

Physics

HEAT



When you can't make them see the LIGHT,
make them feel the HEAT!!!

Ronald Reagan

alirahmanarif

DREAM BIG... AIM HIGH... NEVER GIVE UP

HEAT

A form of **energy**

SI UNIT: **Joule** (J)

Derived Quantity

Measuring instrument:
Joulemeter



TEMPERATURE

Degree of **hotness** of a body

SI UNIT: **kelvin** (K)

Basic Quantity

Measuring instrument:
Thermometer



To bring up the temperature of cold milk

Thermal equilibrium is a condition where two objects in contact has the same temperature net flow of heat is zero



Put a wet towel on the forehead of a fever patient



Measuring body temperature

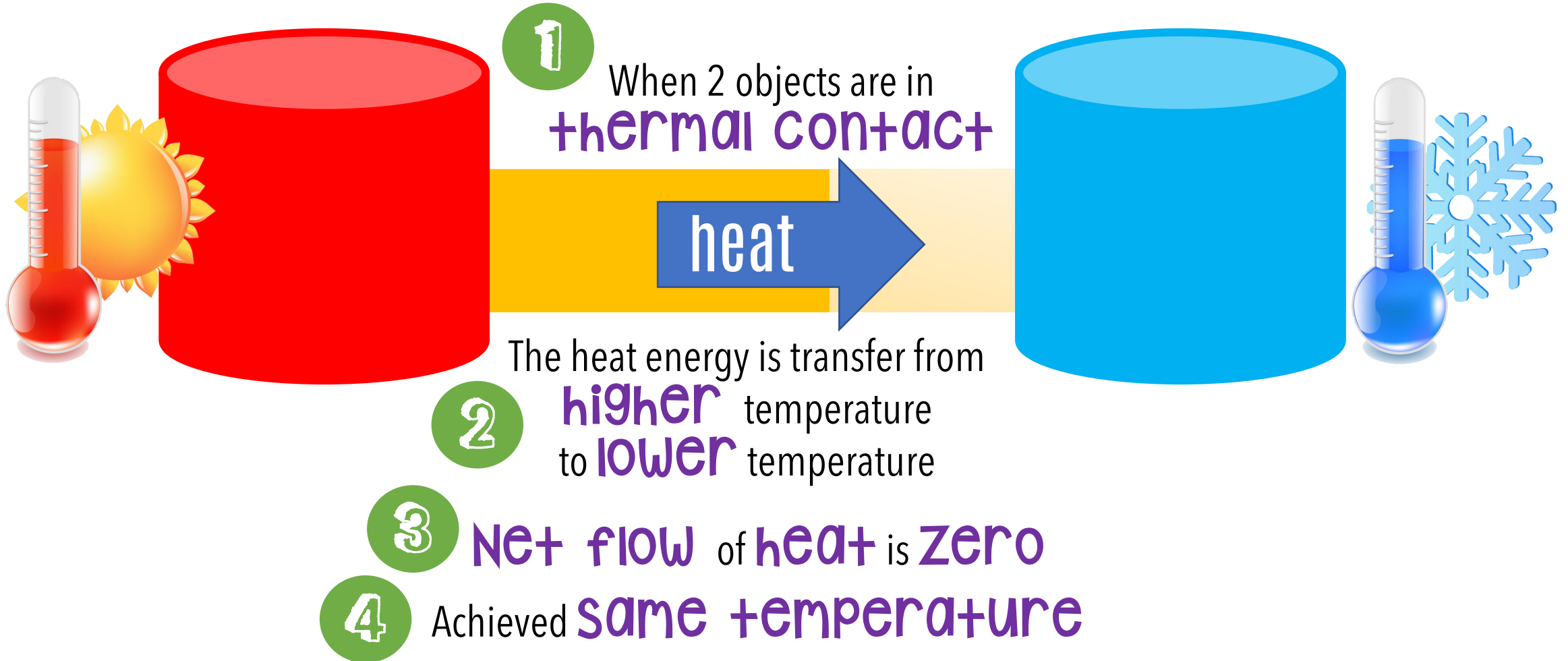


Hot soup inside a bowl





Explain **Thermal** occur. how **equilibrium**



EXAMPLE



Diagram shows a cup of hot coffee with a metal spoon.



When the hot coffee and the metal spoon are in contact with each other:

Energy is transferred from the hot coffee → metal spoon & also from the metal spoon → hot coffee.

after a short while:

Temperature metal spoon = hot coffee

Net flow of heat = 0 Joule

Physics concept:

THERMAL EQUILIBRIUM

Diagram shows a thermometer clinic is used by a doctor to check the temperature of a patient's body.

EXAMPLE



Explain how a doctor can check her patient temperature.

1

When the thermometer is put under the tongue (**thermal contact**)

2

The heat energy is transfer from **patient's** body To the **thermometer** (**heat transfer**)

3

Net flow of **heat** is **zero**

4

Temperature of **thermometer** = **patient's body**



EXAMPLE

Thermometer working principle

1

When the thermometer inserted in hot water (**thermal contact**)

2

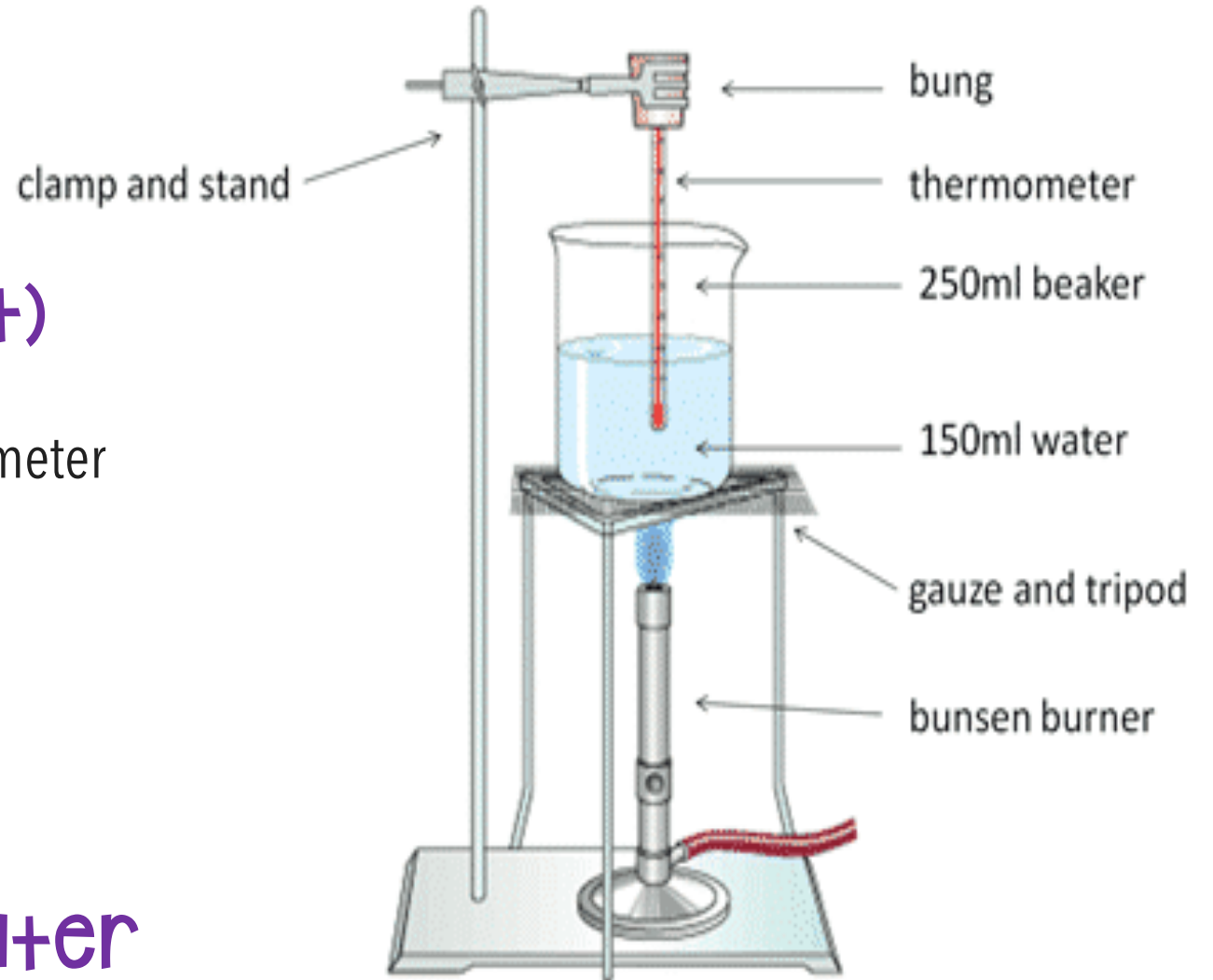
Heat flowing from hot water to thermometer (**heat transfer**)

3

Net flow of **heat** is **zero**

4

Temperature of **thermometer** = **hot water**



thermometric
properties of
mercury

Volume
expand



Liquid-in glass thermometer

Liquid properties used in
liquid-in-glass thermometers

expands uniformly when heated
opaque liquid

(does not allow light to pass through //
can be seen easily)

good conductor of **heat**
high boiling point (357°C)
low frozen point (-38.83°C)

Liquid-in glass thermometer

- Heat transfer to mercury faster

THIN GLASS WALL

- Can detect the small changes in temperature

SMALL SCALE

- Transparent
- so level of liquid can be seen easily
- strong & not easy to break
- acts as a magnifying glass

GLASS TUBE



BULB



LARGE BULB

- To increase the rate of expansion of mercury

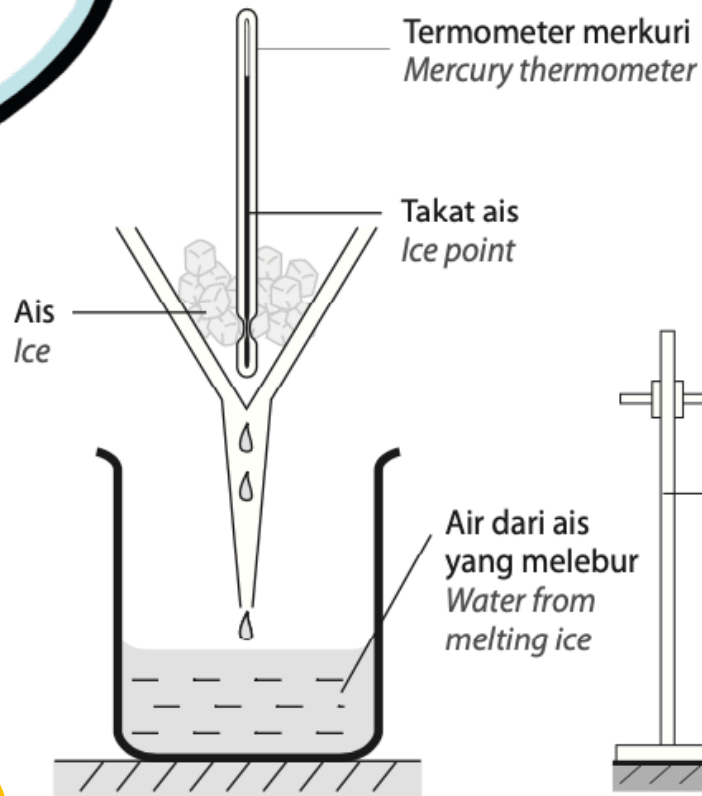


NARROW CAPILLARY TUBE

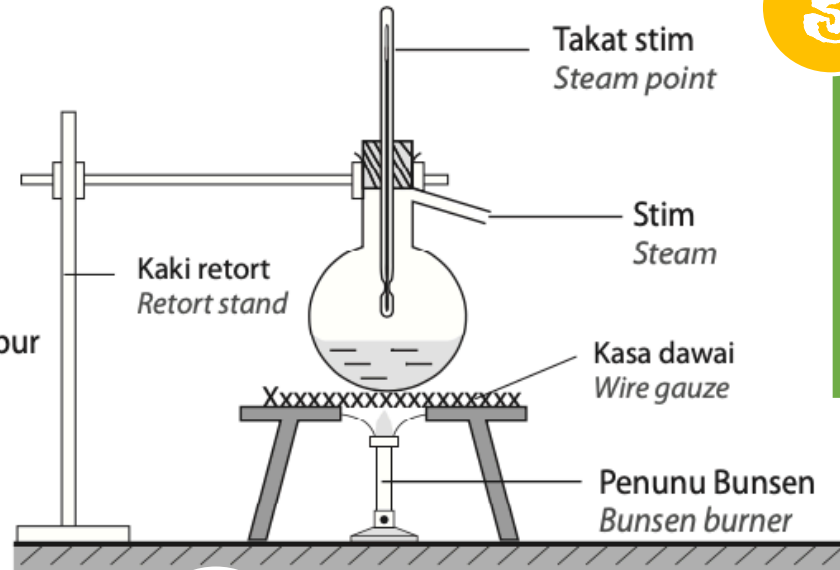
- increase its sensitivity
- to increase in volume of mercury

Liquid-in glass thermometer

How to calibrate the thermometer?



1 Uncalibrated mercury thermometer placed in a beaker containing ice cubes and water at 0 °C. The length of mercury column, $l = l_0$

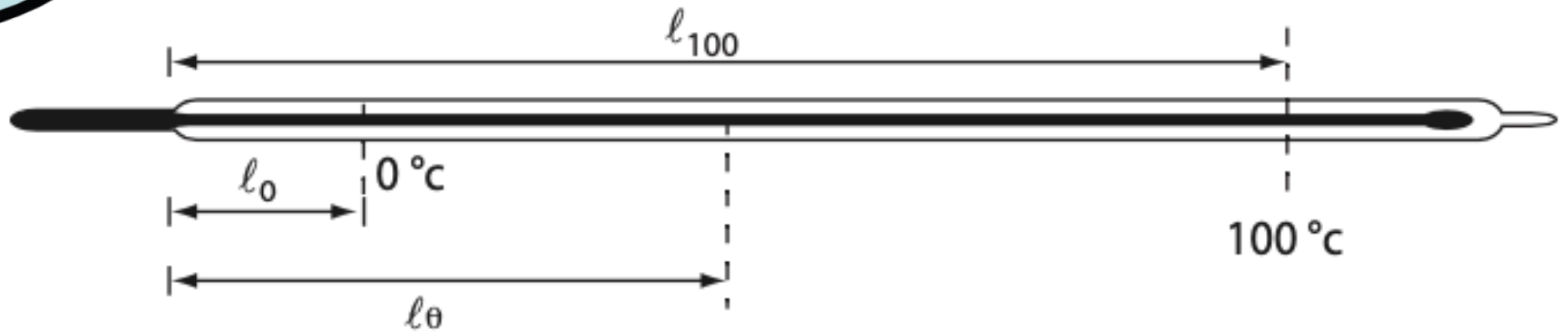


2 The length of mercury column, $l = l_{100}$ when the ice cubes and water in the beaker are boiled until 100 °C

3 The length of mercury column, $l = l_\theta$ when the thermometer is placed in a hot liquid with temperature, θ °C

Liquid-in glass thermometer

How to calibrate the thermometer?



4


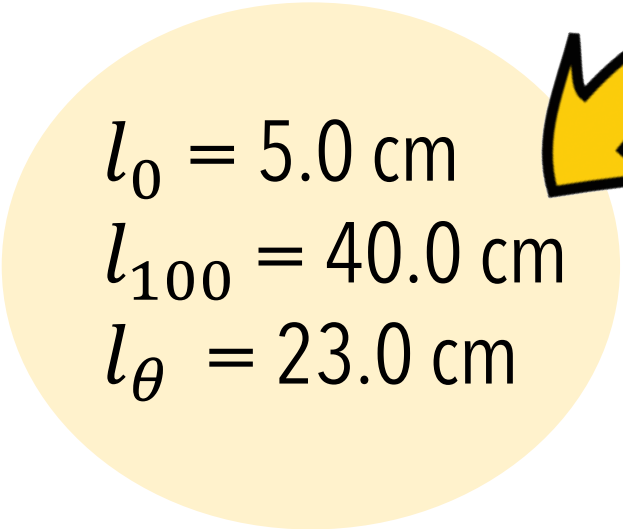
The temperature of the liquid can be calculated by using the formula:

$$T(\theta) = \frac{l_\theta - l_0}{l_{100} - l_0} \times 100^\circ\text{C}$$

1

Example:

The length of the mercury column at the ice point and steam point are 5.0 cm and 40.0 cm respectively. When the thermometer is immersed in the liquid P, the length of the mercury column is 23.0 cm. What is the temperature of the liquid P in SI unit?

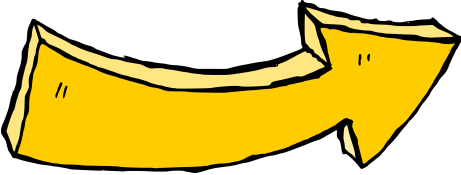

$$\begin{aligned}l_0 &= 5.0 \text{ cm} \\l_{100} &= 40.0 \text{ cm} \\l_\theta &= 23.0 \text{ cm}\end{aligned}$$

$$T(\theta) = \frac{l_\theta - l_0}{l_{100} - l_0} \times 100 \text{ }^\circ\text{C}$$

$$T(\theta) = \frac{23 - 5}{40 - 5} \times 100 \text{ }^\circ\text{C}$$

$$T(\theta) = 51.43 \text{ }^\circ\text{C}$$

Temperature in SI unit


$$\begin{aligned}T(K) &= T(\theta) + 273 \\&= 51.43 + 273 \\&= 324.43 \text{ K}\end{aligned}$$

2

Example:

The distance between 0°C and 100°C is 25.0 cm. When the thermometer is put into a beaker of water, the length of mercury column is 16.0 cm above the lower fixed point.

(a) What is the temperature of the water?

(b) What is the length of mercury column from the bulb at temperatures 30°C ?

$$l_0 = 0.0 \text{ cm}$$

$$l_{100} = 25.0 \text{ cm}$$

$$l_{\theta} = 16.0 \text{ cm}$$

$$T(\theta) = \frac{l_{\theta} - l_0}{l_{100} - l_0} \times 100^{\circ}\text{C}$$

$$T(\theta) = \frac{16 - 0}{25 - 0} \times 100^{\circ}\text{C}$$

$$T(\theta) = 64^{\circ}\text{C}$$

$$30^{\circ}\text{C} = \frac{l_{\theta} - 0}{25 - 0} \times 100^{\circ}\text{C}$$

$$l_{\theta} = 7.5 \text{ cm}$$

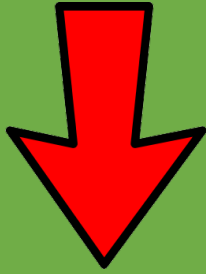
Specific Heat Capacity

The quantity of heat required to raise the temperature of 1 kg of material by 1°C or 1 K.

Q = Heat absorbed or released, J
 m = Mass of material, kg
 θ = The difference in temperature of the starting and ending unit, °C



C

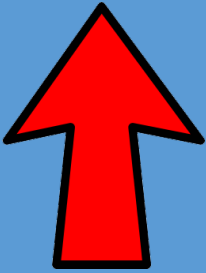


heat **faster**

cool **faster**

higher in increase in temperature

C



heat **slower**

cool **slower**

lower in increase in temperature

$$Q = mc\theta$$

$$c = \frac{Q}{m\theta}$$

$$\text{Jkg}^{-1} \text{ } ^\circ\text{C}^{-1}$$

Transformation of energy:

Kinetic energy \rightarrow Heat energy

$$\frac{1}{2}mv^2 = mc\theta$$

Gravitational Potential energy \rightarrow Heat energy

$$mgh = mc\theta$$

Electrical energy \rightarrow Heat energy

$$Pt = mc\theta$$



application

Transparent pot cover

Able to cook to **see** the food
Food cover will **trap the heat**

Handle is made
of a **insulator**

do not become hot easily
Poor conductor of heat



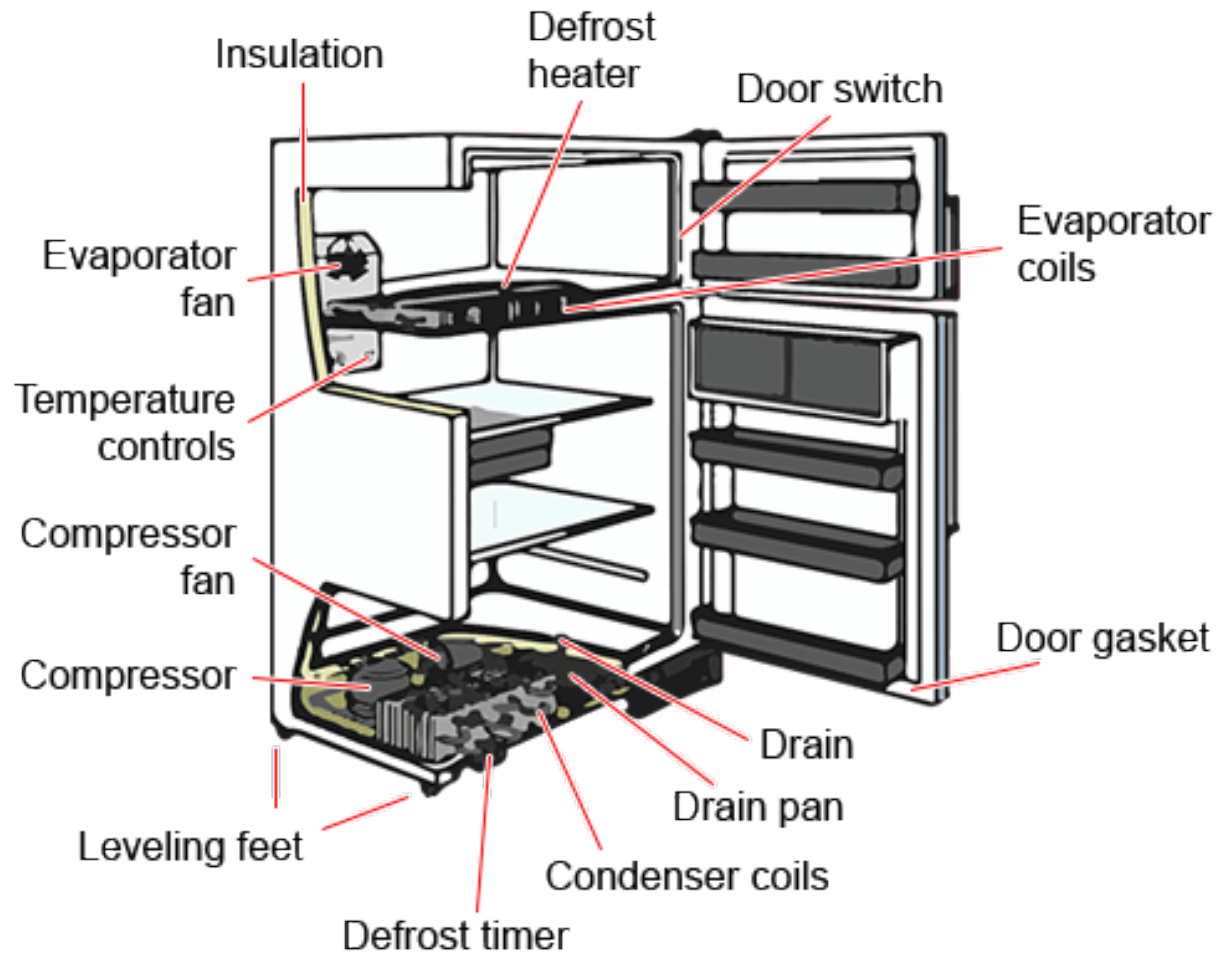
High density
of base

Stable and
not topple

Base is made of a **Copper**

low heat capacity it become hot very quickly

Explain why we cannot use a cooling system of a refrigerator to cool the hot room.

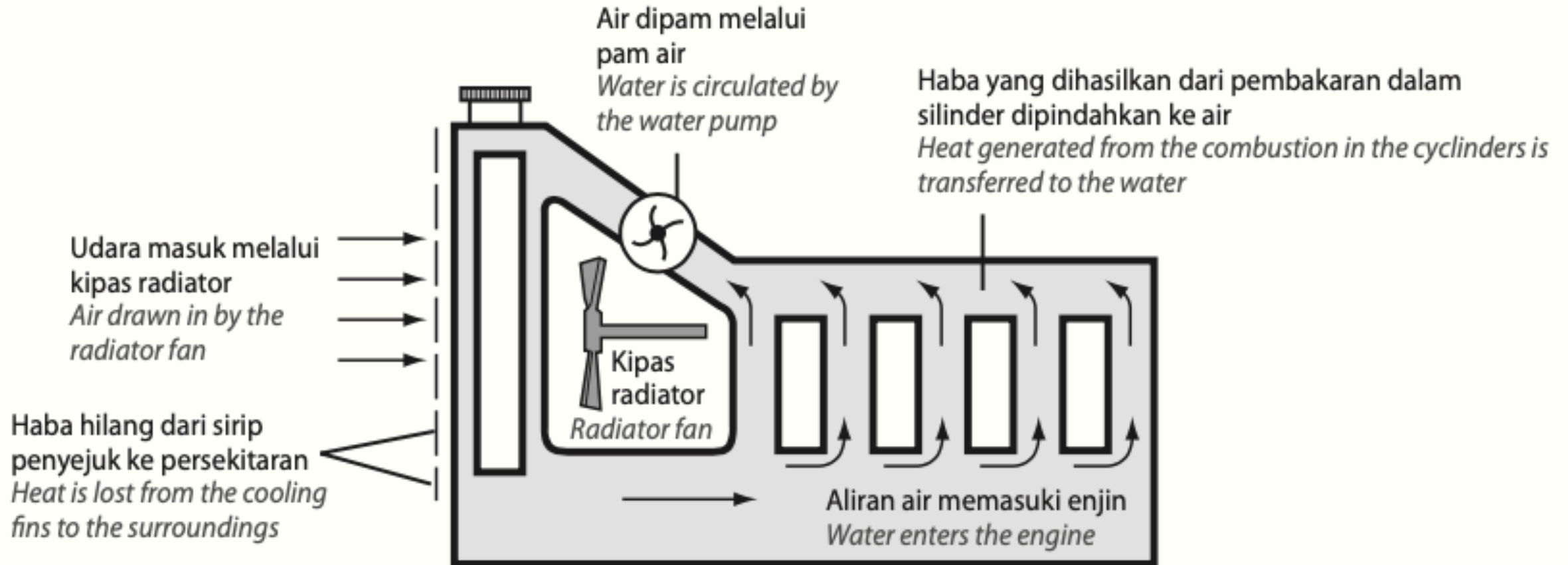


application

- Cooling system of a refrigerator is smaller
- Less cool air from refrigerator flow out compare to the hot air flow in
- Position of refrigerator is on the floor
- The cool air does not flow upward

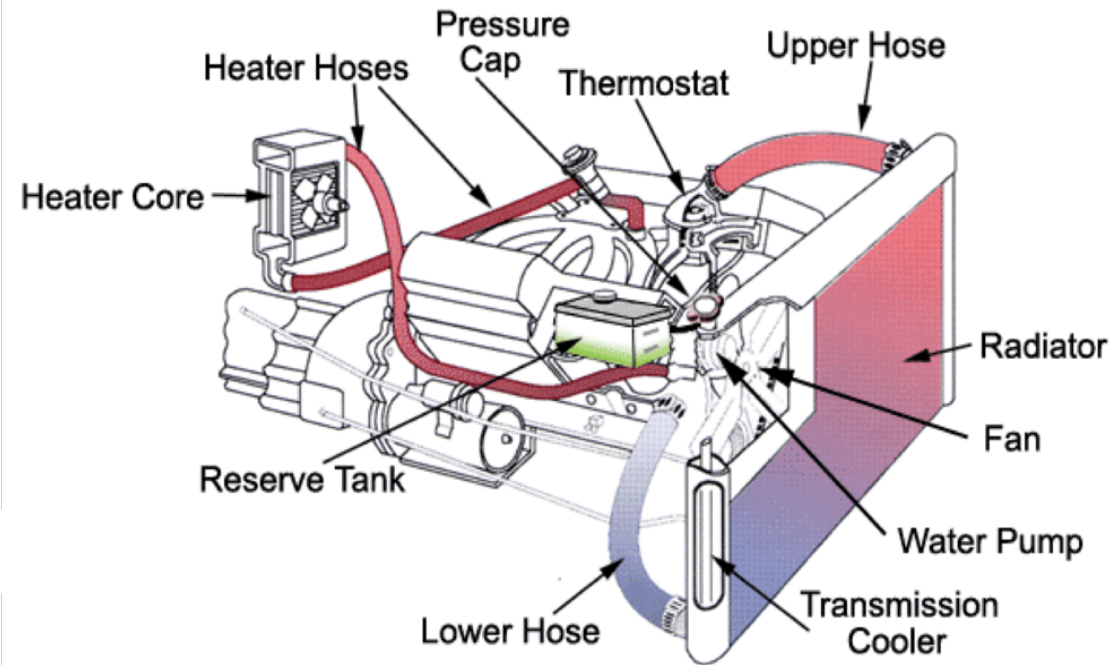
application

Water as a coolant car in a car engine



Characteristics	Reason
Specific heat of capacity of the liquid High	Can absorb and release more heat
Freezing point of the liquid LOW	Not easy to freeze
Boiling point of the liquid High	Not easy evaporate // Not easy change its state when temperature increase
Volume of the liquid High	Can prevent overheating
Rusting rate of metal LOW	Long lasting // Not easy rusting

application



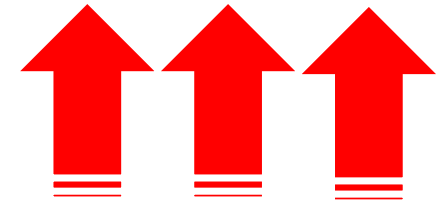
The cooling system of a car engine.

Heat generated in the car engine has to be removed effectively to avoid overheating.

Sea Breeze



3 **Hot** air rises up



4

Cold air blows from sea to land



SEA

LAND

1

Lower specific heat capacity

2

Higher in increase in temperature (hotter)

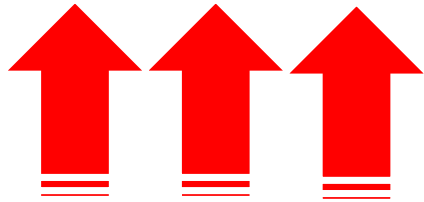
Land Breeze



4

Cold air blows from land to sea

3 **HOT** air rises up



SEA

LAND

1 **higher** specific heat capacity

2 **lower** in increase in temperature (hotter)

124 J of heat is absorbed by a piece of copper of mass 150 g at an initial temperature of 32°C. What is the final temperature of the copper?
(Specific heat capacity of copper = 387 Jkg⁻¹ °C⁻¹)

EXAMPLE



$$Q = mc\theta$$

$$124 = 0.15 (387) (\theta - 32)$$

$$124 = 58.05 \theta - 1857.6$$

$$1981.6 = 58.05 \theta$$

$$\theta = 34.136 \text{ } ^\circ\text{C}$$

EXAMPLE



A hot glass marble of mass 60 g and temperature 95°C is added to 200 g of water at 25°C in a plastic container. What is the equilibrium temperature of the system, assuming there is no exchange of heat with the surroundings?

(Specific heat capacity of glass = 840 Jkg⁻¹ °C⁻¹)

$$m = 60 \text{ g} = 0.06 \text{ kg}$$

$$T = 95^\circ\text{C}$$

 Released heat

absorbed heat

$$m = 200 \text{ g} = 0.2 \text{ kg}$$

$$T = 25^\circ\text{C}$$

Heat released = Heat absorbed

$$m_1 c_1 \theta_1 = m_2 c_2 \theta_2$$

$$(0.06)(840)(95 - \theta) = (0.2)(4200)(\theta - 25)$$

$$4788 - 50.4 \theta = 840 \theta - 21000$$

$$890.4 \theta = 25788$$

$$\theta = 28.96^\circ\text{C}$$

A bullet travelling at a speed of 360 ms^{-1} is stopped by a sandbag.
Assuming **half of the energy** of the bullet becomes heat energy that is absorbed by the bullet, calculate the increase in temperature of the bullet.
(Specific heat capacity of the bullet = $160 \text{ Jkg}^{-1} \text{ }^{\circ}\text{C}^{-1}$)

Transformation of energy:
Kinetic energy \rightarrow Heat energy

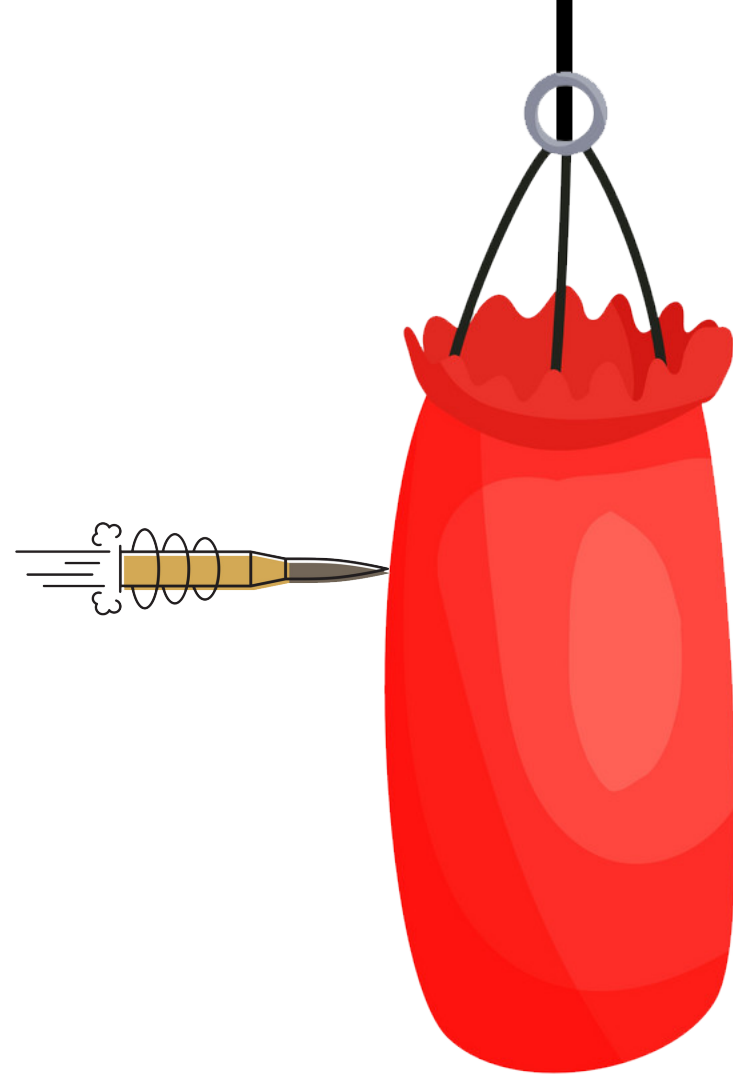
$$\frac{1}{2} \left(\frac{1}{2} m v^2 \right) = m c \theta$$

$$v^2 = 4 c \theta$$

$$\theta = \frac{v^2}{4 c} = \frac{(360)^2}{4(160)}$$

$$\theta = 202.5 \text{ }^{\circ}\text{C}$$

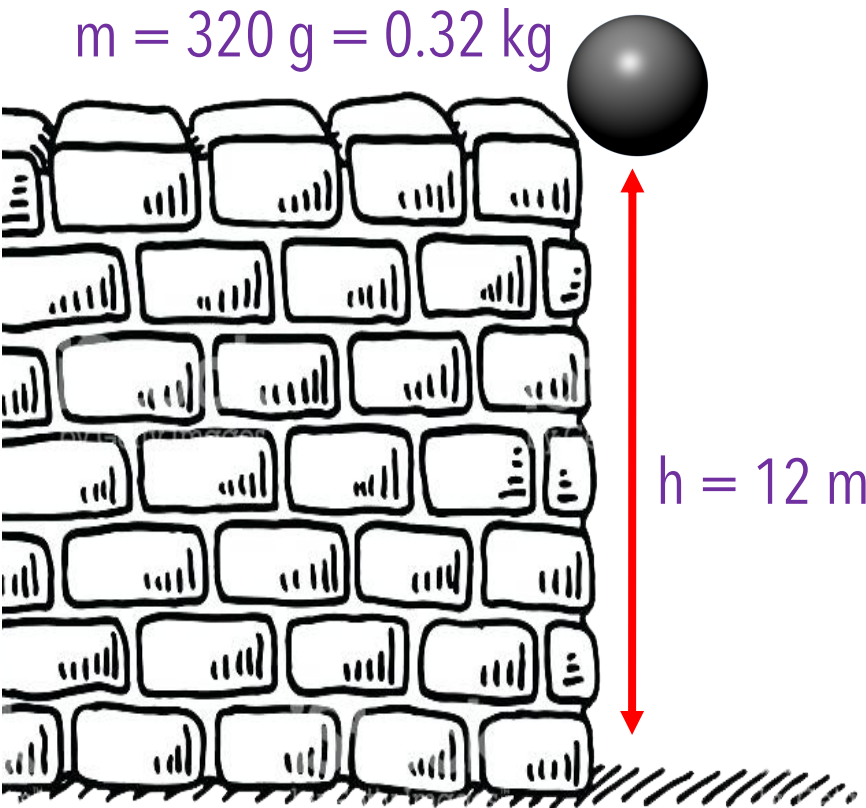
EXAMPLE



EXAMPLE



A lead ball of mass 320 g is dropped from a height of 12 m. The collision between the ball and the ground is completely inelastic. Assuming all the energy of the ball goes into heating it, calculate the change in temperature of the ball.
(Specific heat capacity of lead = $128 \text{ Jkg}^{-1} \text{ }^\circ\text{C}^{-1}$)



Transformation of energy:

Gravitational Potential energy \rightarrow Heat energy

$$mgh = mc\theta$$

$$gh = c\theta$$

$$\theta = \frac{gh}{c} = \frac{10(12)}{128}$$

$$\theta = 0.9375 \text{ }^\circ\text{C}$$

Explain why the kids prefer to walk along waterfront rather than on the sand during a hot day.

EXAMPLE



- sand and sea water receive same **amount of heat**
- **Specific heat capacity** of sand is lower than sea water
- sand become hot faster than sea water
- **temperature** of sand higher than temperature of sea water



EXAMPLE

Explain the use of suitable material and design to improve the ventilation of the house and to ensure the temperature inside the house is not high.

Assemble ventilation fan
Sucking hot air out
From inside the house

Low specific heat capacity of wall
Poor heat conductor

Clay roof

high specific heat capacity
Can absorb and release more heat

Window: Big size

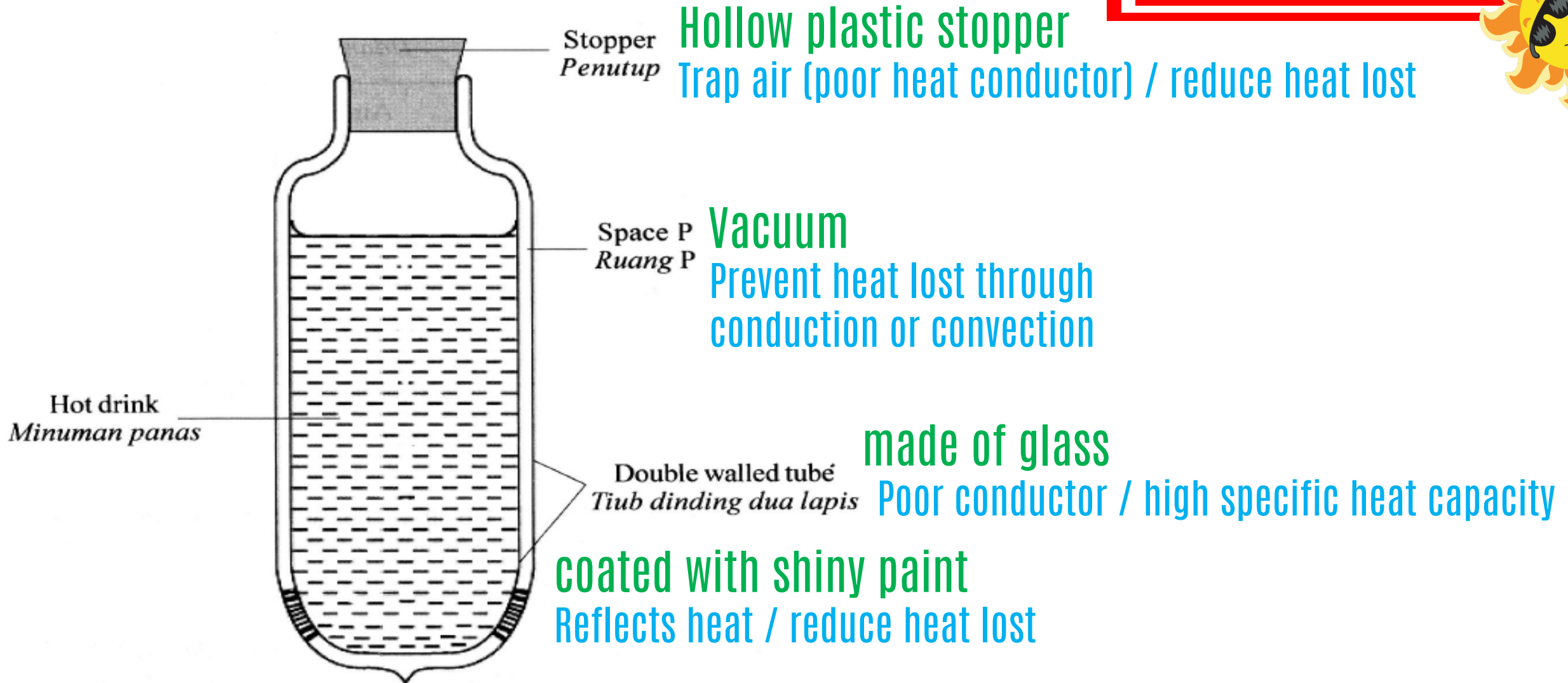
Allow more air flow in and out

More windows
more air can flow in and out



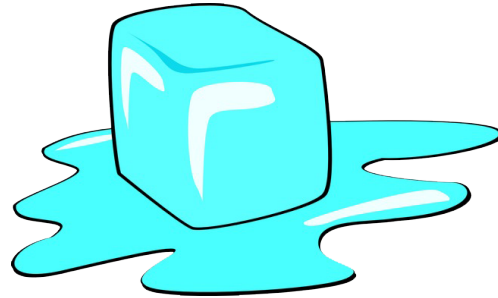
A thermos flask used to maintain the temperature of a hot drink for a long time.

EXAMPLE



Specific Latent Heat

The amount of heat required to **Change** 1kg **OBJECT** physically **Without Change** in its **temperature**



Solid → Liquid

Specific latent heat of fusion, ℓ_f



Liquid → Gas

Specific latent heat of vaporization, ℓ_v

$$Q = m\ell$$

Q = Heat absorbed or released, J

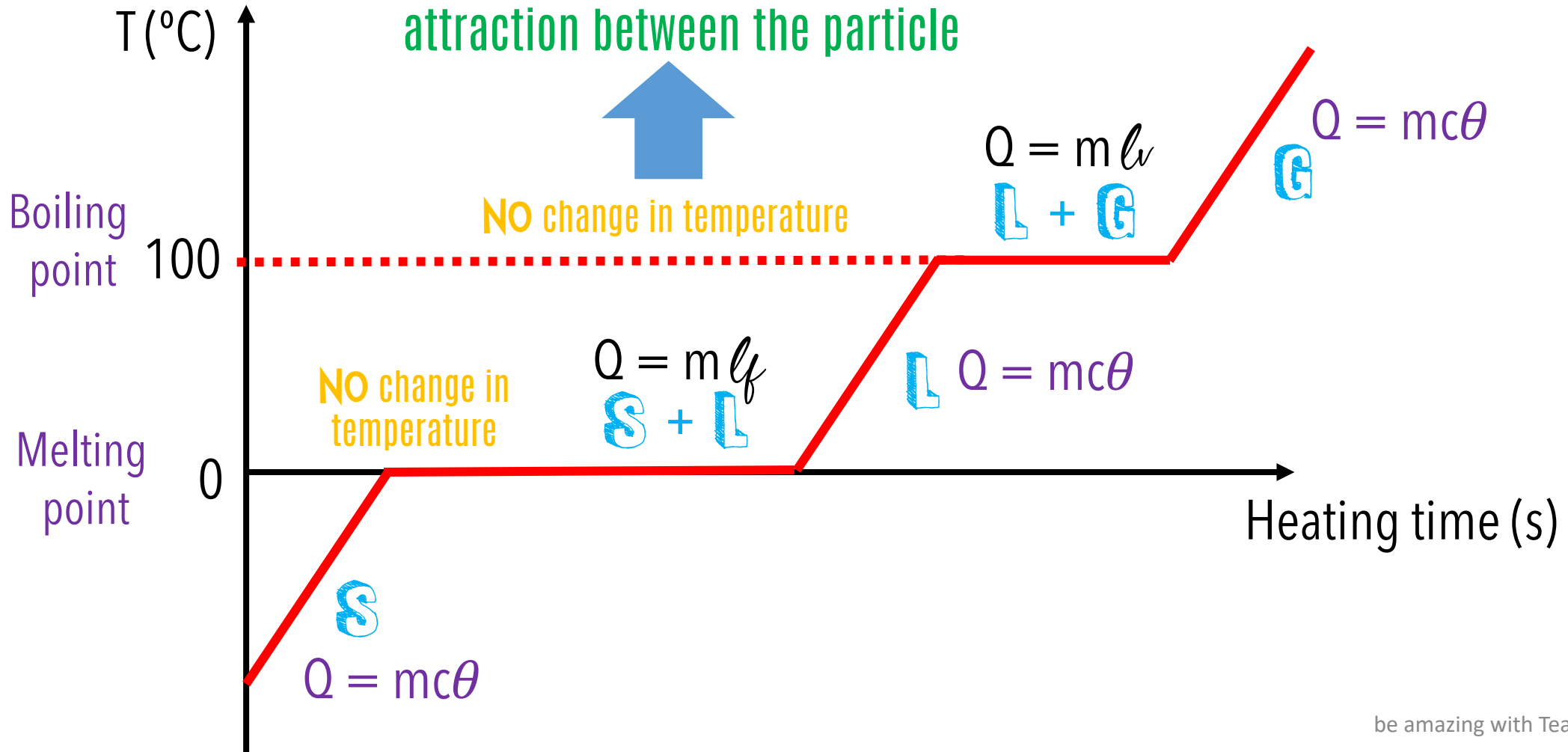
m = Mass of material, kg

ℓ = Specific latent heat, J kg^{-1}

Heating curve for water

Average kinetic energy constant
Temperature unchanged

Heat use to overcome the force attraction between the particle



An ice cube tray in a refrigerator holds 0.40 kg water at 0°C. How much heat must the freezer remove from the water to make ice cubes at 0°C? (Specific latent heat of fusion of water = $3.36 \times 10^5 \text{ Jkg}^{-1}$)

EXAMPLE

$$\begin{aligned} Q &= m l_f \\ Q &= 0.4(3.36 \times 10^5) \\ &= 1.344 \times 10^5 \text{ J} \end{aligned}$$



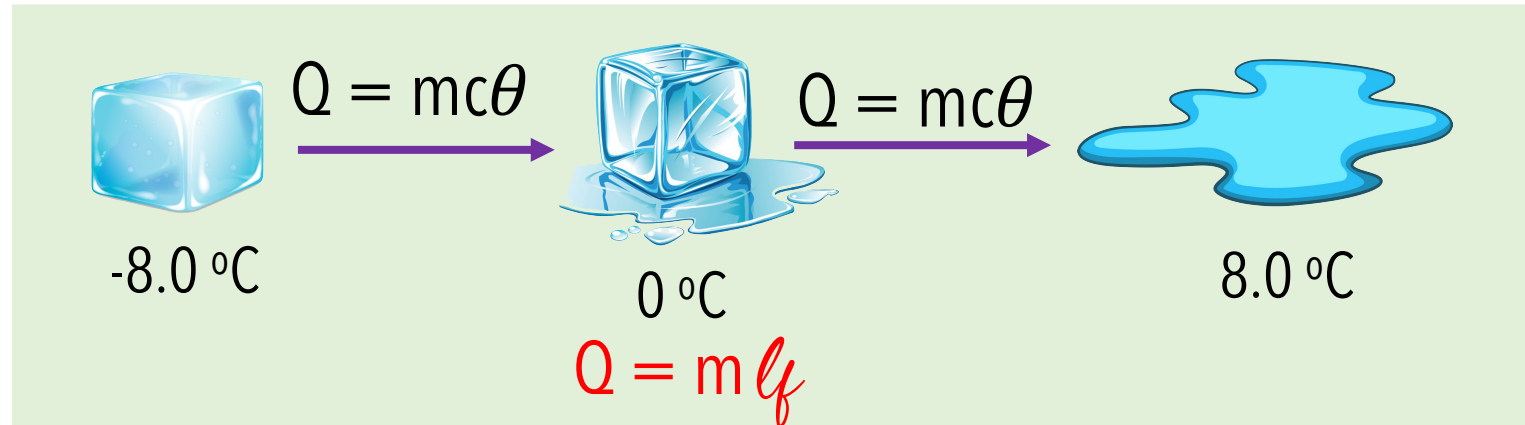
EXAMPLE

A heat transfer of 7.2×10^5 J is required to convert a block of ice at -8.0 °C to water at 8.0 °C. What is the mass of the block of ice?

(Specific heat capacity of ice = 2.0×10^3 Jkg⁻¹ °C⁻¹)

Specific heat capacity of water = 4200 Jkg⁻¹ °C⁻¹

Specific latent heat of fusion of water = 3.36×10^5 Jkg⁻¹)



$$Q = mc\theta + m l_f + mc\theta$$

$$7.2 \times 10^5 = m [2.0 \times 10^3 (8) + (3.36 \times 10^5) + (4200 \times 8)]$$

$$7.2 \times 10^5 = 403200 m$$

$$m = 1.87 \text{ kg}$$

EXAMPLE

Water is boiling in a 3 600 W electric kettle.

How long does it take for 0.12 kg of water to boil?

(Specific latent heat of vaporization of water = $2.26 \times 10^6 \text{ Jkg}^{-1}$)



$$Q = m l_v$$

$$Pt = m l_v$$

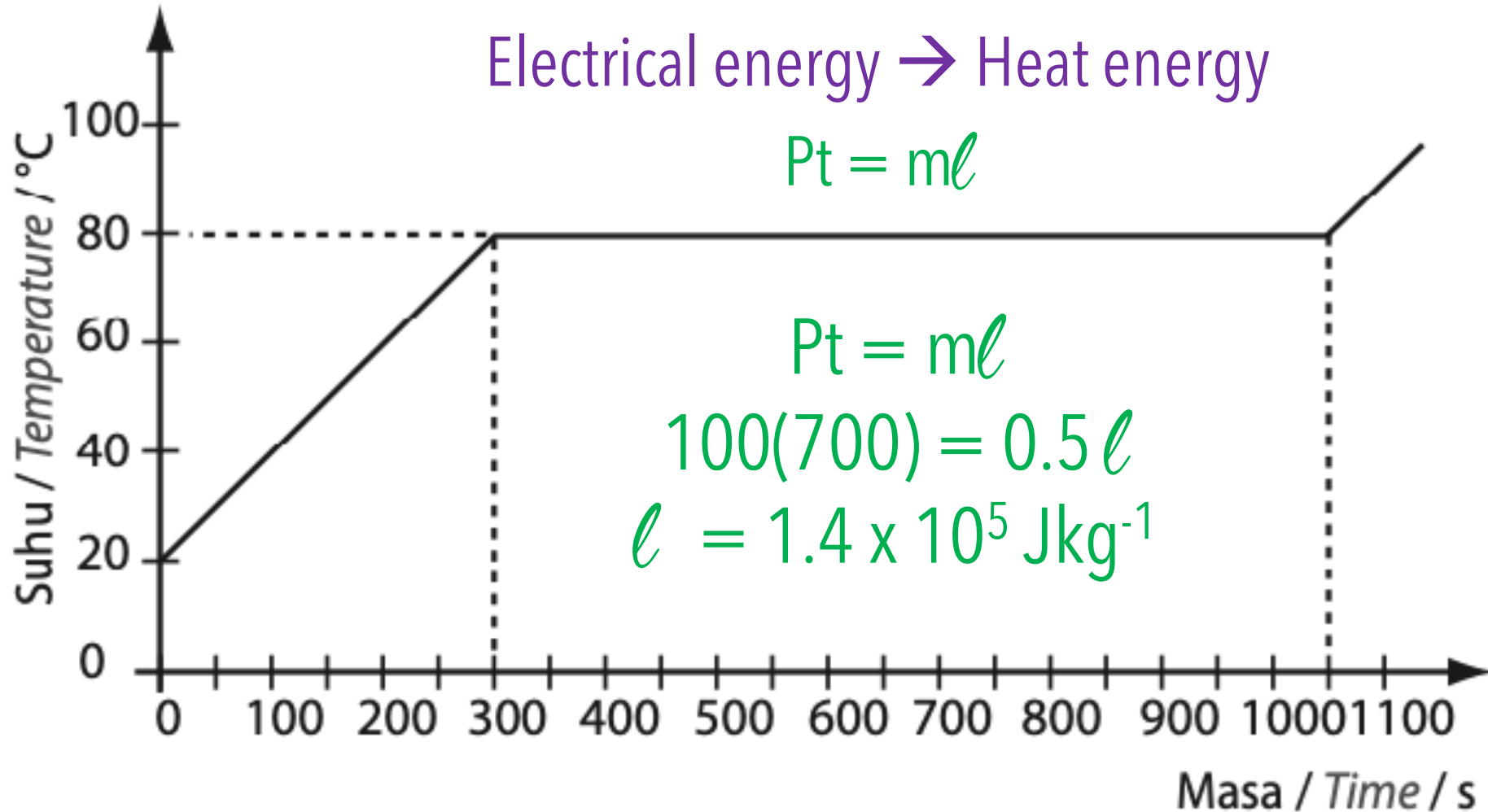
$$3600t = 0.12(2.26 \times 10^6)$$

$$3600t = 271200$$

$$t = 75.33 \text{ s}$$

EXAMPLE

0.5 kg of a solid block is heated by a 100 W heater. The graph shows the temperature varies with time. Calculate the specific latent heat of fusion of the solid.



application



Cooling Drinks

When the ice is melting, the latent heat of fusion is absorbed from the drinks. The temperature of the drinks is lowered.

Sweating

The sweat evaporates and the body's heat is removed as the latent heat of vaporization, thus our body's temperature is decreased.



Steaming food

Food such as cakes, eggs, fish, buns and others receive a large amount of energy when the latent heat of vaporization of steam released from condensing steam.

GAS LAW

Behavior of gas molecules

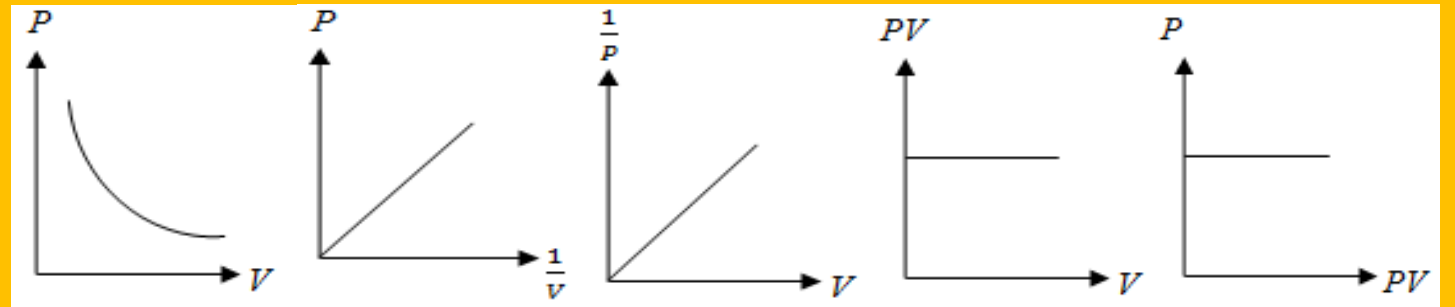
Property of gas	Explanation
Volume, V • m^3	<ul style="list-style-type: none">• The molecules move freely in random motion and fill up the whole space in the container.• The volume of the gas is = to the volume of the container
Temperature, T • K (Kelvin)	<ul style="list-style-type: none">• The molecules are in continuous random motion and have an average kinetic energy which is proportional to the temperature.
Pressure, P • Pa (Pascal)	<ul style="list-style-type: none">• The molecules are in continuous random motion.• When a molecules collides with the wall of the container and bounces back, there is a change in momentum and a force is exerted on the wall• The force per unit area is the pressure of gas

Boyle's law

for a fixed mass of gas,
**the pressure of the gas is
inversely proportional
to its volume**
when the **TEMPERATURE** is kept constant

$$P \propto \frac{1}{V}$$

$$P_1 V_1 = P_2 V_2$$



Boyle's law



$$P \propto \frac{1}{V}$$

$$P_1 V_1 = P_2 V_2$$



example

An air bubble at the bottom of a pond has a volume of 4.0 mm^3 . The air bubble is at a depth of 5.0 m from the surface of the pond. Assume that there is no change in temperature, find the volume of the bubble when it rises to the surface of the pond.

$$P_1 V_1 = P_2 V_2$$
$$(10 + 5) 4 = 10 \times V_2$$
$$V_2 = 6 \text{ mm}^3$$

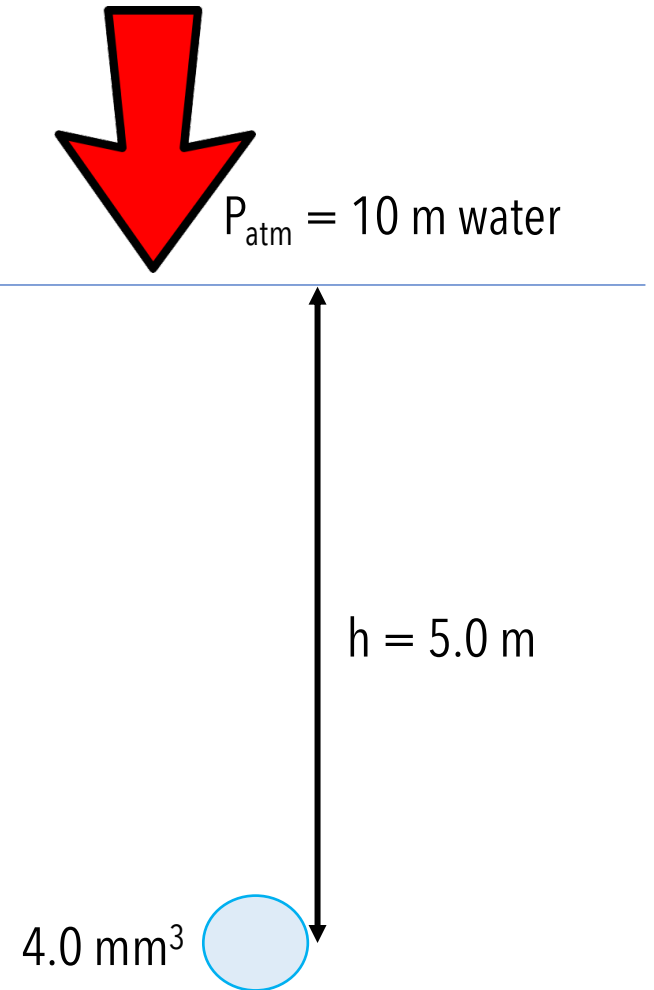
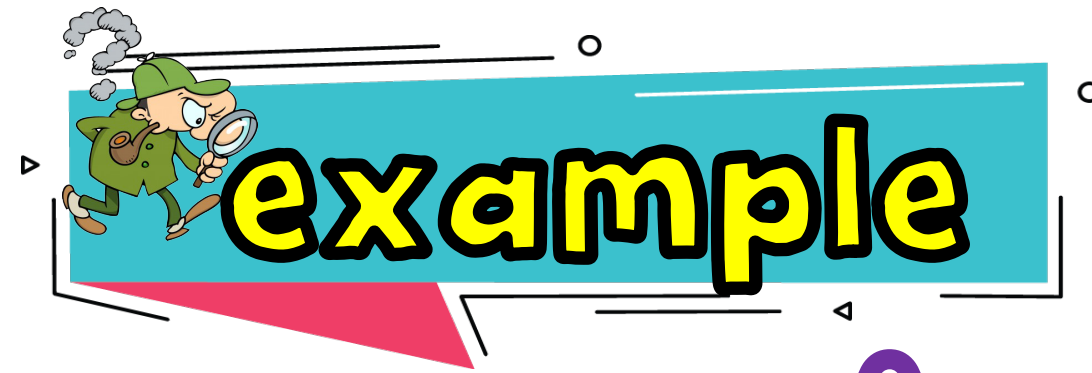


Diagram shows air bubbles P and Q by a diver.

- Compare the size of the air bubbles, the depth of the air bubbles and the pressure on the air bubbles P and Q.
- Relate the size of the air bubble with the depth of the air bubble.
- Relate the depth of the air bubble with the pressure on the air bubble.



- SIZE : $P < Q$
- DEPTH : $P > Q$
- PRESSURE : $P > Q$
- The **bigger** the **depth**, the **smaller** the **size** of the air bubble
- The **bigger** the **depth**, the **higher** the **pressure** on the air bubble
- The **higher** the **pressure**, the **smaller** the **volume**

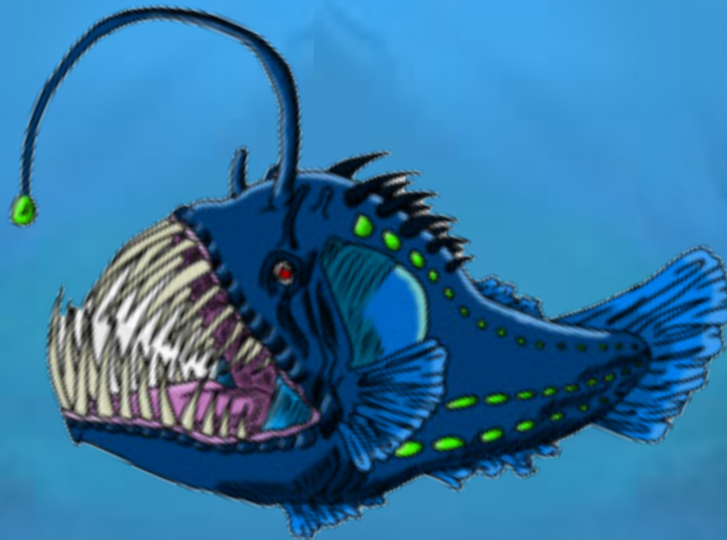




example

- An Angler fish, a type of fish that lives only in deep sea. When it is brought to the surface of the seawater, the fish will die. By using physics concept, explain why the fish dies.

- the **ocean** is **deep** so the **pressure** is **high** at seabed
- the **nature** of the fish is to stay in the **high pressure** surrounding
- when brought towards the surface, the **pressure decreases**, **volume** of the fish **increases**.
- the **gas** in the body will **expand** so the **internal organ** of the fish will **burst**.



Charles' law

for a fixed mass of gas, the **VOLUME of gas is directly proportional to its absolute temperature**

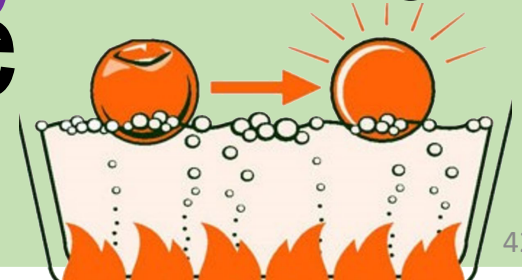
when the **PRESSURE** of gas is kept constant



$$V \propto T$$

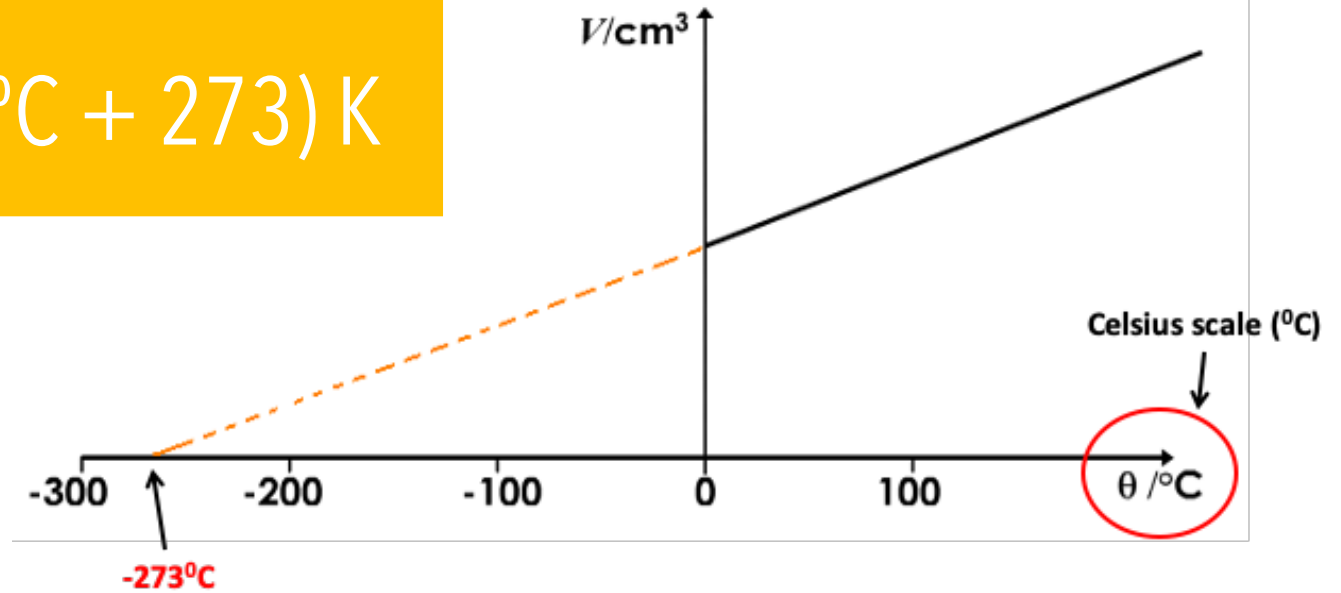
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Temperature increase, Kinetic energy increase
Collision between the **particle increase**
Volume of gas **increase**

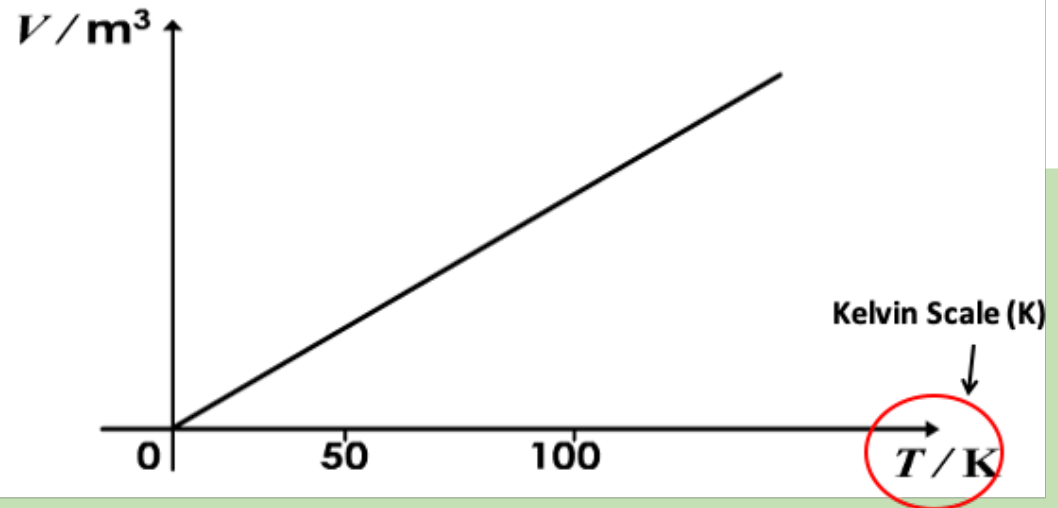


Charles' law

$$T = (\theta \text{ } ^\circ\text{C} + 273) \text{ K}$$



absolute zero of temperature - 273°C is equivalent to 0K



absolute zero:

The lowest temperature in theory in which the pressure and the kinetic energy of gas molecules are zero



A cylinder of volume 0.2 ℓ contains a mixture of air and petrol at atmospheric pressure at a temperature of 25°C. The gas is expanded by pulling a piston until the volume is 0.25 ℓ under constant pressure. Find the new temperature of mixture, in Celsius.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \rightarrow \quad \frac{0.2}{25 + 273} = \frac{0.25}{T_2}$$

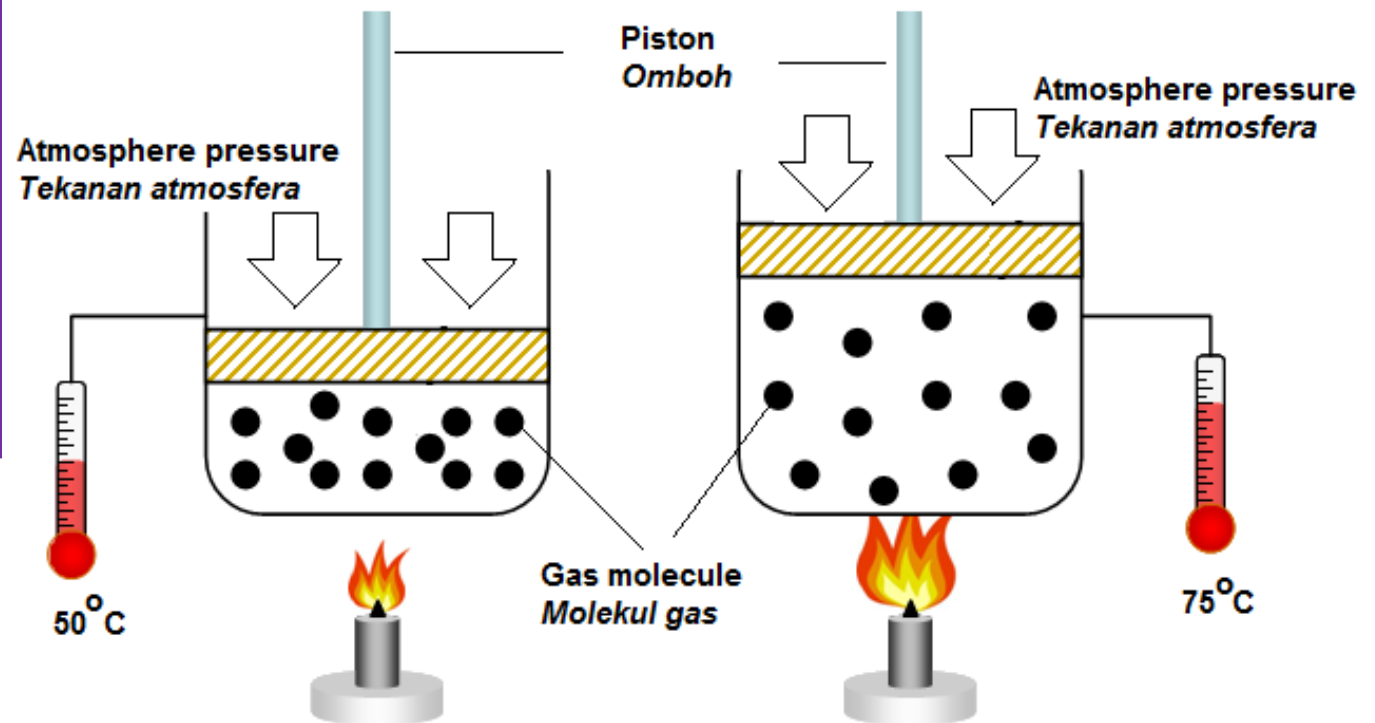
$$T_2 = 372.5 \text{ K} \\ = 99.5 \text{ }^\circ\text{C}$$

Important Notes → Temperature in Kelvin

Diagram show a trapped gas being heated in an enclosed space.

By using the kinetic theory of molecule, explain why volume increases when the temperature of air increases.

- Temperature increases, Kinetic energy will increases
- Collisions between the molecule increase, thus the volume will increases



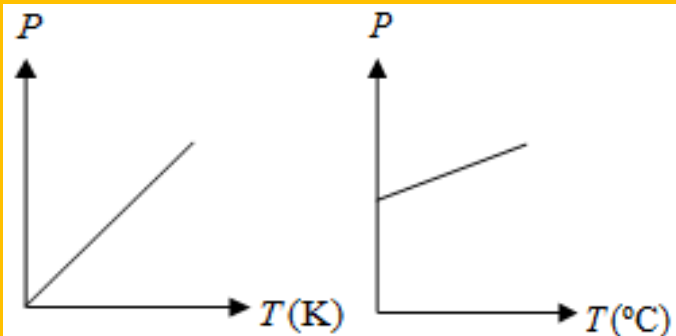


A gas of volume 35 m³ at temperature 40 ° C is heated at a fixed pressure.
Calculate the volume of the gas when its temperature reaches 70 ° C.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$
$$\frac{35}{40 + 273} = \frac{V_2}{70 + 273}$$
$$V_2 = 38.35 \text{ m}^3$$

Pressure law

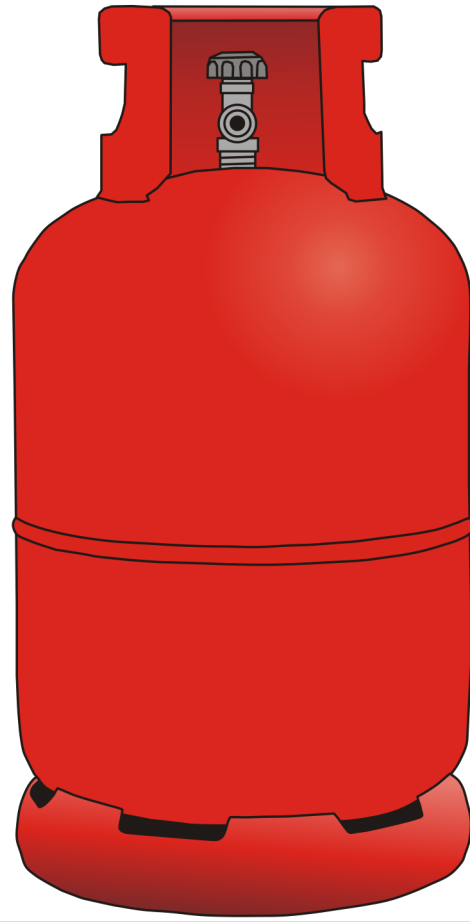
for a fixed mass of gas, the **pressure of gas is directly proportional to its absolute temperature** when the **VOLUME** of gas is kept constant



at -273°C ,
the **pressure**
becomes **zero**

$$P \propto T$$
$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Pressure law



Temperature increase, Kinetic energy increase

Collision between the **particle** and the **wall increase**

Rate of change of momentum is produced

Pressure increase

$$P \propto T$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

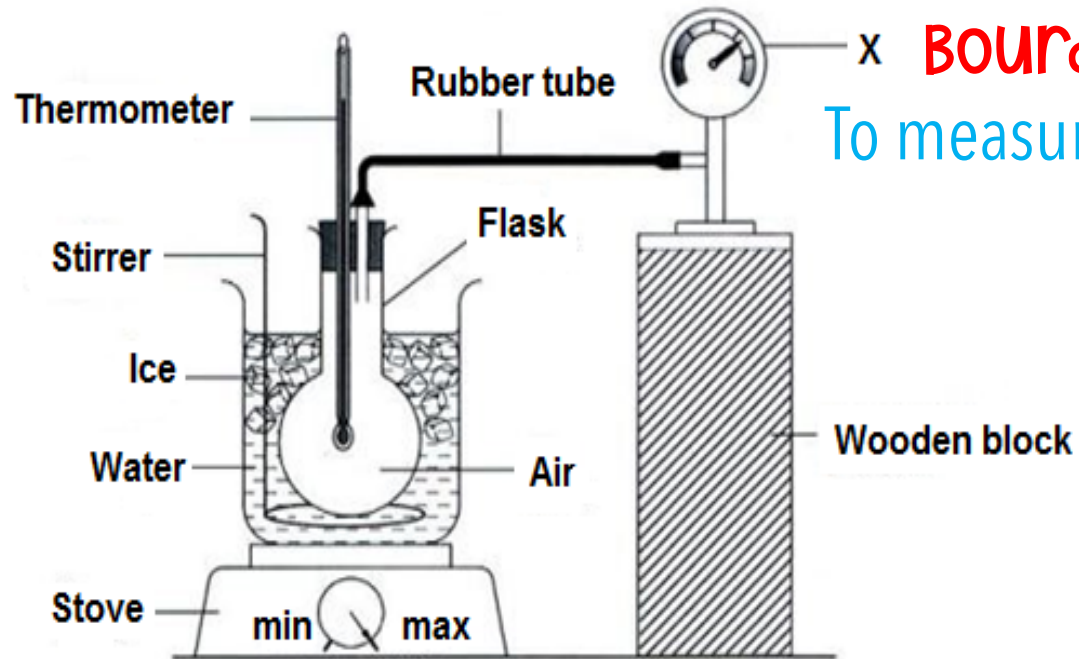


The pressure of some oxygen at 1.5 atmospheres is to be increased to 2.7 atmospheres. If the initial temperature of oxygen is 12°C. What is the final; temperature of oxygen?

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \rightarrow \quad \frac{1.5}{12 + 273} = \frac{2.7}{T_2}$$

$$T_2 = 513 \text{ K} \\ = 240 \text{ }^\circ\text{C}$$

The apparatus is set up to used to investigate the relationship between pressure and temperature of air at constant volume and mass.



By using the kinetic theory of molecule, explain why the reading of X increases when the temperature of air in the flask increases.

- Kinetic energy // speed of air molecules increases
- Frequency collision between air molecules and wall of the flask increase
- Rate of change of momentum increase / pressure increase



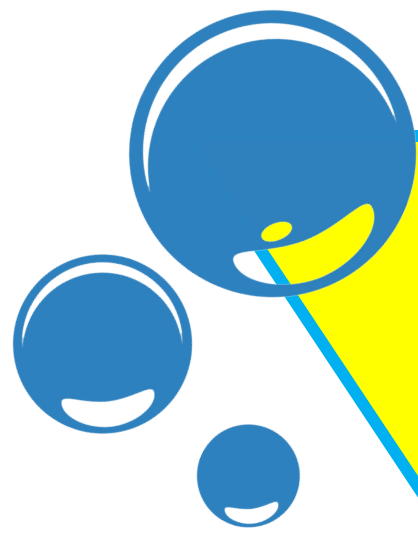
example

A motorist blows up his motorcycle tyres to a pressure of 2.7×10^5 Pa in a cold morning when the temperature is 15°C . What is the pressure in the tyres on a hot day of temperature 37°C ?

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$
$$\frac{2.7 \times 10^5}{15 + 273} = \frac{P_2}{37 + 273}$$
$$P_2 = 2.91 \times 10^5 \text{ Pa}$$



Important Notes → Temperature in **kelvin**



Boyle's law

$$P_1 V_1 = P_2 V_2$$

P V

Pressure law

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Charles' law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

T



Important Notes → $T = (\theta \text{ } ^\circ\text{C} + 273) \text{ K}$

be **AMAZING!**

and enjoy learning
Physics with Teacher Alina



The
expert in
anything
was
once a
beginner.