

It is rocket science!

Homework 5

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Handed out: 4 October 2017

Due: 22 October 2017 (>2 weeks to complete)

Aim

In this homework, you will act like a real rocket scientist!

After doing this homework, you can handle control structures and tackle common bugs caused by computer's finite precision and accuracy.

Don't be intimidated by the length of the homework. It's quite a lot of reading but it is very doable.

1. Description

After months of a challenging interview process, you were hired to National Aeronautics and Space Administration. Your first project as a Rocket Scientist is to design a 338-kilogram robotic space probe, *the Mars Voyager '17 Orbiter*, that will be fitted with the most advanced technology of our time and will be launched on November 2027 to study the Martian climate, atmosphere and inhabitants.

For this first challenge, you need to develop a C++ program to a ground-based computer. The program should read important values from the sensors of the space probes and convert the values from non-SI units of pound-seconds (in this context pounds meaning force) to the SI units of newton-seconds (N·s). Pound-force (symbol lbf) is used for example in English Engineering units and the British Gravitational System, and it can be converted to newtons ¹:

$$\begin{aligned} 1 \text{ lbf} &= 1 \text{ lb} \times 0.45359237 \frac{\text{kg}}{\text{lb}} \times g_n \\ &= 0.45359237 \text{ kg} \times 9.80665 \frac{\text{m}}{\text{s}^2} \\ &= 4.4482216152605 \text{ N} \end{aligned}$$

After the unit conversion, your program needs to store the values into a **vector**. Finally, the engineers in the control room can ask the program to convert values back from newton-seconds to pound-seconds while the probe is on its way to Mars, just to make sure that everything is going as expected. This is a very expensive experiment after all, with a budget of \$193.1 million on spacecraft development, \$91.7 million on the launch and \$42.8 million on operations!

¹Thanks Wikipedia!

2. Getting started

Your mission is to make a C++ program that

1. reads the input data file. The probe's sensor stored all the values in the text file: `valuesInLbf.dat`.
2. does the unit conversion from pound-seconds to newton-seconds
3. saves the values (both pound-seconds and newton-seconds) to **vector**
4. prints out the values from the vectors
5. allows users to give numbers to the program that will then convert the values to pound-seconds

Start by making a new `.cpp` file, include the needed libraries and make a `main()` function of a type `int`. Eventually, you should also implement other functions than `main`!

The output should look as follows:

```
Reading values from valuesInLbf.dat...
Converting values from pound-seconds to newton-seconds...
Value in lbf*s: 2.6, value in N*s: 11.5653
Value in lbf*s: 6, value in N*s: 26.6892
Value in lbf*s: 20, value in N*s: 88.964
Value in lbf*s: 43, value in N*s: 191.273
Value in lbf*s: 4.95e+06, value in N*s: 2.20186e+07
Value in lbf*s: 2.2e+07, value in N*s: 9.78604e+07
Value in lbf*s: 1.6e+10, value in N*s: 7.11712e+10
Dear engineer in a control room! Give a value in N*s. I will convert it: 75
75 N*s is 16.8608 lbf*s
Give another number (0 if you want to exit): 100
100 N*s is 22.481 lbf*s
Give another number (0 if you want to exit): 0
```

Pay extra attention to the following guidelines:

- Use meaningful names for your variables!
- Implement also other functions than `main`
- Your code should be well readable, follow best coding practices, be highly efficient, well structured and well commented!

3. Finalize the mission

Congratulations! You have now developed a program that could have saved 200 million dollars if it was done in 1999. ² Hindsight is always easy but this example shows how sometimes even the greatest of programmers make mistakes that could be easily avoided.

You can now be promoted to Captain Rocket Scientist, but only under one condition. In addition to handing in your excellent code (see the procedure below), please answer the following questions. Short answers are ok.

²Very costly unit conversion mistake was actually made; the Mars Climate Orbiter used non-SI units instead of newton-seconds. The real spacecraft was steered too close to Mars, causing it to pass through the upper atmosphere and disintegrate. Be better than the previous workers at NASA! https://en.wikipedia.org/wiki/Mars_Climate_Orbiter. Read 6 September 2017.

- What is the largest number you can convert?
- If a short integer can run out of room, why not always use long integers?
- What is the difference between passing arguments to a function by value and passing arguments to a function by reference?
- What was the most difficult part in this exercise? What was the easiest?
- How would you make your program better?

Hand-in procedure

1. Save

Save your solution: both your code file(s) and another file with your answers (if you want to become Captain Rocket Scientist). Make a single tar.gz file.

2. Time and collaboration info

At the start of the file, write down the time (approximately) you spent on this homework, and the names of students you may have collaborated with. You need to complete the homework independently but of course you may discuss and think about the problems together.

Example of the beginning of the code file:

```
/*  
Homework: It is rocket science!  
Name:  
Collaborators:  
Time:  
*/  
... your code...
```

3. Submit your .tar.gz to Live@Lund by 22 October 2017!

Note: Homework is mandatory! Don't hesitate to ask help from teachers if you get stuck.