Task 1

Initial length of the square-shaped steel plate edge	L_1	[m]
Final length of the square-shaped steel plate edge	L_2	[m]
Initial area of the square-shaped steel plate	A_1	[m^2]
Final area of the square-shaped steel plate	A_2	[m^2]
Initial temperature of the steel plate	T_1	[°C]
Final temperature of the steel plate	T_2	[°C]
Percentage of area increase	AI	[%]
Coefficient of thermal expansion	α	[1/K]

Formulas:

$$L_2 = L_1 + \alpha L_1 \Delta T$$

$$A = L^2$$

$$AI = \frac{A_2 - A_1}{A_1} \cdot 100\ \%$$

Solution:

$$AI = \frac{A_2 - A_1}{A_1} \cdot 100\ \%$$

Substitute expressions

$$AI = \frac{L_2^2 - L_1^2}{L_1^2}$$

Use algebra

$$AI = \frac{L_2^2}{L_1^2} - 1 = \left(\frac{L_2}{L_1}\right)^2 - 1$$

Substitute expressions

$$AI = \left(\frac{L_1 + \alpha L_1 \Delta T}{L_1}\right)^2 - 1$$

Use algebra

$$AI = (1 + \alpha\Delta T)^2 - 1 = 1 + 2\alpha\Delta T + (\alpha\Delta T)^2 - 1 = 2\alpha\Delta T + (\alpha\Delta T)^2$$

$(\alpha\Delta T)^2$ can be omitted as it is very small

$$\boldsymbol{AI = 2\alpha\Delta T}$$

Substitute initial values

Task 2

Initial pressure of the car tire	p_1	[Pa]
Final pressure of the car tire	p_2	[Pa]
Initial temperature inside the car tire	T_1	[K]
Final temperature inside the car tire	T_2	[K]
Initial molar amount of gas inside the car tire	N_1	[mol]
Final molar amount of gas inside the car tire	N_2	[mol]
Initial volume of gas inside the car tire	V_1	$[\mathrm{m}^3]$
Final volume of gas inside the car tire	V_2	$[\mathrm{m}^3]$
Universal gas constant	R	[J/(mol K)]

Constants:

R = J/(mol K)]

Unit conversions:

1 bar = 100,000 Pa

$T = (T_{\mathrm{CEL}} + 273.15)\ \mathrm{K}$

Formulas:

$p_1V_1 = N_1RT_1$

$p_2V_2 = N_2RT_2$

$V_1 = V_2$

$N_1 = N_2$

Solution:

$p_1V_1 = N_1RT_1$

solve for V_1/N_1

$\frac{V_1}{N_1} = \frac{RT_1}{p_1}$

$p_2V_2 = N_2RT_2$

solve for V_2/N_2

$\frac{V_2}{N_2} = \frac{RT_2}{p_2}$

substitute expressions

$\frac{V_2}{N_2} = \frac{V_1}{N_1} = \frac{RT_1}{p_1} = \frac{RT_2}{p_2}$

Solve for p_2

$\boldsymbol{p_2 = \frac{T_2}{T_1}p_1}$

substitute initial values

Task 3

Initial pressure of the car tire	p_1	[Pa]
Final pressure of the car tire	p_2	[Pa]
Initial temperature inside the car tire	T_1	[K]
Final temperature inside the car tire	T_2	[K]
Initial molar amount of gas inside the car tire	N_1	[mol]
Final molar amount of gas inside the car tire	N_2	[mol]
Initial volume of gas inside the car tire	V_1	$[\mathrm{m}^3]$
Final volume of gas inside the car tire	V_2	$[\mathrm{m}^3]$
Universal gas constant	R	[J/(mol K)]

Constants:

R = J/(mol K)]

Unit conversions:

1 bar = 100,000 Pa

$$T = (T_{\mathrm{CEL}} + 273.15)\ \mathrm{K}$$

Formulas:

$$p_1 V_1 = N_1 R T_1$$

$$p_2 V_2 = N_2 R T_2$$

$$N_1 = N_2$$

Solution:

$$p_1 V_1 = N_1 R T_1$$

solve for $N_1 R$

$$N_1 R = \frac{p_1 V_1}{T_1}$$

$$p_2 V_2 = N_2 R T_2$$

solve for $N_2 R$

$$N_2 R = \frac{p_2 V_2}{T_2}$$

Substitute expressions

$$N_2 R = N_1 R = \frac{p_2 V_2}{T_2} = \frac{p_1 V_1}{T_1}$$

Solve for V_2

$$\boldsymbol{V_2 = \frac{p_1}{p_2}\frac{T_2}{T_1} V_1}$$

Substitute initial values

Task 4

Temperature of the condenser	T_1	[K]
Temperature of the water vapor entering the steam turbine	T_2	[K]
Temperature rise of the conder water	ΔT	[K]
Specific heat capacity of liquid water	c	[J/(kg K)]
Theoretic maximum efficiency	η	[-]
Electric power output of the plant	P	[W]
Cooling requirement in the condenser	Φ	[W]
Mass flow rate of the condenser water	$\dot{m}$	[kg/s]

Unit conversions:

1 kW = 1000 W

$$T = (T_{\mathrm{CEL}} + 273.15)\ \mathrm{K}$$

Formulas:

$$\eta = \frac{T_2 - T_1}{T_2}$$

$$\eta = \frac{P}{\Phi}$$

$$\Phi = \dot{m}c\Delta T$$

Solution:

Temperature of the condenser:

$$\eta = \frac{T_2 - T_1}{T_2}$$

Solve for T_1

$$\boldsymbol{T_1 = (1 - \eta)T_2}$$

Substitute initial values

Condenser water requirement:

$$\eta = \frac{P}{\Phi}$$

solve for Φ

$$\Phi = \frac{P}{\eta}$$

$$\Phi = \dot{m}c\Delta T$$

solve for $\dot{m}$

$$\dot{m} = \frac{\Phi}{c\Delta T}$$

substitute expressions

$$\boldsymbol{\dot{m} = \frac{P}{\eta c \Delta T}}$$

Substitute initial values

Task 5

Total mass of water	m	[kg]
Mass of water that evaporates	m_{evap}	[kg]
Power of the electric heater	P	[W]
Electric energy consumed by the electric heater	E_{heater}	[J]
Electric energy needed to heat the water to its boiling point and evaporate part of it	E_{water}	[J]
Percentage of electric energy transferred to water	*EP*	[%]
Heating time	t	[s]
Initial temperature of the water	T_1	[K]
Boiling point of water	T_{b}	[K]
Specific enthalpy of evaporation of water	h_{fg}	[J/kg]
Specific heat capacity of liquid water	c	[J/(kg K)]

Unit conversions:

$$T = (T_{\mathrm{CEL}} + 273.15)\ \mathrm{K}$$

$$1\ \mathrm{minute} = 60\ \mathrm{s}$$

$$1\ \mathrm{kg} = 1000\ \mathrm{g}$$

Constants:

$$h_{\mathrm{fg}} = 2{,}260{,}000\ \mathrm{J/kg}$$

Formulas:

$$E_{\mathrm{heater}} = Pt$$

$$E_{\mathrm{water}} = cm(T_{\mathrm{b}} - T_1) + m_{\mathrm{evap}} h_{\mathrm{fg}}$$

$$EP = \frac{E_{\mathrm{water}}}{E_{\mathrm{heater}}} \cdot 100\ \%$$

Solution:

$$EP = \frac{E_{\mathrm{water}}}{E_{\mathrm{heater}}} \cdot 100\ \%$$

substitute expressions

$$\boldsymbol{EP = \frac{cm(T_{\mathrm{b}} - T_1) + m_{\mathrm{evap}} h_{\mathrm{fg}}}{Pt} \cdot 100\ \%}$$

substitute initial values

Task 6

Mass of the ice	m_{ice}	[kg]
Mass of the water in the pool before adding the ice	m_{water}	[kg]
Pool width	w	[m]
Pool length	l	[m]
Pool depth before adding the ice	d_1	[m]
Pool depth after adding the ice	d_2	[m]
Pool surface rise	Δd	[m]
Density of the ice	ρ_{ice}	$[\mathrm{kg/m^3}]$
Density of the water	ρ_{water}	$[\mathrm{kg/m^3}]$
Energy needed to transform the ice into liquid water	$E_{\mathrm{icetowater}}$	[J]
Energy released when the pool of water cools to the final temperature	E_{water}	[J]
Initial temperature of the ice	$T_{1,\mathrm{ice}}$	[K]
Temperature of the pool before adding the ice	$T_{1,\mathrm{water}}$	[K]
Melting point of ice	T_{f}	[K]
Final temperature of the pool when all ice has melted and water and melted ice have reached a common temperature	T_2	[K]
Specific heat capacity of the water	c_{water}	[J/(kg K)]
Specific heat capacity of the ice	c_{ice}	[J/(kg K)]
Specific enthalpy of fusion of water	h_{f}	[J/kg]
Initial volume of the pool	V_1	$[\mathrm{m^3}]$
Final volume of the pool	V_2	$[\mathrm{m^3}]$
Volume of the ice	V_{ice}	$[\mathrm{m^3}]$

Unit conversions:

$$1\ \mathrm{m} = 100\ \mathrm{cm}$$

Constants:

$$h_{\mathrm{f}} = 333{,}550\ \mathrm{J/kg}$$
$$c_{\mathrm{water}} = 4{,}180\ \mathrm{J/kg}$$
$$c_{\mathrm{ice}} = 2{,}090\ \mathrm{J/kg}$$
$$\rho_{\mathrm{water}} = 1000\ \mathrm{kg/m^3}$$
$$T_{\mathrm{f}} = 0\ \mathrm{°C}$$

Formulas:

$$E_{\mathrm{icetowater}} = m_{\mathrm{ice}}[c_{\mathrm{ice}}(T_{\mathrm{f}} - T_{1,\mathrm{ice}}) + h_{\mathrm{f}} + \mathrm{c}_{\mathrm{water}}(T_2 - T_{\mathrm{f}})]$$

$$E_{\mathrm{water}} = m_{\mathrm{water}} c_{\mathrm{water}} (T_{1,\mathrm{water}} - T_2)$$

$$E_{\mathrm{icetowater}} = E_{\mathrm{water}}$$

$$m_{\mathrm{water}} = V_1 \rho_{\mathrm{water}}$$

$$\Delta d = d_2 - d_1$$

$$V_{\mathrm{ice}} = \frac{m_{\mathrm{ice}}}{\rho_{\mathrm{ice}}}$$

$$V_1 = wld_1$$

$V_2 = wld_2$

$V_2 = V_1 + V_{\mathrm{ice}}$

Solution:

Water surface rise:

$V_2 = V_1 + V_{\mathrm{ice}}$

Substitute expression

$wld_1 + \frac{m_{\mathrm{ice}}}{\rho_{\mathrm{ice}}} = wld_2$

solve for $d_2 - d_1$

$d_2 - d_1 = \frac{m_{\mathrm{ice}}}{wl\rho_{\mathrm{ice}}}$

substitute expression

$\boldsymbol{\Delta d} = \frac{\boldsymbol{m_{\mathrm{ice}}}}{\boldsymbol{wl\rho_{\mathrm{ice}}}}$

Substitute initial values

Note, if you 1: have calculated how much the surface has risen after the ice has melt or 2: assume that the ice floats on the water as it is less dense than liquid water, then

$\boldsymbol{\Delta d} = \frac{\boldsymbol{m_{\mathrm{ice}}}}{\boldsymbol{wl\rho_{\mathrm{water}}}}$

Substitute initial values

Final temperature of the water:

$E_{\mathrm{icetowater}} = E_{\mathrm{water}}$

Substitute expressions

$m_{\mathrm{ice}}\left[c_{\mathrm{ice}}\left(T_{\mathrm{f}} - T_{1,\mathrm{ice}}\right) + h_{\mathrm{f}} + \mathrm{c}_{\mathrm{water}}(T_2 - T_{\mathrm{f}})\right] = m_{\mathrm{water}}c_{\mathrm{water}}(T_{1,\mathrm{water}} - T_2)$

solve for T_2

$$\boldsymbol{T_2 = \frac{m_{\mathrm{water}}c_{\mathrm{water}}T_{1,\mathrm{water}} - m_{\mathrm{ice}}\left[c_{\mathrm{ice}}\left(T_{\mathrm{f}} - T_{1,\mathrm{ice}}\right) + h_{\mathrm{f}} - \mathrm{c}_{\mathrm{water}}T_{\mathrm{f}}\right]}{c_{\mathrm{water}}(m_{\mathrm{water}} + m_{\mathrm{ice}})}}$$

Substitute initial values