4 FLUID STATICS AND DYNAMICS

FLUIDS–1

Which statement is true for a fluid?

(A) It cannot sustain a shear force.
(B) It cannot sustain a shear force at rest.
(C) It is a liquid only.
(D) It has a very regular molecular structure.

A fluid is defined as a substance that deforms continuously under the application of a shear force. This means that it cannot sustain a shear force at rest. Therefore, option (B) is true.

The answer is (B).

FLUIDS–2

Which of the following is NOT a basic component of motion of a fluid element?

(A) translation (B) rotation
(C) angular distortion (D) twist

The motion of a fluid element may be divided into three categories: translation, rotation, and distortion. Distortion can be further subdivided into angular and volume distortion. The only choice that is not a basic component of fluid element motion is twist.

The answer is (D).

FLUIDS–3

Which of the following must be satisfied by the flow of any fluid, real or ideal?

I. Newton's second law of motion
II. the continuity equation
III. the requirement of a uniform velocity distribution
IV. Newton's law of viscosity
V. the principle of conservation of energy

(A) I, II, and III (B) I, II, and IV (C) I, II, and V (D) I, II, III, and IV

Newton's second law, the continuity equation, and the principle of conservation of energy always apply for any fluid.

The answer is (C).

FLUIDS–4

What is the definition of pressure?

(A) $\frac{\text{area}}{\text{force}}$ (B) $\lim_{\text{force}\to 0} \frac{\text{force}}{\text{area}}$ (C) $\lim_{\text{area}\to 0} \frac{\text{force}}{\text{area}}$ (D) $\lim_{\text{force}\to 0} \frac{\text{area}}{\text{force}}$

The mathematical definition of pressure is

$$\lim_{\text{area}\to 0} \frac{\text{force}}{\text{area}}$$

The answer is (C).

FLUIDS–5

For a fluid, viscosity is defined as the constant of proportionality between shear stress and what other variable?

(A) time derivative of pressure
(B) time derivative of density
(C) spatial derivative of velocity
(D) spatial derivative of density

By definition,

$$\tau = \mu \frac{dv}{dy}$$

Thus, viscosity, μ, is the constant of proportionality between the shear stress, τ, and the gradient (spatial derivative) of the velocity.

The answer is (C).

FLUIDS–6

Surface tension has which of the following properties?

I. It has units of force per unit length.
II. It exists whenever there is a density discontinuity.
III. It is strongly affected by pressure.

(A) I only (B) II only (C) III only (D) I and II

III is incorrect because pressure only slightly affects surface tension. I and II are correct.

The answer is (D).

FLUIDS–7

A leak from a faucet comes out in separate drops. Which of the following is the main cause of this phenomenon?

(A) gravity (B) air resistance (C) viscosity of the fluid (D) surface tension

Surface tension is caused by the molecular cohesive forces in a fluid. It is the main cause of the formation of the drops of water.

The answer is (D).

FLUIDS–8

The surface tension of water in air is approximately 0.0756 N/m. If the atmospheric pressure is 101 kPa (abs), what is the pressure inside a droplet 0.254 mm in diameter?

(A) 99.83 kPa (abs) (B) 101.0 kPa (abs) (C) 101.5 kPa (abs) (D) 102.2 kPa (abs)

For a spherical droplet,

$$\Delta p = p_{\text{in}} - p_{\text{out}} = \frac{2\sigma}{r}$$

$$\begin{aligned} p_{\text{in}} &= p_{\text{out}} + \frac{2\sigma}{r} \\ &= 101 \text{ kPa} + \frac{(4)\left(7.56 \times 10^{-5} \ \frac{\text{kN}}{\text{m}}\right)}{25.4 \times 10^{-5} \text{ m}} \\ &= 102.2 \text{ kPa (abs)} \end{aligned}$$

The answer is (D).

FLUIDS–9

Which of the following describes shear stress in a moving Newtonian fluid?

(A) It is proportional to the absolute viscosity.
(B) It is proportional to the velocity gradient at the point of interest.
(C) It is nonexistent.
(D) both A and B

$$\tau = \mu \frac{dv}{dy}$$

Shear stress is proportional to the velocity gradient at a point, as well as the absolute viscosity.

The answer is (D).

FLUIDS–10

If the shear stress in a fluid varies linearly with the velocity gradient, which of the following describes the fluid?

(A) It is inviscid.
(B) It is a perfect gas.
(C) It is a Newtonian fluid.
(D) It is at a constant temperature.

In order for shear stress to vary linearly with the velocity gradient, the fluid must be Newtonian.

The answer is (C).

FLUIDS–11

How are lines of constant pressure in a fluid related to the force field?

(A) They are parallel to the force field.
(B) They are perpendicular to the force field.
(C) They are at a 45° angle to the force field.
(D) They are perpendicular only to the force of gravity.

Lines of constant pressure are always perpendicular to the direction of the force field.

The answer is (B).

FLUIDS–12

Which of the following statements about a streamline is most accurate?

(A) It is a path of a fluid particle.
(B) It is a line normal to the velocity vector everywhere.
(C) It is fixed in space in steady flow.
(D) It is defined for nonuniform flow only.

Streamlines are tangent to the velocity vectors at every point in the field. Thus, for a steady flow $dv/dt = 0$, a streamline is fixed in space.

The answer is (C).

FLUIDS–13

Which of the following describes a streamline?

I. It is a mathematical concept.
II. It cannot be crossed by the flow.
III. It is a line of constant entropy.

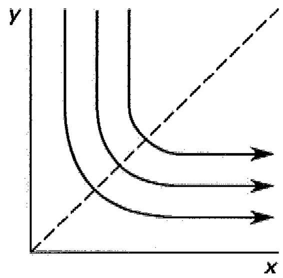
(A) I only (B) II only (C) I and II (D) I and III

A streamline is a mathematical concept that defines lines that are tangential to the velocity vector. Therefore, no flow can cross a streamline. Entropy is not related to streamlines.

The answer is (C).

FLUIDS–14

The following illustration shows several streamlines near the corner of two infinite plates. Which of the following could be the correct expression for the stream function, Ψ, of this potential flow?



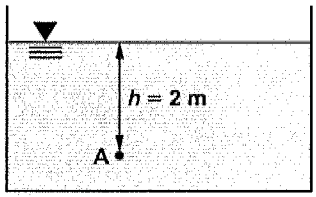
(A) $\Psi = x - y$ (B) $\Psi = 2xy$ (C) $\Psi = x$ (D) $\Psi = y$

Streamlines are graphs of constant values for the stream function. The graph shows hyperbolas that are of the form $axy = b$, where a and b are constants. Thus, of the choices shown, the stream function could only be $\Psi = 2xy$.

The answer is (B).

FLUIDS–15

What is most nearly the gage pressure at point A in the tank of water if $h = 2$ m?



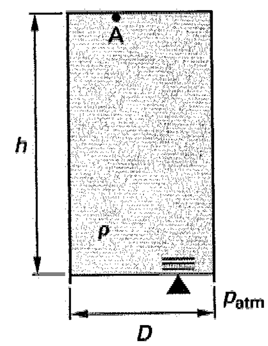
(A) 12 kPa (B) 13 kPa (C) 16 kPa (D) 20 kPa

$$\begin{aligned} p &= \rho g h \\ &= \left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2\ \text{m}) \\ &= 19\,620\ \text{Pa} \quad (20\ \text{kPa}) \end{aligned}$$

The answer is (D).

FLUIDS–16

A drinking glass filled with a fluid of density ρ is quickly inverted. The top of the glass, which becomes the bottom after the glass is inverted, is open. What is the pressure at the closed end at point A?



(A) p_{atm} (B) $p_{\text{atm}} + \rho gh$ (C) $p_{\text{atm}} - \rho gh$ (D) ρgh

The pressure at point A, p, plus the pressure exerted by the fluid equals the pressure outside the glass.

$$p + \rho gh = p_{\text{atm}}$$

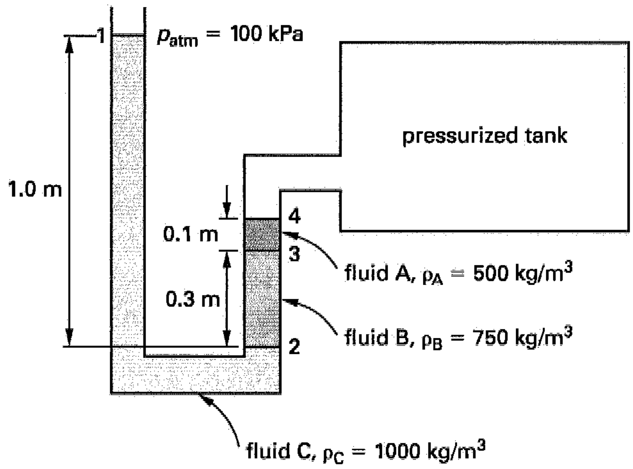
Therefore,

$$p = p_{\text{atm}} - \rho gh$$

The answer is (C).

FLUIDS–17

Find the pressure in the tank from the manometer readings shown.



(A) 102 kPa (B) 108 kPa (C) 112 kPa (D) 118 kPa

$$p_2 - p_1 = \rho_C g(z_1 - z_2)$$

$$p_3 - p_2 = \rho_B g(z_2 - z_3)$$

$$p_4 - p_3 = \rho_A g(z_3 - z_4)$$

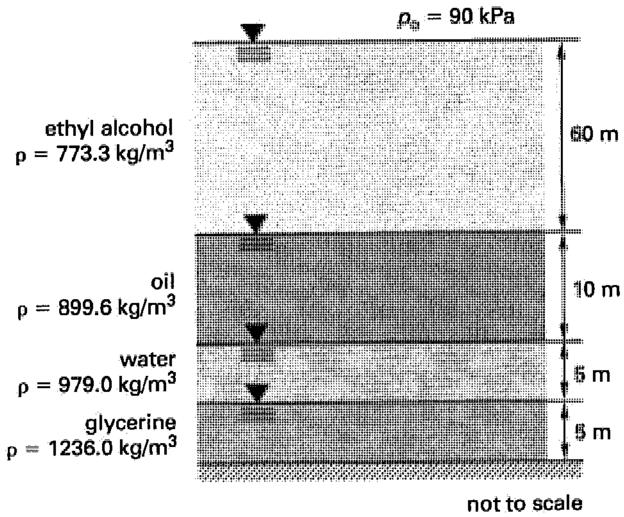
$$p_4 - p_1 = (p_4 - p_3) + (p_3 - p_2) + (p_2 - p_1)$$

$$\begin{aligned} p_4 &= p_1 + g\big(\rho_C(z_1 - z_2) + \rho_B(z_2 - z_3) + \rho_A(z_3 - z_4)\big) \\ &= 100\,000 \text{ Pa} + \left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)\left(\left(1000 \ \frac{\text{kg}}{\text{m}^3}\right)(1 \text{ m}) \right. \\ &\quad \left. + \left(750 \ \frac{\text{kg}}{\text{m}^3}\right)(-0.3 \text{ m}) + \left(500 \ \frac{\text{kg}}{\text{m}^3}\right)(0.1 \text{ m})\right) \\ &= 108\,100 \text{ Pa} \quad (108 \text{ kPa}) \end{aligned}$$

The answer is (B).

FLUIDS–18

In which fluid will a pressure of 700 kPa occur?



(A) ethyl alcohol (B) oil (C) water (D) glycerin

Let p_i be the maximum pressure that can be measured in fluid level i. If $p_i \geq 700$ kPa, then a pressure of 700 kPa can be measured at that level.

$$p_0 = 90 \text{ kPa}$$

$$p_1 = p_0 + \rho_1 g z_1$$

$$= 90 \text{ kPa} + \frac{\left(773.3 \ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(60 \text{ m})}{\frac{1000 \ \frac{\text{N}}{\text{m}^2}}{1 \text{ kPa}}}$$

$$= 545.16 \text{ kPa}$$

$$p_1 < 700 \text{ kPa}$$

$$p_2 = p_1 + \rho_2 g z_2$$

$$= 545.56 \text{ kPa} + \frac{\left(899.6 \ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(10 \text{ m})}{\frac{1000 \ \frac{\text{N}}{\text{m}^3}}{1 \text{ kPa}}}$$

$$= 633.81 \text{ kPa}$$

$$p_2 < 700 \text{ kPa}$$

$$p_3 = p_2 + \rho_3 g z_3$$

$$= 633.81 \text{ kPa} + \frac{\left(979.0 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(5 \text{ m})}{\frac{1000 \frac{\text{N}}{\text{m}^2}}{1 \text{ kPa}}}$$

$$= 681.83 \text{ kPa}$$

$$p_3 < 700 \text{ kPa}$$

$$p_4 = p_3 + \rho_4 g z_4$$

$$= 681.83 \text{ kPa} + \frac{\left(1236 \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \frac{\text{m}}{\text{s}^2}\right)(5 \text{ m})}{\frac{1000 \frac{\text{N}}{\text{m}^2}}{1 \text{ kPa}}}$$

$$= 742.46 \text{ kPa}$$

$$p_4 > 700 \text{ kPa}$$

Thus, a pressure of 700 kPa occurs in the glycerin level.

The answer is (D).

FLUIDS–19

The pressure drop across a turbine is 200 kPa. The flow rate is 0.25 m^3/min. What is most nearly the power output of the turbine?

(A) 0.41 kW (B) 0.83 kW (C) 0.95 kW (D) 1.3 kW

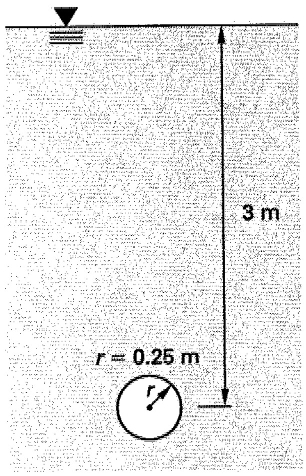
$$P = (\text{pressure drop})(\text{flow rate}) = (200 \text{ kPa})\left(\frac{0.25 \text{ m}^3}{\text{min}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$$

$$= 0.833 \text{ kW} \quad (0.83 \text{ kW})$$

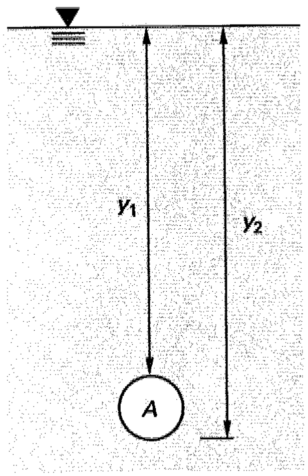
The answer is (B).

FLUIDS–20

A circular window with a radius of 0.25 m has its center 3 m below the water's surface. The window is vertical. What is most nearly the force acting on the window?



(A) 2.9 kN (B) 5.8 kN (C) 18 kN (D) 29 kN



$$F = \overline{p}A$$

$$\overline{p} = \left(\frac{y_1 + y_2}{2}\right)(\rho g \sin\alpha)$$

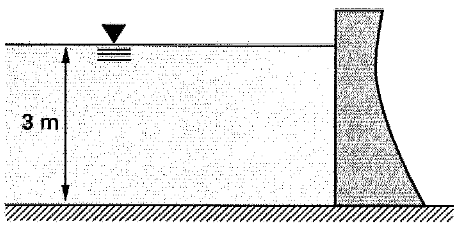
With $y_1 = 2.75$ m, $y_2 = 3.25$ m, the angle α between the surface of the water and the surface of the window $= \pi/2$, and $A = \pi r^2$,

$$\begin{aligned} F &= \left(\frac{y_1 + y_2}{2}\right)(\rho g \sin\alpha)A \\ &= \left(\frac{2.75\text{ m} + 3.25\text{ m}}{2}\right)\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(\frac{9.81\text{ m}}{\text{s}^2}\right)(1)\pi(0.25\text{ m})^2 \\ &= 5780\text{ N}\quad (5.78\text{ kN}) \end{aligned}$$

The answer is (B).

FLUIDS–21

What is most nearly the overturning moment per unit width due to water acting on the dam shown?



(A) 15 kN·m (B) 30 kN·m (C) 44 kN·m (D) 72 kN·m

The hydrostatic force per unit width of dam is

$$F = \tfrac{1}{2}\rho g h A$$

$A = (3\text{ m})(1\text{ m}) = 3\text{ m}^2$ per meter of width.

$$\begin{aligned} F &= \left(\frac{1}{2}\right)\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(3\text{ m})(3\text{ m}) \\ &= 44\,145\text{ N}\quad (44.145\text{ kN·m/m}) \end{aligned}$$

This force acts one-third up from the base.

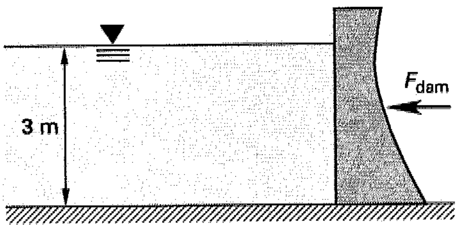
The overturning moment is

$$M_{dam} = Fy = \left(44.145\ \frac{\text{kN·m}}{\text{m}}\right)\left(\frac{3\ \text{m}}{3}\right)$$
$$= 44.1\ \text{kN·m} \quad (44\ \text{kN·m})$$

The answer is (C).

FLUIDS–22

What is most nearly the minimum required force per unit width, F_{dam}, to prevent the dam shown from sliding?



(A) 15 kN (B) 30 kN (C) 44 kN (D) 72 kN

$$F = \tfrac{1}{2}\rho g h A$$

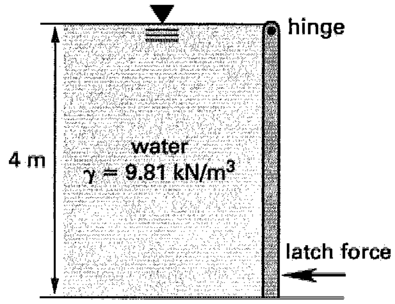
$A = (3\ \text{m})(1\ \text{m}) = 3\ \text{m}^2$ per meter of width.

$$F = \left(\frac{1}{2}\right)\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(3\ \text{m})(3\ \text{m})$$
$$= 44\,145\ \text{N} \quad (44\ \text{kN})$$

The answer is (C).

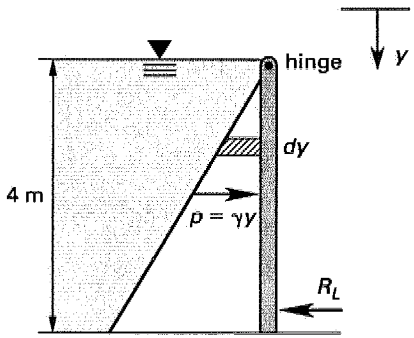
FLUIDS–23

Water is held in a tank by the sluice gate shown. What force per unit width of the dam must the latch supply to keep the gate closed?



(A) 25 kN/m (B) 34 kN/m (C) 52 kN/m (D) 74 kN/m

Draw a free-body diagram of the gate.



Use the coordinate system in the diagram. For the gate to stay in place, the sum of the moments around the hinge must be zero.

$$\begin{aligned}\sum M_{\text{hinge}} &= 0\\ &= (4\ \text{m})R_L - \int_{0\ \text{m}}^{4\ \text{m}} \gamma y y dy\end{aligned}$$

$$\begin{aligned}(4\text{ m})R_L &= \int_{0\text{ m}}^{4\text{ m}} p y dy = \int_{0\text{ m}}^{4\text{ m}} \gamma y y dy \\ &= \int_{0\text{ m}}^{4\text{ m}} \gamma y^2 dy \\ &= \left.\frac{\left(9.81\ \frac{\text{kN}}{\text{m}^3}\right) y^3}{3}\right|_{0\text{ m}}^{4\text{ m}} \\ &= 209.3\text{ kN}\end{aligned}$$

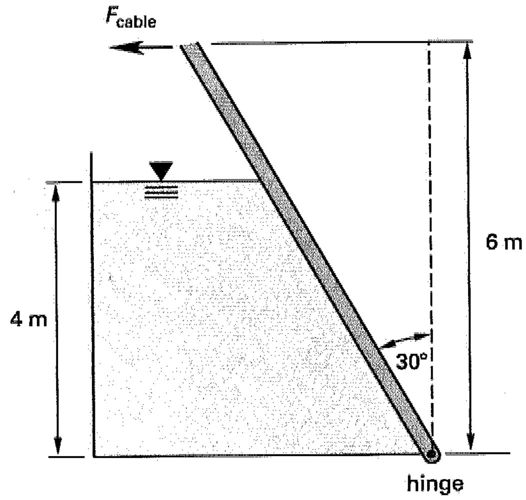
Rearranging to solve for R_L,

$$\begin{aligned}R_L &= \frac{209.3\text{ kN}}{4\text{ m}} \\ &= 52.3\text{ kN/m} \quad (52\text{ kN/m})\end{aligned}$$

The answer is (C).

FLUIDS–24

A tank with one hinged wall is filled with water. The tank wall is held at a 30° angle by a horizontal cable. What is most nearly the tension in the cable per meter of the tank?



(A) 19 kN (B) 23 kN (C) 25 kN (D) 40 kN

The average pressure is

$$\begin{aligned}\overline{p} &= \overline{h}\gamma \\ &= \left(\frac{0+4\text{ m}}{2}\right)\left(9.81\ \frac{\text{kN}}{\text{m}^3}\right) \\ &= 19.6\text{ Pa}\end{aligned}$$

The length of the wetted inclined wall is

$$l = \frac{h}{\cos 30^\circ} = \frac{4\text{ m}}{\cos 30^\circ} = 4.62\text{ m}$$

The wall area per foot of wall is

$$A = lw = (4.62\text{ m})(1\text{ m}) = 4.62\text{ m}^2$$

The resultant force is

$$R = \overline{p}A = (19.6\text{ Pa})\left(4.62\text{ m}^2\right) = 90.6\text{ kN}$$

This resultant acts perpendicular to the wall at

$$\frac{2h}{3} = \frac{(2)(4\text{ m})}{3} = 2.67\text{ m} \quad \text{[vertical distance measured from surface]}$$

Taking moments about the hinge at the bottom,

$$\begin{aligned}\sum M = 0 &= \frac{(90.6\text{ kN})(4\text{ m} - 2.67\text{ m})}{\cos 30^\circ} - \frac{(T_{\text{cable}})(\cos 30^\circ)(6\text{ m})}{\cos 30^\circ} \\ &= 139.1\text{ kN·m} - (6\text{ m})T_{\text{cable}}\end{aligned}$$

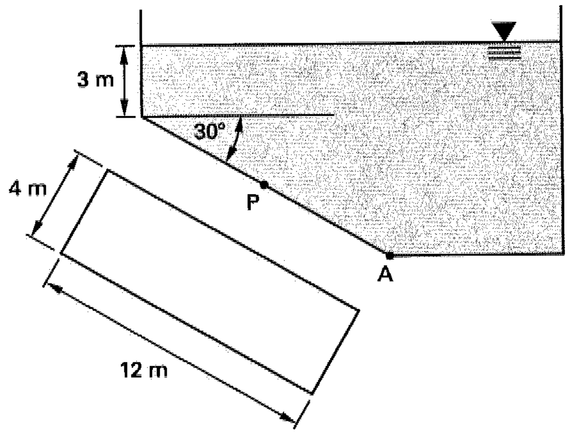
Rearranging to solve for T_{cable},

$$\begin{aligned}T_{\text{cable}} &= \frac{139.1\text{ kN·m}}{6\text{ m}} \\ &= 23.2\text{ kN} \quad (23\text{ kN})\end{aligned}$$

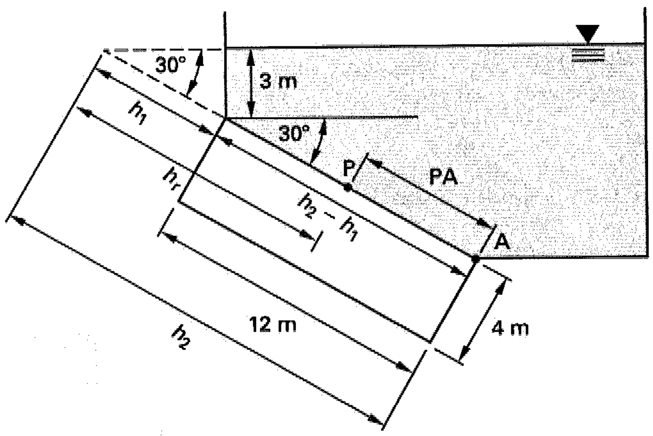
$\boxed{\text{The answer is (B).}}$

FLUIDS–25

A tank of water has a rectangular panel at its lower left side, as shown. The location of the center of pressure on the panel is at the point P. Describe the distance along the panel from the bottom of the tank to the center of pressure as PA. Determine the length of PA.



(A) 4 m (B) 5 m (C) 6 m (D) 7 m



The distance along the surface of an object from the surface of the fluid to the center of pressure, h_r, is given by

$$h_r = \frac{2}{3}\left(h_1 + h_2 - \frac{h_1 h_2}{h_1 + h_2}\right)$$

In the preceding equation, h_1 is the distance along the surface of the object from the surface of the fluid to the object's upper edge, and h_2 is the distance along the surface of the object from the surface of the fluid to the object's lower edge.

From the illustration,

$$\text{PA} = h_2 - h_r$$

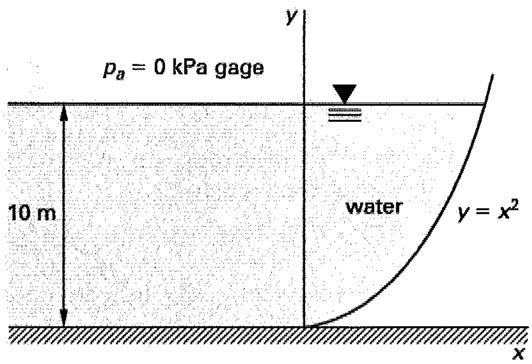
The plane is inclined at 30° below horizontal, has its upper edge at 3 m (vertically) below the surface of the fluid, and is 12 m long. Thus, the following can be determined.

$$\begin{aligned} h_1 &= \frac{3 \text{ m}}{\sin 30°} \\ &= 6 \text{ m} \\ h_2 - h_1 &= 12 \text{ m} \\ h_2 &= h_1 + 12 \text{ m} = 6 \text{ m} + 12 \text{ m} \\ &= 18 \text{ m} \\ h_r &= \left(\frac{2}{3}\right)\left(6 \text{ m} + 18 \text{ m} - \frac{(6 \text{ m})(18 \text{ m})}{6 \text{ m} + 18 \text{ m}}\right) \\ &= 13 \text{ m} \\ \text{PA} &= h_2 - h_r = 18 \text{ m} - 13 \text{ m} \\ &= 5 \text{ m} \end{aligned}$$

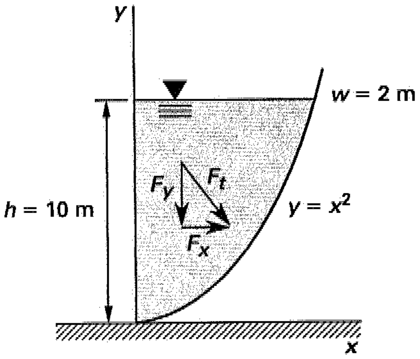
$\boxed{\text{The answer is (B).}}$

FLUIDS–26

What is most nearly the total force exerted on the curved surface described by the equation $y = x^2$? The width of the curved plate is 2 m, and the specific weight of water is 9.81 kN/m^3.



(A) 1020 kN (B) 1070 kN (C) 1260 kN (D) 1380 kN



w is the width of the tank.

$$F_t = \sqrt{F_x^2 + F_y^2}$$

The weight of the water in the portion of the tank above the curved surface, F_y, is

$$\begin{aligned}F_y &= \gamma \text{V} \\ &= \gamma w \int_{0\text{ m}}^{\sqrt{10}\text{ m}} (10\text{ m} - y)dx \\ &= \gamma w \int_{0\text{ m}}^{\sqrt{10}\text{ m}} (10\text{ m} - x^2)dx \\ &= \gamma w \left(10x - \frac{x^3}{3}\right)\Big|_{0\text{ m}}^{\sqrt{10}\text{ m}} \\ &= \left(9.81\ \frac{\text{kN}}{\text{m}^3}\right)(2\text{ m})\left(10\text{ m}\sqrt{10}\text{ m} - \frac{10\text{ m}\sqrt{10}\text{ m}}{3}\right) \\ &= 413.6\text{ kN}\end{aligned}$$

$$F_x = \overline{p}A_x$$

$$\overline{p} = \gamma\left(\frac{0+h}{2}\right)$$

The area of the tank perpendicular to the x-axis, A_x, is

$$A_x = wh$$

$$\begin{aligned}F_x &= \left(9.81\ \frac{\text{kN}}{\text{m}^3}\right)\left(\frac{10\text{ m}}{2}\right)((2\text{ m})(10\text{ m})) \\ &= 981.0\text{ kN}\end{aligned}$$

$$\begin{aligned}F_t &= \sqrt{(413.6\text{ kN})^2 + (981.0\text{ kN})^2} \\ &= 1065\text{ kN} \quad (1070\text{ kN})\end{aligned}$$

The answer is (B).

FLUIDS-27

The stream potential, Φ, of a flow is given by $\Phi = 2xy - y$. Determine the stream function, Ψ, for this potential.

(A) $\Psi = x^2 - y^2 + C$
(B) $\Psi = x - x^2 + y^2 + C$
(C) $\Psi = x + x^2 - y^2 + C$
(D) $\Psi = x^2 + y^2 + C$

$$u = \frac{dx}{dt} \quad \mathrm{v} = \frac{dy}{dt}$$

By definition,

$$\begin{aligned} u &= \frac{d\Phi}{dx} \\ &= \frac{d\Psi}{dy} \\ \mathrm{v} &= \frac{d\Phi}{dy} \\ &= -\frac{d\Psi}{dx} \end{aligned}$$

Substituting $u = 2y$,

$$\frac{d\Psi}{dy} = 2y$$

Rearranging,

$$\begin{aligned} \Psi &= \int 2y dy + f(x) \\ &= y^2 + f(x) \end{aligned}$$

Substituting $\mathrm{v} = 2x - 1$,

$$-\frac{df(x)}{dx} = 2x - 1$$

Rearranging,

$$f(x) = x - x^2 + C$$

Therefore,

$$\Psi = x - x^2 + y^2 + C$$

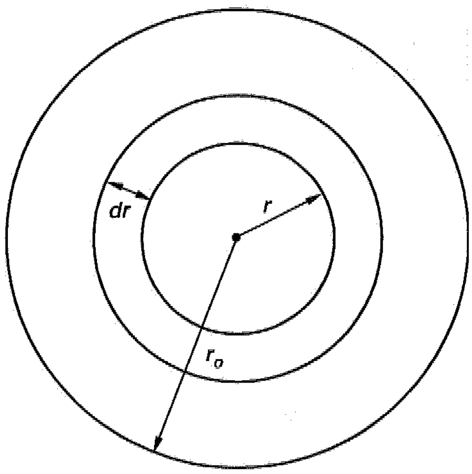
$\boxed{\text{The answer is (B).}}$

FLUIDS–28

Determine the average velocity through a circular section in which the velocity distribution is given as $v = v_{max}(1 - (r/r_o)^2)$. The distribution is symmetric with respect to the longitudinal axis, $r = 0$. r_o is the outer radius and v_{max} is the velocity along the longitudinal axis.

(A) $v_{max}/4$ (B) $v_{max}/3$ (C) $v_{max}/2$ (D) v_{max}

$$\begin{aligned}
v_{ave} &= \frac{1}{A}\int v\,dA \\
&= \frac{1}{\pi r_o^2}\int_0^{r_o} v_{max}\left(1-\left(\frac{r}{r_o}\right)^2\right)2\pi r\,dr \\
&= \frac{2\pi v_{max}}{\pi r_o^2}\int_0^{r_o} r\left(1-\left(\frac{r}{r_o}\right)^2\right)dr \\
&= \left(\frac{2v_{max}}{r_o^2}\right)\left(\frac{r^2}{2}-\frac{r^4}{4r_o^2}\right)\Big|_0^{r_o} \\
&= \left(\frac{2v_{max}}{r_o^2}\right)\left(\frac{r_o^2}{2}-\frac{r_o^2}{4}\right) \\
&= v_{max}/2
\end{aligned}$$



The answer is (C).

FLUIDS–29

Under what conditions is mass conserved in fluid flow?

(A) The fluid is baratropic.
(B) The flow is isentropic.
(C) The flow is adiabatic.
(D) It is always conserved.

Mass is always conserved in fluid flow.

The answer is (D).

FLUIDS–30

What is the absolute velocity of a real fluid at a surface?

(A) the same as the bulk fluid velocity
(B) the velocity of the surface
(C) zero
(D) proportional to the smoothness of the surface

For a real (nonzero viscosity) fluid there is no slip at the boundaries. In other words, the velocity of the surface is the same as the velocity of the fluid at the surface. Thus, option (B) is true.

Option (C) is true only if the velocity of the surface is zero.

The answer is (B).

FLUIDS–31

Which of the statements is true concerning the following continuity equation?

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} + \frac{\partial(\rho \mathrm{v})}{\partial y} + \frac{\partial(\rho w)}{\partial z} = 0$$

ρ is density, u is velocity in the x direction, v is velocity in the y direction, and w is velocity in the z direction.

(A) It is valid only for incompressible flow.
(B) It is valid only for steady flow.
(C) It is derived from the principle of conservation of mass.
(D) It is derived from the principle of conservation of energy.

In essence, the continuity equation states that the mass flux entering a control volume is equal to the mass flux leaving the control volume plus the rate of accumulation of mass within the control volume. Thus, it is derived from the principle of conservation of mass. It is valid for all real and ideal fluids, and for all types of fluid flow.

The answer is (C).

FLUIDS–32

Which of the following sets of dimensional flow equations satisfies the continuity equation? (u, v, and w are the components of velocity in the x, y, and z directions, respectively.)

I. $u = x + 2y - t$
$\mathrm{v} = t - 2y + z$
$w = t - 2x + z$

II. $u = y^2 - x^2$
$\mathrm{v} = 2xy$
$w = 2tz$

III. $u = x^2 - y^2$
$\mathrm{v} = -2xy + ty$
$w = -tz$

(A) I and II (B) I and III (C) II and III (D) I, II, and III

The continuity equation states that $\nabla \cdot \mathbf{V} = 0$. Check to see if this is true for each of the given flows.

$$\text{I.}\quad \frac{\partial u}{\partial x} + \frac{\partial \mathrm{v}}{\partial y} + \frac{\partial w}{\partial z} = 1 + (-2) + 1 = 0$$

$$\text{II.}\quad \frac{\partial u}{\partial x} + \frac{\partial \mathrm{v}}{\partial y} + \frac{\partial w}{\partial z} = -2x + 2x + 2t = 2t \neq 0$$

$$\text{III.}\quad \frac{\partial u}{\partial x} + \frac{\partial \mathrm{v}}{\partial y} + \frac{\partial w}{\partial z} = 2x + (-2x + t) - t = 0$$

Thus, flows I and III both satisfy the continuity equation.

$\boxed{\text{The answer is (B).}}$

FLUIDS–33

A pipe has a diameter of 100 mm at section AA and a diameter of 50 mm at section BB. The velocity of an incompressible fluid is 0.3 m/s at section AA. What is the flow velocity at section BB?

(A) 0.95 m/s (B) 1.2 m/s (C) 2.1 m/s (D) 3.5 m/s

Use the continuity equation.

$$\text{mass through AA} = \text{mass through BB}$$
$$\rho A_1 \mathrm{v}_1 = \rho A_2 \mathrm{v}_2$$

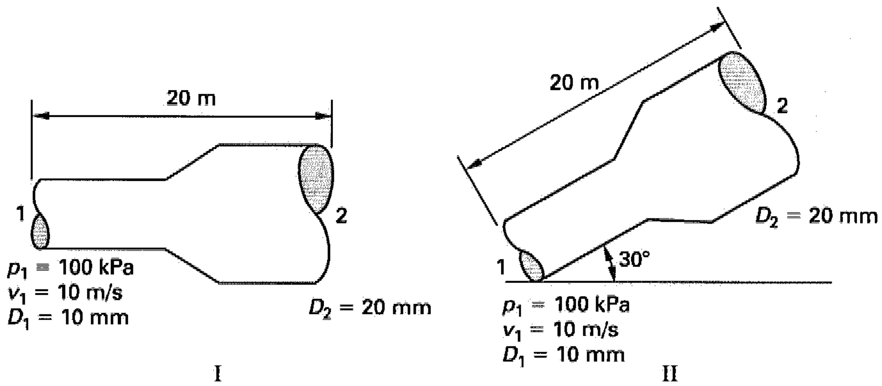
Rearranging to solve for v_2,

$$\begin{aligned} v_2 &= \frac{\rho A_1 v_1}{\rho A_2} \\ &= \left(\frac{A_1}{A_2}\right) v_1 \\ &= \left(\frac{\pi(0.10 \text{ m})^2}{\pi(0.05 \text{ m})^2}\right)\left(\frac{0.3 \text{ m}}{\text{s}}\right) \\ &= 1.2 \text{ m/s} \end{aligned}$$

The answer is (B).

FLUIDS–34

Consider the following two flows of water.



What is the relation between v_2(I) and v_2(II)?

(A) $v_2(\text{I}) = v_2(\text{II})$ (B) $v_2(\text{I}) = \dfrac{v_2(\text{II})}{2}$

(C) $v_2(\text{I}) = 2v_2(\text{II})$ (D) $v_2(\text{I}) = 4\, v_2(\text{II})$

From the continuity equation,

$$A_1 \mathrm{v}_1 = A_2 \mathrm{v}_2$$

Rearranging to solve for v_2,

$$\mathrm{v}_2 = \left(\frac{A_1}{A_2}\right)\mathrm{v}_1 \quad \text{[independent of tilt angle]}$$

$$\mathrm{v}_2(\mathrm{I}) = \mathrm{v}_2(\mathrm{II})$$

$\boxed{\text{The answer is (A).}}$

FLUIDS–35

A constant-volume mixing tank mixes two inlet streams containing salt. The salt concentration in stream 1 is 5% by weight, and in stream 2 it is 15% by weight. Stream 1 flows at 25 kg/s, and stream 2 flows at 10 kg/s. There is only one exit stream. Find the salt concentration in the exit stream.

(A) 5.5% (B) 7.9% (C) 11% (D) 13%

$$\sum_{\text{inlet}} \dot{m}_{\text{salt}} = \sum_{\text{outlet}} \dot{m}_{\text{salt}}$$

$$(0.05)\left(25\ \frac{\text{kg}}{\text{s}}\right) + (0.15)\left(10\ \frac{\text{kg}}{\text{s}}\right) = x\left(35\ \frac{\text{kg}}{\text{s}}\right)$$

Rearranging to solve for x, the salt concentration in the exit stream,

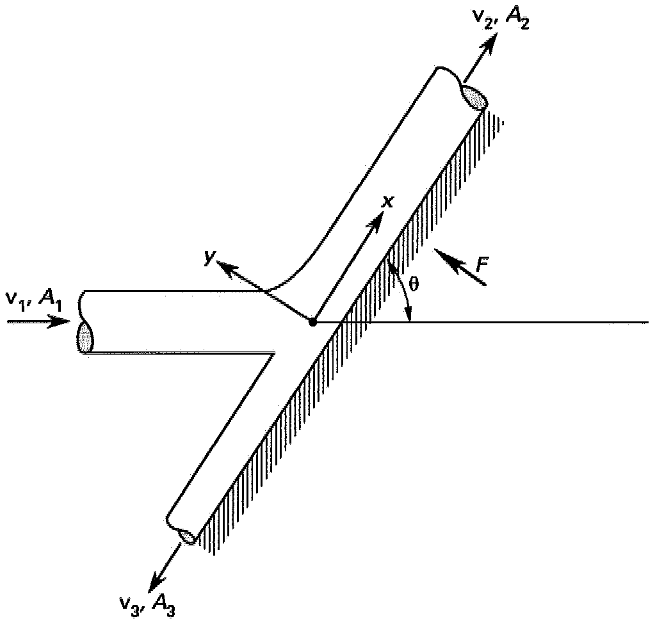
$$x = \frac{(0.05)\left(25\ \frac{\text{kg}}{\text{s}}\right) + (0.15)\left(10\ \frac{\text{kg}}{\text{s}}\right)}{35\ \frac{\text{kg}}{\text{s}}}$$

$$= 0.0786 \quad (7.9\%)$$

$\boxed{\text{The answer is (B).}}$

FLUIDS–36

Water flowing with a velocity of v_1 in a pipe is turned to flow in the x direction, as shown. What is the relation between the y component of the force of the water jet acting on the inclined plate and the inclination angle?



(A) $F_y = \rho A_1 v_1^2 \cos\theta$ (B) $F_y = \rho A_1 v_1 \sin\theta$
(C) $F_y = \rho A_1 v_1 \cos\theta$ (D) $F_y = \rho A_1 v_1^2 \sin\theta$

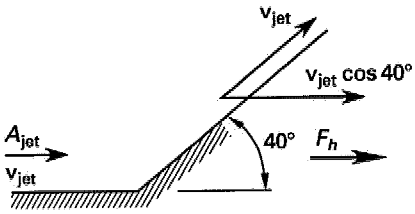
Evaluate momentum in the y direction. The y component of velocity v_1 is $v_y = v_1 \sin\theta$.

$$\begin{aligned} F_y &= \dot{m} v_y \\ &= (\rho A_1 v_1)(v_1 \sin\theta) \\ &= \rho A_1 v_1^2 \sin\theta \end{aligned}$$

$\boxed{\text{The answer is (D).}}$

FLUIDS–37

The vane shown deflects a jet of velocity v_{jet}, density ρ, and cross-sectional area A_{jet} through an angle of 40°. Calculate F_h, the horizontal force on the vane.



(A) $\rho A_{jet} v_{jet}^2$

(B) $\rho A_{jet} v_{jet}^2 \cos 40°$

(C) $\rho A_{jet} v_{jet}^2 (1 - \cos 40°)$

(D) $\rho A_{jet} v_{jet}^2 (1 - \sin 40°)$

Using the momentum equation, the rate of change of horizontal momentum, F_h, is

$$\begin{aligned} F_h &= \dot{m}(\text{horizontal velocity in} - \text{horizontal velocity out}) \\ &= \dot{m}(v_{jet} - v_{jet} \cos 40°) \end{aligned}$$

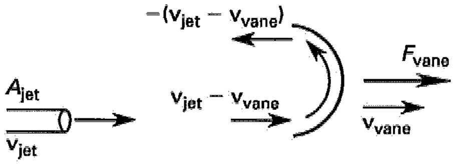
Substituting,

$$\dot{m} = \rho A_{jet} v_{jet}$$
$$F_h = \rho A_{jet} v_{jet} (v_{jet} - v_{jet} \cos 40°) = \rho A_{jet} v_{jet}^2 (1 - \cos 40°)$$

The answer is (C).

FLUIDS–38

A jet of velocity v_{jet}, cross-sectional area A_{jet}, and density ρ_{jet} impinges on a reversing vane and is turned through an angle of 180°. The vane is moving with velocity v_{vane} in the direction of the original jet. What is the force, F_{vane}, exerted on the vane by the water?



(A) $2\rho A_{jet} v_{jet}$
(B) $\rho A_{jet} v_{jet}$
(C) $2\rho A_{jet} v_{vane}$
(D) $2\rho A_{jet} (v_{jet} - v_{vane})^2$

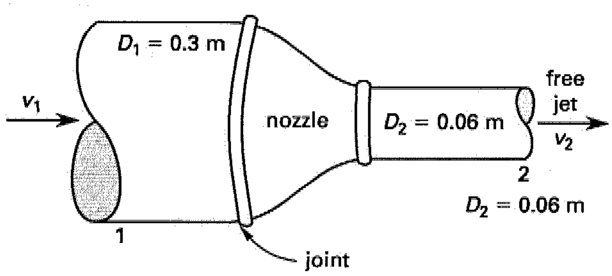
Use the momentum equation. The rate of change of momentum, F_{vane}, is

$$\begin{aligned} F_{vane} &= \dot{m}\Delta v \\ \Delta v &= (v_{jet} - v_{vane}) - \big(-(v_{jet} - v_{vane})\big) \\ &= 2(v_{jet} - v_{vane}) \\ &= \big(\rho A_{jet}(v_{jet} - v_{vane})\big)\big(2(v_{jet} - v_{vane})\big) \\ &= 2\rho A_{jet}(v_{jet} - v_{vane})^2 \end{aligned}$$

The answer is (D).

FLUIDS–39

Oil (specific gravity = 0.8) at 3000 Pa flows at a constant rate of 1 m^3/s through the circular nozzle shown. What is most nearly the net force exerted by the joint to hold the nozzle in place?



(A) 140 kN (B) 190 kN (C) 240 kN (D) 270 kN

$$\mathrm{v} = \frac{Q}{A}$$

$$\mathrm{v}_1 = \frac{1\ \frac{\mathrm{m}^3}{\mathrm{s}}}{\pi\left(\frac{0.3\ \mathrm{m}}{2}\right)^2}$$

$$= 14.15\ \mathrm{m/s}$$

$$\mathrm{v}_2 = \frac{1\ \frac{\mathrm{m}^3}{\mathrm{s}}}{\pi\left(\frac{0.06\ \mathrm{m}}{2}\right)^2}$$

$$= 353.68\ \mathrm{m/s}$$

$$\dot{m} = \rho Q$$

$$= (0.8)\left(1000\ \frac{\mathrm{kg}}{\mathrm{m}^3}\right)\left(1\ \frac{\mathrm{m}^3}{\mathrm{s}}\right)$$

$$= 800\ \mathrm{kg/s}$$

$$\sum F_x = \dot{m}\Delta\mathrm{v}$$

$$F_h - F_1 = \dot{m}(\mathrm{v}_2 - \mathrm{v}_1)$$

Rearranging to solve for F_h, the horizontal force holding the nozzle in place,

$$F_h = F_1 + \dot{m}(\mathrm{v}_2 - \mathrm{v}_1)$$

The force exerted by the pressurized fluid, F_1, is

$$F_1 = pA_1 = \left(3000\ \frac{\mathrm{N}}{\mathrm{m}^2}\right)\left(\pi\left(\frac{0.3\ \mathrm{m}}{2}\right)^2\right)$$

$$= 212.06\ \mathrm{N}$$

$$F_h = 212.06\ \mathrm{N} + \left(800\ \frac{\mathrm{kg}}{\mathrm{s}}\right)\left(353.68\ \frac{\mathrm{m}}{\mathrm{s}} - 14.15\ \frac{\mathrm{m}}{\mathrm{s}}\right)$$

$$= 271\,800\ \mathrm{N}\quad (270\ \mathrm{kN})$$

The answer is (D).

FLUIDS–40

What is the origin of the energy conservation equation used in flow systems?

(A) Newton's first law of motion
(B) Newton's second law of motion
(C) the first law of thermodynamics
(D) the second law of thermodynamics

The energy equation for fluid flow is based on the first law of thermodynamics, which states that the heat input into the system added to the work done on the system is equal to the change in energy of the system.

The answer is (C).

FLUIDS–41

Which of the following is the basis for Bernoulli's law for fluid flow?

(A) the principle of conservation of mass
(B) the principle of conservation of energy
(C) the continuity equation
(D) the principle of conservation of momentum

Bernoulli's law is derived from the principle of conservation of energy.

The answer is (B).

FLUIDS–42

Under which of the following conditions is Bernoulli's equation valid?

(A) all points evaluated must be on the same streamline
(B) the fluid must be incompressible
(C) the fluid must be inviscid
(D) all of the above

Bernoulli's equation is valid only for incompressible, inviscid fluids. In order for Bernoulli's equation to be valid for two particular points, they must lie on the same streamline. Thus, options (A), (B), and (C) are all valid conditions for Bernoulli's equation.

The answer is (D).

FLUIDS–43

Under certain flow conditions, the expression for the first law of thermodynamics for a control volume reduces to Bernoulli's equation.

$$gz_1 + \frac{v_1^2}{2} + \frac{p_1}{\rho} = gz_2 + \frac{v_2^2}{2} + \frac{p_2}{\rho}$$

Which combination of the following conditions is necessary and sufficient to reduce the first law of thermodynamics for a control volume to Bernoulli's equation?

I. steady flow
II. incompressible fluid
III. no frictional losses of energy
IV. no heat transfer or change in internal energy

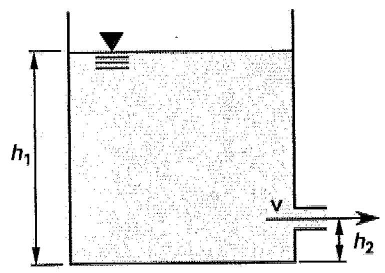
(A) I only (B) I and II (C) I and IV (D) I, II, III, and IV

Bernoulli's equation is essentially a statement of conservation of energy for steady flow of an inviscid, incompressible fluid. Bernoulli's equation does not account for any frictional losses or changes in internal energy of the fluid. For Bernoulli's equation to be valid, I, II, III, and IV must all describe the flow.

$\boxed{\text{The answer is (D).}}$

FLUIDS–44

Determine the velocity of the liquid at the exit, given that $h_1 = 1.5$ m and $h_2 = 0.3$ m.



(A) 1.9 m/s (B) 2.9 m/s (C) 3.9 m/s (D) 4.9 m/s

Use Bernoulli's equation. v_1 is essentially zero.

$$\rho g h_1 = \rho g h_2 - \frac{\rho v_2^2}{2}$$

$$v_2 = \sqrt{2g(h_1 - h_2)}$$

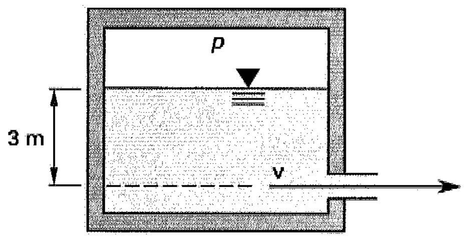
$$= \sqrt{(2)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.5\text{m} - 0.3\text{m})}$$

$$= 4.9\ \text{m/s}$$

$$\boxed{\text{The answer is (D).}}$$

FLUIDS–45

A pressurized tank contains a fluid with a density of 1300 kg/m^3. The pressure in the air space above the fluid is 700 kPa. Fluid exits to the atmosphere from an opening 3 m below the fluid surface. What is most nearly the exit velocity, v?



(A) 11 m/s (B) 22 m/s (C) 31 m/s (D) 52 m/s

Apply Bernoulli's equation between the free surface and the exit.

$$\frac{p_{\text{tank}}}{\rho} + gz_1 + \frac{v_1^2}{2} = \frac{p_{\text{atm}}}{\rho} + gz_2 + \frac{v^2}{2}$$

$$v_1 = 0 \quad \text{[at the free surface]}$$

$$z_2 = 0 \quad \text{[at the exit]}$$

$$\frac{p_{\text{tank}}}{\rho} + gz_1 = \frac{p_{\text{atm}}}{\rho} + \frac{v_2^2}{2}$$

$$v_2 = \sqrt{2g\left(\frac{p_{\text{tank}} - p_{\text{atm}}}{\rho g} + z_1\right)}$$

Substituting,

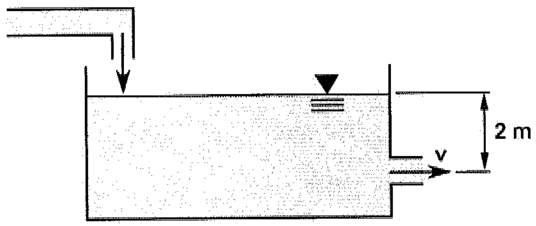
$$v_2 = \sqrt{(2)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\left(\frac{700\ \frac{\text{kN}}{\text{m}^2} - 101\ \frac{\text{kN}}{\text{m}^2}}{\left(1300\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)\left(\frac{1}{1000\ \frac{\text{N}}{\text{kN}}}\right)} + 3\ \text{m}\right)}$$

$$= 31.3\ \text{m/s} \quad (31\ \text{m/s})$$

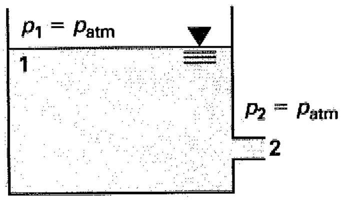
$\boxed{\text{The answer is (C).}}$

FLUIDS–46

Consider the holding tank shown. The tank volume remains constant. What is most nearly the velocity of the water exiting to the atmosphere?



(A) 3 m/s (B) 4 m/s (C) 5 m/s (D) 6 m/s



Apply Bernoulli's equation between the free surface (point 1) and the exit (point 2).

$$gz_1 + \frac{v_1^2}{2} + \frac{p_1}{\rho} = gz_2 + \frac{v_2^2}{2} + \frac{p_2}{\rho}$$

$$p_1 = p_2 \quad \text{[both are at atmospheric pressure]}$$

$$v_1 = 0 \quad \text{[the free surface is stationary]}$$

$$gz_1 = gz_2 + \frac{v_2^2}{2}$$
$$v_2 = \sqrt{2g(z_1 - z_2)}$$
$$= \sqrt{(2)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2\ \text{m})}$$
$$= 6.3\ \text{m/s}$$

The answer is (D).

FLUIDS–47

Water is pumped at 1 m^3/s to an elevation of 5 m through a flexible hose using a 100% efficient pump rated at 100 kW. Using the same length of hose, what size motor is needed to pump 1 m^3/s of water to a tank with no elevation gain? Both ends of the hose are at atmospheric pressure. Neglect kinetic energy effects.

(A) 18 kW (B) 22 kW (C) 37 kW (D) 51 kW

From a mechanical power balance for the first case,

$$\dot{m}g\Delta z + \sum P_{\text{friction}} = P_{\text{motor}}$$
$$\sum P_{\text{friction}} = P_{\text{motor}} - \dot{m}g\Delta z$$
$$= P_{\text{motor}} - \rho Q g \Delta z$$
$$= 100\,000\ \text{W} - \left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(1\ \frac{\text{m}^3}{\text{s}}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(5\ \text{m})$$
$$= 51\ \text{kW}$$

In the second case, $\Delta z = 0$. Thus, a mechanical power balance yields the following.

$$\sum P_{\text{friction}} = P_{\text{motor}}$$
$$= 51\ \text{kW} \quad \text{[because the same hose is used]}$$
$$P_{\text{motor}} = 51\ \text{kW}$$

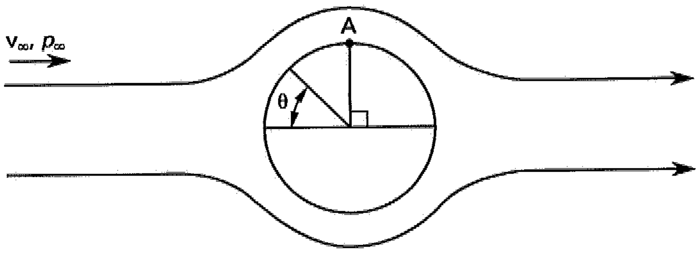
The answer is (D).

FLUIDS–48

The potential flow velocity distribution of atmospheric air around a cylinder is

$$v = 2v_\infty \sin\theta$$

The free-stream velocity is 30 m/s. The air density is approximately 1.202 kg/m^3. What is most nearly the pressure at point A?



(A) 64 kN/m^2 (B) 76 kN/m^2 (C) 80 kN/m^2 (D) 99 kN/m^2

Apply Bernoulli's equation between the free stream and point A.

$$\begin{aligned} p_\infty + \tfrac{1}{2}\rho_\infty v_\infty^2 &= p_A + \tfrac{1}{2}\rho v_A^2 \\ p_{atm} + \tfrac{1}{2}\rho_{air} v_\infty^2 &= p_A + \tfrac{1}{2}\rho_{air} v_A^2 \\ v_A &= 2v_\infty \sin 90^\circ \\ &= 2v_\infty \\ p_A &= p_{atm} + \rho_{air}\left(v_\infty^2 - 4v_\infty^2\right) \\ &= p_{atm} - \tfrac{3}{2}\rho_{air} v_\infty^2 \end{aligned}$$

Therefore,

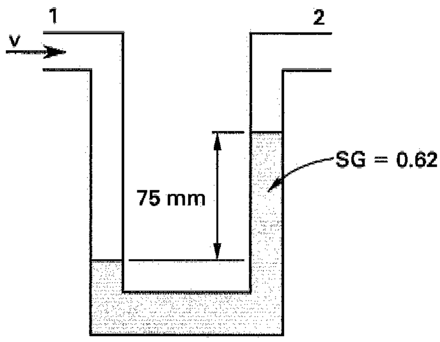
$$\begin{aligned} p_A &= 101\,000 \text{ Pa} - \left(\frac{3}{2}\right)\left(1.202 \frac{\text{kg}}{\text{m}^3}\right)\left(30 \frac{\text{m}}{\text{s}}\right)^2 \\ &= 99\,377 \text{ Pa} \quad (99.4 \text{ kPa}) \end{aligned}$$

$\boxed{\text{The answer is (D).}}$

FLUIDS–49

Two tubes are mounted to the roof of a car. One tube points to the front of the car while the other points to the rear. The tubes are connected to a manometer filled with a fluid of specific gravity 0.62. The density of air is approximately 1.202 kg/m^3. When the height difference is 75 mm, what is the car's speed?

(A) 11 m/s (B) 15 m/s (C) 28 m/s (D) 96 m/s



Apply Bernoulli's equation between the front tube (point 1) and the tube facing the rear (point 2).

$$p_1 + \tfrac{1}{2}\rho_{\text{air}}\text{v}^2 = p_2 + \rho_f g h$$

$$p_1 = p_2 \quad \text{[both are at atmospheric pressure]}$$

The speed of the car, v, is

$$\text{v} = \sqrt{\frac{2\rho_f g h}{\rho_{\text{air}}}}$$

$$\rho_f = (\text{SG})(\rho_{\text{water}}) = (0.62)\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)$$
$$= 620\ \text{kg/m}^3$$

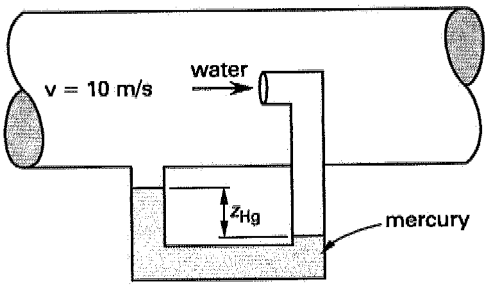
Therefore,

$$\text{v} = \sqrt{\frac{(2)\left(620\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(0.075\ \text{m})}{1.202\ \frac{\text{kg}}{\text{m}^3}}}$$
$$= 27.6\ \text{m/s} \quad (28\ \text{m/s})$$

The answer is (C).

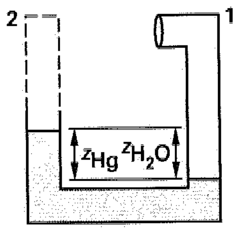
FLUIDS–50

Water is flowing through a pipe with a manometer as shown.



The density of mercury is 13 567 kg/m^3, and the velocity of the water is 10 m/s. Determine the height difference, z_{Hg}, in centimeters of mercury.

(A) 41 cm (B) 47 cm (C) 57 cm (D) 69 cm



From Bernoulli's equation,

$$gz_1 + \frac{v_1^2}{2} + \frac{p_1}{\rho} = gz_2 + \frac{v_2^2}{2} + \frac{p_2}{\rho}$$

$$\Delta z = 0$$

$$p_1 - p_2 = \left(\frac{v_2^2 - v_1^2}{2}\right)\rho$$

$$v_1 = 0$$

$$v_2 = 10 \text{ m/s}$$

$$p_1 - p_2 = \left(\frac{\left(10\ \frac{\text{m}}{\text{s}}\right)^2 - 0}{2}\right)\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)$$

$$= 50\,000 \text{ Pa}$$

$$= \rho_{Hg} g z_{Hg} - \rho_{H_2O} g z_{H_2O}$$

$$z_{Hg} = z_{H_2O}$$

$$50\,000 \text{ Pa} = (\rho_{Hg} - \rho_{H_2O}) g z_{Hg}$$

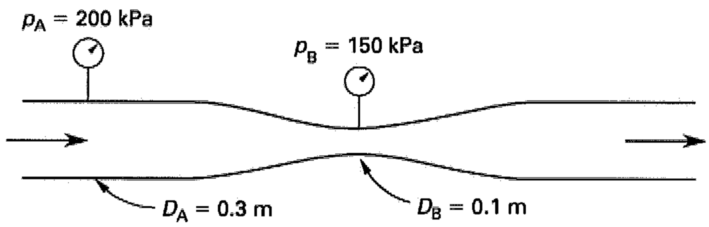
$$z_{Hg} = \frac{50\,000 \text{ Pa}}{\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)\left(13\,567 \ \frac{\text{kg}}{\text{m}^3} - 1000 \ \frac{\text{kg}}{\text{m}^3}\right)}$$

$$= 0.406 \text{ m} \quad (41 \text{ cm})$$

The answer is (A).

FLUIDS–51

Given the venturi meter and the two pressures shown, calculate the mass flow rate of water in the circular pipe.



(A) 52 kg/s (B) 61 kg/s (C) 65 kg/s (D) 79 kg/s

From the continuity equation,

$$A_A v_A = A_B v_B$$

$$v_A \pi (0.15 \text{ m})^2 = v_B \pi (0.05 \text{ m})^2$$

$$v_A = \left(\frac{(0.05 \text{ m})^2}{(0.15 \text{ m})^2}\right) v_B$$

$$= 0.111 \ v_B$$

Use Bernoulli's equation along the streamline in the center of the pipe.

$$g z_A + \frac{v_A^2}{2} + \frac{p_A}{\rho} = g z_B + \frac{v_B^2}{2} + \frac{p_B}{\rho}$$

$$\Delta z = 0$$

$$p_A - p_B = 200 \text{ kPa} - 150 \text{ kPa} = 50 \text{ kPa}$$

$$\frac{v_B^2 - v_A^2}{2} = \frac{50\,000 \text{ Pa}}{1000 \ \frac{\text{kg}}{\text{m}^3}}$$

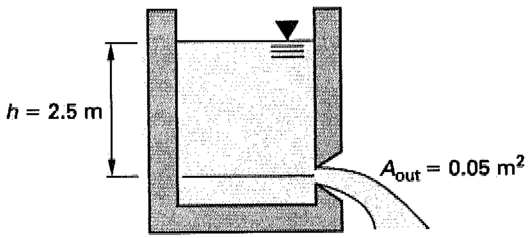
Rearranging,

$$\begin{aligned}
v_B^2 - v_A^2 &= 100\ \text{m}^2/\text{s}^2 \\
v_B^2 - (0.111 v_B)^2 &= 100\ \frac{\text{m}^2}{\text{s}^2} \\
v_B^2\left(1 - (0.111)^2\right) &= 100\ \frac{\text{m}^2}{\text{s}^2} \\
v_B &= 10.06\ \text{m/s} \\
\dot{m} &= \rho v_B A_B \\
&= \left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(10.06\ \frac{\text{m}}{\text{s}}\right)\pi(0.05\ \text{m})^2 \\
&= 79\ \text{kg/s}
\end{aligned}$$

The answer is (D).

FLUIDS–52

What is the volumetric discharge rate for the tank shown? The coefficient of contraction for the orifice is 0.61, and the coefficient of velocity is 0.98.



(A) 0.21 m^3/s (B) 0.33 m^3/s (C) 0.41 m^3/s (D) 0.52 m^3/s

$$\dot{V}_{\text{actual}} = C_c A_{\text{out}} v_{\text{out}}$$

In the preceding equation, C_c is the coefficient of contraction, and A_{out} is the area of the outlet.

$$v_{\text{out}} = C_v\sqrt{2gh}$$

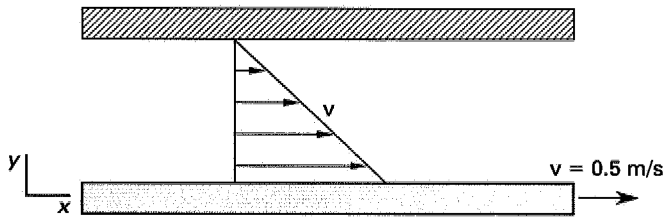
In the preceding equation, C_v is the coefficient of velocity, and h is the vertical distance from the exit to the fluid's surface.

$$\begin{aligned}\dot{V}_{\text{actual}} &= C_c C_v A_{\text{out}} \sqrt{2gh} \\ &= (0.61)(0.98)(0.05\ \text{m}^2)\sqrt{(2)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(2.5\ \text{m})} \\ &= 0.21\ \text{m}^3/\text{s}\end{aligned}$$

The answer is (A).

FLUIDS–53

The upper plate illustrated is fixed, while the lower plate moves in the positive x direction at 0.5 m/s. The plate separation is 0.001 m, the fluid viscosity is 7×10^{-4} Pa·s, and the velocity profile is linear. Calculate the shear stress, τ_{xy}, in the moving fluid.



(A) 0.050 Pa (B) 0.15 Pa (C) 0.25 Pa (D) 0.35 Pa

$$\tau_{xy} = -\mu \frac{d\text{v}_x}{dy}$$

$$\mu = 0.7\ \text{cP} \quad (0.7\ \text{g/m·s}^2)$$

$$\begin{aligned}\frac{d\text{v}_x}{dy} &= \frac{\Delta \text{v}_x}{\Delta y} \\ &= \frac{0.5\ \frac{\text{m}}{\text{s}}}{0.001\ \text{m}} \\ &= 500\ \text{s}^{-1}\end{aligned}$$

$$\begin{aligned}\tau_{xy} &= (0.0007\ \text{Pa·s})\left(500\ \frac{1}{\text{s}}\right) \\ &= 0.35\ \text{Pa}\end{aligned}$$

The answer is (D).

FLUIDS–54

What are the units of Reynolds number for pipe flow?

(A) m/s (B) m^2/s (C) $kg/m{\cdot}s^2$ (D) none of the above

The Reynolds number is dimensionless.

$\boxed{\text{The answer is (D).}}$

FLUIDS–55

Which of the following ratios represents a physical interpretation of the Reynolds number?

(A) $\text{Re} = \dfrac{\text{buoyant forces}}{\text{inertial forces}}$

(B) $\text{Re} = \dfrac{\text{viscous forces}}{\text{inertial forces}}$

(C) $\text{Re} = \dfrac{\text{drag forces}}{\text{viscous forces}}$

(D) $\text{Re} = \dfrac{\text{inertial forces}}{\text{viscous forces}}$

$$\text{Re} = \frac{\rho \text{v} D}{\mu}$$

By definition, the Reynolds number is the ratio of the inertial forces on an element of fluid to the viscous forces.

$\boxed{\text{The answer is (D).}}$

FLUIDS–56

Which of the following statements is FALSE?

(A) The Reynolds number is the ratio of the viscous force to the inertial force.
(B) Steady flows do not change with time at any point.
(C) The Navier-Stokes equation is the equation of motion for a viscous Newtonian fluid.
(D) Bernoulli's equation only holds on the same streamline.

The Reynolds number is the ratio of the inertial forces to the viscous forces.

$\boxed{\text{The answer is (A).}}$

FLUIDS–57

Calculate the Reynolds number for water at 20°C flowing in an open channel. The water is flowing at a volumetric rate of 0.8 m^3/s. The channel has a height of 1.2 m and a width of 2.5 m. At this temperature, water has a kinematic viscosity of 1.02×10^{-6} m^2/s.

(A) 6.5×10^5 (B) 8.5×10^5 (C) 9.2×10^5 (D) 1.2×10^6

$$\begin{aligned}
\mathrm{Re} &= \frac{\rho \mathrm{v} D_e}{\mu} \\
&= \frac{\mathrm{v} D_e}{\nu} \\
D_e &= 4\left(\frac{\text{cross-sectional area}}{\text{wetted perimeter}}\right) \\
&= (4)\left(\frac{(1.2\ \mathrm{m})(2.5\ \mathrm{m})}{1.2\ \mathrm{m} + 2.5\ \mathrm{m} + 1.2\ \mathrm{m}}\right) \\
&= 2.45\ \mathrm{m} \\
\dot{V} &= \mathrm{v}A
\end{aligned}$$

Rearranging,

$$\begin{aligned}
\mathrm{v} &= \frac{\dot{V}}{A} \\
&= \frac{0.8\ \frac{\mathrm{m}^3}{\mathrm{s}}}{(1.2\ \mathrm{m})(2.5\ \mathrm{m})} \\
&= 0.27\ \mathrm{m/s} \\
\mathrm{Re} &= \frac{\left(0.27\ \frac{\mathrm{m}}{\mathrm{s}}\right)(2.45\ \mathrm{m})}{1.02 \times 10^{-6}\ \frac{\mathrm{m}^2}{\mathrm{s}}} \\
&= 6.5 \times 10^5
\end{aligned}$$

$\boxed{\text{The answer is (A).}}$

FLUIDS–58

A fluid with a kinematic viscosity of 2.5×10^{-6} m^2/s is flowing at 0.03 m/s from an orifice 75 mm in diameter. How can the fluid be described?

(A) The fluid is completely turbulent.
(B) The fluid is in the transition zone.
(C) The fluid is laminar.
(D) The fluid's turbulence cannot be calculated from the information given.

$$\begin{aligned}\text{Re} &= \frac{\text{v}D}{\nu} \\ &= \frac{\left(0.03\ \frac{\text{m}}{\text{s}}\right)(0.075\ \text{m})}{2.5 \times 10^{-6}\ \frac{\text{m}^2}{\text{s}}} \\ &= 900\end{aligned}$$

A Reynolds number of 900 means that the flow is well within the laminar (Re < 2000) region.

$\boxed{\text{The answer is (C).}}$

FLUIDS–59

The Reynolds number of a sphere falling in air is 1×10^6. If the sphere's radius is 0.5 m, what is most nearly its velocity? ($\rho_{\text{air}} = 1.225$ kg/m^3, $\mu_{\text{air}} = 1.789 \times 10^{-5}$ Pa·s)

(A) 2.5 m/s (B) 5.2 m/s (C) 11 m/s (D) 15 m/s

$$\begin{aligned}\text{Re} &= \frac{\text{v}D}{\nu} = \frac{\rho \text{v} D}{\mu} \\ \text{v} &= \frac{\mu \text{Re}}{\rho D} \\ &= \frac{(1.789 \times 10^{-5}\ \text{Pa·s})(1 \times 10^6)}{\left(1.225\ \frac{\text{kg}}{\text{m}^3}\right)(1\ \text{m})} \\ &= 14.6\ \text{m/s} \quad (15\ \text{m/s})\end{aligned}$$

$\boxed{\text{The answer is (D).}}$

FLUIDS–60

Which of the following is NOT true regarding the Blasius boundary layer solution?

(A) It is valid only for potential flow.
(B) It is valid for laminar flow
(C) It is an approximate solution.
(D) It permits one to calculate the skin friction on a flat plate.

The Blasius solution is an approximate solution to the boundary layer equations and makes some simplifying assumptions. It is valid for laminar, viscous flow and permits the evaluation of shear stress and skin friction.

The Blasius solution or any other boundary layer concept has no meaning for potential flow.

The answer is (A).

FLUIDS–61

From the Blasius solution for laminar boundary layer flow, the average coefficient of skin friction is $C_f = 1.328/\sqrt{\mathrm{Re}}$. If air ($\rho_{\mathrm{air}} = 1.225\ \mathrm{kg/m^3}$ and $\mu_{\mathrm{air}} = 1.789 \times 10^{-5}\ \mathrm{Pa{\cdot}s}$) is flowing past a 10 m long flat plate at a velocity of 30 m/s, what is most nearly the force per unit width on the plate?

(A) 0.85 N (B) 1.0 N (C) 1.3 N (D) 1.6 N

$$\begin{aligned}
\mathrm{Re}_L &= \frac{\rho_{\mathrm{air}} \mathrm{v}_{\mathrm{air}} L_{\mathrm{plate}}}{\mu_{\mathrm{air}}} \\
&= \frac{\left(1.225\ \frac{\mathrm{kg}}{\mathrm{m}^3}\right)\left(30\ \frac{\mathrm{m}}{\mathrm{s}}\right)(10\ \mathrm{m})}{1.789 \times 10^{-5}\ \mathrm{Pa{\cdot}s}} \\
&= 2.054 \times 10^7
\end{aligned}$$

$$\begin{aligned}
C_f &= \frac{1.328}{\sqrt{\mathrm{Re}_L}} \\
&= \frac{1.328}{\sqrt{2.054 \times 10^7}} \\
&= 2.93 \times 10^{-4}
\end{aligned}$$

$$C_f = \frac{F}{\frac{1}{2}\rho_{\mathrm{air}} \mathrm{v}_{\mathrm{air}}^2 L_{\mathrm{plate}} w}$$

Rearranging to solve for F,

$$\begin{aligned}\frac{F}{w} &= \tfrac{1}{2}C_f \rho_{\text{air}} \text{v}_{\text{air}}^2 L_{\text{plate}} \\ &= \left(\frac{1}{2}\right)(2.93 \times 10^{-4})\left(1.225\ \frac{\text{kg}}{\text{m}^3}\right)\left(30\ \frac{\text{m}}{\text{s}}\right)^2 (10\ \text{m}) \\ &= 1.62\ \text{N/m} \quad \text{(1.6 N per unit width of plate)}\end{aligned}$$

The answer is (D).

FLUIDS–62

From what were the curves of the Moody friction factor diagram for pipe flow determined?

(A) calculations based on potential flow
(B) theoretical solutions of the Navier-Stokes equations
(C) experimental results for inviscid fluids
(D) experimental results for viscous fluids

The curves in the Moody diagram are experimental data plots. They are valid for viscous fluids.

The answer is (D).

FLUIDS–63

What is most nearly the friction factor for flow in a circular pipe where the Reynolds number is 1000?

(A) 0.008 (B) 0.06 (C) 0.08 (D) 0.1

For Re < 2000, the friction factor, f, is given by the following.

$$\begin{aligned}f &= \frac{64}{\text{Re}} \\ &= \frac{64}{1000} \\ &= 0.064 \quad (0.06)\end{aligned}$$

The answer is (B).

FLUIDS–64

For pipe flow in the laminar flow region, how is the friction factor related to the Reynolds number?

(A) $f \propto \frac{1}{\text{Re}}$ (B) $f \propto \left(\frac{1}{\text{Re}}\right)^2$ (C) $f \propto \text{Re}$ (D) $f \propto \text{Re}^2$

In the laminar region, $f = 64/\text{Re}$.

The answer is (A).

FLUIDS–65

Which of the following flow meters measure(s) the average fluid velocity rather than a point or local velocity in a pipe?

I. venturi meter
II. pitot tube
III. impact tube
IV. orifice meter
V. hot-wire anemometer

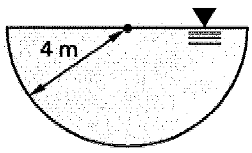
(A) I only (B) II only (C) I and IV (D) II and V

Of the four choices given, only venturi and orifice meters measure average velocity.

The answer is (C).

FLUIDS–66

What is the hydraulic radius of the semicircular channel shown?



(A) 2 m (B) 3 m (C) 4 m (D) 6 m

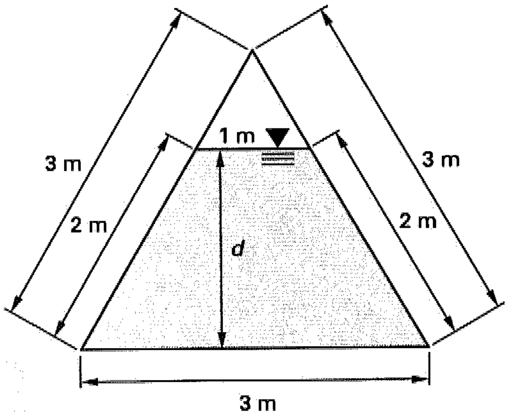
The hydraulic radius, r_h, is

$$\begin{aligned} r_h &= \frac{\text{cross-section area}}{\text{wetted perimeter}} \\ &= \frac{\frac{1}{2}(\pi r^2)}{\pi r} \\ &= \frac{r}{2} \\ &= \frac{4\ \text{m}}{2} \\ &= 2\ \text{m} \end{aligned}$$

$\boxed{\text{The answer is (A).}}$

FLUIDS–67

What is the hydraulic radius of the channel shown?



(A) 0.33 m (B) 0.43 m (C) 0.49 m (D) 1.5 m

$$d = \sqrt{(2\ \text{m})^2 - (1\ \text{m})^2} = \sqrt{3}\ \text{m}$$

$$\begin{aligned} \text{cross-sectional area} &= \left(\frac{1\ \text{m} + 3\ \text{m}}{2}\right) d \\ &= (2\ \text{m})(\sqrt{3}\ \text{m}) \\ &= 3.46\ \text{m}^2 \end{aligned}$$

Substituting,

$$\begin{aligned} r_h &= \frac{\text{cross-sectional area}}{\text{wetted perimeter}} \\ &= \frac{3.46\ \text{m}^2}{2\ \text{m} + 3\ \text{m} + 2\ \text{m}} \\ &= 0.49\ \text{m} \end{aligned}$$

> The answer is (C).

FLUIDS–68

For fully developed laminar flow of fluids through circular pipes, the average velocity is what fraction of the maximum velocity?

(A) 1/8 (B) 1/4 (C) 1/2 (D) 3/4

For laminar flow in pipes,

$$\text{v}_{\text{ave}} = \frac{\text{v}_{\text{max}}}{2}$$

> The answer is (C).

FLUIDS–69

The flow rate of water through a cast-iron pipe is 20 m^3/min. The diameter of the pipe is 0.3 m, and the coefficient of friction is $f = 0.0173$. What is most nearly the pressure drop over a 30 m length of pipe?

(A) 9.8 kPa (B) 13 kPa (C) 17 kPa (D) 19 kPa

$$\begin{aligned} \dot{V} &= \frac{20\ \frac{\text{m}^3}{\text{min}}}{60\ \frac{\text{s}}{\text{min}}} \\ &= 0.333\ \text{m}^3/\text{s} \end{aligned}$$

$$\begin{aligned} \text{v} &= \frac{\dot{V}}{A} = \frac{\dot{V}}{\pi r^2} \\ &= \frac{0.333\ \frac{\text{m}^3}{\text{s}}}{\pi \left(\frac{0.3\ \text{m}}{2}\right)^2} \\ &= 4.71\ \text{m/s} \end{aligned}$$

The head loss, Δh, is

$$\begin{aligned}\Delta h &= f\left(\frac{l}{d}\right)\left(\frac{\mathrm{v}^2}{2g}\right)\\ &= (0.0173)\left(\frac{30\ \mathrm{m}}{0.3\ \mathrm{m}}\right)\left(\frac{\left(4.71\ \frac{\mathrm{m}}{\mathrm{s}}\right)^2}{(2)\left(9.81\ \frac{\mathrm{m}}{\mathrm{s}^2}\right)}\right)\\ &= 1.96\ \mathrm{m}\end{aligned}$$

Rearranging to solve for Δp,

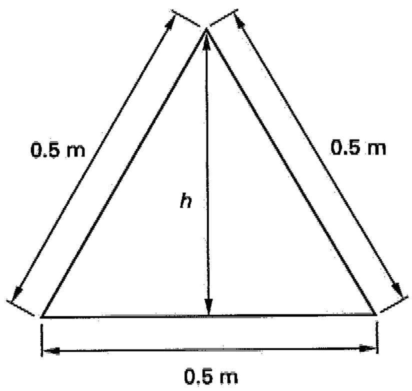
$$\begin{aligned}\Delta h &= \frac{\Delta p}{\rho g}\\ \Delta p &= \rho g \Delta h = \left(1000\ \frac{\mathrm{kg}}{\mathrm{m}^3}\right)\left(9.81\ \frac{\mathrm{m}}{\mathrm{s}^2}\right)(1.96\ \mathrm{m})\\ &= 19\,200\ \mathrm{Pa}\quad (19\ \mathrm{kPa})\end{aligned}$$

The answer is (D).

FLUIDS–70

A completely full cast-iron pipe of equilateral triangular cross section (vertex up) and with side length of 0.5 m has water flowing through it. The flow rate is 22 $\mathrm{m}^3/\mathrm{min}$, and the friction factor for the pipe is 0.017. What is most nearly the pressure drop in a 30 m length of pipe?

(A) 6.8 kPa (B) 9.8 kPa (C) 10 kPa (D) 15 kPa



$$h = \sqrt{(0.5\ \text{m})^2 - \left(\frac{0.5\ \text{m}}{2}\right)^2}$$

$$= 0.433\ \text{m}$$

$$\text{cross-sectional area} = \tfrac{1}{2}bh$$

$$= \left(\frac{1}{2}\right)(0.5\ \text{m})(0.433\ \text{m})$$

$$= 0.108\ \text{m}^2$$

$$D_e = 4\left(\frac{\text{cross-sectional area}}{\text{wetted perimeter}}\right)$$

$$= (4)\left(\frac{0.108\ \text{m}^2}{0.5\ \text{m} + 0.5\ \text{m} + 0.5\ \text{m}}\right)$$

$$= 0.288\ \text{m}$$

$$\dot{V} = \frac{22\ \frac{\text{m}^3}{\text{min}}}{60\ \frac{\text{sec}}{\text{min}}}$$

$$= 0.367\ \text{m}^3/\text{s}$$

$$\text{v} = \frac{\dot{V}}{A}$$

$$= \frac{0.367\ \frac{\text{m}^3}{\text{s}}}{0.108\ \text{m}^2}$$

$$= 3.40\ \text{m/s}$$

The head loss, Δh, is

$$\Delta h = f\left(\frac{L}{D_e}\right)\left(\frac{\text{v}^2}{2g}\right)$$

$$= (0.017)\left(\frac{30\ \text{m}}{0.288\ \text{m}}\right)\left(\frac{\left(3.40\ \frac{\text{m}}{\text{s}}\right)^2}{(2)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)}\right)$$

$$= 1.043\ \text{m}$$

$$\begin{aligned}\Delta p &= \rho g \Delta h = \gamma \Delta h \\ &= \left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(1.043\ \text{m}) \\ &= \left(9.81\ \frac{\text{kN}}{\text{m}^3}\right)(1.043\ \text{m}) \\ &= 10.2\ \text{kN/m}^2 \quad (10\ \text{kPa})\end{aligned}$$

The answer is (C).

FLUIDS–71

A circular cylinder 4 m long and 3 m in diameter is in an air stream. The flow velocity is 5 m/s perpendicular to the longitudinal axis of the cylinder. Given that the coefficient of drag on the cylinder is 1.3, and the density of air is 1.225 kg/m^3, what is most nearly the drag force on the cylinder?

(A) 0.090 kN (B) 0.11 kN (C) 0.24 kN (D) 0.91 kN

A is the frontal area of the cylinder.

$$\begin{aligned}F_D &= \tfrac{1}{2} C_D \rho \text{v}^2 A \\ &= \left(\frac{1}{2}\right)(1.3)\left(1.225\ \frac{\text{kg}}{\text{m}^3}\right)\left(5\ \frac{\text{m}}{\text{s}}\right)^2(3\ \text{m})(4\ \text{m}) \\ &= 238.9\ \text{N} \quad (0.24\ \text{kN})\end{aligned}$$

The answer is (C).

FLUIDS–72

Air flows past a 50 mm diameter sphere at 30 m/s. What is most nearly the drag force experienced by the sphere? The sphere has a coefficient of drag of 0.5. The density of the air is 1.225 kg/m^3.

(A) 0.26 N (B) 0.34 N (C) 0.54 N (D) 0.68 N

A is the frontal area of the sphere.

$$\begin{aligned}
F_D &= \tfrac{1}{2}C_D\rho_{\text{air}}\text{v}_{\text{air}}^2 A \\
&= \tfrac{1}{2}C_D\rho_{\text{air}}\text{v}_{\text{air}}^2\pi\left(\frac{d_{\text{sphere}}}{2}\right)^2 \\
&= \frac{C_D\rho_{\text{air}}\text{v}_{\text{air}}^2\pi d_{\text{sphere}}^2}{8} \\
&= \frac{(0.5)\left(1.225\ \frac{\text{kg}}{\text{m}^3}\right)\left(30\ \frac{\text{m}}{\text{s}}\right)^2\pi(0.05\ \text{m})^2}{8} \\
&= 0.541\ \text{N} \quad (0.54\ \text{N})
\end{aligned}$$

The answer is (C).

FLUIDS–73

A cylinder 10 m long and 2 m in diameter is suspended in air flowing at 8 m/s. The air flow is perpendicular to the longitudinal axis of the cylinder. The density of air is 1.225 kg/m^3, and the coefficient of drag of the cylinder is 1.3. What is most nearly the drag force on the cylinder?

(A) 0.31 kN (B) 0.85 kN (C) 1.0 kN (D) 2.3 kN

$$\begin{aligned}
F_D &= \tfrac{1}{2}C_D\rho\text{v}^2A \\
&= \left(\frac{1}{2}\right)(1.3)\left(1.225\ \frac{\text{kg}}{\text{m}^3}\right)\left(8\ \frac{\text{m}}{\text{s}}\right)^2(10\ \text{m})(2\ \text{m}) \\
&= 1019.2\ \text{N} \quad (1.02\ \text{kN})
\end{aligned}$$

The answer is (C).

FLUIDS–74

What is most nearly the terminal velocity of a 50 mm diameter, solid aluminum sphere falling in air? The sphere has a coefficient of drag of 0.5, the density of aluminum, ρ_{alum}, is 2650 kg/m^3, and the density of air, ρ_{air}, is 1.225 kg/m^3.

(A) 25 m/s (B) 53 m/s (C) 88 m/s (D) 130 m/s

Let v_t be the terminal velocity. At terminal velocity, the drag force, F_D, equals the weight.

$$F_D = \tfrac{1}{2}C_D\rho_{\text{air}}\text{v}_t^2A = mg$$

$$mg = \tfrac{4}{3}\pi\left(\frac{d}{2}\right)^3\rho_{\text{alum}}g$$

$$A = \pi\left(\frac{d}{2}\right)^2$$

$$\left(\frac{1}{2}\right)C_D\rho_{\text{air}}\text{v}_t^2\pi\left(\frac{d}{2}\right)^2 = \tfrac{4}{3}\pi\left(\frac{d}{2}\right)^3\rho_{\text{alum}}g$$

$$\begin{aligned}\text{v}_t &= \sqrt{\frac{(2)(4\pi)\left(\frac{d}{2}\right)^3\rho_{\text{alum}}g}{3C_D\rho_{\text{air}}\pi\left(\frac{d}{2}\right)^2}} \\ &= \sqrt{\frac{4d\rho_{\text{alum}}g}{3C_D\rho_{\text{air}}}} \\ &= \sqrt{\frac{(4)(0.05\ \text{m})\left(2650\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)}{(3)(0.5)\left(1.225\ \frac{\text{kg}}{\text{m}^3}\right)}} \\ &= 53.2\ \text{m/s}\end{aligned}$$

The answer is (B).

FLUIDS–75

In a flow of air ($\rho = 1.225\ \text{kg/m}^3$) around a cylinder, the circulation is calculated to be $3.97\ \text{m}^2/\text{s}$. If the free-stream velocity is 30 m/s, what is most nearly the lift generated per meter length of the cylinder?

(A) 150 N/m (B) 160 N/m (C) 170 N/m (D) 200 N/m

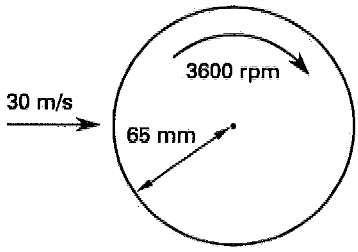
The Kutta-Joukowsky theorem states that

$$\begin{aligned}\frac{\text{lift}}{L} &= \rho_\infty\text{v}_\infty\Gamma \\ &= \left(1.225\ \frac{\text{kg}}{\text{m}^3}\right)\left(30\ \frac{\text{m}}{\text{s}}\right)\left(3.97\ \frac{\text{m}^2}{\text{s}}\right) \\ &= 146\ \text{N/m}\quad (150\ \text{N/m})\end{aligned}$$

The answer is (A).

FLUIDS–76

A 65 mm radius cylinder rotates at 3600 rpm. Air is flowing past the cylinder at 30 m/s. The density of air is 1.225 kg/m^3. Approximately how much lift is generated by the cylinder per unit length?



(A) 190 N/m (B) 220 N/m (C) 290 N/m (D) 370 N/m

From the Kutta-Joukowsky theorem,

$$\frac{\text{lift}}{L} = \rho \mathrm{v}_\infty \Gamma$$

$$\begin{aligned}
\Gamma &= \oint \mathbf{V}\cdot d\ell \\
&= \int_0^{2\pi} (r\omega)(r\,d\theta) \\
&= 2\pi r^2 \omega \\
&= 2\pi(0.065 \text{ m})^2 \left(\left(3600 \ \frac{\text{rev}}{\text{min}}\right)\left(2\pi \ \frac{\text{rad}}{\text{rev}}\right)\left(\frac{1 \text{ min}}{60 \text{ s}}\right)\right) \\
&= 10 \text{ m}^2/\text{s}
\end{aligned}$$

$$\begin{aligned}
\frac{\text{lift}}{L} &= \rho \mathrm{v}\Gamma = \left(1.225 \ \frac{\text{kg}}{\text{m}^3}\right)\left(30 \ \frac{\text{m}}{\text{s}}\right)\left(10 \ \frac{\text{m}^2}{\text{s}}\right) \\
&= 367.5 \text{ N/m}
\end{aligned}$$

The answer is (D).

FLUIDS–77

A pump produces a head of 10 m. The volumetric flow rate through the pump is 6.3×10^{-4} m^3/s. The fluid pumped is oil with a specific gravity of 0.83. Approximately how much energy does the pump consume in one hour?

(A) 8.7 kJ (B) 17 kJ (C) 180 kJ (D) 200 kJ

$$P = \Delta p\dot{V}$$

The change in pressure, Δp, is

$$\begin{aligned}\Delta p &= \rho g h \\ &= (0.83)\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)(10\ \text{m}) \\ &= 81\,423\ \text{Pa} \\ E &= Pt \\ &= \Delta p\dot{V}t \\ &= (81\,423\ \text{Pa})\left(6.3\times10^{-4}\ \frac{\text{m}^3}{\text{s}}\right)(3600\ \text{s}) \\ &= 184\,667\ \text{N·m}\quad (180\ \text{kJ})\end{aligned}$$

The answer is (C).

FLUIDS–78

A pump has an efficiency of 65%. It is driven by a 550 W motor. The pump produces a pressure rise of 120 Pa in water. What is the required flow rate?

(A) 3.0 m^3/s (B) 3.4 m^3/s (C) 4.6 m^3/s (D) 4.8 m^3/s

The power supplied by the pump to the water, P_r, is

$$P_r = \eta P_i$$

In the preceding equation, η is efficiency and P_i is ideal power.

$$P_r = \Delta p\dot{V}$$

In the preceding equation, Δp is pressure rise and $\dot{V}$ is the volumetric flow rate.

$$\Delta p\dot{V} = \eta P_i$$

Rearranging,

$$\dot{V} = \frac{\eta P_i}{\Delta p}$$

$$P_i = 550\ \text{W}$$

Therefore,

$$\begin{aligned}\dot{V} &= \frac{(0.65)(550\ \text{W})}{120\ \text{Pa}} \\ &= 2.98\ \text{m}^3/\text{s}\quad (3.0\ \text{m}^3/\text{s})\end{aligned}$$

The answer is (A).