Diploma Programme

# Physics data booklet

For use during the course and in the examinations
First assessment 2025

Version 1.1

*Annotated by YPhysics (Version 1.0)*

International Baccalaureate
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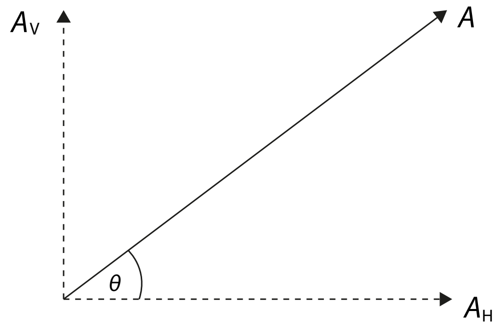
# Contents

# Mathematical equations

| | |
|---|---|
| Area of a triangle | $A = \frac{1}{2}(bh)$ where $b$ is the base, $h$ is the height |
| Area of a circle | $A = \pi r^2$ where $r$ is the radius |
| Circumference of a circle | $C = 2\pi r$ |
| Volume of a cuboid | $V = lwh$ where $l$ is the length, $w$ is the width, $h$ is the height |
| Volume of a cylinder | $V = \pi r^2 h$ |
| Volume of a prism | $V = Ah$ where $A$ is the area of cross-section |
| Volume of a sphere | $V = \frac{4}{3}\pi r^3$ |
| Area of the curved surface of a cylinder | $A = 2\pi rh$ |
| Vectors |   $A_H = A\cos\theta$ <br> $A_V = A\sin\theta$ |
| Trigonometric relationships | $\tan\theta = \frac{\sin\theta}{\cos\theta}$ <br> $\sin^2\theta + \cos^2\theta = 1$ |

# Uncertainties

| | |
|---|---|
| If: $y = a \pm b$ | then: $\Delta y = \Delta a + \Delta b$ |
| If: $y = \frac{ab}{c}$ | then: $\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$ |
| If: $y = a^n$ | then: $\frac{\Delta y}{y} = \left\| n \frac{\Delta a}{a} \right\|$ |

*Δy: absolute/raw uncertainty in y*
*y: value of y*

*Δa: absolute/raw uncertainty in a*
*a: value of a*

*Δb: absolute/raw uncertainty in b*
*b: value of b*

*Δc: absolute/raw uncertainty in c*
*c: value of c*

# Fundamental constants

| **Quantity** | **Symbol** | **Approximate value** |
|---|---|---|
| Acceleration of free fall | $g$ | $9.8\,\text{m}\,\text{s}^{-2}$ (Earth's surface) |
| Gravitational constant | $G$ | $6.67 \times 10^{-11}\,\text{N}\,\text{m}^2\,\text{kg}^{-2}$ |
| Avogadro constant | $N_A$ | $6.02 \times 10^{23}\,\text{mol}^{-1}$ |
| Gas constant | $R$ | $8.31\,\text{J}\,\text{K}^{-1}\,\text{mol}^{-1}$ |
| Boltzmann constant | $k_B$ | $1.38 \times 10^{-23}\,\text{J}\,\text{K}^{-1}$ |
| Stefan–Boltzmann constant | $\sigma$ | $5.67 \times 10^{-8}\,\text{W}\,\text{m}^{-2}\,\text{K}^{-4}$ |
| Coulomb constant | $k$ | $8.99 \times 10^{9}\,\text{N}\,\text{m}^2\,\text{C}^{-2}$ |
| Permittivity of free space | $\varepsilon_0$ | $8.85 \times 10^{-12}\,\text{C}^2\,\text{N}^{-1}\,\text{m}^{-2}$ |
| Permeability of free space | $\mu_0$ | $4\pi \times 10^{-7}\,\text{T}\,\text{m}\,\text{A}^{-1}$ |
| Speed of light in vacuum | $c$ | $3.00 \times 10^{8}\,\text{m}\,\text{s}^{-1}$ |
| Planck constant | $h$ | $6.63 \times 10^{-34}\,\text{J}\,\text{s}$ |
| Elementary charge | $e$ | $1.60 \times 10^{-19}\,\text{C}$ |
| Electron rest mass | $m_e$ | $9.110 \times 10^{-31}\,\text{kg} = 0.000549\,\text{u} = 0.511\,\text{MeV}\,\text{c}^{-2}$ |
| Proton rest mass | $m_p$ | $1.673 \times 10^{-27}\,\text{kg} = 1.007276\,\text{u} = 938\,\text{MeV}\,\text{c}^{-2}$ |
| Neutron rest mass | $m_n$ | $1.675 \times 10^{-27}\,\text{kg} = 1.008665\,\text{u} = 940\,\text{MeV}\,\text{c}^{-2}$ |
| (Unified) atomic mass unit | u | $1.661 \times 10^{-27}\,\text{kg} = 931.5\,\text{MeV}\,\text{c}^{-2}$ |
| Solar constant | $S$ | $1.36 \times 10^{3}\,\text{W}\,\text{m}^{-2}$ |
| Fermi radius | $R_0$ | $1.20 \times 10^{-15}\,\text{m}$ |

# Metric (SI) multipliers

| Prefix | Abbreviation | Value |
|---|---|---|
| peta | P | $10^{15}$ |
| tera | T | $10^{12}$ |
| giga | G | $10^{9}$ |
| mega | M | $10^{6}$ |
| kilo | k | $10^{3}$ |
| hecto | h | $10^{2}$ |
| deca | da | $10^{1}$ |
| deci | d | $10^{-1}$ |
| centi | c | $10^{-2}$ |
| milli | m | $10^{-3}$ |
| micro | μ | $10^{-6}$ |
| nano | n | $10^{-9}$ |
| pico | p | $10^{-12}$ |
| femto | f | $10^{-15}$ |

# Unit conversions

$1 \text{ radian (rad)} \equiv \frac{180°}{\pi}$

$\text{Temperature}(\text{K}) = \text{temperature}(°\text{C}) + 273$

$1 \text{ light year}(\text{ly}) = 9.46 \times 10^{15} \text{ m}$

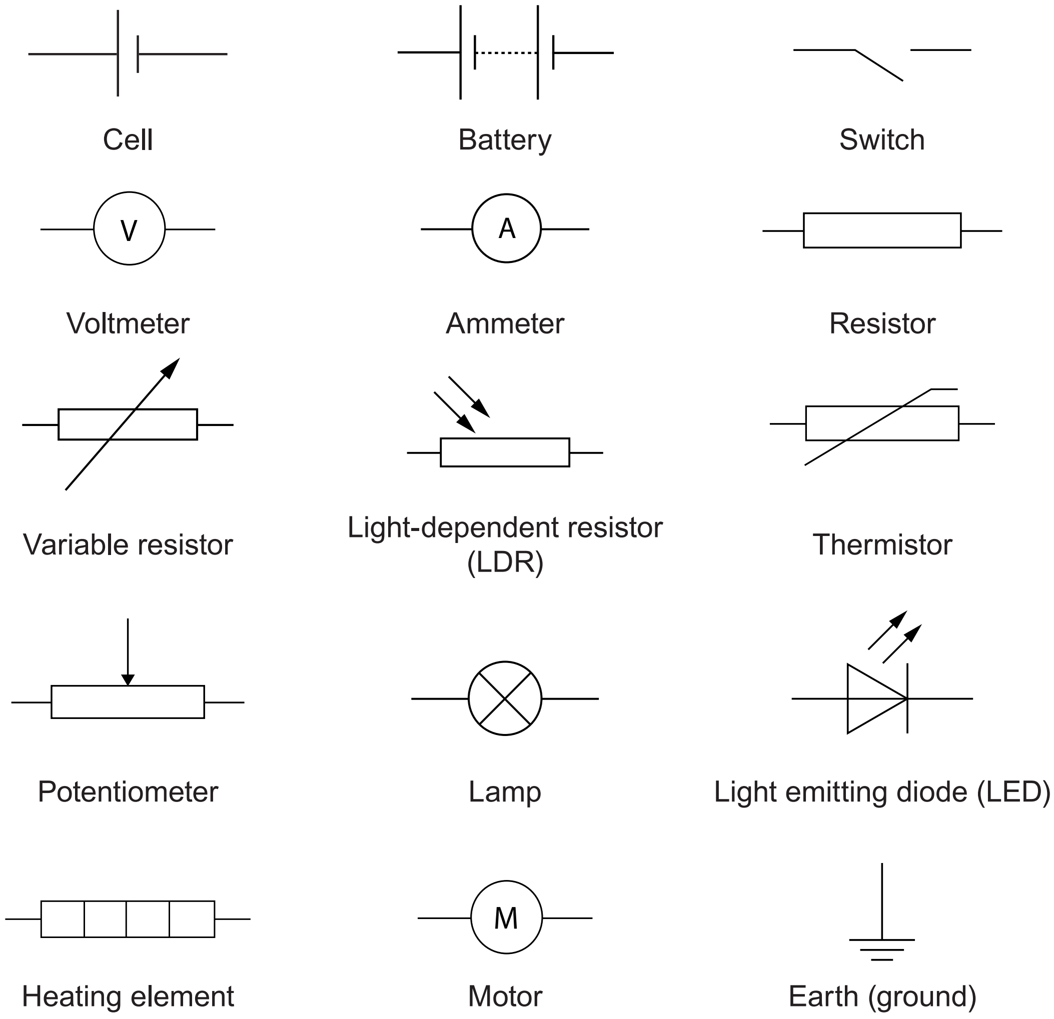
$1 \text{ parsec}(\text{pc}) = 3.26 \text{ ly}$

$1 \text{ astronomical unit } (\text{AU}) = 1.50 \times 10^{11} \text{ m}$

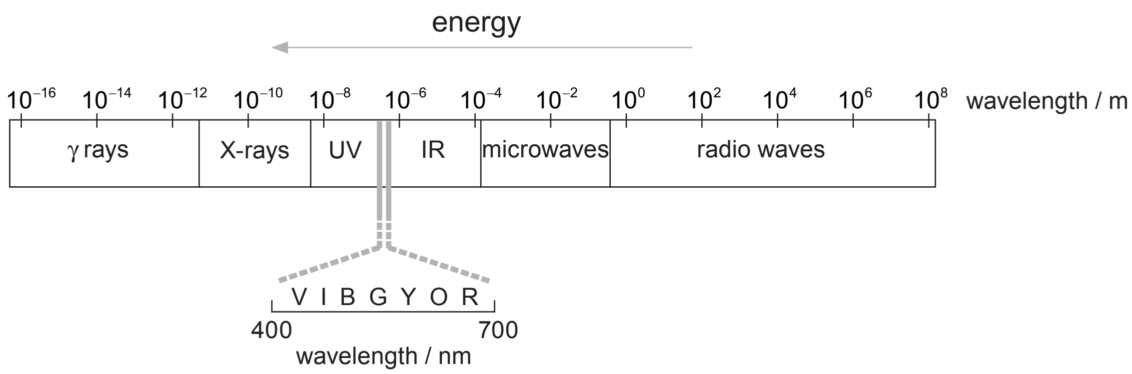
$1 \text{ kilowatt-hour}(\text{kWh}) = 3.60 \times 10^{6} \text{ J}$

$hc = 1.99 \times 10^{-25} \text{ J m} = 1.24 \times 10^{-6} \text{ eV m}$

# Electrical circuit symbols




# Electromagnetic spectrum



# A. Space, time and motion

## Standard level and higher level

### A.1 Kinematics

$$s = \frac{u + v}{2} t$$

$$v = u + at$$

$$s = ut + \frac{1}{2} at^2$$

$$v^2 = u^2 + 2as$$

*s*: displacement
*u*: initial velocity
*v*: final velocity
*a*: acceleration
*t*: time

(Use + or - to include direction)

### A.2 Forces and momentum

$$F_f \le \mu_s F_N$$

$$F_f = \mu_d F_N$$

$F_f$: frictional force (friction)
$\mu_s$: coefficient of static friction
$\mu_d$: coefficient of dynamic friction
$F_N$: normal contact force

$$F_H = -kx$$

$F_H$: elastic force from helical spring (Hooke's Law)
*k*: spring's constant
*x*: extension or compression of spring

$$F_d = 6\pi\eta r v$$

$F_d$: drag force (resistive force from fluids)
$\eta$: coefficient of viscosity
*r*: radius
*v*: speed

$$F_b = \rho V g$$

$F_b$: buoyant force (upthrust)
$\rho$: density of fluid
*V*: volume submerged in fluid
*g*: acceleration of free fall

$$F_g = mg$$

$F_g$: gravitational force (weight close to Earth's surface)
*m*: mass
*g*:acceleration of free fall

$$p = mv$$

*p*: momentum
*m*: mass
*v*: velocity

$$J = F\Delta t$$

*J*: impulse
*F*: force
$\Delta t$: time taken

$$F = ma = \frac{\Delta p}{\Delta t}$$

*F*: resultant/net force
*m*: mass
*a*: acceleration
$\Delta p$: change in momentum ($\Delta p = mv - mu$)
$\Delta t$: time taken

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

$$v = \frac{2\pi r}{T} = \omega r$$

*a*: centripetal acceleration
*v*: linear speed
*r*: radius
*T*: period
$\omega$: angular speed

### A.3 Work, energy and power

$$W = Fs\cos\theta$$

*W*: work done by force *F*
*F*: force
*s*: displacement of point of action of force *F*
$\theta$: angle between direction of *F* and direction of *s*

$$E_k = \frac{1}{2} mv^2 = \frac{p^2}{2m}$$

$E_k$: kinetic energy
*m*: mass
*v*: speed
*p*: momentum

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

$\Delta E_p$: change in gravitational potential energy
*m*: mass
*g*: acceleration of free fall
$\Delta h$: change in height

$$E_H = \frac{1}{2} k\Delta x^2$$

$E_H$: elastic potential energy stored in helical spring
*k*: spring's constant
$\Delta x$ : extension or compression of the spring

$$P = \frac{\Delta W}{\Delta t} = Fv$$

*P*: Power
$\Delta W$: work done / energy transferred
$\Delta t$: time taken
*F*: average force
*v*: average speed

$$\eta = \frac{\text{useful work out}}{\text{total work in}} = \frac{\text{useful power out}}{\text{total power in}}$$

$\eta$: efficiency

## Additional higher level

### A.4 Rigid body mechanics

$\tau = Fr\sin\theta$

τ: torque
F: force
r: distance from axis to point of action of F
θ: angle between direction of F and direction of r

$\Delta\theta = \frac{\omega_f + \omega_i}{2}t$

$\omega_f = \omega_i + \alpha t$

$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$

$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$

Δθ: angular displacement
$\omega_f$: final angular velocity
$\omega_i$: initial angular velocity
a: angular acceleration
t: time
(use + and - to include direction )

$I = \Sigma mr^2$

I: moment of inertia
m: mass
r: distance from point or axis of rotation
(Note: Σ means sum i.e $\Sigma mr^2 = m_1r_1^2 + m_2r_2^2 + m_3r_3^2 + \ldots$)

$\tau = I\alpha$

τ: resultant/net torque
I: moment of inertia
a: angular acceleration

$L = I\omega$

L: angular momentum
I: moment of inertia
ω: angular velocity

$\Delta L = \tau\Delta t$

ΔL: change in angular momentum
τ: resultant/net torque
Δt: time taken

$\Delta L = \Delta(I\omega)$

ΔL: change in angular momentum
I: moment of inertia
ω: angular velocity

$E_k = \frac{1}{2}I\omega^2 = \frac{L^2}{2I}$

$E_k$: rotational kinetic energy
I: moment of inertia
ω: angular speed
L: angular momentum

### A.5 Galilean and special relativity

$x' = x - vt$

$t' = t$

$u' = u - v$

$x' = \gamma(x - vt)$ where $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$

$t' = \gamma\left(t - \frac{vx}{c^2}\right)$

$u' = \frac{u - v}{1 - \frac{uv}{c^2}}$

x':position of an event in an inertial frame of reference moving with relative speed v to the original frame of reference

x:position of the same event in the original frame of reference

v: relative speed between the two inertial frames of reference

t': time of an event in an inertial frame of reference moving with relative speed v to the original frame of reference

t: time of the same event in the original frame of reference

u': velocity of body in n inertial frame of reference moving with relative speed v to the original frame of reference

u: velocity of the same body in the original frame of reference

γ: the Lorrentz factor

c: speed of light in vacuum (constant)

$(\Delta s)^2 = (c\Delta t)^2 - \Delta x^2$

Δs: space-time interval between two events
c: speed of ligh
Δt: time interval
Δx: distance between the events

$\Delta t = \gamma\Delta t_0$

Δt: time interval between two observed events (2 different clocks)

γ: the Lorrentz factor

$\Delta t_0$: proper time (time interval measured by same clock)

$L = \frac{L_0}{\gamma}$

L: observed length
$L_0$: proper length
γ: the Lorrentz factor

$\tan\theta = \frac{v}{c}$

θ: angle of worldline from the vertical axis in a space-time diagram
v: speed of the body

# B. The particulate nature of matter

## Standard level and higher level

### B.1 Thermal energy transfers

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

ρ: density
m: mass
V: volume

$\overline{E}_k = \frac{3}{2} k_B T$

$E_k$: average random kinetic energy of particles
$k_B$: Boltzmann constant
T: temperature

$Q = mc\Delta T$

$Q = mL$

Q: heat (energy transferred)
m: mass
c: specific heat capacity
L: specific latent heat
ΔT: change in temperature

$\frac{\Delta Q}{\Delta t} = kA \frac{\Delta T}{\Delta x}$

ΔQ: amount of heat (energy) transfer
Δt: time taken
k: thermal conductivity of material
A: surface area of the surface that emits heat
ΔT: temperature difference between hot and cold sides
Δx: thickness (distance between hot and cold sides)

$L = \sigma A T^4$

L: luminosity (total power output)
σ: Steffan-Boltzmann constant
A: surface area of body
T: temperature

$b = \frac{L}{4\pi d^2}$

b: brightness (intensity)
L: luminosity
d: distance from the source

$\lambda_{max} T = 2.9 \times 10^{-3}\,\text{mK}$

$\lambda_{max}$: peak wavelength
T: temperature

### B.2 Greenhouse effect

$\text{emissivity} = \frac{\text{power radiated per unit area}}{\sigma T^4}$

σ: Steffan-Boltzmann constant
T : temperature

$\text{albedo} = \frac{\text{total scattered power}}{\text{total incident power}}$

### B.3 Gas laws

$P = \frac{F}{A}$

P: pressure
F: force
A: area

$n = \frac{N}{N_A}$

n: number of moles
N: number of particles (atoms or molecules)
$N_A$: Avogadro constant

$\frac{PV}{T} = \text{constant}$

$PV = nRT = Nk_B T$

P: pressure
V: volume
T: temperature
N:number of moles
R: gas constant
N: number of particles
$K_B$: Boltzmann constant
U: internal energy of gas

$P = \frac{1}{3}\rho v^2$

P: pressure
ρ: density of gas
v: root mean square speed of particles (r.m.s speed)

$U = \frac{3}{2} nRT = \frac{3}{2} Nk_B T$

## B.5 Current and circuits

$I = \frac{\Delta q}{\Delta t}$

*I: current*
*Δq: amount of charge passing through a surface*
*Δt: time taken*

$V = \frac{W}{q}$

*V: potential difference*
*W: work done*
*q: charge*

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

*R: resistance*
*V: potential difference*
*I: current*

$\rho = \frac{RA}{L}$

*ρ: resistivity*
*R: resistance*
*A: cross-sectional area*
*L: length*

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

*P: power*
*I: current*
*V: potential difference*
*R: resistance*

| Series circuits | Parallel circuits |
|---|---|
| $I = I_1 = I_2 = \ldots$ | $I = I_1 + I_2 + \ldots$ |
| $V = V_1 + V_2 + \ldots$ | $V = V_1 = V_2 = \ldots$ |
| $R_s = R_1 + R_2 + \ldots$ | $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$ |

$\varepsilon = I(R + r)$

*ε: electromotive force (emf)*
*I: current*
*R: resistance of connected circuit*
*r: internal resistance*

## Additional higher level

## B.4 Thermodynamics

$Q = \Delta U + W$

*Q: amount of thermal energy (heat)*
*ΔU: change in internal energy*
*W: work done by the gas*

$W = P\Delta V$

*W: work done by gas*
*P: pressure*
*ΔV: change in volume*

$\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}Nk_B\Delta T$

*ΔU: change in internal energy of a gas*
*n: number of moles*
*R: Gas constant*
*ΔT: change in temperature*
*N: number of atoms*
*$k_B$: Boltzmann constant*

$\Delta S = \frac{\Delta Q}{T}$

*ΔS: change in entropy*
*ΔQ: amount of thermal energy (heat) that flows into a body*
*T: temperature*

$S = k_B \ln \Omega$

*S: entropy*
*$k_B$: Boltzmann constant*
*Ω: number of possible micro states of the system*

$PV^{\frac{5}{3}} = \text{constant}$

*(Model for* ***adiabatic*** *processes)*
*P: Pressure of monatomic ideal gas*
*V: Volume of monatomic ideal gas*

$\eta = \frac{\text{useful work}}{\text{input energy}}$

$\eta_{\text{Carnot}} = 1 - \frac{T_c}{T_h}$

*η: efficiency*
*$\eta_{Carnot}$: efficiency of a Carnot cycle*
*$T_c$: temperature of cold gas*
*$T_h$: temperature of hot gas*

# C. Wave behaviour

## Standard level and higher level

### C.1 Simple harmonic motion

$$a = -\omega^2 x$$

a: acceleration
ω: angular frequency
x: displacement from equilibrium position

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$

T: period
$f$: frequency
ω: angular frequency

$$T = 2\pi\sqrt{\frac{m}{k}}$$

T: period of a mass-spring system
m: mass
k: spring's constant

$$T = 2\pi\sqrt{\frac{l}{g}}$$

T: period of simple pendulum
l: length
g: acceleration of free fall (constant)

### C.2 Wave model

$$v = f\lambda = \frac{\lambda}{T}$$

v: wave speed
$f$: frequency
λ: wavelength

### C.3 Wave phenomena

$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1}$$

$n_1$: refractive index of medium 1
$n_2$: refractive index of medium 2
$\theta_1$: angle of incidence
$\theta_2$: angle of refraction
$v_1$: speed of wave in medium 1
$v_2$: speed of wave in medium 2

Constructive interference:
path difference $= n\lambda$

Destructive interference:
path difference $= (n + \frac{1}{2})\lambda$

n= 0, 1, 2, 3, …
λ: wavelength

$$s = \frac{\lambda D}{d}$$

s: distance between adjacent maxima
λ: wavelength
D: distance between slits and screen
d: distance between slits

### C.5 Doppler effect

$$\frac{\Delta f}{f} = \frac{\Delta\lambda}{\lambda} \approx \frac{v}{c}$$

$\Delta f$: change/shift in frequency
$f$: frequency of emitted wave
Δλ: change/shift in wavelength
λ: wavelength of emitted wave
v: relative speed between source and observer
c: speed of light (constant)

## Additional higher level

### C.1 Simple harmonic motion

$$x = x_0 \sin(\omega t + \phi)$$

$$v = \omega x_0 \cos(\omega t + \phi)$$

$$v = \pm\omega\sqrt{x_0^2 - x^2}$$

$$E_T = \frac{1}{2}m\omega^2 x_0^2$$

$$E_p = \frac{1}{2}m\omega^2 x^2$$

x: displacement from equilibrium position
$x_0$: amplitude
ω: angular frequency
t: time
ϕ: initial phase
v: velocity
$E_T$: total energy of simple harmonic oscillator
$E_p$: potential energy of simple harmonic oscillator
m: mass

θ: angle at which first diffraction minimum appears
λ: wavelength
b: slit width

′

| | |
|---|---|
| C.3 Wave phenomena | $\theta = \frac{\lambda}{b}$<br>$n\lambda = d\sin\theta$ |
| C.5 Doppler effect | Moving source: $f' = f\left(\frac{v}{v \pm u_s}\right)$<br>Moving observer: $f' = f\left(\frac{v \pm u_o}{v}\right)$ |

n: order (1, 2, 3, … )
λ: wavelength
d: distance between slits of diffraction grating
θ: angle at which this order minimum will appear

$f'$: observed frequency
$f$: emitted frequency
v: wave speed
$u_o$: speed of observer
$u_s$: speed of source

# D. Fields

## Standard level and higher level

### D.1 Gravitational fields

$$F = G\frac{m_1 m_2}{r^2}$$

F: gravitational force
G: gravitational constant
$m_1$: mass of body 1
$m_2$: mass of body 2
r: distance between the centres of the 2 bodies

$$g = \frac{F}{m} = G\frac{M}{r^2}$$

g: gravitational field strength
F: gravitational force
m: mass
G: gravitational constant
M: mass of the body that creates the gravitational field
r: distance from the centre of that body

### D.2 Electric and magnetic fields

$$F = k\frac{q_1 q_2}{r^2} \quad \text{where} \quad k = \frac{1}{4\pi\varepsilon_0}$$

F: electric field force between two charged particles
k: Coulomb's constant
$\varepsilon_0$: permittivity of free space (constant)
$q_1$: charge of particle 1
$q_2$: charge of particle 2

$$E = \frac{F}{q}$$

E: electric field strength
F: electric field force
q: charge

$$E = \frac{V}{d}$$

E: electric field strength of a uniform electric field
V: potential difference between two points (or metal plates)
d: distance between the two points (or metal plates)

### D.3 Motion in electromagnetic fields

$$F = qvB\sin\theta$$

F: magnetic force on moving charged particle
q: charge of particle
v: speed of particle
B: magnetic field strength
θ: angle between magnetic field lines and direction of speed

$$F = BIL\sin\theta$$

F: magnetic force on current currying wire
B: magnetic field strength
I: current
L: length of wire in the magnetic field
θ: angle between magnetic field lines and current

$$\frac{F}{L} = \mu_0\frac{I_1 I_2}{2\pi r}$$

F: magnetic force between current currying wire
L: length of wire
$\mu_0$: permeability of free space (constant)
$I_1$: current in wire 1
$I_2$: current in wire 2
r: distance between wires

## Additional higher level

### D.1 Gravitational fields

$$E_p = -G\frac{m_1 m_2}{r}$$

$E_p$: gravitational potential energy
G: gravitational constant
$m_1$: mass of body 1
$m_2$: mass of body 2
r: distance between the centres of bodies

$$V_g = -G\frac{M}{r}$$

$V_g$: gravitational potential at a point in a gravitational field
G: gravitational constant
M: mass of the body creating the field
r: distance of the point from the centre of the body.

$$g = -\frac{\Delta V_g}{\Delta r}$$

g: gravitational field strength
$\Delta V_g$: change in the gravitational potential between two points
Δr: distance between the two points

$$W = m\Delta V_g$$

W: work done to move a mass in a gravitational field
m: mass of body that is moving
$\Delta V_g$: change in the gravitational potential between two points

$$v_{esc} = \sqrt{\frac{2GM}{r}}$$

$$v_{orbital} = \sqrt{\frac{GM}{r}}$$

$v_{esc}$: speed needed to escape a gravitational field
$v_{orbital}$: orbital speed
G: gravitational constant
M: mass of body creating the gravitational field
r: distance from the centre of that body

### D.2 Electric and magnetic fields

$$E_p = k\frac{q_1 q_2}{r}$$

$E_p$: electric potential energy
k: Coulomb's constant
$q_1$: charge on body 1
$q_2$: charge on body 2
r: distance between the centres of the bodies

$$V_e = \frac{kQ}{r}$$

$V_e$: electric potential at a point in an electric field
k: Coulomb's constant
Q: charge creating the field
r: distance between point and centre of charge

$$E = -\frac{\Delta V_e}{\Delta r}$$

E: electric field strength
ΔV: electric potential difference between two points in the field
Δr: distance between the points

$$W = q\Delta V_e$$

W: work done to move a charge in an electric field
q: charge moved
$\Delta V_e$: electric potential difference between the points

| | | |
|---|---|---|
| D.4 Induction | $\varepsilon$: induced emf<br>N: number of loops on coil<br>ΔΦ: change in magnetic flux<br>Δt: time taken | $\Phi = BA\cos\theta$<br>Φ: magnetic flux<br>B: magnetic field strength<br>A: area<br>θ: angle between magnetic field lines and the perpendicular direction to the surface<br><br>$\varepsilon = -N\dfrac{\Delta\Phi}{\Delta t}$<br><br>$\varepsilon = BvL$<br>ε: emf induced across the ends of a straight conductor moving in a magnetic field<br>B: magnetic field strength<br>v: speed of conductor<br>l: length of conductor in field |

# E. Nuclear and quantum physics

| **Standard level and higher level** | |
|---|---|
| E.1 Structure of the atom | $E = hf$<br>E: energy of a photon<br>h: Planck's constant<br>$f$: frequency |
| E.3 Radioactive decay | $E = mc^2$<br>E: energy released<br>m: mass 'loss' (change in mass)<br>c: speed of light (constant) |
| E.5 Fusion and stars | $\text{d(parsec)} = \dfrac{1}{\text{p(arc-second)}}$<br>d: distance to star<br>p: parallax angle |
| **Additional higher level** | |
| E.1 Structure of the atom<br>E: energy value of energy level<br>n: quantum number of energy level (n= 1,2,3,..)<br>(eV is just the unit, energy here is calculated in electrovolts) | $R = R_0 A^{\frac{1}{3}}$<br>R: radius of atom<br>$R_0$: Fermi radius (constant)<br>A: atomic number (number of protons)<br><br>$E = -\dfrac{13.6}{n^2}\text{eV}$<br><br>$mvr = \dfrac{nh}{2\pi}$<br>mvr: angular momentum<br>m: mass<br>v: linear speed<br>r: radius of circular path<br>n: quantum number (n=1,2,3,4,…)<br>h: Planck's constant |
| E.2 Quantum physics<br>$E_{max}$: maximum kinetic of energy of emitted electrons<br>h: Planck's constant<br>$f$: frequency of incident radiation<br>Φ: work function of metal surface | $E_{\text{max}} = hf - \Phi$<br><br>$\lambda = \dfrac{h}{p}$<br>λ: wavelength<br>h: Planck's constant<br>p: momentum<br><br>$\lambda_f - \lambda_i = \Delta\lambda = \dfrac{h}{m_e c}(1-\cos\theta)$<br>$\lambda_f$: final wavelength<br>$\lambda_i$: initial wavelength<br>Δλ: change in wavelength<br>h: Planck's constant<br>$m_e$: mass of electron (constant)<br>c: speed of light in vacuum (constant)<br>θ: scattering angle |
| E.3 Radioactive decay<br>N: number of nuclei left after time t<br>$N_0$: original number of nuclei in the sample (at t=0)<br>λ: decay constant of material<br>t: time<br>A: activity (number of decays per second)<br>$T_{1/2}$: half-life | $N = N_0 e^{-\lambda t}$<br><br>$A = \lambda N = \lambda N_0 e^{-\lambda t}$<br><br>$T_{\frac{1}{2}} = \dfrac{\ln 2}{\lambda}$ |