

PCON — Complete 2018 CODATA Physical Constants for the HP 50g

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Description

PCON provides about 350 physical constants defined by the 2018 CODATA revision of suggested values ([1], [2]). Unlike the 50g built-in constants library, PCON includes all CODATA constants with the best current numerical values.

The constants are retrieved through a simple menu interface, designed to return a single constant with as few keystrokes as possible. The constants are identified with tag labels, and PCON observes system flag 61 to return a unit object.

When PCON is started, the following main menu is shown.

Common Constants	Frequently-used constants. Can be customized.
Universal Constants	Speed of light, Newton's gravitational constant, etc.
Atomic, Nuclear	General; specific particle (electron, neutron, etc.) constants
Electromagnetic	General; magnetons; conventional electrical units.
Physiochemical	Gas, molar, radiation, and atomic mass constants.
X-ray	Angstrom(*), x-units, lattice parameters.
Atomic Unit	Atomic units of mass, energy, length, time, etc.
Natural Units	Natural units of action, energy, length, mass, etc.
Energy Equivalents	Energy conversions for atomic mass, joule, hertz, etc.

Some menus have submenus but the menu depth is never more than four. Pressing **ENTER** or the soft menu key **OK** (**F6**) puts the selected constant

on the stack. If flag 61 is clear, the unit (if any) is attached to the numeric value, otherwise only the numeric value is returned. No constant is returned and PCON is exited if **[ON]** or the soft menu key **[CANCL] (F5)** is pressed.

Menu choices are displayed as description; tag where description is the description of the constant and tag is attached to the constant put on the stack. For example, the Newtonian gravitational constant is shown as Newtonian grav; G.

PCON is distributed as library CODATA with ROM ID 1005 and requires the ListExt library, which speeds up menu response with the large list of constants. The library requires about 31 kB of memory in the installed port. System flag 90 should be *set* so menu items are displayed with the mini font and the complete menu descriptions are shown.

It is likely than PCON has errors, although substantial checking was done. Values were copied and pasted where possible, but some numeric values required manual editing and all of the units were manually entered.

Abbreviations

Where possible, PCON uses the conventional CODATA symbols for constants. The 50g character set is missing some necessary symbols, so I substitute approximations, for example, h^- for \hbar .

Conventional CODATA Constant Symbols











α	fine-structure constant	c_2	2nd radiation constant
α^{-1}	inverse fine-structure constant	C_{1L}	1st radiation constant, spectral
γ_x	gyromagnetic ratio of x	e	elementary charge
γ'_x	gyromagnetic ratio of shielded x	E_h	Hartree energy
ϵ_0	vacuum electric permittivity	F	Faraday constant
λ_C	Compton wavelength	g_n	standard gravity acceleration
$\lambda-C$	Compton wavelength, reduced	g_x	g-factor of x
μ_0	vacuum magnetic permeability	G	Newtonian gravitation constant
μ_B	Bohr magneton	h	Planck constant
μ_N	nuclear magneton	\hbar	Planck constant, reduced
μ_x	Magnetron of particle x	k	Boltzmann constant
μ'_x	Magnetron of shielded x	K_J	Josephson constant
σ	Stefan-Boltzmann constant	K_{CD}	luminous efficacy
σ_e	Thomson cross section	m_e	electron mass
Φ_0	magnetic flux quantum	m_u	atomic mass constant
a	silicon lattice parameter	n_0	Loschmidt constant
a_0	Bohr radius	N_A	Avogadro constant
a_x	magnetic moment anomaly of x	r_e	classical electron radius
$A_r(x)$	Relative atomic mass of x	R	molar gas constant
\AA^*	Angstrom-star	R_L	von Klitzing constant
b	Wein displacement law constant	R_∞	Rydberg constant
b'	Wein frequency disp. law constant	S_0/R	Sackur-Tetrode constant
c	speed of light in vacuum	u	unified atomic mass unit
c_1	1st radiation constant	V_m	molar volume of ideal gas

PCON Symbols and Abbreviations

e	electron	gyrom	gyromagnetic
p	proton	imp	impedance
n	neutron	m	mass
α	alpha particle	M	molar
d	deuteron	mx	mass of x
h	helion	mag	magnetic
μ	muon	meq	mass energy equivalent
τ	tau particle	mgtn	magneton
t	triton	mmt	magnetic moment
\$	shielded, shielding	mnt	moment
/	ratio; quotient	Mo	molybdenum
x_s	x_s	nuq	natural unit of q
λ	wavelength	nuc	nuclear
λC	Compton wavelength	permeab	permeability
au	atomic unit	permitt	permittivity
char	characteristic	pol	polarizability
circ	circulation	qpole	quadropole
cons	constant	rad	radiation
Cu	copper	red	reduced
den	density	rel	relative
Eh	Hartree energy	Si	silicon
Ex	energy of x	spect	spectral
elec	electric	Std	standard
elem	elementary	u	atomic mass unit
eqv	equivalent	unif	unified
freq	frequency	vac	vacuum
grad	gradient	vol	volume
grav	gravity		

CHOOSE Menu Shortcuts

PCON uses the built-in CHOOSE command for its menus, so keystrokes and time can be saved with some keyboard short-cuts:

		Select the first menu item
		Select the last menu item
		Select the first menu item currently displayed
		Select the last menu item currently displayed
		Select the next item which starts with letter or number x

Common Constants Menu

The Common Constants menu is a collection of more frequently-used constants. Of course, one person's 'frequently used' is another person's 'never used', so the selection is a matter of personal choice. The constants in this menu can be selected by modifying the list of CONS indices in the menuC program. The table below shows the constants in the menu by default.

Common Constants

Symbol	Full Description	Menu Description
c	speed of light in vacuum	speed of light; c
G	Newtonian constant of gravitation	Newtonian grav; G
e	elementary charge	elem charge; e
α	fine structure constant	fine structure; α
α^{-1}	inverse fine structure constant	1/fine structure; α^{-1}
N_A	Avogadro constant	Avogadro; N_A
F	Faraday constant	Faraday; F
k	Boltzmann constant	Boltzmann, J/K; k
h	Planck constant	Planck, J/Hz; h
\hbar	reduced Planck constant ($h/2\pi$)	Planck reduced; \hbar
Z_0	characteristic impedance of vacuum	vacuum char imp; Z0
ϵ_0	vacuum electric permittivity	vac elec permitt; ϵ_0
μ_0	vacuum magnetic permeability	vac mag permeab; μ_0
R	molar gas constant	molar gas constant; R
m_u	atomic mass constant	atomic mass const; mu
g_n	standard acceleration of (earth) gravity	std gravity accel; gn
atm	standard atmosphere	std atmosphere; atm
ssp	standard-state pressure	std-state press.; ssp

Program menuC defines the entries in the Common Constants menu. The integers in the list are the indices into the CONS list of constants objects.

```
« "Common constants"
{318 252 120 124 157 43 122 50 259 292 54 348 349 194 10 319 320 321} cmenu »
```

Suppose we would rather have a menu of the masses of the nine atomic particles, in the order proton, neutron, electron, alpha particle, deuteron, helion, muon, tau, and triton. The default menuC list would be replaced with {276 237 95 2 74 141 209 326 339} to accomplish this. The library must be rebuilt after this edit, which can be accomplished with the provided makelib program (p18).

Universal Constants Menu

Symbol	Full Description	Menu Description
c	speed of light in vacuum	speed of light; c
G	Newtonian constant of gravitation	Newtonian grav; G
$G/h \cdot c$	G over reduced Planck constant $\times c$	$G/(\hbar \cdot c)$; Ghc
Z_0	characteristic impedance of vacuum	vac char imp; Z0
ϵ_0	vacuum electric permittivity	vac elec perm; ϵ_0
μ_0	vacuum magnetic permeability	vac mag perm; μ_0
h	Planck constant	Planck, J/Hz; h
h	Planck constant, eV/Hz	Planck, h
\hbar	reduced Planck constant ($h/2\pi$)	Planck reduced; \hbar
\hbar	reduced Planck constant, eV·s	Planck red, eVs; \hbar
$\hbar \cdot c$	reduced Planck constant $\times c$, MeV·fm	$\hbar \cdot c$
l_P	Planck length	Planck length; l_P
m_P	Planck mass	Planck mass; m_P
t_P	Planck time	Planck time; t_P
T_P	Planck temperature	Planck temp; T_P
$m_P c^2$	Planck mass energy equivalent, GeV	Planck meq, GeV; EmP

Atomic, Nuclear Constants Menus

These menus group the constants specific to particular atomic and nuclear particles. The constants include mass, mass energies, mass ratios, magnetic moment ratios, and others. The particle submenus are:

Electron	Proton	Neutron
Alpha	Deuteron	Helion
Muon	Tau	Triton

A complete list of the constants in these menus can be found starting on p12.

Atomic, Nuclear: General		
Symbol	Full Description	Menu Description
u	unified atomic mass unit	atomic mass unit; u
α	fine structure constant	Fine structure; α
α^{-1}	inverse fine structure constant	1/fine structure; α^{-1}
a_0	Bohr radius	Bohr radius; a0
$G_F/(\hbar c)^3$	Fermi coupling constant	Fermi coupling; GF0
E_h	Hartree energy	Hartree, J; Eh
R_∞	Rydberg constant	Rydberg; R ∞
$R_\infty \cdot c$	Rydberg constant $\times c$	Rydberg-c; R ∞ c
$R_\infty \cdot h \cdot c$	Rydberg constant $\times h \times c$	Rydberg-h-c, Hz; R ∞ hc
$\pi\hbar/m_e$	quantum of circulation	circ quantum; qc
$2\pi\hbar/m_e$	$2 \times$ quantum of circulation	2-circ quantum; 2qc
σ_{dp}	shielding difference of d and p in HD	d-p shielding HD; σ_{dp}
σ_{tp}	shielding difference of t and p in HT	t-p shielding HT; σ_{tp}
m_W/m_Z	W to Z mass ratio	W/Z mass; W/Z m
$\sin^2\theta_W$	Weak mixing angle	weak mixing angle; θ_W
$\Delta\nu_{Cs}$	hyperfine transition frequency of Cs-133	Cs133 freq; $\Delta\nu_{Cs}$

Electromagnetic Constants Menus

General		
Symbol	Full Description	Menu Description
e	elementary charge	elem charge; e
e/\hbar	elementary charge over \hbar	e/\hbar
K_J	Josephson constant	Josephson; K_J
R_K	von Klitzing constant	von Klitzing; RK
Φ_0	magnetic flux quantum	mag flux quantum; ϕ_0
G_0	conductance quantum	cond quantum; G0
$1/G_0$	conductance quantum inverse	1/cond quantum; G0 $^{-1}$

The Magneton menu collects constants related to the Bohr and nuclear magnetons. Magneton ratios which are specific to a particular particle are found in the menus of the Atomic, Nuclear menu.

Magneton		
Symbol	Full Description	Menu Description
μ_B	Bohr magneton, J/T	Bohr mgtn., J/T; μ_B
μ_B	Bohr magneton, eV/T	μ_B eV/T; μ_B
μ_B	Bohr magneton, Hz/T	μ_B/h Hz/T; μ_B
μ_B	Bohr magneton, 1/(m·T)	μ_B (m·T) ⁻¹ ; μ_B
μ_B	Bohr magneton, K/T	μ_B K/T; μ_B
μ_N	nuclear magneton, J/T	nuc mgtn, J/T; μ_N
μ_N	nuclear magneton, eV/T	nuc mgtn, eV/T; μ_N
μ_N	nuclear magneton, 1/(m·T)	nuc mgtn, 1/mT; μ_N
μ_N	nuclear magneton, K/T	nuc mgtn, K/T; μ_N
μ_N	nuclear magneton, MHz/T	nuc mgtn, MHz/T; μ_N

The Conventional menu contains electrical metrology units. In the 2018 adjustment the Josephson and von Klitzing constants are exact in SI units, so the conventional (1990) values can be calculated as exact values.

Conventional		
Symbol	Full Description	Menu Description
K_{J-90}	Josephson constant, conventional	Josephson-90; KJ90
R_{K-90}	von Klitzing constant, conventional	von Klitzing-90; RK90
C_{90}	1 coulomb, conventional	Coulomb-90; C90
V_{90}	1 volt, conventional	Volt-90; V90
A_{90}	1 ampere, conventional	Ampere-90; A90
Ω_{90}	1 ohm, conventional	Ohm-90; Ω 90
S_{90}	1 siemen, conventional	Siemen-90; S90
W_{90}	1 watt, conventional	Watt-90; W90
F_{90}	1 farad, conventional	Farad-90; F90
H_{90}	1 henry, conventional	Henry-90; H90
Wb_{90}	1 weber, conventional	Weber-90; Wb90
T_{90}	1 tesla, conventional	Tesla-90; T90

Physiochemical Constants Menus

General		
Symbol	Full Description	Menu Description
m_u	atomic mass constant	atomic mass const; mu
$m_u c^2$	m_u energy equivalent, J	amu meq, J; Emu
$m_u c^2$	m_u energy equivalent, MeV	amu meq, MeV; Emu
N_A	Avogadro constant	Avogadro; N_A
F	Faraday constant	Faraday; F
S_0/R	Sackur-Tetrode constant; 1 K, 100 kPa	Sackur 100 kPa; S0/R
S_0/R	Sackur-Tetrode constant; 1 K, 101.325 kPa	Sackur 101 kPa; S0/R
g_n	standard (earth) gravity acceleration	std gravity accel; gn
atm	standard atmosphere	std atmosphere; atm
ssp	standard-state pressure	std-state press; ssp

Boltzmann constant

Symbol	Full Description	Menu Description
k	Boltzmann constant, J/K	Boltzmann, J/K; k
k	Boltzmann constant, eV/K	Boltzmann, eV/K; k
k/h	Boltzmann constant, Hz/K	Boltzmann, Hz/K; k
k/hc	Boltzmann constant, 1/(m·K)	Boltzmann (m ·K) ⁻¹ ; k

Molar constants

Symbol	Full Description	Menu Description
R	molar gas constant	molar gas const; R
M_u	molar mass constant	molar mass; Mu
V_m	molar volume of ideal gas; 273.15 K, 100 kPa	id. gas vol 100K; Vm
V_m	molar volume of ideal gas; 273.15 K, 101.325 kPa	id. gas vol 101K; Vm
$N_A h$	molar Planck constant	Planck, molar; NAh
n_o	Loschmidt constant; 273.15 K, 100 kPa	Loschmidt 100 kPa; n0
n_o	Loschmidt constant; 273.15 K, 101.325 kPa	Loschmidt 101 kPa; n0
$M(^{12}\text{C})$	molar mass of carbon-12	molar mass C-12; M12C

Radiation constants

Symbol	Full Description	Menu Description
σ	Stefan-Boltzmann constant	Stefan-Boltzmann; σ
c_1	first radiation constant	1st rad constant; c1
c_2	second radiation constant	2nd rad constant; c2
c_{1L}	first radiation constant, spectral radiance	1st rad spectral; c1L
b'	Wien frequency displacement law constant	Wien freq disp; b'
b	Wien wavelength displacement law constant	Wien λ disp; b
K_{cd}	luminous efficacy	luminous efficacy; Kcd

X-ray Constants Menu

Symbol	Full Description	Menu Description
\AA^*	Angstrom-star	Angstrom-star; A*
xu(CuK α_1)	copper x unit	copper x-unit; xuCu
xu(MoK α_1)	molybdenum x unit	molyb x-unit; xuMo
a	silicon lattice parameter	Si lattice par; a
d_{220}	ideal Si (220) lattice spacing	Si220 lattice; d220
$V_m(\text{Si})$	silicon molar volume	Si molar vol; VmSi

Atomic Unit Constants Menu

Symbol	Full Description	Menu Description
u	atomic mass unit - kilogram relationship	amu~kg equiv; amu~kg
\hbar	atomic unit of action	au action; \hbar^-
e	atomic unit of charge	au charge; e
e/a_0^3	atomic unit of charge density	au charge dens; auQd
eE_h/\hbar	atomic unit of current	au current; auI
\hbar/E_h	atomic unit of time	au time; auT
a_0	atomic unit of length	au length; a0
a_0E_h/\hbar	atomic unit of velocity	au velocity; auS
m_e	atomic unit of mass	au mass; me
E_h/a_0	atomic unit of force	au force; auF
E_h	atomic unit of energy	au energy; Eh
\hbar/a_0	atomic unit of momentum	au momentum; auP
e^2/a_0E_h	atomic unit of permittivity	au permittivity; auc
E_h/e	atomic unit of electrical potential	au elec pot; auV
E_h/ea_0	atomic unit of electric field	au E-field; auE
E_h/ea_0^2	atomic unit of electric field gradient	au E-field grad; auEΔ
ea_0	atomic unit of electric dipole moment	au dipole mnt; auDp
ea_0^2	atomic unit of electric quadropole moment	au elec qpole; auQp
$e^2a_0^2/m_e$	atomic unit of magnetizability	au magnetize; auMa
$\hbar e/m_e$	atomic unit of magnetic dipole moment	au mag dipole; auDpm
\hbar/ea_0^2	atomic unit of magnetic flux density	au mag flux dens; auβ
$e^2a_0^2/E_h$	atomic unit of electric polarizability	au E-field pol; auEp
$e^3a_0^3/E_h^2$	atomic unit of 1st hyperpolarizability	au 1st hyperpol; Hy1
$e^4a_0^4/E_h^3$	atomic unit of 2nd hyperpolarizability	au 2nd hyperpol; Hy2

Natural Unit Constants Menu

Symbol	Full Description	Menu Description
\hbar	natural unit of action, J-s	action, J-s; nuA
\hbar	natural unit of action, eV-s	action, eV-s; nuA
λ	natural unit of length	length; nuL
$\hbar/m_e c^2$	natural unit of time	time; nuT
m_e	natural unit of mass	mass; num
c	natural unit of velocity	velocity; nuV
$m_e c^2$	natural unit of energy, J	energy, J; nuE
$m_e c^2$	natural unit of energy, MeV	energy, MeV; nuE
$m_e c$	natural unit of momentum, kg-m/s	momentum, kg-m/s; nuM
$m_e c$	natural unit of momentum, MeV/c	momentum; MeV/c; nuM

Energy Equivalents Menus

The Energy Equivalents menu has eight submenus for energy conversions:

Atomic mass unit
Inverse meter

Electron volt
Joule

Hartree energy
Kelvin

Hertz
Kilogram

The symbol ‘~’ indicates the equivalence, for example, amu~eV is the energy equivalence between the atomic mass unit and the electron volt.

Atomic mass (amu)

Symbol	Full Description	Menu Description
$(1\text{ u})\,c^2$	atomic mass unit – electron volt	amu~eV eqv; amu~eV
$(1\text{ u})\,c^2$	atomic mass unit – hartree energy	amu~Eh eqv; amu~Eh
$(1\text{ u})\,c^2/h$	atomic mass unit – hertz	amu~Hz eqv; amu~Hz
$(1\text{ u})\,c/h$	atomic mass unit – inverse meter	amu~m ⁻¹ eqv; amu~m ⁻¹
m_0c^2	atomic mass unit – joule	amu~J eqv; amu~J
$(1\text{ u})\,c^2/k$	atomic mass unit – kelvin	amu~K eqv; amu~K
u	atomic mass unit – kilogram	amu~kg eqv; amu~kg

Electron volt (eV)

Symbol	Full Description	Menu Description
$(1\text{ eV})/c^2$	electron volt – atomic mass unit	eV~amu eqv; eV~amu
1 eV	electron volt – hartree energy	eV~Eh eqv; eV~Eh
$(1\text{ eV})/h$	electron volt – hertz	eV~Hz eqv; eV~Hz
$(1\text{ eV})/hc$	electron volt – inverse meter	eV~m ⁻¹ eqv; eV~m ⁻¹
eV	electron volt – joule	eV~Joule eqv; eV~J
$(1\text{ eV})/k$	electron volt – kelvin	eV~Kelvin eqv; eV~K
$(1\text{ eV})/c^2$	electron volt – kilogram	eV~kg eqv; eV~kg

Hartree energy (Eh)

Symbol	Full Description	Menu Description
E_h	hartree energy in eV	Hartree, eV; Eh
$(1E_h)/c^2$	hartree energy – atomic mass unit	Hartree~amu; Eh~amu
E_h	hartree energy – electron volt	Hartree~eV; Eh~eV
$(1E_h)/h$	hartree energy – hertz	Hartree~Hz; Eh~Hz
$(1E_h)/hc$	hartree energy – inverse meter	Hartree~m ⁻¹ ; Eh~m ⁻¹
$1\,E_h$	hartree energy – joule	Hartree~J; Eh~J
$(1E_h)/k$	hartree energy – kelvin	Hartree~kelvin; Eh~K
$(1E_h)/c^2$	hartree energy – kilogram	Hartree~kg; Eh~kg

Hertz (Hz)

Symbol	Full Description	Menu Description
$(1\text{ Hz})\,h/c^2$	hertz – atomic mass unit	Hz~amu eqv; Hz~amu
$(1\text{ Hz})\,h$	hertz – electron volt	Hz~eV eqv; Hz~eV
$(1\text{ Hz})\,h$	hertz – hartree energy	Hz~Eh eqv; Hz~Eh
$(1\text{ Hz})/c$	hertz – inverse meter	Hz~m ⁻¹ eqv; Hz~m ⁻¹
$(1\text{ Hz})\,h$	hertz – joule	Hz~J eqv; Hz~J
$(1\text{ Hz})\,h/k$	hertz – kelvin	Hz~K eqv; Hz~K
$(1\text{ Hz})\,h/c^2$	hertz – kilogram	Hz~kg eqv; Hz~kg

Inverse meter (m^{-1})		
Symbol	Full Description	Menu Description
$(1 \text{ m}^{-1}) h/c$	inverse meter – atomic mass unit	$\text{m}^{-1} \sim \text{amu}$ eqv; $\text{m}^{-1} \sim \text{u}$
$(1 \text{ m}^{-1}) hc$	inverse meter – electron volt	$\text{m}^{-1} \sim \text{eV}$ eqv; $\text{m}^{-1} \sim \text{eV}$
$(1 \text{ m}^{-1}) hc$	inverse meter – hartree energy	$\text{m}^{-1} \sim \text{Eh}$ eqv; $\text{m}^{-1} \sim \text{Eh}$
$(1 \text{ m}^{-1}) c$	inverse meter – hertz	$\text{m}^{-1} \sim \text{Hz}$ eqv; $\text{m}^{-1} \sim \text{Hz}$
$(1 \text{ m}^{-1}) hc$	inverse meter – joule	$\text{m}^{-1} \sim \text{J}$ eqv; $\text{m}^{-1} \sim \text{J}$
$(1 \text{ m}^{-1}) hc/k$	inverse meter – kelvin	$\text{m}^{-1} \sim \text{K}$ eqv; $\text{m}^{-1} \sim \text{K}$
$(1 \text{ m}^{-1}) h/c$	inverse meter – kilogram	$\text{m}^{-1} \sim \text{kg}$ eqv; $\text{m}^{-1} \sim \text{kg}$

Joule (J)		
Symbol	Full Description	Menu Description
$(1 \text{ J})/c^2$	joule – atomic mass unit	$\text{J} \sim \text{amu}$ eqv; $\text{J} \sim \text{amu}$
1 J	joule – electron volt	$\text{J} \sim \text{eV}$ eqv; $\text{J} \sim \text{eV}$
1 J	joule – hartree energy	$\text{J} \sim \text{Hartree}$ eqv; $\text{J} \sim \text{Eh}$
$(1 \text{ J})/h$	joule – hertz	$\text{J} \sim \text{Hertz}$ eqv; $\text{J} \sim \text{Hz}$
$(1 \text{ J})/hc$	joule – inverse meter	$\text{J} \sim \text{m}^{-1}$ eqv; $\text{J} \sim \text{m}^{-1}$
$(1 \text{ J})/k$	joule – kelvin	$\text{J} \sim \text{K}$ eqv; $\text{J} \sim \text{K}$
$(1 \text{ J})/c^2$	joule – kilogram	$\text{J} \sim \text{kg}$ eqv; $\text{J} \sim \text{kg}$

Kelvin (K)		
Symbol	Full Description	Menu Description
$(1 \text{ K}) k/c^2$	kelvin – atomic mass unit	$\text{K} \sim \text{amu}$ eqv; $\text{K} \sim \text{amu}$
k	Kelvin – electron volt	$\text{K} \sim \text{eV}$ eqv; $\text{K} \sim \text{eV}$
$(1 \text{ K}) k$	kelvin – hartree energy	$\text{K} \sim \text{Hartree}$ eqv; $\text{K} \sim \text{Eh}$
$(1 \text{ K}) k/h$	kelvin – hertz	$\text{K} \sim \text{Hertz}$ eqv; $\text{K} \sim \text{Hz}$
$(1 \text{ K}) k/hc$	kelvin – inverse meter	$\text{K} \sim \text{m}^{-1}$ eqv; $\text{K} \sim \text{m}^{-1}$
$(1 \text{ K}) k$	kelvin – joule	$\text{K} \sim \text{Joule}$ eqv; $\text{K} \sim \text{J}$
$(1 \text{ K}) k/c^2$	kelvin – kilogram	$\text{K} \sim \text{kg}$ eqv; $\text{K} \sim \text{kg}$

kilogram (kg)		
Symbol	Full Description	Menu Description
1 kg	kilogram – atomic mass unit	$\text{kg} \sim \text{amu}$ eqv; $\text{kg} \sim \text{u}$
$(1 \text{ kg}) c^2$	kilogram – electron volt	$\text{kg} \sim \text{eV}$ eqv; $\text{kg} \sim \text{eV}$
$(1 \text{ kg}) c^2$	kilogram – hartree energy	$\text{kg} \sim \text{Eh}$ eqv; $\text{kg} \sim \text{Eh}$
$(1 \text{ kg}) c^2/h$	kilogram – hertz	$\text{kg} \sim \text{Hz}$ eqv; $\text{kg} \sim \text{Hz}$
$(1 \text{ kg}) c/h$	kilogram – inverse meter	$\text{kg} \sim \text{m}^{-1}$ eqv; $\text{kg} \sim \text{m}^{-1}$
$(1 \text{ kg}) c^2$	kilogram – joule	$\text{kg} \sim \text{J}$ eqv; $\text{kg} \sim \text{J}$
$(1 \text{ kg}) c^2/k$	kilogram – kelvin	$\text{kg} \sim \text{K}$ eqv; $\text{kg} \sim \text{K}$

Retrieving Constants: CONS, getcon

The constants are stored in a single list in the CONS program. Each constant object is a sublist defined as

$\{\text{value}, \text{tag}, \text{description}, \text{unc}\}$

<i>value</i>	The numeric value of the constant. The unit, if any, is attached.
<i>tag</i>	The tag attached to the returned constant.
<i>description</i>	The menu description of the constant.
<i>unc</i>	The standard uncertainty of the constant.

A constant object sublist can be retrieved to the stack by calling CONS with input $\{n\}$, where $\{n\}$ is the index into the constants list. For example, $n = 318$ for the speed of light constant, so

$$\{318\} \text{ CONS} \Rightarrow \{\{'299792458_m/s' \text{ "c" "speed of light" 0}\}\}$$

Note that the constant list is returned in double braces; HEAD can be used to remove the outer braces. c is defined as an exact constant, so the error is 0.

If you only need the numeric value of a constant, the program `getcon` can be used. `getcon` takes the index n as input and returns the value, for example,

$$318 \text{ getcon} \Rightarrow '299792458_m/s'$$

Both CONS and `getcon` observe the units flag 61. Units are attached to the constant if flag 61 is *clear*, otherwise, not.

The indices n for all the constants are listed in CONS Contents Listing (p12).

Constant Uncertainty: `conunc`

The database for PCON includes the standard uncertainty U_S for each constant, which can be put on the stack with the program `conunc`. The input to `conunc` is the CONS index number n for the constant, and the outputs are U_S and the relative uncertainty $U_R = U_S/x$, where x is the value of the constant.

$$\begin{array}{c|c} 2 & \\ \hline 1 & n \end{array} \Rightarrow \begin{array}{c|c} & U_S \\ \hline & U_R \end{array}$$

The 2018 CODATA revision defines eight constants as exact, shown below. These constants have zero uncertainty by definition.

Exact CODATA Constants			
Quantity	Symb.	Value	Unit
^{133}Cs hyperfine transition frequency	$\Delta\nu_{\text{Cs}}$	9 192 631 770	Hz
speed of light in vacuum	c	299 792 458	m s^{-1}
Planck constant	h	$6.626\,070\,15 \times 10^{-34}$	J Hz^{-1}
reduced Planck constant	\hbar	$1.054\,571\,817 \dots \times 10^{-34}$	J s
elementary charge	e	$1.602\,176\,634 \times 10^{-19}$	C
Boltzmann constant	k	$1.380\,649 \times 10^{-23}$	J K^{-1}
Avogadro constant	N_A	$6.022\,140\,76 \times 10^{23}$	mol^{-1}
luminous efficacy	K_{cd}	683	lm W^{-1}

Constants which are combinations of exact constants also have zero uncertainty, for example, the Faraday constant $F = N_A e$. Other constants with zero uncertainty are those which are combinations of only exact constants and numeric constants such as integers, fractions, and π . A third type of constant with zero uncertainty are those with arbitrary or traditional values; examples include the acceleration due to earth's gravity, and standard pressure and temperature.

CONS Contents Listing

This section uses the following abbreviations.

n	index into CONS list	nuc	nuclear
MMR	magnetic moment ratio	mag.	magnetic
sh.	shielding or shielded		

Universal constants

n	Description	n	Description
318	speed of light in vacuum, c	292	reduced Planck constant, \hbar , J s
252	Newtonian gravitation constant, G	293	reduced Planck constant, \hbar , eV/Hz
253	$G/\hbar c$	294	$\hbar c$, MeV·fm
54	vacuum characteristic impedance, Z_0	261	Planck length, l_p
348	vacuum electric permittivity, ϵ_0	262	Planck mass, m_p
349	vacuum magnetic permeability, μ_0	265	Planck time, t_p
259	Planck constant, h , J/Hz	264	Planck temperature, T_p
260	Planck constant h , eV/Hz	263	Planck mass energy GeV, $m_p c^2$

Atomic, Nuclear constants: General

n	Description	n	Description
347	unified atomic mass unit, u	300	$R_\infty \hbar c$, J
124	fine-structure constant, α	287	circulation quantum, $\pi \hbar / m_e$
157	inverse fine-structure constant, α^{-1}	288	$2\times$ circulation quantum, $2\pi \hbar / m_e$
49	Bohr radius, a_0	316	shielding difference of d and p in HD, σ_{dp}
123	Fermi coupling constant, $G_F/(\hbar c)^3$	317	shielding difference of t and p in HT, σ_{tp}
129	Hartree energy, E_h	354	W to Z mass ratio m_W/m_Z
297	Rydberg constant R_∞ , [m ⁻¹]	351	weak mixing angle $\sin^2 \theta_W$
298	$R_\infty c$, Hz	156	¹³³ Cs hyperfine transition frequency $\Delta \nu_{Cs}$
299	$R_\infty \hbar c$, eV		

Atomic, Nuclear constants: Electron, General

n	Description	n	Description
95	electron mass, m_e , kg	84	electron charge/mass ratio, $-e/m_e$
98	electron mass, m_e , u	55	classical electron radius, r_e
99	electron molar mass, M_e	333	Thomson cross section, σ_e
106	electron relative atomic mass, $A_r(e)$	56	Compton wavelength, λ_c
96	electron mass energy, $m_e c^2$, J	289	reduced Compton wavelength, $\lambda_c -$
97	electron mass energy, $m_e c^2$, MeV		

Atomic, Nuclear constants: Electron, Mass Ratio

n	Description	n	Description
108	electron/alpha particle mass ratio, m_e/m_α	103	electron/neutron mass ratio, m_e/m_n
86	electron/deuteron mass ratio, m_e/m_d	105	electron/proton mass ratio, m_e/m_p
90	electron/helion mass ratio, m_e/m_h	107	electron/tau mass ratio, m_e/m_τ
101	electron/muon mass ratio, m_e/m_μ	111	electron/triton mass ratio, m_e/m_t

Atomic, Nuclear constants: Electron (e), Magnetic Moment

n	Description	n	Description
87	electron g factor, g_e	104	electron/proton MMR, μ_{e^-}/μ_p
88	electron gyromagnetic ratio, γ_e , 1/sT	102	electron/neutron MMR, μ_{e^-}/μ_n
89	electron gyromagnetic ratio, γ_e , MHz/T	85	electron/deuteron MMR, μ_e/μ_d
91	electron magnetic moment, μ_e	100	electron/muon MMR, μ_e/μ_μ
92	electron mag. moment anomaly, a_e	109	electron/sh. helion MMR, μ_e/μ'_h
93	electron/Bohr magneton MMR, μ_e/μ_B	110	electron/sh. proton MMR, μ_e/μ'_p
94	electron/nuc magneton MMR, μ_e/μ_N		

Atomic, Nuclear constants: Proton (p), General

n	Description	n	Description
276	proton mass, m_p , kg	278	proton mass energy, $m_p c^2$, MeV
279	proton mass, m_p , u	266	proton charge/mass ratio, e/m_p
280	proton molar mass, M_p	285	proton rms charge radius, r_p
284	proton relative atomic mass, $A_r(p)$	267	proton Compton wavelength, $\lambda_{C,p}$
277	proton mass energy, $m_p c^2$, J	295	reduced proton Compton wavelength, $\lambda_{-C,p}$

Atomic, Nuclear constants: Proton (p), Mass Ratio

n	Description	n	Description
268	proton/electron mass ratio, m_p/m_e	283	proton/neutron mass ratio, m_p/m_n
281	proton/muon mass ratio, m_p/m_μ	286	proton/tau mass ratio, m_p/m_τ

Atomic, Nuclear constants: Proton (p), Magnetic Moment

n	Description	n	Description
269	proton g factor, g_p	275	proton mag. shielding correction, σ'_p
270	proton gyromagnetic ratio, γ_p , 1/sT	311	sh. proton gyromagnetic ratio, γ'_p , 1/sT
271	proton gyromagnetic ratio, γ_p , MHz/T	312	sh. proton gyromagnetic ratio, γ'_p , MHz/T
272	proton magnetic moment, μ_p	313	shielded proton magnetic moment, μ'_p
273	proton/Bohr magneton MMR, μ_p/μ_B	314	sh. proton/Bohr magneton MMR, μ'_p/μ_B
274	proton/nuclear magneton MMR, μ_p/μ_N	315	sh. proton/nuc magneton MMR, μ'_p/μ_N
282	proton/neutron MMR, μ_p/μ_n		

Atomic, Nuclear constants: Neutron (n), General

n	Description	n	Description
237	neutron mass, m_n , kg	244	neutron-proton mass difference, $m_n - m_p$, kg
240	neutron mass, m_n , u	247	neutron-proton mass difference, $m_n - m_p$, u
241	neutron molar mass, M_n	245	neutron-proton mass difference energy, J
249	neutron relative atomic mass, $A_r(n)$	246	neutron-proton mass difference energy, MeV
238	neutron mass energy, $m_n c^2$, J	228	neutron Compton wavelength, $\lambda_{C,n}$
239	neutron mass energy, $m_n c^2$, MeV	291	red. neutron Compton wavelength, $\lambda_{-C,n}$

Atomic, Nuclear constants: Neutron (n), Mass Ratio

n	Description	n	Description
230	neutron/electron mass ratio, m_n/m_e	242	neutron/muon mass ratio, m_n/m_μ
248	neutron/proton mass ratio, m_n/m_p	250	neutron/tau mass ratio, m_n/m_τ

Atomic, Nuclear constants: Neutron (n), Magnetic Moment

n	Description	n	Description
231	neutron g factor, g_n	236	neutron/nuc magneton MMR, μ_n/μ_N
232	neutron gyromagnetic ratio, γ_n , 1/sT	243	neutron/proton MMR, μ_n/μ_p
233	neutron gyromagnetic ratio, γ_n , MHz/T	229	neutron/electron MMR, μ_n/μ_e
234	neutron magnetic moment, μ_n	251	neutron/sh. proton MMR, μ_n/μ_p'
235	neutron/Bohr magneton MMR, μ_n/μ_B		

Atomic, Nuclear constants: Alpha particle (α)

n	Description	n	Description
2	alpha particle mass, m_α , kg	3	alpha particle mass energy, $m_\alpha c^2$, J
5	alpha particle mass, m_α , u	4	alpha particle mass energy, $m_\alpha c^2$, MeV
6	alpha particle molar mass, M_α	1	alpha/electron mass ratio, m_α/m_e
8	alpha relative atomic mass, $A_r(\alpha)$	7	alpha/proton mass ratio, m_α/m_p

Atomic, Nuclear constants: Deuteron (d), General

n	Description	n	Description
74	deuteron mass, m_d , kg	76	deuteron mass energy, $m_d c^2$, MeV
77	deuteron mass, m_d , u	83	deuteron rms charge radius, r_d
78	deuteron molar mass, M_d	69	deuteron/electron mass ratio, m_d/m_e
82	deuteron relative atomic mass, $A_r(d)$	81	deuteron/proton mass ratio, m_d/m_e
75	deuteron mass energy, $m_d c^2$, J		

Atomic, Nuclear constants: Deuteron (d), Magnetic Moment

n	Description	n	Description
70	deuteron g factor, g_d , kg	68	deuteron/electron MMR, μ_d/μ_e
71	deuteron magnetic moment, μ_d	79	deuteron/neutron MMR, μ_d/μ_n
72	deuteron/Bohr MMR, μ_d/μ_B	80	deuteron/proton MMR, μ_d/μ_p
73	deuteron/nuclear MMR, μ_d/μ_N		

Atomic, Nuclear constants: Helion (h), General

n	Description	n	Description
141	helion mass, m_h , kg	143	helion mass energy, $m_h c^2$, MeV
144	helion mass, m_h , u	136	helion/electron mass ratio, m_h/m_e
145	helion molar mass, M_h	146	helion/proton mass ratio, m_h/m_p
147	helion relative atomic mass, $A_r(h)$	148	helion shielding shift, σ_h
142	helion mass energy equivalent, $m_h c^2$, J		

Atomic, Nuclear constants: Helion (h), Magnetic Moment

n	Description	n	Description
137	helion g factor, g_h	306	shielded helion magnetic moment, μ_h'
304	sh. helion gyromagnetic ratio, γ_h' , 1/st	307	sh. helion/Bohr magneton MMR, μ_h'/μ_B
305	sh. helion gyromagnetic ratio, γ_h' , MHz/T	308	sh. helion/nuclear magneton MMR, μ_h'/μ_N
138	helion magnetic moment, μ_h	309	sh. helion/proton MMR, μ_h'/μ_p
139	helion/Bohr magneton MMR, μ_h/μ_B	310	sh. helion/sh. proton MMR, μ_h'/μ_p'
140	helion/nuclear magneton MMR, μ_h/μ_N		

Atomic, Nuclear constants: Muon (μ), General

n	Description	n	Description
209	muon mass, m_μ , kg	211	muon mass energy, $m_\mu c^2$, MeV
212	muon mass, m_μ , u	202	muon Compton wavelength, $\lambda_{C,\mu}$
213	muon molar mass, M_μ	290	muon red. Compton wavelength, $\lambda_{-C,\mu}$
210	muon mass energy equivalent, $m_\mu c^2$, J		

Atomic, Nuclear constants: Muon (μ), Mass Ratio

n	Description	n	Description
203	muon/electron mass ratio, m_μ/m_e	216	muon/proton mass ratio, m_μ/m_p
214	muon/neutron mass ratio, m_μ/m_n	217	muon/tau mass ratio, m_μ/m_τ

Atomic, Nuclear constants: Muon (μ), Magnetic Moment

n	Description	n	Description
204	muon g factor, g_μ	207	muon/Bohr magneton MMR, μ_μ/μ_B
205	muon magnetic moment, μ_μ	208	muon/nuclear magneton MMR, μ_μ/μ_N
206	muon magnetic moment anomaly, a_μ	215	muon/proton MMR, μ_μ/μ_p

Atomic, Nuclear constants: Tau (τ)

n	Description	n	Description
326	tau mass, m_τ , kg	332	tau/proton mass ratio, m_τ/m_p
328	tau mass, m_τ , u	331	tau/neutron mass ratio, m_τ/m_n
329	tau molar mass, M_τ	330	tau/muon mass ratio, m_τ/m_μ
327	tau mass energy equivalent, $m_\tau c^2$, J	323	tau Compton wavelength, $\lambda_{C,\tau}$
325	tau mass energy equivalent, $m_\tau c^2$, MeV	296	reduced tau Compton wavelength, $\lambda_{-C,\tau}$
324	tau/electron mass ratio, m_τ/m_e		

Atomic, Nuclear constants: Triton (t)

n	Description	n	Description
339	triton mass, m_t , kg	344	triton/proton mass ratio, m_t/m_p
342	triton mass, m_t , u	335	triton g factor, g_t
343	triton molar mass, M_t	336	triton magnetic moment, μ_t
345	triton relative atomic mass, $A_r(t)$	337	triton/Bohr magneton MMR, μ_t/μ_B
340	triton mass energy equivalent, $m_t c^2$, J	338	triton/nuclear magneton MMR, μ_t/μ_N
341	triton mass energy equiv., $m_t c^2$, MeV	346	triton/proton MMR, μ_t/μ_p
334	triton/electron mass ratio, m_t/m_e		

Electromagnetic, General

n	Description	n	Description
120	elementary charge, e	193	magnetic flux quantum, Φ_0
121	e/\hbar	57	conductance quantum, G_0
166	Josephson constant, K_J	165	conductance quantum inverse, G_0^{-1}
350	von Klitzing constant, R_K		

Electromagnetic, Bohr Magnetron

n	Description	n	Description
44	Bohr magneton, μ_B , J/T	47	Bohr magneton, $\mu_B/\hbar c$, 1/mT
45	Bohr magneton, μ_B , eV/T	48	Bohr magneton, μ_B/k , K/T
46	Bohr magneton, μ_B/\hbar , Hz/T		

Electromagnetic, Nuclear Magnetron

n	Description
254	nuclear magneton, μ_N , J/T
255	nuclear magneton, μ_N , eV/T
256	nuclear magneton, μ_N/hc , 1/mT

Electromagnetic, Conventional

n	Description
62	Josephson constant, K_{J-90}
65	von Klitzing constant, R_{K-90}
59	coulomb-90, C_{90}
64	volt-90, V_{90}
58	ampere-90, A_{90}
63	ohm-90, Ω_{90}

Physiochemical, General

n	Description
10	atomic mass constant, m_u
11	m_u energy equivalent, $m_u c^2$, J
12	m_u energy equivalent, $m_u c^2$, MeV
43	Avogadro constant, N_A
122	Faraday constant, F

Physiochemical, Boltzmann Constant

n	Description
50	Boltzmann constant, k , J/K
51	Boltzmann constant, k , eV/K

Physiochemical, Molar Constants

In the table below, $T_0 = 273.15$ K, $P_0 = 100$ kPa, $P_1 = 101.325$ kPa.

n	Description
194	molar gas constant, R
195	molar mass constant, M_u
198	ideal gas molar volume (T_0 , P_0), V_m
199	ideal gas molar volume (T_0 , P_1), V_m

Physiochemical, Radiation Constants

n	Description
322	Stefan-Boltzmann constant, σ
125	first radiation constant, c_1
303	second radiation constant, c_2
126	1st rad constant, spectral radiance, C_{1L}

X-ray Constants

n	Description
9	Angstrom star, \AA^*
67	Copper x unit, $xu(\text{CuK}\alpha_1)$
201	Molybdenum x unit, $xu(\text{MoK}\alpha_1)$

n	Description
257	nuclear magneton, μ_N/k , K/T
258	nuclear magneton, μ_N/h , MHz/T

n	Description
355	seimen-90, S_{90}
66	watt-90, W_{90}
60	farad-90, F_{90}
61	henry-90, H_{90}
356	weber-90, Wb_{90}
357	tesla-90, T_{90}

n	Description
301	Sackur-Tetrode (1 K, 100 kPa), S_0/R
302	Sackur-Tetrode (1K, 101.325 kPa), S_0/R
319	standard earth gravity acceleration, g_n
320	standard atmosphere, atm
321	standard-state pressure, ssp

n	Description
52	Boltzmann constant, k/h , Hz/K
53	Boltzmann constant, k/hc , 1/mK

n	Description
197	molar Planck constant, $N_A h$
190	Loschmidt constant (T_0 , P_0), n_0
191	Loschmidt constant (T_0 , P_1), n_0
196	molar mass of carbon-12, $M(^{12}\text{C})$

n	Description
352	Wien frequency displacement law, b'
353	Wien wavelength displacement law, b
192	luminous efficacy, K_{cd}

n	Description
188	Silicon lattice parameter, a
189	ideal Si(220) lattice spacing, d_{220}
200	silicon molar volume, $V_m(\text{Si})$

Atomic Units

n	Description
22	action, \hbar
38	mass, m_e
34	length, a_0
41	time, \hbar/E_h
42	velocity, $a_0 E_h/\hbar$
33	force, E_h/a_0
32	energy, E_h
39	momentum, \hbar/a_0
23	charge, e
24	charge density, e/a_0^3
25	current, eE_h/\hbar
27	electric field, E_h/ea_0

n	Description
28	electric field gradient, E_h/ea_0^2
30	electric potential, E_h/e
26	electric dipole moment, ea_0
29	electric polarizability, $e^2 a_0^2/E_h$
31	electric quadrupole moment, ea_0^2
40	permittivity, $e^2/a_0 E_h$
37	magnetizability, $e^2 a_0^2/m_e$
35	magnetic dipole moment, $\hbar e/m_e$
36	magnetic flux density, \hbar/ea_0^2
20	first hyperpolarizability, $e^3 a_0^3/E_h^2$
21	second hyperpolarizability, $e^4 a_0^4/E_h^3$

Natural Units

n	Description
218	action, \hbar , J s
219	action, \hbar , eV s
222	length, λ_c
226	time, $\hbar/m_e c^2$
223	mass, m_e

n	Description
227	velocity, c
220	energy, $m_e c^2$, J
221	energy, $m_e c^2$, MeV
224	momentum, $m_e c$, kg m/s
225	momentum, $m_e c$, MeV/c

Energy equivalent relationships, atomic mass unit

n	Description
13	atomic mass unit – electron volt
14	atomic mass unit – hartree energy
15	atomic mass unit – hertz
16	atomic mass unit – inverse meter

n	Description
17	atomic mass unit – joule
18	atomic mass unit – kelvin
19	atomic mass unit – kilogram

Energy equivalent relationships, electron volt

n	Description
112	electron volt
113	electron volt – atomic mass unit
114	electron volt – hartree energy
115	electron volt – hertz

n	Description
116	electron volt – inverse meter
117	electron volt – joule
118	electron volt – kelvin
119	electron volt – kilogram

Energy equivalent relationships, hartree energy

n	Description
130	hartree energy, eV
127	hartree energy – atomic mass unit
128	hartree energy – electron volt
131	hartree energy – hertz

n	Description
132	hartree energy – inverse meter
133	hartree energy – joule
134	hartree energy – kelvin
135	hartree energy – kilogram

Energy equivalent relationships, hertz

n	Description
149	hertz – atomic mass unit
150	hertz – electron volt
151	hertz – hartree energy
152	hertz – inverse meter

n	Description
153	hertz – joule
154	hertz – kelvin
155	hertz – kilogram

Energy equivalent relationships, inverse meter

n	Description
158	inverse meter – atomic mass unit
159	inverse meter – electron volt
160	inverse meter – hartree energy
161	inverse meter – hertz

n	Description
162	inverse meter – joule
163	inverse meter – kelvin
164	inverse meter – kilogram

Energy equivalent relationships, joule

n	Description
167	joule – atomic mass unit
168	joule – electron volt
169	joule – hartree energy
170	joule – hertz

n	Description
171	joule – inverse meter
172	joule – kelvin
173	joule – kilogram

Energy equivalent relationships, kelvin

n	Description
174	kelvin – atomic mass unit
175	kelvin – electron volt
176	kelvin – hartree energy
177	kelvin – hertz

n	Description
178	kelvin – inverse meter
179	kelvin – joule
180	kelvin – kilogram

Energy equivalent relationships, kilogram

n	Description
181	kilogram – atomic mass unit
182	kilogram – electron volt
183	kilogram – hartree energy
184	kilogram – hertz

n	Description
185	kilogram – inverse meter
186	kilogram – joule
187	kilogram – kelvin

Create the PCON Library

The included program `makelib` can be used to rebuild the PCON library, for example, if `menuC` is modified to change the common constants `menu`. `makelib` can also be used to change the library ROM ID number. The code for `makelib` is shown below. Before running `makelib`:

- Create the directory `PHCON` in the `HOME` directory.
- Copy the source programs to `PHCON`.

`makelib` executes the following operations:

- Clear the stack, and detach and purge the existing library, if any.
- Set the current directory to `PHCON`.
- Initialize the library system variables.
- Create the library.
- Save the library to port 2 (FLASH).
- Purge the library creation variables.
- Attach the library to the home directory

If you modify `makelib` to change the ROM ID number, note that 1005 must be changed to the new number at five places.

```

makelib:
« CLEAR
1005 DETACH :2:1005 PURGE
{HOME PHCON} EVAL
"CODATA" '$TITLE' STO
1005 '$ROMID' STO
«1005 ATTACH » '$CONFIG' STO
{PCON CONS getcon conunc} '$VISIBLE' STO
{cmenu menuC menuU menuA menuE menuP menuX menuAU
menuN menuEN menuAG menuAE menuAP menuAN menuAA
menuAD menuAH menuAM menuAT menuATr}
'$HIDDEN' STO
CRLIB
:2:CODATA STO
{'$TITLE $ROMID $CONFIG $VISIBLE $HIDDEN'} PURGE
HOME 1005 ATTACH »

```

Calculation of Some Constants

Reference [1] gives numerical values with different numbers of significant digits for different constants. Constants defined with more than 12 digits of precision have been rounded to the 12 significant digit precision of the 50g. As described in *Constant Uncertainty* above, some constants are exact and can be calculated to any number of significant digits. The CODATA source usually gives these constants to ten significant digits as *d.dddddddd*... . Although admittedly overkill, I calculated these constants to get twelve digits for the PCON database.

I used Mathematica for these calculations. The general method is to first define the source constants as exact values, then calculate the constant value with exact arithmetic, then round the result to 12 significant digits. For example, the Stefan-Boltzmann constant is defined as $\sigma = \pi^2 k^4 / 60 \hbar^3 c^2$. All the terms in this expression are either constants defined as exact values (k , \hbar , c) or exact numerical constants (π , 60). The NIST CODATA reference gives the value as $5.670374419 \dots \times 10^{-8}$, which is only 10 significant digits, but the 12-digit value can be calculated as $5.67037441918 \times 10^{-8}$.

Many of the energy equivalent constants required calculation for 12-digit precision. For example, the kilogram-hertz energy equivalence is defined as $(1 \text{ kg})c^2/h = [\text{kg } c^2 / \text{Hz } h]\text{Hz}$, with the numerical value $1.356392489 \dots \times 10^{50} \text{ Hz}$. The conversion factor is c^2/h . c is defined exactly as 299792458 m/s. h is also defined exactly as $6.62607015 \times 10^{-34} \text{ J/Hz}$, which can be expressed as the fraction $132521403/2 \times 10^{41}$. Using exact arithmetic to find c^2/h and rounding the result to 12 significant digits gives $c^2/h \approx 1.35639248965 \times 10^{50}$.

Code Summary

PCON is coded in a straight-forward, somewhat modular way. The table below lists the program modules with a brief description.

PCON	The main program
CONS	Return a constant object by list index.
cmenu	Display a menu of specified constants.
menuC	Display the menu of common constants.
menuU	Display the menu of universal constants.
menuA	Display the submenus for atomic and nuclear constants.
menuAG	Display the menu of general atomic and nuclear constants.
menuAE	Display submenus for electron constants.
menuAP	Display submenus for proton constants.
menuAN	Display submenus for neutron constants.
menuAA	Display the menu of alpha particle constants.
menuAD	Display submenus for deuteron constants.
menuAH	Display submenus for helion constants.
menuAM	Display the submenus for muon constants.
menuAT	Display the menu of tau constants.
menuATr	Display the menu of triton constants.
menuE	Display the submenus for electromagnetic constants.
menuP	Display the submenus for physiochemical constants.
menuX	Display the menu of X-ray constants.
menuAU	Display the menu of atomic units constants.
menuN	Display the menu of natural units constants.
menuEN	Display the submenus for energy equivalents.

The following programs are included in the CODATA library but are not called by PCON. They are described elsewhere in this document.

getcon	Return a single constant object to the stack.
conunc	Return a constant's uncertainties to the stack.
makelib	Build the CODATA library from the source.

PCON requires that the listext list operations extensions library. The only list-ext command used is LPICK, in CONS. Use of LPICK considerably reduces menu display time, because of the large size of the CONS list.

The menuU program for the universal constants can be used a general example of all of the menu programs.

```
menuU:
«
"Universal"
{ 318 252 253 54 348 349 259 260 292 293 294 261 262 265 264 263 }
cmenu
»
```

All that the menu programs need do is to initialize the stack with the inputs for cmenu: the menu title on stack level 2, and a list of CONS list indices on stack level 1. cmenu displays a CHOOSE menu of the constants' labels, then returns the selected constant, with or without the unit attached, depending on flag 61. DOLIST is used to build the menu list items without using loops.

```
cmenu:
«
{} → lo
«
@ Save CONS to local variable for DOLIST argument
```

```

CONS 'lo' STO
@ Build the menu items list and display the menu
@ ... build list of menu prompts with descriptions and tags
lo 1 « 2 3 SUB LIST→ DROP "; " + SWAP + » DOLIST
@ ... insert constant values as execution objects
lo 2 « 2 →LIST » DOLIST
1 CHOOSE
@ Return if no menu item selected, else remove unit from constant
@ if flag 61 set, then attach display tag
0 ==
« »
« DUP 1 GET 61 FS? « UVAL » IFT SWAP 2 GET →TAG »
IFTE
»
»

```

The program objects in the *Source Code* folder of the distribution are intended for use with the Debug4x development environment. Each file starts with a single header line before the program, and ends with '*name*' STO to save the program when it is sent to the emulator.

References

- [1] *The NIST Reference on Constants, Units, and Uncertainty*
<https://physics.nist.gov/cuu/Constants/index.html>
 This web page gives the recommended values for most of the constants used by PCON. It also has many other resources related to constants and units, such as the ability to find the correlation coefficient of pairs of constants. An exhaustive bibliography on physical constants is also available.
 This page is also the source for the expressions used to calculate 12-digit values used by PCON.
- [2] *CODATA Recommended Values of the Fundamental Physical Constants: 2018*, EITE TIESINGA, PETER J. MOHR, DAVID B. NEWELL, et al. Journal of Physical and Chemical Reference Data, 2021.
<https://physics.nist.gov/cuu/pdf/JPCRD2018CODATA.pdf>
 This paper gives a very detailed explanation of the 2018 CODATA adjustment of the constants. In this documentation for PCON I have not described any of the background on how the recommended values are calculated, but this paper does just that.
- [3] *The Fundamental Physical Constants and the Frontier of Measurement*, B. W. PETLEY, Adam Hilger, 1988.
 While not strictly a reference for PCON and also much out-of-date, this book is nonetheless a useful and informative background source on many of the physical constants.