Appendix I

Correlation Coefficients*

This table shows the probability to obtain a given correlation coefficient r for two variables for which there is in fact no correlation. This probability is a strong function of the number of data pairs n. As an illustration of the table, consider the case of $n=12$. There is a 10% probability of obtaining a value of $r \geq 0.497$, a 2% probability of obtaining a value of $r \geq 0.658$, and a 0.1% probability of obtaining a value of $r \geq 0.823$ for data for which no actual correlation exists. For many cases in this laboratory manual, you will take data which produces values of r greater than the 0.1% probability for the particular value of n. In those cases one can conclude that the data is strong evidence for a linear relationship between the variables.

Probability (%)

n	10	5	2	1	0.1
3	0.988	0.997	0.999	1.000	1.000
4	0.900	0.950	0.980	0.990	0.999
5	0.805	0.878	0.934	0.959	0.992
6	0.729	0.811	0.882	0.917	0.974
7	0.669	0.754	0.833	0.874	0.951
8	0.621	0.707	0.789	0.834	0.925
9	0.582	0.666	0.750	0.798	0.898
10	0.549	0.632	0.716	0.765	0.872
11	0.521	0.602	0.685	0.735	0.847
12	0.497	0.576	0.658	0.708	0.823
15	0.441	0.514	0.592	0.641	0.760
20	0.378	0.444	0.516	0.561	0.679

*This table is adapted from Table VI of Fisher and Yates, "Statistical Tables for Biological, Agricultural, and Medical Research," published by Oliver & Boyd, Ltd., Edinburgh, by permission of the authors and publishers.

Appendix II

Properties of Materials

Table II A Density of Substances (kg/m^3)

Substance	Density	Substance	Density
Aluminum	2.7×10^3	Cork	$0.22\text{-}0.26 \times 10^3$
Brass	8.4×10^3	Oak wood	$0.60\text{-}0.90 \times 10^3$
Copper	8.9×10^3	Maple wood	$0.62\text{-}0.75 \times 10^3$
Gold	19.3×10^3	Pine wood	$0.35\text{-}0.50 \times 10^3$
Iron	7.85×10^3	Alcohol, ethyl	0.79×10^3
Lead	11.3×10^3	Alcohol, methyl	0.81×10^3
Nickel	8.7×10^3	Mercury	13.6×10^3
Steel	7.8×10^3	Pure water	1.000×10^3
Zinc	7.1×10^3	Sea water	1.025×10^3

Table II B Specific Heats (Calories/gram-^{0}C)

Substance	Specific heat	Substance	Specific heat
Aluminum	0.22	Mercury	0.033
Brass	0.092	Steel	0.12
Copper	0.093	Tin	0.054
Iron	0.11	Water	1.000
Lead	0.031	Zinc	0.093

Table II C Thermal Coefficients of Expansion$(^0C)^{-1}$

Substance	α	Substance	α
Aluminum	24×10^{-6}	Brass and bronze	19×10^{-6}
Copper	17×10^{-6}	Lead	29×10^{-6}
Pyrex glass	3.2×10^{-6}	Ordinary glass	9×10^{-6}
Steel	11×10^{-6}	Concrete	12×10^{-6}
Gold	14×10^{-6}	Tin	27×10^{-6}

Table II D Resistivities and Temperature Coefficients

Substance	Resistivity (Ω-m)	Temperature Coefficient $(^0C)^{-1}$
Aluminum	2.82×10^{-8}	3.9×10^{-3}
Copper	1.72×10^{-8}	3.9×10^{-3}
Silver	1.59×10^{-8}	3.8×10^{-3}
Gold	2.44×10^{-8}	3.4×10^{-3}
Nickel-silver	33×10^{-8}	0.4×10^{-3}
Tungsten	5.6×10^{-8}	4.5×10^{-3}
Iron	10×10^{-8}	5.0×10^{-3}
Lead	22×10^{-8}	3.9×10^{-3}
Carbon	3.5×10^{-5}	-0.5×10^{-3}

Appendix III

Some Fundamental Constants*

Quantity	Symbol	Value†
Atomic mass unit	u	$1.660\ 540\ 2(10) \times 10^{-27}$ kg 931.434 32(28) MeV / c^2
Avogadro's number	N_A	$6.022\ 136\ 7(36) \times 10^{23}$ $(\text{mol})^{-1}$
Bohr magneton	$\mu_B = \frac{eh}{2m_e}$	$9.274\ 015\ 4(31) \times 10^{-24}$ J/T
Bohr radius	$a_0 = \frac{\hbar^2}{m_e e^2 k_e}$	$0.5929\ 177\ 249(24) \times 10^{-10}$ m
Boltmann's constant	$k_B = R/N_A$	$1.380\ 658(12) \times 10^{-23}$ J/K
Compton wavelength	$\lambda_C = \frac{h}{m_e c}$	$2.426\ 310\ 58(22) \times 10^{-12}$ m
Deuteron mass	m_d	$3.343\ 586\ 0\ (20) \times 10^{-27}$ kg 2.013 553 214(24) u
Electron mass	m_e	$9.109\ 389\ 7(54) \times 10^{-31}$ kg $5.485\ 799\ 03(13) \times 10^{-4}$ u 0.510 999 06(15) MeV/c^2
Electron-volt	eV	$1.602\ 177\ 33\ (49) \times 10^{-19}$ J
Elementary charge	e	$1.602\ 177\ 33\ (49) \times 10^{-19}$ C
Gas Constant	R	8.314 510(70) J/K · mol
Gravitational constant	G	$6.672\ 59(85) \times 10^{-11}$ N · m^2/kg^2
Hydrogen ground state	$E_0 = \frac{m_e c^2 k_e^2}{2\hbar^2} = \frac{e^2 k_e}{2a_0}$	13.605 698(40) eV
Josephson frequency-voltage ratio	$2e/h$	$4.835\ 976\ 7(14) \times 10^{14}$ Hz/V
Magnetic flux quantum	$\Phi_0 = \frac{h}{2e}$	$2.067\ 834\ 61(61) \times 10^{-15}$ Wb
Neutron mass	m_n	$1.674\ 928\ 6(10) \times 10^{-27}$ kg 1.008 664 904(14) u 939.565 63(28) MeV/c^2
Nuclear magneton	$\mu_n = \frac{eh}{2m_p}$	$5.050\ 786\ 6(17) \times 10^{-27}$ J/T
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2 (exact)
Permittivity of free space	$\varepsilon_0 = 1/\mu_0 c^2$	$8.854\ 187\ 817 \times 10^{-12}$ $C^2/N \cdot m^2$ (exact)
Planck's constant	h	$6.626\ 075(40) \times 10^{-34}$ J · s
	$\hbar = h/2\pi$	$1.054\ 572\ 66(63) \times 10^{-34}$ J · s
Proton mass	m_p	$1.672\ 623(10) \times 10^{-27}$ kg 1.007 276 470(12) u 938.272 3(28) MeV/c^2
Quantized Hall resistance	h/e^2	25812.805 6(12) Ω
Rydberg constant	R_H	$1.097\ 373\ 153\ 4(13) \times 10^7$ m^{-1}
Speed of light in vacuum	c	$2.997\ 924\ 58 \times 10^8$ m/s (exact)

* These constants are the values recommended in 1986 by CODATA, based on a least squares adjustment of data from different measurements. For a more complete list, see Cohen, E. Richard, and Barry N. Taylor, *Rev. Mod. Phys.* **59**:1121, 1987

† The numbers in parentheses for the values below represent the uncertainties in the last decimal places.

Solar System Data

Body	Mass (kg)	Mean Radius (m)	Period (s)	Distance from Sun (m)
Mercury	3.18×10^{23}	2.43×10^{6}	7.60×10^{6}	5.79×10^{10}
Venus	4.88×10^{24}	6.06×10^{6}	1.94×10^{7}	1.08×10^{11}
Earth	5.98×10^{24}	6.37×10^{6}	3.156×10^{7}	1.496×10^{11}
Mars	6.42×10^{23}	3.37×10^{6}	5.94×10^{7}	2.28×10^{11}
Jupiter	1.90×10^{27}	6.99×10^{7}	3.74×10^{8}	7.78×10^{11}
Saturn	5.68×10^{26}	5.85×10^{7}	9.35×10^{8}	1.43×10^{12}
Uranus	8.68×10^{25}	2.33×10^{7}	2.64×10^{9}	2.87×10^{12}
Neptune	1.03×10^{26}	2.21×10^{7}	5.22×10^{9}	4.50×10^{12}
Pluto	$\approx 1.4 \times 10^{22}$	$\approx 1.5 \times 10^{6}$	7.82×10^{9}	5.91×10^{12}
Moon	7.36×10^{22}	1.74×10^{6}	—	—
Sun	1.991×10^{30}	6.96×10^{8}	—	—

Physical Data Often Used*

Average Earth-Moon distance	3.84×10^{8} m
Average Earth-Sun distance	1.496×10^{11} m
Average radius of the Earth	6.37×10^{6} m
Density of air (20°C and 1 atm)	1.20 kg/m^3
Density of water (20°C and 1 atm)	1.00×10^{3} kg/m^3
Free-fall acceleration	9.80 m/s^2
Mass of the Earth	5.98×10^{24} kg
Mass of the Moon	7.36×10^{22} kg
Mass of the Sun	1.99×10^{30} kg
Standard atmospheric pressure	1.013×10^{5} Pa

* These are the values of the constants as used in the text.

Some Prefixes for Powers of Ten

Power	Prefix	Abbreviation	Power	Prefix	Abbreviation
10^{-18}	atto	a	10^{1}	deka	da
10^{-15}	femto	f	10^{2}	hecto	h
10^{-12}	pica	p	10^{3}	kilo	k
10^{-9}	nano	n	10^{6}	mega	M
10^{-6}	micro	μ	10^{9}	giga	G
10^{-3}	milli	m	10^{12}	tera	T
10^{-2}	centi	c	10^{15}	peta	P
10^{-1}	deci	d	10^{18}	exa	E

Standard Abbreviations and Symbols for Units

Symbol	Unit	Symbol	Unit
A	ampere	in.	inch
Å	angstrom	J	joule
u	atomic mass unit	K	kelvin
atm	atmosphere	kcal	kilocalorie
Btu	British thermal unit	kg	kilogram
C	coulomb	kmol	kilomole
°C	degree Celsius	lb	pound
cal	calorie	m	meter
deg	degree (angle)	min	minute
eV	electron volt	N	newton
°F	degree Fahrenheit	Pa	pascal
F	farad	rev	revolution
ft	foot	s	second
G	gauss	T	Tesla
g	gram	V	volt
H	henry	W	watt
h	hour	Wb	weber
hp	horsepower	μm	micrometer
Hz	hertz	Ω	ohm

Mathematical Symbols Used in the Text and Their Meaning

Symbol	Meaning
$=$	is equal to
$\equiv$	is defined as
$\neq$	is not equal to
$\propto$	is proportional to
$>$	is greater than
$<$	is less than
$\gg (\ll)$	is much greater (less) than
$\approx$	is approximately equal to
Δx	the change in x
$\sum_{i=1}^{n} x_i$	the sum of all quantities x_i from $i = 1$ to $i = n$
$\lvert x \rvert$	the magnitude of x (always a nonnegative quantity)
$\Delta x \to 0$	Δx approaches zero
$\frac{dx}{dt}$	the derivative of x with respect to t
$\frac{\partial x}{\partial t}$	the partial derivative of x with respect to t
$\int$	integral

Conversions

Length

1 in. = 2.54 cm
1 m = 39.37 in. = 3.281 ft
1 ft = 0.3048 m
12 in. = 1 ft
3 ft = 1 yd
1 yd = 0.9144 m
1 km = 0.621 mi
1 mi = 1.609 km
1 mi = 5280 ft
1 Å = 10^{-10} m
1 μm = 1μ = 10^{-6}m = 10^{4} Å
1 lightyear = 9.461×10^{15} m

Area

1 m^2 = 10^4 cm^2 = 10.76 ft^2
1 ft^2 = 0.0929 m^2 = 144 in^2
1 in^2 = 6.452 cm^2

Volume

1 m^3 = 106 cm^3 = 6.102×10^4 in^3
1 ft^3 = 1728 in^3 = 2.83×10^{-2} m^3
1 liter = 1000 cm^3 = 1.0576 qt = 0.0353 ft^3
1 ft^3 = 7.481 gal = 28.32 liters = 2.832×10^{-2} m^3
1 gal = 3.786 liters = 231 in^3

Mass

1000 kg = 1 t (metric ton)
1 slug = 14.59 kg
1 u = 1.66×10^{-27} kg

Force

1 N = 10^5 = dyne = 0.2248 lb
1 lb = 4.448 N
1 dyne = 10^{-5} = N = 2.248×10^{-6} lb

Velocity

1 mi/h = 1.47 ft/s = 0.447 m/s = 1.61 km/h
1 m/s = 100 cm/s = 3.281 ft/s
1 mi/min = 60 mi/h = 88 ft/s

Acceleration

1m/s^2 = 3.28 ft/s^2 = 100 cm/s^2
1ft/s^2 = 0.3048 m/s^2 = 30.48 cm/s^2

Pressure

1 bar = 10^5 N/m^2 = 14.50 lb/in^2
1 atm = 760 mm Hg = 76.0 cm Hg
1 atm = 14.7 lb/in^2 = 1.013 3 10^5 N/m^2
1 Pa = 1 N/m^2 = 1.45×10^{-4} lb/in^2

Time

1 year = 365 days = 3.16×10^7 s
1 day = 24 h = 1.44×10^3 min = 8.64×10^4 s

Energy

1 J = 0.738 ft · lb = 10^7 erg
1 cal = 4.186 J
1 Btu = 252 cal = 1.054×10^3 J
1eV = 1.6×10^{-19} J
931.5 $\frac{\text{MeV}}{c^2}$ is equivalent to 1 u
1 kWh = 3.60×10^6 J

Power

1 hp = 550 ft · lb/s = 0.746 kW
1 W = 1 J/s = 0.738 ft · lb/s
1 Btu/h = 0.293 W

The Greek Alphabet

Alpha	A	α	Iota	I	ι	Rho	P	ρ
Beta	B	β	Kappa	K	κ	Sigma	Σ	σ
Gamma	Γ	γ	Lambda	Λ	λ	Tau	T	τ
Delta	Δ	δ	Mu	M	μ	Upsilon	Y	υ
Epsilon	E	ε	Nu	N	ν	Phi	Φ	ϕ
Zeta	Z	ζ	Xi	Ξ	ξ	Chi	X	χ
Eta	H	η	Omicron	O	o	Psi	Ψ	ψ
Theta	Θ	θ	Pi	Π	π	Omega	Ω	ω