系所別：水文科學研究所　科目：大氣動力學

1. In the rotating Earth coordinate, the equation of horizontal wind (V) is written as
$dV/dt = -\nabla\phi - f\mathbf{k}\times V + F_r$, (1)
where $d/dt = \partial/\partial t + V\bullet\nabla + \omega\,\partial/\partial p$, $\delta\phi = g\delta z$, $f = 2\Omega\sin\varphi$, the earth angular velocity $\Omega = 7.292\text{x}10^{-5}\ s^{-1}$, F_r is friction

(a) what approximations have been made in deriving the above equation ? (5 %)

(b) explain each of the forcing terms in (1), (10 %)

(c) $f\mathbf{k}\times V$ is an "apparent force", explain why? (5 %)

(d) draw the steady state force balance expressed by equation (1) at point P in the following ϕ field at an isobaric surface (10 %)

---------- $\phi - 2\delta\phi$

----------● **P** ---------- $\phi - \delta\phi$

---------- ϕ

(e) define geostrophic wind V_g (10 %)

(f) derive $\nabla\bullet V_g = -(v_g/f)(\partial f/\partial y)$, (2)
give a physical meaning of the result. (5 %)

(g) compute the div of the geostrophic wind (2) at 45°N for $v_g = 15\ m\ s^{-1}$ (5 %)

2. The concepts of geostrophic and gradient wind are valid for large-scale atmospheric motions. In mesoscale and convective-scale motions the force balance in the momentum equation is very different. For motion in the vertical (w),
$dw/dt = -(1/\rho)(\partial p/\partial z) - g + F_z$,
where p is pressure, ρ density, F_z is friction, and Coriolis force neglected.

(a) By letting $\rho = \rho_o + \rho'$, $p = p_o + p'$, where basic state variables ρ_o and p_o are functions of z only and satisfy the hydrostatic balance.
Show that $(1/\rho)(\partial p/\partial z) + g = (1/\rho_o)(\partial p'/\partial z) + (\rho'/\rho_o)g$ (10 %)

(b) From $\theta = (p/\rho R)(p_s/p)^{\kappa}$, $\theta = \theta_o + \theta'$, where θ is potential temperature, $\kappa = -R/c_p$, $p_s = 1000$ mb,.
Show that $\theta'/\theta_o \approx (1-\kappa)(p'/p_o) - \rho'/\rho_o$ (10 %)

(c) From the above, $dw/dt \approx -(1/\rho_o)(\partial p'/\partial z) - (\theta'/\theta_o)g + F_z$ (3)
Explain the meaning of each term in (3) (10 %)

3. Explain the following

(a) Thermally direct circulation transport sensible heat upward. (10 %)

(b) The "Hadley circulation" does not extend from pole to equator in the earth's atmosphere. (10 %)