PHYSICS FORMULAE TO MEMORISE

AF. May 2015.

MECHANICS

Displacement is the ***area*** under a (**time**, **velocity**) graph, where a *negative area means a negative displacement*

> Displacement, velocity and acceleration are **vector** quantities. The definitions here refer to a particular direction (e.g horizontal, or vertical)

Average speed = total distance travelled / total time taken

Velocity is the ***gradient*** of a (**time**, **displacement**) graph

Acceleration is the ***gradient*** of the (**time**, **velocity**) graph

Newton's First Law: A object will move at *constant velocity* if it is *not accelerating*, and therefore the vector sum of forces is zero. It is in ***equilibrium***.

Newton's Second Law: **mass x acceleration = vector sum of forces**

Weight: **gravitational force = mass x acceleration due to gravity** $W = mg$

Elastic force: **restoring force = spring constant x extension** $F = kx$

Newton's Third Law: If body A imposes a contact force $\mathbf{F}$ upon body B, body B will in turn impose a contact force $-\mathbf{F}$ upon body A

Moment of a force is **force** x **perpendicular distance from a rotation axis**. In **equilibrium**, the sum of moments (clockwise or anticlockwise) is **zero**, regardless of the axis position chosen!

Equations of constant acceleration motion: u initial velocity, a acceleration, t time, v final velocity, x displacement,' x_0 initial displacement

$$v = u + at$$
$$x = x_0 + \tfrac{1}{2}(u + v)t$$
$$x = x_0 + ut + \tfrac{1}{2}at^2$$
$$v^2 = u^2 + 2ax$$

For **projectile motion**, in the **y** direction the acceleration **is** $g = 9.81\text{ms}^{-2}$ *downwards*, and 0 ms^{-2} in the **x** direction i.e. a **constant velocity in the x direction.**

Conservation of momentum: The **vector sum** of **mass x velocity** for every object in a collision is the **same** after the collision. (Although the momenta of individual objects might change in the event).

Impulse is a **change** in **momentum**, and the ***area*** under a (**time**, **force**) graph

Conservation of energy: Kinetic energy + gravitational potential energy + elastic potential energy + ... is a **constant** in a closed system.

Kinetic energy: $\tfrac{1}{2}mv^2$ **Gravitational Potential Energy:** mgh **Elastic potential energy:** $\tfrac{1}{2}kx^2$

Work done = ***area*** under a (**displacement**, **force**) graph

Power = **rate** of use of **energy**. For a moving vehicle, **power = driving force x velocity**

ELECTRICITY & MAGNETISM

Ohm's Law: $V = IR$

V **Voltage** or **'potential difference'** *across* a resistive element. I **current**, R **resistance**.

Electrical Power $P = VI$ P power, V voltage, I current

Resistive power loss: $P = I^2 R$ P power, I current, R resistance

Resistance of a wire: $R = \frac{\rho l}{A}$

R **resistance**, l **length**, A **cross sectional area**, ρ **resistivity**. Assume uniform resistivity and cross sectional area along length of wire. Copper: $\rho = 1.68 \times 10^{-8}$, Aluminium : $\rho = 2.82 \times 10^{-8}\ \Omega\text{m}$

Addition of **resistors** wired in **series**: $R = R_1 + R_2 + ...$

Addition of **resistors** wired in **parallel**: $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + ...$

Faraday's law of induction: **Voltage** induced is proportional to the **rate of change of magnetic flux linked**

'Right hand thumbs up rule' for **magnetic field** (fingers) due to a **current** (thumb)

Fleming's Left hand rule: (Thumb: **Motion**, First finger: **magnetic Field**, Index finger: **Current**)

Transformers: $\frac{V_2}{V_1} = \frac{N_2}{N_1}$ $\frac{I_2}{I_1} = \frac{N_1}{N_2}$ V_1, I_1 Voltage, current in primary coil,

V_2, I_2 voltage, current in secondary coil, N_1, N_2 number of turns in primary, secondary coils

THERMAL PHYSICS

Ideal gas law: $pV = nRT$

p pressure, V volume, n number of moles of gas, molar gas constant R = 8.314 $\text{Jmol}^{-1}\text{K}^{-1}$,
T absolute temperature (in Kelvin)

$V \propto T$ **Charles' Law**

$p \propto \frac{1}{V}$ **Boyle's Law**

$\Delta E = mc\Delta T$ Energy ΔE required to raise the temperature of a mass m by ΔT

where c is the specific heat capacity (i.e. heat capacity per kilogram of thermal mass)

Temperature conversions: **Fahrenheit** to **Celsius** to **Kelvin**: $T_K = T_C + 273.15$, $T_F = \frac{9}{5}T_C + 32$

Pressure of a column of fluid: $p = \rho g h$

p pressure, ρ fluid density, g gravitational acceleration, h height of fluid column

WAVES & OPTICS

Angle of incidence = angle of reflection $\theta_i = \theta_r$

Snell's law of refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

n = refractive index (**speed of light in a vacuum / speed of light in a medium**). Angles θ are measured from the **normal** to the reflecting surface

Total internal reflection at glass : air interface i.e. no **refraction** if

$$\theta_i > \sin^{-1}\left(\frac{n_{air}}{n_{glass}}\right) \Rightarrow \theta_i > \sin^{-1}\left(\frac{1}{1.52}\right) \Rightarrow \theta_i > 41.1^{\circ}$$

This is the *critical angle*

Wave speed: $c = f\lambda$ — c speed , f frequency, λ wavelength

Frequency: $f = \frac{1}{T}$ — f frequency, T time period of oscillation

Speed of light in a vacuum: 2.998 x 10^8 ms^{-1}

Speed of sound in air ($20^{o}C$): 344 ms^{-1}

Speed of sound in water: 1482 ms^{-1}

Lens Formula: $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ — u object distance , v image distance, f focal length of a lens

NUCLEAR PHYSICS

The number of decays of a radioactive element per second (**'activity'**) is **proportional** to the **number of radioactive atoms that have not yet decayed**

$T_{\frac{1}{2}}$ **half life**. The time taken for half of the number of radioactive elements in a sample to decay.

The graph of the **activity** vs **time** is an **exponential decay.**

Alpha decay:

$$^{Z+N}_{Z}\mathrm{X} \rightarrow {}^{Z+N-4}_{Z-2}\mathrm{Y} + \alpha$$
$$^{229}_{90}\mathrm{Th} \rightarrow {}^{225}_{88}\mathrm{Ra} + \alpha$$

Atomic number (Z) *reduces* by 2. **Mass number** (A) *reduces* by 4

Kinetic energy of alpha particle (a Helium nucleus) is approximately 5MeV. (100,000 x ionization energy for an air molecule).

Beta decay:

$$^{Z+N}_{Z}\mathrm{X} \rightarrow {}^{Z+N}_{Z+1}\mathrm{Y} + \beta$$
$$^{14}_{6}\mathrm{C} \rightarrow {}^{14}_{7}\mathrm{N} + \beta$$

Atomic number (Z) *increases* by 1. Mass number (A) *stays the same*

Kinetic energy of beta particles (high energy electrons) are 0.01 to 10MeV, i.e. a *spectrum* of energies.

[1MeV = 1.60 x 10^{-13} J]

Gamma rays: Very high energy photos, i.e. electromagnetic waves of *very* high frequency.

Gamma radiation is more **penetrating** than **beta**, which is more penetrating than **alpha**.

Periodic Table of the Elements

Atomic Number
Symbol
Name
Atomic Mass

Atomic mass values reflect the IUPAC accepted values as of 09/2013.

Masses expressed in [a;b] format show the lower and upper limit of atomic mass depending on the physical and chemical history of the element.

Masses expressed in < > format are the mass numbers of the longest-lived isotope for elements with no stable nucleus.

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen [1.00784;1.00811]																	2 He Helium 4.002602(2)
3 Li Lithium [6.938;6.997]	4 Be Beryllium 9.0121831(5)											5 B Boron [10.806;10.821]	6 C Carbon [12.0096;12.0116]	7 N Nitrogen [14.00643;14.00728]	8 O Oxygen [15.99903;15.99977]	9 F Fluorine 18.998403163(6)	10 Ne Neon 20.1797(6)
11 Na Sodium 22.98976928(2)	12 Mg Magnesium [24.304,24.307]											13 Al Aluminum 26.9815386(8)	14 Si Silicon [28.084;28.086]	15 P Phosphorus 30.973761998(5)	16 S Sulfur [32.059;32.076]	17 Cl Chlorine [35.446;35.457]	18 Ar Argon 39.948(1)
19 K Potassium 39.0983(1)	20 Ca Calcium 40.078(4)	21 Sc Scandium 44.955908(5)	22 Ti Titanium 47.867(1)	23 V Vanadium 50.9415(1)	24 Cr Chromium 51.9961(6)	25 Mn Manganese 54.938045(5)	26 Fe Iron 55.845(2)	27 Co Cobalt 58.933194(4)	28 Ni Nickel 58.6934(4)	29 Cu Copper 63.546(3)	30 Zn Zinc 65.38(2)	31 Ga Gallium 69.723(1)	32 Ge Germanium 72.630(8)	33 As Arsenic 74.921595(6)	34 Se Selenium 78.971(8)	35 Br Bromine [79.901,79.907]	36 Kr Krypton 83.798(2)
37 Rb Rubidium 85.4678(3)	38 Sr Strontium 87.62(1)	39 Y Yttrium 88.90584(2)	40 Zr Zirconium 91.224(2)	41 Nb Niobium 92.90637(2)	42 Mo Molybdenum 95.95(1)	43 Tc Technetium <98>	44 Ru Ruthenium 101.07(2)	45 Rh Rhodium 102.90550(2)	46 Pd Palladium 106.42(1)	47 Ag Silver 107.8682(2)	48 Cd Cadmium 112.414(4)	49 In Indium 114.818(1)	50 Sn Tin 118.710(7)	51 Sb Antimony 121.760(1)	52 Te Tellurium 127.60(3)	53 I Iodine 126.90447(3)	54 Xe Xenon 131.293(6)
55 Cs Cesium 132.90545196(6)	56 Ba Barium 137.327(7)	57-71	72 Hf Hafnium 178.49(2)	73 Ta Tantalum 180.94788(2)	74 W Tungsten 183.84(1)	75 Re Rhenium 186.207(1)	76 Os Osmium 190.23(3)	77 Ir Iridium 192.217(3)	78 Pt Platinum 195.084(9)	79 Au Gold 196.966569(5)	80 Hg Mercury 200.592(3)	81 Tl Thallium [204.382;204.385]	82 Pb Lead 207.2(1)	83 Bi Bismuth 208.98040(1)	84 Po Polonium <209>	85 At Astatine <210>	86 Rn Radon <222>
87 Fr Francium <223>	88 Ra Radium <226>	89-103	104 Rf Rutherfordium <267>	105 Db Dubnium <268>	106 Sg Seaborgium <271>	107 Bh Bohrium <272>	108 Hs Hassium <270>	109 Mt Meitnerium <276>	110 Ds Darmstadtium <281>	111 Rg Roentgenium <280>	112 Cn Copernicium <285>	113 Uut Ununtrium unknown	114 Fl Flerovium <289>	115 Uup Ununpentium unknown	116 Lv Livermorium <293>	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

Lanthanide Series	57 La Lanthanum 138.90547(7)	58 Ce Cerium 140.116(1)	59 Pr Praseodymium 140.90766(2)	60 Nd Neodymium 144.242(3)	61 Pm Promethium <145>	62 Sm Samarium 150.36(2)	63 Eu Europium 151.964(1)	64 Gd Gadolinium 157.25(3)	65 Tb Terbium 158.92535(2)	66 Dy Dysprosium 162.500(1)	67 Ho Holmium 164.93033(2)	68 Er Erbium 167.259(3)	69 Tm Thulium 168.93422(2)	70 Yb Ytterbium 173.054(5)	71 Lu Lutetium 174.9668(1)
Actinide Series	89 Ac Actinium <227>	90 Th Thorium 232.0377(4)	91 Pa Protactinium 231.03588(2)	92 U Uranium 238.02891(3)	93 Np Neptunium <237>	94 Pu Plutonium <244>	95 Am Americium <243>	96 Cm Curium <247>	97 Bk Berkelium <247>	98 Cf Californium <251>	99 Es Einsteinium <252>	100 Fm Fermium <257>	101 Md Mendelevium <258>	102 No Nobelium <259>	103 Lr Lawrencium <262>