Diagnostic Exam

Topic III: Fluid Mechanics/Dynamics

1. Oil flows through a 0.12 m diameter pipe at a velocity of 1 m/s. The density and the dynamic viscosity of the oil are 870 kg/m^3 and 0.082 kg/s·m^2, respectively. If the pipe length is 100 m, the head loss due to friction is most nearly

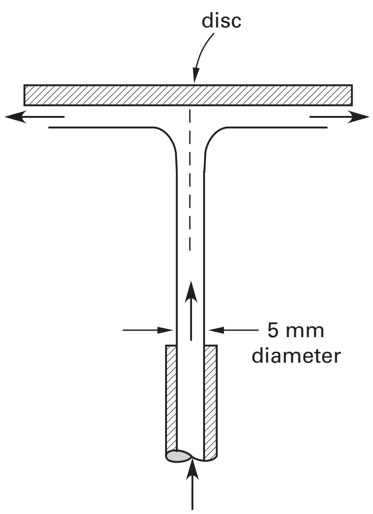
(A) 1.2 m

(B) 1.5 m

(C) 1.8 m

(D) 2.1 m

2. A thin metal disc of mass 0.01 kg is kept balanced by a jet of air, as shown.



The diameter of the jet at the nozzle exit is 5 mm. Assuming atmospheric conditions at 101.3 kPa and 20°C, the velocity of the jet as it leaves the nozzle is most nearly

(A) 45 m/s

(B) 65 m/s

(C) 85 m/s

(D) 95 m/s

3. Water flows at 14 m^3/s in a 6 m wide rectangular open channel. The critical velocity is most nearly

(A) 0.82 m/s

(B) 1.8 m/s

(C) 2.8 m/s

(D) 14 m/s

4. To measure low flow rates of air, a laminar flow meter is used. It consists of a large number of small-diameter tubes in parallel. One design uses 4000 tubes, each with an inside diameter of 2 mm and a length of 25 cm. The pressure difference through the flow meter is 0.5 kPa, and the absolute viscosity of the air is 1.81×10^{-8} kPa·s. The flow rate of atmospheric air at 20°C is most nearly

(A) 0.1 m^3/s

(B) 0.2 m^3/s

(C) 0.4 m^3/s

(D) 0.5 m^3/s

5. Carbon tetrachloride has a specific gravity of 1.56. The height of a column of carbon tetracholoride that supports a pressure of 1 kPa is most nearly

(A) 0.0065 cm

(B) 6.5 cm

(C) 10 cm

(D) 64 cm

6. A model of a dam has been constructed so that the scale of dam to model is 15:1. The similarity is based on Froude numbers. At a certain point on the spillway of the model, the velocity is 5 m/s. At the corresponding point on the spillway of the actual dam, the velocity would most nearly be

(A) 6.7 m/s

(B) 7.5 m/s

(C) 15 m/s

(D) 19 m/s

7. A 10 cm diameter sphere floats half submerged in 20°C water. The density of water at 20°C is 998 kg/m^3. The mass of the sphere is most nearly

(A) 0.26 kg

(B) 0.52 kg

(C) 0.80 kg

(D) 2.6 kg

Table 11.1 *Properties of Water (SI units)*

temperature (°C)	specific weight, γ (kN/m^3)	density, ρ (kg/m^3)	viscosity, $\mu \times 10^3$ (Pa·s)	kinematic viscosity, $\nu \times 10^6$ (m^2/s)	vapor pressure, p_v (kPa)
0	9.805	999.8	1.781	1.785	0.61
5	9.807	1000.0	1.518	1.518	0.87
10	9.804	999.7	1.307	1.306	1.23
15	9.798	999.1	1.139	1.139	1.70
20	9.789	998.2	1.002	1.003	2.34
25	9.777	997.0	0.890	0.893	3.17
30	9.764	995.7	0.798	0.800	4.24
40	9.730	992.2	0.653	0.658	7.38
50	9.689	988.0	0.547	0.553	12.33
60	9.642	983.2	0.466	0.474	19.92
70	9.589	977.8	0.404	0.413	31.16
80	9.530	971.8	0.354	0.364	47.34
90	9.466	965.3	0.315	0.326	70.10
100	9.399	958.4	0.282	0.294	101.33

Table 11.2 *Properties of Water (customary U.S. units)*

temperature (°F)	specific weight, γ (lbf/ft^3)	density, ρ (lbm-sec^2/ft^4)	viscosity, $\mu \times 10^{-5}$ (lbf-sec/ft^2)	kinematic viscosity, $\nu \times 10^{-5}$ (ft^2/sec)	vapor pressure, p_v (lbf/ft^2)
32	62.42	1.940	3.746	1.931	0.09
40	62.43	1.940	3.229	1.664	0.12
50	62.41	1.940	2.735	1.410	0.18
60	62.37	1.938	2.359	1.217	0.26
70	62.30	1.936	2.050	1.059	0.36
80	62.22	1.934	1.799	0.930	0.51
90	62.11	1.931	1.595	0.826	0.70
100	62.00	1.927	1.424	0.739	0.95
110	61.86	1.923	1.284	0.667	1.24
120	61.71	1.918	1.168	0.609	1.69
130	61.55	1.913	1.069	0.558	2.22
140	61.38	1.908	0.981	0.514	2.89
150	61.20	1.902	0.905	0.476	3.72
160	61.00	1.896	0.838	0.442	4.74
170	60.80	1.890	0.780	0.413	5.99
180	60.58	1.883	0.726	0.385	7.51
190	60.36	1.876	0.678	0.362	9.34
200	60.12	1.868	0.637	0.341	11.52
212	59.83	1.860	0.593	0.319	14.70

Example

A vessel is initially connected to a reservoir open to the atmosphere. The connecting valve is then closed, and a vacuum of 65.5 kPa is applied to the vessel. Assume standard atmospheric pressure. What is most nearly the absolute pressure in the vessel?

(A) 36 kPa

(B) 66 kPa

(C) 86 kPa

(D) 110 kPa

Solution

From Eq. 11.7, for vacuum pressures,

$$\begin{aligned}\text{absolute pressure} &= \text{atmospheric pressure} \\ &\quad - \text{vacuum gage pressure reading} \\ &= 101.3 \text{ kPa} - 65.5 \text{ kPa} \\ &= 35.8 \text{ kPa} \quad (36 \text{ kPa})\end{aligned}$$

The answer is (A).

Fluid Mechanics/ Dynamics

Diagnostic Exam

Topic IV: Thermodynamics

1. 2 m^3 of an ideal gas is compressed from 100 kPa to 200 kPa. As a result of the process, the internal energy of the gas increases by 10 kJ, and 140 kJ of heat is lost to the surroundings. What is most nearly the work done by the gas during the process?

(A) −150 kJ

(B) −130 kJ

(C) −85 kJ

(D) −45 kJ

2. A cylinder fitted with a frictionless piston contains an ideal gas at temperature T and pressure p. The gas expands isothermally and reversibly until the pressure is $p/3$. Which statement is true regarding the work done by the gas during expansion?

(A) It is equal to the change in enthalpy of the gas.

(B) It is equal to the change in internal energy of the gas.

(C) It is equal to the heat absorbed by the gas.

(D) It is greater than the heat absorbed by the gas.

3. Consider the following balanced actual combustion reaction for propane.

$$C_3H_8 + 14.29(\text{air}) \rightarrow 4H_2O + 3CO + 11.29N_2$$

Assume air is 21% oxygen and 79% nitrogen by volume. What is most nearly the percent theoretical air?

(A) 50%

(B) 60%

(C) 68%

(D) 75%

4. In 1 hour, approximately how much black-body radiation escapes a 1 cm × 2 cm rectangular opening in a kiln whose internal temperature is 980°C?

(A) 20 kJ

(B) 100 kJ

(C) 130 kJ

(D) 150 kJ

5. Refrigerant HFC-134a at 0.8 MPa and 70°C is cooled and condensed at constant pressure in a steady-state process until it is a saturated liquid. Cooling water enters the condenser at 20°C and leaves at 30°C. If the mass flow rate of the refrigerant is 0.1 kg/s, the mass flow rate of the cooling water is most nearly

(A) 0.51 kg/s

(B) 0.65 kg/s

(C) 0.70 kg/s

(D) 0.75 kg/s

6. What is most nearly the melting temperature of sodium chloride, given that the latent heat of fusion is 30 kJ/mol, and the associated entropy change is 28 J/mol·K?

(A) 370K

(B) 880K

(C) 930K

(D) 1100K

7. Most nearly, what is the volume of 0.05 kg of refrigerant HFC-134a at 1.3 MPa with a quality of 37.5%?

(A) 9.6×10^{-5} m^3

(B) 1.7×10^{-4} m^3

(C) 3.1×10^{-4} m^3

(D) 2.2×10^{-3} m^3

8. Hot air at an average temperature of 100°C flows through a 3 m long tube with an inside diameter of 60 mm. The temperature of the tube is 20°C along its entire length. The average convective film coefficient is 20.1 W/m^2·K. What is most nearly the rate of convective heat transfer from the air to the tube?

(A) 520 W

(B) 850 W

(C) 910 W

(D) 1100 W

Example

Destruction of the nuclear membrane of a cell would be LEAST lethal to which of the following cell types?

(A) eukaryotic animal cell
(B) eukaryotic plant cell
(C) prokaryotic animal cell
(D) prokaryotic bacterium cell

Solution

All cells have a cell membrane that separates cytoplasm from the surrounding environment. However, only eukaryotic cells have membranes surrounding their nuclei. Not all prokaryotic cells have a nuclear membrane. All animal cells are eukaryotic, so prokaryotic animal cells do not exist.

The answer is (D).

Example

What is the difference between a gram-positive cell and a gram-negative cell?

(A) Gram-negative cell walls have more surface proteins than gram-positive cell walls.
(B) Gram-negative cell walls have more lipid outer layers than gram-positive cell walls.
(C) Gram-negative cell walls are less hydrophobic than gram-positive cell walls.
(D) Gram-negative cell walls are less complex than the gram-positive cell walls.

Solution

Gram-negative cells have more complex walls with hydrophobic, lipid outer layers than gram-positive cells.

The answer is (B).

2. METABOLISM/METABOLIC PROCESSES

Metabolism is a term given to describe all chemical activities performed by a cell. The cell uses *adenosine triphosphate* (ATP) as the principle energy currency in all processes. Those processes that allow the bacterium to synthesize new cells from the energy stored within its body are said to be *anabolic*. All biochemical processes in which cells convert substrate into useful energy and waste products are said to be *catabolic*.

3. CELL TRANSPORT

The transfer of nutrients and other solutes across membrane barriers occurs by means of several mechanisms.

- *Passive diffusion* in cells is similar to the transfer that occurs in nonliving systems. Material moves spontaneously from a region of high concentration to a region of low concentration. The rate of transfer obeys Fick's law, the principle governing passive diffusion in dilute solutions. The rate is proportional to the concentration gradient across the membrane. Since this form of diffusion is powered only by a concentration gradient, it does not require the expenditure of chemical or biological energy (e.g., ATP).

Some cell walls are made up of lipid (fat) layers that are *hydrophobic* (i.e., that are repelled by water). Passive diffusion through lipid cell walls proceeds more easily when a nutrient (or other solute) is small, uncharged or un-ionized (including nonpolar), and lipid-soluble. Lipid-soluble substances include oxygen, carbon dioxide, fatty acids, and some steroidal hormones. Large, charged, polar, and water-soluble nutrients must be carried through cell walls by permeases (i.e., using facilitated diffusion). A *partition coefficient*, K_a, or the solubility of the solute in lipid relative to its solubility in water, can be used to describe the effect of lipid solubility on transport.

$$K_a = \frac{\text{solubility in lipid}}{\text{solubility in water}}$$

It is more common to report $\log K_a$ than K_a because the relationship between pK_a and permeability is fairly linear.

$$pK_a = \log K_a = \log\left(\frac{\text{solubility in lipid}}{\text{solubility in water}}\right)$$

The permeability of a molecule across a membrane of thickness x is

$$\text{permeability}_{\text{cm/s}} = \frac{pK_a \begin{pmatrix}\text{diffusion}\\ \text{coefficient}\\ \text{in water}\end{pmatrix}_{\text{cm}^2\text{/s}}}{x_{\text{cm}}}$$

The pH of a solution will have an effect on the partition coefficient. Although the relationship is complex, for weakly acidic and basic solutions, pK_a and pH are approximately related by the *Henderson-Hasselbach equation*. Square brackets designate the molar concentration of component X.

The dissociation of a weak acid may be represented in one of two ways.

$$HA + H_2O \rightleftharpoons H_3O^+ + A^-$$

$$HA \rightleftharpoons H^+ + A^-$$

The Henderson-Hasselbach equation for a weak acid is

$$pK_a - pH = \log\left(\frac{\text{nonionized form}}{\text{ionized form}}\right) = \log\frac{[HA]}{[A^-]} \quad \text{[weakly acidic]}$$

Chemistry