Section 1.1.4 – Temperature

VCAA Study Design Dot Points

- convert between Celsius and kelvin scales
- describe temperature with reference to the average translational kinetic energy of the atoms and molecules within a system

The Kinetic Theory of Matter

The kinetic theory of matter states that;

- matter is made of **small particles** (atoms) which can group to form larger particles (molecules)
- these particles are in a constant state of **random motion**

This theory helps explain observable properties and behaviours of **solids**, **liquids** and **gases.**

Table 1 below displays the relationship between the arrangement/motion of the particles in each state of matter and the macroscopic properties of each state.

State of matter	Particle diagram	Particle arrangement	Particle motion	Properties of object	Example
Solid		• Stuck close together • Regular pattern	• Vibrate about a fixed point • No overall movement	• Fixed volume • Fixed shape	Ice  Image: Valentyn Volkov/Shutterstock.com
Liquid		• Close together • Random arrangement	• Free to move around each other • Random collisions	• Fixed volume • Shape can change to fit container	Water  Image: Cozine/Shutterstock.com
Gas		• Far apart • Random arrangement	• Free to move at high speed • Random collisions	• Volume and shape can change to fill a container	Steam  Image: naibank/Shutterstock.com

Table 1 Structures and properties of the states of matter

Internal Energy

The **internal energy** of a system comprises of two types of energy:

- **kinetic energy (E_k)**, due to the random disordered motion of all the particles in the system, and
- **potential energy (E_P)**, due to the interactions between the particles in the system.

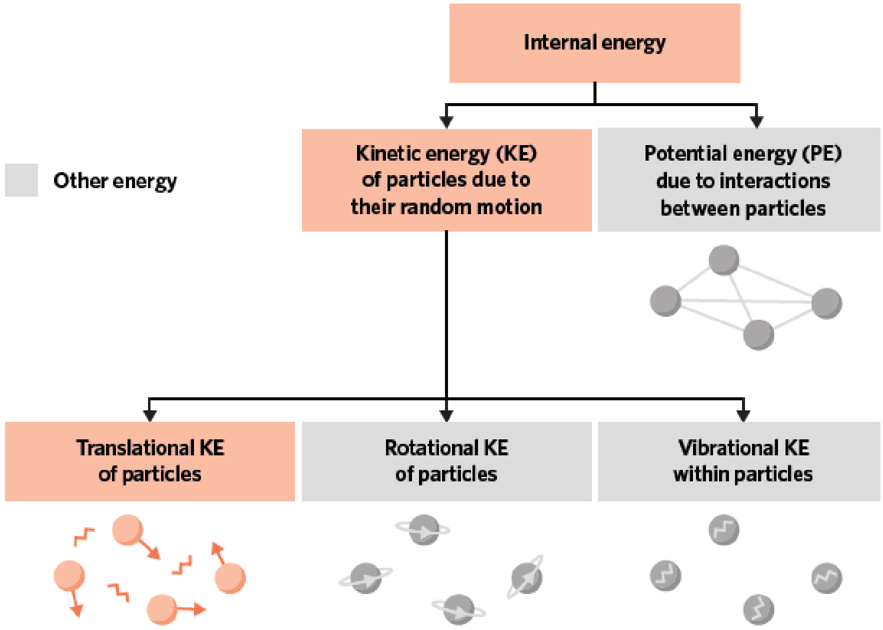

Figure 1 *The internal energy of a system*

Figure 1 above displays the various sub classifications of kinetic energy (E_K):

- **translational** motion of particles,
- **rotational** motion of particles, and
- **vibrational** motion within the particles.

Internal energy is not the same as temperature.
Temperature is a measure of the **average translational kinetic energy.**

Example.1
The Pacific Ocean contains 660 million cubic kilometres of water at an average temperature of 3.5 °C . Whereas a cup of hot team tea has a volume of approximately 240 mL and a temperature of 70 °C.

Which system has the higher internal energy and the higher average translational energy?

The Pacific Ocean, due to its total number of water molecules would have the higher internal energy.

The cup of hot tea due to its higher temperature would have a higher translation kinetic energy.

Temperature Scales

Temperature is the measure of the **average translational kinetic energy** of the particles within a system.

Two system that have the **same temperature** are said to be in **thermal equilibrium**.

There are several different **temperature scales** used across the globe to measure temperature. The two most common today would be the **Degrees Celsius (℃)** and then **degrees Fahrenheit (°F).**

The Celsius or "centigrade" scale (℃)
Developed by the Swedish astronomer Anders Celsius in 1742.
Celsius used the following reference points;

- Melting point of ice is 0 °C
- Boiling point of water is 100 °C

However, the **SI unit** used by the world's scientific community to measure temperature is the **kelvin (K)**.

The Kelvin scale is an **absolute scale**. Meaning that a zero on the Kelvin scale is the lowest possible temperature. All temperatures measure using the Kelvin scale are either **zero or positive**.

$0\ K$, or **absolute zero** as it is called, represents zero kinetic energy inside a system. At this point all atomic movement stops.

The Kelvin scale (K)
Belfast-born physicist William Lord Kelvin proposed in 1848 for temperature measurement based upon an absolute scale.
Kelvin used the following reference points:

- Absolute zero (0 K)
- Melting point of ice (273 K)

NB: Changing temperature by 1 ℃ is the same as changing temperature by 1 K

$$\Delta T(℃) = \Delta T(K)$$

Where $\Delta T(℃)$ = the change in temperature in degrees Celsius.
$\Delta T(K)$ = the change in temperature in Kelvin

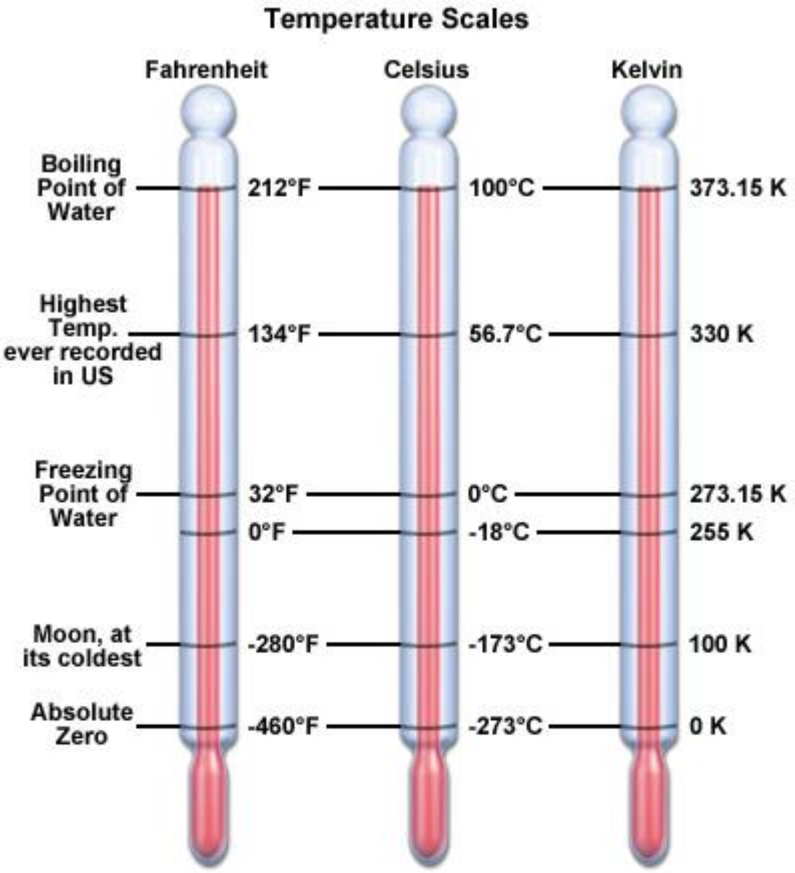

Figure 2 *Temperature comparison scales*

Figure 2 above shows the comparison of the commonly used temperature scales. For the purpose of VCE Units 1 – 4 Physics course, students only need to be able to convert between °C and K. The equations used for this conversion is as follows:

$$T_K = T_{°C} + 273.15$$

$$T_{°C} = T_K - 273.15$$

Where T_K = Temperature in kelvin (K)
$T_{°C}$ = Temperature in degrees Celsius (°C)

Example.2

A change of temperature of 150 K is equal to what change in temperature in degrees Celsius (°C)?

$\Delta T_{°C} = ?$
$\Delta T_K = 150\ K$

$$\Delta T(°C) = \Delta T(K)$$
$$= 150$$

The change in temperature would equal 150 °C

Example.3

In Chemistry, the temperature for a "standard laboratory conditions" (SLC) is $20°C$. What is this temperature in kelvin (K)?

$$T_K = ?$$
$$T_{°C} = 20°C$$

$$T_K = T_{°C} + 273.15$$
$$= 20 + 273.15$$
$$= 293.15\ K$$

Example.4

Liquid nitrogen has a freezing point of $63\ K$. What is its freezing point in degrees Celsius (°C)?

$$T_{°C} = ?$$
$$T_K = 63\ K$$

$$T_{°C} = T_K - 273.15$$
$$= 63 - 273.15$$
$$= -210.15\ °C$$

Exam Styled Questions

Question 1
The water of an Olympic swimming pool is measured to be at a temperature of 18℃. The human body has a standard internal temperature of 37℃.

Compare the kinetic energies of the swimming pool water and a human, making reference to their temperatures.

A human has a greater average kinetic energy than the swimming pool water **1 mark**
because they have a higher average temperature. **1 mark**

The swimming pool water has a greater total kinetic energy than a human because it has a greater volume of particles than the human. **1 mark**

Note: *For full marks, students must differentiate between average kinetic energy and total kinetic energy.*

Question 2
During a thermodynamics experiment, a block of iron is cooled from $300\ K$ to $286\ K$. Which one of the following gives the fall in temperature and the final temperature of the iron block, both in °C?

	Fall in temperature (℃)	Final temperature (℃)
A.	14	13
B.	14	295
C.	260	13
D.	260	295

A

The fall in temperature = 300 – 286 = 14 K or 14°C
The final temperature = 286 – 273 = 13°C

Question 3
Assuming it is behaving like an ideal gas, the Kelvin temperature of carbon dioxide gas at room temperature is a measure of the average

A. speed of the carbon dioxide molecules.
B. kinetic energy of the carbon dioxide molecules.
C. potential energy of the carbon dioxide molecules.
D. mechanical energy of the carbon dioxide molecules.

B

The kinetic energy of carbon dioxide gas is a measure of its Kelvin temperature.

Question 4

A Physics student measures his body temperature with a thermometer to be 37°C. He needs to covert this to a temperature in Kelvin.

What is his temperature in Kelvin?

A. –310 K
B. –236 K
C. 233 K
D. 310 K

D

37 + 273 = 310 K