# 3.1 Physics: Work Energy Power, Kinetic Model of Matter, Temperature, Thermal Properties

**Work, Energy and Power:**

Work Done:

- Work is said to be done when an object moves in the direction of the force applied
- Work done by a constant force = force x distance moved in the direction of the force
- Work done = F x d = Fscosθ (where s refers to the displacement)
- SI unit of work is the joule ($kgm^2s^{-2}$)

Energy:

- Defined as the capacity to do work

Kinetic Energy: $\frac{1}{2}mv^2$

- The energy a body possess due to its motion

Potential Energy: mgh (GPE on Earth)

- Potential energy is the energy stored in an object due to its position, shape or state, which gives it the stored ability to do work
- GPE: energy a body possesses because of its position relative to a reference plane
- Thermal Energy: represents the total kinetic energy of the particles in the body

Principle of Conservation of Energy:

- **Energy can neither be created nor destroyed. It can be transformed or transferred but the total amount in any isolated system must remain constant.**
- This means that the sum of the initial kinetic and potential energies of a system must be equal to the sum of the final kinetic and potential energies of the same system, without any external effects

Power:

- Defined as the rate of doing work/converting energy
- Power = work done/time taken = W/t
- Instantaneous power = F x v (Force x velocity)
- SI unit of power is the watt ($kgm^2s^{-3}$)

**Kinetic Model of Matter:**

Classification of Matter:

Element:

- Consists of only one type of atom
- Cannot be broken into a simpler type of matter by either physical or chemical means
- Can exist as either atoms (argon) or molecules (nitrogen)

Compound:

- Consists of atoms of two or more different elements bound together
- Can be broken down into a simpler type of matter (elements) by chemical means
- Has properties that are different from its component elements
- Component atoms are always in fixed ratios (like H2O)

Mixture:

- Consists of two or more different elements and/or compounds physically intermingled
- Can be separated into its components by physical means

Kinetic Model of Matter:

- All matter is made up of a very large number of particles (tiny atoms or molecules)
- These particles are in a state of continuous random motion

Explanation of Events:

- Particles of a solid vibrate in place
- As the temperature rises, the particles will vibrate more vigorously
- This will lead to an expansion of the material: the particles need more space
- Eventually, the particles will have so much kinetic energy that they leave their fixed positions and start to move about: the solid melts into a liquid
- More heating may lead to vapourization of the liquid into a gas (boiling)

States of Matter:

| | Solid | Liquid | Gas |
|---|---|---|---|
| Arrangement of Particles | Regular | Less regular | No fixed position |
| Distance between Particles | Very small | Slightly larger than in solid | Very large |
| Intermolecular Forces | Very strong | Slightly weaker than in solid | Negligible |
| Motion of molecules | Vibrate about fixed positions | Vibrations and random movements throughout the liquid but particles cling along together | On top of vibrational motion, particles can move about freely |
| Shape | Fixed shape | No fixed shape | No fixed shape (takes |

| | | | |
|---|---|---|---|
| | | (takes the shape of container) | shape of container) |
| Volume | Fixed volume | Fixed volume | No fixed volume (gases are compressible) |

Diffusion:

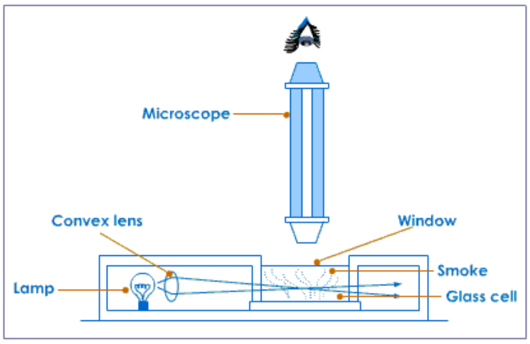
- Diffusion is the random movement of particles from a region of higher concentration to a region of lower concentration
- In solids, particles can only vibrate about fixed positions, so no diffusion occurs
- In liquids, particles can move around and diffusion will take place
- In gases, particles move faster and more space is available, thus diffusion is faster

Brownian Motion:

- The haphazard movement of microscopic particles suspended in a fluid (liquid or gas) due to uneven bombardment of suspended particles by the fluid's molecules

Observation:

- The smoke particles are barely visible
- The smoke particles appear as bright specks of light moving in a **jerky, random and erratic motion**




Explanation:

- Random motion of smoke particles is due to air molecules **bombarding them randomly** and at different velocities
- CLARIFICATION: it is not the air particles are seen moving, but the smoke particles (it is difficult/impossible to see air particles using a lower-powered microscope)

Effects of Temperature:

- At higher temperatures, the motion of smoke particles will become more **vigorous** and agitated since air molecules have greater average speeds at higher temperatures
- Thermal energy is converted to greater average kinetic energy of the air molecules, causing them to move faster

Change of State:

Melting:

- When heated, particles gain kinetic energy
- The particles vibrate faster and move further apart
- Melting point: the particles have enough kinetic energy to overcome intermolecular forces and particles start to break away from one another
- The solid becomes a liquid (Freezing is reverse)

Boiling:

- When heated, the particles gain kinetic energy

- The particles slide over one another more rapidly and move further apart
- Boiling point: the particles have enough kinetic energy to overcome intermolecular forces and particles start to break away from one another
- The liquid becomes a gas

<u>Pressure in gases:</u>

- Since pressure is the force exerted per unit area, the air molecules exert a pressure on the surface of the wall of the container
- This pressure depends on the <u>force per collision</u> and <u>frequency of collision</u>, with respect to the wall of the container

**Pressure-Temperature Relationship**

- The air molecules have greater average speeds at higher temperatures
- The air molecules will have more frequent and forceful collisions with the walls of the container, increasing the pressure within the container
- Pressure is directly proportional to temperature

**Volume-Temperature Relationship:**

- Pressure-temperature relationship (same explanation)
- Hence, greater pressure is exerted and to keep the pressure constant, the gas will expand, increasing the volume of the fixed mass of gas
- Volume is directly proportional to temperature

**Pressure-Volume Relationship:**

- Boyle's Law
- P1V1=P2V2
- Pressure is inversely proportionate to volume

**<u>Temperature:</u>**

- Refers to a measure of **how hot or cold an object is**
- Also refers to: average kinetic energy of all the particles in the system

<u>Heat:</u>

- Amount of thermal energy that is being transferred from a hotter to a colder region
- Temperature vs Heat:
  - Matter **does not contain heat**
  - Heat is the energy transferred from a body of higher temperature to one of a lower temperature

<u>Internal Energy:</u>

- **Total kinetic energy and potential energy** of the molecules in the body

<u>Thermometers:</u>

- An instrument used to measure temperature accurately
- Substances must have physical properties that vary continuously in one direction with temperature (thermometric substances), known as thermometric properties

| **Thermometric Property** | **Thermometer** |
|---|---|
| Volume of a liquid | Liquid in glass thermometer |
| Pressure of a gas held at constant volume | Constant Volume Gas Thermometer |
| Electrical resistance of a conductor | Resistance Thermometer |
| Electromotive force | Thermocouple |
| Length of a solid | Bimetallic Thermometer |
| Colour of a hot object | Thermostrips/Liquid crystal thermometer |

Good Thermometers:

- Easy to read scale
- Safe to use
- Responsive to temperature changes
- Sensitive to small temperature changes
- Able to measure wide range of temperatures

| | Responsiveness | Sensitivity | Ranges |
|---|---|---|---|
| Cross Sectional Area of Bore Increases | Unchanged | Decreases | Increases |
| Length of Stem Increases | Unchanged | Unchanged | Increases |
| Size of Bulb Increases | Decreases | Increases | Decreases |
| Thickness of Bulb Wall Increases | Decreases | Unchanged | Unchanged |

Comparison of Liquids

| Thermometric Liquid | Advantages | Disadvantages |
|---|---|---|
| Mercury | • Good thermal conductor<br>• Expands uniformly as temperature increase<br>• Has a high boiling point at 357°C<br>• Does not wet the bore | • Has a high freezing point and therefore not suitable to measure very cold temperatures<br>• Poisonous<br>• Expensive |
| Alcohol | • Lower melting point, ability to measure low temperatures<br>• Not poisonous<br>• Cheap and readily available | • Lower boiling point of 78°C and cannot measure high temperatures<br>• Not a uniform expansion over a temperature change<br>• Poor thermal conductor compared to mercury |

Resistance Thermometer:

- Usually made of platinum because of its liner resistance temperature with an increase in themperature
- Platinum is also used because of its chemical inertess (the current of the cyce depends on the coil of resistance (entirely affected by mainland)
- Resistance of the platinum wire increases in proportionately with an increase in temperature

<u>Thermocouple:</u>

- Consists of two wires of different metals joined together to form two junctions (one hot and one cold): small tips
- If the two junctions are at different temperatures, a small electromotive force or voltage is produced by the wires (the greater the temperature difference, the larger the electromotive force produced)

<u>Constructing a temperature scale:</u>

i. Choose an appropriate substance
   - Choose a suitable thermometric substance and its physical properties
ii. Choose two fixed points
   - Choose two standard degrees of hotness or coldness which are easily obtainable and reproducible (such as the temperature of pure melting ice as the lower fixed point, and the temperature of steam at one atmospheric pressure as the upper fixed point)
iii. Set up the scale
   - Divide the temperature range between the two fixed points into a fixed number of equal parts to obtain a scale
   - Centigrade scale has 100 equal parts between the upper and lower fixed points

<u>Temperature Formula:</u>

- $\theta$°C= ($X_\theta - X_L$ / $X_H - X_L$ ) x ($\theta_H - \theta_L$ ) + $\theta_L$
- $X_L$ refers to the physical property at the lower fixed point
- $X_H$ refers to the physical property at the upper fixed point
- $X_\theta$ is the physical property at $\theta$°C

<u>**Thermal Property of Matter:**</u>

- Heat Capacity: the heat capacity of a substance is the amount of energy required to raise the **temperature of the substance by 1°C or 1K**
- Specific heat capacity: c, of a substance is the amount of energy required to raise the **temperature of a unit mass of a substance by 1K or 1°C**
  - It is represented by the formula: $Q=mc\Delta\theta$, where Q is the amount of energy transferred, m is the mass of the substance, and c is the specific heat capacity
  - $\Delta\theta$ refers to the change in temperature

    - Ensure that J $kg^{-1}$ $C^{-1}$ and J $g^{-1}$ $C^{-1}$ are not mixed up (the specific heat capacity of water is 4200 J $kg^{-1}C^{-1}$, and 4.20 J $g^{-1}C^{-1}$
- Transfer of energy without a change of state:
    - When two bodies of different temperatures are placed in thermal contact and reach thermal equilibrium, the Principle of Conservation of Energy means that the amount of heat lost by a hot body is equivalent to the amount of heat gained by a cold body
    - Assuming that there is no heat loss to the environment
    - $M_1C_1\Delta\theta=M_2C_2\Delta\theta$
- Latent heat: energy that is absorbed or released by a substance when there is a **change of state of the substance without a change in its temperature**
- Specific Latent Heat: the amount of energy needed to **change the state of a unit mass of the substance, without a change in its temperature**
- Specific Latent Heat of Fusion: the amount of energy needed to change a unit mass of the substance from the **solid to liquid state** (or liquid to solid) without a change in its temperature
    - Indicated by the formula: $Q=ml_f$, where m is the mass of the substance and l is the specific latent heat of fusion
- Specific Latent Heat of Vaporization: the amount of energy needed to change a unit mass of the substance from **liquid to gas** (or gas to liquid) without a change in its temperature