Answer 2.2

a) Estimate the following time scales:

$T_{sink} = 3/k_{sink} = 3/\ (0.15\ d^{-1}) = 20\ d$

$T_{air} = 3/k_{air} = 3/(0.9 d^{-1}) = 3.3\ d$

$T_D = h^2/D = (10m)^2/\ (0.5\ m^2\ d^{-1}\ ) = 200\ d$

b) *At some time $t > 0$ profiles of O_2 show that the bottom of the pond is depleted of oxygen, but the surface is not. Using the above time scales explain why this is so.*

The delivery of O_2 from the atmosphere is fast enough to balance the sink [$T_{air} < T_{sink}$]. However, the atmospheric flux of oxygen occurs at the water surface. The transport of oxygen to lower waters depends on vertical diffusion. The time-scale for the delivery of new oxygen to the lower waters by diffusion, T_D, is much longer than the time-scale for consumption [$T_D >> T_{sink}$], so oxygen will be depleted there.

c) Find the near-surface depth, Δz, for which diffusion can restore oxygen fast enough to keep up with the consumption.

The time-scale for diffusion is proportional to the length scale squared, so for depths less than h, T_D will be smaller than the value given above. Consider a distance $\Delta z < h$ from the water surface. The time scale to mix over this depth is $\Delta z^2/D$. Depths for which $\Delta z^2/D < T_{sink}$ will not be depleted of oxygen, because oxygen is restored by diffusion faster than it is consumed. Thus, we expect that depths less than

$\Delta z = (T_{sink}\ D)^{1/2} = 3.2\ m,$

should not be depleted of oxygen.