1. A uniform heating wire is put inside a water tank horizontally as shown in Fig. 1. With the wire being heated, it is observed that the vapor bubble on the wire always moves along the wire for a distance on either direction before it moves away from the wire. Please explain this phenomenon physically and mathemmatically. (20%)

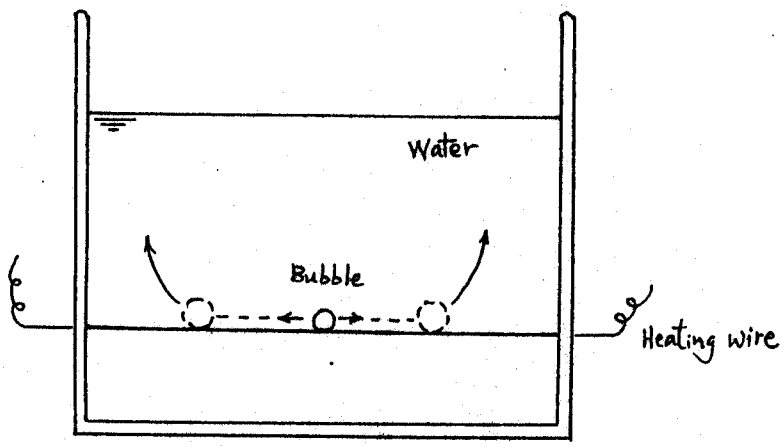

Fig. 1

2. A city has a fire truck whose pump and hose can deliver 1000 gal/min of water with a nozzle velocity of 120 ft/sec. The tallest building in the city is 100 ft high. The firefighters hold the nozzle at an angle of 75° from the ground. Find the minimum distance, d, the firefighters must stand from the building to put out a fire on the roof without the aid of a ladder (see Fig. 2). The firefighters hold the hose 5ft above the ground. Assume that the water velocity is not reduced by air resistance. (Note that you need to write an expression for d. 1 gal/min=1/7.481ft^3/min) (20%)

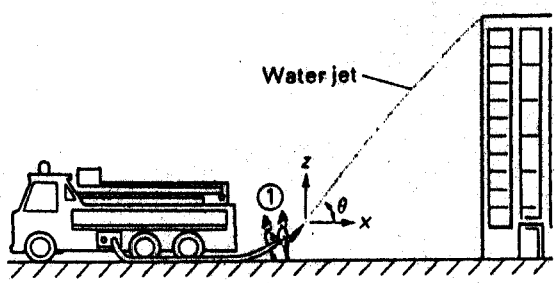

Fig. 2

3. (a) For a two-dimensional irrotational flow, let Φ be the velocity potential and Ψ be the stream function, and $F(z) = \Phi(x, y) + i\Psi(x, y)$ be the complex potential. The complex potential for a source of strength m located at $z = z_0$ will be

$$F(z) = \frac{m}{2\pi} \log (z - z_0) \circ$$

Please draw the graph of its streamlines and explain the physical meaning of m. (10%)

(b) Write down the complex potential for a source and a sink of equal strength m positioned at $x = \pm a$ along the x axis. Using the identity,

$$\tan^{-1} A - \tan^{-1} B = \tan^{-1}\left(\frac{A - B}{1 + AB}\right),$$

Find out the equation of streamlines. (10%)

4. A flat plate shown in the Fig. 3 is moving at angle of attack $\alpha = 5$ degrees with the flow (air).

(a) Sketch the pressure distributions on the upper and lower surface. Will the flat plate produce any lift? How? (5%)

(b) Where is the largest pressure difference across the plate? Why? (5%)

(c) If the plate is 2 foot in chord length, the relative free stream velocity is 40 ft/sec, calculate the lift (in pound force/ft)on the plate (approximate)using 2D theory. The air density is 0.00238 slug/cubic ft.(5%)

(d) If the answer in 1 is yes, why no one uses flat plate as a wing section ? Explain(give at least 3 reasons).(5%)

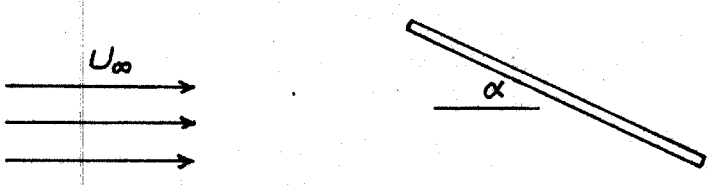

Fig. 3

5. (a) For a rectangular wing, whose wing section is composed of an NACA2412 airfoil, we can employ lifting line theory to approximate the lift force. Plot the schematic diagram of the lift distribution along the lifting line and the horseshoe vortice to explain the theory. (7%)

(b) Explain the induced angle of attack due to the wing tip vortice. (6%)

(c) Suppose that the lift coefficient is C_L at a speed of 80m/s. How about the lift coeffcient at a speed of 300m/s where the local sound speed is 330m/s ? Explain your estimation and estimate the accuracy if the wing speed becomes faster and faster. (7%)