**Problem 1.** A particle is moving with acceleration $\mathbf{a}(t) = -g\,\mathbf{j}$ where $t$ is the time, $g$ is a constant parameter and $\mathbf{i}$ and $\mathbf{j}$ represent two mutual orthogonal constant unit vectors. Determine (a) the velocity $\mathbf{v}(t)$ if the initial velocity is $\mathbf{v}_0 = V_{x0}\,\mathbf{i} + V_{y0}\,\mathbf{j}$, (b) the position vector $\mathbf{r}(t)$ if the initial position vector is $\mathbf{r}_0 = x_0\,\mathbf{i} + y_0\,\mathbf{j}$, and (c) the relationship between $x$ and $y$, i.e., the function $y(x)$. (25%)

**Problem 2.** As shown in Fig. 1, an aircraft of mass $m$ is flying with

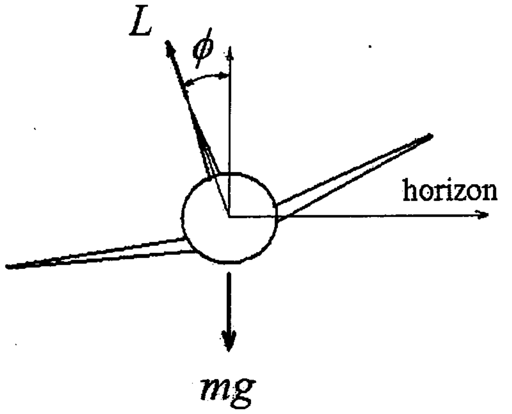


Figure 1: Rear view of the aircraft.

horizontal level (constant altitude) turn. If the velocity of the aircraft is $V$, the bank (inclined) angle $\phi$, the lift $L$, and the gravity $g$. Determine (a) the lift $L$ in terms of $m$, $g$, and $\phi$, (b) the radius of turn and the time for one revolution (i.e., a 360° turn) in terms of $V$, $g$, and $\phi$. Both $V$ and $\phi$ are assumed to be constant. (25%)

**Problem 3.** The mean atmospheric temperature variation on earth is found to drop off linearly from 15° on sea level to −56.5° at an altitude of 11 km and then remain isothermal till an altitude of 20.1 km. Please derive an equation (or equations) of atmospheric pressure variation in terms of the altitude. Also calculate the pressure at an altitude of 15 km. Assume that the atmospheric pressure at sea level is 101.33 kpa. (25%)

**Problem 4.** Consider a less restrictive situation from thermodynamics. Let's start with the one-dimensional steady flow energy equation with one inlet (point 1) and one outlet (point 2) with heat transfer, and work should be included in the equation,

$$\frac{\dot{W}_{\rm cv}}{\dot{m}} = \frac{\dot{Q}_{\rm cv}}{\dot{m}} + (h_1 - h_2) + \frac{V_1^2 - V_2^2}{2} + g(z_1 - z_2) \tag{1}$$

where $\dot{W}_{\rm cv}$, $\dot{Q}_{\rm cv}$, $\dot{m}$, $h$, $V$ and $z$ are the work, heat transfer, enthalpy, velocity, and gravitational height, respectively, and the subscript "cv" denotes the control volume.

On the other hand, the Bernoulli equation (usually found in fluid mechanics) can usually be expressed between two specific points, points 1 and 2, as

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 = \text{const.} \tag{2}$$

where $p$ and $\rho$ are the pressure and density, respectively.

Please (a) rearrange the equation in Eq. (1) into a form similar to the above Bernoulli equations, i.e., Eq. (2) with suitable assumptions, (b) compare Eq. (2) with Eq. (1) and explain the meaning of the *const.* in Eq. (2), (c) state the assumptions and conditions for Eq. (2), (d) explain the meaning of Eq. (2), and (e) answer that can you write down a general Bernoulli equation for a flow process including work and heat transfer? (25%)