Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Learner Registration Number

Pearson BTEC Level 3 Nationals Extended Diploma

Thursday 25 May 2023

Morning (Time: 2 hours)

Paper reference **31706H**

Engineering

UNIT 1: Engineering Principles

You must have:
Information Booklet of Formulae and Constants (enclosed), ruler, protractor, pencil and calculator.

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and learner registration number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- You may need to recall a few formulae and constants that are not provided in the Information Booklet of Formulae and Constants and you may be rewarded for doing so.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- You may use a non-programmable calculator that does not have the facility for symbolic algebraic manipulation or allow the storage and retrieval of mathematical formulae.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question, show all your working and always answer to an appropriate degree of accuracy.
- Check your answers if you have time at the end.

Turn over ▶

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SECTION A

Applied Mathematics

Answer ALL questions. Write your answers in the spaces provided.

1 The relationship between the planned direction of flight of an aeroplane and the distance (in km) it would move off course due to crosswinds is represented by the tangent function:

$y = \tan\theta$

(a) Find the distance y for values of θ between $-80°$ and $80°$.

Record the distance values in the table below to 1 decimal place.

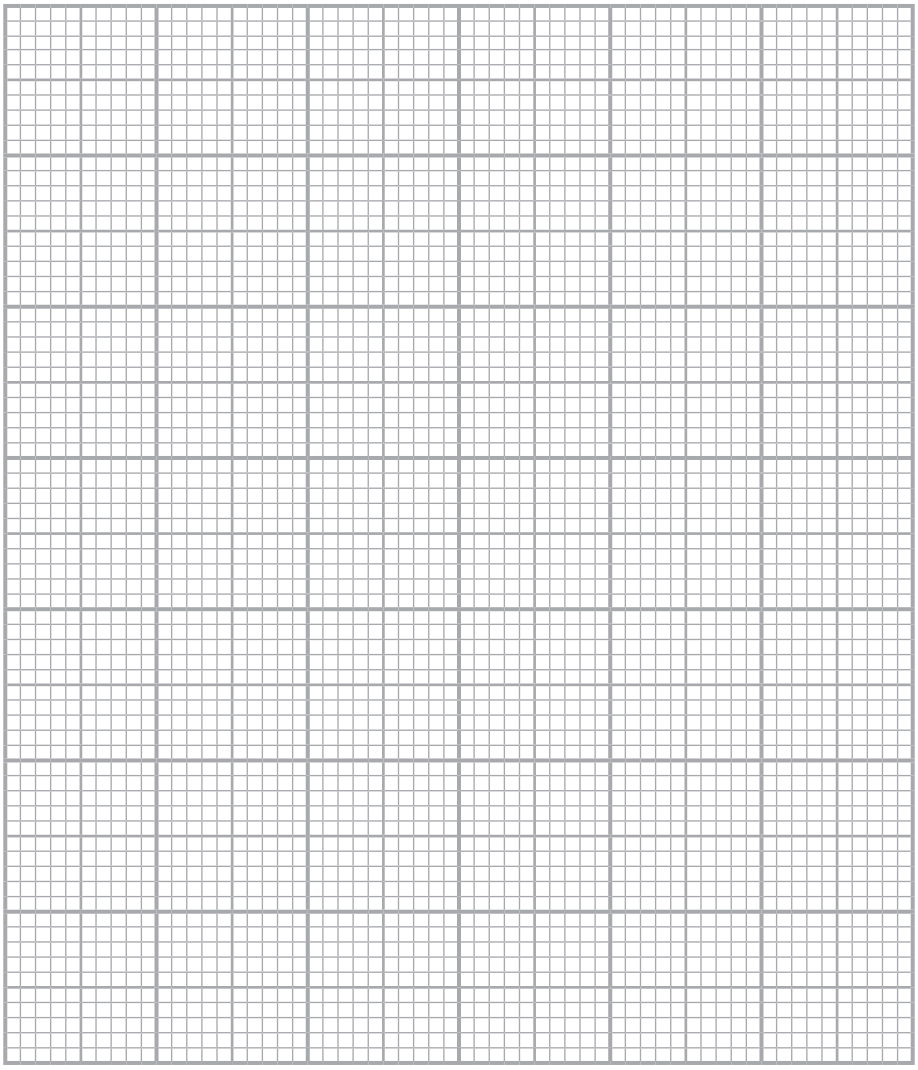
(1)

Angle (θ)	$-80°$	$-60°$	$-30°$	$0°$	$30°$	$60°$	$80°$
y (km)							

(b) Draw a curved graph to represent the function $y = \tan\theta$ for values of θ between $-80°$ and $80°$.

You should include labels and axes values on your diagram.

(3)



(Total for Question 1 = 4 marks)

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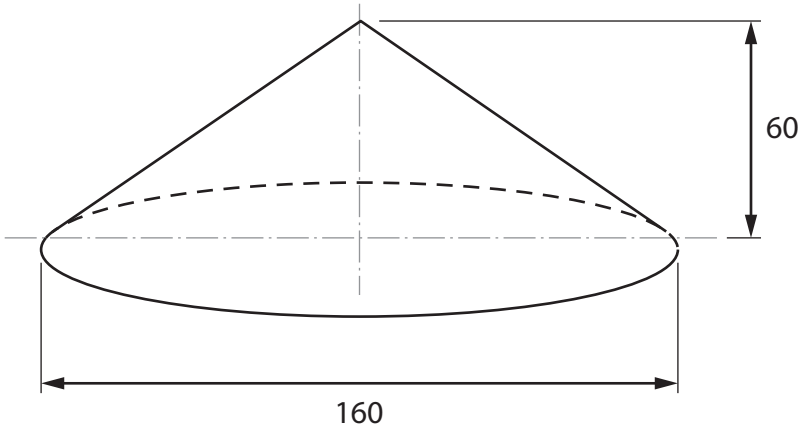
2 A solid conical component has been turned from a piece of brass.



All dimensions in mm

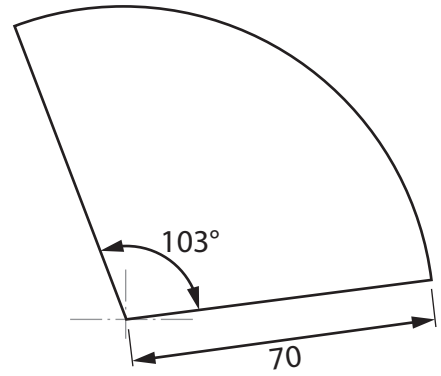
Diagram not to scale

Calculate the volume of the conical component.

Answer: .....

(Total for Question 2 = 3 marks)

3 The diagram shows a component cut from a sheet of polymer.



All dimensions in mm

Diagram not to scale

(a) Convert 103° into radians.

(2)

Answer: .....

(b) Calculate the area of the component.

(2)

Answer: .....

(Total for Question 3 = 4 marks)

4 The diagram shows part of an electricity transmission tower.

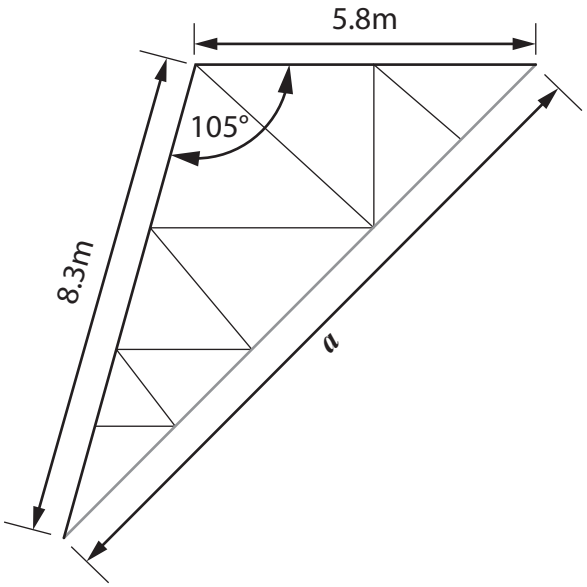


Diagram not to scale

Calculate the length of side *a*.

Answer: .....

(Total for Question 4 = 4 marks)

5 A car on a fairground ride follows a path represented by the expression

$-2t^2 + 11t - h = 0$

where t is the time since the ride started (in seconds), and h is the height of the ride.

Find, **by factorisation**, the two values of t when the height of the ride is 15m.

Time 1: .....

Time 2: .....

(Total for Question 5 = 5 marks)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

Mechanical Principles

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

6 The diagram shows a free body diagram of three opposing forces.

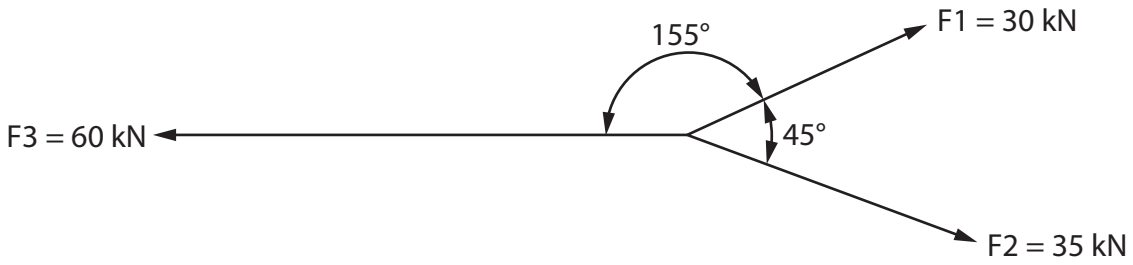

Diagram not to scale

Identify the term used to describe the force F3.

☒ **A** Converter

☒ **B** Emitter

☒ **C** Equilibrant

☒ **D** Moment

(Total for Question 6 = 1 mark)

7 Identify the unit of measure for centripetal acceleration.

☒ **A** Metres per second squared

☒ **B** Metres squared per second

☒ **C** Radians per second squared

☒ **D** Radians squared per second

(Total for Question 7 = 1 mark)

8 A car of mass 580kg has been raised vertically from ground level by a hoist.

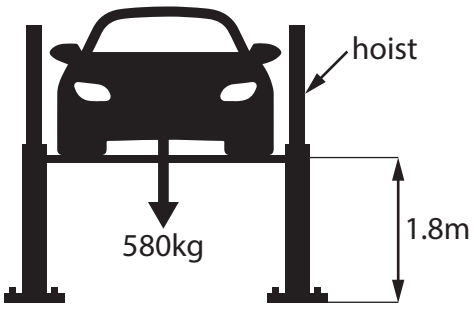

Diagram not to scale

(a) Calculate the force exerted by the car on the hoist.

(2)

Answer: .....

(b) Calculate the work done raising the car vertically from ground level to a height of 1.8m.

Give your answer in an appropriate unit.

(3)

Answer: .....

(Total for Question 8 = 5 marks)

9 A simply supported beam has a concentrated load and a uniformly distributed load (UDL) along part of its length.

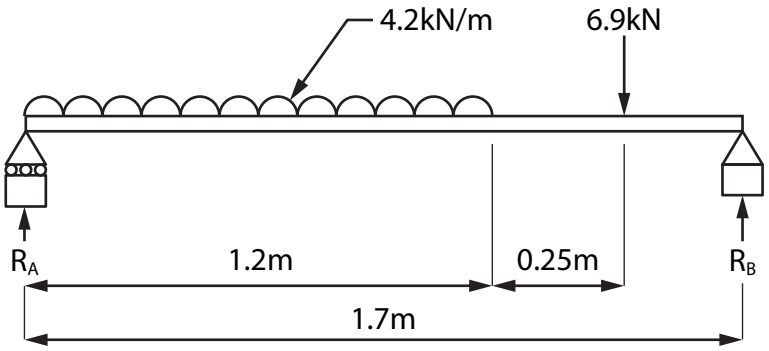

Diagram not to scale

(a) Calculate the value of the UDL when it is treated as a concentrated load.

(1)

(b) Calculate the reaction force R_B.

(6)

Answer: .....

(Total for Question 9 = 7 marks)

10 A space probe is moving through space at a constant velocity.

Describe how Newton's first law of motion applies to the space probe.

.....

.....

.....

.....

(Total for Question 10 = 2 marks)

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11 A full storage tank has a volume of $5m^3$ and contains 4250kg of an incompressible liquid fuel.

The liquid fuel flows through a rigid tapering pipe.

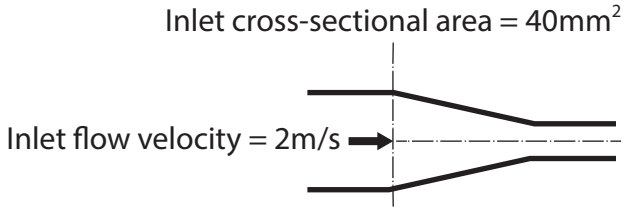


Diagram not to scale

Calculate the mass flow rate ($\dot{m}$) of the liquid fuel.

Answer: .....

(Total for Question 11 = 6 marks)

12 A sports bicycle wheel is a solid disc (cylinder) that has a radius of 0.3m. The bicycle travels at a constant velocity of 5m/s.

The mass of the wheel is 2kg.

Calculate the rotational kinetic energy of the wheel.

Answer: .....

(Total for Question 12 = 8 marks)

TOTAL FOR SECTION B = 30 MARKS

SECTION C

Electrical and Electronic Principles

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

13 Identify the electrical theory that states the algebraic sum of all voltages within a closed loop network must be equal to zero.

- ☒ **A** Bernoulli's principle
- ☒ **B** Fleming's rule
- ☒ **C** Kirchhoff's law
- ☒ **D** Lenz's law

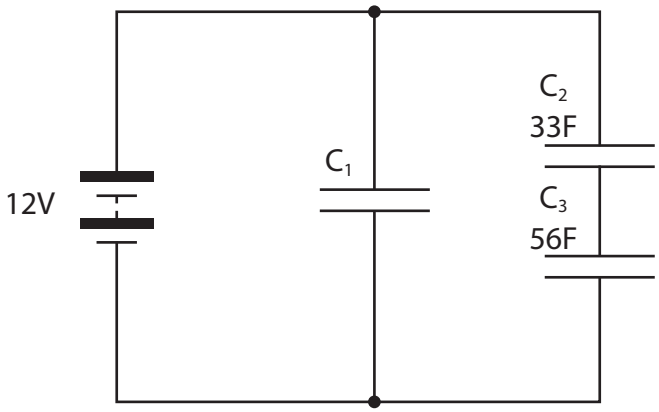
(Total for Question 13 = 1 mark)

14 Identify a unit of measure for reluctance.

- ☒ **A** Ampere-turns per weber
- ☒ **B** Farads per second
- ☒ **C** Ohm-turns per coulomb
- ☒ **D** Volts per metre

(Total for Question 14 = 1 mark)

15 A DC power source is connected to three capacitors in a combined series and parallel arrangement.



Calculate the total capacitance of the two capacitors connected in series (C_2 and C_3).

Answer: .....

(Total for Question 15 = 3 marks)

16 An engineer takes readings across the terminals of a DC electric motor. They record a supply voltage of 120V and a current of 5A.

(a) Calculate the input power of the DC motor.

Give your answer in an appropriate unit.

(3)

Answer: .....

The engineer tests the DC motor and finds it to be 65% efficient.

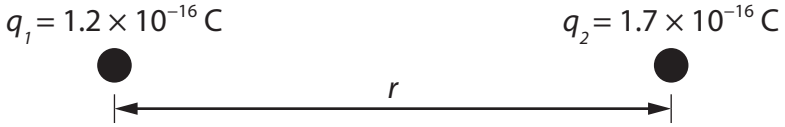
(b) Calculate the output power of the DC motor.

(3)

Answer: .....

(Total for Question 16 = 6 marks)

17 A maintenance engineer services powder-coating equipment that works on the principle of electrostatic attraction. The charges on two particles have been recorded.



The force between the two particles is 8.2×10^{-8} N.

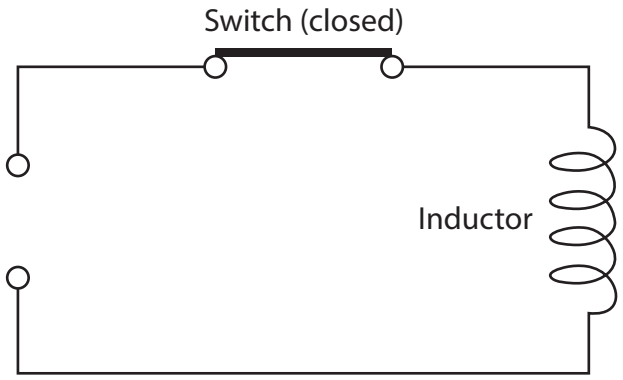
Calculate the distance (*r*) between the two charged particles.

Answer: .....

(Total for Question 17 = 4 marks)

18 A steady state direct current of 10A passes through an inductor coil that has 500 turns.

The energy stored in the inductor coil is 37.5 J.

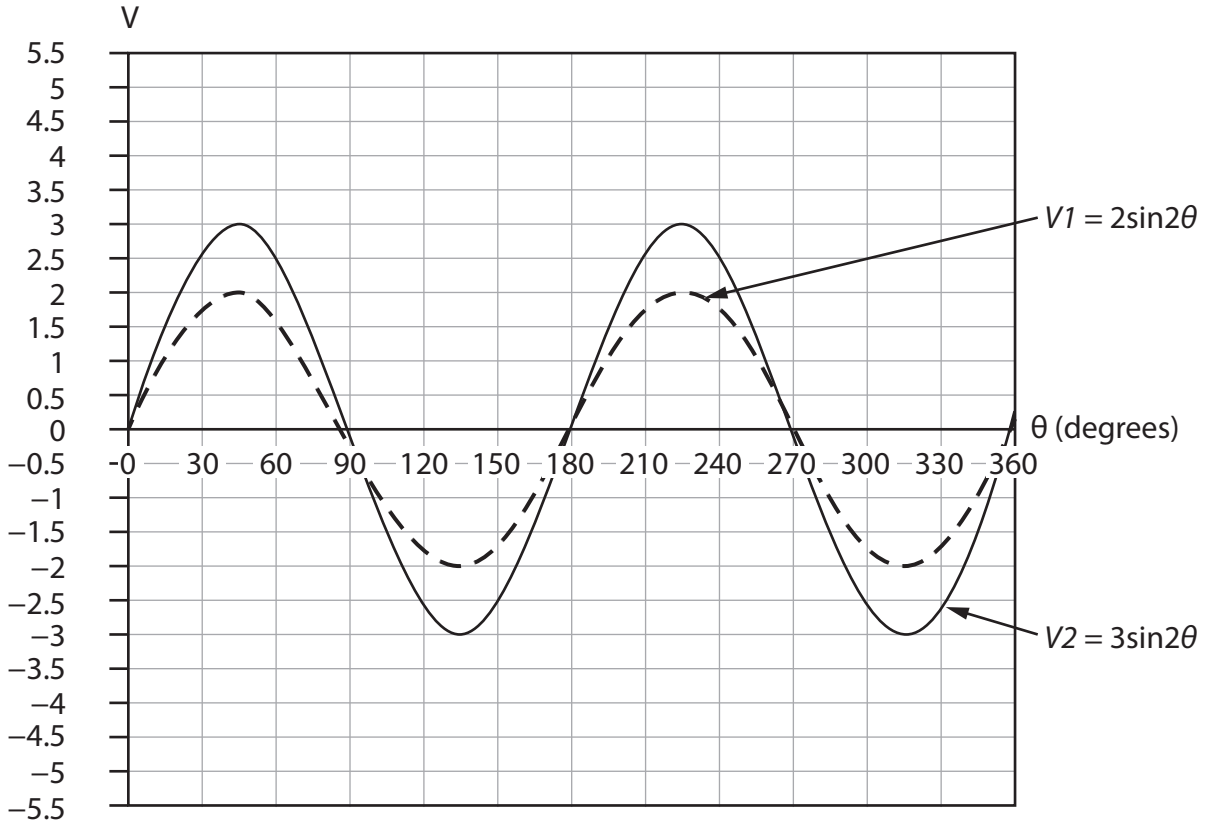


Calculate the induced back EMF voltage in the coil after the switch has been opened for 2ms.

Answer: .....

(Total for Question 18 = 7 marks)

19 A technician has measured the waveforms of two sinusoidal AC supplies. Both waveforms have the same frequency.



$V1 = 2\sin 2\theta$

$V2 = 3\sin 2\theta$

Calculate the form factor of the combined AC supplies ($V1 + V2$).

Answer: .....

(Total for Question 19 = 8 marks)

TOTAL FOR SECTION C = 30 MARKS
TOTAL FOR PAPER = 80 MARKS

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Pearson BTEC Level 3 Nationals Extended Diploma

Thursday 25 May 2023

Morning (Time: 2 hours)

Paper reference **31706H**

Engineering

UNIT 1: Engineering Principles

Information Booklet of Formulae and Constants

Do not return this Booklet with the question paper.

Instructions

- You will need the information in this booklet to answer most questions. You may need to recall a few formulae and constants that are not provided in this booklet and you may be rewarded for doing so.
- Read the information carefully.
- You must not write your answers in this booklet.
- Only your answers given in the question paper will be marked.

Turn over ▶

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Formulae and constants

Maths

Laws of indices

$a^m \times a^n = a^{(m+n)}$

$\frac{a^m}{a^n} = a^{(m-n)}$

$\left(a^m\right)^n = a^{mn}$

Laws of logarithms

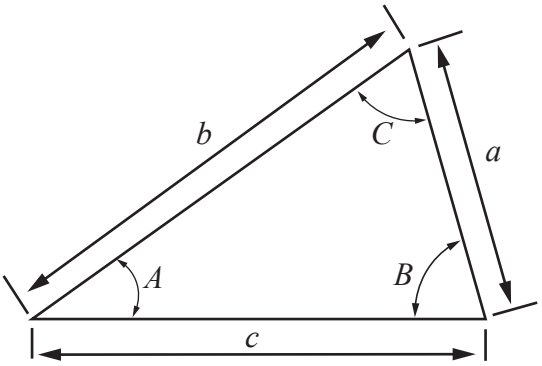
$\log AB = \log A + \log B$

$\log \frac{A}{B} = \log A - \log B$

$\log A^n = n \log A$

Note: the laws apply to Naperian/natural logarithms $ln(\square)$

Trigonometric rules



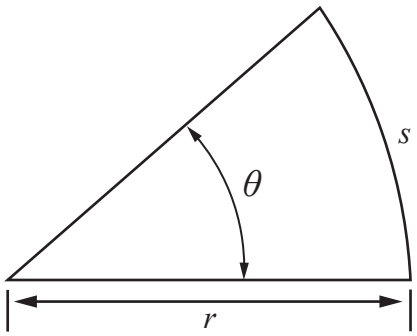
Sine rule

$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$ or $\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$

Cosine rule

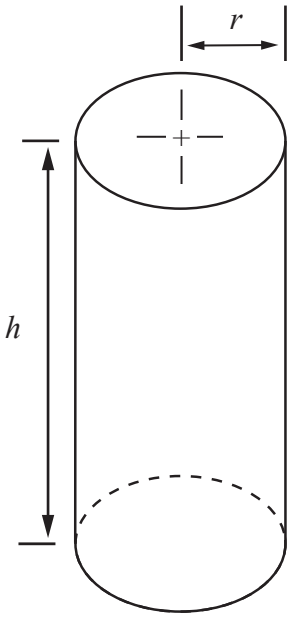
$a^2 = b^2 + c^2 - 2bc\cos A$

Volume and area of regular shapes



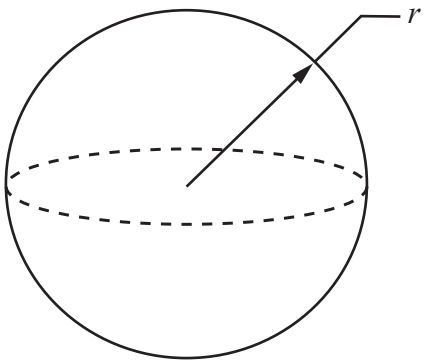
Length of an arc of a circle $s = r\theta$ (where θ is expressed in radians)

Area of a sector of a circle $A = \frac{1}{2}r^2\theta$ (where θ is expressed in radians)



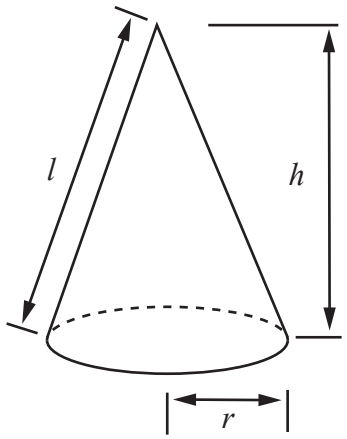
Volume of a cylinder $V = \pi r^2 h$

Total surface area of a cylinder $TSA = 2\pi rh + 2\pi r^2$



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

Surface area of a sphere $SA = 4\pi r^2$



Volume of a cone $V = \frac{1}{3}\pi r^2 h$

Curved surface area of a cone $CSA = \pi rl$

Quadratic formula

To solve $ax^2 + bx + c = 0,\ a \neq 0$

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

Physical constants

Acceleration due to gravity $g = 9.81\text{m/s}^2$

Permittivity of free space $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F/m}$

Permeability of free space $\mu_0 = 4\pi \times 10^{-7}\ \text{H/m}$

Equations of linear motion with uniform acceleration

v = final velocity, u = initial velocity, a = acceleration, t = time and s = distance

$$v = u + at$$

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

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

$$s = \frac{1}{2}(u+v)t \text{ or } s = \frac{u+v}{2}t$$

Stress and strain

Direct stress	$\sigma = \frac{F}{A}$
Direct strain	$\varepsilon = \frac{\Delta l}{l}$
Shear stress	$\tau = \frac{F}{A}$
Shear strain	$\gamma = \frac{a}{b}$
Young's Modulus (modulus of elasticity)	$E = \frac{\sigma}{\varepsilon}$
Modulus of rigidity	$G = \frac{\tau}{\gamma}$

Work, power, energy and forces

Force	$F = ma$
Components of forces	$F_x = F\cos\theta$, $F_y = F\sin\theta$ (where θ is measured from the horizontal)
Mechanical work	$W = Fs$
Mechanical power	$P = Fv, P = \frac{W}{t}$
Mechanical efficiency	$\text{Efficiency } (\eta) = \frac{P_{out}}{P_{in}}$
Force to overcome limiting friction	$F = \mu N$ (where N is the normal force)
Gravitational potential energy	$PE = mgh$
Kinetic energy	$KE = \frac{1}{2}mv^2$

Angular parameters

Centripetal acceleration	$a = \omega^2 r$ or $a = \frac{v^2}{r}$
Power	$P = T\omega$
Rotational inertia	$I = kmr^2$ The inertial constant: k = 0.5 for a solid cylinder (flywheel) k = 1 for a thin walled hollow cylinder (along the axis of rotation).
Rotational kinetic energy	$KE = \frac{1}{2} I\omega^2$
Angular frequency	$\omega = 2\pi f$
Frequency	$f = \frac{1}{\text{time period}}$
Radians to degrees conversion	$\theta_{(\text{degrees})} = \frac{360\theta_{(\text{radians})}}{2\pi}$ (where 2π radians = $360°$)
Degrees to radians conversion	$\theta_{(\text{radians})} = \frac{2\pi\theta_{(\text{degrees})}}{360}$

Fluid principles

Continuity of volumetric flow	$A_1 v_1 = A_2 v_2$
Continuity of mass flow	$\rho A_1 v_1 = \rho A_2 v_2$
Hydrostatic thrust on an immersed plane surface	$F = \rho g A x$
Density	$\rho = \frac{m}{V}$

Static and DC electricity theory

Current/electron flow	$I = \frac{q}{t}$
Coulomb's law	$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$
Resistance	$R = \frac{\rho l}{A}$
Resistance: temperature coefficient	$\frac{\Delta R}{R_0} = \alpha \Delta T$
Ohm's Law DC circuit	$I = \frac{V}{R}$
Total for resistors in series	$R_T = R_1 + R_2 + R_3 ...$
Total for resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} ...$
Power	$P = IV,\ P = I^2 R,\ P = \frac{V^2}{R}$
Electrical efficiency	$\text{Efficiency } (\eta) = \frac{P_{out}}{P_{in}}$
Kirchhoff's Current Law	$I = I_1 + I_2 + I_3 \ldots$
Kirchhoff's Voltage Law	$V = V_1 + V_2 + V_3 \ldots$ or $\sum pd = \sum IR$

Capacitance

Capacitance	$C = \frac{\varepsilon A}{d}$
Time constant	$\tau = RC$
Charge stored	$Q = CV$
Energy stored in a capacitor	$W = \frac{1}{2} CV^2$
Capacitors in series	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots$
Capacitors in parallel	$C_T = C_1 + C_2 + C_3 \ldots$
Voltage across a discharging capacitor	$V_C = V_S \mathrm{e}^{\left(\frac{-t}{\tau}\right)}$
	(where V_c = capacitor voltage and V_s = supply voltage)

Magnetism and electromagnetism

Electric field strength	$E = \frac{F}{q}$ or $E = \frac{V}{d}$ for uniform electric fields
Magnetic flux density	$B = \frac{\Phi}{A}$
Magneto motive force	$F_m = NI$
Magnetic field strength or magnetising force	$H = \frac{NI}{l}$
Permeability	$\frac{B}{H} = \mu_0 \mu_r$
Reluctance	$S = \frac{F_m}{\Phi}$
Induced EMF	$E = Blv,\ E = -N\frac{\mathrm{d}\Phi}{\mathrm{d}t} = -L\frac{\mathrm{d}i}{\mathrm{d}t}$
Energy stored in an inductor	$W = \frac{1}{2}LI^2$
Inductance of a coil	$L = N\frac{\Phi}{I}$
Transformer equation	$\frac{V_1}{V_2} = \frac{N_1}{N_2}$

Single Phase Alternating Current Theory

Time period	$T = \frac{1}{f}$
Capacitive reactance	$X_C = \frac{1}{2\pi fC}$
Inductive reactance	$X_L = 2\pi fL$
Ohm's Law AC circuits	$I = \frac{V}{Z}$
Root mean square voltage	$\text{r.m.s voltage} = \frac{\text{peak voltage}}{\sqrt{2}}$
Total impedance of an inductor in series with a resistance	$Z = \sqrt{X_L{}^2 + R^2}$
Total impedance of a capacitor in series with a resistance	$Z = \sqrt{X_C{}^2 + R^2}$
Waveform average value	$\text{Average value} = \frac{2}{\pi} \times \text{maximum value}$
Form factor of a waveform	$\text{Form factor} = \frac{\text{r.m.s. value}}{\text{average value}}$