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.

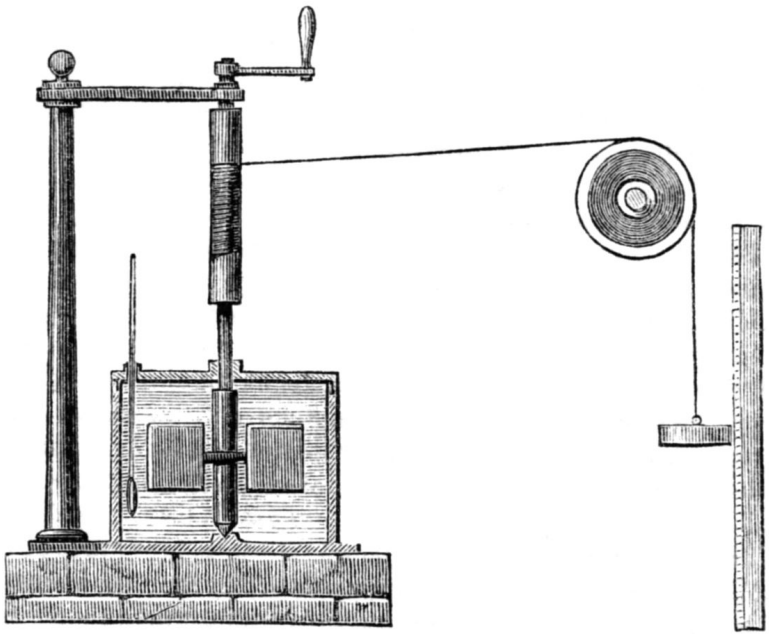

Figure 1.1: Joule's test setup

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 Automobile engine - Hand-in

An automobile engine converts the chemical energy in fuel into mechanical energy to propel the vehicle. Suppose you want to calculate the amount of energy required to travel a certain distance using a gasoline engine. The engine has a mechanical power output of 150 horsepower and an efficiency of 25%. The distance to be traveled within 80 minutes is 100 kilometers. The density of gasoline is 0.75 kg/L and its heating value is 45.3 MJ/kg and costs €1.87 per liter. The car has a fuel tank capacity of 50 liters. The mass of the engine is 200 kg and has a specific heat capacity of 0.5 kJ/kgK.

a) What is the required amount of energy in kWh to travel the distance of 100 kilometers?

b) Suppose the tank is filled at the beginning, how often would we need to refill travel the distance of 100 kilometers?

c) Calculate the final in temperature of the engine if it initially was at 20 °C, assuming no cooling of the engine and the temperature to remain homogeneous at all times.

d) Compare the cost of using gasoline to power the car with the cost of using an electric car to travel the same distance in the given time. Assume that the electric car has an energy efficiency of 80% and the cost of electricity is €0.15 per kilowatt-hour. Which of the two options do you recommend?