2020

RANK Improvement WORKBOOK

Answer key and Hint of
Objective & Conventional *Questions*

Electrical Engineering

Electrical Materials

MADE EASY
Publications

1

Crystalline Structure

LEVEL 1 Objective Solutions

1. (c)

2. (a)

3. (c)

4. (c)

5. (b)

6. (a)

7. (d)

8. (c)

9. (d)

10. (c)

11. (b)

12. (d)

13. (d)

14. (a)

LEVEL 3 Conventional Solutions

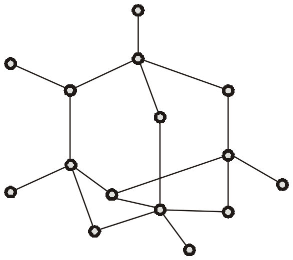
Solution: 1

(i) Covalent bonding of Carbon in diamond:

In diamond, every carbon atom bonds with four other adjoining atoms in a continuous network. No electrons are left unbonded. This results in very strong bonds between carbon atoms and is responsible for the great hardness of diamonds and their clear colorless appearance. Their great density bend light more than other crystals do making their appearance so spectacular.

Valance electrons of carbon atoms in diamonds are bond to 4 electrons in *Tetrahedral arrangement*. The covalent bond is very strong, this makes diamonds have high melting points, the covalent bond in three dimensional structure causes diamond to become the hardest material.

The bonding of electrons, diamonds have dame shaped structures. Dame is one of the strongest structures. Diamond forcing more carbon atoms into a smaller dense package. Since there are no free electrons to wander through the structure, diamonds are excellent insulators. The brilliance and fire of cut diamonds is due to a very high index of refraction (2.42) and the strong dispersion of light, properties which are related to the structure of diamonds.

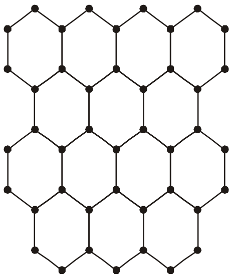


Dimaond

(ii) Covalent bonding of Carbon in Graphite:

In graphite, each carbon atoms shares electrons with only three neighbouring carbon atoms, leaving the fourth electron relatively free to roam around from one carbon atom to another, in much the same way as metals do. The carbon atoms form a network consisting of layers of interconnected carbons able to slide against each other making in a pencil. Unlike diamond, graphite is soft, pitch black in color, and conducts electricity due to the free roaming valence electrons.

Valence electrons of graphite are only bonded to 3 valence electrons, so the covalent bond in hexagonal ring. Graphite is softer than diamond because they are held by weak intermolecular force. Graphite sheet like array of carbon atoms joined with minimal pressure.



Graphite

Solution: 2

$$d = 1.731\ \text{Å}$$

Solution: 3

In free e^- theory developed by Arnold Sommerfeld we assume the electron to be completely free. But it fails mainly because for most part electrons are not completely free. They interact with

(i) lattice (ii) with each other (iii) impurities

Drude incorporated into his model in the form of a hard sphere interaction but completely neglected the other interactions Sommerfeld made some corrections to this purely classical model by insuring that the electron gas obey fermi statistics. This faced some problems (like the overestimate of the electronic heat capacity but still didn't cover for the missing interaction in the model.

Due to its limitations, the free electron model was unable to account for things like magnetoresistance, thermal dependence of conductivity, optical properties and the host of many body phenomenon that result from electron-electron interaction being of importance.

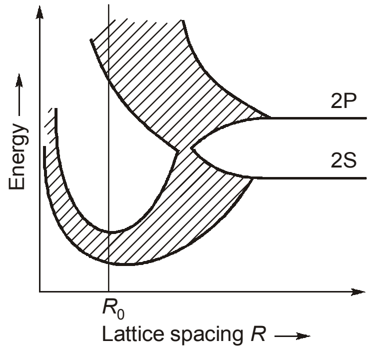
In band theory of e^{-s}, A solid is assumed to contain many bands in which electrons in it are packed. The most important are valence band and conduction band. The energy of electrons in these bands will be different. The difference in valence band and conduction determines whether solid is a conductor, semi-conductor, or insulator.

So it clearly explains the dependence of conductivity on temperature which can't be explain by free e^- theory. When temperature increases the energy of e^{-s} increases so e^{-s} started to jump from valence band to conduction so conduction of e^{-s} changes with temperature in *CB* so as conductivity changes with temperature.

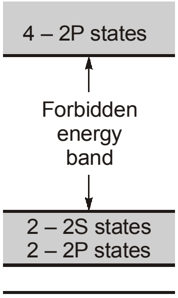
It also explains many other properties like optical, magneto resistance etc. easily so shortcomings of free e^- theory is overcome by band theory in which we assume there is interaction between e^{-s} only energy state of different e^{-s} is different.

We also take in account the interaction of e^- with lattice and impurities.

Diamond is the crystalline form of carbon and is of interest because it lies in the same period and has the same type of bonding as silicon and germanium. The shape of the energy-band structure of diamond as a function of atomic spacing is shown in Fig. (a), it is shown that there is a crossover point at which two of the 2 P states form a band with the two 2*s* state, thus making available a band with four available states. The remaining four of the total of six 2*p* states off and form a higher band of their own. At normal atomic spacing, the forbidden gap between the higher and lower bands is wide. Since there is a total of four electrons in the 2*s* and 2*p* states of carbon, all these electrons are used up in filling the lower band. The upper band is left empty, and hence diamond is a very good insulator. Fig. (b) shows the stable energy level of diamond.



(a) The energy levels in the tetrahedral of diamond as a function of lattice spacing.



(b) The stable energy level of the diamond crystal.

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2

Dielectric and Ceramic Materials

LEVEL 1 Objective Solutions

1. (a)

2. (b)

3. (c)

4. (c)

5. (d)

6. (d)

7. (d)

8. (b)

9. (b)

10. (c)

11. (a)

12. (c)

13. (d)

LEVEL 3 Conventional Solutions

Solution: 1

Component values of the quartz crystals are as below:

$$L = 28.488\text{ H}$$
$$R = 200\ \Omega$$
$$C = 0.02223\text{ pF}$$
$$C' = 8.8859\text{ pF}$$

Solution: 2

"Elemental solid dielectrics" are the materials consisting of single type of atoms (e.g. Diamond, Sulphur, Germanium etc.) These materials contain neither ions nor permanent dipoles and thus it exhibits only electronic polarization.

Let us consider 'α_e' is the polarizability per atom in such materials then,

$$\text{Polarization } (\vec{P}) = N\alpha_e\vec{E}_i \qquad \text{...(i)}$$

where, N = Number of atoms/m^3

and E_i = The internal field seen by the atom

we have also,
$$\vec{E}_i = \vec{E} + \frac{\gamma}{\varepsilon_0}\vec{P} \qquad \text{...(ii)}$$

where, γ = proportionality constant which is referred to as the internal field constant.

E = Applied field.

Here, we assume for macroscopic relation,

Then,
$$\text{Polarization } (\vec{P}) = \varepsilon_0\chi_e\vec{E} = \varepsilon_0(\varepsilon_r - 1)\vec{E} \qquad \text{...(iii)}$$

From equation (i) and (ii) we get,

$$\vec{P} = N\alpha_e\left[\vec{E} + \frac{\gamma}{\varepsilon_0}\vec{P}\right]$$

or
$$\varepsilon_0\chi_e\vec{E} = N\alpha_e\left[\vec{E} + \frac{\gamma}{\varepsilon_0}\left(\varepsilon_0\chi_e\vec{E}\right)\right]$$

or
$$\varepsilon_0\chi_e = N\alpha_e[1 + \gamma\chi_e]$$

or
$$\chi_e = \frac{N\alpha_e}{\varepsilon_0}\cdot[1 + \gamma\chi_e]$$

Since, susceptibility $(\chi_e) = \varepsilon_r - 1$ so,

or
$$\chi_e = \frac{N\alpha_e}{\varepsilon_0}\cdot\gamma\chi_e + \frac{N\alpha_e}{\varepsilon_0}$$

or
$$(\varepsilon_r - 1)\left[1 - \frac{\gamma N\alpha_e}{\varepsilon_0}\right] = \frac{N\alpha_e}{\varepsilon_0}$$

or
$$\varepsilon_r = \frac{(N\alpha_e/\varepsilon_0)}{\left(1 - \dfrac{\gamma N\alpha_e}{\varepsilon_0}\right)} + 1$$

or
$$\varepsilon_r = \frac{1+\left(\frac{N\alpha_e}{\varepsilon_0}\right)-\gamma\left(\frac{N\alpha_e}{\varepsilon_0}\right)}{1-\gamma\left(\frac{N\alpha_e}{\varepsilon_0}\right)}$$

⇒
$$\varepsilon_r = \frac{1+(1-\gamma)\left(\frac{N\alpha_e}{\varepsilon_0}\right)}{1-\gamma\left(\frac{N\alpha_e}{\varepsilon_0}\right)} \qquad \text{...(iv)}$$

If the internal field $\vec{E}_i$ is taken as the Lorentz field then for a cubical lattice structure, $\gamma = \frac{1}{3}$ then equation (iv) may reduce to

$$\varepsilon_r = \frac{1+\frac{2}{3}\left(\frac{N\alpha_e}{\varepsilon_0}\right)}{1-\frac{1}{3}\left(\frac{N\alpha_e}{\varepsilon_0}\right)} \qquad \text{...(v)}$$

Let, $\frac{N\alpha_e}{\varepsilon_0} = x$ then equation (v) may be,

$$\varepsilon_r = \frac{1+\frac{2}{3}x}{1-\frac{1}{3}x} \qquad \text{...(vi)}$$

After solving equation (vi) we get,

$$x = \frac{3(\varepsilon_r - 1)}{(\varepsilon_r + 2)}$$

The equation (vi) may be written as,

$$\varepsilon_r = \frac{1+\frac{2}{3}\left\{\frac{3(\varepsilon_r-1)}{(\varepsilon_r+2)}\right\}}{1-\frac{1}{3}\left\{\frac{3(\varepsilon_r-1)}{(\varepsilon_r+2)}\right\}}$$

∵
$$x = \frac{N\alpha_e}{\varepsilon_0} = \frac{3(\varepsilon_r-1)}{(\varepsilon_r+2)}$$

Final equation is,

$$\frac{N\alpha_e}{3\varepsilon_0} = \frac{\varepsilon_r - 1}{\varepsilon_r + 2} \qquad \text{...(vii)}$$

This equation (vii) represents the well known **"CLAUSIUS-MOSOTTI RELATION".**
This Clausius-Mossotti relation contains the following assumptions:

- The polarizability of molecules is isotropic.
- The arrangement of molecules is isotropic.
- Polarization of the molecules is by elastic displacement only.
- Absence of short range (non-dipolar) interactions.

All these conditions are fulfilled by the rare gases and by little else.

Solution: 3

Strain = 0.0166

Voltage generated, $E = 3\text{ V}$

Charge, $Q = F \times \text{charge sensitivity} = 750\text{ pC}$

Capacitance, $C_p = 250\text{ pF}$

Solution: 4

Ceramics are a compound formed by the combination of a metallic and non-metallic elements. Unlike metals, they do not have large number of free electrons, the electrons being shared covalently as in ionic bonds. Crystal structure of ceramics contain atoms of different sizes.

Due to the presence of ionic and covalent bond, ceramics possess high hardness, brittleness, high melting, point, chemical inertness and electrical insulation.

The main characteristics are low water absorption, low thermal expansion and good electrical properties.

Ceramic material may be divided in to two groups, depending whether the permittivity is less or greater than 12. Material with high permittivity below 12 are more advantageously used in bulk as insulators, bushing, housing.

1. Example: Porcelain, Alumina etc. ($\epsilon_r < 12$)
   Porcelain is used as insulators in transmission and distribution, fuse links, plugs and sockets.
2. Material with high permittivity ($\epsilon_r > 12$), is used in capacitor in which permittivity should be as large as possible, for reducing the size of the capacitor barium titanate ($B_aT_iO_3$), which has permittivity of 2000, is used.

Solution: 5

(i)
- The absorption of electric energy by a dielectric material subjected to an alternating *E*-field is known as dielectric loss. This result in dissipation of the electric energy as heat in the material and dielectric constant in such case is a complex quantity where imaginary part corresponds the loss. So, complex dielectric constant is expressed as

$$\epsilon_r^* = \epsilon_r' - j\epsilon_r''$$

- The complex dielectric constant incorporates all the contributions of polarization.
- The imaginary part of the equation is so that rise to absorption of energy by the material from the alternating field.

(ii)
- Ceramics are dielectric material having large band gap E_g. So in working temperature range they behave as a insulator.
- Some materials (ceramic) such as glass, paper, Teflon are very good electric insulators.
- These ceramics are used for high voltage power transmission because of their good insulating properties. These are normally glass, porcelain, or composite polymer materials.
- Insulators made from porcelain rich in alumina are used where high mechanical strength is criterion.
- Porcelain has a dielectric strength of 4 – 10 kV/mm.
- Recently some electric utilities have begun converting to polymer composite materials for some types of insulators.
- Ceramic insulator are also used at railway.

Solution: 6

Polarization, $\vec{P} = N\vec{p} = 3.6 \times 10^{-8}\vec{a}_x \text{ C/m}^2$

$\epsilon_r = 1.041$

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3

Magnetic Materials

LEVEL 1 Objective Solutions

1.	(c)
2.	(a)
3.	(a)
4.	(a)
5.	(b)
6.	(a)
7.	(d)
8.	(a)
9.	(d)
10.	(b)
11.	(b)
12.	(d)
13.	(d)
14.	(d)
15.	(b)
16.	(d)
17.	(a)
18.	(d)
19.	(d)
20.	(b)

LEVEL 3 Conventional Solutions

Solution: 1

$$\mu_r = \chi + 1 = 1.000005$$

Flux density, $B_0 = \mu_0 \mu_r H = 1.256$ Weber/m^2

Solution: 2

(i) Flux density, $B = \mu_0(\bar{H} + \bar{m}) = 1.41 \times 10^{-3}$ Wb/m^2

(ii) Magnetic field intensity, $B = 1.64 \times 10^{-3}$ Wb/m^2

(iii) $B = 1.545 \times 10^{-3}$ Wb/m^2

Solution: 3

Hard magnetic materials are those which retain a considerable amount of their magnetic energy after the magnetizing force has been removed i.e. materials are difficult to demagnetize . These materials are also called permanent magnetic materials. For these materials to be used as permanent magnets should have following characteristics.

1. High permeability insured by a large content of magnetic atoms or ions.
2. High coercive force
3. Appreciable remanent flux density
4. High Curie temperature.
5. Low cost.

Solution: 4

Intensity of magnetization $= M = \chi H = 5$ A/m

Flux density, $B_0 = \mu_0 \mu_r H = 1.256$ Wb/m^2

Solution: 5

Change in magnetization (M) $= M_1 - M_2 = 4{,}76{,}664$

$$\text{Percentage change} = \left(\frac{M_1 - M_2}{M_2}\right) \times 100\% = 30\%$$

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4 Conductors & Superconductors

LEVEL 1 Objective Solutions

1.	(a)
2.	(c)
3.	(c)
4.	(c)
5.	(a)
6.	(c)
7.	(b)
8.	(a)
9.	(d)
10.	(a)
11.	(c)
12.	(a)
13.	(c)
14.	(b)

LEVEL 3 Conventional Solutions

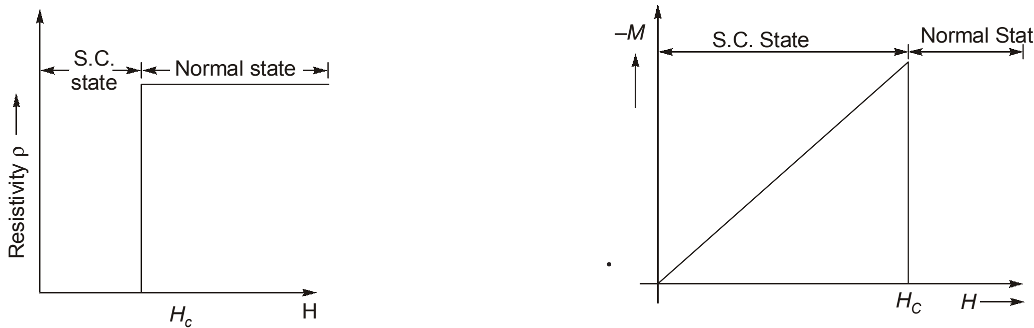
Solution: 1

A state of material in which it has zero resistivity is called superconductivity.

- At the state of superconductivity material has zero resistivity as well as perfect diamagnetism.
- The temperature at which superconductivity appears is called the critical temperature or transition temperature.
- Superconductors are materials which show superconductivity under certain conditions of temperature and magnetic field.
- It shows Meissner effect.
- Superconductor exhibits perfect diamagnetism ($\mu_r = 0$). Because of diamagnetic nature, superconductor material strongly repel external magnetic field.

Type-I superconductor

- Type-I or ideal superconductors, while in superconducting state are completely diamagnetic upto the critical field H_c and to normal state above critical field as



(a)

M v/s *H* for type-I superconductor

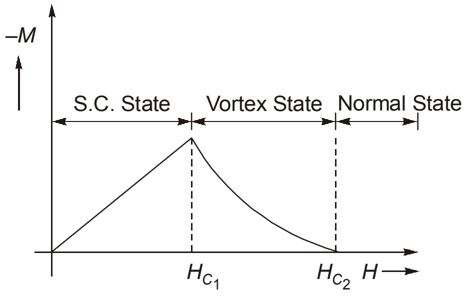
(b)

ρ versus H for Type-I superconductors

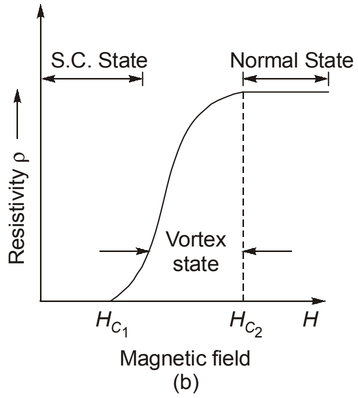
- Soft metals such as lead or indium belongs to this group. The critical field of these superconductors are low.
- They have low melting point.
- These materials obey Silsbee's rule and show complete Meissner effect.
- The transition from normal to superconducting state is sharp. They have low value of H_C and T_C.

Type-II Superconductor:

- Hard metals and alloy have different magnetization characteristic as shown below are called type-II superconductors.



- They are characterized by high transition temperature, high critical field, incomplete Meissner effect, break down of Silsbee's rule and broad transition region.
- Type-II are those in which the ideal behaviour is seen up to a lower critical field H_{C_1} beyond which the magnetization gradually changes and attains zero at an upper critical field designated as H_{C_2} .



ρ versus H for Type-II superconductors.

Solution: 2

- **Superconductivity:**
- A state of material in which it has zero resistivity is called superconductivity. Superconductivity appears at low temperatures and in magnetic fields lower than a particular level. Superconductors are also perfect diamagnet. This is the Meissner effect. Perfect diamagnetism is an independent property of superconductors and shows that superconductivity involves a change of thermodynamic state, not just a spectacular change in electrical resistance.

In a superconductor, magnetic flux density B is zero. i.e. $B = 0$

or $\mu_0 (H + M) = 0$

or $H = -M$

⇒ Since χ_m = M/H, it can be stated that the magnetic susceptibility in a superconductor is negative. This is referred to as perfect diamagnetism.

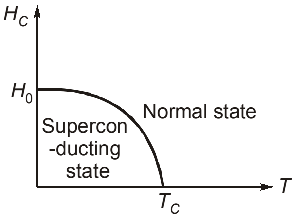
⇒ Thus, a perfect diamagnetism and zero resistivity are two independent, essential properties of the superconducting state.

⇒ The critical value of magnetic field for the destruction of superconductivity, H_C is a function of temperature. Mathematically,

$$H_C = H_0\left[1-\left(\frac{T}{T_C}\right)^2\right]$$

where H_0 is the critical field at absolute zero and T_C is the transition temperature.

⇒ For any particular super conductor the shape of variation of 'H_C' with temperature (T) is shown below as:



⇒ Some other features of superconductivity are following :

(i) Superconductivity is observed for d.c. and upto radio frequencies. It is not observed for higher frequencies.

(ii) Entropy increases on going from superconducting state to normal state.

(iii) In an ideal superconductor, there is a marked drop in the thermal conductivity when superconductivity sets in.

(iv) The critical temperature of superconductors varies with isotopic mass. The relation is

$$M^{1/2}T_C = \text{Constant}$$

where M is the mass of the isotope.

⇒ Superconducting materials are used as electronic switching devices called cryotrons (based on the destruction of superconductive state in a strong magnetic field).

⇒ Superconducting magnets find applications in the following areas :

(i) Magnets for nuclear fusion
(ii) Magnetically Levitated Transportation
(iii) Magnetic Resonance Imaging (MRI)
(iv) Generators and motors
(v) Super conducting magnets for energy storage device
(vi) It is also used in the field of electronics.

Current flow through disk,

$$I = 3.7 \times 10^2 \text{ A}$$

Solution: 3

$$H_{CT} = 4.038 \times 10^5 \text{ Amp/m}$$

Solution : 4

Fermi energy at 0°K is, $E_{FO} = 7 \text{ eV}$

$$v = \sqrt{\frac{6E_{FO}}{5m_e}} = 1.22 \times 10^6 \text{ m/sec}$$

Solution: 5

$$E_{\text{internal}} = 1.232 \text{ V/m}$$

Solution: 6

$$\mu_p = 4.7348 \times 10^8 \text{ m}^2\text{/V-sec}$$
$$\mu_e = 1.42 \times 10^9 \text{ m}^2\text{/V-sec}$$

Solution: 7

$$\text{Relaxation time } (\tau) = 3.95 \times 10^{-14} \text{ sec}$$
$$V_d = 0.69 \text{ m/sec}$$

Mean free path, $\lambda = 0.55 \times 10^{-7}$ m

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5

Nano Materials

LEVEL 1 Objective Solutions

1. (d)

2. (b)

3. (a)

4. (b)

5. (c)

6. (b)

7. (a)

8. (b)

9. (d)

LEVEL 3 Conventional Solutions

Solution : 1

Superior, lightweight materials: Imagine materials ten times stronger than steel at a fraction of the weight. With such materials, nanotechnology could revolutionize tanks, airframes, spacecraft, skyscrapers, bridges, and body armor, providing unprecedented protection. Composite nanomaterials may one day lead to shape-shifting wings instead of the mechanical flaps on current designs (a product known as shape memory alloy is working in this field). Kevlar, the backbone fiber of bulletproof vests, will be replaced with materials that not only provide better protection but store energy and monitor the health status of our soldiers. A taste of what's to come: MIT was awarded a $50 million Army contract in 2002 to launch the Institute for Soldier Nanotechnologies (ISN) developing artificial muscles, biowarfare sensors, and communications systems.

Advanced computing: More powerful and smaller computers will encrypt our data and provide round-the-clock security. Quantum cryptography — cryptography that utilizes the unique properties of quantum mechanics — will provide unbreakable security for businesses, government, and military. These same quantum mechanics will be used to construct quantum computers capable of breaking current encryption techniques (a needed advantage in the war against terror). Additionally, quantum computers provide better simulations to predict natural disasters and pattern recognition to make biometrics — identification based on personal features such as face recognition — possible.

Increased situational awareness: Chemical sensors based on nanotechnology will be incredibly sensitive — capable, in fact, of pinpointing a single molecule out of billions. These sensors will be cheap and disposable, forewarning us of airport-security breaches or anthrax-laced letters. These sensors will eventually take to the air on military unmanned aerial vehicles (UAVs), not only sensing chemicals but also providing incredible photo resolutions. These photos, condensed and on an energy-efficient, high resolution, wristwatch-sized display, will find their way to the soldier, providing incredible real-time.

Powerful munitions: Nanometals, nano-sized particles of metal such as nanoaluminum, are more chemically reactive because of their small size and greater surface area. Varying the size of these nanometals in munitions allows us to control the explosion, minimizing collateral damage. Incorporating nanometals into bombs and propellants increases the speed of released energy with fewer raw materials consumed — more (and better-directed) "bang" for your buck.

Diagnostics: Hospitals will benefit greatly from nanotechnology with faster, cheaper diagnostic equipment. The lab-on-a-chip is waiting in the wings to analyze a patient's ailments in an instant, providing point-of care testing and drug application, thus taking out a lot of the diagnostic guesswork that has plagued healthcare up to now. New contrast agents will float through the bloodstream, lighting up problems such as tumors with incredible accuracy. Not only will nanotechnology make diagnostic tests better, but it will also make them more portable, providing time sensitive diagnostics out in the field on ambulances. Newborn children will have their DNA quickly mapped, pointing out future potential problems, allowing us to curtail disease before it takes hold.

Novel drugs: Nanotechnology will aid in the delivery of just the right amount of medicine to the exact spots of the body that need it most. Nanoshells, approximately 100 nm in diameter, will float through the body, attaching only to cancer cells. When excited by a laser beam, the nanoshells will give off heat — in effect, cooking the tumor and destroying it. Nanotechnology will create biocompatible joint replacements and artery stents that will last the life of the patient instead of having to be replaced every few years.

Energy: Nanotechnology is set to provide new methods to effectively utilize our current energy resources while also presenting new alternatives. Cars will have lighter and stronger engine blocks and frames and will use new additives making fuel more efficient. House lighting will use quantum dots — nanocrystals 5 nm across — in order to transform electricity into light instead of wasting away into heat. Solar cells will finally become cost effective and hydrogen fuel cells will get a boost from nanomaterials and nanocomposites. Our Holy Grail will be a reusable catalyst that quickly breaks down water in the presence of sunlight, making that long-wished-for hydrogen economy realistic. That catalyst, whatever it is, will be constructed with nanotechnology.

Water: Nanotechnology will provide efficient water purification techniques, allowing third-world countries access to clean water. When we satisfy our energy requirements, desalinization of water from our oceans will not only provide enough water to drink but also enough to water our crops.

Renewable Energy Generation: The main source of power today is the burning of carbon containing fuels. This is generally inefficient, frequently non-renewable and dumps carbon dioxide and other waste products into the atmosphere. Nanotechnology may transform energy production and storage by providing alternatives to current practices. For example, nanoparticulate catalysts for fossil fuels, which will lead to reduced emissions or better energy efficiency, higher storage capacity for hydrogen, biohydrogen production and more effective and cheaper solar cells or coatings on windows that reduce heat loss. Nanoparticles can increase the storage capacity of batteries and rechargeable batteries or are used in flat screens where they reduce the amount of heavy metals. Some new nanocatalysts can be used at much lower temperatures than conventional catalysts and therefore require less energy input. Nanomaterials can be substituted for conventional materials that require more raw materials and are more energy intensive to produce. Another example of how nanotechnology can reduce energy costs is nanomaterials coatings on ships, which are expected to realize fuel savings. The most advanced nanotechnology projects related to energy are storage, conversion, manufacturing improvements by reducing materials and process rates, energy saving e.g., by better thermal insulation and enhanced renewable energy sources applications.

Nanotechnology in Tissue Engineering: Nanobiosystem research is a priority to develop medical devices that once implanted will replace or enhance tissue function to impair diseases, injury or age with special reference to tissue engineering. Biomaterial devices are created by seeding scaffold with cells at the nanoscale, which have certain properties to solve medical challenge and cater need in the area of nanomedical research. Depending on the type of tissue, the design process can involve a variety of disciplines including mechanical engineering, molecular biology, physiology, medicine, polymer chemistry and nanotechnoiogy. Tissue engineering involves engineering and life sciences towards fundamental understanding and development of biological substitutes to restore, maintain and improve tissue functions.

Solution : 2

There are two different approaches of material fabrication. One is the top-down approach and the other is the bottom-up approach. In top-down technique, generally a bulk material is tab and machined it to modify into the desired shape and product. Examples of this type of technique are the manufacturing of integrated circuits using a sequence of steps such as crystal growth, lithography, etching, ion implantation, etc. For nanomaterial synthesis, ball-milling is an important top-down approach, where macrocrystalline structures are broken down to nanocrystalline structures, but original integrity of the material is retained. Sometimes this method is used to prepare nanostructured metal oxides by chemical reaction between two constituents during crushing. The crystallites are allowed to react with each other by the supply of kinetic energy during milling process to form the required nanostructured oxide.

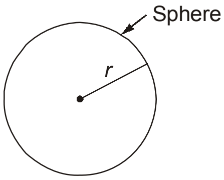
On the other hand, bottom-up technique is used to build something from basic materials, for example, assembling materials from the atoms/molecules up, and, therefore very important for nano-fabrication. Unlike lithographic technique of top-down approach, which is extensively used in silicon industry, this bottom-up nonlithographic approach of nanomaterial synthesis is not completely proven in manufacturing yet, but has great potential to become important alternative to lithographic process. Examples of bottom-up technique are self-assembly of nanomaterials, solgel technology, electrodeposition, physical and chemical vapour deposition (PVD. CVD), epitaxial growth, laser ablation, etc. Details of these procedures are discussed in the subsequent sections.

Solution: 3

Surface to volume ratio of nano particle relation:

Surface to volume ratio in nano particles have a significant effect on the nano particles properties firstly, nano particles have a relative large surface area when compared to the same volume of the material.

Let us consider a sphere of radius 'r'.



The surface area of the sphere, $S = 4\pi r^2$

and the volume of sphere, $V = \frac{4}{3}\pi r^3$

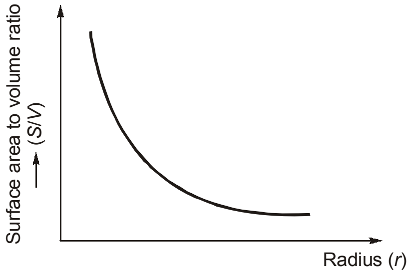
Therefore the surface area to volume ratio,

$$\frac{S}{V} = \frac{4\pi r^2}{\left(\frac{4}{3}\pi r^3\right)} = \frac{3}{r} \Rightarrow \frac{S}{V} \propto \frac{1}{r}$$

It means that the surface area to volume ratio increases with the decrease in radius of the sphere and vice-versa. It can also be concluded that when given volume is divided into smaller piece, the surface area increases. Therefore as particle size decreases, a greater portion of the atoms are found at the surface compared to those inside.

For example, a particle of size 3 nm has 50% of its atom on its surface, at 10 nm 20% of its atoms and at 30 nm has 5% of its atoms on its surface.

Therefore nano particles have a much greater surface area per unit volume compared with the large particles. It leads to nano particles more chemically reactive. As growth and catalytic chemical reaction occur at surfaces, therefore a given mass of nano material will be much more reactive than the same mass of nano material made up of large particles. It is also found that material which are insert in their bulk form are reactive when produced in their nano scale form. It can improve their properties. Surface area to volume ratio vs radius plots.



$$\frac{S}{V} = \frac{3}{r}; \qquad \frac{S}{V} \propto \frac{1}{r}$$

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