UNIVERSITY DJILLALI LIABES
FACULTY OF TECHNOLOGY
DEPARTMENT OF SCIENCE ET TECHNOLOGY
BASIC TEACHING DEPARTMENT
2nd YEAR LMD

# COURSE: TECHNICAL ENGLISH

**prepared by :**
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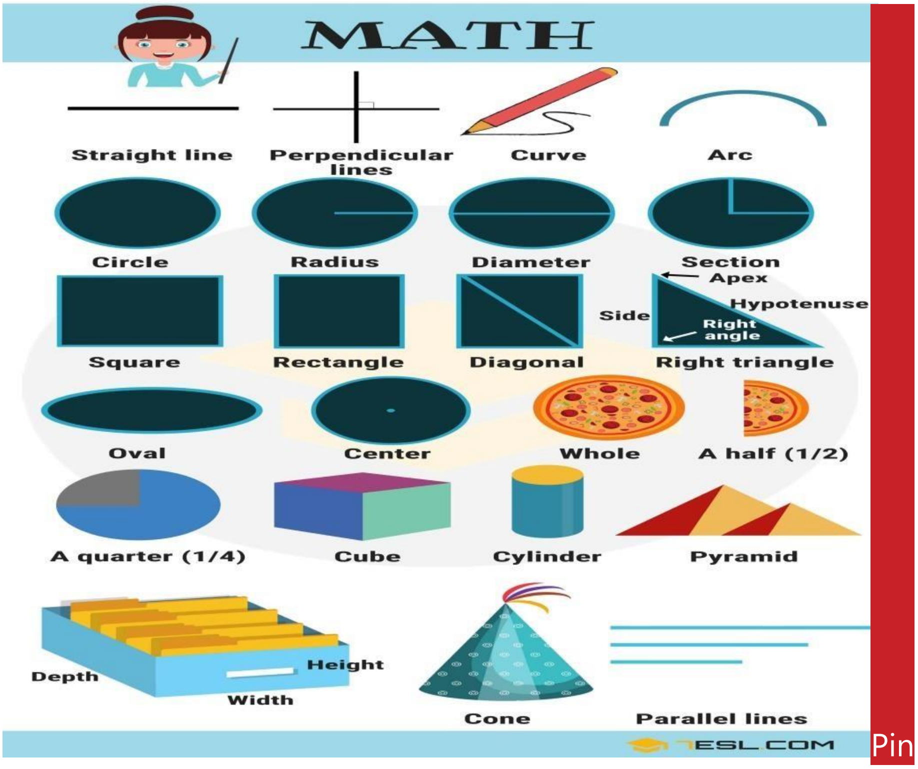
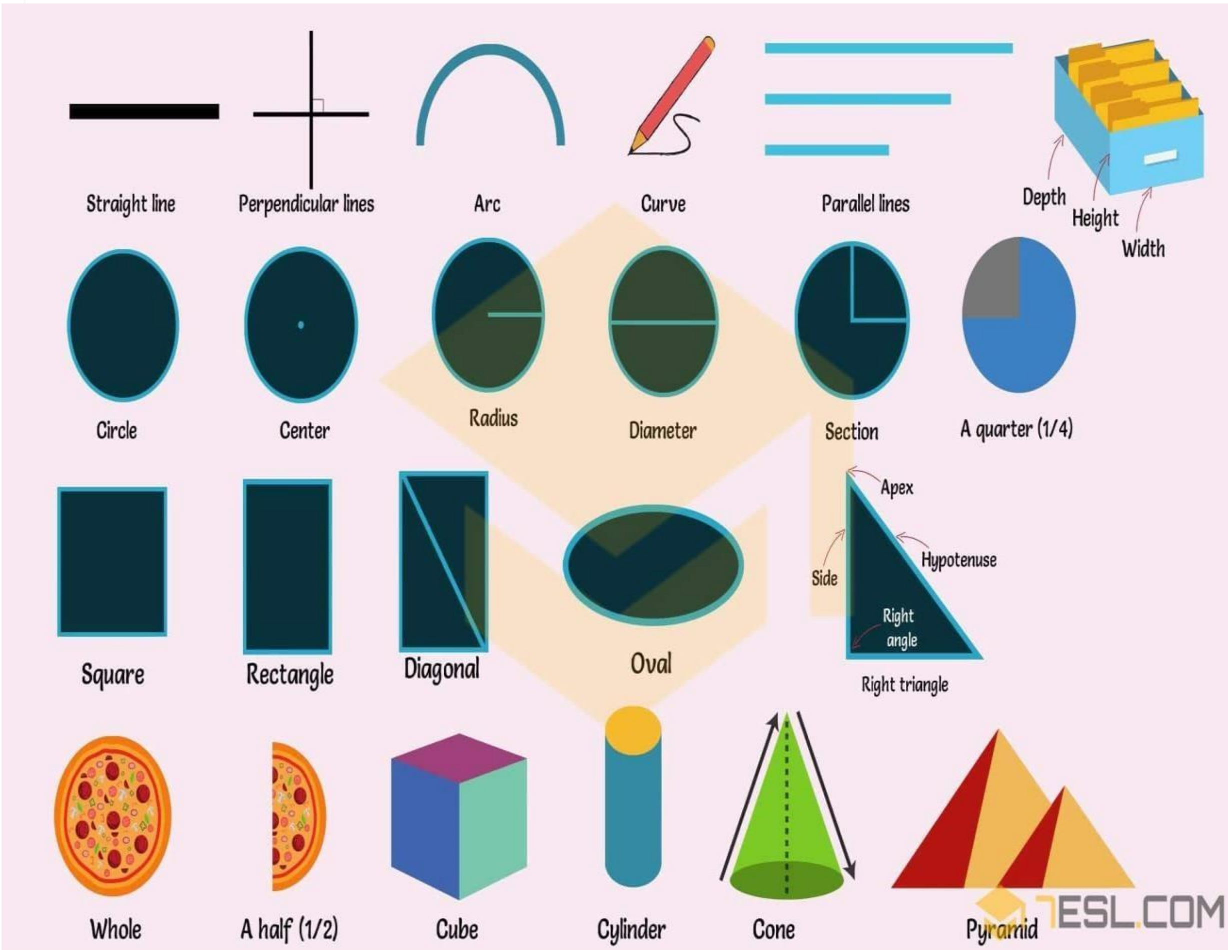
# *Math Vocabulary/ Math Terms*




# List of Mathematics Vocabulary Words

- Straight line
- Perpendicular
- Curve
- Arc
- Circle
- Radius
- Diameter
- Section
- Square
- Rectangle
- Diagonal
- Right triangle
- Oval
- Center
- Whole
- A half (1/2)
- A quarter (1/4)
- Cube

- Cylinder
- Pyramid
- Cone
- Parallel lines

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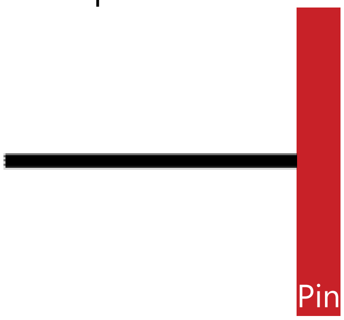
# Math Vocabulary Words with Examples and Pictures

These useful Mathematical terms with video lessons help English students and ESL learners improve their English vocabulary.

## Straight line

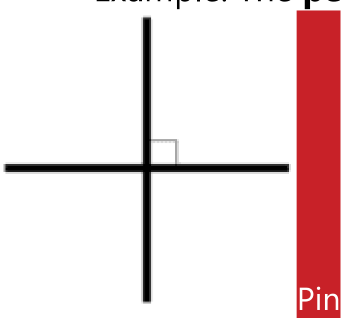
- A line that extends infinitely in both directions, with all points on the line being equidistant from each other.

- Example: The **straight line** was used to measure the distance between two points.



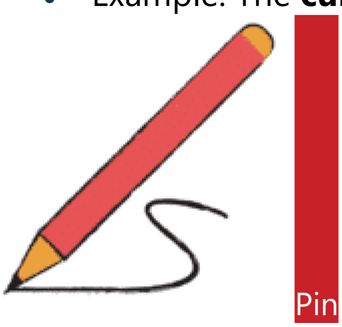

## Perpendicular

- Two lines that intersect at a 90-degree angle, forming four right angles.
- Example: The **perpendicular** lines formed the corners of the square.



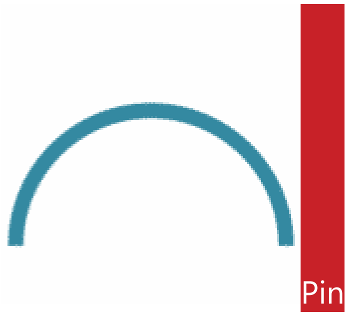

## Curve

- A line that bends or changes direction, often forming a smooth and flowing shape.
- Example: The **curve** of the road followed the contours of the hillside.



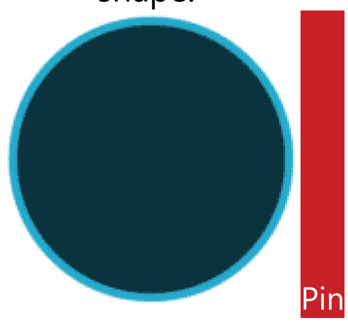

## Arc

- A portion of a curve, often measured in degrees or radians.
- Example: The **arc** of the rainbow spanned the sky, creating a beautiful and colorful display.



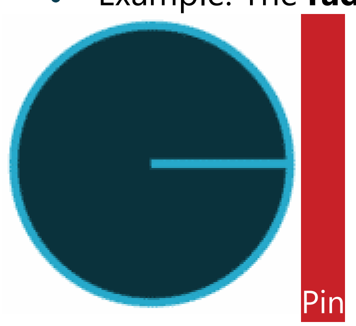

## Circle

- A closed curve with all points equidistant from a central point, often used in geometry and mathematics.
- Example: The **circle** was drawn with a compass, creating a perfect round shape.



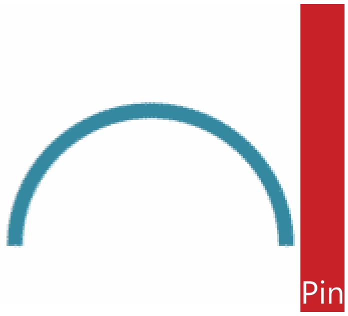

## Radius

- The distance from the center of a circle to any point on the circumference, often used in geometry and mathematics.
- Example: The **radius** of the circle was six inches.



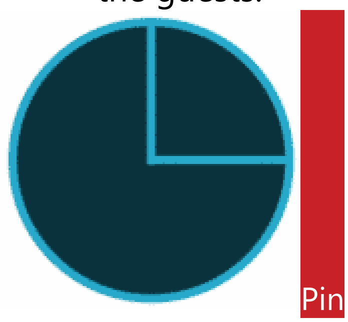

## Diameter

- The distance across a circle, passing through the center, often used in geometry and mathematics.
- Example: The **diameter** of the circle was twelve inches.



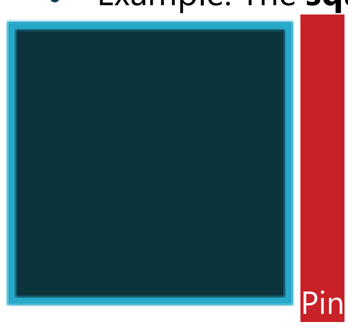

## Section

- A part or portion of something that has been divided or separated.
- Example: The **section** of the cake was cut into small pieces and served to the guests.




## Square

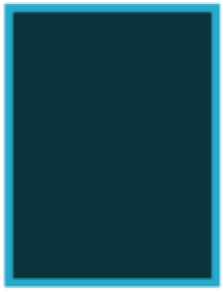
- A four-sided polygon with equal sides and angles, often used in geometry and mathematics.
- Example: The **square** had sides that were each eight inches long.




## Rectangle

- A four-sided polygon with opposite sides that are equal in length and parallel, often used in geometry and mathematics.

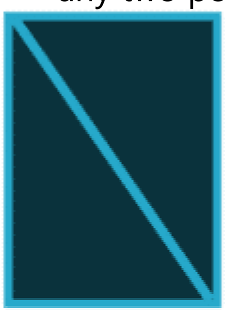
- Example: The **rectangle** had a length of ten inches and a width of six inches.





## Diagonal

- A straight line that connects two opposite corners of a polygon, often used in geometry and mathematics.
- Example: The **diagonal** of the square was the longest distance between any two points.





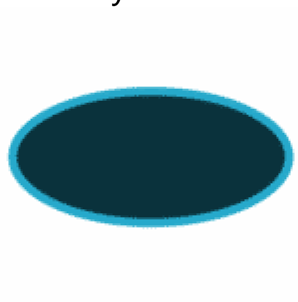
## Right triangle

- A triangle with one 90-degree angle, often used in geometry and mathematics.
- Example: The **right triangle** had a hypotenuse that was twice as long as one of the legs.



## Oval

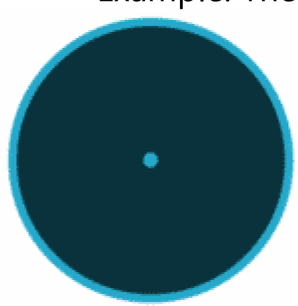
- A closed curve that resembles an elongated circle, often used in geometry and mathematics.
- Example: The **oval** was drawn with a pair of compasses, creating a symmetrical and smooth shape.





### Center

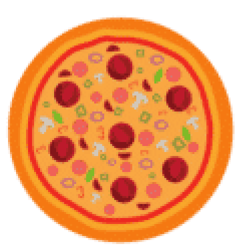
- The point that is equidistant from all points on a circle or sphere, often used in geometry and mathematics.
- Example: The **center** of the circle was marked with a dot.





### Whole

- The complete amount or quantity of something, without any parts missing or removed.
- Example: The **whole** cake was decorated with frosting and candles.





### A half (1/2)

- One of two equal parts of a whole, often used in fractions and mathematics.
- Example: She cut the sandwich in **half**, giving one piece to her friend.

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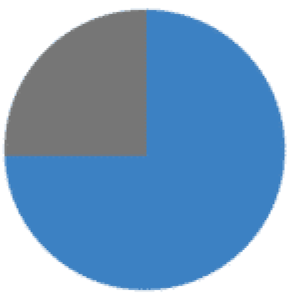
### A quarter (1/4)

- One of four equal parts of a whole, often used in fractions and mathematics.
- Example: The pizza was sliced into **quarters**, with each piece having the same amount of toppings.



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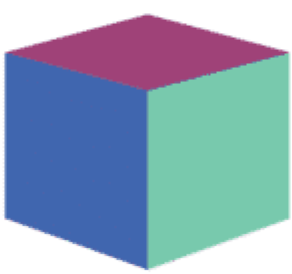
### Cube

- A three-dimensional shape with six square faces of equal size, often used in geometry and mathematics.
- Example: The **cube** had a volume of 27 cubic inches.



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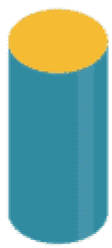
### Cylinder

- A three-dimensional shape with two circular faces of equal size and a curved surface, often used in geometry and mathematics.
- Example: The **cylinder** had a volume of 100 cubic inches.





## Pyramid

- A three-dimensional shape with a base that is a polygon and triangular faces that meet at a common vertex, often used in geometry and mathematics.
- Example: The **pyramid** had a height of 10 inches and a volume of 120 cubic inches.



## Cone

- A three-dimensional shape with a circular base and a curved surface that tapers to a point, often used in geometry and mathematics.
- Example: The **cone** had a height of 8 inches and a volume of 50 cubic inches.



## Parallel lines

- Two lines that are always the same distance apart and never intersect, often used in geometry and mathematics.
- Example: The **parallel lines** were drawn with a ruler, creating a perfectly straight and even spacing.



# Mathematics Symbols Vocabulary

**Mathematics** is used to communicate information about a wide range of different subjects.

This is a list of common **Math symbols** found in all branches of **mathematics** to express a formula or to represent a constant.

- *Addition*
- *Subtraction*
- *Multiplication*
- *Division*
- *Plus-minus*
- *Strict inequality*
- *Equality*
- *Inequation*
- *Tilde*
- *Congruence*
- *Infinity*
- *Inequality*
- *Material equivalence*
- *Material implication*
- *Theta*
- *Empty set*
- *Triangle or delta*
- *For all*

- *Pi constant*
- *Integral*
- *Intersection*
- *Union*
- *Factorial*
- *Therefore*
- *Square root*
- *Perpendicular*
- *Exists*
- *Line*
- *Line segment*
- *Ray*
- *Right angle*
- *Angle*
- *Summation*
- *Braces (grouping)*
- *Brackets*
- *Parentheses (grouping)*

**Mathematics Symbols Chart**

Pin

## Geometric Lines Names

Here are some basic **lines** in geometry.

- *Straight*
- *Diagonal*
- *Vertical*
- *Parallel lines*
- *Curved*
- *Horizontal*
- *Dotted*
- *Wavy*
- *Zigzag*

# Numbers 100%

**32%**
Thirty two per cent

**10m x 3m**
Ten metres by three metres

**8.3**
Eight point three

**$1\frac{2}{3}$**
One and two thirds

**$\frac{3}{4}$**
Three fourths

**$3^2$**
Three squared

**$2^3$**
Two cubed

**$2^4$**
Two to the power of four

**1975**
Nineteen seventy-five

**2001**
Two thousand and one

**263-3847**
Two-six-three, three-eight-four-seven

**26°c**
Twenty six degrees

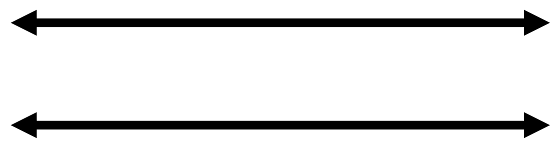
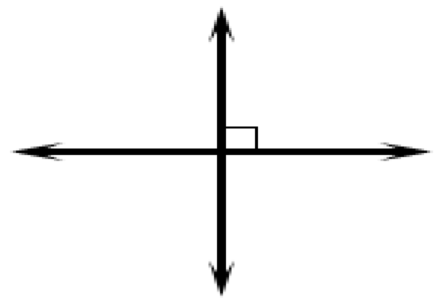
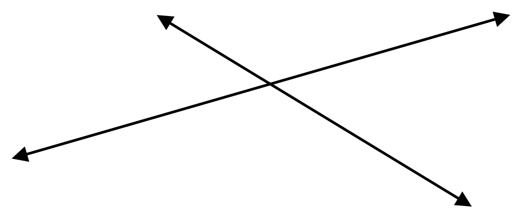
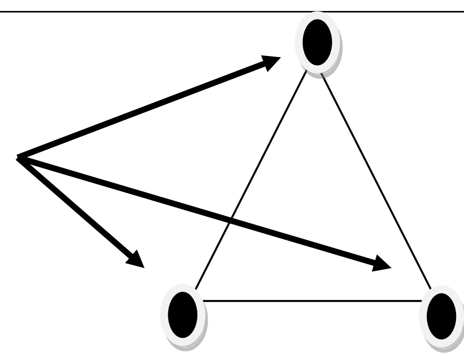
**1,325,476**
One million, three hundred and twenty-five thousand, four hundred seventy-six

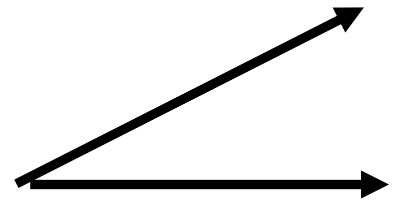
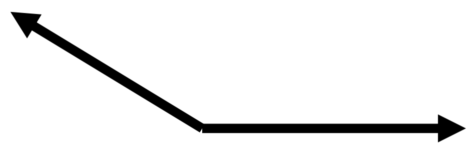
**21st**
Twenty-first

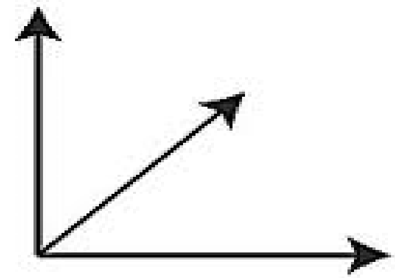
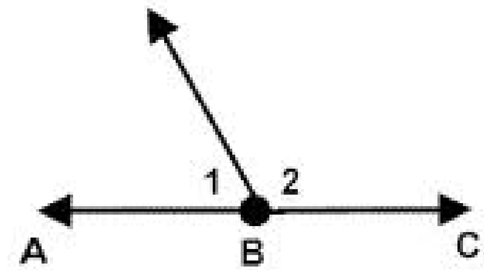
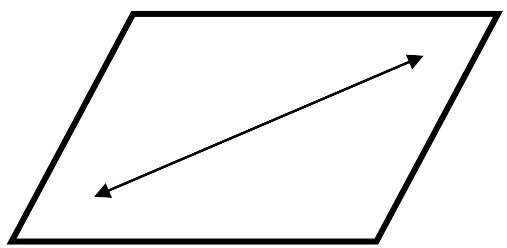
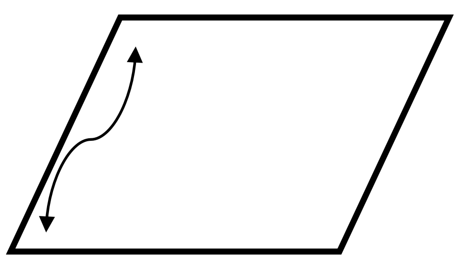
**92nd**
Ninety-second

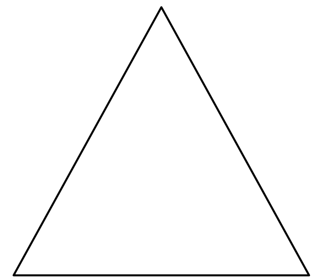
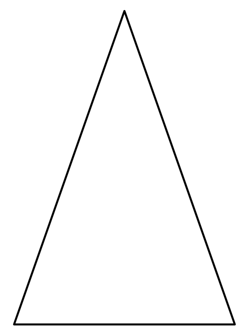
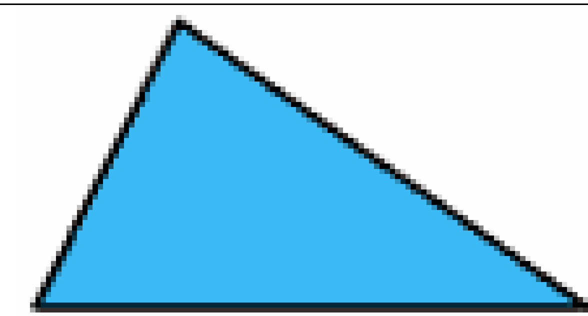
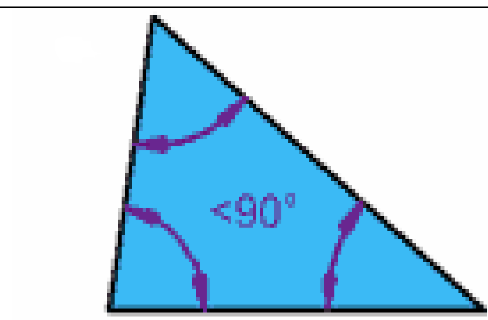
**53rd**
Fifty-third

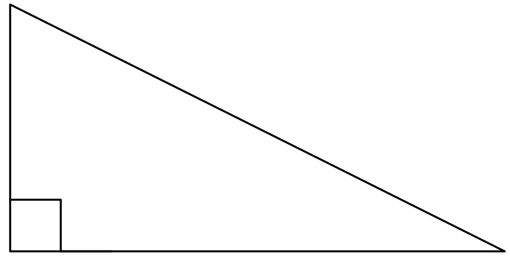
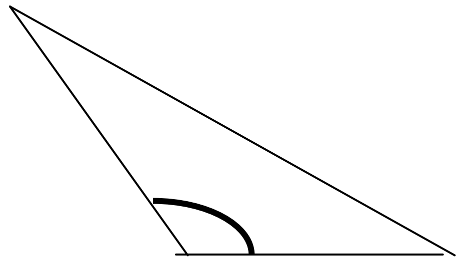
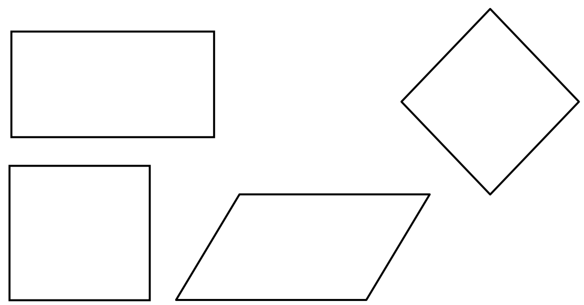
**67th**
Sixty-seventh

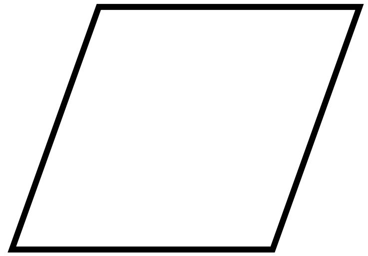
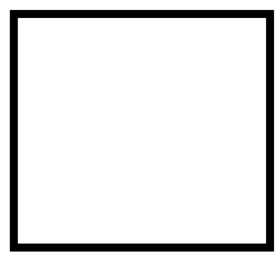
| | | |
|---|---|---|
| **parallel lines** |  | lines that stay same distance from each other forever and never intersect |
| **perpendicular lines** |  | lines that cross at a point and form 90° angles |
| **intersecting lines** |  | lines that cross at a point |
| **vertices** |  | a point where two or more lines come together; also called a corner on a polygon |

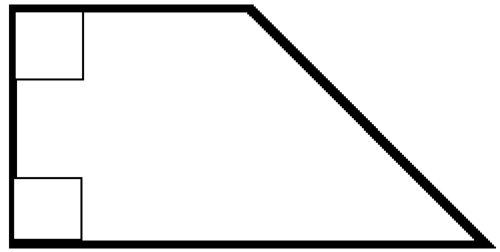
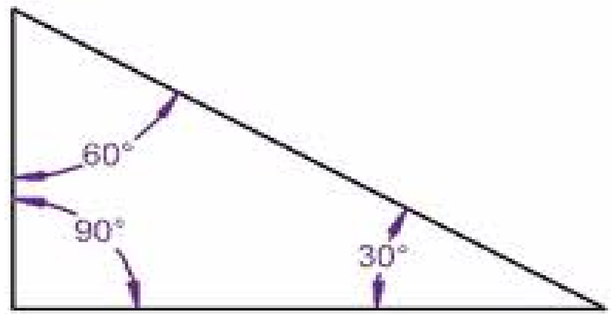
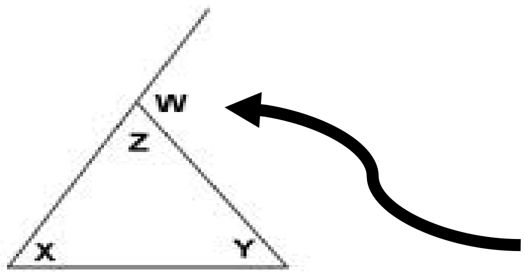
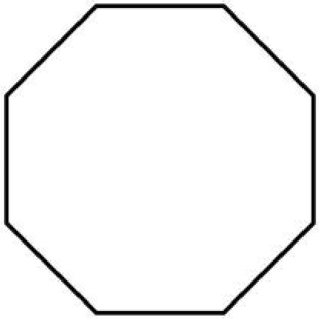
| | | |
|---|---|---|
| **acute angle** |  | an angle that is less than 90° |
| **obtuse angle** |  | an angle that is more than 90° and less than 180° |
| **right angle** |  | an angle that is exactly 90° |
| **straight angle** |  | an angle that is exactly 180° |

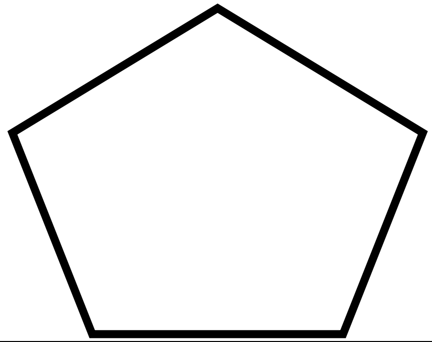
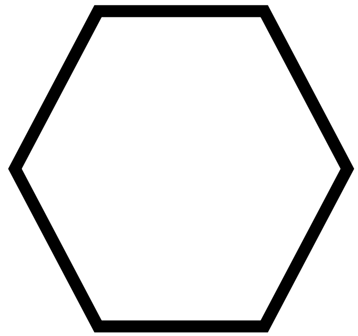
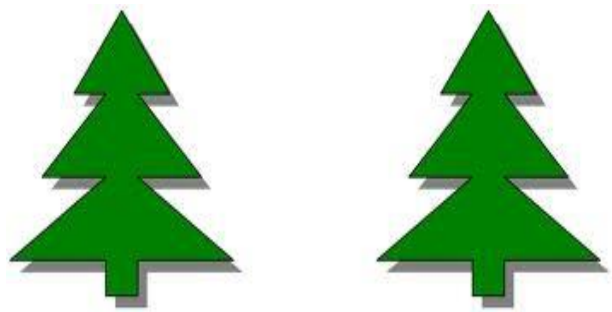
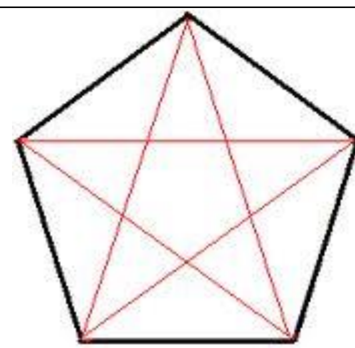
| | | |
|---|---|---|
| **complementary angles** |  | two angles that add up to 90° |
| **supplementary angles** |  | two angles that add up to 180° |
| **opposite angles** |  | angles that are across from each other; they do not share a side or vertex |
| **adjacent angles** |  | two angles that are formed with a common side |

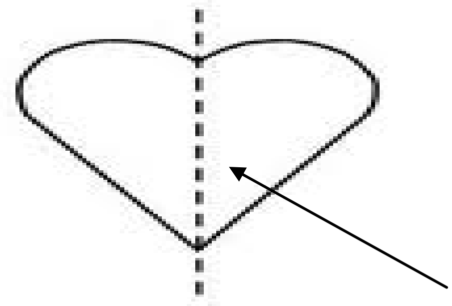
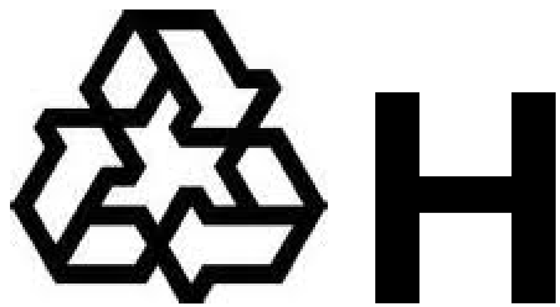
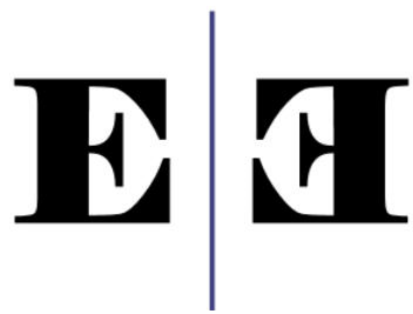
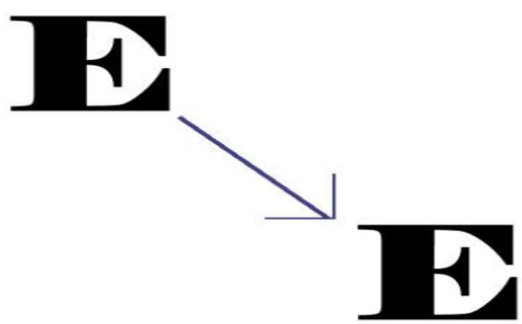
| | | |
|---|---|---|
| **equilateral triangle** |  | a triangle with three equal sides |
| **isosceles triangle** |  | a triangle with two equal sides |
| **scalene triangle** |  | a triangle with no equal sides |
| **acute triangle** |  | A triangle with all acute angles |

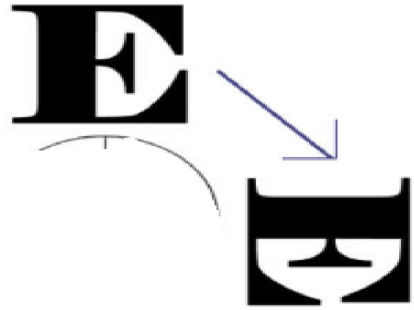
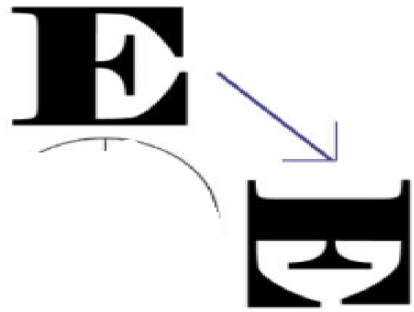
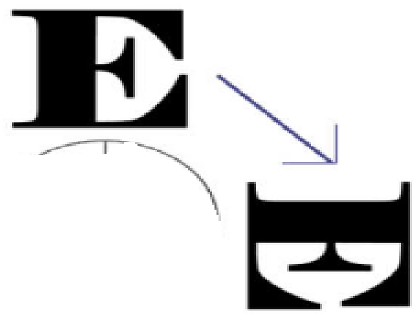
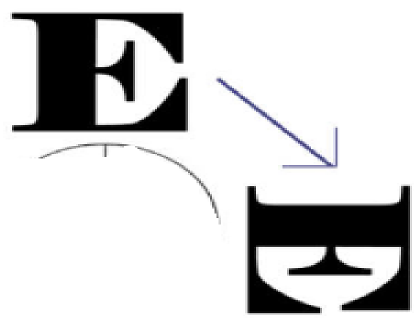
| | | |
|---|---|---|
| **right triangle** |  | A triangle with one right angle |
| **obtuse triangle** |  | A triangle with one obtuse angle |
| **quadrilateral** |  | a four sided polygon; angles total 360° |
| **parallelogram** |  | contains two sets of parallel sides |

| | | |
|---|---|---|
| **rhombus** |  | contains two sets of parallel sides that are all congruent |
| **rectangle** |  | contains two sets of parallel sides that form four 90° angles |
| **square** |  | contains two sets of parallel sides that form four 90° angles; all sides are congruent |
| **isosceles trapezoid** |  | **a quadrilateral that contains one set of parallel sides; also contains two opposite congruent sides** |

| | | |
|---|---|---|
| **right trapezoid** |  | a quadrilateral that contains on set of parallel sides and contains two right angles |
| **interior angles** |  | the angles inside of a figure; in a triangle, these add up to 180° |
| **exterior angles** |  | the angles on the outside of a figure when the sides are extended |
| **octagon** |  | an 8-sided polygon |

| | | |
|---|---|---|
| **pentagon** |  | a 5-sided polygon |
| **hexagon** |  | a 6-sided polygon |
| **congruent** |  | a word meaning equal or same; it is used to describe figures, sides, and angles |
| **diagonal** |  | a line that cuts across a figure connecting two vertices that are not adjacent |

| | | |
|---|---|---|
| **line symmetry** |  | a figure has this when a line can divide it into two congruent parts |
| **rotational symmetry** |  | **a figure has this when can be turned around a point and look exactly the same as its original image after some rotating** |
| **reflection** |  | a transformation that moves a figure by flipping it across a line |
| **translation** |  | a transformation that moves a figure in a straight line without turning or flipping |

| | | |
|---|---|---|
| **rotation** |  | a transformation that moves a figure by turning it |
| **rotation** |  | a transformation that moves a figure by turning it |
| **rotation** |  | a transformation that moves a figure by turning it |
| **rotation** |  | a transformation that moves a figure by turning it |

| Vocabulary Term | Definition | Example |
| --- | --- | --- |
| **VARIABLE** | A letter or symbol that represents a quantity that can change. | $3a + 10$ |
| **COEFFICIENT** | A number in front of a variable. In the expression 2x, 2 is the coefficient. | $3a + 10$ |
| **CONSTANT** | A quantity that does not change. | $3a + 10$ |
| **EXPRESSION** | A mathematical phrase containing one or more variables and may contain operation symbols. *(NO equal sign!)* | 7p 3+1<br>2 3/y<br>$4x^2-7$ |
| **EQUATION** | A number sentence with two sides with an equal sign. Each side is "balanced." | $3+1=4$<br>$x - 3 = 13\frac{1}{2}$<br>$14x = 28$<br>$y/13 = 2$ |
| **SOLUTION** | Values that give a true statement when substituted into an equation. | $x+1=4$<br>The solution is "3" becaus<br>3 makes the equation true |
| **EVALUATE** | Find the value of. | Another word for solve or calculate.<br>*Evaluate 21 x 3*<br>*The value of 21 x 3 is 63.* |

# Unit 4 Vocabulary

Name: ________________________

Date: ________________________

# Algebra

**Section 1** – Algebra Vocabulary

Identify the terms, coefficient, variables, and constants in each expression. The first one is completed for you as an example.

| Expressions | Term(s) | Coefficient(s) | Variable(s) | Constant(s) |
|---|---|---|---|---|
| Ex.) 4x - 12 | 4x, 12 | 4 | x | 12 |
| 1) a + 3b | | | | |
| 2) 6y + 7 | | | | |
| 3) 5 + 10k | | | | |
| 4) ab - c | | | | |
| 5) 2k + 15 - m | | | | |

**Section 2** – Writing Algebra Expressions

Write the letter of the expression on the right next to the words on the left that describe it.

1) _______ x minus 6 (a) $\frac{x}{6}$

2) _______ sixty plus y (b) 6 - x

3) _______ y less than 6 (c) 6x

4) _______ sixteen plus x (d) 60 + y

5) _______ x divided by 6 (e) 16 + x

6) _______ y take away 6 (f) z - 6

7) _______ six minus x (g) x - 6

8) _______ six less than z (h) x + 16

9) _______ six times x (i) 6 - y

10) _______ x plus sixteen (j) y - 6

# Algebra I Vocab

Name: ____________________

**I. Match the following terms with the appropriate function.**

| | |
|---|---|
| 1)_____ Abscissa | A) steps that produce a desired outcome |
| 2)_____ Absolute Value | B) input into an algorithm |
| 3)_____ Algorithm | C) points that are a fixed distance from a given point |
| 4)_____ Argument | D) x-value of an ordered pair |
| 5)_____ Arithmetic Sequence | E) sum of terms of an arithmetic sequence |
| 6)_____ Arithmetic Series | F) distance from zero on a # line |
| 7)_____ Asymptote | G) sum or difference of two monomials |
| 8)_____ Binomial | H) a+bi, a and b are real #'s and $i = \sqrt{-1}$ |
| 9)_____ Circle | I) terms have common differences |
| 10)_____ Complex Numbers | J) line that closely approaches a given curve |

**A level COMPONENT 1**

| Section | Item | Definition |
|---|---|---|
| 1.1 (a) | Quantity | In S.I. a quantity is represented by a number $\times$ a unit, (e.g. $m$ = 3.0 kg). |
| 1.1 (d) | Scalar | A scalar is a quantity that has magnitude only. |
| | Vector | A vector is a quantity that has magnitude and direction. |
| 1.1 (f) | Resolving a vector into components in particular directions | This means finding vectors (the so-called *components*) in these directions, which add together vectorially to make the original vector, and so, together, are equivalent to this vector. |
| 1.1 (g) | Density of a material, $\rho$ | $\text{density} = \frac{\text{mass}}{\text{volume}}$ **Unit: kg m$^{-3}$** or **g cm$^{-3}$** in which mass and volume apply to any sample of the material. |
| 1.1 (h) | Moment (or torque) of a force | The moment (or torque) of a force about a point is defined as the force $\times$ the perpendicular distance from the point to the line of action of the force, i.e. moment = $F \times d$ **Unit: N m** [N.B. the unit is not J] |
| 1.1 (i) | The principle of moments | For a system to be in equilibrium, $\sum$ anticlockwise moments about a point = $\sum$ clockwise moments about the same point. |
| 1.1 (j) | Centre of gravity | The centre of gravity is the single point within a body at which the entire weight of the body may be considered to act. |
| 1.2 (a) | Displacement | The displacement of a point B from a point A is the shortest distance from A to B, together with the direction. **Unit: m** |
| | Mean speed | $\text{Mean speed} = \frac{\text{total distance travelled}}{\text{total time taken}} = \frac{\Delta x}{\Delta t}$ **Unit: m s$^{-1}$** |
| | Instantaneous speed | Instantaneous speed = rate of change of distance **Unit: m s$^{-1}$** |
| | Mean velocity | $\text{Mean velocity} = \frac{\text{total displacement}}{\text{total time taken}}$ **Unit: m s$^{-1}$** |
| | Instantaneous velocity | The velocity of a body is the rate of change of displacement. **Unit: m s$^{-1}$** |
| | Mean acceleration | $\text{Mean acceleration} = \frac{\text{change in velocity}}{\text{time taken}} = \frac{\Delta v}{\Delta t}$ **Unit: m s$^{-2}$** |
| | Instantaneous acceleration | The instantaneous acceleration of a body is its rate of change of velocity. **Unit: m s$^{-2}$** |
| 1.2 (e) | Terminal velocity | The terminal velocity is the constant, maximum velocity of an object when the resistive forces on it are equal and opposite to the ‘accelerating’ force (e.g. pull of gravity). |
| 1.3 (a) | Force, $F$ | A force on a body is a push or a pull acting on the body from some external body. **Unit: N** |

| | | |
|---|---|---|
| | Newton's 3rd law | If a body **A** exerts a force on a body **B**, then **B** exerts an equal and opposite force on **A**. |
| 1.3 (c) | $\Sigma F = m a$ | The mass of a body × its acceleration is equal to the vector sum of the forces acting on the body. This vector sum is called the *resultant force*. |
| 1.3 (d) | Momentum | The momentum of an object is its mass multiplied by its velocity. ($p = mv$). It is a vector.<br>**UNIT: kg m s$^{-1}$** or **Ns** |
| 1.3 (e) | Newton's 2nd law | The rate of change of momentum of an object is proportional to the resultant force acting on it, and takes place in the direction of that force. |
| 1.3 (f) | The principle of conservation of momentum | The vector sum of the momenta of bodies in a system stays constant even if forces act between the bodies, provided there is no external resultant force. |
| | Elastic collision | A collision in which there is no change in total kinetic energy. |
| | Inelastic collision | A collision in which kinetic energy is lost. |
| 1.4 (a) | Work, $W$ | Work done by a force is the product of the magnitude of the force and the distance moved in the direction of the force.( W.D. = $Fx\cos\theta$ )<br>**Unit: J** |
| 1.4 (c) | Principle of conservation of energy | Energy cannot be created or destroyed, only transferred from one form to another. Energy is a scalar. |
| | Potential energy, $E_p$ | This is energy possessed by an object by virtue of its position. $E_p = mgh$ **Unit: J** |
| | Kinetic energy, $E_k$ | This is energy possessed by an object by virtue of its motion. $E_k = \frac{1}{2}mv^2$ **Unit: J** |
| | Elastic potential energy | This is the energy possessed by an object when it has been deformed due to forces acting on it.<br>$E_{\text{elastic}} = \frac{1}{2} F_x$ or $\frac{1}{2} kx^2$ **Unit: J** |
| 1.4 (d) | Energy | The energy of a body or system is the amount of work it can do. **Unit: J** |
| 1.4 (e) | Power, $P$ | This is the work done per second, or energy transferred per second.<br>**Unit: W [= J s$^{-1}$]** |
| 1.5 (a) | Period, $T$ for a point describing a circle | Time taken for one complete circuit. |
| | Frequency, $f$ | The number of circuits or cycles per second. |
| 1.5 (b) | Radian | A unit of measurement of angles equal to about 57.3°, equivalent to the angle subtended at the centre of a circle by an arc equal in length to the radius. **UNIT: rad** |
| 1.5 (d) | Angular velocity, $\omega$ | For an object describing a circle at uniform speed, the angular velocity $\omega$ is equal to the angle $\theta$ swept out by the radius in time $\Delta t$ divided by $t$ ($\omega = \frac{\Delta\theta}{\Delta t}$)<br>**UNIT: rad s$^{-1}$** |
| 1.6 (a) | Simple harmonic motion (shm) | Shm occurs when an object moves such that its acceleration is always directed toward a fixed point and is proportional to its distance from the fixed point. ($a = -\omega^2 x$)<br>**Alternative definition:** |

| | | |
|---|---|---|
| | | The motion of a point whose displacement $x$ changes with time $t$ according to $x = A \cos(\omega t + \varepsilon)$, where $A$, $\omega$ and $\varepsilon$ are constants. [Variations of this kind are said to be *sinusoidal*.] |
| 1.6 (e) | Period, $T$ for an oscillating body | The time taken for one complete cycle. |
| | Amplitude, $A$ of an oscillating object | The maximum value of the object's displacement (from its equilibrium position). |
| | Phase | The phase of an oscillation is the angle $(\omega t + \varepsilon)$ in the equation $x = A \cos(\omega t + \varepsilon)$. [$\varepsilon$ is called the *phase constant*.]<br>**UNIT: rad** |
| | Frequency, $f$ | The number of oscillations per second. **UNIT: Hz** |
| 1.6 (l) | Free oscillations [Natural oscillations] | Free oscillations occur when an oscillatory system (such as a mass on a spring, or a pendulum) is displaced and released.<br>[The frequency of the free oscillations is called the system's *natural frequency*.] |
| | Damping | Damping is the dying away, due to resistive forces, of the amplitude of free oscillations. |
| 1.6 (n) | Critical damping | Critical damping is the case when the resistive forces on the system are just large enough to prevent oscillations occurring at all when the system is displaced and released. |
| 1.6 (o) | Forced oscillations | These occur when a sinusoidally varying 'driving' force is applied to an oscillatory system, causing it to oscillate with the frequency of the applied force. |
| | Resonance | If, in forced vibrations, the frequency of the applied force is equal to the natural frequency of the system (e.g. mass on spring), the amplitude of the resulting oscillations is large. This is resonance. |
| 1.7 (a) | Ideal gas | An ideal gas strictly obeys the equation of state $pV = nRT$, in which $n$ is the number of moles, $T$ is the kelvin temperature and $R$ is the *molar gas constant*. $R = 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$. With the exception of very high densities a real gas approximates well to an ideal gas. |
| 1.7 (d) | The mole | The mole is the S.I. unit of an 'amount of substance'. It is the amount containing as many particles (e.g. molecules) as there are atoms in 12 g of carbon-12. |
| | Avogadro constant, $N_A$ | This is the number of particles per mole.<br>($N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$) |
| 1.8 (a) | Internal energy, $U$, of a system | This is the sum of the kinetic and potential energies of the particles of a system. |
| 1.8 (d) | Heat, $Q$ | This is energy flow from a region at higher temperature to a region at lower temperature, due to the temperature difference. In thermodynamics we deal with heat going into or out of a system. It makes no sense to speak of heat *in* a system. |
| 1.8 (f) | Work, $W$ | If the system is a gas, in a cylinder fitted with a piston, the gas does work of amount $p\Delta V$ when it exerts a pressure $p$ and pushes the piston out a small way, so the gas volume increases by $\Delta V$. Work, like heat, is energy in transit from (or to) the system. |
| 1.8 (i) | First law of | The increase, $\Delta U$, in internal energy of a system is |

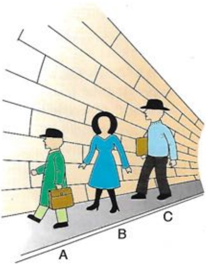
| | | |
|---|---|---|
| | thermodynamics | $\Delta U = Q - W$ in which $Q$ is the heat **entering** the system and $W$ is the work done **by** the system. Any of the terms in the equation can be positive or negative, e.g. if 100 J of heat is *lost* from a system $Q$ = –100 J**.** |
| 1.8 (k) | Specific heat capacity, $c$ | The heat required, per kilogram, per degree celsius or kelvin, to raise the temperature of a substance.<br>**UNIT: J kg$^{-1}$ K$^{-1}$ or J kg$^{-1}$ °C$^{-1}$** |

Chapter 2

# Measuring Length, Area and Volume

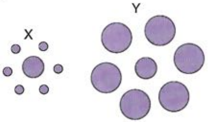
***In this unit, you will learn***

- *the meaning of physical quantities and their appropriate units of measurement.*
- *how to interpret and use the prefixes milli-, centi- and kilo-.*
- *how to use the metre rule, calipers and vernier calipers.*
- *how to find the area of regular- and irregular-shaped objects.*
- *how to measure the volume of regular- and irregular-shaped objects.*
- *how to measure the volume of liquids.*




Who is the tallest?


Which line is longer, PQ or RS?




Which circle in the centre is larger, X or Y?

Check your answers with a ruler. It has been shown that human senses are limited and not always reliable. That is why we need instruments for making accurate scientific measurements.

## 2.1 Physical Quantities and SI Units

A physical quantity is a quantity which can be measured. Length, volume, mass, time and temperature are examples of physical quantities. In the past, methods of measuring physical quantities were inaccurate and many different types of units of measurement were used in different parts of the world.

Balance

Arm

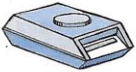
Hourglass

Jar

Elbow

Today, accurate measurements are obtained by using better developed methods and more accurate instruments.

Electronic balance



Metre rule

Electronic stopwatch

Measuring cylinder

Mercury thermometer

Historical and modern measurements of length may be compared by carrying out the following activity.

Measure the length of your desk

(a) in hands (with your hand),

Length of desk = ______ hands

(b) in hands (with your partner's hand),

Length of desk = ______ hands

(c) in centimetres (with your ruler),

Length of desk = ______ cm

= one hand

(d) in centimetres (with your partner's ruler).

Length of desk = ______ cm

Why is it better to measure lengths with a ruler than with a hand?

Since 1960, scientists from different parts of the world have agreed to adopt a single system of units called the **SI units** (SI stands for Système International d'Unités in French). Table 2.1 shows five common physical quantities and their corresponding SI units and symbols.

Table 2.1 Common physical quantities and units

| Physical quantity | SI unit | Symbol for unit |
|---|---|---|
| Length | metre | m |
| Mass | kilogram | kg |
| Time | second | s |
| Temperature | kelvin | K |
| Electric current | ampere | A |

The prefixes listed in Table 2.2 are useful in expressing physical quantities that are either very big or very small.

Table 2.2 Some commonly used SI prefixes

| Prefix | Symbol | Meaning |
|---|---|---|
| Milli | m | One thousandth ($\frac{1}{1\,000}$) |
| Centi | c | One hundredth ($\frac{1}{100}$) |
| Kilo | k | One thousand (1 000) |

For example,

One millimetre (mm) is equal to one thousandth of a metre (1 mm = $\frac{1}{1\,000}$ m).

One centimetre (cm) is equal to one hundredth of a metre (1 cm = $\frac{1}{100}$ m).

One kilometre (km) is equal to one thousand metres (1 km = 1 000 m).

### Mini-Exercise

Convert the following readings to the units indicated.

**(a)** 0.05 m = ______ cm

**(b)** 50 g = ______ kg

**(c)** 25 mm = ______ km

## 2.2 Measuring Length

**Length** is the distance between two points and its SI unit is the **metre (m)**. Short distances are measured in centimetres (cm) or millimetres (mm). Long distances are measured in kilometres (km).

### *Mini-Exercise*

Copy and complete the following table.

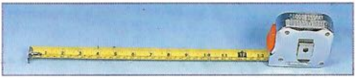
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | km = | ________ | m = | ________ | cm = | ________ | mm |
| ________ | km = | 1 | m = | ________ | cm = | ________ | mm |
| ________ | km = | ________ | m = | 1 | cm = | ________ | mm |
| ________ | km = | ________ | m = | ________ | cm = | 1 | mm |

### *Science Tidbits*

The standard metre is the distance travelled by light in $\frac{1}{299\ 792\ 458}$ of a second through a vacuum.

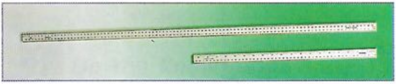
## 2.3 Instruments for Measuring Length

### *The Measuring Tape*



The photographs above show two types of measuring tapes. Measuring tapes measure length in centimetres and metres, and sometimes in feet and inches. Can you name an occupation associated with each type of measuring tape?

### *The Metre Rule*



The photograph above shows the metre rule and half-metre rule commonly used to measure length in the laboratory. The metre rule measures length in centimetres, with an **accuracy of 0.1 cm**.

For accurate measurements using the metre rule, the eye must be placed vertically above the mark being read. If the eye is wrongly positioned, incorrect readings due to parallax error will be obtained (see Fig. 2.1). **Parallax error** is an error in a measurement due to the eye not being in the correct position when taking a reading.

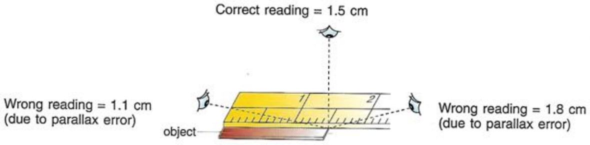
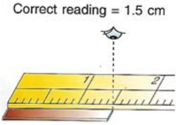
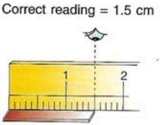


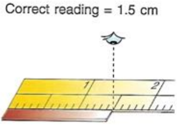

Fig. 2.1 Parallax error

Parallax errors can be avoided by

- placing the eye vertically above the marking on the scale to be read.
- placing the metre rule on its edge beside the object to be measured so that the scale is touching it.
- using a thin rule so that the scale is touching the object to be measured.

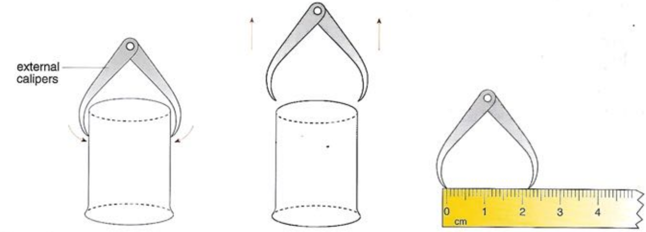



### *External and Internal Calipers*

Calipers, together with the metre rule, may be used to measure the diameters of spheres or cylinders. Calipers are made up of a pair of jaws hinged at one end. External calipers are used for measuring external diameters while internal calipers are used to measure internal diameters (see Fig. 2.2 and Fig. 2.3). Which type of calipers should you use to measure the diameter of a sphere?

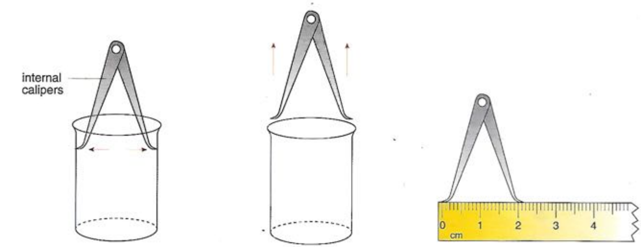



Close the jaws until they touch the object to be measured.

Slide the closed jaws out of the object.

Measure the distance between the closed jaws on a metre rule.

Fig. 2.2 Measuring the external diameter of a beaker




Open the jaws until they touch the object to be measured.

Slide the opened jaws out of the object.

Measure the distance between the opened jaws on a metre rule.

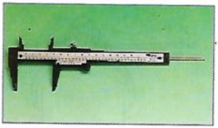
Fig. 2.3 Measuring the internal diameter of a beaker

## *Do You Know?*

Measurements of lengths made by using calipers with the metre rule do not have parallax error. Do you know how the parallax error has been avoided?
(Hint: The answer can be found in Fig. 2.2 and Fig. 2.3.)

### *The Vernier Calipers*

Vernier calipers are used to measure internal and external lengths with an **accuracy of 0.01 cm or 0.1 mm**. Some vernier calipers have a 'tail' which is used to measure the depth of narrow tubes or holes. Fig. 2.4 shows the different parts of the vernier calipers and how its reading is taken. Each division on the main scale is 1 mm and each division on the vernier scale is 0.9 mm.



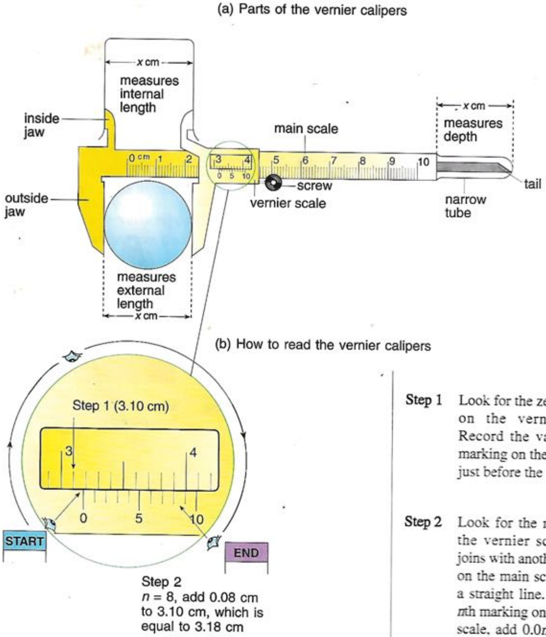



Fig. 2.4 Vernier calipers

**Step 1** Look for the zero marking on the vernier scale. Record the value of the marking on the main scale just before the zero mark.

**Step 2** Look for the marking on the vernier scale which joins with another marking on the main scale to form a straight line. If it is the $n$th marking on the vernier scale, add $0.0n$ cm to the value recorded earlier in step 1.

As in the case of the internal and external calipers, measurements obtained by using the vernier calipers do not have any parallax error because the vernier scale of the calipers is touching the main scale.

### *How to Use the Vernier Calipers*

**Step 1** Close the jaws and check that the zero marking on the main scale is in line with the zero marking on the vernier scale. If the two zero markings are in line, there is no zero error (see Fig. 2.5).

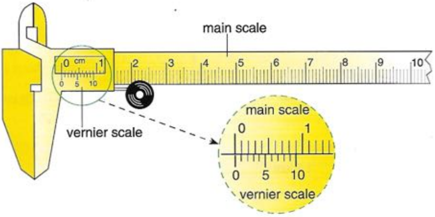



Fig. 2.5 To check for zero error

However, if the two zero markings are not in line, then there is a zero error. (A more detailed explanation on zero error will be given in a later section.) Read and record the zero error.

**Step 2** Open the jaws wide enough to hold the object to be measured by sliding the vernier scale. If you are measuring an internal length, continue to open the inside jaws until they just touch the object (see Fig. 2.6). If you are measuring an external length, close the outside jaws until they just touch the object (see Fig. 2.7).

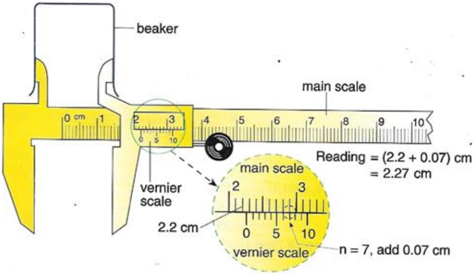



Fig. 2.6 Measuring an internal length

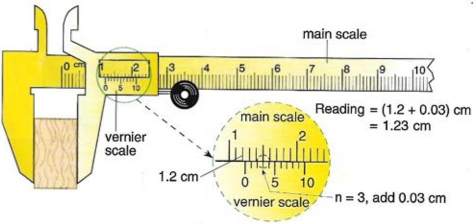



Fig. 2.7 Measuring an external length

**Step 3** Read and record the reading shown on the vernier calipers.

### **Zero Error in Vernier Calipers*

If the jaws are closed and the zero of the vernier scale is to the right of the zero of the main scale, there is a **positive zero error** (see Fig. 2.8). This means that measurements taken with this pair of vernier calipers will be more than the actual value by the value of the zero error. To get the correct value, the zero error must be recorded and then subtracted from each reading.

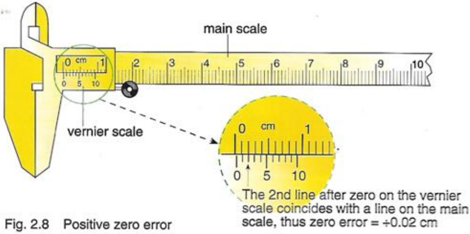



Fig. 2.8 Positive zero error

If the jaws are closed and the zero of the vernier scale is to the left of the zero of the main scale, there is a **negative zero error** (see Fig. 2.9). This means that measurements taken with this pair of vernier calipers will be less than the actual value by the value of the zero error. To get the correct value, the numerical value of the zero error must be recorded and then added to each reading.

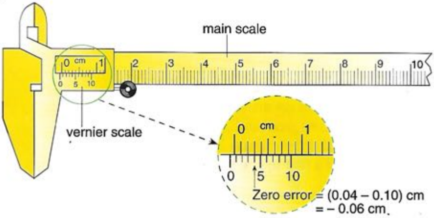



Fig. 2.9 Negative zero error

## 2.4 Measuring Area

**Area** is a measure of the extent of a surface. The SI unit for area is the **square metre ($m^2$)**. Other common units for area include $mm^2$, $cm^2$ and $km^2$. One $m^2$ is the area of a square which measures 1 m on every side.

The areas of regular surfaces can be calculated by using formulae. The formulae for some common regular surfaces are shown in Fig. 2.10.

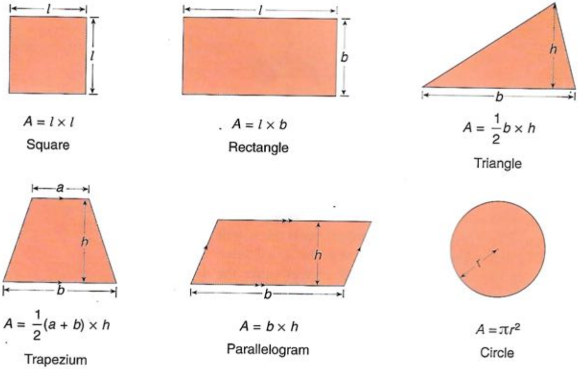
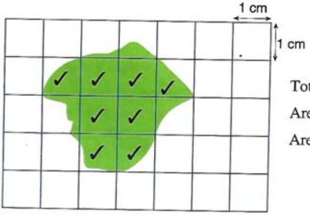



Fig. 2.10 Area ($A$) of regular surfaces

For irregular surfaces, approximations of their areas are made by dividing them into small unit squares of known areas and counting them. Incomplete squares are counted if their areas are equal to half or more than half of the area of a unit square.

***Example***




Total number of squares = 8

Area of one square = 1 cm × 1 cm = 1 $cm^2$

Area of the irregular object = 8 × 1 $cm^2$
= 8 $cm^2$

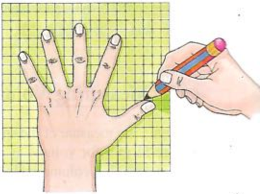
Points to remember when measuring lengths and areas:

- Always choose the most suitable instrument. Which length-measuring instrument would you choose to measure your waist? Give a reason.

- If an appropriate measuring instrument is not available, make an approximation or estimation of the measurement to be made.

  *Example*

  To find the area of your palm, trace the outline of your palm on a piece of graph paper. Count the number of 1-cm squares (half or more than half) covered by your palm. Then, calculate the approximate area of your palm.



- Whenever possible, take a few measurements and find their average value.

  *Example*

  To measure the external diameter of a boiling tube, measure the diameter of the tube at different positions (for example, A, B, C and D) as shown in Fig. 2.11. At each position, measure the diameter along two perpendicular directions.

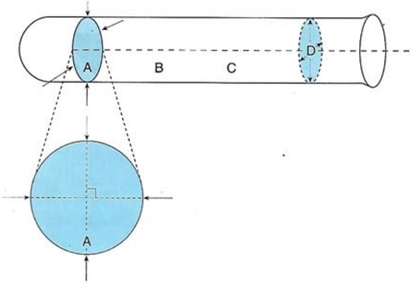



Fig. 2.11 Measuring the external diameter of a boiling tube

- Readings should be recorded in their correct units and should not be more accurate than the smallest division on the scale of the measuring instrument.

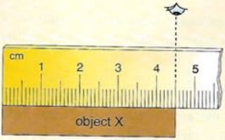
## *Mini-Exercise*

Mun Ling has wrongly recorded the length of object X as follows:

Length of object X = 4.50 $cm^2$

Can you correct Mun Ling's recording?

Length of object X = __________




## 2.5 Measuring Volume

**Volume** is a measure of the space occupied by a substance. The SI unit for volume is the **cubic metre ($m^3$)**. Other common units for volume include $mm^3$, $cm^3$, millilitre (m$l$) and litre ($l$).

1 m$l$ = 1 $cm^3$
1 $l$ = 1 000 m$l$ = 1 000 $cm^3$

Some objects have regular shapes, for example, books, basketballs, pyramids, soft-drink cans. The volume of regular-shaped objects can be calculated using formulae. The formulae for some common regular-shaped objects are shown in Fig. 2.12.

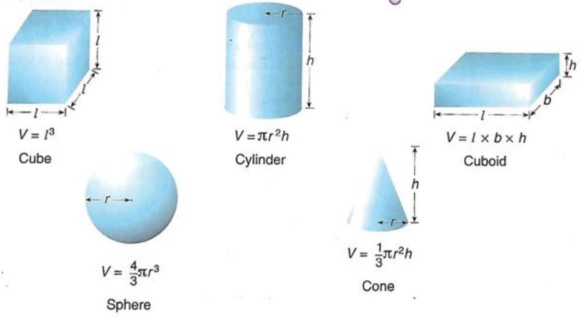



Fig. 2.12 Volume ($V$) of regular-shaped objects

The volume of irregular-shaped objects can be found by the displacement method using measuring cylinders or displacement cans.

### *Meniscus Reading*

If you pour water into a measuring cylinder and place it on the bench or any flat surface, you will observe that the water surface is curved as shown in Fig. 2.13.

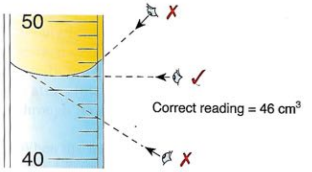



Fig. 2.13 Meniscus curving downwards

The meniscus of most liquids curves downwards. The correct way to read the meniscus is to position the eye at the same level as the meniscus (see Fig. 2.13). The mark that corresponds to the bottom of the meniscus is taken as the reading. What type of error is avoided by placing the eye at the same level as the meniscus?

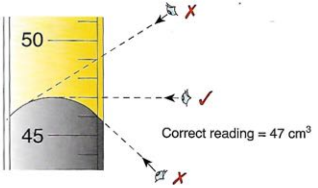



Fig. 2.14 Meniscus curving upwards

The meniscus of mercury curves upwards. The correct reading is the mark that corresponds to the top of the meniscus (see Fig. 2.14).

***Measuring the Volume of Small Irregular-shaped Objects which Sink in Water by Using a Measuring Cylinder***

**Step 1** Fill a measuring cylinder with water until it is about half full. Record the volume of water, $V_0$, in the measuring cylinder (see Fig. 2.15a).

**Step 2** Tie the irregular-shaped object with a piece of thread. Lower it gently into the measuring cylinder. Observe and record the water level, $V_1$, after putting the object in (see Fig. 2.15b).

**Step 3** The volume of the irregular-shaped object is given by $V = V_1 - V_0$.

## Mini-Exercise

Fill in the blanks using information found in Fig. 2.15.

Volume of irregular-shaped object,

$V = V_1 - V_0$

$= \_\_\_\_\_ - \_\_\_\_\_$

$= \_\_\_\_\_\ \text{cm}^3$

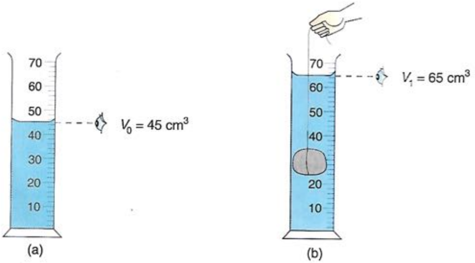



Fig. 2.15 Measuring the volume of a small irregular-shaped object

## Do You Know?

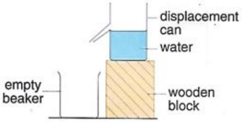
Can you find the volume of a small piece of rock sugar using the above method? If not, give a reason. Suggest what needs to be changed in the above method so that it can be used to measure the volume of the rock sugar.

### *Measuring the Volume of Large Irregular-shaped Objects which Sink in Water by Using a Measuring Cylinder and a Displacement Can*

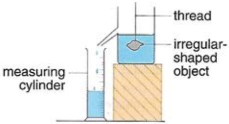
Step 1 Fill a displacement can with water until excess water flows out of its spout into a beaker. Remove the beaker when water stops flowing into it.

Step 2 Place an empty measuring cylinder below the spout of the displacement can. Tie the irregular-shaped object with a piece of thread. Lower it gently into the displacement can. Observe the water flowing out of the displacement can through its spout into the measuring cylinder.

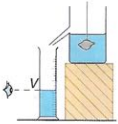
Step 3 When the water stops flowing into the measuring cylinder, record the volume of water displaced by the object and collected in the measuring cylinder. The volume of water in the measuring cylinder is equal to the volume of the irregular-shaped object.




(a) Before immersing the object




(b) After immersing the object




(c) After all displaced water is collected

Fig. 2.16 Steps for measuring the volume of a large irregular-shaped object

## *Do You Know?*

How do you find the volume of an irregular-shaped piece of cork which floats on water?

You will learn more about the methods of measuring the volumes of solids and liquids in your practical book.

## 2.6 Instruments for Measuring the Volumes of Liquids

Besides the measuring cylinder, other instruments commonly used in the laboratory for measuring volumes of liquids are the burette, pipette and volumetric flask as shown in Fig. 2.17.

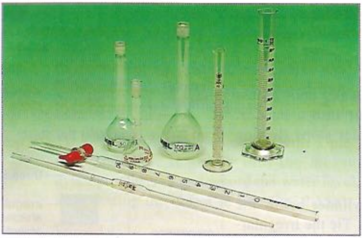


Fig. 2.17 Common laboratory instruments for measuring volumes

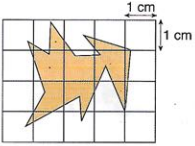
A liquid is sucked into a pipette by means of a pipette filler up to a mark showing the exact volume of liquid in the pipette. Sucking by mouth is not recommended because of safety and hygiene reasons.

## Key Points

1. A physical quantity is a quantity that can be measured.
2. The SI units are the standard units which people use nowadays for measurement.
3. Prefixes such as milli-, centi- and kilo- are added to a SI base unit to form smaller or larger units.
4. Length is a measure of distance and its SI unit is the metre (m).
5. Some common length-measuring instruments are measuring tape, metre rule, calipers and vernier calipers.
6. Parallax error is caused by the wrong positioning of the eye during measurement.
7. Area is a measure of the extent of a surface and its SI unit is the square metre ($m^2$).
8. Volume is a measure of the space occupied by a substance and its SI unit is the cubic metre ($m^3$).
9. The eye should be placed at the correct position when taking a meniscus reading.

# Review Questions

1. Write down **five** physical quantities and their SI units.
2. Complete the following.
   1 km = ______ m = ______ cm = ______ mm
   1 g = ______ mg = ______ kg
3. Which instrument would you use to measure
   (a) the diameter of a marble,
   (b) the depth of a hole,
   (c) the internal diameter of a test tube,
   (d) the height of a table,
   (e) the width of a door?
4. What is the approximate area of the shaded figure on the right?
5. A cylinder has a radius of 5 cm and height of 10 cm. Calculate its base area, and hence, its volume.
6. Write down the readings.
   (a) (b) (c)


# Think-Tank

1. Why is it desirable for scientists to use the SI units in their work?
2. A thirsty crow found some water at the bottom of a long-necked flask but could not reach the water. How can it drink the water inside the flask without toppling it?
3. Mr Tan wanted to buy a big, irregular-shaped plot of land. How can he check the size of the land?
4. 'I can weigh myself to see how heavy I am. I can measure my height to see how tall I am. But how can I find out my own volume?' asked Min Min.

   Help Min Min to solve her problem.
5. It is easy to measure the length of a pole or the diameter of a ball bearing but how can one measure vast distances such as the depth of a deep ocean or the diameter of the Earth?

# BASIC OF CIVIL ENGINEERING

# Module 1

- **General Introduction to Civil Engineering:** Relevance of Civil Engineering in the overall infrastructural development of the country. Responsibility of an engineer in ensuring the safety of built environment. Brief introduction to major disciplines of Civil Engineering like Transportation Engineering, Structural Engineering, Geo-technical Engineering, Water Resources Engineering and Environmental Engineering.
- **Introduction to buildings:** Types of buildings, selection of site for buildings, components of a residential building and their functions.
- **Building rules and regulations:** Relevance of NBC, KBR & CRZ norms (brief discussion only).
- **Building area:** Plinth area, built up area, floor area, carpet area and floor area ratio for a building as per KBR.

# Introduction

- Civil engineering is one of the oldest engineering disciplines
- Includes planning, designing, and construction and maintenance of building structures, and facilities, such as roads, railroads, airports, bridges, harbours, channels, dams, irrigation projects, and water and sewage systems.

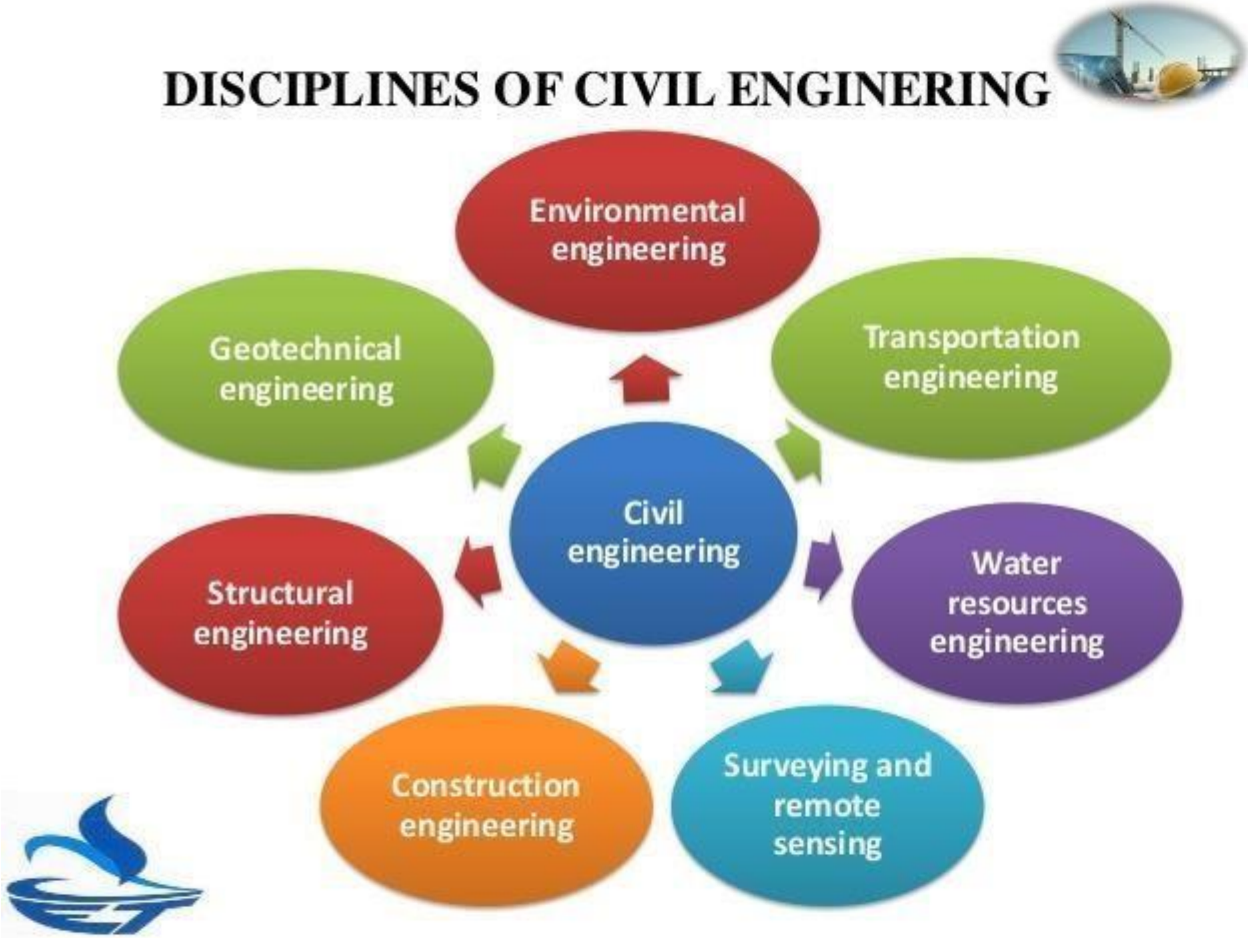
# Role of Civil Engineers in Infrastructural Development

- ✓ Construction of residential , commercial and industrial buildings
- ✓ Town and city planning
- ✓ Construction of roads , railway, harbours and airports
- ✓ Construction of dams , water and sewage treatment plants
- ✓ Providing safe domestic ,agricultural and industrial water supply
- ✓ Secure and scientific waste disposal
- ✓ Monitoring pollution and adopting preventive measures
- ✓ Rehabilitation and rebuilding of structures

# Impacts of Infrastructural Development

- Healthy and comfortable living condition
- Improvement in communication and transportation
- Protection from flood and drought
- Safe domestic and industrial water supply
- Generation of electricity
- Increase in food production
- Safe and scientific disposal of waste
- Improved wealth , prosperity and standard of living

# Various Disciplines of Civil Engineering



# Various disciplines of Civil Engineering

- **Structural Engineering**
- **Construction Engineering**
- **Geotechnical Engineering**
- **Transportation Engineering**
- **Environmental Engineering**
- **Water resource Engineering**
- **Surveying and Remote Sensing**

# Structural Engineering

- ✓ Deals with design of RCC structures like water tank , retaining wall , bridges, residential buildings etc
- ✓ Design of steel structures like railway platform, steel bridges etc
- ✓ Design of earthquake resistant structures

# Structural Engineering

- ✓ Analysis and design of structures subjected to self weight , external loads acting on it and resist forces due to wind ,earthquake ,temperature etc
- ✓ Structural engineers develops proper combinations of steel , timber, concrete, plastic etc
- ✓ Ensure aesthetically pleasing , safe and durable structures

# Construction Engineering

- ✓ Turn designs into reality on time and within budget
- ✓ Management of resources - money, materials, labours , time , equipment's
- ✓ Construction management involves planning , scheduling and execution of project from its beginning to its completion
- ✓ Application of knowledge , skills ,tools and techniques to project activities in order to meet project requirements for the successful completion of project .

# Geotechnical Engineering

- ✓ Deals with projects below ground (eg: tunnels , foundations)
- ✓ Analyse soil properties and rock that support and affect the behaviour of structures.
- ✓ Evaluate stability of slopes and fill, seepage of ground water
- ✓ Helps on design and construction of dams, embankments and retaining walls

# Geotechnical Engineering

**Soil Mechanics**

- branch of science concerned with the properties and behaviour of soil and its application as engineering material in construction

**Foundation Engineering**

- application of soil mechanics and rock mechanics (Geotechnical engineering) in the design of foundation elements of structures

# Transportation Engineering

- ✓ Focuses on planning, design , construction and management of transportation facilities
- ✓ Upgrading our transportation capability by improving traffic control

1. Airport engineering
2. Highway engineering
3. Railway engineering
4. Tunnel engineering
5. Traffic engineering
6. Harbour and dock engineering

# Environmental Engineering

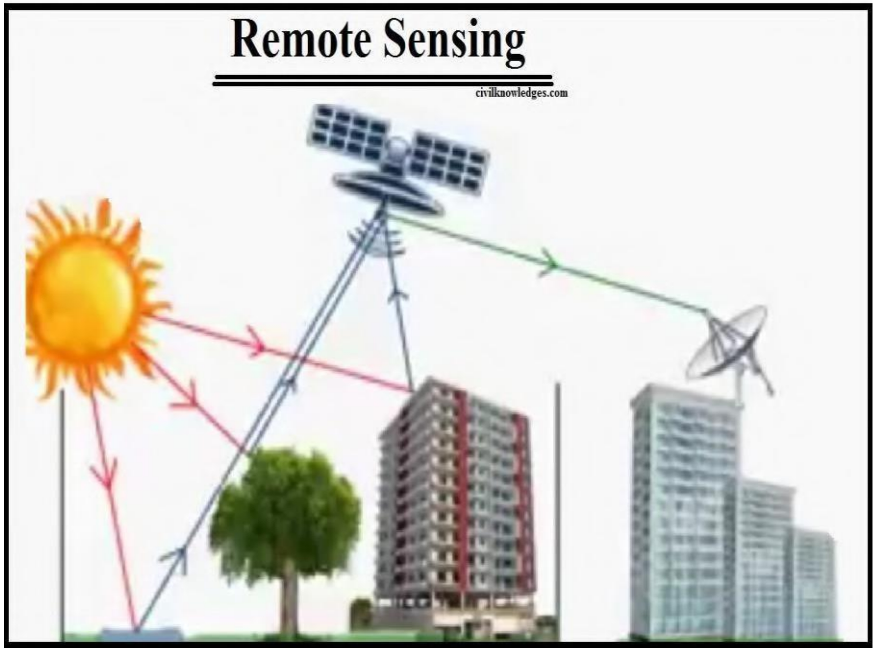
- ✓ Deals with purification of air and water , sewage treatment , hazardous waste management , pollution reduction ,water supply etc
- ✓ Environmental engineers translate physical , chemical and biological processes into systems to destroy toxic substances, remove pollutants from water, reduce non hazardous solid waste volumes, and eliminate contaminants from air .

# Water Resource Engineering

- ✓ Deals with physical control of water
- ✓ Works related to Prevents floods, supply of water , protect beaches or to manage and redirect rivers
- ✓ Design , construct and maintain hydro electric power plant facilities, canal, dams and pipelines, pumping stations etc

# Surveying and Remote Sensing

- ✓ Art of determining the relative positions of points on, above or beneath the surface of the earth by means of direct or indirect measurements of distance, direction and elevation.
- ✓ Objective of surveying is to prepare plan or map
- ✓ Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it.



# Surveying and Remote Sensing

# What is Mechanical Engineering?

**6.1 Definition:** Mechanical engineering is a diverse subject that derives its breadth from the need to design and manufacture everything from small individual parts and devices (e.g., microscale sensors and inkjet printer nozzles) to large systems (e.g., spacecraft and machine tools). The role of a mechanical engineer is to take a product from an idea to the marketplace. In order to accomplish this, a broad range of skills are needed. The mechanical engineer needs to acquire particular skills and knowledge. He/she needs to understand the forces and the thermal environment that a product, its parts, or its subsystems will encounter; to design them for functionality, aesthetics, and the ability to withstand the forces and the thermal environment they will be subjected to; and to determine the best way to manufacture them and ensure they will operate without failure. Perhaps the one skill that is the mechanical engineer's exclusive domain is the ability to analyze and design objects and systems with motion.

Since these skills are required for virtually everything that is made, mechanical engineering is perhaps the broadest and most diverse of engineering disciplines. Mechanical engineers play a central role in such industries as automotive (from the car chassis to its every subsystem—engine, transmission, sensors); aerospace (airplanes, aircraft engines, control systems for airplanes and spacecraft); biotechnology (implants, prosthetic devices, fluidic systems for pharmaceutical industries); computers and electronics (disk drives, printers, cooling systems, semiconductor tools); microelectromechanical systems, or MEMS (sensors, actuators, micropower generation); energy conversion (gas turbines, wind turbines, solar energy, fuel cells); environmental control (HVAC, air-conditioning, refrigeration, compressors); automation (robots, data and image acquisition, recognition, control); manufacturing (machining, machine tools, prototyping, microfabrication).

To put it simply, mechanical engineering deals with anything that moves, including the human body, a very complex machine. Mechanical engineers learn about materials, solid and fluid mechanics, thermodynamics, heat transfer, control, instrumentation, design, and manufacturing to understand mechanical systems. Specialized mechanical engineering subjects include biomechanics, cartilage-tissue engineering, energy conversion, laser-assisted materials processing, combustion, MEMS, microfluidic devices, fracture mechanics, nanomechanics, mechanisms, micropower generation, tribology (friction and wear), and vibrations. The American Society of Mechanical Engineers (ASME) currently lists 36 technical divisions, from advanced energy systems and aerospace engineering to solid-waste engineering and textile engineering.

The breadth of the mechanical engineering discipline allows students a variety of career options beyond some of the industries listed above. Regardless of the particular path they envision for themselves after they graduate, their education will have provided them with the creative thinking that allows them to design an exciting product or system, the analytical tools to achieve their design goals, the ability to overcome all constraints, and the teamwork needed to design, market, and produce a system. These valuable skills could also launch a career in medicine, law, consulting, management, banking, finance, and so on.

For those interested in applied scientific and mathematical aspects of the discipline, graduate study in mechanical engineering can lead to a career of research and teaching.

**6.2 Modern Tools:** Many mechanical engineering companies, especially those in industrialized nations, have begun to incorporate computer-aided engineering (CAE) programs into their existing design and analysis processes, including 2D and 3D solid modeling computer-aided design (CAD). This method has many benefits, including easier and more exhaustive visualization of products, the ability to create virtual assemblies of parts, and the ease of use in designing mating interfaces and tolerances.

Other CAE programs commonly used by mechanical engineers include product lifecycle management (PLM) tools and analysis tools used to perform complex simulations. Analysis tools may be used to predict product response to expected loads, including fatigue life and manufacturability. These tools include finite element analysis (FEA), computational fluid dynamics (CFD), and computer-aided manufacturing (CAM).

Using CAE programs, a mechanical design team can quickly and cheaply iterate the design process to develop a product that better meets cost, performance, and other constraints. No physical prototype need be created until the design nears completion, allowing hundreds or thousands of designs to be evaluated, instead of a relative few. In addition, CAE analysis programs can model complicated physical phenomena which cannot be solved by hand, such as viscoelasticity, complex contact between mating parts, or non-Newtonian flows.

As mechanical engineering begins to merge with other disciplines, as seen in mechatronics, multidisciplinary design optimization (MDO) is being used with other CAE programs to automate and improve the iterative design process. MDO tools wrap around existing CAE processes, allowing product evaluation to continue even after the analyst goes home for the day. They also utilize sophisticated optimization algorithms to more intelligently explore possible designs, often finding better, innovative solutions to difficult multidisciplinary design problems.

**6.3 Sub-disciplines:** The field of mechanical engineering can be thought of as a collection of many mechanical engineering science disciplines. Several of these subdisciplines which are typically taught at the undergraduate level are listed below, with a brief explanation and the most common application of each. Some of these subdisciplines are unique to mechanical engineering, while others are a combination of mechanical engineering and one or more other disciplines. Most work that a mechanical engineer does uses skills and techniques from several of these subdisciplines, as well as specialized subdisciplines. Specialized subdisciplines, as used in this article, are more likely to be the subject of graduate studies or on-the-job training than undergraduate research. Several specialized subdisciplines are discussed in this section.

**Mechanics:** Mechanics is, in the most general sense, the study of forces and their effect upon matter. Typically, engineering mechanics is used to analyze and predict the acceleration and deformation (both elastic and plastic) of objects under known forces (also called loads) or stresses. Subdisciplines of mechanics include:

- Statics, the study of non-moving bodies under known loads, how forces affect static bodies
- Dynamics (or kinetics), the study of how forces affect moving bodies
- Mechanics of materials, the study of how different materials deform under various types of stress
- Fluid mechanics, the study of how fluids react to forces[25]
- Kinematics, the study of the motion of bodies (objects) and systems (groups of objects), while ignoring the forces that cause the motion. Kinematics is often used in the design and analysis of mechanisms.
- Continuum mechanics, a method of applying mechanics that assumes that objects are continuous (rather than discrete)

Mechanical engineers typically use mechanics in the design or analysis phases of engineering. If the engineering project were the design of a vehicle, statics might be employed to design the frame of the vehicle, in order to evaluate where the stresses will be most intense. Dynamics might be used when designing the car's engine, to evaluate the forces in the pistons and cams as the engine cycles. Mechanics of materials might be used to choose appropriate materials for the frame and engine. Fluid mechanics might be used to design a ventilation system for the vehicle (see HVAC), or to design the intake system for the engine.

**Mechatronics and robotics:** Mechatronics is the combination of mechanics and electronics. It is an interdisciplinary branch of mechanical engineering, electrical engineering and software engineering that is concerned with integrating electrical and mechanical engineering to create hybrid systems. In this way, machines can be automated through the use of electric motors, servo-mechanisms, and other electrical systems in conjunction with special software. A common example of a mechatronics system is a CD-ROM drive. Mechanical systems open and close the drive, spin the CD and move the laser, while an optical system reads the data on the CD and converts it to bits. Integrated software controls the process and communicates the contents of the CD to the computer.

Robotics is the application of mechatronics to create robots, which are often used in industry to perform tasks that are dangerous, unpleasant, or repetitive. These robots may be of any shape and size, but all are preprogrammed and interact physically with the world. To create a robot, an engineer typically employs kinematics (to determine the robot's range of motion) and mechanics (to determine the stresses within the robot).

Robots are used extensively in industrial engineering. They allow businesses to save money on labor, perform tasks that are either too dangerous or too precise for humans to perform them economically, and to ensure better quality. Many companies employ assembly lines of robots,especially in Automotive Industries and some factories are so robotized that they can run by themselves. Outside the factory, robots have been employed in bomb disposal, space exploration, and many other fields. Robots are also sold for various residential applications, from recreation to domestic applications.

**Structural analysis:** Structural analysis is the branch of mechanical engineering (and also civil engineering) devoted to examining why and how objects fail and to fix the objects and their performance. Structural failures occur in two general modes: static failure, and fatigue failure. *Static structural failure* occurs when, upon being loaded (having a force applied) the object being analyzed either breaks or is deformed plastically, depending on the criterion for failure. *Fatigue failure* occurs when an object fails after a number of repeated loading and unloading cycles. Fatigue failure occurs because of imperfections in the object: a microscopic crack on the surface of the object, for instance, will grow slightly with each cycle (propagation) until the crack is large enough to cause ultimate failure.

Failure is not simply defined as when a part breaks, however; it is defined as when a part does not operate as intended. Some systems, such as the perforated top sections of some plastic bags, are designed to break. If these systems do not break, failure analysis might be employed to determine the cause.

Structural analysis is often used by mechanical engineers after a failure has occurred, or when designing to prevent failure. Engineers often use online documents and books such as those published by ASM to aid them in determining the type of failure and possible causes.

Structural analysis may be used in the office when designing parts, in the field to analyze failed parts, or in laboratories where parts might undergo controlled failure tests.

**Thermodynamics and thermo-science:** Thermodynamics is an applied science used in several branches of engineering, including mechanical and chemical engineering. At its simplest, thermodynamics is the study of energy, its use and transformation through a system. Typically, engineering thermodynamics is concerned with changing energy from one form to another. As an example, automotive engines convert chemical energy (enthalpy) from the fuel into heat, and then into mechanical work that eventually turns the wheels.

Thermodynamics principles are used by mechanical engineers in the fields of heat transfer, thermofluids, and energy conversion. Mechanical engineers use thermo-science to design engines and power plants, heating, ventilation, and air-conditioning (HVAC) systems, heat exchangers, heat sinks, radiators, refrigeration, insulation, and others.

**Design and drafting:** Drafting or technical drawing is the means by which mechanical engineers design products and create instructions for manufacturing parts. A technical drawing can be a computer model or hand-drawn schematic showing all the dimensions necessary to manufacture a part, as well as assembly notes, a list of required materials, and other pertinent information. A U.S. mechanical engineer or skilled worker who creates technical drawings may be referred to as a drafter or draftsman. Drafting has historically been a two-dimensional process, but computer-aided design (CAD) programs now allow the designer to create in three dimensions.

Instructions for manufacturing a part must be fed to the necessary machinery, either manually, through programmed instructions, or through the use of a computer-aided manufacturing (CAM) or combined CAD/CAM program. Optionally, an engineer may also manually manufacture a part using the technical drawings, but this is becoming an increasing rarity, with the advent of computer numerically controlled (CNC) manufacturing. Engineers primarily manually manufacture parts in the areas of applied spray coatings, finishes, and other processes that cannot economically or practically be done by a machine.

Drafting is used in nearly every subdiscipline of mechanical engineering, and by many other branches of engineering and architecture. Three-dimensional models created using CAD software are also commonly used in finite element analysis (FEA) and computational fluid dynamics (CFD).

**Frontiers of research:** Mechanical engineers are constantly pushing the boundaries of what is physically possible in order to produce safer, cheaper, and more efficient machines and mechanical systems. Some technologies at the cutting edge of mechanical engineering are listed below (see also exploratory engineering).

**Micro electro-mechanical systems (MEMS)**

Micron-scale mechanical components such as springs, gears, fluidic and heat transfer devices are fabricated from a variety of substrate materials such as silicon, glass and polymers like SU8. Examples of MEMS components are the accelerometers that are used as car airbag sensors, modern cell phones, gyroscopes for precise positioning and microfluidic devices used in biomedical applications.

**Friction stir welding (FSW)**

Friction stir welding, a new type of welding, was discovered in 1991 by The Welding Institute (TWI). The innovative steady state (non-fusion) welding technique joins materials previously un-weldable, including several aluminum alloys. It plays an important role in the future construction of airplanes, potentially replacing rivets. Current uses of this technology to date include welding the seams of the aluminum main Space Shuttle external tank, Orion Crew Vehicle test article, Boeing Delta II and Delta IV Expendable Launch Vehicles and the SpaceX Falcon 1 rocket, armor plating for amphibious assault ships, and welding the wings and fuselage panels of the new Eclipse 500 aircraft from Eclipse Aviation among an increasingly growing pool of uses.

## Composites

Composites or composite materials are a combination of materials which provide different physical characteristics than either material separately. Composite material research within mechanical engineering typically focuses on designing (and, subsequently, finding applications for) stronger or more rigid materials while attempting to reduce weight, susceptibility to corrosion, and other undesirable factors. Carbon fiber reinforced composites, for instance, have been used in such diverse applications as spacecraft and fishing rods.

## Mechatronics

Mechatronics is the synergistic combination of mechanical engineering, electronic engineering, and software engineering. The purpose of this interdisciplinary engineering field is the study of automation from an engineering perspective and serves the purposes of controlling advanced hybrid systems.

## Nanotechnology

At the smallest scales, mechanical engineering becomes nanotechnology —one speculative goal of which is to create a molecular assembler to build molecules and materials via mechanosynthesis. For now that goal remains within exploratory engineering. Areas of current mechanical engineering research in nanotechnology include nanofilters, nanofilms, and nanostructures, among others.

## Finite element analysis

This field is not new, as the basis of Finite Element Analysis (FEA) or Finite Element Method (FEM) dates back to 1941. But evolution of computers has made FEA/FEM a viable option for analysis of structural problems. Many commercial codes such as ANSYS, Nastran and ABAQUS are widely used in industry for research and design of components. Calculix is an open source and free finite element program. Some 3D modeling and CAD software packages have added FEA modules. Other techniques such as finite difference method (FDM) and finite-volume method (FVM) are employed to solve problems relating heat and mass transfer, fluid flows, fluid surface interaction etc.

**Biomechanics:** Biomechanics is the application of mechanical principles to biological systems, such as humans, animals, plants, organs, and cells.[33] Biomechanics also aids in creating prosthetic limbs and artificial organs for humans.

Biomechanics is closely related to engineering, because it often uses traditional engineering sciences to analyse biological systems. Some simple applications of Newtonian mechanics and/or materials sciences can supply correct approximations to the mechanics of many biological systems.

Over the past decade the Finite element method (FEM) has also entered the Biomedical sector highlighting further engineering aspects of Biomechanics. FEM has since then established itself as an alternative to in vivo surgical assessment and gained the wide acceptance of academia. The main advantage of Computational Biomechanics lies in its ability to determine the endo-anatomical response of an anatomy, without being subject to ethical restrictions.[34] This has led FE modelling to the point of becoming ubiquitous in several fields of Biomechanics while several projects have even adopted an open source philosophy (e.g. BioSpine).

## Computational fluid dynamics

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

## Acoustical engineering

Acoustical engineering is one of many other sub disciplines of mechanical engineering and is the application of acoustics. Acoustical engineering is the study of Sound and Vibration. These engineers work effectively to reduce noise pollution in mechanical devices and in buildings by soundproofing or removing sources of unwanted noise. The study of acoustics can range from designing a more efficient hearing aid, microphone, headphone, or recording studio to enhancing the sound quality of an orchestra hall. Acoustical engineering also deals with the vibration of different mechanical systems.

# Hydraulic engineering

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Hydraulic Flood Retention Basin (HFRB)


View from Church Span Bridge, Bern, Switzerland


Riprap lining a lake shore

**Hydraulic engineering** as a sub-discipline of civil engineering is concerned with the flow and conveyance of fluids, principally water and sewage. One feature of these systems is the extensive use of gravity as the motive force to cause the movement of the fluids. This area of civil engineering is intimately related to the design of bridges, dams, channels, canals, and levees, and to both sanitary and environmental engineering.

Hydraulic engineering is the application of the principles of fluid mechanics to problems dealing with the collection, storage, control, transport, regulation, measurement, and use of water.[1] Before beginning a hydraulic engineering project, one must figure out how much water is involved. The hydraulic engineer is concerned with the transport of sediment by the river, the interaction of the water with its alluvial boundary, and the occurrence of scour and deposition.[1] "The hydraulic engineer actually develops conceptual designs for the various features which interact with water such as spillways and outlet works for dams, culverts for highways, canals and related structures for irrigation projects, and cooling-water facilities for thermal power plants." [2]

# Fundamental principles[edit]

A few examples of the fundamental principles of hydraulic engineering include fluid mechanics, fluid flow, behavior of real fluids, hydrology, pipelines, open channel hydraulics, mechanics of sediment transport, physical modeling, hydraulic machines, and drainage hydraulics.

## Fluid mechanics[edit]

*Fundamentals of Hydraulic Engineering* defines hydrostatics as the study of fluids at rest.[1] In a fluid at rest, there exists a force, known as pressure, that acts upon the fluid's surroundings. This pressure, measured in N/m$^2$, is not constant throughout the body of fluid. Pressure, p, in a given body of fluid, increases with an increase in depth. Where the upward force on a body acts on the base and can be found by the equation:

where,

$\rho$ = density of water
$g$ = specific gravity
$y$ = depth of the body of liquid

Rearranging this equation gives you the pressure head . Four basic devices for pressure measurement are a piezometer, manometer, differential manometer, Bourdon gauge, as well as an inclined manometer.[1]

As Prasuhn states:

On undisturbed submerged bodies, pressure acts along all surfaces of a body in a liquid, causing equal perpendicular forces in the body to act against the pressure of the liquid. This reaction is known as equilibrium. More advanced applications of pressure are that on plane surfaces, curved surfaces, dams, and quadrant gates, just to name a few.[1]

## Behavior of real fluids[edit]

### Real and Ideal fluids[edit]

The main difference between an ideal fluid and a real fluid is that for ideal flow $p_1 = p_2$ and for real flow $p_1 > p_2$. Ideal fluid is incompressible and has no viscosity. Real fluid has viscosity. Ideal fluid is only an imaginary fluid as all fluids that exist have some viscosity.

#### Viscous flow[edit]

A viscous fluid will deform continuously under a shear force by the pascles law, whereas an ideal fluid does not deform.

#### Laminar flow and turbulence[edit]

The various effects of disturbance on a viscous flow are a stable, transition and unstable.

#### Bernoulli's equation[edit]

For an ideal fluid, Bernoulli's equation holds along streamlines.

As the flow comes into contact with the plate, the layer of fluid actually "adheres" to a solid surface. There is then a considerable shearing action between the layer of fluid on the plate surface and the second layer of fluid. The second layer is therefore forced to decelerate (though it is not quite brought to rest), creating a shearing action with the third layer of fluid, and so on. As the fluid passes further along with the plate, the zone in which shearing action occurs tends to spread further outwards. This zone is known as the "boundary layer". The flow outside the boundary layer is free of shear and viscous-related forces so it is assumed to act as an ideal fluid. The intermolecular cohesive forces in a fluid are not great enough to hold fluid together. Hence a fluid will flow under the action of the slightest stress and flow will continue as long as the stress is present.[3] The flow inside the layer can be either vicious or turbulent, depending on Reynolds number.[1]

## Applications[edit]

Common topics of design for hydraulic engineers include hydraulic structures such as dams, levees, water distribution networks including both domestic and fire water supply, distribution and automatic sprinkler systems, water collection networks, sewage collection networks, storm water management, sediment transport, and various other topics related to transportation engineering and geotechnical engineering. Equations developed from the principles of fluid dynamics and fluid mechanics are widely utilized by other engineering disciplines such as mechanical, aeronautical and even traffic engineers.

Related branches include hydrology and rheology while related applications include hydraulic modeling, flood mapping, catchment flood management plans, shoreline management plans, estuarine strategies, coastal protection, and flood alleviation.

# History[edit]

## Antiquity[edit]

*See also: Sanitation of the Indus Valley Civilization*

*See also: Architecture of the Philippines and Cultural achievements of pre-colonial Philippines*

Earliest uses of hydraulic engineering were to irrigate crops and dates back to the Middle East and Africa. Controlling the movement and supply of water for growing food has been used for many thousands of years. One of the earliest hydraulic machines, the water clock was used in the early 2nd millennium BC.[4] Other early examples of using gravity to move water include the Qanat system in ancient Persia and the very similar Turpan water system in ancient China as well as irrigation canals in Peru.[5]

In ancient China, hydraulic engineering was highly developed, and engineers constructed massive canals with levees and dams to channel the flow of water for irrigation, as well as locks to allow ships to pass through. Sunshu Ao is considered the first Chinese hydraulic engineer. Another important Hydraulic Engineer in China, Ximen Bao was credited of starting the practice of large scale canal irrigation during the Warring States period (481 BC–221 BC), even today hydraulic engineers remain a respectable position in China. Before becoming General Secretary of the Chinese Communist Party in 2002, Hu Jintao was a hydraulic engineer and holds an engineering degree from Tsinghua University

The Banaue Rice Terraces in the Philippine Cordilleras, ancient sprawling man-made structures which are a UNESCO World Heritage Site.

In the Archaic epoch of the Philippines, hydraulic engineering also developed specially in the Island of Luzon, the Ifugaos of the mountainous region of the Cordilleras built irrigations, dams and hydraulic works and the famous Banaue Rice Terraces as a way for assisting in growing crops around 1000 BC.[6] These Rice Terraces are 2,000-year-old terraces that were carved into the mountains of Ifugao in the Philippines by ancestors of the indigenous people. The Rice Terraces are commonly referred to as the "Eighth Wonder of the World".[7][8][9] It is commonly thought that the terraces were built with minimal equipment, largely by hand. The terraces are located approximately 1500 metres (5000 ft) above sea level. They are fed by an ancient irrigation system from the rainforests above the terraces. It is said that if the steps were put end to end, it would encircle half the globe.[10]

Eupalinos of Megara, was an ancient Greek engineer who built the Tunnel of Eupalinos on Samos in the 6th century BC, an important feat of both civil and hydraulic engineering. The civil engineering aspect of this tunnel was the fact that it was dug from both ends which required the diggers to maintain an accurate path so that the two tunnels met and that the entire effort maintained a sufficient slope to allow the water to flow.

Hydraulic engineering was highly developed in Europe under the aegis of the Roman Empire where it was especially applied to the construction and maintenance of aqueducts to supply water to and remove sewage from their cities.[3] In addition to supplying the needs of their citizens they used hydraulic mining methods to prospect and extract alluvial gold deposits in a technique known as hushing, and applied the methods to other ores such as those of tin and lead.

In the 15th century, the Somali Ajuran Empire was the only hydraulic empire in Africa. As a hydraulic empire, the Ajuran State monopolized the water resources of the Jubba and Shebelle Rivers. Through hydraulic engineering, it also constructed many of the limestone wells and cisterns of the state that are still operative and in use today. The rulers developed new systems for agriculture and taxation, which continued to be used in parts of the Horn of Africa as late as the 19th century.[11]

Further advances in hydraulic engineering occurred in the Muslim world between the 8th to 16th centuries, during what is known as the Islamic Golden Age. Of particular importance was the 'water management technological complex' which was central to the Islamic Green Revolution and,[12] by extension, a precondition for the emergence of modern technology.[13] The various components of this 'toolkit' were developed in different parts of the Afro-Eurasian landmass, both within and beyond the Islamic world. However, it was in the medieval Islamic lands where the technological complex was assembled and standardized, and subsequently diffused to the rest of the Old World.[14] Under the rule of a single Islamic Caliphate, different regional hydraulic technologies were assembled into "an identifiable water management technological complex that was to have a global impact." The various components of this complex included canals, dams, the *qanat* system from Persia, regional water-lifting devices such as the *noria, shaduf* and screwpump from Egypt, and the windmill from Islamic Afghanistan.[14] Other original Islamic developments included the *saqiya* with a flywheel effect from Islamic Spain,[15] the reciprocating suction pump[16][17][18] and crankshaft-connecting rod mechanism from Iraq,[19][20] the geared and hydropowered water supply system from Syria,[21] and the water purification methods of Islamic chemists.[22]

## Modern times[edit]

In many respects, the fundamentals of hydraulic engineering have not changed since ancient times. Liquids are still moved for the most part by gravity through systems of canals and aqueducts, though the supply reservoirs may now be filled using pumps. The need for water has steadily increased from ancient times and the role of the hydraulic engineer is a critical one in supplying it. For example, without the efforts of people like William Mulholland the Los Angeles area would not have been able to grow as it has because it simply does not have enough local water to support its population. The same is true for many of our world's largest cities. In much the same way, the central valley of California could not have become such an important agricultural region without effective water management and distribution for irrigation. In a somewhat parallel way to what happened in California, the creation of the Tennessee Valley Authority (TVA) brought work and prosperity to the South by building dams to generate cheap electricity and control flooding in the region, making rivers navigable and generally modernizing life in the region.

Leonardo da Vinci (1452–1519) performed experiments, investigated and speculated on waves and jets, eddies and streamlining. Isaac Newton (1642–1727) by formulating the laws of motion and his law of viscosity, in addition to developing the calculus, paved the way for many great developments in fluid mechanics. Using Newton's laws of motion, numerous 18th-century mathematicians solved many frictionless (zero-viscosity) flow problems. However, most flows are dominated by viscous effects, so engineers of the 17th and 18th centuries found the inviscid flow solutions unsuitable, and by experimentation they developed empirical equations, thus establishing the science of hydraulics.[3]

Late in the 19th century, the importance of dimensionless numbers and their relationship to turbulence was recognized, and dimensional analysis was born. In 1904 Ludwig Prandtl published a key paper, proposing that the flow fields of low-viscosity fluids be divided into two zones, namely a thin, viscosity-dominated boundary layer near solid surfaces, and an effectively inviscid outer zone away from the boundaries. This concept explained many former paradoxes and enabled subsequent engineers to analyze far more complex flows. However, we still have no complete theory for the nature of turbulence, and so modern fluid mechanics continues to be combination of experimental results and theory.[23]

The modern hydraulic engineer uses the same kinds of computer-aided design (CAD) tools as many of the other engineering disciplines while also making use of technologies like computational fluid dynamics to perform the calculations to accurately predict flow characteristics, GPS mapping to assist in locating the best paths for installing a system and laser-based surveying tools to aid in the actual construction of a system.

What Is Aeronautical Engineering?

A degree in aeronautical engineering provides you with a broad understanding of aeronautics and a wide range of skills you may use to explore careers in the aviation industry.

What is aeronautical engineering? By studying aeronautical engineering, you will learn how to design, build, test, and analyze military or commercial aircraft and aircraft parts. With this knowledge, you can work toward pursuing a career as an aeronautical engineer where you create new technologies, improve aeronautical systems, research and develop different types of machines that fly, and more.
Continue reading to learn more about aeronautical engineering, meaning what to expect from an aeronautical engineering degree, what do aeronautical engineers do, and more.

What Is Aeronautical Engineering?

Aeronautical engineering is a branch of engineering addressing the design, production, and maintenance of aircraft. Unlike aerospace engineering, which involves working on rockets and other spacecrafts going beyond the earth’s atmosphere, aeronautical engineering only focuses on aircrafts and parts that stay within the earth’s orbit.

Aeronautical vs. Aerospace Engineering: What’s the Difference?

Many people think aeronautical engineering and aerospace engineering are the same, but there is a significant difference: Aerospace engineering is an umbrella term that covers aeronautical and astronautical engineering. It focuses on designing both aircraft and spacecraft, the machinery used within and outside of the earth’s atmosphere.

The aeronautical engineering definition is the study of aircraft operating within the earth’s atmosphere, whereas astronautical engineering deals with spacecrafts traveling beyond it. When designing aircraft and spacecraft, aeronautical and astronautical engineers must consider a variety of operational and environmental factors, as well as rely on the fundamental concepts of physics. Though aeronautical engineering and astronautical engineering can overlap in certain situations, the job role of an aeronautical engineer is very different.

What Does an Aeronautical Engineer Do?

A common question asked about potential engineering careers is “what do aeronautical engineers do?” The duties of an aeronautical engineer may vary, depending on the job role, but can include work such as:

- Analyzing project proposals to see if they are technically and financially feasible
- Evaluating proposed projects goals and safety
- Controlling and overseeing the development, production, and testing of aviation products
- Making sure designs adhere to engineering principles, customer requirements, and environmental regulations
- Creating acceptance criteria for design approaches, quality benchmarks, delivery sustainability, and completion dates
- Making projects adhere to quality standards
- Examining defective or damaged products to find the causes of issues and potential fixes

An aeronautical engineer works in industries that design or build aircraft parts, systems, and structures. Let’s take a closer look at some of the industries where aeronautical engineers are in high demand.

Who Employs Aeronautical Engineers?

Now that you know what is aeronautical engineering, it is also important to understand what kind of job opportunities this career pathway can offer. As aeronautical engineers are mostly employed in manufacturing, design, research and development, and government, there are a wide variety of potential roles.

**What Is Aeronautical Engineering? Definition and Career Tips**

Indeed Editorial Team
Updated 16 March 2023

Aeronautical engineering is a popular branch of engineering for those who are interested in the design and construction of flight machines and aircraft. However, there are several requirements in terms of skills, educational qualifications and certifications that you must meet in order to become an aeronautical engineer. Knowing more about those requirements may help you make an informed career decision. In this article, we define aeronautical engineering and discover what aeronautical engineers do, their career outlook, salary and skills.

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## What is aeronautical engineering?

Aeronautical engineering is the science of designing, manufacturing, testing and maintaining flight-capable machines. These machines can include satellites, jets, space shuttles, helicopters, military aircraft and missiles. Aeronautical engineers also are responsible for researching and developing new technologies that make flight machines and vehicles more efficient and function better.

## What do aeronautical engineers do?

Aeronautical engineers might have the following duties and responsibilities:

- Planning aircraft project goals, budgets, timelines and work specifications
- Assessing the technical and financial feasibility of project proposals
- Designing, manufacturing and testing different kinds of aircraft
- Developing aircraft defence technologies
- Drafting and finalising new designs for flight machine parts
- Testing and modifying existing aircraft and aircraft parts
- Conducting design evaluations to ensure compliance with environmental and safety guidelines
- Checking damaged or malfunctioning aircraft and finding possible solutions
- Researching new technologies to develop and implement in existing and upcoming aircraft
- Gathering, processing and analysing data to understand aircraft system failures
- Applying processed data in-flight simulations to develop better functioning aircraft
- Writing detailed manuals and protocols for aircraft
- Working on existing and new space exploration and research technologies
- Providing consultancy services for private and military manufacturers to develop and sell aircraft

## What is the salary of an aeronautical engineer?

The salary of an aeronautical engineer can vary, depending on their educational qualifications, work experience, specialised skills, employer and location. The national average salary for aeronautical engineers is ₹2,77,920 per year.

**Related: How Much Does An Aircraft Maintenance Engineer Make?**

**Is aeronautical engineering a good career?**

If you have a background in mathematics and a desire for discovering the science behind aircraft, then aeronautical engineering can be a good career for you. This profession can give you immense job satisfaction, knowing that you are helping people around the world fly safely. You may also get a chance to travel the world and test new, innovative tools and technologies. With increased focus on reducing noise and improving fuel efficiency of aeroplanes, there are plenty of job opportunities for skilled aeronautical engineers.

You can choose to specialise in the design, testing and maintenance of certain types of aircraft. For instance, some engineers may focus on commercial jets, helicopters or drones, while others may concentrate on military aircraft, rockets, space shuttles, satellites or missiles.

# Process engineering

**Process engineering** is the understanding and application of the fundamental principles and laws of nature that allow humans to transform raw material and energy into products that are useful to society, at an industrial level.[1] By taking advantage of the driving forces of nature such as pressure, temperature and concentration gradients, as well as the law of conservation of mass, process engineers can develop methods to synthesize and purify large quantities of desired chemical products.[1] Process engineering focuses on the design, operation, control, optimization and intensification of chemical, physical, and biological processes. Process engineering encompasses a vast range of industries, such as agriculture, automotive, biotechnical, chemical, food, material development, mining, nuclear, petrochemical, pharmaceutical, and software development. The application of systematic computer-based methods to process engineering is "process systems engineering".

## Overview

Process engineering involves the utilization of multiple tools and methods. Depending on the exact nature of the system, processes need to be simulated and modeled using mathematics and computer science. Processes where phase change and phase equilibria are relevant require analysis using the principles and laws of thermodynamics to quantify changes in energy and efficiency. In contrast, processes that focus on the flow of material and energy as they approach equilibria are best analyzed using the disciplines of fluid mechanics and transport phenomena. Disciplines within the field of mechanics need to be applied in the presence of fluids or porous and dispersed media. Materials engineering principles also need to be applied, when relevant.[1]

Manufacturing in the field of process engineering involves an implementation of process synthesis steps.[2] Regardless of the exact tools required, process engineering is then formatted through the use of a process flow diagram (PFD) where material flow paths, storage equipment (such as tanks and silos), transformations (such as distillation columns, receiver/head tanks, mixing, separations, pumping, etc.) and flowrates are specified, as well as a list of all pipes and conveyors and their contents, material properties such as density, viscosity, particle-size distribution, flowrates, pressures, temperatures, and materials of construction for the piping and unit operations.[1]

The process flow diagram is then used to develop a piping and instrumentation diagram (P&ID) which graphically displays the actual process occurring. P&ID are meant to be more complex and specific than a PFD.[3] They represent a less muddled approach to the design. The P&ID is then used as a basis of design for developing the "system operation guide" or "functional design specification" which outlines the operation of the process.[4] It guides the process through operation of machinery, safety in design, programming and effective communication between engineers.[5]

From the P&ID, a proposed layout (general arrangement) of the process can be shown from an overhead view (plot plan) and a side view (elevation), and other engineering disciplines are involved such as civil engineers for site work (earth moving), foundation design, concrete slab design work, structural steel to support the equipment, etc. All previous work is directed toward defining the scope of the project, then developing a cost estimate to get the design installed, and a schedule to communicate the timing needs for engineering, procurement, fabrication, installation, commissioning, startup, and ongoing production of the process.

Depending on needed accuracy of the cost estimate and schedule that is required, several iterations of designs are generally provided to customers or stakeholders who feed back their requirements. The process engineer incorporates these additional instructions (scope revisions) into the overall design and additional cost estimates, and schedules are developed for funding approval. Following funding approval, the project is executed via project management.[6]

## Principal areas of focus in process engineering

Process engineering activities can be divided into the following disciplines:

- Process design: synthesis of energy recovery networks, synthesis of distillation systems (azeotropic), synthesis of reactor networks, hierarchical decomposition flowsheets, superstructure optimization, design multiproduct batch plants, design of the production reactors for the production of plutonium, design of nuclear submarines.

- Process control: model predictive control, controllability measures, robust control, nonlinear control, statistical process control, process monitoring, thermodynamics-based control, denoted by three essential items, a collection of measurements, method of taking measurements, and a system of controlling the desired measurement.[8]
- Process operations: scheduling process networks, multiperiod planning and optimization, data reconciliation, real-time optimization, flexibility measures, fault diagnosis.
- Supporting tools: sequential modular simulation, equation-based process simulation, AI/expert systems, large-scale nonlinear programming (NLP), optimization of differential algebraic equations (DAEs), mixed-integer nonlinear programming (MINLP),[9] global optimization, optimization under uncertainty,[10][11] and quality function deployment (QFD).[12]
- Process Economics:[13] This includes using simulation software such as ASPEN, Super-Pro to find out the break even point, net present value, marginal sales, marginal cost, return on investment of the industrial plant after the analysis of the heat and mass transfer of the plant.[13]
- Process Data Analytics: Applying data analytics and machine learning methods for process manufacturing problems.[14][15]

# History of process engineering

Various chemical techniques have been used in industrial processes since time immemorial. However, it wasn't until the advent of thermodynamics and the law of conservation of mass in the 1780s that process engineering was properly developed and implemented as its own discipline. The set of knowledge that is now known as process engineering was then forged out of trial and error throughout the industrial revolution.[1]

The term *process*, as it relates to industry and production, dates back to the 18th century. During this time period, demands for various products began to drastically increase, and process engineers were required to optimize the process in which these products were created.[1]

By 1980, the concept of process engineering emerged from the fact that chemical engineering techniques and practices were being used in a variety of industries. By this time, process engineering had been defined as "the set of knowledge necessary to design, analyze, develop, construct, and operate, in an optimal way, the processes in which the material changes".[1] By the end of the 20th century, process engineering had expanded from chemical engineering-based technologies to other applications, including metallurgical engineering, agricultural engineering, and product engineering.

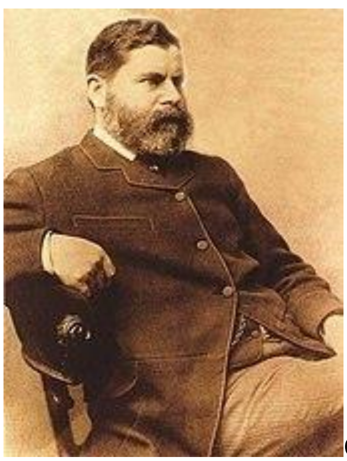
# *Chemical engineering*

Chemical engineers design,construct
and operate process plants (fractionating columns pictured).

**Chemical engineering** is an engineering field which deals with the study of operation and design of chemical plants as well as methods of improving production. Chemical engineers develop economical commercial processes to convert raw materials into useful products. Chemical engineering uses principles of chemistry, physics, mathematics, biology, and economics to efficiently use, produce, design, transport and transform energy and materials. The work of chemical engineers can range from the utilization of nanotechnology and nanomaterials in the laboratory to large-scale industrial processes that convert chemicals, raw materials, living cells, microorganisms, and energy into useful forms and products. Chemical engineers are involved in many aspects of plant design and operation, including safety and hazard assessments, process design and analysis, modeling, control engineering, chemical reaction engineering, nuclear engineering, biological engineering, construction specification, and operating instructions.

Chemical engineers typically hold a degree in Chemical Engineering or Process Engineering. Practicing engineers may have professional certification and be accredited members of a professional body. Such bodies include the Institution of Chemical Engineers (IChemE) or the American Institute of Chemical Engineers (AIChE). A degree in chemical engineering is directly linked with all of the other engineering disciplines, to various extents.

## Etymology[edit]

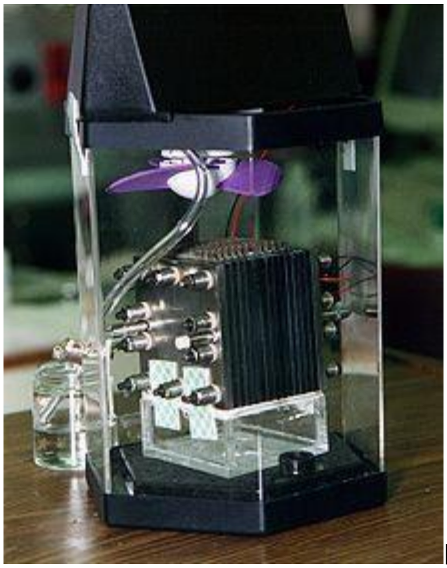

George E. Davis

A 1996 article cites James F. Donnelly for mentioning an 1839 reference to chemical engineering in relation to the production of sulfuric acid.[1] In the same paper, however, George E. Davis, an English consultant, was credited with having coined the term.[2] Davis also tried to found a Society of Chemical Engineering, but instead, it was named the Society of Chemical Industry (1881), with Davis as its first secretary.[3][4] The *History of Science in United States: An Encyclopedia* puts the use of the term around 1890.[5] "Chemical engineering", describing the use of mechanical equipment in the chemical industry, became common vocabulary in England after 1850.[6] By 1910, the profession, "chemical engineer," was already in common use in Britain and the United States.[7]

# History[edit]

*Main article: History of chemical engineering*

## New concepts and innovations[edit]


Demonstration model of a direct-methanol fuel cell. The actual fuel cell stack is the layered cube shape in the center of the image.

In the 1940s, it became clear that unit operations alone were insufficient in developing chemical reactors. While the predominance of unit operations in chemical engineering courses in Britain and the United States continued until the 1960s, transport phenomena started to receive greater focus.[8] Along with other novel concepts, such as process systems engineering (PSE), a "second paradigm" was defined.[9][10] Transport phenomena gave an analytical approach to chemical engineering[11] while PSE focused on its synthetic elements, such as those of a control system and process design.[12] Developments in chemical engineering before and after World War II were mainly incited by the petrochemical industry;[13] however, advances in other fields were made as well. Advancements in biochemical engineering in the 1940s, for example, found application in the pharmaceutical industry, and allowed for the mass production of various antibiotics, including penicillin and streptomycin.[14] Meanwhile, progress in polymer science in the 1950s paved way for the "age of plastics".[15]

## Safety and hazard developments[edit]

Concerns regarding large-scale chemical manufacturing facilities' safety and environmental impact were also raised during this period. *Silent Spring*, published in 1962, alerted its readers to the harmful effects of DDT, a potent insecticide.[16] The 1974 Flixborough disaster in the United Kingdom resulted in 28 deaths, as well as damage to a chemical plant and three nearby villages.[17] 1984 Bhopal disaster in India resulted in almost 4,000 deaths.[*citation needed*] These incidents, along with other incidents, affected the reputation of the trade as industrial safety and environmental protection were given more focus.[18] In response, the IChemE required safety to be part of every degree course that it accredited after 1982. By the 1970s, legislation and monitoring agencies were instituted in various countries, such as France, Germany, and the United States.[19] In time, the systematic application of safety principles to chemical and other process plants began to be considered a specific discipline, known as process safety.[20]

### Recent progress[edit]

Advancements in computer science found applications for designing and managing plants, simplifying calculations and drawings that previously had to be done manually. The completion of the Human Genome Project is also seen as a major development, not only advancing chemical engineering but genetic engineering and genomics as well.[21] Chemical engineering principles were used to produce DNA sequences in large quantities.[22]

## Concepts

Chemical engineering involves the application of several principles. Key concepts are presented below.

### Plant design and construction[edit]

Chemical engineering design concerns the creation of plans, specifications, and economic analyses for pilot plants, new plants, or plant modifications. Design engineers often work in a consulting role, designing plants to meet clients' needs. Design is limited by several factors, including funding, government regulations, and safety standards. These constraints dictate a plant's choice of process, materials, and equipment.[23]

Plant construction is coordinated by project engineers and project managers,[24] depending on the size of the investment. A chemical engineer may do the job of project engineer full-time or part of the time, which requires additional training and job skills or act as a consultant to the project group. In the USA the education of chemical engineering graduates from the Baccalaureate programs accredited by ABET do not usually stress project engineering education, which can be obtained by specialized training, as electives, or from graduate programs. Project engineering jobs are some of the largest employers for chemical engineers.[25]

## Process design and analysis[edit]

*Main article: Process design*

A unit operation is a physical step in an individual chemical engineering process. Unit operations (such as crystallization, filtration, drying and evaporation) are used to prepare reactants, purifying and separating its products, recycling unspent reactants, and controlling energy transfer in reactors.[26] On the other hand, a unit process is the chemical equivalent of a unit operation. Along with unit operations, unit processes constitute a process operation. Unit processes (such as nitration, hydrogenation, and oxidation involve the conversion of materials by biochemical, thermochemical and other means. Chemical engineers responsible for these are called process engineers.[27]

Process design requires the definition of equipment types and sizes as well as how they are connected and the materials of construction. Details are often printed on a Process Flow Diagram which is used to control the capacity and reliability of a new or existing chemical factory.

Education for chemical engineers in the first college degree 3 or 4 years of study stresses the principles and practices of process design. The same skills are used in existing chemical plants to evaluate the efficiency and make recommendations for improvements.

## Transport phenomena[edit]

*Main article: Transport phenomena*

Modeling and analysis of transport phenomena is essential for many industrial applications. Transport phenomena involve fluid dynamics, heat transfer and mass transfer, which are governed mainly by momentum transfer, energy transfer and transport of chemical species, respectively. Models often involve separate considerations for macroscopic, microscopic and molecular level phenomena. Modeling of transport phenomena, therefore, requires an understanding of applied mathematics.[28]

# Applications and practice[edit]

Chemical engineers use computers to control automated systems in plants.[29]

Chemical engineers "develop economic ways of using materials and energy".[30] Chemical engineers use chemistry and engineering to turn raw materials into usable products, such as medicine, petrochemicals, and plastics on a large-scale, industrial setting. They are also involved in waste management and research.[31][32] Both applied and research facets could make extensive use of computers.[29]

Chemical engineers may be involved in industry or university research where they are tasked with designing and performing experiments, by scaling up theoretical chemical reactions, to create better and safer methods for production, pollution control, and resource conservation. They may be involved in designing and constructing plants as a project engineer. Chemical engineers serving as project engineers use their knowledge in selecting optimal production methods and plant equipment to minimize costs and maximize safety and profitability. After plant construction, chemical engineering project managers may be involved in equipment upgrades, troubleshooting, and daily operations in either full-time or consulting roles. [33]