April 13, 2006

Homework II: Due April 20^{th}, 2006

Question 1: Lagrangian vs. Eulerian perspectives.
(i) A ship is steaming northward at a rate of 10 km h^{-1}. The surface pressure increases towards the northwest at the rate of 5 Pa km^{-1}. What is the pressure tendency recorded at the nearby island station if the pressure aboard the ship decreases at at the rate of 100 Pa/3 h?
(ii) The temperature at a point 50 km north of a station is 3 ^oC cooler than at the station. If the wind is blowing from the northeast at 20 m s^{-1} and the air is being heated by radiation at the rate of 1 ^{o}C h^{-1}, what is the local temperature change at the station?

Question 2: Scale Analysis
(i) Verify by scale analysis that the water emptying out of your bathtub does not care which hemisphere it is in.
(ii) Roughly, how big a bath tub would you need before it would 'feel' the Earth's rotation, and if it did in which sense would it circulate in Melbourne?
N.B. there is no single right answer to the above obviously. Just make some sensible assumptions. Remember that the pressure gradient comes from the 'dip' in the surface of the water above the drain-hole.
(iii) Friction. Neglecting the acceleration term in the horizontal momentum equation (i.e. $d\vec{v}/dt = 0$). Using the rule-of-thumb that the winds vectors make an approximately 15^o angle to the pressure gradient contours, calculate the associated frictional timescale in midlatitudes (discussed in class).

Question 3: Geostrophic balance
(i) The height-averaged pressure in the vicinity of an atmospheric high system in the northern hemisphere is given by the function

$$p(x, y) = p_0 exp[-((x - x_0)^2 + (y - y_0)^2)/\gamma^2] \quad (1)$$

where x and y are east and north coordinates, (x_0, y_0) is the center point of the high, and p_0 and γ are constants. γ is on the order of several hundred kilometers. (a) Sketch the pressure distribution as a function of x and y. (b) Derive an expression for and sketch the geostrophic velocity field in the vicinity of the atmospheric high pressure system.
(ii) What is the magnitude of the pressure gradient required at the Earth's surface at 45^oN to maintain a geostrophic wind of 30 ms^{-1}?
(iii) For motion around a center of pressure 100 km away, at 30^o latitude, compute the wind speed for which the Coriolis term will be equal to the acceleration term.
(iv) Consider again the pressure distribution in part (i) above. How would an observer in an inertial reference frame interpret the terms in Newtons Law that lead to this pressure distribution, and what would be the velocity field seen by this observer?

Question 4: Random physics question: angular momentum If the U.S. changed to driving on the left hand side of the road (i.e., as in Britain), would the length of a day increase, decrease, or remain the same?