Dr/A.ElShabasy
physics

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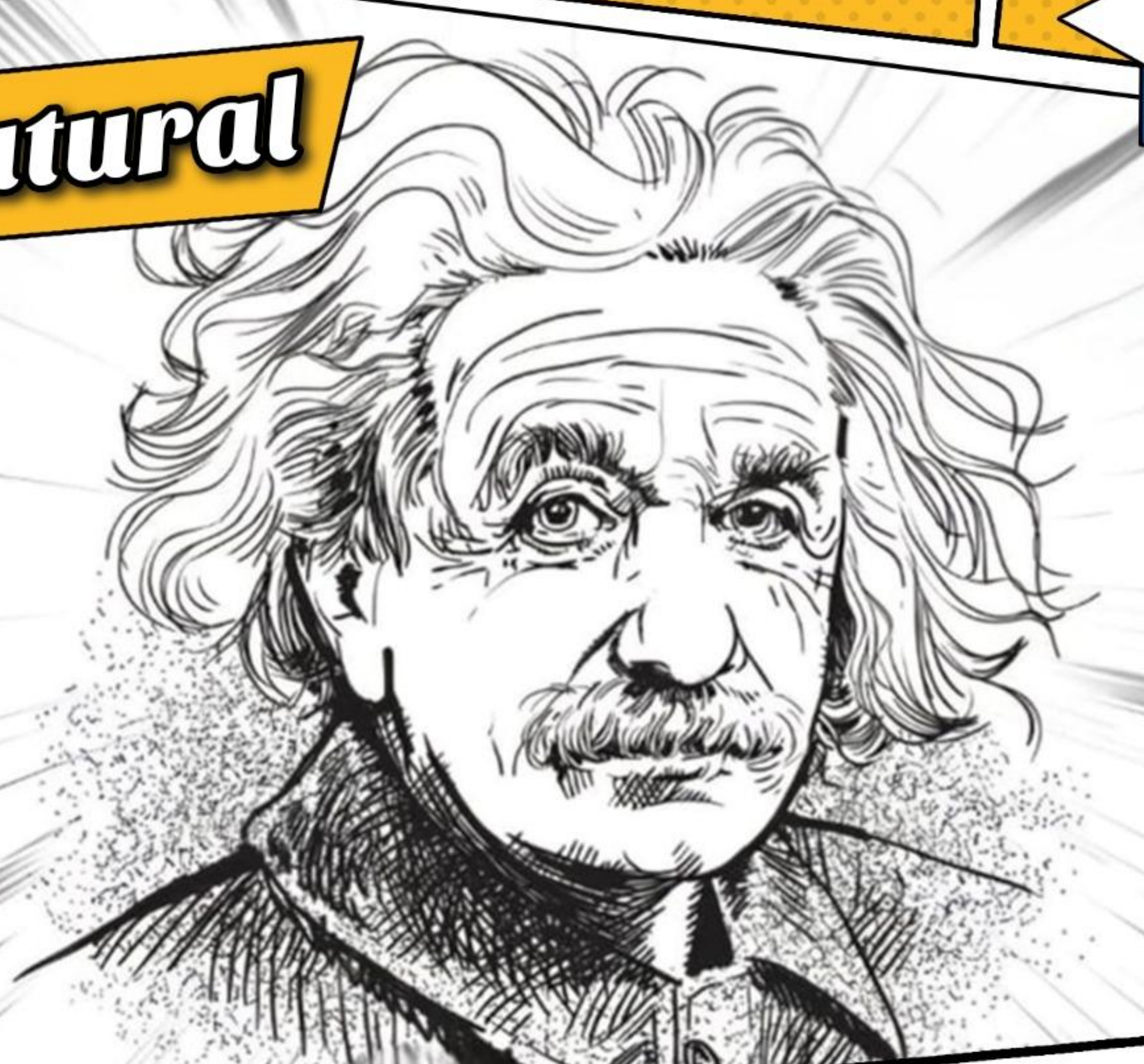
NO 2

Natural



Heat
(Specific heat capaciy)

Physics 1 Dr.Elsahbasy

WhatsApp group

Specific Heat Capacity

Specific Heat

(The heat energy required to raise the temperature of 1 kg of a substance by 1°K without a change in state)

☞ SI units for specific heat capacity → ***J / kg K.***

Note

The specific heat capacity of water is $\boldsymbol{4200\,J\,kg^{-1}\,K^{-1}}$, which means that it takes $\boldsymbol{4200\,J}$ of heat energy to raise the temperature of 1 kg of water by $\boldsymbol{1°K}$.

$$\boxed{Q = m\,c\,\Delta T}$$

$$\boxed{Power\ (P) = \frac{energy\ (Q)}{time\ (t)}}$$

Where:

☞ **Q** → heat energy supplied **(J)**

☞ **M** → mass of substance heated **(kg)**

☞ **c** → specific heat capacity of substance

☞ **ΔT** → change in temperature of substance

Example 1

Calculate the heat required to raise the temperature of 4 kg of water from 20℃ to its boiling point. (Specific heat of water = 4200 $J\ kg^{-1}\ K^{-1}$)

Solution

$Q = ?\ , m = 4\ kg\ , c = 4200\ J\ kg^{-1}\ K^{-1}\ ,\ \Delta T = 100 - 20 = 80℃$

$\because Q = m\,c\,\Delta T = 4 \times 4\,200 \times 80 = 1.34 \times 10^{6}\ J$

Example 2

If 6.7 kJ of energy are supplied to 100 g of glass which is initially at 20℃, what is its final temperature? (Specific heat capacity of glass = 670 $J\ kg^{-1}\ K^{-1}$)

Solution

$Q = 6.7\ kJ = 6700\ J, \quad m = 100\ g = 0.1\ kg,$

$c = 670\ J\ kg^{-1}\ K^{-1}\ ,\ \Delta T = ?$

$\because Q = m\,c\,\Delta T$

$\therefore 6700 = 0.1 \times 670 \times \Delta T$

$\therefore 6700 = 67 \times \Delta T$

$\therefore 6700/67 = \Delta T = 100°K$

$\therefore Ti = 20℃,\ \Delta T = 100°K$

$\therefore T_f = (20 + 273) + 100K = 393°K$

Example 3

A 40 kg iron vat contains 10 kg of water at 15℃.

(i) Calculate the heat required to raise the temperature to 75℃.

(ii) How long will take if a 5 kW heater is used. ($S_w = 4\,200\ J\ kg^{-1}\ K^{-1}$), $S_i = 460 J\ kg^{-1}\ K^{-1}$)

Solution

(I) $\because Q_{total} = (m\ c\ \Delta T)_{water} + (m\ c\ \Delta T)_{iron}$

$$\therefore Q_{total} = (10 \times 4200 \times 60) + (40 \times 460 \times 60)$$

$$\therefore Q_{total} = 3.6 \times 106\ J$$

(ii) $\because Power = energy/time$

$$\therefore P = Q/t$$

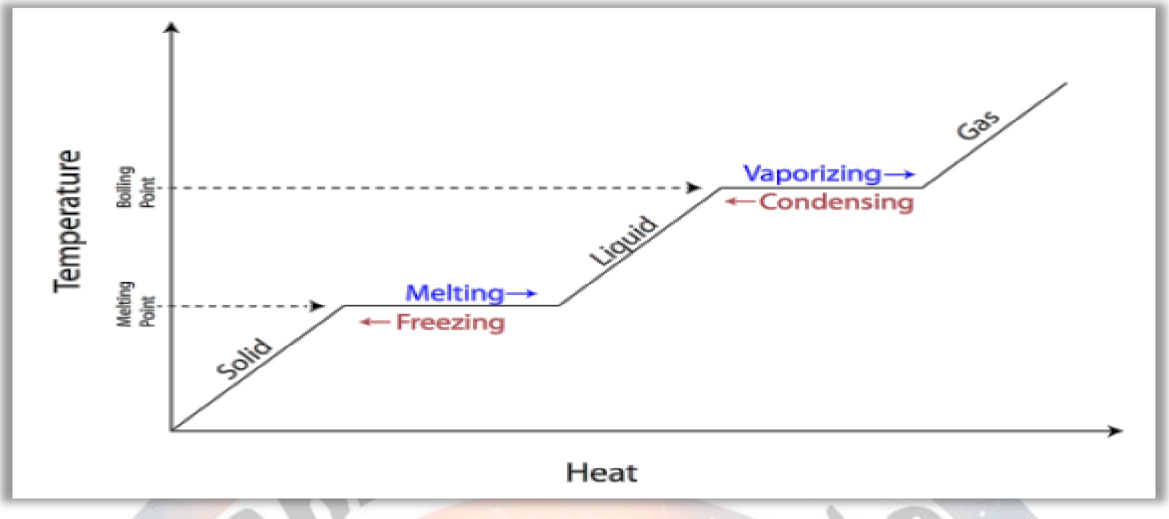
$$\therefore t = Q/P$$

$$\therefore t = \frac{3.6 \times 10^6}{5000} = 7200\ s$$

$$\therefore t = \frac{7200}{60} = 120\ \text{min}$$

Changing State and Latent Heat

- Heat which produces a change in state without any change in temperature.



- **Section A :** the solid is heated and its temperature rises
- **Section B :** at the materials melting point,
- **Section C :** the liquid rises in temperature until
- **Section D :** at the materials boiling point,
- **Section E :** when all the liquid has been converted to gas.

Common types of phase change

- Solid → Liquid (fusion) or melting
- Liquid → Solid (Solidification)
- Liquid → Vapor (Vaporization)
- Vapor → Liquid (condensation)
- Solid → Vapor (sublimation)

- The heat required to melt a substance of mass "m" with no change in its temp is proportional to the mass of the substance.

$$\because Q \propto m$$

$$\therefore \; Q = Lm$$

Where:

L → latent heat (J/Kg)

Latent heat of fusion (L_f):

It is the amount of heat required to convert 1 kg of the substance from solid state to liquid state without change in temp. (at the melting point)

$$L_f = \frac{Q_f}{m} = 3.30 \times 10^5 \, J \, kg^{-1}$$

Latent heat of vaporization (L_v):

It is the amount of heat required to convert 1 kgof the substance from Liquid state to Vapor state without change in temp. (at the boiling point)

$$L_V = \frac{Q_V}{m} = 2.25 \times 106 \, J \, kg^{-1}$$

Example 1

How much heat energy is required to convert 2 kg of ice at 0°C to water at the same temperature? (Specific latent heat of fusion for water = $3.3 \times 10^5 J\ kg^{-1}$)

Solution

$$Q = ? \quad , m = 2\ kg \quad , L_f = 3.30 \times 10^5\ J\ kg^{-1}$$

$$Q = m\,L_F = 2 \times 3.3 \times 10^5 = 6.6 \times 10^5\ J$$

Example 2

5 kg of water at 80°C have to be converted to steam at 100 °C. Determine: -

(i) the quantity of heat required

(ii) how long will take with a 1.5 kW heater

Solution

$$Q_1 = m\,c\,\Delta T,$$

$$m = 5\ kg, \quad c = 4200\ J\ kg^{-1}\ K^{-1} \quad , \Delta T = 100 - 80$$

$$= 20\ °C$$

$$Q_1 = 5 \times 4200 \times 20 = 420000\ J$$

$$Q_2 = m\,L_V$$

$$L_V = 2.25 \times 106\ J\ kg^{-1}$$

$$Q_2 = 5 \times 2.25 \times 10^6 = 11.25 \times 10^6\ J$$

$$Q_{\ total} = Q_1 + Q_2$$

$$Q_t = 420000 + 11.25 \times 10^6 = 11.65 \times 10^6\ J$$

(ii) $Power\ of\ heater, P = 1.5\ kW = 1\ 500\ W \quad Q$

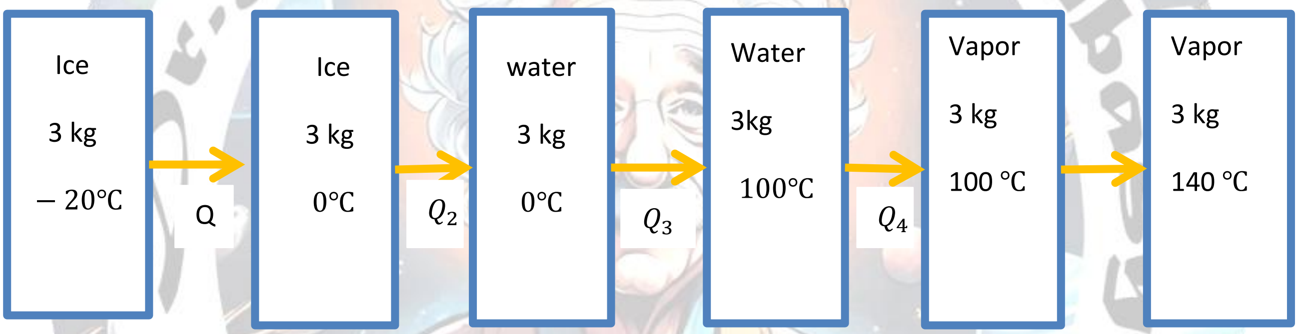
$= 17.4\ x\ 106\ J,$

$t = ?\ Power, P = Q/t$

$$t = \frac{Q}{P} = \frac{11.65 \times 10^6}{1500} = 7766.66\ s = 129.4\ mins = 2.15\ h$$

Example 3

How much heat energy is required to convert 3 kg of ice at − 20℃ to steam at 140℃.



Solution

$$Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5$$

$$Q = (mS\Delta t)_{ice} + (mL)_{ice} + (mS\Delta t)_w + (mL)_w + (mS\Delta t)_{Vapor}$$

$$Q_1 = 3 \times 2100 \times 20 = 126000\ J$$

$$Q_2 = 3 \times 3.3 \times 10 \times^5 = 9.9\ x\ 10^5\ J$$

$$Q_3 = 3 \times 4200 \times 100 = 1.26 \times 10^6\ J$$

$$Q_4 = 3 \times 2.25 \times 10^6 = 6.75 \times 10^6\ J$$

$$Q_5 = 3 \times 1400 \times 40 = 168000\ J$$

$$Q_{total} = 9.294 \times 10^6\ J$$