1 Entropy Basics

(a) **(T3B.5)** Objects A and B have different temperatures and initial entropies of 22 J/K and 47 J/K. We bring the objects into thermal contact and allow them to come to equilibrium (the objects are isolated from everything else). What is the most quantitative statement that we can make about the combined system's entropy after the two objects come to equilibrium?

(b) **(T3B.8)** Suppose that we increase an object's internal energy 10 J by heating the object. The temperature of the object remains roughly constant at 20 C. By how much does the object's entropy increase?

2 Gasoline Sun

(long answer format)

(a) Electromagnetic radiation energy from the Sun arrives at the upper atmosphere of our planet at a rate of about 1350 J/(s $\cdot$ m^2). Use this information, together with the average radius of the Earth's orbit, to show that the Sun radiates energy at a rate of about 4×10^{26} J/s.

(b) We know from radiometric dating of rocks on Earth (and the Moon and Mars) that our solar system is about 4 billion years old. Let's make a naïve hypothesis (like scientists did in the early 1900s) that the Sun is powered by burning hydrocarbons. What mass of gasoline would be needed to power the Sun at a rate of 4×10^{26} J/s for 4 billion years? Compare to the actual mass of the Sun.

Note: The energy density of hydrocarbon fuels, including gasoline, natural gas, dry logs of wood, chocolate, croissants, gummy bears, etc. etc. is $\approx$ 40 MJ/kg.

3 Hydrocarbon Fuels

(long answer format)

Hydrocarbon fuels have an energy density of about 40 MJ/kg. This means that burning 1 kg of hydrocarbon fuel releases 40 MJ of thermal energy. (For comparison, a modern lithium-ion battery has an energy density of about 0.7 MJ/kg). There are many forms of hydrocarbon fuel: gasoline for cars, wood for campfires, and butter/chocolate/croissants etc. for people.

(a) In class we analyzed a gas-powered car driving at 70 mph (30 m/s). There was a flow of energy going into the kinetic energy of the wind trail behind the car, and an additional flow of heat energy warming the environment. Approximately how many gallons of gas does it take to drive a car 100 miles at this speed? Show how you worked it out, remember that you can't use the equation you derived in class as a starting point.

(b) Make a similar calculation for a person riding a bicycle. Remember that humans also produce waste heat as they consume hydrocarbon fuel. How many kilograms of chocolate (or similar fuel) would a professional bicycle rider need to travel 100 miles at 20 mph?