the industry standard

power engineering
TRAINING SYSTEMS

Handbook of Formulae and Physical Constants

For The Use Of Students And Examination Candidates

Approved by the Interprovincial Power Engineering Curriculum Committee and the Provincial Chief Inspectors' Association's Committee for the standardization of Power Engineer's Examinations in Canada.

Table of Contents

Names in the Metric System

VALUE	EXPONENT	SYMBOL	PREFIX
1 000 000 000 000	10^{12}	T	tera
1 000 000 000	10^{9}	G	giga
1 000 000	10^{6}	M	mega
1 000	10^{3}	k	kilo
100	10^{2}	h	hecto
10	10^{1}	da	deca
0.1	10^{-1}	d	deci
0.01	10^{-2}	c	centi
0.001	10^{-3}	m	milli
0.000 001	10^{-6}	μ	micro
0.000 000 001	10^{-9}	n	nano
0.000 000 000 001	10^{-12}	p	pico

Conversion Chart for Metric Units

To Convert

	To Milli-	To Centi-	To Deci-	To Metre, Gram, Litre	To Deca-	To Hecto-	To Kilo-
Kilo-	x 10^{6}	x 10^{5}	x 10^{4}	x 10^{3}	x 10^{2}	x 10^{1}	
Hecto-	x 10^{5}	x 10^{4}	x 10^{3}	x 10^{2}	x 10^{1}		x 10^{-1}
Deca-	x 10^{4}	x 10^{3}	x 10^{2}	x 10^{1}		x 10^{-1}	x 10^{-2}
Metre, Gram, Litre	x 10^{3}	x 10^{2}	x 10^{1}		x 10^{-1}	x 10^{-2}	x 10^{-3}
Deci-	x 10^{2}	x 10^{1}		x 10^{-1}	x 10^{-2}	x 10^{-3}	x 10^{-4}
Centi-	x 10^{1}		x 10^{-1}	x 10^{-2}	x 10^{-3}	x 10^{-4}	x 10^{-5}
Milli-		x 10^{-1}	x 10^{-2}	x 10^{-3}	x 10^{-4}	x 10^{-5}	x 10^{-6}

BASIC UNITS

SI	IMPERIAL
DISTANCE	
1 metre (1 m) = 100 centimetres (100 cm) = 1000 millimetres (1000 mm)	12 in. = 1 ft 3 ft = 1 yd 5280 ft = 1 mile 1760 yd = 1 mile
1 kilometre (1 km) = 1000 m	

Conversions:

1 in. = 25.4 mm
1 ft = 30.48 cm
1 mile = 1.61 km
1 yd = 0.914 m
1 m = 3.28 ft

Area

1 sq metre (1 m^2) = 10 000 cm^2 = 1 000 000 mm^2	1 ft^2 = 144 $in.^2$ 1 yd^2 = 9 ft^2 1 sq mile = 640 acre = 1 section
10 000 m^2 = 1 hectare (1 ha)	
1 sq km (1 km^2) = 1 000 000 m^2	

Conversions:

1 $in.^2$ = 6.45 cm^2 = 645 mm^2
1 m^2 = 10.8 ft^2
1 acre = 0.405 ha
1 sq mile = 2.59 km^2

SI	IMPERIAL

Volume

1 m^3	=	1 000 000 cm^3
	=	1 x 10^9 mm^3
1 dm^3	=	1 litre
1 litre	=	1000 cm^3
1 mL	=	1 cm^3
1 m^3	=	1000 litres

1 ft^3	=	1728 $in.^3$
1 yd^3	=	27 ft^3
1(liquid) U.S. gallon	=	231 $in.^3$
	=	4 (liquid) quarts
1 U.S. barrel (bbl)	=	42 U.S. gal.
1 imperial gallon	=	1.2 U.S. gal.

Conversions:

1 $in.^3$	=	16.4 cm^3
1 m^3	=	35.3 ft^3
1 litre	=	61 $in.^3$
1 U.S.gal	=	3.78 litres
1 U.S. bbl	=	159 litres
1 litre/s	=	15.9 U.S. gal/min

Mass and Weight

1 kilogram (1 kg)	=	1000 grams
1000 kg	=	1 tonne

2000 lb	=	1 ton (short)
1 long ton	=	2240 lb

Conversions:

1 kg (on Earth) results in a weight of 2.2 lb

Density

$$\text{mass density} = \frac{\text{mass}}{\text{volume}}$$

$$\rho = \frac{m}{V} \quad \left(\frac{kg}{m^3}\right)$$

$$\text{weight density} = \frac{\text{weight}}{\text{volume}}$$

$$\rho = \frac{w}{V} \quad \left(\frac{lb}{ft^3}\right)$$

Conversions:

(on Earth) a mass density of 1 $\frac{kg}{m^3}$ results in a weight density of 0.0623 $\frac{lb}{ft^3}$

SI	Imperial

RELATIVE DENSITY

In SI R.D. is a comparison of mass density to a standard. For solids and liquids the standard is fresh water.

In Imperial the corresponding quantity is **specific gravity**; for solids and liquids a comparison of weight density to that of water.

Conversions:

In both systems the same numbers hold for R.D. as for S.G. since these are equivalent ratios.

RELATIVE DENSITY (SPECIFIC GRAVITY) OF VARIOUS SUBSTANCES

Water (fresh)	1.00	Mica	2.9
Water (sea average)	1.03	Nickel	8.6
Aluminum	2.56	Oil (linseed)	0.94
Antimony	6.70	Oil (olive)	0.92
Bismuth	9.80	Oil (petroleum)	0.76-0.86
Brass	8.40	Oil (turpentine)	0.87
Brick	2.1	Paraffin	0.86
Calcium	1.58	Platinum	21.5
Carbon (diamond)	3.4	Sand (dry)	1.42
Carbon (graphite)	2.3	Silicon	2.6
Carbon (charcoal)	1.8	Silver	10.57
Chromium	6.5	Slate	2.1-2.8
Clay	1.9	Sodium	0.97
Coal	1.36-1.4	Steel (mild)	7.87
Cobalt	8.6	Sulphur	2.07
Copper	8.77	Tin	7.3
Cork	0.24	Tungsten	19.1
Glass (crown)	2.5	Wood (ash)	0.75
Glass (flint)	3.5	Wood (beech)	0.7-0.8
Gold	19.3	Wood (ebony)	1.1-1.2
Iron (cast)	7.21	Wood (elm)	0.66
Iron (wrought)	7.78	Wood (lignum-vitae)	1.3
Lead	11.4	Wood (oak)	0.7-1.0
Magnesium	1.74	Wood (pine)	0.56
Manganese	8.0	Wood (teak)	0.8
Mercury	13.6	Zinc	7.0

Greek Alphabet

Alpha	α	Iota	ι	Rho	ρ
Beta	β	Kappa	κ	Sigma	Σ, σ
Gamma	γ	Lambda	λ	Tau	τ
Delta	Δ	Mu	μ	Upsilon	υ
Epsilon	ε	Nu	ν	Phi	Φ, ϕ
Zeta	ζ	Xi	ξ	Kai	χ
Eta	η	Omicron	O	Psi	ψ
Theta	θ	Pi	π	Omega	Ω, ω

MATHEMATICAL FORMULAE

Logarithms

$P=V^x$ or $x = \log P/\log V$

Algebra

1. Quadratic Equation

If $ax^2 + bx + c = 0$,

Then $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

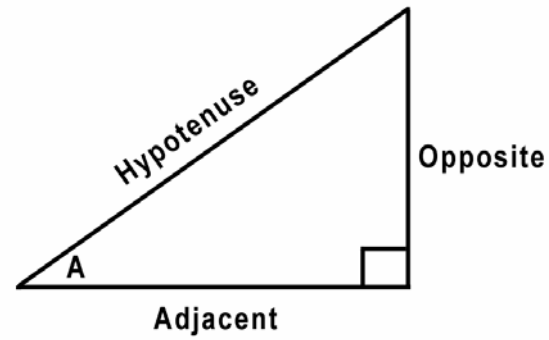
Trigonometry

1. Basic Ratios

$$\sin A = \frac{\text{opposite}}{\text{hypotenuse}},$$

$$\cos A = \frac{\text{adjacent}}{\text{hypotenuse}},$$

$$\tan A = \frac{\text{opposite}}{\text{adjacent}}$$



2. Pythagoras' Law (applies to right angle triangles)

$\text{opposite}^2 + \text{adjacent}^2 = \text{hypotenuse}^2$

3. Trigonometric Function Values

Sin is positive from 0° to 90° and positive from 90° to 180°

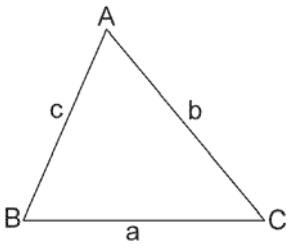
Cos is positive from 0° to 90° and negative from 90° to 180°

Tan is positive from 0° to 90° and negative from 90° to 180°

4. Solution of Triangles

a. Sine Law

$$\frac{a}{\text{Sin A}} = \frac{b}{\text{Sin B}} = \frac{c}{\text{Sin C}}$$



b. Cosine Law

$$c^2 = a^2 + b^2 - 2\,ab\,\text{Cos C}$$

$$a^2 = b^2 + c^2 - 2\,bc\,\text{Cos A}$$

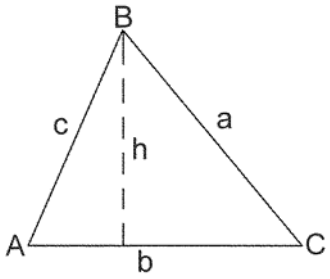
$$b^2 = a^2 + c^2 - 2\,ac\,\text{Cos B}$$

Geometry

1. Areas of Triangles

a. All Triangles

$$\text{Area} = \frac{\text{base} \times \text{perpendicular height}}{2}$$



$$\text{Area} = \frac{bc\,\text{Sin A}}{2} = \frac{ab\,\text{Sin C}}{2} = \frac{ac\,\text{Sin B}}{2}$$

and,

$$\text{Area} = \sqrt{s\,(s-a)\,(s-b)\,(s-c)}$$

where, s is half the sum of the sides, or $s = \frac{a+b+c}{2}$

b. Equilateral Triangles

$$\text{Area} = 0.433 \times \text{side}^2$$

2. Circumference of a Circle

$$C = \pi d$$

3. Area of a Circle

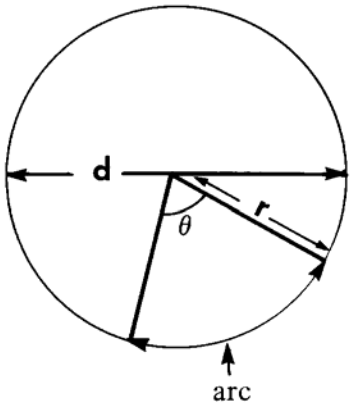
$$A = \pi r^2 = \frac{\text{circumference} \times r}{2} = \frac{\pi}{4} d^2 = 0.7854 d^2$$

4. Area of a Sector of a Circle

$$A = \frac{\text{arc} \times r}{2}$$

$$A = \frac{\theta^\circ}{360} \times \pi r^2 \qquad (\theta = \text{angle in degrees})$$

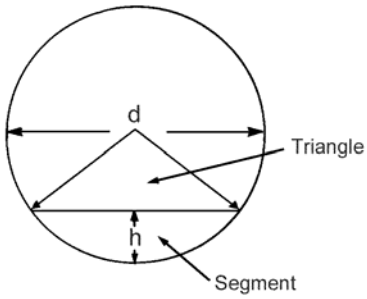
$$A = \frac{\theta^\circ r^2}{2} \qquad (\theta = \text{angle in radians})$$



5. Area of a Segment of a Circle

A = area of sector – area of triangle

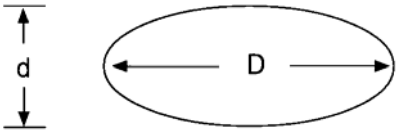
Also approximate area = $\frac{4}{3} h^2 \sqrt{\frac{d}{h} - 0.608}$



6. Ellipse

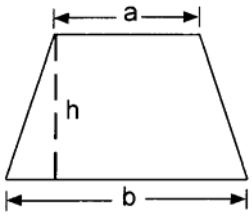
$$A = \frac{\pi}{4} Dd$$

Approx. circumference = $\pi \frac{(D + d)}{2}$



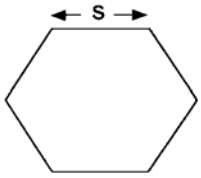
7. Area of Trapezoid

$$A = \left(\frac{a + b}{2}\right) h$$

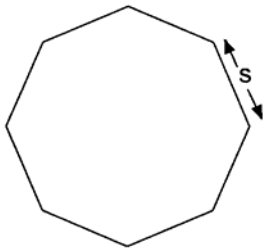


8. Area of Hexagon

$A = 2.6s^2$ where s is the length of one side



9. Area of Octagon

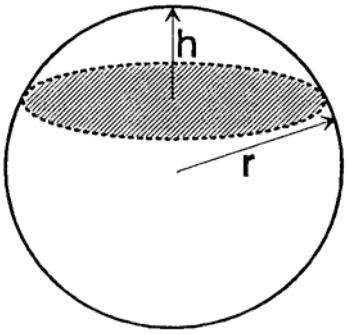


$A = 4.83s^2$ where s is the length of one side

10. Sphere

Total surface area $A = 4\pi r^2$

Surface area of segment $A_s = \pi dh$



Volume $V = \frac{4}{3}\pi r^3$

Volume of segment

$V_s = \frac{\pi h^2}{3}(3r - h)$

$V_s = \frac{\pi h}{6}(h^2 + 3a^2)$ where a = radius of segment base

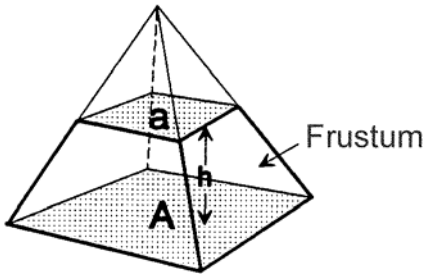
11. Volume of a Cylinder

$V = \frac{\pi}{4}d^2L$ where L is cylinder length

12. Pyramid

Volume

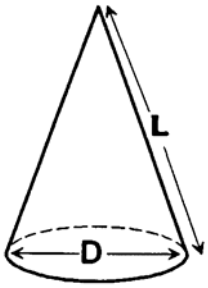
$V = \frac{1}{3}$ base area x perpendicular height



Volume of frustum

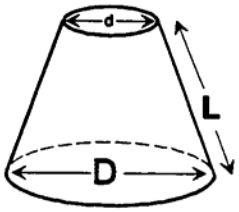
$V_F = \frac{h}{3}(A + a + \sqrt{Aa})$ where h is the perpendicular height, A and a are areas as shown

13. Cone



Area of curved surface of cone:

$$A = \frac{\pi DL}{2}$$



Area of curved surface of frustum

$$A_F = \frac{\pi (D + d)L}{2}$$

Volume of cone:

$$V = \frac{\text{base area} \times \text{perpendicular height}}{3}$$

Volume of frustum:

$$V_F = \frac{\text{perpendicular height} \times \pi\ (R^2 + r^2 + Rr)}{3}$$

Velocity - vector property equal to $\frac{\text{displacement}}{\text{time}}$

In SI the basic unit is $\frac{m}{s}$, in Imperial $\frac{ft}{s}$

Other common units are $\frac{km}{h}$, $\frac{mi}{h}$

Conversions: $1\frac{m}{s} = 3.28\frac{ft}{s}$

$$1\frac{km}{h} = 0.621\frac{mi}{h}$$

Speed of sound in dry air is 331 $\frac{m}{s}$ at 0°C and increases by about 0.61 $\frac{m}{s}$ for each °C rise

Speed of light in vacuum equals 3×10^8 $\frac{m}{s}$

Acceleration - vector property equal to $\frac{\text{change in velocity}}{\text{time}}$

In SI the basic unit is $\frac{m}{s^2}$, in Imperial $\frac{ft}{s^2}$

Conversion: $1\frac{m}{s^2} = 3.28\frac{ft}{s^2}$

Acceleration due to gravity, symbol "g", is 9.81 $\frac{m}{s^2}$ or 32.2 $\frac{ft}{s^2}$

Linear Velocity and Acceleration

u initial velocity
v final velocity
t elapsed time
s displacement
a acceleration

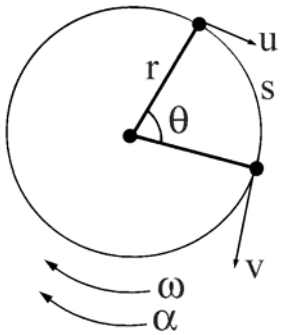
$$v = u + at$$

$$s = \left(\frac{v + u}{2}\right)t$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Angular Velocity and Acceleration



θ angular displacement (radians)
ω angular velocity (radians/s); ω_1 = initial, ω_2 = final
α angular acceleration (radians/s^2)

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

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

$$\theta = \omega_1 t + \tfrac{1}{2}\alpha t^2$$

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

linear displacement, $s = r\theta$
linear velocity, $v = r\omega$
linear, or tangential acceleration, $a_T = r\alpha$

radians/sec = 2πrpm/60

Tangential, Centripetal and Total Acceleration

Tangential acceleration a_T is due to angular acceleration α

$$a_T = r\alpha$$

Centripetal (Centrifugal) acceleration a_c is due to change in direction only

$$a_c = v^2/r = r\,\omega^2$$

Total acceleration, a, of a rotating point experiencing angular acceleration is the vector sum of a_T and a_c

$$a = a_T + a_c$$

Force

In SI the unit of force is the newton, N, defined as a $\frac{kg\ m}{s^2}$

In Imperial the unit of force is the pound lb

Conversion: 9.81 N = 2.2 lb

Weight

In SI weight can be calculated from

$$\text{Weight} = F = mg, \quad \text{where } g = 9.81\ m/s^2$$

In Imperial, the mass of an object (rarely used), in slugs, can be calculated from the known weight in pounds

$$m = \frac{\text{Weight}}{g} \qquad g = 32.2\frac{ft}{s^2}$$

Newton's Second Law of Motion

An unbalanced force F will cause an object of mass m to accelerate a, according to:

$F = ma$ (Imperial $F = \frac{w}{g} a$, where w is weight)

Torque Equation

Torque = force x radius

$T = I \alpha$ where T is the acceleration torque in Nm, I is the moment of inertia in kg m^2 and α is the angular acceleration in radians/s^2

Momentum

Vector quantity, symbol p,

$p = mv$ (Imperial $p = \frac{w}{g} v$, where w is weight)

in SI unit is $\frac{kg\ m}{s}$

Work

$W = F s$

In SI the unit of work is the joule, J, or kilojoule, kJ

1 J = 1 Nm

In Imperial the unit of work is the ft-lb

Kinetic Energy

Energy due to motion

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

In Imperial this is usually expressed as $E_k = \frac{w}{2g}v^2$ where w is weight

Kinetic Energy of Rotation

$$E_R = \frac{1}{2} m k^2 \omega^2$$ where k is radius of gyration, ω is angular velocity in rad/s

or

$$E_R = \frac{1}{2} I \omega^2$$ where $I = mk^2$ is the moment of inertia

Centripetal (Centrifugal) Force

$$F_C = \frac{mv^2}{r}$$ where r is the radius

or

$F_C = m\ \omega^2\ r$ where ω is angular velocity in rad/s

Potential Energy

Energy due to position in a force field, such as gravity

$E_p = m\ g\ h$

In Imperial this is usually expressed $E_p = w\ h$ where w is weight, and h is height above some specified datum

Thermal Energy

In SI the common units of thermal energy are J, and kJ, (and kJ/kg for specific quantities)

In Imperial, the units of thermal energy are British Thermal Units (Btu)

Conversions: 1 Btu = 1055 J
1 Btu = 778 ft-lb

Electrical Energy

In SI the units of electrical energy are J, kJ and kilowatt hours kWh. In Imperial, the unit of electrical energy is the kWh

Conversions: 1 kWh = 3600 kJ
1 kWh = 3412 Btu = 2.66×10^6 ft-lb

Power

In SI the unit is the Watt W (or kW)

$$1\ W = 1\frac{J}{s}$$

In Imperial, the units are:

Mechanical Power - $\frac{ft - lb}{s}$, horsepower h.p.

Thermal Power - $\frac{Btu}{s}$

Electrical Power - W, kW, or h.p.

Conversions: 746 W = 1 h.p.

$$1\ h.p. = 550\ \frac{ft - lb}{s}$$

$$1\ kW = 0.948\ \frac{Btu}{s}$$

Pressure

A vector quantity, force per unit area

In SI the basic units of pressure are pascals Pa and kPa

$$1\ Pa = 1\ \frac{N}{m^2}$$

In Imperial, the basic unit is the pound per square inch, psi

Atmospheric Pressure

At sea level atmospheric pressure equals 101.3 kPa or 14.7 psi

Pressure Conversions

1 psi = 6.895 kPa

Pressure may be expressed in standard units, or in units of static fluid head, in both SI and Imperial systems

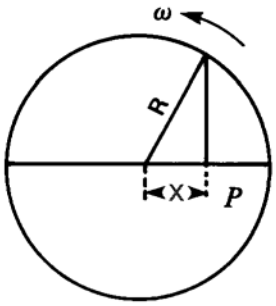
Common equivalencies are:

1 kPa = 0.294 in. mercury = 7.5 mm mercury
1 kPa = 4.02 in. water = 102 mm water
1 psi = 2.03 in. mercury = 51.7 mm mercury
1 psi = 27.7 in. water = 703 mm water
1 m H_2O = 9.81 kPa

Other pressure unit conversions:

1 bar = 14.5 psi = 100 kPa
1 kg/cm^2 = 98.1 kPa = 14.2 psi = 0.981 bar
1 atmosphere (atm) = 101.3 kPa = 14.7 psi

Simple Harmonic Motion



Velocity of P = $\omega\sqrt{R^2 - x^2}\ \frac{m}{s}$

Acceleration of P = ω^2 x m/s^2

The period or time of a complete oscillation = $\frac{2\pi}{\omega}$ seconds

General formula for the period of S.H.M.

$$T = 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}}$$

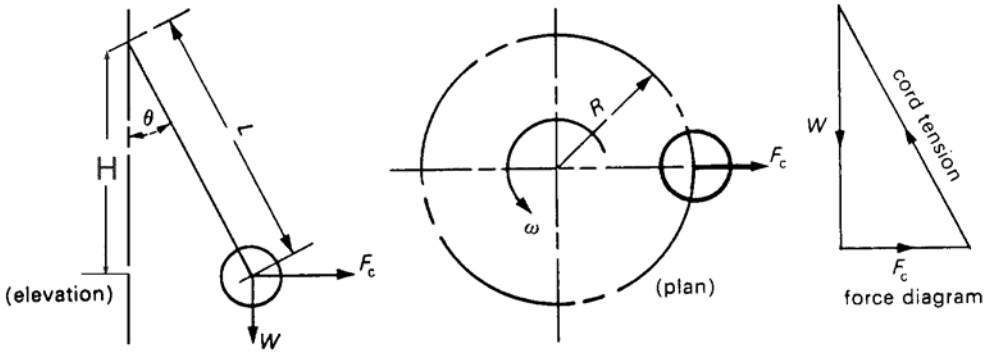
Simple Pendulum

$$T = 2\pi\sqrt{\frac{L}{g}}$$

T = period or time in seconds for a double swing

L = length in metres

The Conical Pendulum



$R/H = \tan\theta = F_c/W = \omega^2 R/g$

Lifting Machines

W = load lifted, F = force applied

$$\text{M.A.} = \frac{\text{load}}{\text{effort}} = \frac{W}{F}$$

$$\text{V.R. (velocity ratio)} = \frac{\text{effort distance}}{\text{load distance}}$$

$$\eta = \text{efficiency} = \frac{\text{M.A.}}{\text{V.R.}}$$

1. Lifting Blocks

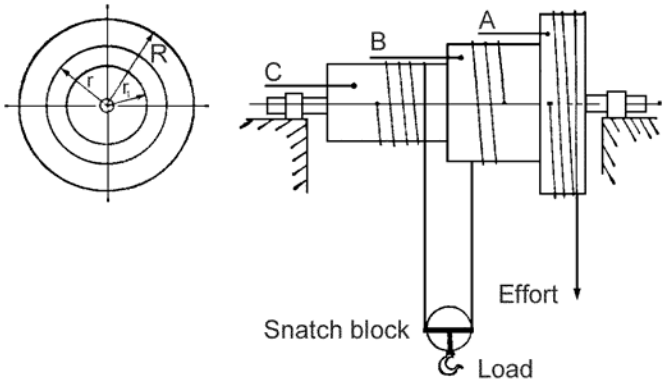
V.R. = number of rope strands supporting the load block

2. Wheel & Differential Axle

$$\text{Velocity ratio} = \frac{2\pi R}{\frac{2\pi(r - r_1)}{2}}$$

$$= \frac{2R}{r - r_1} \underline{2\,R}$$

$$\text{Velocity ratio} = \frac{2D}{(d - d_1)}$$



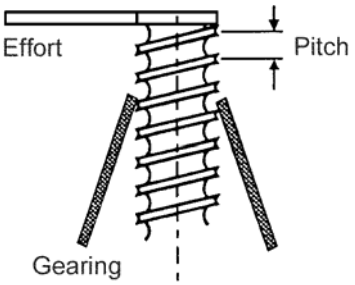
Or, using diameters instead of radii,

3. Inclined Plane

$$\text{V.R.} = \frac{\text{length}}{\text{height}}$$

4. Screw Jack

$$\text{V.R.} = \frac{\text{circumference of leverage}}{\text{pitch of thread}}$$



Indicated Power

$I.P. = P_m A L N$ where I.P. is power in W, P_m is mean or "average" effective pressure in Pa, A is piston area in m^2, L is length of stroke in m and N is number of power strokes per second

Brake Power

$B.P. = T\omega$ where B.P. is brake power in W, T is torque in Nm and ω is angular velocity in radian/second

STRESS, STRAIN and MODULUS OF ELASTICITY

$$\text{Direct stress} = \frac{\text{load}}{\text{area}} = \frac{P}{A}$$

$$\text{Direct strain} = \frac{\text{extension}}{\text{original length}} = \frac{\Delta\ell}{L}$$

Modulus of elasticity

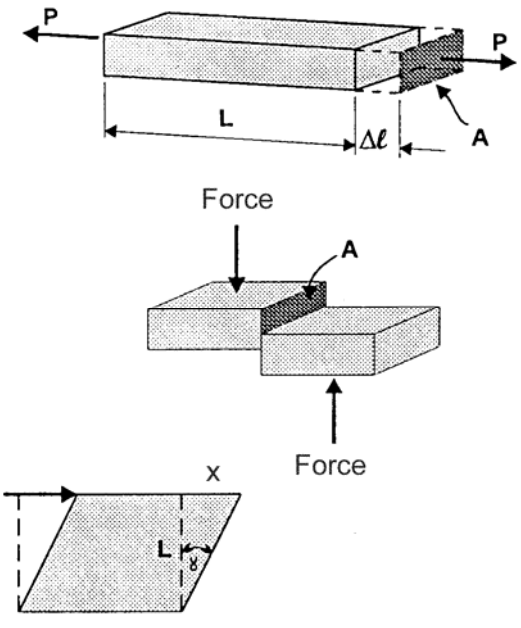
$$E = \frac{\text{direct stress}}{\text{direct strain}} = \frac{P/A}{\Delta\ell / L} = \frac{PL}{A\Delta\ell}$$

$$\text{Shear stress } \tau = \frac{\text{force}}{\text{area under shear}}$$

$$\text{Shear strain} = \frac{x}{L}$$

Modulus of rigidity

$$G = \frac{\text{shear stress}}{\text{shear strain}}$$



General Torsion Equation (Shafts of circular cross-section)

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\,\theta}{L}$$

1. For Solid Shaft

$$J = \frac{\pi}{2} r^4 = \frac{\pi d^4}{32}$$

2. For Hollow Shaft

$$J = \frac{\pi}{2}(r_1^4 - r_2^4)$$

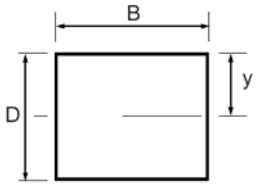
$$= \frac{\pi}{32}(d_1^4 - d_2^4)$$

T = torque or twisting moment in newton metres
J = polar second moment of area of cross-section about shaft axis.
τ = shear stress at outer fibres in pascals
r = radius of shaft in metres
G = modulus of rigidity in pascals
θ = angle of twist in radians
L = length of shaft in metres
d = diameter of shaft in metres

Fundamental Bending Equation

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

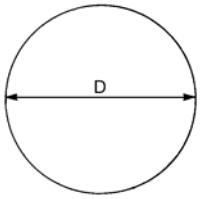
1. For Rectangle



$$I = \frac{BD^3}{12}$$

M = external bending moment in newton metres
I = second moment of area in m^4
σ = bending stress at outer fibres in pascals
y = distance from centroid to outer fibres in metres
E = modulus of elasticity in pascals
R = radius of curative in metres

2. For Solid Shaft



$$I = \frac{\pi D^4}{64}$$

THERMODYNAMICS

The Fundamental Energy Equation

Heat Supplied = Increase in Internal Energy + Work Done
$Q = \Delta U + WD$

Temperature Scales

$$^\circ C = \frac{5}{9}(^\circ F - 32) \qquad ^\circ F = \frac{9}{5}\,^\circ C + 32$$

$^\circ R = ^\circ F + 460$ (R Rankine) $\quad K = ^\circ C + 273$ (K Kelvin)

Sensible Heat Equation

$$Q = mc\Delta T$$

m is mass
c is specific heat
ΔT is temperature change

Latent Heat

Latent heat of fusion of ice	=	335 kJ/kg
Latent heat of steam from and at 100°C	=	2257 kJ/kg
1 tonne of refrigeration	=	335 000 kJ/day
	=	233 kJ/min

Gas Laws

1. Boyle's Law

When gas temperature is constant

$PV = \text{constant}$ or

$P_1V_1 = P_2V_2$

where P is absolute pressure and V is volume

2. Charles' Law

When gas pressure is constant, $\frac{V}{T} = \text{constant}$

or $\frac{V_1}{T_1} = \frac{V_2}{T_2}$, where V is volume and T is absolute temperature

3. Gay-Lussac's Law

When gas volume is constant, $\frac{P}{T} = \text{constant}$

Or $\frac{P_1}{T_1} = \frac{P_2}{T_2}$, where P is absolute pressure and T is absolute temperature

4. General Gas Law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \text{constant}$$

$P\,V = m\,R\,T$ where P = absolute pressure (kPa)
V = volume (m^3)
T = absolute temp (K)
m = mass (kg)
R = characteristic constant (kJ/kgK) = Cp - Cv

Also

$PV = nR_oT$ where P = absolute pressure (kPa)
V = volume (m^3)
T = absolute temperature K
N = the number of kmoles of gas
R_o = the universal gas constant 8.314 kJ/kmol/K

SPECIFIC HEATS OF GASES

GAS	Specific Heat at Constant Pressure kJ/kgK or kJ/kg °C	Specific Heat at Constant Volume kJ/kgK or kJ/kg °C	Ratio of Specific Heats $\gamma = c_p / c_v$
Air	1.005	0.718	1.40
Ammonia	2.060	1.561	1.32
Carbon Dioxide	0.825	0.630	1.31
Carbon Monoxide	1.051	0.751	1.40
Helium	5.234	3.153	1.66
Hydrogen	14.235	10.096	1.41
Hydrogen Sulphide	1.105	0.85	1.30
Methane	2.177	1.675	1.30
Nitrogen	1.043	0.745	1.40
Oxygen	0.913	0.652	1.40
Sulphur Dioxide	0.632	0.451	1.40

Efficiency of Heat Engines

Carnot Cycle $\eta = \dfrac{T_1 - T_2}{T_1}$ where T_1 and T_2 are absolute temperatures of heat source and sink

Air Standard Efficiencies

1. Spark Ignition Gas and Oil Engines (Constant Volume Cycle or Otto Cycle)

$$\eta = 1 - \frac{1}{r_v^{(\gamma - 1)}} \quad \text{where } r_V = \text{compression ratio} = \frac{\text{cylinder volume}}{\text{clearance volume}}$$

$$\gamma = \frac{\text{specific heat (constant pressure)}}{\text{specific heat (constant volume)}}$$

2. Diesel Cycle

$$\eta = 1 - \frac{(R^{\gamma} - 1)}{r_v^{\gamma - 1}\,\gamma(R - 1)}$$

where r = ratio of compression

R = ratio of cut-off volume to clearance volume

3. High Speed Diesel (Dual-Combustion) Cycle

$$\eta = 1 - \frac{k\beta^{\gamma} - 1}{r_v^{\gamma-1}\left[(k-1) + \gamma k(\beta - 1)\right]}$$

where $r_v = \dfrac{\text{cylinder volume}}{\text{clearance volume}}$

$$k = \frac{\text{absolute pressue at end of constant V heating (combustion)}}{\text{absolute pressue at beginning of constant V combustion}}$$

$$\beta = \frac{\text{volume at end of constant P heating (combustion)}}{\text{clearance volume}}$$

4. Gas Turbines (Constant Pressure or Brayton Cycle)

$$\eta = 1 - \frac{1}{r_p^{\left(\frac{\gamma-1}{\gamma}\right)}}$$

where r_p = pressure ratio = $\dfrac{\text{compressor discharge pressure}}{\text{compressor intake pressure}}$

THERMODYNAMIC EQUATIONS FOR PERFECT GASES (Non_Flow Processes)

Name of Process	Value of n	$P-V-T$ Relationships			Heat Added ${}_1Q_2$ kJ	Work Done ${}_1W_2$ kJ	Change In Internal Energy $U_2 - U_1$ kJ	Change In Enthalpy $H_2 - H_1$ kJ	Change In Entropy $S_2 - S_1$ kJ/K
		$P-V$	$T-P$	$T-V$					
Constant Volume V = Const.	∞	———	$\frac{T_1}{T_2} = \frac{P_1}{P_2}$	———	$mc_v(T_2 - T_1)$	0	$mc_v(T_2 - T_1)$	$mc_p(T_2 - T_1)$	$mc_v \ln \frac{T_2}{T_1}$
Constant Pressure P = Const.	0	———	———	$\frac{T_1}{T_2} = \frac{V_1}{V_2}$	$mc_p(T_2 - T_1)$	$P(V_2 - V_1)$	$mc_v(T_2 - T_1)$	$mc_p(T_2 - T_1)$	$mc_p \ln \frac{T_2}{T_1}$
Isothermal T = Const.	1	$\frac{P_1}{P_2} = \frac{V_2}{V_1}$	———	———	$mRT \ln \frac{P_1}{P_2}$	$WD = PV \ln \frac{V_2}{V_1}$	0	0	$mR \ln \frac{P_1}{P_2}$
Isentropic* S = Const.	γ	$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}$	$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}}$	$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$	0	$\frac{P_1V_1 - P_2V_2}{\gamma - 1}$	$mc_v(T_2 - T_1)$	$mc_p(T_2 - T_1)$	0
Polytropic PV^n = Const.	n	$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{n}$	$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{n-1}{n}}$	$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{n-1}$	$mc_n(T_2 - T_1)$	$\frac{P_1V_1 - P_2V_2}{n-1}$	$mc_v(T_2 - T_1)$	$mc_p(T_2 - T_1)$	$mc_n \ln \frac{T_2}{T_1}$

*Can be used for reversible adiabatic processes

c_v = Specific heat at constant volume, kJ/kgK
c_p = Specific heat at constant pressure, kJ/kgK
c_n = Specific heat for a polytropic process = $c_v \left(\frac{\gamma - n}{1 - n}\right)$ kJ/kgK
H = Enthalpy, kJ
γ = Isentropic exponent, c_p/c_v
n = Polytropic exponent
P = Absolute Pressure, kPa

R = Gas Constant, kJ/kgK
S = Entropy, kJ/K
T = Absolute temperature, K = 273 + °C
U = Internal energy, kJ
V = Volume, m^3
m = Mass of gas, kg

Heat Transfer by Conduction

$$Q = \frac{\lambda A t \Delta T}{d}$$

where Q = heat transferred in joules

λ = thermal conductivity or coeficient of heat transfer in $\frac{J \times m}{m^2 \times s \times °C}$ or $\frac{W}{m \times °C}$

A = area in m^2

t = time in seconds

ΔT = temperature difference between surfaces in °C

d = thickness of layer in m

Heat transfer by conduction through a cylindrical wall:

$$Q = \frac{2\pi\lambda t \Delta T L}{\ln\left(\frac{D}{d}\right)}$$

Where D = outside diameter

d = inside diameter

L = length in metres

λ = thermal conductivity

t = time (seconds)

ΔT = temperature difference (degrees C)

COEFFICIENTS OF THERMAL CONDUCTIVITY

Material	Coefficient of Thermal Conductivity W/m °C
Air	0.025
Aluminum	206
Brass	104
Brick	0.6
Concrete	0.85
Copper	380
Cork	0.043
Felt	0.038
Glass	1.0
Glass, fibre	0.04
Iron, cast	70
Plastic, cellular	0.04
Steel	60
Wood	0.15
Wallboard, paper	0.076

Thermal Expansion of Solids

Increase in length $= L \alpha (T_2 - T_1)$
where L = original length
α = coefficient of linear expansion
$(T_2 - T_1)$ = rise in temperature

Increase in volume $= V \beta (T_2 - T_1)$
Where V = original volume
β = coefficient of volumetric expansion
$(T_2 - T_1)$ = rise in temperature

coefficient of volumetric expansion = coefficient of linear expansion x 3
$\beta = 3\alpha$

SPECIFIC HEAT and LINEAR EXPANSION OF SOLIDS

Solid	Mean Specific Heat between 0°C and 100°C kJ/kgK or kJ/kg °C	Coefficient of Linear Expansion between 0°C and 100°C (Multiply by 10^{-6})	Solid	Mean Specific Heat between 0°C and 100°C kJ/kgK or kJ/kg °C	Coefficient of Linear Expansion between 0°C and 100°C (Multiply by 10^{-6})
Aluminum	0.909	23.8	Iron (cast)	0.544	10.4
Antimony	0.209	17.5	Iron (wrought)	0.465	12.0
Bismuth	0.125	12.4	Lead	0.131	29.0
Brass	0.383	18.4	Nickel	0.452	13.0
Carbon	0.795	7.9	Platinum	0.134	8.6
Cobalt	0.402	12.3	Silicon	0.741	7.8
Copper	0.388	16.5	Silver	0.235	19.5
Glass	0.896	9.0	Steel (mild)	0.494	12.0
Gold	0.130	14.2	Tin	0.230	26.7
Ice (between -20°C and 0°C)	2.135	50.4	Zinc	0.389	16.5

SPECIFIC HEAT and VOLUME EXPANSION FOR LIQUIDS

Liquid	Specific Heat (at 20° C) kJ/kgK or kJ/kg° C	Coefficient of Volume Expansion (Multiply by 10^{-4})	Liquid	Specific Heat (at 20°) kJ/kgK or kJ/kg° C	Coefficient of Volume Expansion (Multiply by 10^{-4})
Alcohol (ethyl)	2.470	11.0	Olive Oil	1.633	
Ammonia	0.473		Petroleum	2.135	
Benzine	1.738	12.4	Gasoline	2.093	12.0
Carbon Dioxide	3.643	1.82	Turpentine	1.800	9.4
Mercury	0.139	1.80	Water	4.183	3.7

Chemical Heating Value of a Fuel

$$\text{Chemical Heating Value MJ per kg of fuel} = 33.7\,C + 144\left(H_2 - \frac{O_2}{8}\right) + 9.3\,S$$

C is the mass of carbon per kg of fuel
H_2 is the mass of hydrogen per kg of fuel
O_2 is the mass of oxygen per kg of fuel
S is the mass of sulphur per kg of fuel

Theoretical (Stoichiometric) Air Required to Burn Fuel

$$\text{Air (kg per kg of fuel)} = \left[\frac{8}{3}C + 8\left(H_2 - \frac{O_2}{8}\right) + S\right]\frac{100}{23}$$

Air Supplied from Analysis of Flue Gases

$$\text{Air in kg per kg of fuel} = \frac{N_2}{33\,(CO_2 + CO)} \times C$$

C is the percentage of carbon in fuel by mass
N_2 is the percentage of nitrogen in flue gas by volume
CO_2 is the percentage of carbon dioxide in flue gas by volume
CO is the percentage of carbon monoxide in flue gas by volume

Boiler Formulae

$$\text{Equivalent evaporation} = \frac{\dot{m}_s\,(h_1 - h_2)}{2257\ \text{kJ/kg}}$$

$$\text{Factor of evaporation} = \frac{(h_1 - h_2)}{2257\ \text{kJ/kg}}$$

$$\text{Boiler efficiency} = \frac{\dot{m}_s\,(h_1 - h_2)}{\dot{m}_f \times \text{calorific value of fuel}}$$

where $\dot{m}_s$ = mass flow rate of steam
h_1 = enthalpy of steam produced in boiler
h_2 = enthalpy of feedwater to boiler
$\dot{m}_f$ = mass flow rate of fuel

Discharge from an Orifice

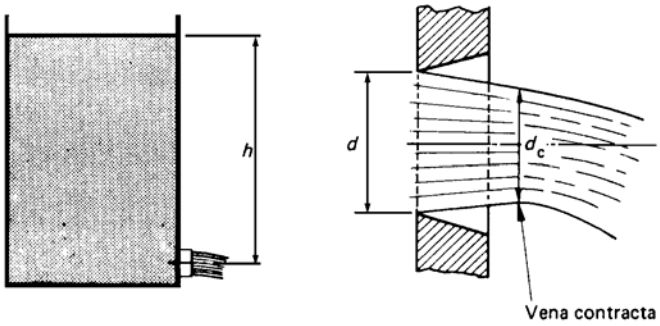
Let A = cross-sectional area of the orifice = $(\pi/4)d^2$

and A_c = cross-sectional area of the jet at the vena conrtacta = $(\pi/4)\,d_c^2$

then $A_c = C_c A$

or $C_c = \dfrac{A_c}{A} = \left(\dfrac{d_c}{d}\right)^2$

where C_c is the coefficient of contraction



At the vena contracta, the volumetric flow rate Q of the fluid is given by

Q = area of the jet at the vena contracta × actual velocity

$= A_c v$

or $Q = C_c A C_v \sqrt{2gh}$

The coefficients of contraction and velocity are combined to give the coefficient of discharge, C_d

i.e. $C_d = C_c C_v$

and $Q = C_d A \sqrt{2gh}$

Typically, values for C_d vary between 0.6 and 0.65

Circular orifice: $Q = 0.62\ A \sqrt{2gh}$

Where Q = flow (m^3/s) A = area (m^2) h = head (m)

Rectangular notch: $Q = 0.62\ (B \times H)\ \frac{2}{3}\sqrt{2gh}$

Where B = breadth (m) H = head (m above sill)

Triangular Right Angled Notch: $Q = 2.635\ H^{5/2}$

Where H = head (m above sill)

Bernoulli's Theory

$$H = h + \frac{P}{w} + \frac{v^2}{2g}$$

H = total head (metres)
h = height above datum level (metres)
P = pressure (N/m^2 or Pa)
w = force of gravity on 1 m^3 of fluid (N)
v = velocity of water (metres per second)

Loss of Head in Pipes Due to Friction

$$\text{Loss of head in metres} = f\frac{L}{d}\frac{v^2}{2g}$$

L = length in metres
d = diameter in metres
v = velocity of flow in metres per second
f = constant value of 0.01 in large pipes to 0.02 in small pipes

Note: This equation is expressed in some textbooks as
$\text{Loss} = 4f\frac{L}{d}\frac{v^2}{2g}$ where the f values range from 0.0025 to 0.005

Pump Calculations

$$Q_2 = Q_1 \times \frac{n_2}{n_1} \times \frac{D_2}{D_1}$$

$$h_1 = h_2 \times \left(\frac{n_2}{n_1}\right)^2 \times \left(\frac{D_2}{D_1}\right)^2$$

$$kW_2 = kW_1 \times \left(\frac{n_2}{n_1}\right)^3 \times \left(\frac{D_2}{D_1}\right)^3$$

where $\eta_1 = \eta_2$

kW = pump power required
h = head developed by pump, m
D = impeller diameter, mm
η = pump efficiency
n = pump speed in rpm
Q = quantity pumped in ℓ/min

Actual Pipe Dimensions

Nom. pipe size imp. units	Equiv. nom. pipe size mm	Out-side dia-meter	SCHEDULE												
			10	20	30	Std. wall	40	60	Extra Strong	80	100	120	140	160	Dou-ble Extra Strong
1/2	12.70	21.34	---	--	---	2.77	2.77	---	3.73	3.73	---	---	---	4.75	7.47
			---	---	---	1.26	1.26	---	1.61	1.61	---	---	---	1.92	2.53
3/4	19.05	26.67	---	---	---	2.87	2.87	---	3.91	3.91	---	---	---	5.54	7.82
			---	---	---	1.67	1.67	---	2.17	2.17	---	---	---	4.20	5.41
1	25.4	33.40	---	---	---	3.38	3.38	---	4.55	4.55	---	---	---	6.35	9.70
			---	---	---	2.48	2.48	---	3.21	3.21	---	---	---	4.20	5.41
1-1/4	31.75	42.16	---	---	---	3.56	3.56	---	4.85	4.85	---	---	---	6.35	9.70
			---	---	---	3.36	3.36	---	4.43	4.43	---	---	---	5.57	7.70
1-1/2	38.10	48.26	---	---	---	3.68	3.68	---	5.08	5.08	---	---	---	7.14	10.16
			---	---	---	4.02	4.02	---	5.37	5.37	---	---	---	7.18	9.47
2	50.80	60.33	---	---	---	3.91	3.91	---	5.54	5.54	---	---	---	8.71	11.07
			---	---	---	5.39	5.39	---	7.42	7.42	---	---	---	11.00	13.35
2-1/2	63.50	73.03	---	---	---	5.16	5.16	---	7.01	7.01	---	---	---	9.53	14.02
			---	---	---	8.56	8.56	---	11.32	11.32	---	---	---	14.79	20.25
3	76.20	88.90	---	---	---	5.49	5.49	---	7.62	7.62	---	---	---	11.13	15.24
			---	---	---	11.20	11.20	---	15.15	15.15	---	---	---	21.16	27.47
3-1/2	88.90	101.60	---	---	---	5.74	5.74	---	8.08	8.08	---	---	---	---	16.15
			---	---	---	13.46	13.46	---	18.49	18.49	---	---	---	---	33.77
4	101.60	114.30	---	---	---	6.02	6.02	---	8.56	8.56	---	11.13	---	13.49	17.12
			---	---	---	15.95	15.95	---	22.14	22.14	---	28.10	---	33.27	40.70
5	127.00	141.30	---	---	---	6.55	6.55	---	9.53	9.53	---	12.70	---	15.88	19.05
			---	---	---	21.61	21.61	---	30.71	30.71	---	39.97	---	48.71	56.98
6	152.40	168.28	---	---	---	7.11	7.11	---	10.97	10.97	---	14.27	---	18.24	21.95
			---	---	---	28.04	28.04	---	42.23	42.23	---	53.78	---	66.95	78.57
8	203.20	219.08	---	6.35	7.04	8.18	8.18	10.31	12.70	12.70	15.06	18.24	20.62	23.01	22.23
			---	33.05	36.51	42.20	42.20	52.68	64.13	64.13	75.18	89.61	100.15	110.39	111.47
10	250.40	273.05	---	6.35	7.80	9.27	9.27	12.70	12.70	15.06	18.24	21.41	25.40	28.58	---
			---	41.44	50.61	59.83	59.83	80.91	80.91	95.08	113.17	131.84	153.90	170.93	---
12	304.80	323.85	---	6.35	8.38	9.53	10.31	14.27	12.70	17.45	21.41	25.40	28.58	33.32	---
			---	49.34	64.69	73.25	79.16	108.13	96.69	130.82	158.44	185.47	206.45	236.88	---
14	355.60	355.60	6.35	7.92	9.53	9.35	11.13	15.06	12.70	19.05	23.80	27.76	31.75	35.71	---
			54.26	67.52	80.65	80.65	93.66	125.50	106.55	156.86	193.22	222.69	251.59	279.52	---
16	406.40	406.40	6.35	7.92	9.53	9.53	12.70	16.66	12.70	21.41	26.19	30.94	36.53	40.46	---
			62.15	77.39	92.49	92.49	122.33	158.89	122.33	201.69	243.62	284.20	330.33	362.27	---
18	457.20	457.20	6.35	7.92	11.13	9.53	14.27	19.05	12.70	23.80	29.36	34.93	39.67	45.24	---
			70.04	87.25	121.28	104.33	154.82	204.22	138.12	252.37	307.36	360.84	405.31	455.98	---
20	508.00	508.00	6.35	9.53	12.70	9.53	150.06	20.62	12.70	26.19	32.54	38.10	44.45	49.99	---
			77.93	116.17	153.90	116.17	181.66	245.94	153.90	308.71	378.52	438.03	504.15	560.18	---
24	609.60	609.60	6.35	9.53	14.27	9.53	17.45	24.59	12.70	30.94	38.89	46.02	52.37	59.51	---
			93.72	139.85	208.10	139.85	252.99	341.33	185.74	438.02	543.02	634.84	714.07	800.99	---
30	762.00	762.00	8.03	12.70	15.88	9.53	---	---	12.70	---	---	---	---	---	---
			117.40	232.83	289.81	175.36	---	---	232.83	---	---	---	---	---	---

Note: The upper figures in each square demote wall thickness in mm and the lower figures denote mass per meter, in kilograms.

ELECTRICITY

Ohm's Law

$$I = \frac{E}{R}$$

or $E = IR$

where I = current (amperes)
E = electromotive force (volts)
R = resistance (ohms)

Conductor Resistivity

$$R = \rho \frac{L}{a}$$

where ρ = specific resistance (or resistivity) (ohm metres, Ω·m)
L = length (metres)
a = area of cross-section (square metres)

Temperature correction

$$R_t = R_o (1 + \alpha t)$$

where R_o = resistance at 0ºC (Ω)
R_t = resistance at tºC (Ω)
α = temperature coefficient which has an average value for copper of 0.004 28 (Ω/ΩºC)

$$R_2 = R_1 \frac{(1 + \alpha t_2)}{(1 + \alpha t_1)}$$

where R_1 = resistance at t_1 (Ω)
R_2 = resistance at t_2 (Ω)

α Values	Ω/ΩºC
copper	0.00428
platinum	0.00385
nickel	0.00672
tungsten	0.0045
aluminum	0.0040

Dynamo Formulae

$$Average\ e.m.f. = \frac{\phi ZNP}{b60}$$

where N = rotational speed of armature in r/min

ϕ = flux per pole in webers

P = total number of field poles

Z = total number of armature conductors

b = number of armature paths,

for wave winding b = 2

for lap winding b = P

Generator Terminal volts = $E_G - I_aR_a$

Motor Terminal volts = $E_B + I_aR_a$

where E_G = generated e.m.f.
E_B = generated back e.m.f.
I_a = armature current
R_a = armature resistance

Alternating Current

R.M.S. value of sine curve = 0.707 maximum value
Mean value of sine curve = 0.637 maximum value

Form factor of sinusoidal = $\frac{\text{R.M.S. value}}{\text{Mean value}} = \frac{0.707}{0.637} = 1.11$

Frequency of alternator = $\frac{pN}{60}$ cycles per second

Where p = number of pairs of poles
N = rotational speed in r/min

Instantaneous value = Maximum value × Sin ($2\pi ft$)

Note: calculator must be in radian mode

Slip of Induction Motor

$$\frac{\text{Slip speed of field - speed of rotor}}{\text{Speed of field}} \times 100$$

Inductive Reactance

Reactance of AC circuit (X) = $2\pi fL$ ohms

where L = inductance of circuit (henries)

Inductance of an iron cored solenoid = $\frac{1.256T^2\mu A}{L \times 10^8}$ henries

where T = turns on coil
μ = magnetic permeablility of core
A = area of core (square centimetres)
L = length (centimetres)

Capacitance Reactance

Capacitance reactance of AC circuit = $\frac{1}{2\pi fC}$ ohms

where C = capacitance (farads)

Total reactance = $\left(2\pi fL - \frac{1}{2\pi fC}\right)$ohms

Impedence (Z) = $\sqrt{(\text{resistance})^2 + (\text{reactance})^2}$

= $\sqrt{R^2 + (2\pi fL - \frac{1}{2\pi fC})^2}$ ohms

Current in AC Circuit

$$\text{Current} = \frac{\text{impressed volts}}{\text{impedance}}$$

Force on conductors:

The force produced = BIL

Where B = the flux density in teslas (webers / m^2)
I = current
L = the total *effective* length of conductors

Power Factor

$$\text{p.f.} = \frac{\text{true watts}}{\text{volts x amperes}}$$

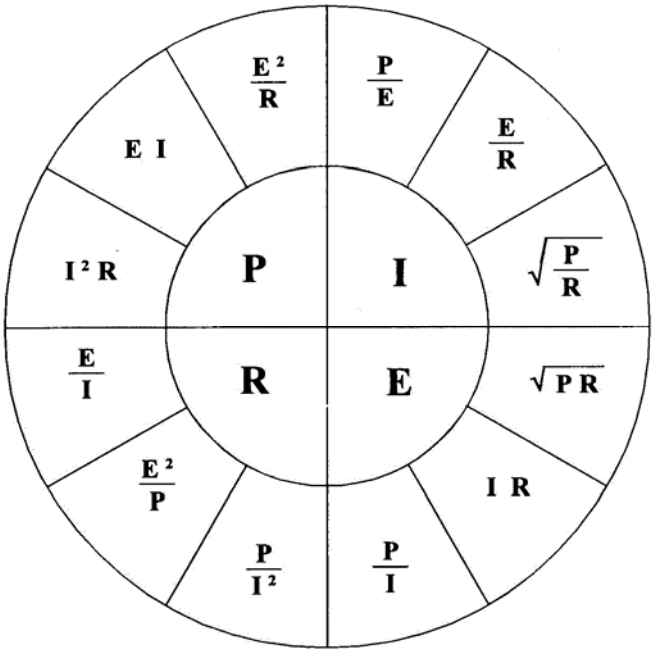
also p.f. = cos Φ, where Φ is the angle of lag or lead

Three Phase Alternators

Star connected
Line voltage = $\sqrt{3}$ x phase voltage
Line current = phase current

Delta connected
Line voltage = phase voltage
Line current = $\sqrt{3}$ x phase current

Three phase power
$P = \sqrt{3}\ E_L I_L \cos \Phi$
E_L = line voltage
I_L = line current
cos Φ = power factor



PERIODIC TABLE OF THE ELEMENTS

Key: 6 — Atomic Number; C — Symbol; 12.011 — Atomic Mass; 2-4 — Electron Configuration; -4+2+4 — Selected Oxidation States

PERIOD / GROUP	IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA	VIIIA	VIIIA	IB	IIB	IIIB	IVB	VB	VIB	VIIB	VIII
1	1 H 1.00794 1 +1 -1																	2 He 4.00260 2 0
2	3 Li 6.941 2-1 +1	4 Be 9.01218 2-2 +2											5 B 10.81 2-3 +3	6 C 12.0111 2-4 -4+2+4	7 N 14.0067 2-5 -3-2-1+1+2+3+4+5	8 O 15.9994 2-6 -2	9 F 18.998403 2-7 -1	10 Ne 20.179 2-8 0
3	11 Na 22.98977 2-8-1 +1	12 Mg 24.305 2-8-2 +2											13 Al 25.98154 2-8-3 +3	14 Si 28.0855 2-8-4 -4+2+4	15 P 30.97376 2-8-5 -3+3+5	16 S 32.06 2-8-6 -2+4+6	17 Cl 35.453 2-8-7 -1+1+3+5+7	18 Ar 39.948 2-8-8 0
4	19 K 39.0983 2-8-8-1 +1	20 Ca 40.08 8-8-2 +2	21 Sc 44.9559 2-8-9-2 +3	22 Ti 47.89 2-8-10-2 +2+3+4	23 V 50.9415 2-8-11-2 +2+3+4+5	24 Cr 51.996 2-8-13-1 +2+3+6	25 Mn 54.9380 2-8-13-2 +2+3+4+7	26 Fe 55.847 2-8-14-2 +2+3	27 Co 58.9332 2-8-15-2 +2+3	28 Ni 58.69 2-8-16-2 +2+3	29 Cu 63.546 2-8-18-1 +1+2	30 Zn 65.39 2-8-18-2 +2	31 Ga 69.72 2-8-18-3 +3	32 Ge 72.59 2-8-18-4 -4+2+4	33 As 74.9216 2-8-18-5 -3+3+5	34 Se 78.96 2-8-18-6 -2+4+6	35 Br 79.904 2-8-18-7 -1+1+5	36 Kr 83.80 2-8-18-8 0+2
5	37 Rb 85.4678 2-8-18-1 +1	38 Sr 87.62 2-8-18-8-2 +2	39 Y 88.9059 2-8-18-9-2 +3	40 Zr 91.224 2-8-18-10-2 +4	41 Nb 92.9064 2-8-18-12-1 +3+5	42 Mo 95.94 2-8-18-13-1 +3+6	43 Tc (98) 2-8-18-14-1 +4+6+7	44 Ru 101.07 2-8-18-15-1 +3	45 Rh 102.906 2-8-18-16-1 +3	46 Pd 106.42 2-8-18-18 +2+4	47 Ag 107.868 2-8-18-18-1 +1	48 Cd 112.41 2-8-18-18-2 +2	49 In 114.82 2-8-18-18-3 +3	50 Sn 118.71 2-8-18-18-4 +2+4	51 Sb 121.75 2-8-18-18-5 -3+3+5	52 Te 127.60 2-8-18-18-6 -2+4+6	53 I 126.905 2-8-18-18-7 -1+1+5+7	54 Xe 131.29 2-8-18-18-8 0+2+4+6
6	55 Cs 132.905 2-8-18-18-8-1 +1	56 Ba 137.33 2-8-18-18-8-2 +2		72 Hf 178.49 **18-32-10-2 +4	73 Ta 180.948 -18-32-11-2 +5	74 W 183.85 -18-32-12-2 +6	75 Re 186.207 -18-32-13-2 +4+6+7	76 Os 190.2 -18-32-14-2 +3+4	77 Ir 192.22 -18-32-15-2 +3+4	78 Pt 195.08 -18-32-17-1 +2+4	79 Au 196.957 -18-32-18-1 +1+3	80 Hg 200.59 -18-32-18-2 +1+2	81 Tl 204.383 -18-32-18-3 +1+3	82 Pb 207.2 -18-32-18-4 +2+4	83 Bi 208.980 -18-32-18-5 +3+5	84 Po (209) -18-32-18-6 +2+4	85 At (210) -18-32-18-7	86 Rn (222) -18-32-18-8 0
7	87 Fr (223) -18-32-18-8-1 +1	88 Ra 226.025 -18-32-18-8-2 +2		104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (264)	108 Hs (265)	109 Mt (268)	110 Uun (269)	111 Uuu (272)	112 Uub (277)						

57 La 138.906 +3	58 Ce 140.12 +3+4	59 Pr 140.908 +3	60 Nd 144.24 +3	61 Pm (145) +3	62 Sm 150.36 +2+3	63 Eu 151.96 +2+3	64 Gd 157.25 +3	65 Tb 158.925 +3	66 Dy 162.50 +3	67 Ho 164.930 +3	68 Er 167.26 +3	69 Tm 168.934 +3	70 Yb 173.04 +2+3	71 Lu 174.967 +3
89 Ac 227.028 +3	90 Th 232.038 +4	91 Pa 231.036 +4+5	92 U 238.029 +3+4+5+6	93 Np 237.048 +3+4+5+6	94 Pu (244) +3+4+5+6	95 Am (243) +3+4+5+6	96 Cm (247) +3	97 Bk (247) +3+4	98 Cf (251) +3	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (250)

ION NAMES AND FORMULAE

MONATOMIC

Ag^{+}	silver ion
Al^{3+}	aluminum ion
Au^{+} and Au^{2+}	gold ion
Be^{2+}	beryllium ion
Ca^{2+}	calcium ion
Co^{2+} and Co^{3+}	cobalt ion
Cr^{2+} and Cr^{3+}	chromium ion
Cu^{+} and Cu^{2+}	copper ion
Fe^{2+} and Fe^{3+}	iron ion
K^{+}	potassium ion
Li^{+}	lithium ion
Mg^{2+}	magnesium ion
Na^{+}	sodium ion
Zn^{2+}	zinc ion

POLYATOMIC

BO_3^{3-}	borate ion
$C_2H_3O_2^{-}$	acetate ion
ClO^{-}	hypochlorite ion
ClO_2^{-}	chlorite ion
ClO_3^{-}	chlorate ion
ClO_4^{-}	perchlorate ion
CN^{-}	cyanide ion
CO_3^{2-}	carbonate ion
$C_2O_4^{2-}$	oxalate ion
CrO_4^{2-}	chromate ion
$Cr_2O_7^{2-}$	dichromate ion
HCO_3^{-}	hydrogen carbonate or bicarbonate ion
H_3O^{+}	hydronium ion
HPO_4^{2-}	hydrogen phosphate ion
$H_2PO_4^{-}$	dihydrogen phosphate ion
HSO_3^{-}	hydrogen sulphite or bisulphite ion
HSO_4^{-}	hydrogen sulphate or bisulphate ion
MnO_4^{-}	permanganate ion
N_3^{-}	azide ion
NH_4^{+}	ammonium ion
NO_2^{-}	nitrite ion
NO_3^{-}	nitrate ion
O_2^{2-}	peroxide ion
OCN^{-}	cyanate ion
OH^{-}	hydroxide ion
PO_3^{3-}	phosphite ion
PO_4^{3-}	phosphate ion
SCN^{-}	thiocyanate ion
SO_3^{2-}	sulphite ion
SO_4^{2-}	sulphate ion
$S_2O_3^{2-}$	thiosulphate ion

USEFUL DATA

1 atmosphere (atmos. Press. At sea level)		= 10.33 m water
	or	= 760 mm mercury
	or	= 101.325 kPa
1 mm mercury		= 0.133 kPa
1 litre fresh water		= 1 kg
1 m^3 fresh water		= 1000 kg = 1 tonne (t)
1 m^3		= 1000 litre
100 kPa		= 10.19 m head of water
1 m head of water		= 9.81 kPa
1 mm head of water		= 9.81 Pa
Work done in joules		= force in newtons × distance in metres
or		
J		= Nm
Power in watts		= work in joules done per second
or		
W		= J/s = Nm/s
Power (W)		= force (N) × velocity (m/s)
1 kg steam:		
Latent heat of steam,		
From and at 100^0C		= 2257 kJ
Latent heat of fusion of ice		= 335 kJ/kg
1 tonne of refrigeration		= 335 × 1000
		= 335000 kJ
1 tonne of refrigeration / 24 h		$= \frac{335000}{24}$
		= 13958 kJ / h
		= 233 kJ / min

Temperature Scales

Freezing point of water	= 0^0C
	= 273 K
Boiling point of water	= 100^0C
	= 373 K
One degree Celsius	= one Kelvin

Velocities and Acceleration

Acceleration due to gravity (g)	= 9.80665 m/s^2 (9.8/m/s^2)
1 knot	= 0.514 m/s

Velocity of sound in air about 335 m/s or 1206 km/h

Velocity of light	= 299757 km/s

Angular Measure

1 revolution	= 360 degrees = 4 right-angles
1 degree	= 60 minutes
1 minute	= 60 seconds
1 radian	= 57^0 17' 45" or approx. 57.3^0

Base of Napierian Logarithms	= 2.7183
Log_e (In)	= 2.3 × $\log_{10}$

INTEREST FORMULAS

i = interest rate per period.
n = number of interest periods.
P = a present sum of money or the principal.
F = a sum of money at the end of n periods equivalent to P with ir
A = an end of period payment for the next n periods equivalent to
(often called annual or monthly payment)

1. $F = P(1+i)^n$
2. $P = \dfrac{F}{(1+i)^n}$
3. $A = F\dfrac{i}{(1+i)^n - 1}$
4. $F = A\dfrac{(1+i)^n - 1}{i}$
5. $A = P\dfrac{i(1+i)^n}{(1+i)^n - 1}$
6. $P = A\dfrac{(1+i)^n - 1}{i(1+i)^n}$
7. $A = (P - L)\dfrac{i(1+i)^n}{(1+i)^n - 1}$

Where P is purchase cost and L is salvage value.

1% Compound Interest Factors

	Single Payment		Uniform Series				
n	Compound Amount Factor F/P	Present Worth Factor P/F	Sinking Fund Factor A/F	Capital Recovery Factor A/P	Compound Amount Factor F/A	Present Worth Factor P/A	n
1	1.0100	0.9901	1.000 00	1.010 00	1.000	0.990	1
2	1.0201	0.9803	0.497 51	0.507 51	2.010	1.970	2
3	1.0303	0.9706	0.330 02	0.340 02	3.030	2.941	3
4	1.0406	0.9610	0.246 28	0.256 28	4.060	3.902	4
5	1.0510	0.9515	0.196 04	0.206 04	5.101	4.853	5
6	1.0615	0.9420	0.162 55	0.172 55	6.152	5.795	6
7	1.0721	0.9327	0.138 63	0.148 63	7.214	6.728	7
8	1.0829	0.9235	0.120 69	0.130 69	8.286	7.652	8
9	1.0937	0.9143	0.106 74	0.116 74	9.369	8.566	9
10	1.1046	0.9053	0.095 58	0.105 58	10.462	9.471	10
11	1.1157	0.8963	0.086 45	0.096 45	11.567	10.368	11
12	1.1268	0.8874	0.078 85	0.088 85	12.683	11.255	12
13	1.1381	0.8787	0.072 41	0.082 41	13.809	12.134	13
14	1.1495	0.8700	0.066 90	0.076 90	14.947	13.004	14
15	1.1610	0.8613	0.062 12	0.072 12	16.097	13.865	15
16	1.1726	0.8528	0.057 94	0.067 94	17.258	14.718	16
17	1.1843	0.8444	0.054 26	0.064 26	18.430	15.562	17
18	1.1961	0.8360	0.050 98	0.060 98	19.615	16.398	18
19	1.2081	0.8277	0.048 05	0.058 05	20.811	17.226	19
20	1.2202	0.8195	0.045 42	0.055 42	22.019	18.046	20
21	1.2324	0.8114	0.043 03	0.053 03	23.239	18.857	21
22	1.2447	0.8034	0.040 86	0.050 86	24.472	19.660	22
23	1.2572	0.7954	0.038 89	0.048 89	25.716	20.456	23
24	1.2697	0.7876	0.037 07	0.047 07	26.973	21.243	24
25	1.2824	0.7798	0.035 41	0.045 41	28.243	22.023	25
26	1.2953	0.7720	0.033 87	0.043 87	29.526	22.795	26
27	1.3082	0.7644	0.032 45	0.042 45	30.821	23.560	27
28	1.3213	0.7568	0.031 12	0.041 12	32.129	24.316	28
29	1.3345	0.7493	0.029 90	0.039 90	33.450	25.066	29
30	1.3478	0.7419	0.028 75	0.038 75	34.785	25.808	30
31	1.3613	0.7346	0.027 68	0.037 68	36.133	26.542	31
32	1.3749	0.7273	0.026 67	0.036 67	37.494	27.270	32
33	1.3887	0.7201	0.025 73	0.035 73	38.869	27.990	33
34	1.4026	0.7130	0.024 84	0.034 84	40.258	28.703	34
35	1.4166	0.7059	0.024 00	0.034 00	41.660	29.409	35
40	1.4889	0.6717	0.020 46	0.030 46	48.886	32.835	40
45	1.5648	0.6391	0.017 71	0.027 71	56.481	36.095	45
50	1.6446	0.6080	0.015 51	0.025 51	64.463	39.196	50
55	1.7285	0.5785	0.013 73	0.023 73	72.852	42.147	55
60	1.8167	0.5504	0.012 24	0.022 24	81.670	44.955	60
65	1.9094	0.5237	0.011 00	0.021 00	90.937	47.627	65
70	2.0068	0.4983	0.009 93	0.019 93	100.676	50.169	70
75	2.1091	0.4741	0.009 02	0.019 02	110.913	52.587	75
80	2.2167	0.4511	0.008 22	0.018 22	121.672	54.888	80
85	2.3298	0.4292	0.007 52	0.017 52	132.979	57.078	85
90	2.4486	0.4084	0.006 90	0.016 90	144.863	59.161	90
95	2.5735	0.3886	0.006 36	0.016 36	157.354	61.143	95
100	2.7048	0.3697	0.005 87	0.015 87	170.481	63.029	100

2% Compound Interest Factors

n	Single Payment: Compound Amount Factor F/P	Single Payment: Present Worth Factor P/F	Uniform Series: Sinking Fund Factor A/F	Uniform Series: Capital Recovery Factor A/P	Uniform Series: Compound Amount Factor F/A	Uniform Series: Present Worth Factor P/A	n
1	1.0200	0.9804	1.000 00	1.020 00	1.000	0.980	1
2	1.0404	0.9612	0.495 05	0.515 05	2.020	1.942	2
3	1.0612	0.9423	0.326 75	0.346 75	3.060	2.884	3
4	1.0824	0.9238	0.242 62	0.262 62	4.122	3.808	4
5	1.1041	0.9057	0.192 16	0.212 16	5.204	4.713	5
6	1.1262	0.8880	0.158 53	0.178 53	6.308	5.601	6
7	1.1487	0.8706	0.134 51	0.154 51	7.434	6.472	7
8	1.1717	0.8535	0.116 51	0.136 51	8.583	7.325	8
9	1.1951	0.8368	0.102 52	0.122 52	9.755	8.162	9
10	1.2190	0.8203	0.091 33	0.111 33	10.950	8.983	10
11	1.2434	0.8043	0.082 18	0.102 18	12.169	9.787	11
12	1.2682	0.7885	0.074 56	0.094 56	13.412	10.575	12
13	1.2936	0.7730	0.068 12	0.088 12	14.680	11.348	13
14	1.3195	0.7579	0.062 60	0.082 60	15.974	12.106	14
15	1.3459	0.7430	0.057 83	0.077 83	17.293	12.849	15
16	1.3728	0.7284	0.053 65	0.073 65	18.639	13.578	16
17	1.4002	0.7142	0.049 97	0.069 97	20.012	14.292	17
18	1.4282	0.7002	0.046 70	0.066 70	21.412	14.992	18
19	1.4568	0.6864	0.043 78	0.063 78	22.841	15.678	19
20	1.4859	0.6730	0.041 16	0.061 16	24.297	16.351	20
21	1.5157	0.6598	0.038 78	0.058 78	25.783	17.011	21
22	1.5460	0.6468	0.036 63	0.056 63	27.299	17.658	22
23	1.5769	0.6342	0.034 67	0.054 67	28.845	18.292	23
24	1.6084	0.6217	0.032 87	0.052 87	30.422	18.914	24
25	1.6406	0.6095	0.031 22	0.051 22	32.030	19.523	25
26	1.6734	0.5976	0.029 70	0.049 70	33.671	20.121	26
27	1.7069	0.5859	0.028 29	0.048 29	35.344	20.707	27
28	1.7410	0.5744	0.026 99	0.046 99	37.051	21.281	28
29	1.7758	0.5631	0.025 78	0.045 78	38.792	21.844	29
30	1.8114	0.5521	0.024 65	0.044 65	40.568	22.396	30
31	1.8476	0.5412	0.023 60	0.043 60	42.379	22.938	31
32	1.8845	0.5306	0.022 61	0.042 61	44.227	23.468	32
33	1.9222	0.5202	0.021 69	0.041 69	46.112	23.989	33
34	1.9607	0.5100	0.020 82	0.040 82	48.034	24.499	34
35	1.9999	0.5000	0.020 00	0.040 00	49.994	24.999	35
40	2.2080	0.4529	0.016 56	0.036 56	60.402	27.355	40
45	2.4379	0.4102	0.013 91	0.033 91	71.893	29.490	45
50	2.6916	0.3715	0.011 82	0.031 82	84.579	31.424	50
55	2.9717	0.3365	0.010 14	0.030 14	98.587	33.175	55
60	3.2810	0.3048	0.008 77	0.028 77	114.052	34.761	60
65	3.6225	0.2761	0.007 63	0.027 63	131.126	36.197	65
70	3.9996	0.2500	0.006 67	0.026 67	149.978	37.499	70
75	4.4158	0.2265	0.005 86	0.025 86	170.792	38.677	75
80	4.8754	0.2051	0.005 16	0.025 16	193.772	39.745	80
85	5.3829	0.1858	0.004 56	0.024 56	219.144	40.711	85
90	5.9431	0.1683	0.004 05	0.024 05	247.157	41.587	90
95	6.5617	0.1524	0.003 60	0.023 60	278.085	42.380	95
100	7.2446	0.1380	0.003 20	0.023 20	312.232	43.098	100

5% Compound Interest Factors

n	Single Payment: Compound Amount Factor F/P	Single Payment: Present Worth Factor P/F	Uniform Series: Sinking Fund Factor A/F	Uniform Series: Capital Recovery Factor A/P	Uniform Series: Compound Amount Factor F/A	Uniform Series: Present Worth Factor P/A	n
1	1.0500	0.9524	1.000 00	1.050 00	1.000	0.952	1
2	1.1025	0.9070	0.487 80	0.537 80	2.050	1.859	2
3	1.1576	0.8638	0.317 21	0.367 21	3.153	2.723	3
4	1.2155	0.8227	0.232 01	0.282 01	4.310	3.546	4
5	1.2763	0.7835	0.180 97	0.230 97	5.526	4.329	5
6	1.3401	0.7462	0.147 02	0.197 02	6.802	5.076	6
7	1.4071	0.7107	0.122 82	0.172 82	8.142	5.786	7
8	1.4775	0.6768	0.104 72	0.154 72	9.549	6.463	8
9	1.5513	0.6446	0.090 69	0.140 69	11.027	7.108	9
10	1.6289	0.6139	0.079 50	0.129 50	12.578	7.722	10
11	1.7103	0.5847	0.070 39	0.120 39	14.207	8.306	11
12	1.7959	0.5568	0.062 83	0.112 83	15.917	8.863	12
13	1.8856	0.5303	0.056 46	0.106 46	17.713	9.394	13
14	1.9800	0.5051	0.051 02	0.101 02	19.599	9.899	14
15	2.0789	0.4810	0.046 34	0.096 34	21.579	10.380	15
16	2.1829	0.4581	0.042 27	0.092 27	23.657	10.838	16
17	2.2920	0.4363	0.038 70	0.088 70	25.840	11.274	17
18	2.4066	0.4155	0.035 55	0.085 55	28.132	11.690	18
19	2.5270	0.3957	0.032 75	0.082 75	30.539	12.085	19
20	2.6533	0.3769	0.030 24	0.080 24	33.066	12.462	20
21	2.7860	0.3589	0.028 00	0.078 00	35.719	12.821	21
22	2.9253	0.3418	0.025 97	0.075 97	38.505	13.163	22
23	3.0715	0.3256	0.024 14	0.074 14	41.430	13.489	23
24	3.2251	0.3101	0.022 47	0.072 47	44.502	13.799	24
25	3.3864	0.2953	0.020 95	0.070 95	47.727	14.094	25
26	3.5557	0.2812	0.019 56	0.069 56	51.113	14.375	26
27	3.7335	0.2678	0.018 29	0.068 29	54.669	14.643	27
28	3.9201	0.2551	0.017 12	0.067 12	58.403	14.898	28
29	4.1161	0.2429	0.016 05	0.066 05	62.323	15.141	29
30	4.3219	0.2314	0.015 05	0.065 05	66.439	15.372	30
31	4.5380	0.2204	0.014 13	0.064 13	70.761	15.593	31
32	4.7649	0.2099	0.013 28	0.063 28	75.299	15.803	32
33	5.0032	0.1999	0.012 49	0.062 49	80.064	16.003	33
34	5.2533	0.1904	0.011 76	0.061 76	85.067	16.193	34
35	5.5160	0.1813	0.011 07	0.061 07	90.320	16.374	35
40	7.0400	0.1420	0.008 28	0.058 28	120.800	17.159	40
45	8.9850	0.1113	0.006 26	0.056 26	159.700	17.774	45
50	11.4674	0.0872	0.004 78	0.054 78	209.348	18.256	50
55	14.6356	0.0683	0.003 67	0.053 67	272.713	18.633	55
60	18.6792	0.0535	0.002 83	0.052 83	353.584	18.929	60
65	23.8399	0.0419	0.002 19	0.052 19	456.798	19.161	65
70	30.4264	0.0329	0.001 70	0.051 70	588.529	19.343	70
75	38.8327	0.0258	0.001 32	0.051 32	756.654	19.485	75
80	49.5614	0.0202	0.001 03	0.051 03	971.229	19.596	80
85	63.2544	0.0158	0.000 80	0.050 80	1 245.087	19.684	85
90	80.7304	0.0124	0.000 63	0.050 63	1 594.607	19.752	90
95	103.0357	0.0097	0.000 49	0.050 49	2 040.694	19.806	95
100	131.5013	0.0076	0.000 38	0.050 38	2 610.025	19.848	100

10% Compound Interest Factors

n	Single Payment: Compound Amount Factor F/P	Single Payment: Present Worth Factor P/F	Uniform Series: Sinking Fund Factor A/F	Uniform Series: Capital Recovery Factor A/P	Uniform Series: Compound Amount Factor F/A	Uniform Series: Present Worth Factor P/A	n
1	1.1000	0.9091	1.000 00	1.100 00	1.000	0.909	1
2	1.2100	0.8264	0.476 19	0.576 19	2.100	1.736	2
3	1.3310	0.7513	0.302 11	0.402 11	3.310	2.487	3
4	1.4641	0.6830	0.215 47	0.315 47	4.641	3.170	4
5	1.6105	0.6209	0.163 80	0.263 80	6.105	3.791	5
6	1.7716	0.5645	0.129 61	0.229 61	7.716	4.355	6
7	1.9487	0.5132	0.105 41	0.205 41	9.487	4.868	7
8	2.1436	0.4665	0.087 44	0.187 44	11.436	5.335	8
9	2.3579	0.4241	0.073 64	0.173 64	13.579	5.759	9
10	2.5937	0.3855	0.062 75	0.162 75	15.937	6.144	10
11	2.8531	0.3505	0.053 96	0.153 96	18.531	6.495	11
12	3.1384	0.3186	0.046 76	0.146 76	21.384	6.814	12
13	3.4523	0.2897	0.040 78	0.140 78	24.523	7.103	13
14	3.7975	0.2633	0.035 75	0.135 75	27.975	7.367	14
15	4.1772	0.2394	0.031 47	0.131 47	31.772	7.606	15
16	4.5950	0.2176	0.027 82	0.127 82	35.950	7.824	16
17	5.0545	0.1978	0.024 66	0.124 66	40.545	8.022	17
18	5.5599	0.1799	0.021 93	0.121 93	45.599	8.201	18
19	6.1159	0.1635	0.019 55	0.119 55	51.159	8.365	19
20	6.7275	0.1486	0.017 46	0.117 46	57.275	8.514	20
21	7.4002	0.1351	0.015 62	0.115 62	64.002	8.649	21
22	8.1403	0.1228	0.014 01	0.114 01	71.403	8.772	22
23	8.9543	0.1117	0.012 57	0.112 57	79.543	8.883	23
24	9.8497	0.1015	0.011 30	0.111 30	88.497	8.985	24
25	10.8347	0.0923	0.010 17	0.110 17	98.347	9.077	25
26	11.9182	0.0839	0.009 16	0.109 16	109.182	9.161	26
27	13.1100	0.0763	0.008 26	0.108 26	121.100	9.237	27
28	14.4210	0.0693	0.007 45	0.107 45	134.210	9.307	28
29	15.8631	0.0630	0.006 73	0.106 73	148.631	9.370	29
30	17.4494	0.0573	0.006 08	0.106 08	164.494	9.427	30
31	19.1943	0.0521	0.005 50	0.105 50	181.943	9.479	31
32	21.1138	0.0474	0.004 97	0.104 97	201.138	9.526	32
33	23.2252	0.0431	0.004 50	0.104 50	222.252	9.569	33
34	25.5477	0.0391	0.004 07	0.104 07	245.477	9.609	34
35	28.1024	0.0356	0.003 69	0.103 69	271.024	9.644	35
40	45.2593	0.0221	0.002 26	0.102 26	442.593	9.779	40
45	72.8905	0.0137	0.001 39	0.101 39	718.905	9.863	45
50	117.3909	0.0085	0.000 86	0.100 86	1 163.909	9.915	50
55	189.0591	0.0053	0.000 53	0.100 53	1 880.591	9.947	55
60	304.4816	0.0033	0.000 33	0.100 33	3 034.816	9.967	60
65	490.3707	0.0020	0.000 20	0.100 20	4 893.707	9.980	65
70	789.7470	0.0013	0.000 13	0.100 13	7 887.470	9.987	70
75	1 271.8952	0.0008	0.000 08	0.100 08	12 708.954	9.992	75
80	2 048.4002	0.0005	0.000 05	0.100 05	20 474.002	9.995	80
85	3 298.9690	0.0003	0.000 03	0.100 03	32 979.690	9.997	85
90	5 313.0226	0.0002	0.000 02	0.100 02	53 120.226	9.998	90
95	8 556.6760	0.0001	0.000 01	0.100 01	85 556.760	9.999	95
100	13 780.6123	0.0001	0.000 01	0.100 01	137 796.123	9.999	100

12% Compound Interest Factors

	Single Payment		Uniform Series				
n	Compound Amount Factor F/P	Present Worth Factor P/F	Sinking Fund Factor A/F	Capital Recovery Factor A/P	Compound Amount Factor F/A	Present Worth Factor P/A	n
1	1.1200	0.8929	1.000 00	1.120 00	1.000	0.893	1
2	1.2544	0.7972	0.471 70	0.591 70	2.120	1.690	2
3	1.4049	0.7118	0.296 35	0.416 35	3.374	2.402	3
4	1.5735	0.6355	0.209 23	0.329 23	4.779	3.037	4
5	1.7623	0.5674	0.157 41	0.277 41	6.353	3.605	5
6	1.9738	0.5066	0.123 23	0.243 23	8.115	4.111	6
7	2.2107	0.4523	0.099 12	0.219 12	10.089	4.564	7
8	2.4760	0.4039	0.081 30	0.201 30	12.300	4.968	8
9	2.7731	0.3606	0.067 68	0.187 68	14.776	5.328	9
10	3.1058	0.3220	0.056 98	0.176 98	17.549	5.650	10
11	3.4785	0.2875	0.048 42	0.168 42	20.655	5.938	11
12	3.8960	0.2567	0.041 44	0.161 44	24.133	6.194	12
13	4.3635	0.2292	0.035 68	0.155 68	28.029	6.424	13
14	4.8871	0.2046	0.030 87	0.150 87	32.393	6.628	14
15	5.4736	0.1827	0.026 82	0.146 82	37.280	6.811	15
16	6.1304	0.1631	0.023 39	0.143 39	42.753	6.974	16
17	6.8660	0.1456	0.020 46	0.140 46	48.884	7.120	17
18	7.6900	0.1300	0.017 94	0.137 94	55.750	7.250	18
19	8.6128	0.1161	0.015 76	0.135 76	63.440	7.366	19
20	9.6463	0.1037	0.013 88	0.133 88	72.052	7.469	20
21	10.8038	0.0926	0.012 24	0.132 24	81.699	7.562	21
22	12.1003	0.0826	0.010 81	0.130 81	92.503	7.645	22
23	13.5523	0.0738	0.009 56	0.129 56	104.603	7.718	23
24	15.1786	0.0659	0.008 46	0.128 46	118.155	7.784	24
25	17.0001	0.0588	0.007 50	0.127 50	133.334	7.843	25
26	19.0401	0.0525	0.006 65	0.126 65	150.334	7.896	26
27	21.3249	0.0469	0.005 90	0.125 90	169.374	7.943	27
28	23.8839	0.0419	0.005 24	0.125 24	190.699	7.984	28
29	26.7499	0.0374	0.004 66	0.124 66	214.583	8.022	29
30	29.9599	0.0334	0.004 14	0.124 14	241.333	8.055	30
31	33.5551	0.0298	0.003 69	0.123 69	271.292	8.085	31
32	37.5817	0.0266	0.003 28	0.123 28	304.847	8.112	32
33	42.0915	0.0238	0.002 92	0.122 92	342.429	8.135	33
34	47.1425	0.0212	0.002 60	0.122 60	384.520	8.157	34
35	52.7996	0.0189	0.002 32	0.122 32	431.663	8.176	35
40	93.0510	0.0107	0.001 30	0.121 30	767.091	8.244	40
45	163.9876	0.0061	0.000 74	0.120 74	1 358.230	8.283	45
50	289.0022	0.0035	0.000 42	0.120 42	2 400.018	8.305	50
∞				0.120 00		8.333	∞

15% Compound Interest Factors

	Single Payment		Uniform Series				
n	Compound Amount Factor F/P	Present Worth Factor P/F	Sinking Fund Factor A/F	Capital Recovery Factor A/P	Compound Amount Factor F/A	Present Worth Factor P/A	n
1	1.1500	0.8696	1.000 00	1.150 00	1.000	0.870	1
2	1.3225	0.7561	0.465 12	0.615 12	2.150	1.626	2
3	1.5209	0.6575	0.287 98	0.437 98	3.472	2.283	3
4	1.7490	0.5718	0.200 26	0.350 27	4.993	2.855	4
5	2.0114	0.4972	0.148 32	0.298 32	6.742	3.352	5
6	2.3131	0.4323	0.114 24	0.264 24	8.754	3.784	6
7	2.6600	0.3759	0.090 36	0.240 36	11.067	4.160	7
8	3.0590	0.3269	0.072 85	0.222 85	13.727	4.487	8
9	3.5179	0.2843	0.059 57	0.209 57	16.786	4.772	9
10	4.0456	0.2472	0.049 25	0.199 25	20.304	5.019	10
11	4.6524	0.2149	0.041 07	0.191 07	24.349	5.234	11
12	5.3503	0.1869	0.034 48	0.184 48	29.002	5.421	12
13	6.1528	0.1625	0.029 11	0.179 11	34.352	5.583	13
14	7.0757	0.1413	0.024 69	0.174 69	40.505	5.724	14
15	8.1371	0.1229	0.021 02	0.171 02	47.580	5.847	15
16	9.3576	0.1069	0.017 95	0.167 95	55.717	5.954	16
17	10.7613	0.0929	0.015 37	0.165 37	65.075	6.047	17
18	12.3755	0.0808	0.013 19	0.163 19	75.836	6.128	18
19	14.2318	0.0703	0.011 34	0.161 34	88.212	6.198	19
20	16.3665	0.0611	0.009 76	0.159 76	102.444	6.259	20
21	18.8215	0.0531	0.008 42	0.158 42	118.810	6.312	21
22	21.6447	0.0462	0.007 27	0.157 27	137.632	6.359	22
23	24.8915	0.0402	0.006 28	0.156 28	159.276	6.399	23
24	28.6252	0.0349	0.005 43	0.155 43	184.168	6.434	24
25	32.9190	0.0304	0.004 70	0.154 70	212.793	6.464	25
26	37.8568	0.0264	0.004 07	0.154 07	245.712	6.491	26
27	43.5353	0.0230	0.003 53	0.153 53	283.569	6.514	27
28	50.0656	0.0200	0.003 06	0.153 06	327.104	6.534	28
29	57.5755	0.0174	0.002 65	0.152 65	377.170	6.551	29
30	66.2118	0.0151	0.002 30	0.152 30	434.745	6.566	30
31	76.1435	0.0131	0.002 00	0.152 00	500.957	6.579	31
32	87.5651	0.0114	0.001 73	0.151 73	577.100	6.591	32
33	100.6998	0.0099	0.001 50	0.151 50	664.666	6.600	33
34	115.8048	0.0086	0.001 31	0.151 31	765.365	6.609	34
35	133.1755	0.0075	0.001 13	0.151 13	881.170	6.617	35
40	267.8635	0.0037	0.000 56	0.150 56	1 779.090	6.642	40
45	538.7693	0.0019	0.000 28	0.150 28	3 585.128	6.654	45
50	1 083.6574	0.0009	0.000 14	0.150 14	7 217.716	6.661	50
∞				0.150 00		6.667	∞

20% Compound Interest Factors

n	Single Payment: Compound Amount Factor F/P	Single Payment: Present Worth Factor P/F	Uniform Series: Sinking Fund Factor A/F	Uniform Series: Capital Recovery Factor A/P	Uniform Series: Compound Amount Factor F/A	Uniform Series: Present Worth Factor P/A	n
1	1.2000	0.8333	1.000 00	1.200 00	1.000	0.833	1
2	1.4400	0.6944	0.454 55	0.654 55	2.200	1.528	2
3	1.7280	0.5787	0.274 73	0.474 73	3.640	2.106	3
4	2.0736	0.4823	0.186 29	0.386 29	5.368	2.589	4
5	2.4883	0.4019	0.134 38	0.334 38	7.442	2.991	5
6	2.9860	0.3349	0.100 71	0.300 71	9.930	3.326	6
7	3.5832	0.2791	0.077 42	0.277 42	12.916	3.605	7
8	4.2998	0.2326	0.060 61	0.260 61	16.499	3.837	8
9	5.1598	0.1938	0.048 08	0.248 08	20.799	4.031	9
10	6.1917	0.1615	0.038 52	0.238 52	25.959	4.192	10
11	7.4301	0.1346	0.031 10	0.231 10	32.150	4.327	11
12	8.9161	0.1122	0.025 26	0.225 26	39.581	4.439	12
13	10.6993	0.0935	0.020 62	0.220 62	48.497	4.533	13
14	12.8392	0.0779	0.016 89	0.216 89	59.196	4.611	14
15	15.4070	0.0649	0.013 88	0.213 88	72.035	4.675	15
16	18.4884	0.0541	0.011 44	0.211 44	87.442	4.730	16
17	22.1861	0.0451	0.009 44	0.209 44	105.931	4.775	17
18	26.6233	0.0376	0.007 81	0.207 81	128.117	4.812	18
19	31.9480	0.0313	0.006 46	0.206 46	154.740	4.844	19
20	38.3376	0.0261	0.005 36	0.205 36	186.688	4.870	20
21	46.0051	0.0217	0.004 44	0.204 44	225.026	4.891	21
22	55.2061	0.0181	0.003 69	0.203 69	271.031	4.909	22
23	66.2474	0.0151	0.003 07	0.203 07	326.237	4.925	23
24	79.4968	0.0126	0.002 55	0.202 55	392.484	4.937	24
25	95.3962	0.0105	0.002 12	0.202 12	471.981	4.948	25
26	114.4755	0.0087	0.001 76	0.201 76	567.377	4.956	26
27	137.3706	0.0073	0.001 47	0.201 47	681.853	4.964	27
28	164.8447	0.0061	0.001 22	0.201 22	819.223	4.970	28
29	197.8136	0.0051	0.001 02	0.201 02	984.068	4.975	29
30	237.3763	0.0042	0.000 85	0.200 85	1 181.882	4.979	30
31	284.8516	0.0035	0.000 70	0.200 70	1 419.258	4.982	31
32	341.8219	0.0029	0.000 59	0.200 59	1 704.109	4.985	32
33	410.1863	0.0024	0.000 49	0.200 49	2 045.931	4.988	33
34	492.2235	0.0020	0.000 41	0.200 41	2 456.118	4.990	34
35	590.6682	0.0017	0.000 34	0.200 34	2 948.341	4.992	35
40	1 469.7716	0.0007	0.000 14	0.200 14	7 343.858	4.997	40
45	3 657.2620	0.0003	0.000 05	0.200 05	18 281.310	4.999	45
50	9 100.4382	0.0001	0.000 02	0.200 02	45 497.191	4.999	50
∞				0.200 00		5.000	∞

25% Compound Interest Factors

n	Single Payment: Compound Amount Factor F/P	Single Payment: Present Worth Factor P/F	Uniform Series: Sinking Fund Factor A/F	Uniform Series: Capital Recovery Factor A/P	Uniform Series: Compound Amount Factor F/A	Uniform Series: Present Worth Factor P/A	n
1	1.2500	0.8000	1.000 00	1.250 00	1.000	0.800	1
2	1.5625	0.6400	0.444 44	0.694 44	2.250	1.440	2
3	1.9531	0.5120	0.262 30	0.512 30	3.813	1.952	3
4	2.4414	0.4096	0.173 44	0.423 44	5.766	2.362	4
5	3.0518	0.3277	0.121 85	0.371 85	8.207	2.689	5
6	3.8147	0.2621	0.088 82	0.338 82	11.259	2.951	6
7	4.7684	0.2097	0.066 34	0.316 34	15.073	3.161	7
8	5.9605	0.1678	0.050 40	0.300 40	19.842	3.329	8
9	7.4506	0.1342	0.038 76	0.288 76	25.802	3.463	9
10	9.3132	0.1074	0.030 07	0.280 07	33.253	3.571	10
11	11.6415	0.0859	0.023 49	0.273 49	42.566	3.656	11
12	14.5519	0.0687	0.018 45	0.268 45	54.208	3.725	12
13	18.1899	0.0550	0.014 54	0.264 54	68.760	3.780	13
14	22.7374	0.0440	0.011 50	0.261 50	86.949	3.824	14
15	28.4217	0.0352	0.009 12	0.259 12	109.687	3.859	15
16	35.5271	0.0281	0.007 24	0.257 24	138.109	3.887	16
17	44.4089	0.0225	0.005 76	0.255 76	173.636	3.910	17
18	55.5112	0.0180	0.004 59	0.254 59	218.045	3.928	18
19	69.3889	0.0144	0.003 66	0.253 66	273.556	3.942	19
20	86.7362	0.0115	0.002 92	0.252 92	342.945	3.954	20
21	108.4202	0.0092	0.002 33	0.252 33	429.681	3.963	21
22	135.5253	0.0074	0.001 86	0.251 86	538.101	3.970	22
23	169.4066	0.0059	0.001 48	0.251 48	673.626	3.976	23
24	211.7582	0.0047	0.001 19	0.251 19	843.033	3.981	24
25	264.6978	0.0038	0.000 95	0.250 95	1 054.791	3.985	25
26	330.8722	0.0030	0.000 76	0.250 76	1 319.489	3.988	26
27	413.5903	0.0024	0.000 61	0.250 61	1 650.361	3.990	27
28	516.9879	0.0019	0.000 48	0.250 48	2 063.952	3.992	28
29	646.2349	0.0015	0.000 39	0.250 39	2 580.939	3.994	29
30	807.7936	0.0012	0.000 31	0.250 31	3 227.174	3.995	30
31	1 009.7420	0.0010	0.000 25	0.250 25	4 034.968	3.996	31
32	1 262.1774	0.0008	0.000 20	0.250 20	5 044.710	3.997	32
33	1 577.7218	0.0006	0.000 16	0.250 16	6 306.887	3.997	33
34	1 972.1523	0.0005	0.000 13	0.250 13	7 884.609	3.998	34
35	2 465.1903	0.0004	0.000 10	0.250 10	9 856.761	3.998	35
40	7 523.1638	0.0001	0.000 03	0.250 03	30 088.655	3.999	40
45	22 958.8740	0.0001	0.000 01	0.250 01	91 831.496	4.000	45
50	70 064.9232	0.0000	0.000 00	0.250 00	280 255.693	4.000	50
∞				0.250 00		4.000	∞

30% Compound Interest Factors

	Single Payment		Uniform Series				
n	Compound Amount Factor F/P	Present Worth Factor P/F	Sinking Fund Factor A/F	Capital Recovery Factor A/P	Compound Amount Factor F/A	Present Worth Factor P/A	n
1	1.3000	0.7692	1.000 00	1.300 00	1.000	0.769	1
2	1.6900	0.5917	0.434 78	0.734 78	2.300	1.361	2
3	2.1970	0.4552	0.250 63	0.550 63	3.990	1.816	3
4	2.8561	0.3501	0.161 63	0.461 63	6.187	2.166	4
5	3.7129	0.2693	0.110 58	0.410 58	9.043	2.436	5
6	4.8268	0.2072	0.078 39	0.378 39	12.756	2.643	6
7	6.2749	0.1594	0.056 87	0.356 87	17.583	2.802	7
8	8.1573	0.1226	0.041 92	0.341 92	23.858	2.925	8
9	10.6045	0.0943	0.031 24	0.331 24	32.015	3.019	9
10	13.7858	0.0725	0.023 46	0.323 46	42.619	3.092	10
11	17.9216	0.0558	0.017 73	0.317 73	56.405	3.147	11
12	23.2981	0.0429	0.013 45	0.313 45	74.327	3.190	12
13	30.2875	0.0330	0.010 24	0.310 24	97.625	3.223	13
14	39.3738	0.0254	0.007 82	0.307 82	127.913	3.249	14
15	51.1859	0.0195	0.005 98	0.305 98	167.286	3.268	15
16	66.5417	0.0150	0.004 58	0.304 58	218.472	3.283	16
17	86.5042	0.0116	0.003 51	0.303 51	285.014	3.295	17
18	112.4554	0.0089	0.002 69	0.302 69	371.518	3.304	18
19	146.1920	0.0068	0.002 07	0.302 07	483.973	3.311	19
20	190.0496	0.0053	0.001 59	0.301 59	630.165	3.316	20
21	247.0645	0.0040	0.001 22	0.301 22	820.215	3.320	21
22	321.1839	0.0031	0.000 94	0.300 94	1 067.280	3.323	22
23	417.5391	0.0024	0.000 72	0.300 72	1 388.464	3.325	23
24	542.8008	0.0018	0.000 55	0.300 55	1 806.003	3.327	24
25	705.6410	0.0014	0.000 43	0.300 43	2 348.803	3.329	25
26	917.3333	0.0011	0.000 33	0.300 33	3 054.444	3.330	26
27	1 192.5333	0.0008	0.000 25	0.300 25	3 971.778	3.331	27
28	1 550.2933	0.0006	0.000 19	0.300 19	5 164.311	3.331	28
29	2 015.3813	0.0005	0.000 15	0.300 15	6 714.604	3.332	29
30	2 619.9956	0.0004	0.000 11	0.300 11	8 729.985	3.332	30
31	3 405.9943	0.0003	0.000 09	0.300 09	11 349.981	3.332	31
32	4 427.7926	0.0002	0.000 07	0.300 07	14 755.975	3.333	32
33	5 756.1304	0.0002	0.000 05	0.300 05	19 183.768	3.333	33
34	7 482.9696	0.0001	0.000 04	0.300 04	24 939.899	3.333	34
35	9 727.8604	0.0001	0.000 03	0.300 03	32 422.868	3.333	35
∞				0.300 00		3.333	∞

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