

A-level Physics data and formulae

For use in exams from the June 2017 Series onwards

DATA - FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	С	3.00×10^{8}	m s ⁻¹
permeability of free space	$\mu^{}_0$	$4\pi\times10^{-7}$	$\mathrm{H}\;\mathrm{m}^{-1}$
permittivity of free space	$arepsilon_0$	8.85×10^{-12}	F m ⁻¹
magnitude of the charge of electron	e	1.60×10^{-19}	С
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$N m^2 kg^{-2}$
the Avogadro constant	$N_{\rm A}$	6.02×10^{23}	mol⁻¹
molar gas constant	R	8.31	$\rm J~K^{-1}~mol^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K ⁻¹
the Stefan constant	σ	5.67×10^{-8}	$W m^{-2} K^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to $5.5 \times 10^{-4} \mathrm{u}$)	$m_{ m e}$	9.11×10^{-31}	kg
electron charge/mass ratio	$rac{e}{m_{ m e}}$	1.76×10^{11}	$\rm C~kg^{-1}$
proton rest mass (equivalent to 1.00728 u)	$m_{ m p}$	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$rac{e}{m_{ m p}}$	9.58×10^7	$\mathrm{C}\mathrm{kg}^{-1}$
neutron rest mass (equivalent to 1.00867 u)	$m_{ m n}$	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	${ m N~kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m}\;\mathrm{s}^{-2}$
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

ALGEBRAIC EQUATION

quadratic equation $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

ASTRONOMICAL DATA

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^{8}
Earth	5.97×10^{24}	6.37×10^6

GEOMETRICAL EQUATIONS

arc length	$= r\theta$
circumference of circle	$=2\pi r$
area of circle	$=\pi r^2$
curved surface area of cylinder	$=2\pi rh$
area of sphere	$=4\pi r^2$
volume of sphere	$=\frac{4}{3}\pi r^3$

Version 1.5



Particle Physics

Class	Name	Symbol	Rest energy/MeV
photon	photon	γ	0
lepton	neutrino	$v_{ m e}$	0
		v_{μ}	0
	electron	e^{\pm}	0.510999
	muon	μ^{\pm}	105.659
mesons	π meson	π^{\pm}	139.576
		π^0	134.972
	K meson	K [±]	493.821
		K ⁰	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
S	$-\frac{1}{3}e$	$+\frac{1}{3}$	- 1

Properties of Leptons

		Lepton number
Particles:	e^- , v_e ; μ^- , v_μ	+ 1
Antiparticles:	$e^+,\overline{\nu_e},\mu^+,\overline{\nu_\mu}$	- 1

Photons and energy levels

$$E = hf = \frac{hc}{\lambda}$$

$$photoelectricity \qquad hf = \phi + E_{k \, (max)}$$

$$energy \ levels \qquad hf = E_1 - E_2$$

$$de \ Broglie \ wavelength \qquad \lambda = \frac{h}{p} = \frac{h}{mv}$$

Waves

wave speed
$$c = f\lambda$$
 period $f = \frac{1}{T}$

first harmonic $f = \frac{1}{2l} \sqrt{\frac{T}{\mu}}$

fringe spacing $w = \frac{\lambda D}{s}$ diffraction grating $d \sin \theta = n\lambda$

refractive index of a substance s, $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 and n_2 , law of refraction $n_1 \sin \theta_1 = n_2 \sin \theta_2$ critical angle $\sin \theta_c = \frac{n_2}{n_1} \text{for } n_1 > n_2$

Mechanics

moments	moment = Fd	
velocity and acceleration	$v = \frac{\Delta s}{\Delta t}$	$a = \frac{\Delta v}{\Delta t}$
equations of motion	v = u + at	$s = \left(\frac{u+v}{2}\right) t$
	$v^2 = u^2 + 2as$	$s = ut + \frac{at^2}{2}$
force	F = ma	
force	$F = \frac{\Delta(mv)}{\Delta t}$	
impulse	$F \Delta t = \Delta(mv)$	
work, energy and power	$W = F s \cos \theta$ $E_{k} = \frac{1}{2} m v^{2}$	$\Delta E_{\mathrm{p}} = mg\Delta h$
	$P = \frac{\Delta W}{\Delta t}, P = Fv$	
	$efficiency = \frac{usef}{i}$	ul output power

Materials

density
$$\rho = \frac{m}{v}$$
 Hooke's law $F = k \Delta L$

Young modulus = $\frac{tensile\ stress}{tensile\ strain}$ tensile\ stress = $\frac{F}{A}$

tensile\ strain = $\frac{\Delta L}{L}$

energy stored $E = \frac{1}{2}F\Delta L$

input power

Electricity

$$current \ and \ pd \qquad \qquad I \ = \frac{\Delta Q}{\Delta t} \qquad V \ = \frac{W}{Q} \qquad R \ = \frac{V}{I}$$

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

resistors in series
$$R_T = R_1 + R_2 + R_3 + ...$$

resistors in parallel
$$\frac{1}{R_{\rm T}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

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

$$\varepsilon = \frac{E}{Q} \qquad \qquad \varepsilon = I(R + r)$$

Circular motion

magnitude of angular speed
$$\omega = \frac{v}{r}$$

$$\omega = 2\pi f$$

centripetal acceleration
$$a = \frac{v^2}{r} = \omega^2 r$$

centripetal force
$$F = \frac{mv^2}{r} = m\omega^2 r$$

Simple harmonic motion

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

displacement
$$x = A \cos(\omega t)$$

speed
$$v = \pm \omega \sqrt{(A^2 - x^2)}$$

maximum speed
$$v_{\text{max}} = \omega A$$

maximum acceleration
$$a_{\text{max}} = \omega^2 A$$

for a mass-spring system $T = 2\pi \sqrt{\frac{m}{k}}$

for a simple pendulum
$$T = 2\pi \int_{-\pi}^{\pi} \frac{l}{g}$$

Thermal physics

energy to change
$$Q = mc\Delta\theta$$

energy to change
$$Q = ml$$

$$gas\ law \qquad \qquad pV \ = \ nRT$$

$$pV = NkT$$
$$pV = NkT$$

kinetic theory model
$$pV = \frac{1}{3}Nm (c_{rms})^2$$

kinetic energy of gas
$$\frac{1}{2}m(c_{\text{rms}})^2 = \frac{3}{2}kT = \frac{3RT}{2N_{\Delta}}$$

Gravitational fields

force between two masses
$$F = \frac{Gm_1m_2}{r^2}$$

gravitational field strength
$$g = \frac{F}{m}$$

magnitude of gravitational field strength in a radial field
$$g = \frac{GM}{r^2}$$

work done
$$\Delta W = m\Delta V$$

gravitational potential
$$V = -\frac{GM}{r}$$

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

Electric fields and capacitors

force between two point charges
$$F = \frac{1}{4\pi\varepsilon_0} \frac{Q_1 Q_2}{r^2}$$

force on a charge
$$F = EQ$$

field strength for a uniform field
$$E = \frac{V}{d}$$

work done
$$\Delta W = Q\Delta V$$

field strength for a
$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$$

electric potential
$$V = \frac{1}{4\pi\varepsilon_0} \frac{Q}{r}$$

field strength
$$E = \frac{\Delta V}{\Delta r}$$

capacitance
$$C = \frac{Q}{V}$$

$$C = \frac{A\varepsilon_0\varepsilon_r}{d}$$

capacitor energy stored
$$E = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$$

capacitor charging
$$Q = Q_0(1 - e^{-\frac{t}{RC}})$$

decay of charge
$$Q = Q_0 e^{-\frac{t}{RC}}$$



Magnetic fields

force on a current F = BIIforce on a moving charge F = BQv

magnetic flux $\Phi = BA$

magnetic flux linkage $N\Phi = BAN \cos \theta$

magnitude of induced emf $\varepsilon = N \frac{\Delta \Phi}{\Delta t}$

 $N\Phi = BAN\cos\theta$

emf induced in a rotating coil $\varepsilon = BAN\omega \sin \omega t$

alternating current $I_{\rm rms} = \frac{I_0}{\sqrt{2}}$ $V_{\rm rms} = \frac{V_0}{\sqrt{2}}$

transformer equations $\frac{N_{\rm S}}{N_{\rm D}} = \frac{V_{\rm S}}{V_{\rm D}}$

 $efficiency = \frac{I_{s}V_{s}}{I_{p}V_{p}}$

Nuclear physics

inverse square law for γ radiation $I = \frac{k}{\chi^2}$

radioactive decay $\frac{\Delta N}{\Delta t} = -\lambda N, N = N_0 e^{-\lambda t}$

activity $A = \lambda N$

half-life $T_{1/2} = \frac{\ln 2}{\lambda}$

nuclear radius $R = R_0 A^{1/3}$

energy-mass equation $E = mc^2$

OPTIONS

Astrophysics

1 astronomical unit = $1.50 \times 10^{11} \, \mathrm{m}$

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

1 parsec = $2.06 \times 10^5 \text{ AU} = 3.08 \times 10^{16} \text{ m}$

= 3.26 ly

Hubble constant, $H = 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$

 $M = \frac{angle \ subtended \ by \ image \ at \ eye}{angle \ subtended \ by \ object \ at \ unaided \ eye}$

telescope in normal $M = \frac{f_0}{f_e}$

Rayleigh criterion $\theta \approx \frac{\lambda}{D}$

magnitude equation $m - M = 5 \log \frac{d}{10}$

Wien's law $\lambda_{\text{max}} T = 2.9 \times 10^{-3} \text{ m K}$

Stefan's law $P = \sigma A T^4$

Schwarzschild radius $R_{\rm s} \approx \frac{2GM}{c^2}$

Doppler shift for $v \ll c$ $\frac{\Delta f}{f} = -\frac{\Delta \lambda}{\lambda} = \frac{v}{c}$

red shift $z = -\frac{v}{c}$

Hubble's law v = Hd

Medical physics

lens equations $P = \frac{1}{f}$

 $m = \frac{v}{u}$

 $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

threshold of hearing $I_0 = 1.0 \times 10^{-12} \, \mathrm{W \, m^{-2}}$

intensity level intensity level = $10 \log \frac{I}{I_0}$

absorption $I = I_0 e^{-\mu x}$

 $\mu_{\rm m} = \frac{\mu}{\rho}$

ultrasound imaging Z = p c

 $\frac{I_{\rm r}}{I_{\rm i}} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1}\right)^2$

half-lives $\frac{1}{T_{\rm E}} = \frac{1}{T_{\rm R}} + \frac{1}{T_{\rm P}}$

Engineering physics

 $I = \Sigma mr^2$ moment of inertia

 $E_k = \frac{1}{2}I\omega^2$ angular kinetic energy

equations of angular motion

 $\omega_2 = \omega_1 + \alpha t$

 $\omega_2^2 = \omega_1^2 + 2\alpha\theta$

 $\theta = \omega_1 t + \frac{\alpha t^2}{2}$

 $\theta = \frac{(\omega_1 + \omega_2) t}{2}$

 $T = I \alpha$ torque

T = F r

angular momentum angular momentum = $I\omega$

angular impulse $T\Delta t = \Delta(I\omega)$

work done $W = T\theta$

 $P = T\omega$ power

 $O = \Delta U + W$ thermodynamics

 $W = p\Delta V$

adiabatic change $pV^{\gamma} = constant$

isothermal change pV = constant

heat engines

efficiency = $\frac{W}{Q_{\rm H}} = \frac{Q_{\rm H} - Q_{\rm C}}{Q_{\rm H}}$

 $\begin{array}{cc} \textit{maximum theoretical} & \underline{T_{\rm H} - T_{\rm C}} \\ \textit{efficiency} = & \overline{T_{\rm H}} \end{array}$

work done per cycle = area of loop

 $input power = calorific value \times fuel flow rate$

 $indicated\ power = (area\ of\ p - V\ loop)$

× (number of cycles per second)

 \times (number of cylinders)

output or brake power $P = T\omega$

friction power = indicated power - brake power

heat pumps and refrigerators

refrigerator: $COP_{ref} = \frac{Q_C}{W} = \frac{Q_C}{Q_V - Q_C}$

heat pump: $COP_{hp} = \frac{Q_H}{W} = \frac{Q_H}{Q_{HP} - Q_C}$

Turning points in physics

 $F = \frac{eV}{d}$ electrons in fields

F = Bev

 $r = \frac{mv}{Ro}$

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

Millikan's experiment

 $\frac{QV}{d} = mg$

 $F = 6\pi nrv$

 $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ Maxwell's formula

 $\lambda = \frac{h}{n} = \frac{h}{\sqrt{2meV}}$

special relativity

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

 $l = l_0 \sqrt{1 - \frac{v^2}{c^2}}$

 $E = m c^2 = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$

Electronics

resonant frequency

 $f_0 = \frac{1}{2\pi \sqrt{IC}}$

O-factor

 $Q = \frac{f_0}{f_-}$

operational amplifiers:

open loop

 $V_{\rm out} = A_{\rm OL}(V_+ - V_-)$

inverting amplifier

 $\frac{V_{\text{out}}}{V_{\text{in}}} = -\frac{R_{\text{f}}}{R_{\text{in}}}$

non-inverting amplifier

 $\frac{V_{\text{out}}}{V_{\text{in}}} = 1 + \frac{R_{\text{f}}}{R_{\text{l}}}$

summing amplifier

 $V_{\text{out}} = -R_{\text{f}} \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_2} + \cdots \right)$

difference amplifier

 $V_{\text{out}} = (V_+ - V_-) \frac{R_{\text{f}}}{R_{\text{out}}}$

Bandwidth requirement:

for AM

 $bandwidth = 2f_{M}$

for FM

 $bandwidth = 2(\Delta f + f_{M})$



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