Name ______________________________

SCI-123:Meteorology | Spring 2026

Introduction to Meteorology
Forces & Wind Exercises

Directions: Except for certain parts of exercise #2, **work each of the following exercises on paper separate from this one**. Be sure to show intermediate, necessary steps. You may work cooperatively, but each student must turn in her or his own work.

1. Suppose a 2 kg parcel of air near the surface of the earth has a velocity vector $\vec{v}_0 = (5, 10)$ at time $t_1 = 0$, and at time $t_2 = 1$ hour the parcel has a velocity vector of $\vec{v}_2 = (7, 3)$. The component speeds u and v of the velocity vectors $\vec{v} = (u, v)$ are in meters per second. **[10 points]**

   (a) Calculate the speed s ($s(t) = \|\vec{v}\| = \sqrt{u^2 + v^2}$) of the parcel at both times t_1 and t_2.

   (b) Find the change in velocity vector $\Delta\vec{v} = (\Delta u, \Delta v)$.

   (c) Find the the acceleration vector $\vec{a} = (a_x, a_y)$ in m·sec^{-2}.

   (d) Calculate the magnitude of the components of the force vector $\vec{F} = (F_x, F_y)$

2. Figure 1 shows surface pressure in the northern hemisphere with isobars drawn every 4 mb. Answer the following questions by referring to the figure. **[12 points]**

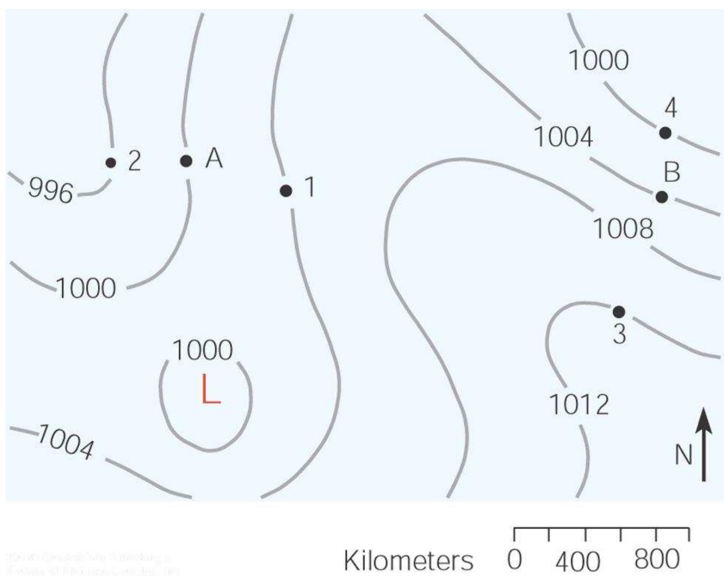

Figure 1: Sea-level pressure chart.

   (a) Draw a solid line through the ridge and a dotted line through the trough.

   (b) Draw an arrow to represent the wind direction at point A. Do the same for point B. (NOTE: This motion at the surface, so include the force due to friction and consider Buys-Ballot's law.)

   (c) Compute the pressure gradient, in N/m^2/m, between points 1 and 2, and between points 3 and 4.

   (d) Of the two locations A and B, which would have the greater wind speed? Explain why? (HINT: Consider the relative sizes of the pressure gradients calculated above.)

   (e) Suppose points A and B are located at 41° N, and the density of air is 1.2 kg/m^3. Use the geostrophic wind equation to compute the geostrophic wind, in m/sec, at points A and B.

   (f) Would the actual wind speed at points A and B be less than, equal to, or greater than the speed you calculated in part 2e? Explain.

3. Suppose a 3 kg parcel of air near the surface of the earth has a velocity vector $\vec{v}_0 = (-1, 8)$ at time $t_1 = 0$, and at time $t_2 = 1$ hour the parcel has a velocity vector of $\vec{v}_2 = (4, 3)$. The component speeds u and v of the velocity vectors $\vec{v} = (u, v)$ are in meters per second. 10 points

   (a) Calculate the speed s ($s(t) = \|\vec{v}\| = \sqrt{u^2 + v^2}$) of the parcel at both times t_0 and t_1.

   (b) Find the change in velocity vector $\Delta\vec{v} = (\Delta u, \Delta v)$.

   (c) Find the the acceleration vector $\vec{a} = (a_x, a_y)$ in m·sec^{-2}.

   (d) Calculate the magnitude of the components of the force vector $\vec{F} = (F_x, F_y)$

4. (a) Suppose the atmospheric pressure at the bottom of a deep air column 5.6 km thick is 1000 mb. If the average air density of the column is 0.91 kg/m^3, and the acceleration of gravity is 9.8 m/sec^2, use the hydrostatic equation to estimate the pressure at the top of the column. 4 points

   (b) If the air in the column of problem (a) becomes much colder than average, would the atmospheric pressure at the top of the 5.6 km tall column be greater than, less than, or equal to the pressure computed in problem (a)? Use the hydrostatic equation to justify your answer. 4 points

   (c) Determine the atmospheric pressure at the top of the 5.6 km tall column in problem (a) if the column is quite cold and has an average density of 0.97 kg/m^3. 4 points

5. Suppose points A and B lie on the 40° N latitude line, with point B 100 km east of point A. At a point midway between A and B there is a southerly geostrophic wind blowing with a speed of 10 m/sec. If the surface pressure at point B is 1000 mb, determine the surface pressure at point A. The surface density is 1.2 g/L. 5 points

6. In this exercise you will calculate the speed of the gradient wind around a low pressure system. The pressure gradient force on the parcel is the same as that in the geostrophic wind example shown in the handout (0.0017 Nm^{-2}/m) as well as the latitude (45° north) and the parcel density (1.22 kg/m^3). The radius of curvature of flow is r=200 km = 200,000 m. Calculate the speed of the parcel and compare it with that of geostrophic case with the same pressure gradient. Recall the equation for the speed of the gradient wind around a low is

$$\frac{v^2}{r} + 2\Omega v \sin\phi - \frac{1}{\rho}\frac{\Delta P}{\Delta r} = 0$$

   (NOTE: You will need to use the quadratic formula to find the speed v. By design, the speed must be positive. Use this as a means of determining which of the values to use as a result of the quadratic formula.) 5 points

7. Atmospheric mathematical modeling is frequently done using atmospheric pressure as a vertical coordinate instead of elevation. Consequently, vertical motion (speed) is given in units of microbars per second (μb/sec). Suppose an air parcel is moving in such a way that its speed is given as -50 μb/sec. Determine the parcel's vertical speed in meters per second and miles per hour. Is the parcel rising of falling? Explain. (Hint : Use the hydrostatic approximation to equate pressure change to height change. Assume the parcel is located at a pressure level of 850 mb.) 5 points