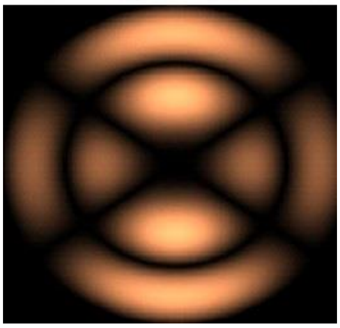

VISUAL PHYSICS ONLINE

EQUATION MINDMAPS

Equations are essential part of physics, without them, we can't start to explain our physical world and make predictions. An equation tells a story – a collection of a few symbols contains a wealth of information. Many examination questions can be answered by having an in-depth understanding of equations. To help you maximize your examination marks, you should use the equation mindmaps to gain this in-depth understanding. You need to commit to memory much of the information contained in the equation mindmaps so that you can appreciate the story told by each equation.

- State what the symbols represent (meaning & interpretation), S.I. units, other units, typical values, vector or scalar, positive or negative quantity.
- A visualisation of what the equation is about, is it a definition or a law, when is it applicable, comments and an interpretation.
- Alternative forms of the equation.
- Graphical representations of the equation.
- Numerical examples.

MECHANICS (Kinematics and Dynamics)

$v_{av} = \frac{\Delta r}{\Delta t}$	Average velocity
$v_x = \frac{dx}{dt}$	Instantaneous velocity in X direction
$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v-u}{t}$	Average acceleration
$a = \frac{dv}{dt}$	Instantaneous acceleration in X direction
$\sum \vec{F} = m\vec{a}$	Newton's Second Law
$\vec{a} = \frac{\sum \vec{F}}{m}$	acceleration
$F = mg$	Weight of an object
$F_C = m\frac{v^2}{r}$	Centripetal force: uniform circular motion
$a_C = \frac{F_c}{m} = \frac{v^2}{r}$	Centripetal acceleration
$\vec{F}_{AB} = -\vec{F}_{BA}$	Newton's Third Law

- $F_{rocket} = -F_{gases}$ eg rocket propulsion

- $\vec{p} = m\vec{v}$ Momentum of a moving object

  $impulse \quad \vec{J} = \vec{F}\,t$ Impulse of a force *F* acting for a time interval *t*

  $J = F\,\Delta t = mv - mu$ Impulse = change in momentum

  $\sum \vec{F} = 0 \quad \Rightarrow \Delta\vec{p} = 0$ Law of Conservation of momentum

$W = F\,s$	Work done by a force during a displacement (force and displacement in same direction [1D]
$E_K = K = \frac{1}{2} m v^2$	Kinetic energy of a moving object
$W = F\,\Delta s = \frac{1}{2} m v^2 - \frac{1}{2} m u^2$	Work done = change in KE [1D] only
$W = qV$	Work done on a charge in an electric field
$E_K = K = \frac{1}{2} m v^2 = e\,V$	Gain in KE electron due to a constant accelerating voltage

$$v = u + at \qquad u \equiv v_0$$

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

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

$$v_{av} = \frac{u+v}{2}$$

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

Equation for uniform accelerated motion in one-dimension

a = constant

$$+\rightarrow \quad a_x = 0$$

$$u_x = u\cos\theta$$

$$v_x = u_x \qquad x = u_x t$$

$$+\uparrow \quad a_y = -g$$

$$u_y = u\sin\theta$$

$$v_y = u_y + a_y t$$

$$v_y^{\,2} = u_y^{\,2} + 2a_y\,\Delta y$$

$$y = u_y t + \tfrac{1}{2}a_y t^2$$

$$y = \frac{u_y + v_y}{2}t$$

$$s^2 = s_x^{\,2} + s_y^{\,2} \qquad \tan\theta_s = \frac{s_y}{s_x}$$

$$v^2 = v_x^{\,2} + v_y^{\,2} \qquad \tan\theta_v = \frac{v_y}{v_x}$$

Equations for

Projectile Motion

g = 9.8 m.s^{-2}

a_y = - g = - 9.8 m.s^{-1}

$F = \dfrac{G\,m_1\,m_2}{r^2}$	Gravitational force
$g_{planet} = \dfrac{G\,M_{planet}}{R_{planet}}$	Acceleration due to gravity at surface of a planet
$E_p = U = -G\,\dfrac{m_1\,m_2}{r}$	Gravitational potential energy
$E_p = U = m\,g\,h$	Gravitational potential energy near Earth’s surface
$g = \dfrac{G\,M_E}{r^2} = \dfrac{G\,M_E}{\left(R_E + h\right)^2}$	Acceleration due to gravity (Earth)
$T = 2\pi\sqrt{\dfrac{L}{g}}$	Period of pendulum → *g*

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

Kepler's Third Law for satellite motion

$$\frac{r_1^3}{T_1^2} = \frac{r_2^3}{T_2^2}$$

$$\frac{r_1^3}{T_1^2} = \frac{r_2^3}{T_2^2}$$

$$T_2 = T_1\left(\frac{r_2}{r_1}\right)^{\frac{3}{2}}$$

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

orbital velocity

$$T = \frac{2\pi r}{v_{orb}}$$

orbital period

geostationary satellite
T = 24 hours

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

escape velocity

SPECIAL RELATIVITY

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \qquad \beta = \frac{v}{c}$$

mass *m* is a constant

$$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma\, t_0$$

time dilation

$$L = L_0 \sqrt{1-\frac{v^2}{c^2}} = \frac{L_0}{\gamma}$$

length contract

$$E = m c^2$$

total energy

$$p = \frac{m v}{\sqrt{1-\frac{v^2}{c^2}}} = \gamma\, m v$$

momentum

$$E^2 = p^2 c^2 + m^2 c^4 = p^2 c^2 + E_0{}^2$$

total energy

$$K = E - E_0 = \frac{m c^2}{\sqrt{1-\frac{v^2}{c^2}}} - m c^2$$

kinetic energy

$$K = \tfrac{1}{2} m v^2$$

kinetic energy $v << c$

$$E_0 = 0 \qquad E = p c \qquad p = \frac{E}{c}$$

photon

ELECTRICITY

$R = \frac{V}{I}$	Resistance
$P = V\,I$	Electrical power
$Energy = V\,I\,t$	Electrical energy

MAGNETISM

$$\frac{F}{L} = k\frac{I_1 I_2}{d}$$	Magnetic force between two parallel conductors
$$F = B\,I\,L\,\sin\theta$$	Magnetic force on a conductor
$$B = \frac{\mu_0 I}{2\pi r}$$	Magnetic field surrounding a long straight conductor
$$\tau = F\,d$$	Torque
$$\tau = n\,B\,I\,A\cos\theta$$	Torque on a coil in a magnetic field
$$\Phi_B = B\,A\cos\theta$$	Magnetic flux
$$\varepsilon = -\frac{\Delta\Phi_B}{\Delta t}$$	average induced emf
$$\varepsilon = -\frac{d\Phi_B}{dt}$$	induced emf
$$\Phi_B = B\,A\cos(\omega t) \quad \theta = \omega t$$ $$\varepsilon = \omega\,B\,A\sin(\omega t)$$	
$$\varepsilon_{battery} = I\,R + \varepsilon_{back}$$	electric motor: back emf ε_{back}

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

Transformer equation: step up or step down voltages

$$V_s = \frac{n_s}{n_p} V_p \qquad I_s = \frac{n_p}{n_s} I_p$$

ideal transformer

$$P_s = P_p \qquad V_s I_s = V_p I_p$$

$$P_{loss} = I^2 R$$

Power loss (eddy currents – transformer, induction heating; transmission lines)

$$F = qvB\sin\theta$$

Force on a charged particle moving in a magnetic field

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

Electric field

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

Electric field (constant) between two parallel charged plates

NATURE OF LIGHT

$$E = hf$$

Energy of a photon

$$c = f\lambda$$

Speed of light

Speed of electromagnetic radiation

$$\tfrac{1}{2}mv^2 = eV$$

Gain in KE of electron due to accelerating voltage

Photoelectric Effect

$$hf = \tfrac{1}{2}mv^2 + W$$

$$hf = \tfrac{1}{2}mv_{max}{}^2 + W_{min}$$

$$\tfrac{1}{2}mv_{max}{}^2 = hf - W_{min}$$

Stopping voltage

$$eV_s = \tfrac{1}{2}mv_{max}{}^2$$

$$V_s = \frac{hf}{e} - \frac{W_{min}}{e}$$

Cut-off (critical) frequency

$$eV_s = \tfrac{1}{2}mv_{max}{}^2 = 0$$

$$hf_c = W_{min} \qquad f_c = \frac{W_{min}}{h}$$

THE ATOM

$n\lambda = d \sin\theta$	Bragg's Law – crystal structure (constructive interference)
$\frac{1}{\lambda} = R\left(\frac{1}{n_f^{\,2}} - \frac{1}{n_i^{\,2}}\right)$	Hydrogen atom - spectrum
$\lvert E_2 - E_1 \rvert = h\,f$	Energy levels Bohr Model of atom
$L = m v r = \frac{h}{2\pi}$	Angular momentum quantized
$E_n = -\frac{\lvert E_1 \rvert}{n^2} \quad \lvert E_1 \rvert = 13.6 \text{ eV}$	*n* = 1, 2, 3, … Energy levels hydrogen atom
$r_n = r_1\, n^2 \quad r_1 = 5.29 \times 10^{-11} \text{ m}$	Allowed orbits for electrons in hydrogen atom

$$\lambda = \frac{h}{mv}$$

de Broglie wavelength
de Broglie relationship

$$E = h f \quad c = f \lambda \quad p = \frac{h}{\lambda}$$

Photon

$$\lambda = \frac{h}{p} \quad p = \frac{h}{\lambda}$$

Matter wave

$$\Delta x \, \Delta p \geq \frac{h}{4\pi}$$

Heisenberg Uncertainty Principle

The NUCLUES

$\Delta m = M_{products} - M_{reactants}$

Mass defect

$E = \gamma m c^2$

Einstein – mass/energy

$^{9}Be_{4} + ^{4}He_{2} \rightarrow ^{12}C_{6} + ^{1}n_{0}$

Chadwick discovers **neutron**

Beta plus decay

$p^{+} \rightarrow n + e^{+} + \nu_e$

Beta decay
Pauli & Fermi
neutrino

$^{19}Ne_{10} \rightarrow ^{19}F_{9} + e^{+} + \nu_e$

$e^{+} \equiv \beta^{+}$

p[**d(-1/3)** **u(+2/3)** **u(+2/3)**]

$\rightarrow$ n[**d(-1/3)** **u(+2/3)** **d(-1/3)**]

Beta minus decay

$n \rightarrow p^{+} + e^{-} + \bar{\nu}_e$

$^{232}Th_{90} \rightarrow ^{228}Ra_{88} + ^{4}He_{2}$

$^{4}He_{2} \equiv \alpha$

Alpha decay

Standard model

proton
d (-1/2)
u (+2/3)
u (+2/3)

Proton

neutron
d (-1/3)
u (+2/3)
d (-2/3)

Neutron

$^{235}U_{92}$ + $^{1}n_{0}$ →
$^{236}U_{92}$* →
$^{136}Xe_{56}$ + $^{88}Sr_{36}$ + $12^{1}n_{0}$

Nuclear fission