Daniel's github

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CONTENTS

This is where I put the documentation for my creations.

CHAPTER

ONE

INTRODUCTION

Nomographs are simple, practical tools which can be used to solve complex problems. This is a small sample of nomographs constructed with PyNomo.

CHAPTER

TWO

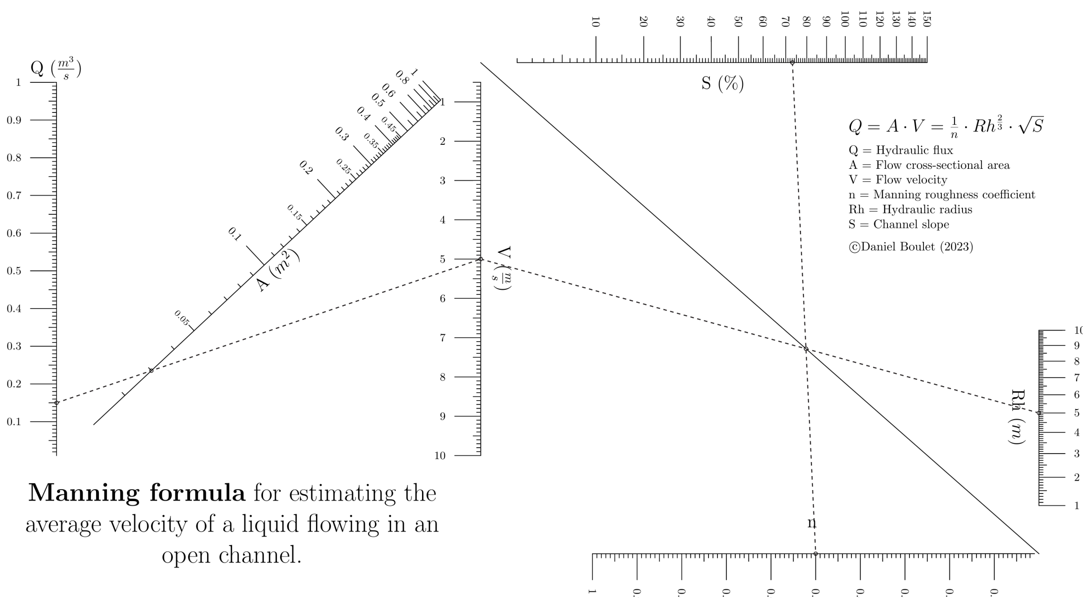
NOMOGRAPHY

A collection of my nomographic creations.

2.1 Manning Formula

The Manning formula or Manning's equation is an empirical formula estimating the average velocity of a liquid flowing in a conduit that does not completely enclose the liquid, i.e., open channel flow. However, this equation is also used for calculation of flow variables in case of flow in partially full conduits, as they also possess a free surface like that of open channel flow. All flow in so-called open channels is driven by gravity. [con]

2.1.1 Nomograph



Manning formula for estimating the average velocity of a liquid flowing in an open channel.

2.1.2 Source code

```
"""
    manning2.py

    Manning formula for open channel flow
"""
import sys
import numpy as np
from pyx import *

outputfile = sys.argv[0].split(".")[0] + ".pdf"
sys.path.insert(0, "..")
text.set(text.LatexEngine)

from pynomo.nomographer import Nomographer

hydraulic_flux = {
    "u_min": 0.01,
    "u_max": 1.0,
    "function": lambda u: u,
    "title": r"\Large Q ($\frac{m^3}{s}$)",
    "tick_levels": 3,
    "tick_text_levels": 1,
    "tick_side": "left",
}

hydraulic_area = {
    "u_min": 0.01,
    "u_max": 1.0,
    "function": lambda u: u,
    "title": r"\Large A ($m^2$)",
    "tick_levels": 3,
    "tick_text_levels": 2,
    "scale_type": "linear smart",
    "tick_side": "left",
    "title_draw_center": True,
}

cross_sectional_velocity2 = {
    "tag": "v",
    "u_min": 0.5,
    "u_max": 10.0,
    "function": lambda u: u,
    # "title": r"V ($\frac{m}{s}$)",
    "tick_levels": 3,
    "tick_text_levels": 1,
    "scale_type": "manual data",
}

flow_block = {
    "block_type": "type_2",
    "f1_params": hydraulic_flux,
```

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```
    "f2_params": hydraulic_area,
    "f3_params": cross_sectional_velocity2,
    # "mirror_x": True,
    "isopleth_values": [[0.15, 0.03, "x"]],
}

cross_sectional_velocity1 = {
    "tag": "v",
    "u_min": 0.5,
    "u_max": 10.0,
    "function": lambda u: u,
    "title": r"\Large V ($\frac{m}{s}$)",
    "tick_levels": 3,
    "tick_text_levels": 1,
    "tick_side": "left",
    "title_draw_center": True,
    "title_distance_center": -0.5,
    # "scale_type": "manual_data",
}
stream_slope = {
    "u_min": 1.0,
    "u_max": 150.0,
    "function": lambda u: pow(u / 100.0, 0.5),
    "title": r"\Large S ($\%$)",
    "tick_levels": 3,
    "tick_text_levels": 1,
    "tick_side": "left",
    "title_draw_center": True,
    "title_distance_center": 0.75,
}
hydraulic_radius = {
    "u_min": 1.0,
    "u_max": 10.0,
    "function": lambda u: pow(u, 2.0 / 3.0),
    "title": r"\Large Rh ($m$)",
    "tick_levels": 3,
    "tick_text_levels": 1,
    "tick_side": "right",
    # "title_opposite_tick": False,
    "title_draw_center": True,
    "title_distance_center": -0.75,
}
manning_coeff = {
    "u_min": 0.01,
    "u_max": 1.0,
    "function": lambda u: u,
    "title": r"\Large n",
    "tick_levels": 3,
    "tick_text_levels": 1,
    "tick_side": "right",
    "title_draw_center": True,
    "title_distance_center": 0.75,
```

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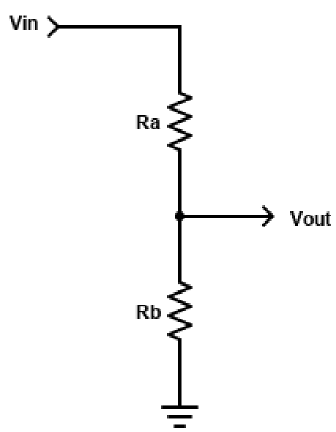
```python
    # "title_opposite_tick": False,
}

manning_block = {
    "block_type": "type_4",
    "f1_params": cross_sectional_velocity1,
    "f2_params": hydraulic_radius,
    "f3_params": stream_slope,
    "f4_params": manning_coeff,
    "padding": 0.8,
    "mirror_x": True,
    "isopleth_values": [["x", 5.0, "x", 0.5]],
}


main_params = {
    "filename": outputfile,
    "paper_height": 5.5 * 2.54,
    "paper_width": 11 * 2.54,
    # "make_grid": True,
    "block_params": [flow_block, manning_block],
    "transformations": [("rotate", 0.01), ("scale paper",)],
    "title_str": r"\huge \textbf{Manning formula} for estimating the average velocity of a liquid flowing in an open channel.",
    "title_x": 5.0,
        'title_y':1.5,
    "extra_texts": [
        {
            "x": 22.0,
            "y": 12.0,
            "text": r"\Large $Q = A \cdot V =  \frac{1}{n} \cdot Rh^\frac{2}{3} \cdot \sqrt{S} $ \normalsize \medskip \
                        \par Q = Hydraulic flux  \
                        \par A = Flow cross-sectional area \
                        \par V = Flow velocity \
                        \par n = Manning roughness coefficient \
                        \par Rh = Hydraulic radius \
                        \par S = Channel slope \
                        \par \medskip \normalsize \copyright Daniel Boulet (2023)",
            "width": 12.0,
        },
    ],
}
Nomographer(main_params)
```

2.2 Voltage Divider

2.2.1 Theory and background

In electronics, resistive voltage dividers are used for a variety of purposes. The formula for a resistive voltage divider is [Wik21c]:

$\frac{V_{out}}{V_{in}} = \frac{R_b}{(R_a+R_b)}$

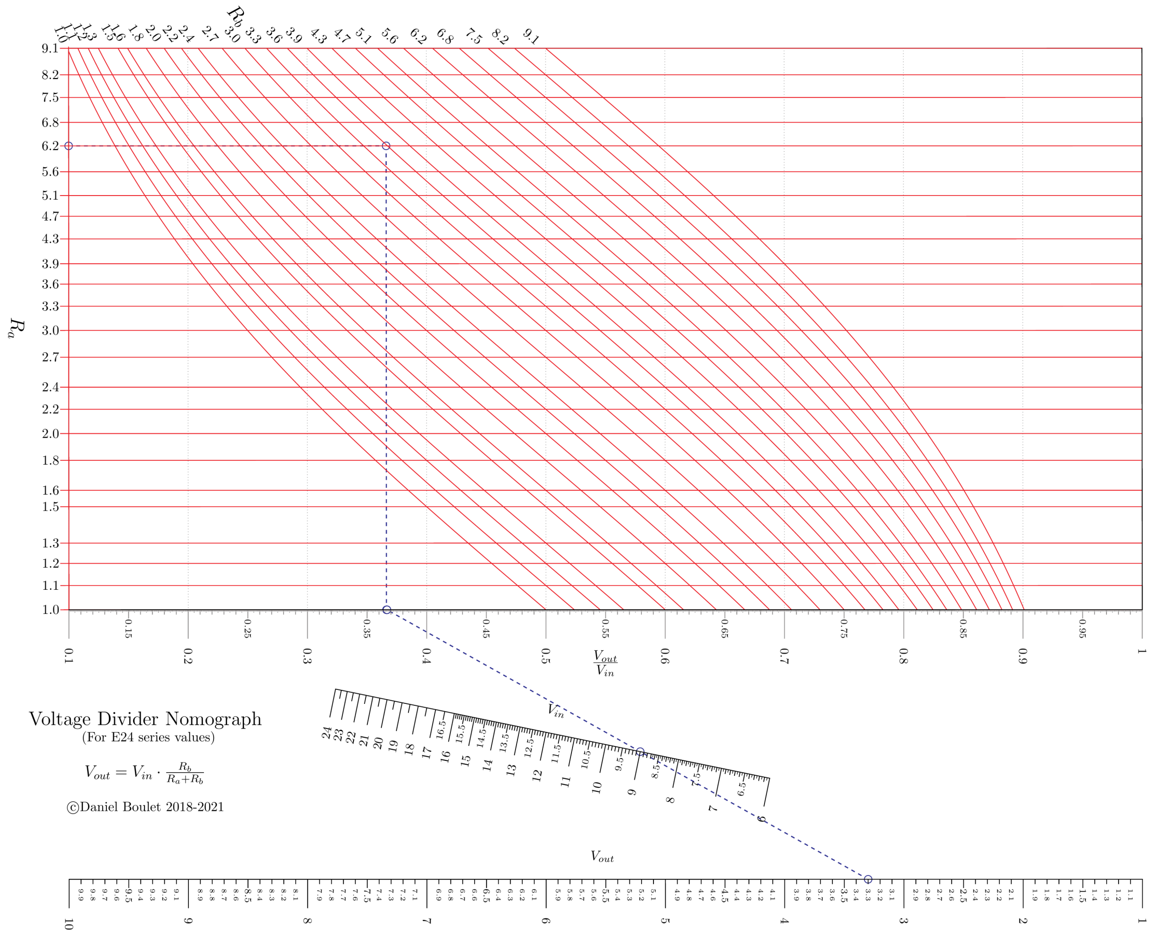


When designing voltage dividers, constraints may demand engineers choose resistors from a set of "preferred values" [Wik21b]. These values are discrete and engineers must select the best combination of resistors based on tolerance and the available preferred values. Similar voltage ratios can be obtained with different combinations of resistor values.

The voltage divider nomograph links input voltage (V_{in}), output voltage (V_{out}) and a pair of resistor values into a single nomograph. Pynomo's **Type 5** blocks are well suited for plotting relationships between pairs of discrete values. A vertical line dropped from the intersection of R_a values and R_b values reveals the V_{out} / V_{in} voltage ratio. Alignment with a **Type 2** block allows the engineer to determine V_{out} given V_{in} (or vice versa).

Of greater benefit is the ability to quickly determine the optimum pair of resistor values for a given application. For example, given an input voltage (9V) and desired output voltage (3.3V), the engineer draws a straight line from the V_{out} axis, through the V_{in} axis to the base of the voltage ratio graph. A perpendicular line is then drawn from the base to the top of the graph. The vertical line's nearest approach to the intersection of the horizontal R_a and curved R_b lines represents the best combination of resistor values. It can be quickly shown that one combination of values (R_a = 6.2 and R_b = 3.6) will produce an output voltage very close to the desired value (3.3061V).

2.2.2 Nomograph



2.2.3 Source code

```python
"""
    voltdiv_E24_resistors.py

    Nomogram to calculate resistor values for simple voltage divider.  This
    along with this program.  If not, see <http://www.gnu.org/licenses/>.
"""

from pynomo.nomographer import *
import sys
sys.path.insert(0, "..")
outputfile = sys.argv[0].split('.')[0]+'.pdf'

from pyx import *
pyx.text.set(text.LatexEngine)

import numpy as np

```

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```
resistors = [
        1.0,        1.1,        1.2,
        1.3,        1.5,        1.6,
        1.8,        2.0,        2.2,
        2.4,        2.7,        3.0,
        3.3,        3.6,        3.9,
        4.3,        4.7,        5.1,
        5.6,        6.2,        6.8,
        7.5,        8.2,        9.1
]

# Type 5 contour
def f1(x, u):
    return np.log10(u * (1 - x) / x)


block_1_params = {
    'width': 12.0,
    'height': 25.0,
    'block_type': 'type_5',

    'u_func': lambda u: np.log10(u),
    'u_values': resistors,
    'u_axis_color': pyx.color.cmyk.Red,
    'u_title': r'\Large{$R_a$}',
    'u_text_format': r"\normalsize{$%3.1f$}",

    'v_func': f1,
    'v_values': resistors,
    'v_axis_color': pyx.color.cmyk.Red,
    'v_title': r'\Large{$R_b$}',
    'v_text_format': r"\normalsize{$%3.1f$}",

    'wd_tag': 'A',
    'wd_tick_side': 'right',
        'wd_title':r'\Large $\frac{V_{out}}{V_{in}}$',
    'wd_tick_levels': 5,
    'wd_tick_text_levels': 2,
    'wd_title_opposite_tick': True,
    'wd_axis_color': pyx.color.cmyk.Gray,
    'isopleth_values': [
        [6.2, 'x', 'x'],
    ],
    'vertical_guide_nr': 10,
        'manual_x_scale': True,                # trick to "decompress" Ra scale

}

# this is non-obvious trick to find bottom edge coordinates of the grid in order
# to align it with N nomogram
block1_dummy = Nomo_Block_Type_5(mirror_x=False)
block1_dummy.define_block(block_1_params)
```

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```
block1_dummy.set_block()

# Let's define the N-nomogram
N_params_3 = {
    'u_min': block1_dummy.grid_box.params_wd['u_min'],
    'u_max': block1_dummy.grid_box.params_wd['u_max'],
    'function': lambda u: u,
    'title': '',
    'tag': 'A',
    'tick_side': 'right',
    'tick_levels': 2,
    'tick_text_levels': 2,
    'reference': False,
    'tick_levels': 0,
    'tick_text_levels': 0,
    'title_draw_center': True
}
N_params_2 = {
    'u_min': 6.0,
    'u_max': 24.0,
    'function': lambda u: u,
    'title': r'$V_{in}$',
    'tag': 'none',
    'tick_side': 'left',
    'tick_levels': 4,
    'tick_text_levels': 3,
    'title_draw_center': True,
    'scale_type': 'linear smart',
}
N_params_1 = {
    'u_min': 1.0,
    'u_max': 10.0,
    'function': lambda u: u,
    'title': r'$V_{out}$',
    'tag': 'none',
    'scale_type': 'linear smart',
    'tick_side': 'right',
    'tick_levels': 3,
    'tick_text_levels': 3,
    'title_draw_center': True
}

block_2_params = {
    'block_type': 'type_2',
    'f1_params': N_params_1,
    'f2_params': N_params_2,
    'f3_params': N_params_3,
    'isopleth_values': [
        # Vout, Vin, ratio
        [3.3, 9.0, 'x'],
    ]
}
```

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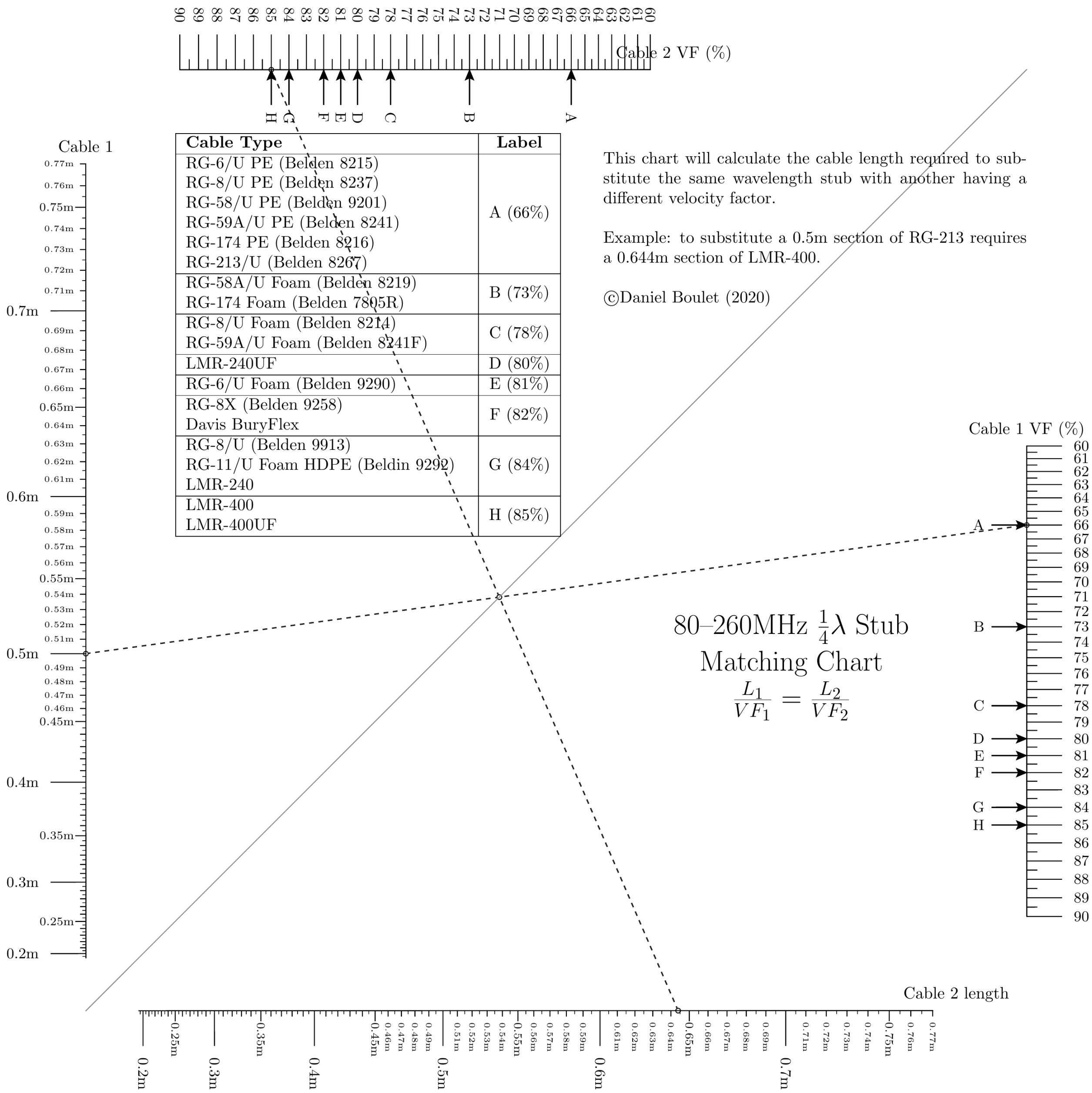
```

main_params = {
        # 'make_grid': True,
    'filename': outputfile,
    'paper_height': 8.5*2.54,
    'paper_width': 11.0*2.54,
    'block_params': [block_1_params, block_2_params],
    'transformations': [('rotate', 0.01), ('scale paper',)],
    'title_str': r'\Large Voltage Divider Nomograph \par \
        \normalsize (For E24 series values) \par \bigskip \
        \large $V_{out}=V_{in} \cdot \frac{R_b}{R_a+R_b}$ \
        \par \bigskip   \normalsize \copyright    Daniel Boulet  2018-2021',
    'title_x': 2.0,
    'title_y': 4.0,
    'isopleth_params': [
        {
            'color': 'blue',
            'linewidth': 'thick',
            'linestyle': 'dashed',
            'circle_size': 0.10,
        },
    ],
}

Nomographer(main_params)
```

2.3 Velocity Factor Calculator

$\frac{1}{4}\lambda$ matching stubs can be created with different types of coax cable. However the velocity factor of coax cables varies by type and manufacturer. This nomograph allows an engineer to substitute one type of cable for another of different length and velocity factor.

2.3.1 Nomograph



2.3.2 Source code

```python
"""
    vf_calculator.py

    Stub matching nomogram for 80 to 260 MHz range.
"""

from pynomo.nomographer import Nomographer
```

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```
import sys
from pyx import *
text.set(text.LatexEngine)
sys.path.insert(0, "..")
outputfile = sys.argv[0].split('.')[0]+'.pdf'

text.preamble(r"\usepackage{array}")

scalingFactor = 2
shortest_wavelength = 0.19250
longest_wavelength = 0.77001

stub_length_1 = {
    'u_min': shortest_wavelength,
    'u_max': longest_wavelength,
    'function': lambda u: u**scalingFactor,
    'title': r'Cable 1',
    'tick_levels': 5,
    'tick_text_levels': 4,
    'text_format': r'$%2.2g$m',
    'scale_type': 'linear smart',
    'tick_side': 'left',
}
vel_factor_1 = {
    'u_min': 60,
    'u_max': 90,
    'function': lambda u: (u/100)**scalingFactor,
    'title': r'Cable 1 VF (\%)',
    'tick_levels': 3,
    'text_format': r'$%2.2g$',
    'tick_text_levels': 1,
    'scale_type': 'linear smart',
    'tick_side': 'right',
    'extra_params': [
        {
            'scale_type': 'manual arrow',
            'arrow_length': 0.75,
            'manual_axis_data': {
                66: r'A',
                73: r'B',
                78: r'C',
                80: r'D',
                81: r'E',
                82: r'F',
                84: r'G',
                85: r'H',
            },
            'tick_side': 'left'
        }
    ]
}

```

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```
stub_length_2 = {
    'u_min': shortest_wavelength,
    'u_max': longest_wavelength,
    'function': lambda u: u**scalingFactor,
    'title': r'Cable 2 length',
    'tick_levels': 5,
    'tick_text_levels': 4,
    'text_format': r'$%2.2g$m',
    'scale_type': 'linear smart',
    'tick_side': 'right',
    'title_x_shift': 0.5,
    'title_rotate_text': True,
}
vel_factor_2 = {
    'u_min': 60,
    'u_max': 90,
    'function': lambda u: (u/100)**scalingFactor,
    'title': r'Cable 2 VF (\%)',
    'tick_levels': 5,
    'tick_text_levels': 4,
    'scale_type': 'linear smart',
    'tick_side': 'left',
    'title_rotate_text':True,
    'title_x_shift': 0.5,
    'extra_params': [
        {
            'scale_type': 'manual arrow',
            'arrow_length': 0.75,
            'manual_axis_data': {
                66: r'A',
                73: r'B',
                78: r'C',
                80: r'D',
                81: r'E',
                82: r'F',
                84: r'G',
                85: r'H',
            },
            'tick_side': 'right'
        }
    ]

}

block_1_params = {
    'block_type': 'type_4',
    'f1_params': stub_length_1,
    'f2_params': vel_factor_1,
    'f3_params': stub_length_2,
    'f4_params': vel_factor_2,
    'isopleth_values': [[0.5, 66, 'x', 85]],
    'reference_color': color.cmyk.Gray
```

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```
}

main_params = {
    'filename': outputfile,
    'paper_height': 20.0,
    'paper_width': 20.0,
    'block_params': [block_1_params],
    'transformations': [('rotate', 0.01), ('scale paper',)],
    'title_box_width':7.0,
    'title_str': r'\LARGE 80--260MHz $\frac{1}{4}\lambda$ Stub Matching Chart \par $\frac{L_1}{VF_1}=\frac{L_2}{VF_2}$',
    'title_x':15.0,
    'title_y': 8.0,
    # 'make_grid': True,
    'extra_texts': [
        {
            'x': 1,
            'y': 19,
            'text': r'\begin{center} \begin{tabular}{| m{6cm} | c | } \hline \bf{Cable Type} & \bf{Label} \\                    \hline RG-6/U PE (Belden 8215) \newline RG-8/U PE (Belden 8237) \newline RG-58/U PE (Belden 9201) \newline RG-59A/U PE (Belden 8241) \newline RG-174 PE (Belden 8216) \newline RG-213/U (Belden 8267) & A (66\%)  \\          \hline RG-58A/U Foam (Belden 8219) \newline RG-174 Foam (Belden 7805R) & B (73\%) \\                    \hline RG-8/U Foam (Belden 8214) \newline RG-59A/U Foam (Belden 8241F) & C (78\%) \\                  \hline LMR-240UF & D (80\%) \\              \hline RG-6/U Foam (Belden 9290) & E  (81\%) \\                 \hline RG-8X (Belden 9258) \newline Davis BuryFlex & F (82\%)  \\                 \hline RG-8/U (Belden 9913) \newline RG-11/U Foam HDPE (Beldin 9292) \newline LMR-240 & G (84\%) \\ \hline LMR-400 \newline LMR-400UF & H (85\%) \\ \hline \end{tabular} \end{center}',
            'width': 10.0,
        },
        {
            'x': 11.0,
            'y': 18,
            'text': r'\noindent This chart will calculate the cable length required to substitute the same wavelength stub with another having a different velocity factor. \newline \newline Example: to substitute a 0.5m section of RG-213 requires a 0.644m section of LMR-400. \newline \newline \copyright Daniel Boulet (2020)',
            'width': 9.0,
        },
    ],


}
Nomographer(main_params)
```

2.4 True VSWR Calculator

2.4.1 Introduction

Amateur radio operators frequently design and build their own antennae. An important performance characteristic of any antenna system is the **Voltage Standing Wave Ratio** (VSWR). The VSWR is a measure of the impedance match between the signal source (transmitter) and the load (antenna). Maximum power transfer from transmitter to antenna occurs when the source's output impedance matches the load's input impedance. A VSWR of 1:1 or simply "1" indicates a perfect match.

2.4.2 VSWR, Return Loss and Cable Attentuation

The VSWR is calculated from the forward and reflected power as follows [Wik21a]:

$VSWR = \frac{1+\sqrt{P_r/P_f}}{1-\sqrt{P_r/P_f}}$.

Return loss (RL) is also an indicator of antenna performance. It is the ratio of forward power to reflected power expressed in decibels (dB) [EN21]:

$RL = 10\log_{10}\frac{P_f}{P_r}$

where P_f and P_r are respectively forward and reflected power in Watts. By converting forward and reflected power readings to a decibel value referenced to 1W (0 dBW) the return loss can be expressed as:

$RL = P_f - P_r$ (dB)

Return loss and VSWR are related [EN21] by the following formulae:

$RL = -20 \times \log_{10}\frac{VSWR-1}{VSWR+1}$

and

$VSWR = \frac{10^{\frac{RL}{20}}+1}{10^{\frac{RL}{20}}-1}$.

A high return loss (>30dB) indicates a high ratio of forward power to reflected power therefore a good impedance match. A return loss approaching 0dB means the reflected power is nearly equal to the forward power indicating a mismatch.

2.4.3 Cable loss and impact on VSWR

VSWR is a useful indicator of power transfer but measured results can be misleading. The transmission line connecting the transmitter to the antenna will introduce some loss therefore the RF power reaching the antenna will be lower than the RF power delivered by the transmitter. Similarly, the power reflected by the antenna will also have been attenuated by the transmission line before it returns to the power meter. The combined effect of attenuated forward and reflected power will make it appear as though the VSWR is lower than it would be if measured at the antenna. It isn't practical to install a power meter at the antenna but the true VSWR can be calculated based on measured VSWR and known cable losses.

Cable attenuation is specified in dB per unit length. Cable attentuation for LMR®-195 is based on the following formula [Sys]:

$Loss = (0.356859) \times \sqrt{f} + (0.000470) \times f$

where $Loss$ is the attentuation per 100 feet and f is the operating frequency in megahertz. Given forward and reflected power readings in dB and cable length, we can easily calculate the true return loss at the antenna:

$RL_{true} = RL_{measured} - 2 * Loss.$

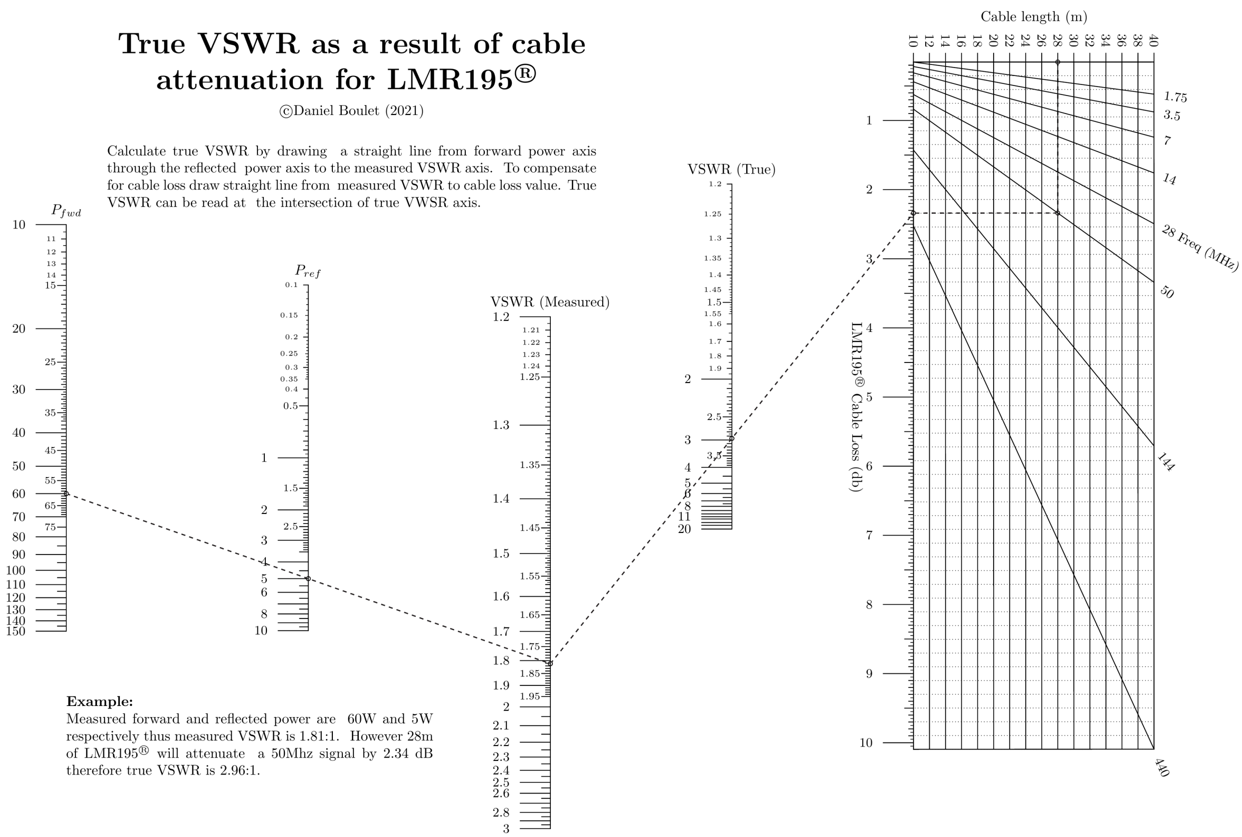
A return loss figure can then be converted to VSWR using the formula described earlier.

2.4.4 Nomograph construction

Both formulae for return loss can be easily put into a form acceptable for Type 1 block. A graph is created using a Type 5 nomograph to calculate cable losses given a length and operating frequency.

Since radio amateurs usually work in terms of power expressed in Watts and VSWR, Type 8 blocks are anchored to the Type 1 blocks to convert dbW and RL into Watts and VSWR respectively. The dB axes are hidden to minimize clutter.

2.4.5 Generated nomograph



2.4.6 Source code

```
"""
    full_vswr.py

    Nomogram to calculate VSWR at antenna given measured VSWR and feedline antenuation.
"""
import sys
import numpy as np
from pyx import *

```

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```
outputfile = sys.argv[0].split(".")[0] + ".pdf"
sys.path.insert(0, "..")
text.set(text.LatexEngine)

from pynomo.nomographer import Nomographer

minimum_return_loss = 6.0
maximum_return_loss = 40.0


# various conversion functions
def vswr2rl(vswr):
    # vswr to return loss in db
    return -20 * np.log10((vswr - 1) / (vswr + 1))


def rl2vswr(rl):
    # return loss to vswr
    return (1 + 10 ** (-rl / 20)) / (1 - 10 ** (-rl / 20))


def watts2dbw(watts):
    # watts to dbW
    return 10 * np.log10(watts)


def dbw2watts(dbw):
    # dbW to watts
    return 10 ** (dbw / 10.0)


def cableloss(freq):
    # cable loss in db per meter at freq
    # source formula is db per 100 feet
    return (np.sqrt(freq) * 0.356859 + freq * 0.000470) / 100.0 / 0.3048


# measured return loss axes and block section
axis1_forward_power_meas_watts = {
    "tag": "axis14",
    "u_min": 10.0,
    "u_max": 150.0,
    "title": r"$P_{fwd}$",
    "tick_levels": 5,
    "tick_text_levels": 4,
    "function": lambda u: watts2dbw(u),
    "align_func": lambda u: watts2dbw(u),
    "scale_type": "linear smart",
    "tick_side": "left",
}

block_forward_watts = {
```

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```
    "block_type": "type_8",
    "f_params": axis1_forward_power_meas_watts,
    "isopleth_values": [["x"]],
}

axis2_reflected_power_meas_watts = {
    "tag": "axis25",
    "title": r"$P_{ref}$",
    "u_min": 0.1,
    "u_max": 10.0,
    "function": lambda u: watts2dbw(u),
    "align_func": lambda u: watts2dbw(u),
    "tick_levels": 5,
    "tick_text_levels": 4,
    "tick_side": "left",
    "scale_type": "linear smart",
}

block_reflected_watts = {
    "block_type": "type_8",
    "f_params": axis2_reflected_power_meas_watts,
    "isopleth_values": [["x"]],
}

axis3_return_loss_meas_vswr = {
    "tag": "axis36",
    "u_min": 1.2,
    "u_max": 3.0,
    "title": r"VSWR (Measured)",
    "function": lambda u: vswr2rl(u),
    "align_func": lambda u: vswr2rl(u),
    "tick_levels": 5,
    "tick_text_levels": 4,
    "tick_side": "left",
    "scale_type": "linear smart",
}

block_return_loss_meas_vswr = {
    "block_type": "type_8",
    "f_params": axis3_return_loss_meas_vswr,
    "isopleth_values": [["x"]],
}

axis4_forward_power_meas_dbw = {
    "tag": "axis14",
    "u_min": watts2dbw(10.0),
    "u_max": watts2dbw(100.0),
    "function": lambda u: -u,
    "title_draw_center": True,
    "tick_side": "left",
    "tick_levels": 5,
    "title_distance_center": 1.7,
```

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```
    "tick_text_levels": 4,
    "scale_type": "manual",
}

axis5_reflected_power_meas_dbw = {
    "tag": "axis25",
    "u_min": watts2dbw(0.1),
    "u_max": watts2dbw(7.0),
    "function": lambda u: u,
    "title_distance_center": -1.7,
    "title_draw_center": True,
    "tick_levels": 5,
    "tick_text_levels": 4,
    "scale_type": "manual",
}

axis6_return_loss_meas_dbw1 = {
    "tag": "axis36",
    "u_min": 7.0,
    "u_max": 30.0,
    "function": lambda u: u,
    "title_distance_center": 1.5,
    "title_draw_center": True,
    "tick_levels": 5,
    "tick_text_levels": 4,
    "scale_type": "manual",
}


block_measured_rl_dbw = {
    "block_type": "type_1",
    "f1_params": axis4_forward_power_meas_dbw,
    "f2_params": axis5_reflected_power_meas_dbw,
    "f3_params": axis6_return_loss_meas_dbw1,
    "height": 20.0,
    "width": 20.0,
    "isopleth_values": [[watts2dbw(60), watts2dbw(5), "x"]],
}


axis8_return_loss_true_dbw = {
    "tag": "axis8-10",
    "u_min": 1.0,
    "u_max": 30.0,
    "function": lambda u: -u,
    "title_draw_center": True,
    "tick_levels": 5,
    "title_distance_center": 1.5,
    "tick_text_levels": 4,
    "scale_type": "manual",
}

```

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```
axis10_return_loss_true_vswr = {
    "tag": "axis8-10",
    "u_min": 1.2,
    "u_max": 20.0,
    "title": r"VSWR (True)",
    "function": lambda u: vswr2rl(u),
    "align_func": lambda u: vswr2rl(u),
    "tick_side": "left",
    "tick_levels": 5,
    "tick_text_levels": 4,
    "scale_type": "linear smart",
}

block_return_loss_true_vswr = {
    "block_type": "type_8",
    "f_params": axis10_return_loss_true_vswr,
    "isopleth_values": [["x"]],
}


axis9_cable_loss = {
    "tag": "axis9",
    "u_min": 0.0,
    "u_max": 10.0,
    "function": lambda u: -2.0 * u,
    "title_distance_center": -1.5,
    "title_draw_center": True,
    "tick_levels": 5,
    "tick_text_levels": 4,
    "scale_type": "manual",
}

block_true_rl_dbw = {
    "block_type": "type_1",
    "f1_params": axis6_return_loss_meas_dbw1,
    "f2_params": axis8_return_loss_true_dbw,
    "f3_params": axis9_cable_loss,
    "isopleth_values": [["x", "x", "x"]],
}

# cable loss block using type 5
block_cable_loss = {
    "block_type": "type_5",
    "u_func": lambda u: u,
    "u_values": list(np.linspace(10.0, 40.0, 16)),
    "u_scale_type": "manual point",
    "u_title_distance_center": 1.0,
    "u_title": "Cable length (m)",
    "v_func": lambda x, v: x / cableloss(v),
    "v_values": [1.75, 3.5, 7.0, 14.0, 28.0, 50.0, 144.0, 440.0],
    "v_title": "Freq (MHz)",
    "wd_tick_levels": 4,
```

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```
    "wd_tick_text_levels": 1,
    "wd_tick_side": "left",
    "wd_title": r"LMR195\textsuperscript{\textregistered} Cable Loss (db)",
    "wd_title_opposite_tick": True,
    "wd_tag": "axis9",
    "isopleth_values": [[28, 50, "x"]],
}

main_params = {
    "filename": outputfile,
    "paper_height": 8.0 * 2.54,
    "paper_width": 10.5 * 2.54,
    "block_params": [
        block_measured_rl_dbw,
        block_true_rl_dbw,
        block_reflected_watts,
        block_forward_watts,
        block_return_loss_meas_vswr,
        block_return_loss_true_vswr,
        block_cable_loss,
    ],
    "transformations": [("rotate", 0.01), ("scale paper",)],
    "title_str": r"\huge \textbf{True VSWR as a result of cable attenuation for LMR195\textsuperscript{\textregistered}} \
                \par\medskip \normalsize \copyright Daniel Boulet (2021)",
    "title_x": 7.0,
    "title_y": 19.0,
    "title_box_width": 12.0,
    "extra_texts": [
        {
            "x": 1.0,
            "y": 16.5,
            "text": r"\noindent Calculate true VSWR by drawing \
                            a straight line from forward power axis through the reflected \
                            power axis to the measured VSWR axis. \
                            To compensate for cable loss draw straight line from \
                            measured VSWR to cable loss value.  True VSWR can be read at \
                            the intersection of true VWSR axis.",
            "width": 12.0,
        },
        {
            "x": 0.0,
            "y": 3.0,
            "text": r"\noindent \textbf{Example:} \
                            \par \noindent Measured forward and reflected power are \
                            60W and 5W respectively thus measured VSWR is 1.81:1. \
                            However 28m of LMR195\textsuperscript{\textregistered} will attenuate \
                            a 50Mhz signal by 2.34 dB therefore true VSWR is 2.96:1.",
```

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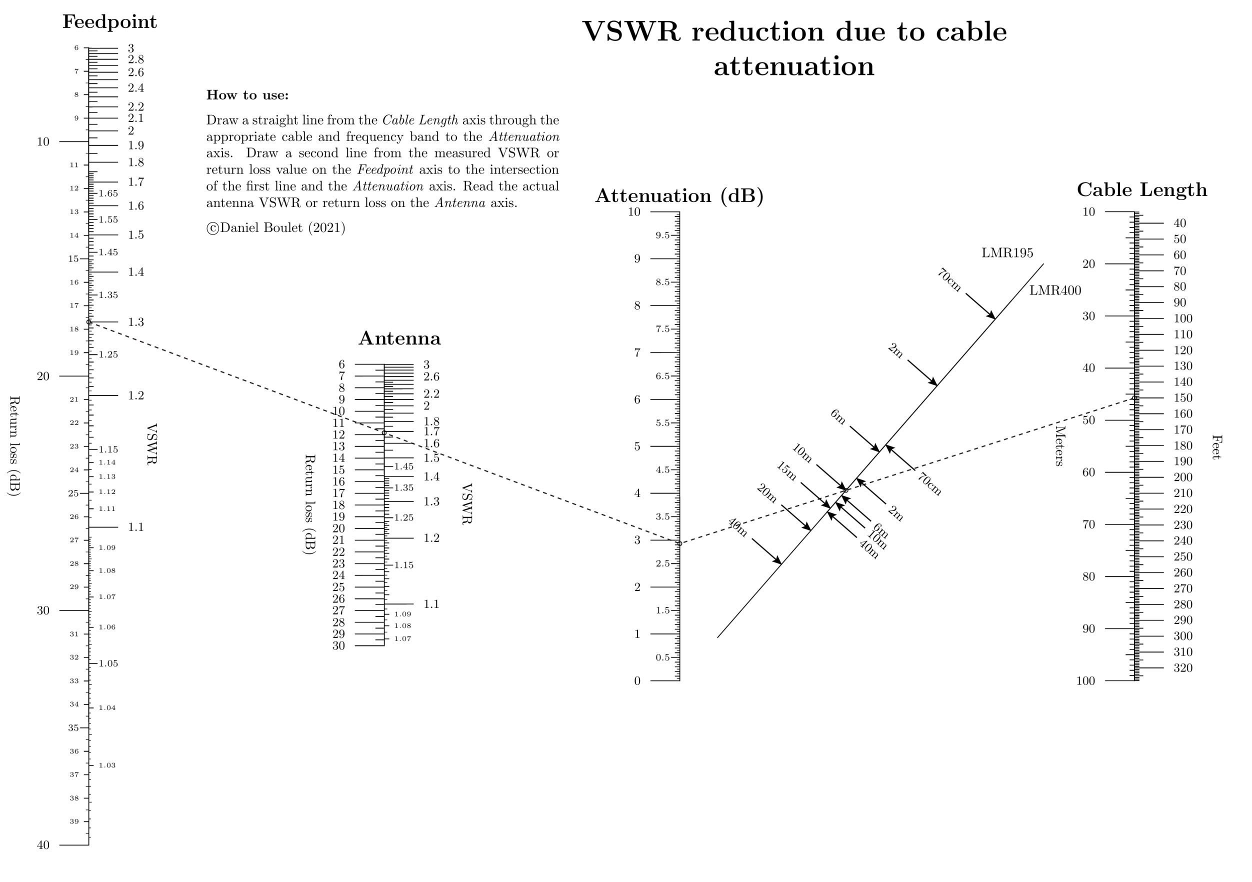
```
            "width": 9.0,
        },
    ],
    # "make_grid": True,
}
Nomographer(main_params)
```

2.5 Return Loss Calculator

The Return Loss Calculator performs the same calculations as the True VSWR calculator but presents the results differently. The Return Loss Calculator allows for direct conversion of VSWR to Return Loss and vice versa. Two cable types are also offered on the right-hand portion of the nomograph. The frequency is choosen by amateur band. Missing from this nomograph is the ability to calcuate VSWR from forward and reflected power readings.

2.5.1 Nomograph



2.5.2 Source code

```
"""
    return_loss.py

    Nomogram to calculate VSWR at antenna given measured VSWR and feedline antenuation.
"""
import sys
import numpy as np
from pyx import *

outputfile = sys.argv[0].split('.')[0]+'.pdf'
sys.path.insert(0, "..")
text.set(text.LatexEngine)

from pynomo.nomographer import Nomographer

minimum_return_loss = 6.0
maximum_return_loss = 40.0


# functions to convert return loss to VSWR and vice-versa


def vswr2rl(vswr):
    return -20 * np.log10((vswr - 1) / (vswr + 1))


def rl2vswr(rl):
    return (1 + 10 ** (-rl / 20)) / (1 - 10 ** (-rl / 20))


# main block items

measured_rl = {
    "tag": "measured",
    "u_min": minimum_return_loss,
    "u_max": maximum_return_loss,
    "function": lambda u: u,
    "scale_type": "linear smart",
    "title": r"Return loss (dB)",
    "title_relative_offset": (0, 1.5),
    "title_draw_center": True,
    "tick_side": "left",
    "tick_levels": 4,
    "tick_text_levels": 3,
    "extra_titles": [
        {
            "dx": -1.2,
            "dy": 0.5,
            "text": r"\Large \textbf{Feedpoint}",
            # 'width':5.0,
        }
```

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```
    ],
}


antenna_rl = {
    "tag": "antenna",
    "u_min": 6,
    "u_max": 30,
    "scale_type": "linear smart",
    "function": lambda u: -u,
    "title": r"Return loss (dB)",
    "title_draw_center": True,
    "extra_titles": [
        {
            "dx": -1.2,
            "dy": 0.5,
            "text": r"\Large \textbf{Antenna}",
            # 'width':5.0,
        }
    ],
    "title_relative_offset": (0, 1.5),
    "tick_levels": 2,
    "tick_text_levels": 1,
    "tick_side": "left",
}

cable_loss = {
    "tag": "cable_loss",
    "u_min": 0,
    "u_max": 10.0,
    "scale_type": "linear smart",
    "function": lambda u: -2 * u,
    "title": r"\Large \textbf{Attenuation (dB)}",
    "title_relative_offset": (0, -2.5),
    # "title_draw_center": True,
    "tick_side": "left",
    "tick_levels": 4,
    "tick_text_levels": 3,
    # "extra_params": [
    #     {
    #         "scale_type": "manual arrow",
    #                 'tick_side':'right',
    #         "manual_axis_data": {
    #             8.5: "100ft LMR195 70cm band",
    #         },
    #     }
    # ],
}

main_block = {
    "block_type": "type_1",
    "f1_params": measured_rl,
```

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```
    "f3_params": cable_loss,
    "f2_params": antenna_rl,
    "isopleth_values": [["x", "x", 'x']],
    "mirror_y": True,
}

# measured vswr items
measured_vswr = {
    "tag": "measured",
    "u_min": rl2vswr(maximum_return_loss),
    "u_max": rl2vswr(minimum_return_loss),
    "function": lambda u: vswr2rl(u),
    "align_func": lambda u: vswr2rl(u),
    "title": r"VSWR",
    "title_draw_center": True,
    "title_relative_offset": (0, 1),
    "tick_levels": 6,
    "tick_text_levels": 3,
    "scale_type": "linear smart",
    "tick_side": "right",
}

measured_vswr_block = {
    "block_type": "type_8",
    "f_params": measured_vswr,
    "isopleth_values": [[1.3]],
}

# antenna vswr items

antenna_vswr = {
    "tag": "antenna",
    "u_min": rl2vswr(30),
    "u_max": rl2vswr(6),
    "function": lambda u: vswr2rl(u),
    "align_func": lambda u: vswr2rl(u),
    "title": r"VSWR",
    "title_relative_offset": (0, 1.5),
    "title_draw_center": True,
    "tick_levels": 6,
    "tick_text_levels": 3,
    "scale_type": "linear smart",
    "tick_side": "right",
}

antenna_vswr_block = {
    "block_type": "type_8",
    "f_params": antenna_vswr,
    "isopleth_values": [["x"]],
}

# cable loss items (type 2 block)
```

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```
cable_loss_arrows = {
    "tag": "cable_loss",
    "u_min": 0.0,
    "u_max": 10.0,
    "function": lambda u: u,
    # "title": r"cable loss",
    "tick_levels": 3,
    "tick_text_levels": 1,
    "scale_type": "manual",
}

loss_per_unit_length_lmr195 = {
    "tag": "cable_type",
    "u_min": 1.0,
    "u_max": 30.0,
    "function": lambda u: u,
    "align_function": lambda u: u,
    "title": r"LMR195",
    "title_rotate_text": True,
    "title_x_shift": -0.1,
    "title_y_shift": 1.1,
    # "title_draw_center": True,
    "tick_levels": 3,
    "tick_text_levels": 2,
    "tick_side": "left",
    "scale_type": "manual arrow",
    "manual_axis_data": {
        3.2: r"40m",
        4.5: r"20m",
        5.5: r"15m",
        6.4: r"10m",
        8.7: r"6m",
        14.5: r"2m",
        25.2: r"70cm",
    },
    # "title_relative_offset": (0, 0),
}

loss_per_unit_length_lmr400 = {
    "tag": "cable_type",
    "u_min": 1.0,
    "u_max": 30.0,
    "function": lambda u: u,
    "align_function": lambda u: u,
    "title": r"LMR400",
    "title_rotate_text": True,
    "title_x_shift": 0.3,
    "title_y_shift": -0.8,
    # "title_draw_center": True,
    "tick_levels": 3,
    "tick_text_levels": 2,
    "tick_side": "right",
```

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```
    "scale_type": "manual arrow",
    "manual_axis_data": {
        1.1: r"40m",
        # 1.5: r"20m",
        # 1.9: r"15m",
        2.2: r"10m",
        3.0: r"6m",
        5.0: r"2m",
        8.9: r"70cm",
    },
    # "title_relative_offset": (0, -2.5),
}

length_meters = {
    "tag": "clength",
    "u_min": 10.0,
    "u_max": 100.0,
    "function": lambda u: u / 100.0,
    "title": r"Meters",
    "tick_levels": 3,
    "tick_text_levels": 1,
    "title_draw_center": True,
    "tick_side": "left",
    "title_relative_offset": (0, 1.5),
    "extra_titles": [
        {
            "dx": -2.0,
            "dy": 0.4,
            "text": r"\Large \textbf{Cable Length}",
        }
    ],
}

length_feet = {
    "tag": "clength",
    "u_min": 10.0 / 0.3048,
    "u_max": 100.0 / 0.3048,
    "function": lambda u: u,
    "align_func": lambda u: u * 0.3048,
    "title": r"Feet",
    "title_draw_center": True,
    "tick_levels": 3,
    "tick_text_levels": 1,
    "title_relative_offset": (0, -2.5),
}
cable_parameters = {
    "block_type": "type_2",
    # "width": 10.0,
    # "height": 10.0,
    "f1_params": cable_loss_arrows,
    "f2_params": loss_per_unit_length_lmr195,
    "f3_params": length_meters,
```

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```
    'isopleth_values': [['x', 6.4, 'x']],
}

cable_parameters2 = {
    "block_type": "type_8",
    "f_params": loss_per_unit_length_lmr400,
        'isopleth_values':[['x']],
}

cable_parameters3 = {
    "block_type": "type_8",
    "f_params": length_feet,
        'isopleth_values':[[150]],
}


main_params = {
    "filename": outputfile,
    "paper_height": 8.0 * 2.54,
    "paper_width": 10.5 * 2.54,
    # "block_params": [main_block],
    "block_params": [
        main_block,
        measured_vswr_block,
        antenna_vswr_block,
        cable_parameters,
        cable_parameters2,
        cable_parameters3,
    ],
    # "block_params": [main_block,measured_vswr_block],
    "transformations": [("rotate", 0.01), ("scale paper",)],
    "title_str": r"\huge \textbf{VSWR reduction due to cable attenuation}",
    "title_x": 18.0,
    "title_y": 20.5,
    "extra_texts": [
        {
            "x": 3.0,
            "y": 19.0,
            "text":r"\noindent \textbf{How to use:} \
                                \par \medskip \noindent Draw a straight line from the \textit{Cable Length} axis through the appropriate cable and frequency band  to the \textit{Attenuation} axis. Draw a second line from the measured VSWR or return loss value on the \textit{Feedpoint} axis to the intersection of the first line and the \textit{Attenuation} axis.  Read the actual antenna VSWR or return loss on the \textit{Antenna} axis. \
                                \par \medskip \noindent  \copyright Daniel Boulet (2021)",
            "width": 9.0,
        },
    ],
    "debug": False,
    # "make_grid": True,
```

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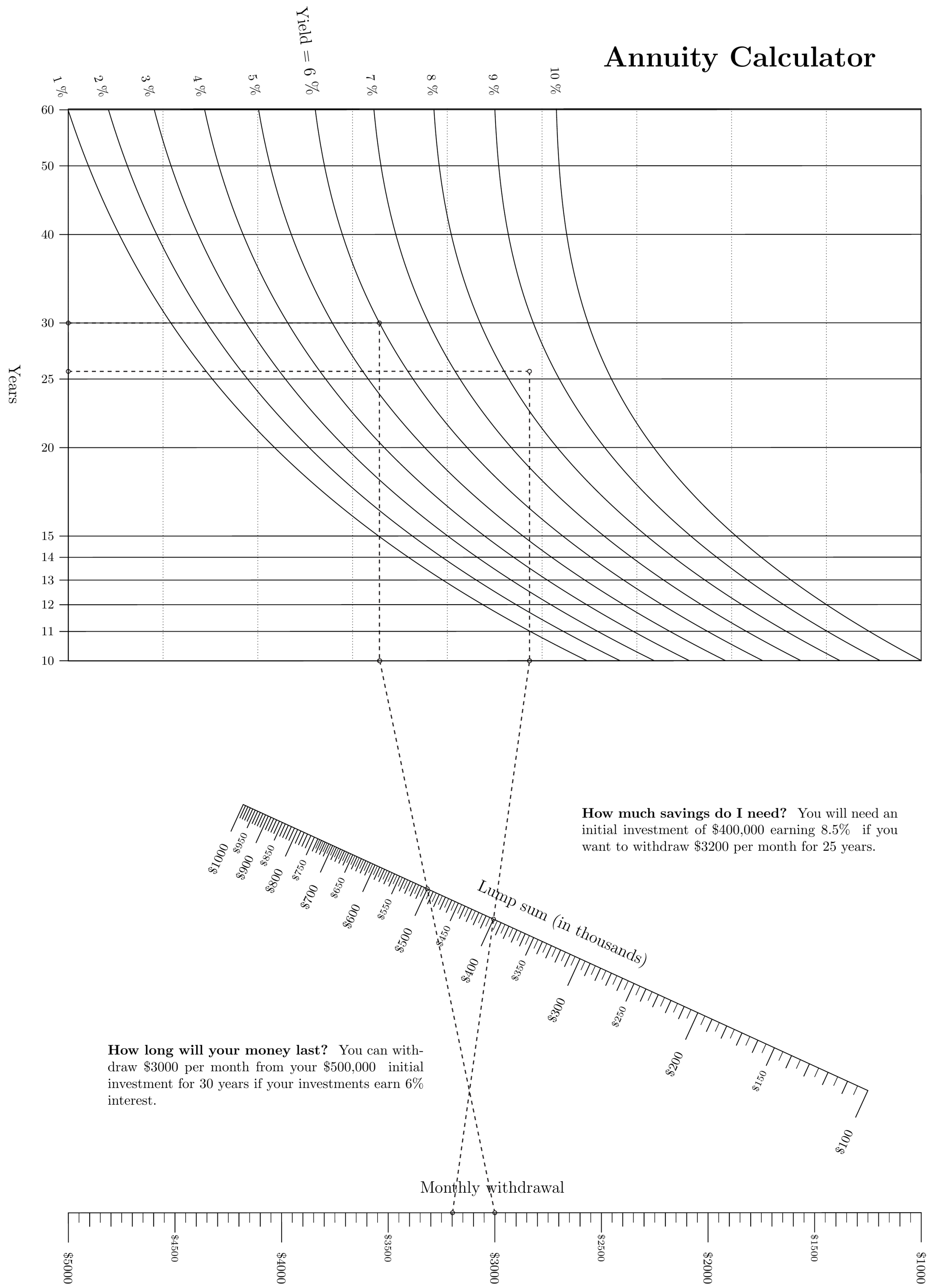
```
}

Nomographer(main_params)
```

2.6 Simple Annuity

The following nomograph is related to the amortized loan calculator example in the PyNomo documentation. However this example calculates income from an annuity rather than the expense of a loan or mortgage.

2.6.1 Nomograph



2.6.2 Source code

```
"""
    simple_annuity.py

    ---
    You should have received a copy of the GNU General Public License
    along with this program.  If not, see <http://www.gnu.org/licenses/>.
"""

from pynomo.nomographer import *

import sys
import numpy as np
outputfile = sys.argv[0].split('.')[0]+'.pdf'

# allows use of latex commands in PyX such as \frac{a}{b} and \par
from pyx import *
pyx.text.set(text.LatexEngine)


def annuity(x, u):
    return np.log(
        np.log(-x/(u/1200.0-x))
        /
        np.log(u/1200.0+1)
    )


block_1_params = {
    'width': 10.0,
    'height': 5.0,
    'block_type': 'type_5',
    'u_func': lambda u: np.log(u*12.0),
    'v_func': annuity,
    'u_values': [10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 20.0, 25.0, 30.0, 40.0, 50.0, 60.0],
    'v_values': [1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0],
    'wd_tag': 'A',
    'u_title': r'\large Years',
    'v_title': r'\large Yield = ',
    'u_text_format': r"$%3.0f$ ",
    'v_text_format': r"$%3.0f$ \%% ",
    'vertical_guide_nr': 10,
    'horizontal_guides': False,
    'v_title_draw_center': True,
    'isopleth_values': [['x', 6, 'x'],['x',8.5,'x']], #['years','yield','ratio']
}

# this is non-obvious trick to find bottom edge coordinates of the grid in order
# to align it with N nomogram
block1_dummy = Nomo_Block_Type_5(mirror_x=False)
block1_dummy.define_block(block_1_params)
block1_dummy.set_block()
```

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```

# Let's define the N-nomogram
N_params_3 = {
    'u_min': block1_dummy.grid_box.params_wd['u_min'],
    'u_max': block1_dummy.grid_box.params_wd['u_max'],
    'function': lambda u: u,
    'title': '',
    'tag': 'A',
    'tick_side': 'right',
    'tick_levels': 2,
    'tick_text_levels': 2,
    'reference': False,
    'tick_levels': 0,
    'tick_text_levels': 0,
    # 'title_draw_center': True
}
N_params_2 = {
    'u_min': 100.0,
    'u_max': 1000.0,
    'function': lambda u: u,
    'title': r'\large Lump sum (in thousands)',
    'tag': 'none',
    'tick_side': 'left',
    'tick_levels': 4,
    'tick_text_levels': 2,
    'title_draw_center': True,
    'grid_length_1': 0.5,
    'grid_length_2': 0.35,
    'grid_length_3': 0.25,
    'text_distance_1': 0.55,
    'text_format': r"$\$%3.0f$ ",
    'scale_type': 'linear smart',
}
N_params_1 = {
    'u_min': 1000.0,
    'u_max': 5000.0,
    'function': lambda u: u/1000.0,
    'title': r'\large Monthly withdrawal',
    'tag': 'none',
    'scale_type': 'linear smart',
    'tick_side': 'right',
    'tick_levels': 4,
    'tick_text_levels': 2,
    'title_draw_center': True,
    'grid_length_1': 0.5,
    'grid_length_2': 0.35,
    'grid_length_3': 0.25,
    'text_distance_1': 0.55,
    'text_format': r"$\$%3.0f$ ",

}

```

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```
block_2_params = {
    'block_type': 'type_2',
    'width': 10.0,
    'height': 20.0,
    'f1_params': N_params_1,    # withdrawal
    'f2_params': N_params_2,    # lump sum (in thousands)
    'f3_params': N_params_3,    # curve
    'isopleth_values': [[3000, 500, 'x'], [3198.25, 400, 'x']]
}

main_params = {
    'filename': outputfile,
    'paper_height': 2.54*11,
    'paper_width': 2.54*8.5,
    # 'make_grid': True,
    'block_params': [block_1_params, block_2_params],
    'transformations': [('rotate', 0.01), ('scale paper',)],
    'title_str': r'\textbf{\huge Annuity Calculator}',
    'title_x': 17,
    'title_y': 29,
    'title_box_width': 8,
    'extra_texts': [
        {
            'text': r'\copyright Daniel Boulet (2018-2020)',
            'x': 16.5,
            'y': -2.5,
        },
        {
            'text': r'\noindent \textbf{How long will your money last?} \
                You can withdraw \$3000 per month from your \$500,000 \
                    initial investment for 30 years if your investments earn 6\% interest.',
            'x': 1,
            'y': 4,
            'width': 8,
        },
        {
            'text': r'\noindent \textbf{How much savings do I need?} \
                You will need an initial investment of \$400,000 earning 8.5\% \
                    if you want to withdraw \$3200 per month for 25 years.',
            'x': 13,
            'y': 10,
            'width': 8,
        },
    ],

}
Nomographer(main_params)
```

2.7 Gasoline Price Compare

2.7.1 Background

Comparing the unit price of a commodity with different units of measure and currencies is greatly simplified with a nomograph. In this example, cross-border travellers between the United States and Canada can easily compare the cost of gasoline (petrol) on both sides of the border. Moreover, by drawing an isopleth through the currency rate at par (1.0000) they can directly convert dollars per litre to dollars per USG. This nomograph implements the following formula:

$\frac{CAD}{L} = \frac{CAD}{USD} \times \frac{USD}{USGal} \div \frac{L}{USGal}$

This equation follows the form of a **Type 2** nomograph where:

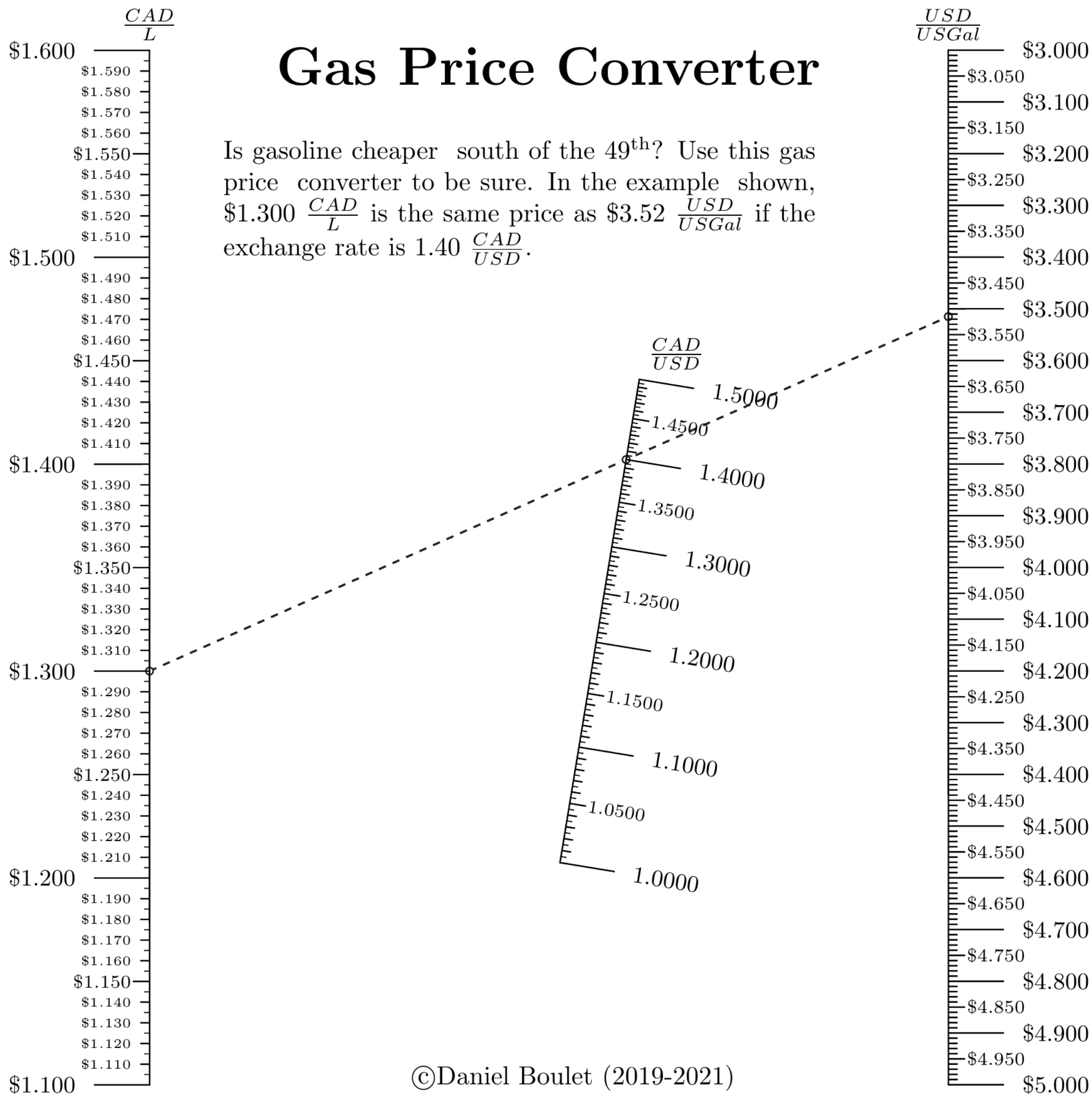
$F_1(u_1) = \frac{CAD}{L}$,

$F_2(u_2) = \frac{CAD}{USD}$

and

$F_3(u_3) = \frac{USD}{USGal} \div 3.78541 \frac{L}{USGal}$

2.7.2 Generated nomograph



2.7.3 Source code

```
"""
    gasolinepricesUSD_CAD.py

    Gasoline price converter
"""

from pynomo.nomographer import *
import sys
from pyx import *

sys.path.insert(0, "..")
outputfile = sys.argv[0].split('.')[0]+'.pdf'
```

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```

# allows use of latex commands in PyX such as \frac{a}{b} and \par
pyx.text.set(text.LatexEngine)

N_params_1 = {
    "u_min": 1.1,
    "u_max": 1.6,
    "function": lambda u: u,
    "title": r"$\frac{CAD}{L}$",
    "tick_levels": 4,
    "tick_text_levels": 3,
    "text_format": r"$\$%3.3f$",
    "scale_type": "linear smart",
    "tick_side": "left",
}

N_params_2 = {
    "u_min": 1.0,
    "u_max": 1.5,
    "function": lambda u: u,
    "title": r"$\frac{CAD}{USD}$",
    "tick_levels": 4,
    "tick_text_levels": 3,
    "text_format": r"$%3.4f$",
    "scale_type": "linear smart",
    "title_x_shift": 0.5,
    "title_rotate_text": True,
}

N_params_3 = {
    "u_min": 3.0,
    "u_max": 5.0,
    "function": lambda u: u / 3.78541,
    "title": r"$\frac{USD}{US Gal}$",
    "tick_levels": 4,
    "tick_text_levels": 2,
    "scale_type": "linear smart",
    "text_format": r"$\$%3.3f$",
    "scale_type": "linear smart",
}


block_1_params = {
    "block_type": "type_2",
    "f1_params": N_params_1,
    "f2_params": N_params_2,
    "f3_params": N_params_3,
    "isopleth_values": [[1.3, 1.4, "x"]],
}

main_params = {
    "filename": outputfile,
```

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```
    "paper_height": 11.0 * 2.54 / 2.0,
    "paper_width": 8.5 * 2.54 / 2.0,
    "block_params": [block_1_params],
    "transformations": [("rotate", 0.01), ("scale paper",)],
    "title_str": r"\huge \textbf{Gas Price Converter}",
    "title_y": 13.50,
    "title_box_width": 15.0,
    "extra_texts": [
        {
            "x": 1.0,
            "y": 12.5,
            "text": r"\noindent Is gasoline cheaper \
                south of the 49\textsuperscript{th}? Use this gas price \
                converter to be sure. In the example \
                shown, \$1.300 $\frac{CAD}{L}$ is the same price as \$3.52 $\frac{USD}{US Gal}$ if the exchange rate is 1.40  $\frac{CAD}{USD}$.",
            "width": 8.0,
        },
        {
            "text": r"\copyright Daniel Boulet (2019-2021)",
            "x": 3.0,
            "y": -0.0,
        },
    ],
    # 'make_grid': True
}
Nomographer(main_params)
```

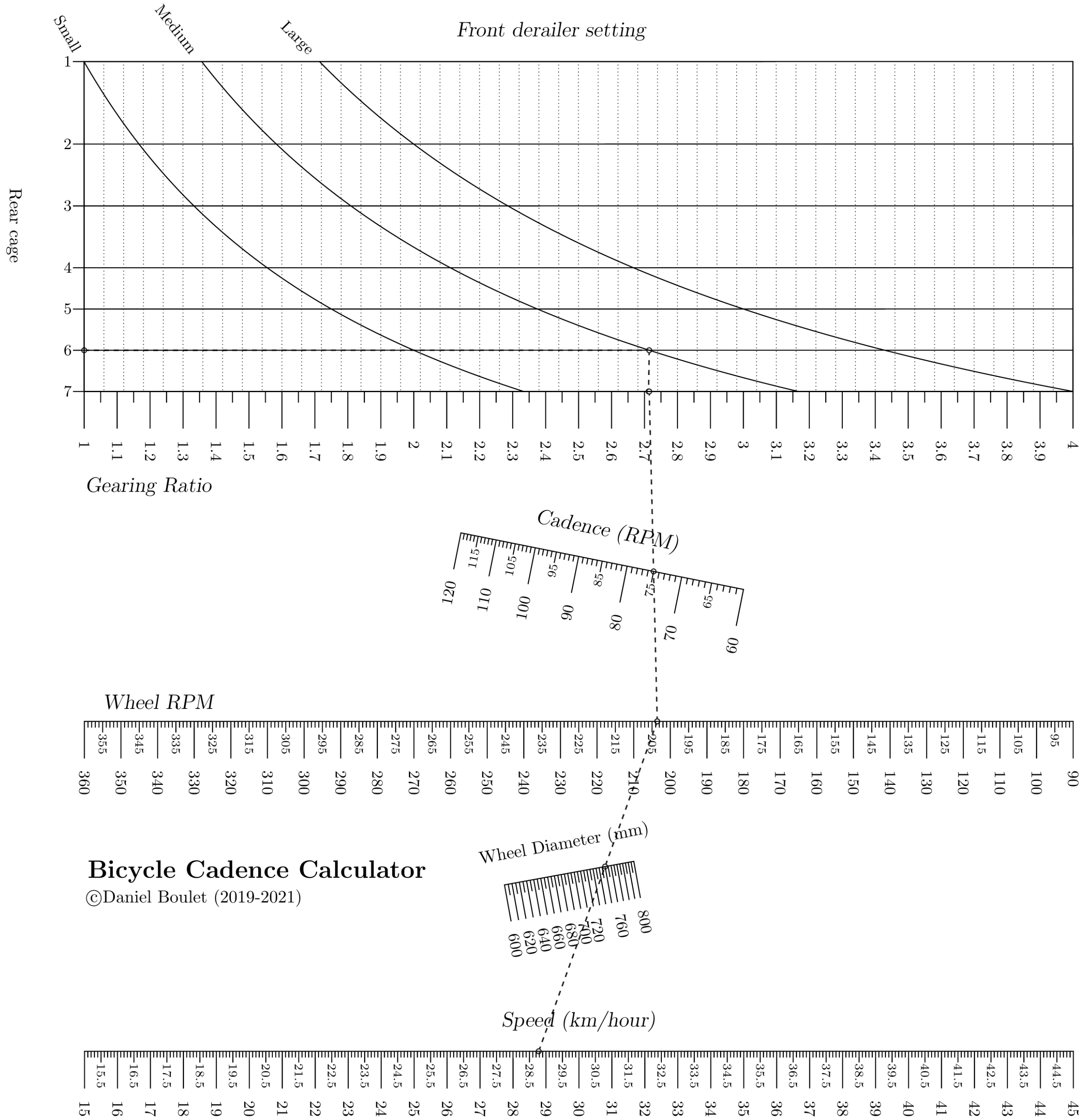
2.8 Bicycle Cadence

2.8.1 Theory and background

Choosing the correct gears on a bicycle allows a cyclist to maintain a comfortable cadence. A higher cadence helps reduce muscle fatigue [tra21] though it does put more stress on heart and lungs. On the other hand a lower cadence for the same power output puts more stress on the rider's knees, hips and back. [the21] Furthermore, cycling cadence will vary widely with beginning cyclists peddling more slowly (60-85 rpm) and professionals exceeding 100 rpm under certain conditions. Generally, a good cadence in cycling is between 80-100 rpm. [Hur21] The correct gear ratio can help the rider maximize their speed with a comfortable cadence.

A bicycle's speed is the product of the wheel diameter (e.g. 700mm), the wheel's rotation rate (in rpm) and π. The wheel's rotation rate is a function of the rider's cadence and the front to rear gear ratio. As in the previous example, pairs of discrete values such as the number of teeth on the front and rear sprockets are easily represented on a **Type 5** block. This nomograph combines a **Type 5** block (to calculate gearing ratio) with a pair of **Type 2** blocks to calculate the rider's speed given their cadence and gear settings.

2.8.2 Nomograph



2.8.3 Source code

```
"""
    bicycle_cadence.py

    Bicycle gearing cadence and speed calculator
"""
from pynomo.nomographer import *
from pyx import *
import sys
outputfile = sys.argv[0].split('.')[0]+'.pdf'

sys.path.insert(0, "..")
pyx.text.set(text.LatexEngine)


gearing = {
    'block_type': 'type_5',
    'wd_tag': 'ratio',

    'u_func': lambda u: u,
    'v_func': lambda x, v: v/x,

        # teeth on rear cage
    'u_values': [12.0, 14.0, 16.0, 18.0, 21.0, 24.0, 28.0],
    'u_scale_type': 'manual point',
    'u_manual_axis_data': {12.0: '7', 14.0: '6', 16.0: '5', 18.0: '4', 21.0: '3', 24.0:
↪'2', 28.0: '1'},
    'u_title': 'Rear cage',

        # teeth on front derailer
    'v_values': [28.0, 38.0, 48.0],
    'v_scale_type': 'manual point',
    'v_manual_axis_data': {28.0: 'Small', 38.0: 'Medium', 48.0: 'Large'},

    'wd_tick_levels': 2,
    'wd_tick_text_levels': 1,
    'wd_tick_side': 'right',
    'wd_title_opposite_tick': True,
    'isopleth_values': [[14.0, 38.0, 'x']],

}


wheelrpm = {
    'tag': 'wheelrpm',
    'u_min': 90.0,
    'u_max': 360.0,
    'scale_type': 'manual point',
    'function': lambda u: u,
}

crankrpm = {
```

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```
    'u_min': 60.0,
    'u_max': 120.0,
    'function': lambda u: u,
    'title': r'\large \slshape Cadence (RPM)',
    'tick_levels': 3,
    'tick_text_levels': 2,
    'scale_type': 'linear smart',
        'tick_side':'left',
    'title_draw_center': True,
    # 'title_distance_center': -0.5,
}

ratio = {
    'scale_type': 'manual point',
    'tag': 'ratio',
    'u_min': 1.0,
    'u_max': 4.0,
    'function': lambda u: u,
    'tick_levels': 3,
    'tick_text_levels': 1,
}


rotation = {
    'block_type': 'type_2',
    'f1_params': wheelrpm,
    'f2_params': crankrpm,
    'f3_params': ratio,
    'isopleth_values': [['x', 75, 'x']],
}


speed = {
    'u_min': 15.0,
    'u_max': 45.0,
    'function': lambda u: u,
    'title': r'\large \slshape Speed (km/hour)',
    'tick_levels': 5,
    'tick_text_levels': 2,
    'scale_type': 'linear smart',
    'title_draw_center': True,
    'title_distance_center': -0.5,
}

diameter = {
    'u_min': 600.0,
    'u_max': 800.0,
    'function': lambda u: u*3.1415927*60.0/1000000.0,
    'title': r'Wheel Diameter (mm)',
    'tick_levels': 2,
    'tick_text_levels': 1,
    'scale_type': 'linear smart',
```

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```
    'title_draw_center': True,
    'title_distance_center': -0.5,

}

wheelrpm2 = {
    'tag': 'wheelrpm',
    'u_min': 90.0,
    'u_max': 360.0,
    'function': lambda u: u,
    'scale_type': 'linear smart',

    'title': r'\large \slshape Wheel RPM',
    'title_x_shift': -18.5,
    'tick_levels': 5,
    'tick_text_levels': 3,
}


speedblock = {
    'block_type': 'type_2',
    'f1_params': speed,
    'f2_params': diameter,
    'f3_params': wheelrpm2,
    'mirror_x': True,
    'isopleth_values': [['x', 750.0, 'x']],
}


main_params = {
    'filename': outputfile,
    'block_params': [gearing, rotation, speedblock],
    'transformations': [('rotate', 0.01), ('scale paper',)],
    'title_str': r'\Large \textbf{Bicycle Cadence Calculator}',
    'title_x': 3.5,
    'title_y': 3.5,

    'extra_texts': [
        {
            'x': -0.5,
            'y': 11.3,
            'text': r'\large \slshape{Gearing Ratio}',
        },
        {
            'x': 7.0,
            'y': 20.5,
            'text': r'\large \slshape{Front derailer setting}',
        },
        {
            'text': r'\copyright Daniel Boulet (2019-2021)',
            'x': -0.5,
            'y': 3.0,
```

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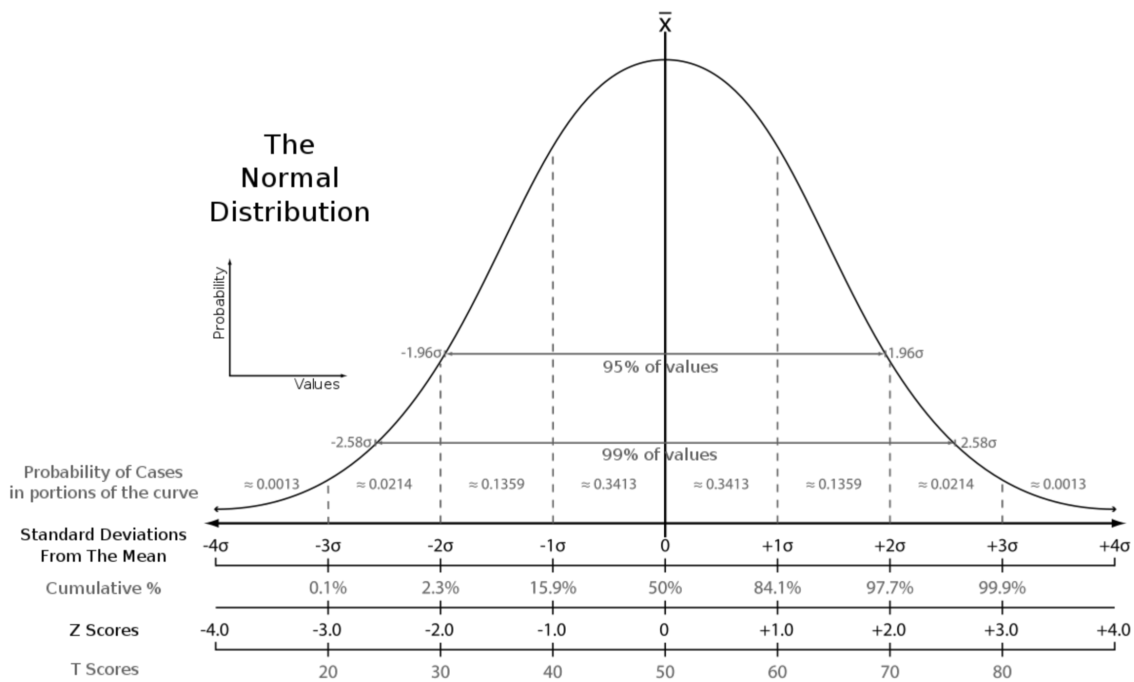
```
        },


    ],
        # 'make_grid':True,

}

Nomographer(main_params)
```

2.9 Z score calculator

2.9.1 Theory and background

This example extends Pynomo's versatility by using external libraries. Python's `scipy` library is the engine behind this nomograph which calculates the area under a normal distribution curve between two Z scores (one negative, the other positive).

To calculate the area between two Z scores (Z_{upper}, Z_{lower}) of a normal distribution one must compute the difference between the respective probability density functions $\mathrm{PDF}(Z_{upper})$ and $\mathrm{PDF}(Z_{lower})$. [wik07]



Recall that the functional relationship for a **Type 1** block is:

$F1(u_1) + F2(u_2) + F3(u_3) = 0$

and

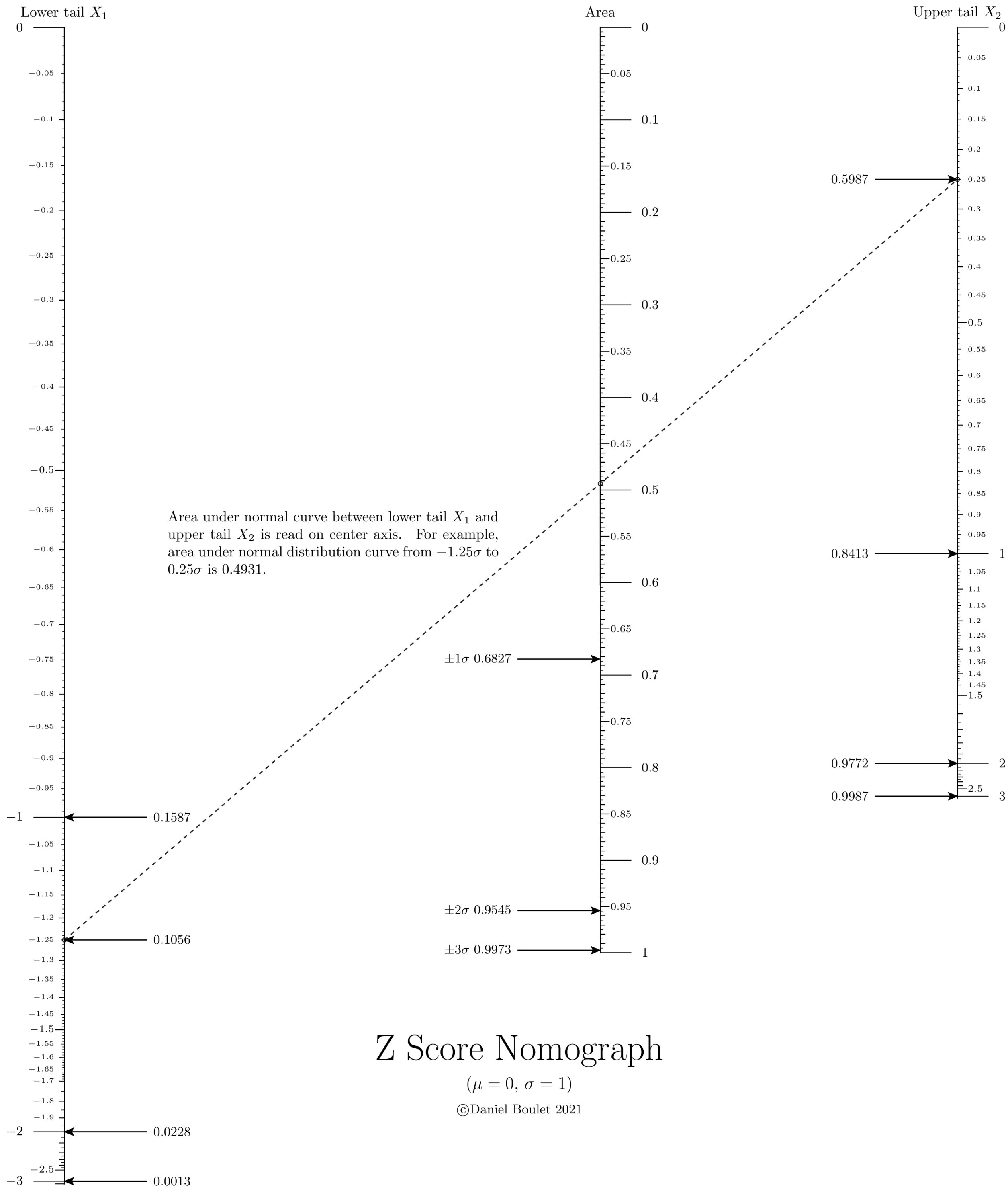
$\mathrm{Area} = \mathrm{PDF}(Z_{upper}) - \mathrm{PDF}(Z_{lower})$

therefore

$\mathrm{PDF}(Z_{upper}) - Area - \mathrm{PDF}(Z_{lower}) = 0.$

Two **Type 8** axes are aligned with $\mathrm{PDF}(Z_{upper})$ and $\mathrm{PDF}(Z_{lower})$ to align a Z score with its associated PDF.

2.9.2 Nomograph



2.9.3 Source code

```
"""
    zscore.py

    Nomograph to calculate area under normal curve from z-score.
"""

import scipy.stats as stats
from pynomo.nomographer import *
import sys
outputfile = sys.argv[0].split('.')[0]+'.pdf'

sys.path.insert(0, "..")
# allows use of latex commands in PyX such as \frac{a}{b} and \par
from pyx import *

pyx.text.set(text.LatexEngine)


def cdf(u):
    return stats.norm.cdf(u)


def ppf(u):
    return stats.norm.ppf(u)


lmin = 0.0001
lmax = 0.9999

sd1 = cdf(1.0) - cdf(-1.0)
sd2 = cdf(2.0) - cdf(-2.0)
sd3 = cdf(3.0) - cdf(-3.0)


leftpdf = {
    "tag": "a",
    "u_min": lmin,
    "u_max": 0.5,
    "function": lambda u: (u),
    "scale_type": "manual point",
    # extra parameters
    "extra_params": [
        {
            "scale_type": "manual arrow",
            "manual_axis_data": {
                cdf(-1.0): r"%4.4f" % cdf(-1.0),
                cdf(-2.0): r"%4.4f" % cdf(-2.0),
                cdf(-3.0): r"%4.4f" % cdf(-3.0),
                cdf(-1.25): r"%4.4f" % cdf(-1.25),
            },
            "arrow_length": 2.0,
```

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```
        },
    ],
}


leftz = {
    "tag": "a",
    "u_min": ppf(lmin),
    "u_max": ppf(0.5),
    "function": lambda u: cdf(u),
    "align_func": lambda u: cdf(u),
    "title": "Lower tail $X_1$",
    "tick_levels": 5,
    "tick_text_levels": 4,
    "scale_type": "linear smart",
    "tick_side": "left",
}


rightpdf = {
    "tag": "c",
    "u_min": 0.5,
    "u_max": lmax,
    "function": lambda u: -(u),
    "scale_type": "manual point",
    # extra parameters
    "extra_params": [
        {
            "scale_type": "manual arrow",
            "tick_side": "left",
            "manual_axis_data": {
                cdf(3.0): r"%4.4f" % cdf(3.0),
                cdf(2.0): r"%4.4f" % cdf(2.0),
                cdf(1.0): r"%4.4f" % cdf(1.0),
                cdf(0.25): r"%4.4f" % cdf(0.25),
            },
            "arrow_length": 2.0,
        },
    ],
}


rightz = {
    "tag": "c",
    "u_min": ppf(0.5),
    "u_max": ppf(lmax),
    "function": lambda u: cdf(u),
    "align_func": lambda u: cdf(u),
    "title": "Upper tail $X_2$",
    "tick_levels": 5,
    "tick_text_levels": 4,
    "scale_type": "linear smart",
```

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```
}

leftblock2 = {"block_type": "type_8", "f_params": leftz, "isopleth_values": [["x"]]}


rightblock2 = {"block_type": "type_8", "f_params": rightz, "isopleth_values": [["x"]]}


delta = {
    "u_min": 0.0,
    "u_max": 1.0,
    "function": lambda u: u,
    "scale_type": "linear smart",
    "title": "Area",
    "tick_levels": 5,
    "tick_text_levels": 4,
    "extra_params": [
        {
            "tick_side": "left",
            "scale_type": "manual arrow",
            "manual_axis_data": {
                sd1: r"$\pm 1 \sigma$ %4.4f" % sd1,
                sd2: r"$\pm 2 \sigma$ %4.4f" % sd2,
                sd3: r"$\pm 3 \sigma$ %4.4f" % sd3,
            },
            "arrow_length": 2.0,
        },
    ],
}

block_diff = {
    "block_type": "type_1",
    "f1_params": leftpdf,
    "f2_params": delta,
    "f3_params": rightpdf,
    "proportion": 1.5,
    "isopleth_values": [[cdf(-1.25), "x", cdf(0.25)]],
}


main_params = {
    "filename": outputfile,
    "paper_height": 11.0 * 2.54,
    "paper_width": 8.5 * 2.54,
    "block_params": [block_diff, leftblock2, rightblock2],
    "cdfations": [("rotate", 0.01), ("scale paper",), ("polygon",)],
    "title_x": 11.0,
    "title_y": 3.0,
    "title_box_width": 15.0,
    "title_str": r"\Huge Z Score Nomograph \par \medskip \large ($\mu = 0$, $\sigma = 1
↪$) \par \medskip  \small \copyright Daniel Boulet  2021",
    # 'make_grid':True,
```

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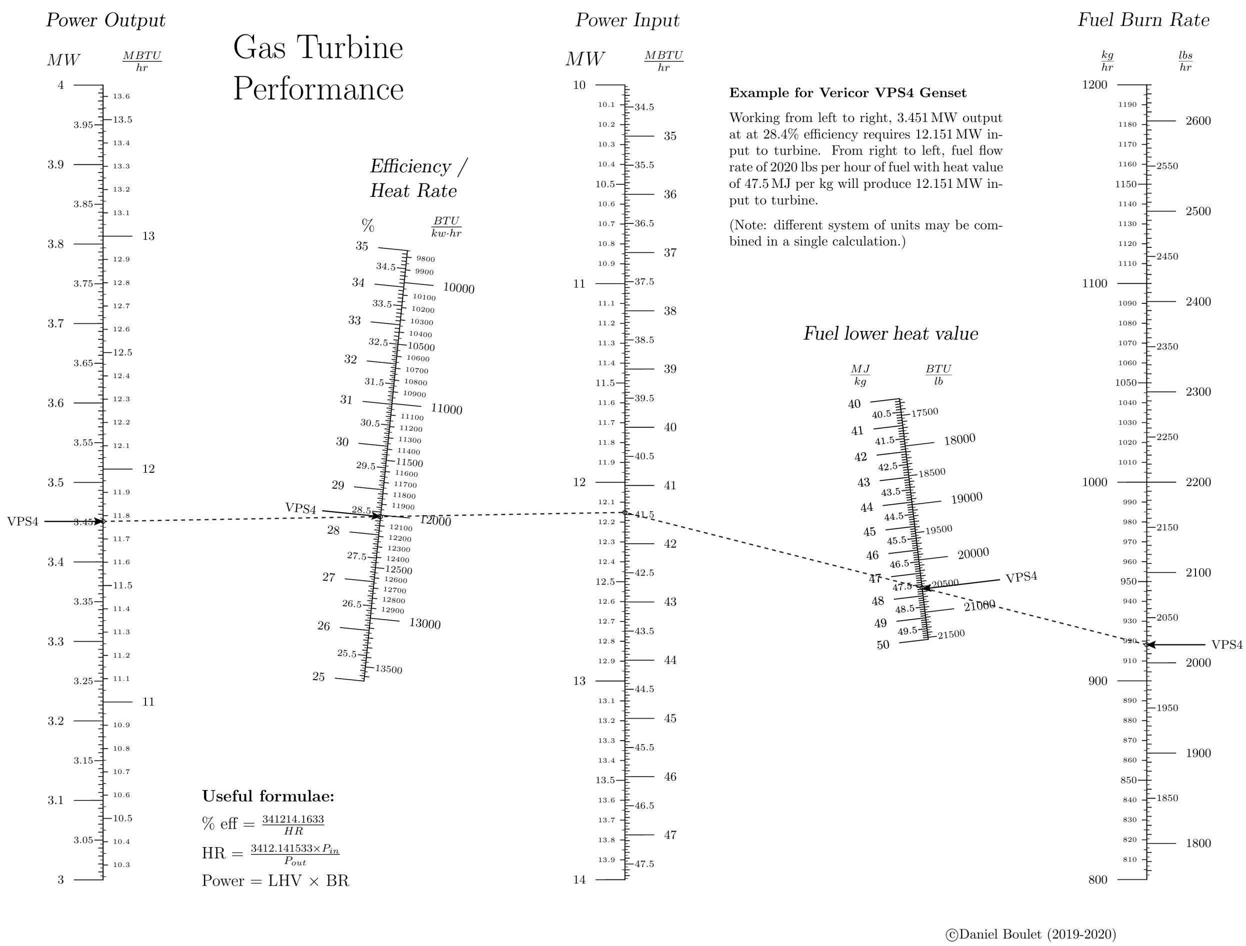
```
    "extra_texts": [
        {
            "x": 2.5,
            "y": 16.0,
            "text": r"\noindent Area under normal curve between lower tail $X_1$ and upper tail $X_2$ is read on center axis. \
                For example, area under normal distribution curve from $%g \sigma$ to $%g \sigma$ is $%4.4f$."
            % (-1.25, 0.25, cdf(0.25) - cdf(-1.25)),
            "width": 8.0,
        },
    ],
}

Nomographer(main_params)
```

2.10 VPS Generator Performance

This nomograph estimates power generation based on fuel consumption of a Vericor VPS4 Genset.

2.10.1 Nomograph



2.10.2 Source code

```
"""
    vps4performance.py

    Gas turbine performance nomograph based on Vericor VPS4 genset.
"""
from pynomo.nomographer import *
import sys
sys.path.insert(0, "..")
outputfile = sys.argv[0].split('.')[0]+'.pdf'

# allows use of latex commands in PyX such as \frac{a}{b} and \par
from pyx import *
text.set(text.LatexEngine)

def watts2btu_hr(watts):
    return watts*3.412141633

```

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```python

def btu_hr2watts(btu_hr):
    return btu_hr/3.412141633


def btu2joule(btu):
    return btu*1055.06


def joule2btu(joule):
    return joule/1055.06


'''
this part is the left handside of the total graph
'''

leftside_u1_left = {
    'tag': 'left_1',

    # range of values (nominal 3451000.0 W )
    'u_min': 3.0,
    'u_max': 4.0,

    # functions
    'function': lambda u: u*1000000.0,

    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',

    # tick and title locations
    'title': r'\large $MW$',
    'title_x_shift': -1.0,
    'title_y_shift': 0.5,
    'tick_side': 'left',

    # extra parameters
    'extra_params': [
        {
            'scale_type': 'manual arrow',
            'manual_axis_data':
            {
                3.451: r'VPS4',
            },
            'arrow_length': 1.5,
        },
    ],


    # additional title information
```

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```
    'extra_titles': [
        {
            'dx': -2.0,
            'dy': 1.5,
            'text': '\slshape \Large Power Output',
            # 'width': 5.0
        },
    ],


}

leftside_u1_right = {
    'tag': 'left_1',

    # range of values (nominal 11778263.0 BTU/hr )
    'u_min': 3.0*watts2btu_hr(1000000.0)/1000000.0,
    'u_max': 4.0*watts2btu_hr(1000000.0)/1000000.0,

    # functions
    'function': lambda u: u*1000000.0,
    'align_func': lambda u: u/watts2btu_hr(1000000.0)*1000000.0,

    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',

    # tick and title locations
    'title': r'\large ${\frac{MBTU}{hr}}$',
    'title_x_shift': 1.0,
    'title_y_shift': 0.5,
    'tick_side': 'right',

}

leftside_u2_left = {
    # range of values (nominal 28%)
    'u_min': 0.25*100.0,
    'u_max': 0.35*100.0,

    # functions
    'function': lambda u: u/100.0,

    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',

    # tick and title locations
    'title': r'\large $\%$',
    'title_x_shift': -1.0,
```

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```
    'title_y_shift': 0.5,
    'tick_side': 'left',

    # additional title information
    'extra_titles': [
        {
            'dx': -1.5,
            'dy': 2.0,
            'text': '\slshape \Large Efficiency / \par Heat Rate',
            # 'width': 5.0
        },
    ],

    # extra parameters
    'extra_params': [
        {
            'scale_type': 'manual arrow',
            'manual_axis_data':
            {
                28.4: r'VPS4',
            },
            'arrow_length': 1.5,
        },
    ],


}

leftside_u2_right = {
    # range of values (nomninal 12025 BTU/kWh )
    'u_min': watts2btu_hr(100000.0)/35.0,
    'u_max': watts2btu_hr(100000.0)/25.0,

    # functions
    'function': lambda u: watts2btu_hr(1000.0)/(u),
    'text_format': r"$%4.0f$",
    # 'align_func': lambda u:341300.0/u,

    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',

    # tick and title locations
    'title': r'\large ${\frac{BTU}{kw \cdot hr}}$',
    'title_x_shift': 1.0,
    'title_y_shift': 0.5,
    'tick_side': 'right',
}

leftside_u3_left = {
    'tag': 'mid',
```

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```
    # range of values (nominal 12325000.0 W )
    'u_min': 10.0,
    'u_max': 14.0,

    # functions
    'function': lambda u: u*1000000.0,

    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',

    # tick and title locations
    'title': r'\Large $MW$',
    'title_x_shift': -1.0,
    'title_y_shift': 0.5,
    'tick_side': 'left',

    # additional title information
    'extra_titles': [
        {
            'dx': -1.8,
            'dy': 1.5,
            'text': '\slshape \Large Power Input',
            # 'width': 5.0
        },
    ],


}

leftside_u3_right = {
    # range of values (nominal 42065225.0 BTU/hr )
    'u_min': 10.0*watts2btu_hr(1000000.0)/1000000.0,
    'u_max': 14.0*watts2btu_hr(1000000.0)/1000000.0,

    # functions
    'function': lambda u: u*1000000.0,
    'align_func': lambda u: u/watts2btu_hr(1000000.0)*1000000.0,

    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',

    # tick and title locations
    'title': r'\large ${\frac{MBTU}{hr}}$',
    'title_x_shift': 1.0,
    'title_y_shift': 0.5,
    'tick_side': 'right',
}
```

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```
'''

this part is the right hand side of the total graph

'''

rightside_u3_left = {
    'tag': 'mid',

    # range of values (nominal 12325000.0 W )
    'u_min': 10.0,
    'u_max': 14.0,

    # functions
    'function': lambda u: u*1000000.0,

    # scale type and detail
    'scale_type': 'manual point',

}

rightside_u3_right = {
    # range of values (nominal 42065225.0 BTU/hr )
    'u_min': 10.0*watts2btu_hr(1000000.0)/1000000.0,
    'u_max': 14.0*watts2btu_hr(1000000.0)/1000000.0,

    # functions
    'function': lambda u: u*1000000.0,
    'align_func': lambda u: u/watts2btu_hr(1000000.0)*1000000.0,


    # scale type and detail
    'scale_type': 'manual point',

}


rightside_u2_left = {
    # range of values (nominal 45000000 MJ / kg )
    'u_min': 40.0,
    'u_max': 50.0,

    # functions
    'function': lambda u: 1.0/(u*1000000.0),

    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',

    # tick and title locations
```

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```
    'title': r'\large ${\frac{MJ}{kg}}$',
    'title_x_shift': -1.0,
    'title_y_shift': 0.5,
    'tick_side': 'left',

    # extra parameters
    'extra_params': [
        {
        },
    ],


    # additional title information
    'extra_titles': [
        {
            'dx': -3.0,
            'dy': 1.5,
            'text': r'\slshape \Large Fuel lower heat value',
            # 'width': 5.0
        },
    ],


}

rightside_u2_right = {
    # range of values (nominal 20000 BTU/lb)
    'u_min': 40000000.0/2321.13,
    'u_max': 50000000.0/2321.13,

    # functions
    'function': lambda u: 1.0/(u),
    # 'align_func':lambda u: u*2326.0/1000000.0,

    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',
    'text_format': r"$%4.0f$",

    # tick and title locations
    'title': r'\large ${\frac{BTU}{lb}}$',
    'title_x_shift': 1.0,
    'title_y_shift': 0.5,
    'tick_side': 'right',

    # extra parameters
    'extra_params': [
        {
            'scale_type': 'manual arrow',
            'manual_axis_data':
            {
```

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```
                20548.0: r'VPS4',
            },
            'arrow_length': 2.0,
        },
    ],


}


rightside_u1_left = {
    'tag': 'right_1',

    # range of values (nominal 1000 kg/hr )
    'u_min': 800.0,
    'u_max': 1200.0,

    # functions
    'function': lambda u: u/3600.0,

    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',

    # tick and title locations
    'title': r'\large ${\frac{kg}{hr}}$',
    'title_x_shift': -1.0,
    'title_y_shift': 0.5,
    'tick_side': 'left',

    # additional title information
    'extra_titles': [
        {
            'dx': -2.3,
            'dy': 1.5,
            'text': '\slshape \Large Fuel Burn Rate',
            # 'width': 5.0
        },
    ],


}

rightside_u1_right = {
    'tag': 'right_1',

    # range of values (nominal 2020 lb/hr )
    'u_min': 800*2.2,
    'u_max': 1200.0*2.2,

    # functions
```

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```
    'function': lambda u: u,
    'align_func': lambda u: u/2.2,
    # scale type and detail
    'tick_levels': 4,
    'tick_text_levels': 3,
    'scale_type': 'linear smart',

    # tick and title locations
    'title': r'\large ${\frac{lbs}{hr}}$',
    'title_x_shift': 1.0,
    'title_y_shift': 0.5,
    'tick_side': 'right',

    # extra parameters
    'extra_params': [
        {
            'scale_type': 'manual arrow',
            'manual_axis_data':
            {
                2020.0: r'VPS4',
            },
            'arrow_length': 1.5,
        },
    ],


}


leftside_SI_block = {
    'block_type': 'type_2',
    'f1_params': leftside_u1_left,
    'f2_params': leftside_u2_left,
    'f3_params': leftside_u3_left,
    'isopleth_values': [[3.451, 28.4, 'x']],
}

leftside_IMP_block = {
    'block_type': 'type_2',
    'f1_params': leftside_u1_right,
    'f2_params': leftside_u2_right,
    'f3_params': leftside_u3_right,
    'isopleth_values': [[watts2btu_hr(3.451), 'x', watts2btu_hr(3.451)/.284]],

}

rightside_SI_block = {
    'block_type': 'type_2',
    'f1_params': rightside_u1_left,
    'f2_params': rightside_u2_left,
    'f3_params': rightside_u3_left,
    'isopleth_values': [[2020.0/2.2, 'x', 'x']],
```

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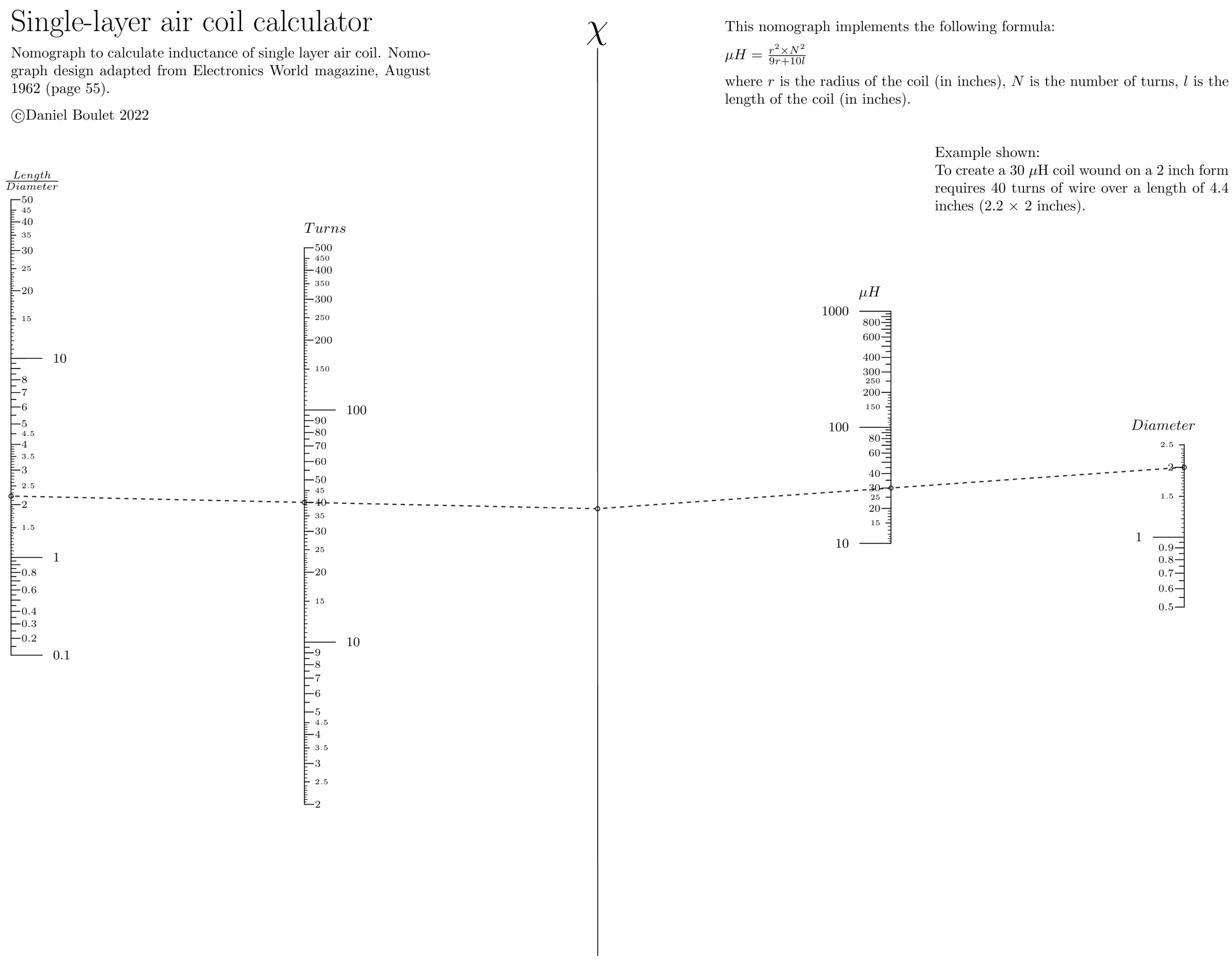
```
    'mirror_x': True,
}

rightside_IMP_block = {
    'block_type': 'type_2',
    'f1_params': rightside_u1_right,
    'f2_params': rightside_u2_right,
    'f3_params': rightside_u3_right,
    'isopleth_values': [[2020.0, 'x', watts2btu_hr(3.451)/.284]],
    'mirror_x': True,
}

main_params = {
    'filename': outputfile,
    'paper_height': 8.0*2.54,
    'paper_width': 10.5*2.54,
    'block_params': [leftside_SI_block, rightside_SI_block, leftside_IMP_block, rightside_IMP_block],
    'transformations': [('rotate', 0.01), ('scale paper',)],
    'title_str': r"\Huge Gas Turbine \par Performance",
    'title_x': 5.5,
    'title_y': 21.0,
    'extra_texts': [
        {
            'text': r'\large \textbf{Useful formulae:} \par \medskip \% eff = ${\frac{341214.1633}{HR}}$ \par \medskip  HR = ${\frac{3412.141533 \times P_{in}}{P_{out}}}$ \par \medskip Power = LHV $\times$ BR',
                'x': 2.0,
                'y': 2.0,
                'width': 10.0
        },
        {
            'text': r'\copyright Daniel Boulet (2019-2020)',
            'x': 21.0,
            'y': -1.5,
        },
        {
            'x': 16.0,
            'y': 20.0,
            'text': r'\noindent \textbf{Example for Vericor VPS4 Genset} \par \medskip \noindent \normalsize Working from left to right, 3.451\,MW output at at 28.4\% efficiency requires 12.151\,MW input to turbine. From right to left, fuel flow rate of 2020 lbs per hour of fuel with heat value of 47.5\,MJ per kg will produce 12.151\,MW input to turbine. \par \medskip \noindent (Note: different system of units may be combined in a single calculation.)',
            'width': 7.0,
        }
    ],
    # 'make_grid': True,
}
Nomographer(main_params)
```

2.11 Air Coil Design

Air coil design nomographs come in a range of shapes, sizes and methods of use. In this example, PyNomo is used to reconstruct part of the single-layer air coil calculator nomograph published in Electronics World (1962).

2.11.1 Nomograph



2.11.2 Source code

```
"""
    air_core_coil.py

        Nomograph to calculate inductance of single layer air coil.  Design
"""
import sys
import numpy as np
from pyx import *

```

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```
outputfile = sys.argv[0].split(".")[0] + ".pdf"
sys.path.insert(0, "..")
text.set(text.LatexEngine)

from pynomo.nomographer import Nomographer

length_over_diameter = {
    "u_min": 0.1,
    "u_max": 50.0,
    "function": lambda u: np.log(18.0 + 40.0 * u),
    "title": r"$\frac{Length}{Diameter}$",
    "tick_levels": 5,
    "title_x_shift": 0.5,
    "title_y_shift": 0.35,
    "tick_text_levels": 4,
    "scale_type": "log smart",
}

number_of_turns = {
    "u_min": 2.0,
    "u_max": 500.0,
    "function": lambda u: -2.0 * np.log(u),
    "title": r"$Turns$",
    "tick_levels": 5,
    "tick_text_levels": 4,
    "title_x_shift": 0.5,
    "title_y_shift": 0.35,
    "scale_type": "log smart",
}

inductance = {
    "u_min": 10.0,
    "u_max": 1000.0,
    "function": lambda u: np.log(u),
    "title": r"$\mu H$",
    "tick_levels": 5,
    "tick_text_levels": 4,
    "title_x_shift": -0.5,
    "tick_side": "left",
    "title_y_shift": 0.35,
    "scale_type": "log smart",
}


diameter = {
    "u_min": 0.5,
    "u_max": 2.5,
    "function": lambda u: -np.log(u),
    "title": r"$Diameter$",
    "tick_levels": 5,
    "tick_text_levels": 4,
    "title_x_shift": -0.5,
```

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```
    "tick_side": "left",
    "title_y_shift": 0.35,
    "scale_type": "log smart",
}


block_1_params = {
    "block_type": "type_3",
    "width": 40.0,
    "height": 40.0,
    "f_params": [
        length_over_diameter,
        number_of_turns,
        inductance,
        diameter,
    ],
    "reference_padding": 0.25,
    "reference_titles": ["\Huge$\chi$"],
    "isopleth_values": [["x", 40, 30.0, 2.0]],
}

main_params = {
    "filename": "air_core_coil.pdf",
    "paper_height": 8.5 * 2.54,
    "paper_width": 11.0 * 2.54,
    "block_params": [block_1_params],
    "transformations": [("rotate", 0.01), ("scale paper",)],
    # "title_str": r"\Huge Single-layer air coil calculator",
    # "make_grid": True,
    "title_y": 23.0,
    "title_x": 5.0,
    "extra_texts": [
        {
            "x": 0.0,
            "y": 22.0,
            "text": r"\noindent \huge Single-layer air coil calculator \par \normalsize \medskip \noindent Nomograph to calculate inductance of single layer air coil. Nomograph design adapted from Electronics World magazine, August 1962 (page 55). \par \medskip   \noindent \copyright    Daniel Boulet  2022",
            "width": 10.0,
        },
        {
            "x": 17.0,
            "y": 22.0,
            "text": r"\noindent This nomograph implements the following formula: \par \medskip \noindent $\mu H = \frac{r^2 \times N^2}{9r + 10l}$ \medskip \par \noindent where $r$ is the radius of the coil (in inches), $N$ is the number of turns, $l$ is the length of the coil (in inches).",
            "width": 12.0,
        },
        {
            "x": 22.0,
```

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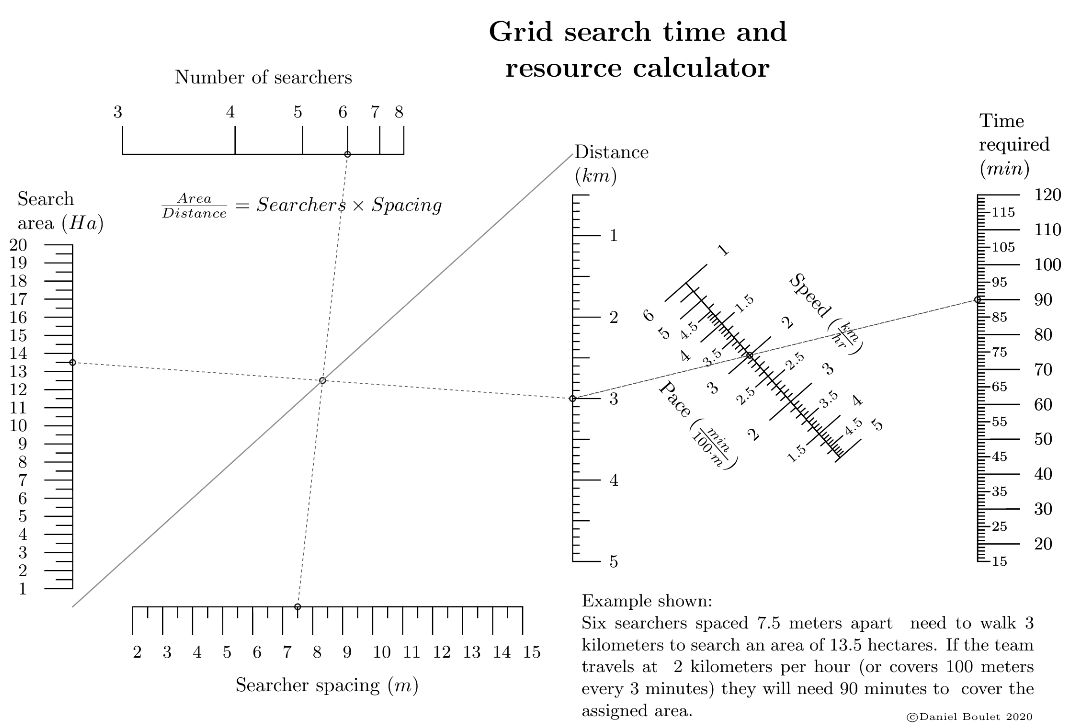
```
            "y": 19.0,
            "text": r"\noindent Example shown: \par \noindent To create a 30 $\mu$H coil wound on a 2 inch form requires 40 turns of wire over a length of 4.4 inches (2.2 $\times$ 2 inches).",
            "width": 7.0,
        },
    ],
}
Nomographer(main_params)
```

2.12 Search Planner

Grid searches when conducted by ground search and rescue personnel are slow and labour intensive tasks. Search planners will want to allocate scarce resources (searchers and time) appropriately. Knowing the length of time required to search a parcel of land can help assign resources effeciently.

2.12.1 Nomograph



2.12.2 Source code

```
"""
search_planner.py

Nomogram to calculate search effort for ground search activities.
along with this program.  If not, see < http: // www.gnu.org/licenses/>.
"""
from pynomo.nomographer import Nomographer
import sys
outputfile = sys.argv[0].split('.')[0]+'.pdf'

from pyx import *
text.set(text.LatexEngine)

searchers = {
    'ID': 'searchers',
    'u_min': 3.0,
    'u_max': 8.0,
    'function': lambda u: 1.0 / u,
    'scale_type': 'linear',
    'title': r'Number of searchers',
    'title_distance_center': -1.25,
    'tick_levels': 1,
    'tick_text_levels': 1,
    'tick_side': 'left',
    'grid_length_0': 0.5,
    'text_distance_0': 0.75,
    'title_draw_center': True,
    # 'title_opposite_tick': False,
    # 'text_horizontal_align': True,
    'extra_angle': 90.0

}


hectares = {
    'ID': 'hectares',
    'u_min': 1.0,
    'u_max': 20.0,
    'function': lambda u: u*10000.0,
    # 'title': r'Search area ($Ha$)',
    'extra_titles': [
        {
            'text': r'Search \par area ($Ha$)',
            'dx': -1.5,
            'dy': 0.7
        }
    ],

    'tick_levels': 3,
    'tick_text_levels': 1,
    'tick_side': 'left',
```

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```
    'grid_length_0': 0.5,
    'grid_length_1': 0.3,
    'text_distance_0': 0.8,
    'scale_type': 'linear smart'
}

distance1 = {
    'ID': 'distance1',
    'tag': 'distance',
    'scale_type': 'linear smart',
    'u_min': 0.5,
    'u_max': 5.0,
    'function': lambda u: u*1000,
    'align_function': lambda u: u * 1000,
    'extra_titles': [
        {
            'text': r'Distance \par ($km$)',
            'dx': -0.5,
            'dy': 0.65
        }
    ],
    'grid_length_0': 0.5,
    'grid_length_1': 0.3,
    'text_distance_0': 0.65,
    'tick_levels': 3,
    'tick_text_levels': 1,
    'tick_side': 'right',
}

spacing = {
    'ID': 'spacing',
    'u_min': 2.0,
    'u_max': 15.0,
    'function': lambda u: u,
    # 'scale_type': 'manual point',
    # 'manual_axis_data': {2.5: '2.5', 5.0: '5.0', 10: '10', 15: '15'},
    'title': r'Searcher spacing ($m$)',
    'title_draw_center': True,
    'title_opposite_tick': False,
    'tick_text_levels': 1,
    'tick_levels': 2,
    'grid_length_0': 0.5,
    'grid_length_1': 0.2,
    'text_distance_0': .8,
    'title_distance_center': -1.5,
    'text_horizontal_align': True,
    'extra_angle': 90.0,
    'turn_relative': True,

    # 'extra_params': [
    #     {
    #         'u_min': 2.5,
```

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```
    #         'u_max': 15.0,
    #         'scale_type': 'linear',
    #         'tick_levels': 3,
    #         'tick_text_levels': 1,
    #         'tick_side': 'right',
    #     }
    # ]
}

area_block = {
    'ID': 'area_block',
    'block_type': 'type_4',
    'height': 8,
    'width':8,
    'f1_params': hectares,
    'f2_params': distance1,
    'f3_params': spacing,
    'f4_params': searchers,
    'reference_color': color.cmyk.Gray,
    'padding': .9,
    'isopleth_values': [['x', 3.0, 7.5, 6]],
}

distance2 = {
    # distance in meters (u3)
    'ID': 'distance2',
    'tag': 'distance',
    'u_min': 0.5,
    'u_max': 5.0,
    'scale_type': 'manual_point',
    'function': lambda u: u*1000,
    'tick_levels': 0,
    'tick_text_levels': 0,
    # 'title_x_shift': 1.0,
}

speed_km_h = {
    # speed in km/hr
    'ID': 'speed_in_km_per_hr',
    'tag': 'speed',
    'u_min': 1.0,
    'u_max': 5.0,
    'function': lambda u: u*1000/3600,
    'title': r'Speed ($\frac{km}{hr}$)',
    'tick_levels': 3,
    'tick_text_levels': 2,
    'title_x_shift': 0.0,
    'title_draw_center': True,
    'title_distance_center': -1.4,
    'grid_length_0': 0.5,
    'grid_length_1': 0.3,
    'text_distance_0': 0.8,
```

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```
    'text_distance_1':0.35

}


time_required = {
    # time in minutes
    'ID': 'time_required',
    'u_min': 15.0,
    'u_max': 120.0,
    'function': lambda u: u*60,
    # 'title': r'Time required ($min$)',
    'tick_levels': 3,
    'tick_text_levels': 2,
    'title_x_shift': 1.0,
    'extra_titles': [
        {
            'text': r'Time \par required \par ($min$)',
            'dx': -0.5,
            'dy': 1.2
        }
    ],

}

distance_speed_time_block = {
    'block_type': 'type_2',
    'f1_params': distance2,
    'f2_params': speed_km_h,
    'f3_params': time_required,
    'isopleth_values': [[3.0, 'x', 90]],
    'mirror_x': True
}

speed_min_100meter = {
    # speed in minutes / 100 meters
    'ID': 'speed_sec_meter',
    'u_min': 0.72*100/60,
    'u_max': 3.6*100/60,
    'function': lambda u: u/100*60,
    'title': r'Pace ($\frac{min}{100\cdot m}$)',
    'tick_levels': 3,
    'tick_text_levels': 2,
    'title_draw_center': True,
    'scale_type': 'linear smart',
    'tick_side': 'left',
    'title_distance_center': -1.6,
    'grid_length_0': 0.5,
    'grid_length_1': 0.3,
    'text_distance_0': 0.8,
    'text_distance_1': 0.35

```

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```
}


distance_speed_time_block2 = {
    'ID': 'distance_speed_time_block2',
    'block_type': 'type_2',
    'f1_params': time_required,
    'f2_params': speed_min_100meter,
    'f3_params': distance2,
    'isopleth_values': [[90, 'x', 3.0]],
    'width':10,
    'mirror_x': True,

}

main_params = {
    'filename': outputfile,
    'paper_height': 8,
    'paper_width': 16,
    'block_params': [area_block, distance_speed_time_block, distance_speed_time_block2],
    'transformations': [('rotate', 0.01), ('scale paper',),  ],
    'title_str': r'\Large \textbf{Grid search time and resource calculator}',
    'title_y': 10.0,
    'title_x':10,
    # 'make_grid': True,
    # 'debug': True,
    'isopleth_params': [
        # {'color': 'black',
        #  'linewidth': 'thin',
        #  'linestyle': 'solid',
        #  'circle_size': 0.08,
        #  'transparency': 0.0,
        #  },
        {'color': 'black',
         'linewidth': 'thin',
         'linestyle': 'dashed',
         'circle_size': 0.05,
         'transparency': 0.25,
         },
    ],
    'extra_texts': [
        {
            'x': 9.0,
            'y': 0.0,
            'text': r'\small \noindent Example shown: \par \noindent Six searchers spaced 7.5 meters apart \
                need to walk 3 kilometers to search an area of 13.5 hectares. If the team travels at \
                2 kilometers per hour (or covers 100 meters every 3 minutes) they will need 90 minutes to \
                cover the assigned area.',
            'width': 8,
```

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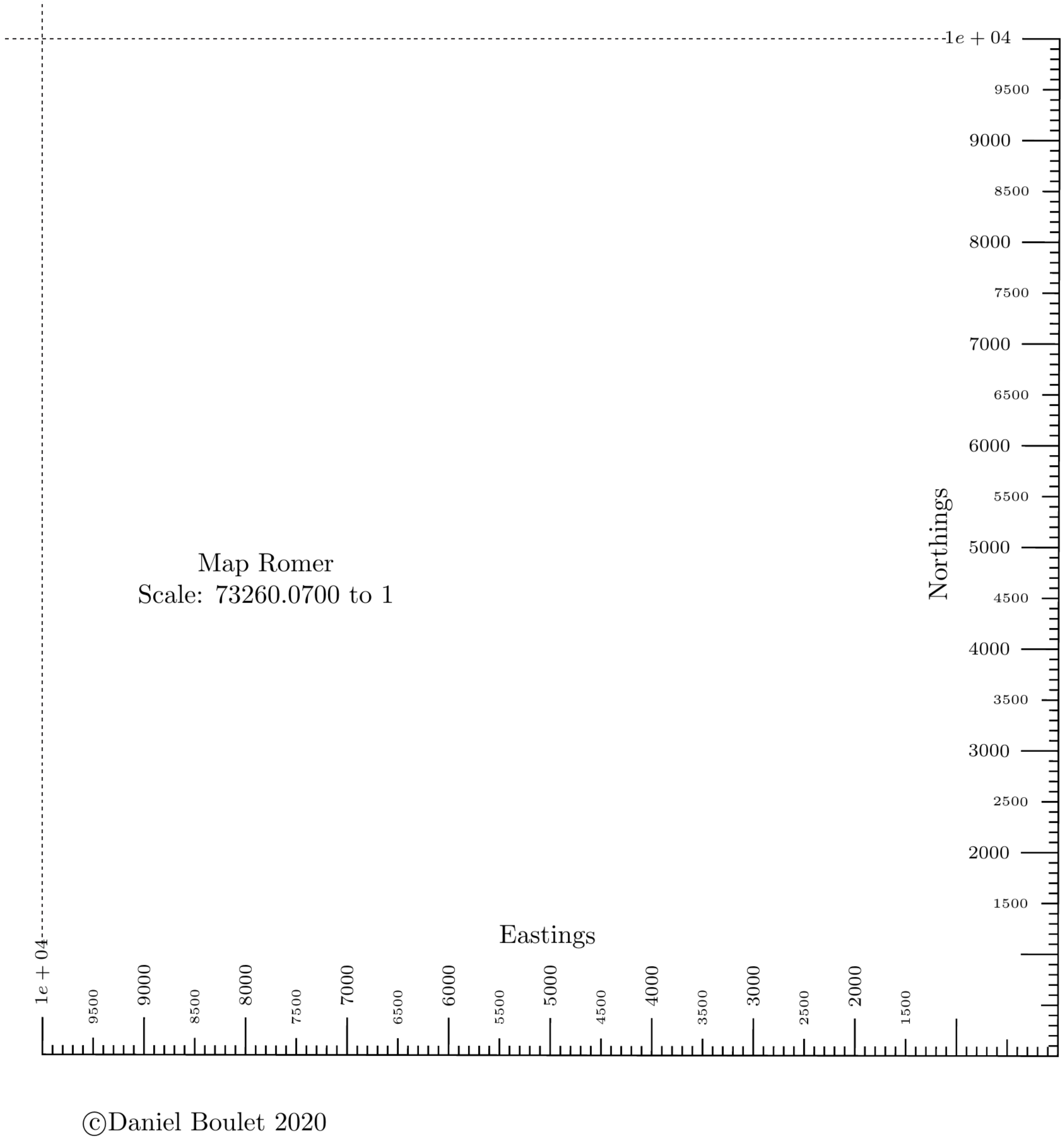
```
        },
        {
            'x': 14.2,
            'y': -2.0,
            'text': r'\tiny \copyright Daniel Boulet  2020',
            'width': 5.0,
        },
        {
            'x': 1,
            'y': 7.0,
            'text': r'$\frac{Area}{Distance}=Searchers \times Spacing$',
            'width': 10.0,

        },

    ],


}


Nomographer(main_params)
```

2.13 Map Romer

Strictly speaking, this not a nomograph. I used PyNomo's axis drawing functions to create a custom map romer to use on printed maps that don't have a standard scale (i.e. 1:25000). The only constraint is that the map's grid must have the same scale vertically and horizontally. Substitute values for actual and printed grids sizes to produce a useful map romer.

2.13.1 Nomograph



2.13.2 Source code

```
"""
    romer.py

    Nomogram to layout a custom romer for map reading. Scale values
    GNU General Public License for more details.

    You should have received a copy of the GNU General Public License
    along with this program.  If not, see <http://www.gnu.org/licenses/>.
"""

```

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```python
from pynomo.nomographer import Nomographer
import sys
import numpy as np
from pyx import *
text.set(text.LatexEngine)

outputfile = sys.argv[0].split('.')[0]+'.pdf'

def deg2rad(deg):
    return np.pi * deg / 180.0


# actual grid size in meters
# actual_grid_size = float(os.environ['ACTUAL_GRID_SIZE'])
actual_grid_size = 10000.0

# printed grid size in centimeters
# printed_grid_size = float(os.environ['PRINTED_GRID_SIZE'])
printed_grid_size = 13.65

map_scale = actual_grid_size / (printed_grid_size / 100.0)
romer_title = "Map Romer \par Scale: " + \
    "{0:.4f}".format(round(map_scale, 2)) + " to 1"

n_params = {
    'u_min': 0.0,
    'u_max': actual_grid_size,
    'function_x': lambda u: u * np.cos(deg2rad(45.0)),
    'function_y': lambda u: u * np.sin(deg2rad(45.0)),
    'tick_levels': 3,
    'tick_text_levels': 0,
    'tick_side': 'left',
    'title': r'Northings',
    'title_draw_center': True,''
    'title_distance_center': -1.5,
    'extra_params': [{
        'u_min': actual_grid_size/10.0 * 1.5,
        'u_max': actual_grid_size,
        'tick_text_levels': 2,
    }],
    'text_distance_0': 0.65,
    'text_distance_1': 0.4,
    'text_size_0': text.size.scriptsize,
    'text_size_1': text.size.tiny,
    'grid_length_0': 0.5,

}

e_params = {
    'u_min': 0.0,
    'u_max': actual_grid_size,
    'function_x': lambda u: u * np.cos(deg2rad(135.0)),
```

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```
    'function_y': lambda u: u * np.sin(deg2rad(135.0)),
    'tick_levels': 3,
    'tick_text_levels': 0,
    'title': r'Eastings',
    'title_draw_center': True,
    'title_distance_center': 1.5,
    'extra_params': [{
        'u_min': actual_grid_size/10.0 * 1.5,
        'u_max': actual_grid_size,
        'tick_text_levels': 2,
    }],
    'text_distance_0': 0.65,
    'text_distance_1': 0.4,
    'grid_length_0': 0.5,
    'text_size_0': text.size.scriptsize,
    'text_size_1': text.size.tiny,
}

block_params_n = {
    'block_type': 'type_8',
    'f_params': n_params,
    # 'width': printed_grid_size * 100.0 * np.sqrt(2.0),
    # 'height': printed_grid_size * 100.0 * np.sqrt(2.0),
    'width': 5.0,
    'height': printed_grid_size / np.sqrt(2.0),
}

block_params_e = {
    'block_type': 'type_8',
    'f_params': e_params,
    'width': 5.0,
    'height': printed_grid_size / np.sqrt(2.0),
}

main_params = {
    'filename': outputfile,
    # 'paper_height': printed_grid_size / np.sqrt(2.0),
    # 'paper_width': printed_grid_size * 2.0 / np.sqrt(2.0),
    'paper_height': printed_grid_size,
    'paper_width': printed_grid_size,
    'block_params': [block_params_n, block_params_e],
    'title_str': romer_title,
    'title_x': 3.0,
    'title_y': 6.5,
    'transformations': [('rotate', 44.9), ('scale paper',)],
    # 'make_grid': True,
    'draw_lines': True,
    'line_params': [
        {
            'coords': [
                [0, 1.5, 0, printed_grid_size + 0.5], [-0.5, printed_grid_size,
                                                       printed_grid_size - 1.5, printed_
↪grid_size],
```

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```
            ],
            'line_style': [color.cmyk.Black, style.linewidth.thin, style.linestyle.dashed],
        },
    ],
    'extra_texts': [
        {
            'x': 0.0,
            'y': -1.0,
            'text': r'\copyright Daniel Boulet  2020',
            'width': 10.0,
        },
    ],

}

Nomographer(main_params)
```

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