Benha University **Faculty of Engineering – Shoubra** **Preparatory Year for Master of Science in Engineering Physics**		**Final Term Exam** **General Engeineering Physics** **Date: 26 / 5 / 2015** **Duration : 3 hours**

- Answer all the following question
- Illustrate your answers with sketches when necessary
- No. of questions: 4 in two pages
- Total Mark: 200 Marks

Question (1) (50 marks)

(A) Differentiate clearly between: **(15 marks)**

(i) Mechanical and electromagnetic waves.

Answer:

Mechanical waves like sound waves and water waves are that they are governed by Newton's second law and required a material medium such as air or water to propagate.

While in electromagnetic waves like light It consists of an electric field component and a magnetic feield component which are perpendicular to each others. It propagates with constant speed in a direction perpendicular to both the electric and magnetic field components. It can propagate even in the absence of any medium.

(ii) Longitudinal and transverse waves.

Answer:

In longitudinal waves, the particles of the medium move forward and back in the same direction of propagation.

(Sound is longitudinal waves)

While, in transverse waves, the particles of the medium move up and down perpendicular to the direction of propagation.

(Light is transverse waves)

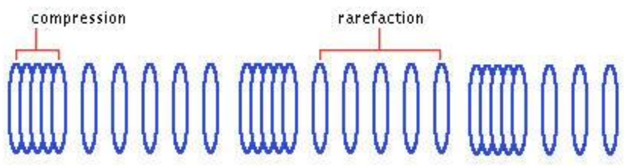


Figure 1: Longitudinal Wave

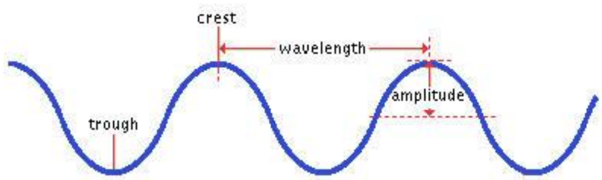


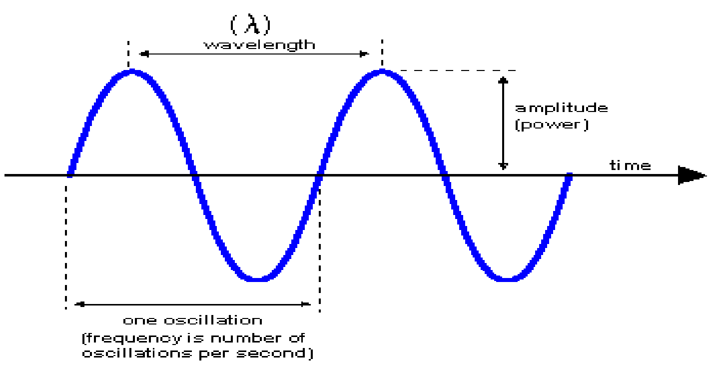
Figure 2: Transverse Wave

(iii) Angular frequency and wave number.

Answer:

Angular frequency $\omega = 2\pi f$

With, f is the frequency of the wave which is the number of complete cycles per one second.



While wave number $K = 2\pi/\lambda$

With, λ is the wavelength of the wave which is the distance between any two consecutive points on the wave.

The wavelength can also be measured between two successive wave crests or between successive troughs.

(B) Consider two sinusoidal waves have the same frequency, wavelength and amplitude and are traveling in the same direction in a linear medium. Use the principle of superposition to find the resultant wave function then give the conditions of constructive and destructive interference? **(20 marks)**

Answer: See the text book pages 140-141

(C) A transverse wave is propagating on a string and is described by the following equation:

$Y = 5 \text{ Sin } [2x + 30t]$. Where, x and t are measured in cm and seconds respectively. Find:

(i) The amplitude of the wave, **(ii)** Its wavelength,

(iii) Its frequency, **(iv)** The time period. **(15 marks)**

Answer:

(i) The amplitude of the wave = 5 cm

(ii) Its wavelength,

$2 = 2\pi/\lambda$

$\lambda = \pi$

(iii) Its frequency,

$30 = 2\pi f$

$f = 15/\pi$

(iv) The time period , $T = 1/f$

$T = \pi/15$

Question (2) (50 marks)

(A) The Doppler Effect had proved that the frequency of a vehicle's sound you hear as the vehicle approaches you is different than the frequency you hear as it moves away from you. Discuss this behavior? **(20 marks)**

Answer: See the text book pages 181-182

(B) Discuss the principle of standing waves and give the conditions of the resonant frequencies for the first, second and third harmonics? **(15 marks)**

Answer: See the text book pages 147-148

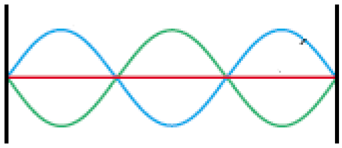
(C) A nylon guitar string has a linear density of 7.2 g/m and is under a tension of 150 N. the fixed supports are 90 cm apart. If the string is oscillating in a standing wave where n = 3, Calculate:

(i) The speed of the wave on the string, **(ii)** The wavelength for a standing wave,

(iii) The corresponding frequency. **(15 marks)**

Answer:

$$L = 0.9\,m, \tau = 150\,N,$$
$$\mu = 7.2\times10^{-3}\,kgm^{-1}.$$



$$a)\quad \upsilon = \sqrt{\frac{\tau}{\mu}} = \sqrt{\frac{150\,N}{7.2\times10^{-3}\,kgm^{-1}}} = 144.3\,ms^{-1}$$

$$b)\quad n = 3$$

$$\lambda = \frac{2l}{3} = \frac{2\times0.9\,m}{3} = 0.6\,m$$

$$c)\quad f = \frac{\upsilon}{\lambda} = \frac{144.3\,ms^{-1}}{0.6\,m} = 240.5\,Hz$$

Question (3) (50 marks)

(A) Define the following: **(15 marks)**

(i) Lattice structure of solids.

Answer:

A regular, periodically repeated, three-dimensional array of the atoms or molecules comprising the solid

(ii) Types of stress.

Answer:

Common types of stress are compression, tension, shear, torsion, impact. There is a chance for occurrence of one, two, or a combination of these stresses, such as fatigue

Compression stresses develop within a material when forces compress or crush the material. A column that supports an overhead beam is in compression, and the internal stresses that develop within the column are compression.

Tension (or tensile) stresses develop when a material is subject to a pulling load; for example, when using a wire rope to lift a load or when using it as a guy to anchor an antenna. "Tensile strength" is defined as resistance to longitudinal stress or pull and can be measured in pounds per square inch of cross section.

Shearing stresses occur within a material when external forces are applied along parallel lines in opposite directions. Shearing forces can separate material by sliding part of it in one direction and the rest in the opposite direction.

(iii) Elasticity.

__Answer__:

When a material has a load applied to it, the load causes the material to deform. Elasticity is the ability of a material to return to its original shape after the load is removed. Theoretically, the elastic limit of a material is the limit to which a material can be loaded and still recover its original shape after the load is removed.

(iv) Plasticity.

__Answer__:

Plasticity is the ability of a material to deform permanently without breaking or rupturing. This property is the opposite of strength. By careful alloying of metals, the combination of plasticity and strength is used to manufacture large structural members. For example, should a member of a bridge structure become overloaded, plasticity allows the overloaded member to flow allowing the distribution of the load to other parts of the bridge structure.

(v) Shear modulus.

__Answer__:

The constant of proportionality in Hooke's law for shear. It is equal to the ratio of the shearing stress to the shearing strain

(B) Define the concept of metal and non-metal materials then discuss briefly the main possible processes for bonding of these two types? **(20 marks)**

Answer:

If an atom has only a few electrons in its outer shell, it will tend to lose them to make this shell "empty". These elements are metals.

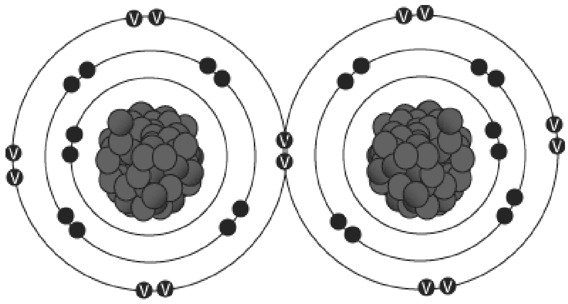
If an atom has a nearly full electron outer shell, it will try to find electrons from another atom so that it can fill its outer shell. These elements are described as nonmetals.

When metal atoms bind, the bond is called metallic

When nonmetal atoms bind, the bond is called covalent bond.

When metal and nonmetal atoms bind, the bond is called ionic bond.

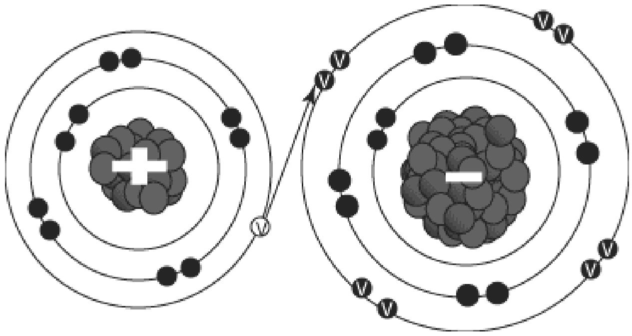
1. Covalent Bond



In *solid materials with covalent bonds*, the binding energies are of ~ 10 eV per molecule and hence covalent bonds are very strong. Generally, solid materials with covalent bonds:

- Are very hard because bond is strong and particles cannot easily slide past one another.
- Are good insulators because there are no free electrons or ions.
- Are transparent because their electrons are not moving from atom to atom and less likely to interact with light photons.
- Are brittle and tend to cleave rather than deform because bonds are strong.

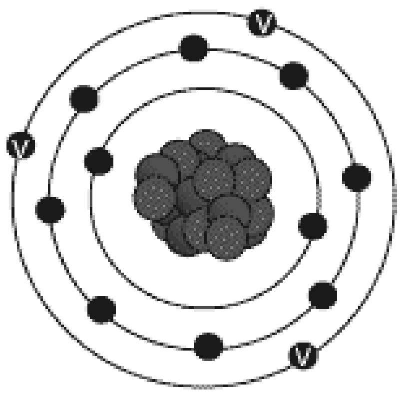
1. Ionic Bond



In *solid materials with ionic bonds*, the binding energies are of ~ (5 – 10) eV per molecule and hence ionic bonds are relatively strong. Solids with ionic bonds:

- Are hard because bond is strong and particles cannot easily slide past one another.
- Are good insulators because there are no free electrons or ions (unless dissolved or melted).
- Are brittle and tend to cleave rather than deform because bonds are strong.
- Are transparent because their electrons are not moving from atom to atom and less likely to interact with light photons.
- Have high melting and boiling point because ionic bonds are relatively strong.

3. Metallic Bond



In *metallic solid*, the binding energies are of ~ (1 – 5) eV per molecule and hence metallic bonds are little strong. Some common features of materials with metallic bonds:

- Considerably hard
- Good electrical and thermal conductors due to their free valence electrons
- Opaque because their electrons are free to move through the electron cloud and more likely to interact with light photons.

Relatively ductile

(C) A solid copper sphere of 0.5 m^3 volume is placed 30 m below the ocean surface where the pressure is 3 x 10^5 N/m^2. What is the change in volume of the sphere?

The bulk modulus for copper is 14 x 10^{10} N/m^2. **<u>(15 marks)</u>**

<u>Answer:</u>

$V = 0.5\ m^3$

$\Delta P = 3 \times 10^5\ N/m^2$

$B = 14 \times 10^{10}\ N/m^2$

$$B = \frac{\Delta P}{\Delta V / V}$$

$$\Delta V = \frac{\Delta P * V}{B}$$

$\Delta V = 3 \times 10^{5} \times 0.5 / 14 \times 10^{10}$

$= 1 \times 10^{-6}\ m^{3}$

Question (4) (50 marks)

(A) In what way do impurities can improve the electrical properties of semiconductors? Discuss using schematic diagrams the main methods of impurity doping? **(15 marks)**

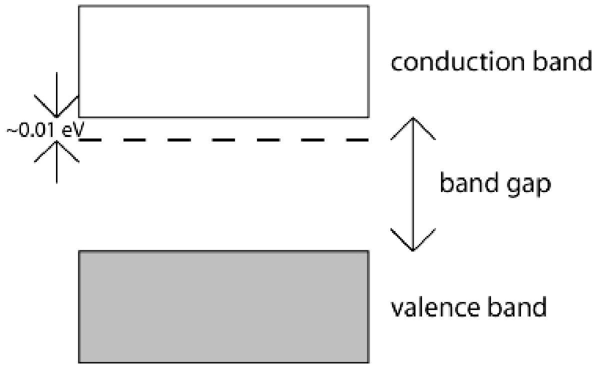
Answer:

In most pure semiconductors, at room temperature, the concentration of charge carriers is much lower than for a metallic conductor. For example, The number of thermally excited electrons in silicon (Si), at 298 K, is 1.5×10^{10} electrons per cm^3. In gallium arsenide (GaAs) the population is only 1.1×10^{6} electrons per cm^3. This may be compared with the number density of free electrons in a typical metal, which is of the order of 10^{28} electrons per cm^3.

Given these numbers of charge carriers within semiconductors, it is no surprise that, when they are extremely pure, silicon and other semiconductors have high electrical resistivities, and therefore low electrical conductivities. This problem can be overcome by doping a semiconducting material with impurity atoms. Even very small controlled additions of impurity atoms at the 0.0001% level can make very large differences to the conductivity of a semiconductor. Electrical conductivity of semiconductors can be increased by two different types of doping which will be described as follows:

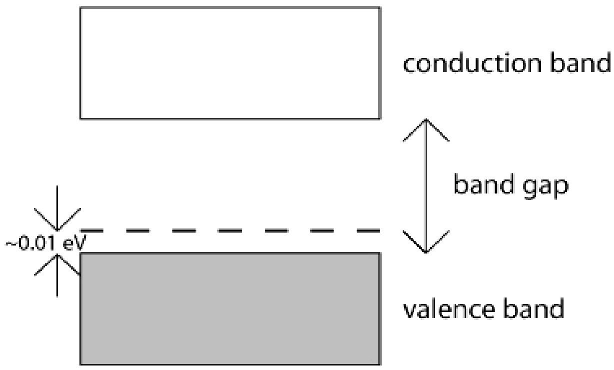
a. n-type semiconductors

In this case, a very small number of atoms of group V elements such as arsenic (As) are added to the silicon (Si) crystal as substitutional atoms in the lattice. Arsenic atoms have five valence electrons while silicon atoms has only four valence electrons so, the fifth electrons of arsenic are bound only weakly to their parent impurity atoms (the bonding energies are of the order of 0.01 eV), This is often represented schematically in band diagrams by the addition of 'donor levels' just below the bottom of the conduction band.



b. p-type semiconductors

In this case, a very small number of atoms of group III elements such as gallium (Ga) are added to the silicon (Si) crystal as substitutional atoms in the lattice. Gallium atoms have three valence electrons while silicon (Si) atoms has only four valence electrons so, this case results in presence of vacancies called holes in the electron structure of the crystal. This is often represented schematically in band diagrams by the addition of 'acceptor levels' just above the highest valence band



(B) Discuss the p-n junction and describe using schematic diagrams the forward and reverse bias configurations? **(15 marks)**

(C) Give a detailed account on composite materials? Explain the major advantages and disadvantage of utilizing such composites? **(20 marks)**

Composite materials: are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials.

Typical engineered composite materials include:

Natural

1) Concrete
2) Woody plants, both true wood from trees and such plants as palms and bamboo

Artificial

1) Reinforced Concrete :
2) Fiber-reinforced polymers or FRPs include carbon-fiber-reinforced polymer or CFRP, and glass-reinforced plastic or GRP. If classified by matrix then there are thermoplastic composites, short fiber thermoplastics, long fiber thermoplastics or long fiber-reinforced thermoplastics. There are numerous thermoset composites, but advanced systems usually incorporate aramid fiber and carbon fiber in an epoxy resin matrix.

Advantages of Composites

1) Light Weight - Composites are light in weight, compared to most woods and metals. Their lightness is important in automobiles and aircraft, for example, where less weight means better fuel efficiency (more miles to the gallon). People who design airplanes are greatly 0concerned with weight, since reducing a craft's weight reduces the amount of fuel it needs and increases the speeds it can reach. Some modern airplanes are built with more composites than metal including the new Boeing 787, Dreamliner.
2) High Strength - Composites can be designed to be far stronger than aluminum or steel. Metals are equally strong in all directions. But composites can be engineered and designed to be strong in a specific direction.
3) Corrosion Resistance - Composites resist damage from the weather and from harsh chemicals that can eat away at other materials. Composites are good choices where chemicals are handled or stored. Outdoors, they stand up to severe weather and wide changes in temperature.
4) High-Impact Strength - Composites can be made to absorb impacts—the sudden force of a bullet, for instance, or the blast from an explosion. Because of this property, composites are used in bulletproof vests and panels, and to shield airplanes, buildings, and military vehicles from explosions.
5) *Design Flexibility* - Composites can be molded into complicated shapes more easily than most other materials. This gives designers the freedom to create almost any shape or form. Most recreational boats today, for example, are built from fiberglass composites because these materials can easily be molded into complex shapes, which improve boat design while lowering costs. The surface of composites can also be molded to mimic any surface finish or texture, from smooth to pebbly.
6) *Dimensional Stability* - Composites retain their shape and size when they are hot or cool, wet or dry. Wood, on the other hand, swells and shrinks as the humidity changes. Composites can be a better choice in situations demanding tight fits that do not vary. They

are used in aircraft wings, for example, so that the wing shape and size do not change as the plane gains or loses altitude.

7) *Nonconductive* - Composites are nonconductive, meaning they do not conduct electricity. This property makes them suitable for such items as electrical utility poles and the circuit boards in electronics. If electrical conductivity is needed, it is possible to make some composites conductive.
8) *Nonmagnetic* - Composites contain no metals; therefore, they are not magnetic. They can be used around sensitive electronic equipment. The lack of magnetic interference allows large magnets used in MRI (magnetic resonance imaging) equipment to perform better. Composites are used in both the equipment housing and table. In addition, the construction of the room uses composites rebar to reinforced the concrete walls and floors in the hospital.
9) *Low Thermal Conductivity* - Composites are good insulators—they do not easily conduct heat or cold. They are used in buildings for doors, panels, and windows where extra protection is needed from severe weather.
10) *Durable* - Structures made of composites have a long life and need little maintenance. We do not know how long composites last, because we have not come to the end of the life of many original composites. Many composites have been in service for half a century.

<u>Disadvantage of composites</u>

Even though composites have distinct features over metals, they do have few limitations or drawbacks. So the drawbacks or limitations in use of composites include

1) *High Cost:* High cost of fabrication of composites is a critical issue. For example, part made of graphite/epoxy composite may cost up to 10 to 15 times the material costs. A finished graphite/epoxy composite part may cost as much as \$300 to \$400 per pound (\$650 to \$900 per kilogram). Improvements in processing and manufacturing techniques will lower these costs in the future.
2) *Complex Repair Procedure:* Repair of composites is not a simple process compared to that for metals. Sometimes critical flaws and cracks in composite structures may go undetected.
3) *Mechanical Characterization:* Mechanical characterization of a composite structure is more complex than that of a metal structure. Unlike metals, composite materials are not isotropic, that is, their properties are not the same in all directions. Therefore, they require more material parameters. For example, a single layer of a graphite/epoxy composite requires nine stiffness and strength constants for conducting mechanical analysis. In the case of a monolithic material such as steel, one requires only four stiffness and strength constants. Such complexity makes structural analysis computationally and experimentally more complicated and intensive. In addition, evaluation and measurement techniques of some composite properties, such as compressive strengths, are still being debated.

GOOD LUCK *Dr. Hytham Abdelghany*