Measurement Units for Automotive Engineering.

Measurement is required for a number of areas within automotive disciplines so we can be sure that the vehicle is operating within the limits prescribed by the manufacturer. There are a number of different units of measurement used within this area and the common ones are identified below.

In engineering we have to understand and use different quantities, size, temperature and force. These quantities need to be measured in a standard system of units i.e. if a piston made in one country has a diameter of 100mm then it should able to be matched with an engine block from another country.

An international agreement defines these units. This is called the System International d'Unites, and the symbol is SI. This more commonly known as the metric system. The quantities we deal with most in automotive engineering are:

Quantity	Symbol	Unit	Unit symbol
Length	I	Metres	m
Mass	m	Kilogram	kg
Time	t	Second	s
Current	I	Ampere	A
Temperature	T	Kelvin	K
Area	A	Metre squared	m2
Volume	V	Metre cubed	m3
Pressure	P	bar	bar
Velocity	v	Metres per second	mls
Force	F	Newton's	N

Other units that we use are derived from these units, for example if we need to find the area of a square we multiply the length by the breadth, if we are multiplying using the same Units e.g. metres by metres we would have metres^2.

It is not always convenient to measure everything in its core units, for example a spark plug gap would not be measured in metres, 0.0005m, so it makes things simpler to use the SI prefixes as the core units. These multiples are the same no matter what base units they are applied to.

Prefix	Symbol	Factor by which it is multiplied.	
Giga	G	10^9	1000000000
Mega	M	10^6	1000000
Kilo	k	10^3	1000
Deca	da	10^1	10
Deci	d	10^{-1}	0.1
Centi	c	10^{-2}	0.01
Milli	m	10^{-3}	0.001
Micro	□	10^{-6}	0.000001

The Imperial System

For many years in the UK, and in many other parts of the world the imperial system was used. Many classic vehicle components are still measured in imperial units. It is useful to be able to convert from imperial to metric and vice versa.

The imperial system is based in feet, pounds and seconds. No conversion is required for time, as it remains the same; however the foot (ft) is $^1/_3$ of a yard, which is 0.94536 metres. The pound (lb) is measured at 0.453 kilograms.

There are tables of charts for conversion in diaries, on wall charts and in many technical data manuals, but you still need to be careful as mistakes can easily happen, leading to a wrong answer. You must either multiply or divide to do the conversion.

The chart below shows the conversion for a number of common Units.

Length (distance)					
Inches (in)	x 25.4	= Millimetres (mm)	x 0.0394	=	Inches (in)
Feet (ft)	x 0.305	= Metres (m)	x 3.281	=	Feet (ft)
Miles	x 1.609	= Kilometres (km)	x 0.621	=	Miles
Volume (capacity)					
Cubic inches (cu in; in³)	x 16.387	= Cubic centimetres (cc; cm³)	x 0.061	=	Cubic inches (cu in; in³)
Imperial pints (Imp pt)	x 0.568	= Litres (l)	x 1.76	=	Imperial pints (Imp pt)
Imperial quarts (Imp qt)	x 1.137	= Litres (l)	x 0.88	=	Imperial quarts (Imp qt)
Imperial quarts (Imp qt)	x 1.201	= US quarts (US qt)	x 0.833	=	Imperial quarts (Imp qt)
US quarts (US qt)	x 0.946	= Litres (l)	x 1.057	=	US quarts (US qt)
Imperial gallons (Imp gal)	x 4.546	= Litres (l)	x 0.22	=	Imperial gallons (Imp gal)
Imperial gallons (Imp gal)	x 1.201	= US gallons (US gal)	x 0.833	=	Imperial gallons (Imp gal)
US gallons (US gal)	x 3.785	= Litres (l)	x 0.264	=	US gallons (US gal)
Mass (weight)					
Ounces (oz)	x 28.35	= Grams (g)	x 0.035	=	Ounces (oz)
Pounds (lb)	x 0.454	= Kilograms (kg)	x 2.205	=	Pounds (lb)
Force					
Ounces-force (ozf; oz)	x 0.278	= Newtons (N)	x 3.6	=	Ounces-force (ozf; oz)
Pounds-force (lbf; lb)	x 4.448	= Newtons (N)	x 0.225	=	Pounds-force (lbf; lb)
Newtons (N)	x 0.1	= Kilograms-force (kgf; kg)	x 9.81	=	Newtons (N)
Pressure					
Pounds-force per square inch (psi; lbf/in²; lb/in²)	x 0.070	= Kilograms-force per square centimetre (kgf/cm²; kg/cm²)	x 14.223	=	Pounds-force per square inch (psi; lbf/in²; lb/in²)
Pounds-force per square inch (psi; lbf/in²; lb/in²)	x 0.068	= Atmospheres (atm)	x 14.696	=	Pounds-force per square inch (psi; lbf/in²; lb/in²)
Pounds-force per square inch (psi; lbf/in²; lb/in²)	x 0.069	= Bars	x 14.5	=	Pounds-force per square inch (psi; lbf/in²; lb/in²)
Pounds-force per square inch (psi; lbf/in²; lb/in²)	x 6.895	= Kilopascals (kPa)	x 0.145	=	Pounds-force per square inch (psi; lbf/in²; lb/in²)
Kilopascals (kPa)	x 0.01	= Kilograms-force per square	x 98.1	=	Kilopascals (kPa)

Length

The base unit of length is the metre, all other measurements are based on this. For large distances we can use the kilometre, which is 1000 metres, and for small lengths the metre is split into centimetres and millimetres. In the UK we still use the Mile for large distances instead of the kilometre.

Area

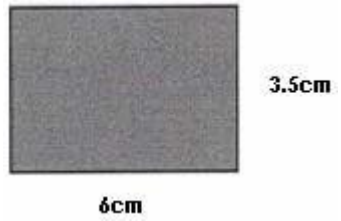
The area of a surface is calculated using a formula, depending on the shape of the area to be found. The unit of measurement is the metre squared (m^2 or cm^2).

The Area of a Rectangle

The area of a rectangle is found by multiplying length x breadth.

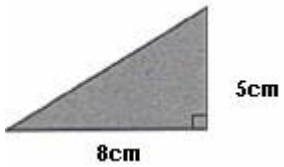
For this rectangle;

Area = length x breadth
= 6 x 3.5
= 21 cm^2



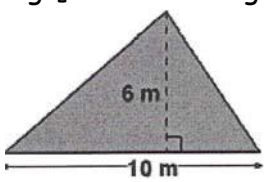
The Area of a Triangle

The area of a triangle is found by multiplying $\frac{1}{2}$ x base x height.



For this triangle:

Area = $\frac{1}{2}$ x base x height
= $\frac{1}{2}$ x 8 x 5
= 20 cm^2



For this triangle:

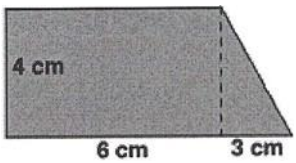
Area = $\frac{1}{2}$ x base x height
= $\frac{1}{2}$ x 10 x 6
= 30 cm^2

The Area of a Combined Shape

This shape is made up of a rectangle and a triangle.

We can find the area by working out the area of each and adding them together.

Area of rectangle = length x breadth
= 6 x 4
= 24 cm^2



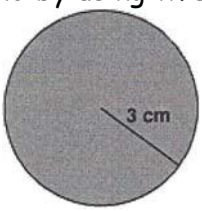
Area of triangle = $\frac{1}{2}$ x base x height
= $\frac{1}{2}$ x 3 x 4
= 6 cm^2

Total Area = 24 + 6
= 30 cm^2

The Area of a Circle

For any circle with radius, r the area, A is found by using this formula: $A = \pi r^2$

For this circle:



$A = \pi r^2$

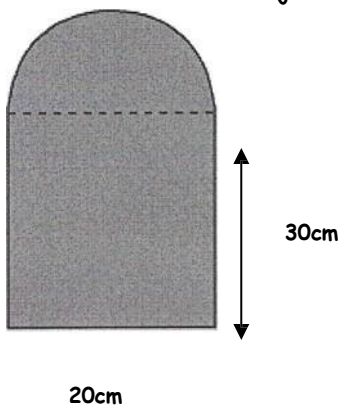
$\pi = 3.14$

$= 3.14 \times 3 \times 3$

$= 28.26 \text{ cm}^2$

The Area of a Combined Shape

This shape is made up of a rectangle and a semicircle. To find the total area we just find the area of each part and add them together.



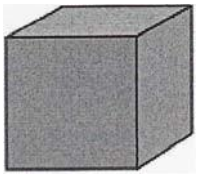
Area of rectangle = length x breadth
= 20 x 30
= 600 mm^2

Area of semicircle = $\frac{1}{2}$ π r^2
= $\frac{1}{2}$ x 3.14 x 10 x 10
= 157 mm^2

Total area = 600 + 157
= 757 mm^2

The Volume of a Cube

For a cube the length, breadth and height are all the same so the volume is found by multiplying length x length x length.



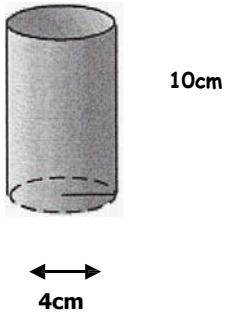
For this cube:

Volume = Length x Length x Length
= 4 x 4 x 4
= 64 cm^3

The Volume of a Cylinder

A cylinder has a circular base and a height. The volume is found by multiplying the area of the base x height. So,

Volume = $\pi r^2 h$ (you are given this form in the formula list)



For this cylinder:

Volume = π r^2 h
= 3.14 x 4 x 4 x 10
= 502.4 cm^3

Force is the effort applied to an object in order to try and make that object move. Giving a trolley a push will start it moving. Force is measured in Newtons.

Velocity and Acceleration

A force acting on an object causes it to accelerate. There are two things to remember about the acceleration of an object when a force acts on it:

- The bigger the unbalanced force acting on the object the bigger the acceleration of the object.
- The more mass the object has the more it will resist any change to its motion. For example, if you apply the same force to a mass of 1000 kg and a mass of 1 kg, the acceleration (change in motion) of the 1000 kg mass will be much less than that of the 1 kg mass.

Newton's Second Law provides a relationship between the force on the object, the mass of the object and the acceleration that is produced. The amazing thing is that the relationship can be expressed neatly by a straightforward mathematical equation.

Force = mass x acceleration or F = ma

The force F is measured in Newtons (N), the mass m is measured in kilograms (kg) and acceleration is measured in metres per second per second (m/s2).

During the course of your studies, and when you go in to industry; you are expected to know and be able to use each of the following terms.

- average speed
- instantaneous speed (normally referred to as "velocity")
- acceleration.

You will be expected to understand these terms, and depending upon your job role, use them for calculations on motion and in describing different types of motion. Make sure that you can remember what is meant by each of these terms.

- Average speed is defined by this mathematical relationship. Average speed = distance travelled/time taken ($S=\frac{D}{T}$). Average speed is measured in metres per second (m/s).
- Instantaneous speed is the speed of an object at a particular moment in time. Instantaneous speed is measured in metres per second (m/s).
- Acceleration is defined as follows: acceleration = change in speed ÷ time taken = final speed – initial speed ÷ time taken. ($A=\frac{C}{T}$). or ($A=F-I/T$)

Acceleration is measured in metres per second per second (m/s^2).

When describing motion we use the terms "steady speed" or "constant speed".

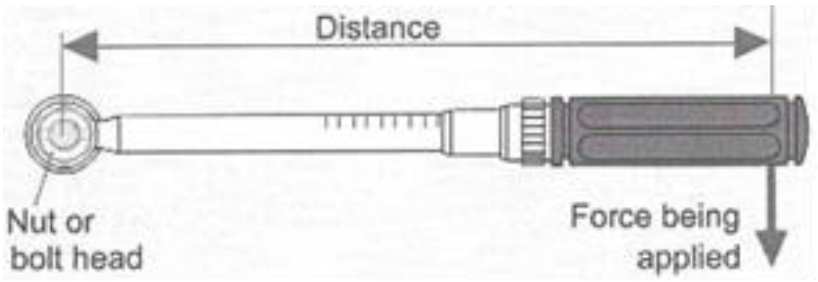
An object is travelling at a steady or constant speed when its instantaneous speed has the same value throughout its journey. For example, if a car is travelling at a constant speed the reading on the car's speedometer does not change. The speedometer reads the speed of the car at each moment in time throughout the car's journey. In cases like this, where the motion involves constant speed, the instantaneous speed of the object can be worked out using the relationship.

speed = distance travelled ÷ time taken.

Torque

Torque is turning force. It is calculated by multiplying the force causing the turning by the distance the force is away from the axis (centre) of turning. Think of it as using a spanner on a bolt. You can use a small effort (force) if you have a long spanner, or you can use a lot of force when you are using a shorter spanner.

Torque is the turning effect of a force on an object. A car engine produces torque, which is usually measured at the flywheel. The tightness of nuts and bolts is measured by a torque wrench.



Torque wrench

The units of torque are Newton Metres (Nm) are found by multiplying the force exerted by its distance from the turning point.

Torque = Force (N) x Radius (m) = Nm.

Mass

Mass is the amount of matter in an object. Mass is measured in Kilograms (Kg).

Temperature

Temperature is the measure of how hot, or cold an object is. We need to use a base to measure this against so we normally use 0°C, and we can measure everything against this core unit. Some scientific calculations use degrees Kelvin, which are the same as degrees Celsius, except that they are 273° lower. This is absolute zero, a temperature at which everything has become a solid. 0° = -273°K and 0°K = 273°C

Pressure

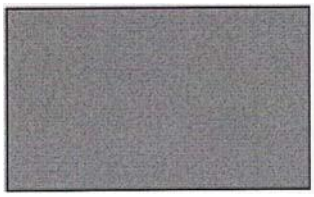
Pressure is the amount of force applied to a certain area. It has various units of measurement, and they can all be converted to each other. (See conversion table).

Useful Information.

- Area of rectangle = length x breadth (units 2).
- Area of circle = $(\pi\ d^2) \div 4$ (units 2).
- Area of triangle = $\frac{1}{2}$ base x height (units 2).
- Volume of a cylinder = $(\pi x\ d^2 x\ h) \div 4$ or $\pi \times r^2 x\ h$
- 1 litre = $1m^3 = 1{,}000cm^3 = 1{,}000{,}000mm^3$
- π (pi) can be taken as approximately 3.142, or use the button on your calculator.
- Circumference of a circle = π x diameter.
- For fractions in most calculators use the a/b/c button.

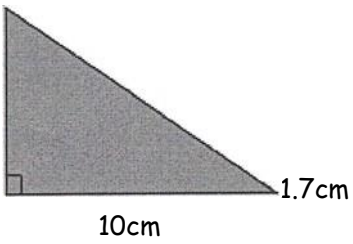
Fill in the answers in the spaces provided.

1. Work out the area of this rectangle.

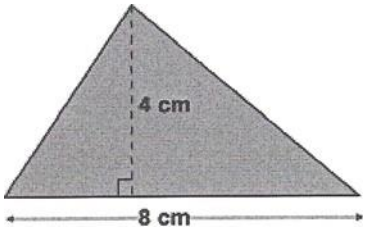


2. Work out the area of this square.

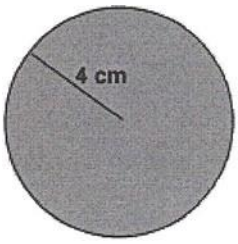
3. Work out the area of this triangle.



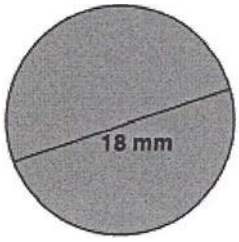
4. Work out the area of this triangle.



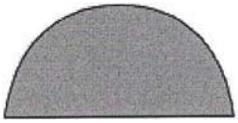
5. Work out the area of this circle.



6. Work out the area of this circle.

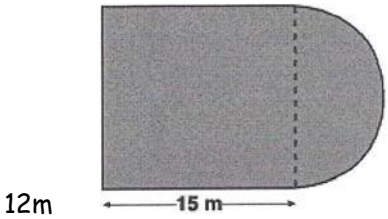


7. Work out the area of this semicircle.

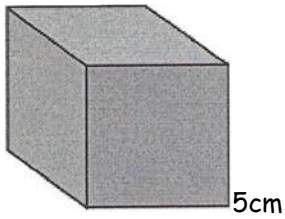


1.4m

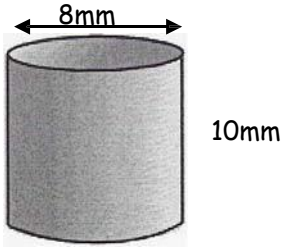
8. Work out the area of this shape.



9. Work out the volume of this cube.



10. Work out the volume of this cylinder.



Answers

	Calculations	Answers
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

The information above is based on the two reference books listed below.

Bibliography	
Author	Champion and Arnold
Title	Motor Vehicle Calculations and Science
Publisher	Edward Arnold
ISBN	0713132302
Chapter	
WWW	
Bibliography	
Author	S.C. Mudd
Title	Technology for Motor Mechanics: 1
Publisher	Edward Arnold
ISBN	0713132701
Chapter	
WWW	