Temperature

Temperature of an object is due to the kinetic energy of the object

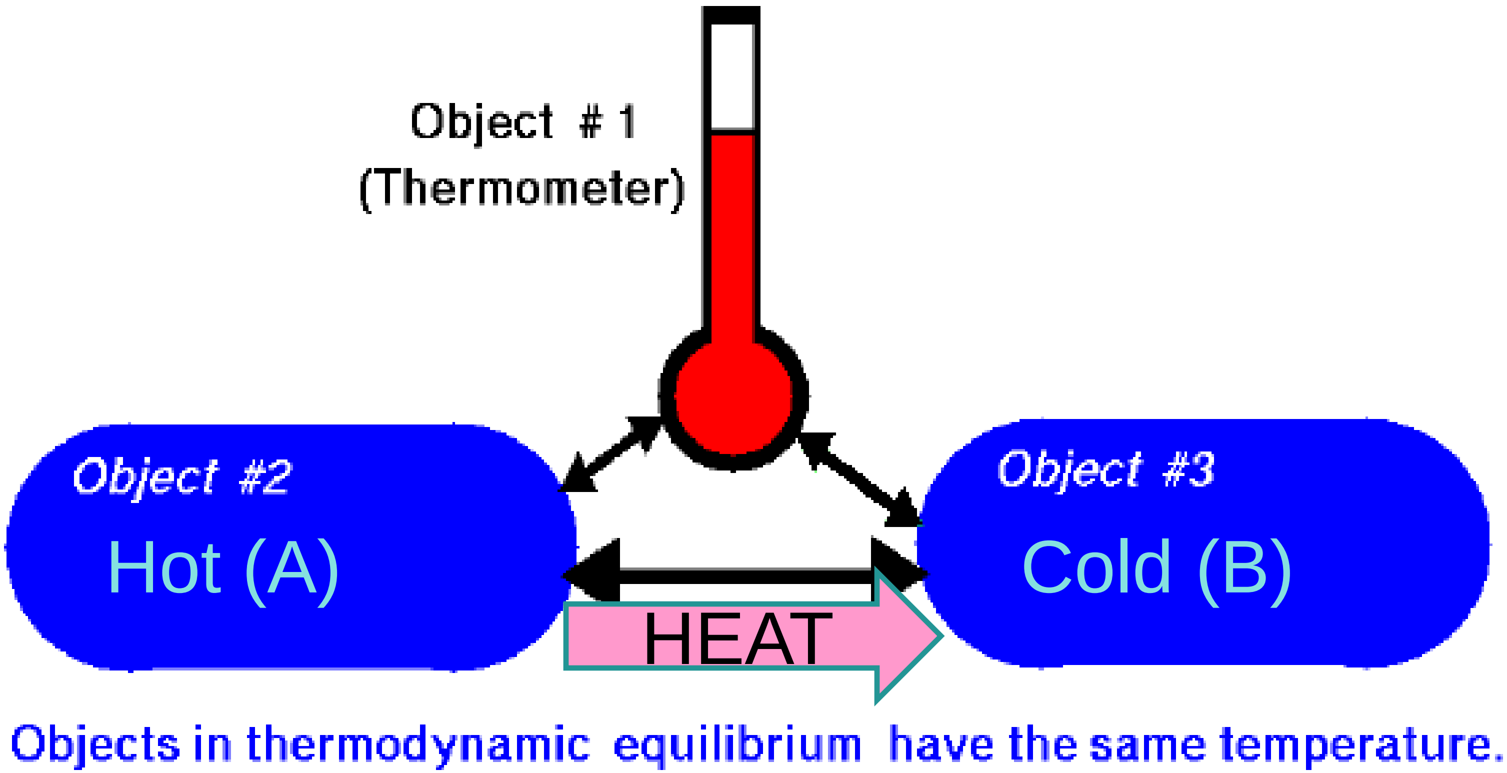
As the kinetic energy of atoms and molecules increase, the temperature of material also increases.

According to Newton's second law of motion;

- Kinetic energy of a moving object depends on the mass and speed of the object.

- If atoms and molecules are moving, they must have the kinetic energy.

Thermal equilibrium :



Temperature measurement :

The properties of

many materials change due to heat or cold.

*the volume of a liquid,

*the length of a metal rod or

*the pressure of a gas at constant volume.

Thermometric object

- whose **physical properties** change depending on the **temperature**

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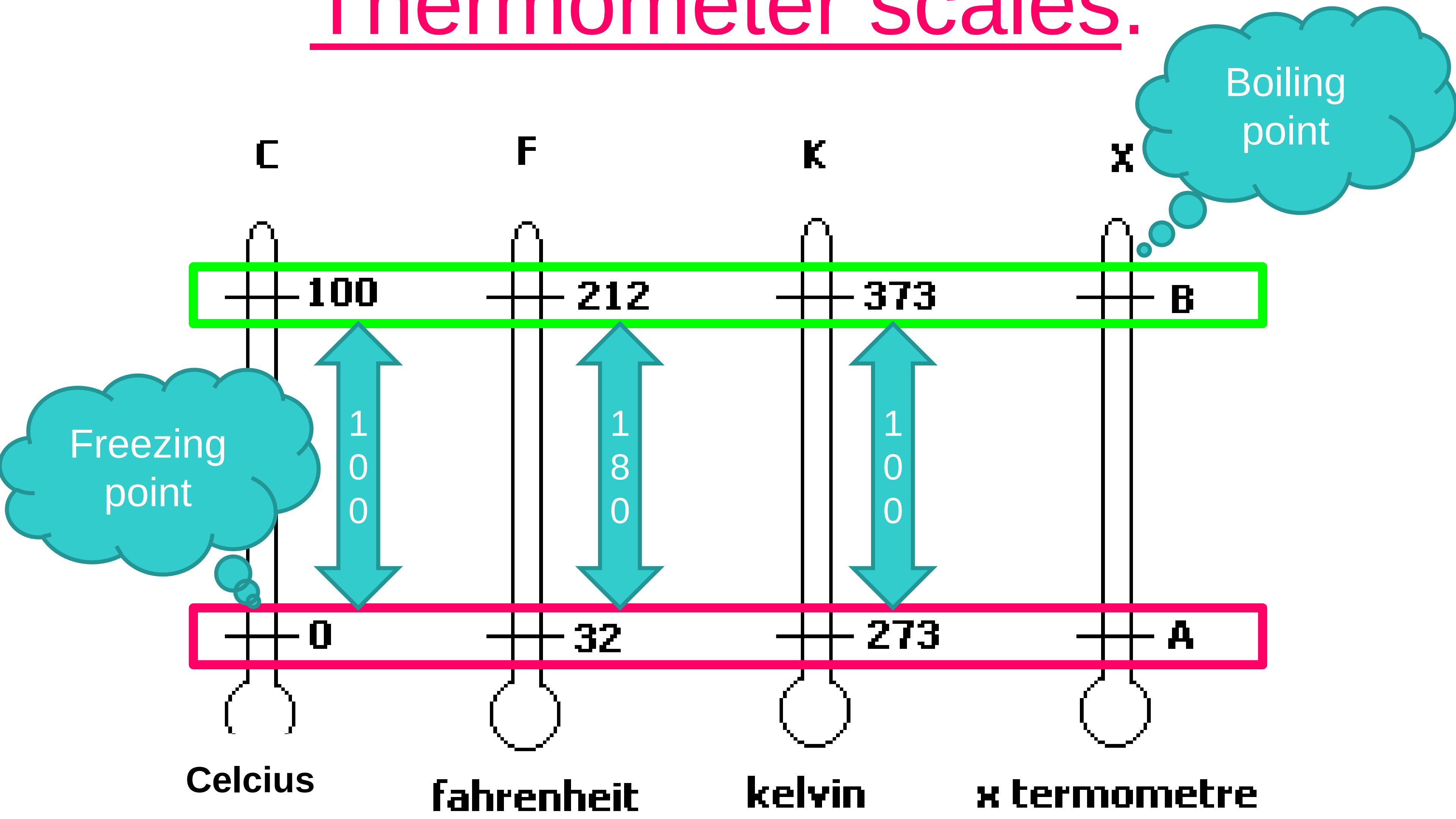
should always result in **the same change** in length in mercury column.

- Example of thermometric ojects: mercury and alcohol

Thermometer scales:



- The Kelvin scale uses **the same graduation** as the Celsius scale.

- The Fahrenheit scale uses **the same graduation** as the Rankine scale.

There are **no negative values** in :

- Kelvin scale
- Rankine scale.

Fahrenheit scale

- Designed in 1724 by German scientist Gabriel Daniel Fahrenheit
- 32 respresents freezing point of water, 212 represents boiling point of water
- The unit is shown with °F symbol.
- This scale consists of 180 (212 – 32 = 180) parts between freezing and boiling points of water.
- There was no physical meaning of zero degree in Fahrenheit scale.
- This temperature scale is still widely used in the U.S. and UK.

Celcius scale

- Designed in 1742 by the Swedish scientist Andreas Celsius
- Zero respresents freezing point of water, 100 represents boiling point of water.
- This scale is also called "centigrade" (cents: 1/100; Grade: grade)
- The unit is shown with °C (Celsius) symbol.
- This scale consists of 100 (100 – 0 = 100) units between freezing and boiling points of water.

Celcius scale

- In both Fahrenheit and Celsius scaled, negative numbers can be measured.
- Despite the Fahrenheit scale has been found earlier, the Celsius scale takes its place in the scientific research. This is because metric system (SI, mks and cgs) is arranged on the basis of 10.
- As well as scientific studies, nowadays, the Celsius scale is widely used in many countries.

Kelvin scale

- Designed in 1854 by Scottish physicist Lord William Kelvin.
- The symbol of Kelvin scale is K and degree symbol (°) is not used.
- Kelvin scale uses the same graduation as the Celsius scale.
- 0 K (absolute zero point) corresponds to –273°C in Celcius scale

(**lowest temperature was measured on earth**).

Rankine scale

- Designed in 1859 by Scottish physicist William John Macquorn Rankine
- The symbol of Rankine scale is R and degree symbol (°) is not used.
- Similar relationship between Kelvin and Celsius scales is valid between Fahrenheit and Rankine scale.
- 0 R (absolute zero point) in Rankine scale corresponds to –460°F in Fahrenheit scale.

(**lowest temperature was measured on earth**)

Absolute zero

- Lowest temperature that can be measured on earth.

SCIENTIFICALLY;

- absolute zero is the temperature of atoms, electrons or molecules when they have the lowest energy (no motion)

Conversions between different scales

$$°F = 1.8 \times °C + 32$$

$$K = °C + 273$$

$$R = °F + 460$$

Temperature differences

$$\frac{(212 - 32)\ \Delta°F}{(100 - 0)\ \Delta°C} = \frac{180\Delta°F}{100\Delta°C} = \frac{1.8\ \Delta°F}{\Delta°C}$$

If the actual scale divisions are the same, the temperature are the same!

- $\Delta T(K) = \Delta T(°C)$
- $\Delta T(R) = \Delta T(°F)$

$$\frac{(373 - 273)\ \mathrm{K}}{(100 - 0)\ ^\circ\mathrm{C}} = \frac{100\ \Delta T\ (\mathrm{K})}{100\ \Delta T\ (^\circ\mathrm{C})} = \frac{\Delta T\ (\mathrm{K})}{\Delta T\ (^\circ\mathrm{C})}$$

$$\frac{(672 - 492)\ \mathrm{R}}{(212 - 32)\ ^\circ\mathrm{F}} = \frac{180\ \Delta T\ (\mathrm{R})}{180\ \Delta T\ (^\circ\mathrm{F})} = \frac{\Delta T\ (\mathrm{R})}{\Delta T\ (^\circ\mathrm{F})}$$

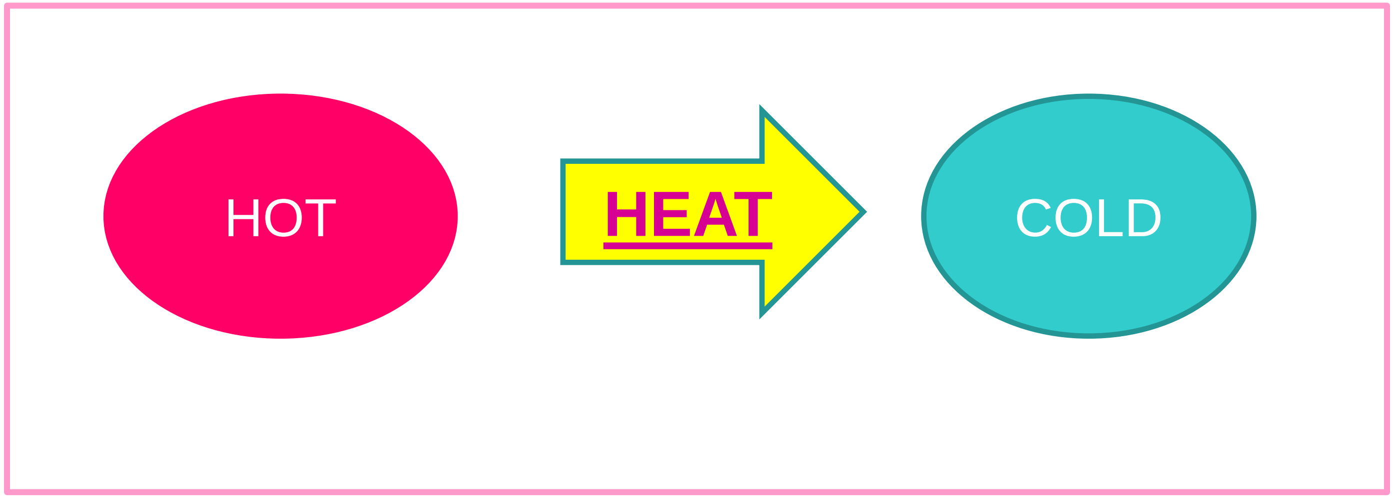
Example 15 : When water at 40°C has been heated to 95°C:

- Find out the initial and final temperature of water in Kelvin scale.
- Find out the initial and final temperature of water in Fahrenheit scale.
- Find out the temperature differences in Celcius (°C), Fahrenheit (°F), Kelvin (K) and Rankine (R) scales.

- **Example 16 :** Temperature of a frozen food (A) has been measured as –20°C, while that of another (B) has been measured –20°F. Find out the temperature of A food as "°F", and that of B food as "°C".

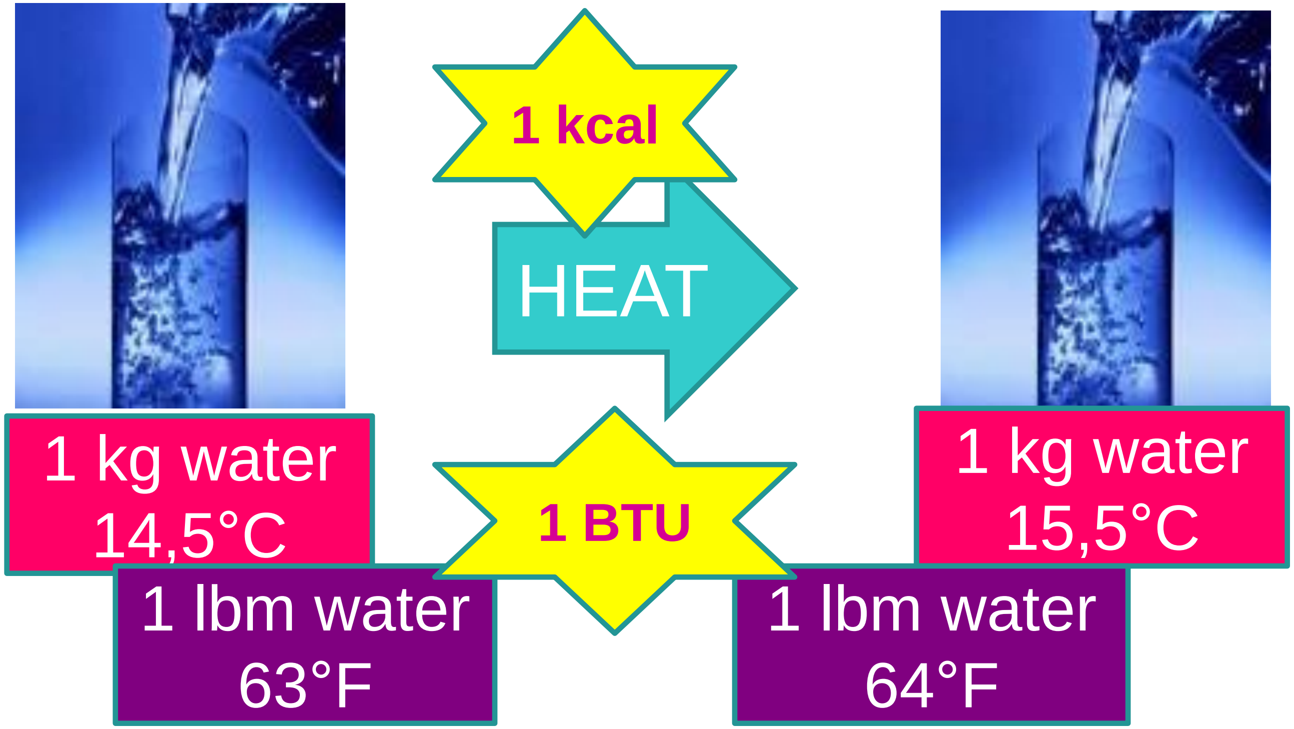
Heat:

- A type of energy



Units of heat

- Heat can be defined in terms of a particular change in an object during a process.



- All forms of energy can be converted into each other.

- Heat energy is equivalent to mechanical energy and was measured by **James Joule** for the first time.

- The unit of heat ⇨ **JOULE (J)**

Relations between units of heat energy

1 cal = 4.186 J

1 kcal = 4.186 kJ

1 BTU = 1055 J

Pressure

- Pressure is expressed as force per unit area.

- The dimensions of pressure are (mass)/(length) $(\text{time})^2$.

Table 2.6 Pressure units

Systems	Units		
	Force	**Area**	**Pressure**
SI	N	m^2	N/m^2 (Pa)
English	lb_f	in^2	lb_f /in^2 (psi)

SI Unit System;

- Force → Newton
- Pressure → Pascal (Pa)

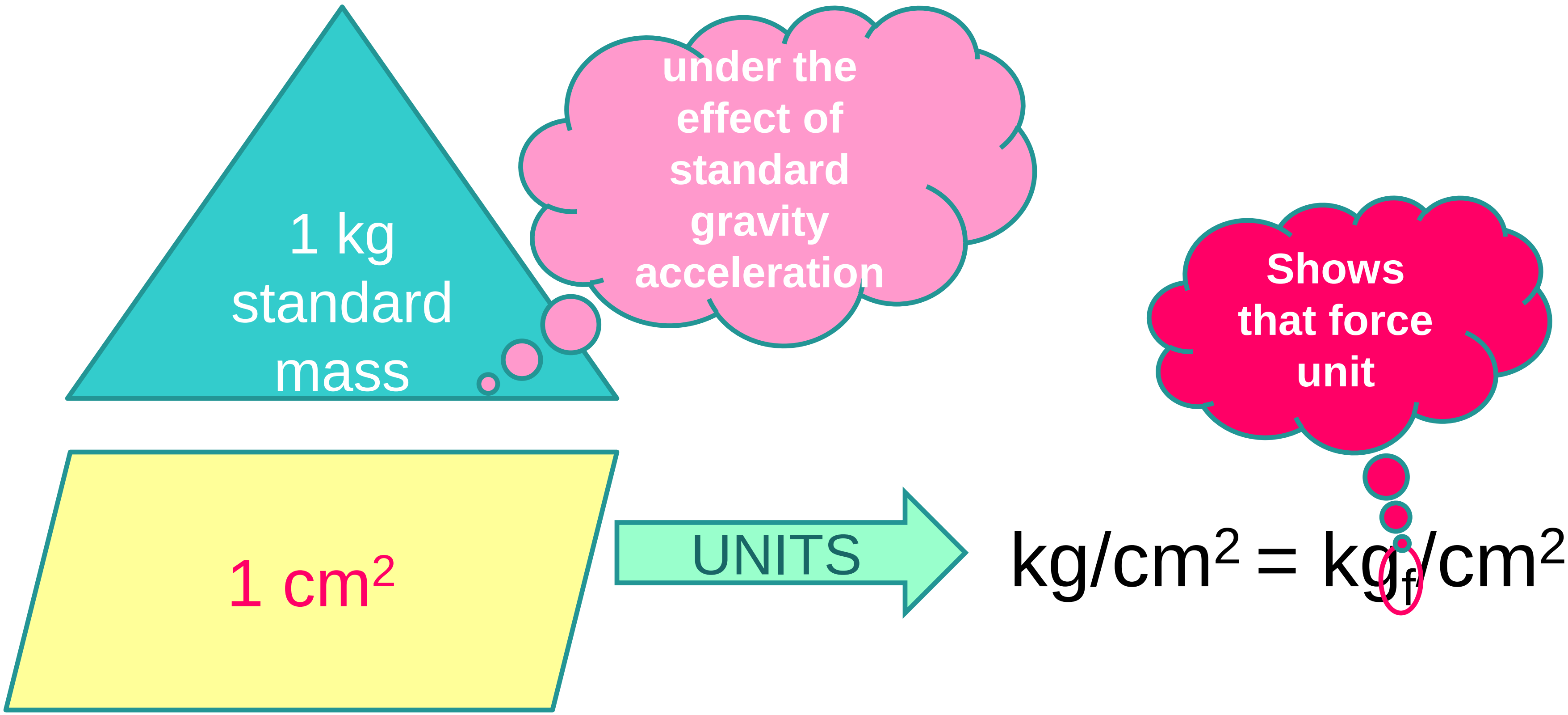
English Engineering System;

- Force → lb_f
- Pressure → lb_f/in^2

The others;

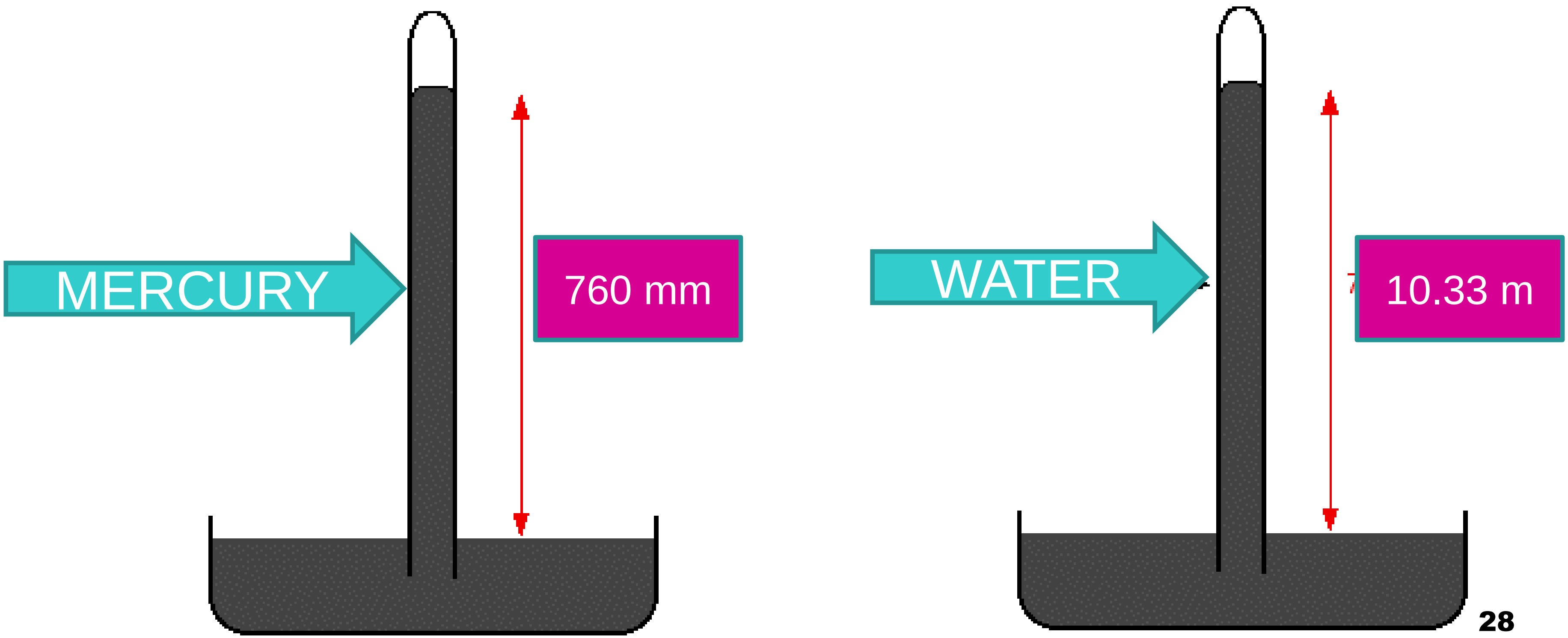
- kg/cm^2, kg_f/cm^2, kp/cm^2, atm, at, ata and atü.

Technical atmosphere (at);



Pressure:

- Pressure is often expressed as **a height of a particular fluid.**
- The air at 0°C and sea level raises the height of mercury in a column as **760 mm.**



760 mmHg = 10.33 m water (standart atm. pressure)

- expression the pressure by the height of the liquid column is generally used for hydrostatic pressures

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- Hydrostatic pressure is the pressure which results from the weight of the liquid column.

Example: Find out 1.0332 kg/cm^2 (at) using the density of mercury (13.5951 g/cm^3).

Standard atmospheric pressure (atm):

- **1 atm:** Pressure which is produced by a column of mercury to 760 mm high.
- It is equal to air pressure at sea level (1 atm).

Units of standard atmospheric pressure:

1 atm = 760 mm Hg

1 atm = 14.696 lb_f/in^2

1 atm = 101 325 Pa

1 bar = 100 000 Pa

1 atm = 1.01325 bar

- **Example 17 :** Atmospheric pressure in Ankara is 690 mm Hg. Find out the equivalent of this pressure in kPa and lb_f/in^2.

Answers:

- 690 mm Hg = 92 kPa
- 690 mm Hg = 13.32 lb_f/in^2

- **Example 18 :** Convert the pressure of 690 mm Hg into lb_f/in^2 without the use of "14.696 lb_f/in^2."

- **Example 19 :** Convert the technical atmosphere of 1.0332 kg/cm^2 into standard atmosphere.

Answer: 1.0332 $kg/cm^2 = 1$ atm

Units of Pressure in SI Unit System;

- $Pa = \dfrac{N}{m^2} = \dfrac{kg\ m / s^2}{m^2} = kg\ m^{-1}\ s^{-2}$

kPa — 10^3 times higher than Pa

Mpa — 10^6 times higher than Pa

Bar — 10^5 times higher than Pa

(kPa, Mpa, Bar:) mostly used instead of Pa

1 atm = 1.01325 bar

Absolute pressure

- ***Absolute pressure*** is the pressure which is measured relative to the absolute zero pressure (the pressure that would occur at absolute vacuum)

(starting point is 0 atm)

Absolute pressure	=	**Manometer pressure**	+	**Atmosphere pressure**

- Pabs = Pgauge + Patm

(psia = psig + Patm)

Pressure measurement is based on two different principles

Starting point is atmospheric pressure (atmopheric pressure is marked as zero)

Effective pressure (manometer or gauge pressure)

Starting point is «real» 0 atm.

Absolute pressure

VACUUM :

- If a system pressure is lower than 1 atm (abs), there is **vacuum** in there.

Vacuum = **Atmosphere pressure** - **Absolute pressure**

- **Example 20:** The pressure in a hermetically closed container is measured as 0.605 atm (abs.). Find out the vacuum in this container.

Manometer

- Instruments that are used **to measure pressure** are called "gauge (manometer)".

normal atmospheric pressure is marked as "zero".

Effective pressure = Manometer pressure

Accordingly;

- Manometer pressure + atmospheric pressure

ABSOLUTE PRESSURE

- PRESSURE → abs?, eff?

- If the pressure type is not given → effective pressure

In EES;

- Pressure → lbf / in^2 → (psi; pound per square)

psi a — Absolute pressure

psi g — manometer

Perfect vacuum → Zero pressure

Absolute pressure → When pressure is measured relative to absolute vacuum

$$P_{absolute} = P_{atmosphere} + P_{gauge}$$ If pres. greater than Patm

$$P_{vacuum} = P_{atmosphere} - P_{absolute}$$ If pres. lower than Patm

- **Example 21:** Convert the pressure value of 20 psig to kPa (abs).

Answer: 20 psig = 238.5 kPa (abs)

Example 22 : An evaporator works on a vacuum of 20 in Hg. Find out absolute pressure of the evaporator in :

- SI and
- English systems.

Answers:

9.87 in Hg (abs) =33 423.8 Pa (abs)= 33.42 kPa (abs)

9.87 in Hg (abs) = 4.84 lb_f/in^2 (abs)

In situation involving fluid flow;

$$P = \rho g h$$

where :

P : fluid pressure (Pa),

ρ : fluid density (kg/m^3),

g : the acceleration due to gravity ($9.81\ m/s^2$)

h : the height of fluid (m).

- **Example 23:** Find out the height (mm) of milk in a tank filled with milk with 0.2 atm pressure. The density of milk is 1.028 g/cm^3.

Answer: h = 2 m

Pressure exerted by the liquid is independent from:

- Diameter of tank
- Weight of liquid

Pressure exerted by the liquid is dependent on:

- Only the **height** of liquid in the tank

- **Example 24:** A spherical tank whose diameter is 2 m has been filled with olive oil whose density is 0.915 g/cm^3. The pressure at the top of the tank is 75 kPa. Thus, calculate the highest pressure in the tank according to SI units.

- The highest pressure in the tank will be in the bottom of tank and is calculated as follows:

$$P_{max} = P_{top\ of\ tank} + P_{olive\ oil}$$

Answer: $P_{max} = 92.95$ kPa

- **Example 25 :** A pressure of 0.69 bar (gauge) is applied to the bottom of a tank filled with water. Calculate the static head (height) of water in SI units.

Answer: h = 7 m

- **Example 26 :** An unclosed tank whose diameter is 1 m will be filled with tomato juice (6% soluble solid content). However, the pressure in the tank must not greater than 120 kPa. Thus, calculate the highest content of tomato juice which can be filled to the tank. The density of tomato juice is 1025 kg/m^3.

Answer: W = 1497 kg tomato juice