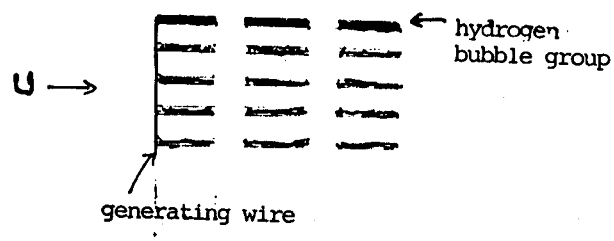
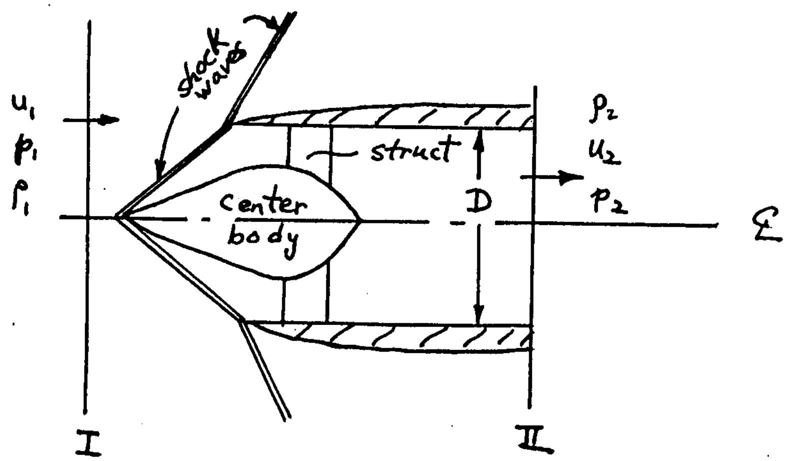
1.

10%(a) It is well known that the water table and the hydrogen bubble generating wire can be employed to perform many experiments of fluid dynamics. Use such device to design a two-dimensional experiment to demonstrate the stream line, the streak line and the path line for both steady and unsteady flow fields. And explain why your experiment can or cannot demonstrate these lines.

10%(b) Suppose that you have a camera and the flow speed can be measured by a pitot tube. Moreover, your hydrogen bubble generator is connected to a function generator, so that blockwise hydrogen bubble groups can be formed as shown. Please design a two-dimensional experiment to measure the drag force for flow over a circular cylinder. Use the concept of the control volume to explain your experiment.



20% 2. An idealized supersonic ramjet diffuser consists of an axisymmetric center body located in a cylindrical duct as shown in the figure. The flow at stations I and II may be assumed uniform at the values indicated and the stream tube which enters the inlet has a diameter D far upstream. What is the aerodynamic drag on the center body and the struct?



3. An experimental setup used to measure the fluid viscosity μ is shown in Fig.1. A tank of height H has a circular exit tube of radius R and length L positioned horizontally at the bottom with R <<H. Neglect the entrance effect and assume that the flow in the tube is fully developed and laminar. The axisymmetric velocity profile in the tube is u(r). The density is constant.

10% (a) Take a circular element of radius r and length d in the tube as your control volume. Suppose the pressure at the ends of the element is P_1 and P_2 respectively. Derive u(r) in terms of P_1, P_2, d, R, μ and r by considering the forces acting on the element.

5% (b) Find the flow rate Q through the tube.

5% (c) Using the results of (a) and (b), relate the viscosity μ to Q, H, L, R and other parameters.

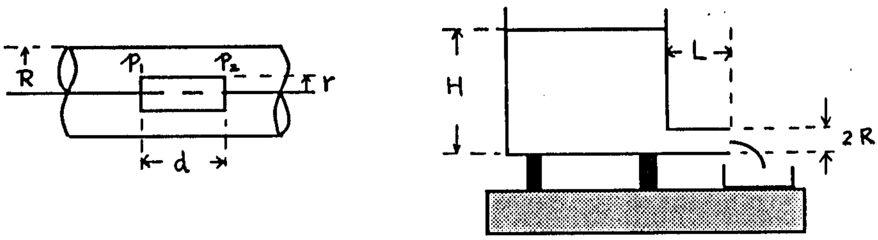


Figure 1

20% 4. A supersonic convergent-divergent diffuser is designed to operate at a Mach number of 1.5. To what Mach number would the inlet have to be accelerated in order to swallow the shock during the start-up? Assume the flow is inviscid and $\gamma = 1.4$. Tables A and B are given for your reference. The flow is assumed to be quasi-one-dimensional.

Table A Isentropic flow tables ($\gamma = 1.4$)

M	p/p_t	T/T_t	A/A^*
.60	.7840	.9328	1.1882
.61	.7778	.9307	1.1767
.62	.7716	.9286	1.1657
.63	.7654	.9265	1.1552
.64	.7591	.9243	1.1452
.65	.7528	.9221	1.1356
.66	.7465	.9199	1.1265
.67	.7401	.9176	1.1179
.68	.7338	.9153	1.1097
.69	.7274	.9131	1.1018
⋮	⋮	⋮	⋮
1.45	.2927	.7040	1.144
1.46	.2886	.7011	1.150
1.47	.2845	.6982	1.156
1.48	.2804	.6954	1.163
1.49	.2764	.6925	1.169
1.50	.2724	.6897	1.176
1.51	.2685	.6868	1.183
1.52	.2646	.6840	1.190
1.53	.2608	.6811	1.197
1.54	.2570	.6783	1.204

Table B Normal shock tables ($\gamma = 1.4$)

M_1	M_2	p_2/p_1	ρ_2/ρ_1	T_2/T_1	p_{t2}/p_{t1}	p_1/p_{t2}
1.80	.6165	3.613	2.359	1.532	.8127	.2142
1.81	.6143	3.655	2.375	1.539	.8082	.2121
1.82	.6121	3.698	2.391	1.547	.8038	.2100
1.83	.6099	3.740	2.407	1.554	.7993	.2080
1.84	.6078	3.783	2.422	1.562	.7948	.2060
1.85	.6057	3.826	2.438	1.569	.7902	.2040
1.86	.6036	3.870	2.454	1.577	.7857	.2020
1.87	.6016	3.913	2.469	1.585	.7811	.2001
1.88	.5996	3.957	2.485	1.592	.7765	.1982
1.89	.5976	4.001	2.500	1.600	.7720	.1963

5. In order to show the effectiveness of separation prevention by boundary layer suction, consider a laminar boundary layer on a porous flat plate with continuous suction. The use of a porous wall is a logical extension of a series of slots by increasing the number of slots infinitely and making their width infinitesimally small. Based on the above description and assumptions (see hint), answer the following questions:

10%(a) According to the boundary layer equations, find out the boundary conditions, continuity and Navier-Stokes equations which are suitable for the present flow problem.

10%(b) From the governing equations and the related boundary conditions, find out the velocity distribution, displacement thickness and momentum thickness.

* Hint: assumptions:
(1) Steady, incompressible flow with constant viscosity coefficient.
(2) The gradients of the velocity profiles with respect to x can be neglected as compared with the gradients with respect to y
(3) The suction and freestream velocities are expressed as $v = -v_w$ and $u = U_\infty$, respectively. In this problem, v_w and U_∞ are constant values.