Answers to Review Questions/5.4:

1. When you heat around the steel cork, it expands faster than glass since its coefficient of thermal expansion exceeds that of glass. Heating helps to open it easily.
2. Heating a thin, circular ring make it wider.
3. **Given**: $\alpha_{st} = 11\times10^{-6}\,°C^{-1}$, L_0 = 60 m, T_0= 0.0°C, T = 40.0°C

   The final length is

   $$L = L_0\left(1+\alpha_{st}\Delta T\right) = 60m\times\left(1+11\times10^{-6}\,°C^{-1}\times 40°C\right)$$
   $$L = 60.0264\,m$$
4. If glass were to expand more than the liquid, the liquid level would fall relative to the tube wall as the thermometer is warmed. If the liquid and the tube material were to expand by equal amounts, the thermometer could not be used because the liquid level would not change with temperature.
5. Mercury is used in thermometers because it has a high coefficient of expansion compared to that of the glass so that even a small rise in temperature brings about sufficient expansion which can be detected in the capillary of the calibrated part of the thermometer.
6. Since rings get wider on heating, the ring gets wider on heating and allows the ball to pass through. When cooled, the ring gets contracted and does not allow the ball to pass through.
7. **Given**: d_p = 10 cm, d_s = 9.9 cm, $\alpha = 11\times10^{-6}\,°C^{-1}$

Change in temperature, ΔT, to increase the diameter of the steel cylinder to d_p is derived from $d_p = d_s\left(1+\alpha_s\Delta T\right)$ to be

$$\Delta T = \frac{d_p - d_s}{\alpha_s d_s} = \frac{10\text{ cm} - 9.9\text{ cm}}{11\times10^{-6}\,°C^{-1}\times 9.9\text{ cm}} = 91.83\,°C$$

Therefore, the desired change in temperature should be

$$\Delta T \geq 91.83°C$$

8. **Given:** V_0 = 300 L, $\gamma_a = \gamma_{r,ethyl} - \gamma_{steel} = 107.8\times10^{-5}\,{}^{O}C$, T_0 = 10°C, T = 100 °C.

The Ethyl alcohol that over flows if the system is heated to 100 °C, is

$$\Delta V = V_0\gamma_a\Delta T = 300L \times 107.8 \times 10^{-5}\,°C^{-1} \times \left(100°C^{-1} - 10°C^{-1}\right) = 29.106L$$

The ethyl alcohol overflown is 29.106L.

9. **Given**: $L_0 = 40.0cm$, $T_0 = 0°C$, $T= 100\,°C$, $\Delta L_1 = 0.08cm$, $\Delta L_2 = 0.05cm$, $\Delta L_3 = 0.06cm$

The change in length of the composite bar is

$$\Delta L_3 = \left[\alpha_1 x + \alpha_2\left(L_0 - x\right)\right]\Delta T$$

Solving this for x, we obtain

$$x = \frac{\Delta L_3 - \alpha_2 L_0 \Delta T}{\left(\alpha_1 - \alpha_2\right)\Delta T}$$

But $\alpha_1 = \dfrac{\Delta L_1}{L_0\Delta T}$ and $\alpha_2 = \dfrac{\Delta L_2}{L_0\Delta T}$. Substituting these into the above and simplifying yields

$$x = \left(\frac{\Delta L_3 - \Delta L_2}{\Delta L_1 - \Delta L_2}\right)L_0 = \left(\frac{0.06cm - 0.05cm}{0.08cm - 0.05cm}\right) \times 40.0cm = 13.3cm$$

And the length of the second bar is $L_0 - x = 40.0cm - 13.3cm = 26.7cm$

10. **Given**: $\Delta T = 5\,°C$, $d_0 = 12{,}742\ km$, $\alpha = 1.2 \times 10^{-5}\,°C^{-1}$

The change in diameter is

$$\Delta d = \alpha d_0\,\Delta T = 1.2 \times 10^{-5}\,°C^{-1} \times 12{,}742km \times 5°C = 0.76452km$$

The all round clearance between the hoop and the earth's surface becomes

$$\Delta r = \frac{1}{2}\Delta d = 0.38226km = 38.226cm$$

11. The new length, L, is

$$L = 3L_0 + (2\alpha_b + \alpha_s)(L_0\Delta T)$$
$$L = [3 + (2\alpha_b + \alpha_s)T]\,L_0$$

12. $L_{0s} - L_{0Cu} = 0.05\ cm$, $T_0 = 0°C$

The temperature, T, at which $L_s = L_{Cu}$, is obtained as follows.

$$L_{0Cu}\left[1 + \alpha_{Cu}\left(T - T_0\right)\right] = L_{0s}\left[1 + \alpha_s\left(T - T_0\right)\right]$$

But $L_{0s} = L_{0Cu} + 0.05cm$, then

$$L_{0Cu}\left[1 + \alpha_{Cu}\left(T - T_0\right)\right] = \left(L_{0Cu} + 0.05cm\right)\left[1 + \alpha_s\left(T - T_0\right)\right]$$

$$L_{0Cu}\left(1+\alpha_{Cu}T\right) = \left(L_{0Cu} + 0.05cm\right)\left(1+\alpha_s T\right)$$

$$T = \frac{0.05cm}{100cm\times\left(17\times10^{-6}{}^\circ C^{-1} - 11\times10^{-6}{}^\circ C^{-1}\right) - 11\times10^{-6}{}^\circ C^{-1}\times 0.05cm}$$

$$T = 83.41^\circ C$$

13. **Given**: $A_0 = 0.05\ m^2$, $\alpha = 9 \text{ x } 10^{-6}\ {}^\circ C^{-1}$, $\Delta T = 96\ {}^\circ C$

$$\Delta A = \beta\ A_0\ \Delta T = 2\alpha\ A_0 \Delta T$$

$$\Delta A = 2\times 9 \text{ x } 10^{-6}{}^\circ C^{-1}\times 0.05\ m^2\times 96^\circ C = 0.864cm^2$$

14. $\Delta V = \gamma V_0 \Delta T = 2.1 \text{ x } 10^{-4}\ {}^\circ C^{-1}\times 1.0\ m^3 \times 80^\circ C$

$$\Delta V = 0.0168m^3$$