PROBLEMAS RESUELTOS

FISICA UNIVERSITARIA

CAPITULO 14 VOLUMEN 1

EDICION 11 SEARS ZEMANSKY

Sección 14.1 Densidad
Sección 14.2 Presión de un fluido
Sección 14.3 Flotación
Sección 14.4 Fuerzas de flotación y principio de Arquímedes
Sección 14.5 Ecuación de BERNOULLI
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Problema 14.1 Sears Zemansky
En un trabajo de medio tiempo, un supervisor le pide traer del almacén una varilla cilíndrica de acero de 85,8 cm de longitud y 2,85 cm de diámetro. ¿Necesitara usted un carrito? (Para contestar calcule el peso de la varilla)

Tabla 14.1 Densidades de algunas sustancias comunes

Material	Densidad (kg/m^3)*	Material	Densidad (kg/m^3)*
Aire (1 atm, 20°C)	1.20	Hierro, acero	7.8×10^3
Etanol	0.81×10^3	Latón	8.6×10^3
Benceno	0.90×10^3	Cobre	8.9×10^3
Hielo	0.92×10^3	Plata	10.5×10^3
Agua	1.00×10^3	Plomo	11.3×10^3
Agua de mar	1.03×10^3	Mercurio	13.6×10^3
Sangre	1.06×10^3	Oro	19.3×10^3
Glicerina	1.26×10^3	Platino	21.4×10^3
Concreto	2×10^3	Estrella enana blanca	10^{10}
Aluminio	2.7×10^3	Estrella de neutrones	10^{18}

*Para obtener las densidades en gramos por centímetro cúbico, divida entre 10^3.

$$w = m * g = \rho * V * g$$

ρ = 7,8 * 10^3 kg/m^3 (densidad del acero)
V = volumen de la varilla de acero
g = gravedad = 9,8 m/seg^2
V = área de la varilla * longitud de la varilla
d = diámetro de la varilla = 2,85 cm = 0,0285 metros
l = longitud de la varilla = 85,8 cm = 0,858 m

$$\text{area de la varilla} = \frac{\pi d^2}{4} = \frac{3.14 * (0{,}0285)^2}{4} = \frac{3{,}14 * 0{,}00081225}{4} = \frac{0{,}002551}{4} = 6{,}3793 * 10^{-4}\ m^2$$

V = 6,3793 * 10^{-4} * 0,858 = 5,4735 * 10^{-4} m^3

$$w = \rho * V * g$$

$$w = 7{,}8 * 10^3 \frac{kg}{m^3} * 5{,}4735 * 10^{-4}\ m^3 * 9{,}8 \frac{m}{seg^2} = 41{,}83 \text{ Newton}$$

No es necesario el carrito.

Problema 14.2 Sears Zemansky
El radio de la luna es de 1740 km. Su masa es de 7,35 * 10^{22} kg. Calcule su densidad media?

V = volumen de la luna
R = radio de la luna = 1740 km = 174 * 10^4 m

$$V = \frac{4}{3} * \pi * r^3$$

$$V = \frac{4}{3} * 3,14 * \left(174 * 10^4\right)^3$$

$$V = \frac{4}{3} * 3,14 * 5268024 * 10^{12} = 22066647,32 * 10^{12}\ m^3$$

m = masa de la luna = 7,35 * 10^{22} kg.

$$\rho = \frac{m}{V} = \frac{\left(7,35 \times 10^{22}\ kg\right)}{22066647,32 * 10^{12}\ m^3} = 3.33 \times 10^3\ kg/m^3.$$

Problema 14.3 Sears Zemansky

Imagine que compra una pieza rectangular de metal de 5 * 15 * 30 mm y masa de 0,0158 kg. El vendedor le dice que es de oro. Para verificarlo, usted calcula la densidad media de la pieza. Que valor obtiene? ¿Fue una estafa?

V = volumen de pieza rectangular

V = 5 * 15 * 30 mm = 2250 mm^3

$$V = 2250\ mm^3 * \frac{(1\ m)^3}{(1000\ mm)^3} = \frac{2250\ m^3}{10^9} = 0,00000225\ m^3$$

m = masa de la pieza rectangular de metal = 0,0158 kg.

$$\rho = \frac{m}{V} = \frac{(0.0158\ kg)}{0,00000225\ m^3} = 7,022 \times 10^3\ kg/m^3.$$

La densidad del oro = 19,3 * 10^3 kg/m^3

La densidad de la pieza rectangular de metal 7,022 * 10^3 kg/m^3

Por lo anterior fue engañado.

Problema 14.4 Sears Zemansky

Un secuestrador exige un cubo de platino de 40 kg como rescate . ¿Cuánto mide por lado?

L = longitud del cubo

V = volumen del cubo.

V = L * L * L = L^3

$$L = \sqrt[3]{V}$$

m = masa del platino = 40 kg.

ρ = la densidad del platino = 21,4 * 10^3 kg/m^3

$$V = \frac{m}{\rho}$$

$$V = \frac{m}{\rho} = \frac{40\ kg}{21,4 * 10^3\ \frac{kg}{m^3}} = 1,869158 * 10^{-3}\ m^3$$

$$L = \sqrt[3]{V}$$

$$L = \sqrt[3]{1{,}869158 * 10^{-3}\ m^3} = 0{,}12318\ m$$

L = longitud del cubo = 12,31 cm

Problema 14.5 Sears Zemansky
Una esfera uniforme de plomo y una de aluminio tienen la misma masa. ¿Qué relación hay entre el radio de la esfera de aluminio y el de la esfera de plomo?

m_{plomo} = masa esfera de plomo
$m_{aluminio}$ = masa esfera de aluminio

m_{plomo} = Volumen de la esfera de plomo * densidad del plomo

$$V_{plomo} = \frac{4}{3} * \pi * r_{plomo}^3$$
$$m_{plomo} = \frac{4}{3} * \pi * r_{plomo}^3 * \rho_{plomo}$$
$$V_{aluminio} = \frac{4}{3} * \pi * r_{aluminio}^3$$
$$m_{aluminio} = \frac{4}{3} * \pi * r_{aluminio}^3 * \rho_{aluminio}$$

$m_{plomo} = m_{aluminio}$
$$\frac{4}{3} * \pi * r_{plomo}^3 * \rho_{plomo} = \frac{4}{3} * \pi * r_{aluminio}^3 * \rho_{aluminio}$$

Cancelando términos semejantes
$$r_{plomo}^3 * \rho_{plomo} = r_{aluminio}^3 * \rho_{aluminio}$$

Despejando
$$\frac{\rho_{plomo}}{\rho_{aluminio}} = \frac{(r_{aluminio})^3}{(r_{plomo})^3} = \left(\frac{r_{aluminio}}{r_{plomo}}\right)^3$$

$$\left(\frac{\rho\ plomo}{\rho_{aluminio}}\right)^{\frac{1}{3}} = \left(\frac{r_{aluminio}}{r_{plomo}}\right)$$

$\rho_{aluminio}$ = 2,7 * 10^3 kg/m^3 (densidad del aluminio)

ρ_{plomp} = 11,3 * 10^3 kg/m^3 (densidad del plomo)

$$\left(\frac{11,3*10^3}{2,7*10^3}\right)^{\frac{1}{3}} = \left(\frac{r_{aluminio}}{r_{plomo}}\right)$$

$$(4,1851)^{\frac{1}{3}} = \left(\frac{r_{aluminio}}{r_{plomo}}\right)$$

$$\left(\frac{r_{aluminio}}{r_{plomo}}\right) = 1,61$$

Problema 14.6 Sears Zemansky

a) Calcule la densidad media del sol. B) Calcule la densidad media de una estrella de neutrones que tiene la misma masa que el sol pero un radio de solo 20 km.

m_{sol} = masa del sol = 1,99 * 10^{30} kg.
V_{sol} = volumen del sol

r_{sol} = radio del sol = 6,96 * 10^8 m

$$V_{sol} = \frac{4}{3} * \pi * (r_{sol})^3$$

$$V = \frac{4}{3} * 3,14 * \left(6,96 * 10^8\right)^3$$

$$V = \frac{4}{3} * 3,14 * 337,15 * 10^{24} = 1412,2654 * 10^{24}\ m^3$$

a) $$\rho = \frac{m_{sol}}{V_{sol}} = \frac{1.99 \times 10^{30}\ kg}{1412,2654 * 10^{24}\ m^3} = 1,409 * 10^3\ \frac{kg}{m^3}$$

$m_{estrella}$ = masa de la estrella de neutrones = 1,99 * 10^{30} kg.
$V_{estrella}$ = volumen de la estrella de neutrones
r_{sol} = radio de la estrella de neutrones = 20000 m

$$V_{estrella} = \frac{4}{3} * \pi * (r_{estrella})^3$$

$$V = \frac{4}{3} * 3,14 * (20000)^3$$

$$V = \frac{4}{3} * 3,14 * 8 * 10^{12} = 33,510321 * 10^{12}\ m^3$$

b) $$D = \frac{1.99 \times 10^{30}\ kg}{33,510321 * 10^{12}\ m^3} = 0.05938 \times 10^{18}\ kg/m^3$$

$$= 5.93 * 10^{16}\ kg/m^3$$

Problema 14.7 Sears Zemansky
¿A que profundidad del mar hay una presión manométrica de 1 * 10^5 Pa?

$p - p_0 = \rho * g * h$

ρ = 1,03 * 10^3 kg/m^3 (densidad del agua de mar)

g = gravedad = 9,8 m/seg^2

$$h = \frac{p - p_0}{\rho * g} = \frac{1 * 10^5 \text{ Pa}}{(1{,}03 * 10^3 \text{ kg/m}^3) * (9{,}80 \text{ m/s}^2)} = \frac{100000 \frac{\text{Newton}}{\text{m}^2}}{10{,}094 \frac{\text{Newton}}{\text{m}^3}} = 9{,}906 \text{ m}$$

Problema 14.8 Sears Zemansky
En la alimentación intravenosa, se inserta una aguja en una vena del brazo del paciente y se conecta un tubo entre la aguja y un depósito de fluido (densidad 1050 kg/m^3) que esta a una altura h sobre el brazo. El deposito esta abierto a la atmosfera por arriba. Si la presión manométrica dentro de la vena es de 5980 Pa, ¿Qué valor minino de h permite que entre fluido en la vena?. Suponga que el diámetro de la aguja es lo bastante grande para despreciar la viscosidad (sección 14.6) del fluido.

La diferencia de presión entre la parte superior e inferior del tubo debe ser de al menos 5980 Pa para forzar el líquido en la vena

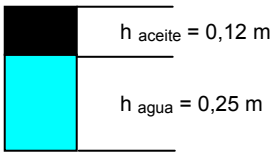
$p - p_0$ =

$\rho * g * h = 5980 \text{ Pa}$
ρ = 1050 kg/m^3 (densidad del fluido)
g = gravedad = 9,8 m/seg^2

$$h = \frac{5980 \text{ Pa}}{\rho * g} = \frac{5980 \text{ N/m}^2}{(1050 \text{ kg/m}^3)(9{,}80 \text{ m/s}^2)} = \frac{5980 \frac{\text{Newton}}{\text{m}^2}}{10290 \frac{\text{Newton}}{\text{m}^3}} = 0{,}581 \text{ m}$$

h = 58,1 cm

Problema 14.9 Sears Zemansky
Un barril contiene una capa de aceite (densidad de 600 kg/m^3) de 0,12 m sobre 0,25 m de agua.
a) Que presión manométrica hay en la interfaz aceite-agua?
b) ¿Qué presión manométrica hay en el fondo del barril?



ρ_{aceite} = 600 kg/m^3 (densidad del aceite)
g = gravedad = 9,8 m/seg^2

a) $\rho * g * h = \left(600 \text{ kg/m}^3\right)\left(9{,}80 \text{ m/s}^2\right)(0{,}12 \text{ m}) = 706 \text{ Pa.}$

ρ_{agua} = 1000 kg/m^3 (densidad del agua)
g = gravedad = 9,8 m/seg^2

b) $706\,\text{Pa} + \left(1000\ \text{kg}/\text{m}^3\right)\left(9{,}8\ \text{m}/\text{s}^2\right)(0{,}25\ \text{m}) = 706\ \text{Pa} + 2450\ \text{Pa} = 3156\ \text{Pa}.$

Problema 14.10 Sears Zemansky

Una vagoneta vacía pesa 16,5 KN. Cada neumático tiene una presión manométrica de 205 KPa (29,7 lb/pulg^2).

Calcule el área de contacto total de los neumáticos con el suelo. (Suponga que las paredes del neumático son flexibles de modo que la presión ejercida por el neumático sobre el suelo es igual a la presión de aire en su interior.)

Con la misma presión en los neumáticos, calcule el área después de que el auto se carga con 9,1 KN de pasajeros y carga.

The pressure used to find the area is the gauge pressure, and so the total area is

W = Peso de la vagoneta vacia = 16,5 KN. = 16500 Newton

P= presión manométrica de cada neumático = 205 KPa = 205000 Pa.

$$P = \frac{W}{A}$$

$$A = \frac{W}{P} = \frac{(16500\ \text{N})}{(205000\ \text{Pa})} = 0{,}0804\ \text{m}^2 \cdot$$

A = 804 cm^2

b) $P = \frac{W}{A}$

$$A = \frac{W}{P} = \frac{(16500\ \text{N} + 9100\ \text{N})}{(205000\ \text{Pa})} = \frac{25600\ \text{N}}{205000\ \frac{\text{N}}{\text{m}^2}} = 0{,}1248\ \text{m}^2 * \frac{(100\ \text{cm})^2}{(1\ \text{m})^2} = 1248\ \text{cm}^2 \cdot$$

A = 1248 cm^2

Problema 14.11 Sears Zemansky

Se esta diseñando una campana de buceo que resista la presión del mar a 250 m de profundidad.

a) cuanto vale la presión manométrica a esa profundidad.
b) A esta profundidad, ¿Qué fuerza neta ejercen el agua exterior y el aire interior sobre una ventanilla circular de 30 cm de diámetro si la presión dentro de la campana es la que hay en la superficie del agua? (desprecie la pequeña variación de presión sobre la superficie de la ventanilla)

a) $\rho gh = (1.03\times10^3\ \text{kg}/\text{m}^3)(9.80\ \text{m}/\text{s}^2)(250\ \text{m}) = 2.52\times10^6\ \text{Pa}.$

b) The pressure difference is the gauge pressure, and the net force due to the water and the air is $(2.52\times10^6\ \text{Pa})(\pi(0.15\ \text{m})^2) = 1.78\times10^5\ \text{N}.$

Problema 14.12 Sears Zemansky

¿Qué presión barométrica (en Pa y atm.) debe producir una bomba para subir agua del fondo del Gran cañón (elevación 730 m) a Indian Gardens (elevación 1370 m)?

$p = \rho gh = (1.00\times10^3\ \text{kg}/\text{m}^3)(9.80\ \text{m}/\text{s}^2)(640\ \text{m}) = 6.27\times10^6\ \text{Pa} = 61.9\ \text{atm}.$

Problema 14.13 Sears Zemansky

El liquido del manómetro de tubo abierto de la fig 14.8 a es mercurio, y_1 = 3 cm y y_2 7 cm. La presion atmosferica es de 980 milibares.

a) ¿Qué presion absoluta hay en la base del tubo en U?
b) Y en el tubo abierto 4 cm debajo de la superficie libre?
c) Que presion absoluta tiene el aire del tanque?
d) ¿Qué presion manométrica tiene el gas en pascales?

a) $p_a + \rho g y_2 = 980 \times 10^2 \text{ Pa} + (13.6 \times 10^3 \text{ kg/m}^3)(9.80 \text{ m/s}^2)(7.00 \times 10^{-2} \text{ m}) =$
1.07×10^5 Pa. b) Repeating the calcultion with $y = y_2 - y_1 = 4.00$ cm instead of y_2 gives 1.03×10^5 Pa.
c) The absolute pressure is that found in part (b), 1.03×10^5 Pa.
d) $(y_2 - y_1)\rho g = 5.33 \times 10^3$ Pa (this is not the same as the difference between the results of parts (a) and (b) due to roundoff error).

Problema 14.14 Sears Zemansky

Hay una profundidad máxima la que un buzo puede respirar por un snorkel (Fig. 14.31) pues, al aumentar la profundidad, aumenta la diferencia de presión que tiende a colapsar los pulmones del buzo. Dado que el snorkel conecta los pulmones con la atmosfera, la presión en ellos es la atmosférica. Calcule la diferencia de presión interna-externa cuando los pulmones del buzo están a 6,1 m de profundidad. Suponga que el buzo esta en agua dulce. (un buzo que respira el aire comprimido de un tanque puede operar a mayores profundidades que uno que usa snorkel, por que la presión del aire dentro de los pulmones aumenta hasta equilibrar la presión externa del agua)

$\rho g h = (1.00 \times 10^3 \text{kg/m}^3)(9.80 \text{ m/s}^2)(6.1 \text{ m}) = 6.0 \times 10^4$ Pa.

Problema 14.15 Sears Zemansky

Un cilindro alto con área transversal de 12 cm^2 se lleno parcialmente con mercurio hasta una altura de 5 cm. Se vierte lentamente agua sobre el mercurio (los dos líquidos no se mezclan). ¿Qué volumen de agua deberá añadirse para aumentar al doble la presión manométrica en la base del cilindro.

With just the mercury, the gauge pressure at the bottom of the cylinder is $p = p_0 + p_m g h_m$. With the water to a depth h_w, the gauge pressure at the bottom of the cylinder is $p = p_0 + \rho_m g h_m + p_w g h_w$. If this is to be double the first value, then $\rho_w g h_w = \rho_m g h_m$.

$$h_w = h_m(\rho_m/\rho_w) = (0.0500 \text{ m})(13.6 \times 10^3/1.00 \times 10^3) = 0.680 \text{ m}$$

The volume of water is $V = hA = (0.680 \text{ m})(12.0 \times 10^{-4} \text{ m}^2) = 8.16 \times 10^{-4} \text{ m}^3 = 816 \text{ cm}^3$

Problema 14.16 Sears Zemansky

aire dentro de los pulmones aumenta hasta equilibrar la presión externa del agua.)

14.15 Un cilindro alto con área transversal de 12.0 cm^2 se llenó parcialmente con mercurio hasta una altura de 5.00 cm. Se vierte lentamente agua sobre el mercurio (los dos líquidos no se mezclan). ¿Qué volumen de agua deberá añadirse para aumentar al doble la presión manométrica en la base del cilindro?

14.16 Un recipiente cerrado se llena parcialmente con agua. En un principio, el aire arriba del agua está a presión atmosférica (1.01×10^5 Pa) y la presión manométrica en la base del recipiente es de 2500 Pa. Después, se bombea aire adicional al interior, aumentando la presión del aire sobre el agua en 1500 Pa. a) Calcule la nueva presión manométrica en el fondo. b) ¿Cuánto deberá reducirse el nivel del agua en el recipiente (extrayendo agua a través de una válvula en el fondo) para que la presión manométrica en el fondo vuelva a ser de 2500 Pa? La presión del aire sobre el agua se mantiene a 1500 Pa sobre la presión atmosférica.

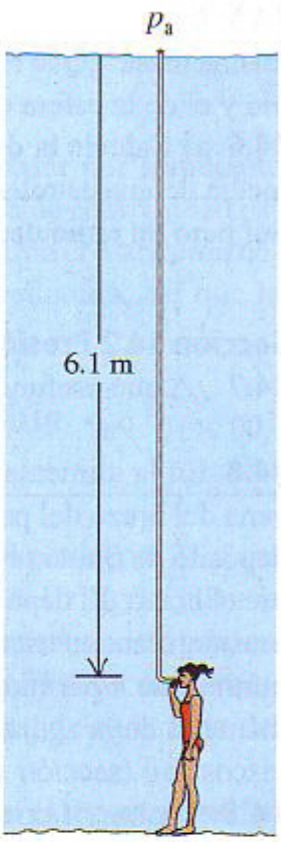


Figura 14.31 Ejercicio 14.14.

14.17 Un corto deja sin electricidad a un submarino que está 30 m bajo la superficie del mar. Para escapar, la tripulación debe empujar hacia afuera una escotilla en el fondo que tiene un área de 0.75 m^2 y pesa 300 N. Si la presión interior es de 1.0 atm, ¿qué fuerza hacia abajo se debe ejercer sobre la escotilla para abrirla?

14.18 Imagine que le encargan diseñar un tanque de agua cilíndrico presurizado para una futura colonia en Marte, donde la aceleración debida a la gravedad es de 3.71 m/s^2. La presión en la superficie del agua será de 130 kPa, y la profundidad del agua será de 14.2 m. La presión del aire en la construcción afuera del tanque será de 93 kPa. Calcule la fuerza neta hacia abajo que el agua y el aire interior y el aire exterior ejercen sobre la base plana del tanque (área = 2.00 m^2).

Un recipiente cerrado se llena parcialmente con agua. en un principio, el aire arriba del agua esta a presion atmosferica (1,01 * 10^5 Pa) y la presion manometrica en la base del recipiente es de 2500 Pa. Despues, se bombea aire adicional al interior aumentando la presion del aire sobre el agua en 1500 Pa)

a) Gauge pressure is the excess pressure above atmospheric pressure. The pressure difference between the surface of the water and the bottom is due to the weight of the water and is still 2500 Pa after the pressure increase above the surface. But the surface pressure increase is also transmitted to the fluid, making the total difference from atmospheric 2500 Pa+1500 Pa = 4000 Pa.

b) The pressure due to the water alone is 2500 Pa $= \rho g h$. Thus

$$h = \frac{2500\ \text{N/m}^2}{(1000\ \text{kg/m}^3)\,(9.80\ \text{m/s}^2)} = 0.255\ \text{m}$$

To keep the bottom gauge pressure at 2500 Pa after the 1500 Pa increase at the surface, the pressure due to the water's weight must be reduced to 1000 Pa:

$$h = \frac{1000\ \text{N/m}^2}{(1000\ \text{kg/m}^3)(9.80\ \text{m/s}^2)} = 0.102\ \text{m}$$

Thus the water must be lowered by $0.255\ \text{m} - 0.102\ \text{m} = 0.153\ \text{m}$

Problema 14.17 Sears Zemansky

The force is the difference between the upward force of the water and the downward forces of the air and the weight. The difference between the pressure inside and out is the gauge pressure, so

$F = (\rho g h)\,A - w = (1.03\times10^3)\,(9.80\ \text{m/s}^2)\,(30\ \text{m})\,(0.75\ \text{m}^2) - 300\ \text{N} = 2.27\times10^5\ \text{N}.$

Problema 14.18 Sears Zemansky

$$= 1.79\times10^5\ \text{N}.$$
$$\left[130\times10^3\ \text{Pa} + (1.00\times10^3\ \text{kg/m}^3)(3.71\ \text{m/s}^2)(14.2\ \text{m}) - 93\times10^3\ \text{Pa}\right](2.00\ \text{m}^2)$$

Problema 14.19 Sears Zemansky

The depth of the kerosene is the difference in pressure, divided by the product $\rho g = \frac{mg}{V}$,

$$h = \frac{(16.4\times10^3\ \text{N})/(0.0700\ \text{m}^2) - 2.01\times10^5\ \text{Pa}}{(205\ \text{kg})(9.80\ \text{m/s}^2)\ /(0.250\ \text{m}^3)} = 4.14\ \text{m}.$$

Problema 14.20 Sears Zemansky

$$p = \frac{F}{A} = \frac{mg}{\pi(d/2)^2} = \frac{(1200\ \text{kg})(9.80\ \text{m/s}^2)}{\pi(0.15\ \text{m})^2} = 1.66\times10^5\ \text{Pa} = 1.64\ \text{atm}.$$

Problema 14.21 Sears Zemansky

The buoyant force must be equal to the total weight; $\rho_{\text{water}} V\text{g} = \rho_{\text{ice}} V\text{g} + mg$, so

$$V = \frac{m}{\rho_{\text{water}} - \rho_{ice}} = \frac{45.0\ \text{kg}}{1000\ \text{kg/m}^3 - 920\ \text{kg/m}^3} = 0.563\ \text{m}^3,$$

or $0.56\ \text{m}^3$ to two figures.

Problema 14.22 Sears Zemansky

14.22: The buoyant force is $B = 17.50\ \text{N} - 11.20\ \text{N} = 6.30\ \text{N},$ and

$$V = \frac{B}{\rho_{\text{water}} g} = \frac{(6.30\ \text{N})}{(1.00\times10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)} = 6.43\times10^{-4}\ \text{m}^3.$$

The density is

$$\rho = \frac{m}{V} = \frac{w/g}{B/\rho_{\text{water}} g} = \rho_{\text{water}} \frac{w}{B} = (1.00\times10^3\ \text{kg/m}^3)\left(\frac{17.50}{6.30}\right) = 2.78\times10^3\ \text{kg/m}^3.$$

Problema 14.23 Sears Zemansky

Un objeto con densidad media ρ flota sobre un fluido de densidad ρ_{fluido}
a)?Que relacion debe haber entre las dos densidades?
b) A la luz de su respuesta a la parte(a), ¿Cómo pueden flotar barcos de acero en el agua?
c) En terminos de ρ y ρ_{fluido} ¿Qué fraccion del objeto esta sumergida y que fraccion esta sobre el fluido? Verifique que sus respuestas den el comportamiento correcto en el limite donde $\rho \rightarrow \rho_{\text{fluido}}$ y donde $\rho \rightarrow 0$.
d) durante un paseo en yate, su primo Tito recorta una pieza rectangular (dimensiones: 5 * 4 *3 cm) de un salvavidas y la tira al mar, donde flota. La masa de la pieza es de 42 gr. ¿Qué porcentaje de su volumen esta sobre la superficie ?

a) The displaced fluid must weigh more than the object, so $\rho < \rho_{\text{fluid}}$. b) If the ship does not leak, much of the water will be displaced by air or cargo, and the average density of the floating ship is less than that of water. c) Let the portion submerged have volume *V*, and the total volume be V_0. Then, $\rho V_{\text{o}} = \rho_{\text{fluid}} V$, so $\frac{V}{V_0} = \frac{\rho}{\rho_{\text{fluid}}}$. The fraction above the fluid is then $1 - \frac{P}{P_{\text{fluid}}}$. If $p \rightarrow 0,$ the entire object floats, and if $\rho \rightarrow \rho_{\text{fluid}}$, none of the object is above the surface. d) Using the result of part (c),

$$1 - \frac{\rho}{\rho_{\text{fluid}}} = 1 - \frac{(0.042\text{kg})/(5.0\times4.0\times3.0\times10^{-6}\ \text{m}^3)}{1030\ \text{kg/m}^3} = 0.32 = 32\%.$$

Problema 14.24 Sears Zemansky

Un cable anclado al fondo de un lago de agua dulce sostiene una esfera hueca de plástico bajo la superficie. El volumen de la esfera es de 0,650 m^3 y la tensión en el cable es de 900 N.
a) Calcule la fuerza de flotación ejercida por el agua sobre la esfera.
b) ¿Qué masa tiene la esfera
b) El cable se rompe y la esfera sube a la superficie. En equilibrio, ¿Qué fracción de volumen de la esfera estará sumergida?

a) $B = \rho_{\text{water}} gV = \left(1.00 \times 10^3 \text{ kg/m}^3\right)\left(9.80 \text{ m/s}^2\right)\left(0.650 \text{ m}^3\right) = 6370 \text{ N}.$

b) $m = \frac{w}{g} = \frac{B-T}{g} = \frac{6370 \text{ N} - 900 \text{ N}}{9.80 \text{ m/s}^2} = 558 \text{ kg}.$

c) (See Exercise 14.23.) If the submerged volume is V',

$$V' = \frac{w}{\rho_{\text{water}} g} \text{ and } \frac{V'}{V} = \frac{w}{\rho_{\text{water}} gV} = \frac{5470 \text{ N}}{6370 \text{ N}} = 0.859 = 85.9\%.$$

Problema 14.25 Sears Zemansky

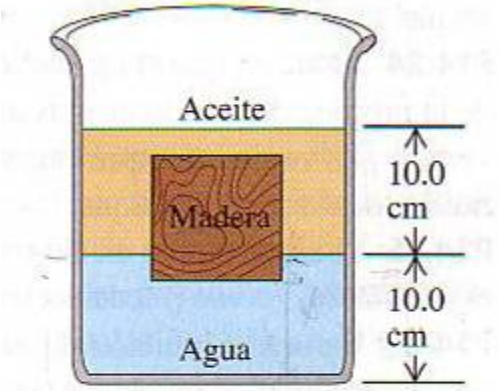


Figura 14.32 Ejercicio 14.25.

Un bloque cubico de Madera de 10 cm. Por lado flota en la interfaz entre aceite y agua con su superficie inferior 1,5 cm. Bajo la interfaz (fig 14.32). La densidad del aceite es de 790 kg/m^3
a) ¿Qué presion manometrica hay en la superficie de arriba del bloque?
b) ¿y en la cara inferior
c) ¿Qué masa y densidad tiene el bloque?

a) $\rho_{\text{oil}}\, g h_{\text{oil}} = 116 \text{ Pa}.$

b) $\left(\left(790 \text{ kg/m}^3\right)\left(0.100 \text{ m}\right) + \left(1000 \text{ kg/m}^3\right)\left(0.0150 \text{ m}\right)\right)\left(9.80 \text{ m/s}^2\right) = 921 \text{ Pa}.$

c) $$m = \frac{w}{g} = \frac{\left(p_{\text{bottom}} - p_{\text{top}}\right)A}{g} = \frac{\left(805 \text{ Pa}\right)\left(0.100 \text{ m}\right)^2}{\left(9.80 \text{ m/s}^2\right)} = 0.822 \text{ kg}.$$

The density of the block is $p = \frac{0.822 \text{ kg}}{(0.10 \text{ m})^3} = 822 \frac{\text{kg}}{\text{m}^3}$. Note that is the same as the average density of the fluid displaced, $(0.85)\left(790 \text{ kg/m}^3\right) + (0.15)(1000 \text{ kg/m}^3)$.

Problema 14.26 Sears Zemansky

Un lingote de aluminio sólido pesa 89 N en el aire.
a) ¿Qué volumen tiene?
b) el lingote se cuelga de una cuerda y se sumerge por completo en agua. ¿Qué tensión hay en la cuerda (el peso aparente del lingote en agua)?

a) Neglecting the density of the air,

$$V = \frac{m}{\rho} = \frac{w/g}{\rho} = \frac{w}{g\rho} = \frac{(89\ \text{N})}{(9.80\ \text{m/s}^2)(2.7\times10^3\ \text{kg/m}^3)} = 3.36\times10^{-3}\ \text{m}^3,$$

or $3.4\times10^{-3}\,\text{m}^3$ to two figures.

b) $$T = w - B = w - g\rho_{\text{water}}V = \omega\left(1 - \frac{\rho_{\text{water}}}{\rho_{\text{aluminum}}}\right) = (89\ \text{N})\left(1 - \frac{1.00}{2.7}\right) = 56.0\ \text{N}.$$

Problema 14.27 Sears Zemansky

a) The pressure at the top of the block is $p = p_0 + \rho g h,$ where h is the depth of the top of the block below the surface. h is greater for block B, so the pressure is greater at the top of block B.

b) $B = \rho_{\text{fl}} V_{\text{obj}} g.$ The blocks have the same volume V_{obj} so experience the same buoyant force.

c) $T - w + B = 0$ so $T = w - B.$

$w = \rho V g.$ The object have the same V but ρ is larger for brass than for aluminum so w is larger for the brass block. B is the same for both, so T is larger for the brass block, block B.

Problema 14.28 Sears Zemansky

The rock displaces a volume of water whose weight is $39.2\,\text{N} - 28.4\,\text{N} = 10.8\,\text{N}.$ The mass of this much water is thus $10.8\,\text{N}/9.80\,\text{m/s}^2 = 1.102\,\text{kg}$ and its volume, equal to the rock's volume, is

$$\frac{1.102\ \text{kg}}{1.00\times10^3\ \text{kg/m}^3} = 1.102\times10^{-3}\,\text{m}^3$$

The weight of unknown liquid displaced is $39.2\ \text{N} - 18.6\ \text{N} = 20.6\ \text{N},$ and its mass is $20.6\ \text{N}/9.80\ \text{m/s}^2 = 2.102\ \text{kg}.$ The liquid's density is thus $2.102\,\text{kg}/1.102\times10^{-3}\,\text{m}^3 = 1.91\times10^3\,\text{kg/m}^3,$ or roughly twice the density of water.

Problema 14.29 Sears Zemansky

$v_1 A_1 = v_2 A_2, v_2 = v_1(A_1/A_2)$

$A_1 = \pi(0.80\,\text{cm})^2,\ A_2 = 20\pi(0.10\,\text{cm})^2$

$$v_2 = (3.0\,\text{m/s})\frac{\pi(0.80)^2}{20\pi(0.10)^2} = 9.6\,\text{m/s}$$

Problema 14.30 Sears Zemansky

$$v_2 = v_1\frac{A_1}{A_2} = \frac{(3.50\,\text{m/s})(0.0700\,\text{m}^2)}{A_2} = \frac{0.245\,\text{m}^3/\text{s}}{A_2}.$$

a) (i) $A_2 = 0.1050\,\text{m}^2, v_2 = 2.33\,\text{m/s}.$ (ii) $A_2 = 0.047\,\text{m}^2, v_2 = 5.21\,\text{m/s}.$

b) $v_1 A_1 t = v_2 A_2 t = (0.245\,\text{m}^3/\text{s})\,(3600\,\text{s}) = 882\,\text{m}^3.$

Problema 14.31 Sears Zemansky

a) $$v = \frac{dV/dt}{A} = \frac{(1.20\,\text{m}^3/\text{s})}{\pi(0.150\,\text{m})^2} = 16.98.$$

b) $r_2 = r_1\sqrt{v_1/v_2} = \sqrt{(dV/dt)/\pi v_2} = 0.317\,\text{m}.$

Problema 14.32 Sears Zemansky

a) From the equation preceding Eq. (14.10), dividing by the time interval *dt* gives Eq. (14.12). b) The volume flow rate decreases by 1.50% (to two figures).

Problema 14.33 Sears Zemansky

Un tanque sellado que contiene agua de mar hasta una altura de 11 metros contiene también aire sobre el agua a una presión manométrica de 3 atmósferas. Sale agua del tanque a través de un agujero pequeño en el fondo. Calcule la rapidez de salida del agua

The hole is given as being “small,”and this may be taken to mean that the velocity of the seawater at the top of the tank is zero, and Eq. (14.18) gives

El agujero se da como "pequeño", y esto puede interpretarse en el sentido que la velocidad del agua de mar en la parte superior del tanque es cero, y la ecuación. (14.18) es

$$v = \sqrt{2(gy + (p/\rho))}$$

$$= \sqrt{2((9.80\ \text{m/s}^2)(11.0\ \text{m}) + (3.00)(1.013\times10^5\ \text{Pa})/(1.03\times10^3\ \text{kg/m}^3))}$$
$$= 28.4\ \text{m/s}.$$

Note that $y = 0$ and $p = p_a$ were used at the bottom of the tank, so that p was the given gauge pressure at the top of the tank.
Tenga en cuenta que y = 0 y p = $_{p0}$ se utilizaron en la parte inferior del tanque, de modo que p es la presión manométrica dada en la parte superior del tanque

Problema 14.34 Sears Zemansky
Se corta un agujero circular de 6 mm de diámetro en el costado de un tanque de agua grande, 14 m debajo del nivel del agua en el tanque. El tanque esta abierto al aire por arriba. Calcule
a) la rapidez de salida
b) el volumen descargado por unidad de tiempo.

v = velocidad en m/seg.
g = gravedad = 9,8 m/seg^2
h = altura en metros.

$$v^2 = 2 * g * h$$

$$v = \sqrt{2 * g * h} = \sqrt{2 * 9{,}8 \frac{m}{seg^2} * 14\ m} = \sqrt{274{,}4 \frac{m^2}{seg^2}} = 16{,}56 \frac{m}{seg}$$

b) el volumen descargado por unidad de tiempo.
V = volumen en m^3/ seg
V = v * A
A = area = π * r^2
r = 3 mm = 0,003 m
A = π * r^2 = 3,14 * (0,003)^2 = 2,8274 * 10^{-5} m^2
V = v * A = 16,56 m/seg * 2,8274 * 10^{-5} m^2
V = 4,68 * 10^{-4} m^3/seg

Problema 14.35 Sears Zemansky
¿Que presión manométrica se requiere en una toma municipal de agua para que el chorro de una manguera de bomberos conectada a ella alcance una altura vertical de 15 m?. (Suponga que la toma tiene un diámetro mucho mayor que la manguera).

The assumption may be taken to mean that $v_1 = 0$ in Eq. (14.17). At the maximum height, $v_2 = 0$, and using gauge pressure for p_1 and p_2, $p_2 = 0$ (the water is open to the atmosphere),

$$p_1 = \rho * g * y_2 = 1000 \frac{kg}{m^3} * 9{,}8 \frac{m}{seg^2} * 15\ m = 147000 \frac{Newton}{m^2} = 1{,}47 * 10^5\ Pa$$

p_1 = 1,47 * 10^5 Pa

Problema 14.36 Sears Zemansky

Using $v_2 = \frac{1}{4} v_1$ in Eq. (14.17),

$$p_2 = p_1 + \frac{1}{2}\rho(v_1^2 - v_2^2) + \rho g(y_1 - y_2) = p_1 + \rho\left[\left(\frac{15}{32}\right)v_1^2 + g(y_1 - y_2)\right]$$

$$= 5.00\times10^4\ \text{Pa} + (1.00\times10^3\ \text{kg/m}^3)\left(\frac{15}{32}(3.00\ \text{m/s})^2 + (9.80\ \text{m/s}^2)(11.0\ \text{m})\right)$$
$$= 1.62\times10^5\ \text{Pa}.$$

Problema 14.37 Sears Zemansky

Neglecting the thickness of the wing (so that $y_1 = y_2$ in Eq. (14.17)), the pressure difference is $\Delta p = (1/2)\rho(v_2^2 - v_1^2) = 780\ \text{Pa}$. The net upward force is then $(780\ \text{Pa})\times(16.2\ \text{m}^2) - (1340\ \text{kg})(9.80\ \text{m/s}^2) = -496\ \text{N}$.

Problema 14.38 Sears Zemansky

a) $\frac{(220)(0.355\ \text{kg})}{60.0\ \text{s}} = 1.30\ \text{kg/s}$. b) The density of the liquid is $\frac{0.355\ \text{kg}}{0.355\times10^{-3}\ \text{m}^3} = 1000\ \text{kg/m}^3$, and so the volume flow rate is $\frac{1.30\ \text{kg/s}}{1000\text{kg/m}^3} = 1.30\times10^{-3}\ \text{m}^3/\text{s} = 1.30\,\text{L/s}$. This result may also be obtained from $\frac{(220)(0.355\ \text{L})}{60.0\ \text{s}} = 1.30\ \text{L/s}$. c) $v_1 = \frac{1.30\times10^{-3}\ \text{m}^3/\text{s}}{2.00\times10^{-4}\ \text{m}^2}$
$= 6.50\,\text{m/s}, v_2 = v_1/4 = 1.63\,\text{m/s}.$

d) $$p_1 = p_2 + \frac{1}{2}\rho\left(v_2^2 - v_1^2\right) + \rho g\left(y_2 - y_1\right)$$
$$= 152\ \text{kPa} + (1/2)\left(1000\,\text{kg/m}^3\right)\left((1.63\ \text{m/s})^2 - (6.50\,\text{m/s})^2\right)$$
$$+ \left(1000\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)\left(-1.35\,\text{m}\right)$$
$$= 119\ \text{kPa}$$

Problema 14.39 Sears Zemansky

The water is discharged at a rate of $v_1 = \frac{4.65\times10^{-4}\ \text{m}^3/\text{s}}{1.32\times10^{-3}\ \text{m}^2} = 0.352\ \text{m/s}$. The pipe is given as horizonatal, so the speed at the constriction is $v_2 = \sqrt{v_1^2 + 2\Delta p/\rho} = 8.95\ \text{m/s},$ keeping an extra figure, so the cross-section are at the constriction is $\frac{4.65\times10^{-4}\ \text{m}^3/\text{s}}{8.95\ \text{m/s}} = 5.19\times10^{-5}\ \text{m}^2,$ and the radius is $r = \sqrt{A/\pi} = 0.41\,\text{cm}.$

Problema 14.40 Sears Zemansky

From Eq. (14.17), with $y_1 = y_2$,

$$p_2 = p_1 + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right) = p_1 + \frac{1}{2}\rho\left(v_1^2 - \frac{v_1^2}{4}\right) = p_1 + \frac{3}{8}\rho v_1^2$$
$$= 1.80\times10^4\ \text{Pa} + \frac{3}{8}\left(1.00\times10^3\ \text{kg/m}^3\right)\left(2.50\ \text{m/s}\right)^2 = 2.03\times10^4\ \text{Pa},$$

where the continutity relation $v_2 = \frac{v_1}{2}$ has been used.

Problema 14.41 Sears Zemansky

Let point 1 be where $r_1 = 4.00\,\text{cm}$ and point 2 be where $r_2 = 2.00\,\text{cm}$. The volume flow rate has the value $7200\,\text{cm}^3/\text{s}$ at all points in the pipe.

$v_1 A_1 = v_1 \pi r_1^2 = 7200\,\text{cm}^3$, so $v_1 = 1.43\ \text{m/s}$

$v_2 A_2 = v_2 \pi r_2^2 = 7200\,\text{cm}^3$, so $v_2 = 5.73\ \text{m/s}$

$$p_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = p_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$$

$y_1 = y_2$ and $p_2 = 2.40 \times 10^5\ \text{Pa}$, so $p_2 = p_1 + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right) = 2.25 \times 10^5\ \text{Pa}$

Problema 14.42 Sears Zemansky

a) The cross-sectional area presented by a sphere is $\pi \frac{D^2}{4}$, therefore $F = (p_0 - p)\pi \frac{D^2}{4}$. b) The force on each hemisphere due to the atmosphere is $\pi\left(5.00 \times 10^{-2}\ \text{m}\right)^2 \left(1.013 \times 10^5\ \text{Pa}\right)(0.975) = 776\text{N}.$

Problema 14.43 Sears Zemansky

a) $\rho g h = \left(1.03 \times 10^3\ \text{kg/m}^3\right)\left(9.80 \times \text{m/s}^2\right)\left(10.92 \times 10^3\ \text{m}\right) = 1.10 \times 10^8\ \text{Pa}.$

b) The fractional change in volume is the negative of the fractional change in density. The density at that depth is then

$$\rho = \rho_0\left(1 + k\Delta p\right) = \left(1.03 \times 10^3\ \text{kg/m}^3\right)\left(1 + \left(1.16 \times 10^8\ \text{Pa}\right)\left(45.8 \times 10^{-11}\ \text{Pa}^{-1}\right)\right)$$

$$= 1.08 \times 10^3\ \text{kg/m}^3,$$

A fractional increase of 5.0%. Note that to three figures, the gauge pressure and absolute pressure are the same.

Problema 14.44 Sears Zemansky

a) The weight of the water is

$$\rho g V = \left(1.00 \times 10^3\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)\left((5.00\,\text{m})(4.0\,\text{m})(3.0\,\text{m})\right) = 5.88 \times 10^5\ \text{N},$$

or $5.9 \times 10^5\ \text{N}$ to two figures. b) Integration gives the expected result the force is what it would be if the pressure were uniform and equal to the pressure at the midpoint;

$$F = \rho g A \frac{d}{2}$$

$$= \left(1.00 \times 10^3\ \text{kg/m}^3\right)\left(9.80\ \text{m/s}^2\right)\left((4.0\,\text{m})(3.0\,\text{m})\right)(1.50\,\text{m}) = 1.76 \times 10^5\ \text{N},$$

or $1.8 \times 10^5\ \text{N}$ to two figures.

Problema 14.45 Sears Zemansky

Let the width be *w* and the depth at the bottom of the gate be H. The force on a strip of vertical thickness dh at a depth h is then $dF = \rho g h(wdh)$ and the torque about the hinge is $d\tau = \rho g w h(h - H/2)dh$; integrating from $h = 0$ to $h = H$ gives $\tau = \rho g \omega H^3/12 = 2.61\times10^4\ \mathrm{N\cdot m}$.

Problema 14.46 Sears Zemansky

a) See problem 14.45; the net force is $\int dF$ from $h = 0$ to $h = H, F = \rho g \omega H^2/2 = \rho g A H/2,$ where $A = \omega H.$ b) The torque on a strip of vertical thickness dh about the bottom is $d\tau = dF(H - h) = \rho g w h(H - h)dh,$ and integrating from $h = 0$ to $h = H$ gives $\tau = \rho g w H^3/6 = \rho g A H^2/6.$ c) The force depends on the width and the square of the depth, and the torque about the bottom depends on the width and the cube of the depth; the surface area of the lake does not affect either result (for a given width).

Problema 14.47 Sears Zemansky

The acceleration due to gravity on the planet is

$$g = \frac{\Delta p}{\rho d} = \frac{\Delta p}{\frac{m}{V} d}$$

and so the planet's mass is

$$M = \frac{gR^2}{G} = \frac{\Delta p V R^2}{mGd}$$

Problema 14.48 Sears Zemansky

The cylindrical rod has mass M, radius R, and length L with a density that is proportional to the square of the distance from one end, $\rho = Cx^2$.

a) $M = \int \rho dV = \int Cx^2 dV.$ The volume element $dV = \pi R^2 dx.$ Then the integral becomes $M = \int_0^L Cx^2 \pi R^2 dx.$ Integrating gives $M = C\pi R^2 \int_0^L x^2 dx = C\pi R^2 \frac{L^3}{3}.$ Solving for $C, C = 3M/\pi R^2 L^3.$

b) The density at the $x = L$ end is $\rho = Cx^2 = \left(\frac{3M}{\pi R^2 L^3}\right)(L^2) = \left(\frac{3M}{\pi R^2 L}\right).$ The denominator is just the total volume V, so $\rho = 3M/V,$ or three times the average density, $M/V.$ So the average density is one-third the density at the $x = L$ end of the rod.

Problema 14.49 Sears Zemansky

a) At $r = 0,$ the model predicts $\rho = A = 12{,}700\ \mathrm{kg/m^3}$ and at $r = R,$ the model predicts

$\rho = A - BR = 12{,}700\ \text{kg/m}^3 - (1.50\times10^{-3}\ \text{kg/m}^4)(6.37\times10^6\ \text{m}) = 3.15\times10^3\ \text{kg/m}^3.$

b), c)

$$M = \int dm = 4\pi\int_0^R [A - Br]r^2 dr = 4\pi\left[\frac{AR^3}{3} - \frac{BR^4}{4}\right] = \left(\frac{4\pi R^3}{3}\right)\left[A - \frac{3BR}{4}\right]$$

$$= \left(\frac{4\pi(6.37\times10^6\ \text{m})^3}{3}\right)\left[12{,}700\ \text{kg/m}^3 - \frac{3(1.50\times10^{-3}\ \text{kg/m}^4)(6.37\times10^6\ \text{m})}{4}\right]$$

$$= 5.99\times10^{24}\ \text{kg},$$

which is within 0.36% of the earth's mass. d) If $m(r)$ is used to denote the mass contained in a sphere of radius r, then $g = Gm(r)/r^2$. Using the same integration as that in part (b), with an upper limit of r instead of R gives the result.

e) $g = 0$ at $r = 0$, and g at $r = R$, $g = Gm(R)/R^2 = (6.673\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)$
$(5.99\times10^{24}\ \text{kg})/(6.37\times10^6\ \text{m})^2 = 9.85\ \text{m/s}^2.$

f) $$\frac{dg}{dr} = \left(\frac{4\pi G}{3}\right)\frac{d}{dr}\left[Ar - \frac{3Br^2}{4}\right] = \left(\frac{4\pi G}{3}\right)\left[A - \frac{3Br}{2}\right];$$

setting ths equal to zero gives $r = 2A/3B = 5.64\times10^6$ m, and at this radius

$$g = \left(\frac{4\pi G}{3}\right)\left(\frac{2A}{3B}\right)\left[A - \left(\frac{3}{4}\right)B\left(\frac{2A}{3B}\right)\right]$$

$$= \frac{4\pi GA^2}{9B}$$

$$= \frac{4\pi(6.673\times10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(12{,}700\ \text{kg/m}^3)^2}{9(1.50\times10^{-3}\ \text{kg/m}^4)} = 10.02\ \text{m/s}^2.$$

Problema 14.50 Sears Zemansky

a) Equation (14.4), with the radius r instead of height y, becomes $dp = -\rho g\, dr = -\rho g_s(r/R)dr$. This form shows that the pressure decreases with increasing radius. Integrating, with $p = 0$ at $r = R$,

$$p = -\frac{\rho g_s}{R}\int_R^r r\, dr = \frac{\rho g_s}{R}\int_r^R r\, dr = \frac{\rho g_s}{2R}(R^2 - r^2).$$

b) Using the above expression with $r = 0$ and $\rho = \frac{M}{V} = \frac{3M}{4\pi R^3}$,

$$p(0) = \frac{3(5.97\times10^{24}\ \text{kg})(9.80\ \text{m/s}^2)}{8\pi(6.38\times10^6\ \text{m})^2} = 1.71\times10^{11}\ \text{Pa}.$$

c) While the same order of magnitude, this is not in very good agreement with the estimated value. In more realistic density models (see Problem 14.49 or Problem 9.99), the concentration of mass at lower radii leads to a higher pressure.

Problema 14.51 Sears Zemansky

a) $\rho_{\text{water}} g h_{\text{water}} = (1.00\times10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(15.0\times10^{-2}\ \text{m}) = 1.47\times10^3\ \text{Pa}.$

b) The gauge pressure at a depth of 15.0 $\text{cm} - h$ below the top of the mercury column must be that found in part (a); $\rho_{\text{Hg}} g(15.0\,\text{cm} - h) = \rho_{\text{water}} g(15.0\,\text{cm}),$ which is solved for $h = 13.9\,\text{cm}.$

Problema 14.52 Sears Zemansky

Following the hint,

$$F = \int_0^{\text{h}} (\rho g y)(2\pi R)dy = \rho g \pi R h^2$$

where *R* and *h* are the radius and height of the tank (the fact that $2R = h$ is more or less coincidental). Using the given numerical values gives $F = 5.07\times10^8\ \text{N}.$

14.53: For the barge to be completely submerged, the mass of water displaced would need to be $\rho_{\text{water}} V = (1.00\times10^3\ \text{kg/m}^3)(22\times40\times12\,\text{m}^3) = 1.056\times10^7\ \text{kg}.$ The mass of the barge itself is

$$(7.8\times10^3\,\text{kg/m}^3)((2(22+40)\times12 + 22\times40)\times4.0\times10^{-2}\ \text{m}^3) = 7.39\times10^5\ \text{kg},$$

so the barge can hold 9.82×10^6 kg of coal. This mass of coal occupies a solid volume of $6.55\times10^3\ \text{m}^3,$ which is less than the volume of the interior of the barge $(1.06\times10^4\ \text{m}^3),$ but the coal must not be too loosely packed.

Problema 14.54 Sears Zemansky

The difference between the densities must provide the "lift" of 5800 N (see Problem 14.59). The average density of the gases in the balloon is then

$$\rho_{\text{ave}} = 1.23\ \text{kg/m}^3 - \frac{(5800\ \text{N})}{(9.80\ \text{m/s}^2)(2200\,\text{m}^3)} = 0.96\ \text{kg/m}^3.$$

Problema 14.55 Sears Zemansky

a) The submerged volume V' is $\frac{w}{\rho_{\text{water}} g},$ so

$$\frac{V'}{V} = \frac{w/\rho_{\text{water}} g}{V} = \frac{m}{\rho_{\text{water}} V} = \frac{(900\,\text{kg})}{(1.00\times10^3\ \text{kg/m}^3)\,(3.0\,\text{m}^3)} = 0.30 = 30\%\cdot$$

b) As the car is about to sink, the weight of the water displaced is equal to the weight of the car plus the weight of the water inside the car. If the volume of water inside the car is V'',

$$V\rho_{water} g = w + V''p_{water} g, \text{ or } \frac{V''}{V} = 1 - \frac{w}{Vp_{water} g} = 1 - 0.30 = 0.70 = 70\%\cdot$$

Problema 14.56 Sears Zemansky

a) The volume displaced must be that which has the same weight and mass as the ice, $\frac{9.70\ \text{gm}}{1.00\ \text{gm/cm}^3} = 9.70\,\text{cm}^3$ (note that the choice of the form for the density of water avoids conversion of units). b) No; when melted, it is as if the volume displaced by the $9.70\,\text{gm}$ of melted ice displaces the same volume, and the water level does not change. c) $\frac{9.70\ \text{gm}}{1.05\ \text{gm/cm}^3} = 9.24\,\text{cm}^3\cdot$ d) The melted water takes up more volume than the salt water displaced, and so $0.46\,\text{cm}^3$ flows over. A way of considering this situation (as a thought experiment only) is that the less dense water "floats" on the salt water, and as there is insufficient volume to contain the melted ice, some spills over.

Problema 14.57 Sears Zemansky

The total mass of the lead and wood must be the mass of the water displaced, or

$$V_{\text{Pb}}\rho_{\text{Pb}} + V_{\text{wood}}\rho_{\text{wood}} = (V_{\text{Pb}} + V_{\text{wood}})\rho_{\text{water}};$$

solving for the volume V_{Pb},

$$V_{\text{Pb}} = V_{\text{wood}}\frac{\rho_{\text{water}} - \rho_{\text{wood}}}{\rho_{\text{Pb}} - \rho_{\text{water}}}$$

$$= (1.2\times10^{-2}\ \text{m}^3)\frac{1.00\times10^3\ \text{kg/m}^3 - 600\ \text{kg/m}^3}{11.3\times10^3\ \text{kg/m}^3 - 1.00\times10^3\ \text{kg/m}^3}$$

$$= 4.66\times10^{-4}\ \text{m}^3,$$

which has a mass of 5.27 kg.

Problema 14.58 Sears Zemansky

The fraction *f* of the volume that floats above the fluid is $f = 1 - \frac{\rho}{\rho_{\text{fluid}}}$, where ρ is the average density of the hydrometer (see Problem 14.23 or Problem 14.55), which can be expressed as $\rho_{\text{fluid}} = \rho\frac{1}{1-f}$.

Thus, if two fluids are observed to have floating fraction f_1 and f_2, $\rho_2 = \rho_1 \dfrac{1-f_1}{1-f_2}$. In this form, it's clear that a larger f_2 corresponds to a larger density; more of the stem is above the fluid. Using $f_1 = \frac{(8.00\text{ cm})(0.400\text{ cm}^2)}{(13.2\text{ cm}^3)} = 0.242,\ f_2 = \frac{(3.20\text{ cm})(0.400\text{ cm}^2)}{(13.2\text{ cm}^3)} = 0.097$ gives $\rho_{\text{alcohol}} = (0.839)\,\rho_{\text{water}} = 839\text{ kg/m}^3$.

Problema 14.59 Sears Zemansky

a) The "lift" is $V(\rho_{\text{air}} - \rho_{\text{H}_2})g$, from which

$$V = \frac{120{,}000\text{ N}}{(1.20\text{ kg/m}^3 - 0.0899\text{ kg/m}^3)(9.80\text{ m/s}^2)} = 11.0\times10^3\text{ m}^3.$$

b) For the same volume, the "lift" would be different by the ratio of the density differences,

$$(120{,}000\text{ N})\left(\frac{\rho_{\text{air}} - \rho_{\text{He}}}{\rho_{\text{air}} - \rho_{\text{H}_2}}\right) = 11.2\times10^4\text{ N}.$$

This increase in lift is not worth the hazards associated with use of hydrogen.

Problema 14.60 Sears Zemansky

a) Archimedes' principle states $\rho gLA = Mg$, so $L = \dfrac{M}{\rho A}$.

b) The buoyant force is $\rho gA(L+x) = Mg + F$, and using the result of part (a) and solving for *x* gives $x = \frac{F}{\rho gA}$.

c) The "spring constant," that is, the proportionality between the displacement *x* and the applied force *F*, is $k = \rho gA$, and the period of oscillation is

$$T = 2\pi\sqrt{\frac{M}{k}} = 2\pi\sqrt{\frac{M}{\rho gA}}.$$

Problema 14.61 Sears Zemansky

1: a) $x = \dfrac{w}{\rho gA} = \dfrac{mg}{\rho gA} = \dfrac{m}{\rho A} = \dfrac{(70.0\text{ kg})}{(1.03\times10^3\text{ kg/m}^3)\pi(0.450\text{ m})^2} = 0.107\text{ m}.$

b) Note that in part (c) of Problem 14.60, M is the mass of the buoy, not the mass of the man, and A is the cross-section area of the buoy, not the amplitude. The period is then

$$T = 2\pi\sqrt{\frac{(950\,\text{kg})}{(1.03\times10^3\ \text{kg/m}^3)(9.80\,\text{m/s}^2)\pi(0.450\,\text{m})^2}} = 2.42\,\text{s}.$$

Problema 14.62 Sears Zemansky

To save some intermediate calculation, let the density, mass and volume of the life preserver be ρ_0, m and $v,$ and the same quantities for the person be ρ_1, M and V. Then, equating the buoyant force and the weight, and dividing out the common factor of $g,$

$$\rho_{\text{water}}((0.80)V + v) = \rho_0 v + \rho_1 V,$$

Eliminating V in favor of ρ_1 and $M,$ and eliminating *m* in favor of ρ_0 and $v,$

$$\rho_0 v + M = \rho_{\text{water}}\left((0.80)\frac{M}{\rho_1} + v\right).$$

Solving for $\rho_0,$

$$\rho_0 = \frac{1}{v}\left(\rho_{\text{water}}\left((0.80)\frac{M}{\rho_1} + v\right) - M\right)$$

$$= \rho_{\text{water}} - \frac{M}{v}\left(1 - (0.80)\frac{\rho_{\text{water}}}{\rho_1}\right)$$

$$= 1.03\times10^3\ \text{kg/m}^3 - \frac{75.0\,\text{kg}}{0.400\,\text{m}^3}\left(1 - (0.80)\frac{1.03\times10^3\ \text{kg/m}^3}{980\ \text{kg/m}^3}\right)$$

$$= 732\ \text{kg/m}^3\cdot$$

Problema 14.63 Sears Zemansky

To the given precision, the density of air is negligible compared to that of brass, but not compared to that of the wood. The fact that the density of brass may not be known the three-figure precision does not matter; the mass of the brass is given to three figures. The weight of the brass is the difference between the weight of the wood and the buoyant force of the air on the wood, and canceling a common factor of $g,\ V_{\text{wood}}\ (\rho_{\text{wood}} - \rho_{\text{air}}) = M_{\text{brass,}}$ and

$$M_{\text{wood}} = \rho_{\text{wood}} V_{\text{wood}} = M_{\text{brass}}\frac{\rho_{\text{wood}}}{\rho_{\text{wood}} - \rho_{\text{air}}} = M_{\text{brass}}\left(1 - \frac{\rho_{\text{air}}}{\rho_{\text{wood}}}\right)^{-1}$$

$$= (0.0950\,\text{kg})\left(1 - \frac{1.20\ \text{kg/m}^3}{150\ \text{kg/m}^3}\right)^{-1} = 0.0958\,\text{kg}.$$

Problema 14.64 Sears Zemansky

The buoyant force on the mass *A*, divided by g, must be $7.50\ \text{kg} - 1.00\ \text{kg} - 1.80\ \text{kg} = 4.70\ \text{kg}$ (see Example 14.6), so the mass block is $4.70\ \text{kg} + 3.50\ \text{kg} = 8.20\ \text{kg}$. a) The mass of the liquid displaced by the block is $4.70\ \text{kg}$, so the density of the liquid is $\frac{4.70\ \text{kg}}{3.80\times10^{-3}\ \text{m}^3} = 1.24\times10^3\ \text{kg/m}^3$. b) Scale *D* will read the mass of the block, $8.20\ \text{kg}$, as found above. Scale *E* will read the sum of the masses of the beaker and liquid, $2.80\ \text{kg}$.

Problema 14.65 Sears Zemansky

Neglecting the buoyancy of the air, the weight in air is

$$g(\rho_{\text{Au}}V_{\text{Au}} + \rho_{\text{Al}}V_{\text{Al}}) = 45.0\ \text{N}.$$

and the buoyant force when suspended in water is

$$\rho_{\text{water}}(V_{\text{Au}} + V_{\text{Al}})g = 45.0\ \text{N} - 39.0\ \text{N} = 6.0\ \text{N}.$$

These are two equations in the two unknowns V_{Au} and V_{Al}. Multiplying the second by ρ_{Al} and the first by ρ_{water} and subtracting to eliminate the V_{Al} term gives

$$\rho_{\text{water}}V_{\text{Au}}g\,(\rho_{\text{Au}} - \rho_{\text{Al}}) = \rho_{\text{water}}(45.0\ \text{N}) - \rho_{\text{Al}}(6.0\ \text{N})$$

$$w_{\text{Au}} = \rho_{\text{Au}}gV_{\text{Au}} = \frac{\rho_{\text{Au}}}{\rho_{\text{water}}(\rho_{\text{Au}} - \rho_{\text{Al}})}(\rho_{\text{water}}(45.0\ \text{N}) - \rho_{\text{Au}}(6.0))$$

$$= \frac{(19.3)}{(1.00)(19.3 - 2.7)}((1.00)(45.0\ \text{N}) - (2.7)(6.0\ \text{N}))$$

$$= 33.5\ \text{N}.$$

Note that in the numerical determination of w_{Au}, specific gravities were used instead of densities.

Problema 14.66 Sears Zemansky

The ball's volume is

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(12.0\ \text{cm})^3 = 7238\ \text{cm}^3$$

As it floats, it displaces a weight of water equal to its weight. a) By pushing the ball under water, you displace an additional amount of water equal to 84% of the ball's volume or $(0.84)(7238\ \text{cm}^3) = 6080\ \text{cm}^3$. This much water has a mass of $6080\ g = 6.080\ \text{kg}$ and weighs $(6.080\ \text{kg})(9.80\ \text{m/s}^2) = 59.6\ \text{N}$, which is how hard you'll have to push to submerge the ball.

b) The upward force on the ball in excess of its own weight was found in part (a): $59.6\ \text{N}$. The ball's mass is equal to the mass of water displaced when the ball is floating:

$$(0.16)(7238\ \text{cm}^3)(1.00\ \text{g/cm}^3) = 1158\ \text{g} = 1.158\ \text{kg},$$

and its acceleration upon release is thus

$$a = \frac{F_{\text{net}}}{m} = \frac{59.6\ \text{N}}{1.158\ \text{kg}} = 51.5\ \text{m/s}^2$$

Problema 14.67 Sears Zemansky

a) The weight of the crown of its volume *V* is $w = \rho_{\text{crown}} gV$, and when suspended the apparent weight is the difference between the weight and the buoyant force,

$$fw = f\rho_{\text{crown}} gV = (\rho_{\text{crown}} - \rho_{\text{water}})gV.$$

Dividing by the common factors leads to

$$-\rho_{\text{water}} + \rho_{\text{crown}} = f\rho_{\text{crown}} \text{ or } \frac{\rho_{\text{crown}}}{\rho_{\text{water}}} = \frac{1}{1-f}.$$

As $f \to 0,$ the apparent weight approaches zero, which means the crown tends to float; from the above result, the specific gravity of the crown tends to 1. As $f \to 1,$ the apparent weight is the same as the weight, which means that the buoyant force is negligble compared to the weight, and the specific gravity of the crown is very large, as reflected in the above expression. b) Solving the above equations for *f* in terms of the specific gravity, $f = 1 - \frac{\rho_{\text{water}}}{\rho_{\text{crown}}},$ and so the weight of the crown would be $\left(1 - (1/19.3)\right)(12.9\ \text{N}) = 12.2\ \text{N}.$ c) Approximating the average density by that of lead for a “thin” gold plate, the apparent weight would be $\left(1 - (1/11.3)\right)(12.9\ \text{N}) = 11.8\ \text{N}.$

Problema 14.68 Sears Zemansky

a) See problem 14.67. Replacing *f* with, respectively, w_{water}/w and w_{fluid}/w gives

$$\frac{\rho_{\text{steel}}}{\rho_{\text{fluid}}} = \frac{w}{w - w_{\text{fluid}}}, \frac{\rho_{\text{steel}}}{\rho_{\text{fluid}}} = \frac{w}{w - w_{\text{water}}},$$

and dividing the second of these by the first gives

$$\frac{\rho_{\text{fluid}}}{\rho_{\text{water}}} = \frac{w - w_{\text{fluid}}}{w - w_{\text{water}}}.$$

b) When w_{fluid} is greater than $w_{\text{water,}}$ the term on the right in the above expression is less than one, indicating that the fluids is less dense than water, and this is consistent with the buoyant force when suspended in liquid being less than that when suspended in water. If the density of the fluid is the same as that of water $w_{\text{fluid}} = w_{\text{water}}$, as expected. Similarly, if w_{fluid} is less than w_{water}, the term on the right in the above expression is greater than one, indicating the the fluid is denser than water. c) Writing the result of part (a) as

$$\frac{\rho_{\text{fluid}}}{\rho_{\text{water}}} = \frac{1 - f_{\text{fluid}}}{1 - f_{\text{water}}}.$$

and solving for f_{fluid},

$$f_{\text{fluid}} = 1 - \frac{\rho_{\text{fluid}}}{\rho_{\text{water}}}\left(1 - f_{\text{water}}\right) = 1 - \left(1.220\right)\left(0.128\right) = 0.844 = 84.4\%.$$

Problema 14.69 Sears Zemansky

a) Let the total volume be *V*; neglecting the density of the air, the buoyant force in terms of the weight is

$$B = \rho_{\text{water}} g V = \rho_{\text{water}} g\left(\frac{(w/g)}{\rho_{\text{m}}} + V_0\right),$$

or

$$V_0 = \frac{B}{\rho_{water} g} - \frac{w}{\rho_w g}.$$

b) $\frac{B}{\rho_{\text{water}} g} - \frac{w}{\rho_{\text{Cu}} g} = 2.52 \times 10^{-4}\ \text{m}^3$. Since the total volume of the casting is $\frac{\text{B}}{\rho_{\text{water}} g}$, the cavities are 12.4% of the total volume.

Problema 14.70 Sears Zemansky

a) Let *d* be the depth of the oil layer, *h* the depth that the cube is submerged in the water, and *L* be the length of a side of the cube. Then, setting the buoyant force equal to the weight, canceling the common factors of *g* and the cross-section area and supressing units,
$(1000)h + (750)d = (550)L.d$, *h* and *L* are related by $d + h + (0.35)L = L$, so $h = (0.65)L -$ *d*. Substitution into the first relation gives $d = L\frac{(0.65)(1000)-(550)}{(1000)-(750)} = \frac{2L}{5.00} = 0.040\ \text{m}.$ b) The gauge pressure at the lower face must be sufficient to support the block (the oil exerts only sideways forces directly on the block), and $p = \rho_{\text{wood}} gL = (550\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(0.100\ \text{m}) = 539\ \text{Pa}.$ As a check, the gauge pressure, found from the depths and densities of the fluids, is
$((0.040\ \text{m})(750\ \text{kg/m}^3) + (0.025\ \text{m})(1000\ \text{kg/m}^3))(9.80\ \text{m/s}^2) = 539\ \text{Pa}.$

Problema 14.71 Sears Zemansky

The ship will rise; the total mass of water displaced by the barge-anchor combination must be the same, and when the anchor is dropped overboard, it displaces some water and so the barge itself displaces less water, and so rises.
To find the amount the barge rises, let the original depth of the barge in the water be
$h_0 = \left(m_{\text{b}} + m_{\text{a}}\right)/\left(\rho_{\text{water}} A\right)$, where m_{b} and m_{a} are the masses of the barge and the anchor, and *A* is the area

of the bottom of the barge. When the anchor is dropped, the buoyant force on the barge is less than what it was by an amount equal to the buoyant force on the anchor; symbolically,

$$h'\rho_{\text{water}}Ag = h_0\rho_{\text{water}}Ag - \left(m_{\text{a}}/\rho_{\text{steel}}\right)\rho_{\text{water}}g,$$

which is solved for

$$\Delta h = h_0 - h' = \frac{m_{\text{a}}}{\rho_{\text{steel}}A} = \frac{(35.0\,\text{kg})}{\left(7860\ \text{kg/m}^3\right)\left(8.00\,\text{m}^2\right)} = 5.57\times10^{-4}\ \text{m},$$

or about 0.56 mm.

Problema 14.72 Sears Zemansky

a) The average density of a filled barrel is $\rho_{\text{oil}} + \frac{m}{V} = 750\ \text{kg/m}^3 + \frac{15.0\ \text{kg}}{0.120\ \text{m}^3} = 875\ \text{kg/m}^3$, which is less than the density of seawater, so the barrel floats.

b) The fraction that floats (see Problem 14.23) is

$$1 - \frac{\rho_{\text{ave}}}{\rho_{\text{water}}} = 1 - \frac{875\ \text{kg/m}^3}{1030\ \text{kg/m}^3} = 0.150 = 15.0\%.$$

c) The average density is $910\,\frac{\text{kg}}{\text{m}^3} + \frac{32.0\ \text{kg}}{0.120\ \text{m}^3} = 1172\,\frac{\text{kg}}{\text{m}^3}$ which means the barrel sinks. In order to lift it, a tension $T = (1177\,\frac{\text{kg}}{\text{m}^3})(0.120\,\text{m}^3)(9.80\,\frac{\text{m}}{\text{s}^2}) - (1030\,\frac{\text{kg}}{\text{m}^3})(0.120\,\text{m}^3)(9.80\,\frac{\text{m}}{\text{s}^2}) = 173\ \text{N}$ is required.

Problema 14.73 Sears Zemansky

a) See Exercise 14.23; the fraction of the volume that remains unsubmerged is $1 - \frac{\rho B}{\rho L}$. b) Let the depth of the liquid be *x* and the depth of the water be *y*. Then $\rho Lgx + \rho wgy = \rho_B gL$ and $x + y = L$. Therefore $x = L - y$ and $y = \frac{(\rho_L - \rho_B)L}{\rho_L - \rho_\omega}$. c) $y = \frac{13.6-7.8}{13.6-1.0}(0.10\,\text{m}) = 0.046\,\text{m}$.

Problema 14.74 Sears Zemansky

a) The change is height Δy is related to the displaced volume ΔV by $\Delta y = \dfrac{\Delta V}{A}$, where *A* is the surface area of the water in the lock. ΔV is the volume of water that has the same weight as the metal, so

$$\Delta y = \frac{\Delta V}{A} = \frac{w/\rho_{\text{water}} g}{A} = \frac{w}{\rho_{\text{water}} g A}$$
$$= \frac{(2.50\times10^6\ \text{N})}{(1.00\text{x}10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)((60.0\,\text{m})(20.0\,\text{m}))} = 0.213\,\text{m}.$$

b) In this case, ΔV is the volume of the metal; in the above expression, ρ_{water} is replaced by $\rho_{\text{metal}} = 9.00\rho_{\text{water}}$, which gives $\Delta y' = \frac{\Delta y}{9}$, and $\Delta y - \Delta y' = \frac{8}{9}\Delta y = 0.189\,\text{m}$; the water sinks by this amount.

Problema 14.75 Sears Zemansky

a) Consider the fluid in the horizontal part of the tube. This fluid, with mass ρAl, is subject to a net force due to the pressure difference between the ends of the tube, which is the difference between the gauge pressures at the bottoms of the ends of the tubes. This difference is $\rho g(y_{\text{L}} - y_{\text{R}})$, and the net force on the horizontal part of the fluid is

$$\rho g\,(y_{\text{L}} - y_{\text{R}})\,A = \rho Ala\ ,$$

or

$$(y_{\text{L}} - y_{\text{R}}) = \frac{a}{g} l.$$

b) Again consider the fluid in the horizontal part of the tube. As in part (a), the fluid is accelerating; the center of mass has a radial acceleration of magnitude $a_{\text{rad}} = \omega^2 l/2$, and so the difference in heights between the columns is $(\omega^2 l/2)(l/g) = \omega^2 l^2/2g$.

Anticipating Problem, 14.77, an equivalent way to do part (b) is to break the fluid in the horizontal part of the tube into elements of thickness *dr*; the pressure difference between the sides of this piece is $dp = \rho(\omega^2 r)dr$ (see Problem 14.78), and integrating from $r = 0$ to $r = l$ gives $\Delta p = \rho\omega^2 l^2/2$, giving the same result.

c) At any point, Newton's second law gives $dpA = pAdla$ from which the area *A* cancels out. Therefore the cross-sectional area does not affect the result, even if it varies. Integrating the above result from 0 to *l* gives $\Delta p = pal$ between the ends. This is related to the height of the columns through $\Delta p = pg\Delta y$ from which *p* cancels out.

Problema 14.76 Sears Zemansky

a) The change in pressure with respect to the vertical distance supplies the force necessary to keep a fluid element in vertical equilibrium (opposing the weight). For the rotating fluid, the change in pressure with respect to radius supplies the force necessary to keep a fluid element accelerating toward the axis;

specifically, $dp = \frac{\partial_p}{\partial_p} dr = \rho a\, dr,$ and using $a = \omega^2 r$ gives $\frac{\partial_p}{\partial_p} = \rho\omega^2 r.$ b) Let the pressure at $y = 0, r = 0$ be p_a (atmospheric pressure); integrating the expression for $\frac{\partial_p}{\partial_p}$ from part (a) gives

$$p(r, y = 0) = p_{\mathrm{a}} + \frac{\rho\omega^2}{2} r^{2.}$$

c) In Eq. $(14.5), p_2 = p_{\mathrm{a}}, p_1 = p(r, y = 0)$ as found in part (b), $y_1 = 0 \text{ and } \mathrm{y}_2 = h(r),$ the height of the liquid above the $y = 0$ plane. Using the result of part (b) gives $h(r) = \omega^2 r^2 / 2g.$

Problema 14.77 Sears Zemansky

a) The net inward force is $(p + dp)A - pA = Adp,$ and the mass of the fluid element is $\rho A dr'.$ Using Newton's second law, with the inward radial acceleration of $\omega^2 r',$ gives $dp = \rho\omega^2 r' dr'.$ b) Integrating the above expression,

$$\int_{p0}^{p} dp = \int_{r0}^{r} \rho\omega^2 r' dr'$$

$$p - p_0 = \left(\frac{\rho\omega^2}{2}\right)\left(r^2 - r^2{}_0\right),$$

which is the desired result. c) Using the same reasoning as in Section 14.3 (and Problem 14.78), the net force on the object must be the same as that on a fluid element of the same shape. Such a fluid element is accelerating inward with an acceleration of magnitude $\omega^2 R_{\mathrm{cm},}$ and so the force on the object is $\rho V\omega^2 R_{\mathrm{cm}}.$ d) If $\rho \mathrm{R}_{\mathrm{cm}} > \rho_{\mathrm{ob}} R_{cmob,}$ the inward force is greater than that needed to keep the object moving in a circle with radius R_{cmob} at angular frequency ω, and the object moves inward. If $\rho R_{\mathrm{cm}} < \rho_{\mathrm{ob}} R_{cmob,}$, the net force is insufficient to keep the object in the circular motion at that radius, and the object moves outward. e) Objects with lower densities will tend to move toward the center, and objects with higher densities will tend to move away from the center.

Problema 14.78 Sears Zemansky

(Note that increasing x corresponds to moving toward the back of the car.)

a) The mass of air in the volume element is $\rho dV = \rho A dx$, and the net force on the element in the forward direction is $(p + dp)A - pA = Adp.$ From Newton's second law, $Adp = (\rho A\, dx)a,$ from which $dp = \rho \mathrm{a} dx.$ b) With ρ given to be constant, and with $p = p_0 at\ x = 0, p = p_0 + \rho a x.$ c) Using

$\rho = 1.2\ \text{kg/m}^3$ in the result of part (b) gives $(1.2\ \text{kg/m}^3)(5.0\ \text{m/s}^2)(2.5\ \text{m}) = 15.0\ \text{Pa} \sim 15 \times 10^{-5}\ p_{atm}$, so the fractional pressure difference is negligble. d) Following the argument in Section 14-4, the force on the balloon must be the same as the force on the same volume of air; this force is the product of the mass ρV and the acceleration, or $\rho V a.$ e) The acceleration of the balloon is the force found in part (d) divided by the mass $\rho_{\text{bal}} V, or (\rho/\rho_{\text{bal}})a.$ The acceleration relative to the car is the difference between this acceleration and the car's acceleration, $a_{\text{rel}} = [(\rho/\rho_{\text{bal}}) - 1]a.$ f) For a balloon filled with air, $(\rho/\rho_{\text{bal}}) < 1$ (air balloons tend to sink in still air), and so the quantity in square brackets in the result of part (e) is negative; the balloon moves to the back of the car. For a helium balloon, the quantity in square brackets is positive, and the balloon moves to the front of the car.

Problema 14.79 Sears Zemansky

If the block were uniform, the buoyant force would be along a line directed through its geometric center, and the fact that the center of gravity is not at the geometric center does not affect the buoyant force. This means that the torque about the geometric center is due to the offset of the center of gravity, and is equal to the product of the block's weight and the horizontal displacement of the center of gravity from the geometric center, $(0.075\ \text{m})/\sqrt{2}.$ The block's mass is half of its volume times the density of water, so the net torque is

$$\frac{(0.30\ \text{m})^3(1000\ \text{kg/m}^3)}{2}(9.80\ \text{m/s}^2)\frac{0.075\ \text{m}}{\sqrt{2}} = 7.02\ \text{N}\cdot\text{m},$$

or $7.0\ \text{N}\cdot\text{m}$ to two figures. Note that the buoyant force and the block's weight form a couple, and the torque is the same about any axis.

Problema 14.80 Sears Zemansky

a) As in Example 14.8, the speed of efflux is $\sqrt{2gh}.$ After leaving the tank, the water is in free fall, and the time it takes any portion of the water to reach the ground is $t = \sqrt{\frac{2(H-h)}{g}},$ in which time the water travels a horizontal distance $R = vt = 2\sqrt{h(H-h)}.$

b) Note that if $h' = H - h, h'(H - h') = (H - h)h,$ and so $h' = H - h$ gives the same range. A hole $H - h$ below the water surface is a distance *h* above the bottom of the tank.

Problema 14.81 Sears Zemansky

The water will rise until the rate at which the water flows out of the hole is the rate at which water is added;

$$A\sqrt{2gh} = \frac{dV}{dt},$$

which is solved for

$$h = \left(\frac{dV/dt}{A}\right)^2 \frac{1}{2g} = \left(\frac{2.40\times10^{-4}\ \text{m}^3/\text{s}}{1.50\times10^{-4}\ \text{m}^2}\right)^2 \frac{1}{2(9.80\ \text{m/s}^2)} = 13.1\,\text{cm}.$$

Note that the result is independent of the diameter of the bucket.

Problema 14.82 Sears Zemansky

14.82: a) $v_3 A_3 = \sqrt{2g(y_1 - y_3)}A_3 = \sqrt{2(9.80\ \text{m/s}^2)(8.00\,\text{m})}(0.0160\,\text{m}^2) = 0.200\ \text{m}^3/\text{s}.$

b) Since p_3 is atmospheric, the gauge pressure at point 2 is

$$p_2 = \frac{1}{2}\rho(v_3^2 - v_2^2) = \frac{1}{2}\rho v_3^2\left(1 - \left(\frac{A_3}{A_2}\right)^2\right) = \frac{8}{9}\rho g(y_1 - y_3),$$

using the expression for v_3 found above. Subsititution of numerical values gives $p_2 = 6.97\times10^4$ Pa.

Problema 14.83 Sears Zemansky

The pressure difference, neglecting the thickness of the wing, is $\Delta p = (1/2)\,\rho(v_{\text{top}}^2 - v_{\text{bottom}}^2),$ and solving for the speed on the top of the wing gives

$$v_{\text{top}} = \sqrt{(120\ \text{m/s})^2 + 2(2000\,\text{Pa})/(1.20\ \text{kg/m}^3)} = 133\ \text{m/s}.$$

The pressure difference is comparable to that due to an altitude change of about $200\,\text{m},$ so ignoring the thickness of the wing is valid.

Problema 14.84 Sears Zemansky

a) Using the constancy of angular momentum, the product of the radius and speed is constant, so the speed at the rim is about $(200\ \text{km/h})\left(\frac{30}{350}\right) = 17\ \text{km/h}.$ b) The pressure is lower at the eye, by an amount

$$\Delta p = \frac{1}{2}(1.2\ \text{kg/m}^3)((200\ \text{km/h})^2 - (17\ \text{km/h})^2)\left(\frac{1\ \text{m/s}}{3.6\ \text{km/h}}\right)^2 = 1.8\times10^3\ \text{Pa}.$$

c) $\frac{v^2}{2g} = 160\,\text{m}$ to two figures. d) The pressure at higher altitudes is even lower.

Problema 14.85 Sears Zemansky

The speed of efflux at point *D* is $\sqrt{2gh_1}$, and so is $\sqrt{8gh_1}$ at *C*. The gauge pressure at *C* is then $\rho gh_1 - 4\rho gh_1 = -3\rho gh_1$, and this is the gauge pressure at *E*. The height of the fluid in the column is $3h_1$.

Problema 14.86 Sears Zemansky

a) $v = \frac{dV/dt}{A}$, so the speeds are

$$\frac{6.00\times10^{-3}\ \text{m}^3/\text{s}}{10.0\times10^{-4}\ \text{m}^2} = 6.00\ \text{m/s and}\ \frac{6.00\times10^{-3}\ \text{m}^3/\text{s}}{40.0\times10^{-4}\ \text{m}^2} = 1.50\ \text{m/s}.$$

b) $\Delta p = \frac{1}{2}\rho(v_1^2 - v_2^2) = 1.688\times10^4$ Pa, or 1.69×10^4 Pa to three figures.

c) $\Delta h = \frac{\Delta p}{\rho_{\text{H}_2\text{O}} g} = \frac{(1.688\times10^4\ \text{Pa})}{(13.6\times10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)} = 12.7\ \text{cm}.$

Problema 14.87 Sears Zemansky

a) The speed of the liquid as a function of the distance *y* that it has fallen is $v = \sqrt{v_0^2 + 2gy}$, and the cross-section area of the flow is inversely proportional to this speed. The radius is then inversely proportional to the square root of the speed, and if the radius of the pipe is r_0, the radius *r* of the stream a distance *y* below the pipe is

$$r = \frac{r_0\sqrt{v_0}}{(v_0^2 + 2gy)^{1/4}} = r_0\left(1 + \frac{2gy}{v_0^2}\right)^{-1/4}.$$

b) From the result of part (a), the height is found from $(1 + 2gy/v_0^2)^{1/4} = 2$, or

$$y = \frac{15v_0^2}{2g} = \frac{15(1.2\ \text{m/s})^2}{2(9.80\ \text{m/s}^2)} = 1.10\ \text{m}.$$

Problema 14.88 Sears Zemansky

a) The volume *V* of the rock is

$$V = \frac{B}{\rho_{\text{water}} g} = \frac{w - T}{\rho_{\text{water}} g} = \frac{((3.00\,\text{kg})(9.80\,\text{m/s}^2) - 21.0\,\text{N})}{(1.00 \times 10^3\,\text{kg/m}^3)(9.80\,\text{m/s}^2)} = 8.57 \times 10^{-4}\,\text{m}^3.$$

In the accelerated frames, all of the quantities that depend on *g* (weights, buoyant forces, gauge pressures and hence tensions) may be replaced by $g' = g + a,$ with the positive direction taken upward. Thus, the tension is $T = mg' - B' = (m - \rho V)g' = T_0 \frac{g'}{g},$ where $T_0 = 21.0\,\text{N}.$

b) $g' = g + a$; for $a = 2.50\,\text{m/s}^2, T = (21.0\,\text{N})\frac{9.80+2.50}{9.80} = 26.4\,\text{N}.$

c) For $a = -2.50\,\text{m/s}^2, T = (21.0\,\text{N})\frac{9.80-2.50}{9.80} = 15.6\,\text{N}.$

d) If $a = -g, g' = 0$ and $T = 0.$

Problema 14.89 Sears Zemansky

a) The tension in the cord plus the weight must be equal to the buoyant force, so

$$\begin{aligned} T &= Vg(\rho_{\text{water}} - \rho_{\text{foam}}) \\ &= (1/2)(0.20\,\text{m})^2(0.50\,\text{m})(9.80\,\text{m/s}^2)(1000\,\text{kg/m}^3 - 180\,\text{kg/m}^3) \\ &= 80.4\,\text{N}. \end{aligned}$$

b) The depth of the bottom of the styrofoam is not given; let this depth be $h_0.$ Denote the length of the piece of foam by *L* and the length of the two sides by *l*. The pressure force on the bottom of the foam is then $(p_0 + \rho g h_0)L\left(\sqrt{2}l\right)$ and is directed up. The pressure on each side is not constant; the force can be found by integrating, or using the result of Problem 14.44 or Problem 14.46. Although these problems found forces on vertical surfaces, the result that the force is the product of the average pressure and the area is valid. The average pressure is $p_0 + \rho g(h_0 - (l/(2\sqrt{2}))),$ and the force on one side has magnitude $(p_0 + \rho g(h_0 - l/(2\sqrt{2})))Ll$

and is directed perpendicular to the side, at an angle of $45.0°$ from the vertical. The force on the other side has the same magnitude, but has a horizontal component that is opposite that of the other side. The horizontal component of the net buoyant force is zero, and the vertical component is

$$B = (p_0 + \rho g h_0)Ll\sqrt{2} - 2(\cos 45.0°)(p_0 + \rho g(h_0 - l/(2\sqrt{2})))Ll = \rho g \frac{Ll^2}{2},$$

the weight of the water displaced.

Problema 14.90 Sears Zemansky

When the level of the water is a height *y* above the opening, the efflux speed is $\sqrt{2gy},$ and $\frac{dV}{dt} = \pi(d/2)^2\sqrt{2gy}.$ As the tank drains, the height decreases, and

$$\frac{dy}{dt} = -\frac{dV/dt}{A} = -\frac{\pi(d/2)^2\sqrt{2gy}}{\pi(D/2)^2} = -\left(\frac{d}{D}\right)^2\sqrt{2gy}.$$

This is a separable differential equation, and the time *T* to drain the tank is found from

$$\frac{dy}{\sqrt{y}} = -\left(\frac{d}{D}\right)^2\sqrt{2g}\,dt,$$

which integrates to

$$\left[2\sqrt{y}\,\right]_H^0 = -\left(\frac{d}{D}\right)^2\sqrt{2g}\,T,$$

or

$$T = \left(\frac{D}{d}\right)^2\frac{2\sqrt{H}}{\sqrt{2g}} = \left(\frac{D}{d}\right)^2\sqrt{\frac{2H}{g}}.$$

Problema 14.91 Sears Zemansky

a) The fact that the water first moves upwards before leaving the siphon does not change the efflux speed, $\sqrt{2gh}$. b) Water will not flow if the absolute (not gauge) pressure would be negative. The hose is open to the atmosphere at the bottom, so the pressure at the top of the siphon is $p_a - \rho g(H+h)$, where the assumption that the cross-section area is constant has been used to equate the speed of the liquid at the top and bottom. Setting $p = 0$ and solving for *H* gives $H = (p_a/\rho g) - h$.

Problema 14.92 Sears Zemansky

Any bubbles will cause inaccuracies. At the bubble, the pressure at the surfaces of the water will be the same, but the levels need not be the same. The use of a hose as a level assumes that pressure is the same at all point that are at the same level, an assumption that is invalidated by the bubble.