Course C^{++}, Exercise List 10

Deadline: 02.06.2017

We will use templates for the modeling of physical units:

```
template< int M, int L, int T = 0, int I = 0 >
struct si
{
   double val;

   explicit si( double val )
      : val{ val }
   { }
};
```

Each instance of `si<M,L,T,I>` defines a different type. M stands for *mass* (**kg**), L stands for *length* (**m**), T stands for *time* (**sec**), and I stands for *electric current* (**A**).

1. Define `operator <<` that prints a physical quantity together with its unit in a reasonable fashion, e.g.

   ```
   auto g = 9.81 * 1.0_m / ( 1.0_sec * 1.0_sec );
   std::cout << g << "\n";
      9.81ms^{-2}
   std::cout << 1.0_m << "      " << 2.0_hr << "\n";
      1m      7200s
   ```

   Units that are not used should not be printed, and units that are used with power one should be printed without power symbol.

2. Define a function

   ```
   template< int M1, int L1, int T1, int I1,
             int M2, int L2, int T2, int I2 >
   constexpr bool same_quantity( si<M1,L1,T1,I1> q1, si<M2,L2,T2,I2> q2 );
   ```

   that returns true if `q1` and `q2` have the same physical quantity (same unit). It is **constexpr** because it depends only on the types of `q1` and `q2`.

3. Define the following multiplication operators in file **units.h**:

```
template< int M1, int L1, int T1, int I1,
          int M2, int L2, int T2, int I2 >
si<M1+M2, L1+L2, T1+T2, I1+I2 >
operator * ( si<M1,L1,T1,I1> q1, si<M2,L2,T2,I2> q2 );

template< int M1, int L1, int T1, int I1,
          int M2, int L2, int T2, int I2 >
si<M1-M2, L1-L2, T1-T2, I1-I2 >
operator / ( si<M1,L1,T1,I1> q1, si<M2,L2,T2,I2> q2 );

template< int M, int L, int T, int I >
si<M,L,T,I> operator * ( si<M,L,T,I> q, double d );

template< int M, int L, int T, int I >
si<M,L,T,I> operator * ( double d, si<M,L,T,I> q );

template< int M, int L, int T, int I >
si<M,L,T,I> operator / ( si<M,L,T,I> q, double d );
```

4. Also define the following addition and subtraction operators:

```
template< int M, int L, int T, int I >
si<M,L,T,I> operator - ( si<M,L,T,I> q );

template< int M, int L, int T, int I >
si<M,L,T,I> operator + ( si<M,L,T,I> q1, si<M,L,T,I> q2 );

template< int M, int L, int T, int I >
si<M,L,T,I> operator - ( si<M,L,T,I> q1, si<M,L,T,I> q2 );
```

5. Consider a recharcheable battery with a capacity of 800mAh and a voltage of 1.2V. How much energy does it contain, when fully charged?

6. Consider a car (A) driving at the autostrada with a speed of 100 kmh. There is another car (B) that overtakes car A, which, seen from the first car has a speed of 30 kmh. Compute the speed of car B, as seen seen by a viewer who stands still on the side of the autostrada.

   Assuming that car B (in total) has a mass of 1200kg, what is its kinetic energy?

   Since both cars are actually travelling quite fast, one might wish to take into account relativistic effects. For this, we can use the formula $u = \frac{v_1 + v_2}{1 + v_1 . v_2 / c^2}$, where c is the speed of light. (Define a **const** variable c with proper unit) Compute the speed with which a standing viewer sees car B passing by, according to the addition law of special relativity.

7. We conclude this task with the study of nuclear weapons. Tsar Bomba seemed to be able to convert 2.3kg of pure mass into energy. We know that $E = mc^2$, where c is again the speed of light. How much energy is released by Tsar Bomba? Knowing that TNT (trinitrotoluene) contains 4184 Joule / gram (define a **const** variable for this with proper unit), compute the TNT-equivalent of Tsar Bomba.