Assignment #2 – Wind Power Calculation

Part 1 Due Monday, April 15th 2024 at Midnight
Part 2 Due Monday, April 22th 2024 at Midnight

Assignment Overview and Outcomes

The focus of this project is on how to solve simple problems using programming language data types, variables, and arithmetic operations. At the end of this project, you will:

- Develop a program to read data from the standard input and produce data to the standard output.
- Translate a given mathematical expression into equivalent syntactically correct programming statements.
- Write a program that conforms to a programming style specified by the instructor.

Be sure to properly document the program. Consult the class Programming Style Guidelines document (provided by the instructor) for style expectations. A well-written program is easier to debug, easier to maintain over time, and easier to extend as new requirements arise.

Sustainability Motivation

The United Nations (UN) has set forth 17 goals for sustainable development. Goal 7 is designed to "Ensure access to affordable, reliable, sustainable and modern energy for all". Access to energy resources is necessary for quality of life, including jobs, agriculture, and climate-related issues. Energy resources includes electricity as well as access to clean, renewable fuels and the technologies for harnessing and distributing energy.

There are a number of renewable, clean energy sources available. In this project, we will consider wind power as a renewable energy source.

Wind Turbine Technology Background

Basic wind technology has been used for thousands of years. In order to produce electricity, turbine blades turn a generator located at the top of the turbine tower. **Watch this quick video on wind power**. In the United States, it has been estimated that the installed wind power capacity is around 122 GW (gigawatts) as of 2021, and it is expected to grow to over 400 GW by 2050. Texas installed the most wind power capacity in 2020. This capacity is the result of over 54,000 wind turbines installed in 41 states and U.S. territories. The electricity generated by wind sources accounts for more than 10% of electricity in 16 states, and over 30% in Iowa, Kansas, Oklahoma, South Dakota, and North Dakota. However, the US ranks lower compared to many other countries in terms of wind energy as a share of total electricity generation, with countries like Mexico, Lithuania, Belgium, and the EU with a higher share. Source: U.S. DOE

Calculating the Energy Produced by a Wind Turbine: 2-part assignment

Suppose you wanted to install a wind turbine to generate electricity. One question you might ask is: what is the amount of power my wind turbine can produce? To answer this question, you will need at least the following information:

- The average wind speed (in m/s)
- The radius of the blades on your wind turbine (in meters)
- The operating efficiency of your wind turbine (in %)

To compute the maximum power output for your wind turbine, you would need the following math formulas:

- $A = \pi r^2$, which represents the cross-sectional area of a circle (use the `M_PI` constant from the cmath library).
- $P_{max} = 0.5\rho A v^3$, which calculates the **maximum** available power given the wind speed in m/s (v), cross-sectional area of the blades in m^2 (A), and the density of the air (ρ = 1.293 kg/m^3).

Once you have the *maximum* available power, computing the **actual** amount of power (not the maximum) produced by the wind turbine is a matter of determining the amount of power based on the operating efficiency.

Program to Write
Your program will ultimately compute the amount of power produced by a farm of wind turbines. First, *get the 1) average wind speed (m/s), 2) operating efficiency of the wind turbine (%), 3) radius of the wind turbine blades (m) from the user, and 4) how many wind turbines you plan to install on the wind farm.*

Next, *create a function to calculate the maximum turbine power as output given the average wind speed and radius of the wind turbine blades* as input. Make sure the function works before calculating the actual power produced.

Then, *create a function to calculate the actual turbine power as output given the operating efficiency* as input. *Output the maximum and actual turbine power to the screen*. Be sure to print the units in your output to the screen.

Last, *create a function to calculate the actual wind farm power given the power produced by one turbine and the number of turbines to build on the farm* as input. *Output the actual power produced by the wind farm to the screen*. Be sure to print the units in your output to the screen.

Part 1: Program Design

First, you will begin by going through Polya's problem-solving steps. Use the Polya template provided to assist with this step.

Understanding the Problem. (5 pts)

- Do you understand everything in the problem? What are the functional requirements of the program, i.e. what does it need to do? (List anything you do not fully understand.)

- What assumptions are you making?
- What are the inputs, outputs, etc.?

Devise a Plan. (15 pts)

- What are the sequence of steps you need to complete?
- How are you going to calculate the power?
- What functions will you have in your program and what names and instructions will be part of each?

Based on your answers above, **provide the algorithm as pseudocode or provide a flowchart** of the specific steps that are needed to create this program, including the error checking. Be very explicit!!!

Looking Back. (5 pts)

Create a test plan with the test cases (bad and good cases).

- What are the good and bad cases for ALL input in the program?

Part 2: Write a C++ Program

After your design, you will write the program to calculate the output power of your wind farm, and you will run your program with examples to make sure the program works correctly.

Carry out the plan. **(75 pts)**

(60 pts) Write the program that takes the average wind speed (m/s), the operating efficiency of the wind turbine (%), the radius of the wind turbine blades (m) as input, the number of wind turbines on the farm, and has three functions (not including main) to calculate the maximum and actual wind turbine power from one turbine and the actual power produced by the wind farm.

(15 pts) Remember, you will be graded on having the proper spacing, comments/function descriptions, and good variable/function names, as well as good, clear prompts and output messages.

Here are few sample tests you can run to check if your program is working correctly.

Average Wind Speed (m/s): 8.5
Blade Radius (m): 25.8
Operating Efficiency (%): 21
Number of Turbines: 1
Maximum Turbine Power: 830.261 kW
Actual Turbine Power: 174.355 kW
Actual Farm Power: 174.355 kW

Average Wind Speed (m/s): 7.9
Blade Radius (m): 46.0
Operating Efficiency (%): 29
Number of Turbines: 5
Maximum Turbine Power: 2118.92 kW
Actual Turbine Power: 614.488 kW
Actual Farm Power: 3072.44 kW