1.818J/2.65J/3.564J/10.391J/11.371J/22.811J/ESD166J

SUSTAINABLE ENERGY

Spring 2005

PROBLEM SET #5

Due March 31, 2005

In answering the questions below please clearly state and justify all assumptions made

1. Lead-acid batteries come at a price. Estimate the weight of lead-acid batteries that you would need to carry on board a fully electric car to have a range of 200 miles without having to recharge. You can assume that the minimum power needed to drive the vehicle safely is about 50 hp for speeds up to 60 mph.

2 Pumped hydro energy storage. Consider a pumped hydro system that is used for energy storage. During off-peak hours, excess electricity is used to pump water up to a storage reservoir. During peak demand periods the flow is reversed and electric power is generated by flowing the water thru a hydraulic turbine. Estimate the theoretical energy and power density of the system that stores water during the times that power is generated. The storage reservoir is 100 m above the hydro turbine/pump units and the hydraulic turbine can accommodate up to 650 kg/s of flow. Express your answer in J/m^3 for energy density and W/m^3 for power density. Referring to the Ragone plot shown in Figure 16.5, how does pumped hydro compare to other storage technologies? How large (area) would this pumped storage reservoir need to be to store 1000 MWh of hydro energy if its average depth were 10 m? Is this reasonable?

Relevant data are given below problem 3.

3 Tidal power when you need it. What is the maximum energy per square meter of water surface area that could be obtained from a tidal power station located at the Bay of Fundy where the mean tidal height is 5 m? What additional energy could be extracted if the mean flow velocity of water through the tidal basin is 1 m/s throughout the year? How does the KE portion compare with the PE portion in the tidal flow?

For the purpose of this evaluation you can assume that the portion of surface area (width x length) of the Bay of Fundy to be used for tidal power to be A m^2. Also keep in mind that PE part of the tidal energy content is distributed over a range of depths in Earth's gravitational field.

Data for problems 2 and 3

- density of water is 1000 kg/m^3
- acceleration of gravity is 9.8 m/s^2
- heat capacity of water is 4200 J/kgK
- viscosity of water is about 1 centipoise

4. **Geopower in Alaska – the colder the better!!** As quoted in the January 1983 *New York Journal American*– "As incongruous as it may seem, there is a plan afoot to use waters of the Atrric Ocean as a source of power to generate electricity. And while the idea is a long way from being perfected, the theory is almost too simple to be true." A young engineer at the University of Alaska, Rocky Jones Byrd, and his cousin Larry have come up with a practical scheme to do just what the *Journal* reported. Power would be generated in an organic Rankine cycle that is designed to take advantage of the temperature difference between the cold Arctic air averaging about -20^{o}C and the warmer Arctic Ocean beneath the polar cap at -1^{o}C.

(a) assuming a flow rate of seawater of 100 kg/s is available what is the maximum power that could be produced, for seawater you can assume the heat capacity C_p = 4200 J/kgK and density = 1030 kg/m^3

(b) qualitatively sketch out a temperature-enthalpy diagram for the Rankine cycle and Arctic ocean and air streams and describe where losses occur to make the actual power produced less than the maximum you calculated in part (a)