Paper 2 Cheat Sheet

1 Thermal physics

1.1 Thermal energy transfer

Specific heat capacity - The energy required to raise the temperature of a unit mass of a given substance by one degree
Specific latent heat - The energy required to change the state of a material without changing the temperature
Temperature - The average kinetic energy of the atoms or molecules in the system
Heat - Energy transfer due to a difference in temperature

1.1.1 Continuous flow

By dividing the specific heat capacity formula by t it can be found that

$$IV = mc\frac{\Delta T}{t}$$

This gives the power per second, where a mass m flows in a time t

1.2 Ideal gases

Law	Proportionality	Constant	Equation
Boyle's	$p \propto \frac{1}{v}$	Temperature, moles	$p_1 v_1 = p_2 v_2$
Charles'	$V \propto T$	Pressure, moles	$\frac{v_1}{T_1} = \frac{v_2}{T_2}$
Gay-Lussac	$p \propto T$	Volume, moles	$\frac{p_1}{T_1} = \frac{p_2}{T_2}$

The two formulas on the formula book for the gas laws have n moles and N molecules

1.2.1 Deriving Pressure volume work formula

$$W = FS = F \times \Delta L = \frac{F}{A} \times A\Delta L = P\Delta V$$

1.2.2 Types of masses

Molar mass - The mass of a mole of a substance
Molecular mass - The mass of the molecules

1.3 Molecular kinetic theory model

1.3.1 Brownian motion as evidence for the existence of atoms

Brownian motion - The random motion of smoke particles in a gas
As Newton's first law states that objects remain in motion until acted on by a force, the smoke particles should remain in motion, instead they move randomly, suggesting collisions with something else

1.3.2 Explanation of relationships between p,V and T

Increase pressure - More collisions, increase temperature. Same number of molecules, volume must decrease

1.3.3 Empirical gas laws but theoretical kinetic theory

By changing variables of a gas, the gas laws can be derived, however the kinetic theory is based on what else would be expected to be required to be constant.

1.3.4 Derivation

Newton's 3$^{\text{rd}}$ law - Every action has an equal and opposite reaction
$\Delta mc = mc_{x1} - -mc_{x1} = 2mc_{x1}$

Use Velocity $= \dfrac{\text{Distance}}{\text{Time}}$

Time$=\dfrac{\text{Distance}}{\text{Velocity}} = \dfrac{2l}{c_{x1}}$

Use force$= \dfrac{\text{Change in momentum}}{\text{time}}$

Force $= \dfrac{\Delta mc}{\Delta t} = \dfrac{2mcx1}{2l/c_{x1}} = \dfrac{mc_{x1}^2}{l}$

Use Pressure$= \dfrac{\text{Force}}{\text{Area}}$

$p_1 = \dfrac{mc_{x1}^2/l}{l^2} = \dfrac{mc_{x1}^2}{l^3}$

Expand for N particles
$p = \Sigma p_n = p_1 + p_2 + p_3 ... + p_N$

$$p = \frac{mc_{x1}^2}{l^3} + \frac{mc_{x2}^2}{l^3} + \frac{mc_{x3}^2}{l^3} + \frac{mc_{xN}^2}{l^3}$$

$$p = \frac{m}{l^3}(c_{x1}^2 + c_{x2}^2 + c_{x3}^2 ... + c_{xN}^2)$$

The mean of all the squares of the velocities is written as $\bar{c_x^2}$

$$\bar{c_x^2} = \frac{c_{x1}^2 + c_{x2}^2 + c_{x3}^2 ... + c_{xN}^2}{N}$$

$$N\bar{c_x^2} = c_{x1}^2 + c_{x2}^2 + c_{x3}^2 ... + c_{xN}^2$$

Simplify expression for pressure

$p=\frac{Nm\bar{c_x^2}}{l^3}$

Consider in 3 dimensions

$\bar{c^2}=\bar{c_x^2}+\bar{c_y^2}+\bar{c_z^2}$

Average of mean square velocity for each dimension are equal

$\bar{c_x^2}=\bar{c_y^2}=\bar{c_z^2}$

Simplify 3D formula

$\frac{\bar{c^2}}{3}=\bar{c_x^2}=\bar{c_y^2}=\bar{c_z^2}$

Simplify pressure formula

$p=\frac{1}{3}\times\frac{Nm\bar{c^2}}{l^3}$

Insert Density formula

$\rho=\frac{\text{Mass}}{\text{Volume}}=\frac{Nm}{l^3}$

Substitute into Pressure formula

$$p=\frac{1}{3}\rho\bar{c^2}$$

2 Fields and their consequences

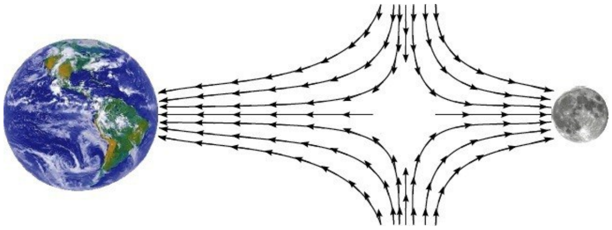
2.1 Fields

Similarities and differences between gravitational and electrostatic forces

Similarities	Differences
• Inverse square laws • Use of field lines • Use of potential • Use of equipotentials	Masses always attract, but charges may attract or repel

2.2 Gravitational fields

2.2.1 Gravitational field strength



2.2.2 Gravitational potential

Gravitational potential has a value of 0 at infinity, then reduces as it approaches the planet.
Gravitational potential - The work done in moving a unit mass from infinity to that point int he field
Gravitational potential difference - The work done in moving a unit mass from one point to another
Equipotential - The group of points with the same potential energy

The sign is negative because a negative amount of work has to be done to move the object from infinity to earth because the object is attracted to earth.

2.2.3 Orbits of planets and satellites

2.2.3.1 Kepler's law

$$F = \frac{GMm}{r^2} = \frac{mv^2}{r} \quad \therefore \frac{GM}{r} = v^2$$

$$v = \frac{s}{t} = \frac{2\pi r}{T}$$

$$v^2 = \frac{4\pi^2 r^2}{T^2} = \frac{GM}{r}$$

$$\frac{r^2}{T^2} = \frac{GM}{4\pi^2}$$

RHS is a constant

$$r^2 \propto T^2$$

2.2.3.2 Escape velocity

$$\frac{1}{2}mv^2 = \frac{GMm}{r} \quad \therefore v = \sqrt{\frac{2GM}{r}}$$

$$g = \frac{GM}{r^2} \quad \therefore gr = \frac{GM}{r}$$

$$v = \sqrt{2gr}$$

2.2.3.3 Total energy of an orbiting satellite

$$\text{Total energy=KE+GPE}$$

$$KE = \frac{1}{2}mv^2$$

$$\frac{GM}{r^2} = \frac{v^2}{r} \quad \therefore v^2 = \frac{GM}{r}$$

$$KE = \frac{1}{2}m\frac{GM}{r}$$

$$GPE = mV \quad V = -\frac{GM}{r} \quad \therefore E_p = -\frac{GMm}{r}$$

$$E_T = E_K + E_P = \frac{GMm}{2r} + -\frac{GMm}{r} = -\frac{GMm}{2r}$$

2.2.3.4 Synchronous orbits

Geosynchronous orbit - Time period of 24h, will be seen at the same place at the same time every day

Geostationary orbit - Time period of 24h, but in the plane of the equator and travelling the same direction as the earth, appears stationary to an observer on the ground

The height at which these satellites must be is determined by Kepler's law

2.3 Electric fields

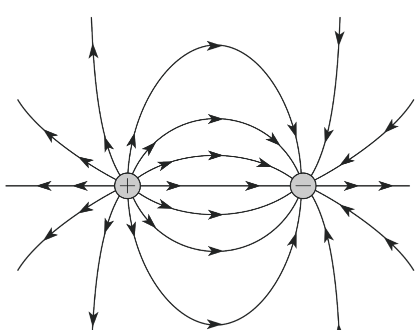
2.3.1 Coulomb's law

This is the first equation under electric fields on the data sheet, it describes the force between two point charges in a vacuum

Permittivity of free space - The charge per unit area in coulombs per square metre on oppositely charged plates when the electric field strength between the plates is one volt per metre

The difference between the permittivity of free space and the permittivity of air is so insignificant air can be treated as a vacuum.

Electric field strength - At a point in an electric field, the force per unit charge on a small positively charged object in that field



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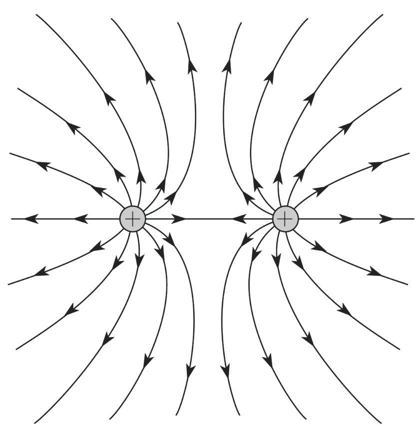

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2.3.1.1 Derive $Fd = Q\Delta V$

$$F = EQ \quad E = \frac{V}{d} \quad \therefore F = \frac{QV}{d} \quad \therefore Fd = QV$$

2.3.1.2 Particle in a uniform electric field