Institut Teknologi Sepuluh Nopember
Surabaya

Ekspansi Termal dari Material Padat dan Cair

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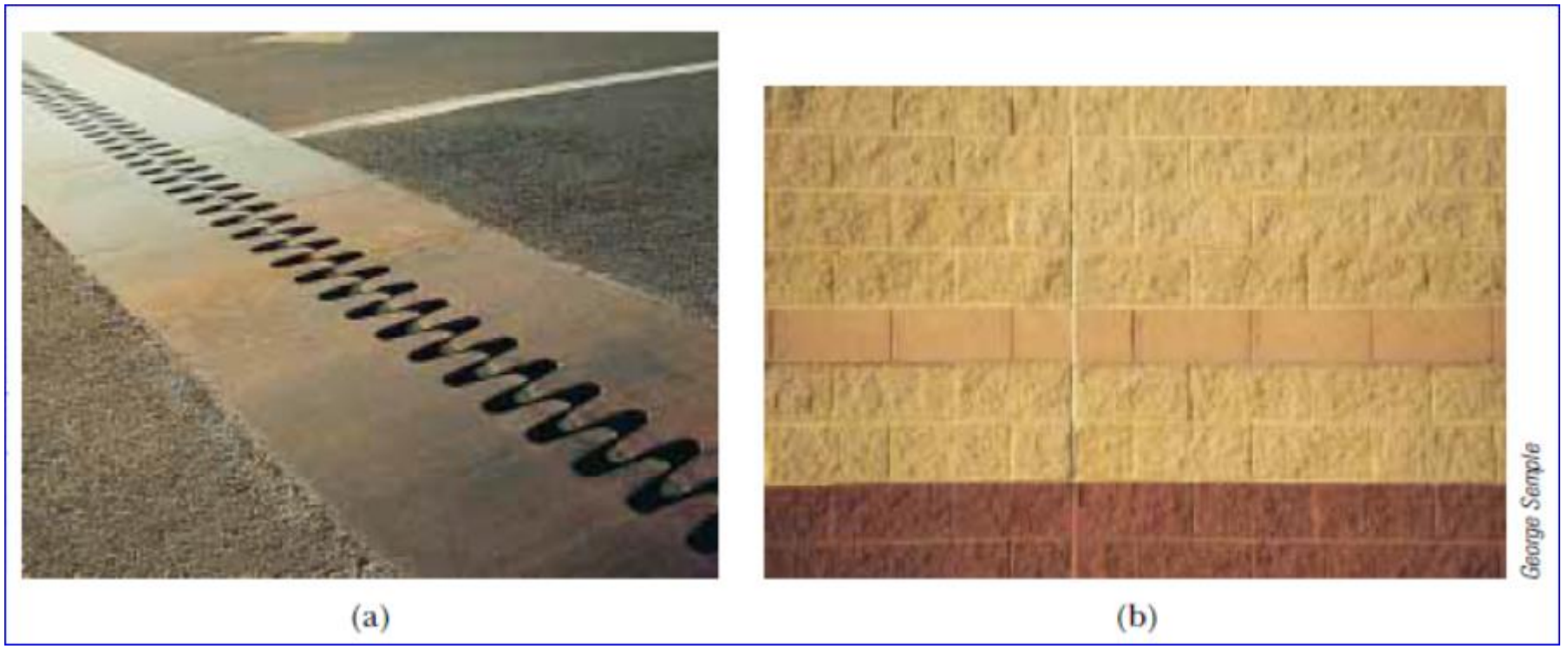
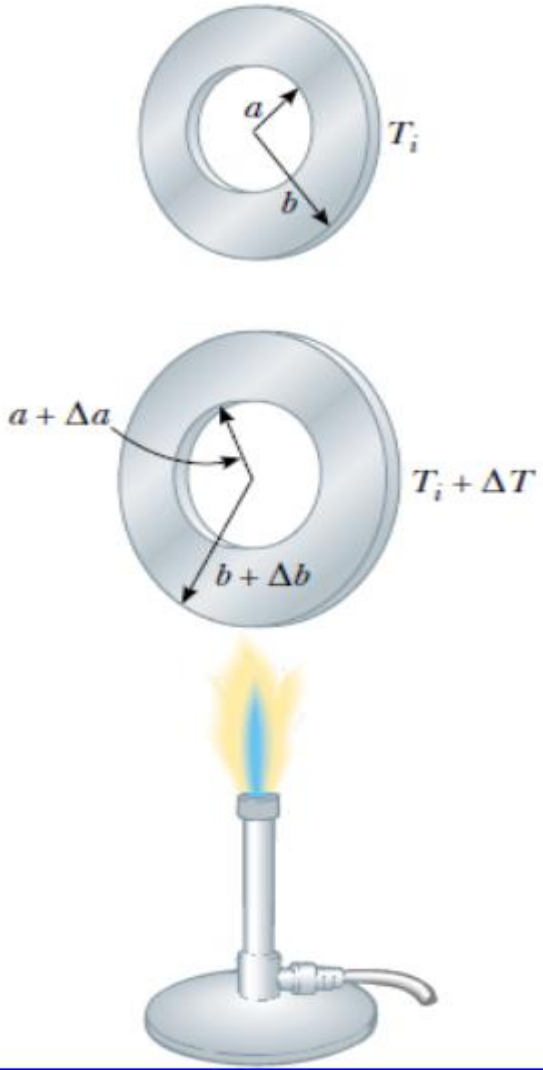


(a) (b)

Perhatikan gambar – sambungan (baja) pada jembatan (a)
Dan terkadang ada retakan pada sebuah dinding (b)



Perubahan ukuran / ketebalan jari-jari sebuah silinder terjadi akibat adanya energi panas (termal) yang diberikan kepada benda.

Sebuah koefisien pemuaian linier material / benda:

$$\alpha \equiv \frac{\Delta L / L_i}{\Delta T}$$

Pertambahan panjang sebuah benda:

$$\Delta L = \alpha L_i \Delta T$$

$$L_f - L_i = \alpha L_i (T_f - T_i)$$

Table 19.1

Average Expansion Coefficients for Some Materials Near Room Temperature

Material	Average Linear Expansion Coefficient $(\alpha)(^\circ C)^{-1}$	Material	Average Volume Expansion Coefficient $(\beta)(^\circ C)^{-1}$
Aluminum	24×10^{-6}	Alcohol, ethyl	1.12×10^{-4}
Brass and bronze	19×10^{-6}	Benzene	1.24×10^{-4}
Copper	17×10^{-6}	Acetone	1.5×10^{-4}
Glass (ordinary)	9×10^{-6}	Glycerin	4.85×10^{-4}
Glass (Pyrex)	3.2×10^{-6}	Mercury	1.82×10^{-4}
Lead	29×10^{-6}	Turpentine	9.0×10^{-4}
Steel	11×10^{-6}	Gasoline	9.6×10^{-4}
Invar (Ni–Fe alloy)	0.9×10^{-6}	Air[a] at 0°C	3.67×10^{-3}
Concrete	12×10^{-6}	Helium[a]	3.665×10^{-3}

Sebuah benda yang berukuran Panjang, Lebar dan Ketebalan tertentu (Volume tertentu), bila terkena energi panas, maka secara alami akan mengalami perubahan volume.

$$\Delta V = \beta V_i \Delta T$$

Perubahan Volume (pertambahan / pengurangan) sebanding dengan besarnya koefisien ekspansi volume dan besarnya perubahan (pertambahan / pengurangan) suhu

$$\begin{aligned} V_i + \Delta V &= (\ell + \Delta\ell)(w + \Delta w)(h + \Delta h) \\ &= (\ell + \alpha\ell\,\Delta T)(w + \alpha w\,\Delta T)(h + \alpha h\,\Delta T) \\ &= \ell w h(1 + \alpha\,\Delta T)^3 \\ &= V_i[1 + 3\alpha\,\Delta T + 3(\alpha\,\Delta T)^2 + (\alpha\,\Delta T)^3] \end{aligned}$$

Pendekatan koefisien ekspansi Volume, diperoleh dari bentuk persamaan di samping

$$\frac{\Delta V}{V_i} = 3\alpha\,\Delta T + 3(\alpha\,\Delta T)^2 + (\alpha\,\Delta T)^3$$

Untuk kondisi $\Delta T < 100$ deg C, maka akan berlaku:

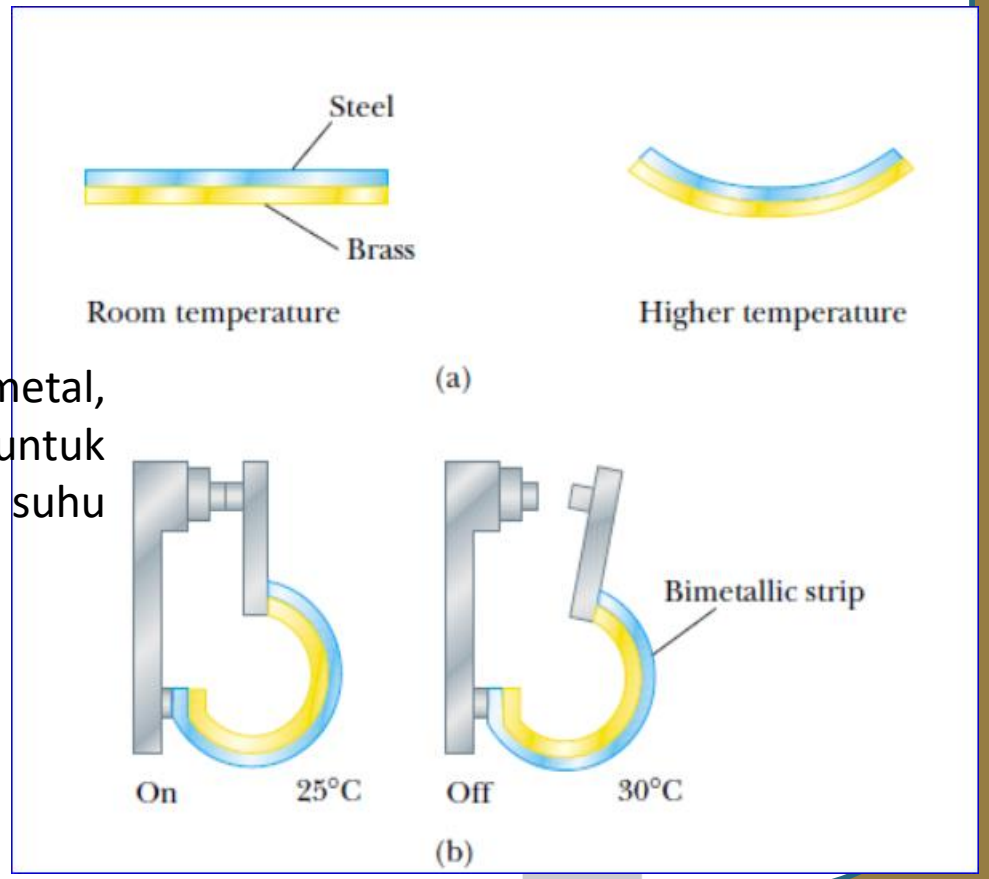
$$\frac{\Delta V}{V_i} = 3\alpha\,\Delta T + 3(\alpha\,\Delta T)^2 + (\alpha\,\Delta T)^3$$

$$\frac{\Delta V}{V_i} = 3\alpha\,\Delta T$$

$$3\alpha = \frac{1}{V_i}\frac{\Delta V}{\Delta T}$$

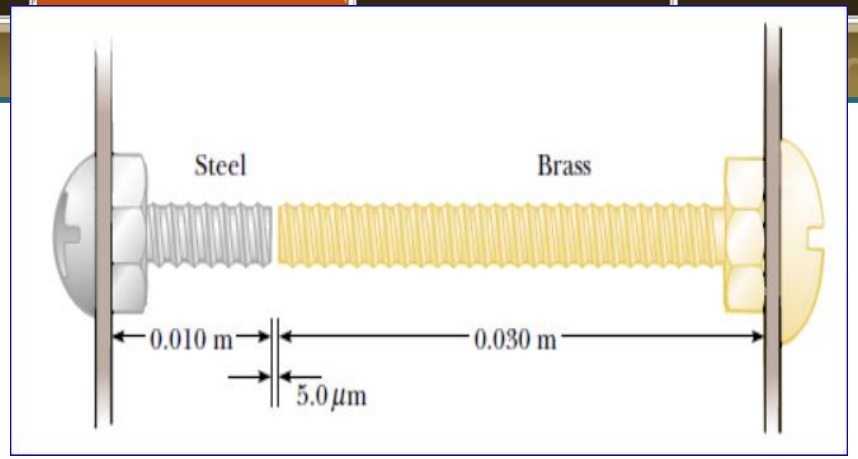
$$3\alpha = \beta,$$

Beberapa bentuk bimetal, yang digunakan untuk pengukuran suhu



Quick Quiz 19.3 If you are asked to make a very sensitive glass thermometer, which of the following working liquids would you choose? (a) mercury (b) alcohol (c) gasoline (d) glycerin

Quick Quiz 19.4 Two spheres are made of the same metal and have the same radius, but one is hollow and the other is solid. The spheres are taken through the same temperature increase. Which sphere expands more? (a) solid sphere (b) hollow sphere (c) They expand by the same amount. (d) not enough information to say



An electronic device has been poorly designed so that two bolts attached to different parts of the device almost touch each other in its interior, as in Figure 19.10. The steel and brass bolts are at different electric potentials and if they touch, a short circuit will develop, damaging the device. (We will study electric potential in Chapter 25.) If the initial gap between the ends of the bolts is 5.0 μm at 27°C, at what temperature will the bolts touch?

Solution We can conceptualize the situation by imagining that the ends of both bolts expand into the gap between them as the temperature rises. We categorize this as a thermal expansion problem, in which the *sum* of the changes in length of the two bolts must equal the length of the initial gap between the ends. To analyze the problem, we write this condition mathematically:

$$\Delta L_{br} + \Delta L_{st} = \alpha_{br} L_{i,br} \Delta T + \alpha_{st} L_{i,st} \Delta T = 5.0 \times 10^{-6}\ \text{m}$$

Solving for ΔT, we find

$$\Delta T = \frac{5.0 \times 10^{-6}\ \text{m}}{\alpha_{br} L_{i,br} + \alpha_{st} L_{i,st}}$$

$$= \frac{5.0 \times 10^{-6}\ \text{m}}{(19 \times 10^{-6}\,^{\circ}\text{C}^{-1})(0.030\ \text{m}) + (11 \times 10^{-6}\,^{\circ}\text{C}^{-1})(0.010\ \text{m})}$$

$$= 7.4^{\circ}\text{C}$$

Thus, the temperature at which the bolts touch is 27°C + 7.4°C = 34°C To finalize this problem, note that this temperature is possible if the air conditioning in the building housing the device fails for a long period on a very hot summer day.

Terima Kasih