1.

$\ell = 1000\,m$

$T_{winter} = 0.00\,^\circ C$

$T_{summer} = 40.0\,^\circ C$

$\alpha_{steel} = 10.5 \times 10^{-6}\,K^{-1}$

$\Delta L = \alpha \ell_0 \Delta T$

$\Delta L = (10.5 \times 10^{-6}\,K^{-1})(1000\,m)(40.0^\circ C - 0.00^\circ C)$

$\boxed{\Delta L = 0.42\,m}$

2.

$\alpha_{aluminum} = 24 \times 10^{-6}\,K^{-1}$

$T_0 = 15^\circ C$

$\ell_0 = 62.1\,m$

$T_1 = 200^\circ C$

$\Delta L = \alpha \ell_0 \Delta T$

$\Delta L = (24 \times 10^{-6}\,K^{-1})(62.1\,m)(200^\circ C - 15^\circ C)$

$\Delta L = 0.276\,m = \boxed{27.6\,cm}$

3.

$\ell_{brass} = 40.1\,cm = 0.401\,m$

$\ell_{aluminum} = 79.3\,cm = 0.793\,m$

$T_o = 0°C$

$d = 0.60\,cm = 0.0060\,m$

$\alpha_{brass} = 2.0 \times 10^{-5}\,K^{-1}$

$\alpha_{aluminum} = 2.4 \times 10^{-5}\,K^{-1}$

$$\Delta L_{brass} + \Delta L_{aluminum} = d$$

$$\alpha_{brass}\,\ell_{brass}\,\Delta T + \alpha_{alum}\,\ell_{alum}\,\Delta T = d$$

$$\Delta T = \frac{d}{\alpha_{brass}\,\ell_{brass} + \alpha_{alum}\,\ell_{alum}}$$

$$\Delta T = \frac{0.0060\,m}{(2.0 \times 10^{-5}\,K^{-1})(0.401\,m) + (2.4 \times 10^{-5}\,K^{-1})(0.793\,m)}$$

$$\Delta T = 221.795°C \approx 220°C$$

4.

$m = 199.0\,g = 0.199\,kg$

$Q = 16.0\,J$

$\Delta T = 10.0^\circ C$

$c = ?$

$$Q = mc\Delta T$$

$$c = \frac{Q}{m\Delta T}$$

$$c = \frac{16.0\,J}{(0.199\,kg)(10.0^\circ C)}$$

$$\boxed{c = 8.04\,J\,kg^{-1}\,^\circ C^{-1}}$$

5.

$m = 905\,g = 0.905\,kg$

$v_0 = 1629\,m/s$

$\Delta T = ?$

$c = 472\,J\,kg^{-1}K^{-1}$

$$KE = Q$$

$$\frac{1}{2}mv^2 = mc\Delta T$$

$$\Delta T = \frac{v^2}{2c}$$

$$\Delta T = \frac{(1629\,m/s)^2}{2(472\,J\,kg^{-1}K^{-1})}$$

$$\Delta T = 2811.06^\circ C \approx \boxed{2810^\circ C}$$

6.

$T_{melt} = 20°C$

$L_f = 3.9 \times 10^4 \, J \, kg^{-1}$

$T_{boil} = 150°C$

$L_v = 7.8 \times 10^4 \, J \, kg^{-1}$

$c_{solid} = 600 \, J \, kg^{-1} K^{-1}$

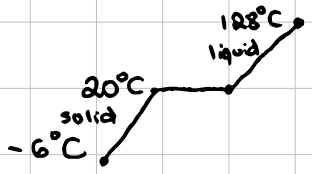
$c_{liquid} = 1000 \, J \, kg^{-1} K^{-1}$

$c_{gas} = 400 \, J \, kg^{-1} K^{-1}$

$m = 3.80 kg$

$T_0 = -6°C$

$T_1 = 128°C$



$Q_0 + Q_1 + Q_2 = Q_{Total}$

$m(c_{solid} \Delta T_{0,1} + L_f + c_{liquid} \Delta T_{1,2}) = Q_{total}$

$Q_{total} = (3.80 kg)[(600 J kg^{-1} K^{-1})(20°C - (-6°C)) + 3.9 \times 10^4 J kg^{-1}$
$+ (1000 J kg^{-1} K^{-1})(128°C - 20°C)]$

$Q_{total} = 617880 J = 6.179 \times 10^5 J$

$= 617.88 kJ \approx 620 kJ$

7.

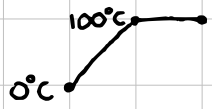
$m = 2.0\,g$

$T_o = 0.00^\circ C$

$c = 1.0\ cal\ g^{-1}K^{-1}$

$L_f = 80\ cal\ g^{-1}$

$L_v = 539\ cal\ g^{-1}$



$Q_{total} = Q_0 + Q_1$

$Q_{total} = m(c\Delta T_{1,0} + L_v)$

$Q_{total} = (2.0g)[(1.0\ cal\ g^{-1}K^{-1})(100.0^\circ C - 0.0^\circ C) + 539\ cal\ g^{-1}]$

$Q_{total} = 1278\ cal \approx 1300\ cal$

8.

$m_{water} = 330\,g = 0.330\,kg$

$T_{water_0} = 45^\circ C$

$m_{container} = 855\,g = 0.855\,kg$

$T_{container_0} = 10^\circ C$

$c_{water} = 4190\,J\,kg^{-1}K^{-1}$

$c_{aluminum} = 900\,J\,kg^{-1}K^{-1}$

$T_1 = ?$

$$Q_0 + Q_1 = 0$$

$$m_w c_w (T_1 - T_{water_0}) + m_c c_{alum} (T_1 - T_{c_0}) = 0$$

$$T_1 (m_w c_w + m_c c_{alum}) = m_w c_w T_{w_0} + m_c c_a T_{c_0}$$

$$T_1 = \frac{m_w c_w T_{w_0} + m_c c_a T_{c_0}}{m_w c_w + m_c c_{alum}}$$

$$T_1 = \frac{(0.330kg)(4190\,J\,kg^{-1}K^{-1})(45^\circ C) + (0.855kg)(900\,J\,kg^{-1}K^{-1})(10^\circ C)}{(0.330kg)(4190\,J\,kg^{-1}K^{-1}) + (0.855\,kg)(900\,J\,kg^{-1}K^{-1})}$$

$T_1 = 32.4861^\circ C \approx 32.0^\circ C$

9.

$T_{melt} = -10°C$

$m_{frozen} = 200g = 0.200\,kg$

$T_{frozen_0} = -10°C$

$m_{water} = 300g = 0.300\,kg$

$T_{water_0} = 20.0°C$

$T_1 = 5.0°C$

$m_f = 0.200\,kg$

$m_w' = 0.500\,kg$

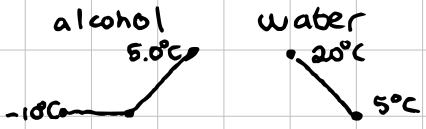
$T_{w_0}' = 20°C$

$T_1' = 10°C$

$Q_0' + Q_1' = Q_2'$

$m_f L_f + m_f c\,\Delta T_{1,f_0}' = m_w' c_w \Delta T_{1,w_0}'$

$$c = \frac{m_w' c_w \Delta T_{1,w_0}' - m_f L_f}{m_f \Delta T_{1,f_0}'}$$



$Q_0 + Q_1 = Q_2$

$m_f L_f + m_f c\,\Delta T_{1,f_0} = m_w c_w \Delta T_{1,w_0}$

$$m_f L_f + m_f \Delta T_{1,f_0}\left[\frac{m_w' c_w \Delta T_{1,w_0}' - m_f L_f}{m_f \Delta T_{1,f_0}'}\right] = m_w c_w \Delta T_{1,w_0}$$

$$L_f\left[m_f - \frac{m_f \Delta T_{1,f_0}}{\Delta T_{1,f_0}'}\right] = c_w\left[m_w \Delta T_{1,w_0} - \frac{m_w' \Delta T_{1,w_0}' \Delta T_{1,f_0}}{\Delta T_{1,f_0}'}\right]$$

$$L_f = c_w\left[m_w \Delta T_{1,w_0} - \frac{m_w' \Delta T_{1,w_0}' \Delta T_{1,f_0}}{\Delta T_{1,f_0}'}\right]\left[\frac{\Delta T_{1,f_0}'}{m_f(\Delta T_{1,f_0}' - \Delta T_{1,f_0})}\right]$$

$$L_f = (4190\,J\,kg^{-1}K^{-1})\left[(0.300kg)(5°C-20°C) - \frac{(0.500kg)(10°C-20°C)(5°C-(-10°C))}{(10°C-(-10°C))}\right]$$

$$\left[\frac{10°C-(-10°C)}{(0.200kg)\left[(10°C-(-10°C))-(5°C-(-10°C))\right]}\right]$$

$L_f = 62850\,J\,kg^{-1} = 6.29\times10^4\,J\,kg^{-1} \approx 6.3\times10^4\,J\,kg^{-1}$

10.

$m_{tea} = 1.8\ kg$

$T_{tea_0} = 80°C$

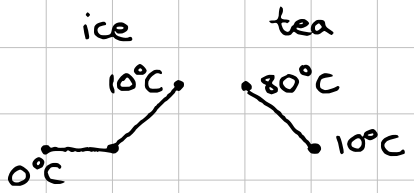
$m_{ice} = ?$

$T_{ice_0} = 0.00°C$

$T_1 = 10°C$

$L_f = 334\ kJ\ kg^{-1} = 334000\ J\ kg^{-1}$

$c_{tea} = 4190\ J\ kg^{-1} K^{-1}$



$$Q_{water,ice} + Q_{1,ice_0} = -Q_{1,tea_0}$$

$$m_{ice} L_f + m_{ice} c_{water} \Delta T_{1,ice_0} = -m_{tea} c_{tea} \Delta T_{1,tea_0}$$

$$m_{ice} = \frac{-m_{tea} c_{tea} \Delta T_{1,tea_0}}{L_f + c_{water}(T_1 - T_{ice_0})}$$

$$m_{ice} = \frac{-(1.8kg)(4190\ J\ kg^{-1} K^{-1})[10°C - 80°C]}{334000 J kg^{-1} + (4190 J kg^{-1} K^{-1})[10°C - 0°C]}$$

$m_{ice} = 1.40\ kg$

11.

$w = 40.0\text{cm} = 0.40\text{m}$

$h = 30.0\text{cm} = 0.30\text{m}$

$l = 4.00\text{mm} = 0.004\text{m}$

$T_C = -10.0^\circ\text{C}$

$T_H = 25.0^\circ\text{C}$

$k_{glass} = 0.105\ \text{W m}^{-1}\text{K}^{-1}$

$A = (0.30\text{m})(0.40\text{m})$

$A = 0.12\text{m}^2$

$$\frac{Q}{t} = \frac{kA(T_H - T_C)}{l}$$

$$\frac{Q}{t} = \frac{(0.105\text{Wm}^{-1}\text{K}^{-1})(0.12\text{m}^2)(25^\circ\text{C} - (-10.0^\circ\text{C}))}{0.40\text{m}}$$

$$\frac{Q}{t} = 110.25\text{W} \approx 110\text{W}$$

12.

$\rho_{glass} = 2300\ kg\ m^{-3}$

$Q_{glass} = 840\ J\ kg^{-1}\ ^\circ C^{-1}$

$\alpha_{glass} = 8.5 \times 10^{-6}\ ^\circ C^{-1}$

$k_{glass} = 0.80\ W\ m^{-1}\ ^\circ C^{-1}$

$h = 2.7m$

$\omega = 2.4m$

$l = 2.00mm = 0.002m$

$T_H = 22^\circ C$

$T_c = 4.0^\circ C$

$A = (2.7m)(2.4m) = 6.48m^2$

$$\frac{Q}{t} = \frac{kA(T_H - T_c)}{l}\ [3600]$$

$$\frac{Q}{t} = \left[\frac{(0.80\ W m^{-1} ^\circ C^{-1})(6.48 m^2)(22.0^\circ C - 4.0^\circ C)}{0.002m}\right](3600)$$

$$\frac{Q}{t} = 1.75 \times 10^8\ J \approx 1.7 \times 10^8\ J$$

13.

$l = 2.00\,mm = 0.002\,m$

$k = 0.00300\ W m^{-1} {}^{\circ}K^{-1}$

$A = 1.20\,m^2$

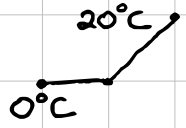
$m = 4.00\,kg$

$T_0 = 0.00^{\circ}C$

$T_1 = 20.0^{\circ}C$

$t = ?$

$L_f = 334\,kJ\,kg^{-1} = 3.34 \times 10^5\,J\,kg^{-1}$



$Q_0 = Q_1$

$$mL_f = \frac{tkA(T_1 - T_0)}{l}$$

$$t = \frac{mL_f l}{kA(T_1 - T_0)}$$

$$t = \frac{(4.00\,kg)(3.34 \times 10^5\,J\,kg^{-1})(0.002\,m)}{(0.0030\,W m^{-1} K^{-1})(1.20\,m^2)(20.0^{\circ}C - 0^{\circ}C)}$$

$t = 37111.1\,s = 10.3\,h$

14.

$d = 0.050\,mm = 5.0 \times 10^{-5}\,m$

$e = 1.0$

$T = 3000°C$

$\ell = ?$

$H = 60\,W$

$\sigma = 5.670 \times 10^{-8}\,W m^{-2} K^{-4}$

$r = \frac{d}{2} = 2.5 \times 10^{-5}\,m$

$$H = Ae\sigma T^4$$

$$\ell = \frac{H}{2\pi r^2 e \sigma T^4}$$

$$\ell = \frac{60\,W}{\pi(2.5\times10^{-5}\,m)(1)(5.670\times10^{-8}\,W m^{-2} K^{-4})(3000°C)^4}$$

$\ell = 0.059_m = 5.9\,cm$

15.

$H_{Betelgeuse} = 2.70 \times 10^{30}\,W$

$T_{Betelgeuse} = 3000K$

$e = 1.0$

$$H = Ae\sigma T^4$$

$$r = \sqrt{\frac{H}{4\pi e \sigma T^4}}$$

$$r = \sqrt{\frac{2.70\times10^{30}\,W}{4\pi(1.0)(5.670\times10^{-8}\,W m^{-2} K^{-4})(3000K)^4}}$$

$r = 2.16 \times 10^{11}\,m$