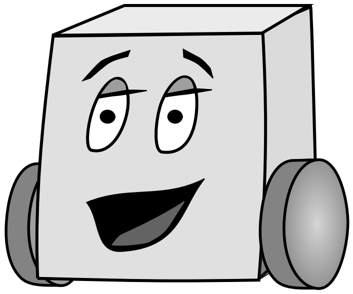


E11: Autonomous Vehicles

Fall 2010

Harris & Lape with Keeter & Ong

Problem Set 5: Fuel Cell Power and Energy Conservation

Due Wednesday, 27 October 2010 at the start of class.

1. Solid-Oxide Fuel Cell

Solid-Oxide Fuel Cells (SOFCs) are often used in large-scale stationary power systems due to their long-term stability and high efficiency. They can use either carbon monoxide or hydrogen as fuel.

a) Determine the number of households consuming an average of 1 kW each that could be powered by a hydrogen-oxygen solid-oxide fuel cell (SOFC) running at standard temperature and pressure* with the following specs:

- 20 g/s hydrogen fed to the SOFC
- 50% hydrogen utilization
- 85% of maximum power output

b) If the portion of the maximum possible power that is not harnessed as useful work output is instead all lost as heat transfer to the environment, what is the rate of heat transfer from the SOFC to the environment?

c) What is the enthalpy change across this fuel cell? You may assume that there are no changes in kinetic or potential energy and the heat loss is what you calculated in part b). Be careful with the signs of heat and work in this calculation!

* In reality, SOFCs are run at elevated temperatures (order of 700°C).

2. Climb that hill! (Adapted from Cengel and Boles "Thermodynamics: An Engineering Approach")

Determine the power required for a 2000-kg car to climb a 100-m-long uphill road with a slope of 30° (from the horizontal) in 10 seconds:

a) At constant velocity;

b) From rest to a final velocity of 30 m/s; and

c) From 35 m/s to a final velocity of 20 m/s.

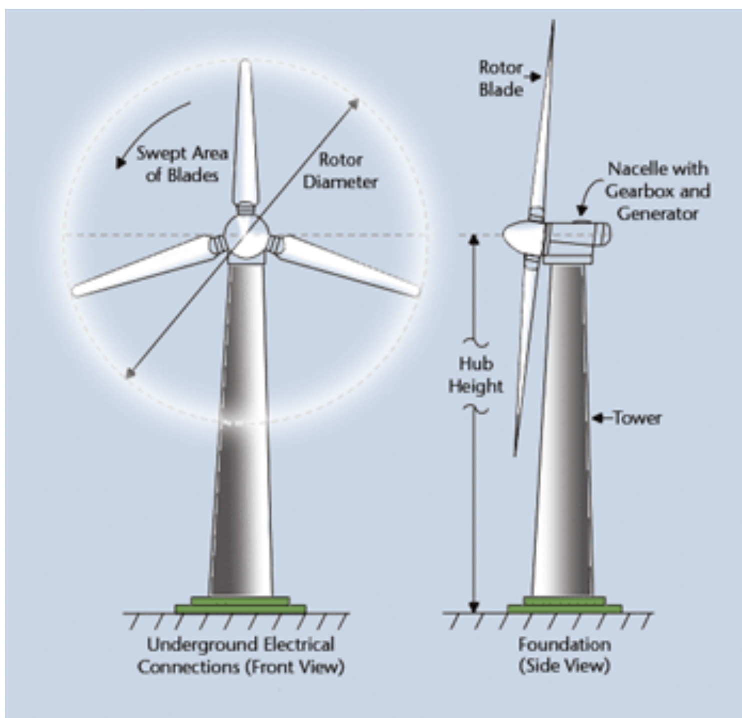
Disregard friction, air drag, and rolling resistance for the above calculations, but

d) Comment on how including friction, air drag, and rolling resistance would affect your results (e.g. would the power requirement be higher or lower and why?).

3. Wind Power (Adapted from Cengel and Boles "Thermodynamics: An Engineering Approach")

a) Determine the power generation potential (i.e. power that could be produced if all entering kinetic energy were converted to work output) in kW of a wind turbine with 60-m-diameter blades (called "Rotor Diameter" on the diagram below) at a location where wind blows steadily at 10 m/s. Take the full circular area circumscribed by the blades as the entrance area for the air ("Swept Area" on the diagram below). You may assume the air density is 1.25 kg/m^3.

b) If a typical household consumes power at a rate of 1 kW, how many households could one wind turbine power?



Drawing of the rotor and blades of a wind turbine, courtesy of ESN

Image from http://www.daviddarling.info/images/wind_turbine_blades.gif