EVST201a/G&G 140a (2011)
The Atmosphere, Ocean and Environmental Change
Third Exam

Useful physical and mathematical constants:
\[ R = 8314 \text{ J} / \text{kmole} \cdot \text{Kelvin} ; \quad \sigma = 5.735 \times 10^{-8} \text{Wm}^{-2} \text{K}^{-4} ; \quad \pi = 3.14159 \quad g = 6.674 \times 10^{-11} \text{m}^3 \text{kg}^{-1} \text{s}^{-2} \]

Earth parameters:
\[ R_E = 6371 \text{km} ; \quad a_E = 0.33 ; \quad g = 9.81 \text{ m/s}^2 ; \quad \Gamma = -g/c_p = -9.8^\circ \text{C/km} , \quad \text{Tilt}=23.5^\circ \]
\[ H_s = R_s T / g = 8.4 \text{km} ; \quad S = 1380 \text{ W/m}^2 ; \quad \Omega = 7.27 \times 10^{-5} \text{ s}^{-1} ; \quad M = 5.974 \times 10^{24} \text{kg} \]

Properties of air:
\[ R_{air} = 287 \text{ J} / \text{kg} \cdot \text{C} ; \quad \rho_{air} = 1.2 \text{ kg/m}^3 ; \quad C_{p_{air}} = 1004 \text{ J/ kg} \cdot \text{C} \]

Properties of water:
\[ \rho_{water} = 1000 \text{ kg/m}^3 ; \quad \rho_{ice} = 917 \text{ kg/m}^3 ; \quad \rho_{SEA} = 1025 \text{ kg/m}^3 \]
\[ L_{\text{COND}} = 2.5 \times 10^6 \text{ J/kg} ; \quad L_{\text{FREEZE}} = 3.34 \times 10^5 \text{ J/kg} \]
\[ C_{\text{phase}} = 4218 \text{ J/ kg} \cdot \text{C} \]

Useful definitions:
\[ RH = P / P_{sat} ; \quad \text{ResTime} = C / F ; \quad \delta D = \left( \frac{D}{D_{\text{REF}}} \right) - 1 \times 1000 \]

Useful physical laws and balances:
\[ gM = PA ; \quad F_G = \frac{G M m}{r^2} ; \quad p = \rho RT ; \quad \Delta p = -\rho g \Delta Z ; \quad \text{Rgas} = \text{Runiversal} / \text{M} \]
\[ V_e = \sqrt{2g R_E} ; \quad V_m = \sqrt{\frac{3RT}{M}} ; \quad Q = MC_p \Delta T ; \quad Q = L \Delta m_v \]
\[ R = \sqrt{K \cdot T} ; \quad R_{\text{apace}} = \sqrt{Kx / U} \]
\[ CF = 2MU_\text{EKM} \sin \phi ; \quad \tau = 0.003 \rho A U_A^2 ; \quad U_{\text{EKM}} = \frac{1}{2} \rho DD_0 \sin \phi , \quad \Delta S = S_0 \left( \frac{d}{d+d} \right) \]
\[ F = \sigma T^4 ; \quad \lambda_m = 2898 \text{microns} \cdot \text{K} \]
\[ \text{PET(month/mm)} = 5 \times T(C) ; \quad P = P_0 e^{-A_H} ; \quad \rho = \rho_0 e^{-Z/H_s} \]
\[ T = \frac{4}{12} \left[ \frac{(S(1-a))}{4a} \right] ; \quad T_{zH} = T \left( 1 - \frac{Z}{2} \right)^{1/4} \]
\[ A_S = 4\pi R^2 V = (4/3)\pi R^3 ; \quad F = S \cos(\phi) \Delta T \]
\[ \Delta S = S_0 \left( \frac{d}{d+d} \right) \]}
WaterFlux = ρ_w U_A; SaltFlux = Sρ_w U_A; HeatFlux = C_p Tρ_w U_A

(Δp / L) Vol = ρ × 2 × Ω × sin φ × U × Vol

PE = Mgz ; EFF = ΔT/T; Qout = Ksqrt eff , P(t) = P(t = 0)exp(yt)

P_{Wind} = \left(\frac{1}{2}\right)ερU^3 A, \quad P_{Solar} = εS\tau_A cos(φ), P_{HYDRO} = ερWgzA

Unit Conversions:

ppmv = \frac{M_{AIR}}{M} ppm; 1 mb = 100 Pascals; 0°C = 273.1 K

1 knot = 0.54 m/s; 1 inch = 2.54 cm; °C = \frac{5}{9}(°F - 32) 1 tonne = 10^3 kg

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>P_{sat} (mb)</th>
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<tbody>
<tr>
<td>-10</td>
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</tr>
<tr>
<td>0</td>
<td>6.1</td>
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<td>10</td>
<td>12.3</td>
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Molecular Weights

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<tbody>
<tr>
<td>H_2</td>
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<tr>
<td>N_2</td>
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<tr>
<td>O_2</td>
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<tr>
<td>CO_2</td>
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<tr>
<td>Air</td>
<td>29</td>
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1. [10] Assuming that the Gulf Stream is in geostrophic balance, answer the following. If the Gulf Stream at 35N latitude is 50km wide, 1km deep and has a pressure difference across it of 4000 Pascal, compute the volumetric flow rate in the current. Express your answer in Sverdrups (i.e. 1SV= one million cubic meters per second)

2. [10] Consider two water masses (A and B) found near each other in the Atlantic Ocean. Mass A has S=36.0ppt and T=16°C while Mass B has 35.5 and T=9°C.
   a. Determine the density of each water mass
   b. Which water mass will be found higher in the water column?
3. [10] Consider a region of the tropical Atlantic with S=35ppt. A heavy rain adds a half meter of freshwater on the ocean surface and it mixes down to 50 meters. What is the new salinity of the surface waters?

4. [10] In El Nino, the conditions in the eastern tropical Pacific Ocean are:
   a. SST high or low?
   b. Air pressure high or low?
   c. Precipitation high or low?
   d. Biological productivity high or low?
   e. Explain the physical connection between (a) and (d)

5. [10] During the last glacial maximum the conditions were
   a. CO2 in the atmosphere high or low?
   b. Isotopes in fresh snow on Greenland heavy or light?
   c. Oxygen isotopes in new deep sea sediments heavy or light?
   d. Sea level high or low?
   e. Explain the relationship between (c) and (d).
6. [10] In recent centuries, we have the perihelion in January. Explain how the climate would be different if, due to precession, perihelion occurred in June.

7. [10] Explain the difference between sea ice and icebergs emphasizing their origin, thickness and salinity.

8. [10] Compare recent trends in sea ice extent in the Arctic and Southern oceans. Be specific. In what months are they best compared?

9. [10] Estimate the mass of salt in the world ocean (in kg)

10. [10] Define
    a. Antarctic Bottom Water
    b. Terminal moraine
    c. Equatorial upwelling
    d. Mid-ocean ridge
    e. Ekman layer