## FE-STYLE EXAM PROBLEMS

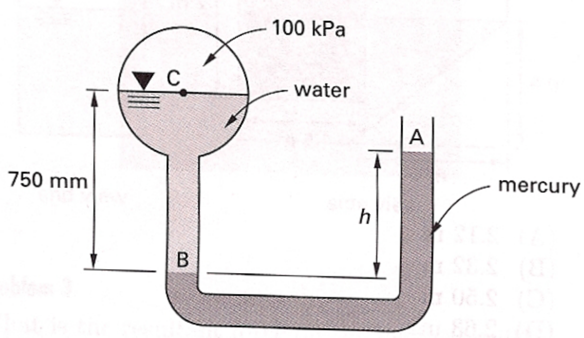
**1.** What height of mercury column is equivalent to a pressure of 700 kPa? The density of mercury is 13 500 kg/m$^3$.

(A) 0.75 m
(B) 1.5 m
(C) 3.4 m
(D) 5.3 m

**2.** A fluid with a vapor pressure of 0.2 Pa and a specific gravity of 12 is used in a barometer. If the fluid's column height is 1 m, what is the atmospheric pressure?

(A) 9.80 kPa
(B) 11.8 kPa
(C) 101 kPa
(D) 118 kPa

**3.** One leg of a mercury U-tube manometer is connected to a pipe containing water under a gage pressure of 100 kPa. The mercury in this leg stands 750 mm below the water. What is the height of mercury in the other leg, which is open to the air? The specific gravity of mercury is 13.5.

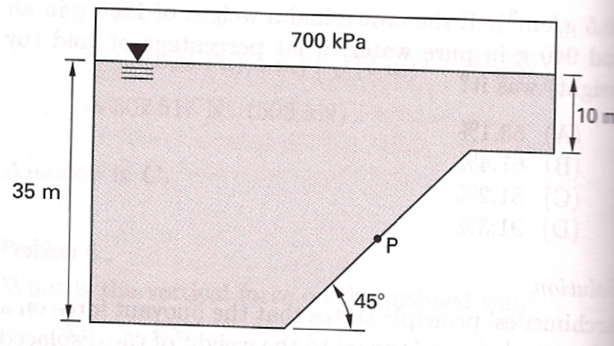



(A) 0.2 m
(B) 0.5 m
(C) 0.8 m
(D) 1 m

**4.** What is the resultant force on one side of a 25 cm diameter vertical circular plate standing at the bottom of a 3 m pool of water?

(A) 1.38 kN
(B) 1.63 kN
(C) 1.91 kN
(D) 2.72 kN

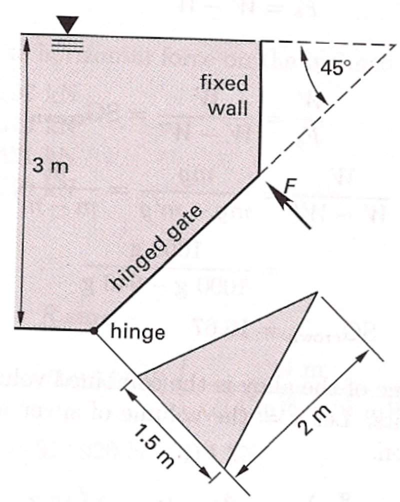
**5.** A special closed tank with the dimensions shown contains water. If the pressure of the air is 700 kPa, what is the pressure at point P, which is located halfway up the inclined wall?




(A) 922 kPa
(B) 7.22 MPa
(C) 7.56 MPa
(D) 8.13 MPa

**For the following problems use the NCEES Handbook as your only reference.**

**6.** A triangular gate with a horizontal base 1.5 m long and an altitude of 2 m is inclined 45° from the vertical with the vertex pointing upward. The hinged horizontal base of the gate is 3 m below the water surface. What normal force must be applied at the vertex of the gate to keep it closed?




(A) 9.35 kN
(B) 10.3 kN
(C) 10.9 kN
(D) 11.3 kN

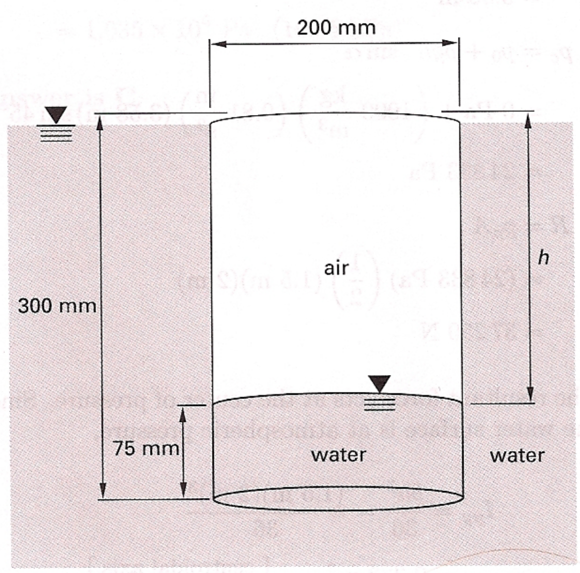
**7.** Which of the following statements concerning buoyancy are false?

I. Buoyancy is the tendency of a fluid to exert a supporting force on a body placed in that fluid.
II. Buoyancy is the ability of a body to return to its original position after being tilted on its horizontal axis.
III. The buoyant force is measured by multiplying the specific weight of the object by the displaced volume of the fluid.
IV. Buoyant forces occur both when an object floats in a fluid and when an object sinks in a fluid.
V. The buoyant force acts vertically upward through the centroid of the displaced volume.

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

Problems 8–10 refer to the following situation.

A 300 mm long rigid metal cylindrical container with a diameter of 200 mm is closed at one end. The container is held vertically, barely submerged, and closed-end-up in water, as shown. The atmospheric pressure is 101.3 kPa. The water rises 75 mm inside the container under these conditions.




**8.** What is the approximate total pressure of the air inside the container?

(A) 101.3 kPa
(B) 102.1 kPa
(C) 103.5 kPa
(D) 110.4 kPa

**9.** The container is slowly moved vertically downward until the pressure in the container is 105 kPa. What will be the depth of the water surface measured from the free water surface (i.e., what is the vertical distance between the free water surface and the water surface in the container)?

(A) 160 mm
(B) 170 mm
(C) 300 mm
(D) 380 mm

**10.** The container is slowly moved vertically downward until the pressure in the container is 105 kPa. What will be the height of the air space in the container (i.e., the vertical distance between the closed upper end and the water surface in the container)?

(A) 217 mm
(B) 222 mm
(C) 227 mm
(D) 230 mm

## SOLUTIONS TO FE-STYLE EXAM PROBLEMS

**1.** Pressure increases linearly with depth.

$$p = \rho g h$$
$$h = \frac{p}{\rho g}$$
$$= \frac{700 \times 10^3 \ \frac{\text{N}}{\text{m}^2}}{\left(13\,500 \ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)}$$
$$= 5.29 \text{ m} \quad (5.3 \text{ m})$$

**Answer is D.**

**2.**

$$p_a = p_v + \rho g h$$
$$= 0.2 \text{ Pa} + (12)\left(1000 \ \frac{\text{kg}}{\text{m}^3}\right) \times \left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(1 \text{ m})$$
$$= 117\,720 \text{ Pa} \quad (118 \text{ kPa})$$

**Answer is D.**

$$\frac{\epsilon}{D} = \frac{0.00005 \text{ m}}{0.025 \text{ m}} = 0.002$$

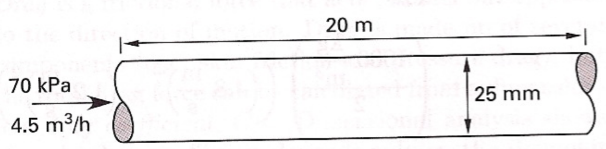
From the Moody chart,

$$f = 0.026$$

**Answer is C.**

**Problem 3**

A steel pipe has an inside diameter of 25 mm, is 20 m long, and carries 10°C water at a rate of 4.5 $m^3/h$. At this rate, the friction factor of the pipe is 0.0259. If the static pressure at the inlet is 70 kPa, what is the static pressure of the water at the outlet?




(A) 1.1 kPa
(B) 2.6 kPa
(C) 4.2 kPa
(D) 5.4 kPa

*Solution*

$$\text{v} = \frac{Q}{A} = \frac{\left(4.5 \ \frac{\text{m}^3}{\text{h}}\right)\left(\frac{1}{3600 \ \frac{\text{s}}{\text{h}}}\right)}{\left(\frac{\pi}{4}\right)(0.025 \text{ m})^2} = 2.55 \text{ m/s}$$

$$h_f = \frac{\text{v}^2 L f}{2gD} = \frac{\left(2.55 \ \frac{\text{m}}{\text{s}}\right)^2 (20 \text{ m})(0.0259)}{(2)\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(0.025 \text{ m})} = 6.87 \text{ m}$$

Use the energy equation.

$$\frac{p_1}{\rho g} + \frac{\text{v}_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{\text{v}_2^2}{2g} + z_2 + h_f$$

$$z_1 = z_2$$

$$\text{v}_1 = \text{v}_2$$

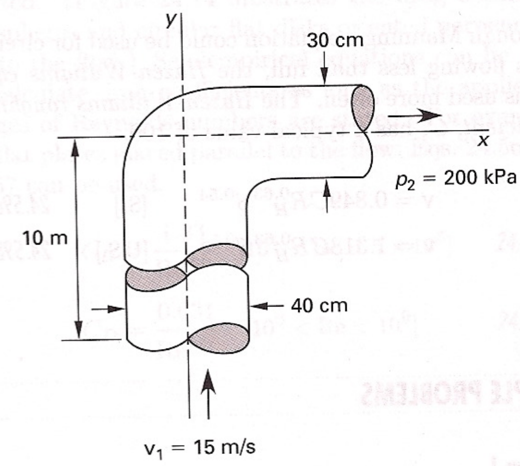
Therefore, the field equation becomes

$$p_2 = p_1 - \rho g h_f = 70 \times 10^3 \text{ Pa} - \left(1000 \ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)(6.87 \text{ m}) = 2605 \text{ Pa} \quad (2.6 \text{ kPa})$$

**Answer is B.**

**Problem 4**

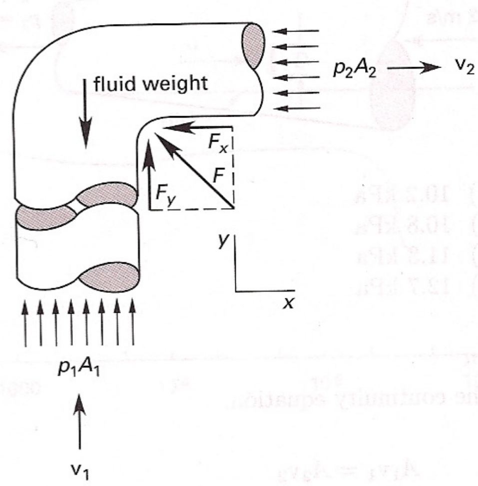
A 90° reducing elbow is in the vertical plane, and water flows through it. What is the horizontal force required to hold the reducer elbow in a stationary position?




(A) 24.20 kN to the right
(B) 57.45 kN to the left
(C) 64.43 kN to the right
(D) 71.17 kN to the left

*Solution*

The free-body diagram of the fluid control volume in the reducer is



(A) 0.2 kPa
(B) 2.3 kPa
(C) 28 kPa
(D) 110 kPa

2. What is the mass flow rate of a liquid ($\rho = 0.690$ g/cm$^3$) flowing through a 5 cm (inside diameter) pipe at 8.3 m/s?

(A) 11 kg/s
(B) 69 kg/s
(C) 140 kg/s
(D) 340 kg/s

3. The mean velocity of 40°C water in a 44.7 mm (inside diameter) tube is 1.5 m/s. The kinematic viscosity is $\nu = 6.58 \times 10^{-7}$ m$^2$/s. What is the Reynold's number?

(A) $8.13 \times 10^3$
(B) $8.54 \times 10^3$
(C) $9.06 \times 10^4$
(D) $1.02 \times 10^5$

4. What is the head loss for water flowing through a horizontal pipe if the gage pressure at point 1 is 1.03 kPa, the gage pressure at point 2 downstream is 1.00 kPa, and the velocity is constant?

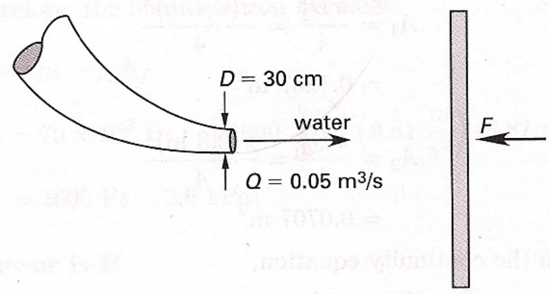
(A) $3.1 \times 10^{-3}$ m
(B) $3.1 \times 10^{-2}$ m
(C) $2.3 \times 10^{-2}$ m
(D) 2.3 m

5. The *hydraulic radius* is

(A) the mean radius of the pipe.
(B) the radius of the pipe bend on the line.
(C) the wetted perimeter of a conduit divided by the area of flow.
(D) the cross-sectional fluid area divided by the wetted perimeter.

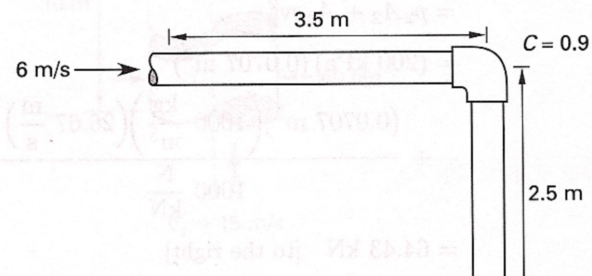
**For the following problems use the NCEES Handbook as your only reference.**

6. What horizontal force is required to hold the plate stationary against the water jet? (All of the water leaves parallel to the plate.)



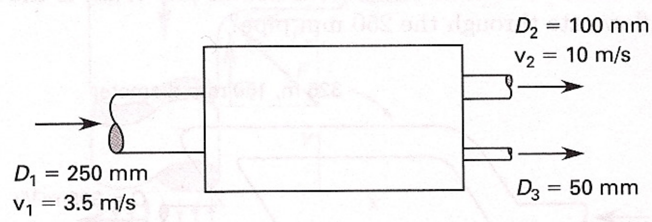

(A) 17.7 N
(B) 35.4 N
(C) 42.2 N
(D) 67.5 N

7. Water flows with a velocity of 6 m/s through 6 m of cast-iron pipe (specific roughness = 0.0003 m). The pipe has an inside diameter of 43 mm. The kinematic viscosity of the water is $1.00 \times 10^{-6}$ m$^2$/s. The loss coefficient for the standard elbow is 0.9. What percentage of the total head loss is caused by the elbow?




(A) 4.86%
(B) 6.27%
(C) 8.83%
(D) 15.9%

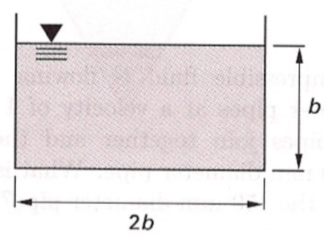
8. The pipe manifold shown is at a steady-state condition. What is the fluid velocity $v_3$ (in m/s) in the 50 mm diameter outlet?




(A) 8.3 m/s
(B) 20 m/s
(C) 30 m/s
(D) 48 m/s

Problems 9–12 refer to the following situation.

A rectangular open channel has a base of length $2b$. Water is flowing through the channel at a depth of $b$.




**9.** What is the wetted perimeter of the channel?

(A) $\frac{b}{8}$
(B) $\frac{b}{4}$
(C) $2b$
(D) $4b$

**10.** What is the area in flow?

(A) $\frac{2}{3}b^2$
(B) $1.5b^2$
(C) $2b^2$
(D) $3b^2$

**11.** What is the hydraulic radius?

(A) $\frac{b}{4}$
(B) $\frac{b}{3}$
(C) $\frac{b}{2}$
(D) $\frac{2b}{3}$

**12.** If the flow rate in the channel is 35 $m^3/s$, what is the critical depth (i.e., the depth of flow that minimizes the total energy of flow)?

(A) $2.12b^{-2/3}$ m
(B) $3.15b^{-2/3}$ m
(C) $3.36b^{-2/3}$ m
(D) $5.00b^{-2/3}$ m

**13.** What are minor losses?

(A) decreases in pressure due to friction in fully developed turbulent flow through pipes of constant area
(B) decreases in pressure due to friction in valves, tees, and elbows, and other frictional effects
(C) decreases in pressure due to friction that can usually be ignored
(D) decreases in pressure due to friction in fully developed turbulent flow in nonconstant area pipes

**14.** A nozzle directs a jet of water vertically upward with a velocity v and a flow rate $Q$. A horizontal plate is located directly above the nozzle at a height $h$. If the density of water is $\rho$, what reaction force is required to keep the plate stationary against the force of the water jet?

(A) $Q\rho\mathrm{v}$
(B) $Q\rho\sqrt{2gh}$
(C) $\frac{Q\rho gh}{\mathrm{v}}$
(D) $Q\rho\sqrt{\mathrm{v}^2 - 2gh}$

Problems 15–17 refer to the following situation.

A 1 m penstock is anchored by a thrust block at a point where the flow makes a 20° change in direction. The water flow rate is 5.25 $m^3/s$. The water pressure is 140 kPa everywhere in the penstock.

**15.** Assuming the initial flow direction is parallel to the $x$-direction, what is the magnitude of the force on the thrust block in the $x$-direction?

(A) 6.8 kN
(B) 8.3 kN
(C) 8.7 kN
(D) 9.2 kN

**16.** Assuming the initial flow direction is perpendicular to the $y$-direction, what is the force on the thrust block in the $y$-direction?

(A) 40.4 kN
(B) 44.7 kN
(C) 47.2 kN
(D) 49.6 kN

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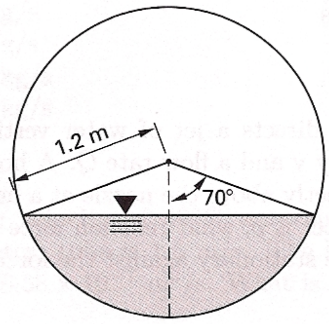
**17.** What is the resultant force on the thrust block?

(A) 10.8 kN
(B) 43.5 kN
(C) 50.4 kN
(D) 146 kN

**18.** A pipe with a radius of 1.2 m flows partially full as shown. What is the approximate hydraulic radius?

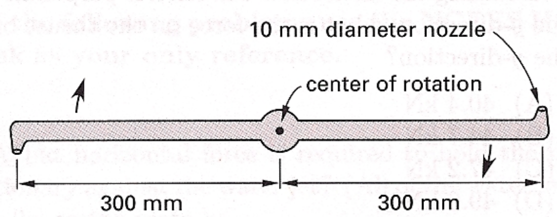



(A) 0.44 m
(B) 0.88 m
(C) 1.30 m
(D) 1.80 m

**19.** Water jets horizontally from a nozzle installed near the base of a tank. The water level is 10 m above the level of the nozzle. The nozzle necks down from a 75 mm diameter to a 25 mm diameter. The coefficient of velocity, $C_v$, for the nozzle is 0.962. What is the maximum power that can be extracted from the water jet?

(A) 550 W
(B) 600 W
(C) 650 W
(D) 1200 W

**20.** A lawn sprinkler consists of a rotating runner with two nozzles. The nozzles are oriented at right angles to the runner. The diameter of the runner is 20 mm; the diameter of the sprinkler nozzles is 10 mm. Water is supplied by the attached hose (not shown) at a rate of 14 $m^3/h$. What single force must be placed on one side of the runner at a distance of 100 mm from the center of rotation in order to stop the sprinkler from rotating?




(A) 12 N
(B) 50 N
(C) 75 N
(D) 290 N

**21.** An incompressible fluid is flowing through two 75 mm diameter pipes at a velocity of 1 m/s in each pipe. The pipes join together and the fluid flows through a 150 mm diameter pipe. What is the velocity of the fluid in the 150 mm diameter pipe?

(A) 0.5 m/s
(B) 1 m/s
(C) 2 m/s
(D) 3 m/s

**22.** What is the correct definition of the "hydraulic radius" of a fluid conduit?

(A) the mean radius from the center of flow to the wetted side of the conduit
(B) the cross-sectional area of the conduit divided by the wetted perimeter
(C) the wetted perimeter of the conduit divided by the area of flow
(D) the cross-sectional area in flow divided by the wetted perimeter

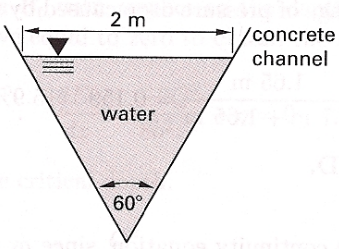
**23.** A rectangular flume is 13 cm wide and 7 cm high. The freeboard is 25 percent of the flume height. What is the hydraulic radius?

(A) 2.3 cm
(B) 2.9 cm
(C) 3.2 cm
(D) 3.4 cm

**24.** A 2 m wide, 3000 m long rectangular channel carries 2 $m^3/s$ of water. The depth of flow is 1 m. The channel is constructed from rough-formed concrete with a roughness coefficient of $n = 0.017$. What is the difference in elevation between the two ends of the channel?

(A) 1.2 m
(B) 1.6 m
(C) 2.2 m
(D) 2.7 m

Problems 25–27 refer to the open channel shown in the following figure. The channel is constructed of smooth concrete.




**25.** The width of flow is 2 m at the surface. What is the hydraulic radius of the channel?

(A) $\frac{1}{6}$ m

(B) $\frac{\sqrt{3}}{4}$ m

(C) $\frac{1}{2}$ m

(D) $\frac{\sqrt{3}}{2}$ m

**26.** [Note: For this problem, use a reasonable value of the Manning's roughness coefficient.] Water flows at 3 $m^3$/s in uniform flow. What is the minimum slope?

(A) 0.0002
(B) 0.001
(C) 0.002
(D) 0.01

**27.** [Note: For this problem, use a slope of 0.005 and a reasonable value of the Hazen-Williams roughness coefficient.] The channel's water level is adjusted so that the fluid depth is reduced to 50% of its original value. What is the flow rate?

(A) 0.80 $m^3$/s
(B) 1.30 $m^3$/s
(C) 1.45 $m^3$/s
(D) 2.20 $m^3$/s

## SOLUTIONS TO FE-STYLE EXAM PROBLEMS

**1.** From the Bernoulli equation,

$$\frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 = \frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1$$

$$z_2 = z_1 \quad \text{[since the pipe is on the ground]}$$

$$\begin{aligned}
\Delta p &= p_2 - p_1 \\
&= \rho g\left(\frac{v_1^2 - v_2^2}{2g}\right) \\
&= \left(\frac{\rho}{2}\right)(v_1^2 - v_2^2) \\
&= \left(\frac{1000\ \frac{\text{kg}}{\text{m}^3}}{2}\right)\left(\left(3.0\ \frac{\text{m}}{\text{s}}\right)^2 - \left(2.1\ \frac{\text{m}}{\text{s}}\right)^2\right) \\
&= 2295\ \text{Pa} \quad (2.3\ \text{kPa})
\end{aligned}$$

**Answer is B.**

**2.**

$$\begin{aligned}
\dot{m} &= \rho A v \\
&= \left(0.690\ \frac{\text{g}}{\text{cm}^3}\right)\left(\left(\frac{\pi}{4}\right)(5\ \text{cm})^2\right) \\
&\quad \times \left(8.3\ \frac{\text{m}}{\text{s}}\right)\left(100\ \frac{\text{cm}}{\text{m}}\right) \\
&= 11\,245\ \text{g/s} \quad (11\ \text{kg/s})
\end{aligned}$$

**Answer is A.**

**3.**

$$\begin{aligned}
\text{Re} &= \frac{\rho v D}{\mu} \\
&= \frac{vD}{\nu} \\
&= \frac{\left(1.5\ \frac{\text{m}}{\text{s}}\right)(0.0447\ \text{m})}{6.58 \times 10^{-7}\ \frac{\text{m}^2}{\text{s}}} \\
&= 1.02 \times 10^5
\end{aligned}$$

**Answer is D.**

**4.** From the Bernoulli equation,

$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + h_f$$

$$z_1 = z_2$$

$$v_1 = v_2$$

$$\frac{p_1}{\rho g} = \frac{p_2}{\rho g} + h_f$$

$$\begin{aligned}
h_f &= \frac{p_1 - p_2}{\rho g} = \frac{p_1 - p_2}{\rho g} \\
&= \frac{(1.03\ \text{kPa} - 1.0\ \text{kPa})\left(1000\ \frac{\text{Pa}}{\text{kPa}}\right)}{\left(1000\ \frac{\text{kg}}{\text{m}^3}\right)\left(9.81\ \frac{\text{m}}{\text{s}^2}\right)} \\
&= 3.1 \times 10^{-3}\ \text{m}
\end{aligned}$$

**Answer is A.**

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