ESR 320
ENVIRONMENTAL SYSTEMS I
PROBLEM SET 2
DUE NEXT THURSDAY (OCTOBER 22)

1. How much solar energy does it take to evaporate water in a pond on a summer day?

    a. Suppose we have a small pond with a surface area of 100 m^2. We make careful measurements of the evaporation rate and we observe that, during the day, the water level drops by 6.0 mm every 12 h. What is the evaporation rate in mm/d (mm d^{-1})?
    b. How many liters of water evaporate from the whole pond when the water surface drops by 1.0 mm?
    c. How many liters evaporate from *each square meter* of the pond surface when there is 1.0 mm of evaporation? (I.e., how many L/m^2 for each mm of evaporation?)
    d. Use the answer from parts a) and c) to calculate the *rate* at which *mass* of water evaporates from the pond. Your answer should be in units of (g m^{-2} s^{-1})
    e. The latent heat of water at 15°C is 589 cal g^{-1}. How many calories of latent heat are required each second to create the evaporation rate per m^2 you calculated in part d)? I.e., what is the heat inflow in cal m^{-2} s^{-1}?
    f. Convert the values of part e) into units of J m^{-2} s^{-1}? (J = Joule)
    g. A watt (W) of power is defined as a joule/sec (J s^{-1}). Can your answer in part f) then be expressed as a "power density" with units of watts per sq. meter (W m^{-2})?
    h. If the sun provides all the heat to drive this evaporation, what is the minimum average power density of sunlight on the pond in W m^{-2}?

2. The air near this pond is measured to have a temperature of 82°F. The relative humidity (RH) is measured at 62%.

    a. What is the dew point of this air in °C? In °F?
    b. Use the table on the next page to find the *partial* pressure of water vapor in the air in mm-Hg. Use linear interpolation to find the value for the given temperature and remember factor in RH.
    c. What is the partial pressure of water vapor in units of atm?
    d. What is the actual vapor density of the air in units of g m^{-3}? You can get this directly from the table and RH, as you did for partial pressure above.
    e. Your answer in part c) tells you how many grams of water are in one cubic meter of air. If we assume all the moisture in the air near the pond came from the pond, what is the volume of moist air that corresponds to the evaporation of 1.0 mm of water off of the entire pond surface? (Hint: Figure out the number of grams of water in that amount of evaporation, then compute how many cubic meters of air it would take to "absorb" that amount of water vapor at the vapor density from part d).)

Saturated Vapor Pressure, Density for Water

Temp (°C)	Temp (°F)	Saturated Vapor Pressure (mmHg)	Saturated Vapor Density (g/m³)	Temp (°C)	Temp (°F)	Saturated Vapor Pressure (mmHg)	Saturated Vapor Density (g/m³)
-10	14	2.15	2.36	40	104	55.3	51.1
0	32	4.58	4.85	60	140	149.4	130.5
5	41	6.54	6.8	80	176	355.1	293.8
10	50	9.21	9.4	95	203	634	505
11	51.8	9.84	10.01	96	205	658	523
12	53.6	10.52	10.66	97	207	682	541
13	55.4	11.23	11.35	98	208	707	560
14	57.2	11.99	12.07	99	210	733	579
15	59	12.79	12.83	100	212	760	598
20	68	17.54	17.3	101	214	788	618
25	77	23.76	23	110	230	1074.6	...
30	86	31.8	30.4	120	248	1489	...
37	98.6	47.07	44	200	392	11659	7840