Oxford Cambridge and RSA

Level 3 Alternative Academic Qualification Cambridge Advanced Nationals in Engineering

H027/H127

Formulae Booklet

Unit F130: Principles of engineering

This booklet contains formulae which learners studying the above unit and taking associated examination papers may need to access.

Other relevant formulae may be provided in some questions within examination papers. However, in most cases suitable formulae will need to be selected and applied by the learner. Clean copies of this booklet will be supplied alongside examination papers to be used for reference during examinations.

Formulae have been organised by topic rather than by unit as some may be suitable for use in more than one context.

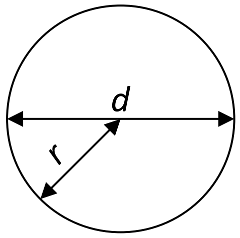
Note for teachers

This booklet does not replace the taught content in the unit specification or contain an exhaustive list of required formulae. You should ensure all unit content is taught before learners take associated examinations.

1. Mathematics

Mensuration

Circle



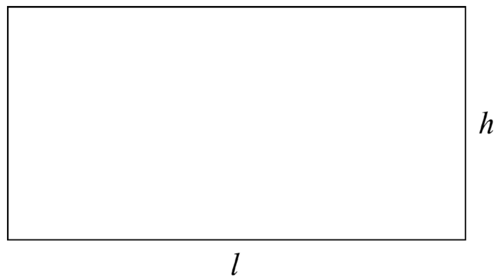
Radius $= \mathrm{r}$

Diameter $= d$

Area of a circle $= \pi r^2$ or $= \frac{\pi}{4}d^2$

Circumference of a circle $= 2\pi r$ or $= \pi d$

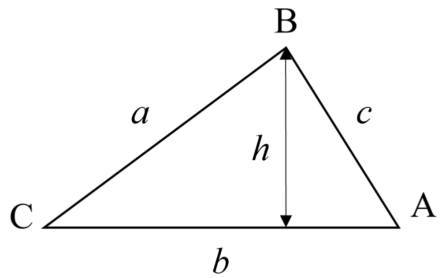
Rectangle



Area $= lh$

Perimeter $= 2l + 2h$

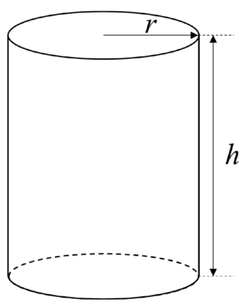
Triangle



Area $= \frac{1}{2}bh$ or $\frac{1}{2}bc\sin A$

Perimeter $= a + b + c$

Cylinder

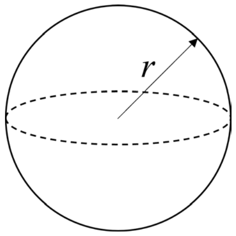


Curved surface area $= 2\pi rh$

Total surface area $= 2\pi r^2 + 2\pi rh$

Volume $= \pi r^2 h$

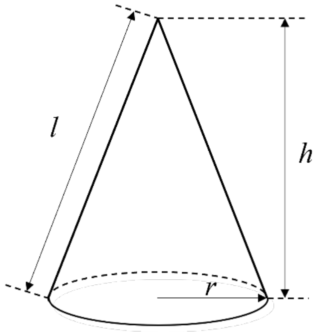
Sphere



Surface area $= 4\pi r^2$

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

Cone



Curved surface area $= \pi r l$

Total surface area $= \pi r^2 + \pi r l$

Volume $= \frac{1}{3}\pi r^2 h$

Density

Density $= \frac{mass}{volume}$

$\rho = \frac{m}{v}$

Algebra – straight-lines

Straight-line

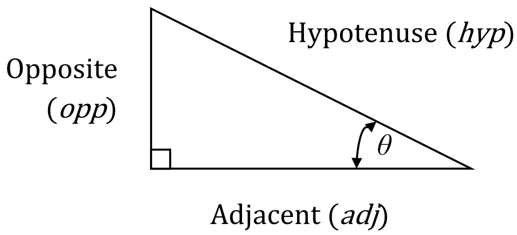
$y = mx + c$, where:

gradient $m = \frac{\Delta y}{\Delta x}$

the intercept = c

Trigonometry

Trigonometric Ratios



$sin\,\theta = \frac{opp}{hyp}$

$cos\,\theta = \frac{adj}{hyp}$

$tan\,\theta = \frac{opp}{adj}$

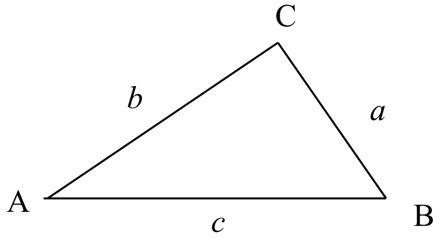
Pythagoras' rule: $hyp^2 = opp^2 + adj^2$

Converting between radians and degrees

$radians = degrees \times \frac{\pi}{180}$

$degrees = radians \times \frac{180}{\pi}$

Sine and Cosine rules



Sine rule: $\frac{sin\,A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$

Cosine rule: $a^2 = b^2 + c^2 - 2bc\cos A$

$b^2 = a^2 + c^2 - 2ac\cos B$

$c^2 = b^2 + a^2 - 2ab\cos C$

2. Mechanical equations

Systems of forces

Moment = force × distance	$M = Fd$
Vertical component of force	$F_v = F \sin\theta,\ \theta$ from the horizontal
Horizontal component of force	$F_h = F \cos\theta,\ \theta$ from the horizontal
Resultant force	$F_R = \sqrt{\sum F_v^2 + \sum F_h^2}$
Direct tensile or compressive stress	$\sigma = \frac{F}{A}$
Direct tensile or compressive strain	$\varepsilon = \frac{\Delta L}{L}$
Modulus of elasticity or Young's modulus	$E = \frac{\sigma}{\varepsilon}$
Shear stress	$\tau = \frac{F}{A}$
Shear strain	$\gamma = \frac{\Delta L}{L}$
Modulus of rigidity	$G = \frac{\tau}{\gamma}$

Linear dynamic systems

Force = mass × acceleration	$F = ma$
Weight = mass × acceleration due to gravity	$W = mg$
Work done = force × distance	$W = Fd$
Gravitational potential energy = mass × gravitational acceleration × height	$E_p = mgh$
Kinetic energy $= \frac{1}{2}\text{mass} \times \text{velocity}^2$	$E_k = \frac{1}{2}mv^2$
Average power $= \frac{\text{work done}}{\text{time}}$	$P = \frac{W}{t}$
Instantaneous power = force × velocity	$P = Fv$
Efficiency	$\eta = \frac{E_{out}}{E_{in}} \times 100\%$
Static friction	$F \leq \mu N$
Momentum = mass × velocity	$p = mv$

SUVAT equations:

(s – distance, u – initial velocity, v – final velocity, a – acceleration and t – time.)

- $v = u + at$
- $v^2 = u^2 + 2as$
- $s = ut + \frac{1}{2}at^2$
- $s = \frac{1}{2}(u + v)t$

Conservation of momentum:

- Collisions between two bodies $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
- Perfectly inelastic collisions between two bodies $m_1u = (m_1 + m_2)v$

3. Electrical/electronic equations

Electrical principles

Charge = current × time	$Q = It$
Electrical energy = charge × voltage (potential difference)	$E = QV$
Electrical energy = power × time	$E = Pt$
Resistivity = $\frac{resistance \times cross\ sectional\ area}{length\ of\ the\ conductor}$	$\rho = \frac{RA}{l}$
Ohm's Law for DC circuits, resistance = $\frac{voltage}{current}$	$R = \frac{V}{I}$
Ohm's law for purely resistive AC circuits, impedance = $\frac{voltage}{current}$	$z = \frac{V}{I}$
Total resistance of series resistors	$R_T = R_1 + R_2 + R_3 \ldots$
Total resistance of parallel resistors	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$
Electrical power $= voltage \times current$	$P = VI$
$= current^2 \times resistance$	$P = I^2R$
$= \frac{Voltage^2}{resistance}$	$P = \frac{V^2}{R}$
Kirchhoff's current law (KCL) – for a junction	$\sum I_{In} = \sum I_{out}$
Kirchhoff's voltage law (KVL) – for a loop	$\sum V = 0$
Permittivity = permittivity of free space × relative permittivity	$\varepsilon = \varepsilon_0 \times \varepsilon_r$
Capacitance = permittivity × $\frac{Cross\ sectional\ area}{distance\ between\ plates}$	$C = \varepsilon\frac{A}{d}$
Capacitance = $\frac{Quantity\ of\ charge}{Voltage}$	$C = \frac{Q}{V}$
Energy stored in a capacitor = $\frac{1}{2}$ × capacitance × Voltage^2	$E = \frac{1}{2}CV^2$
Time constant of a capacitor = resistance × capacitance	$\tau = RC$
Inductance of a coil = $\frac{\text{Magnetic Flux} \times \text{Number of Turns}}{\text{current}}$	$L = \frac{\Phi N}{I}$
Energy stored in an inductor = $\frac{1}{2}$ × inductance × current^2	$E = \frac{1}{2}LI^2$
Force on conductor = flux density × current × length × sine angle	$F = BIl \sin\theta$
AC voltage waveform = max. Voltage × sine (angular velocity × time)	$v = V_{max}\sin(\omega t)$
Angular velocity of a waveform = 2 × π × frequency	$\omega = 2\pi f$
Frequency = $\frac{1}{\text{Time Period}}$	$f = \frac{1}{T}$

Root-Mean-Square (RMS) Voltage $= \frac{\text{Peak Voltage}}{\sqrt{2}}$ $V_{RMS} = \frac{V_{PK}}{\sqrt{2}}$

Energy efficiency $\eta = \frac{\text{energy output}}{\text{energy input}} \text{ x } 100\%$

Analogue Circuits

Voltage amplifier gain/loss $= \frac{\text{Voltage}_{\text{out}}}{\text{Voltage}_{\text{in}}}$ $A_v = \frac{V_{out}}{V_{in}}$

Current amplifier gain/loss $= \frac{\text{Current}_{\text{out}}}{\text{Current}_{\text{in}}}$ $A_I = \frac{I_{out}}{I_{in}}$

Power amplifier gain/loss = Voltage gain/loss × Current gain/loss $A_P = A_v \times A_I$

Voltage gain/loss in Decibels $a_v(dB) = 20 \times Log A_v$

Current gain/loss in Decibels $a_I(dB) = 20 \times Log A_I$

Power gain/loss in Decibels $a_P(dB) = 10 \times Log A_P$

Gain of an op-amp: Non-inverting $\text{Gain } (A_v) = 1 + \frac{R_1}{R_2}$

Inverting $\text{Gain } (A_v) = -\frac{R_1}{R_2}$

4. Mathematical, Mechanical and Electrical/Electronic constants

- Acceleration due to gravity $g = 9.81$ ms^{-2}
- Permittivity of free space $\mathcal{E}_0 = 8.85 \times 10^{-12}$ Fm^{-1}
- Relative permittivity $\mathcal{E}_r$:
  - Relative permittivity of a vacuum $\mathcal{E}_{vacuum} = 1$
  - Relative permittivity of air $\mathcal{E}_{air} = 1.0006$
  - Relative permittivity of a ceramic $\mathcal{E}_{\text{Ceramic}} = 2$