Physical Basics for the Physics of Star Trek

Base Units for Physical Quantities

Quantity	Symbol	Unit	Description
Length	l, x, s	m	Meter
Mass	m	kg	Kilogram
Time	t	s	Second
Electric Current	I	A	Ampere
Temperature	T	K	Kelvin (freezing: 273.15 K, boiling: 373.15 K)
Temperature	ϑ	°C	Degree Celsius (freezing: 0 °C, boiling 100 °C)

Units and their descriptions

10^{-3}	Milli	m	10^{3}	Kilo	k
10^{-6}	Micro	µ	10^{6}	Mega	M
10^{-9}	Nano	n	10^{9}	Giga	G
10^{-12}	Pico	p	10^{12}	Tera	T
10^{-15}	Femto	f	10^{15}	Peta	P
10^{-18}	Atto	a	10^{18}	Exa	E
10^{-21}	Zepto	z	10^{21}	Zetta	Z
10^{-24}	Yocto	y	10^{24}	Yotta	Y

Units for amount of data

(1 kilobyte is per definition 2^{10} bytes = 1024 bytes)

prefix	symbol	physics	amount of data
Kilo	k	10^{3}	$2^{10} \approx 1.02 \cdot 10^{3}$
Mega	M	10^{6}	$2^{20} \approx 1.05 \cdot 10^{6}$
Giga	G	10^{9}	$2^{30} \approx 1.07 \cdot 10^{9}$
Tera	T	10^{12}	$2^{40} \approx 1.10 \cdot 10^{12}$
Peta	P	10^{15}	$2^{50} \approx 1.13 \cdot 10^{15}$
Exa	E	10^{18}	$2^{60} \approx 1.15 \cdot 10^{18}$
Zetta	Z	10^{21}	$2^{70} \approx 1.18 \cdot 10^{21}$
Yotta	Y	10^{24}	$2^{80} \approx 1.21 \cdot 10^{24}$

Derived Units for Physical Quantities

Quantity	Symbol	Unit	Description
Displacement	x, s, d, h	m	Meter
Volume	V	m^3	Meter cubed
Velocity	v	$\frac{m}{s}$	Meter per second
Angle Velocity	ω	$\frac{1}{s}$	1 per Second
Acceleration	a	$\frac{m}{s^2}$	Meter per second squared
Force	F	$N = \frac{kg \cdot m}{s^2}$	Newton
Work	W	J = Nm	Joule or Newton Meter
Energy	E	$J = \frac{kg \cdot m^2}{s^2}$	Joule
Power	P	$W = \frac{J}{s}$	Watt
Wavelength	λ	m	Meter
Charge	q	C = As	Coulomb (Ampere Second)

Special Units for Physical Quantities

Quantity	Symbol	Unit	Description
Energy	E	eV	Electron Volt = $1.602 \cdot 10^{-19}$ J
Force	F	Dyne	1 dyne = 10^{-5} N
Distance	Å	Angstrom	1 Å = 10^{-10} m
Displacement	ly	Light year	1 ly = 9,460,730,472,580.8 km ≈ $9.5 \cdot 10^{15}$ m
Displacement	AU	Astronomical Unit	149 Million km
Displacement	pc	Parsec	1 pc = $3.0857 \cdot 10^{16}$ m = 3.262 ly

Energy of a Proton/Antiproton-Annihilation: E = 2 GeV = $3.2 \cdot 10^{-10}$ J

Fundamental Physical Constants

Quantity	Symbol	Value
Speed of light	c	299,792.458 $\frac{km}{s}$
Mass of electron	m_e	$9.11 \cdot 10^{-31}$ kg
Mass of proton	m_p	$1.67 \cdot 10^{-27}$ kg
Elementary charge	e	$1.602 \cdot 10^{-19}$ C
Gravitation constant	γ	$6.67 \cdot 10^{-11} \frac{m^3}{kg \cdot s^2}$
Gravitational acceleration	g	9.81 $\frac{m}{s^2}$ (for Earth)
Planck constant	h	$6.626 \cdot 10^{-34} \frac{kg \cdot m^2}{s}$

Important formulas from the classic physics

Growth (Compound Interest)	$A = A_0 \cdot (1+q)^n$ *(see footnote)
Uniform Velocity	$s = v \cdot t$
Kinetic Force	$F = m \cdot a$ **or** $F = m \cdot g$ (free fall)
Uniform Acceleration ($v_0 = 0$)	$v = a \cdot t$ **or** $v = g \cdot t$ (free fall)
Uniform Acceleration	$v = v_0 + a \cdot t$ **or** $v = v_0 + g \cdot t$ (free fall)
Uniform Acceleration	$s = \frac{1}{2} \cdot a \cdot t^2$ **or** $h = \frac{1}{2} \cdot g \cdot t^2$ (free fall)
Velocity for free fall	$v = \sqrt{2 \cdot g \cdot h}$
Work	$W = F \cdot s$
Power	$P = \frac{W}{t}$
Kinetic Energy	$E_{kin} = \frac{1}{2} \cdot m \cdot v^2$
Conservation of Energy	$E_1 = E_2$
Momentum (Impulse)	$p = m \cdot v$
Conservation of Momentum	$m_1 \cdot v_1 = m_2 \cdot v_2$
Law of Gravity	$F = \gamma \cdot \frac{m_1 \cdot m_2}{d^2}$
Velocity for circular motion	$v = r \cdot \omega$ (r = radius)
Centrifugal force	$F_C = m \cdot r \cdot \omega^2 = \frac{m \cdot v^2}{r}$ (r = radius)
Energy of a photon	$E = h \cdot \nu = \frac{h}{\lambda}$ (ν = frequency, λ= wavelength)

Conversion in other units

Miles ↔ Kilometer	1 mile = 1.609 km	1 km = 0.6215 miles
Feet ↔ Meter	1 foot = 0.3048 m	1 m = 3.28 feet
Kilowatt ↔ Horse Power	1 kW = 1.36 HP	1 HP = 0.736 kW
Kilowatt Hours ↔ Joule	1 kWh = $3.60 \cdot 10^6$ J	1 J = $0.278 \cdot 10^{-6}$ kWh
Electron Volt ↔ Joule	1 eV = $1.602 \cdot 10^{-19}$ J	1 J = $6.242 \cdot 10^{18}$ eV
Pound↔ kg	1 lb = 0.453 kg	1 kg = 2.207 lb
Metric ton↔ kg	1 t = 1,000 kg	1 kg = 0.001 t
m/s ↔ km/h	1 m/s = 3.6 km/h	1 km/h = $\frac{1}{3.6}$ m/s

* e.g.: 100 $ with 3 % compound interest for 5 years: $A = 100\ \$ \cdot (1+0.03)^5$

Formulas from the Theory of Relativity

Addition of velocities	$v_{tot} = \frac{v_1 + v_2}{1 + \frac{v_1 \cdot v_2}{c^2}}$
Lorentz Factor	$r = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$
Mass in special relativity	$m(v) = m_0 \cdot r = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$
Time dilation	$\Delta t(v) = \Delta t_0 \cdot r = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$
Length contraction	$\Delta x(v) = \frac{\Delta x}{r} = \Delta x \cdot \sqrt{1 - \frac{v^2}{c^2}}$
Energy (common)	$E = m \cdot c^2$
Energy of rest mass	$E_0 = m_0 \cdot c^2$
Total energy of a moving body	$E(v) = m(v) \cdot c^2 = E_0 \cdot r = \frac{m_0 \cdot c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$
Kinetic energy of a moving body	$E_{kin}(v) = E(v) - E_0 = \frac{m_0 \cdot c^2}{\sqrt{1 - \frac{v^2}{c^2}}} - m_0 \cdot c^2$

v as a part of c	**r**
0.25	1.0327
0.5	1.1547
0.75	1.5118
0.92	2.5316
0.99	7.08
0.999	22.36
0.999999	707
0.999999999	22360
0.999999999999	707075

Background Information about Star Trek

Starship U.S.S. Enterprise (NCC 1701 D)

Mass	4.9 Million metric tons
Decks	24
Length	642.5 m
Width	467 m
Height	137.5 m
Deuterium on board	5,380 metric tons
Antimatter on board	240 metric tons
maximum cruising speed	Warp 9.2 = 1649·c (see next page)
maximum top speed	Warp 9.6 for 12 hours (see next page)

Transporter Systems

Range personnel transporters	40,000 km
Range emergency transporters	15,000 km
Time for one transport	5 seconds

The human body consists of ca. 10^{28} atoms or molecules.
Approximation for a humanoid: ca. 10^{28} kilobytes amount of data
(ca. one kilobyte for each atom or molecule)

Impulse Drive

Acceleration (Full Impulse Power)	10 $\frac{\text{km}}{\text{s}^2}$ (ca. 1000 g)
Acceleration (¼ Impulse Power)	2.5 $\frac{\text{km}}{\text{s}^2}$ (ca. 250 g)
Full Impulse Speed	¼ of speed of light (75,000 $\frac{\text{km}}{\text{s}}$ = 270,000,000 $\frac{\text{km}}{\text{h}}$)
¼ Impulse Speed	$\frac{1}{16}$ of speed of light (18,750 $\frac{\text{km}}{\text{s}}$ = 67,500,000 $\frac{\text{km}}{\text{h}}$)

Warp Drive

Warp factor Kirk-Era:

$v = f^3$ with v: velocity f: warp factor

warp factor	velocity	time for 1 light year	
1	1	365.25 d	
2	8	45.6 d	Note:
3	27	13.5 d	velocity = 27 means 27 times c (speed of light)
4	64	5.7 d	
5	125	2.9 d	
6	216	1.7 d	
7	343	1.1 d	
8	512	17.1 h	
9	729	12.0 h	
10	1000	8.8 h	
11	1331	6.6 h	
12	1728	5.1 h	
13	2197	4.0 h	

Warp factor Picard-Era:

$f = \sqrt[\frac{10}{3}]{\frac{v}{c}}$ or $v = f^{\frac{10}{3}} \cdot c$ with v: velocity c: speed of light f: warp factor (for warp factors up to 9)

warp factor	velocity	time for 1 light year	
1	1	365.25 d	
2	10	36.5 d	
3	39	9.4 d	
4	102	3.6 d	
5	214	1.7 d	Note:
6	392	22.3 h	Unit for subspace field stress in Star Trek TNG:
7	656	13.4 h	**Cochrane (cr)**
8	1024	8.5 h	named after Zefram Cochrane (2030 - 2117?)
9	1516	5.8 h	Cochrane corresponds with the velocity
9.2	1649	5.3 h	warp factor 1 = 1 Cochrane (speed of light)
9.6	1909	4.5 h	warp factor 5 = 214 Cochranen (214 times sol.)
9.9	3053	2.8 h	
9.99	7912	1.1 h	
9.9999	199512	2.6 min	
10	infinite	-	