8×2=16
19×3 57
73

Solutions to Exercises

1. increases

2. increases

3. turbulent

4. They are trying to control the airflow around them to reduce turbulence and the drag force.

5. (c) and (d)

6. (a) $F_{drag} = \eta \frac{Av}{\Delta y}$

12 cm = 0.12 m; 15 cm = 0.15 m; 0.4 cm/s = 0.004 m/s; 1.5 mm = 0.0015 m

$$F_{drag} = (1 \text{ Pa·s}) \frac{(0.12 \text{ m} \times 0.15 \text{ m})\left(0.004 \frac{\text{m}}{\text{s}}\right)}{0.0015 \text{ m}}$$

$$F_{drag} = 4.8 \times 10^{-2} \text{ Pa·m}^2 = 0.048 \text{ N}$$

(b) All of the other factors in the equation remain the same. Multiply both sides of the equation by ½. If the force is halved the speed is halved.

v = ½(0.4 cm/s) = 0.2 cm/s

7. (a) There is no net force for a constant speed, so $F_{drag} = F$. The direction is opposite the velocity. Therefore, F_{drag} = 0.048 N to the left.

(b) $$F_{drag} = (0.0010 \text{ Pa·s}) \frac{(0.12 \text{ m} \times 0.15 \text{ m})\left(0.004 \frac{\text{m}}{\text{s}}\right)}{0.0015 \text{ m}} = 4.8 \times 10^{-5} \text{ N}$$

(c) $$F_{drag} = (1.9 \times 10^{-5} \text{ Pa·s}) \frac{(0.12 \text{ m} \times 0.15 \text{ m})\left(0.004 \frac{\text{m}}{\text{s}}\right)}{0.0015 \text{ m}} = 9.1 \times 10^{-7} \text{ N}$$

(d) air

8. At terminal speed there is no net force on the sky diver, so $F_{drag} = F_g$. The direction is opposite the velocity. Therefore, F_{drag} = 168 lb directed upward.

or 743 N

9. At terminal speed, $F_{\text{drag}} = F_g$.

$$F_{\text{drag}} = 6\pi r v \eta$$

$$r = \tfrac{1}{2}(1.5 \text{ mm}) = 0.75 \text{ mm} = 7.5 \times 10^{-4} \text{ m}$$

$$7.4 \times 10^{-5} \text{ N} = 6\pi\left(7.5 \times 10^{-4} \text{ m}\right)(v)(2.8 \text{ Pa·s})$$

$$\frac{7.4 \times 10^{-5} \text{ N}}{6\pi\left(7.5 \times 10^{-4} \text{ m}\right)\left(2.8 \frac{\text{N·s}}{\text{m}^2}\right)} = v$$

$$v = 1.9 \times 10^{-3} \frac{\text{m}}{\text{s}}$$

10. (a) The slope represents the fluid resistance of the pipe. Therefore, pipe A has the higher resistance.

(b) Since the lengths are the same, the larger diameter would have the lower resistance. Therefore, pipe B has the larger diameter.

(c) Since the pipes have the same diameter, the longer pipe will have the higher resistance. Therefore, pipe A is the longer pipe.

11. (a) $\dot{V} = -\frac{\pi}{8}\frac{r^4 \Delta P}{\eta L}$

$$\left(\frac{1}{\dot{V}} \times \frac{8\eta L}{\pi r^4}\right) \times \dot{V} = -\frac{\pi}{8}\frac{r^4 \Delta P}{\eta L} \times \left(\frac{1}{\dot{V}} \times \frac{8\eta L}{\pi r^4}\right)$$

$$\frac{8\eta L}{\pi r^4} = -\frac{\Delta P}{\dot{V}}$$

Therefore, $R = \frac{8\eta L}{\pi r^4}$

The units are $\frac{(\text{Pa}\cdot\text{s})(\text{m})}{\text{m}^4}$, or $\frac{\text{Pa}\cdot\text{s}}{\text{m}^3}$

(b) $r = ½(0.32\text{ cm}) = 0.16\text{ cm} = 0.0016\text{ m}$;

40 cm = 0.4 m

$$R = \frac{8\eta L}{\pi r^4} = \frac{8 \times 0.0010\ \text{Pa}\cdot\text{s} \times 0.40\ \text{m}}{\pi \times (0.0016\ \text{m})^4}$$

$$R = 1.55 \times 10^8\ \text{Pa}\cdot\text{s/m}^3$$

(c) $R = -\frac{\Delta P}{\dot{V}}$ or $\dot{V} = -\frac{\Delta P}{R}$

$$\dot{V} = -\frac{\Delta P}{R} = -\frac{-1.5 \times 10^3\ \text{Pa}}{1.55 \times 10^8\ \frac{\text{Pa}\cdot\text{s}}{\text{m}^3}} = 9.7 \times 10^{-6}\ \text{m}^3/\text{s}$$

(d) If the length of pipe is doubled, the resistance is doubled and the fluid flow rate is cut in half. Therefore, the water flow rate is approximately $4.9 \times 10^{-6}\ \frac{\text{m}^3}{\text{s}}$.

12. (a) $r = \frac{1}{2}(12 \text{ in}) = 6 \text{ in}$

$$\dot{V} = -\frac{\pi}{8}\frac{r^4 \Delta P}{\eta L} = -\frac{\pi}{8} \times \frac{(6 \text{ in})^4 (-850 \text{ psi})}{\left(1.9 \times 10^{-4} \text{ psi·s}\right)\left(54.4 \text{ mi} \times \frac{63{,}360 \text{ in}}{\text{mi}}\right)}$$

$$\dot{V} \approx 660 \text{ in}^3/\text{s}$$

(b) $V = \dot{V}\Delta t = 660 \frac{\text{in}^3}{\text{s}} \times 1 \text{ s} = 660 \text{ in}^3$

Calculate the work done by the fluid to overcome resistance. This is the work required of the pumps to keep the fluid moving.

$$W = -V\Delta P = -\left(660 \text{ in}^3\right)\left(-850 \frac{\text{lb}}{\text{in}^2}\right) = 561{,}000 \text{ in·lb}$$

Change to ft·lb

$$W = 561{,}000 \text{ in·lb} \times \frac{1 \text{ ft}}{12 \text{ in}} = 46{,}800 \text{ ft·lb}$$

(c) $\dot{V} = -\frac{\pi}{8}\frac{r^4 \Delta P}{\eta L}$

$$660 \frac{\text{in}^3}{\text{s}} = -\frac{\pi}{8} \frac{(7 \text{ in})^4 \Delta P}{\left(1.9 \times 10^{-4} \text{ psi·s}\right)\left(54.4 \text{ mi} \times \frac{63{,}360 \text{ in}}{\text{mi}}\right)}$$

$$\Delta P = \frac{\left(660 \frac{\text{in}^3}{\text{s}}\right)(8)\left(1.9 \times 10^{-4} \text{ psi·s}\right)\left(54.4 \text{ mi} \times \frac{63{,}360 \text{ in}}{\text{mi}}\right)}{\pi (7 \text{ in})^4} = 460 \text{ psi}$$

13. The top pipe has four sharp bends, while the bottom pipe has a gentle bend. As fluid flows through the pipes, the top pipe produces more turbulence than the bottom. Thus, the fluid drag in the top pipe is greater than that in the bottom pipe. As the fluid drag increases, the pressure drop in the pipe increases. Since the top pipe has a higher fluid drag, the pressure drop is greater than that of the bottom pipe.

14. $F_{drag} = \eta \frac{Av}{\Delta y}$

The area is the lateral surface of the cylinder.

12.5 cm = 0.125 m; 15 cm = 0.15 m; 0.0127 cm = 0.000127 m

$A = \pi d h = \pi(0.125 \text{ m})(0.15 \text{ m}) = 0.0589 \text{ m}^2$

$$F_{drag} = 0.35 \text{ Pa·s} \times \frac{(0.0589 \text{ m}^2)\left(43.0 \frac{\text{m}}{\text{s}}\right)}{0.000127 \text{ m}}$$

$$F_{drag} = 6980 \text{ Pa·m}^2 = 6980 \text{ N}$$

15. (a) $F_{drag} = \eta \frac{Av}{\Delta y}$

0.3 mm = 0.0003 m

$$223 \text{ N} = 0.0010 \text{ Pa·s} \times \frac{(21.5 \text{ m}^2)v}{0.0003 \text{ m}}$$

$$v = \frac{(223 \text{ N})(0.0003 \text{ m})}{(0.0010 \text{ Pa·s})(21.5 \text{ m}^2)} = 3.11 \frac{\text{N·m}}{\text{Pa·s·m}^2} \text{ or about } 3.1 \text{ m/s}$$

(b) A 15% reduction means the new area is 85% of the original area.

$$v = \frac{(223 \text{ N})(0.0003 \text{ m})}{(0.0010 \text{ Pa·s})\left[(21.5 \text{ m}^2)(0.85)\right]} = 3.66 \frac{\text{m}}{\text{s}} \text{ or about } 3.7 \frac{\text{m}}{\text{s}}$$