

### Problems for Chapter 4 – Basics of Fluid Flow.

[1]. A liquid with a specific gravity  $s = 1.75$  flows through a pipe with a diameter of 3 inches. (a) What is the volumetric flow rate (discharge) if the mean velocity in the pipe cross-section is 1.2 ft/s? If the pipe undergoes an expansion to a 6-in-diameter pipe, what will the flow velocity?

[2]. The velocity in a circular cross-section of radius  $r_0$  is given by

$$u(r) = u_{max} \cdot \left(1 - \left(\frac{r}{r_0}\right)^3\right)$$

where  $u_{max}$  is the maximum velocity (i.e., the velocity at the centerline,  $r=0$ ). (a) Determine an expression for the discharge in terms of  $u_{max}$  and  $r_0$ . (b) Determine the mean velocity in the cross-section in terms of  $u_{max}$ .

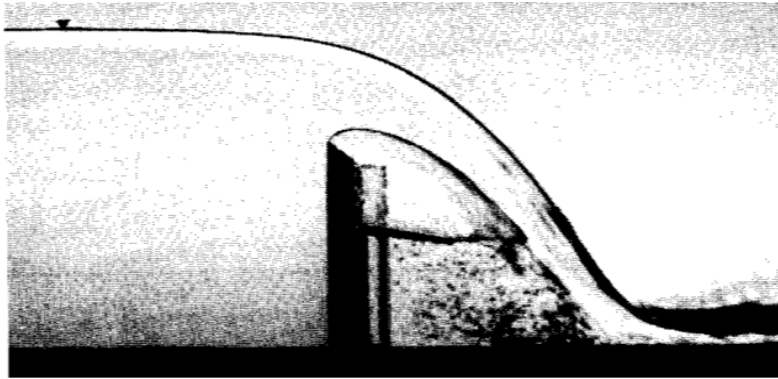
[3]. Water flows through a rectangular duct with dimensions  $0.75\text{ m}$  by  $0.50\text{ m}$  which is then connected through a transition into a square duct  $0.60\text{ m}$  on the side. (a) What is the velocity in the rectangular cross-section if the volumetric discharge is  $Q = 750\text{ L/s}$ ? (b) What is the mean velocity in the square cross-section of the duct?

[4]. A river can be approximated by a rectangular cross-section with a width of  $25.6\text{ ft}$ , which is then diverted into a culvert with  $10.0\text{ ft}$  of width. If the mean velocity in the river is  $0.5\text{ ft/s}$  when the depth is  $1.5\text{ ft}$ , (a) what is the discharge in the river? If the culvert is flowing at a depth of  $2.5\text{ ft}$ , what is the mean flow velocity in the culvert?

[5]. While measuring the discharge in the Logan River during the Spring runoff you find that there are  $80\text{ cfs}$  of water passing through a cross-section just downstream of Second Dam [call it Section (1)], while the flow rate is  $65\text{ cfs}$  in a cross-section just upstream of first dam [call it Section (2)]. (a) Determine the rate of volume storage per unit time in that section of the Logan River. (b) If the segment between the two dams as described above can be approximated by a rectangular cross-section with a width of  $10.5\text{ ft}$ , and the original depth in this segment averages  $3.5\text{ ft}$ , what are the average flow velocities in sections (1) and (2) at that instant? What will be the average depth of flow in the segment of the Logan River between sections (1) and (2) if the storage rate stays constant for 15 minutes? The distance between sections (1) and (2) is approximately 2.5 miles.

NOTE: The Figures in the next page show photographs of the flow over a sharp-crested weir and under a sluice gate, both in rectangular channels. The next two problems refer to those figures. The photographs and flow nets were taken from *Rouse, H., 1946, "Elementary Mechanics of Fluids,"* Dover Publications, Inc., New York (reproduced in 1978). This is a classic book on hydraulics by one of the foremost American fluid mechanicians of the 20<sup>th</sup> Century. Professor Rouse was Director of the Iowa Institute of Hydraulic Research in the 1940's and 1950's, and used to teach a course on Fluid Mechanics at Colorado State University up to the time of his death in more recent years. Our Department Head, Dr. Rahmeyer, was able to "survive" that fluid mechanics course at CSU sometime in the 1970s.

[6]. Read problem statement below.



The picture above shows the flow over a sharp-crested weir on a rectangular cross-section. A sharp-crested weir is simply a thin barrier placed across the flow in a rectangular open channel. A tube, attached to the weir, is used to air the area under the water flow. The following picture shows the flow net corresponding to an aerated flow over a sharp-crested weir.

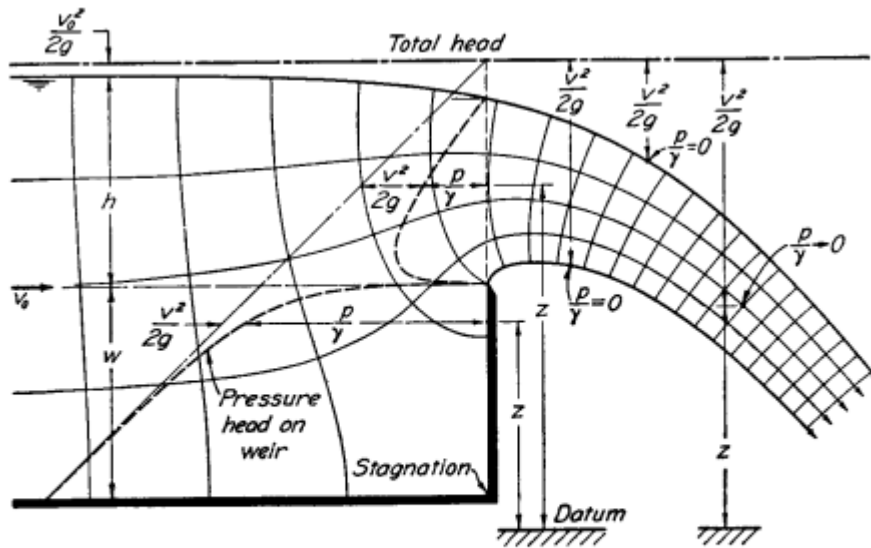


FIG. 47. Flow net for gravity discharge over a sharp-crested weir.

The flow velocity  $v_0$  in the approach channel for the sharp-crested weir shown above is  $v_0 = 0.75 \text{ fps}$ , while the depth at the approach section is  $1.5 \text{ ft}$ . Using a ruler measure the picture above and scale it so that the depth of approach is  $1.5 \text{ ft}$ , and determine: (a) The height of the sharp crested weir; (b) the dimension of the jet at the downstream section, and, (c) the velocity at the downstream section of the jet. (d) What is the discharge through the weir if the channel is  $1.5 \text{ ft}$  wide?

[7]. Read the problem statement below.

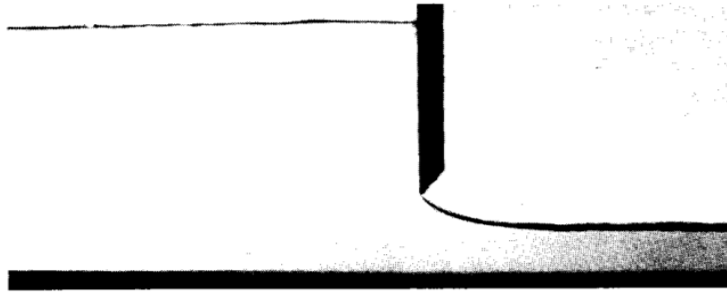


PLATE VIII. Profile of flow under a vertical sluice gate.

A vertical sluice gate is a flat gate used to hold water in a channel as depicted in the figure above. The flow under the sluice gate shows a strong curvature in the free surface resulting in a contraction of the water depth downstream from the gate. A picture of the flow net corresponding to the flow under a sluice gate is shown below.

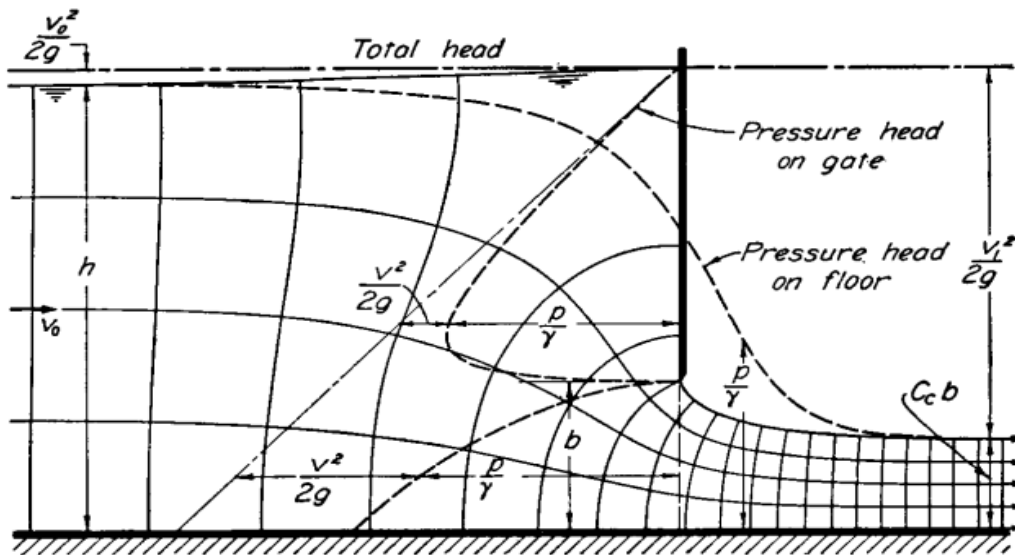


FIG. 48. Flow net for gravity discharge under a sluice gate.

If the gate opening is  $b$  as shown, the flow downstream (this region is referred to as the *vena contracta*) is given by  $h' = C_c b$ , where  $C_c$  is a *contraction coefficient*. (a) Using a ruler to measure the gate opening and the depth at the *vena contracta*, determine the contraction coefficient for the figure above.

If the approach velocity is  $v_o = 0.5 \text{ ft/s}$  and the depth of flow is  $h = 3.0 \text{ ft}$ , use your ruler to scale the drawing and determine (b) the gate opening, and (c) the depth at the *vena contracta*. Also, calculate (d) the discharge through the channel if the width is  $2.0 \text{ ft}$ , and (e) the velocity at the *vena contracta*.

[8]. A large water supply pipeline with a diameter of 1.5 ft carries water at a speed of 0.5 fps. The pipeline is connected to a manifold from which three pipelines branch out. If the diameters of these three pipelines are 0.5 ft, 0.75 ft, and 1.00 ft, respectively, determine the flow velocity in each of the three branching pipelines if each of them carries one third of the total discharge.

[9]. A shower is connected to a water pipe with a diameter of  $\frac{1}{2}$  inch. If the shower head contains 60 holes, each  $\frac{1}{20}$  inch in diameter, what is the velocity of the water out of each of the shower holes if the water velocity in the supply pipe is 2.5 fps?