A. ***Balanced Chemical Equations***

- ***1) Know the name and formula of the following polyatomic ions: ammonium, chlorate, ethanoate, hydroxide, nitrate, nitrite, permanganate, hydrogen carbonate, hydrogen sulphate, carbonate, dichromate, sulphate, sulphite, phosphate***

Name	Symbol	Name	Symbol
Ammonium	NH_4^{1+}	Thiocyanate	CNS^{1-}
Hydroxide	OH^{1-}	Ethanoate	CH_3COO^{1-}
Nitrate	NO_3^{1-}	Carbonate	CO_3^{2-}
Nitrite	NO_2^{1-}	Sulphate	SO_4^{2-}
Cyanide	CN^{1-}	Sulphite	SO_3^{2-}
Hydrogen Carbonate	HCO_3^{1-}	Chromate	CrO_4^{2-}
Hydrogen Sulphate	HSO_4^{1-}	Dichromate	$Cr_2O_7^{2-}$
Chlorate	ClO_3^{1-}	Thiosulphate	$S_2O_3^{2-}$
Permanganate	MnO_4^{1-}	Phosphate	PO_4^{3-}
Iodate	IO_3^{1-}		

- ***2) Write chemical formulae using the periodic table and knowledge of polyatomic ions***

Core Questions 2

2.1) Write down the chemical formulae for the following chemical compounds

a) Sodium Chloride
b) Magnesium Oxide
c) Calcium Fluoride
d) Lithium Sulphide
e) Boron Bromide
f) Aluminium Oxide
g) Copper (II) Bromide
h) Iron (III) Oxide

2.2) Write down the chemical formulae for the following chemical compounds

a) Sodium Sulphate
b) Ammonium Chloride
c) Calcium Carbonate
d) Lithium Sulphite
e) Boron Chlorate
f) Aluminium Phosphate
g) Beryllium Hydrogen Carbonate
h) Potassium Dichromate
i) Copper (I) Ethanoate
j) Zinc (II) Nitrite
k) Mercury (II) Oxide
l) Chromium (III) Chromate
m) Lead (IV) Iodate
n) Lead (IV) Phosphate

2.3) Write down the scientific name for the following chemical compounds

a) H_2SO_4
b) $(NH_4)_2SO_4$
c) $Li_2Cr_2O_7$
d) K_2SO_3
e) $Al(IO_3)_3$
f) MgS_2O_3
g) $CuMnO_4$
h) $Ca(OH)_2$
i) $Pb(HSO_4)_2$
k) $PbCNS$
l) $Au_2(CO_3)_3$
m) $Zn(HSO_4)_2$
n) Ag_3PO_4
o) $FeCH_3COO$

Chemical Bonding and Energy

Lewis Structures

- **Lewis structures** are diagrams that show the bonding between atoms of a molecule and the lone pairs of electrons that may exist in the molecule.
- The chemical symbol stands for the nucleus and the inner electrons. The dots or crosses show the outermost electrons (known as **valence electrons**) arranged evenly around the nucleus. For example:

Lithium atom $1s^2\ 2s^1$  Li •

Chlorine atom $1s^2\ 2s^2 2p^6\ 3s^2 3p^5$  

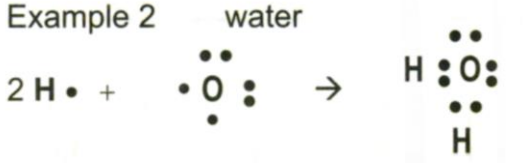
Group	1	2	3	4	5	6	7
Valence electrons	s^1	s^2	s^2p^1	s^2p^2	s^2p^3	s^2p^4	s^2p^5
Lewis structure	X •	• X •	X •	• X •	• X •	: X •	: X :

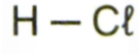
- When ionic bonds form, electrons are transferred between atoms and ions form. For example: lithium chloride:

- When covalent bonds form each atom donates one electron to the bond and a molecule forms. The atoms try to gain the structure of a noble gas by sharing one or more pairs of electrons.

Example 1 hydrogen chloride:

Example 2 water



- If an atom has a lone pair of electrons these cannot be used to make an ordinary covalent bond. Oxygen has two lone pairs.
- **The Structural Formula** of a chemical compound is a graphic representation of its molecular structure, showing how the atoms are arranged. Each line represents a pair of bonding electrons.
  For example 

Questions

Draw Lewis structures and Structural formulae for the following substances that adhere to the octet rule:

a) O_2, H_2, Cl_2, NH_3, N_2, PCl_3, CH_4, H_2O, H_2S, HCl, O_2, CO_2, CO, I_2, SiO_2, PO_4^{3-} , CO_3^{2-}, NH_4^{1+}, CCl_4 , NO_3^{1-}, Ne

Substance	Number of valence electrons	Lewis Structure	Structural Formula

Substance	Number of valence electrons	Lewis Structure	Structural Formula

Substance	Number of valence electrons	Lewis Structure	Structural Formula

The Mole Concept

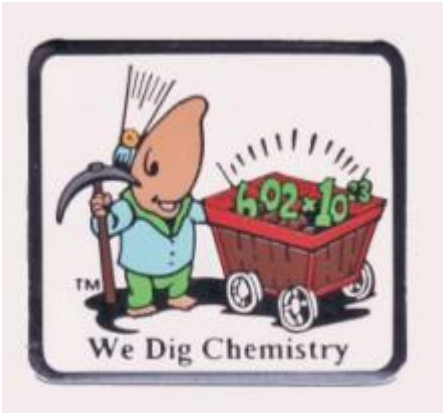
- ***6a) The mole as the SI unit for amount of substance***
  6b) State that one mole contains Avogadro's number of particles

$$\left(N_A = 6{,}02 \times 10^{23}\, mol^{-1}\right)$$

Formula: **#(Elementary Particles) = n (6.02 ×10^{23})**

Introduction

- **One mole** of a substance contains 6.02 x 10^{23} formula units.
- The term **formula unit** is a general term that relates to the type of particles that make up a substance. In general, it refers to the formula normally used for the substance:
- In diamond, one formula unit is a carbon **atom.**
- In oxygen gas, one formula unit is an oxygen **molecule.**
- In sodium chloride, one formula unit is one sodium **ion** and one chloride **ion**
- In silicon dioxide, one formula unit is one silicon **atom** and two oxygen **atoms** that can make up one silcon dioxide **molecule.**
- The number of 6.02 x 10^{23} is known as the **Avogadro Constant**.
- The mass of one mole of a substance is its **Relative Molecular Mass (M_r)**, and is measured in g.mol^{-1}.
- The idea of the **mole** links the **mass of a substance** to the **number of formula units** it contains.
- The calculations below involve calculating number of formula units, given number of moles, and vice versa.
- The link here is: 1 mole ↔ 6.02 × 10^{23} formula units



Core Questions 6a

6.1a) How many moles of SO_2 are contained in 7,5 g of sulphur dioxide, SO_2?

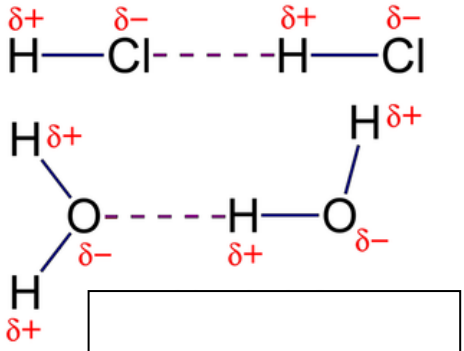
6.1b) How many SO_2 molecules are contained in 7,5 g of sulphur dioxide, SO_2?

6.1c) How sulphur atoms are contained in 7,5 g of sulphur dioxide, SO_2?

6.1d) How oxygen atoms are contained in 15 g of sulphur dioxide, SO_2?

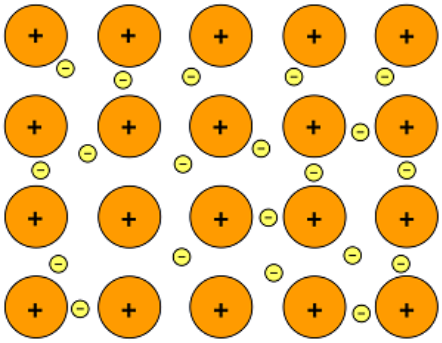
Summary of Intramolecular Forces and Electronegativity: Mindmap Supplement

Use the diagram below to differentiate between a Intramolecular Bond and Intermolecular Force.



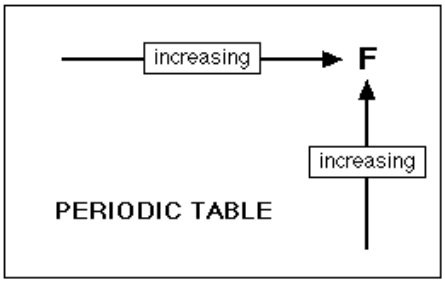
Key:

Explanation of Metallic Bonding



In metallic bonding, the valence electrons will move randomly from one atom to another.
Once the valence electrons detach from their original atomic owners and float around in the sea, the metal atoms become positive ions.
The result is an orderly structure of positive metal atoms surrounded by a sea of negative electrons that hold the ions together like glue.

Electronegativity



Electronegativity is a measure of the tendency of an atom to attract a bonding pair of electrons.
The Pauling scale is the most commonly used. Fluorine (the most electronegative element) is assigned a value of 4.0, and values range down to caesium and francium which are the least electronegative at 0.7.

Use the diagram above to derive two conclusions electronegativity trends.
Use specific answers form the Periodic Table to substantiate your answers.

Covalent Bonding

Nature of Covalent Bond

- **Covalent Bonding** is a form of chemical bonding where pairs of electrons are shared between atoms.

- Covalent bonding occurs between the atoms of **non-metals**.

- The outermost orbitals of the atoms overlap so that unpaired electrons in each of the bonding atoms can be shared.

- By overlapping orbitals, the outer energy shells of all the bonding atoms are filled. The shared electrons move in the orbitals around *both* atoms.

- As they move, there is an attraction between these negatively charged electrons and the positively charged nuclei.

- This attractive force holds the atoms together in a covalent bond.

Properties of Covalent Compounds

- Covalent compounds have several properties that distinguish them from ionic compounds and metals. These properties are:

- The melting and boiling points of covalent compounds are generally lower than those of ionic compounds.

- Covalent compounds are generally more flexible than ionic compounds. The molecules in covalent compounds are able to move around to some extent and can sometimes slide over each other (as is the case with graphite, which is why the lead in your pencil feels slightly slippery). In ionic compounds, all the ions are tightly held in place.

- Covalent compounds generally are not very soluble in water, for example plastics are covalent compounds and many plastics are water resistant.

- Covalent compounds generally do not conduct electricity when dissolved in water, for example iodine dissolved in pure water does not conduct electricity.

- You should also have noticed from your knowledge of Lewis Structures that compounds can have a mixture of single, double and triple bonds and that an atom can have several bonds.

Important terms associated with Covalent Compounds

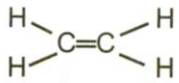
- We can say the following:

  A **single covalent** bond is formed when two electrons are shared between the same two atoms, one electron from each atom.

  A **double covalent** bond is formed when four electrons are shared between the same two atoms, two electrons from each atom.

  A **triple covalent** bond is formed when six electrons are shared between the same two atoms, three electrons from each atom.

  Examples: oxygen O=O nitrogen N ≡ N carbon dioxide O=C=O

  hydrogen cyanide H—C ≡ N ethene  ethyne H—C≡C—H

  Lewis structures can be drawn to determine whether single, double or triple bonds exist between atoms in a compound, e.g: Draw the Lewis structure for molecular nitrogen:

- We can say that the **valency** of the atoms is different, which refers to the binding capacity of each element. It is the number of unpaired electrons in the outer shell of an atom which are able to be used to form bonds with other atoms.

- A polar covalent molecule can undergo ionization when dissolved in water, e.g: Hydrochloric acid is produced for this preparation by the **ionisation** of hydrogen chloride gas in water.

- **Ionisation** is when a molecule/molecular substance dissolves in water to produce ions.

- **Electronegativity** is a measure of the tendency of an atom to attract a bonding pair of electrons

- A **dipole** can be described as a molecular structure with the following characteristics:

a) two distinct regions of relative electrostatic charge.

b) an asymmetrical charge distribution

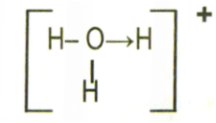
c) partial positive and partially negative ends

- A **Dative Covalent Bond** is formed by the overlapping of a filled orbital containing a lone pair with the empty orbital of another atom or ion. Once it has formed this bond is no different from the covalent bonds which have already been discussed.
We represent a dative covalent bond by the symbol (→)

Example 1

$H_2O + [H]^+$

Hydronium ion



Example 2

$NH_3 + [H]^+$

Ammonium ion

- **Polar Molecules** (or dipoles) have one end slightly positive (δ+) and the other slightly negative (δ-). To form a dipole the molecule must have polar covalent bonds and it must be asymmetrical, e.g: HCl ; H_2O; NH_3

Diagram shows a molecule of HCl. The chlorine atom carries a δ- charge and the hydrogen atom carries a δ+ charge.

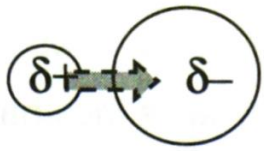
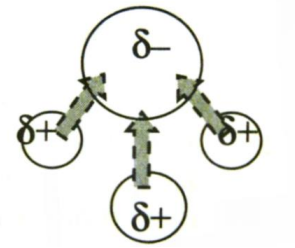


Diagram shows a molecule of NH_3 in which the nitrogen atom carries a δ- charge and the hydrogen atoms carry a δ+ charge.

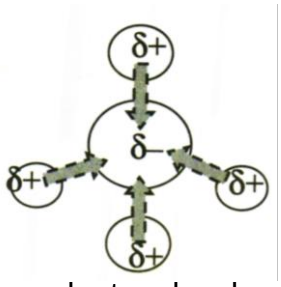


- **Non-Polar Molecules** do not have charged ends.

  Either the bond is pure covalent e.g. diatomic molecules and nobles gases OR

  the molecule has polar covalent bonds but the ends are not charged because of its symmetry e.g. CH_4 ; CO_2; CCl_4

  Diagram shows a molecule of CH_4



- **Permanent dipoles** are found in polar covalent molecules
- **Temporary/Instantaneous dipoles** are found in non-polar covalent molecules
- **Permanent/Temporary Dipoles** can result in an adjacent non-polar molecule to becoming dipole resulting in an **Induced Dipole**, shown as follows:

Questions

1) Diffrentiate between a Lewis structure and Couper structure.

2) What is the ‘octet rule’ and explain how each molecule in (1a) and (1e) adheres to this rule.

3) Explain the difference and link between the *valence electrons* and the *valency* of an element.

4) Differentiate between electronegativity and ionization.

5) Complete the table below:

Element	Group number	No. of valence electrons	Number of electrons needed to fill outer shell and valency
He			
Li			
B			
C			
F			
Ne			
Na			
Al			
P			
S			
Ca			
Kr			

Ionic Bonding

Nature of Ionic Bond

- An **Ionic Bond** is a type of chemical bond where one or more electrons are transferred from one atom to another.
- When electrons are *transferred* from one atom to another it is called **ionic bonding**.
- Electronegativity is a property of an atom, describing how strongly it attracts or holds onto electrons. Ionic bonding takes place when the difference in electronegativity between the two atoms is more than 1,7.
- This usually happens when a metal atom bonds with a non-metal atom. When the difference in electronegativity is large, one atom will attract the shared electron pair much more strongly than the other, causing electrons to be transferred to the atom with higher electronegativity.
- When ionic bonds form, a metal donates one or more electrons, due to having a low electronegativity, to form a positive ion or **cation**.
- The non-metal atom has a high electronegativity, and therefore readily gains electrons to form a negative ion or **anion.** The two ions are then attracted to each other by electrostatic forces**.**
- **Dissociation** occurs when ionic substances dissolve in water to produce ions

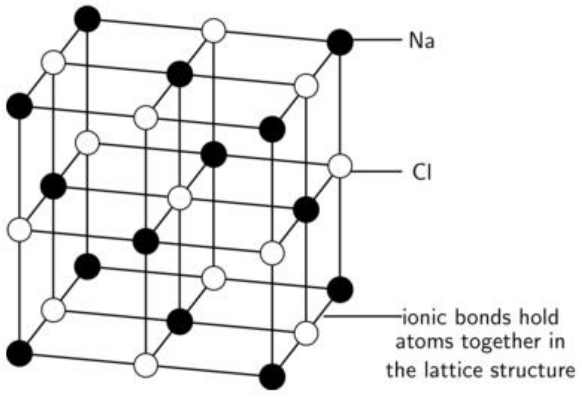
Example

- In the case of NaCl , the difference in electronegativity between Na (0,93) and Cl (3,16) is 2,1. Sodium has only one valence electron, while chlorine has seven.
- Because the electronegativity of chlorine is higher than the electronegativity of sodium, chlorine will attract the valence electron of the sodium atom very strongly.
- This electron from sodium is transferred to chlorine.
- Sodium loses an electron and forms an Na^+ ion. Chlorine gains an electron and forms a Cl^- ion.

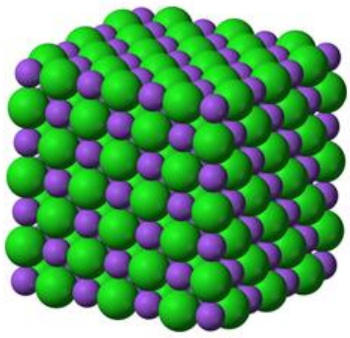
Draw a Lewis Dot Diagram and balanced chemical equation to show the formation of NaCl. Use these representations to explain in words how NaCl is formed

Crystal Lattice

- Ionic substances are actually a combination of lots of ions bonded together into a giant molecule.
- The arrangement of ions in a regular, geometric structure is called a **crystal lattice**.
- So in fact NaCl does not contain one Na and one Cl ion, but rather a lot of these two ions arranged in a crystal lattice where the ratio of Na to Cl ions is 1:1.
- The structure of the crystal lattice is shown below.



The crystal lattice arrangement in $NaCl$



A space filling model of the sodium chloride lattice

Properties of Ionic Compounds

- Ions are arranged in a lattice structure
- Ionic solids are crystalline at room temperature
- The ionic bond is a strong electrostatic attraction. This means that ionic compounds are often hard and have high melting and boiling points
- Ionic compounds are brittle and bonds are broken along planes when the compound is put under pressure (stressed)
- Solid crystals do not conduct electricity, but ionic solutions do
- Ionic substances such as Calcium chloride is **soluble in water.** The structure of its crystal lattice is broken down by the water molecules to form aqueous ions in solution.
  The solubility of ionic substances will be explained in more detail in Intermolecular Forces.

Questions

1) Magnesium and chlorine react to form magnesium chloride.
   a) What is the difference in electronegativity between these two elements?

   b) Give the chemical formula for:

      i) a magnesium ion

      ii) a chloride ion

      iii) the ionic compound that is produced during this reaction

   c) Write a balanced chemical equation for the reaction that takes place.

   d) Draw the Lewis structure for magnesium chloride.

3) Draw Lewis diagrams to represent the following ionic compounds:

   a) sodium iodide

   b) calcium bromide

Metallic Bonding

- **Metallic Bonding** is the electrostatic attraction between the positively charged atomic nuclei of metal atom and negatively charged delocalised electrons in the metal.

- The structure of a metallic bond is quite different from covalent and ionic bonds.

- In a metallic bond, the valence electrons are *delocalised*, meaning that an atom's electrons do not stay around that one nucleus.

- In a metallic bond, the positive atomic nuclei (sometimes called the “atomic kernels”) are surrounded by a sea of delocalised electrons which are attracted to the nuclei

Properties of Metals

- Metals are *shiny*.

- Metals *conduct electricity* because electrons are free to move.

- Metals *conduct heat* because the positive nuclei are packed closely together and can easily transfer the heat.

- Metals have a *high melting point* because the bonds are strong and a *high density* because of the tight packing of the nuclei.

Questions Intramolecular Bonding

1) Define the term Intramolecular Bond.
2) Identify three types of intramolecular bonds.
3) Identify 3 unique characteristics for each type of intramolecular bond.
4) What type of intramolecular bond exists in NH_3? Use a Lewis structure and the concept of electronegativity to substantiate your answer.
5) What type of intramolecular bond exists in N_2? Use a Lewis structure and the concept of electronegativity to substantiate your answer.
6) What type of intramolecular bond exists in MgO? Use a Lewis structure and the concept of electronegativity to substantiate your answer.
7) What type of intramolecular bond exists in CH_4? Use a Lewis structure and the concept of electronegativity to substantiate your answer.
8) Why is CO_2 considered to be a non-polar covalent molecule, even though it has polar covalent bonds?

8.3 Crests and troughs (ESACM)

Waves have moving *crests* (or *peaks*) and *troughs*. A crest is the highest point the medium rises to and a trough is the lowest point the medium sinks to.

Crests and troughs on a transverse wave are shown in Figure 8.2.

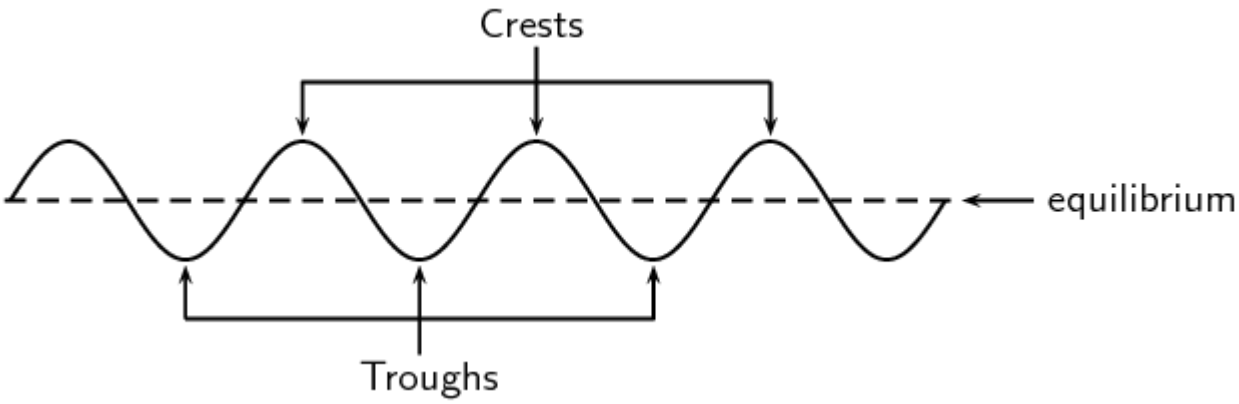


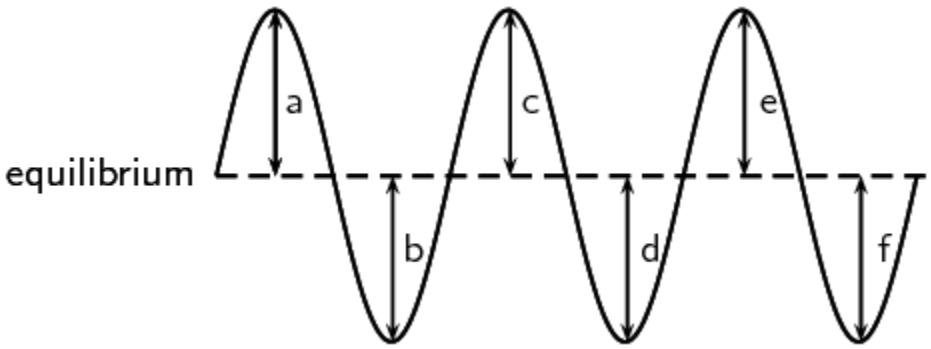
Figure 8.2: Crests and troughs in a transverse wave.

Crests and troughs

A *crest* is a point on the wave where the displacement of the medium is at a maximum. A point on the wave is a *trough* if the displacement of the medium at that point is at a minimum.

8.4 Amplitude (ESACN)

Amplitude



Fill in the table below by measuring the distance between the equilibrium and each crest and trough in the wave above. Use your ruler to measure the distances.

Crest/Trough	Measurement (cm)
A	
B	
C	
D	
E	
F	

1.

What can you say about your results?

2.

Are the distances between the equilibrium position and each crest equal?

3.

Are the distances between the equilibrium position and each trough equal?

4.

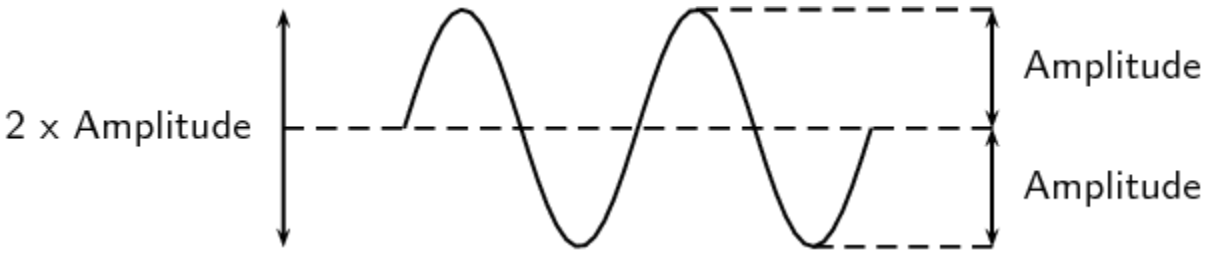
Is the distance between the equilibrium position and crest equal to the distance between equilibrium and trough?

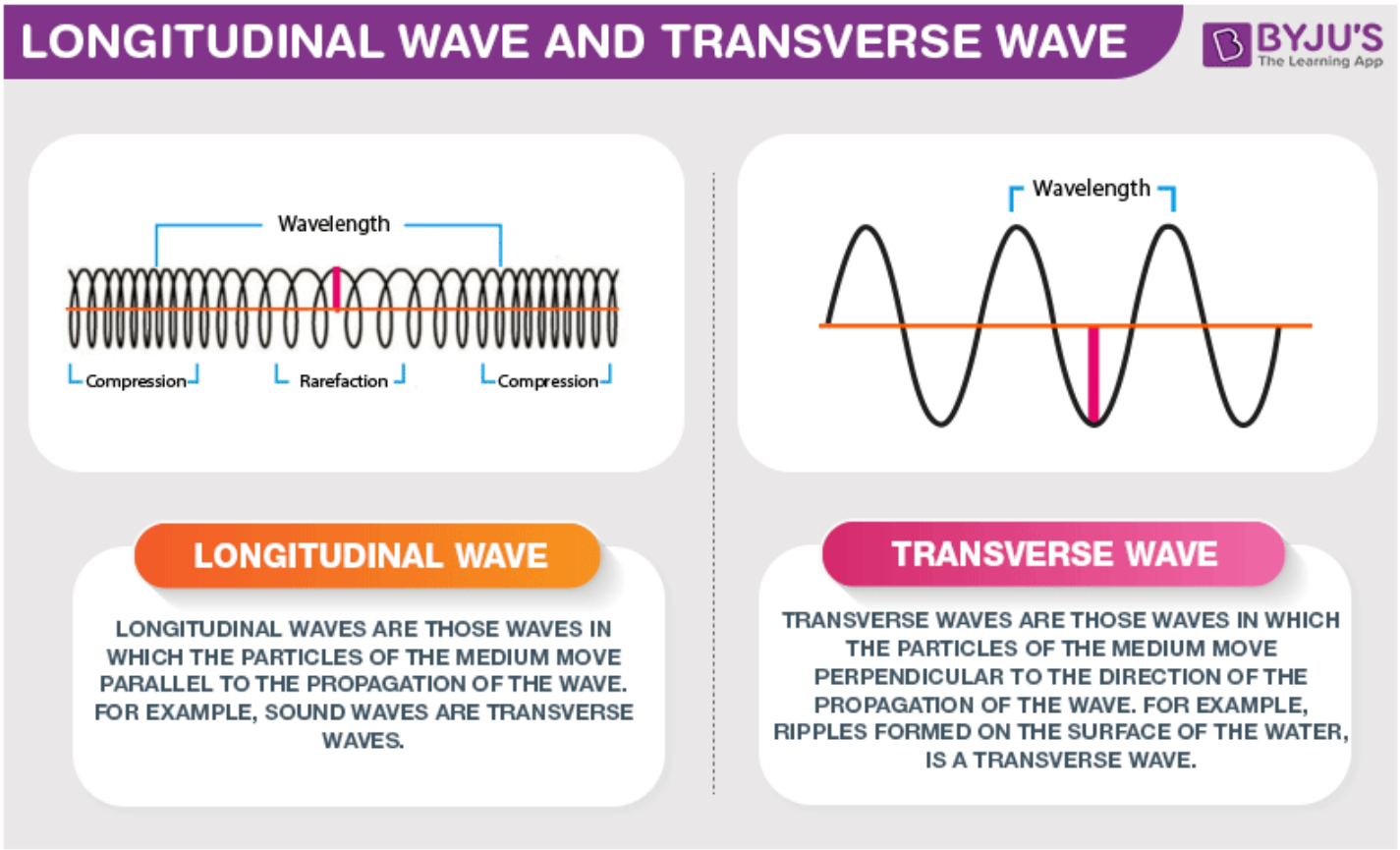
As we have seen in the activity on amplitude, the distance between the crest and the equilibrium position is equal to the distance between the trough and the equilibrium position. This distance is known as the *amplitude* of the wave, and is the characteristic height of the wave, above or below the equilibrium position. Normally the symbol A is used to represent the amplitude of a wave. The SI unit of amplitude is the metre (m).

Amplitude

The amplitude of a wave is the maximum disturbance or displacement of the medium from the equilibrium (rest) position.

Quantity: Amplitude (A) Unit name: metre Unit symbol: m





Difference Between Longitudinal and Transverse Wave

There are various types of waves and the two of those would be longitudinal and transverse waves. In a longitudinal wave, the medium or the channel moves in the same direction with respect to the wave. Here, the movement of the particles is from left to right and force other particles to vibrate.

Whereas, a transverse wave will have the medium or the channel moving perpendicular to the direction of the wave. Here, the particles move up and down as the waves move horizontally.

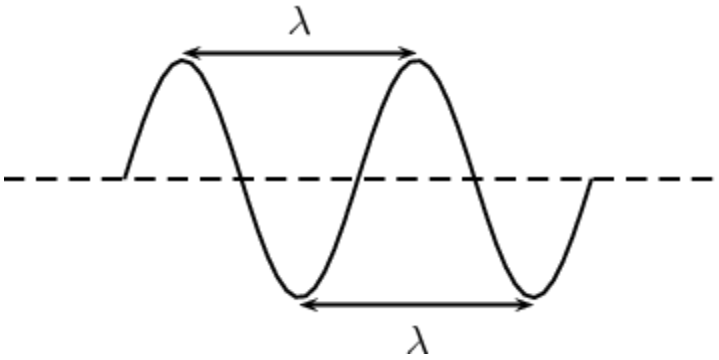
Difference Between Longitudinal and Transverse Wave	
Longitudinal	Transverse
The medium moves in the same direction of the wave	The medium is moving perpendicular to the direction of wave
It acts in one dimension	It acts in two dimension
The wave cannot be polarized or aligned	The wave can be polarized or aligned
This wave can be produced in any medium such as gas, liquid or solid	This wave can be produced in solid and liquid's surface
The earthquake P wave is an example	Earthquake S wave is an example
It is made of rarefactions and compressions	It is made of troughs and crests

Define the following terms relating to waves

1) Define the term wave. (2)

2) Define the term wavelength and provide the SI unit of measurement. (2)

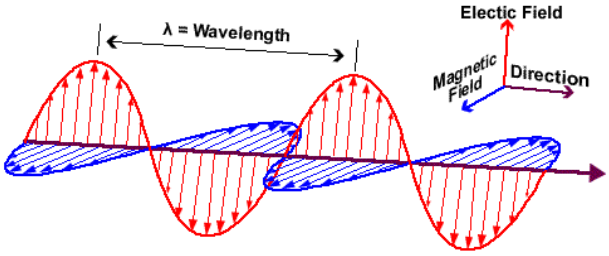
The symbol for the wavelength is λ (the Greek letter lambda). On the diagram below, indicate the wavelength for another part on the diagram.

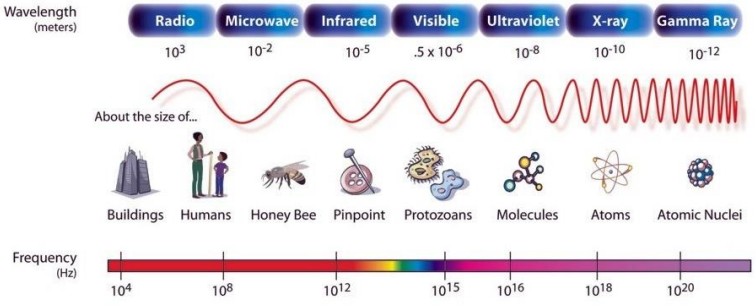


3) Define the term frequency of a wave and provide the SI unit of measurement. (2)

4) Differentiate between frequency and period. Use a suitable formula to substantiate your answer. (3)

5) Define the terms electromagnetic wave and electromagnetic spectrum. (4)





6) What is the period of a 300 Hz wave? (2)

7) The mathematical expression to show the link between frequency and wavelength for the electromagnetic spectrum is $c=f\lambda$ *or* $f=c/\lambda$ (3)