

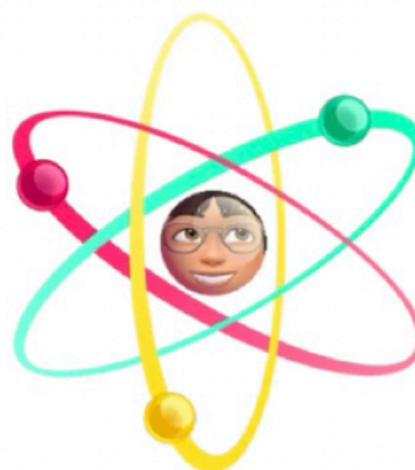
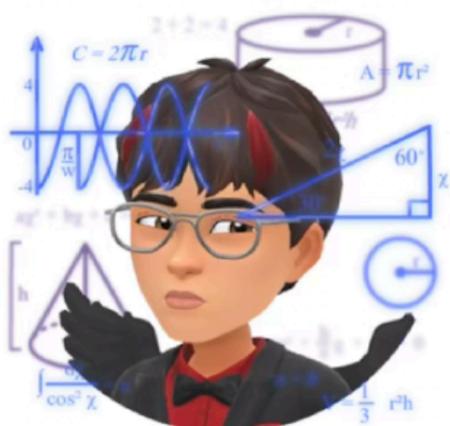
Chemistry & Physics

Rio Holmes

7405 / 7408

Version 4.2

Data Book



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The Periodic Table of the Elements

1		2												3	4	5	6	7	0
S-Block				D-Block										P-Block					(18)
(1)	(2)	Key										(13)	(14)	(15)	(16)	(17)	(18)		
6.9 Li lithium 3	9.0 Be beryllium 4	relative atomic mass symbol name atomic (proton) number										10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10		
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18		
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36		
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	96.0 Mo molybdenum 42	[97] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54		
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86		
[223] Fr francium 87	[226] Ra radium 88	[227] Ac† actinium 89	[267] Rf rutherfordium 104	[270] Db dubnium 105	[269] Sg seaborgium 106	[270] Bh bohrium 107	[270] Hs hassium 108	[278] Mt meitnerium 109	[281] Ds darmstadtium 110	[281] Rg roentgenium 111	[285] Cn copernicium 112	[286] Nh nihonium 113	[289] Fl flerovium 114	[289] Mc moscovium 115	[293] Lv livermorium 116	[294] Ts tennessine 117	[294] Og oganesson 118		

* 58 – 71 Lanthanides

† 90 – 103 Actinides

140.1 Ce cerium 58	140.9 Pr praseodymium 59	144.2 Nd neodymium 60	[145] Pm promethium 61	150.4 Sm samarium 62	152.0 Eu europium 63	157.3 Gd gadolinium 64	158.9 Tb terbium 65	162.5 Dy dysprosium 66	164.9 Ho holmium 67	167.3 Er erbium 68	168.9 Tm thulium 69	173.0 Yb ytterbium 70	175.0 Lu lutetium 71
232.0 Th thorium 90	231.0 Pa protactinium 91	238.0 U uranium 92	[237] Np neptunium 93	[244] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[247] Bk berkelium 97	[251] Cf californium 98	[252] Es einsteinium 99	[257] Fm fermium 100	[258] Md mendelevium 101	[259] No nobelium 102	[262] Lr lawrencium 103

F-Block

Data Sheet

Table A

Infrared absorption data

Bond	Wavenumber /cm ⁻¹
N-H (amines)	3300-3500
O-H (alcohols)	3230-3550
C-H	2850-3300
O-H (acids)	2500-3000
C≡N	2220-2260
C=O	1680-1750
C=C	1620-1680
C-O	1000-1300
C-C	750-1100

Table B

¹H NMR chemical shift data

Type of proton	δ/ppm
ROH	0.5-5.0
RCH ₃	0.7-1.2
RNH ₂	1.0-4.5
R ₂ CH ₂	1.2-1.4
R ₃ CH	1.4-1.6
	2.1-2.6
	3.1-3.9
RCH ₂ Cl or Br	3.1-4.2
	3.7-4.1
	4.5-6.0
	9.0-10.0
	10.0-12.0

Handwritten notes:
 - "basically anywhere" and "very shielded" with arrows pointing to the 0.5-5.0 ppm range.
 - "deshielded due to C=O" with an arrow pointing to the 2.1-2.6 ppm range.
 - "electrons pulled away from H" with an arrow pointing to the 3.1-3.9 ppm range.

Table C

¹³C NMR chemical shift data

Type of carbon	δ/ppm
	5-40
	10-70
	20-50
	25-60
	alcohols, ethers or esters 50-90
	90-150
R-C≡N	110-125
	110-160
	esters or acids 160-185
	aldehydes or ketones 190-220

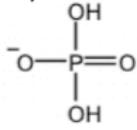
$$q = mc\Delta t$$

$$m = \frac{2K_e t^2}{d^2}$$

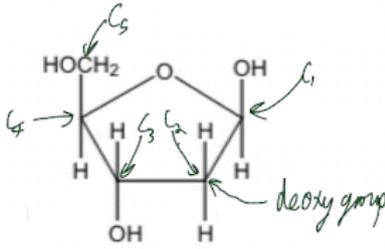
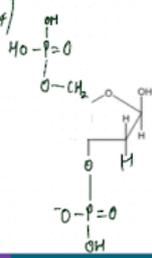
Note: Reordered on this sheet.

Phosphate and sugars

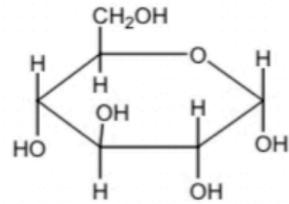
PO_4^{3-} ion (coming from H_3PO_4)



phosphate



2-deoxyribose

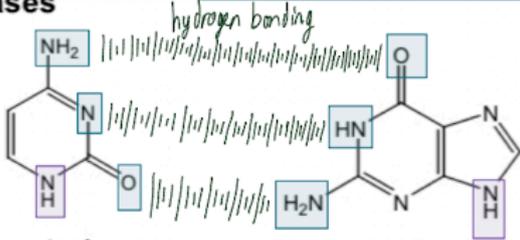


glucose

Bonding to	Hydrogen bonding with base partner
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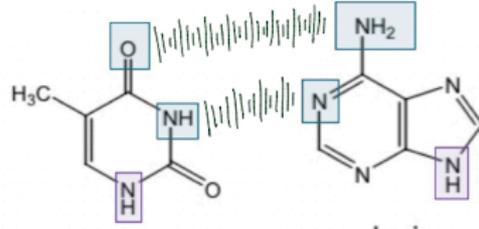


Bases



cytosine

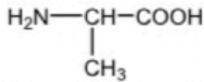
guanine



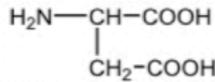
thymine

adenine

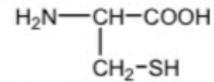
Amino acids



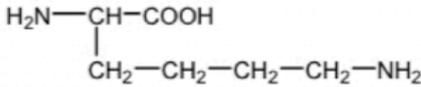
alanine



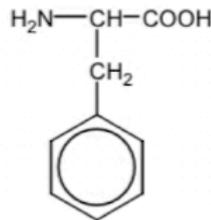
aspartic acid



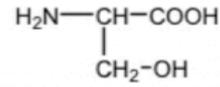
cysteine



lysine

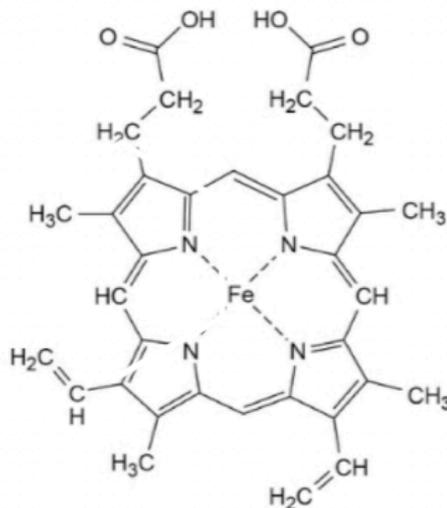


phenylalanine



serine

Haem B



Thermodynamics

$$\Delta G = \Delta H - T\Delta S$$

$$K = A e^{-\frac{E_a}{RT}}$$

rate constant = Arrhenius $\frac{\text{Action}}{3.3}$

DATA - FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^8	m s^{-1}
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	C kg^{-1}
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^7	C kg^{-1}
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	m 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 = πr^2

curved surface area of cylinder = $2\pi r h$

area of sphere = $4\pi r^2$

volume of sphere = $\frac{4}{3}\pi r^3$

Particle Physics

Class	Name	Symbol	Rest energy/MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	e^\pm	0.510999
		μ^\pm	105.659
		π^\pm	139.576
mesons	π meson	π^0	134.972
		K^\pm	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: $e^-, \nu_e; \mu^-, \nu_\mu$	+1
Antiparticles: $e^+, \bar{\nu}_e, \mu^+, \bar{\nu}_\mu$	-1

Photons and energy levels

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

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

energy levels $hf = E_1 - E_2$

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

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 $\sin \theta_c = \frac{n_2}{n_1}$ 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 $W = F s \cos \theta$

$E_k = \frac{1}{2} m v^2$ $\Delta E_p = mg\Delta h$

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

efficiency = $\frac{\text{useful output power}}{\text{input power}}$

Materials

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

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

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

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

Electricity

current and pd	$I = \frac{\Delta Q}{\Delta t}$	$V = \frac{W}{Q}$	$R = \frac{V}{I}$
resistivity	$\rho = \frac{RA}{L}$		
resistors in series	$R_T = R_1 + R_2 + R_3 + \dots$		
resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$		
power	$P = VI = I^2R = \frac{V^2}{R}$		
emf	$\varepsilon = \frac{E}{Q}$	$\varepsilon = I(R + r)$	

Gravitational fields

$E = -\frac{GMm}{r^2}$

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

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

Circular motion - DO NOT USE SUVAT

$f = \frac{1}{T}$ magnitude of angular speed

angular velocity $\omega = \frac{v}{r}$ linear velocity

for frictionless banks $\tan\theta = \frac{v^2}{gr}$

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 $a = -\omega^2 x$ a.k.a. $a \propto -x$ displacement

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

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

maximum speed $v_{max} = \omega A$ maximum displacement amplitude

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

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

for a simple pendulum $T = 2\pi \sqrt{\frac{l}{g}}$

Thermal physics

energy to change temperature	$Q = mc\Delta\theta$
energy to change state	$Q = ml$
gas law	$pV = NkT$
kinetic theory model	$pV = \frac{1}{3}Nm(c_{rms})^2$
kinetic energy of gas molecule	$\frac{1}{2}m(c_{rms})^2 = \frac{3}{2}kT = \frac{3RT}{2N_A}$

Since $k = \frac{R}{N_A}$ linked $pV = NkT$

moles $n = \frac{N}{N_A}$ no. particles

Maxwell-Boltzmann Constant in JK^{-1}

$\frac{R \text{ in } JK^{-1}mol^{-1}}{N_A \text{ (particles)}mol^{-1}} = JK^{-1}$

$n = \frac{N}{N_A}$ no. particles Av. com.

Amount of substance / mol $n = 24dm^3 = 24L$

$m(C-12 \text{ atom}) = \frac{0.012}{(6.022 \times 10^{23})} = 1.99 \times 10^{-26}$

$c_{rms} = \left(\frac{v_x^2 + v_y^2 + v_z^2}{3}\right)^{0.5}$ at RTP, rms of air particles: $\approx 300 ms^{-1}$

Electric fields and capacitors

force between two point charges	$F = \frac{1}{4\pi\epsilon_0} \frac{Q_1Q_2}{r^2}$
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 radial field	$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$
electric potential	$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$
field strength	$E = \frac{\Delta V}{\Delta r}$
capacitance	$C = \frac{Q}{V}$
	$C = \frac{A\epsilon_0\epsilon_r}{d}$
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	$Q = Q_0e^{-\frac{t}{RC}}$
time constant	RC



Magnetic fields

force on a current	$F = BIl$
force on a moving charge	$F = BQv$
magnetic flux	$\Phi = BA$
magnetic flux linkage	$N\Phi = BAN \cos \theta$
magnitude of induced emf	$\epsilon = N \frac{\Delta\Phi}{\Delta t}$
emf induced in a rotating coil	$\epsilon = BAN\omega \sin \omega t$
alternating current	$I_{rms} = \frac{I_0}{\sqrt{2}} \quad V_{rms} = \frac{V_0}{\sqrt{2}}$
transformer equations	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$
	efficiency = $\frac{I_s V_s}{I_p V_p}$

Nuclear physics

inverse square law for γ radiation	$I = \frac{k}{x^2}$
radioactive decay	$\frac{\Delta N}{\Delta t} = -\lambda N, N = N_0 e^{-\lambda t}$
activity	$A = \lambda N$ <i>See below</i>
half-life	$T_{1/2} = \frac{\ln 2}{\lambda}$
nuclear radius	$R = R_0 A^{1/3}$
energy-mass equation	$E = mc^2$

activity of radioactive sample / Becquerels, Bq
OR Nucleus decays/second
cannot be measured experimentally / can be calculated.

$A = \lambda N$
Arbitrary no. of atoms
Directly proportional to C.R.
Statistically
Probability of a radioactive (unstable) nuclei decaying in a 1 second interval.
e.g. $\lambda = 0.2$ = There is 20% of a nucleus decaying each second OR 20% of nuclei will decay/s⁻¹
(average number of decays per unstable nucleus/second)

amount of substance / moles
 $n = \frac{N}{N_A}$
 $n = \frac{m}{M_r} \text{ mol} = \frac{\text{mass}}{M_r}$

Ave. = 6.02×10^{23}

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

OPTIONS

Astrophysics

1 astronomical unit	$= 1.50 \times 10^{11} \text{ m}$
1 light year	$= 9.46 \times 10^{15} \text{ m}$
1 parsec	$= 2.06 \times 10^5 \text{ AU} = 3.08 \times 10^{16} \text{ m} = 3.26 \text{ ly}$
Hubble constant, H	$= 65 \text{ km s}^{-1} \text{ Mpc}^{-1}$
$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$	
telescope in normal adjustment	$M = \frac{f_o}{f_e}$
Rayleigh criterion	$\theta \approx \frac{\lambda}{D}$
magnitude equation	$m - M = 5 \log \frac{d}{10}$
Wien's law	$\lambda_{max} T = 2.9 \times 10^{-3} \text{ m K}$
Stefan's law	$P = \sigma AT^4$
Schwarzschild radius	$R_s \approx \frac{2GM}{c^2}$
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	$P = \frac{1}{f}$ $m = \frac{v}{u}$ $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
intensity level	$I_0 = 1.0 \times 10^{-12} \text{ W m}^{-2}$ intensity level = $10 \log \frac{I}{I_0}$
absorption	$I = I_0 e^{-\mu x}$ $\mu_m = \frac{\mu}{\rho}$
ultrasound imaging	$Z = \rho c$ $\frac{I_r}{I_i} = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1} \right)^2$
half-lives	$\frac{1}{T_E} = \frac{1}{T_B} + \frac{1}{T_P}$

Engineering physics

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

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

equations of angular motion

$$\omega_2 = \omega_1 + \alpha t$$

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

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

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

torque

$$T = I\alpha$$

$$T = Fr$$

angular momentum

$$\text{angular momentum} = I\omega$$

angular impulse

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

work done

$$W = T\theta$$

power

$$P = T\omega$$

thermodynamics

$$Q = \Delta U + W$$

$$W = p\Delta V$$

adiabatic change

$$pV^\gamma = \text{constant}$$

isothermal change

$$pV = \text{constant}$$

heat engines

$$\text{efficiency} = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$$

$$\text{maximum theoretical efficiency} = \frac{T_H - T_C}{T_H}$$

work done per cycle = area of loop

input power = calorific value \times fuel flow rate

$$\text{indicated power} = (\text{area of } p - V \text{ loop}) \times (\text{number of cycles per second}) \times (\text{number of cylinders})$$

output or brake power $P = T\omega$

friction power = indicated power - brake power

heat pumps and refrigerators

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

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

Turning points in physics

electrons in fields

$$F = \frac{eV}{d}$$

$$F = Bev$$

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

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

Millikan's experiment

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

$$F = 6\pi\eta rv$$

Maxwell's formula

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

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

special relativity

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

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

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

Electronics

resonant frequency

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

Q-factor

$$Q = \frac{f_0}{f_B}$$

operational amplifiers:

open loop

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

inverting amplifier

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

non-inverting amplifier

$$\frac{V_{\text{out}}}{V_{\text{in}}} = 1 + \frac{R_f}{R_1}$$

summing amplifier

$$V_{\text{out}} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} + \dots \right)$$

difference amplifier

$$V_{\text{out}} = (V_+ - V_-) \frac{R_f}{R_1}$$

Bandwidth requirement:

for AM

$$\text{bandwidth} = 2f_M$$

for FM

$$\text{bandwidth} = 2(\Delta f + f_M)$$