1. For the manometer shown in figure 1, if the absolute pressure at point A is $1.013\times10^5 Pa$, the *absolute* pressure at point B is ($\rho_{water} = 10^3\ kg/m^3$, $\rho_{Hg} = 13.56\times10^3\ kg/m^3$, $\rho_{oil} = 800 kg/m^3$):

(a) 107.34 kPa (b) 5570 Pa (c) 106.87 kPa (d) 106.87 MPa.

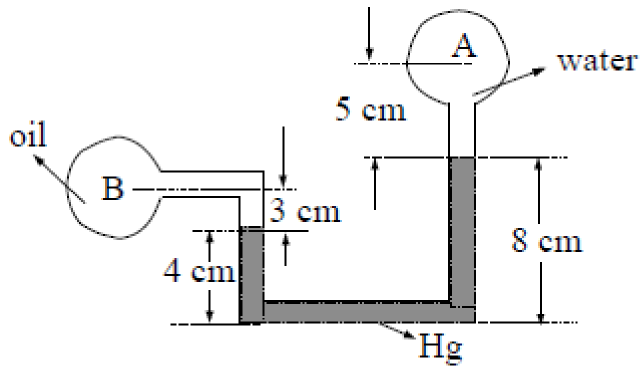

Figure 1: **Problem 1**

2. A solid sphere (of diameter 1*m*) floats at the interface between water and air such that 40% of the sphere is submerged in water. The density of the sphere is:

(a) 400 kg/m^3 (b) 2500 kg/m^3 (c) 250 kg/m^3 (d) 600 kg/m^3.

3. Consider the geometry of a dam shown in figure 2 (each step is 0.3m high, 0.3m deep and 3m wide [into the paper]). The vertical force exerted by the fluid on the steps of the dam is:

(a) 26.46 kN (b) 264.6 kN (c) 3.9114 kN (d) 391.14 kN

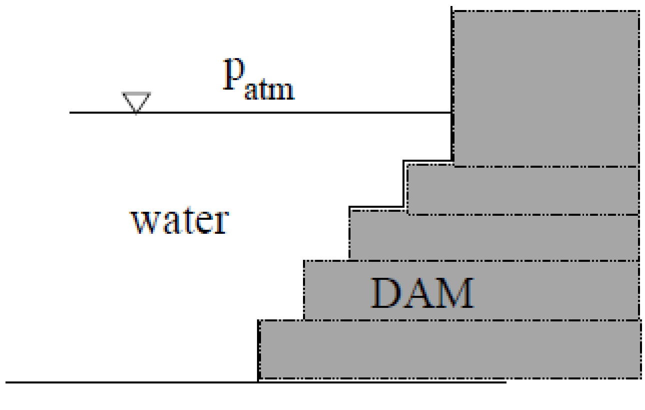

Figure 2: **Problem 3**

4. A 2-D velocity field is given (in arbitrary units) by $\mathbf{v} = x\mathbf{i} - y\mathbf{j}$

The acceleration at ($x = 1$, $y = 1$) is

(a) $\mathbf{i} + \mathbf{j}$ (b) 0 (c) $\mathbf{i} - \mathbf{j}$ (d) $-\mathbf{i} + \mathbf{j}$

5. Which of the following statements are TRUE:

P. A streamline is perpendicular to the local velocity vector in the fluid.

Q. Path lines and streak lines are the same in an unsteady flow.

R. Streak lines are produced by continuously injecting a dye at a point, and observing its consequent evolution.

S. Stream lines and streak lines are the same in a steady flow.

(a) P and R (b) R and S (c) Q and S (d) Q and R

6. Given the Eulerian velocity field $\mathbf{v} = 5t\mathbf{i} + 2xz\mathbf{j} + ty^2\mathbf{k}$

the acceleration of the material particle that is present at $x = 1$, $y = 1$, $z = -1$ at $t = 2$ is :

(a) 5**i**−16**j**−7**k** (b) 5**i**+**k** (c) 10**i**−2**j**+2**k** (d) 5**i**+16**j**+7**k**.

7. For the system shown in figure 3, both the tank and the tube are open to the atmosphere (here, s.g. denotes specific gravity of the liquid). If $\theta = 30^0$, the length L of the liquid in the inclined tube is

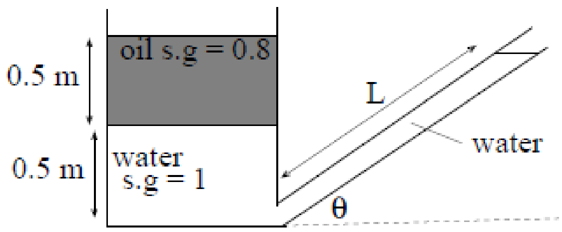

Figure 3: **Problem 7**

(a) 0.9 m (b) 1.8 m (c) 2.7 m (d) 3.6 m

8. For the system shown in figure 4, the Gate B is 30 cm high, 60 cm wide (into the paper), and is hinged at the top. There is a rigid stopper that prevents the gate to move into the water. The water depth H that will first cause the gate to open is:

(a) 0.56 m (b) 2.24 m (c) 1.12 m (d) 3.36 m

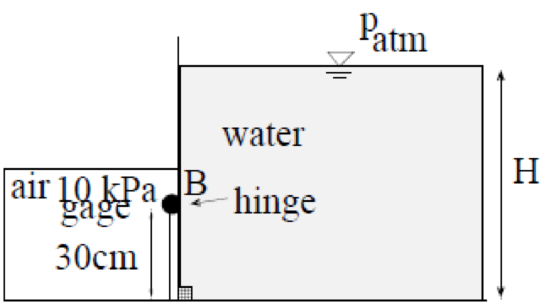

Figure 4: **Problem 8**

9. For two-dimensional flow in a channel with velocity profile shown in figure 5, the viscous shear stress on the surface AA of the fluid element shown (shaded in the figure) is in the direction of the unit vector

(a) $\mathbf{i}$ (b) $\mathbf{j}$ (c) $-\mathbf{i}$ (d) $-\mathbf{j}$

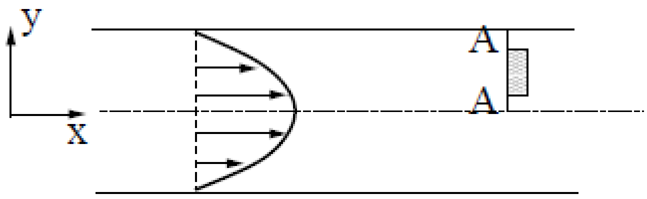

Figure 5: **Problem 9**

10. A two-dimensional velocity field in Cartesian coordinates is given by

$$\mathbf{v} = \left(x^2 - axy\right)\mathbf{i} + \left(bxy - \frac{y^2}{2}\right)\mathbf{j}$$

If the flow is incompressible, the values of a and b are

(a) $a = 1, b = 2$ (b) $a = -1, b = 2$ (c) $a = -1, b = -2$ (d) $a = 1, b = 2$

11. For fully-developed fluid (viscosity m, density r) flow in a pipe with an average velocity V, diameter D, if the pipe length L is doubled, the friction factor f will

(a) increase twice (b) remain the same (c) increase four times (d) decrease by a factor of two

12. If a stream of fluid flowing past a sphere of diameter D causes a force F on the sphere that depends *only* on U, D and m, then the force must be proportional to

(a) $\dfrac{\rho UD}{\mu}$ (b) $\rho U^2 D^2$ (c) $\dfrac{\mu U}{D}$ (d) μUD

13. A solid block (mass M) slides down an inclined plane while lubricated by a thin film of very viscous oil, as shown in figure 6. The contact area between the block and the liquid is A and the liquid film thickness is h. Assume a *linear* velocity distribution in the film. If M = 6 kg, h = 1 mm, A = 40 cm^2, $\theta = 45^0$, and μ = 1 Pa s, the velocity V with which the block will slide is (use g = 9.8 m/s^2):

(a) 0.103944 m/s (b) 100.3944 m/s (c) 10.3944 m/s (d) 1.03944 m/s

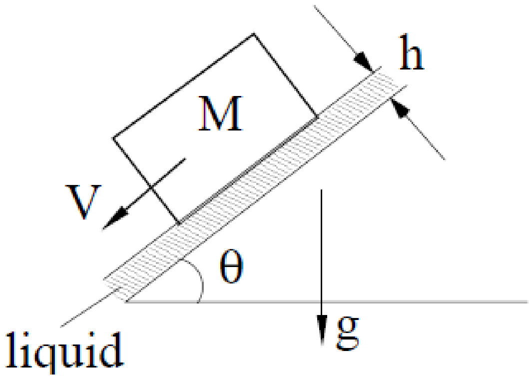

Figure 6: **Problem 13**

14. Consider the motion of a very tiny spherical particle (radius R, velocity V) in a fluid (viscosity μ). Owing to the small dimensions, the viscous forces in the flow are very large compared to inertial forces, and hence the density (ρ) of the fluid is ***not*** a relevant physical parameter. Which one of the following non-dimensional groups is a correct representation of the drag force F experienced by the sphere:

(a) $F/(\mu V/R)$ (b) $F/(\mu V^2/R)$ (c) $F/(\mu VR)$ (d) $F/(\mu VR^2)$

15. Consider the flow in the annular region formed between two concentric cylinders (see figure 7) of inner diameter D_i and outer diameter D_o. If $D_o = 2D_i$, the hydraulic diameter for flow in the annular region is:

(a) $2D_i$ (b) $D_i/2$ (c) D_i (d) $4D_i$

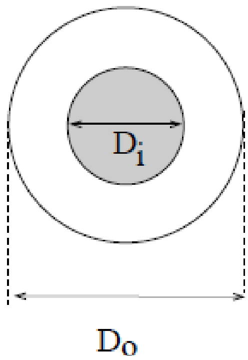

Figure 7: **Problem 15**

16. Consider the fully-turbulent flow of water in a very rough pipe, where the friction factor is independent of the Reynolds number. The pressure difference across the ends of the pipe $4P$ and the length L of the pipe are kept constant. If the diameter of the pipe is ***increased*** by two times, i.e., $D_2 = 2D_1$, the volumetric flow rate Q_2 (for pipe with diameter D_2) is related to the flow rate Q_1 (for pipe with diameter D_1) as:

(a) $Q_2 = Q_1\sqrt{32}$ (b) $Q_2 = Q_1/\sqrt{32}$ (c) $Q_2 = Q_1/2$ (d) $Q_2 = 2Q_1$

17. A large pump is to deliver $1.5m^3/s$ of water from a $40cm$ dia impeller with a pressure rise of $400kPa$. To design this, a lab-scale model with an $8cm$ dia impeller is to be used with water as the fluid with identical properties as in the prototype. The pressure rise ΔP in the pump is related to the volumetric flow rate Q, density of fluid ρ, viscosity μ, diameter of the impeller D. Using dimensional analysis, the flow rate Q_m (in m^3/s) and pressure rise ΔP (in kPa) to be expected in the model are respectively given by:

(a) $Q_m = 7.5$, $\Delta P = 8$ (b) $Q_m = 0.3$, $\Delta P = 8$ (c) $Q_m = 7.5$, $\Delta P = 10^4$ (d) $Q_m = 0.3$, $\Delta P = 10^4$.

18. Within a boundary layer (for laminar flow past a flat plate), as the Reynolds number increases, the velocity gradient at the surface of the plate

(a) decreases (b) increases (c) remains the same (d) is zero

19. Consider uniform laminar flow past a flat plate with velocity U. Let the total drag force on the plate of length L be F_{old}. If the length of the plate is increased to $4L$, the drag force F_{new} for this case is related to F_{old} as

(a) $F_{new} = 4F_{old}$ (b) $F_{new} = F_{old}$ (c) $F_{new} = F_{old}/2$ (d) $F_{new} = 2F_{old}$ (e) $F_{new} = F_{old}/4$

20. A line vortex is located at $x = 2$, $y = 2$, and the velocity component vq at $x = 0$, $y = 0$ is 12 m/s. The values of vr and vq (in m/s) at $x = 1$, $y = 1$ are respectively given by:

(a) 0, 1 (b) 1, 0 (c) 1, 1 (d) 0, 0

21. For uniform, 2-D, potential flow past a circular cylinder (as shown in figure 8), the velocity components at points A and B are given by:

(a) Point A: $v_r = 2U$, $v_\theta = 0$ Point B: $v_r = 2U$, $v_\theta = 0$.

(b) Point A: $v_r = 0$, $v_\theta = 0$ Point B: $v_r = 0$, $v_\theta = 2U$

(c) Point A: $v_r = 0$, $v_\theta = 2U$ Point B: $v_r = -2U$, $v_\theta = -2U$

(d) Point A: $v_r = 0$, $v_\theta = 0$ Point B: $v_r = 0$, $v_\theta = -2U$

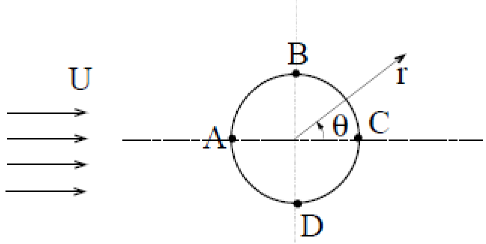

Figure 8: **Problems 21 and 22**

22. For uniform, 2-D, potential flow past a circular cylinder (as shown in figure 8), the pressures at various points (as shown in the figure) satisfy:

(a) $p_A > p_B$, $p_C < p_B$

(b) $p_A < p_B$, $p_C > p_D$

(c) $p_A > p_B$, $p_C > p_D$

(d) $p_A < p_C$, $p_B > p_D$

23. Which of the following statements are **FALSE** for 2-D potential flows:

(P) Stream function and velocity potential satisfy the Laplace equation.

(Q) Streamlines and equipotentials are orthogonal.

(R) Streamlines and equipotentials are parallel.

(S) No-slip condition is always satisfied by the velocity field on solid surfaces.

(a) P and S (b) S and Q (c) P and Q (d) R and S

24. Consider the two configurations shown in figure 9, wherein two identical plates (of infinitesimal thickness, length L and width W) are joined along the width (in arrangement A) and along the length (in arrangement B). There is steady, uniform, boundary-layer flow **over the top** surface of these two arrangements (hatched surfaces in the figure) with identical uniform velocity outside the boundary layer. The drag forces F_A (for arrangement A) and F_B (for arrangement B) are related as:

(a) $F_A = \sqrt{2}F_B$ (b) $F_A = F_B$ (c) $F_A = 2F_B$ (d) $F_A = F_B/\sqrt{2}$

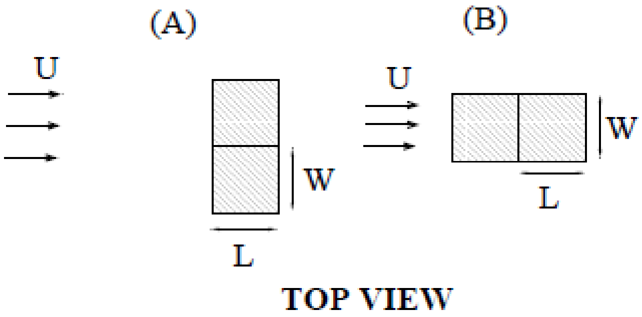

Figure 9: **Problem 24**