

# Thermal Physics

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## Thermal Physics 1 [Definitions]

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1. **Heating:** The temperature *dependent* process whereby the internal energy of a system changes as a consequence of *thermal energy* transfer to or from another system at a different temperature (input energy distribution is *random*).
2. **Working:** The temperature *independent* process whereby the internal energy of a system changes as a consequence of *mechanical work* performed on or by another system (input energy distribution is *uniform*).
3. **Thermal Equilibrium:** Systems in thermal contact remain at the *same*, constant temperature (hence *no* net flow of thermal energy).
4. **Steady State:** Systems in thermal contact remain at *different*, constant temperatures (hence *no* net flow of thermal energy).
5. **Absolute Zero:** Temperature at which a body has zero internal kinetic energy (and hence internal energy is a minimum).
6. **Sublimation:** The process by which a solid vaporises directly without first turning into a liquid.

7. **Rate of mass flow equation:** 
$$\frac{m}{t} = \rho Av$$

## Thermal Physics 2 [Specific and Latent Heat]

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1. **Thermal energy (Q)** joules [J]
2. **Internal energy of system (U)** joules [J]
3. **Internal energy** of a body is the sum of the random distribution of its molecular kinetic and potential energies.  
$$\Sigma U = \Sigma U_k + \Sigma U_p$$
4. **Specific Heat Capacity (c)** joules per kilogram kelvin [J kg<sup>-1</sup> K<sup>-1</sup>]
5. **Specific Heat Capacity:** The energy input required to raise unit mass of a substance by unit temperature without changing state.

$$c = \frac{\Delta E}{m\Delta T}$$

6. **Specific Latent Heat (l)** joules per kilogram [J kg<sup>-1</sup>]
7. **Specific Latent Heat of Fusion [Vaporisation]:** The energy input required to change unit mass of a substance from solid to liquid [liquid to vapour] without changing temperature.

$$l = \frac{\Delta E}{m}$$

## Thermal Physics 3 [Quantities]

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1. **Pressure of system** ( $p$ ) pascals [Pa]
2. **Volume of system** ( $V$ ) metres cubed [ $\text{m}^3$ ]
3. **Thermodynamic temperature** ( $T$ ) kelvin [K]
4. **Celsius temperature** ( $\theta$ ) degrees celsius [ $^{\circ}\text{C}$ ]
5. **Number of moles** ( $n$ ) moles [mol]
6. **Number of molecules** ( $N$ ) [no units]
7. **Root mean square speed** ( $c_{rms}$ ) metres per second [ $\text{m s}^{-1}$ ]

## Thermal Physics 4 [Gas Laws]

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1. **Boyle's Law:** For a fixed mass of gas at constant temperature, the pressure is inversely proportional to the volume ( $p \propto 1/V$ ).
2. **Charles's Law:** For a fixed mass of gas at constant pressure, the volume is directly proportional to the thermodynamic temperature ( $V \propto T$ ).
3. **Gay-Lussac's [Pressure] Law:** For a fixed mass of gas at a constant volume, the pressure is directly proportional to the thermodynamic temperature ( $p \propto T$ ).
4. **Ideal Gas Assumptions:** (1) all gas molecules are identical; (2) number of molecules is large (and can therefore be treated statistically); (3) molecular volume is  $\ll$  gas volume (i.e. molecules act as point masses); (4) molecular movement is random; (5) Newtonian mechanics apply; (6) collisions are perfectly elastic; (7) molecules move in straight lines between collisions; (8) intermolecular forces are ignored between collisions; (9) collision time  $\ll$  time between collisions.

5. **Ideal Gas Equation:**  $pV = nRT$   $\left[ = \frac{N}{N_A} RT \right]$   $[= NkT]$

6. **Mean Square Speed Equation:**  $pV = \frac{1}{3} Nm(c_{rms})^2$  [from  $p = \frac{1}{3} \rho(c_{rms})^2$ ]

7. **Mean Kinetic Energy Equation:**  $\bar{E}_k = \frac{1}{2} m(c_{rms})^2$   $\left[ = \frac{3RT}{2N_A} \right]$   $\left[ = \frac{3kT}{2} \right]$

## Thermal Physics 5 [Pressure]

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1. **Brownian Motion** involves observable bodies (such as pollen or smoke particles) moving in short, straight, random paths as a result of collisions with unobservable bodies (fluid molecules) which can be concluded as moving in a similar manner. The larger the mass of the observable body, the lower its acceleration, and hence the less pronounced the effect.
2. **Random motion** involves a range of speeds but no preferred direction of travel.
3. **Gases exert pressure** through collisions between the gas molecules and container walls, which results in a rate of change in the momentum of the gas molecules and hence a reciprocal (NIII) force pair between these molecules and the container walls (as  $F = \Delta mv / \Delta t$ ).
4. **These forces** generate a pressure over the area of the container walls (as  $p = F/A$ ).
5. **Increasing the number of gas molecules** for a fixed  $V$  and  $T$  will increase gas pressure ( $p \propto N$ ) because molecules hit the container walls more frequently ( $\therefore \Delta mv / \Delta t$  increases).
6. **Decreasing the volume of the gas** for a fixed  $N$  and  $T$  will increase gas pressure ( $p \propto 1/V$ ) because the gas molecules travel a shorter distance between collisions and therefore hit the container walls more frequently ( $\therefore \Delta mv / \Delta t$  increases).
7. **Increasing the temperature of the gas** for a fixed  $N$  and  $V$  will increase gas pressure ( $p \propto T$ ) because the gas molecules travel with a higher average speed (as  $\langle E_k \rangle \propto T$ ) and therefore hit the container walls more frequently and with greater momentum ( $\therefore \Delta mv / \Delta t$  increases).