GCSE Physics Formulae Sheet

Yicheng Shao

Version 1. March 21, 2023

Contents

1 Mechanics **2**
- 1.1 Kinematics . . . 2
- 1.2 Statics and Energy . . . 3
- 1.3 Effect of Forces . . . 5

2 Thermal Physics **6**
- 2.1 Ideal Gas . . . 6
- 2.2 Temperature . . . 7

3 Waves **8**
- 3.1 Waves . . . 8
- 3.2 Optics . . . 9

4 Electricity **9**
- 4.1 Electrical Quantities . . . 9
- 4.2 Circuits . . . 10
- 4.3 Electromagnetism . . . 10

5 Space Physics **10**
- 5.1 Orbits . . . 10
- 5.2 Hubble's Constant . . . 10

What is this and why this?

Most calculation error in GCSE Physics exams is caused by not knowing the formulae, not knowing the derived form and not knowing the meaning of the symbols. I made this document based on the CIE IGCSE Physics (9-1) Syllabus from 2023 onwards. I hope this could help with you IGCSE studies!

I am also an IGCSE student so errors are inevitable in this document. Feel free to email eason.syc@icloud.com to point out any mistakes or submit an issue on the GitHub page!

Problem 1 Mechanics

§1.1 Kinematics

1. **Definition of speed:**
$$v = \frac{\Delta s}{\Delta t}.$$
Meaning of Symbols (and Units): v stands for speed, $\mathrm{m\,s^{-1}}$; Δs stands for distance elapsed, m; Δt stands for time elapsed, s.

   Word Explanation: Speed equals distance covered per unit time.

   Derived Formulae: $\Delta s = v\Delta t, t = \frac{\Delta s}{v}$.

   Note: Speed and distance are both scalars.

2. **Definition of velocity:**
$$\boldsymbol{v} = \frac{\Delta \boldsymbol{s}}{\Delta t}.$$
Meaning of Symbols (and Units): $\boldsymbol{v}$ stands for velocity, $\mathrm{m\,s^{-1}}$; $\Delta \boldsymbol{s}$ stands for displacement, m; Δt stands for time elapsed, s.

   Word Explanation: Velocity equals the displacement over the time elapsed.

   Derived Formulae: $\Delta \boldsymbol{s} = \boldsymbol{v}\Delta t, \Delta t = \frac{\Delta \boldsymbol{s}}{\boldsymbol{v}}$.

   Note: Velocity and displacement are both vectors.

3. **Definition of average speed:**
$$\bar{v} = \frac{s}{t}$$
Meaning of Symbols (and Units): $\bar{v}$ stands for average speed, $\mathrm{m\,s^{-1}}$; s stands for distance, m; t stands for time, s.

   Word Explanation: Average speed equals the total distance over total time.

   Derived Formulae: $s = \bar{v}t, t = \frac{s}{\bar{v}}$.

   Note: Difference between average speed and speed: one is over a period, another is at a certain time.

4. **Definition of acceleration:**
$$\boldsymbol{a} = \frac{\Delta \boldsymbol{v}}{\Delta t}.$$
Meaning of Symbols (and Units): $\boldsymbol{a}$ stands for acceleration, $\mathrm{m\,s^{-2}}$; $\Delta \boldsymbol{v}$ stands for change in velocity, $\mathrm{m\,s^{-1}}$; Δt stands for time elapsed, s.

   Word Explanation: Acceleration is the rate of change in velocity.

   Derived Formulae: $\Delta \boldsymbol{v} = \Delta t\boldsymbol{a}, \Delta t = \frac{\Delta \boldsymbol{v}}{\boldsymbol{a}}$,
$$\boldsymbol{v} = \boldsymbol{v_0} + \boldsymbol{a}t$$
Note: Acceleration is (usually) a vector.

You are not expected to know the *suvat* equation, but please draw a $\boldsymbol{v} - t$ graph if necessary.

§1.2 Statics and Energy

1. **Weight:**

$$\boldsymbol{W} = m\boldsymbol{g}.$$

Meaning of Symbols (and Units): $\boldsymbol{W}$ stands for the weight (a force), N; m stands for mass, kg; $\boldsymbol{g}$ stands for gravitational acceleration or gravitational field strength, $\mathrm{m\,s^{-2}}$ or $\mathrm{N\,kg^{-1}}$.

Word Explanation: The gravitational acceleration is the gravitational force (weight) per unit time (and equivilant to gravitational acceleration).

Derived Formulae: $\boldsymbol{g} = \frac{\boldsymbol{W}}{m}, m = \frac{\boldsymbol{W}}{\boldsymbol{g}}$.

Note: Weight and gravitational acceleration/gravitational field strength are both vectors.

2. **Density:**

$$\rho = \frac{m}{V}$$

Meaning of Symbols (and Units): ρ stands for density, $\mathrm{kg\,m^{-3}}$; m stands for mass, kg; V stands for volume, $\mathrm{m^3}$.

Word Explanation: The density is mass per unit volume.

Derived Formulae: $m = \rho V, V = \frac{\rho}{m}$.

Note: Density is a scalar, and it is a property of a material (usually), which could also be determined floating and sinking.

3. **Definition of pressure (General):**

$$p = \frac{F}{A}.$$

Meaning of Symbols (and Units): p stands for pressure, Pa or $\mathrm{N\,m^{-2}}$; F stands for the magnitude of the normal force, N; A stands for area, $\mathrm{m^2}$.

Word Explanation: Pressure is the magnitude of force excerted per unit area.

Derived Formulae: $F = pA, A = \frac{F}{p}$.

Note: Though force is a vector, pressure is a scalar. This will be more significant in the next formula.

4. **Pressure (Liquid and Prism):**

$$\Delta p = \rho g \Delta h.$$

Meaning of Symbols (and Units): Δp stands for change in pressure, Pa; ρ stands for the density, $\mathrm{kg\,m^{-3}}$; g stands for gravitational acceleration, $\mathrm{N\,kg^{-1}}$; Δh stands for difference in depth/height, m.

Word Explanation: The change in the pressure (over a depth) is the gravitational acceleration times the density times the change in depth.

Derived Formulae: $\rho = \frac{\Delta p}{g\Delta h}, \Delta h = \frac{\Delta p}{\rho g}$.

Note: Pressure is excerted to all directions in the liquid.

5. **Definition of work:**

$$W = \Delta E = \boldsymbol{F} \cdot \boldsymbol{d} = Fd\cos\theta.$$

Meaning of Symbols (and Units): W stands for work, J or N m; ΔE stands for change in energy, J; $\boldsymbol{F}$ stands for force, N; $\boldsymbol{d}$ stands for displacement, m; θ stands for the angle between the force and the direction of travel, ° or rad (note that radianis just a dimension of 1).

Word Explanation: Work is energy transferred. Work is the force times distance travelled in the direction of the force.

Derived Formulae: $F = \frac{W}{d\cos\theta}, d = \frac{W}{F\cos\theta}$.

Note: Usually the $\cos\theta$ can be ignored, but please remember the distance travelled in the direction of the force.

6. **Kinetic energy:**

$$E_k = \frac{1}{2}mv^2.$$

Meaning of Symbols (and Units): E_k stands for kinetic energy, J; m stands for mass, kg; v stands for speed or magnitude of velocity, $\mathrm{m\,s^{-1}}$.

Word Explanation: The kinetic energy is half the mass times energy squared.

Derived Formulae: $v = \sqrt{\frac{2E_k}{m}}$.

Note: Energy is always a scalar. It makes no difference using speed or dot product of velocity here. Note that $\Delta E_k \neq \frac{1}{2}m\Delta v^2$.

7. **Gravitational potential energy (in a uniform gravitational field):**

$$\Delta E_p = mg\Delta h.$$

Meaning of Symbols (and Units): E_p stands for gravitational potential energy, J; m stands for mass, kg; g stands for gravitational acceleration (magnitude), $\mathrm{m\,s^{-2}}$; Δh stands for change in height, m.

Word Explanation: The change in gravitational potential energy is the mass times the gravitational field strength times change in the height.

Derived Formulae: $m = \frac{\Delta E_p}{g\Delta h}, g = \frac{\Delta E_p}{m\Delta h}, \Delta h = \frac{\Delta E_p}{mg} = \frac{\Delta E_p}{W}, E_p = W\Delta h$.

Note: This is the formula stands for the one in a uniform gravitational field, the one in more complexd gravitational fields (e.g. Newtonian Gravity and Einstein General Relativity).

8. **Definition of power:**

$$P = \frac{\Delta E}{\Delta t}.$$

Meaning of Symbols (and Units): P stands for power, W or $\mathrm{J\,s^{-1}}$; ΔE stands for energy transferred $= W$, J; Δt stands for time elapsed, s.

Word Explanation: Power is the rate of energy transferred.

Derived Formulae: $P = \frac{W}{\Delta t}, \Delta E = W = P\Delta t, t = \frac{W}{P} = \frac{\Delta E}{P}$,

$$P = \boldsymbol{F} \cdot \boldsymbol{v}.$$

Note: This formula also works for electrical power.

9. **Efficiency:**

$$\eta = \frac{P_{\text{useful}}}{P_{\text{total}}}.$$

Meaning of Symbols (and Units): η stands for efficiency, dimension of 1 without unit; P_{useful} stands for useful power (output), W; P_{total} stands for total power (input), W.

Word Explanation: The efficiency is the percentage/proportion of useful energy/power output to total energy.power input.

Derived Formulae:

$$\eta = \frac{W_{\text{useful}}}{W_{\text{total}}}.$$

Note: You can times 100% which is basically 1 to get a percentage.

§1.3 Effect of Forces

1. **Definition of momentum:**

$$\boldsymbol{p} = m\boldsymbol{v}.$$

Meaning of Symbols (and Units): $\boldsymbol{p}$ stands for momentum, $\mathrm{kg\,m\,s^{-1}}$; m stands for mass, kg; $\boldsymbol{v}$ stands for velocity, $\mathrm{m\,s^{-1}}$.

Word Explanation: Momentum is the product of mass and its velocity.

Derived Formulae: $m = \frac{\boldsymbol{p}}{\boldsymbol{v}}, \boldsymbol{v} = \frac{\boldsymbol{p}}{m}$.

Note: Momentum itself is a vector and has a direction.

2. **Newton's 2nd Law:**

$$\boldsymbol{F} = \frac{\Delta\boldsymbol{p}}{\Delta t}.$$

Meaning of Symbols (and Units): $\boldsymbol{F}$ stands for force, N; $\Delta\boldsymbol{p}$ stands for change in momentum, $\mathrm{kg\,m\,s^{-1}}$; Δt stands for time elapsed, s.

Word Explanation: Force is equal to the rate of change in momentum.

Derived Formulae: $\Delta\boldsymbol{p} = \boldsymbol{F}\Delta t, \Delta t = \frac{\Delta\boldsymbol{p}}{\boldsymbol{F}}$,

$$\boldsymbol{F} = m\boldsymbol{a}.$$

Note: This is a very important equation in physics, and it could lead to discussions about inertial mass/gravitational mass, Lagrange – d'Almbert's Principle (turning non-inertial frames into inertial ones), special relativity, etc.

3. **Impulse:**

$$\boldsymbol{I} = \Delta\boldsymbol{p}.$$

Meaning of Symbols (and Units): $\boldsymbol{I}$ stands for impulse, $\mathrm{kg\,m\,s^{-1}}$; $\Delta\boldsymbol{p}$ stands for change in momentum, $\mathrm{kg\,m\,s^{-1}}$.

Word Explanation: Impulse is equal to the change in momentum.

Derived Formulae: The following is derived from Newton's 2nd Law:

$$\boldsymbol{I} = \boldsymbol{F}\Delta t.$$

Note: This is only meaningful if momentum is conserved - just like work and energy.

4. **Moment:**

$$\boldsymbol{M} = \boldsymbol{r} \times \boldsymbol{F}.$$

Meaning of Symbols (and Units): $\boldsymbol{M}$ stands for moment (of a force), N m (according to SI standards, we don't write it as a J); $\boldsymbol{r}$ stands for the position vector of the force, m; $\boldsymbol{F}$ stands for the force, N.

Word Explanation: The magnitude of the moment of a force is equal to the magnitude of the force times the perpendicular distance between the pivot and the line of action of the force.

Derived Formulae: To be simple, denote d as the perpendicular distance between the pivot and the line of action of the force, m, then we have $M = Fd, F = \frac{M}{d}, d = \frac{M}{F}$.

Note: I wrote this in terms of vector and their cross product just for the sake of science but this is not required at all.

5. **Hooke's Law:**

$$\boldsymbol{F} = k\boldsymbol{x}.$$

Meaning of Symbols (and Units): $\boldsymbol{F}$ stands for force, N; k stands for the spring constant, $\mathrm{N\,m^{-1}}$; $\boldsymbol{x}$ stands for the extension (vector).

Word Explanation: The force to extend or compress a spring (within the limit of linearlity) is perpendicular to the extension.

Derived Formulae: $k = \frac{\boldsymbol{F}}{\boldsymbol{x}}, \boldsymbol{x} = \frac{\boldsymbol{F}}{k}$.

Note: Remember to use extension for the $\boldsymbol{x}$ not the total length.

Problem 2 Thermal Physics

§2.1 Ideal Gas

1. **Boyle's Law:**

$$pV = \text{const.}$$

Meaning of Symbols (and Units): p stands for pressure, Pa; V stands for volume, $\mathrm{m^3}$.

Word Explanation: The pressure of a gas is inversly proportional to its volume given that its temperature remains the same.

Derived Formulae: $p_1V_1 = p_2V_2$.

Note: This only remains true if temperature is a constant.

2. **Charles's Law:** (it popped out on the MTR, and stating this will get you a mark!)

$$\frac{V}{T} = \text{const.}$$

Meaning of Symbols (and Units): V stands for volume, $\mathrm{m^3}$; T stands for temperature, K.

Word Explanation: The volume of a gas is directly proportional to its temperature given that its pressure remains the same.

Derived Formulae: $\frac{V_1}{T_1} = \frac{V_2}{T_2}, \frac{V_1}{V_2} = \frac{T_1}{T_2}$.

Note: This only remains true if pressure is a constant.

3. **Gay-Lussac's Law:** (just for the sake of knowing it)

$$\frac{p}{T} = \text{const.}$$

Meaning of Symbols (and Units): p stands for pressure, Pa; T stands for temperature, K.

Word Explanation: The pressure of a gas is directly proportional to its temperature given that its volume remains the same.

Derived Formulae: $\frac{p_1}{T_1} = \frac{p_2}{T_2}$, $\frac{p_1}{p_2} = \frac{T_1}{T_2}$.

Note: This only remains true if volume is a constant.

4. **Avogardo's Equation (Chemistry!):**

No that's not my work.

5. **Ideal Gas Law:** (a.k.a. Clapeyron Equation, the boss, just for reference)

$$pV = nRT = Nk_BT$$

Meaning of Symbols (and Units): p stands for pressure, Pa; V stands for volume, m^3; n stands for moles, mol; R stands for the ideal gas constant (which is equal to the Boltzmann constant times the Avogardo constant), $R = k_BN_A = 8.31\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$; T stands for the temperature, K; N stands for the number of gas molecules, no unit; k_B stands for the Boltzmann constant, $k_B = 1.38 \times 10^{-34}\,\text{J}\,\text{K}^{-1}$.

Note: This is really the boss but it is A-Level knowledge, so just for the sake of knowing it.

6. **van der Waals Equation (a more boss equation)**

No I won't talk about this, this is too much for now.

§2.2 Temperature

1. **Conversion between kelvin and degree celsius:**

$$T\text{K}^{-1} = \theta{}^\circ\text{C}^{-1} + 273(.15).$$

Meaning of Symbols (and Units): T stands for (thermodynamic) temperature in kelvin, K; θ stands for temperature in degree celsius, °C.

Word Explanation: The temperature in kelvin is equal to the temperature in degree celsius plus 273.15.

Derived Formulae: $\theta{}^\circ\text{C}^{-1} = T\text{K}^{-1} - 273(.15)$.

Note: Please note that in all the ideal gas equations you need to use the thermodynamic temperature, but in the following equation you do not need to convert, as change in one degree celsius equals change in one kelvin.

2. **Thermal capacity:**

$$Q = mc\Delta T.$$

Meaning of Symbols (and Units): Q stands for thermal energy transferred, J; m stands for mass, kg; c stands for thermal capacity, $\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$ or $\text{J}\,\text{kg}^{-1}\,{}^\circ\text{C}^{-1}$; ΔT stands for change in temperature, K or °C.

Word Explanation: The thermal capacity is defined as the heat energy transferred per unit mass per unit change in temperature.

Derived Formulae: $m = \frac{Q}{c\Delta T}, c = \frac{Q}{m\Delta T}, \Delta T = \frac{Q}{mc}$.

Note: Thermal capacity is a property of a material. It doesn't matter whether you calculate with degrees celsius or kelvin, but make sure you use the same unit to calculate the change in temperature.

3. **Latent heat:** (old syllabus, but it popped up before!)

$$Q = ml.$$

Meaning of Symbols (and Units): Q stands for thermal energy transferred, J; m stands for mass, kg; l stands for specific latent heat, $\mathrm{J\,kg^{-1}}$.

Word Explanation: The latent heat is defined as the heat energy transferred per unit mass to convert a substance from one state to another state.

Derived Formulae: $m = \frac{Q}{l}, l = \frac{Q}{m}$.

Note: Latent heat is a property of a material and the state conversion it is in.

Problem 3 Waves

§3.1 Waves

1. **Frequency and Period:**

$$f = \frac{1}{T}.$$

Meaning of Symbols (and Units): f stands for the frequency, Hz or $\mathrm{s^{-1}}$; T stands for the period, s.

Word Explanation: Frequency is the reciprocal of the period.

Derived Formulae: $fT = 1, T = \frac{1}{f}$.

Note: This is true for all waves.

2. **The wave equation:**

$$v = f\lambda.$$

Meaning of Symbols (and Units): v stands for the wavespeed, $\mathrm{m\,s^{-1}}$; f stands for the frequency, Hz; λ stands for the wavelength, m.

Word Explanation: The wavespeed of a wave is equal to its frequency times its wavelength.

Derived Formulae: $f = \frac{v}{\lambda}, \lambda = \frac{v}{f}$.

Note: The frequency of a wave will not change (Doppler Effect! but that's observation), so usually we can just say $\lambda \propto v$.

§3.2 Optics

1. **Refractive index:**

$$n = \frac{c}{v}$$

Meaning of Symbols (and Units): n stands for the refractive index, dimension of 1; c stands for the speed of light in vacuum, $c = 3.00 \times 10^8\,\mathrm{m\,s^{-1}}$; v stands for the speed of light in that certain medium.

Word Explanation: The refractive index of a medium is the ratio of the speed of light in vacuum and the speed of light in that certain medium.

Derived Formulae: $c = nv, v = \frac{c}{n}$.

Note: As speed of light in vacuum is the fastest thing in the world (special relativity!), n is always no smaller than one i.e. $n \geq 1$ and $n = 1$ iff. the medium is vacuum. For simplicity we take $n_{\text{air}} = 1$.

2. **Snell's law:**

$$n_1 \sin\theta_1 = n_2 \sin\theta_2.$$

Meaning of Symbols (and Units): n_1 stands for the refractive index in the first medium, dimension of 1; θ_1 stands for the angle between the incident ray and the normal (i.e. incidence angle), °; n_2 stands for the refractive index in the second medium, dimension of 1; θ_2 stands for the angle between the refracted ray and the normal (i.e. refraction angle), °.

Word Explanation: The product of the refractive index and the angle between the ray and the normal is the same while light is refracting.

Derived Formulae: $\theta_2 = \arcsin\frac{n_1 \sin\theta 1}{n_2}, n_2 = \frac{n_1 \sin\theta_1}{\sin\theta_2}$.

Note: This can be derived from the Fermat's Principle, or maybe, least action principle!

3. **Critical angle:**

$$\sin c = \frac{n_{\text{quick}}}{n_{\text{slow}}}.$$

Meaning of Symbols (and Units): c stands for the critical angle, °; n_{quick} stands for the refractive index in the quick medium, dimension of 1; n_{slow} stands for the refractive index in the slow medium, dimension of 1.

Word Explanation: The sine of the critical angle is equal to the ratio between the refractive index of the fast medium and the slow medium.

Derived Formulae: $n_{\text{slow}} = \frac{n_{\text{quick}}}{\sin c}$.

Note: This is a special case of the general Snell's law where a θ equals 90°. We see $\sin c = \frac{1}{n}$ as we take the quick n_{quick} as 1 (in the case of air).

Problem 4 Electricity

§4.1 Electrical Quantities

§4.2 Circuits

§4.3 Electromagnetism

Problem 5 Space Physics

§5.1 Orbits

§5.2 Hubble's Constant