GCSE Physics Formulae Sheet

Eason's Quantitative Toolbox

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Version 1. March 21, 2023

Contents

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!

P.S. I want to try my best to include quantitative formulae for qualitative requirements at GCSE, but they usually require more Mathematical tools so it is normal to have unexpected symbols.

Section 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, kg m s^{-1}; m stands for mass, kg; $\boldsymbol{v}$ stands for velocity, 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, 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:**
$$I = \Delta p.$$

Meaning of Symbols (and Units): I stands for impulse, $\mathrm{kg\,m\,s^{-1}}$; Δp 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:
$$I = F\Delta t.$$

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

4. **Moment:**
$$M = r \times F.$$

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

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

Note: Remember to use extension for the x not the total length.

6. **Circular Motion:** (qualitative explanation required)
$$F = \frac{mv^2}{r}.$$

Meaning of Symbols (and Units): F stands for the centropical force (i.e.) the force pointing to the centre of the circular motion (perpendicular to velocity), N; m stands for mass, kg; v stands for speed, $\mathrm{m\,s^{-1}}$; r stands for radius, m.

Word Explanation: The centropical force for a circular motion is proportional to its mass, the square of its speed, and inversly proportional to its radius.

Derived Formulae: $r = \frac{mv^2}{F}, m = \frac{Fr}{v^2}, v = \sqrt{\frac{Fr}{m}}$.

Note: The quantitative form is not required but you are required to know the qualitative aspect. Circular motion is accelerating!

Section 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, m^3.

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

   Derived Formulae: $p_1 V_1 = p_2 V_2$.

   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, 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)

$$pV = nRT = Nk_B T$$

   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), $R = k_B N_A = 8.31\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$; 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, $^\circ$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 $^\circ$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, $\text{J}\,\text{kg}^{-1}$.

   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.

Section 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 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, 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, $c = 3.00 \times 10^8$ 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).

Section 4 Electricity

§4.1 Electrical Quantities

1. **Definition of electromotive force (e.m.f.):**

$$E = \frac{W}{Q}.$$

Meaning of Symbols (and Units): E stands for the e.m.f., V or $\text{J}\,\text{C}^{-1}$; W stands for work, J; Q stands for charge, C.

Word Explanation: The e.m.f. is equal to the electrical work done per unit charge to move it around a circuit.

Derived Formulae: $W = EQ, Q = \frac{W}{E}$.

Note: The e.m.f. is not electromagnetic force, it is electromotive force! But not really a force.

2. **Definition of potential difference (p.d.):**

$$V = \frac{W}{Q}.$$

Meaning of Symbols (and Units): V stands for the p.d., V or $\text{J}\,\text{C}^{-1}$; W stands for work, J

Word Explanation: The p.d. is the work done per unit charge passing through an electric component.

Derived Formulae: $W = VQ, Q = \frac{W}{V}$.

Note: The p.d. is effectively the same with e.m.f. – but e.m.f. is converting other forms of energy into electrical energy while p.d. is the other way round.

3. **Definition of current:**

$$I = \frac{Q}{t}.$$

Meaning of Symbols (and Units): I stands for the current, A or $\mathrm{C\,s^{-1}}$; Q stands for the charge, C; t stands for time, s.

Word Explanation: The current is the charge flowing through a point per unit time. (Techinically it should be ΔQ and Δt but we don't mind here.)

Derived Formulae: $Q = It, t = \frac{Q}{I}$.

Note: We don't care about $I = \frac{\Delta Q}{\Delta t}$ because we only study constant current at this stage. Current is **not** a vector, but current density is (we don't need to know that yet but just fyi.)

4. **Formula for electrical work and electrical power:**

$$P = VI, W = Pt = VIt = VQ.$$

Meaning of Symbols (and Units): P stands for power, W; V stands for voltage, V; I stands for current, A; W stands for work, J; t stands for time, s.

Word Explanation: The electrical power is equal to the voltage times the current; the electrical work done is equal to the voltage times the current times the time elapsed, which is also equal to the voltage times the charge.

Derived Formulae: $V = \frac{P}{I}, I = \frac{P}{V}$.

Note: These are derived formulae from the definition of work and the definition of current so it shouldn't be surprising if these are true. We will see updated version of these in the next section.

§4.2 Circuits

1. **Ohm's Law and Definition of Resistance:** (simplified version)

$$R = \frac{V}{I}.$$

Meaning of Symbols (and Units): R stands for resistance, Ω or $\mathrm{V\,A^{-1}}$; V stands for voltage (usually p.d.), V; I stands for current, A.

Word Explanation: The resistance of an electrical component is the potential difference across it over the current passing through it.

Derived Formulae: $V = RI, I = \frac{V}{R}$.

Note: This is a very important thing in electrical circuit calculation – please remember this as it links some of the most important quantities together. Note that $R \neq \frac{\Delta V}{\Delta I}$ which means resistance is not a gradient at a point!

2. **More Power:**

$$P = VI = I^2 R = \frac{V^2}{R}.$$

Meaning of Symbols (and Units): P stands for electrical power, W; V stands for voltage, V; I stands for current, A; R stands for resistance, Ω.

Word Explanation: The power is the product of the square of current and the resistance, which is equal to the square of voltage over the resistance.

Derived Formulae: Too many.

Note: This is a direct corollary of the Ohm's Law.

3. **Kirchoff's First Law:**

$$\sum I_{\text{in}} = \sum I_{\text{out}}.$$

Meaning of Symbols (and Units): $\sum$ stands for the sum; I_{in} stands for the current flowing into a junction, A; I_{out} stands for the current flowing out a junction, A.

Word Explanation: The current flowing into a junction is equal to the current flowing out of a junction.

Derived Formulae: The parallel circuit law (which will appear later).

Note: This is a direct corollary from the conservation of charge.

4. **Kirchoff's Second Law:** (may be useful)

$$\sum V = \sum E.$$

Meaning of Symbols (and Units): $\sum$ stands for the sum; V stands for the p.d., V; E stands for the e.m.f., V.

Word Explanation: The sum of the p.d. is equal to the sum of the e.m.f. in a closed loop.

Derived Formulae: $\sum V = 0$ if no e.m.f., $\sum E = 0$ if no p.d.

Note: This is a direct corollary from the conservation of energy. Notice that the loop itself is 'directional' – that is, some 'batteries' may act as a p.d. rather than an e.m.f. on the loop.

5. **Parallel Circuit Laws:**

$$I = I_1 + I_2 + \cdots + I_n,$$
$$V = V_1 = V_2 = \cdots + V_n,$$
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}.$$

Meaning of Symbols (and Units): I stands for the total current, A; I_i stands for the current passing through the ith component, A; V stands for the e.m.f., V; V_i stands for the p.d. over the ith component, V; R stands for the total resultant resistance, Ω; R_i stands for the resistance of the ith component, Ω.

Word Explanation: The total current in a parallel circuit is the sum of all the current in each branch; the e.m.f. of the parallel circuit is equal to the p.d. over each component; the resistance of the circuit is equal to the reciprocal of the sum of reciprocal of the resistances.

Derived Formulae: Too many.

Note: The p.d. and the e.m.f. are the same, as you are effectively measuring the same thing. The result of the current follows from the Kirchoff's Current Law and the resistance formula follows.

6. **Series Circuit Laws:**

$$I = I_1 = I_2 = \cdots = I_n,$$
$$V = V_1 + V_2 + \cdots + V_n,$$
$$R = R_1 + R_2 + \cdots + R_n.$$

Meaning of Symbols (and Units): I stands for the total current, A; I_i stands for the current passing through the ith component, A; V stands for the e.m.f., V; V_i stands for the p.d. over the ith component, V; R stands for the total resultant resistance, Ω; R_i stands for the resistance of the ith component, Ω.

Word Explanation: The current in a series circuit is all the same; the e.m.f. in a series circuit is the sum of the p.d.s of the components; the resistance of a series circuit is the sum of each component's resistance.

Derived Formulae: Potential divider:

$$V_{\text{out}} = V_{\text{in}} \cdot \frac{R_{\text{output}}}{R_{\text{total}}}.$$

Note: The current law follows from Kirchoff's Current Law and the voltage follows from the Voltage Law, the resistance result is a corollary of them.

7. **Resistance v.s. Length and Area**:

$$R = \frac{\rho l}{A}.$$

Meaning of Symbols (and Units): R stands for the resistance, Ω; ρ stands for the electrical resistivity, $\Omega\,\text{m}$; l stands for the length, m; A stands for the cross-sectional area, m^2.

Word Explanation: The resistance of a resistor is proportional to its length and inversly proportional of the area.

Derived Formulae: $\rho = \frac{RA}{l}, A = \frac{\rho l}{R}, l = \frac{RA}{A}$.

Note: This formula and its calculations is not required. However, you need to know everythign apart from the ρ!

§4.3 Electromagnetism

1. **Transformer:**

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}.$$

Meaning of Symbols (and Units): V_1 stands for the primary coil voltage, V; V_2 stands for the secondary coil voltage, V; N_1 stands for the number of coils on the primary coil, dimensionless; N_2 stands for the number of coils on the secondary coil, dimensionless.

Word Explanation: The coil voltage is proportional to the number of coils on that respective coil.

Derived Formulae: By conservation of energy,

$$I_1 N_1 = I_2 N_2.$$

Note: This is a very simple equation, so don't get it wrong! Be careful with the corresponding primary and secondary.

2. **Coulomb's Law:** (qualitative required)

$$F = \frac{1}{4\pi\varepsilon_0} \frac{Qq}{r^2} l.$$

Meaning of Symbols (and Units): F stands for the attraction received by q caused by the electrical field created by Q, N; ε_0 stands for the electrical permittivity in vacuum, $\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$; Q stands for the charge causing the force, C; q stands for the charge receiving the force, C; r stands for the distance between Q and q, m; l stands for the unit vector pointing from Q to q (which basically states the direction), dimensionless.

Word Explanation: The electrostatic force between two charges is proportional to the product of those two charges and inversly proportional to the distance between them squared, with attraction if different symbols charge and repulsion if same symbol of charge.

Note: This is also an inverse square law! Please remember electromagnetic forces are not caused directly by the particles but by field interactions.

3. **Electrical Field:** (qualitative (and diagram) description required, formula not required at this stage)

$$E = \frac{F}{q} = \frac{1}{4\pi\varepsilon_0} \frac{Q}{r^2} l.$$

Meaning of Symbols (and Units): E stands for the electrical field (a vector field), $\mathrm{V\,m^{-1}}$; F stands for the attraction received by q caused by the electrical field created by Q, N; ε_0 stands for the electrical permittivity in vacuum, $\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$; Q stands for the charge causing the force, C; q stands for the charge receiving the force, C; r stands for the distance between Q and q, m; l stands for the unit vector pointing from Q to q (which basically states the direction), dimensionless.

Word Explanation: The electrical field is defined by the force received per unit charge.

Note: E is a vector field, which basically means there is a vector at any point in the space. Field lines can represent most vector fields.

4. **Potential Difference and Electrical Field:** (not required, just me being a nerd)

$$E = -\nabla V.$$

Meaning of Symbols (and Units): E stands for the electrical field, $\mathrm{V\,m^{-1}}$; ∇ stands for the 3-D gradient operator, $\mathrm{m^{-1}}$; V stands for the voltage, V.

Word Explanation: The electrical field is equal to the opposite of the gradient in voltage.

Note: The definition of the ∇, in fact a 3-D gradient:

$$\frac{\hat{x}\partial}{\partial x} + \frac{\hat{y}\partial}{\partial y} + \frac{\hat{z}\partial}{\partial z}.$$

5. **Magnetic Force on Current-Carrying Conductor:** (qualitative required)

$$F = BI \times l.$$

Meaning of Symbols (and Units): F stands for the magnetic force received by the wire, N; B stands for the magnetic field (to be percise, magnetic flux density field), T; I stands for the current, A; l stands

for the vector pointing from the start of the wire to the end of wire (direction defined by the current), m.

Word Explanation: The magnitude of the force the current-carrying wire receives is proportional to the strength of the magnetic field, the current and its length, and the direction fits Flemming's LH rule (cross product).

Derived Formulae: Let θ be the angle between the wire and the magnetic field, we have

$$F = BIl\sin\theta.$$

Note: This is cool, and this could be used to define the $\boldsymbol{B}$ field. The cross product simply represents the direction without the need to use the Cartesian coordinate formed by Flemming's LH rule.

6. **Lorentz Force (for a charge moving in a magnetic field):** (qualitative required)

$$\boldsymbol{F} = q\boldsymbol{v} \times \boldsymbol{B}.$$

Meaning of Symbols (and Units): $\boldsymbol{F}$ stands for the magnetic force received by the charge, N; q stands for the charge, C; $\boldsymbol{v}$ stands for the velocity of the charge, $\mathrm{m\,s^{-1}}$; $\boldsymbol{B}$ is the magnetic field, T.

Word Explanation: The magnitude of the magnetic force received by a charge is proportional to its charge, its velocity and the strength of the magnetic field, with its direction fitting Flemming's LH rule.

Derived Formulae: Let θ be the angle between the velocity and the magnetic field, we have

$$F = qvB\sin\theta.$$

Note: Based on the cross product, unsurprisingly, the Lorentz Force does not do work on the charge (as the force is always perpendicular to the velocity of charge hence no power hence no work), and a charge will do circular motion in a uniform magnetic field (cool!). Note that when we use the Flemming's LH rule on a charge which is negative, we need to reverse its velocity to get its current.

7. **Magnetic Flux:** (not required at this stage)

$$\Phi = \boldsymbol{B} \cdot \boldsymbol{S}.$$

Meaning of Symbols (and Units): Φ stands for the magnetic flux, Wb or $\mathrm{V\,s}$ or $\mathrm{T\,m^2}$; $\boldsymbol{B}$ stands for the magnetic flux density, T; $\boldsymbol{S}$ stands for the surface vector (direction perpendicular to the surface), $\mathrm{m^2}$.

Word Explanation: The magnetic flux is the dot product of the magnetic flux density and the surface (as the name suggests).

Derived Formulae: Let θ be the angle between the surface vector and the magnetic field, we have

$$\Phi = BS\cos\theta.$$

Furthermore,

$$\Phi = \iint_{\Sigma} \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S}.$$

Note: This will be useful for the next part: the Faraday's Law of Induction.

8. **Faraday's Law of Induction:** (with Lenz's Law) (qualitative required)

$$E = -N\frac{\Delta\Phi}{\Delta t}$$

Meaning of Symbols (and Units): E stands for the e.m.f. created, V; N stands for the number of coils, dimensionless; $\Delta\Phi$ stands for the change in magnetic flux, Wb; Δt stands for time elapsed, s.

Word Explanation: The electromotive force created by a coil cutting through the magnetic field lines is proportional to the number of turning coils it has and the rate of change in magnetic flux (i.e. the rate cutting across magnetic field lines), and by Lenz's Law will have a direction opposing the change causing it.

Note: This is the reason why generator creates a.c. current.

9. **Poynting Vector:** (not required, stands for direction of energy transfer in an electromagnetic wave)

$$\boldsymbol{S} = \frac{1}{\mu_0}\boldsymbol{E} \times \boldsymbol{B}.$$

Meaning of Symbols (and Units): $\boldsymbol{S}$ stands for the Poynting Vector, $\mathrm{W\,m^{-2}}$; μ_0 stands for the vacuum magnetic permeability, $\mu_0 = 1.26 \times 10^{-6}\,\mathrm{N\,A^{-2}}$; $\boldsymbol{E}$ stands for the electrical field, $\mathrm{V\,m^{-1}}$l; $\boldsymbol{B}$ stands for the magnetic field, T.

Word Explanation: The Poynting Vector is defined as the cross product of the electrical field and the magnetic field over the vacuum magnetic permeability.

Note: It represents the directional energy flux (the energy transfer per unit area per unit time), and demostrates why electromagnetic wave is a transverse wave.

10. **Maxwell's Equations:** (the boss of everything, not required)

$$\nabla \cdot \boldsymbol{E} = \frac{\rho}{\varepsilon_0},$$
$$\nabla \cdot \boldsymbol{B} = 0,$$
$$\nabla \times \boldsymbol{E} = -\frac{\partial \boldsymbol{B}}{\partial t},$$
$$\nabla \times \boldsymbol{B} = \mu_0\left(\boldsymbol{J} + \varepsilon_0\frac{\partial \boldsymbol{E}}{\partial t}\right).$$

Meaning of Symbols (and Units): $\nabla\cdot$ stands for the divergence, which means 'the source of a field', $\mathrm{m^{-1}}$; $\nabla\times$ stands for the curl, which means 'the circulation of a field', $\mathrm{m^{-1}}$; ε_0 stands for vacuum electrical permittivity, $\mathrm{F\,m^{-1}}$; μ_0 stands for the vacuum magnetic permeability, $\mathrm{N\,A^{-2}}$; ρ stands for the charge density, $\mathrm{C\,m^{-3}}$; t stands for time, s; $\boldsymbol{E}$ stands for the electrical field, $\mathrm{V\,m^{-1}}$; $\boldsymbol{B}$ stands for the magnetic flux density, T; $\boldsymbol{J}$ stands for the current density, $\mathrm{A\,m^{-2}}$.

Word Explanation: Electrical field has a source, magnetic field does not; magnetic field causes effect on electrical fields, and vice versa.

(a) **Gauss's Law:** Electrical field has a source which is caused by a charge.

(b) **Gauss's Law for Magnetism:** Magnetic field does not have a source (i.e. magnetic monopole doesn't exist).

(c) **Faraday's Law of Induction:** Electrical field is caused by a changing magnetic field, and its strength is proportional to the rate of change in magnetic flux.

(d) **Ampere's Circuital Law:** Magnetic field is caused by a changing electrical field (but remember that electrical charge can exist individually and that's why the current density term exists).

Derived Formulae: The integration version: (longer)

$$\oiint_{\partial\Omega} \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{S} = \frac{1}{\varepsilon_0} \iiint_{\Omega} \rho \mathrm{d}V,$$

$$\oiint_{\partial\Omega} \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S} = 0,$$

$$\oint_{\partial\Sigma} \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{l} = -\frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Sigma} \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S},$$

$$\oint_{\partial\Sigma} \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{l} = \mu_0 \left(\iint_{\Sigma} \boldsymbol{J} \cdot \mathrm{d}\boldsymbol{S} + \varepsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Sigma} \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{S} \right).$$

Note: Well I can't really calculate all this but it's cool, isn't it? Just like Einstein's field equation. There is no reason (so far) for magnetic monopole not to exist but we haven't found it yet. The equations can be very slightly adjusted for magnetic field to exist. In terms of symmetry, I would actually love magnetic monopoles to exist!

Electromagnetism is one of the coolest part in Physics, but due to the limitation of Mathematical tools we can only stop here. (Sorry if this confused you, you just need to know the first one (transformer) for GCSE!) Well actually I just wrote the Physics I like.

Section 5 Space Physics

§5.1 Orbits

The orbit period:
$$T = \frac{2\pi r}{v}.$$

Meaning of Symbols (and Units): T stands for the orbit period, s; r stands for the orbit radius, m; v stands for the orbit speed, $\mathrm{m\,s^{-1}}$.

Word Explanation: The orbit period is the circumference of the orbit over the orbit speed (trivial).

Derived Formulae: $v = \frac{2\pi r}{T}, r = \frac{Tv}{2\pi}$.

Note: This can be used to derive the escape velocity (together with Newton's Law of Gravity).

§5.2 Hubble's Constant

1. **The Hubble's Constant:**
$$H_0 = \frac{v}{d}.$$

Meaning of Symbols (and Units): H_0 stands for the Hubble Constant, $H_0 \approx 2.2 \times 10^{-18}\,\mathrm{s^{-1}}$; v stands for the receding velocity, $\mathrm{m\,s^{-1}}$; d stands for the distance, m.

Word Explanation: The Hubble Constant is defined as the ratio of the speed at which the galaxy is moving away from the Earth to its distance from the Earth.

Derived Formulae: $v = H_0 d, d = \frac{v}{H_0}$.

Note: According to the syllabus, you need to know the approximate value of the Hubble Constant.

2. **Edge of Time:**

$$t = \frac{1}{H_0}.$$

Meaning of Symbols (and Units): t stands for the age of the universe, s, H_0 stands for the Hubble Constant, s^{-1}.

Word Explanation: The Hubble Constant is equal to the reciprocal of the age of the universe.

Derived Formulae: Not really, but $tH_0 = 1$.

Note: $t \approx 1.38 \times 10^{10}$ yr.

Afterwords

This sheet really took me some time to populate, but I would genuinely like to share my understanding of GCSe Physics (and beyond) with all of you.

My deeps thanks to all of my Physics teacher I have met and my friends who helped me with producing this.

I would like to give special thanks to Mr. Blundell, my current Physics teacher, and Dr. Yun, my private tutor for proving me with all this knowledge.

Finally, I really hoped this helped you gain a better understanding of Physics. Feel free to email eason.syc@icloud.com to send me a feedback.