

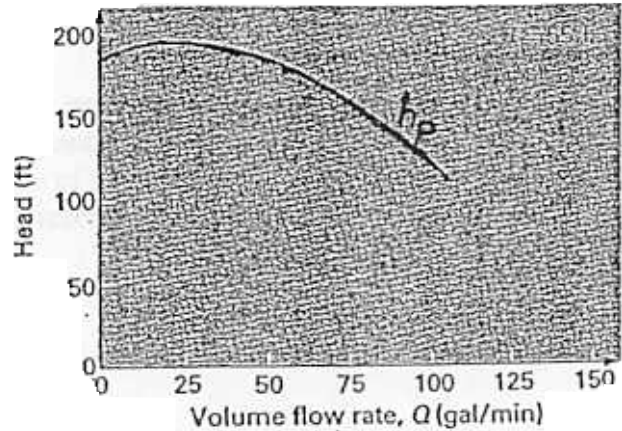
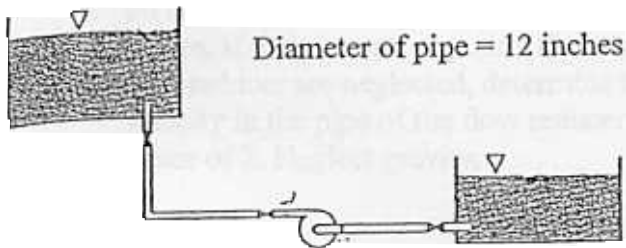
National Exams December 2002
98-Mec-A2, Fluid Mechanics and Applications

3 Hours Duration

Notes:

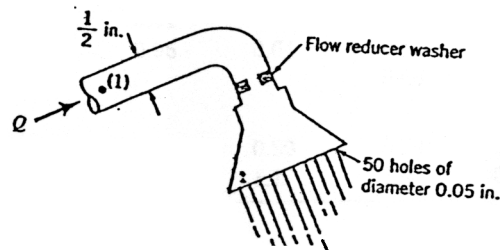
1. If doubt exists as to the interpretation of any question the candidate is urged to submit with the answer paper a clear statement of the assumption made.
2. Candidates may use a calculator of either the Casio or Sharp approved models. The exam is CLOSED BOOK. The candidate is permitted to bring into the exam and use both sides of an 8.5 x 11 inch hand-written sheet.
3. Answer any 5 questions. Five (5) questions constitute the exam. If 6 or more questions are answered, the first 5 appearing in the exam booklet will be marked.
4. Each question of equal value.

- A centrifugal pump having the head characteristics shown in the figure is used in the piping system shown to pump water from the low reservoir to the high reservoir. The system includes 250 feet of straight galvanised pipe, three fully open globe valves and 2 standard elbows (only one shown). The elevation difference between the reservoir surfaces is 150 ft. All connections are flanged. Derive an expression for the head required as a function of the volume flow rate and then plot the system response on the pump characteristic curve. Where the two curves intersect is the system operating point. What is the volume flow rate?



- In a jet engine running on a test stand, the stagnation pressure and stagnation temperature just upstream of the convergent nozzle are measured to be 70 kPa gage and 700°C. The diameter of the nozzle exit is 0.5 m. Calculate the mass flow, jet exit velocity and thrust of the nozzle.
- The drag of a body is to be predicted, based on wind tunnel test data. If the drag force, F , is a function of the diameter, velocity and fluid properties determine the non-dimensional relations governing this situation. The prototype, a 1-m diameter sphere, is to be towed at 5 kilometres per hour in water. The model is 25 cm in diameter. Determine the required test speed in air. If the drag of the model at test conditions is 20 N, estimate the drag of the prototype.
- Air flows isentropically in a converging-diverging nozzle, with an exit area of 0.001 m². The nozzle is fed from a large plenum where the stagnation temperature and the absolute stagnation pressure are 350 K and 1.0 Mpa, respectively. The exit pressure is 954 kPa (abs), and the Mach number at the throat is 0.68. Determine the flow conditions at the throat and the exit Mach number.

5. Water of kinematic viscosity $\nu = 1 \times 10^{-5} \text{ ft}^2/\text{s}$ is flowing steadily over a smooth flat plate at zero angle-of-attack with a velocity of 5 ft/s. The length l of the plate is 5 ft. Calculate (a) the thickness of the boundary layer at 6 in. from the leading edge, (b) the boundary layer rate of growth at 6 in. from the leading edge, and (c) the total drag coefficient on both sides of the plate up to 6 in. from the leading edge. Recalculate (a), (b) and (c) above at the end of the plate where $l = 5 \text{ ft}$.
6. The flow near a wall has the velocity profile described by $u(y)/U = A + B(y/\delta) + C(y/\delta)^2$. Determine the values of A, B and C and use the momentum integral method to determine expressions for the boundary layer thickness, wall shear stress, displacement and momentum thickness.
7. To conserve water and energy, a flow reducer is installed in the showerhead as shown. If the pressure at point (1) remains constant and all losses except that for the flow reducer are neglected, determine the value of the loss coefficient (based on the velocity in the pipe of the flow reducer) if its presence is to reduce the flow rate by a factor of 2. Neglect gravity.



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Figures to Accompany the Exam

Typical loss coefficients for commercial pipe fittings

Nominal Diameter (in.)	Screwed or Soldered				Flanged				
	$\frac{1}{2}$	1	2	4	1	2	4	8	20
Valves (fully open)									
Globe	14	8.2	6.9	5.7	13	8.5	6.0	5.8	5.5
Gate	0.30	0.24	0.16	0.11	0.80	0.35	0.16	0.07	0.03
Swing check	5.1	2.9	2.1	2.0	2.0	2.0	2.0	2.0	2.0
Angle	9.0	4.7	2.0	1.0	4.5	2.4	2.0	2.0	2.0
Elbows									
45° standard	0.39	0.32	0.30	0.29					
45° long radius					0.21	0.20	0.19	0.16	0.14
90° standard	2.0	1.5	0.95	0.64	0.50	0.39	0.30	0.26	0.21
90° long radius	1.0	0.72	0.41	0.23	0.40	0.30	0.19	0.15	0.10
180° standard	2.0	1.5	0.95	0.64	0.41	0.35	0.30	0.25	0.20
180° long radius					0.40	0.30	0.21	0.15	0.10
Tees									
Line flow	0.90	0.90	0.90	0.90	0.24	0.19	0.14	0.10	0.07
Branch flow	2.4	1.8	1.4	1.1	1.0	0.80	0.64	0.58	0.41

AVERAGE ROUGHNESS OF COMMERCIAL PIPES

Material (new)	ϵ	
	ft	mm
Riveted steel	0.003-0.03	0.9-9.0
Concrete	0.001-0.01	0.3-3.0
Wood stave	0.0006-0.003	0.18-0.9
Cast iron	0.00085	0.26
Galvanized iron	0.0005	0.15
Asphalted cast iron	0.0004	0.12
Commercial steel or wrought iron	0.00015	0.046
Drawn tubing	0.000005	0.0015
Glass	"Smooth"	"Smooth"

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Figures to Accompany the Exam

