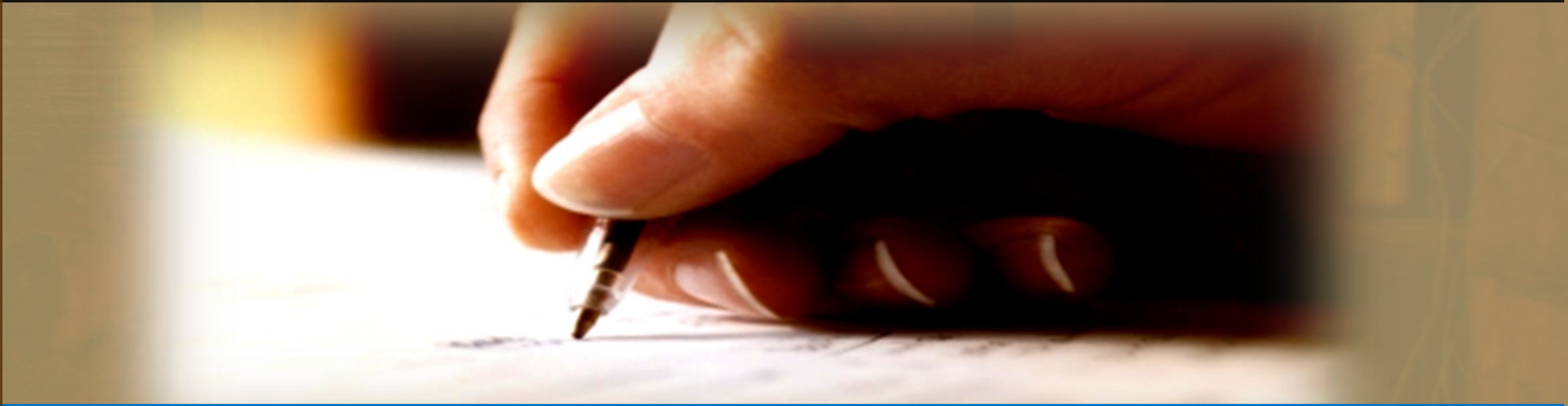
Institut Teknologi Sepuluh Nopember
Surabaya



STATIKA FLUIDA

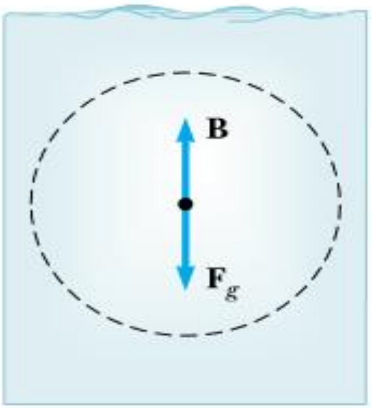
Oleh: Aulia Siti Aisjah
Tutug Dhanardono

OUT LINE

- Pengantar
- **Materi**
  - Statika Fluida
  - Tekanan Fluida
- Contoh Soal
- Ringkasan
- Latihan
- Asesmen

Capaian Pembelajaran:
Mampu menggunakan konsep Hukum Pasca dalam menentukan tekanan pada fluida statika

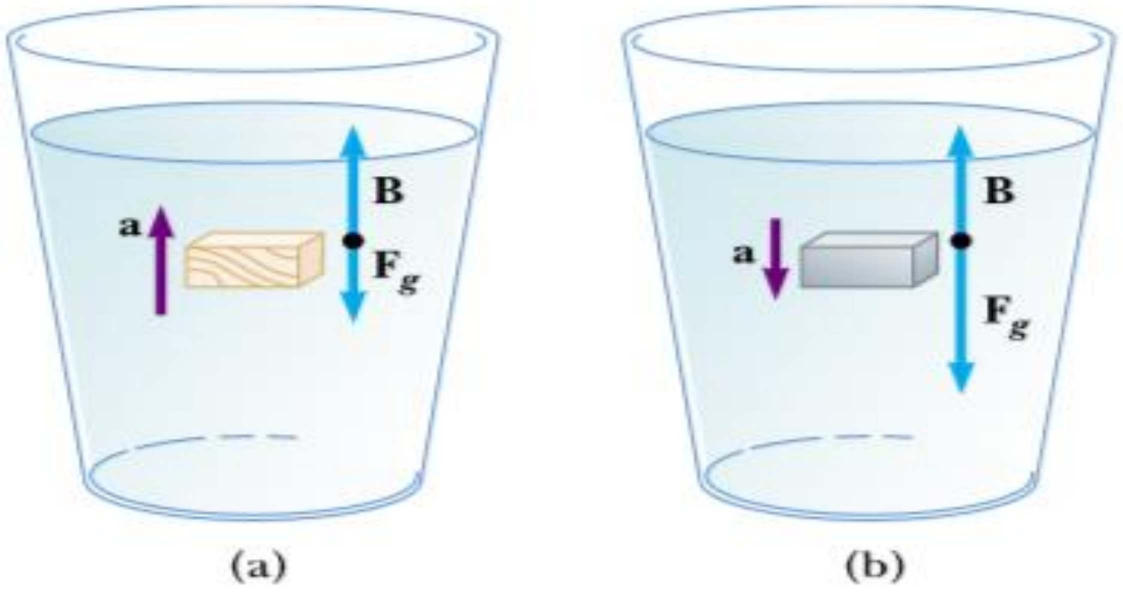
(a)



(b)

Perhatikan gambar di samping,

- Mengapa perempuan tsb harus memegang balon?
- Apakah yang akan terjadi bila dia tidak memegang balon?
- Apa peran balon thd posisi perempuan tsb?



Benda yang tercelup akan bergerak ke atas

Benda yang tercelup akan bergerak ke bawah

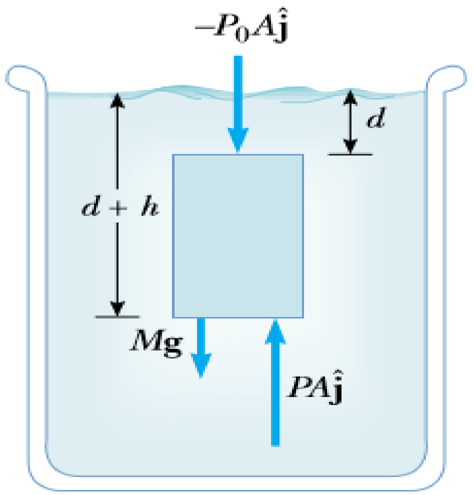
Ingatkah saat pelajaran Fisika di SMA, gaya apa saja yang akan terjadi pada benda yang dicelupkan di dalam air? Perhatikan gambar di samping.

TEKANAN DI DALAM FLUIDA

- Tekanan didefinisikan sebagai gaya normal persatuan luas.

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

P = tekanan (Pascal, N/m^2)
F = Gaya (Newton)
A = luas (m^2)



Tekanan udara luar

$$P_0 = 1.00 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$$

$$\sum \mathbf{F} = PA\hat{\mathbf{j}} - P_0A\hat{\mathbf{j}} - M\mathbf{g}\hat{\mathbf{j}} = 0$$

$$PA - P_0A - \rho Ahg = 0$$

$$PA - P_0A = \rho Ahg$$

$$P = P_0 + \rho gh$$

Quick Quiz 14.2 The pressure at the bottom of a filled glass of water (ρ = 1 000 kg/m^3) is P. The water is poured out and the glass is filled with ethyl alcohol (ρ = 806 kg/m^3). The pressure at the bottom of the glass is (a) smaller than P (b) equal to P (c) larger than P (d) indeterminate.

Sumber: Serway, Physics for Scientiest and Engineers

Tekanan di titik 2 = $P_2 = P_0 + \rho gh$

$P_2 - P_0 = \rho gh$ atau $\Delta P = \rho gh$

Tekanan ini tidak tergantung pada bentuk tempat.

Pada kedalaman yang sama tekanannya sama

Contoh soal :

Berapa selisih tekanan pada dasar tangki bila diisi penuh dengan bensin dan bila diisi penuh dengan alkohol. Tinggi tangki 3 m, dan gravitasi bumi g = 10 m/det^2.

Penyelesaian :

Bila diisi penuh dengan bensin : $P_2 = P_0 + \rho_{bensin}\, gh$

Bila diisi penuh dengan alkohol : $P_2 = P_0 + \rho_{alkohol}\, gh$

Sehingga selisihnya adalah :

$$\Delta P_2 = (P_0 + \rho_{alkohol}\, gh) - (P_0 + \rho_{bensin}\, gh) = (\rho_{alkohol} - \rho_{bensin})\, gh$$

$$\Delta P_2 = (0{,}79 \times 10^3 - 0{,}68 \times 10^3)\ 10 \times 3 = 3{,}3 \times 10^3 \text{ Pa}$$

Table 14.1

Densities of Some Common Substances at Standard Temperature (0°C) and Pressure (Atmospheric)

Substance	ρ (kg/m^3)	Substance	ρ (kg/m^3)
Air	1.29	Ice	0.917×10^3
Aluminum	2.70×10^3	Iron	7.86×10^3
Benzene	0.879×10^3	Lead	11.3×10^3
Copper	8.92×10^3	Mercury	13.6×10^3
Ethyl alcohol	0.806×10^3	Oak	0.710×10^3
Fresh water	1.00×10^3	Oxygen gas	1.43
Glycerin	1.26×10^3	Pine	0.373×10^3
Gold	19.3×10^3	Platinum	21.4×10^3
Helium gas	1.79×10^{-1}	Seawater	1.03×10^3
Hydrogen gas	8.99×10^{-2}	Silver	10.5×10^3

Sumber: Serway, Physics for Scientiest and Engineers

Water is filled to a height H behind a dam of width w (Fig. 14.5). Determine the resultant force exerted by the water on the dam.

Solution Because pressure varies with depth, we cannot calculate the force simply by multiplying the area by the pressure. We can solve the problem by using Equation 14.2 to find the force dF exerted on a narrow horizontal strip at depth h and then integrating the expression to find the total force. Let us imagine a vertical y axis, with $y = 0$ at the bottom of the dam and our strip a distance y above the bottom.

We can use Equation 14.4 to calculate the pressure at the depth h; we omit atmospheric pressure because it acts on both sides of the dam:

$$P = \rho g h = \rho g(H - y)$$

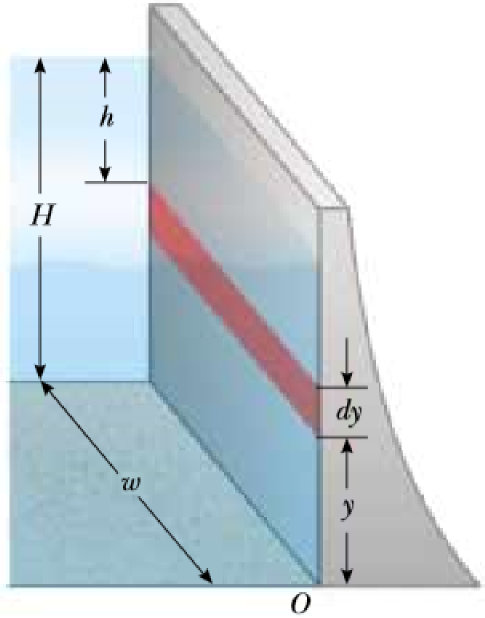


Figure 14.5 (Example 14.4)

Sumber: Serway, Physics for Scientiest and Engineers

Using Equation 14.2, we find that the force exerted on the shaded strip of area $dA = w\,dy$ is

$$dF = P\,dA = \rho g(H - y)w\,dy$$

Therefore, the total force on the dam is

$$F = \int P\,dA = \int_0^H \rho g(H - y)w\,dy = \frac{1}{2}\rho g w H^2$$

Note that the thickness of the dam shown in Figure 14.5 increases with depth. This design accounts for the greater and greater pressure that the water exerts on the dam at greater depths.

What If? **What if you were asked to find this force without using calculus? How could you determine its value?**

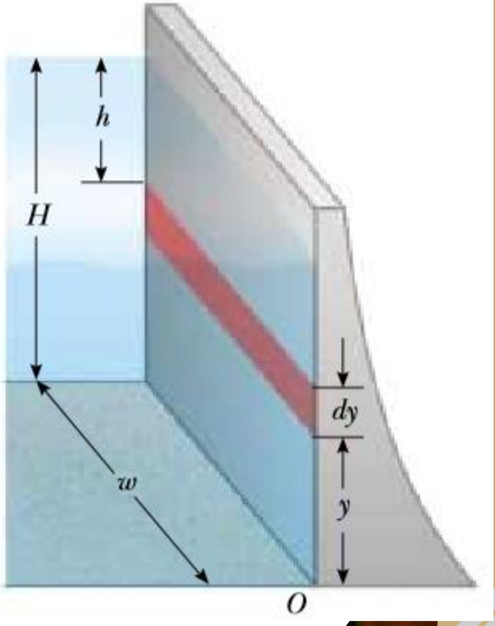
Answer We know from Equation 14.4 that the pressure varies linearly with depth. Thus, the average pressure due to the water over the face of the dam is the average of the pressure at the top and the pressure at the bottom:

$$P_{av} = \frac{P_{top} + P_{bottom}}{2} = \frac{0 + \rho g H}{2} = \frac{1}{2}\rho g H$$

Now, the total force is equal to the average pressure times the area of the face of the dam:

$$F = P_{av}A = (\tfrac{1}{2}\rho g H)(Hw) = \tfrac{1}{2}\rho g w H^2$$

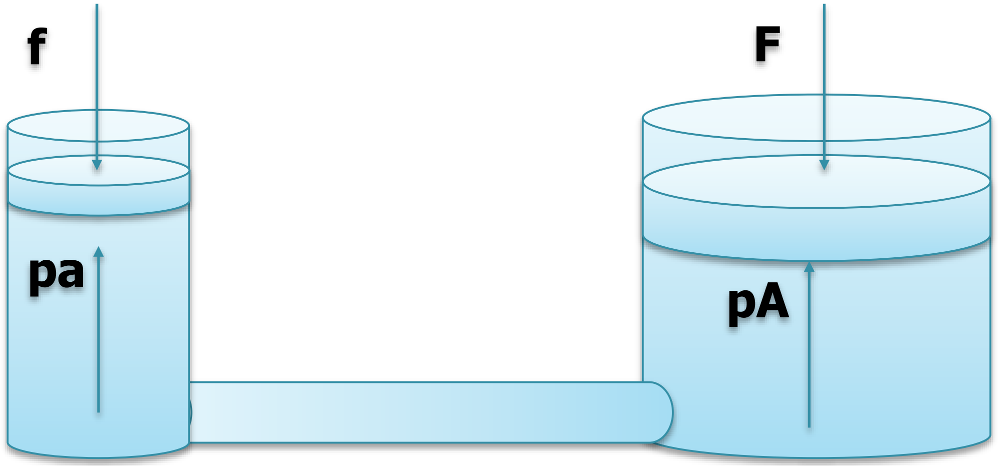
which is the same result we obtained using calculus.



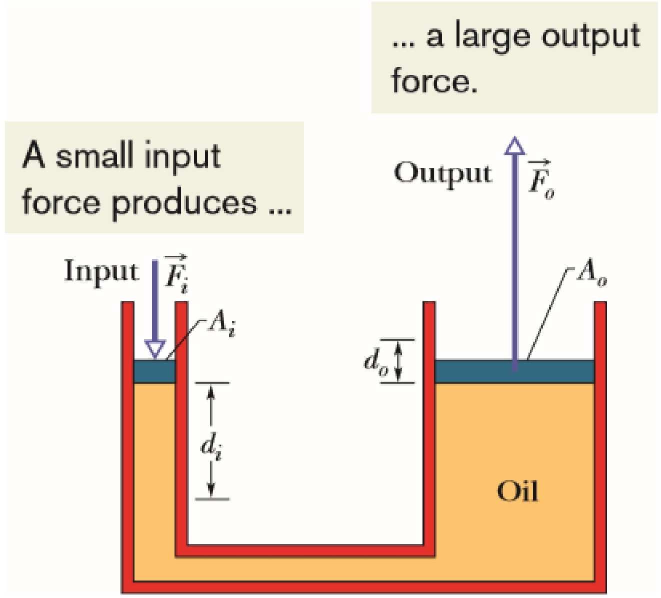
Sumber: Serway, Physics for Scientiest and Engineers

HUKUM PASCAL

Tekanan yang diberikan pada fluida diteruskan kesetiap bagian fluida dengan sama besar (termasuk pada dinding tempat fluida)



Tekanan hidrolis, diteruskan kesetiap bagian fluida dengan sama besar
Tekanan di kaki kiri = tekanan di kaki kanan



$$p = \frac{f}{a} = \frac{F}{A} \quad \text{atau} \quad F = f\,\frac{A}{a}$$

Misal a= 0,1 m^2 , A = 1 m^2, f = 1 N, maka F =1 (1/0,1) = 10 N

Manometer

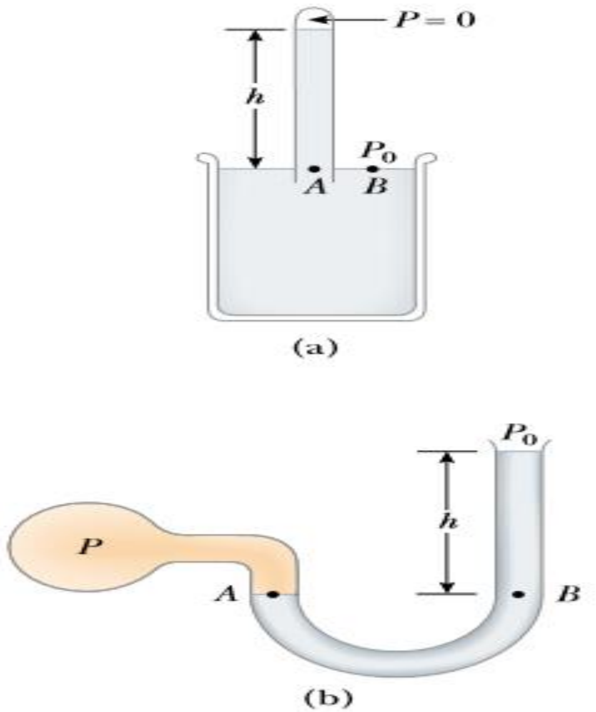


Figure 14.6 Two devices for measuring pressure: (a) a mercury barometer and (b) an open-tube manometer.

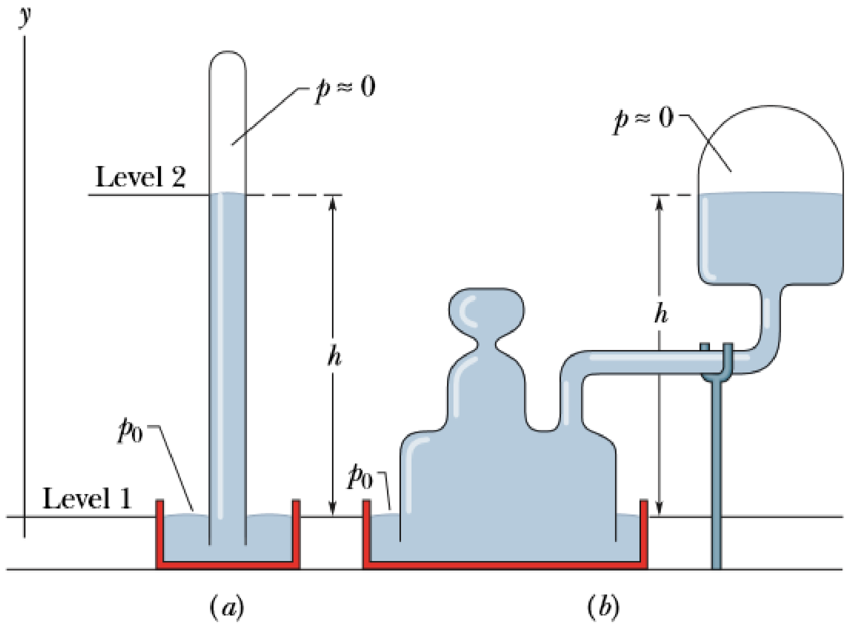
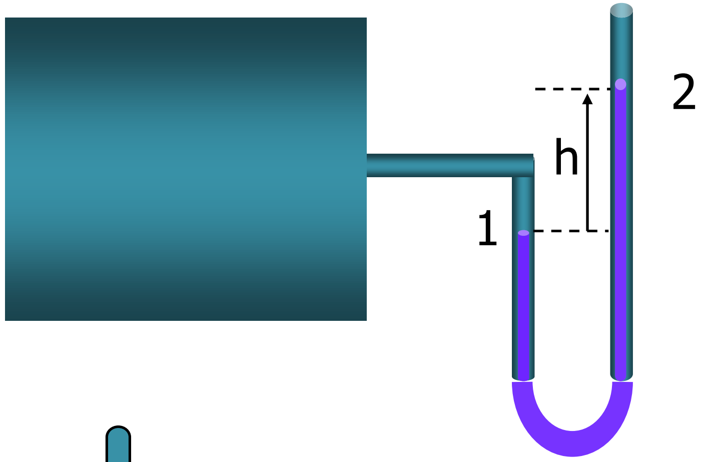


Fig. 14-5 (*a*) A mercury barometer. (*b*) Another mercury barometer. The distance *h* is the same in both cases.

ALAT UKUR TEKANAN

MANOMETER : ALAT UKUR TEKANAN RUANG TERTUTUP



Tekanan Pada titik 1 (pada pipa kiri = pada pipa kanan) :

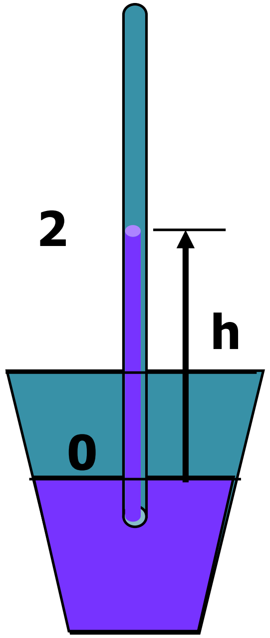
$P = p_1 = \rho\, g\, h + p_2$

Jadi $p_1 - p_2 = \rho\, g\, h$

Atau $p - p_o = \rho\, g\, h$

$P - P_o$ = selisih tekanan di dalam tabung dan diluar tabung, disebut ***Pressure gauge***

BAROMETER : ALAT UKUR TEKANAN RUANG TERBUKA



$P_o = \rho\, g\, h + p_2$

$P_2 = 0$

$P_o = \rho\, g\, h$

Quick Quiz 14.3 Several common barometers are built, with a variety of fluids. For which of the following fluids will the column of fluid in the barometer be the highest? (a) mercury (b) water (c) ethyl alcohol (d) benzene

Quick Quiz 14.4 You have invented a spacesuit with a straw passing through the faceplate so that you can drink from a glass while on the surface of a planet. Out on the surface of the Moon, you attempt to drink through the straw from an open glass of water. The value of g on the Moon is about one sixth of that on Earth. Compared to the difficulty in drinking through a straw on Earth, you find drinking through a straw on the Moon to be (a) easier (b) equally difficult (c) harder (d) impossible.

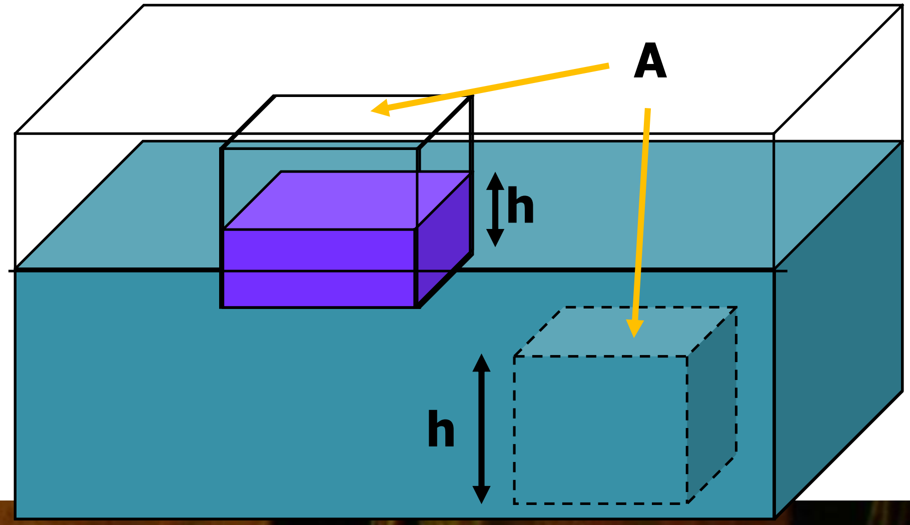
PRINSIP ARCHIMEDES

Gaya tekan ke atas yang dialami oleh benda yang tercelup di dalam fluida sama dengan berat fluida yang dipindahkan

Massa fluida yang dipindahkan = rapat massa fluida x volume fluida yang dipindahkan

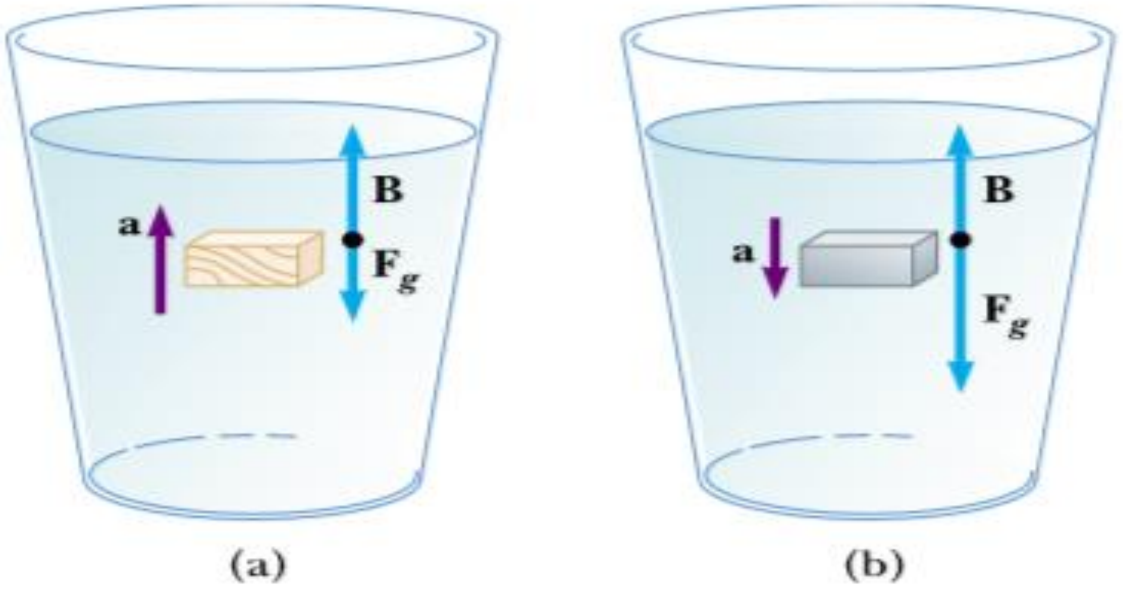
Volume fluida yang dipindahkan = volume benda yang tercelup

V = A x h



$$\textit{Gaya tekan ke atas} = \textit{berat fluida yang dipindahkan}$$

$$F_B = \rho_f V_f \, g = \frac{m_f}{V_f} V_f \, g = m \, g$$



Benda yang tercelup akan bergerak ke atas

Bila:

$\rho_f > \rho_{obj}$

Benda yang tercelup akan bergerak ke bawah

Bila:

$\rho_f < \rho_{obj}$

$$B - F_g = \rho_f V_{obj}\, g - \rho_{obj} V_{obj}\, g$$

$$= (\rho_f - \rho_{obj})\, V_{obj}\, g$$

Quick Quiz 14.5 An apple is held completely submerged just below the surface of a container of water. The apple is then moved to a deeper point in the water. Compared to the force needed to hold the apple just below the surface, the force needed to hold it at a deeper point is (a) larger (b) the same (c) smaller (d) impossible to determine.

Quick Quiz 14.6 A glass of water contains a single floating ice cube (Fig. 14.11). When the ice melts, does the water level (a) go up (b) go down (c) remain the same?

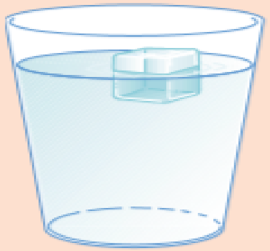


Figure 14.11 (Quick Quiz 14.6) An ice cube floats on the surface of water. What happens to the water level as the ice cube melts?

Quick Quiz 14.7 You are shipwrecked and floating in the middle of the ocean on a raft. Your cargo on the raft includes a treasure chest full of gold that you found before your ship sank, and the raft is just barely afloat. To keep you floating as high as possible in the water, should you (a) leave the treasure chest on top of the raft (b) secure the treasure chest to the underside of the raft (c) hang the treasure chest in the water with a rope attached to the raft? (Assume that throwing the treasure chest overboard is not an option you wish to consider!)

Archimedes supposedly was asked to determine whether a crown made for the king consisted of pure gold. Legend has it that he solved this problem by weighing the crown first in air and then in water, as shown in Figure 14.12. Suppose the scale read 7.84 N in air and 6.84 N in water. What should Archimedes have told the king?

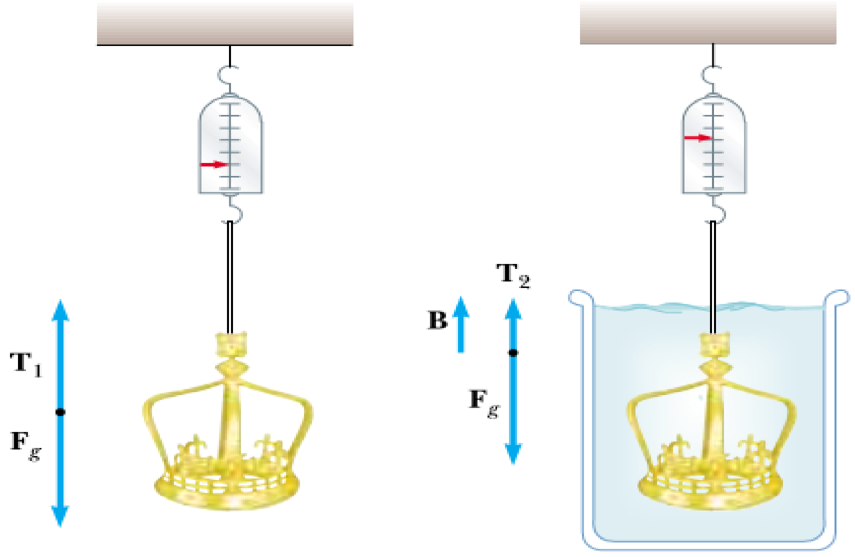
Solution Figure 14.12 helps us to conceptualize the problem. Because of our understanding of the buoyant force, we realize that the scale reading will be smaller in Figure 14.12b than in Figure 14.12a. The scale reading is a measure of one of the forces on the crown, and we recognize that the crown is stationary. Thus, we can categorize this as a force equilibrium problem. To analyze the problem, note that when the crown is suspended in air, the scale reads the true weight $T_1 = F_g$ (neglecting the buoyancy of air). When it is immersed in water, the buoyant force **B** reduces the scale reading to an *apparent* weight of $T_2 = F_g - B$. Because the crown is in equilibrium, the net force on it is zero. When the crown is in water,

$$\sum F = B + T_2 - F_g = 0$$

so that

$$B = F_g \quad T_2 = 7.84\ \text{N} \quad 6.84\ \text{N} = 1.00\ \text{N}$$

Because this buoyant force is equal in magnitude to the weight of the displaced water, we have $\rho_w g V_w = 1.00$ N, where V_w is the volume of the displaced water and ρ_w is its



(a) (b)

Figure 14.12 (Example 14.5) (a) When the crown is suspended in air, the scale reads its true weight because $T_1 = F_g$ (the buoyancy of air is negligible). (b) When the crown is immersed in water, the buoyant force **B** changes the scale reading to a lower value $T_2 = F_g - B$.

density. Also, the volume of the crown V_c is equal to the volume of the displaced water because the crown is completely submerged. Therefore,

$$V_c = V_w = \frac{1.00\ \text{N}}{\rho_w g} = \frac{1.00\ \text{N}}{(1\,000\ \text{kg/m}^3)(9.80\ \text{m/s}^2)}$$
$$= 1.02 \times 10^{-4}\ \text{m}^3$$

Finally, the density of the crown is

$$\rho_c = \frac{m_c}{V_c} = \frac{m_c g}{V_c g} = \frac{7.84\ \text{N}}{(1.02 \times 10^{-4}\ \text{m}^3)(9.80\ \text{m/s}^2)}$$
$$= 7.84 \times 10^3\ \text{kg/m}^3$$

To finalize the problem, from Table 14.1 we see that the density of gold is $19.3 \times 10^3\ \text{kg/m}^3$. Thus, Archimedes should have told the king that he had been cheated. Either the crown was hollow, or it was not made of pure gold.

What If? Suppose the crown has the same weight but were indeed pure gold and not hollow. What would the scale reading be when the crown is immersed in water?

Answer We first find the volume of the solid gold crown:

$$V_c = \frac{m_c}{\rho_c} = \frac{m_c g}{\rho_c g} = \frac{7.84\ \text{N}}{(19.3 \times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)}$$
$$= 4.15 \times 10^{-5}\ \text{m}^3$$

Now, the buoyant force on the crown will be

$$B = \rho_w g V_w = \rho_w g V_c$$
$$= (1.00 \times 10^3\ \text{kg/m}^3)(9.80\ \text{m/s}^2)(4.15 \times 10^{-5}\ \text{m}^3)$$
$$= 0.406\ \text{N}$$

and the tension in the string hanging from the scale is

$$T_2 = F_g - B = 7.84\ \text{N} - 0.406\ \text{N} = 7.43\ \text{N}$$

CONTOH SOAL

Contoh Soal

Sebuah patung kuno 70 kg terbaring di dasar laut. Volumenya 3.10^4 cm^3. Berapa gaya yang diperlukan untuk mengangkatnya

Penyelesaian :

Gaya apung (gaya tekan ke atas) pada patung disebabkan air laut sama dengan berat air laut yang dipindahkan

$3.10^4\ cm^3 = 3.10^{-2}\ m^3$

Massa jenis air laut $\rho_{air\ laut}$ = **1,025 x 10^3 kg/m^3.**

F_B = $m_{air\ laut}$ x g = $\rho_{air\ laut}\ g\ V_{patung}$

= **1,025 x 10^3 (9,8)** $(3.10^{-2}) = 3.10^2$ N

Berat patung = m_{patung} g = 70 x 9,8 = 6,9 10^2 N

Jadi gaya yang diperlukan untuk mengangkat = 6,9 10^2 - 3.10^2

= $3{,}9.10^2$ N

Bongkah es dengan volume 10 cm^3 mengapung didalam gelas yang berisi air. Berapa cm^3 bagian yang menonjol diatas permukaan air ?. (massa jenis es = 0.917 x 10^3 kg/m^3. = 0,917 g/cm^3, massa jenis air = 1 x 10^3 kg/m^3. = 1 g/cm^3)

Penyelesaian : Menurut prinsip Archimedes :

Gaya tekan ke atas = berat fluida yang dipindahkan

Volume es seluruhnya V = 10 cm^3,

Massa es seluruhnya $m_{es} = \rho_{es} V = 0{,}917 \times 10 = 9{,}17$ gram

Berat es seluruhnya $W_{es} = m_{es}\, g = 9{,}17\, g$ Newton

Misal bagian es yang tercelup volumenya = $V_{c,}$ dan bagian es yang terapung volumenya = V_a

Jadi : $V_c = V - V_a = (10 – V_a)$ cm^3.

Volume es yang tercelup V_c = volume air yang dipindahkan

Berat air yang dipindahkan $W_a = m_a\, g$

$W_a = \rho_a V_c g = 1 \times (10 – V_a)\, g = (10 – V_a)\, g$

W_a ini adalah gaya apung Archimedes, B. Jadi B = $(10 – V_a)\, g$

Dalam kead.setimbang : Gaya apung (keatas) = berat es seluruhnya (kebawah)

Gaya apung B = $(10 – V_a)\, g$ = Berat es seluruhnya $W_{es} = m_{es}\, g = 9{,}17\, g$

$(10 – V_a)\, g = 9{,}17\, g$

$V_a = 10 – 9{,}17 = 0{,}83$ cm^3.

Jadi volume es yang terapung adalah 0,83 cm3.

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7. The spring of the pressure gauge shown in Figure 14.2 has a force constant of 1 000 N/m, and the piston has a diameter of 2.00 cm. As the gauge is lowered into water, what change in depth causes the piston to move in by 0.500 cm?

8. The small piston of a hydraulic lift has a cross-sectional area of 3.00 cm^2, and its large piston has a cross-sectional area of 200 cm^2 (Figure 14.4). What force must be applied to the small piston for the lift to raise a load of 15.0 kN? (In service stations, this force is usually exerted by compressed air.)

9. What must be the contact area between a suction cup (completely exhausted) and a ceiling if the cup is to support the weight of an 80.0-kg student?

10. (a) A very powerful vacuum cleaner has a hose 2.86 cm in diameter. With no nozzle on the hose, what is the weight of the heaviest brick that the cleaner can lift? (Fig. P14.10a) (b) **What If?** A very powerful octopus uses one sucker of diameter 2.86 cm on each of the two shells of a clam in an attempt to pull the shells apart (Fig. P14.10b). Find the greatest force the octopus can exert in salt water 32.3 m deep. *Caution:* Experimental verification can be interesting, but do not drop a brick on your foot. Do not overheat the motor of a vacuum cleaner. Do not get an octopus mad at you.

Sekian dan Terimakasih