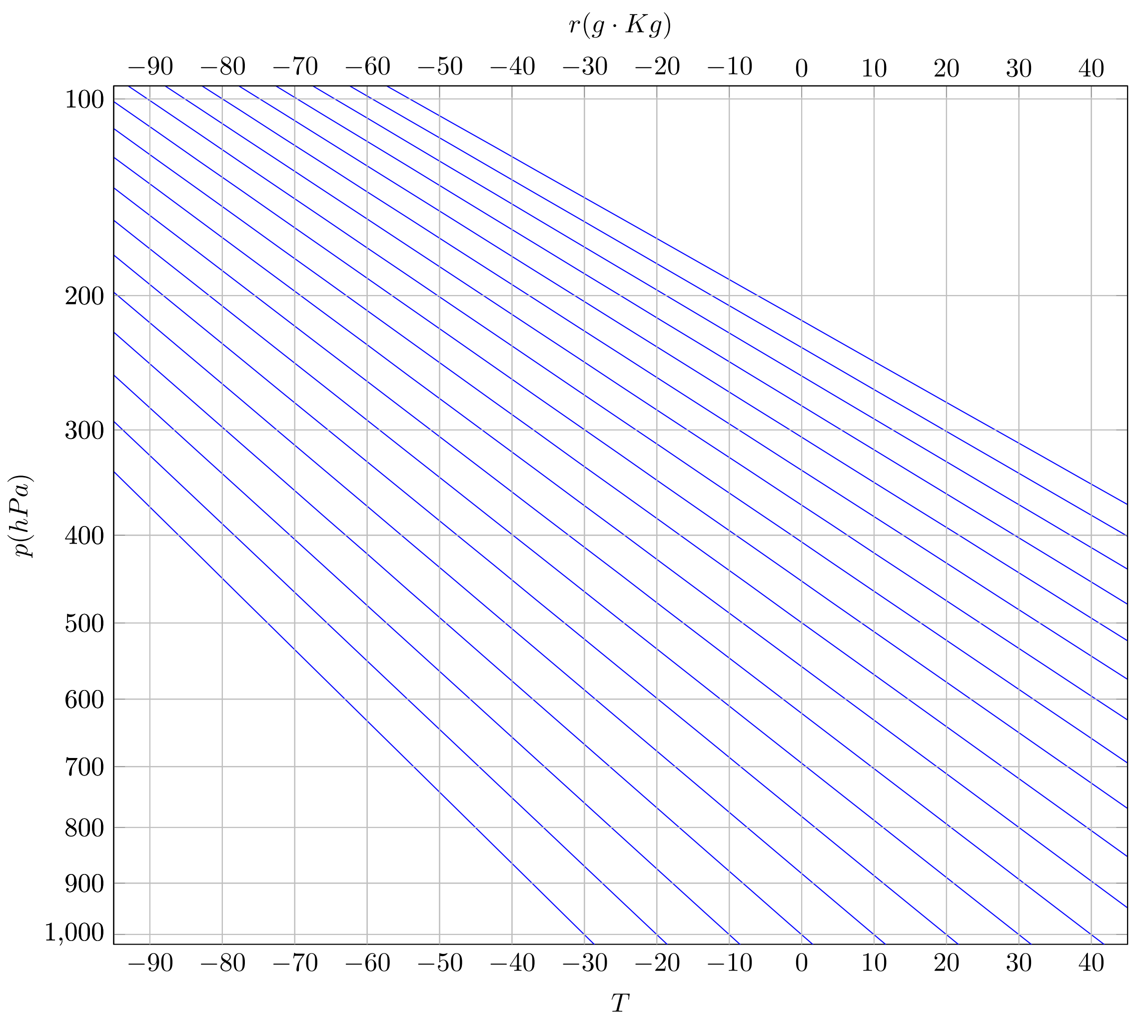

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