MAE 101A, Summer Session 1, 2011
Introductory Fluid Mechanics
Quiz 10, July 28, 2011
(closed book, closed notes, Scantron form #881-ES, #882-ES, 4 letter CodeWord)

Problem 1-5: Consider a steady, laminar, incompressible and frictionless flow of water into the atmosphere horizontally through a converging nozzle. Compare the following quantities between the inlet and outlet.

(a) IN = OUT  (b) IN > OUT  (c) IN < OUT  (d) undetermined

1. Velocity (c)
2. Pressure (b)
3. Volume flow rate (a)
4. Momentum flux (c)
5. Total heads (a)

Problem 6-8: A vane turns a water jet by an angle \( \alpha \) as shown in figure. The vane is held stationary by a force \( F = (F_x, F_y) \). Assume steady, incompressible flow with density \( \rho \), constant jet area \( A \) over the vane. Neglect the weight of water and the vane.

6. What is \( F_x \)?
   (a) \( \rho A V^2 (1 - \cos \alpha) \)
   (b) \( \rho A V^2 \cos \alpha \)
   (c) \( \rho A V^2 (1 - \sin \alpha) \)
   (d) \( \rho A V^2 \sin \alpha \)
   (e) \( \rho A V^2 (1 - \cos 25^\circ) \)

7. What is \( F_y \)?
   (a) \( \rho A V^2 \sin \alpha \)
   (b) \( \rho A V^2 \cos \alpha \)
   (c) \( \rho A V^2 (1 - \sin \alpha) \)
   (d) \( \rho A V^2 (1 - \cos \alpha) \)
   (e) \( \rho A V^2 \sin \alpha \)

8. What is the angle \( \alpha \)? Use trigonometric identity: \( \tan \theta = (1 - \cos 20)/\sin 20 \)
   (a) 12.5
   (b) 25
   (c) 30
   (d) 40
   (e) 50

Problem 9-11: Consider a container of height \( H \), with an aperture at a height \( h \) and gravity \( g \) as shown in figure. A water jet with constant area \( A \) exits horizontally at the aperture and lands on the ground at a distance \( X \) from the container. Assume steady, incompressible, laminar and inviscid flow.

9. What is the exit velocity at the aperture?
   (a) \( [2g(H-h)]^{1/2} \)
   (b) \( [2gh]^{1/2} \)
   (c) \( [gh]^{1/2} \)
   (d) \( [g(H-h)]^{1/2} \)
   (e) \( [g(H-2h)]^{1/2} \)

10. When the jet hits the ground, the horizontal component of the velocity is equal to the jet exit velocity at the aperture. What is the vertical velocity of the jet at the ground?
    (a) \( -[2g(H-h)]^{1/2} \)
    (b) \( -[2gh]^{1/2} \)
    (c) \( [-gh]^{1/2} \)
    (d) \( -[g(H-h)]^{1/2} \)
    (e) \( -[g(H-2h)]^{1/2} \)

11. Along the jet, the magnitude of the velocity increases because
    (a) pressure increases  (b) pressure decreases  (c) energy increases  (d) energy decreases  (e) none of the above

12. According to the third universal similarity hypothesis of Kolmogorov (1962) the probability laws of turbulent motions at large Reynolds numbers should depend only on the separation distance \( r \) between two points in the fluid, the viscous dissipation rate \( \varepsilon \) and the variance of the natural logarithm of \( \varepsilon \), termed the intermittency factor \( s_\text{int} \). Turbulence always cascades from small scales to large limited by forces that exceed \( \sqrt{\varepsilon w} \) only at very large scales (~100 km). The larger the range of turbulence scales the larger the intermittency factor and the larger the undersampling error if only a few measurements are made of \( \varepsilon \). Extreme intermittency of turbulence and turbulent mixing was probably responsible for the Air France 447 disaster June 1, 2009, flying across the equator. What factors were important?
    (a) the Coriolis force goes to zero at the equator, permitting huge horizontal eddies to develop with large \( s_\text{int} \) values, particularly if the winds are high (b) atmospheric and ocean scientists generally don’t know the definitions of turbulence and fossil turbulence or the implications of the Kolmogorov (1962) intermittency hypothesis to clear air turbulence and icing probabilities at low latitudes (c) it is particularly dangerous to fly across the equator at the beginning of hurricane season (d) MAE 101a is not universally mandatory (e) abc

13. Self gravitational forces balance viscous forces at the viscous gravitational scale \( L_{SV} \). Use dimensional analysis to determine \( L_{SV} \) assuming the relevant dimensional parameters are \( \gamma, G, \rho, \) and \( v \). Hint, combine \( \rho \) and \( G \) to give a gravitational free fall time \( \tau = (\rho G)^{-1/2} \) and use this to form a length scale with the rate of strain \( \gamma \) and \( v \). \( L_{SV} \) is thus

   (a) \( V_{sound} \tau \)  (b) \( (\sqrt{\gamma} \rho G)^{1/2} \)  (c) \( (D^2 \tau^2)^{1/4} \)  (d) \( (v^2 \varepsilon)^{1/2} \)  (e) \( e \tau \)