Approach

The approach below gives a guideline in how to solve the problems presented during this course. Correctly applying this approach will lead to a good understanding of the concepts presented in this course.

Analysis

1. Explain the problem: which physical phenomena are important in this problem?
2. Make a sketch of the problem
3. Give the known variables (with the appropriate units!)

Approach

1. Explain the assumptions you make to solve the problem
2. Show the solution method for solving the problem

Elaboration

1. Show the calculation steps and explain the equations you use
2. Give references if values are found online or in tables

Evaluation

1. Check the units of your solution
2. Is the answer realistic/expected?
3. Did you answer all the questions asked?
4. Iterate if this is required

Lecture 1

1.1 Joule's test setup

Consider Joule's test setup for energy conversion in figure 1.1. Suppose that a load of 50 kg drops over a distance of 20 m. All mechanical energy is then absorbed by the water volume of 5.0 L and converted into thermal energy. The water is contained in a well-insulated vessel. There is a small gap between the top of the vessel and the rotating axis, but the heat loss from the water can still be considered negligible.

a) Determine the temperature increase of the water after the load has been displaced.

To lift the load after every test, a diesel engine is installed.

b) Suppose that this engine is highly efficient. With a budget of €1, how often can you lift the load over a distance of 20 m? The chemical energy of diesel is equal to 45.5 $\mathrm{MJ\,kg^{-1}}$. Other values for diesel can be found online.

c) A proposal is made to use an engine that has a power of 2.5 horse power (paardenkracht, pk). Is this engine suitable if the load should be lifted in 5 seconds?

d) If the engine would run on bars of chocolate, for how many days can the tests be performed with two bars of 200 g and 2 bars of 250 g? Suppose that the weight has to be lifted 120 times per day.

Because of environmental considerations, the diesel engine is replaced by an electromotor with the same power.

e) Which option is cheaper? The diesel engine or the electromotor? The price for electricity is €0.17 per kWh.

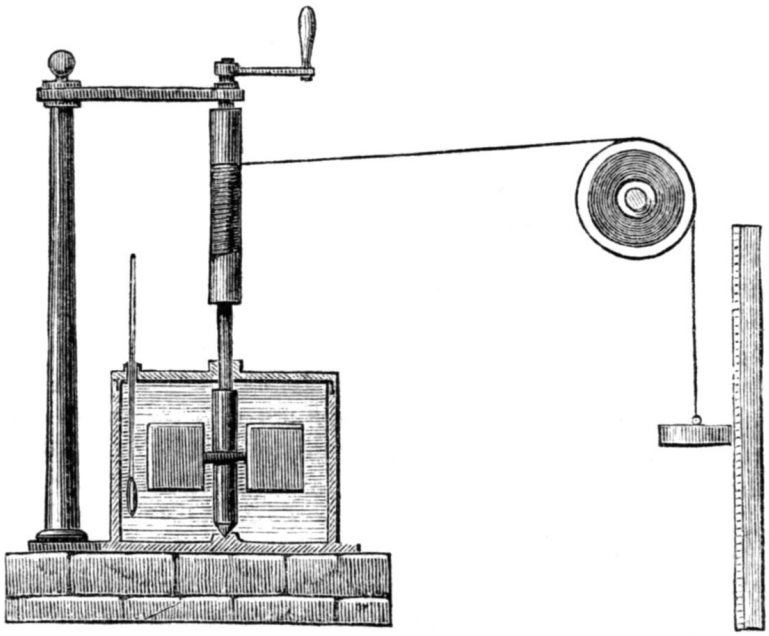

Figure 1.1: Joule's test setup

1.2 Transport by car and bus

A group of 24 students wants to attend an industrial design conference in Zwolle. They have the option to go either by cars or by a bus (which has to be hired). The travelling distance is 75 km from Enschede to Zwolle. If the students decide to go by car, they would be using six cars with an average gasoline consumption of 7.2 L per 100 km. A bus uses diesel: 35 L per 100 km. The energy in gasoline is 42 $\mathrm{MJ\,kg^{-1}}$, for diesel this is 43 $\mathrm{MJ\,kg^{-1}}$. The specific mass of gasoline is 0.70 $\mathrm{kg\,L^{-1}}$, for diesel this is 0.85 $\mathrm{kg\,L^{-1}}$

a) Determine the amount of fuel consumed for a return trip to Zwolle per person, for both car and bus.

b) Determine the total amount of energy that is used for both alternatives, and per person.

c) Which option is cheaper? The cars are owned by students, hiring a bus costs €200. Diesel costs €1.14 per litre and gasoline costs €1.49 per litre.

d) An international conference is hosted in Belgium. What is the minimum amount of kilometers the same group has to travel for the bus to be cheaper then the cars?

e) Now lets go back to the trip to Zwolle. A few sporty students decide to go by bicycle! How many Calvé's are required to cycle to Zwolle and back? How much energy (in MJ) is this equivalent to?

f) Is it possible to say, based on this data, which transportation method is the most energy efficient?

1.3 Boiling water - Hand in

There are various appliances that are suitable for boiling water. Two possible options are using a kettle on a gas stove and an electric kettle. Determine which option is cheaper, by answering the following questions.

a) Determine the amount of energy (in kJ) required to heat one liter of water from room temperature (20 °C) to 100 °C.
Hint: use the definition of kcal and the conversion factor between kcal and kJ.

b) Determine the volume of gas that has to be burnt when 40% of the energy is transferred to the water in the kettle. The chemical energy in the gas is 50 MJ/kg. The density is 0.7 kg/m^3.

c) Almost all electrical energy that is used in an electric kettle is transferred to the water. When the kettle has a power input of 2000 W, make an estimation of the time it will take before the water boils.

d) What is the amount of energy (in kWh) required to heat the water, using an electric kettle?

e) Which option consumes more energy? Only include energy conversions inside the house. If necessary, convert the answers of questions *b* and *d* to the same unit.

f) Which option is cheapest, when 1 m^3 of gas costs €0.67 and 1 kWh of electricity costs €0.22?