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1650210
Automotive Materials and Sustainability

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Section A)

a)

With both of the following technologies dramatically improving current tailpipe emission levels as they either meet or very nearly meet the set goal of 0 tail pipe emissions.

Electric vehicles.

Electricity in the form of Battery electric vehicles and fuel cells as EV's are dependant on the energy production sources their carbon footprint can further decrease depending on the availability of renewable energies.

Hydrogen vehicles .

A disadvantage of hydrogen vehicle is the success of the electric vehicle but that could change in the near future as precious metals becoming scarcer for the batteries from which BEV's are so dependant

As hydrogen production and storage technology develops more projects like that of the teeside blue hydrogen project, which is hydrogen produced from natural gas, the likelihood of affordable hydrogen is much more plausible for consumers.

Section B
Question 2
a)
Ionic Bonding occurs when there is a transfer and acceptance of electrons from the outermost/valence shell. An ionic bond is a type of chemical bond that has formed as a result of the complete transfer of valence electrons from one molecule to another. Metals will transfer their valence electrons to non-metals forming a positively-charged ions. The atoms that accept the electrons then become negatively-charged. The two opposite charges will be attracted towards themselves and there form an ionic bond.
Compounds formed by ionic bonds are known as ionic compounds. Different types of salts are ionic compounds. Examples of Ionic Bonds:
Sodium chloride - NaCl - table salt, Sodium fluoride - NaF – fluoride in toothpaste, Iron Oxide – Fe_2O_3 - rust

Covalent Bonding involves equal sharing of electrons in the valence shell from both participating electrons. This ensures stability in the outer shell of the atoms. Covalent bonds result in the formation of massive structures or molecules. An example of a covalent bond is H2O/water (Hydrogen and oxygen bonding together).

Metallic Bonding Its the force that holds together closely packed atoms within a metallic substance. It entails attraction between the delocalised electrons present in the lattice of metals. It is a form of chemical bonding that arises from electrostatic attractive force between conduction electrons and positively charged ions. The metallic bond occurs in the solid state of matter.
Examples of Metallic bonding include Aluminium (Al), Iron (FE), Copper (CU), Magnesium (Mg).
Characteristics of metallic bonding include being ductile and malleable and also good conductor traits as metals can conduct heat and electricity through them. Metals are also good conductors of electricity as free electrons are present which carries current. Metals required high temperatures to cleave bonds between them, hence having high melting points and boiling points. When one end of the metal is heated, mobile electrons absorb heat energy and move rapidly towards another end hence metal shows thermal conductivity.

The Valency of an atom refers to its ability to combine with other atoms
The outermost shell of an atom is called the valancy shell because it swaps/interchanges other valance electrons with other atoms thereby forming chemical compounds and or molecules.

Section B
Question 2

b) Calculate the atomic Radius of copper

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Q2
b) 4 atoms per unit cell

$a = 0.362nm$

Body centered cubic $a = \frac{4R}{\sqrt{3}}$ = Net of atoms in unit cell

Face centered cubic $a = 2\sqrt{2}R$

$\therefore 0.362 = 2\sqrt{2}R$

$R = \frac{0.362}{2\sqrt{2}} = 0.128m$

Section B
Question 2
c)
There are two types of point defects;
Vacancies = missing atoms when the lattice forms leaves vacancies in the structure which leads to the distortion of other surrounding atoms.
Self interstitials = These occour when the atoms become positioned between the normal lattice structure of the atoms.

Line defects
When distortion in the lattice occour hence defect in the structure These distortions allow layers of the lattice to move from their adjacent layers. And its this slip movement that produces a permanent plastic deformation of the structure.

Area defects
Grain boundaries create area defects in a crystalline structures since the grain boundaries are the boundaries between the crystals in a material the bonding structure changes.

Section B
Question 2
d) identify and explain creep failure

Creep
Plastic deformation of a material due to prolonged or increased exposure to stress and or heat. Design considerations with reference to allowable stresses approximates 1% for the deformation/ creep expansion. Secondary creep rate marks plastic flow in which strain hardening/softening are in what is almost an equilibrium.
Additional alloying elements are added to prevent creep from occurring such as cobalt, chromium and nickel.

Question 4

a)

I. In Aluminium 7000 the main alloying element is zinc. This enables the material to be heat-treated, to achieve increased strength properties. Limitations occur due to the brittleness of the material because of this it often requires other alloying elements to compensate for its brittleness to avoid failure. This type of steel is found in the aviation industry due to its light weight and strength properties.

II. The numbers represent a global grading system that ensures materials standards are met to avoid failure. 1045 steel (mild steel) Second digit = percentage of alloying elements. The last two numbers represent the amount of carbon percentage in the steel.

b) 3 composite classifications.

Particle-reinforced

Smaller particles form bonds on atomic or molecular levels to surrounding matrix and restricts plastic deformation. Within this classification the particulates are harder and stiffer than the matrix materials. Particles are of macro, micro, or nano-scopic scale. Improvement of mechanical behaviour depends on the interface bonding.

Split into 2 groups Large particle and dispersion strengthened. Distinction between the two is based on the reinforcement/strengthening mechanism. 'Large particle' refers to the interaction with the matrix material not being on the atomic level. Dispersion strengthened consists of smaller particles of reinforcing material with a particle size between 0.01 – 0.1 microns.

Fibre reinforced (FRC)

Most technological important composites; these include Fibre glass and carbon fibre.

FRC is high-performance fibre composite achieved and made possible by cross-linking cellulosic fibre molecules with resins in the FRC material matrix through molecular re-engineering process, resulting in exceptional structural properties.

Design objectives for these composites are; High strength and or stiffness on a weight basis , Characteristics are expressed in terms of specific strength and Specific modulus. Produced versions of high specific strengths and moduli that use low density fibre and matrix materials. Fibre length in this classification is critical to achieving required strength as short fibres don't produce a significant improvement in strength. The Length of the Fibre determines how much Load the matrix can transfer to the stronger fibres. Critical fibre length is necessary for the effective strengthening and stiffening of the composite material. The fibres are the discontinuous or dispersed phase. The matrix as the continuous phase.

Structural composites

Structural composites are made up of both composite and homogenous materials. Upon being combined, these create material with properties from both. The composite properties are not only dependant on the material properties of the component materials, but the geometric construction of the composite as well.

Examples of structural composites include.. Multi – ply carbon fibre and Aluminium honeycomb.

Question 4

C)

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$E_f = 65 \times 10^5 \, Pa$

$E_m = 3.2 \times 10^5 \, Pa$

$A = 300 \times 10^{-6} \, m^2$

$\sigma = 30 \times 10^6 \, N$

$E_c = E_f \times V_f + E_m \times V_m$

$E_c = (65 \times 10^5 \times 0.45) + (3.2 \times 10^5 \times 0.55)$

$E_c = 31.019 \, Pa$

$$\frac{F_f}{F_m} = \frac{E_f V_f}{E_m V_m} = \frac{65 \times 10^9 \times 0.45}{3.2 \times 10^9 \times 0.55} = 16.619$$

$\Rightarrow F_f = 16.619 \times F_m$

$F_c = \sigma A_c = 30 \times 10^6 \times 300 \times 10^{-6} = 9000 N$

$F_c = F_f + F_m$

$9000 = 16.619 \times F_m + F_m$

$$F_m = \frac{9000}{17.619} = 510.812 \, N$$

$F_f = 16.619 \times F_m = 16.619 \times 510.812 = 8489.185 N$