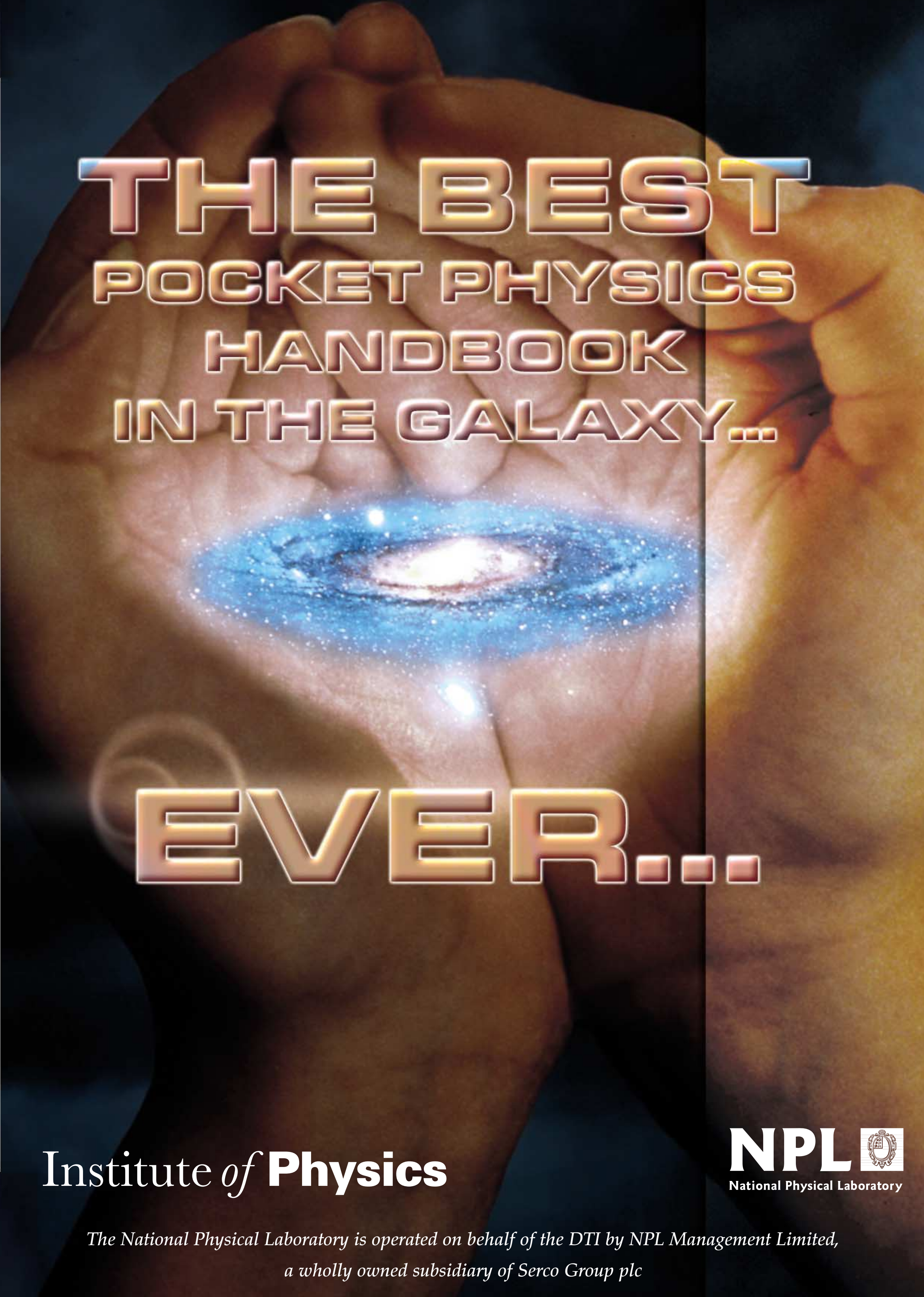

THE BEST POCKET PHYSICS HANDBOOK IN THE GALAXY...

EVER...

Institute *of* **Physics**

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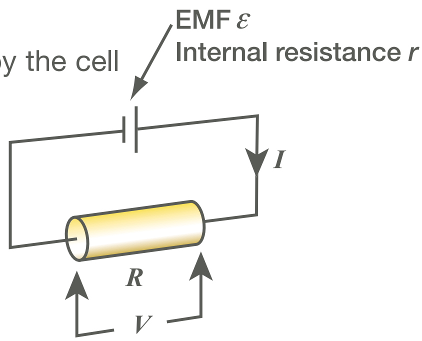
ELECTRIC CIRCUITS

CURRENT AND CIRCUITS

Charge (Q) coulomb (C)	1 coulomb is the basic unit of charge
Current (I) ampere (A)	1 ampere is a current of 1 coulomb per second *
Potential difference (V) volt (V)	1 volt is the PD between two points when 1 joule is lost or gained by each coulomb moving between those points
Power (P) watt (W)	Energy dissipated per second = IV
Resistance (R) ohm (Ω)	1 ohm is one volt per amp $R = V/I$ *
In series:	$R_{Total} = R_1 + R_2$
In parallel:	$1/R_{Total} = 1/R_1 + 1/R_2$

Cells and EMF

The EMF ($\mathcal{E}$) = the energy supplied to each coulomb by the cell



Some energy transferred in **external resistance** R and some in **internal resistance** r

Energy loss per coulomb through **R** is $V = IR$

Energy loss per coulomb through cell **r** is $v = Ir$

So $\mathcal{E} = IR + Ir$ **PD** across cell $V = \mathcal{E} - v$

CAPACITORS

Q is the charge displaced from one plate to the other via the circuit

Capacitance (C) Farad (F): number of coulombs displaced per volt

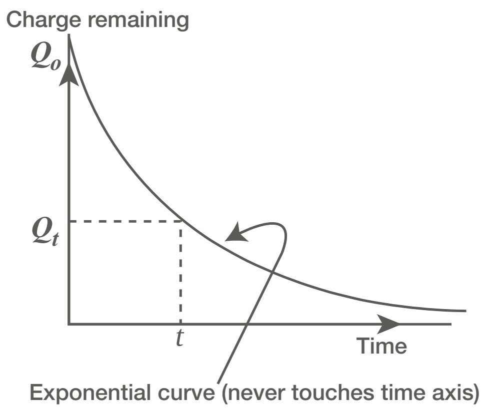
$C = Q/V = \varepsilon_o A/d$ (A = Area of each plate d = plate separation) (in a vacuum)

Energy stored = $\frac{1}{2}QV = \frac{1}{2}CV^2 = \dfrac{\frac{1}{2}Q^2}{C}$ (Compare with a elastic materials)

In series: $1/C_{Total} = 1/C_1 + 1/C_2$ in parallel: $C_{Total} = C_1 + C_2$

Capacitor Discharge

(Compare with Radioactive Decay)



PD across R : $V = Q/C$, and $I = V/R$

Thus $I = Q/RC$ so I is proportional to Q

So rate of loss of Q (i.e. I) is proportional to Q

Therefore $Q_t = Q_o\, e^{\left(\frac{-t}{RC}\right)}$

RC is the time constant

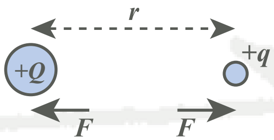
= time for Q to fall to $1/e$ of original value

"Full" discharge in about $5RC$ seconds

FIELDS

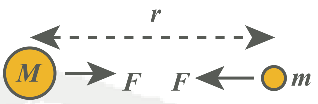
FIELDS DUE TO AN ISOLATED SPHERICAL CHARGE OR MASS

Inverse Square Law of Force Due to an isolated charge (Q) or mass (M)



$F = kQ\,q/r^2$

$\left(k = \dfrac{1}{4\pi\varepsilon_o} \text{ in vacuum}\right)$



$F = -\,GMm/r^2$

Field Strength (E) *Vector* Force per unit charge (or unit mass) E, g

E: F on 1 coulomb $= \dfrac{+\,k\,Q}{r^2}$ (since $q = 1$)

g: F on 1 kilogram $= \dfrac{-\,G\,M}{r^2}$ (since $m = 1$)

(In general ε_o is multiplied by ε_r the relative permittivity)

Field Strength = Negative Potential gradient = $-\,dV/dr$ (always)

Field Potential (V) *Scalar* Potential energy of unit electric charge (or unit mass)

Energy required to bring unit electric charge (or mass) from infinity to the point in question.

Electrical: (repulsive force for positive Q so energy supplied) $V_{elec} = kQ/r$

Gravitation: (attractive force for positive M so potential well) $V_{grav} = -\,GM/r$

Potential Energy of charge q (mass m) in the field: qV_{elec} ; mV_{grav}

PARALLEL FIELDS

Field Strength is uniform and the negative of the potential gradient $E = -V/d$

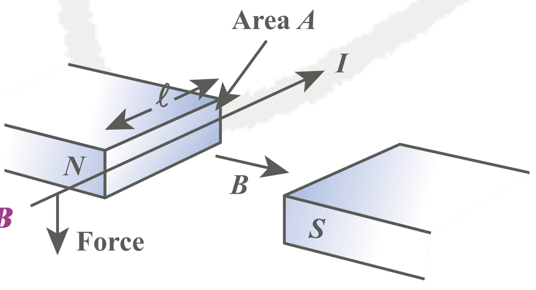
MAGNETIC FIELDS

Magnetic Field Strength (B) tesla (T) *Vector* 1 tesla is the magnetic field strength that gives rise to a force of 1 N per metre of a wire carrying 1 amp.
Density of field lines in diagrams is proportional to field strength.

Forces in a magnetic field

1) on a wire length ℓ carrying current I
(assume all are perpendicular). $F = B\,I\,\ell$

2) on a charge q travelling with speed v
perpendicular to magnetic field: $F = Bqv$
Charge moves in arc of circle of radius $r = mv/qB$



Magnetic Flux (ϕ) weber (Wb)

Through an area A: $\phi = BA$ (field lines perpendicular to A).

Induced EMF in a magnetic field

For a coil with N turns, each with flux ϕ, $\mathcal{E} = -\,N\,d\phi/dt$

ENERGY TRANSFER BY WAVES

Transfer of energy without the transfer of matter

Transverse and Longitudinal $v = f\lambda$: v = velocity: f = frequency: λ = wavelength

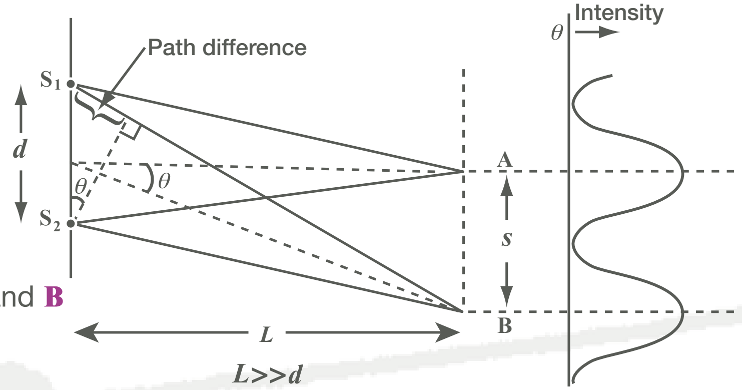
INTERFERENCE

Two-source

Assume that waves at S_1 and S_2 are a) Coherent b) In phase

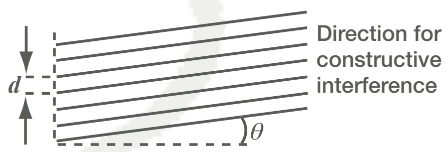
If Path Difference = $n\lambda$ then in phase at **A** and **B** so **Constructive Interference** at **A** and **B**

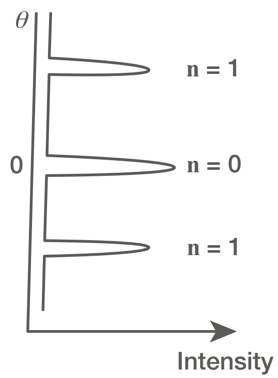
$\sin\theta = n\lambda/d$ $\quad \lambda/d = s/L$



Diffraction grating (multiple source)

Different wavelengths produce constructive interference at different angles $n\lambda = d\sin\theta$
Same formula as two source, but narrow distinct lines,
d usually small so θ large.

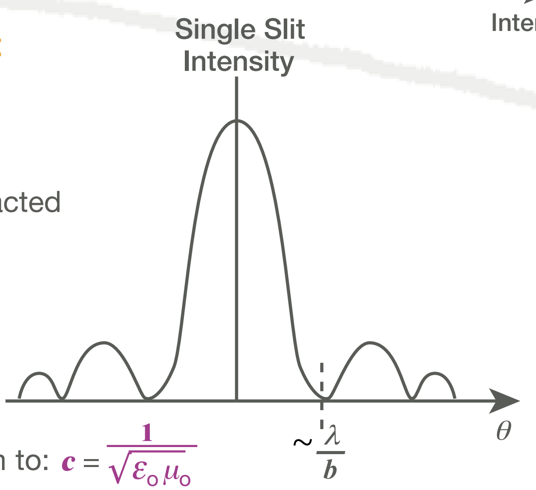




DIFFRACTION

Diffraction Pattern from Single Slit

Diffraction (i.e. spreading) results from interruption of part of the wave front.
Radiation wavelength λ. Slit width b.
Electrons and other particles can be diffracted to show their wave properties.



ELECTROMAGNETIC RADIATION

Speed

Interaction of electric and magnetic fields limits the speed of light in a vacuum to: $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$

Energy of a photon

$E = hf$ (h is the Planck constant)

RADIOACTIVITY

NUCLEAR STRUCTURE

Atomic (proton) number Z = number of protons (and electrons) in the atom (determines the chemical properties)

Mass (nucleon) number A = number of protons plus number of neutrons

The strong nuclear force holds together all the nucleons.

(Number of neutrons (n) approximately the same as the number of protons (p)).

Isotopes

Atoms with same atomic number (and so chemically similar) but different atomic mass number

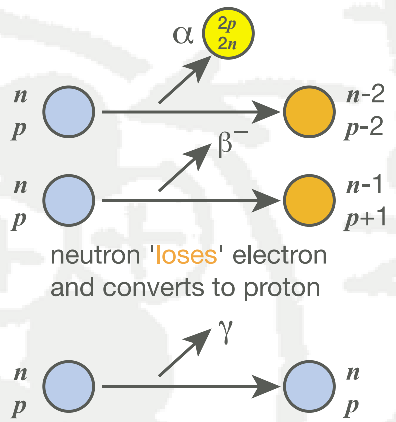
NUCLEAR DECAY

Alpha emission

(Helium nucleus: ${}^{4}_{2}\mathrm{He}$, $2p + 2n$)

Beta minus emission

High-energy electron (and antineutrino): emission by “weak interaction”



Gamma emission

Electromagnetic radiation (high frequency)

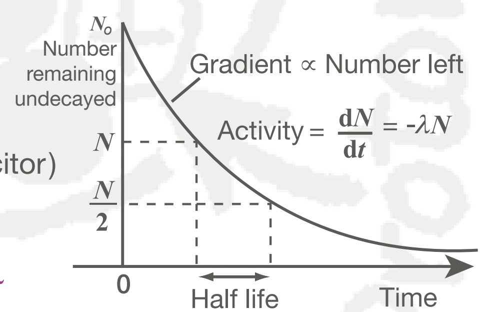
Decay Constant

λ = probability of decay in a fixed time

$= -\left(\frac{dN}{dt}\right)/N$

When some have decayed fewer remain so the rate of decay falls.

$N_t = N_0\, e^{-\lambda t}$ (*cf.* decay of charge on a capacitor)



Half-life ($T_{1/2}$)

Time for half to decay $T_{1/2} = \ln 2 / \lambda = 0.69 / \lambda$

Radiation Quantities and Units

Activity becquerel (**Bq**) is one disintegration per second
Absorbed dose gray (**Gy**) is the dose when 1 joule is absorbed by 1 kg of tissue
Dose equivalent sievert (**Sv**) is related to the biological harm caused by the absorbed dose. *

Binding energy

If nucleus is bound its mass will be less (Δm) than the sum of its parts.

Binding energy = $\Delta m\, c^2$

MISCELLANEOUS

IDEAL GASES

Pressure (P) pascal (Pa): **1 Pa** = 1 **newton** per square metre

$P = {}^{1}/_{3}\,\rho\,\overline{c^2}$ For 1 mole $PV_m = RT$

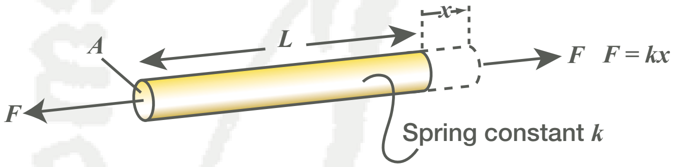
THERMAL EFFECTS

$\Delta Q = mc\Delta\theta$ Particles have energy of the order kT. T (kelvin) = $\theta\,^{\circ}$C + **273.15**

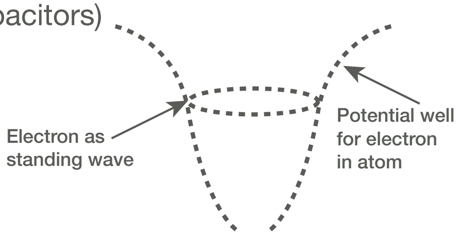
Boltzmann factor $n_1 / n_2 = e^{\left(\frac{-E}{kT}\right)}$

ELASTIC MATERIALS

Stress $\sigma = F/A$ (Pa) Strain $\varepsilon = x/L$ (no unit) The Young Modulus (E) = σ / ε (Pa)

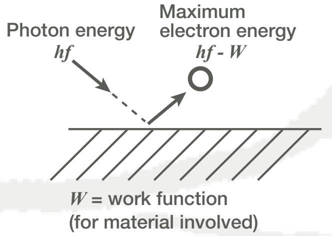


Elastic Strain Energy = ${}^{1}/_{2}\,k\,x^2$ (Compare with capacitors)



ATOMIC ENERGY AND LINE SPECTRA

Electrons in atoms regarded as matter waves
De Broglie wavelength for electrons $\lambda = h/mv$
Series of "*allowed*" energy levels and consequent characteristic spectrum

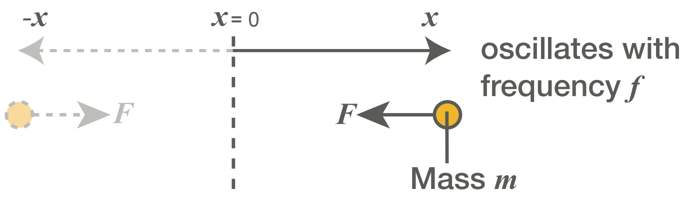


PHOTOELECTRIC EFFECT

Photons incident on a surface may cause electrons to be emitted. Energy of electron is determined by frequency of incident radiation and surface material

SIMPLE HARMONIC MOTION

Occurs when the force on an object is directed towards a point and its magnitude is proportional to the distance from a point. $F = -kx$



Acceleration = $-\omega^2 x = -\left({}^{k}/_{m}\right) x$ $T = {}^{2\pi}/_{\omega}$ $T = 2\pi\left({}^{m}/_{k}\right)^{1/2}$

Maximum velocity = ωA (A = **amplitude**). Displacement = $A\cos(\omega t + \phi)$

Energy of oscillation = ${}^{1}/_{2}\,kA^2 = {}^{1}/_{2}\,mv^2 + {}^{1}/_{2}\,kx^2$

MECHANICAL QUANTITIES

Mass (m) kilogram (kg) *Scalar*

The mass of an object is a measure of the difficulty of changing its velocity. *

1 kg is the mass of the international prototype of the kilogram stored in Paris.

Force (F) newton (N) *Vector*

An unbalanced force causes a mass to accelerate: $F = ma$
1 newton is the force required to accelerate **1 kg** at **1 m s^{-2}**
Weight of an object: is the gravitational force between it and the Earth
On the Earth's surface **1 kg** weighs approximately **10 N**

Energy (E) joule (J) *Scalar*

1 joule is the energy change when a force of 1 newton acts through 1 metre
gravitational potential energy change = weight x vertical distance moved = mgh
Kinetic energy = $\frac{1}{2} m v^2$

Power (P) watt (W) *Scalar*

Rate of transforming energy 1 watt = **1 J s^{-1}**

Momentum (p) mass x velocity. (kg ms^{-1}) or Ns *Vector*

Force = rate of change of momentum: Force x time (impulse) = momentum change

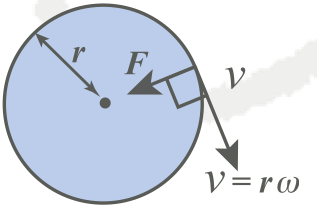
Equations of Motion $v = u + at$ $\quad v^2 - u^2 = 2as$ $\quad s = ut + \frac{1}{2} at^2$

CONSERVATION LAWS

Always apply providing the entire system is taken into account.
Energy is conserved, but can transform from one form to another.
Momentum is conserved

CIRCULAR MOTION

Assume speed is constant (but velocity changing)
ω = angular velocity (v/r) (radian/second)
T = period for 1 rotation $T = 2\pi/\omega$



Acceleration (toward centre) = $v^2/r = \omega^2 r$

Prefixes

10^{-24}	10^{-21}	10^{-18}	10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}
yocto	zepto	atto	femto	pico	nano	μ (micro)	milli

DATA

Acceleration of free fall (in UK) g	$= 9.81\ \mathrm{m\,s^{-2}}$
Gravitational field strength (in UK) g	$= 9.81\ \mathrm{N\,kg^{-1}}$
Gravitational constant G	$= 6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$
Electric force constant $k = 1 / 4\,\pi\,\varepsilon_o$	$= 8.98 \times 10^{9}\ \mathrm{N\,m^2\,C^{-2}}$
Speed of light in a vacuum c	$= 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
Permeability of free space μ_o	$= 4\pi \times 10^{-7}\ \mathrm{N\,A^{-2}}$
Permittivity of free space ε_o	$= 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
Planck constant h	$= 6.63 \times 10^{-34}\ \mathrm{J\,s}$
Elementary electron charge e	$= -1.60 \times 10^{-19}\ \mathrm{C}$
Electron rest mass m_e	$= 9.11 \times 10^{-31}\ \mathrm{kg}$
Electronvolt eV	$= 1.60 \times 10^{-19}\ \mathrm{J}$
Unified atomic mass constant u	$= 1.66 \times 10^{-27}\ \mathrm{kg}$
Proton rest mass m_p	$= 1.673 \times 10^{-27}\ \mathrm{kg}$
Neutron rest mass m_n	$= 1.675 \times 10^{-27}\ \mathrm{kg}$
Molar gas constant R	$= 8.31\ \mathrm{J.\,mol^{-1}K^{-1}}$
Boltzmann constant k	$= 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
Avogadro constant N_A	$= 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
Standard Temperature & Pressure (STP) is	$273.15\ \mathrm{K}$ and $1.01 \times 10^{5}\ \mathrm{Pa}$
Molar volume at STP V_m	$= 22.4 \times 10^{-3}\ \mathrm{m^3 mol^{-1}}$

Helpful Websites

- www.bubl.ac.uk/link ▸ A general source
- www.psigate.ac.uk ▸ Search information portal
- www.eevl.ac.uk ▸ Engineering (and some science) data
- www.npl.co.uk/thelearningroom ▸ National Physical Laboratory
- http://education.iop.org ▸ Institute of Physics site
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YOUR GUIDE TO PHYSICS ON THE INTERNET

Author’s Note

This is intended as a quick revision guide and not a definitive reference. While some of the equations are ‘correct’, they are not a true definition. Where this occurs this is indicated with an asterix (*). Bold is for emphasis and does not signify a vector.

10^{3}	10^{6}	10^{9}	10^{12}	10^{15}	10^{18}	10^{21}	10^{24}
kilo	**Mega**	**Giga**	**Tera**	**Peta**	**Exa**	**Zetta**	**Yotta**