Answers to Exercises
Chapter 12

Exercise 12.1

Equation (5.15) describes radiative cooling:

$$q_{rad} = \epsilon\sigma\left(T_{surf}^4 - T_a^4\right) \ ,$$

whereas Equation (12.1) describes convective cooling:

$$q_{conv} = F_{conv} = \rho_a c_a \gamma \left(\frac{g' \alpha_a \kappa_a^2}{\nu_a}\right)^{1/3} \left(T_{surf} - T_a\right)^{4/3} \ .$$

For <u>subaerial</u> conditions using the appropriate values ($\epsilon = 0.9$, $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}, T_{surf} = 800–1200˚C, T_a = 20˚C) gives a range of radiative heat fluxes, $\boldsymbol{q_{rad}}$ **= 6.7 × 10^4 to 2.4 × 10^5 W m^{-2}**, depending on the surface temperature. (Remember to convert temperatures to Kelvin!)

Convective heat fluxes under subaerial conditions (using ρ_a = 1.2 kg m^{-3}, c_a = 1000 J kg^{-1} K^{-1}, $g' = g$ = 9.8 m s^{-2}, $\alpha_a = 3 \times 10^{-3}$ K^{-1}, $\kappa_a = 10^{-7}$ m^2 s^{-1}, $\nu_{a\,=}$ = 1.5 × 10^{-5} m^2 s^{-1}) are $\boldsymbol{q_{conv}}$ **= 2.9 × 10^2 to 1.5 × 10^3 W m^{-2}**.

For <u>submarine</u> conditions, using T_{surf} = 500–1200˚C gives radiative cooling fluxes of $\boldsymbol{q_{rad}}$ **= 1.8 × 10^4 to 2.4 × 10^5 W m^{-2}**. In contrast, using the physical properties of seawater (ρ_a = 1025 kg m^{-3}, c_a = 4000 J kg^{-1} K^{-1}, g' = 6.2 m s^{-2} (Eq. 12.2), $\alpha_a = 3 \times 10^{-4}$ K^{-1}, $\kappa_a = 1.4 \times 10^{-7}$ m^2 s^{-1}, $\nu_a = 10^{-6}$ m^2 s^{-1}, and $\gamma = 0.1$) yields values of convective heat flux of $\boldsymbol{q_{conv}}$ **= 2.6 × 10^5 to 9.7 × 10^6 W m^{-2}**.

Therefore in the subaerial case, $q_{rad} > q_{conv}$, whereas for the submarine case, $q_{conv} > q_{rad}$.

Exercise 12.2

Equation (12.6) is $u = \sqrt{\dfrac{8rg\Delta\rho}{3\rho_a C_d}}$. When u = 0.35 m s^{-1}, and adopting the values r = 1 m, g = 9.8 m s^{-2}, ρ_a = 1025 kg m^{-3}, and C_d = 0.5, this equation yields $\Delta\rho$ = 2.4 kg m^{-3}.

Exercise 12.3

Extending Figure 12.6 to the left allows the Ψ-lines to be extrapolated to reach the x-axis, thereby allowing the effusion rates for a viscosity of 100 Pa s to be determined. For a pillowed EPR submarine flow, $Q < 2 \times 10^{-10}$ m^3 s^{-1} (point source), and $q < 5 \times 10^{-13}$ m^2 s^{-1} (fissure). For a rifted flow, $2 \times 10^{-10} < Q < 10^{-8}$ m^3 s^{-1} (point source), and $5 \times 10^{-13} < q < 3 \times 10^{-12}$ m^2 s^{-1} (fissure).